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U.S. FISH AND WILDLIFE SERVICE BIOMONITORING OPERATIONS MANUAL

APPENDIX A
LEGISLATIVE BACKGROUND AND KEY TO RELEVANT LEGISLATION

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PREFACE

This is Appendix A of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
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H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

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The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
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Document Revision Worksheet

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Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

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ACRONYMS

AFCA	Anadromous Fish Conservation Act
BAT	best available technology
BLM	Bureau of Land Management
BOM	Bureau of Mines
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
CEQ	Council on Environmental Quality
CFC	Chloroflorocarbons
CFC	Code of Federal Regulations
CWA	Clean Water Act
DOC	Department of Commerce
DOI	Department of Interior
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FEPCA	Federal Environmental Pesticide Control Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FWCA	Fish and Wildlife Coordination Act
FWPCA	Federal Water Pollution Control Act
FWS	U.S. Fish and Wildlife Service
INEL	Idaho National Engineering Laboratory
MACT	maximum available control technology
MBTA	Migratory Bird Treaty Act
MCL	maximum contaminant level
MCLGs	maximum contaminant level goals
MMPA	Marine Mammal Protection Act
MOU	Memorandum of Understanding
MPRSA	Marine Protection, Research, and Sanctuaries Act
MSDS	Material Data Safety Sheet
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NPDWR	National Primary Drinking Water Regulation
NPL	National Priorities List
NPS	National Park Service
NSPS	New Source Performance Standards
NWR	National Wildlife Refuge
OPA	Oil Pollution Act
P.L.	public law
PNRS	Preliminary National Resource Survey
POTWs	publicly owned treatment works
PSDs	Prevention of Significant Deterioration
RACT	reasonable available control technology

RCRA	Resource Conservation and Recovery Act
RFM	Reference Field Method
SARA	Superfund Amendments and Reauthorization Act
SIPs	State Implementation Plans
SMCRA	Surface Mining Control and Reclamation Act
SDWA	Safe Drinking Water Act
TSCA	Toxic Substances Control Act
UIC	underground injection control
USCA	U.S. Code Annotated
USGS	U.S. Geological Survey

U.S. FISH AND WILDLIFE SERVICE
BIOMONITORING OPERATIONS MANUAL

APPENDIX A
LEGISLATIVE BACKGROUND AND
KEY TO RELEVANT LEGISLATION

1. INTRODUCTION

Environmental laws are designed to minimize, prevent, punish, or remedy the consequences of actions which damage or threaten the environment or the public's health and safety (Arbuckle et al., 1991). Most environmental laws can be grouped into one of the following categories:

- Notification requirements (disclose releases of pollutants, discharge violations, etc)
- Discharge controls (prevent or minimize the pollutants released)
- Process controls (minimize the hazardous characteristics pollutants)
- Product controls (assure that products do not present unreasonable risks to human health or the environment when used or disposed of)
- Regulation of activities (protect resources, species, or ecological amenities)
- Transportation requirements (minimize the inherent risks during transportation)
- Response and remediation requirements (develop plans to clean up pollutants released)
- Compensation requirements (make responsible parties pay for damage done to the public health or environment)

Environmental laws and regulations can also be used to justify monitoring activities or support funding proposals. This document serves only as an introduction to some Federal legislation that may be relevant to a biomonitoring program. To fully utilize all the environmental legislation and regulations available is complex and would require expert legal advice.

Section 2 describes (in alphabetical order) some of the more pertinent legislative acts and identifies what roles and responsibilities the Fish and Wildlife Service (FWS) has under the legislation. Some examples are provided regarding how legislation might be incorporated into a biomonitoring program.

Section 3 includes a matrix (Table 1) that serves as a quick reference to sections of legislation that may be applicable to FWS biomonitoring activities. Table 2 is a more comprehensive list of environmental legislation that may be useful for a biomonitoring program.

FWS personnel should contact the Department of Interior's, Office of the Solicitor at (202) 208-4423 for any questions concerning the applicability of any piece of environmental legislation. Comprehensive reviews of environmental legislation, in addition to the specific statutes, are available through public and private sources. It is emphasized that FWS personnel consider each legislation in the context of biomonitoring and how it might be applied to the FWS lands for which they are responsible. Some references that provide additional information about environmental legislation are included at the end of this document (Sections 4 and 5).

2. LEGISLATION RELEVANT TO FWS BIOMONITORING

Justification for biomonitoring is often provided through legislation that authorizes the FWS and other Federal agencies to prevent or alleviate contaminant related problems. Therefore, it is necessary to be aware of pertinent legislation and its relevance to contaminant monitoring issues. The following legislation have been included because of their applicability to FWS biomonitoring activities. This section lists the legislative acts in alphabetical order, identifies the administrating agency, and presents a synopsis of pertinent sections of the acts.

2.1 Anadromous Fish Conservation Act (AFCA) - 1965

The AFCA (16 USCA §§ 1823 et seq.) authorizes the Department of the Interior and the Department of Commerce to conduct research and biological investigations on the nation's anadromous fish (Section 2). The Act identifies the Great Lakes, Lake Champlain, and all interstate or navigable waters and their tributaries.

Section 6 authorizes the Secretary of the Interior to make recommendations to the Secretary of Health, Education, and Welfare and the Administrator of the Environmental Protection Agency (EPA) regarding eliminating or decreasing pollutants harmful to fish and wildlife. The EPA then acts on these recommendations by developing enforcement regulations designed to enhance these aquatic resources.

A 1979 amendment (Section 7) authorizes the National Marine Fisheries Service (NMFS) and the FWS to conduct Striped bass research to study the general decline of striped bass populations. The decline in some areas appears to be linked to environmental contaminants. This Act can be used to justify monitoring activities at a variety of habitats used by anadromous fish such as freshwater streams and lakes, estuaries, and marine areas.

2.2 Bald and Golden Eagle Protection Act - 1940

The Bald and Golden Eagle Protection Act (16 USCA §§ 668 - 668d) prohibits the taking, possessing, selling, purchasing, and import or export of Bald or Golden Eagles. This includes eagles dead or alive, any eagle parts, eagle nests, or eagle eggs. The FWS is authorized to issue permits for taking specimens for scientific, exhibition, and religious purposes. The Act also outlines criminal penalties and fines for violators.

2.3 Clean Air Act (CAA) 1970 and 1990 Amendments

The purpose of the CAA (42 USCA §§ 7401 et seq.) is to prevent and control air pollution with the goal of protecting and enhancing the nation's air quality. The Act requires EPA to establish standards for six criteria pollutants; NO_x, SO_2, CO, O_3, Pb, and particulate matter smaller than 10 micron in size (PM10). The CAA establishes National Ambient Air Quality Standards (NAAQS) for each of the criteria pollutants (Section 109). There are two NAAQS (Section 302) for each pollutant; a) the primary NAAQS is the level that will protect public health (public health means providing adequate margins of safety to the public), and b) the secondary NAAQS protects the public welfare (public welfare protects parts of the environment, such as soils, water, vegetation, and wildlife). The

primary and secondary NAAQS for the seven criteria pollutants can be found in 40 CFR 50. Section 120 discusses how penalties for noncompliance with the CAA are established.

A land classification scheme is established to protect air quality in specified areas including national wildlife refuges. Section 163 establishes maximum increments and ceilings allowable for sulfur dioxide and particulate matter over baseline concentrations (ambient levels existing on August 7, 1977). In Section 162, refuges are designated as either Class I or Class II. In Class I areas, only minor degradation of air quality is allowed. In Class II areas, degradation that usually goes along with moderate, well-controlled growth is acceptable. To date, there are 21 refuges in the Class I category; the remainder are Class II. Federal lands may be redesignated as outlined in Section 164.

Section 111 states that EPA shall establish standards of performance for new stationary sources. Known as new source performance standards (NSPS), these are guidelines and limitations set for a variety of industrial and commercial processes. The NSPS can be found in 40 CFR 60.

The purpose of the 1990 amendments to the CAA (P.L. 101-549) is to strengthen the authority of federal and state governments to reduce air pollution from industry, transportation, and community operations. A brief explanation of key 1990 amendments is provided (Quarles and Lewis, 1990).

Nonattainment--These are special requirements for areas not currently meeting NAAQS. State Implementation Plans (SIPs) will be required for nonattainment areas along with requirements for installing reasonable available control technology (RACT). Special attention has been given to ozone nonattainment. Note: the Prevention of Significant Deterioration (PSD) program can overlap the nonattainment amendment as applied to each regulated pollutant.

Mobile Sources and Clean Fuels--More stringent standards for auto, truck, and bus emissions are established. New requirements are outlined for petroleum companies to produce alternative clean fuels (methanol, ethanol, reformulated gasoline, natural gas, liquified petroleum, and electricity) and for the auto industry to produce vehicles capable of using such alterative fuels.

Air Toxins--The amendment list 189 hazardous air pollutants (Section 112) and requires the EPA to promulgate new control standards for the sources of emissions in a two-phase strategy. The first phase is based on available technology standards and will require companies to install maximum achievable control technology (MACT). The second phase will involve determining Residual Risk whereby the EPA must determine if even more stringent standards are required.

Acid Rain--Amendments are aimed primarily at coal-fired plants and are designed to cut national emissions of sulfur dioxide approximately in half, with reductions of nitrogen oxides also required.

Chlorofluorocarbons (CFCs)--The amendments outline a) requirements to restrict emissions of CFCs, b) timeline for eventual phase-out of CFC production, and c) timeline for eventual phase-out of CFC sales.

Permit Requirements--The amendments call upon states to establish comprehensive new permit programs (comparable to the NPDES permit program under the Clean Water Act) for all significant air emission sources. The permits will establish detailed requirements governing emissions, monitoring, record keeping, and reporting.

Enforcement--The amendments strengthen enforcement authorities by adding new civil and criminal sanctions. It authorizes the EPA to establish a "field citation program" and offer a "bounty" to whistle-blowers. Other agencies and private citizens are now authorized to seek civil penalties.

All federal agencies are directed to assist the EPA with gathering information deemed necessary to carry out the provisions of the CAA (Sec. 303 (d)).

Sections 410 and 411 (P.L. 101-549 amendment) appropriates $500,000 to the FWS to fund research related to acid deposition and the monitoring of high altitude lakes. Section 411 (P.L. 101-549 amendment) appropriates $250,000 to the FWS to research neutralizing agents used to restore lakes and streams damaged by acid deposition.

The FWS's Branch of Air Quality specializes in air quality issues. This branch has expertise concerning air legislation, SIPs, PSDs, ambient air concentrations, air classification, and air monitoring. Any questions or problems related to air quality issues should be directed to the FWS Branch of Air Quality in Denver Colorado. Additional information on the CAA and other air monitoring information is in Appendix C (Air Monitoring).

2.4 Clean Water Act (CWA) - 1977, Federal Water Pollution Control Act (FWPCA) - 1972, and Water Quality Act (WQA) - 1987

The Federal government began legislating water pollution controls by enacting the Federal Water Pollution Control Act in 1972 (33 USCA §§ 1251 et seq.). In 1977, Congress amended and renamed the FWPCA to the Clean Water Act (CWA). These two Acts will be discussed together as the CWA. The Water Quality Act (WQA) of 1987 (P.L. 100-4) is a reauthorization of the CWA.

Administered by the EPA, the objective of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the nation's waters" (Sec. 101). In order to achieve the objective, two goals were established: (1) the attainment of a water quality level that allows for the protection, growth, and reproduction of fish, shellfish, and wildlife and for aquatic recreation by July 1, 1983; and (2) eliminating the discharge of pollutants into U.S. waters by 1985.

Section 301 states that the discharge of any contaminant is illegal (with certain exceptions) and that effluent limitations must be set for point sources and publicly owned treatment works. Section 305 requires a biennial report of how well state waters support balanced populations of shellfish, fish, and wildlife. The report will recommend ways to achieve balanced populations by outlining methods to control nonpoint sources of pollutants. Section 309 outlines penalties for violators of limitations or permit conditions.

It should be noted that although there is an established Federal criteria for pollutants, the states have their own standards. According to Section 510 of the CWA, the states' standards concerning discharges of pollutants cannot be less stringent than the standards in effect under the CWA and, in fact, may be more stringent. A pollutant may meet the Federal limits, but not the state's, therefore, FWS personnel should also be familiar with standards established by the state.

Under Section 311, the discharge of oil and hazardous substances into navigable waters is prohibited (excluding discharges made in compliance with a NPDES permit). The National Contingency Plan (301d) states that after a spill, the discharger must contain and clean up the spill or pay the responsible government agencies to do so. Because it is often debated how 'clean' a site must be after a spill, monitoring baseline data before the spill would be of great importance.

Section 402 states that the EPA is authorized to issue permits for the discharge of all point source pollutants into U.S. waters (40 CFR 122-125) under the National Pollutant Discharge Elimination System (NPDES) program. The FWS may review and comment on all permit applications.

Section 404 gives the U.S. Army Corps of Engineers and EPA authority to issue permits for the discharge of dredged or fill material into navigable waters. The FWS is authorized to review these proposed permits and submit comments to the EPA.

Section 302 of the WQA authorizes the states to estimate the total maximum daily thermal load and total maximum daily load of pollutants listed in 45 CFR 79318-41. Section 319 requires states to identify waters that cannot reach or maintain water quality standards given in this WQA without additional nonpoint source controls. An important aspect of the WQA is that it requires each state to submit a management program for assessing and controlling nonpoint source pollution within its boundaries.

Section 306 states that EPA shall establish national standards of performance for a variety of industrial and commercial processes. These standards can be found in 40 CFR 125.

The WQA provides a number of provisions to further improve municipal wastewater treatment. Section 406 sets forth a comprehensive program for reducing the environmental risks of sludge disposal. The WQA also establishes a 1992 deadline for the development of a NPDES permits for storm-water discharges from industrial and municipal storm sewers.

Section 105 authorizes the EPA, in conjunction with the FWS, to conduct research on the bioaccumulation of pollutants in aquatic organisms and on methods designed to decrease and eliminate these pollutants from the affected organisms.

2.5 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Superfund) - 1980 and Superfund Amendments and Reauthorization Act (SARA) - 1986

The CERCLA (42 USCA §§ 9601 et seq.) is administered by the EPA and establishes a program to identify sites from which releases of hazardous wastes might occur (or have already occurred) and to ensure that these sites will be cleaned up by the responsible parties. Until such cleanup does occur by those parties, or if no responsible parties can be identified, EPA may use Federal funds ("Superfund") to do so. The Department of the Interior has a Memorandum of Understanding (MOU) with the EPA to carry out Preliminary Natural Resource Surveys (PNRS) on identified waste sites. The FWS is responsible for the biological assessments of these sites.

Section 103 states that if a release of a hazardous substance does occur, the National Response Center established by the Clean Water Act must be notified or a penalty will be imposed. Section 107 addresses liability for the cost of removal or remedial action in response to a release of a hazardous substance. The liability extends to damages or destruction of natural resources. Section 108 addresses financial responsibility for releases from vessels or facilities. Section 109 lists the penalties for violators of Sections 103 and 108 and lists the awards for individuals providing information about violators.

Sections 104 and 105 relate to the removal and remediation of a release or threatened release of a hazardous substance. Section 105 requires EPA to establish a National Priorities List (NPL) of sites to be given priority for such a response. Criteria for the NPL sites are based in part on risk to human health, potential for ecosystem destruction, damage to natural resources, and contamination or potential contamination of the ambient air, all of which may result from a release.

The Superfund Amendments and Reauthorization Act (SARA) of 1986 is a 5-year extension of CERCLA with extensions beyond 1992 expected. SARA sets standards for the health and safety of employees engaged in hazardous waste operations, outlines the cleanup of petroleum from leaking underground storage tanks, and sets up a "Defense Environmental Restoration Account" in the Department of Defense.

The Secretary of Defense may enter into agreements with other federal, state, or local agencies to carry out its responsibilities for the "identification, investigation, and clean-up of any off-site contamination resulting" from Department of Defense facilities. Since FWS refuges may be located on or near such facilities, this Act could be used to justify funding for remediating and monitoring affected FWS lands.

2.6 Emergency Planning and Community Right-to-Know Act - 1986

The Emergency Planning and Community Right-to-Know Act establishes requirements concerning emergency planning and notification, reporting requirements, and other general enforcement provisions. The Act mandates that industry have material safety data sheets (MSDS), emergency and hazardous chemical inventory forms, and toxic chemical release forms. These forms are available to the community, workers, and other appropriate groups and can be obtained from local emergency planning committees, local fire departments, the state commission, or city, state, or regional EPA offices.

Chemical inventories can also be obtained by FWS personnel to estimate the quantity of hazardous chemicals used and released by a facility. These lists will be useful for; a) locating contaminant sources, b) identifying the types of contaminants associated with the sources, c) how the contaminant is processed or used, d) how it is treated, and e) where, and in what quantity, the contaminant is released. EPA's toxic chemical release inventories (TRI) are authorized for public release (Section 313). The TRIs contain data for over 300 chemicals and categories of chemicals from facilities with Standard Industrial Classification (SIC) codes 20 through 39. The TRIs are available on computer compact-disc (CD-ROM) or through computer 'on-line' services (see Volume 1 for more information about environmental databases).

2.7 Endangered Species Act (ESA) - 1973

The Endangered Species Act (16 USCA §§ 1531-43) prohibits the import or trade in any product made from endangered species unless it is used for an approved scientific purpose. The primary responsibility of the FWS with respect to the ESA is to list endangered and threatened species (other than marine) and then protect and restore the species. Selected species are placed on lists along with critical habitats necessary for their survival. The species list is updated on an ongoing bases.

The FWS may list a species as endangered or threatened based on any of the following factors: (1) the present or threatened destruction, modification, or curtailment of habitat or range, (2) over-utilization for commercial, recreational, scientific, or educational purposes, (3) disease or predation, (4) the inadequacy of existing regulatory mechanisms, or (5) other natural or man-made factors affecting its continued existence (Brooks and O'Riordan, 1990). The ESA establishes a private right to action and encourages citizens to "bring civil suits...to force compliance with any provision of the Act".

Section 4 outlines the process for listing species as endangered or threatened. Section 7 requires that all Federal agencies plan their projects to preclude negative impacts on a listed species or its habitat. Agencies must consult with the Secretary of the Interior or the FWS regarding potential impacts to endangered species and their habitats. Among the factors to be considered in planning a project are potential contaminant impacts to threatened and endangered species. Section 9 prohibits "any person" from taking or harming an endangered or threatened species. In 1975 the FWS broadly defined the term "harm" to include habitat modification actions that significantly disrupt essential behavioral patterns (50 CFR 17.3). Section 11 outlines penalties for violators of the Act.

2.8 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) - 1947

The FIFRA (7 USCA §§ 136 et seq.), as amended by the Federal Environmental Pesticide Control Act (FEPCA) of 1972 and the FIFRA amendments of 1975, 1978, 1980, and 1988 is a complex statute. Essentially, the FIFRA authorizes the EPA to regulate the production, registration, marketing, and use of pesticides. This Act also has the mechanisms for taking action against pesticides considered harmful to human health or the environment. Pesticides may be cancelled (initiation of a review on a pesticide) or suspended (an immediate ban on the production and distribution of a pesticide).

Penalties are given in Section 14 for violations of the Act. Section 20 states that the EPA shall monitor air, soil, water, humans, plants, and animals with regard to incidental pesticide exposure, in cooperation with other Federal, state and local agencies, one of which is the FWS. The only organized involvement of the FWS is through Section 7 of the Endangered Species Act (Section 1.3.11).

2.9 Fish and Wildlife Act (FWA) - 1956

The FWA establishes national fish and wildlife policies and directs for continuing research programs for fish and wildlife on national and international levels. Section 7 of the Act directs the

Secretary of the Interior to take the necessary steps to guarantee proper development, management, conservation, and protection of fishery resources.

The FWA identifies research, acquisition of refuge lands, and development of existing facilities as the means of protecting resources. The FWA is the legal basis for FWS's day-to-day involvement with fish and wildlife and is the basis for contaminant research and information transfer (FWS, 1986).

2.10 Fish and Wildlife Coordination Act (FWCA) - 1934

The FWCA (16 USCA §§ 661-67) empowered the Bureau of Biological Survey (now the Fish and Wildlife Service) to study the effects of pollutants on wildlife resources. The Act and its amendments in 1946, 1956, and 1958 state that any public or private entity proposing modifications to any body of water except those under 10 acres or those designated by Federal agencies for land management (Section 662) must consult with the Secretary of the Interior, through the FWS.

Section 665 authorizes the FWS to study "the effects of domestic sewage, mining, petroleum, and industrial wastes; erosion silt; and other pollutant substances on wildlife and to make reports to Congress concerning such investigations and of recommendations for alleviating dangerous and undesirable effects of such pollution." These investigations include determining water quality standards necessary to protect fish and wildlife resources, methods for decreasing and preventing pollution, and the collection and distribution of data involved in such investigations.

Section 666(b) defines "wildlife" as "birds, fishes, mammals, and all classes of wild animals and all types of aquatic and land vegetation upon which wildlife is dependent." This section also provides for penalties for noncompliance with Sections 661 through 666.

2.11 Groundwater Legislation

Groundwater laws can be divided into two main categories; groundwater quantity laws and groundwater quality laws. Groundwater quantity management is mostly a state and local responsibility, with extensive assistance provided by various federal agencies. Groundwater quality law is largely a federal responsibility, with jurisdiction usually under the EPA (Redwine et al., 1991). The federal approach to groundwater management has not been administered by a single comprehensive program. Instead, an array of individual laws that pertain to specific contaminant sources, have gradually been established over time (e.g., CWA, RCRA, TSCA, CERCLA, FIFRA). The Safe Drinking Water Act in particular addresses issues relating to protecting the quality of groundwater.

The EPA groundwater protection plan classifies groundwater into three classes; Class 1 - special or clean groundwater, Class 2 - current and potential groundwater sources, and Class 3 - groundwater not considered potential sources of drinking water or of beneficial use. The EPA accords different levels of protection to each groundwater class.

2.12 Marine Mammal Protection Act (MMPA) - 1972

The purpose of the MMPA (16 USCA §§ 1361-1407) is to protect and conserve marine mammals, and to encourage international research about marine mammals (Arbuckle et al., 1992). The MMPA imposes a moratorium on the taking or import of marine mammals or products made from them into the country. Under this Act commercial whaling in U.S. water is illegal. Permits may be issued to indigenous people, for scientific research, public display, and for incidental taking during commercial fishing operations. The Secretary of Commerce is given management responsibility for cetaceans and pinnipeds other than walruses. The Secretary of Interior is given responsibility for all other marine mammals.

Execution of the MMPA goals (the conservation, preservation and research of marine mammals) must be based upon a better understanding of marine ecosystems. A biomonitoring program can help achieve these goals. The MMPA can justify the use of marine mammals in a biomonitoring program.

2.13 Marine Protection, Research and Sanctuaries Act (MPRSA) - 1972

The MPRSA (33 USCA §§ 1401-2623) authorizes EPA to regulate dumping of any material into territorial ocean waters by any person or government agency. It is often referred to as the Ocean Dumping Act. This Act prevents or restricts dumping materials in the ocean that would have deleterious effects on shellfish beds or fishing areas, as well as other fish and wildlife resources.

Section 102 states that the EPA will regulate dumping by issuance of ocean dumping (301) permits. Under the Fish and Wildlife Coordination Act, the FWS has the authority to review and comment on all such proposed ocean dumping permits. The appropriate EPA regional office can be contacted to ensure that permit applications are being received for review by the FWS.

2.14 Migratory Bird Treaty Act (MBTA) - 1918

The MBTA (16 USCA §§ 703-12) implements treaties between the United States, Canada, Mexico, Japan, and the former Soviet Union. Under the MBTA all migratory birds are protected and it is illegal to take any migratory bird. "Taking" has been interpreted to include deaths resulting from pesticide poisoning, as in U.S. versus FMC and U.S. versus Corbin Farm Services, both in 1978. Thus, this Act can be an enforcement tool and a mechanism for involvement when protected birds are impacted by pesticides or other contaminants.

2.15 National Environmental Policy Act (NEPA) - 1970

The NEPA (42 USCA §§ 4321-47) creates a national environmental policy by using all practical means to carry out Federal activities in ways that promote the health of the environment. The Council on Environmental Quality (CEQ) was established by NEPA to monitor progress in implementing this policy. Section 102 of NEPA states that an environmental impact statement (EIS) must be prepared when Federal agencies propose an action that would significantly affect the quality of the human environment; Federal action includes providing funding to others. The EIS must detail the environmental impact of and alternatives to these proposals. The agency preparing the EIS must

consult with and get comments from any other Federal agency, including the FWS, that has jurisdiction by law or special expertise regarding the impacts involved.

2.16 Oil Pollution Act (OPA) - 1990

The OPA (P.L. 101-380) addresses problems associated with preventing, responding to, and compensating for oil pollution from tanker- and facility-caused pollution (Arbuckle et al., 1992). Specific sections of the OPA include:

- Requires better planning and preparedness and measures to increase navigation safety (Section 4101)
- New standards for vessel construction (mandates double-hulls on ships) (Section 4115)
- New standards for crew licensing and manning (Section 4106, 4114)
- Extends the responsibility that owners and operators have to their vessels and facilities (Section 1002) and associated penalties and liabilities (Section 4003, 8201)
- Places a limited moratorium on lease sales on the Outer Banks area off the North Carolina coast (Section 6003)

The FWS qualifies as a Federal trustee of the nation's natural resources (Section 1006) and is directed to "assess natural resource damage" and "develop and implement plans for the restoration, rehabilitation, replacement, or acquisition of natural resources" (Section 1006 (c)). The Director of the FWS is directed to work with other agencies to "promulgate regulations for the assessment of natural resource damage" from discharges of oil (Section 1006 (e)). The FWS is also named into membership of an interagency coordination committee on oil research (Section 7001).

2.17 Pollution Prevention Act (PPA) - 1990

The PPA (P.L. 101-508) establishes a waste management hierarchy with priority given to source reduction. The Act emphasizes the reduction of industrial wastes through changes in equipment and technology, reformulation and redesign of products, substitution of raw materials, and improvements in maintenance, training, and inventory control. Sections 6602 through 6607 requires the EPA to advance industrial pollution prevention using the following measures:

- Identify measurable goals
- Improve measurement, data collection, and access to data
- Assess existing and proposed programs and identify barriers
- Offer grants for state-level technical assistance programs
- Require more data from toxic emitters
- Identify opportunities to use federal procurement to encourage source reduction
- Establish awards programs.

This Act may be used to encourage source reduction of wastes associated with activities impacting FWS lands.

2.18 Refuge Protection Act (RPA) - 1962

The RPA (16 USCA §§ 460 et seq.) allows refuges to be used for public recreation as long as such recreational use will not interfere with the primary purposes for which the areas were established. The Secretary of the Interior is authorized to acquire lands which are a) suitable for fish and wildlife oriented recreation, b) in need of protection of their natural resources, or c) needed to conserve and protect endangered or threatened species. The RPA authorizes the FWS to cooperate with other public and private agencies and accept financial and/or property donations. Under this Act the FWS may establish fees and issue permits for the public use of its lands. This act might be used to limit public access or recreation found to have deleterious effects on wildlife.

2.19 Resource Conservation and Recovery Act (RCRA) - 1976

The RCRA (42 USCA §§ 6901-92) is administered by EPA and regulates the management of hazardous waste by prohibiting future open disposal of such materials and requires that existing open landfills be improved. The FWS consults with EPA on the selection of waste disposal sites so the facility will not adversely impact fish and wildlife resources.

Section 3005 presents the requirements for acquiring permits for the treatment, storage, or disposal of hazardous waste. Under Section 3008, the EPA may issue a compliance order or seek an injunction against a person violating the Act. It also imposes penalties for violators of compliance orders or for "knowingly" violating certain other sections of the Act.

Each state must submit a plan for management of solid waste. Under Section 4005, such plans must include a requirement that all existing open dumps be upgraded to eliminate or decrease health hazards.

2.20 River and Harbor Act - 1899

Section 10 of this Act gives the Army Corps of Engineers the authority to issue permits for excavating or depositing material and for the depositing of refuse in navigable water. The 1958 amendments to the Fish and Wildlife Coordination Act gives the FWS the authority to comment on any activities that could potentially modify the quality of these bodies of water. The Corps is required to give full consideration to the FWS's recommendations.

An MOU was signed in 1967, between the secretaries of the Army and the Interior; and in 1968, the Corps included consideration of fish and wildlife, conservation, and pollution in its permit review policy. Thus, environmental contaminants must be taken into account when issuing permits.

2.21 Safe Drinking Water Act (SDWA) - 1974 and Safe Drinking Water Act Amendments - 1986

The SDWA (42 USCA §§ 300f et seq.) and its amendments regulate the operation of public water systems, protect underground sources of drinking water, and provide other general provisions to assure safe drinking water standards as related to the public health and welfare. The SDWA requires EPA to identify contaminants which may have an adverse effect on human health and, where feasible, specify Maximum Contaminant Levels (MCL). The MCL is the maximum permissible concentration of a contaminant in water which is delivered to any user of a public system. The MCL is usually considered the level for the National Primary Drinking Water Regulations (NPDWR). Eighty-three contaminants have been identified to be regulated under the SDWA (42 CFR 70).

The SDWA regulates the use of subsurface injection wells through the Underground Injection Control (UIC) Program. The UIC program mostly affects hazardous waste disposal, the reinjection of oil and gas production byproducts, and certain mining processes.

The SDWA establishes two 'standards' used to categorize drinking water; a) primary standards are the maximum concentrations allowed of contaminants known to have an adverse effect on human health, and b) secondary standards refer to the maximum contaminant levels for substances which may adversely affect the appearance or aesthetics of drinking water.

2.22 Surface Mining Control and Reclamation Act (SMCRA) - 1973

The SMCRA (30 USCA §§ 1201-1328) establishes a nationwide program, administered by the Office of Surface Mining Reclamation and Enforcement, for the regulation of surface mining activities and the reclamation of surface-mined lands. An Abandoned Mine Reclamation Fund is established under Section 401.

Section 506 authorizes the office to issue surface mining permits. Before permits are issued, the FWS has the authority, given by the FWCA, to comment on such proposed permits. Section 515 requires that all surface coal mining and reclamation operations minimize disturbances and unfavorable impacts on fish and wildlife and achieve enhancement of these resources where possible. Section 522 prohibits any surface coal-mining operations on any of the lands of the National Wildlife Refuge System, except for those already existing when this Act was enacted.

2.23 Toxic Substances Control Act (TSCA) - 1976

The TSCA (15 USCA §§ 2601-71) authorizes EPA to obtain industry data that would assist in identifying and evaluating potential hazards of both new and old chemical substances. Section 6 authorizes the EPA to prohibit or limit the production, distribution, use, and disposal of a substance if it is determined that unreasonable risk or injury to health or the environment may result from its use.

Section 10 states that the EPA shall consult with other appropriate departments and conduct whatever research and monitoring is necessary to implement the act. The FWS should function as advisor to EPA on data needs necessary to evaluate chemical impacts on fish or wildlife resources.

3. GUIDE TO LEGISLATION PERTINENT TO CONTAMINANT MONITORING

It is important that FWS personnel concentrate on problems for which they have a "clear-cut mandate for involvement and favorable probability of achieving . . . [their] goals" (NWRS, 1982). The Legislation Matrix (Table 1) provides a quick reference to legislation and associated sections applicable to FWS biomonitoring activities. The matrix indicates sections of the law that provide a justification for biomonitoring activities as part of protecting fish and wildlife resources.

3.1 Legislation Matrix

All of the legislation in the matrix is as amended and may be found in the U.S. Code Annotated (USCA) by reviewing the general index by popular name and year that the law was enacted. Relevant sections of the law are also provided in the matrix. Each topic addressed by a given section of a law is numbered to indicate its potential application to biomonitoring activities. Only those topics directly addressed by an Act have an associated number. So, if the topic is not specifically mentioned in the law; it is not listed. It is up to the user to determine how the section is applicable. For example, Section 10 of the River and Harbor Act gives the Army Corps of Engineers the authority to issue permits for depositing refuse in navigable water. This will likely affect water quality and habitat. It can be inferred that fish and wildlife in the water will also be affected, although there is not a number under the Fish and Wildlife column. In this regard, the refuse and/or its constituents may be viewed as a contaminant(s) and appropriate monitoring may be warranted.

The regulations column indicates the regulations authorized by the laws and the appropriate Code of Federal Regulations (CFR) where they are found. The CFR contains legally recognized regulations published in the Federal Register by departments and agencies of the Federal Government. The CFR is divided into titles that represent broad domains subject to Federal regulation. FWS personnel will find Title 40, "Protection of the Environment" and Title 50, "Wildlife and Fisheries," especially useful.

The following is a practical example of how the matrix may be used. FWS personnel observe a number of dead bass in a stream on FWS lands. To determine a potential cause of the incident, water samples are taken and a high concentration of chemical "X" is found. It is known that chemical "X" is released from factory "Y" upstream from the FWS lands. The regulations authorized by the CWA are reviewed. Code 40 CFR 405-471 provides effluent guidelines and standards of pollutants, separated by industry; 40 CFR 117.3 lists reportable quantities for hazardous substances; and 45 CFR 79318-41 lists the Federal water quality criteria for freshwater aquatic life for toxic pollutants or pollutant categories. The chemical is found on all three lists and has exceeded its limits. Factory "Y" has not reported the discharge, although it was a reportable quantity. FWS personnel may bring this to the attention of the EPA, which may impose penalties according to 40 CFR 117.22. The owner of factory "Y" is also liable for removal of chemical "X", according to 40 CFR 117.23, and for death of the bass and for costs including assessing loss resulting from the release of chemical "X" (CERCLA, Section 107).

If the concentration of chemical "X" is under the limit, action may still be taken. Section 305 of the CWA requires that biennial analyses of state waters be carried out to determine what level of water quality is necessary to protect and guarantee for the reproduction of these fish, so the FWS may

make recommendations that the water quality standard for chemical "X" be decreased. Also, the factory must have a NPDES permit for the discharge of chemical "X" (CWA, Section 402). The permit may be modified if the level of chemical "X" is judged to be toxic. If the level is above that allowable in the permit, the factory owner will be liable for penalties (CWA, Section 309).

Table 1. LEGISLATION MATRIX - Topics Relevant to the U.S. Fish and Wildlife Service Addressed by the Legislation*

Legislation and Administrating Agency	Section of Legislation	Fish and Wildlife	Water Quality	Air Quality	Habitat	Contaminants	Regulations** (40 CFR unless noted:)
Anadromous Fish Conservation Act (FWS, NMFS)	2 6 7	3 3					
Bald and Golden Eagle Protection Act (FWS)	101	2 4 5					
Clean Air Act (EPA)	109 120 163 164 410 411 707		 3 3 	2 4 7 2 4			7(50.4-50.9) 7(50.11-50.12) 7(60) 7(61)
Clean Water Act (EPA)	105 301 303 305 309 311 319 402 404	3 3 	 2 2 6 4 3,6 5 5			3,6 3,6 	7(117.3) 4(117.22) 4(117.23) 5(122) 5(125) 4(135) 7(45 FR 79318-41) 7(405-471)
Comprehensive Environment Response, Compensation, and Liability Act (EPA)	103 104 105 107 108 109					4 6 6 4 4 4	6(300.32) 6,8(300.74)
Emergency Planning and Right-to-Know Act (EPA)	311 312 324 326 401			 1,2,3,4		2 2 2 4 	

* 1 = Management
2 = Regulations and/or guidelines or provision for establishing regulations
3 = Research
4 = Provisions for litigation, enforcement, penalties, and/or liability
5 = Issuance of permits and/or registration
6 = Remedial action
7 = Limits
8 = Damage assessment

** The CFR regulations authorized by each act are listed in numerical order and do not correspond to the legislation sections on the same line.

Table 1. (continued)

Legislation and Administrating Agency	Section of Legislation	Fish and Wildlife	Water Quality	Air Quality	Habitat	Contaminants	Regulations** (40 CFR unless noted:)
Endangered Species Act (FWS)	7 11	3 4			3		50 CFR 17.3
Federal Insecticide, Fungicide, and Rodenticide Act (EPA)	14 20	3	3	3		4 3	
Fish and Wildlife Act (FWS)	7	1,3				3	
Fish and Wildlife Coordination (FWS, BOM)	665 666	6 4	2 4			1,6 4	
Marine Mammal Protection Act (DOI, FWS, DOC)		1,2,3					50 CFR 18.3 (216)
Marine Protection, Research and Sanctuaries Act (EPA)	102 105 107		5 4 4				5(221-223)
Migratory Bird Treaty (FWS)		4					
National Environmental Policy Act (CEQ)	102	3	3	3	3		
Oil Pollution Act (EPA, FWS)	1002 1006 4003 4106 4115	1,2,3,8	4 4 2 2		4 4		
Pollution Prevention Act (EPA)	6004					1	
Refuge Protection Act (FWS)	460	1	1		1		
Resource Conservation and Recover Act (EPA)	3005 3008 4005					5 4 6	7(264.94)
River and Harbor Act (Army Corps of Engineers)	10		5		5		

* 1 = Management
2 = Regulations and/or guidelines or provision for establishing regulations
3 = Research
4 = Provisions for litigation, enforcement, penalties, and/or liability
5 = Issuance of permits and/or registration
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** The CFR regulations authorized by each act are listed in numerical order and do not correspond to the legislation sections on the same line.

Table 1. (continued)

Legislation and Administrating Agency	Section of Legislation	Fish and Wildlife	Water Quality	Air Quality	Habitat	Contaminants	Regulations** (40 CFR unless noted:)
Safe Drinking Water Act (EPA)	1412 1413 1414 1421 1422		2 1 4 2 4			2	
Surface Mining Control and Reclamation (Office of Surface Mining Reclamation and Enforcement)	401 506 515 522		6		6 5 6 2		
Toxic Substances Control Act (EPA)	6 16					2 4	

* 1 = Management
2 = Regulations and/or guidelines or provision for establishing regulations
3 = Research
4 = Provisions for litigation, enforcement, penalties, and/or liability
5 = Issuance of permits and/or registration
6 = Remedial action
7 = Limits
8 = Damage assessment

** The CFR regulations authorized by each act are listed in numerical order and do not correspond to the legislation sections on the same line.

Table 2. An alphabetical listing of environmentally related federal legislation

Acid Precipitation Act - 1980
Air Quality Act - 1967
Alaskan National Interest Lands Conservation Act - 1980
Antarctic Conservation Act - 1978
Antiquities Act - 1906
Acquired Lands Act - 1947
Archeological Resources Protection Act - 1979
Atomic Energy Act - 1954
Bald and Golden Eagle Protection Act - 1940
Clean Water Act - 1977
Clean Air Act - 1955, 1967, 1970, 1977, 1990
Coastal Barrier Resources Act - 1982
Comprehensive Environmental Response, Compensation, and Liability Act - 1980
Department of Transportation Act - 1966
Eastern Wilderness Act - 1975
Emergency Planning and Community Right-to-know Act - 1986
Endangered Species Act - 1973
Endangered American Wilderness Act - 1978
Endangered Species Preservation Act - 1966
Environmental Education Act - 1990
Federal Land Policy and Management Act - 1976
Federal Roads and Trails Act - 1964
Federal Water Pollution Control Act - 1956
Federal Environmental Pesticide Control Act - 1972
Federal Insecticide, Fungicide, and Rodenticide Act - 1947
Federal Water Power Act - 1920
Federal Aid in Wildlife Restoration Act - 1937
Federal Power Act - 1986
Fish and Wildlife Conservation Act - 1980
Fish and Wildlife Coordination Act - 1934
Fish and Wildlife Improvement Act - 1978
Fisheries Conservation and Management Act - 1976, 1978, 1982
Floodplains Management Act - 1936
Forest Reserves Management Act - 1974, 1976
Forest and Rangeland Renewable Resources Act - 1974, 1978
Forest Reserve Act - 1891
Forest Management Act - 1897
Fur Seal Act - 1966
General Mining Law - 1872
Geothermal Steam Act - 1070
Hazardous Material Transportation Act - 1975
Homestead Act - 1862
International Environmental Protection Act - 1983
Interstate Highway Act - 1956
Lacey Act - 1900

Table 2 (continued)

Land Ordinance Act - 1785
Land And Water Conservation Act - 1964
Liability Act - 1980
Marine Mammal Protection - 1972, 1984
Marine Protection, Research, and Sanctuaries Act - 1972
Marine Plastic Pollution Research and Control Act - 1987
Migratory Bird Treaty - 1918
Mining and Minerals Act - 1970
Morrill Act - 1862
Multiple-Use, Sustained-Yield Act - 1960
National Wild and Scenic Rivers Act - 1968
National Coastal Zone Management Act - 1972, 1980
National Energy Conservation Policy Act - 1978
National Parks and Recreation Act - 1978
National Trails System Act - 1968
National Parks Act - 1916
National Forest Management Act - 1976
National Environmental Policy Act - 1970
National Historic Preservation Act - 1966
National Wildlife Refuge System Administration Act - 1966
Noise Control Act - 1972
Nuclear Waster Policy Act - 1982
Occupational Safety and Health Act - 1970
Ocean Dumping Reform Act - 1988
Oil Pollution Act - 1990
Outdoor Recreation Coordination Act - 1963
Outer Continental Shelf Lands Act - 1978
Pollution Prosecution Act - 1990
Pollution Prevention Act - 1990
Port and Tanker Safety Act - 1978
Public Rangelands Improvement Act - 1978
Reclamation Reform Act - 1982
Reclamation Act - 1902
Refuge Protection Act - 1962
Resource Conservation and Recovery Act - 1976
Resource Recovery Act - 1970
Rivers and Harbors Act - 1899
Safe Drinking Water Act - 1974
Salmon and Steelhead Conservation and Enhancement Act - 1980
Soil Conservation Act - 1935
Soil and Water Conservation Act - 1977
Solid Waste Disposal Act - 1965
Species Conservation Act - 1966, 1969
Superfund Amendments and Reauthorization Act - 1986
Surface Mining Control and Reclamation Act - 1977
Surface Resources Act -1955

Toxic Substances Control Act - 1976
Water Quality Act - 1966, 1987
Water Resources Development Act - 1986
Water Pollution Control Act - 1948, 1956, 1972, 1977, 1987
Weeks Act - 1911
Whale Conservation and Protection Study Act - 1976
Wild, Free-Roaming Horses and Burros Act - 1971
Wilderness Act - 1964
Yellowstone Park Act - 1872

Table 3. Worksheet for listing and evaluating applicable environmental legislation.

NAMES:_____

SERVICE LAND:_____ DATE:_____

LAW	RELEVANCE	ACTION REQUIRED	PRIORITY*

* 1 = Immediate Action
2 = Near Term
3 = Long Term

4. REFERENCES

Arbuckle, J. G., et al. 1992. Environmental Law Handbook, 12th ed., Government Institutes, Inc., Rockville, Maryland.

Brooks, C.E. and W.H. O'Riordan, 1990. The ESA: A Practitioner's Point of View. Natural Resources & Environment, vol. 4.

FWS, 1986. Field Operations Manual for Resource Contaminant Assessment, UDOI, Resource Contaminant Assessment Division, U.S. Fish and Wildlife Service, Washington, DC.

NWRS, 1982. U.S. Fish and Wildlife Service Refuge Manual, National Wildlife Refuge System, U.S. Fish and Wildlife Service.

Quarles and Lewis, 1990. The Clean Air Act of 1990. Morgan, Lewis, & Bockius, Washington D.C.

Redwine, J.C., A.R. Burton, K.W. Boyd, R.J. Tinsley and J.L. Mintz, 1991. Groundwater Manual for the Electric Industry, 2nd ed. Electric Power Research Institute, Calif.

Tiner, R. W., Jr., 1984. Wetlands of the United States: Current Status and Recent Trends. U.S. Department of the Interior, Fish and Wildlife Service.

5. BIBLIOGRAPHY

Beltz, W.A. (ed.). Environmental Reporter. Bureau of National Affairs, Washington D.C.

BOR, 1986. U.S. Bureau of Reclamation, Final Environmental Impact Statement, Volume II, Kesterson Program. Mid-Pacific Region in Cooperation with U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers.

Coggins G.C. and C.F. Wilkinson, 1984. Federal Public Land and Resources Law: Statutory Supplement. The Foundation Press, Inc., Mineola, New York.

DiPolo, C. (ed.). Journal of Environmental Regulation. Executive Enterprises Publications Co., New York, New York.

Environmental Compliance Handbook Series. Executive Enterprises Publications Co. New York, New York.

Environmental Health & Safety. Government Institutes, Rockville, Maryland.

Environmental Nutshell Series. West Publishing Company, St. Paul, Minnesota.

Environmental Law, Volume I (Environmental Decision Making and NEPA), Volume II (Water Pollution and Hazardous Waste), and Volume III (Air Pollution). Anderson Publishing Co., Cincinnati, Ohio.

Environmental Law Series. Clark Boardman, New York, New York.

U.S. EPA. Access EPA. Information Access Branch, Information Management And Services Division, Washington D.C.

U.S. EPA. Inside EPA's Environmental Document Service. Energy & Environmental Document Service, Washington D.C.

U.S. EPA. EPA Journal. Office of Communications, Education, and Public Affairs. Washington D.C.

Federal Interagency Committee for Wetland Delineation. 1989. Federal Manual for Identifying and Delineating Jurisdictional Wetlands. 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, Washington D.C. Cooperative technical publication.

FWS, 1986. Preliminary Survey of Contaminant Issues of Concern on National Wildlife Refuges. U.S. Fish and Wildlife Service, Division of Refuge Management.

U.S. General Accounting Office. Index of Reports and Testimony. Office of Public Affairs, Washington D.C.

Grad, F.P., 1991. Treatise on Environmental Law. Matthew Bender & Co., Washington D.C.

Jacknow, J., J. L. Ludke, N. C. Coon, and K. S. Mayer, 1986. Monitoring Fish and Wildlife for Environmental Contaminants. The National Biomonitoring Program.

Magee, S. (ed.) Federal Facilities Environmental Journal. Executive Enterprises Publications Co., New York, New York.

Mason, R.J. and M.T. Mattson, 1990. Atlas of United States Environmental Issues, Macmillan Publishing Co., New York.

Olive, S. W. and R. L. Johnson, 1986. Environmental Contaminants: Selected Legal Topics. U.S. Fish and Wildlife Service Biol. Rep. 87(1). 78 pp.

Ruhl, J.B. ed. Natural Resources & Environment. Section of Natural Resources, Energy, and Environmental Law of the American Bar Association, Chicago, Illinois.

Salvesen, David. 1990. Wetlands: Mitigating and Regulating Development Impacts. Urban Land Institute, Washington D.C.

State Environmental Law Handbook Series. Government Institutes, Rockville, Maryland.

The Natural Resources Law Newsletter. Section of Natural Resources, Energy, and Environmental Law of the American Bar Association, Chicago, Illinois.

Waters and Water Rights. The Michie Company, Charlottesville, Virginia.

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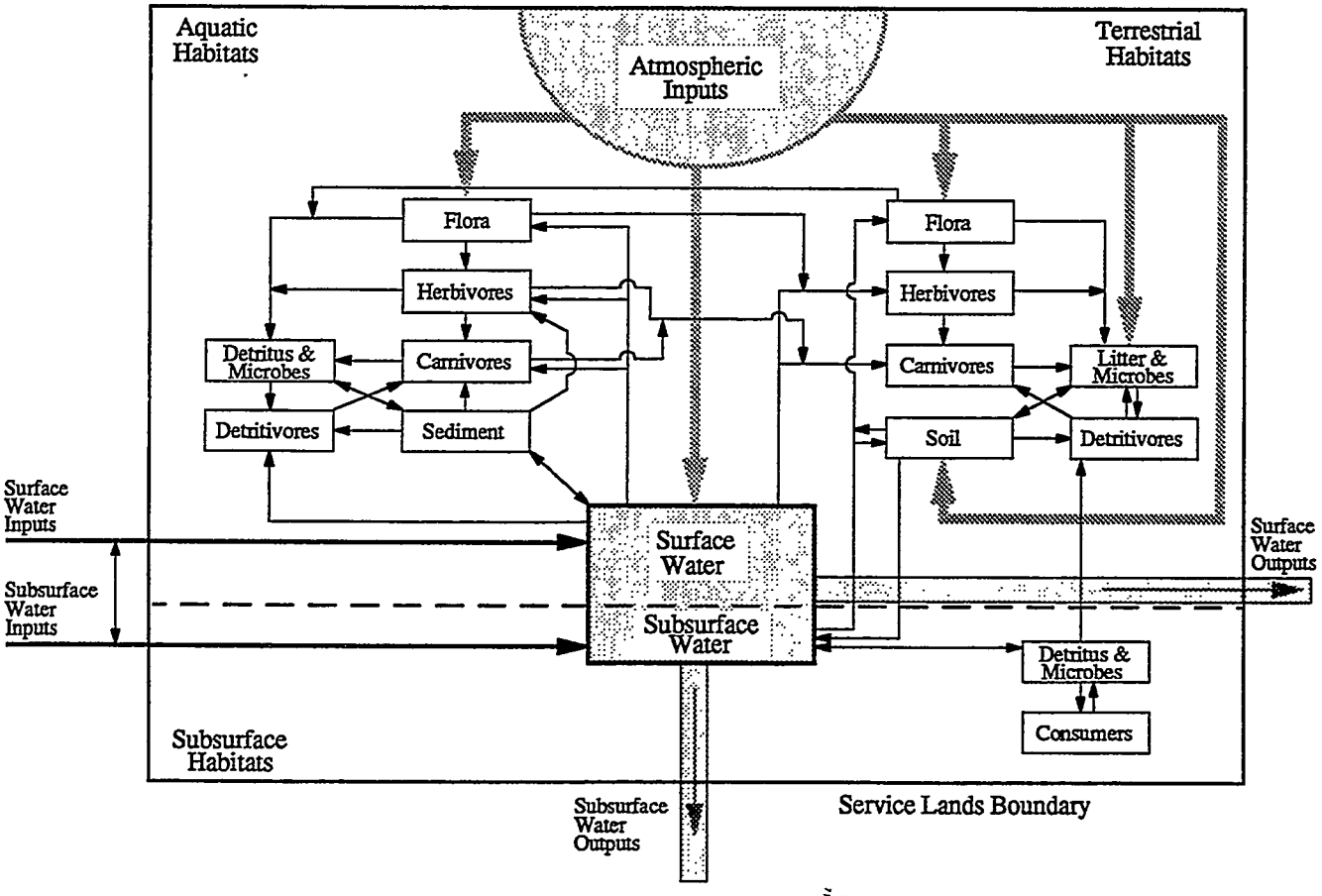
U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

Appendix B

Biomonitoring Operations Workbook



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The opinions, findings, conclusions or recommendations expressed in this document are those of the authors and do not necessarily reflect the views of Research and Development, U.S. Fish and Wildlife Service, Department of the Interior. The mention of trade names or commercial products in this document is for illustrative purposes only and does not constitute endorsement or recommendation for use by the Federal Government.

PREFACE

This is a workbook designed to facilitate the development of contaminant biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the FWS Lands Contaminant Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in contaminant sampling and biomonitoring strategies. A page to document revisions to the Workbook and a sheet for suggested revisions is provided in the front of the Workbook.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
   - D.3 Fish Sampling Reference Field Methods
   - D.4 Flora Sampling Reference Field Methods
   - D.5 Reptiles and Amphibians Sampling Reference Field Methods
   - D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Manual. An example is provided on the first line.

Rev #	Date	Section(s)	Old Pages	New Pages	# of New Pages
EX	10/2/91	2.1	2-4	2-4C	5
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
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18					
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20					

Workbook Revision Worksheet (WS-P)

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

U.S. Fish and Wildlife Service
Division of Environmental Contaminants
4401 North Fairfax Drive, Room 330
Arlington, VA 22201

Commentor's Name		Phone	
Address			
Section to be revised		Page (s)	
Paragraph number(s) (1 = paragraph at very top of page)		Line number(s)	
Suggested Revision:			
References (if applicable):			

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The Workbook Summary is an important component of the Workbook. This will be a summary report that provides a synopsis of the information in the workbook and briefly describes the Service lands, contaminant issues, contaminant biomonitoring strategy, additional information needed, and implementation requirements for the Service lands. This report can reference the workbook and associated worksheets as needed to avoid rewriting detailed information, however, to enhance its use as a stand alone document, this should be minimized. This summary should provide an individual with a general concept of the Service lands, the monitoring goals, issues concerning the health of the ecosystem, requirements necessary for proactive management of the Service lands, and potential future concerns.

Workbook Summary Format

Introduction

Provide the name of the Service lands, its location (state, county, nearest city, etc.), and brief general description [e.g., key species/habitats, associated ecoregion(s) (Omernik), spatial/temporal patterns for the refuge, principal purpose of the Service lands, general information on the area, land use/industries, etc.]. Provide an assessment of the general health of the Service lands and local off-Service land areas extensively used by trust resources.

Monitoring Strategies

Describe the goals of the biomonitoring program, the on- and off-Service lands concerns and whether there have been documented contaminant problems. Also address local habitat degradation issues important to the Service lands and trust resources that use the area.

Provide an overview of the monitoring strategy for the Service lands. Include the media sampled, the environmental variables measured, the chemical analysis conducted, and index period considerations for sampling.

Briefly describe the selected monitoring sites, why they were selected, what is being monitored there, and why. Include information such as: suspected/known contaminants, high risk contaminants, extent of contamination, contaminant sources (industries, land use, etc.), contaminant transport pathways, habitat loss or degradation, potential changes in land use, and other ecosystem health issues.

Discuss monitoring or survey results that have been obtained thus far and provide a summary of the interpretation of these results and their relevance to the Service lands.

Include a section that discusses the logistic issues for monitoring the Service lands. Include information regarding labor requirements, equipment and training needs, sample analyses requirements, climatic and environmental constraints, and other issues that might limit the ability to conduct the monitoring activities. Limitations on available information and research needs should also be discussed here.

As a part of the Workbook Summary, two summary maps should be produced. One map should illustrate the Service lands plus the cities, general land use, and general hydrologic features surrounding the Service lands. This map should include off-Service land areas important to trust resources and those areas being monitored, if any. The second map should provide a larger scale (more detailed) view of the Service lands with the on-Service land monitoring locations identified.

Worksheets WS-1 (below), WS-6.1a, WS-7.3, and WS-8.1 provide summary information that can be used to augment the Workbook Summary.

For Worksheet WS-1, state that the section is "complete" or describe what remains to be done to complete ALL the requested information.

WS-1	STATUS OF INFORMATION FOR WORKBOOK Page __ of __
Section #	Discussion of status and information still needed for each section
2.1	
2.2	
2.3	
2.4	
2.5	
2.6	
2.7	
3.1	
3.2	
3.3	
3.4	
3.5	
4.1	
4.2	
5.	
6.1	

WS-1 STATUS OF INFORMATION FOR WORKBOOK Page ___ of ___	
Section #	Discussion of status and information still needed for each section
6.2	
6.3	
7.1	
7.2	
7.3	
7.4	
8.	

U.S. FISH AND WILDLIFE SERVICE LANDS
BIOMONITORING OPERATIONS MANUAL

APPENDIX B

BIOMONITORING OPERATIONS WORKBOOK

1. INTRODUCTION

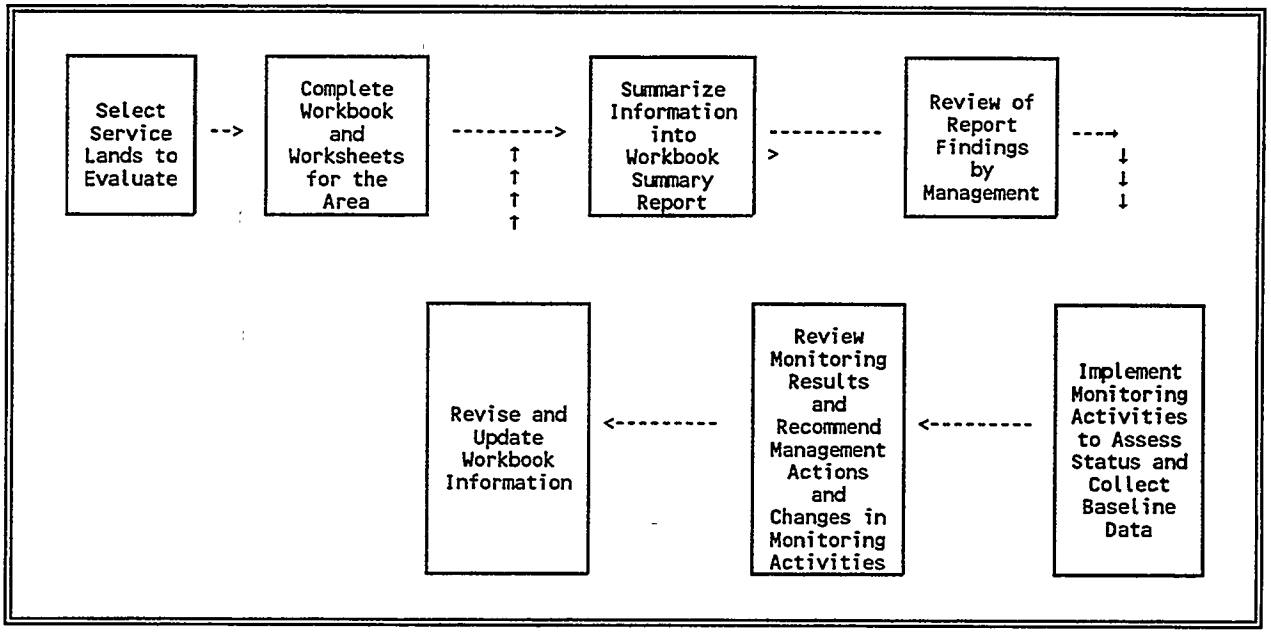
The purpose of this Workbook is to provide a short, concise format to develop and document contaminant biomonitoring strategies for Service Lands and/or other areas used by trust resources. One goal is to monitor contaminant status and trends to determine if contaminants exist that could affect trust resources. Another goal is to monitor the general health of the system and associated trust resources. When this Workbook is complete, much of the information required and decisions necessary to design and implement contaminant biomonitoring activities for this area will be addressed.

The Workbook follows the format and content of Volume 1 of the Fish and Wildlife Service Lands Contaminant Biomonitoring Operations Manual (Manual). Volume 1 **must be read and understood prior** to using this Workbook. The procedures, rationale, and examples for this Workbook are provided in Volume 1. Without guidance from Volume 1, significant defects in the resulting monitoring strategy will occur. Refer to it as you work through the Workbook. It is imperative that the procedures are followed in the order they are presented and that **ALL** relevant information is obtained. Consistent application of the Manual will provide a comprehensive evaluation of the relevant contaminant biomonitoring issues that can be compared with other Service Lands.

This Workbook is designed to be a working document, once completed it can be referred to as necessary to support monitoring decisions. This Workbook and the associated monitoring activities should be reviewed each year. It should be revised as necessary to meet monitoring and management goals and to address questions resulting from monitoring or related activities. Periodic review and evaluation of the monitoring activities and results are critical to a successful monitoring program (See Figure 1).

Some of the tasks described in the Workbook have a space provided to initial when completed. This will help ensure that each task is addressed completely or signal that additional work is needed in that section. Only initial the task when it has been thoroughly completed, this will provide a record of who did the work. If the information collected is incomplete provide a comment in Worksheet WS-1 that describes what still needs to be completed. The Service personnel involved in completing the Workbook must sign and date the space provided on page 2. This will provide future investigators with a contact should questions arise.

Figure 1. Illustration of Process for Completing the Workbook



Follow the procedures provided in Volume 1 and document the information gathered and decisions made in the Workbook. If additional space is required, insert additional rows in the worksheets or additional pages in the appropriate locations of the Workbook. The Workbook is meant to be completed using a computer, this is the reason for the lack of space for handwriting. WordPerfect 5.1 or higher must be used with a 286 or better computer. Once you have completed the Workbook, you can update your Table of Contents by generating a new one (see the end of the electronic Workbook for instruction). It will not affect the existing Table of Contents if you generate it when printing out interim copies.

Complete the following:

Name of Service Lands		FWS Region	
Service Lands Manager			
Phone Number		Fax Number	
Address			
Location (Centroid Coordinates)			
UTM Zone		X (Longitude)	Y (Latitude)
Biomonitoring Coordinator			
	Phone #	Fax #	
Environmental Contaminants Specialist			
	Phone #	Fax #	

	EC SPECIALIST(S)/REFUGE MANAGER UPDATING THE WORKBOOK	DATE
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

2. ASSESS THE SERVICE LAND MANAGEMENT GOALS AND OBJECTIVES RELEVANT TO CONTAMINANT BIOMONITORING

2.1 Management Goals and Objectives for these Service Lands

The purpose of this section is to define and document why these lands are being managed by the Service and associated Service priorities for this area. This information is critical to identifying key trust resources and monitoring goals for the area.

WS-2.1	MANAGEMENT GOALS AND OBJECTIVES FOR THESE SERVICE LANDS Page __ of __
1	
2	
3	
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9	
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2.2 Preliminary Assessment

The purpose of the preliminary assessment is to identify and document existing information, become familiar with previous monitoring studies, assess the AOI relative to contaminant issues, and identify data gaps. The preliminary assessment has two components: 1) compile existing data; and 2) conduct limited field reconnaissance.

____ 1. Conduct a literature search (FWS, other Federal/state agencies, universities, communities, etc.) and compile existing data and data sources for the Service lands that are relevant to contaminant sources, contaminants, receptors, contamination events, land use, etc.

Identify the available information regarding: (check those that apply to this area and complete Worksheet WS-2.2a).

____ • Identify key contacts for existing information
____ • Previous die-offs and suspected causes
____ • Previous notable population effects (e.g., abnormal population declines, malformations, egg shell thinning)
____ • Previous notable abiotic effects (abnormal conditions: suspended solids, water temperature, pH, nitrification, air pollution, etc.)
____ • Previous contaminant events, contaminant sources, specific contaminants, species affected, etc.
____ • Activities on the Service lands that could potentially cause contamination problems (livestock, weed eradication, crops, recreation, etc.)
____ • Results from previous surveys and monitoring efforts
____ • Potential reference site locations or data
____ • Key habitats/communities
____ • Other _____

_____

_____

____ 2. Visit areas on and off the Service lands that might provide useful information, and a perspective that will assist in the characterization process. Complete Worksheet WS-2.2b.

On-Service lands

____ • Visit previous/current contaminant problem areas
____ • Visit suspected contaminated areas
____ • Visit important habitats (based on management goals for the Service Lands)

_____ • Visit areas where surface water is entering the Service Lands
_____ • Visit areas with sensitive habitats and/or key species
_____ • Visit areas that could function as reference or comparison sites
_____ • Visit potential or current monitoring locations (Air,GW,SW,B,SO,SED)
_____ • Other _____

_____ • Other _____

Off-Service lands

_____ • Visit local areas important to trust resources; consider seasonal and daily variability
_____ • Visit previous and/or current problem areas
_____ • Visit surface water and runoff areas that supply the Service lands
_____ • Visit areas where fertilizer/pesticides are used
_____ • Visit areas where potential contaminant sources are located
_____ • Visit areas that could function as reference or comparison sites
_____ • Visit potential or current monitoring locations (Air, SW, SSW, B, SO, SED)
_____ • Other _____

_____ • Other _____

SERVICE LAND NAME "DATE"

WS-2.2a	EXISTING CONTAMINANT AND MONITORING INFORMATION				Page __ of __
	Ref. Material or Contact, Affiliation, & Phone #	Cont. Source *	Cont. Category *	Brief Description of Information	Relevance to Monitoring (location, species, reference site, time of year, etc.)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					

* Use codes from Table 1 at the end of the Workbook.

SERVICE LAND NAME "DATE"

WS-2.2b	FIELD RECONNAISSANCE DATA WORKSHEET				Page __ of __
Personnel on Trip				Date	

	Area Visited (Name/Specific Location)	UTM Coordinates X (long)	Y (lat)	Habitat/Land Use	Flora/Fauna Present	Description	Comments Relevant to Monitoring
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
19							
20							
21							
22							
23							

SERVICE LAND NAME "DATE"

WS-2.2b	FIELD RECONNAISSANCE DATA WORKSHEET				Page __ of __
Personnel on Trip				Date	

	Area Visited (Name/Specific Location)	UTM Coordinates X (long)	Y (lat)	Habitat/Land Use	Flora/Fauna Present	Description	Comments Relevant to Monitoring
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							
36							
37							
38							
39							
40							
41							

2.3 Assessment Considerations for the Service Lands Biomonitoring Activities

The purpose of this section is to identify and document specific characteristics of the Service Lands that should be considered while developing a biomonitoring strategy. These characteristics and associated importance will help identify and prioritize monitoring needs for the area.

WS-2.3 ASSESSMENT CONSIDERATIONS FOR THE SERVICE LANDS BIOMONITORING ACTIVITIES Page __ of __

Rank	Assessment Considerations	Group Code*	Description and Comments Regarding Importance to Monitoring Activities
	Amphibians	AM	
	Anadromous fishes	AF	
	Catadromous fishes and invertebrates	CA	
	Raptors	RA	
	Seabirds	SB	
	Shorebirds	SH	
	Waterfowl	WF	
	Other aquatic birds	QB	
	Other migratory birds	MB	
	Other resident birds	RB	
1	Federally listed threatened & endangered, or candidate species (including research)	ES	
	Exotic/Pest Species	XS	
	Other freshwater species	FW	
	Macroinvertebrates	MI	
	Mammals - Marine	MM	
	Mammals - Terrestrial	MT	
	Marine organisms other than mammals (including invertebrates)	MR	
	Plants-aquatic (food/cover, native habitats, etc.)	AP	
	Plants-terrestrial (food/cover, native habitats, etc.)	TP	
	Reptiles	RE	
	State listed or candidate species	SL	

WS-2.3 ASSESSMENT CONSIDERATIONS FOR THE SERVICE LANDS BIOMONITORING ACTIVITIES Page __ of __

Rank	Assessment Considerations	Group Code*	Description and Comments Regarding Importance to Monitoring Activities
	Wildlife/other resident species	RW	
	Other species	OT	
	On-Site Pest Management Activities	PM	
	Biodiversity		
	Geographic location of the area (feeding/staging area, good climatic conditions, breeding area, etc.)		
	Recreational activities (consumptive and nonconsumptive)		
	Research (for other than T&E species)		
	Economic uses (grazing, haying, mining, logging, oil)		
	Other (e.g. wilderness, subsistence, military)		
	Previous baseline or reference monitoring		
	Documented or suspected contaminant concerns		
	Other:_____		
	Other:_____		

GENERAL HABITATS/COMMUNITIES ON THE SERVICE LANDS

Upland Formations			
	Agricultural Lands	AG	
	Tundra	T	
	Forest (>50' trees)	F	
	Woodland (<50' trees)	W	
	Scrubland (<31'-multibranched)	S	
	Grassland	GR	
	Desertland (<12" precip.)	D	
	Other Uplands: _____	OU	
	Other Uplands: _____	OU	

WS-2.3 ASSESSMENT CONSIDERATIONS FOR THE SERVICE LANDS BIOMONITORING ACTIVITIES Page __ of __			
Rank	Assessment Considerations	Group Code*	Description and Comments Regarding Importance to Monitoring Activities
	Other Uplands: _____	OU	
Wetland/Aquatic Formations			
	Wet Tundra	WT	
	Swampforest/Riparian	SF	
	Swampscrub/Riparian	SS	
	Freshwater Marshland	FM	
	Strandland (beach)	ST	
	Saltflats/Mudflats	SM	
	Submergent Aquatic	SA	
	Managed Wetlands	MW	
	Lake/Pond/Impoundment	L	
	Riverine	RS	
	Marine	M	
	Estuarine	E	
	Other Wetlands: _____	OW	
	Other Wetlands: _____	OW	
	Other Wetlands: _____	OW	

2.4 Assessing Local Off-Service Land Areas Important to Trust Resources

The purpose of this section is to identify, document, and describe local off-Service land areas that are important to trust resources and should be considered in the monitoring strategy.

WS-2.4a INDEX TO LOCAL OFF-SERVICE LAND AREAS IMPORTANT TO TRUST RESOURCES Page __ of __

Off-Service Land Area		Description of Area and Importance to Service Land Monitoring
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		

WS-2.4a INDEX TO LOCAL OFF-SERVICE LAND AREAS IMPORTANT TO TRUST RESOURCES

Page __ of __

Off-Service Land Area		Description of Area and Importance to Service Land Monitoring
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		
Area Name		
Location		
Contact and Phone #		
Status*		

* Status Ranking:
1 Known contaminant sources and documented contamination problems and/or habitat degradation.
2 Known contaminant sources and contaminant presence, no documented contaminant problems or habitat degradation.
3 Known contaminant sources, suspected contaminant presence, no documented contaminant problems or habitat degradation.
4 No known contaminant sources other than global atmospheric input and no known habitat degradation.

Worksheet WS-2.4b is provided if more specific information is needed to describe the off-Service land areas. This Worksheet should be completed for those areas identified in Worksheet WS-2.4a that pose a known, or highly suspect, risk to trust resources using the Service lands. It should also be completed for those areas that might provide reference monitoring sites.

WS-2.4b ASSESSING LOCAL OFF-SERVICE LAND AREAS IMPORTANT TO TRUST RESOURCES					Page __ of __
Area Name					
Distance and Direction from Service Lands					
UTM Coordinates (centroid)	UTM Zone		X (Long.)		
			Y (lat.)		
General Description					
Contact or Agency			Phone #		
Monitoring Activities Relevant to this Area					

Assessment Considerations	Description and Comments Regarding Importance to Monitoring Activities
Amphibians	
Anadromous fishes	
Catadromous fishes and invertebrates	
Raptors	
Seabirds	
Shorebirds	
Waterfowl	
Other aquatic birds	
Other migratory birds	
Other resident birds	
Federally listed threatened & endangered, or candidate species (including research)	
Exotic/Pest Species	
Other freshwater species	
Macroinvertebrates	
Mammals - marine	
Mammals - terrestrial	
Marine organisms other than mammals (including invertebrates)	
Plants - aquatic (food/cover, native habitats, etc.)	

WS-2.4b ASSESSING LOCAL OFF-SERVICE LAND AREAS IMPORTANT TO TRUST RESOURCES Page __ of __	
Area Name	
Plants - terrestrial (food/cover, native habitats, etc.)	
Reptiles	
State listed or candidate species	
Wildlife/other resident species	
Other species	
On-Site Pest Management Activities	
Biodiversity	
Geographic location of the area (feeding or staging area, good climatic conditions, breeding area, etc.)	
Recreational activities (consumptive and nonconsumptive)	
Research (for other than T&E species)	
Economic uses (grazing, haying, mining, logging, oil)	
Other (e.g. wilderness, subsistence, military)	
Previous Baseline or Reference Monitoring	
Documented or Suspected Contaminant Concerns	
Other	
UPLAND FORMATIONS	
Agricultural Lands	
Tundra	
Forest (>50' trees)	
Woodland(<50' trees)	
Scrubland (<31'- multibranched)	
Grassland	
Desertland (<12" precip)	
Other Uplands _____	
Other Uplands _____	
WETLAND/AQUATIC FORMATIONS	
Wet Tundra	
Swampforest/Riparian	

WS-2.4b ASSESSING LOCAL OFF-SERVICE LAND AREAS IMPORTANT TO TRUST RESOURCES Page __ of __	
Area Name	
Swampscrub/Riparian	
Freshwater Marshland	
Strandland (beach)	
Saltflats/Mudflats	
Submergent Aquatic	
Managed Wetlands	
Lake/Pond/Impoundment	
Riverine	
Marine	
Estuarine	
Other Wetlands _____	
Other Wetlands _____	
Other Wetlands _____	

2.5 Regulatory Requirements Relevant to Monitoring

This section is designed to document Federal, State and local regulations pertinent to monitoring. Regulatory requirements may mandate that certain contaminants and/or media be monitored and that specific procedures or techniques be used. Regulations also provide the Service with certain legal authority regarding actions that may be taken to protect trust resources.

WS-2.5a FEDERAL LAWS RELEVANT TO MONITORING Page ___ of ___

X	Federal Laws	Comments/Relevance to Monitoring Strategy
	Anadromous Fish Conservation Act (AFCA) - 1965	
	Clean Air Act (CAA) - 1970	
	Clean Water Act (CWA) - 1977	
	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Superfund) - 1980	
	Endangered Species Act - 1973	
	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) - 1947	
	Federal Water Pollution Control Act (FWPCA) - 1977	
	Fish and Wildlife Act - 1956	
	Fish and Wildlife Coordination Act (FWCA) - 1934	
	Marine Mammal Protection Act - 1972	
	Marine Protection, Research, and Sanctuaries Act - 1972	
	Migratory Bird Treaty Act (MBTA) - 1918	
	National Environmental Policy Act (NEPA) - 1970	
	Oil Pollution Act - 1990	
	Refuge System Administration Act	
	Resource Conservation and Recovery Act (RCRA) - 1976	
	River and Harbor Act - 1899	
	Surface Mining Control and Reclamation Act - 1977	
	Toxic Substances Control Act (TSCA) - 1976	
	Water Quality Act - 1987	

WS-2.5b STATE AND LOCAL LAWS RELEVANT TO MONITORING

Page ___ of ___

State/Local Laws	Comments/Relevance to Monitoring Strategy

2.6 Monitoring Goals for the Service Lands

The purpose of this section is to develop monitoring goals for the Service lands. These will be used later to develop specific monitoring objectives that will be used to design the monitoring activities.

WS-2.6 MONITORING GOALS FOR THE SERVICE LANDS Page __ of __	
1	
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3	
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11	
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14	
15	

2.7 Public Outreach Workshop to Discuss Monitoring Program Goals

The purpose of this process is to inform the public about the goals of the monitoring program and to obtain input regarding their concerns and desires for the area. Local residents and visitors can provide valuable information regarding historic and current land uses, and observations regarding species sightings and population changes.

WS-2.7 PUBLIC OUTREACH WORKSHOP PARTICIPANTS Page __ of __

	Participant Name, Address, Phone #	Affiliation	Discussion Comments/Concerns/Interests
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			

3. ECOLOGICAL CHARACTERIZATION OF THE SERVICE LANDS

3.1 Establish the Area of Interest (AOI) and Identify Potential Contaminant Transport Pathways

The purpose of this section is to identify the relevant contaminant transport mechanisms for the Service lands and their locations. The AOI defines the area to look for contaminant sources and will be used to evaluate the potential for contaminants to reach the Service Lands. It also helps define the area for establishing reference monitoring sites.

3.1.1 Establish the Area of Interest (AOI)

Has an AOI been established for each of the relevant contaminant transport mechanisms for the Service Lands? Mark those that apply and comment if not applicable or if information is unavailable.

Transport Mechanism	Comment
____ Surface Water	_____
____ Subsurface Water	_____
____ Air	_____
____ Biota	_____

3.1.2 Transport Pathways to the Service Lands

Use Worksheets WS-3.1.2a through WS-3.1.2d to document the specific names and locations of **ALL** the potential contaminant transport pathways for each transport mechanism identified above, and identify where they enter the Service Lands. Also use the worksheets for general comments regarding the pathway and its relative importance to the Service lands.

WS-3.1.2a SURFACE WATER TRANSPORT PATHWAYS TO THE SERVICE LANDS			
	Watercourse Name	Location Where It Enters SL	Description/Comments
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

WS-3.1.2b SUBSURFACE WATER TRANSPORT PATHWAYS TO THE SERVICE LANDS		
	Subsurface Watershed Location and Area Where It Enters the Service Lands	Description/Comments
1		
2		
3		
4		
5		
6		
7		
8		
9		

WS-3.1.2c	AIR TRANSPORT PATHWAYS TO THE SERVICE LANDS	
Wind Direction	**General Area Where Inputs Enter Service Lands**	**Description/Comments (common contaminants from atmospheric inputs)**
Global/Regional Inputs (sources > 160 km) - all wind directions	Throughout the SL; inputs would also be transported to the SL via SW runoff	Gases - CO_2, H_2S, CH_3SCH_3, COS, NH_3/N_2O, HNO_3/NO_3 Particulates - trace metals (e.g., Hg, Pb, Cu, Cr, Fe), sulfates, nitrates, benzene-soluble organics, radioactive fallout
Regional Inputs (sources > 50 km, but < 160 km distance) - most wind directions	Throughout the SL; inputs would also be transported to the SL via SW runoff	As above plus: Gases - SO_2 Chlorinated hydrocarbons (pesticides and others) Organophosphate pesticides
In the Space to the Right Identify Specific Regional Sources and Potential Contaminants for the Service Lands		1. 2. 3. 4. 5. 6.
Local Inputs (sources < 50 km distance)	Likely throughout the SL, however, some areas might be more affected than others; SW runoff in some drainages might receive more input than others	As above plus: Gases - CO, NO/NO_2, Ozone Halogens Hydrocarbons (Table 7 - Air RFM) Particulates - specific local inputs (note what could be carried on dust/soil particles)

Wind Direction	**NA for Not Applicable**	**Identify Local Inputs from Each Wind Direction**
N		
NE		
E		
SE		
S		
SW		
W		
NW		

WS-3.1.2d	BIOTIC TRANSPORT PATHWAYS TO THE SERVICE LANDS		
	Species or Species Group Name	Habitats/Locations Used Extensively on SL	Description/Comments (likely locations of exposure, distance (L,R,G)*, and contaminant)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			

NOTE: **These descriptions are for guidance to provide an approximate location (distance) where exposure might occur**

* G = Global/Regional exposure; occurs further than 160 km from the Service lands border
R = Regional exposure; occurs between 50 km and 160 km from the Service lands border
L = Local exposure; occurs within 50 km of Service lands border

3.1.3 Transport Pathways Within and/or Moving off the Service Lands

Has there been an assessment of contaminant sources on the Service lands and the associated transport mechanisms within the Service lands? Are there transport pathways moving from the Service lands to off-site areas? Mark those that apply and comment if not applicable or if information is unavailable.

	Transport Mechanism	Comment
____	Surface Water	_____
____	Subsurface Water	_____
____	Air	_____
____	Biota	_____

The worksheet below is provided to identify the specific contaminant transport pathway(s) (mechanism, names, locations, directions, etc.) moving within and/or off the Service lands and describe its relevance to monitoring.

WS-3.1.3 TRANSPORT PATHWAYS WITHIN AND/OR MOVING OFF THE SERVICE LANDS		Page __ of __
	Transport Mechanism	Description and Relevance to Monitoring
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

3.2 Identify the Contaminant Sources and Associated Contaminants

The purpose of this section is to identify **ALL** the contaminant sources within the AOI for each relevant transport mechanism. The contaminants associated with each source will then be identified. Mark the sources' locations on the map and determine their UTM coordinates. Document this information on Worksheet WS-3.2. Worksheet WS-2.2a can also be used to record information resources and contacts. Initial each task when it is complete.

_____ 1. Place an "X" next to each contaminant source relevant to the AOI for any transport mechanism.

CONTAMINANT SOURCES:	CODE*		CODE*
__ Accident ("spill")	AC	__ Medical Waste	ME
__ Agricultural-aerial spray	AA	__ Mil. firing range/target	MF
__ Agricultural-Drainwater	AD	__ Military other	MO
__ Agricultural runoff-Crop	AC	__ Mining - abandoned	MA
__ Agricultural runoff-Livestock	AL	__ Mining - current	MC
__ Air Pollution-Industrial	IA	__ Nuclear Facilities	NF
__ Air Pollution-Other	AP	__ On site pest management	PM
__ Aquaculture	AQ	__ Petrol. explr/prod/refin	PP
__ Contam. buildings	CB	__ Recreation	RC
__ Contaminated Sediments/Soil	CS	__ Runoff urban/airport/hiwy	UR
__ Forestry/Silviculture	FS	__ Underground tanks	UT
__ Landfill/dump/drums-Indust.	ID	__ Wastewater/disch.-Indust.	IW
__ Landfill/dump/drums-Muni.	MD	__ Wastewater/disch.-Muni.	MW
__ Landfill/dump/drums-Military	ML	__ Other	OT
__ Landfill/dump/drums-Other	OD		

*See Table 1 at end of Workbook for Codes.

_____ 2. On Worksheet WS-3.2, complete the following tasks and mark off each task only when completed. Attach additional pages of the worksheet as necessary. Document additional information needed to complete the task in worksheet WS-1.

_____ A. All contaminant sources and contaminant source codes (from Table 1 at the end of the Workbook) for each category identified in #1 above. Also identify key contacts that might be able to answer questions regarding the contaminant source, associated contaminants, or transport pathways. Locate these sources on the map using a stick pin or mark.

_____ B. The location (UTM coordinates) of each contaminant source identified on Worksheet WS-3.2 and the map.

_____ C. The specific contaminants and/or affected water quality parameters plus the contaminant category codes.

_____ D. The mechanism(s) transporting the contaminants to the Service Lands from the source.

SERVICE LAND NAME :

"DATE"

WS-3.2 **CONTAMINANT SOURCE DOCUMENTATION WORKSHEET** Page __ of __

	Contaminant Source Name, Location and/or Address, Key Contact, and Phone #	UTM Coordinates (Centroid) X (Long)	Y (Lat)	Cont. Source*	Associated Contaminants and/or Affected Water Quality Parameters	Cont. Category*	Transport Mechanism(s) (A, SW, SSW, B)	Specific Pathway(s) to the Service Lands	Sensitive Key Species Group*	Comments Relevant to Monitoring
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										

* Use codes from Table 1 at the end of the Workbook.

3.3 Identify Specific Location(s) where the Contaminant Transport Pathway Enters the Service Lands

The purpose of this section is to identify the specific transport pathway for contaminants from each contaminant source and the location where it enters the Service lands.

____ Using the AOI map(s), identify the location (and name) for each specific transport pathway where it crosses the Service lands boundary. Refer to Worksheets WS-3.1.2a-d for the transport pathways previously identified. Document this information on Worksheet WS-3.2.

____ On Worksheet WS-3.2, identify the "key" species groups (use species group codes on Table 1) that are sensitive to the contaminants recorded. Refer to the comments on key species groups identified for the Service lands (See WS-2.3).

____ Provide comments relevant to monitoring activities associated with this contaminant source.

3.4 Identify Key Species

The purpose of this section is to identify the key species/species groups for the Service lands. This list will be used to help develop a conceptual model for the area and prioritize the contaminants, media, environmental variables, and locations to be monitored. Refer to Worksheet WS-2.3 for key species groups or species already identified. Worksheet WS-3.4 is provided to document the information gathered in this section.

3.5 Develop a Conceptual Model of the Ecosystem

The purpose of this section is to develop a conceptual model for the Service lands ecosystem or a particular community. A conceptual model can be used to illustrate the associations between the contaminant sources and key species. It can help identify key points within the ecosystem where biomonitoring will provide the most information for assessing ecosystem health, contaminant status and trends, and risk to the system. Use the information on Worksheet WS-3.4 to help develop the model. If additional key species are identified while developing the model, add them to Worksheet WS-3.4. The conceptual model(s) developed for the system should be included on the pages following Worksheet WS-3.4.

SERVICE LAND NAME "DATE"

WS-3.4	KEY SPECIES IDENTIFICATION WORKSHEET					Page ___ of ___
	Key Species or Species Group Name	Habitat Code*	Ecol. Compartment **	Primary Food Source	Primary Exposure Media***	Comments Relevant to Monitoring: (sensitivity, pathway, temporal considerations, exposure location, etc.)
1						
2						
3						
4						
5						
6						
7						
9						
10						
11						
12						
13						

* Use Habitat Group Codes from WS-2.3.
** P - Primary producer 1 - 1st order consumer (herbivore) 2 - 2nd order consumer (carnivore) 3 - 3rd order consumer or greater O - omnivore
D - Detritivore/Decomposer
***A = Air, SW = Surface Water, SSW = Subsurface Water, S = Soil, SE = Sediments, AN = Animal, PL = Plant

4. PRIORITIZE THE CONTAMINANTS RELATIVE TO RISK

The purpose of this section is to prioritize the contaminants relative to risk to the trust resources. The information collected during this process will be used to support monitoring decisions.

4.1 Documentation of Toxicity Data

The purpose of this section is to document studies and toxicity data for the identified contaminants and to determine the sensitivity of different key species found on these Service lands. This information will support the prioritization process. The information compiled for different Service lands can be used to create a large reference data base for future Service needs. Worksheet WS-4.1 is provided to document the information. If another reference database is established, it may be used.

Gaps in the toxicity data can help focus research on areas where additional information is needed. The toxicity data can also be used to help develop trigger levels for contaminants on the Service lands.

4.2 Prioritize the Contaminants

The prioritization process will help identify the contaminants that pose the greatest threat to the Service lands and key species. Prioritizing the contaminants threatening the system will also help select appropriate media and environmental variables to monitor, and the associated level of effort for monitoring. The risk information will also support specific monitoring objectives to be developed in Section 5. Worksheet WS-4.2 is provided to document results from this process.

SERVICE LAND NAME "DATE"

WS-4.1	REFERENCES FOR TOXICITY VALUES						Page __ of __
Contaminant or Water Quality Parameter							
Regulatory Limits, if applicable	Freshwater		Marine		Other		
Key Species (WS-3.4)	Species Used for Toxicity Testing	Acute Toxicity (mg/kg, ppm)		Threshold for Chronic/Sublethal Effects (mg/kg, ppm)	Type of Effect	Exposure Method (oral, dermal, aquatic, etc.)	References	#
		LD50	LC50					

SERVICE LAND NAME "DATE"

WS-4.2	CONTAMINANT PRIORITIZATION WORKSHEET																	Page __ of __		
Contaminant or Water Quality Parameter (WS-3.2)	Reg. Lim. Y/N	Bio-acc. Y/N	Bio-mag. Y/N	Syn. Eff. Y/N	Terat Eff. Y/N	Carc. Eff. Y/N	Key Species/Species Groups/Habitat (WS-3.3)														Overall Risk: Tox = (H,M,L) Expos = (1,2,3)	Cont. Prior. Level (H,M,L)	Will Monitor (Y/N)
Overall Sensitivity of Species, Group, or Habitat																							
Primary Habitat(s) Where Exposure Occurs																							

5. ESTABLISH MONITORING OBJECTIVES FOR THE SERVICE LANDS

The purpose of this section is to establish and document specific monitoring objectives for the Service lands. Monitoring objectives provide a specific purpose for data collection, a format for data interpretation, and are specific enough to develop a statistically-relevant sampling plan. Workable monitoring objectives help identify specific variables to measure, locations to focus on, and the frequency and index period to sample.

WS-5 MONITORING OBJECTIVES FOR THE SERVICE LANDS Page __ of __		
	Monitoring Objective	Contaminant Issue/Location/Rationale
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

6. IDENTIFY THE OPTIMUM LOCATION, ENVIRONMENTAL VARIABLES, MEDIA, AND INDEX PERIOD FOR MONITORING

The purpose of this section is to determine the optimum locations, environmental variables, media, and index periods for monitoring. This information will be used with the stated objectives (WS-5) to develop the statistical designs for monitoring activities. An iterative process is required to complete this task. To arrive at a final decision regarding where, what, and when to sample requires that all three be considered. One is not necessarily more important than another. Understanding the characteristics of the contaminant, its source, and the transport mechanisms involved is also necessary. **The stated objectives of the monitoring effort must be used to guide the decision.**

6.1 Identify the Locations for Monitoring

Initial each section once it is complete. If additional information or work is required, do not check the task off and comment on WS-1.

___1. Locate the transport pathway(s) from each source for the contaminant(s) identified on Worksheet WS-4.2 "To Monitor". Identify an optimum location(s) within each transport pathway to collect samples. These will be the Potentially Contaminated Area (PCA) monitoring locations for these contaminants. Once these locations are determined, complete WS-6.1a. This Worksheet will provide an index to all the monitoring locations.

___2. Identify reference monitoring sites within the identified transport pathways (WS-3.1.2a-d) that don't have contaminant sources associated with them. It might be necessary to go outside the AOI to locate good reference monitoring sites for some variables.

___3. On Worksheet WS-6.1b, identify the PCA or reference site number (denote reference sites with an "R" before the number), identify its location, state the purpose and specific objectives for monitoring there, and list the contaminants and water quality parameters to monitor. **Complete a separate WS-6.1b Worksheet for each monitoring site.**

SERVICE LAND NAME "DATE"

WS-6.1a	INDEX TO MONITORING SITES	Page __ of __
PCA or Reference Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		

WS-6.1a	INDEX TO MONITORING SITES	Page __ of __
PCA or Reference Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		
Monitoring Site #		Monitoring Level	
Location and General Description		
Monitoring Issues and Rational for Selecting this Site		

SERVICE LAND NAME "DATE"

WS-6.1b	MONITORING ACTIVITIES FOR MONITORING SITES								Page __ of __
Monitoring Site Number		UTM Coordinates	X (Long)		Y (Lat)				
Project Number									
Specific Purpose & Objectives									

	Contaminant or Water Quality Parameter to Monitor (WS-4.2)	Medium to Sample (6.2)	Variable & Line of Evidence (6.2)	When to Sample: Month/Time (6.3)	Cont. Priority Level (WS-4.2)	Cont. Monit. Level (7.2)	Sampling Method (7.2)	# of Samples/ Sample Period (7.2)	Frequency (# Times) Per Yr. (7.2)	Sample Plot # (7.2)	Comments/Rationale for Decisions
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

Lines of Evidence

1. Biomarker/organism health 2. Bioassay or toxicity testing 3. Population or community indicies 4. Chemical Analysis

6.2 Select the Media and Environmental Variables to Monitor

The purpose of this section is to determine the optimum media and environmental variables to monitor to address the specific objectives for the monitoring site.

The optimum media and variables to monitor for contaminant biomonitoring is one where the contaminant, or its effects, can be measured or observed soon after its introduction into the system and/or it will be found in the greatest concentration relative to other media in the system. It must also satisfactorily address the objectives of the monitoring effort.

For contaminant biomonitoring at least one variable from each of the four lines of evidence (that is applicable) must be selected for each monitoring site. On Worksheet WS-6.1b identify the media to sample, the monitoring technique to use for monitoring, the applicable line of evidence.

6.3 Index Period Considerations

The purpose of this section is to determine the optimum time to to collect samples or conduct environmental measurements. For many contaminants, water quality parameters, biotic variables, and transport pathways, selecting the index period is as important as the media and location selection considerations. Understanding the characteristics of the contaminant source and transport mechanisms is also necessary. It might be necessary to assess temporal considerations for each contaminant and/or contaminant source separately if there are significant differences between their characteristics. Complete a separate Worksheet WS-6.3 for each monitoring site.

SERVICE LAND NAME "DATE"

WS-6.3 INDEX PERIOD CONSIDERATIONS FOR MONITORING Page __ of __						
Monitoring Site #						
	Contaminant, Water Quality Parameter, or Biotic Variable(s) Being Monitored	Transport Mechanism or Exposure Medium (A, SW, SSW, SO, SE, AN, PL)	Most Important Index Period Considerations	Optimum Time to Sample	Selected Time to Sample	Comments: Provide rationale for the optimum and/or selected sampling time
1						
2						
3						
4						
5						
6						
7						
8						
9						

1. Transport/Exposure Mechanism Codes

A = Air
SW = Surface water
SSW = Subsurface
SO = Soil
SE = Sediments
AN = Animal
PL = Plant

2. Index Period Considerations

1 Storm events (pulses of contaminants)
2 Wet vs. dry periods/seasons
3 Temperature affects (DO, respiration, etc.
4 Agricultural activities (fertilizers, amount and type of Pesticides, aerial spraying)
5 Turnover period and stratification of standing water
6 Biotic activities (life cycle, peak population numbers, hormonal cycles, migration, exposure potential, etc.)
7 Wind or storm intensity
8 Wind direction
9 Stagnation events
10 Dryness (resuspension of particulates)
11 Wet deposition vs. dry deposition
12 Seasonal recharge (ground water level fluctuation and water available to sample at seeps or wells
13 Recreational activities, increased tourism (auto emissions, hunting, fishing, etc.)
14 Comparability with another monitoring site or historic data
15 Tidal/sea level rise
16 Contaminant characteristics (persistence, toxicity, variability with temperature, DO, synergistic effects with other contaminants in system, etc.)
17 Estimates regarding inputs from air deposition and subsequent runoff (surface water pathway only)
18 Contaminant source characteristics (discharge pulses, change in the contaminants released)
19 Access to monitoring location
20 Available labor
21 When do other samples need to be collected here or nearby
22 Is sample equipment and storage space available
23 Are appropriate funds and capabilities available for sample collection, transportation, and analysis
24 Other

7. DESIGNING AND IMPLEMENTING CONTAMINANT BIOMONITORING ACTIVITIES

7.1 Contaminant Biomonitoring Design Considerations

Specific sampling designs for each contaminant or environmental variable being monitored should be developed by personnel with a solid background in statistics. You will need to know the specific objectives for the monitoring activities, the characteristics of the area and environmental variables and media being monitored, how the data is to be used, and the confidence level required for the data. Most of this information has been considered in earlier sections of the Workbook and may be documented on a worksheet or in your notes. Review this information as necessary to develop the monitoring designs for the monitoring sites.

Draw a map suitable for field use to identify the monitoring area and develop the sampling design for each site. Define strata as necessary to identify sampling locations and poitns of reference for locating the site (e.g., benchmarks, rock outcrops, GPS location). Identify the maps with the monitoring site number and include them at the end of the Workbook.

7.2 Contaminant Biomonitoring Design Development

The purpose of this section is to determine the monitoring level, sampling methods, number of samples needed, and frequency of sampling for each variable at each monitoring site. Worksheet WS-6.1b will be used to document the decisions and rationale.

The information compiled below will assist in writing a proposal for the contaminant monitoring activities.

____ 1. Determine the Monitoring Level. The monitoring level will provide an indication of the level of effort for monitoring a particular contaminant or environmental variable (e.g., sampling frequency, the number of sample points and associated media/variables, the types of analyses conducted, etc.). The monitoring level is based on the potential for a contaminant to reach the Service lands. Determine the monitoring level for each contaminant or environmental variable identified on Worksheet WS-6.1b.

_____ 2. Insert the Contaminant Priority Level for the contaminant or water quality parameter from Worksheet WS-4.2.

_____ 3. Document the sampling method(s) to be used for monitoring the contaminant or environmental variable.

_____ 4. Document the frequency of sampling to occur.

_____ 5. Determine the number of samples per sample period.

_____ 6. Identify the sample plot number (from monitoring site map developed in 7.1).

_____ 7. Discuss the rationale for the sampling design.

_____ 8. If an overview sheet is desired that summarizes all the monitoring sites and associated contaminants/water quality parameters being monitored, complete WS-7.2.

SERVICE LAND NAME "DATE"

WS-7.2 INDEX TO MONITORING SITES AND CONTAMINANT MONITORING LEVELS Page __ of __

	Contaminants or Water Quality Parameters Being Monitored (WS-4.2)	Monitoring Site Numbers (WS-6.1a)																				Overall Contaminant Monitoring Level
1																						
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						
11																						
12																						
13																						
14																						
15																						
16																						
17																						
18																						
19																						
20																						
21																						
	Monitoring Level for Monitoring Sites																					SL Monitoring Level

7.3 Implement Contaminant Biomonitoring Activities

The purpose of this section is to identify the logistical requirements associated with the planned monitoring. This information will assist in writing a proposal for the contaminant biomonitoring activities. Worksheet WS-7.3 is provided to document funding and personnel requirements for the monitoring activities.

SERVICE LAND NAME "DATE"

WS-7.3 LOGISTIC CONSIDERATIONS AND COSTS FOR MONITORING ACTIVITIES Page __ of __

Monitoring Site #			Project #		Date	
Project Title/Description						

	Contaminant, Water Quality Parameter, or Biotic Variable Being Monitored (WS-6.1b)	Medium to be Collected for Sample Analysis (WS-6.1b)	Personnel or Training Needed? (7.3)	Total # of Samples per Year (WS-6.1b)	Type of Analysis (7.2)	Analysis Cost per Sample (7.3)	Total Sample Analysis Costs	Total Materials Costs	Total Equipment Costs	Total Training Costs	TOTAL COSTS
1							0				0
2							0				0
3							0				0
4							0				0
5							0				0
6							0				0
7							0				0
8							0				0
9							0				0
10							0				0
11							0				0
12							0				0
					GRAND TOTAL		0	0	0	0	0

Personnel/Training Needs:	
Material/Equipment Needs:	
Other Comments:	

7.4 Additional Information Requirements

This concludes the initial Workbook activities. The following information should now be documented:

- Management goals and objectives for the Service lands (WS-2.1)
- Existing information relevant to contaminants and monitoring (WS-2.2a)
- Field reconnaissance information (WS-2.2b)
- Assessment considerations for the Service lands (WS-2.3)
- Information regarding off-Service land areas important to trust resources (WS-2.4a, WS-2.4b)
- Monitoring goals for the Service lands (WS-2.6)
- Public outreach workshop input (WS-2.7)
- Potential contaminant transport mechanisms and pathways associated with the Service lands (WS-3.1.2a-d, WS-3.1.3)
- Contaminant sources and associated contaminants within the AOI (WS-3.2)
- Key species for the Service lands (WS-3.4)
- Key physical and biotic associations between the contaminant sources and key species (conceptual model, Section 3.5)
- Toxicity data for trust resources using the Service lands (WS-4.1) and a priority list of contaminants associated with the Service lands (WS-4.2)
- Monitoring objectives for the Service lands (WS-5)
- An index to all monitoring sites (WS-6.1a)
- A list of PCA(s), reference monitoring sites, the associated contaminants and variables to monitor, the appropriate media to sample, and index period to monitor them (WS-6.1b)
- A map of each PCA with notes regarding its physical/biotic variability (Section 7.2)
- The sampling methods to be used and equipment, personnel, and resources requirements (WS-6.1b, WS-7.3)
- Training requirements (WS-7.3)

Document additional information required to complete this Workbook on Worksheet WS-1. Other information not addressed by this Workbook that is relevant to implementing contaminant monitoring activities should be discussed in the box below (e.g., obtaining permission and access to monitoring sites off Service land).

8. DATA EVALUATION

The purpose of this section is to document and evaluate monitoring results and provide recommendations regarding future monitoring and management activities. This includes reassessment of risk to the Service lands and trust resources from contaminants, addressing compliance issues, and determining the level of effort for future monitoring activities. This information will also be used for summarizing the status of the Service lands in the Workbook Summary.

Worksheet WS-8.3 is provided to document this information. A separate worksheet should be completed for each monitoring site.

SERVICE LAND NAME "DATE"

WS-8.3 DOCUMENTATION OF MONITORING RESULTS AND INTERPRETATION Page __ of __					
Monitoring Site Number		Project Number			
Purpose & Objectives					
	Contaminant, Water Quality Parameter, or Biotic Variable Monitored	Line of Evidence	Results	Interpretation of Results	Recommendations and Rationale for Future Activities
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Lines of Evidence

1. Biomarker/organism health 2. Bioassay or toxicity testing 3. Population or community indicies 4. Chemical Analysis

Table 1. Codes for FWS Contaminant Issues.

CONTAMINANT SOURCES:

Accident ("spill")	AC	Medical Waste	ME
Agricultural-aerial spray	AA	Mil. firing range/target	MF
Agricultural-Drainwater	AD	Military other	MO
Agricultural runoff-Crop	AC	Mining - abandoned	MA
Agricultural runoff-Livestock	AL	Mining - current	MC
Air Pollution-Industrial	IA	Nuclear Facilities	NF
Air Pollution-Other	AP	On site pest management	PM
Aquaculture	AQ	Petrol. explr/prod/refin	PP
Contam. buildings	CB	Recreation	RC
Contaminated Sediments/Soil	CS	Runoff urban/airport/hiwy	UR
Forestry/Silviculture	FS	Underground tanks	UT
Landfill/dump/drums-Indust.	ID	Wastewater/disch.-Indust.	IW
Landfill/dump/drums-Muni.	MD	Wastewater/disch.-Muni.	MW
Landfill/dump/drums-Military	ML	Other	OT
Landfill/dump/drums-Other	OD		

SPECIES GROUPS:

Amphibians	AM	Exotic species	XS
Anadromous fishes	AF	Freshwater species other	FW
Catadromous fishes & invertebrates	CA	Macroinvertebrates	MI
		Mammals-marine	MM
Birds		Mammals-terrestrial	MT
Raptors	RA	Marine organisms	MR
Seabirds	SB	Other	OT
Shorebirds	SH	Plants-aquatic	AP
Waterfowl	WF	Plants-terrestrial	TP
Other-aquatic birds	QB	Reptiles	RE
Other-migratory birds	MB	State listed species	SL
Other-resident birds	RB	Wildlife, other resident	RW
End./threat. species (Fed)	ES		

CONTAMINANT CATEGORIES:

Airborne Particulates	AP	Sediments	SD
Airborne Gaseous Pollutants	GP	Sewage	SG
Asbestos	AB	Solvents	SV
Microbial	MC	Thermal Inputs	TH
Military Debris	MD	Trace Elements	TE
Nutrients (other than sewage)	NU	Chromium	CR
Other Inorganics	OI	Mercury	HG
Other Organics	OD	Selenium	SE
Polyaromatic hydrocarbons	PH	Unexploded Ordnance	OR
Polychlorinated Biphenyls	PC	Water Quality Parameters (e.g. DO, pH, SS)	WQ
Petroleum Products	PT		
Pesticides			
Organophosphates	OP		
Organochlorines	OC		
Synthetic Pyrethroids	SP		
Carbamates	CB		
Other Pesticides	PS		
Radioactive Materials	RM		
Salts	SA		

Source: Adapted from FWS/DEC 6/11/87

TABLE OF CONTENTS

TABLES

FIGURES

WORKSHEETS

EGG-EST-9222
April 1993

U.S. FISH AND WILDLIFE SERVICE BIOMONITORING OPERATIONS MANUAL

APPENDIX C AIR MONITORING A REFERENCE MANUAL

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The opinions, findings, conclusions or recommendations expressed in this document are those of the authors and do not necessarily reflect the views of Research and Development, Fish and Wildlife Service, U.S. Department of the Interior. The mention of trade names or commercial products is for illustrative purposes only and does not constitute endorsement or recommendation for use by the Federal Government.

PREFACE

This is Appendix C of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   D.2 Bird Sampling Reference Field Methods
   D.3 Fish Sampling Reference Field Methods
   D.4 Flora Sampling Reference Field Methods
   D.5 Reptiles and Amphibians Sampling Reference Field Methods
   D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM Benthic Macroinvertebrates
BRD Birds
FSH Fish
FL Flora
HPT Herpetiles
MAM Mammals
DEC Decontamination
DOC Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM Field Instrument Measurements
GW Ground Water Sampling
SED Sediment Sampling
SO Soil Sampling
SW Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
0	10/2/91	2.1	2-4	2-4c	5
1					
2					
3					
4					
5					
6					
7					
8					
9					
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Document Revision Worksheet

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Division of Environmental Contaminants
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ACRONYMS

APTI	Air Pollution Training Institute
CAA	Clean Air Act
DCSM	dichlorosulfitomercurate
DOC	Department of Commerce
DOE	Department of Energy
EC	Environmental contaminants
EFPVN	Eastern Final Particle Visibility Network
EPA	Environmental Protection Agency
ERAMS	Environmental Radiation Ambient Monitoring Systems
ICSU-CODATA	International Council of Scientific Unions Committee on Data for Science and Technology
IMPROVE	Interagency Monitoring and Protected Visual Environmental
MMS	Minerals Management Service
NADP/NTN	National Acid Deposition Program/National Trends Network
NAMS	National Air Monitoring System
NAPAP	National Acid Precipitation Assessment Program
NAAQS	national ambient air quality standards
NASA	National Aeronautic and Space Administration
NDDN	National Dry Deposition Network
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NPS/FWS-AQB	National Park Service/Fish and Wildlife Service - Air Quality Branch
NSF	National Science Foundation
PAN	peroxyactyl nitrate
PCB	polychlorinated biphenyls
PSD	Prevention of Significant Deterioration
PUF	polyurethane foams
RM	Reference Manual
RFM	Reference Field Methods
SCENES	Subregional Cooperative Electric Utility, Department of Defense, National Park Service, and Environmental Protection Agency Study
SIP	State Implementation Plan
SLAMS	State and Local Air Monitoring System
TCE	trichloroethylene
THC	total hydrocarbon
TVA	Tennessee Valley Authority
USGS	United States Geological Survey
VOC	volatile organic compounds
WNO	World Meteorological Organization

U.S. FISH AND WILDLIFE SERVICE
BIOMONITORING OPERATIONS MANUAL

APPENDIX C
AIR MONITORING
A REFERENCE MANUAL

1. INTRODUCTION

1.1 Purpose and Scope

The purpose of this Reference Manual (RM) document, unlike the Reference Field Methods (RFM) documents, is to provide a brief introduction to the relevant issues of air monitoring. Only general information on sampling methods will be presented because of the complexity of the equipment and procedures involved. Generally, it is assumed that if air monitoring is needed at a site, a contractor or government agency personnel already involved with air monitoring will be contacted as a consultant to help develop and setup an air monitoring program. The primary intent of this document is to provide Fish and Wildlife Service (Service) personnel with background information on resources available and enable communication with experts in the field to help determine if air monitoring is warranted.

This document introduces and reviews the Clean Air Act (CAA) as it applies to Service personnel. Major air monitoring programs relevant to Service lands are identified, including information on database availability, useful contacts, and training programs available to Service personnel. An overview of meteorological transport mechanisms is also presented, along with a section on characteristics of airborne contaminants. Sampling methodologies are briefly described to provide guidance for making decisions on sampling needs and assist in establishing a monitoring network appropriate for their particular situation. Guidance reference documents are identified and briefly discussed for Service personnel requiring additional assistance. These documents are pertinent to various air monitoring networks and have been produced by various agencies, such as the Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), the National Park Service (NPS), Minerals Management Service (MMS), Department of Energy (DOE), National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautic and Space Administration (NASA).

2. ISSUES - CONCERNS

2.1 Rationale for Air Monitoring

Air is a medium and pathway by which contaminants move onto Service lands (Table 1). Some sources of air transported contaminants may be local (i.e., overspray from aerial pesticide application), but most are regional, national, or global. Air masses contaminated from natural and man-made sources (e.g., particulates) cross over property lines, state lines, and international boundaries.

The effects upon the resources of Service lands will vary depending upon their location, atmospheric conditions, the concentration and content of the contaminants, and the receptors exposed to the polluted air. For widely distributed atmospheric pollutants (e.g. NO_x, SO_2, etc.), a refuge air monitoring program could be established by determining how data collected by another agency in the same airshed could be used to assess threats to Service lands. However, because certain atmospheric pollutants can be deposited in a localized area (e.g. impact from a smelter or overspray for ag-chemical application) a plan specific to the Service lands needs to be considered with the help of trained specialists. For Service lands located around urban areas or down wind from an industrial area, the Service may decide that an active program with samples collected on the Service lands is warranted.

Table 1. Examples of toxic airborne pollutants and sources

Sources	Type Pollutant
Transportation	Hydrocarbons, organic compounds, sulfur and nitrogen compounds, and PAH
Pesticide application	Organophosphates, carbamates, and pyrethroids
Waste treatment/disposal	Organic, inorganic, and organometallics
Combustion (fossil fuels, waste, biomass)	Sulfur and nitrogen compounds, heavy metals, trace elements, PAH, polychlorinated dibenzodioxins, and polychlorinated dibenzofuranes
Stationary source, industrial manufacturing processes	Organic, inorganic, and organometallic substances, pesticides

The reasons for considering monitoring air associated with Service lands are to:

1. Identify and quantify airborne contaminants.

2. Assess whether airborne contaminants may affect Class I area status or fish, wildlife, or their habitat.

3. Establish baseline values to enable Service land managers to determine if ambient air quality standards [including prevention of significant deterioration (PSD)] are being threatened or exceeded at Service lands.

4. Take steps to reduce harmful compounds entering the Service lands via the air route.

5. Establish baseline values for comparison to urban and industrial air pollution concentrations.

Air monitoring is seldom an end in itself. It usually must be integrated with monitoring of pollutant exposure in other environmental media and include a well-designed monitoring program that considers critical ecosystem processes.

2.2 Program Challenges and Considerations

The methods and procedures for air sampling are often complicated and the equipment is expensive. The initiation of a major air monitoring effort by Service personnel may be difficult. Thus, it is important that sources of air pollution, Service lands needs, and regulatory requirements be given serious consideration and discussed with the environmental contaminants (EC) specialist. Existing data and local air quality experts should be consulted to determine what data are available, where it is being collected, if it is applicable, and if the data indicate a potential concern for the Service lands.

Because of concerns with calibration, maintenance, sample handling, sample analyses, etc., it is recommended that EC specialists and personnel from the NPS Interagency Air Quality Section (Section 4) be contacted to discuss needs and objectives of an air monitoring effort. If warranted, additional expert staff (Section 4) should be contracted to establish and carry out a monitoring program. However, Service personnel involvement is critical to establish program objectives and ensure that the network meets the needs and is appropriate for the situation at hand. Once a network is set up, Service personnel can usually handle on-site operation of sample collection, sample shipping, etc. Additional support may again be needed to evaluate data collected during a monitoring program.

3. CLEAN AIR ACT (CAA)

The CAA (42 USCA §§ 7401 et seq.) is one of the largest and most complex pieces of environmental legislation passed in the United States. It has been amended over twenty times with major overhauls occurring in 1970, 1977, and 1990. This section provides a brief historical background of the CAA and highlights its most important requirements. **FWS personnel should contact the Department of the Interior's, Office of the Solicitor at (202) 208-4423 if they have any questions concerning the applicability of the CAA or any other piece of environmental legislation.** For more information about the CAA refer to Appendix A - Legislative Background.

3.1 Historical Development of the CAA

In 1955 the Air Pollution Control--Research and Technical Assistance Act was passed which authorized the Public Health Service to conduct research and provide support to local agencies with air quality issues. The CAA of 1963 dealt primarily with the development and implementation of emission controls on stationary sources (industrial plants and factories). The 1965 amendments to the CAA authorized federal emission standards for new vehicles. The 1967 amendments allowed the federal government to adopt emission control regulations for areas designated as problem areas. However, none of the Acts or amendments provided much authority for federal enforcement and were limited in effect.

The 1970 CAA amendments were far stronger and more comprehensive, laying the foundation for regulatory efforts. The 1970 amendments expanded the role of the Federal Government and provided the EPA with authority to establish the minimum air quality standards and regulatory goals that states and local government were to achieve. The 1970 amendments required State Implementation Plans (SIPs) to be promulgated by 1972. The 1970 amendments defined clean air goals from three perspectives:

- Title I--Limits on emissions from stationary sources
- Title II--Limits on emissions from mobile sources--primarily cars, trucks, and airplanes
- Title III--Air quality management, provided for citizens suits, and standards for judicial review

The 1977 CAA amendments enacted the PSD program, imposed stringent requirements for areas that failed to attain national standards, restricted the use of dispersion techniques, and strengthened enforcement of statutory provisions.

The purpose of the 1990 CAA amendments was to strengthen the authority of federal and state governments to reduce air pollution from industry, transportation, and community operations. The 1990 amendments improved nonattainment provisions, permit regulations, and legal enforcement; created new technology-based control programs, and added provisions to address acid rain, and chlorofluorocarbons (CFCs).

Service personnel should consult the Refuge Manual for current air quality management responsibilities. Section 8.0 (pg. 8.8N) Section N discusses Service responsibilities. This section, as of October 1990, states the following actions should be taken regarding air quality management issues. The EPA has established national ambient air quality standards (NAAQS) to protect public health and welfare. States have the primary responsibility for implementing and enforcing of these Federally-established air pollution requirements.

The PSD program protects the quality of air in regions of the United States in which the air is now cleaner than required by the NAAQS. This source review process is a preconstruction review and licensing program for major new or expanding sources of air pollution. Any facility seeking a new source permit to locate or expand in a clean air area (usually within 100 km of a Class I area) must meet several tests: no violation of any NAAQS, no violation of increments for sulfur dioxide (SO_2), nitrogen oxides (NO_x), or particulate matter, and resolution of an "adverse impact determination" in the case of Class I areas. The adverse impact determination is site-specific.

The CAA requires that each State adopt a SIP, which assures attainment and maintenance of the NAAQS. Each state is required to survey and report every major source of emissions within its borders and develop strategies to ensure compliance with the legislature-mandated guidelines. Survey results, available from state air quality groups, are a good resource for Service managers looking to identify sources near their lands. Portions of the SIP and PSD program contain provisions to protect Service lands and resources from air pollution damage. The Service should participate in the SIP development and review process to ensure resource protection in their area. Lead responsibility for providing technical assistance to States to incorporate adequate refuge protection measures in the SIPs lies with the FWS and NPS Air Quality Branch (AQB) (see Section 4.1), with assistance from Washington, regional, and refuge staff in maintaining an effective dialogue with State and local air pollution officials.

If air pollution damage is suspected at a refuge, the FWS-AQB can help determine if resource damage is air pollution related. If it is, they will attempt to quantify and document the problem. The documentation will include air pollution damage to resources, the sources responsible, and alternative actions to be taken to reduce or eliminate such damage. Actions may include determining the source, compliance with pollution control regulations, consultation with the source, or initiation of litigation.

The Federal Land Manager for a Class I area (the Assistant Secretary for Fish and Wildlife and Parks), determines whether a proposed facility will adversely affect the air quality related values of that area. The air quality related values are all those values possessed by an area that may be affected by changes in air quality. These values include visibility, odor, flora, fauna, and geological resources; archeological, historical, and other cultural resources; and soils and water quality resources. If the Federal Land Manager determines that the resources will not be adversely affected, then the permitting authority (EPA or State) may authorize facility construction even if the Class I increment would be violated (for Class I, only a very small increment of additional air quality degradation may be allowed). If the Federal Land Manager can demonstrate that the facility would have an adverse impact on resources (even if the Class I increments were not violated), the permitting authority may not authorize the facility. After being informed of a proposal to locate or expand a facility near a Service Class I area, the FWS-AQB consults with the manager of the affected refuge and the appropriate regional office, and begins its analysis of the potential air pollution impacts. Upon completion of the effects analysis, the FWS-AQB coordinates final FWS comments on the

proposed source's permit application. The Director sends the Service recommendation to the Federal Land Manager who makes the final determination of adverse impact.

EPA has set standards for six "criteria" air pollutants, (1) particulate matter smaller than 10 microns in size (PM_{10}), (2) sulfur dioxide (SO_2), (3) nitrogen dioxide (NO_2), (4) hydrocarbons, (5) ozone (O_3), and (6) carbon monoxide (CO). The EPA has also set standards for six hazardous pollutants: asbestos, beryllium, mercury, vinyl chloride, benzene, and radionuclides.

The newest version of the CAA published on November 15, 1990 (PL101-549) focused on during acid deposition (NO_x and SO_2 emissions), encouraging clean fuels, and phasing out chlorofluorocarbons (CFCs). Service personnel should keep informed of new changes in air standards by reviewing the Federal Register, reading regulatory summaries (e.g. the Environmental Reporter), or contacting personnel at the FWS-AQB (Section 4).

The 1990 amendments in Section § 103(d) revised by PL 101-549 state a specific directive to the Director of the FWS to conduct ecosystem research. There are 6 items listed in this section that require "the Director to conduct a research program to improve understanding of the short-term and long-term causes, effects, and trends of ecosystem damage from air pollutants on ecosystems."

3.2 Air Quality Standards

Section 162 [42 USC 7472] of the CAA establishes initial classification for Federal lands. In this section, lands are classified as either Class I or II. In Class I areas, only minor degradation in air quality is allowed. In Class II areas, degradation that usually goes along with moderate, well controlled growth is accepted. To date, there are 21 refuges in the Class I category; the remainder are Class II or III. Federal lands may be redesignated as outlined in Section 164. Monitoring air quality in the Class I areas will help identify and quantify airborne contaminants. These data help to determine if ambient air quality standards are being threatened or exceeded and help determine if the air is moving contaminants onto Service lands. Section 163 of the 1990 CAA specify increments and ceilings for SO_2 and PM_{10} for Class I, II, and III.

National Primary and Secondary Ambient Air Quality Standards are discussed in 40 CFR 50. Primary standards define levels of air quality which the Administrator judges are necessary, to protect public health. National Secondary Ambient Air Quality Standards define levels of air quality judged by the Administrator necessary to protect the public welfare (which includes most Service lands). A summary of the national and secondary standards are presented in Table 2. Standards are discussed in more detail in Section 6.

The need for air sampling/monitoring is more important when Service lands are located near or down wind from "nonattainment" areas. Air polluting industries operating in "non attainment" areas can include: mining, smeltering, refining, pulp and paper mills, primary lead smelters, petroleum storage and transfer facilities, petro-chemical plants, coal and oil-fired power plants, cement plants, acid plants, aluminum ore processing plants, charcoal production plants, sulfur recovery plants, phosphate processing plants, agriculture, and copper, lead, and zinc smelters.

Table 2. National and Secondary Ambient Air Quality Standards as stated in the July 1, 1990 version of 40 CFR Part 50, Subchapter C.

Compounds	National Primary Ambient Air Quality Standard ($\mu g/m^3$)		National Secondary Ambient Air Quality Standard ($\mu g/m^3$)
	Annual Arithmetic Mean	Maximum Concentration	
Sulfur oxides measured as SO_2	80	365(24 hr.)	1,300
Particulates (PM_{10})	50	150(24 hr.)	50
CO		9(8 hr) 35(1 hr)	
O_3		235(1 hr)	235(1 hr)*
NO_2	100		100
Pb	1.5		

* Not to be exceeded an average value of this more than once per year in allotted time noted.

Air sampling procedures selected must take into account the location of actual or potential pollution sources, both stationary and mobile. Using wind roses data (Figure 1) EC specialists and Service personnel can identify the direction from which contaminants can enter the airshed over Service lands. The longer the line from the center circle, the more often the wind comes from that direction. For example, around Los Angeles, California, the wind blows from the west about 30% of the time. Monthly average information can be obtained from local weather stations or NOAA offices.

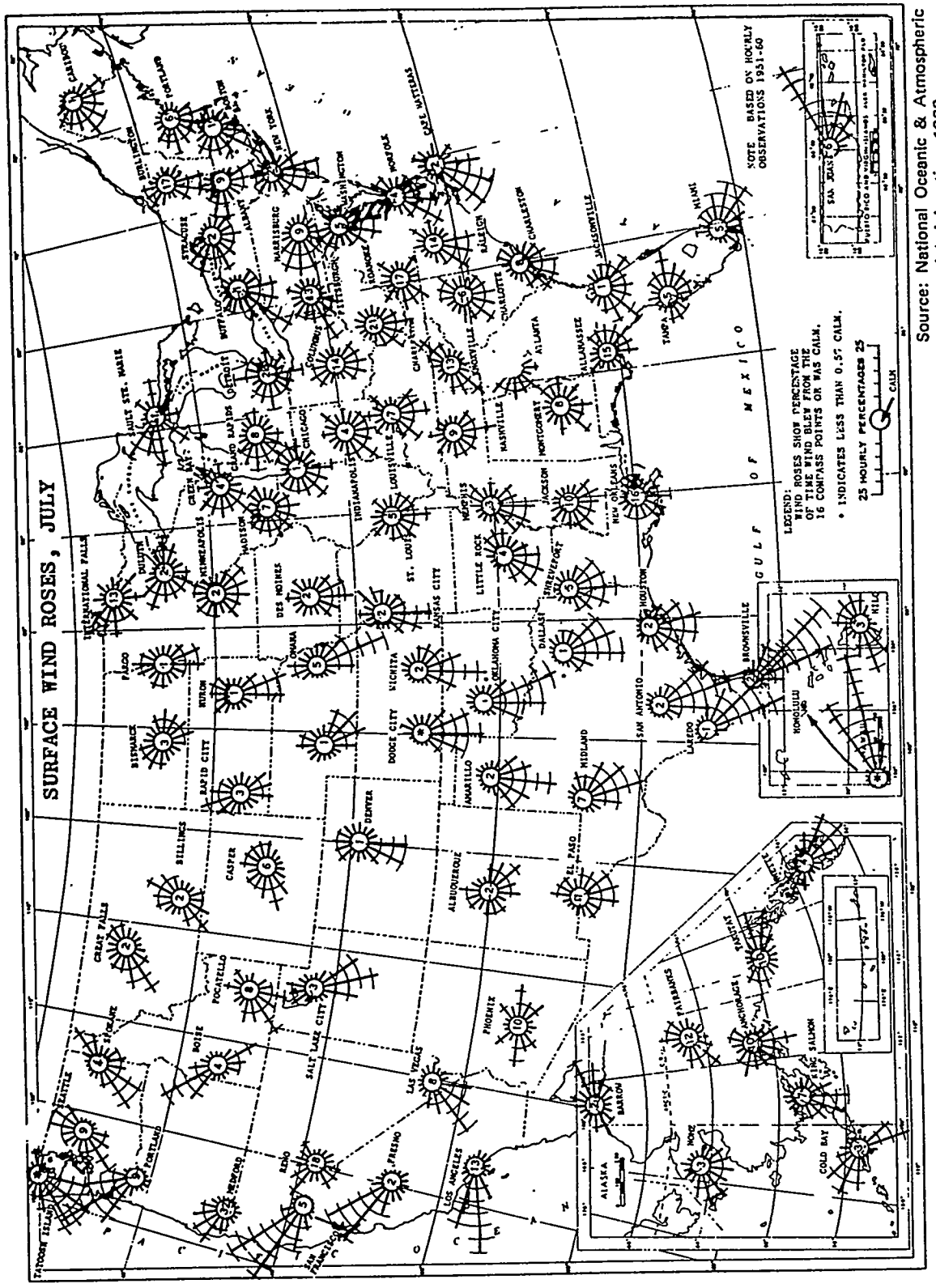

Figure 1. Surface wind roses depicting predominant wind directions for Los Angeles in July (Ludwig and Shelar, 1978).

4. DATA SOURCES AND CONTACTS

State and Federal governments expend a great deal of effort in developing monitoring programs and methods. Knowledge and availability of existing air monitoring programs and accurate monitoring techniques will allow monitoring personnel to maximize use and exchange of existing data.

4.1 Interagency Air Monitoring Service

The initial contact in assessing air monitoring information for Service lands should be with the NPS/FWS - Air Quality Branch (AQB), P.O. Box 25287, Denver, CO 80225 [telephone Sandra Silva: (303) 969-2806]. This position was established so the Service could use the air monitoring network already established by the NPS. According to the 1977 amendments of the CAA, the Service is expected to evaluate the potential adverse impacts of airborne contaminants and pollutant emissions on Service lands located in Class I airsheds of the U.S. As part of its strategy to address this obligation, the Service entered into an agreement with the NPS through their Denver Service Center. The Service has three experts detailed to the NPS which comprise the NPS/FWS-AQB. The details were accomplished through an interagency agreement and are available to address air quality matters. The NPS/FWS-AQB functions as part of a team of policy evaluators, modelers, physicists, biologists, and other scientists addressing air quality issues for the NPS and Service lands. The team is an important source of information because they monitor airborne contaminants, conduct research on their dispersion and adverse effects on natural and cultural resources, and assess potential impacts on these resources by airborne contaminants.

Service personnel needing information can contact the NPS/FWS-AQB for data on how biological systems respond to airborne contaminants. The NPS/FWS-AQB also has an extensive amount of information on bioindicators (sensitive biological systems that can be used to identify impacts from air pollutants) that may be useful for assessing the potential for airborne contaminants to impact Service lands. Contact should be made with the NPS/FWS-AQB to determine if they have a bioindicator that may be useful in your specific area and to find out about the availability of training information useful to Service personnel. Information on a screening procedure to evaluate air pollution effects in western Class I Wilderness Areas is available from the USDA-Forest Service in Fort Collins (Fox et al., 1989). This document and the NPS/FWS-AQB should be consulted if you are located in a Class I area.

4.2 State and Local Air Monitoring Programs

State monitoring programs are required under the provisions of the 1977 amendments to the CAA. Each state is required to survey every major source of emissions within its borders and develop strategies to ensure compliance with the guidelines set forth in the Code of Federal Regulations - 40, parts 50 and 58. Air monitoring data for every state should be available by contacting each state's agency in charge of monitoring air quality. The data are usually available through state air quality offices.

Several major metropolitan areas operate monitoring stations. For example, Chicago's Department of Environmental Control operates several "real time" stations. At these stations, continuous measurements are taken automatically. Readings for particulates, SO_2, CO, NO_x, CH_4,

O_3, and total (non-methane) hydrocarbons. Results from these stations are printed out at regular intervals in the downtown headquarters. Other cities, like New York and Los Angeles, operate similar sophisticated networks. These networks can provide useful information to Service personnel if past records are evaluated to determine those times of the day/month/year when air quality standards were violated (i.e. for ozone). However, because states often place a higher priority on monitoring air quality in urban areas, some caution should be taken if the Service lands are in rural areas. This is an area where local expertise (in Universities) or the NPS/FWS-AQB can help assess the utility of existing monitoring data.

The usefulness of state air quality data will vary depending on the specific location of the Service lands. The location of monitoring stations, predominant wind patterns, and climatic characteristics will all need to be assessed to determine the relevancy of the data to the site. Before use, Service personnel should evaluate the data to ensure that it is of known quality. The NPS/FWS-AQB (Section 4.1) can help in evaluating these data.

Table 3. Summary of national air monitoring programs and databases by agencies (use reference number and Attachment 1 to obtain additional information)

Program	Ref No.	Atmospheric Parameters	Coverage	Map	Database Contact
National Acid Precipitation Assessment Program (NAPAP)	9	Acidity	Nationwide	No	ADS Battelle PNL
National Atmospheric Deposition Program (NADP)/National Trends	10	Wet/dry deposition for H, NO_3, SO_4, NH_4, Ca, Mg, K, Cl, Na	Nationwide	Yes	NADP Database, James Gibson, Natural Resources Ecology Lab, CSU, Fort Collins, Co (30) 491-1978
Interagency Monitoring for Protected Visual Environments (IMPROVE)	11	Particulates, aerosol, optical, visibility	Nationwide		Bill Malm, NPS - Colorado State University (303) 491-8292
Subregional Cooperative	12	Aerosols, optical, meteorological parameters	Southwest	No	Electric Utility, Department of Defense, National Park Service and EPA Study (SCENES)

4.3 Federal Air Monitoring Programs

Several air monitoring networks are currently being operated by Federal agencies (Table 3). These programs can be very useful in monitoring airborne contaminants. Depending on the location of the Service lands, existing data may be adequate to address monitoring needs and should be checked first. The following steps help to determine which data sources are appropriate for particular locations:

1. Identify the air pollution sources and contaminants that may be affecting the airshed [i.e., the general area from which air moves onto Service lands (identified using windrose)] of the Service lands. For example, if there is a coal-fired power plant upwind from the Service lands, monitoring NO_x, SO_2, and particulates might be a concern.

2. Refer to Table 2 to determine if the contaminant is currently monitored in your area. For example, at the Watercress Darter Refuge in Alabama, look at the National Dry Deposition Network (NDDN), National Air Monitoring System (NAMS), State and Local Air Monitoring System (SLAMS), Eastern Fine Particle Visibility Network (EFPVN), NPS-Visibility Monitoring and Criteria/Gaseous Pollutant Monitoring Program, U.S. DOE Multistate Atmospheric Power Production Study, Interagency Monitoring and Protected Visual Environment (IMPROVE) and Subregional Cooperative Electric Utility, Department of Defense, National Park Service, and Environmental Protection Agency Study (SCENES).

3. Contact the NPS/FWS-AQB to determine if an air monitoring network is established for the area by the NPS. Data on how biological systems respond to airborne contaminants, information on appropriate bioindicators, and information on training can be obtained through the NPS/FWS-AQB. If your airshed of concern is located near a National Park monitoring station, the NPS Gaseous Pollutant Monitoring Network should be consulted. This program, with maps and figures for visual range isopleths, biomonitoring locations, and species used to document foliar injury to vascular plants, is summarized in a report on air quality in the National Parks (O'Leary, 1988).

4. Determine if any of the programs identified in Step 2 and 3 have sites near the Service lands. Use the information in Attachment 1. For example, the Watercress Darter Refuge Environmental Radiation Ambient Monitoring Systems (ERAMS) and National Acid Deposition Program/National Trends Network (NADP/NTN) have sites located nearby. For those programs that don't have maps available (e.g., NAMS, SLAMS), the database contact should be called to see if there are applicable data.

5. If sites are located near the Service lands, use wind roses and air monitoring data to calculate mass loading (i.e. concentration x volume of air) of potential air contaminants moving on to your site. Check if the available data is reasonably accurate for your site. Local weather and air quality experts (e.g., NOAA and universities) can assist with the determination.

6. Compare your list of possible pollutants to those presented in Attachment 2. Check to see if there are plants available on the list that could be used as sensitive biomonitors for your site.

7. If data are not available, consult with your EC specialist. If there are potential sources of air pollution affecting the airshed of the Service lands, it is advisable to seek funding to get an air monitoring network established for the Service lands. The information presented in Sections 5, 6, and 7 should be helpful in identifying needs and selecting an appropriate consultant to assist in setting up a program.

4.4 International Air Monitoring Programs

There are numerous international programs that collect data on emissions and background concentrations of trace constituents that can be useful in assessing atmospheric pollution. This may not be a concern for all Service lands, but should be a consideration for those areas that have airsheds that are impacted by international emissions. The International Council of Scientific Unions Committee on Data for Science and Technology (ICSU-CODATA) recently held a workshop to discuss internationally compatible environmental data. The result of this effort is a document (Carter, 1986) that discusses techniques for measurement of atmospheric trace constituents. This information should be considered by any refuge personnel who are considering exchanging their data with other international programs and/or scientists.

In addition to general information on comparable monitoring methods, there are specific reports on emissions that should be considered especially by Service lands on the Canadian Border. The most recent national emission inventory (Kosteltz and Delauriers, 1990) provides information on anthropogenic sources of emissions from the following point and area sources: industrial sources, fuel combustion in stationary sources, fuel combustion in mobile (transportation) sources, waste incineration (including wood waste incineration), and miscellaneous sources. All point sources emitting a minimum of 100 tons per year, of any of the parameters monitored, are included in this inventory. These parameters consist of: total particulate matter (TPM), sulphur dioxide, nitrogen oxides, carbon monoxide, total hydrocarbon (THC) and volatile organic compounds (VOC). The inventory is based on 1985 data and statistics which were used to compile the emissions on a provincial and sectoral basis. These emission estimates were then resolved to 127 x 127 km grids across Canada's provinces and territories for the atmospheric modeling requirements used in studies to determine the long-range transportation of air pollutants.

4.5 Available Training Programs

An extensive amount of training information is available through the EPA. Service employees should review the following information in light of their specific needs. The three types of training courses sponsored and available through EPA are those taught by a trained instructor at a training center (short course) (Table 4), self-study courses using literature, slide-tape shows, and video (Table 5), and satellite telecourses. All courses use material provided by the Air Pollution Training Institute (APTI) located in Research Triangle Park in North Carolina. Telecourses are seminars broadcast over satellite using compressed digital signal technology. These courses have recently been added to the APTI training program. Many of the courses listed in Tables 4 and 5 are being covered. APTI should be contacted for a current list of courses and locations where the telecourse will be offered. The course titles provide some indication of the orientation of each course. For more detail on current course content, available dates and general information, contact:

Environmental Protection Agency
Air Pollution Training Institute
Mail Drop 17
Environmental Research Center
Research Triangle Park, NC 2771
Current Technical Contact: Charles Pratt (919) 541-2355
Current Registrar: Jennifer Nun (919) 541-2497

Table 4. Instructor taught short courses on air pollution available through EPA APTI area training centers.

Course No.	Short Title	Time Required
400	Introduction to Air Toxins	4 days
401	Site Specific Source Monitoring and Evaluation for Air Toxins	4 days
403	Statistical Analysis and Interpretation of Air Toxins Monitoring Data	3 days
423	Air Pollution Dispersion Models Application	4 1/2 days
424	Source Receptor Modeling Workshop	3 days
426	Statistical Evaluation Methods for Air Pollution Data	4 1/2 days
435	Atmospheric Sampling	4 1/2 days
444	Air Pollution Field Enforcement	3 1/2 days
445	Baseline Source Inspection Techniques	3 days
450	Source Sampling for Pollutants	5 days
452	Principles and Practices of Air Pollution Control	3 1/2 days
460	Introduction to Permits	5 days
470	Quality Assurance for Air Pollution Measurement Systems	4 days

Area Training Centers

1. Rutgers, The State University,
   Joseph J. Soporowski, Department of Environmental Science, P.O. Box 231, New Brunswick, NJ 08903
   (908) 932-7715/9444

2. University of Florida
   Dale A. Lundgren, Department of Environmental Engineering Sciences
   Gainesville, FL 32611 (904) 392-0845

3. University of Cincinnati
   Timothy C. Keener, Department of Civil and Environmental Engineering, Location 71, Cincinnati, OH 45221
   (513) 556-2518/3676

4. University of Illinois at Chicago
   Peter A. Scheff, School of Public Health
   2121 West Taylor, Chicago, IL 60612 (312) 996-0800

5. University of Texas-Arlington
   Jerry W. Crowder, Environmental Institute for Technology Transfer, Room 142 Geoscience Building, 522 Cooper St., Arlington, TX 76019-0500
   (817) 273-2300

6. University of Michigan
   Gerald J. Keeler, Department of Environmental and Industrial Health
   School of Public Health, Ann Arbor, MI 48109-2029
   (313) 936-1836

7. California Polytechnic State University
   Harold M. Cota, Department of Environmental Engineering
   San Luis Obispo, CA 93407 (805) 756-2559

8. University of Washington
   Michael J. Pilat, Department of Civil Engineering (FX-10)
   Seattle, WA 98195 (206) 543-4789

Table 5. List of self-study courses available through EPA-APTI

Course No.[a]	Short Title	Time Required	Publish Date
General Courses			
SI:422	Orientation Course		1981
ST:443	Chain of Custody	1 1/2 hours	1983
ST:448	Vegetation Injury	30 hours	1976
SI/ST:453	Prevention of Significant Deterioration (PSD) Regulations	15 hours	1984
SI:473	Environmental Statistics	70 hours	1987
Meteorology-Modeling			
SI:406	Stack Height/Plume Rise	10 hours	1976
SI:409	Basic Air Pollution Meteorology	25 hours	1982
SI:410	Introduction to Dispersion Modeling	35 hours	1984
SI:424	Source Receptor Modeling	30 hours	1987
Atmospheric Monitoring			
CC:434	Ambient Monitoring	50 hours	1984
CC:436	Site Selection for SO_2 and TSP	35 hours	1982
CC:437	Site Selection for Photochemical and CO	35 hours	1982
CC:471	General Quality Assurance	30 hours	1984
Source Monitoring			
CC:414	Quality Assurance	35 hours	1983
ST:438A	Measuring Organic Emissions	30 hours	1984
Source Control Technology			
ST:445	Introduction to Baseline Source Inspection Techniques	88 hours	1985
CC:417	Controlling VOC Leaks	20 hours	1982

a. SI - Self Instructional Courses
CC - Correspondence Courses
ST - Slide-type course

4.6 Biomonitors

Biomonitors as used in this document are plants that are sensitive to a certain air pollutant. Numerous books have been written on this subject. A review was conducted by the National Research Council on "Biological Markers of Air Pollution Stress and Damage in Forests" (National Research Council, 1989). Those Service personnel that have forests in their area of concern should review this reference for guidance. Many of the studies older than 1985 were based on lab response of plants to pollutants. The current science in the area is leaning towards conducting field microcosms to evaluate elevated levels of CO_2, NO_x, and ozone under field conditions. Much of the results from this research is just becoming available; thus, Service personnel should seek council from the joint NPS/FWS AQB.

The APTI has compiled an extensive list of plants and their relative sensitivities to air pollutants. This information (Attachment 2) should be consulted to determine if a biomonitor (i.e. sensitive plant) is located or can be planted on or around your area to assess impact from atmospheric pollutants. This is one of the actions that Service personnel can do themselves (with training from APTI) and involve the public through volunteer programs.

The best way for Service personnel to use the training information from Tables 4 and 5 is to consider the following:

1. Evaluate what potential sources of air pollution affect the Service airshed of the refuge or area of concern. Try to identify known and suspected airborne contaminants (Section 6).

2. Look at Sections on Meteorological Transport Mechanisms and Airborne (Section 5), Contaminant Characteristics (Section 6), and Sampling Methodologies (Section 7) to obtain additional information on conducting monitoring for your specific contaminants. Use this information to formulate monitoring plans and provide background on how specific air contaminants are generated and if they may threaten particular refuges or Service lands.

3. Determine what training you and your staff need to assess impacts from potential air pollution sources. Can you get help from the EC specialist in this area? You or your staff might consider taking a course from EPA-APTI. If needed, look at the time and resources available. The instructed courses provide good opportunities to interact with others and to address specific problems. The disadvantage is that they require travel funds and sometimes students are required to have background information. The advantage of self-study courses is they are free of charge. However, there is no opportunity for class interaction or discussion of specific problems.

4. If you have specific questions on a course contact APTI and discuss your needs.

5. METEOROLOGICAL TRANSPORT MECHANISMS

Meteorological conditions (e.g., wind speed and direction, atmospheric stability, barometric pressure, air temperatures, dew point temperature, relative humidity, ground temperature, precipitation, and weather conditions) play an important role in movement and distribution of atmospheric pollutants. It is not possible in this short section to cover all the meteorological conditions that one must be aware of in interpreting air pollution data. However, some statements and information can help provide general guidance.

The classic work on air pollution has been done by A.C. Stern (1976; 1986), Volume I provides a detailed description of these processes and should be considered as an addition to the library at each Service office. In addition, several of the EPA-APTI courses could provide needed background. Meteorological patterns occur on global, regional, and local levels. On the local scale, emissions from unpaved roads and woodstoves need to be considered in design and site selection for air monitoring stations. Siting and operating of a monitoring site should be consistent with criteria established in CFR 40 Part 58. Air monitoring is done to determine what levels of pollutants are at a point over time.

5.1 Ambient Temperature

Ambient temperature is usually measured as part of most weather programs. Data can be obtained on daily highs and lows as well as records and averages for a site. When trying to assess a pollutant's impact, heating patterns can give a clue to expected changes in meteorological conditions. It also can provide information on time periods when susceptibility to pollution of various receptors can be highest. For example, plants may be more susceptible to pollution at some temperature ranges than others. Temperature can also play a role in the rate of formation of photochemical byproducts. Ambient temperatures can also vary over relatively small distances. For example, cities tend to be warmer than their rural surroundings. This in turn can have a profound effect on the timing of local pollution dispersion.

5.2 Atmospheric Stability

The vertical temperature profile over an area is a key factor influencing pollutant dispersion. Vertical profiles are an indicator of the stability of the air mass (the tendency of an air mass to mix vertically) that is being measured. Highly stable air has little tendency to rise and therefore to mix. Temperature inversions are an example of this phenomenon. The ability of the air to mix influences the fate of pollutants emitted into that air mass. Some of the worst pollution episodes on record have occurred at times of extreme atmospheric stability in river valleys or at the base of mountain ranges. Less stable air is often associated with precipitation. Unfortunately, most small weather stations likely to be used at refuges make no provision for effectively measuring vertical temperature profiles. This can be of special significance for those refuges located in basins where cold air settles in the winter (e.g., Salt Lake Basin).

5.3 Wind Direction and Wind Speed

Wind direction (direction from which the wind is blowing) (Figure 1) and speed are usually measured at small weather systems that are likely to be used at refuges. Wind roses are a standard

way of displaying this data, with the long extension of the chart pointing in the direction the wind predominantly comes from. These data indicate the direction of existing pollution sources as well as indicate where future pollution is likely to come from. Wind direction and stability greatly influence the transport and dispersion of atmospheric pollutants.

5.4 Precipitation

Precipitation measurements are usually made on a localized basis. They are important because precipitation is a mechanism for transferring contaminants from the air into the terrestrial and aquatic environment (some can also be deposited as dry deposition). This is done primarily through washout and rainout. Rainout is the process where a particulate actually becomes part of the cloud process, water condenses around it, and eventually it falls as rain or snow. Washout occurs when the falling raindrops collide with a particulate and then carry them along to be deposited. Both processes are important in transferring pollutants from the atmosphere to the ecosystem.

6. AIRBORNE CONTAMINANT CHARACTERISTICS

Airborne contaminants exist either in the gaseous or particulate phase. The physical form of the contaminant significantly determines the sampling methodology. A great deal has been written on air pollution measurements and it is beyond the scope of this document to duplicate all that information here. However, key references are discussed in this section.

This section is designed to provide enough information for Service personnel to make informed decisions as to what types of air monitoring are needed. Additional source documents are referenced for use as needed. References from Stern (1976, 1986), in particular Volumes I, III, VI, and VII provide a more detailed discussion of specific airborne contaminants and measurement methods. Additional citations are provided where we depart from Stern.

In other companion RFM's, pollutants have sometimes been classified into volatile and semi-volatile compounds. This may have some meaning from an analytical chemistry point of view, but is not particularly helpful in describing air pollutants, since by definition, if they are in the atmosphere and transporting as a gas, they are considered to be in a volatile state.

6.1 Gaseous Pollutants

6.1.1 Carbon Oxides

The two primary oxides of carbon of concern are carbon dioxide (CO_2) and carbon monoxide (CO). The primary sources of both of these compounds is fossil fuel combustion.

6.1.1.1 Carbon Dioxide. Carbon dioxide is a naturally occurring gas that cycles in the global biosphere in very large quantities. The gas is not toxic and is part of the respiration and photosynthesis processes of life. However, since the dawn of the industrial age, very large quantities of CO_2 have been emitted to the atmosphere from primary combustion of fossil energy, mainly oil and coal. The average global atmospheric concentration of CO_2 has increased in the last 100 years from approximately 270 ppm to a current level of 350 ppm. It is estimated that man-made CO_2 emissions in 1968 were approximately 3800×10^6 tons. This value could increase 300% by the year 2000.

The resulting problem with this concentration is that it can contribute to the "greenhouse" effect. CO_2 is an absorber of long wave radiation, particularly those wavelengths that the earth re-radiates as heat back into space. This heat is trapped and re-emitted and warms the atmosphere. Too much heating could affect fundamental changes in the Earth's energy balance.

From the point of view of a localized area like a refuge, the impact from CO_2 would probably be long term. These could include changes in weather (rainfall and temperature) patterns that influence changes in local hydrology, species composition, and sea levels. Long-term monitoring of CO_2 and associated impacts (e.g. rainfall) could be useful to assess these changes.

6.1.1.2 Carbon Monoxide. Carbon monoxide is an odorless and colorless gas. The primary source of carbon monoxide is fossil fuel combustion. The automobile is the leading source within the fossil fuel category. It is a poisonous gas because of its ability to bind with hemoglobin in the blood.

CO has long been known to cause death when exposure to a high concentration (> 750 ppm) is encountered. Not only is it a potential asphyxiant, but relatively low exposure levels (EPA "significant harm level" is no more than 50 ppm for an 8 hr. average) have demonstrated reduced central nervous system performance in humans. Carbon monoxide is oxidized to CO_2 and has a half life in the atmosphere of approximately 0.2 years. Average global background concentrations are about 0.1 ppm, and average city concentrations are in the range of 10-30 ppm.

CO is not toxic to vegetation at concentrations encountered in most polluted atmospheres. Total emissions exceed those of all other pollutants combined. Although it is not a phytotoxicant it is important from the standpoint of human health especially in areas like entrance gates and parking areas. This may need to be monitored to address industrial hygiene concerns of Service personnel. The general public is usually interested in this pollutant and biologists should be aware of the facts concerning it.

If more information is needed, EPA self-study course SI-448, Diagnosing Vegetation Injury Caused by Air Pollution, has a section (Unit 6) that covers carbon monoxide effects on plants. If monitoring is warranted, the EPA has a document that can be used to select sites for CO monitoring (EPA, 1975).

6.1.2 Sulfur Oxides and Other Sulfur Compounds

6.1.2.1 Sulfur dioxide (SO_2). The largest source of SO_2 is from fossil fuel combustion for electric power generation. Internal combustion engines, smelting processes, burning plant material and refuse are the next most important sources. These sources combined make up over 98% of all SO_2 sources in the United States. SO_2 has been known to cause both acute and chronic human respiratory health problems. SO_2 is oxidized to SO_4 in the atmosphere, which when combined with water and other compounds, causes acidic precipitation. Although SO_2 is expected to continue posing a threat to wildlife and habitat, the 1990 CAA requires reductions in SO_2 emissions and these may be noted in future monitoring data. Background concentrations of SO_2 are believed to be less than 1 ppb. Urban values range from 6 ppb to well over 100 ppb.

Service personnel managing lands near large urban areas, industrial sources, and point source fossil energy producers (e.g., power plants) may need to be concerned about SO_2. In more rural and pristine areas, personnel will need to be more concerned about SO_2 input in the form of wet and dry (acid) deposition.

Air Quality Standards--To protect man and his possessions against injury from SO_2 fumigations, primary and secondary standards have been set by the Federal Government. The primary standards, effective April 30, 1971, require that the annual SO_2 average in the atmosphere not exceed 0.03 ppm (80 $\mu g/m^3$). In addition, an average concentration of 0.14 ppm (365 $\mu g/m^3$) of SO_2 for a 24-hour period is not to be exceeded more than once a year. A secondary standard has also been set, requiring that a three-hour average of 0.5 ppm (1,300 $\mu g/m^3$) not be exceeded more than once a year (EPA-APTI SI:448). Various studies have been conducted on the sensitivity of plants to SO_2. This information is presented in Attachment 2 and summarized for SO_2 in Table 6.

6.1.2.2 Other Sulfur Gases. There are numerous other gaseous sulfur compounds that exist in the atmosphere. Some examples are hydrogen sulfide (H_2S), dimethyl sulfide (CH_3SCH_3), and

Table 6. Relative Sensitivities of plants to SO_2.

	CROPS	FLOWERS	TREES	GARDEN PLANTS	MISCELLANEOUS
Sensitive	Alfalfa	Sweet Pea	Quaking Aspen	Peas	Prickly Lettuce
	Buckwheat	Four O'Clock	Jack Pine	Rhubarb	Ragweed
	Barley	Cosmos	White Pine	Spinach	Dock
	Cotton	Bachelor Button	White Birch	Swiss Chard	Bracken Fern
	Red Clover	Aster	Larch	Beans	Wild Mustard
	Oats	Sweet William	Large-Toothed Aspen	Beets	Careless Weed
	Peas	Gladiola	Willow	Turnips	Sow Thistle
	Spinach	Tulip	Alder	Carrots	Yellow Clover
	Sweet Potatoes	Violet	Red Pine	Cucumber	Night Shade
	Lettuce	Zinnia	Austrian Pine	Lettuce	Chickweed
	Beans		Hazel	Radish	Annual Bluegrass
	Broccoli		Apple	Squash	Brazilian Pepper Bush
	Squash		Douglas Fir	Tomato	
	Wheat		Ponderosa Pine	Cultivated Mustard	
	Carrot			Kohlrabi	
	Tomato				
Tolerant	Celery		Cedar	Muskmelon	Privet
	Corn		Citrus	Corn	Lilac
	Onion		Maple	Onion	
	Potato		Linden	Potato	
	Cabbage			Cabbage	
				Turnip	

Source: EPA-APTI SI: 448.

carbonyl sulfide (COS). Only H_2S is of any significant concern from a pollution point of view.

H_2S is a highly toxic gas (to humans) emitted from a number of anthropogenic sources ranging from petroleum refineries, gas plants, and sewage treatment plants to coke ovens and paper mills. Relative to SO_2 emission, H_2S total emissions are small (H_2S accounts for a little over 1% of the total SO_2 emissions). Humans can detect H_2S at levels 5 to 100 ppb but can become sufficiently desensitized to it that they can be exposed to lethal concentrations (< 0.1%) without detecting its presence (Stafford et al., 1984).

On a local basis, H_2S could be a significant concern, although little is known about its direct toxic effects on wildlife. H_2S is non-toxic to vegetation at concentrations far above those that are lethal to humans or wildlife. Because H_2S is rapidly oxidized, it can contribute to the hazards posed by to SO_2. Average background concentrations are in the range from 0.05 to 0.1 ppb. Urban concentrations rarely exceed 100 ppb.

6.1.3 Nitrogen Oxides and Other Nitrogen Compounds

There are a number of nitrogen oxides, but the two most important pollution are nitrogen oxide (NO), and nitrogen dioxide (NO_2).

6.1.3.1 Nitrogen oxide. Nitrogen oxide is a colorless, odorless, and tasteless gas emitted both naturally by biological action, as well as from anthropogenic sources, primarily the combustion

of fossil fuels. It is the primary nitrogen species emitted directly from coal, gas, and oil-fired power plants and forest fires. In the air, NO is rapidly oxidized to NO_2; its half life in the atmosphere is 5 days. Normal background concentrations in the atmosphere range from 0.25 to 6.0 ppb. Because NO rapidly oxides to NO_2, NO_2 is the value usually reported for polluted areas. Because NO is so closely associated with NO_2, the two oxides of nitrogen are often collectively referred to as NO_x.

6.1.3.2 Nitrogen dioxide. The Service's concern regarding NO_xs will center primarily on the effect of increased nitrogen compounds on biogeochemical cycling, production of photochemical smog products and the potential contribution the NO_x can make to acidic deposition. Increased nitrogen compounds into nutrient poor areas can increase fertilization of the soil. Over extended periods this increase in nutrients can affect the community structure of vegetation. Atmospheric nitrogen inputs should be evaluated if Service biologists note changes in community structure. Photochemical smog is a serious pollutant formed in the atmosphere by a complex series of chemical reactions. Basically, NO_2 reacts with sunlight forming a single oxygen atom that can join with an oxygen molecule to form 0_3 (Figure 2). The process is further complicated by the activity of organic molecules (see section on hydrocarbons). This can lead to the production of a wide variety of chemical species in the atmosphere [i.e., peroxyacetyl nitrate (PAN)] many of which can have toxicological impacts on humans, animals, and plants.

Peroxyacetyl nitrate attacks the spongy parenchyma cells surrounding the air space into which the stomata open. The principal visible effect is the silvering or bronzing of the lower leaf area. The threshold concentration for injury is estimated at 0.01 ppm for a 6-hr. exposure, although petunias have been affected at 0.005 ppm for an 8-hr exposure. The youngest leaves in terms of maturity are most sensitivity (Wark and Warner, 1976).

On the basis of several studies, the oxides of nitrogen have been dismissed as a major source of damage to vegetation. Although NO_2 can cause injury to the mesophyll cells, it usually must be present in a concentration in excess of that normally found in the ambient atmosphere. Very sensitive vegetation may be affected by concentrations in the 2- to 10-ppm range. The threshold level is estimated at 2.5 ppm (4700 $\mu g/m^3$) for a 4-hr exposure. There is some evidence that NO_2 at a level of 0.5 ppm over a long time period may depress the growth rate. Injury seems to appear as irregular white or brown lesions.

Nitrogen dioxide is a reddish-brown gas and is partly the cause of the "brown" haze seen in many large urban areas. On Service lands that have visibility problems, an important gas to monitor because it is heavily involved in the initiation of photochemical smog that may impact visibility.

Nitrogen dioxide will eventually oxidize, forming particulate nitrates and nitric acid, which play an important role in acid deposition. Normally, nitrate compounds in the atmosphere will be found as particles and nitric acid as a gas.

The self-study course (EPA-SI-448) has an entire section directed at assessing photochemical oxidants with special attention to PAN.

6.1.3.3 Ammonia (NH_3) and Nitrous Oxide (N_2O). Ammonia and nitrous oxide are additional nitrogen compounds of interest in assessing injury to vegetation. Injury to vegetation from NH_3 is rare, and has usually resulted from accidental spills rather than continuous emissions to the atmosphere. Nitrous oxide is a nontoxic gas naturally present in the atmosphere in concentrations of

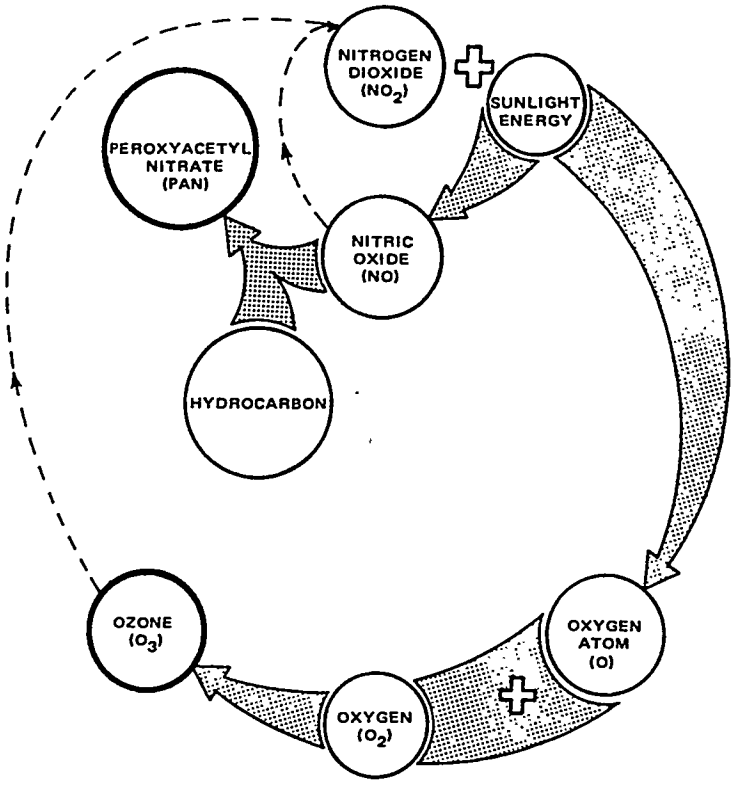

Figure 2. Photolytic Cycle with Hydrocarbons. Hydrocarbons interrupt the cycle by combining with nitric oxide to form PAN (DHEW, 1970).

250 ppb. It has generally been believed to be emitted from power generating plants in very small quantities relative to the other oxides of nitrogen. Ammonia is a naturally occurring gas and is present in the atmosphere in background concentrations of 1 to 20 ppb. It is produced naturally in large quantities and is a critical part of the nitrogen cycle. Pollution sources are from fossil fuel combustion and decomposition of organic matter.

6.1.4 Halogens

The gaseous halogens include the compounds of fluorine, chlorine, bromine, and iodine. Fluorine is typically present in a variety of forms in the atmosphere. It is emitted from a number of different sources such as aluminum smelters and phosphate fertilizer plants. In proximity to pollution sources, fluorine deposited on vegetation can be taken up by grazing animals with resulting significant toxicity. Elevated fluorine levels can cause deformation of bones and modeling (brown spots and fusing together) of teeth. If a fluorine source is located near the refuge, teeth modeling can be included as a routine check of wildlife health when examining species. Guidelines for forage concentrations of fluorine range from 40 to 80 ppm F, dry weight. An EPA self-study course (SI-448) on Vegetative Effects from Air Pollution covers symptoms of and diagnosing vegetation injury caused by fluoride.

Chlorine (Cl_2) is a yellowish green gas that is widely used commercially because of its strong oxidizing property. Nearly 10 million tons of the gas are produced annually in the United States. About 70% of this amount is used by the chemical industry in the manufacture of myriads of products from plastics to pesticides. About 18% is used by the pulp and paper industry, and the balance is used for sanitary purposes, such as water and sewage purification.

Chlorine can occur as a gas and in combination with a number of other compounds. In addition to hydrochloric acid, it occurs as chloroform, carbon tetrachloride, trichloroethylene (TCE), and freon. These compounds have varying environmental significance; TCE has toxicological significance; many of them are suspected carcinogens; and some are implicated in ozone depletion in the stratosphere (freon). Generally, they are all found in the atmosphere in very small quantities (< 1.0 ppb). The number of these chlorine compounds that are potential air pollutants is very large, including such things as pesticides and industrial compounds.

Many chlorinated hydrocarbon compounds are chemicals commonly associated with hazardous waste sites. While concentrations in the air may be relatively low, many of these compounds have the potential for bioaccumulation.

6.1.5 Hydrocarbons

Hydrocarbons are compounds made up of carbon and hydrogen and nitrogen and oxygen. There are extremely large numbers of these compounds; for example, over 60 different compounds have been measured at one time in the atmosphere of Los Angeles. Common examples of hydrocarbons and oxygenated hydrocarbons are alkanes (e.g. hexane), alkenes (e.g. butene), acetylenes, and aromatics (e.g. benzene), and oxygenated hydrocarbons (e.g. alcohols, phenols, ethers, aldehydes, and ketones). The primary source of these compounds is combustion of fossil fuels. The direct effect of these compounds is low. However, they play a key role in forming photochemical oxidants with the associated problems mentioned in this report under ozone and nitrogen oxides.

6.1.6 Ozone

Ozone (O_3) is a naturally occurring gas that is present in the stratosphere in concentrations of 200 ppb. It absorbs much of the sun's ultraviolet (UV) radiation that otherwise would reach the earth's surface where it would be harmful to many life forms.

Ozone is a secondarily formed pollutant in the troposphere (Figure 2). Ozone is formed both naturally and from atmospheric reactions with other pollutants. Probably the most important in the troposphere is the NO_2 sunlight reaction that is described in the photochemical smog discussion (Section 6.1.3.2).

Effects of ozone on vegetation were first noted in the late 1950s. It first attacks the palisade region in the mesophyll. The cell structure collapse, and buff or reddish-brown pigmentation (stipple) appears on the upper surface. Conifer needle tips become brown and necrotic. Spinach, pinto beans, tomatoes, and white pines are especially sensitive. A large number of pine trees in some of the western forests appear to be dying as the result of prolonged exposure to photochemical oxidants. The injury threshold has been estimated at about 0.03 ppm (59 $\mu g/m^3$) for 4-hr exposure. Damage to the plants cited above has been observed at concentrations of 0.1 ppm or less for time periods of 1 to 8 hr. A concentration of 0.06 ppm for 3 to 4 hr damages alfalfa. The retarding of citrus growth has also been attributed to ozone (Wark and Warden, 1976).

In remote locations near the surface of the earth (i.e. the troposphere), O_3 is present at 20 ppb and less. It has been shown to produce respiratory irritation in humans at levels ranging from as low as 100 ppb to 1000 ppb (1 ppm). There is no conclusive evidence that chronic exposure of humans to ozone at these concentrations can cause respiratory disease. However, data from animal studies indicates exposures of 1 to 5 ppm can cause irreversible lung damage. There is little data on the effects of ozone on wildlife. Service lands located near areas that experience heavy vehicular traffic can expect to have exposure to ozone. Most regions of the continental United States have summer ozone concentrations of sufficient magnitude to cause effects to vegetation.

6.2 Particulates

Particles are formed in two basic ways, mechanical action, such a grinding, and condensation of gases and liquids to form solid material. Particles formed by mechanical action range from 1 to 100 microns and those formed by condensation from .005 to .05 microns. Any of the tiny particles can stick together by agglomeration and increase the mean diameter to 2.0 microns.

Combustion products and photochemical aerosols make up a large fraction of the particles in the atmosphere, but these are usually very small in size. Larger particles are contributed by wind blown soil, fine dusts, forest fires, and sea salt along the coast. Man-induced sources of dust include incinerators, cement plant, limestone quarries, industrial furnaces paper mills, wood burning stoves, etc.

The sizes of particulates influence their transport characteristics and potential health hazards. The smaller a particle the longer it can stay suspended in the air, and consequently, the farther it can travel. This is important from both the spread of pollution to remote areas as well as the transport of toxic elements that can become associated with the surface of these particles and transport long

distances with them. A crude rule of thumb is that particles of 10 micron or less diameter have the potential to travel over long distances. Also, the smaller the size, the greater potential health impact they can have. In general, particles less than 2 to 3 micron in diameter can penetrate into the pulmonary region of the lungs.

Particulate loading may be harmful, harmless, or indirectly beneficial to vegetation depending on their composition. However, particulates can also carry many potentially toxic elements, such as lead and cadmium, to remote Service lands. Injury may result from the deposition of a relatively thick crust of lime and the toxic effects of alkaline solutions from cement dust. Cement dust may also result in beneficial effects, however, through changes in the soil reaction. The greatest concern to Service lands from particulates is their impact on visibility. The FWS-AQB and NPS IMPROVE program (See Attachment 1) have a vast amount of experience in dealing with this issue and should be consulted. If visibility is a concern on your Service lands it may be advisable to identify and track impacts of various particulates by conducting a complete aerosol characterization at the site. This type of analysis would include fine particle composition analysis for all particles in the 2.5 to 10 micron range that are responsible for visibility impacts.

6.3 Pesticides

Most of the atmospheric concerns to Service lands from pesticides will be associated with drift from applications that may move onto Service lands via the air pathway. Direct monitoring of these are difficult due to varying application methods and timing of application. Pesticide drift onto Service lands is a concern that can be monitored using sensitive vegetation (Attachment 2).

The class of pesticide most frequently involved in plant injury is herbicides. About 50 different herbicides are in use today. Not all have caused problems. Damage to non-target vegetation has been most frequent with the phenoxy herbicides, because of their high volatility and tendency to drift. For example, 2,4-D has been known to drift as far as 15 miles from the site of application. Other factors affecting drift include the type of equipment used and the method of application, the form of the material being applied (spray or dust), and the micro-climatology of the area.

Potential sources of injurious herbicides, in addition to their normal use (or misuse), include the manufacture, formulation, and packaging processes. No data are available on emission rates. The greatest source is drift from the application process itself. This latter source is interesting because the application of certain classes of pesticides varies with geographic location. Crop insecticides are used mostly heavily in the southern United States, while herbicides are used most heavily in the corn belt.

Most problems with herbicides have been associated with the phenoxy herbicides such as 2,4-D, 2,4,5-T, and 2,4,5-TP. When non-target crop plants are affected by drift, the most common symptom is deformation of leaves, fruits, or other marketable portions of the plant. The leaves develop a "lacy" appearance, and the stem or petiole may become abnormally flattened. Discolorations may also occur.

7. SAMPLING METHODOLOGIES

This section describes briefly various sampling methodologies with emphasis on commonly used techniques. The discussion parallels the description of the pollutants given in the previous section. The intent is to give Service personnel enough information to discuss sampling needs with experts in the field. More than one method is available for most pollutants, but discussion here will be limited to those that can easily be used in a monitoring program. The methods discussed have been field tested and can provide good results monitoring the presence of atmospheric pollutants. The methods discussed are not all regulatory driven. If Service personnel are interested in other methods they should refer to Stern (1976) or Carter (1989) for more details.

If Service personnel are interested in complying with the CAA or need to use methods that obtain comparable data on atmospheric pollutants covered by the CAA, they should refer to 40 CFR Part 53 that discussed ambient air monitoring reference and equivalent methods. A current list (updated about every 6 months) of these methods and some suggested equipment suppliers can be obtained from:

U.S. Environmental Protection Agency, Office of Research and Development
Atmospheric Research and Exposure Assessment Laboratory
Methods Research and Development Division (MD-77)
Research Triangle Park, NC 27711 (919) 541-2622/4599

In general, the large number of sampling and analytical methods can be considered to fall into two large categories: continuous and intermittent samples. Continuous methods draw ambient air through an observation chamber, and the trace gas of interest is detected by a physical effect which is proportional to its concentration. Intermittent methods depend on a sampling procedure which may either be part of the analytical set-up or form a separate unit. The sampling procedure often serves to trap and pre-concentrate the trace gas(es) of interest cryogenically, by adsorption, or by chemical reaction. Then, the amount of trapped compound(s) is determined by colorimetry, chromatography, optical spectroscopy, mass spectrometry, or by other conventional analytical procedures.

Table 7 is a summary of the information discussed in this chapter. With proper training Service personnel can operate monitoring stations for pollutants using either intermittent samples or continuous monitoring methods once they have been set up and calibrated by qualified experts. The intermittent sampling methods usually involve capturing molecules of the contaminants from air pumped through a filter or solution containing a reactive substance. These are then sent to a laboratory for analysis. The laboratory methods employed may involve direct analysis of the contaminant after it is stripped off of filters or through the measurement of chemical reactions that occur in solutions. If measurement of contaminants using continuous methods is needed, the FWS-AQB should be contacted to determine the best approach to install the system. Once in place, Service personnel can assist in operation and calibration checks.

7.1 Sampling Gaseous Pollutants

7.1.1 Carbon Dioxide and Carbon Monoxide

An accepted method (EPA designated equivalent method) for measuring CO_2 and CO concentrations, non-dispersive infrared gas analysis (Stern, 1976), works on the principle of selective

Table 7. Summary of atmospheric monitoring methods for major atmospheric pollutants.

Atmospheric Pollutant	On Site Sampling/Analysis Method	Lab/Analysis Method
CO_2/CO	Continuous - infrared gas analysis	
SO_2	Continuous colorimetric method	
H_2S	Continuous, cadmium hydroxide/methylene blue	Colorimetric method
NO_2	Continuous	Colorimetric using spectrophotometer chemiluminescence
HNO_3	Discontinuous using filter pack trapping system	Ion chromatography
NH_4	Discontinuous trapped electrode on filter	Specific ion
Halogens	Discontinuous trapped on filter	Ion chromatography
Chlorinated Hydrocarbons	Discontinuous TENAX trap	Gas chromatography
Pesticides	Discontinuous porous polyurethane foams	Gas chromatography
Hydrocarbons	Continuous/discontinuous using traps	Gas chromatography
Ozone	Continuous using UV absorption method	Spectrophotometry
Particulates	Discontinuous trapped on a filter and measure air volume	Graphite furnace atomic absorption or other standard analytical technique

absorption by CO_2 of infrared radiation. This is the method of choice of the World Meteorological Organization (WMO). The analyzer has two parallel cells; one cell receives the air sample; and the second is a reference cell with no CO_2. The difference in the energy absorbed in the two cells indicates the concentration of CO_2 present in the sample cell. Calibration with CO_2 standards is necessary since this is a relative method of measurement. Potential interference of other atmospheric gases, such as water vapor, must be accounted for.

7.1.2 Sulfur Dioxide

An older, but more common method for SO_2 measurement is the West - Gaeke method. This is a colorimetric method based on a red-violet color produced by a chemical reaction. Sulfur dioxide is collected in a 0.1 M sodium tetrachloromercurate solution producing a compound called dichlorosulfitomercurate (DCSM). When reacted with hydrochloric acid, pararosaniline and formaldehyde, DCSM produces a red-violet color. The absorbance of this color is then measured on a spectrophotometer. There are a large number of newer methods that have been used at various times and for various purposes, including flame photometric detectors and various fluorescent analyzers. They are referenced and described in some detail in Stern (1976).

7.1.3 Hydrogen Sulfide and Other Sulfur Compounds

A number of different procedures are available for H_2S and have been used over the years. These include the cadmium hydroxide methylene blue method (colorimetric method); absorption on glass beads coated with $KHSO_4$ and $AgSO_4$; and the use of lead acetate treated tapes, mercuric chloride tapes and silver membrane filters. Various techniques that depend on fluorescence have also been developed. Techniques that would be used at many rural locations would have to be able to detect low concentrations of H_2S. Highly sensitive techniques are still in development and not ready for general monitoring applications on Service lands.

7.1.4 Nitrogen Oxide/Nitrogen Dioxide

There are several methods for measuring NO_2 trapped on a medium and treated with sulfanilic acid or sulfonamide to produce a characteristic color. The absorbance of this color is then measured with a spectrophotometer. These methods are described in some detail in Volume III of Stern (1976).

The above referenced methods all require a preconcentration on some collecting medium, a collection of that sample and its eventual analysis in a chemistry laboratory. For most Service applications, a continuous NO/NO_2 monitor will be required. There are many commercial units available employing a larger number of different techniques. Probably the most common are those based on chemiluminescence. In this case, NO is reacted with 0_3 to form a characteristic chemiluminescent reaction. In most of these procedures, the results are expressed in terms of NO_2. Another chemiluminescence method involves the reaction of NO_2 with luminol.

7.1.5 Nitric Acid and Nitrates

A great deal of interest has been centered on measuring nitric acid (HNO_3) and nitrates in the atmosphere because of the concern with acid deposition. Nitric acid can be measured using modifications of various chemiluminescent techniques. It is important to note that nitrates are usually in particulate form and require different sampling procedures. The EPA has developed a filter pack system for measuring both of these compound groups in the atmosphere with two filters in tandem. The first filter, made of Teflon, traps only particulates with associated nitrates. The second filter, made of a nylon material, traps the gaseous HNO_3. The filters are exposed for a given time period (ranging from 1 day to 1 week) to a measured volume of air, They are then collected and sent to a laboratory where the material on the filters is analyzed using ion chromatography. The protocols for this method are still being worked out, however it is far enough along that it could be used in a regular air monitoring program in a rural location. The initial set up, calibration, etc., should be

done by someone familiar with the procedure. Subsequent sample handling could be easily handled by other Service personnel.

7.1.6 Nitrous Oxide and Ammonia

Nitrous oxide is measured using a gas chromatograph with an electron capture detector. Most of the methods used for sampling and analyzing N_20 are rather sophisticated and are usually employed in research programs. We are not aware of instruments that can be routinely employed for monitoring. Problems on Service lands are unlikely to result from N_2O. Ammonia is measured by a number of different techniques, many of them difficult. One of the more common methods is the use of an oxalic acid treated filter. Once the ammonia has been trapped, the filter is then analyzed with a ring oven. The EPA Dry Deposition Network is attempting to measure ammonia because of its role in acid deposition (EPA, 1987). Basically, they use a citric acid treated filter that traps the ammonia. The filter is then removed and sent for chemical analysis by ion specific electrode. This latter method is well developed enough that it could be used in routine monitoring programs.

7.1.7 Sampling Halogens and Chlorinated Hydrocarbons

*7.1.7.1 **Halogens.*** Chloride and fluoride compounds are usually present in the atmosphere as particulates. They are usually trapped on a filter and then taken to an analytical chemistry laboratory where they are analyzed by ion chromatography.

*7.1.7.2 **Chlorinated Hydrocarbons.*** Many of the chlorinated hydrocarbons mentioned earlier, particularly those that are not pesticides, are sampled by means of a trap that is removed and taken to a laboratory for chemical analysis using gas chromatography. Depending on the methodology, laboratories can use electron capture detectors or gas chromatography/mass spectrometry for analysis. The trapping mediums are particularly important and a great deal of time has been spent in developing these methods.

Tenax gas chromatography traps are used for small molecular weight volatile organics. Sometimes these traps are used in conjunction with a backup carbon filter for the more volatile compounds such as vinyl chloride and methyl chloride and vinyl bromide. Nonpolar compounds are sometimes better trapped using XAD 4 and XAD 7 instead of Tenax gas chromatography. XAD 4 has been shown to be particularly good at trapping certain organophosphorus pesticides such as malathion, mevinphos, and parathion. There are a large number of other materials available for selective trapping of organic compounds in the atmosphere, and it is strongly recommended that the refuge manager get together with a good chemist, look at the potential chlorinated hydrocarbons of concern, and make a decision as to which trapping medium should be used. As with most atmospheric sampling, this initial selection, setup, and calibration should be done by technical staff with experience in the specific operation. Once established, Service personnel can change collectors with minimal difficulty and involvement.

Of particular interest in sampling pesticides and larger molecular weight organic compounds are porous polyurethane foams (PUF). They offer little resistance to air flow and have been shown to be particularly effective for polycyclic aromatic hydrocarbons, PCBs, DDT, and over 50 different kinds of pesticides. For these larger molecules they operate with the same efficiency as Tenax gas chromatography traps. However, they are not as effective for the highly volatile organic compounds.

7.1.8 Sampling Hydrocarbons

The traditional concern with these compounds has been their role in photochemical smog formation; therefore, methods for their measurement have been developed that give total non-methane hydrocarbon concentrations. Using flame ionization gas chromatography, methane was measured separately and the differences determined. Usually, gas chromatography is employed for both types of hydrocarbons with different columns and pretreatments used for separation. The literature on this is extensive as is the potential number of compounds of concern. Again, a fairly good review of these procedures is given in Stern, Volume III (1976).

7.1.9 Sampling Ozone

Ozone is measured by a number of different methods. One procedure is a gas phase chemiluminescent reaction between ambient air containing O_3 and ethylene. This produces an excitation that emits light which is analyzed with a photomultiplier tube. This method is good over a range of 5 to 1000 ppb 0_3. Another type of method makes use of the reaction between KI and 0_3. These methods are explained in some detail in Stern, Volume III (1976). Two other methods are the reaction between 0_3 and N_2O which produces chemiluminescence and UV absorption by 0_3. Most of these methods have been engineered into commercially available instruments. The majority of the methodologies have been extensively cross-calibrated. These devices can be placed for routine use in local areas like a refuge as a part of an atmospheric monitoring program.

7.2 Sampling Particulates

7.2.1 Particulates

Particulates are usually measured using a vacuum source (a pump), an air metering device and a filter. There are a wide variety of pumps commercially available for monitoring air. The flow rate, filter medium, and location will contribute to the choice of pumps. A number of commercially available particulate samplers are manufactured and these usually have the motors and air metering device as integral parts of the instrument.

Precise and accurate measure of the air volume sampled is essential to properly express atmospheric concentrations of particulates. An air metering device is placed between the air sampling heads, and the vacuum pump is used to measure sample volume. This arrangement of these devices can introduce changes in air pressure in the sample that should be measured to accurately determine particulate concentrations.

There are two types of metering devices - ratemeters and volume meters. Examples of these different types of meters are ratemeters, orifices, and rotameters in the first category; and wet test meters and dry test meters in the latter category.

A large number of filter materials are used for sampling particulates in the air. Most filters sieve the particles from the air. Trapping efficiency is generally much higher than the stated pore size. Filters are made from a variety of materials depending on the sampling application. Glass fiber-based filters have traditionally been used for measuring total suspended particulates. They are inappropriate for trace metal and particulate sulfate analyses. Quartz-based fiber filters are used for

sulfate analyses. Polycarbonate based filters (Nucleopore) are used for trace element analyses. Teflon-based filters can be used for monitoring particulate nitrate and trace elements, and nylon-based filters have been used for sampling NO_3 (technically not in particulate form). Teflon- and quartz-based filters generally provide the lowest contamination and minimal artifact formation.

Filtering by sieving is only one way to trap particulates. Sampling by impaction is an excellent technique employed when it is desirable to get an estimate of particle size distribution. Cascade impactors employ this method. The Service may require this technology if it is concerned about the rates of particulate deposition into an area. Particle size distribution can be used to obtain estimates of deposition velocities.

7.2.2 Wet and Dry Deposition Measurements

Both gases and particulates enter an ecosystem either through wet deposition (i.e., rain, snow, or fog) or dry deposition. Measurement techniques have not been entirely worked out for dry deposition measurements and will not be discussed in any detail.

7.2.2.1 Wet Deposition Measurements. Methods for wet deposition have been well worked out for certain compounds. A wet deposition monitoring program should use the technology developed in the NADP/NTN. In establishing NADP and NTN, scientists sought to ensure uniformity in equipment, sampling protocol, and analytical procedures by designating specific precipitation collection equipment to be used throughout the network. To encourage sampling to uniformity, the NADP/NTN provides guidance into site selection, sampling strategy, management of sites, and technical support to groups in the public and private sector by providing training and distributing manuals upon request. "Instruction Manual NADP/NTN Site Operations," is provided as a guide to operations at NADP/NTN collection sites, including sample collection procedures and maintenance functions. Also the NADP/NTN Instruction Manual - Site Selection and Installation Guide is available.

Guidance documents can be obtained by directing requests to
Gwen Scott, (303) 491-1465.

Information on training courses can be obtained by directing requests to
Linda Bandhauer (303) 491-1977.

or write to: NADP/NTN Coordination Office
National Resource Ecology Laboratory
Colorado State University
Fort Collins, CO 80523

7.2.2.2 Dry Deposition Monitoring. Under sponsorship of the National Acid Precipitation Assessment Program (NAPAP), the EPA has begun deploying a nationwide NDDN. After 40 eastern sites are operational, installation of 20 western sites will begin. The goal is to have a nationwide network of up to 100 stations providing atmospheric deposition information by the end of FY-89.

As the eastern sites become established, they will be supervised from the regional EPA offices: Gainesville, St. Louis, Research Triangle Park, and Boston. Regional offices at Denver and

Reno will be established as the network is deployed West of the Mississippi River, (Attachment 1, Figure 1-1 Proposed NDDN Sites).

The NDDN guidance documents addressing field operations, siting criteria, etc., can be obtained by directing inquiries to

Steve Bromberg
(919) 541-1919
EPA, Mail Drop 75, Research Triangle Park, NC 27711
or the regional EPA offices; previously identified.

Additionally, the NPS monitors other sampling sites through the NPS Criteria Pollutant Monitoring Program (Attachment 1, Figures 1-3 and 1-4). Since 1979, NPS and EPA have been monitoring particulate concentrations at designated sites using stacked filter samplers. This particulate monitoring program has been expanded to include other Federal agencies with the establishment of the IMPROVE program.

The two programs use the same sampler and nearly identical sampling protocols and are operated by the Air Quality Group of Crocker Nuclear Laboratory at the University of California at Davis.

A new sampler has been designed for these networks called the IMPROVE Modular Aerosol Monitoring Sampler. A general description of the Sampler, criteria for selecting specific sampling sites, and sample changing procedures, are found in the IMPROVE Sampler Manual.

This manual can be obtained by directing requests to

Air Quality Group
Crocker Nuclear Laboratory
University of California
Davis, CA 95616
(916) 752-1123

8. REFERENCES

APTI, 1990. Chronological Schedule of Air Pollution Training Courses: January 1991 through December 1991., U.S. Environmental Protection Agency, Air Pollution Training Institute, Research Triangle Park, North Carolina.

Bigelow, D.S. and S. R. Dossett, 1988. Instruction Manual NADP/NTN Site Operations, Natural Ecology Laboratory, Colorado State University, Fort Collins, Colorado 80523 and Central Analytical Laboratory, Illinois State Water Survey, University of Illinois, 2204 Griffith Drive - Champaign, Illinois.

Carter, G. C. (ed.), 1989. Directions for Internationally Compatible Environmental Data, A CODATA Workshop, McGill University, Montreal, Canada, May 13-24, 1986, in CODATA Bulletin 21:1-2.

DHEW, 1970. Air Quality Criteria for Photochemical Oxidants, U. S. Department of Health, Education, and Welfare, Washington, D.C.

Environmental Protection Agency, 1987. Western National Dry Deposition Network Site Selection, Office of Research and Development, Environmental Monitoring Systems Laboratory, Research Triangle Park, NC.

Eldred, R. A., 1988. IMPROVE Sampler Manual, Air Quality Group, Crocker Nuclear Laboratory, University of California, Davis CA 95615, January.

Environmental Protection Agency, EPA-APTI, 1978. Air Pollution Training Institute, SI:448 - Diagnosing Vegetation Injury Caused by Air Pollution, EPA-450/3-78-005.

Fox, D. G., A. M. Bartuska, J. G. Byrne, E. Cowling, R. Fisher, G. E. Likens, S. E. Lindberg, R. A. Linthurst, J. Messer, and D. S. Nichols, 1989. A Screening procedure to Evaluate Air Pollution Effects on Class I Wilderness Areas, General Technical Report RM-168, U.S.D.A., Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO 80526.

Kosteltz, A. and M. Deslauriers, 1990. Canadian Emissions Inventory of Common Air Contaminants (1985), Environment Canada, Report EPS 5/AP/3.

Ludwig, F. L. and E. Shelar, 1978. Site Selection for the Monitoring of Photochemical Air Pollutants, Environmental Protection Agency, EPA-450/3-78-013.

National Research Council, 1989. Biologic Markers of Air-Pollution Stress and Damage in Forests, National Academy Press, Washington, DC.

O'Leary, D (ed), 1988. Air Quality in the National Parks, U. S. Department of the Interior, National Park Service, Air Quality Division, Washington, DC.

Stafford, D. A., D. L. Hawkes, and R. Horton, 1980. Methane Production from Waste Organic Matter, CRC Press, Inc., Boca Raton, Florida.

Stern, A. C., 1976. Air Pollution, 3rd Edition; Volume I, Air Pollutants, Their Transformation and Transport; Volume III. Measuring, Monitoring and Surveillance of Air Pollution, Academic Press, Inc., New York, New York.

Stern, A. C. 1986. Air Pollution, 3rd Edition. Volume VI, Supplement to Air Pollutants, Their Transformation, Transport and Effects. Volume VII, Supplement to Measurements, Monitoring, Surveillance, and Engineering Control, Academic Press, Inc., New York, NY.

U.S. Department of the Interior, Fish and Wildlife Service, 1979. The Clean Air Act: Its Relation To Fish and Wildlife Resources, Biological Services Program, FWS/DBS-76/20.8.

Wark, K. and C. F. Warner, 1976. Air Pollution: Its Origin and Control, Harper and Row Publishers, New York, New York.

ATTACHMENT 1

DETAILED INFORMATION ON NATIONAL AIR MONITORING PROGRAMS AND DATABASES

Air Monitoring Manual

ATTACHMENT 1
DETAILED INFORMATION ON NATIONAL AIR MONITORING PROGRAMS AND DATABASES

Reference 1 - National Atmospheric Deposition and Air Quality Monitoring of NAPAP

National Dry Deposition Network (NDDN)--The NDDN is an EPA-funded program that began in 1983 and is affiliated with NAPAP. The purpose of the program is to determine spatial and temporal trends in acid deposition through the sampling and analysis of dry deposition. Ambient concentrations are measured for ozone, sulfur dioxide, nitric acid, and particulate sulfate and nitrate at 52 sites nationwide. Meteorological parameters are also measured (e.g., temperature, precipitation amount, relative humidity, wind speed, and direction). A dense network of monitoring sites is located on public land in the northeast. In the west, sites are located where current research shows potential adverse effects (Figure A-1). Monitoring of O_3 and meteorological parameters is continuous; HNO_3, SO_2, SO_4, NO_3 is collected on a sample that runs for one week; the data is collected weekly.

Strict data quality control is exercised at the sites, including frequent equipment testing and calibration. All NDDN deposition data are stored in the Acid Deposition System (ADS).

For more information, contact Steve Bromberg at the EPA in Research Triangle Park, North Carolina 27711, Mail Drop 75, (919) 541-2919.

Reference 2 - Eastern Fine Particle Visibility Network (EFPVN)--In 1986, EPA established a fine particle visibility network in the eastern U.S. to examine visibility impairment from pollution-derived regional haze. The overall purpose of the network is to facilitate the review of particulate matter air quality standards with respect to fine particles and visibility, and to develop a long-term database. The long-term database will be useful for: 1) determining the spatial and temporal variations in the indicators of visibility degradation; 2) refining visibility/particulate component relationships, especially for non-sulfate components; 3) receptor modeling to determine causes of visibility degradation and elevated fine particle concentrations by source and chemical composition; and 4) for elucidating the links between visibility impairment, climatic effects, and acid deposition caused by anthropogenic air pollutants.

The last two functions of the EFPVN may yield information useful to the Fish and Wildlife Service. Visibility impairment could be used as an early warning indicator of potential habitat degradation if strong links do exist between visibility impairment and acid deposition or climatic effects.

The first year of the full operating program will have 5 monitoring sites, one each in New York, Virginia, Illinois, Kentucky, and Tennessee. Plans are to expand the network by cooperating with other existing networks, such as NDDN, Southern Commercial Ozone Network, and Interagency IMPROVE network. Samples will be taken daily.

More information may be obtained from Neil Berg at EPA Air and Radiation, Research Triangle Park, North Carolina, (919) 541-5520.

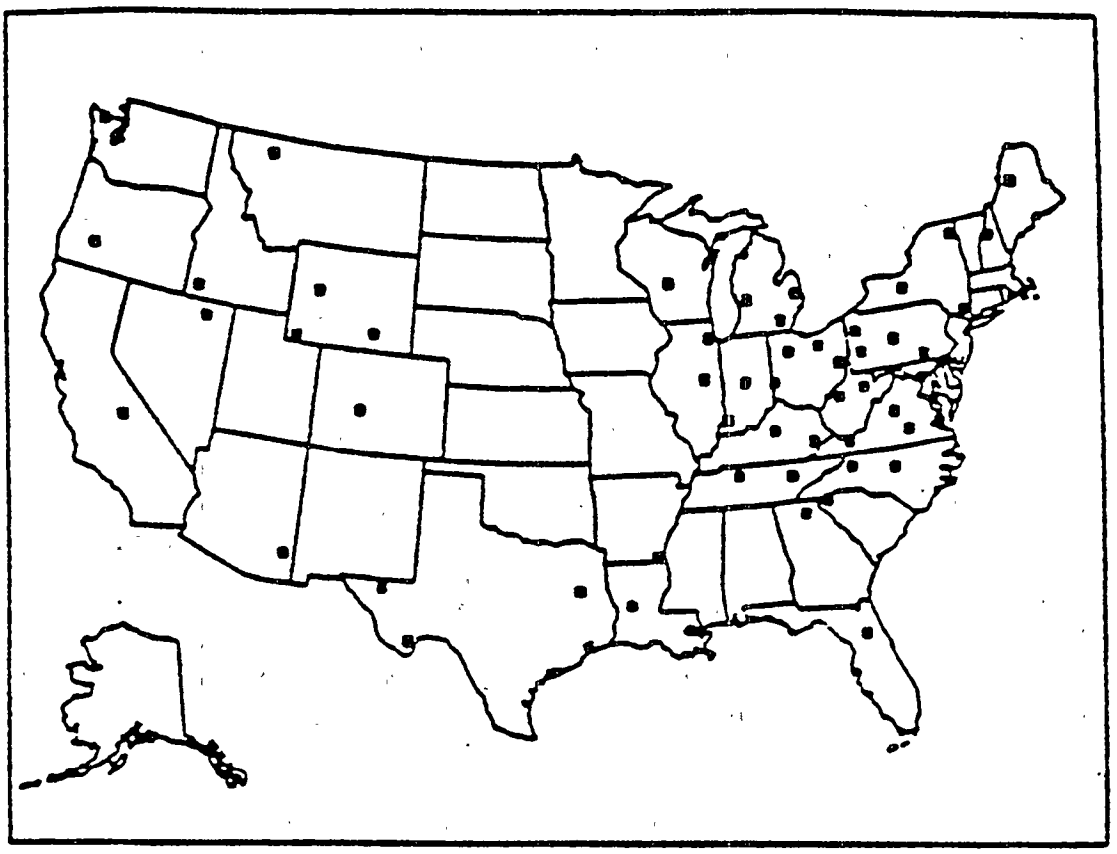

Figure A-1. National Dry Deposition Network Monitoring Sites.

Reference 3 - State and Local Air Monitoring System (SLAMS) and National Air Monitoring System (NAMS)

These two programs were developed to measure ambient air concentrations of six criteria pollutants (lead, sulfur dioxide, ozone, carbon monoxide, nitrogen oxide, particulates) for compliance with the Clean Air Act. Guidance for site locations and sampling design, Quality Assurance/Quality Control, etc., can be found in the Code of Federal Regulations, Title 40, Part 58. Individual states develop the monitoring plans with approval from EPA, and conduct the sampling. The SLAMS is controlled largely by state and local agencies, and includes approximately 3500 monitoring stations nationwide. The NAMS is a subset of the SLAMS, consisting of about 1400 monitoring stations primarily in urban areas. Initial monitoring for the six criteria pollutants began in the early 1960s, but the more comprehensive NAMS and SLAMS network was not established until 1980. Each station may not monitor for all six pollutants. Some samples are collected hourly, every sixth day for 24 hours, every day, every other day, or every sixth day.

Data quality is regulated by the EPA, and data are stored in AIRS. For more information about NAMS and SLAMS, contact Stan Sleva in EPA Air and Radiation at Research Triangle Park, North Carolina, (919) 541-5477.

Reference 4 - Environmental Radiation Ambient Monitoring System (ERAMS)

This program was started in 1973 to document radiation levels in a variety of environmental media such as air and precipitation, drinking water, surface water, and pasteurized milk. Sampling is designed to cover a broad geographic region and areas with high-density population. Samples are also taken in areas close to a potential source of radiation, such as downstream from a nuclear facility. There are 69 field sampling stations for air and precipitation, 78 stations for drinking water, 58 stations for surface water, and 66 locations for milk (Figure A-2). Airborne particulates and precipitation are monitored continuously with filter changes twice weekly. Surface water and drinking water are sampled quarterly and milk is sampled monthly.

ERAMS has its own database (by the same name) which contains ambient levels of radiation in air, milk, and water. Outputs from the database include a quarterly report of ambient levels. For more information contact Jon Broadway (acting chief) at the EPA Eastern Environmental Radiation Facility, Monitoring and Analytical Services, Montgomery, AL, (205) 270-3400.

Reference 5 - Visibility Monitoring

The importance of the aesthetics of NPS resources has gained enough attention that a nationwide program quantifying visibility was launched in 1979, and funding has increased since then. The original NPS network was established to monitor visibility in select Class I areas. Congress increased funding in 1986 and in 1987 to expand the NPS Visibility Network. Currently, the NPS maintains a 50-site visibility (particulate) network (including camera-only sites). The NPS Visibility Network consists of several components, including the IMPROVE network. Table A.1 lists the components of the Visibility and Gaseous Pollutant Networks. Figures A-3 and A-4 depict the distribution of some of the NPS air monitoring stations.

Reference 6 - Criteria (Gaseous) Pollutant Monitoring Program

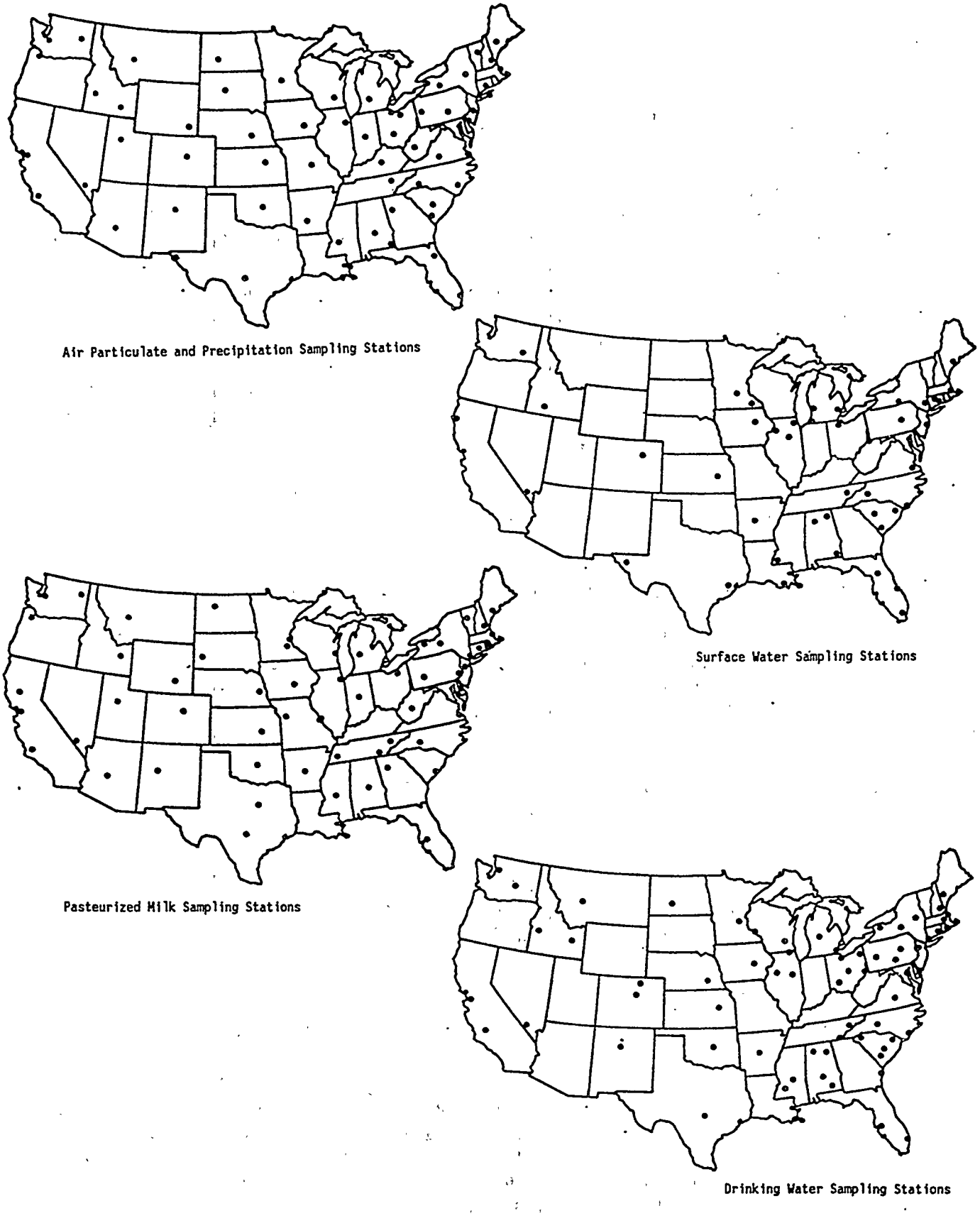

Figure A-2. Environmental Radiation Ambient Monitoring System (ERAMS) field sampling stations.

Table A-1. Components of NPS Air Monitoring Activities

NETWORK	COMPONENTS
Visibility	Aerosol Optical View Particulate (including IMPROVE network)
Gaseous Pollutant	SO_2 O_3 Total suspended particulates NO_2

For more information, contact NPS-Air, CIRA, Foothills Campus, Colorado State University, Fort Collins, Colorado, 80523, Attention: Bill Malm (303) 491-8292.

The NPS cited the need to Congress for criteria (gaseous) pollutant monitoring in remote (Class I) areas because of resource sensitivity to O_3 and SO_2 (John Christiano, private communication). Currently, the Criteria Pollutant Monitoring Network consists of 47 existing and proposed monitoring sites in 38 park units (Figure A-3). SO_2, O_3, and some meteorological parameters are measured at the sites. The network is one of the largest in the country in terms of the number of monitoring sites, and the largest in terms of geographical range.

The NPS manages this large program through the Air Quality Division, but much of the work is awarded to contractors (e.g., Aerovironment, Inc., EMSI, and Desert Research Institute). More information may be obtained through NPS Air Quality Division, Technical Support Branch, P.O. Box 25287, Denver, Colorado, 80225, Attention: Miguel Flores or John Christiano, (303) 969-2070.

Reference 7 - Acid Rain Effects on Watersheds

This program is part of NAPAP'S Aquatic Effects Project. It began in 1982 to determine how anthropogenic acidity affects the chemistry of surface and ground water in forested areas. There are 17 sites nationwide where surface water and precipitation are sampled; groundwater samples are taken at some sites as well (Figure A-5). All of the sites are located in forested watersheds and most sites are sampled on a monthly basis, although some are sampled daily. Wet/dry collectors are used for deposition sampling; hand sampling is used for surface and groundwater.

Analytes are: pH, conductivity, alkali metals, alkali earths, NH_4, Cl, SO_4, NO_3, dissolved silica; and Al, Fe, and Mn at some sites. Data is stored in USGS's water information database, National Water Data Storage and Retrieval (WATSTORE) in Reston, Virginia.

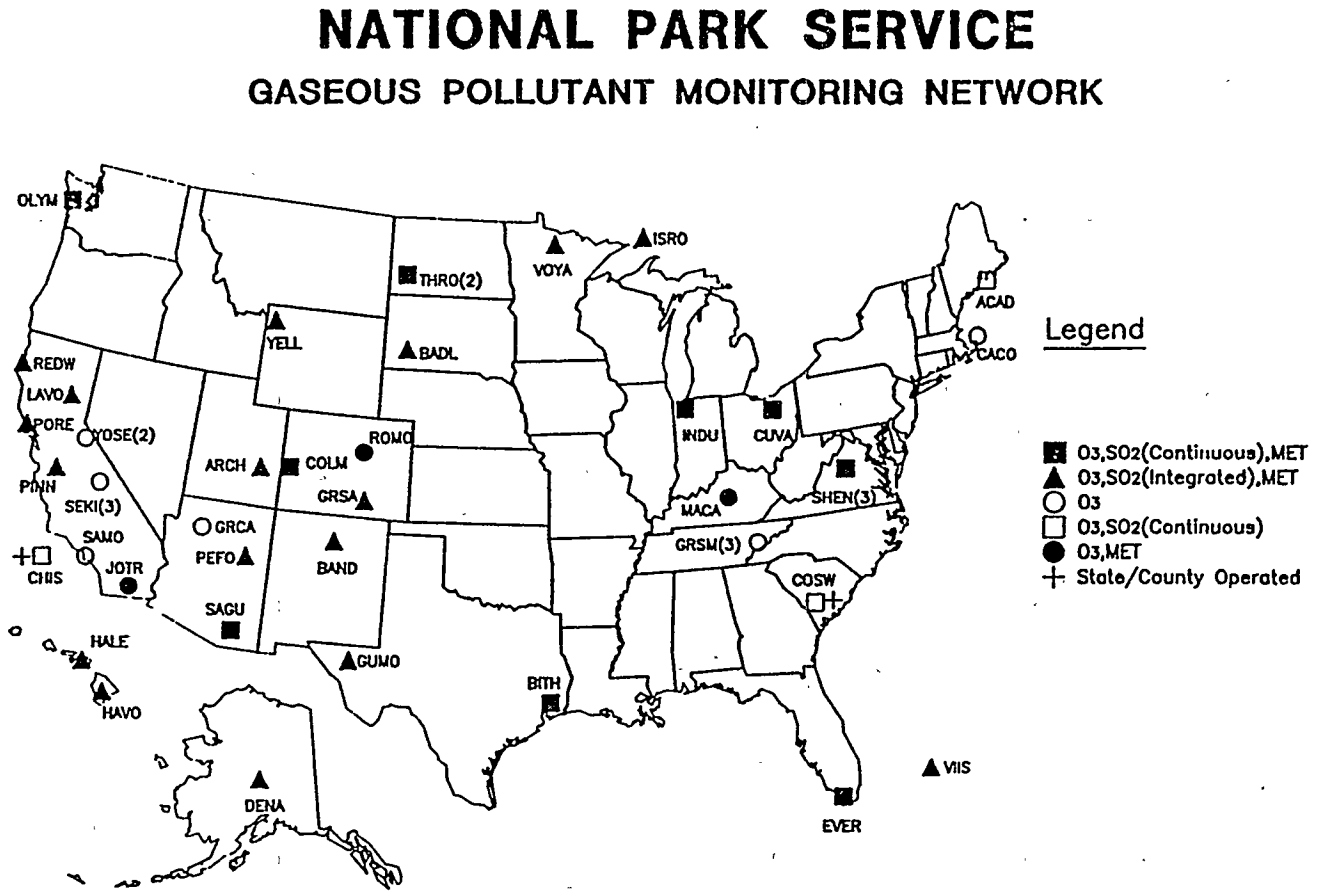

Figure A-3. NPS Gaseous Pollutant Monitoring Network Sites.

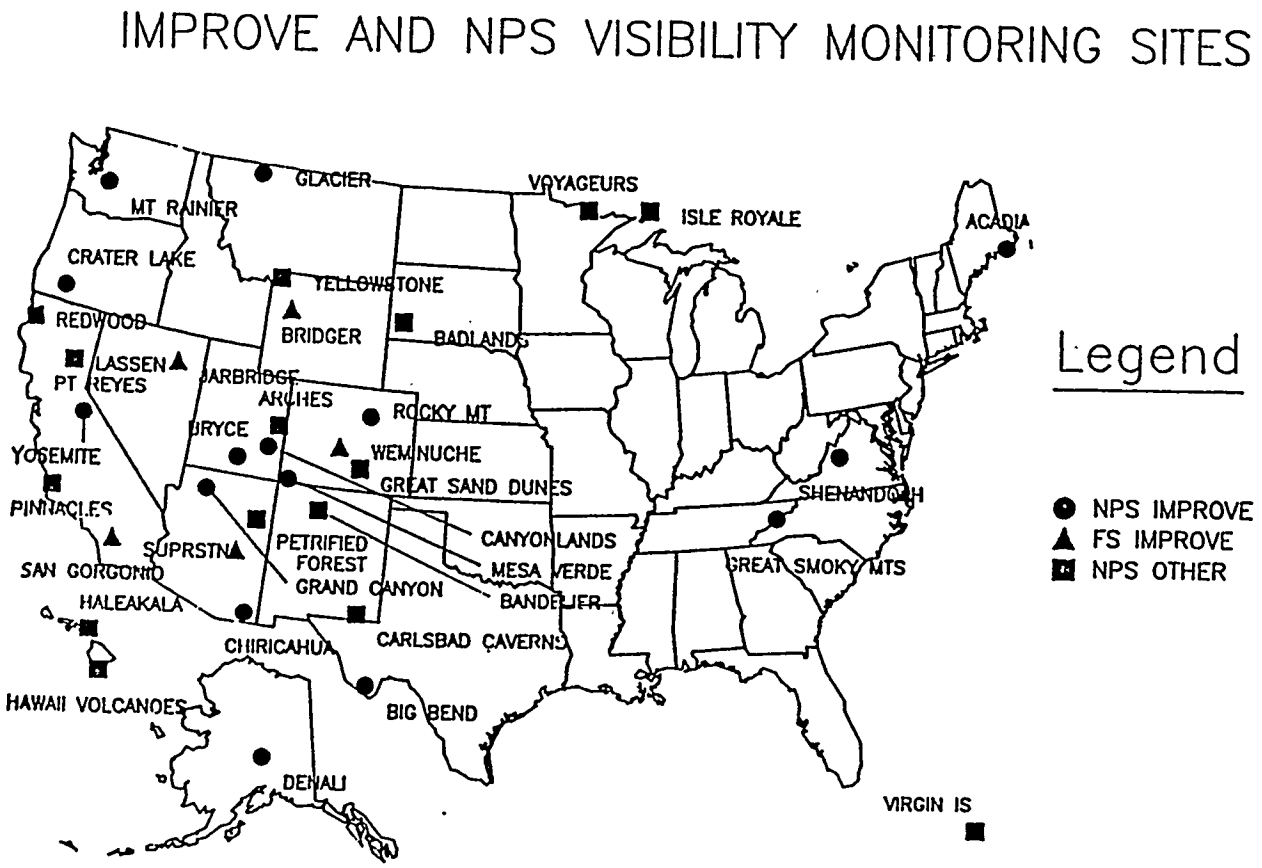

Figure A-4. NPS Monitoring Sites Interagency Monitoring of Protected Visual Environment (IMPROVE), and Visibility Monitoring Programs.

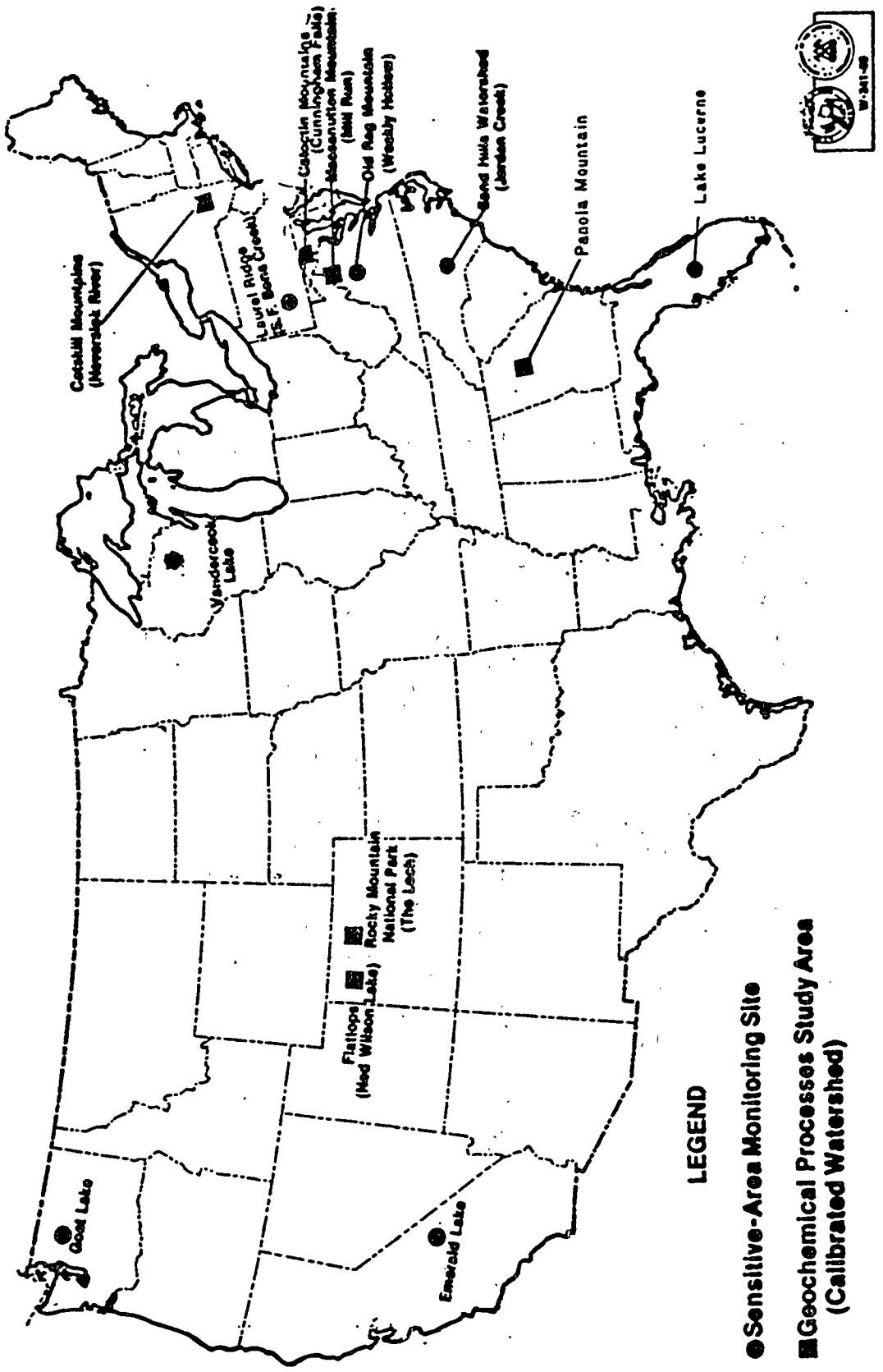

Figure A-5. Monitoring sites in USGS's Acid Rain Effects of Watersheds Program of NAPAP.

For more information on WATSTORE, contact Owen P. Bricker, USGS, Mail Stop 432, National Center, Reston, VA 22092, (703) 648-5824.

Reference 8--Multi-State Atmospheric Power Production Pollution Study/Precipitation Chemistry Network (MAP3S/PCN)

The MAP3S/PCN has been in operation since 1976 collecting event and daily wet only samples, conducting chemical analyses, and reporting the results through quarterly data listings, summary reports, and electronic data transfer to the Atmospheric Deposition System (ADS) database. Chemical analyses for the network were sponsored in 1985 by the EPA; they are currently sponsored by the Environment, Health and Safety Research Program Office of the DOE.

The PCN consists of nine sites, located in the eastern half of the U.S. (Figure A-6). A major objective of the PCN is chemical analysis of precipitation for the major ionic species. Battelle's Pacific Northwest Laboratory is responsible for administering quality control for the network sites. More information may be obtained through Battelle, Pacific Northwest Laboratory, P.O. Box 999, Richland, WA 99352, Attention Tony Olsen, (509) 376-4265.

Reference 9--National Acid Precipitation Assessment Program(NAPAP)

Some of the damage to streams, lakes, forests, materials and human health has been attributed to acid precipitation. To determine the role of acid deposition or air pollution, research has been on-going to develop not only detailed information on dosage of several air pollutants, but also the response of plants to those dosages. NAPAP was initiated by the Acid Precipitation Act of 1980, which established a task force to develop and implement the comprehensive national program. The purpose of NAPAP is to increase our understanding of the causes and effects of acid deposition and their history and prognosis in a manner and time frame that will be of value to decision makers.

NOAA was selected to be the directing agency of NAPAP. This decision evolved in response to concerns over EPA's interest in directing the program. Other agencies felt that EPA's footing in the regulatory approach would result in too much emphasis on legal matters instead of scientific pursuits. The task force implements the national program and is jointly chaired by six federal agencies (NOAA, EPA, USDA, DOE, DOI, and Council on Environmental Quality). The other participating Federal agencies are the Health and Human Services, DOC, DOS, NASA, NSF, and the TVA. The task force also includes four presidential appointees and representatives of Argonne, Brookhaven, Oak Ridge, and Pacific Northwest National Laboratories.

There are seven research categories (task groups) under NAPAP. Each of these task groups are affiliated with an agency. Following is a brief description of these task groups.

Atmospheric Chemistry (EPA and NOAA)

To relate emissions to deposition, the pathway between relevant pollutant sources and sinks must be well understood. This task force works towards: 1) assessing the actual impact of current emissions, 2) predicting the changes in these emissions, and 3) quantifying the uncertainty associated with any such assessments of predictions.

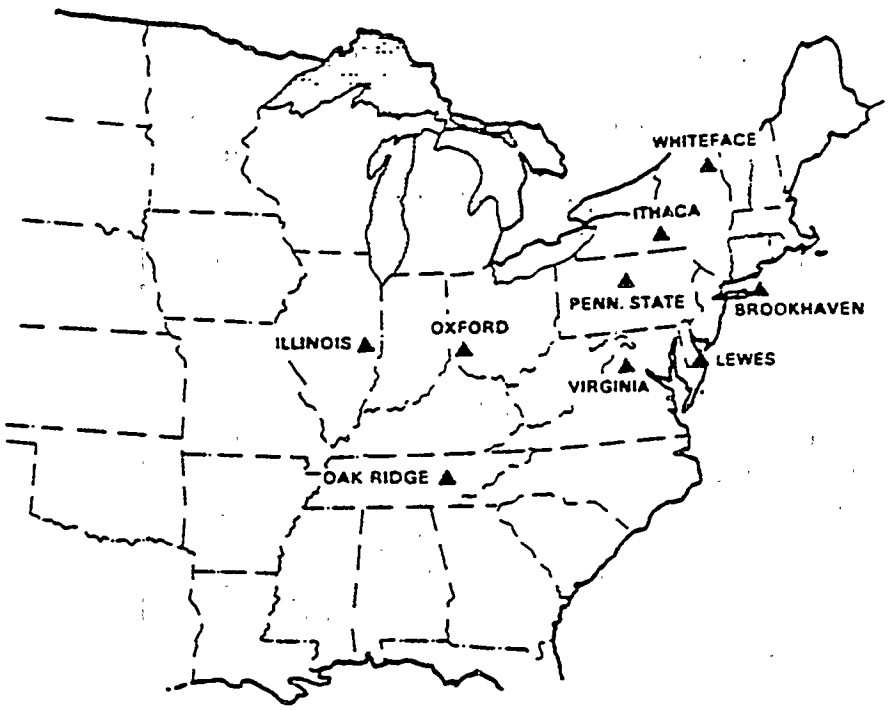

Figure A-6. Locations of the DOE's MAP3S Precipitation Chemistry Network Sites.

Atmospheric Deposition and Air Quality Monitoring (DOI)

To assess the environmental effects of atmospheric deposition, one must know the nationwide distribution of the deposition and its chemical composition. Assessment of national atmospheric deposition is accomplished through the operation of monitoring networks. The NADP/NTN and the NDDN are among these networks.

Atmospheric Transport (EPA)

The primary goal of this task group is to reliably model the relationship between emissions from sources in one region and deposition to receptors in another. This effort entails determining quantitatively the complex dynamics associated with transport, transformation, and deposition.

Emissions and Control (DOE)

Reliable information on emissions is needed to model the atmospheric linkages between emissions sources and the areas where acidic deposition occurs. DOE is the lead agency on NAPAP's Emissions and Controls Task Group. This task group is responsible for providing data on the past, present, and possible future emissions of gases and particles thought to contribute to acidic deposition. Reliable information on emissions is needed to model the atmospheric linkages between emission sources and the areas where acidic deposition occurs.

This task group studies the emissions from electricity generation (SO_2), transportation (VOCs and NO_x), petroleum refining, chemical manufacturing, and paint and solvent use (VOCs). Emissions are calculated based on survey data from all power plants based on fuel use (as reported to the Energy Information Administration). The research objectives are to:

- provide data on the year-to-year trends in the level of emissions of sulfur dioxides, nitrogen oxides, and volatile organic compounds in each of the 48 contiguous states, during the period 1900 through 1980, and on month-to-month emissions trends in recent years (1975 to present)

- provide, with adequate geographic, temporal and sectoral resolution, accurate and complete inventories of 1980 and 1985 emissions of species believed to be important in acid deposition process, from natural and man-made sources in the United States, Canada, and Mexico

- provide a modeling system that projects the ranges in which these emissions may fall in future years, given various assumptions about future fuel use and technology, and the cost of altering future patterns of emissions

- provide performance, cost, and feasibility data on existing and emerging combustion and emissions control technologies that might influence future emissions of sulfur dioxide, nitrogen oxides, and volatile organic compounds.

Reference 10 - National Atmospheric Deposition Program/National Trends Network (NADP/NTN)

The NADP/NTN is a 200 station rural wet-only deposition monitoring network in 47 states and the two territories of American Somoa and Puerto Rico (Figure A-7). The primary objectives of

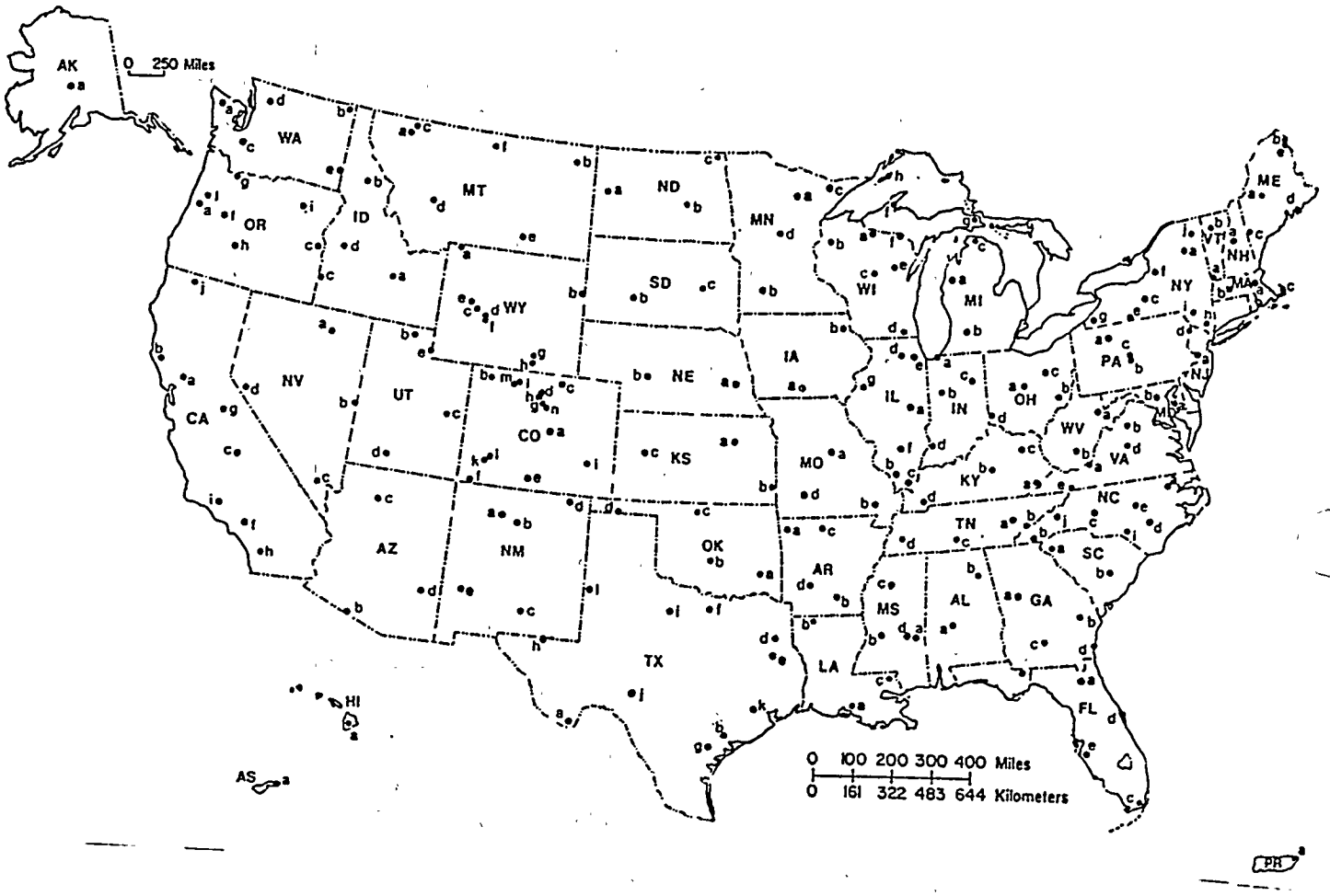

Figure A-7. National Atmospheric Deposition Program/National Trends Network Monitoring Sites (See Appendix F for Specific Sampling Locations).

the network are the determination of spatial patterns and temporal trends in chemical deposition in support of effects research, particularly impacts on aquatic and terrestrial ecosystems. In addition, the analysis of temporal trends will be critical to the evaluation of future sulfur and nitrogen oxide emissions reduction policies. The design seeks regional representation on a national scale by excluding monitoring site locations close to point sources or large urban centers. While original plans called for the measurement of total deposition, both wet and dry, the absence of available methodology precluded dry deposition measurements. Some NADP/NTN sites now have collocated air quality monitors as part of the EPA National Dry Deposition Network.

Weekly precipitation samples are collected in a Aerochem Metrics model 301 wet/dry sampler. The pH and conductivity are measured at the site if there is adequate sample. Chemical variable measures by the laboratory are: SO_4, NO_3, Cl, PO_4, Na, K, Ca, Mg, H+ (pH), and conductivity.

Data summaries are prepared annually, containing summary statistics for each site in addition to temporal trend plots and national isopleth maps. (Annual data summaries are also published by the ADS program at the Pacific Northwest Laboratories). Site description information is maintained at the Coordination Office in computerized files and is available as an aid in data interpretation. Maps and photographs of the sites are also on file. This information, which includes a detailed description of the site and other sampling and meteorological equipment, soil types, surrounding land use, an emission inventory within 50km, and other data is continually updated as a result of new information received from the site and from the site visitation program. A two volume summary of this information was published in 1986.

For more information, write or call: NADP/NTN Coordination Office, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523. Phone 303-491-1978.

Reference 11 - Interagency Monitoring for Protected Visual Environments Program (IMPROVE)

Section 169(a) of the Clean Air Act, as amended August, 1977, declared as a national goal "the prevention of any future, and the remedying of any existing, impairment results from man-made air pollution" (42 U.S.C. 7491). This section required the EPA to promulgate regulations requiring states to develop programs in their state implementation plans (SIPs), providing for visibility protection in these areas. Those states that did not submit revisions for visibility protection to their SIPs could, as of 1985, use the visibility monitoring strategy (IMPROVE) promulgated by the EPA.

The IMPROVE (Interagency Monitoring of PROtected Visual Environments) program is a cooperative visibility monitoring effort between a steering committee of the EPA and several land management agencies (FWS, BLM, USFS, and the NPS).

The objectives of the IMPROVE program are to: 1) establish baseline visibility levels; 2) determine sources and levels of visibility impairment; and 3) promote the development of visibility monitoring technology and of quality assurance, data processing, and documentation procedures.

The steering committee of the five agencies are responsible for designing, deploying, and operating the entire monitoring program, selecting the sites, developing guidance documents, providing data analysis and interpretation, establishing a database, and writing status reports (the committee hires contractors to accomplish those tasks, as needed).

The steering committee decided to expand the selection of monitoring sites from the 19 states that lacked a visibility monitoring strategy to include 36 states containing all of the 156 visibility protected mandatory Class I areas. Representatives of the NPS, NFS, and FWS researched each of their Class I areas. The steering committee reviewed each of the proposed sites and chose 20 for long-term background monitoring--15 on NPS land and 5 on NFS land. FWS Class 1 lands were of lower priority than the sites chosen.

Reference 12 - Sub-regional Cooperative Electric Utility, Department of Defense, National Park Service and EPA Study

To understand the factors influencing visibility in the southwestern U.S., concerned industry and government groups joined forces to conduct a major long-term (five year) field research study, SCENES (Subregional Cooperative Electric Utility, Department of Defense, National Park Service, and Environmental Protection Agency Study.

The purpose of SCENES is to gain an understanding of the origins of the recurring uniform and layered hazes, both local and regional in extent, that contribute to the visibility impairment under certain meteorological conditions in part of the desert southwest (California, Nevada, Utah, and north and central Arizona) (Figure A-8). To reach this goal, three relationships need to be established: emissions to aerosol, aerosol to extinction, and extinction to visibility. The southwest offers a desirable experimental situation because most man-made emissions sources are located relatively far from the environmentally sensitive area being studied.

Routine measurements at SCENES sites include the following:

1. Aerosol
   Two size fractions (PM-15 and M-2.5)
   Three filter materials:
   - Teflon (gravimetric, elemental and ion analyses)
   - Quartz (carbonaceous materials)
   - Nylon (total nitrate)

2. Optical Measurements
   Integrating nephelometer
   - Contrast teleradiometer
   - Camera

3. Meteorological Measurements
   Wind speed, wind direction, relative humidity, temperature and upper air winds at one site.

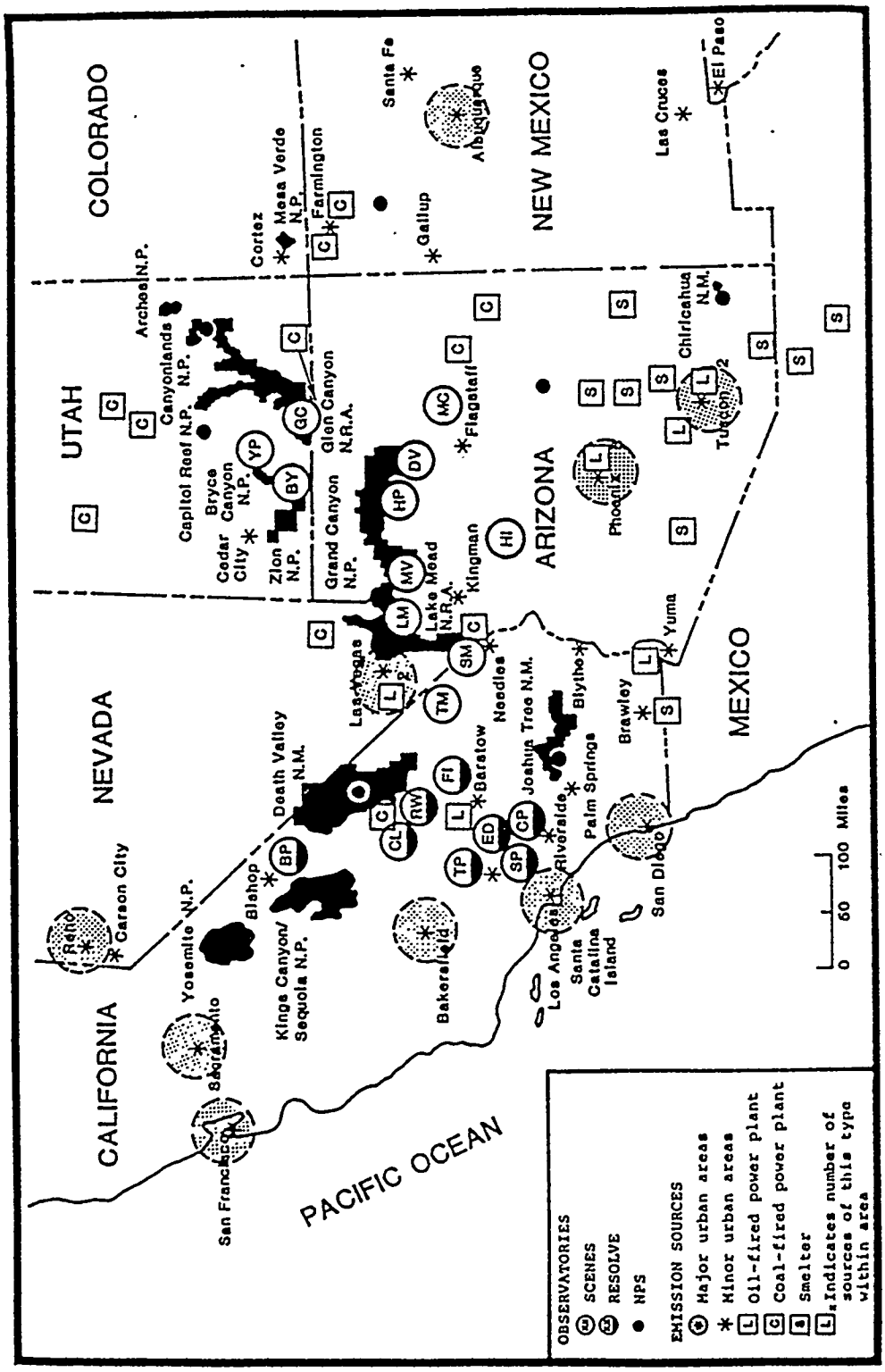

Figure A-8. Subregional Cooperative Electric Utility, Department of Defense, National Park Service, and Environmental Protection Agency monitoring sites

ATTACHMENT 2

COMPOSITE SENSITIVITY CHART AND SCIENTIFIC NAMES OF PLANTS

Air Monitoring Manual

COMPOSITE SENSITIVITY CHART AND SCIENTIFIC NAMES OF PLANTS

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Acacia *Acacia sp.*												T
Adonis *Adonis sp.*									T			
Ageratum *Ageratum sp.*												I
Alder *Alnus sp.*	I		S									
Eruopean black *A. glutinosa (L) Gaertn.*									I			
Alfalfa *Medicago sativa L.*	S	I	S	T	S		S					
Aloe *Aloe sp.*										T		
Anthurium *Anthurium sp.*		T										
Apple *Malus sylvestris Mill.*		T	S	I	S	S						
Apricot *Prunus armeniaca L.*	T											
Chinese *P. armeniaca L.* *var. Chinese*	I			S								
Moorpark *P. Armeniaca L.* *var. Royal*				I								
Royal *P. armeniaca L.* *var. Royal*				S								
Tilton *P. armeniaca L.* *var. Tilton*				I								
Hino *R. hinodegiri Hort.*	S											
Korean *R. poukhanesis* *(Nakai.) Gable*	S											
Snow *R. mucronatum*	S											
Bachelor's Button *Centaurea cyanus L.*			S									
Barley *Hordeum vulgare L.*	S	I	S		S							
Young				S								
Mature				I								
Basil, Sweet *Ocimum*		X										
Basswood *Tilia americana L.*		T								I		
Bean *Phaseolus sp.*	S	S	S							S		

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Ethylene
Bush *P. vulgaris L.*					I	T						
Field *Fragaria chiloensis*					I							
Lima *Phaseolus limensis Macf.*		T										
Pinto *P. vulgaris L.*					S		I		I			
Scotia *P. vulgaris L.*							I					
Snap *P. vulgaris L.*				T								
Arborvitae *Thuja occidentalis L.*	T	T		T					T			
Ash *Fraxinus sp.*						T						
American Mt. *Sorbus americana L.*		T										
European Mt. *S. aucuparia L.*	S			I								
Green *Fraxinus pennsylvanica Marsh.*	S	T		I								
Modesto *F. velutina Torr.*				T								
White *F. americana L.*	S	T										
Asparagus *Asparagus officinalis L.*				T	T							
Aspen, Large-Toothed *Populus, grandidentata Michx.*			S									
Quaking *P. tremuloides Michx.*	S		S	I								
Aster *Aster sp.*		S	S	I		I						
China *Callistephus chinensis*												T
Avocado *Persea americana Mill.*	T											
Azalea *Rhododendron sp.*		T		I	S		T			I		
Campfire *R. kaempheri "campfire" (Planch) Wils. Hort.*	S											
Chinese *R. molle sp.*	T											
Beech *Fagus sp.*												
European *F. sylvatica L.*	T											
Purple *F. sylvatica atropurpurea*					T							

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Beet *Beta sp.*	T		S									
Sugar *B. vulgaris L.*		I										
Table *B. vulgaris L.*		I										
Begonia *Begonia sp.*	I	T					T			I		
Tuberous *Begonia sp.*					S							
Birch *Betula sp.*						S						
Cutleaf *B. pendula var. gracilis Roth*				T								
European White *B. pendula Roth*	T	T			S							
White *B. papyrifera Marsh*			S	T								
Blackberry *Rubus sp.*							S					
Blueberry *Vaccinium sp.*				S								
Bougainvillea *Bougainvillea spectabilis*					S							
Box, Japanese *Buxus sp.*	T											
Boxelder *Acer negundo L.*	I			S		S	S					
Braziliam Pepper Bush *Shinus terebinthifolius*			X									
Bridalwreath *Spiraea prunifolia Sieb. & Zucc.*	S			T								
Brittlewood *Melaleuca leucadendra*					I							
Broccoli *Brassica oleracea L.*	I	T	S									
Bromeliad *Bromeliad sp.*		T										
Browalia *Browalia sp.*	S											
Burdock *Arctium sp.*				T								
Butterflyweed *Asclepias tuberosa L.*										S		
Cabbage *Brassica oleracea L.*	I	T	T	T	T	T						
Cacti *Cactacea sp.*		T					T					
Calendula *Calendula sp.*		T										T

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Camelia *Camelia sp.*		T		T						I		
Cape Jasmine *Gardenia radicans*					I							
Careless Weed *Amaranthus palmeri S. Wats.*			S									
Carissa *Carissa carandas*					T							
Carnation *Dianthus caryophyllus sp.*	I	T										I
Carrot *Daucus carota L.*	I	I	S	T	S							
Catalpa *Catalpa bignonioides Walt.*	I											
Cauliflower *Brassica oleracea botrytis L.*		T		T								
Cedar *Cedrus sp.*			T			I						
Incense *Libocedrus decurrans Torr.*	I											
Celery *Libocedrus decurrans Torr.*	I											
Cheeseweed *Malva parviflora L.*		I			I		I	S			T	
Chenopodium *Chenopodium sp.*							T					
Cherry *Prunus sp.*						I				T		
Bing *P. avium L. var. Bing*	S											
Black *P. serotina Ehrh.*									I			
Choke *P. virginiana L.*				I		I						
Flowering *P. virginiana L.*				I								
Ground *P. tructiosa L.*		S										
Lambert *P. avium L. var. Lambert*	I											
Sweet *P. avium L.*				I								
Chickweed *Stellaria media*		S	S	S	I		S	I			T	
Crysanthemum *Chrysanthemum sp.*	I	T		T			T		I			
Cinquefoil *Potentilla sp.*										S		
Citrus *Citrus sp.*	S		T									
Clover *Trifolium sp.*		S										

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Ethylene
Crimson *T. incarnatum L.*				I								
Red *T. pratense L.*	S		S		S							
Spring *T. incarnatum*					S							
Sweet *Melilotus sp.*				I								
Yellow *Meliotus officinalis Lam.*			S									
Coleus *Coleus sp.*	S	T						T				
Columbine *Aquilegia sp.*									S	I		
Corn *Zea mays L.*		T	T		I	I	I					
Field *Z. mays L.*	I			SI			T					
Sweet *Z. mays L.*	S			SI								
Cornflowers *Centaurea cyanus L.*									S			
Cosmos *Cosmos sp.*			S							I		
Cotoneaster *Cotoneaster sp.*										I		
Rock *C. horizontalis Decne.*	S											
Spreading *C. divarcata Rehd. & Wils.*	S											
Cotton *Gossypium sp.*	T	T	S	T								I
Cowpea *Vigna sinensis Savi*	I						T					I
Crabapple *Malus baccata Borkh.*	I						S					
Croton *Codiaeum variegatum*					T					T		
Cucumber *Cucumis sativus L.*	I	T	S	T			I					
Currant *Ribes sp.*				T								
Cyclamen *Cyclamen sp.*		T										
Dahlia *Dahlia sp.*		S		I	I		I					T
Daisy *Chrysanthemum leucanthemum*					T				S			
Dandelion *Taraxacum officinale Web.*					I		I	I			T	

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Descurainia *Descurainia californica (Gray) Shultz*	T											
Dock *Rumex sp.*			S	T								
Sour *R. crispus L.*		I										
Dogwood *Cornus sp.*		T		T		S						
Gray *C. reacemosa Lam.*	T											
White *C. florida L.*	T											
Eggplant *Solanum melongena L. var. esculentum Nees.*				T		T						
Elder *Robinia pseudoacacia*					T							
Elderberry *Sambucus sp.*				T		S						
Elm *Ulmus sp.*					T							
American *U. americana L.*				T								
Chinese, Siberian *U. pumila L.*				T								
Endive *Cichorium endivia L.*	I	S										
Eunoymus, Dwarf Winged *Euonymus sp.*	T											
Fern												
Boston *Nephrolepis exaltata Schott.*										S		
Bracken *Pteridium aquilinum L.*			S									
Holly *Cyrtomium falcatum Smith*											S	
Fir *Abies sp.*												
Big-Cone Douglas *Pseudotsuga menziesii (Mirb.) Franes*	I											
Balsam *A. balsamea Mill.*	T	T			I		T		T			
Douglas *Pseudotsuga taxifolia Br. H.*	T	T		S					T			
Grand *A. grandis (Dougl.) Lindl.*				I								
White *A. concolor Hoopes.*	IT	T										

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Firethorne *Pyracantha coccinea Depp.*				T								
Laland's *P. coccinea laland Depp.*	T											
Forget-me-not *Myosotis sp.*												T
Forsythia *Forsythia sp.*						S				I		
Lynwood Gold *F. intermedia spectabilis "Lynwood Gold" Koehn*	I											
Four-o-clock *Mirabilis jalapa L.*			S									
Fuchsia *Fuchsia sp.*	T	S			I					I		
Gardenia *Gardenia jasminoides*					I					I		
Geranium *Geranium sp.*	T			I			T			I		
Gingko *Gingko biloba*					T							
Gladiolus *Gladiolus sp.*	T		S	S	T	I						
Gloxinia *Sinningia sp.*	T											
Goldenrod *Solidago sp.*				I					T			
Gomphrena *Gomphrena globosa L.*							S					
Goosefoot, Nettle-Leaf *Chenopodium sp.*				I	T		I	I			S	
Grape *Visit. sp.*	S					S						
Concord *V. labruscana Bailey*	S			I								
European *V. vinifera L.*				S								
Oregon *Mahonia repens (Lindl.) Don*				S								
Thompson seedless *Vitis sp.*	I											
Grapefruit *Citrus paradisi Macf.*				I								
Grass												
Annual Blue *Poa annua L.*		X	S		I		I	S			T	
Bent *Agrostis palustris Huds.*	S											
Brome *Bromus inermis Leyss.*	S											
Crab *Digitaria ischaemum Schreb.*	S			S								

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Ethylene
Johnson *Sorghum halepense Pers.*				I								
Kentucky Blue *Poa pratensis*					T		T	I			T	
Orchard *Dactylis glomerata L.*	S											
Gum, black *Nyssa sylvatica (Marsh.) Pepp.*	T											
Hazel *Corylus sp.*			S									
Heath *Erica sp.*					T							
Hemlock *Tsuga sp.*						I						
Eastern *T. canadensis Carr.*	T	T										
Hibiscus *Hibiscus sp.*					S							
Hickory *Carya sp.*						S						
Holly *Ilex sp.*												
American *I. opacea Ait.*										I		
American (Male)	T											
American (Female)	T											
Chinese *I. chinesis Loes.*										T		
Hetz's Japanese *I. crenata Hetzi (Thurb.) Hetz.*	T											
Honeysuckle, Blue-leaf *Lonicera zaBELI rEHD.*	I											
Hornbeam, European *Tilia sp.*					T							
Horse Chestnut *Aesculus hippocastanum L.*							S					
Hydrangea *Hydrangea sp.*										S		
Hypericum *Hypericum sp.*	I											
Impatiens *Impatiens sp.*	T											
Iris *Iris sp.*				S					T			
Ivy *Hedera sp.*		T								T		
English *H. helix L.*	T											
Ixora *Ixora coccinea*					I							

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Jerusalem Cherry *Solanum pseudo-capsicum L.*	T			SI								
Jimsonweed *Datura stramonium L.*		S										
Juniper *Juniperus sp.*				T								
Shore *J. conferta*					T							
Western *J. occidentalis Hook.*	T											
Kohlrabi *Brassica oleracea cv. gongylodes*			S		T							
Lamb's Quarter *Chenopodium album L.*	T	I		SI	T	S	T	S			S	
Larch *Larix sp.*				S								
European *L. decidua Mill.*	I	T			S							
Japanese *L. leptolepsis (Sieb. & Zucc.) Gord.*	I	T			S							
Western *L. occidentalis Nutt.*				S								
Larkspur *Delphinium sp.*									T			I
Laurel, Mountain *Kalmia latifolia L.*	T			T								
Leek *Allium porrum*					S							
Lemon *Citrus lemon Burm.*	T			I								
Lettuce *Lactuca sativa*	T	S	S		S							
Ligustrum *Ligustrum lucidum*					I							
Lilac *Syringa vulgaris L.*			T	I								
Chinese *S. chinesis L.*	S											
Common *S. vulgaris L.*	S	T										
Lily *Lilium sp.*		T										I
Calla *Zantedeschia aethiopica Spreng.*										I		
Easter *lilium eximum Baker*										I		
Of-the-Valley *Convallaria majalis*					T				T			

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Plantain *Hosta plantaginea (Lam.) Archers*					T				T			
Linden *Tilia sp.*			T		I	S						
American *T. americana L.*	T			T								
Little-Leaf *T. cordata Mill.*	T			I								
Lobelia *Lobelia sp.*												T
Locust												
Black *Robinia pseudoacacia*	T			T	T							
Honey *Gleditsia triacanthos L.*	S	T										
London Plane Tree *Platanus acerifolia (Ait.) Willd.*				T		S						
Lupin *Lupinus sp.*									T			
Maple *Acer. sp.*			T									
Hedge *A. campestre L.*				I								
Japanese *A. palmatum Thumb.*					I					I		
Norway *A. platanoides L.*	T	T		I	I	S			I			
Red *A. rubrum L.*	T											
Silver or White *A. saccharinum L.*		T		I								
Sugar or Rock *A. saccharum Marsh.*	T	T					S		I			
Marigold *Tagetes sp.*	T											
African *T. erecta L.*												S
Mignonette *Reseda lutea L.*							T					
Milo Maize *Sorghum vulgare Pers.*				SI								
Mimosa *Albizzia julibrissin Duratz.*	T									S		
Mimulus *Mimulus sp.*		S										
Mint *Mentha sp.*	T	S										
Mulberry *Morus sp.*						I						
Red *M. rubra L.*				I								

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Muskmelon *Cucumus melo L.*	S		T									
Mustard *Brassica sp.*		S			S		S	S			T	
Cultivated			S									
Wild			S									
Myrtle *Myrtus sp.*							T					
Narcissus *Narcissus sp.*		T		I								
Nasturtium *Tropaeolum sp.*							I					
Nettle, Little-Leaf *Urtica urens L.*		S										
Night Shade *Solanum nigrum L.*			S	T								
Oak *Quercus sp.*				T	T					I		
Black *Q. velutina Lam.*	I					S						
Bur *Q. macrocarpa Michx.*	T											
English *Q. robur L.*	T	T										
Gambel *Q. Gambbelii Nutt.*	S											
Northern Red *Q. rubra L.*	T	T										
Pin *Q. palustris Muench.*	I	T				I	S					
Red *Q. rubra L.*						I			T			
Scarlet *Q. coccinea Muench.*	I											
Shingle *Q. imbricaria michx.*	T											
White *Q. alba*	S	T										
Oats *Aven sativa L.*	S	S	S		ST							
Mature				I								
Wild		S										
Young				I								
Oleander *Nerium oleander*					S							
Olive, Russian *Elaeagnus angustifolia L.*				T								
Onion *Allium cepa sp.*	S	T	T		T		I					

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Orange *Citrus sinensis Osbeck*				I	I							
Mock *Philadelphus sp.*				T								
Mock sweet *P. coronarius L.*	I											
Orchid *Orchidaceae sp.*		T										S
Oriental Poppy *Papaver orientale*									S			
Oxalis *Oxalis sp.*							T			S		
Pachysandra *Pachysandra terminalis Sieb & Zucc.*	T											
Pagoda, Japanese *Sophora japonica L.*	T											
Parsley *Petroselinum crispum NYM*	I				S							
Parsnip *Pastinaca sativa L.*	I											
Peach *Prunus persica Batsch.*	I					I				I		
Fruit				S								
Foliage				I								
Peanut *Arachis hypogaca*	I											
Pear *Pyrus communis L.*				T	S	T						
Bartlett *P. communis L. var. Bartlett*	T											
Pea *Psium sativum L.*	I		S	T	S							
Peony *Paeonia sp.*				I		T						
Pepper *Piper nigrum L.*	I	S					T					I
Bell *Capsicum frutescens L.*				T								
Periwinkle *Vinca minor L.*	T	T										
Persimmon *Diospyros virginiana L.*										I		
Petunia *Petunia sp.*	S	S		T	I		I					
Pheasant's Eye Pink *Dianthus sp.*									T			
Phlox *Phlox sp.*												
Caespitose									S			
Paniculata									T			

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Piggy-Back Plant *Tolmiea menziesii Torr. & Gray*	T											
Pigweed *Amaranthus retroflexus L.*		S		I	T		T	S			T	
Pieris, Japanese *Pieris japonica*	T											
Pine *Pinus sp.*					T		T					
Austrian *P. nigra Arnold*	S	T	S									
Coulter *P. coulteri D. Don*	S											
Digger *P. sabiniana Dougl.*	T											
Eastern White *P. strobus L.*	S	T										
Jack *P. banksiana Lamb.*	S		S									
Jeffrey *P. jeffreyi A. Murr.*	S											
Knobcone *P. attenuata Lemm.*	I											
Lodgepole *P. contorta Loud.*	I			T								
Monterey *P. radiata D. Don*	S											
Mugho *P. mugho Turra.*				T								
Pitch *P. rigida Mill.*	I	T										
Ponderosa *P. ponderosa Laws.*	S			S								
Red *P. resinosa Ait.*	T	T	S									
Scotch *P. sylvestris L.*	I	T		S								
Single-Leaf Pinyon *P. monophylla Torr. & Frem.*	T											
Sugar *P. lambertiana Dougl.*	I											
Torrey *P. torreyana Perry*	I											
Virginia *P. virginiana Miiill.*	S	T										
White *P. strobus L.*			S						I	I		
Pittosporum *Pittosporum tobira*					I							
Plantain *Musa paradisiaca L.*				T								
Plum *Prunus sp.*												

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Bradshaw *P. domestica L.*				S								
Flowering *P. cerasifera Ehrh.*				IT								
Poinsetta *Euphorbia pulcherrima*	I											
Polygonum *Polygonum sp.*							T					
Poplar *Populus sp.*												
Basalm *P. balsamifera L.*				T								
Carolina *P. canadensis Muench.*				I								
Hybrid *P. sp.*	S	T										
Lombardy *P. nigra var. italica Muench.*				I								
Tulip *Liriodendron tulipifera L.*	S	T							S			
Potato *Solanum tuberosum L.*	S		T	T	I	I						
Sweet *Ipomea batatas (L) Lam.*	T		S	SI								
Primrose *Primula sp.*		S										
Privet *Ligustrum sp.*			T	T		I				SI		
Amur North *L. amurense*	T											
Lodense *L. vulgare var. pyramidale*	S											
Common *L. vulgare*	I											
Prune Tree, Italian *Prunus domestica L.*				S								
Purslane *Portulaca oleracea L.*				T								
Pyracantha *Pyracantha sp.*					S							
Radish *Raphanus sativus L.*	S	T	S				S					
Ragweed *Ambrosia artemisiifolia L.*			S			I						
Ranunculus *Ranunculus sp.*		S										
Raspberry, Red *Rubus idaeus L.*				T								
Redbud, Eastern *Cercis canadensis L.*	I											
Redwood *Sequoia sempervirens Endl.*	T											

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Rhododendron *Rhododendron sp.*				I		I						
Carolina *R. carolinianum*	T											
Catawba *R. catawbiense*					I							
Catawbiense Album *R. catawbiense album (Michx.) Hort.*	I											
Nova Zembla *R. nova zembla Hort.*	I											
Roseum Elegans *R. roseum elegans Hort.*	I											
Rhubarb *Rheum rhaponticum L.*		T	S		S	T						
Rice *Lactuca longifolia Lam.*	T											
Rose *Rosa odorata Sweet.*				I	S	I	S					I
Rye *Secale cereale L.*	S				I							
Mature				I								
Young				I								
Safflower *Carthamus tinctorius L.*	S											
Salvia *Salvia sp.*										I		
Sarcococca *Sarcococca sp.*										T		
Saxifrage *Saxifraga sp.*										I		
Sequoia, Giant *Sequoiadendron giantea Buchholz*	T											
Serviceberry *Amelanchier alnifolia*				I								
Silverberry *Eleagnus argentea Pursh. Nutt.*	I											
Smartweed *Polygonum sp.*	S			SI								
Snapdragon *Antirrhinum majus L.*	T	S			S							I
Snowberry *Symphoricarpos sp.*	S											
Sorghum *Sorghum vulgare Pers.*	I	T				T						
Sorrel *Rumex sp.*						S						
Sow Thistle *Sonchus sp.*			S									
Soybean *Glycine max. Merr.*	S	I		IT								

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Spinach *Spinacea oleracea L.*	S	I	S	T								
Spirea *Spiraea sp.*	T											
Spruce *Picea sp.*					I	I						
Black Hills *P. glauca densata Bailey*	T	T										
Blue *P. pungens Engelm.*		T		SI								
Colorado Blue *P. pungens Engelm.*	T											
Norway *P. abies Karst.*	T	T							T			
White *P. glauca Voss.*	T	T		I								
Squash *Curcurbita pepo L.*		T	S				I					
Summer *C. pepo L.*				T								
St. John's Wort *Hypericum perforatum L.*				S								
Stevia *Piqueria trinervia Cav.*	I											
Strawberry *Fragaria sp.*	T	T		I						I		
Sugar Cane *Saccharum officinarum L.*				T								
Sumac *Rhus sp.*	S					S						
Smooth *R. glabra L.*				I								
Staghorn *R. typhina L.*				I								
Sunflower *Helianthus sp.*				I	S		S	S		S	T	
Sweet Pea *Lathyrus odoratus*			S		S							T
Sweet William *Dianthus barbatus L.*			S	I					T			
Sweetgum *Liquidambar styraciflua L.*	I	T		T		I	S					
Swiss Chard *Beta vulgaris var. cicla L.*		S	S									
Sycamore *Platanus sp.*				T								
American *P. occidentalis L.*	S											
Tangerine *Citrus reticulata Blanco.*				I								

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Timothy *Phleum pratense L.*	I											
Tobacco *Nicotiana tabacum L.*	S	I		T	S	S	S			I		
Tomato *Lycopersicum esculentum Mill.*	S	S	S	I	I	S	I	T	S	I		I
Tree-of-Heaven *Ailanthus altissima Swingle*	S			T		S	S					
Tulip *Tulipa gesneriana L.*			S	S			S					
Tulip Tree *Liriodendron tulipifera L.*	S	T							S			
Turnip *Brassica rapa L.*	I		S									
Vetch, Spring *Vicia sativa*					S							
Viburnum *Viburnum sp.*	T									I		
Korean Spice *V. carlesii*	T											
Linden *V. dilatatum Thune*	I											
Tea *V. setigerum Hance.*	I											
Vinca *Vinca sp.*										I		
Violet *Viola sp.*			S	I								T
Virginia Creeper *Parthenocissus quinquefolia Planch.*	T			T			S					
Walnut *Juglans sp.*												
Black *J. nigra L.*	T			I								
English *J. regia L.*	SI			I								
Wandering Jew *Zebrina sp.*							S					
Wheat *Triticum aestivum L.*	S	I	S	I	I							
Buck *Fagopyrum esculentum Muench.*	S		S				I	T				
Willow *Salix sp.*			S	T						S		
Weeping *S. babylonica L.*	I											
Wisteria *Wisteria sp.*						S						
Yellow Wood *Cladrastis lutea Koch.*						S						

S = Sensitive; I = Intermediate; T = Tolerant

Plant	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Eth-ylene
Yew *Taxus bacccata*					T	I						
Dense *T. densiformis Hort.*	T											
Hatfield's Pyramidical *T. media hatfieldi Rehd.*	T											
Spreading Japanese *T. cuspidata Sieb. & Zucc.*				I								
Zinnia *Zinnia sp.*	T		S			S	S					I

S = Sensitive; I = Intermediate; T = Tolerant

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D
AN INTRODUCTION TO THE USE OF FLORA AND FAUNA FOR CONTAMINANT MONITORING

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PREFACE

This is Appendix D of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
   - D.3 Fish Sampling Reference Field Methods
   - D.4 Flora Sampling Reference Field Methods
   - D.5 Reptiles and Amphibians Sampling Reference Field Methods
   - D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
0	10/2/91	2.1	2-4	2-4c	5
1					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

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Arlington, VA 22201

Commentor's Name_____ Phone_____

Address_____ City_____ State___ Zip_____

Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____ Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

References (if applicable):

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ACRONYMS

ALAD	aminolevulinic acid dehydratase
BLM	Bureau of Land Management
DDT	dichlorodiphenyltrichloroethane
EC	environmental contaminants
EPA	Environmental Protection Agency
FWS	U.S. Fish and Wildlife Service
MFO	mixed function oxygenase
NCBP	National Contaminant Biomonitoring Program
NFS	National Fishery Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OCs	organodichlorine pesticides
OPs	organophosphorous pesticides
ppb	parts per billion
PCBs	polychlorinated biphenyls
RFM	Reference Field Methods

U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D AN INTRODUCTION TO THE USE OF FLORA AND FAUNA FOR CONTAMINANT MONITORING

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to discuss general concepts related to using biota to monitor environmental contamination on Service lands. General guidance is provided for selecting the appropriate biotic groups for monitoring contaminants and/or contaminant effects. More detailed information on the use of specific biotic groups for contaminant monitoring is provided in the individual Reference Field Methods (RFMs).

1.2 Scope

The first portion of this document briefly discusses biomonitoring and its potential use for contaminant monitoring on Service lands. It provides some general background information on selection of appropriate biomonitors and the types of responses to monitor. It is not designed to provide specific information regarding which species to use for a given situation. This information is best determined by working with your Environmental Contaminants (EC) specialist. Table 1 summarizes some advantages that the Service land manager should consider when selecting a biotic group for contaminant monitoring purposes.

The second portion of the document provides general information regarding the use of community characteristics for monitoring contaminants and their effects. This section discusses several parameters that are used to characterize a community and how they might be used to provide an indication of contaminant related stress.

This document is not intended to be a comprehensive guide on the use of biomonitoring for contaminant presence; rather, it is to provide enough information to stimulate interest on how these methods could be used by Service personnel for contaminant monitoring. This is a relatively new and developing field; therefore, only a brief discussion of the basic concepts of biomonitoring is provided by this document to encourage the user to seek regional experts to obtain current, detailed information. This information can then be collected on specific biomonitoring methods for selected organisms on the Service lands. Some of this information is available through Service EC specialists and references cited in this document.

Table 1. Comparative advantages of different fauna groups and flora for biological monitoring

	Large Mammals	Small Mammals	Birds	Herptiles	Fish	Benthic macroinver -tebrates	Plants
Collection does not require extensive manpower or equipment		x		x	x	x	x
Most species easily identified or there are many amateurs who know them well	x		x	x	x		
Life history information is extensive for most species	x	x	x	x	x		
All or many species relatively sessile or have small home range, thereby reflecting local conditions		x		x		x	x
Group occupies several trophic levels	x	x	x	x	x	x	
Group displays obvious visual symptoms of stress, or mortality is readily observed	x		x		x	x	x
Public relates to the health of the group	x		x		x		

1.3 Background

Living organisms can be used to monitor contaminant movement, accumulation, and modification in the environment, plus associated biological effects (NRC, 1986). Observations of wildlife populations and their state of health have been important in identifying situations where contaminants have reached unacceptable levels in the environment (Clark et al., 1988). The well known cases of DDT and selenium are good examples of contaminant problems that reached critical levels before action was taken (Blus et al., 1979; Ohlendorf et al., 1986). The goal of a long term contaminant monitoring program is to detect contaminants and/or contaminant induced effects early, before associated impacts are extensive and expensive to correct. While this goal may not always be attainable because of unpredictable events, such as chemical spills, most of the time a properly designed and implemented monitoring program will provide the information necessary to achieve this goal.

The monitoring of various animal and plant species should be an integral part of contaminant monitoring programs since they are known integrators of the effects of environmental anthropogenic contaminants (Clark et al., 1988). Biomonitoring will better integrate contaminant effects over time, reflect synergistic effects among pollutants, and provide direct measures of impacts to biological resources of concern than samples collected at single points in time (NRC, 1986). That is, organisms may be in contact with various contaminants over a period of time and therefore provide more information about environmental contamination than, for example, grab samples of water or sediment.

The use of biota in contaminant studies has taken many forms. Laboratory bioassays determine acute and chronic toxic effects, usually on a single species for a single chemical (NRC, 1986). In situ bioassays (using caged animals) have been used to evaluate the effects of effluent streams or pollutant "pulses," such as agricultural runoff following a rain storm (EPA, 1971; cited in Weber, 1973). Also, animals placed at a study site can be used to measure tissue contaminant levels over time (NRC, 1986). Early studies (e.g. Kolkwitz and Marsson, 1909; Richardson, 1921 and 1929; Liebmann 1942; all cited in Gaufin, 1973) of organic pollution in streams relied on the concept of pollution tolerant organisms ("indicator species") whose presence indicated a pollution problem (or conversely, pollution sensitive organisms, whose absence in otherwise suitable habitat indicated a problem). Analysis of community structure (primarily of benthic invertebrates and fish) has largely replaced this earlier concept, although facets of this are still in use (e.g., Hilsenhoff's biotic index "tolerance values"; see Benthic Macroinvertebrate RFM, Appendix D.1). Most recently, national monitoring programs have adopted the use of naturally occurring species ("biomonitors") to monitor trends of various contaminants. These programs include the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program for Marine Environmental Quality (mussels, oysters, and fish), and the Service's National Contaminant Biomonitoring Program (NCBP) (fish) and the avian portion that is currently being revised. Though these programs were not developed for Service specific monitoring needs, their fundamental concepts and associated methods provide useful information and guidance for Service monitoring activities.

1.4 Information resources

The EC specialist and regional EC coordinator should be contacted for their input on biomonitoring. They will be able to provide information on the studies Service Region 8 (Research and Development) is involved with and associated contacts. Local universities, state fish and wildlife agencies, and federal agencies (e.g., BLM, EPA, NFS, NOAA, NPS) are also good information sources.

Throughout the text, references are cited that may be used for obtaining more specific information on biomonitoring. The Fish and Benthic Macroinvertebrates RFMs also provide additional information. There are textbooks on the subject as well. Because of the vast amount of new information being generated on this subject, the literature should be reviewed to obtain the most current information.

2. MEASURING CONTAMINANT LEVELS AND EFFECTS ON INDIVIDUALS

Biological monitoring for contaminants on Service lands can be conducted by two different but complementary means (a) measurement of contaminant concentrations in selected organisms, and (b) measurement of the effects of contaminants on individual organisms, or on populations and/or communities of organisms. Abnormally high tissue levels of contaminants, particularly in critical organs, have been correlated with stress effects in many species; therefore, when such levels are detected, further evaluation of the severity of contaminant stress on exposed populations is warranted (Sheehan, 1984a). Community analysis with respect to contaminant impact is most developed for aquatic systems (see Appendix D.1, Benthic Macroinvertebrates and Appendix D.3, Fish RFMs). In specialized cases, in situ bioassays may be applicable, and laboratory bioassays will continue to play an important role in the interpretation of contaminant measurements in the environment. These types of studies will likely be carried out by or require the assistance of research (Region 8) personnel.

Certain types of contaminants are not measurable as tissue concentrations. These include stream sedimentation, nutrient loading, and atmospheric acid inputs. These can be measured directly, or can be monitored by observing effects on individuals, populations, or communities. This is discussed in Section 2.2.

The terms "biomonitor," "indicator species," "sentinel," "bioindicator," and others are used interchangeably in the literature to describe species that are either sensitive in some respect to or unusually tolerant of a contaminant, or have a tendency to accumulate or concentrate a contaminant in tissues (Laughlin and Guard, 1986; NRC 1986; Newman, 1979; Farrington et al., 1987). For the purposes of this operations manual, the following terms and definitions are provided.

Biomonitor	A species that accumulates or concentrates a contaminant to measurable levels in tissues. Ideally, the organism remains unaffected by the contaminant.
Indicator species	A species that is either very sensitive to or very tolerant of a contaminant.
Sentinel	Indicator species that are very sensitive to environmental contaminant stresses (e.g., the well-known mine canary that was used to indicate the presence of poisonous gases) (Jenkins, 1980).

2.1 Biomonitor Species

This section provides some guidance on the selection of animal or plant groups for use as biomonitors in various situations. Many species of animals and plants have been used for the purpose of measuring environmental contaminant levels, i.e., as biomonitors. To date, however, there have been few widely-accepted recommendations on specific organisms or groups of organisms to use as biomonitors. The mollusks and fish of NOAA's marine monitoring program and the fish of the NCBP's monitoring program, mentioned previously, are two notable exceptions. Lichens and moss have been widely used for monitoring airborne metal levels (Ferry et al., 1973). The herring gull has been used to monitor contaminants in the Great Lakes of Canada and the United States. (NRC, 1986). Earthworms have been widely studied as potential monitors of soil contaminant levels (Ash and Lee, 1980; Beyer et al., 1982; Gish and Christensen, 1973; Helmke et al., 1979).

2.1.1 Biomonitor Selection Considerations

Many factors regarding the nature of the contaminant and the proposed biomonitor will need to be considered in selecting a species for biomonitoring. These include:

- The contaminant source, its characteristics, and the pathway to the site;
- Likely sinks for contaminants;
- Life history of organism likely to be affected by the contaminant including
  - habitat (sediment vs. benthic vs. pelagic; aerobic vs. anaerobic)
  - food habits,
  - prey and predators,
  - behavior,
  - reproductive cycle,
  - abundance,
  - morphology (including size, coverings, etc.),
  - longevity
- Ability of organism to assimilate contaminant.

Contaminant sources and types and pathways to the Service lands, and how the contaminant moves through the ecosystem are extremely important considerations in selecting a biomonitoring group. Potential biomonitors should be considered from the point of view of how they fit into the source-receptor relationship for contaminants at the site (i.e., the ecological approach to contaminant monitoring; see Volume 1 of the Operations Manual). Contaminant sinks are locations or media where contaminants accumulate. Many metals, for example, are known to sorb to sediments; this association with sediments or other component of the contaminant transport pathway is one of the criteria for selecting a biomonitor for metals in aquatic systems. Lipophilic organic compounds collect in fatty tissues of animals.

The life history of the potential biomonitor is important to consider. Because many animals are exposed to contaminants via the ingestion pathway, it is important to know what and where the animal eats and drinks, and the potential for contamination in food or water. It may be more appropriate to monitor at a lower level in the food chain, especially when a given organism is food for several different higher order consumers. The Service land manager may desire to monitor contaminants in a prey (or forage) species for an important predator, such as an endangered species.

Species with a large home range and/or varied diet may have a greater opportunity to encounter contamination. Using such species as biomonitors has the advantage of "sampling" many potential sources or a large area, however, this may reduce ones ability to locate the contaminant source or pathway (NRC, 1986). These limitations should be kept in mind when considering a migratory species as a biomonitor. Consideration of the timing of the sampling effort may help reduce some of these uncertainties.

Longevity, abundance, and the size of an animal are often interrelated and need to be considered in selecting a biomonitor. Many small, abundant mammals, for instance, are comparatively short lived. While a short life span would seem to limit the animal's exposure to contamination, the high metabolism (and corresponding high energy requirement and potential uptake of contaminants) offsets this limit to some degree. For destructive sampling (e.g., for whole-body or

organ analyses), small, abundant, rapidly reproducing animals are the best choice to provide a sufficient number of samples for statistical purposes, while minimizing impacts on population levels.

The ability of biota to assimilate contaminants or absorb them into their systems varies considerably. Concentrations of essential elements such as zinc are internally regulated by most kinds of organisms; thus, they may be bioconcentrated at low environmental levels but not at high levels (Beyer, 1986). Bivalve mollusks do not appreciably bioconcentrate the more water-soluble chlorinated pesticides, such as hexachlorocyclo- hexane and toxaphene, although they do bioconcentrate heavy metals, halogenated hydrocarbons, and fossil fuel hydrocarbons.

2.1.2 Selection Criteria

Criteria for the selection of biomonitor organisms for toxic trace metals are provided below (modified from Jenkins, 1980):

1. The organism should accumulate relatively high levels of one, or preferably, several types of trace metals without being killed or severely injured.

2. They should be common or abundant; their regular collection should not disturb the ecological relationships of the system.

3. Their population distribution should be widespread geographically in different biomes, allowing integration over geographic areas. Individuals, however, should be relatively sedentary or nonmigratory.

4. They should be easy to collect and handle.

5. They should be of sufficient size to give adequate tissue for analysis or provide tissue (e.g. hair, feathers, nails, eggs, milk, leaves, stems, or fruit) without killing to allow resampling of the same organism.

6. They should occur in both polluted and unpolluted areas for monitoring environmental gradients of trace metals. Specifically, they should occur within the expected transport pathway the contaminant would take to the site.

7. The trace metal levels in the organisms should correlate with environmental levels of the trace metals, with minimum effect of local environmental variables.

8. There should be sufficient background data on the organisms' ecology, the baseline values of the organisms and the metals, accumulation and retention of metals, and effects of biological and environmental variables. Experience in monitoring environmental gradients of trace metals is also helpful.

Generally, these criteria are applicable to selection of biomonitors for other types of contaminants. Table 2 provides some suggested biomonitors for certain contaminant groups. More detailed guidance on particular organs and parts to sample is provided within the individual biota RFMs.

Table 2. Suggestions for selection of biomonitor species.
(modified from FWS, 1986)

	Contaminant Type				
		Pesticides			
Biomonitor	Metals	OCs[a]	OPs[b]	Other Organics	Pthalates
Terrestrial					
Shrews	X	X	X	X	
Harvest mice	X	X	X	X	
Raccoons	X			X	
Mink	X			X	
Birds	X				
(carnivores)	X		X	X	
(other)		X	X		
(eggs)		X		X	
Earthworms	X	X			
Vascular Plants (roots, tubers)	X				
Mosses & Lichens	X				
Aquatic					
Midge larvae					X
Caddisflies	X				X
Dragonfly nymphs	X				
Amphipods		X		X	
Water snakes		X			X
Turtles		X		X	
Shellfish	X	X			X
Fish	X	X	X	X	X
Crayfish	X				X
Algae	X				

[a] OCs - Organochlorine Pesticides
[b] OPs - Organophosphorous Pesticides

2.2 Indicator Species

Species that are either very sensitive to or tolerant of environmental contaminants are termed "indicator species" and monitoring their presence/absence or physical condition is a useful component of a monitoring program. Generally, monitoring sensitive species rather than tolerant species may be more indicative of contaminant problems because tolerant species may occur in both contaminated and uncontaminated environments. It is important to note that there are two distinct approaches to utilizing indicator species:

1. Monitoring "sentinel" organisms for changes in population numbers or extinction (due either to toxicity or avoidance of the contaminant);

2. Collecting individuals for analyses of biochemical, physiological or morphological responses to contaminants.

Generally, Number 1 (above) requires less overall effort than Number 2 and may be an effective component of monitoring activities provided the appropriate organisms are available at the site.

2.2.1 Selection Criteria

Selection criteria for indicator species will be similar in most respects to those for biomonitors (Section 2.1.2):

1. If indicator species are being collected, they should be common or abundant; their regular collection should not impact the population.

2. They should be easily collected and handled.

3. They should be of sufficient size or abundance to give adequate tissue samples for examination or analysis or provide tissue (such as blood, leaves, stems or fruit) without killing the individual.

4. Indicator species should occur in both contaminated and uncontaminated areas so that controls are available. The exception to this is sentinel species, which would die in or avoid contaminated environments, however they should have occurred at the site before the perturbation.

5. There should be sufficient background data on the organism (or it should be acquired) to be able to distinguish contaminant effects from natural variation.

6. Indicator species should show effects (biochemical, physiological, or behavioral) at contaminant concentrations (lower levels) that do not affect most other species.

2.2.2 Types of Response

Contaminant effects on individuals of sensitive species can be categorized according to the severity of damage (Sheehan, 1984a):

1. Acute toxicity causing mortality.

2. Chronically accumulating damage ultimately causing death.

3. Sublethal impairment of various aspects of physiology and morphology.

4. Sublethal behavioral effects.

5. Measurable biochemical changes.

Of particular interest from an ecological perspective is the progression through which injury to individuals may affect the success of the population that in turn may impact the community and ecosystem.

Outright kills of organisms (acute toxicity) from contamination events are comparatively easy to document, either by direct count of dead animals or, if available, from life table statistics on populations. More often continuous, gradual contaminant input leads to accumulation of individual injury and general deterioration of the environment. In these cases, relating population declines to contaminant toxicity is much more difficult. An example of this is the influence of acid precipitation on forest decline. Distinguishing contaminant induced changes from those caused by natural environmental variability requires extensive baseline data.

Individual organism response may be influenced by such factors as sex, age, developmental stage, surface area, reproductive condition, nutritional status and biological rhythms (Sheehan, 1984a). Exposure, dose, sensitivity, and method of intake also affect responses. One problem in interpreting chronic effects is the ability of some organisms to acclimate to certain types of contamination. Types of individual response to contaminants include biochemical, morphological, physiological, behavioral, and altered performance (Sheehan, 1984a). These types of responses are more often interrelated than they are discrete. For example, a biochemical response can affect the physiology of an organism, which in turn may affect behavior. Abnormal morphology of developing embryos (teratogenesis) also is often caused by biochemical responses to contaminants. Various effects are presented in Table 3.

2.2.2.1 Biochemical Responses. Various biochemical responses to different contaminants have been documented (all reported in Sheehan, 1984a). Organophosphorous and carbamate pesticides inhibit brain cholinesterase in fish, birds, and mammals. The depression of delta-aminolevulinic acid dehydratase (ALAD) in the blood, kidney, and liver of birds, fish and mammals is indicative of lead exposure. Mixed function oxygenase (MFO) reactions in fish may be indicative of stress from certain organic compounds such as oil and some halogenated biphenyls. Lysosomal stability of mussels is reduced by chronic exposure to crude oil and oil derivatives, and in hydroids by exposure to copper, cadmium, and mercury. These various biochemical responses are quantifiable and can be monitored in species potentially or actually exposed to these types of contaminants. For example, greater than 20% inhibition of brain cholinesterase levels in birds is considered indicative of exposure to organophosphorous or carbamate insecticides (Hill, 1982).

2.2.2.2 Physiological Responses. Physiological effects of contaminant stress include those on feeding activity, metabolism, osmotic-ionic balance, and photosynthetic activity in plants. These responses are very difficult to detect, even in the laboratory, and would not likely be an effective

Table 3. Effects of selected contaminants on various organisms

Contaminant	Organism	Effects	References
Organophosphorus or carbamate insecticides	Birds, mammals, fish	Brain and/or plasma cholinesterase inhibition: loss of coordination, spasms	Hill, 1982
Polybrominated biphenyls	Mammals Mink	Liver enlargement, loss of appetite, loss of milk production Decreased reproduction and kit survival	Sleight, 1979
PCBs	Mink	Reproductive failure	
Lead	Fish Birds	Deformed embryos Reduced blood delta-amino-levulinic acid dehydratase (ALAD), intranuclear inclusion bodies	Eisler, 1988
Mercury	Mallards Fish	Decreased reproductive success Deformed embryos	Eisler, 1987
Selenium	Birds	Deformed embryos	Ohlendorf et al. 1986
Crude oil	Herring gulls	Reduced Na, K-ATPase activity; impaired osmoregulation; reduced growth	Miller et al., 1979
Petroleum-derived hydrocarbons	Shellfish	Neoplastic lesions; reduced growth	Brown et al., 1979
Fluoride	Mammals	Dental lesions during tooth formation	Shupe et al., 1979

component for a general monitoring program. However, they are briefly mentioned here to indicate that these responses do occur and that they might be important to other, more noticeable responses.

Decreased feeding rates in copepods and trout have been observed with increasing copper levels. Respiratory rate can either increase or decrease, depending on species, contaminant type and concentration. Increased metabolic demand and decreased food conversion have been shown for fish exposed to pulp mill effluent; these responses may weaken an organism, leaving it susceptible to any additional stresses. Various metals (copper, zinc, mercury) and chlorinated hydrocarbons (DDT and PCBs) have been found to affect osmoregulation in a variety of estuarine species, though the implications of this effect on fitness of populations in contaminated estuarine environments are not known. Ozone has been shown to affect water balance and ionic regulation in various plant species (all reported in Sheehan, 1984a).

2.2.2.3 Morphological Responses. Morphological abnormalities are one of the more "easily" observed responses to contaminants. Skeletal anomalies, particularly those of the spinal column have been noted in fish and amphibia in response to heavy metals and chlorinated hydrocarbons (Sinderman et al., 1980). The deformities of waterfowl hatchlings resulting from selenium contamination at Kesterson National Wildlife Refuge are well documented (Ohlendorf et al., 1986). Liver pathology in fishes has been related to chronic exposure to crude oil contaminated sediments (McCain et al., 1978). Rats with high kidney lead levels had kidney pathological symptoms including intranuclear inclusion bodies in cells of the proximal tubules and mitochondrial abnormalities (Mouw et al., 1975). The pathology of the mammalian liver and kidney are well understood; this is a good index for assessing contaminant stress in wild populations.

2.2.2.4 Behavioral Responses. Perception and avoidance of contaminants is the most immediate and perhaps the most important behavioral response for a species exposed to contamination. Various fish species avoid such contaminants as copper and pulp mill effluent; this avoidance is known to inhibit spawning migration of anadromous species. Marine bivalves avoided lead and copper contaminated sediments by closing valves. Midge larvae avoided sediments containing high levels of cadmium and zinc (Sheehan, 1984a).

Many other behavioral responses are the result of physiological or biochemical responses to contaminants. Behavioral abnormalities relating to reproduction, shelter construction, and prey vulnerability can be related to a population's functional success. Reduced courtship activity in ringed turtle doves due to DDE and abnormal nest attendance in herring gulls exposed to organochlorines are two examples of interference with reproductive success (Sheehan, 1984a). Phenol has been shown to increase the time for bivalves to successfully complete burrowing. Organophosphate pesticides are known to inhibit the escape response of marsh crabs to natural bird predation, presumably because of those pesticides' action as cholinesterase inhibitors (Ward and Bush 1976; cited in Sheehan, 1984a).

2.2.2.5 Altered Performance. Growth and reproductive success are the two indices that best reflect individual performance and are most easily related to population fitness (Sheehan, 1984a). Changes in these parameters may be the result of physiological, morphological, or behavioral responses to contaminants. Drastic growth rate reduction has been demonstrated for juvenile brook trout at ppb levels of copper (McKim, 1971; cited in Sheehan, 1984a). Macroinvertebrates have exhibited reduced growth at high but sublethal levels of petroleum derivatives, pulp mill effluent, and metals.

The true test of the long-term impact of sublethal contaminant concentrations on an exposed population is whether the population is capable of reproducing successfully. Reproductive failure or disfunction can occur during several stages: courtship, development of gametes, fertilization, embryo development, hatching and early growth. For aquatic species which release gametes directly into the water, the fertilization stage is very sensitive to contaminants. Levels in the ppb range of lindane and sublethal levels of metals (mercury, iron, cadmium, and chromium) have been shown to be toxic to gametes and to reduce the successful fertilization of fish eggs (Billard, 1978; cited in Sheehan, 1984a).

It should also be noted that contaminant-induced effects may be exacerbated when combined with natural stresses such as disease or variability in climate and/or food supply. An ecosystem may appear to be relatively unaffected by contaminants until such natural stresses occur. A combination of these stresses could significantly disrupt an ecosystem to the point of extinction of some species.

3. CONTAMINANT EFFECTS ON COMMUNITIES

Communities are assemblages of populations structured by biotic interactions and the constraints of their physical and chemical environment (Sheehan, 1984a). The structure of an ecosystem is described by the abundance and biomass of all populations and their spatial, taxonomic and trophic organization. Recently, the term biotic integrity (or biointegrity) has been used to describe the health of a community (Water Resource Legislation PL 92-500, PL 95-217; cited in Karr et al., 1986). Biointegrity has been defined as the ability of an ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of natural habitat of the region (Karr and Dudley, 1981).

3.1 Importance of Community Characterization to Contaminant Monitoring

Biointegrity[1] is conceptually one of the best indicators of ecological health. A high quality biological community can only exist in a high quality chemical/physical environment. Those environments that exhibit biointegrity can be assumed to have chemical and physical integrity as well. There is increasing public and legislative pressure to rationalize contamination control expenditures in terms of environmental results. Biointegrity is a direct, comprehensive indicator of ecological conditions and, as such, may be the best measure of both environmental quality degradation and contamination control (or other habitat improvement) effectiveness. A conceptual scheme for contaminant effects on biointegrity is presented in Figure 1.

Implicit in the assessment of biointegrity is the characterization of the community of interest. Community characterization involves the collection and identification of species and analysis of community structure using various indices (Section 3.2.2). Data are then compared to baseline data (when available) or to data from similar communities (in relatively undisturbed areas) to provide a relative measure of response to perturbations.

3.2 Components of Community Characterization

Characterizing the community is a necessary activity to determine appropriate biomonitor and indicator species and the potential contaminant transport pathways to monitor. The following section briefly discusses a number of components important to community characterization. It is important to note that some indices that are used to describe particular community characteristics are complex, and at times, even controversial in their ability to adequately describe the desired characteristic. It is also important to note that an appropriate statistical design is required if any of these indices are to be meaningful. Regional EC specialists and/or Region 8 personnel should be consulted regarding specific design requirements for studies to be implemented. An excellent introduction to sampling design and appropriate statistical analysis for the nonstatistician biologist is Green (1979). Other texts (e.g. ASC, 1988; Gilbert, 1987) also provide very useful information on environmental sampling design.

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[1]The discussion of biointegrity is derived from Karr et al., 1986 and Sheehan, 1984a.

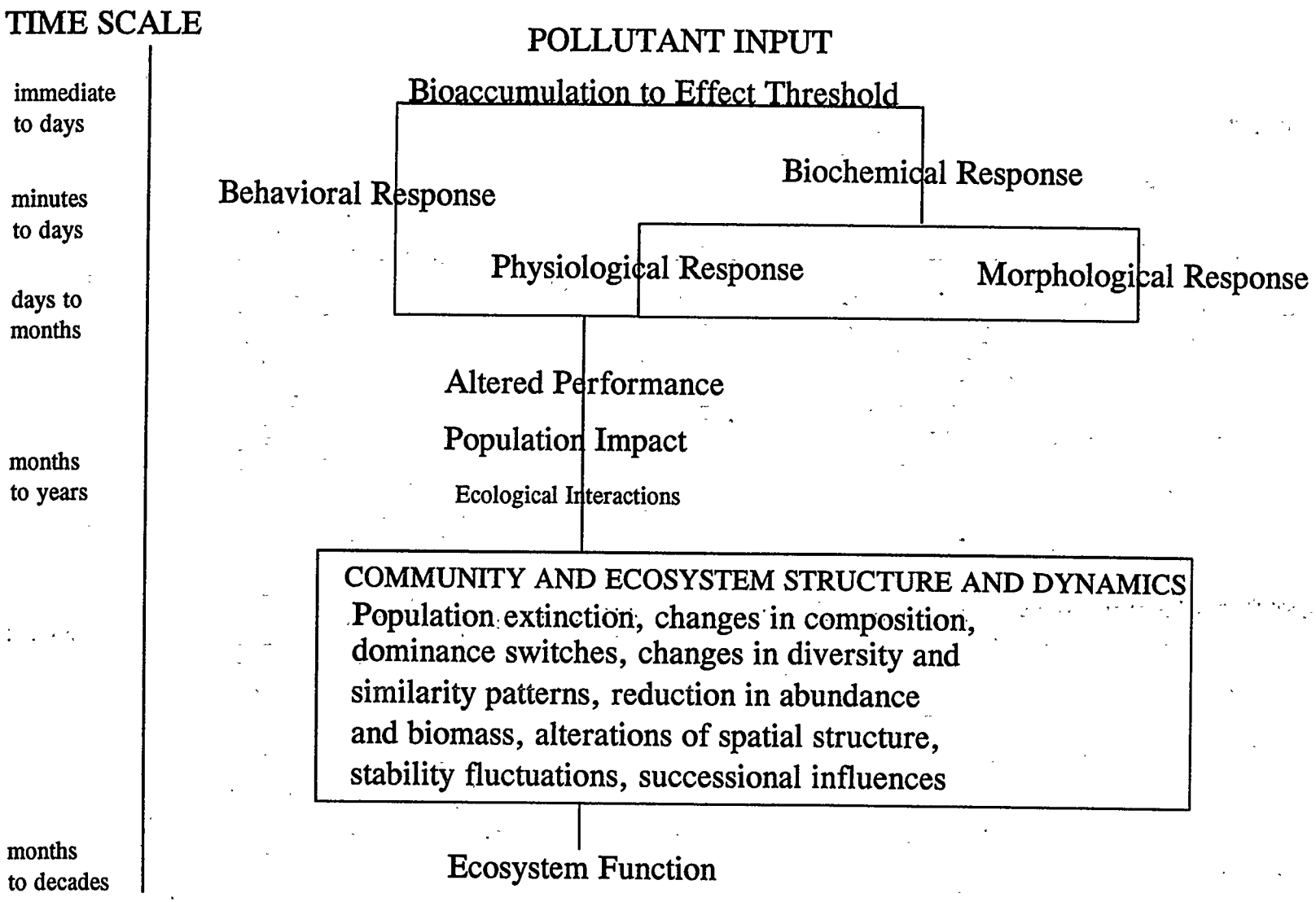

Figure 1. A conceptual chronology of induced effects following exposure to toxic contaminants, emphasizing changes in community and ecosystem structure and dynamics (Sheehan, 1984b).

3.2.1 Species Identification

Of necessity in community characterization is the ability to identify the species comprising that community. In most cases, it will be necessary to collect a representative sample of the biota of interest; many collection methods are described in the respective RFMs. To aid identification, area species lists should be obtained from state Fish and Game or water quality agencies, and/or local universities. In most cases, refuge personnel will be able to identify species using their own knowledge, field guides, and species lists. However, there may be situations, such as for many of the benthic macroinvertebrates, where specialized taxonomic expertise is required. Local universities, private consultants, or state water quality agencies are often good sources of taxonomic expertise and assistance.

Once specimens are collected and identified, it is good practice to preserve and archive representative members of each species. Archives are valuable for aiding future species identification, as well as for retrospective chemical analyses as new chemical hazards are discovered and the means for measuring their levels are developed.

3.2.2 Community Structure

Community structure is described by the abundance and biomass of all populations in the community and their spatial, taxonomic, and trophic organization. Various indices have been used to describe community structure. These include abundance and biomass, reduction in population size and extinction, community composition and species dominance, species diversity and similarity indices, spatial structure, stability, and succession and recovery (Sheehan, 1984a). These vary in their utility and sensitivity in contaminant stress assessment. Collecting and maintaining indices data may provide a useful method for early detection of contaminant effects that might otherwise go unnoticed.

It is outside the scope of this document to suggest which indices to select; however, several considerations should be addressed when selecting them. The most important factor for the application of bioindices is the sample. The validity of the bioindex selected depends on statistically sound sampling procedures. The bioindices to be used in environmental monitoring and assessment activities should reflect (1) the community in the environment of interest, i.e., the variety of organisms present, (2) the level of taxonomic identification, i.e., family, genera, or species, (3) the homogeneity of the sampling area, i.e., whether every point in the sampling area is the same, and (4) the sample size. After a preliminary determination of these factors via literature reviews and/or actual sampling, appropriate indices may be selected before implementing monitoring activities.

3.2.2.1 Abundance and Biomass. Abundance (number of individuals) and biomass (combined weight of individuals) are known to respond to contaminant stress; however, these indices are highly variable over time and space for many species and must be used with caution in assessing stress. Relative abundance, i.e., the number of individuals per species in a community, is a very useful measure of community response. Often, contaminant stress acts to reduce the population of sensitive species while opportunistic species populations may increase in size as a result of decreased competition for food or space. This is an example of when the increased relative abundance of a tolerant indicator species may be used as an indication of a contaminant problem.

3.2.2.2 Reduction in Population Size and Extinction. Reductions in density and the complete extinction of sensitive species because of environmental contamination are the primary factors altering community structure. Such effects can result from direct toxic effects, reduction in the ability to function successfully in competitive and trophic interactions, chronic reproductive failures, or avoidance of the contaminated environment. Most toxic contaminants act to reduce the number of individuals of intolerant populations, as well as the number of species (species richness) in the community. Species richness is quantifiable; however, it may be biased by the number and size of the samples taken, the selectivity of the sampling method, and various life history factors of the biota sampled (e.g. seasonal diurnal variations, predator and prey activities, etc.) This measure has significance relative to the structural integrity of the ecosystem; however, the severity of the impact of extinctions on ecosystem dynamics depends on, among other factors, any redundancy in functional roles that might compensate for losses of individual species. It is easier to appreciate the loss of a species that performs a unique role in the community or is highly visible. An example of such species loss is the accidental killing of pollinator bees by insecticides or impacts to large birds.

3.2.2.3 Community Composition and Dominance. The composition of a community is described by its taxonomic makeup, such as species lists or more complex indices incorporating relative abundance measures or subjective importance values. Some schemes use functional rather than taxonomic categories, such as those for feeding strategies of stream macroinvertebrates: shredders, scrapers, piercers, and predators (Cummins, 1974).

The concept of dominance is an important part of defining community composition. A species is considered dominant if it is present in the greatest abundance. Alternately, the dominant species may be the largest, or one that covers the greatest amount of space (percent cover for plants), or has the greatest impact on community dynamics. Although dominance implies a position of advantage in community interactions, it does not necessarily correlate directly with tolerance to contaminant stress. The dominant species in a polluted environment must be able to perform all essential functions (growth, development, reproduction) effectively, but need not be the most resistant member of the community. With respect to trophic organization in macroinvertebrate communities, generalist feeders appear to have the advantage over specialized predators in polluted streams (Sheehan, 1984b).

3.2.2.4 Diversity and Similarity Indices. Diversity indices (Table 4) have been widely used in the assessment of contaminant effects on community structure. The concept of diversity has two components: 1) the number of species present (species variety or richness) and 2) the distribution of all individuals among these species (evenness or equitability). A number of factors besides contaminant stress affect diversity; these include seasonal variation and the physical condition of the habitat. In moderately contamination-stressed systems, these other factors may have greater influence on community structure than the contamination.

Diversity indices have been applied with varying success to monitor contamination-stressed communities (Sheehan, 1984b). In some cases, simple richness indices or biomass indices have been more sensitive than diversity indices in separating communities along a contamination gradient.

Similarity indices (Table 4) generally compare numbers of species as well as numbers of species in common for two communities. Similarity indices have been shown in many cases to be more sensitive and therefore, more indicative of structural differences at low levels of stress than are

Table 4. Indices used to Assess Contaminant Effects (modified from Sheehan, 1984a)

			Range of Values		
Index	**Author[a]**	**Equation**	**Min.**	**Max.**	**Comments**
		Diversity Indices			
Williams A. index	Fisher et al. (1943)	$S \alpha \ln N/\alpha$	0	∞	S: no. of species, N: no. of individuals, α: index of diversity. Derived from nomogram published by Fisher et al. (1943)
	Margalef (1951)	$D=(S-1)/\ln N$	0	∞	Symbols as above
	Simpson (1949)	$SI=\frac{\sum n_i(n_i-1)}{N(N-1)}$	0	1.0	ni: no. of individuals in the ith species. Higher the value, lower the diversity. Also presented as 1-SI and 1/SI.
Information theory index	Shannon (1948); Shannon and Weaver (1963)	$H'=-\sum p_i \log_2 p_i$	0	∞	$p_i = n_i/N$: proportion of individuals in the ith species. Sometimes referred to as Shannon-Weiner or Shannon-Weaver index
	McIntosh (1967)	$MI=\sum_{i=1}^{s} n_i^2$	1.0	∞	n_i: no. of individuals in each species
Sequential Comparison Index (SCI)	Cairns et al. (1968)	$SCI=R/N'$	0	∞	R: no. of changes in species per scan. N': total number scanned. Can only be derived from examination of sample

			Range of Values		
Index	**Author[a]**	**Equation**	**Min.**	**Max.**	**Comments**
Improved Comparison Index	Keefe and Bergersen (1977)	$TU=1-\frac{N'}{N'-1}\sum_{i=1}^{k} p_i^2$--	0	∞	K: no. of taxa present. $p_i = n_i/N'$, (i=1, 2, 3, ..., K), corrects error in SCI.
		Evenness Indices			
Equitability	Lloyd and Ghelardi (1964)	$\epsilon=\frac{S}{S'}$	0	1.0	S': no. of species according to McArthur's broken stick model
	Pielou (1966)	$J=\frac{H'}{\log_2 S}$	0	1.0	Symbols as above: dependent on Shannon diversity
	Sheldon (1969)	$E=\frac{e^{H'}}{s}$	0	1.0	Symbols as above: dependent on Shannon diversity; problem with lower limit for non-diverse communities, for which it approaches 1/s.
	Heip (1974)	$E=\frac{e^{H'}-1}{S-1}$	0	1.0	Symbols as above: dependent on Shannon Diversity
		Similarity indices			
Coefficient or similarity	Jaccard (1912)	$I=\frac{c}{a+b-c}$	0	1.0	a: no. of species in community A, b: no. of species in community B, c: no. of species in community C
Quotient of similarity	Sorenson (1948)	$I=\frac{2c}{a+b}$	0	1.0	As above: same as coefficient of community (CC), Whittaker (1972)

Index	Author[a]	Equation	Range of Values		Comments
			Min.	Max.	
	Raabe (1952)	$I=\sum \min(a,b,c,..$	0	100%	a,b, etc. are minimum % values of each species common to both communities; same as Sanders (1960) index of affinity
Percentage similarity	Whittaker and Fairbanks (1958)	$PS=100(1-0.5\sum \lvert p_{i:}$	0	100	P_{ij} is the average proportional abundance of a given taxon in control samples and P_{ik} is its proportion in any single sample
Bray-Curtis dissimilarity	Bray and Curtis (1957)	$BC=\frac{\sum \lvert n_{1i}-n_2 i\rvert}{\sum (n_1 i+n_2 i)}$	0	1.0	n_{1i} and n_{2i}; the ln transformed numbers of the ith species at two sites being compared.

[a] All authors cited in Sheehan, 1984a.

diversity measures. This has been shown for zooplankton communities under cadmium stress and plant communities and deciduous forests under air contaminant stress (Sheehan, 1984b).

Table 5 provides some procedures that might be helpful when planning to use biological indices for environmental monitoring and assessment. Table 6 is a list of biological indices and information on their use.

3.2.2.5 Spatial Structure. Spatial structure encompasses horizontal and vertical patterns of communities and is particularly applicable to forest, desert, grassland, coral reef and rocky intertidal systems. The spatial relationships of terrestrial fauna and most aquatic communities, however, are not well defined because of species mobility, the small size of organisms, and heterogeneity of microhabitats. However, changes in plant communities can be expected to effect parallel changes in associated fauna.

3.2.2.6 Stability. Stability is defined as the natural tendency for a system to return to its previous state following a perturbation (Sheehan, 1984a). Ecosystems are not naturally constant and therefore stability does not necessarily refer to the maintenance of a static situation. Periodic fluctuations can be thought of as stable if that same cycle is repeated constantly. There is the possibility that certain systems, once perturbed in a certain way, may re-stabilize in a different configuration. For example, one species may be extinct and others may assume that species role or occupy its niche.

The inertia of an ecosystem, i.e., its ability to resist change, is a measure of that system's resistance to change resulting from contamination or other stresses. It has been suggested that ecosystems with a high degree of specialization and little history of fluctuating environmental parameters have low inertia and are highly vulnerable to environmental stresses, including contamination. Consequently, a system that has low inertia might merit more attention to contaminant monitoring than one with high inertia. The use of this and other stability criteria in contamination effects research, however, is not well developed.

3.2.2.7 Succession and Recovery. When stripped of its original vegetation by fire, flood, or glaciation, an area of bare ground does not remain devoid of plants and animals. The area is rapidly colonized by a variety of species that subsequently modify one or more environmental factors.

Succession has been defined as the change in an area of the earth's surface and its inhabitants over a moderate period of time, during which environmental conditions remain relatively constant (MacMahon, 1980; as cited in Sheehan, 1984b). The sequence by which community structure is simplified by chronic stress has been suggested to be the reverse of succession, or retrogression (Whittaker and Woodwell, 1973; as cited in Sheehan, 1984b).

Recovery from contamination events occurs in two phases: (1) colonization, and (2) reestablishment of biotic interaction. Early colonizing communities consist of opportunists and forms highly resistant to contamination. The recovery phase is dominated by density dependent population regulation. Specialists become more common after the displacement of early dominant opportunists. An indication of this phase is the reestablishment of population equilibria through trophic and competitive interactions.

Table 5. Procedures for the use of biological indices in monitoring/assessment (Modified from Campbell et al., 1980)

Procedure	Source of Information
Stage 1 Identify, quantify, and if possible, isolate the source or sources of the known, suspected, or proposed ecological perturbations.	Field Investigation
Stage 2 Determine the geographic limit of the known or suspected disturbance.	Field investigation and/or composite mapping
Determine the basic physicochemical characteristics of the locale in question.	Literature review, preliminary soil, sediment and water quality samples
Examine and outline the significant lifeforms and communities within the stream reach. This should include the notation of organisms of particular importance as indicators of environmental stress.	Literature review; preliminary biological samples
Stage 3 Selectively review the listing of biological indices (Table 4) to determine an appropriate index.	Use of biological indices in biomonitoring data reduction and analysis
Stage 4 Compile the information located at this stage into a preliminary environmental assessment report.	Assessment
Stage 5 Field collection and examination utilizing standard methods of sample acquisition, e.g., Surber Sampler, electro-shocking devices, and artificial substrate samples, and methods of data manipulation, reduction, and analysis suggested for a particular biological index. The type of organisms collected and the extent of this collection should be a function of (1) the nature of the perturbation, (2) the index to be utilized, (3) the salient features of the biotic and abiotic components of the ecosystem under examination, (4) the manpower and time constraints of the particular monitoring situation, and (5) the professional judgement of the investigator.	Field investigation; monitoring; data reduction
Stage 6 Analyze and display the data	Assessment preparation and review

Table 6. Biological indices and information on their use

Advantages	Disadvantages
BIRDS	
Nearly all birds are easily recognized, there are large numbers of amateurs who know them well	May cover a large range, making identification of contaminant source difficult
Bird censuses (e.g., Christmas birdcounts) have been carried out for decades and are standardized	Most sampling methods are selective for species and size ranges
Birds have high respiration rate, making them potentially good indicators for airborne contaminants	
Occupy several trophic levels	
Most species reproduce in the spring	
BENTHIC MACROINVERTEBRATES	
Many species are very sensitive to slight change sin water quality	Sample processing can take one day or longer per sample
Sample collection is easy and does not require extensive gear or personnel	Identification of most species requires an experiences taxonomist
Most species are sedentary, thereby reflecting the water quality of the immediate vicinity	
FISH	most sampling methods are selective to a certain extent for species and size
Typically present in all but the smallest streams and in all but most polluted waters	Are mobile on diel and seasonal time scales
Occupy positions throughout aquatic food web	Several personnel are typically required for a sampling effort
Many species reproduce once a year and at an established spawning season; therefore populations are relatively stable over a large part of the year	
Are relatively long-lived, permitting a temporal dimension in assessing aquatic conditions. Comparison of recruitment and growth data among years can help to pinpoint periods of unusual stress	
Relatively easy to identify–most, if not all identification can be made in the field	
Life history information is extensive for most species	
Public relates to health of fishery better than to that of other aquatic biota	

Table 6. (continued)

Advantages	Disadvantages
PLANTS	
Vegetation samples can be useful as contaminant indicators, whether the contaminant is known or unknown since plants may exhibit visual symptoms or display obvious mortality, this is a distinct advantage over other media	Considerable experience is necessary before one can associate symptoms with specific agents Symptoms are highly variable (depending upon pollutant concentration, weather exposure, general vigor of the plant, and species of the plants) and one cannot generally presume from symptoms about the distribution of a pollutant Some species may not exhibit symptoms at pollutant concentrations which are much higher than in species with visible symptoms alone For many of the priority pollutants toxic symptoms have not yet been reported or thoroughly verified Selection of indicator species and/or plant part selection is complex and governed by the exposure pathway and uptake characteristics of the species
AMPHIBIANS/REPTILES	
Contaminant point sources may be more easily and accurately identified by sampling herpetofaunal populations which are non-migratory (e.g., permanent residents of lakes and ponds). Amphibians and reptiles are ectothermic and their behavioral adaptations and use of microhabitats are diverse. Sampling of diverse populations may indicate distribution of environmental contaminants Many species are easily trapped during the breeding season or at night when considerable feeding activity may be observed Field guides and keys for identifying various herpetofauna area available for most regions of the United States	Relatively few contaminant-induced physiological and behavioral traits have been researched Radical changes in herpetofaunal populations may indicate natural environmental fluctuations such as precipitation and temperature. Sampling personnel must be cautious when interpreting cause-and-effect data, which may not be contaminant induced Sampling certain species is sometimes dangerous (venomous species) and sampling personnel must be familiar with their habits and habitats Relatively few biologists have had significant eduction in herpetology Sampling success may be adversely affected by daily and weekly patterns, time of day (many species are nocturnal), differences in species morphology, physiology, and activity patterns and movements

4. REFERENCES

ACS, American Chemical Society, 1988. Principles of Environmental Sampling. Ed. by L. H. Keith. American Chemical Society.

Ash, C. P. J. and Lee, D. L., 1980. "Lead, Cadmium, Copper and Iron in Earthworms from Roadside Sites", Environmental Pollution (Series A) 22: 59-67.

Beyer, W. N., Chaney, R. L. and Mulhern, B. M. 1982. Heavy Metal Concentrations in Earthworms.

Beyer, W. N., 1986. "A Reexamination of Biomagnification of Metals in Terrestrial Food Chains," Env. Toxicol. and Chemistry 5:863-864.

Blus, L. J., E. Cromartie, L. McNease and T. Joanen, 1979. "Brown Pelican Population Status, Reproductive Success and Organochlorine Residues in Louisiana, 1971-1976." Bull. Env. Contam. Toxicol. 22:128-135.

Brown, R. S., R. E. Wolke, C. W. Brown, and S. B. Saila. 1979. "Hydrocarbon Pollution and the Prevalence of Neoplasia in New England Soft Shell Clams (Mya arenaria)." In Animals as Monitors of Environmental Pollutants. National Research Council, National Academy of Sciences, Washington, D.C.

Campbell, G., C. Vitello, W. Campbell, R. Frisina, J. Kirkpatrick, 1980. Use of Biological Indices in Biomonitoring Data Reduction and Analysis. #12BIO-CoEn-S2/79-R1. U.S. Army Engineer Waterways Experiment Station, Under Contract No. DACW 39-79-C-0064.

Clark, T., K. Clark, S. Peterson, D. Mackay and R. Norstrim, 1988. "Wildlife monitoring, modeling and fugacity", Environ. Sci. Technol. 22(2):120-127.

Cummins, K. W. 1974. "Structure and Function of Stream Ecosystems." Bioscience 24:631-641.

Eisler, R,. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.11).

Eisler, R,. 1987. Lead hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.14).

Farrington, J. W. et al., 1987. "'Mussel Watch', Measurements of Chemical Pollutants in Bivalves as One Indicator of Coastal Environmental Quality," New Approaches to Monitoring Aquatic Ecosystems, ASTM STP 940, T. P. Boyle (ed.), America Society for Testing and Materials, Philadelphia, Pennsylvania.

Ferry, B. W., M. S. Baddeley, and D. L. Hawksworth, 1973. "Air Pollution and Lichens," The Athlone Press, University of London.

FWS, 1986. U. S. Fish and Wildlife Service. Field Operations Manual for Resource Contaminant Assessment, USFWS Contaminant Assessment Division, Washington, D.C.

Gaufin, A. R. 1973. "Use of Aquatic Invertebrates in the Assessment of Water Quality." In: J. Cairns, Jr. and K. Dickson, ed., Biological Methods for the Assessment of Water Quality, ASTM Special Publication 528, American Society for Testing and Materials, Philadelphia, Pennsylvania.

Gilbert, R. O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, New York, New York.

Gish, C. D. and Christensen, R. E., 1973. "Cadmium, Nickel, Lead and Zinc in Earthworms from Roadside Soil," Environmental Science and Technology 7:1060-1062.

Green, R. H., 1979. Sampling Design and Statistical Methods for Environmental Biologists., John Wiley and Sons.

Helmke, P. A. Robarge, W. P., Korotev, R. L. and Schomberg, P. J. 1979. Effects of Soil-Applied Sewage Sludge on Concentrations of Elements in Earthworms. Journal of Environmental Quality 8:322-327.

Hill, E. F. and W. J. Fleming, 1982. "Anticholinesterase Poisoning of Birds: Field Monitoring and Diagnosis of Acute Poisoning," Environmental Toxicol. Chem., 1, pp. 27-38.

Jenkins, D. W., 1980. Biological Monitoring of Toxic Trace Metals Vol. 1 Biological Monitoring and Surveillance, EPA-600/3-80-089, U.S. EPA, Las Vegas, NV.

Karr, J. R. and D. R. Dudley, 1981. "Ecological Perspective on Water Quality Goals," Environmental Management, 5, pp. 55-68.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser, 1986. "Assessing Biological Integrity in Running Waters - A Method and its Rationale," Illinois National History Survey Special Publication 5.

Laughlin, R. B. and H. E. Guard, 1986. Biomonitors: Practice and Concepts. In: Marine Technology Society Proceedings of Oceans 86 Volume 3, Monitoring Strategies Symposium.

McCain, B. B., H. O. Hodgins, W. D. Gronlund, J. W. Hawkes, D. W. Brown, M. S. Myers, and J. H. Vandermeulen. 1978. Bioavailability of Crude Oil from Experimentally Oiled Sediments to English Sole (Parophrys vetulus) and Pathological Consequences. J. Fish. Res. Board Can., 35:657-664.

Miller, D. S., W. B. Kinter, and D. B. Peaball, 1979. Effects of Crude Oil Ingestion on Immature Pekin Ducks (Anas platyrhynchos) and Herring Gulls (Larus argentatus). In: Animals as Monitors of Environmental Pollutants. National Research Counci3l, National Academy of Sciences Washington, D.C.

Mouw, D., K. Kalitis, M. Anver, J. Schwartz, A. Constan, R. Hartung, B. Cohen, and D. Ringler. 1975. Lead-Possible Toxicity in Urban Versus Rural Rats. Arch. Environ. Health, 30, 276-280.

Newman, J. R. 1979. The Effects of Air Pollution on Wildlife and Their Use as Biological Indicators. In: National Research Council, National Academy of Sciences Animals as Monitors of Environmental Pollutants. NAS, Washington, DC.

NRC (National Research Council), 1986. Ecological Knowledge and Environmental Problem-Solving, National Academy Press, Washington, D.C.

Ohlendorf, H. M., D. J. Hoffman, M. K. Saiki, and T. W. Aldrich. 1986. "Embryonic Mortality and Abnormalities of Aquatic Birds: Apparent Impacts of Selenium from Irrigation Drainwater," Science of the Total Environment, 52:49-63.

Sheehan, P. J. 1984a. Effects on Individuals and Populations. Chapter 4 in P. J. Sheehan et al. (eds), Effects of Pollutants at the Ecosystem Level. Scope 22, John Wiley and Sons.

Sheehan, P. J. 1984b. "Effects on Community and Ecosystem Structure and Dynamics," Chapter 5 in P. J. Sheehan et al. (eds), Effects of Pollutants at the Ecosystem Level. Scope 22, John Wiley and Sons.

Shupe, J. L., H. B. Peterson, and A. E. Olson. 1979. Fluoride Toxicosis in Wild Ungulates of the Western United States. In: Animals as Monitors of Environmental Pollutants, National Research Council, National Academy of Sciences, Washington, D.C.

Sindermann, C. J., F. B. Bang, N. D. Christensen, V. Dethlefsen, J. C. Harshbarger, J. R. Mitchell, and M. F. Mulcahy. 1980. The Role and Value of Pathobiology in Pollution Effects Monitoring Programs. In Biological Effects of Marine Pollution and the Problems of Monitoring, A. D. McIntyre and J. B. Pearce (Eds.), Rapp. P.-v. Reun. Cons. Int. Explor. Mer, 179, 135-151.

Weber, C. I. 1973. Biological Monitoring of the Aquatic Environment. In: Biological Methods for the Assessment of Water Quality, J. Cairns, Jr. and K. Dickson, ed.. ASTM Special Publication 528.

5. BIBLIOGRAPHY

Bailey, N. T. J., 1959. Statistical Methods in Biology. The English University Press Ltd., London, EC4.

Beyer, W. N. and E. J. Cromartie, 1981. "A Survey of Pb, Cu, Zn, Cd, Cr, As, and Se in Earthworms and Soil from Diverse Sites," Environmental Monitoring and Asses., 8, pp. 27-36.

Segar, D. A., D. J. H. Phillips and E. Stamman. 1987. "Strategies for Long-Term Pollution Monitoring of the Coastal Oceans," New Approaches to Monitoring Aquatic Ecosystems, ASTM STP 940, T. P. Boyle (ed.), America Society for Testing and Materials, Philadelphia.

Sleight, S. D. 1979. "Polybrominated Biphenyls: A Recent Environmental Pollutant," In: Animals as Monitors of Environmental Pollutants. National Research Council, National Academy of Sciences NAS, Washington, D.C.

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U.S. FISH AND WILDLIFE SERVICE LANDS CONTAMINANT MONITORING OPERATIONS MANUAL

APPENDIX D.1 BENTHIC MACROINVERTEBRATE SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix D.1 of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   D.2 Bird Sampling Reference Field Methods
   D.3 Fish Sampling Reference Field Methods
   D.4 Flora Sampling Reference Field Methods
   D.5 Reptiles and Amphibians Sampling Reference Field Methods
   D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
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Document Revision Worksheet

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ACRONYMS

BLM	Bureau of Land Management
COC	Chain-of-Custody
CPOM	Course Particulate Organic Matter
EC	Environmental Contaminant
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, or Trichoptera
ETOH	Ethyl Alcohol
NPS	National Park Service
PIBS	Portable Invertebrate Box Sampler
PAH	Polynuclear Aromatic Hydrocarbons
PCBs	Poly-chloronated biphenyls
RFM	Reference Field Method
RBP	Rapid Bioassessment Protocol
SOP	Standard Operating Procedure
STKM	Standardized Traveling Kick Method
USGS	U.S. Geological Service

U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D.1 BENTHIC MACROINVERTEBRATE SAMPLING REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of this Reference Field Methods (RFM) document is to provide guidance for obtaining selected benthic macroinvertebrate samples for physical and chemical analysis. Data generated from benthic macroinvertebrate samples can be used by Fish and Wildlife Service (FWS) personnel to establish baseline data for a site or to help monitor the effects from current or historic contaminant exposure to the site.

1.2 Scope

This RFM is intended to guide Service personnel in collecting benthic macroinvertebrates for contaminant monitoring activities. This document is not intended to provide guidance in sampling design or to include all the procedures for collecting these organisms. There are situations that may require collection devices and procedures other than those presented here. The methods provided here should be acceptable for most field contaminant activities. In special situations, Environmental Contaminant (EC) specialists and experts in the field should be consulted for additional guidance. If methods other than those presented in this document are used, they should be well documented so they can be duplicated in future sampling efforts.

Section 1 provides a brief background discussion on the use of benthic macroinvertebrates for contaminant monitoring activities. It also suggests additional information sources that might be useful when planning and implementing these activities. Table 1 provides an overview of the sampling methods presented in this document.

The collection of benthic macroinvertebrates and the rationale for monitoring their community structure is discussed in Section 2. Community indices in terms of their usefulness for contaminant monitoring the use of selected species for contaminant monitoring and items that should be considered before sampling are discussed in this section.

In Section 3, the collection and handling of benthic macroinvertebrates in various sampling situations is discussed. A number of sampling devices are presented and sampling procedures are discussed for each. Preservation techniques are also discussed.

Table 1. Key to benthic macroinvertebrates sampling methods.

Sampling Procedure	Location in RFM	Type of Monitoring*	Advantages	Disadvantages
PIBs and Modified Surber Sampler	3.1.1.2	A, B, C	Easily used by one person. Area sampled is standardized	High sampling variability, especially in fauna-poor streams
STKM	3.1.1.2	A, B, C	Good for fauna poor streams. Less sampling variability than PIBs or Surber in such streams	Area sampled is more difficult to define than for PIBs and Surber
Drift nets	3.1.1.3	A, C	High sampling efficiency for drifting invertebrates	Subject to clogging in streams with high algal content or other suspended matter. Not possible to know from where upstream drift originated
- Hester-Dendy (Artificial substrate)	3.1.1.4	A, C	Standardized surface area and substrate - used in shallow and deep water	Special care needed for installation and collection; Biased for aquatic insects
- Basket Sampler (Artificial substrate)	3.1.1.4	A, C	Provides more natural substrate than Hester-Dendy	Surface area and substrate less standardized than H-D owing to variability in rocks
Grab Samplers	3.1.2.1	A, B, C	Can be used in deep water, good for soft sediments	Not useful in rocky or hard substrate; Jaws can become blocked from closing completely; May require boat with winch
Core Samplers	3.1.2.2	A, B, C	Good for sampling shallow marsh deposits and peat bogs Easily transported	Area sampled is relatively small Limited in deep water or swift current
Emergence Traps	3.1.2.3	A, B, C	Useful for collection of adult stages which are easier to classify; Useful for analysis of complex communities	Subject to vandalism and tampering

* **A = Initial Screening/Characterization**
B = General Monitoring
C = Special Case Monitoring

Table 1. (Continued)

Sampling Procedure	Location in RFM	Type of Monitoring*	Advantages	Disadvantages
Handpicking	3.3.1	C	Can capture only species one is interested in	Low efficiency
Aerial Nets, Sweep Nets	3.3.1	A, B, C	Capture many insects in short time	Non-specific
Dredge	3.3.2	C	Effective method of capturing oysters in deep water	Requires boat with wiches and adequate power
Tongs	3.3.2	C	Specific to target species (oyster)	Low efficiency
Light Traps	3.3.3	A, B, C	Non-selective; captures many insects in single setting; captures adults which are easily identified	Subject to vandalism and tampering
Baited Traps and Trot Lines	3.3.4	C	Can catch many individuals in single setting	Subject to vandalism and tampering

* A = Initial Screening/Characterization
B = General Monitoring
C = Special Case Monitoring

1.3 Background

Benthic macroinvertebrates are animals inhabiting the substratum of lakes, streams, estuaries, and marine environments, and include aquatic insects, macrocrustaceans, mollusks, annelids, roundworms, flatworms, corals, sponges, and other aquatic and marine invertebrates. By definition, macroinvertebrates are visible to the unaided eye (i.e., large enough to be seen without a microscope) and are retained on a 0.595 mm opening U.S. Standard No. 30 sieve) (APHA 1985). However, the USGS (Greeson et al. 1977) has adopted a lower size limit of 0.210 mm (U.S. Standard No. 70 sieve) for macroinvertebrates in flowing waters.

The importance of benthic macroinvertebrates in aquatic pollution studies has long been recognized. Not only are many macroinvertebrate species bioconcentrators of some contaminants, but their communities are also sensitive indicators of ecosystem stress. As such, in a contaminated system, certain sensitive species may disappear while others may flourish, leading to changes in species diversity, relative abundance, and dominance. Because benthic macroinvertebrates serve as a primary food source to many fish and bird species, changes in the invertebrate community structure can, and often do, impact higher trophic level organisms.

Benthic macroinvertebrates may be collected for chemical analysis and/or physical analysis. Chemical analysis entails the collection of these organisms from selected locations for analysis of chemical residues that have been incorporated into or adsorbed onto their bodies; this requires that enough material be collected and that cross-contamination be avoided. At times it might be desirable to collect a specific organism for chemical analysis if it is a bioconcentrator of a contaminant that is being monitored, or a principal food source for an important species.

Physical analysis is the close visual inspection of individuals to classify the organism and/or to assess morphological abnormalities that might be associated with contaminant exposure. There are two types of monitoring activities associated with physical analysis: (a) monitoring the community; and (b) monitoring selected species. In monitoring the community, there is an intensive effort to collect representative samples of the entire benthic macroinvertebrate community to quantify community structure parameters such as composition, relative abundance, density, etc. This information can then be used to assess and monitor the biointegrity of the ecosystem, establish baseline values for the community, and/or to quantify the degree of damage to the community from contaminant associated stresses. Biointegrity (or biotic integrity) is defined as the ability of a system to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region (Karr et al. 1986).

Monitoring selected species will include collection of bioindicators to assess their presence/absence, monitor their health, and provide biomonitors for contaminant residue analysis. It is important to distinguish between the terms "biomonitor" and "bioindicator." These terms as well as others are used interchangeably throughout the literature to refer to species that accumulate contaminants or are affected in some way. However, in this document, the following definitions are presented:

Biomonitor: A species that accumulates or concentrates a contaminant in tissues to measurable levels. Ideally, the organism is not affected by the contaminant.

Bioindicator (or indicator species): A species that is affected, either negatively or positively, by a contaminant. Negative effects can range from pathological symptoms in individuals to extirpation of the species. An example of a positive response is an increase in a population of a species, usually at the expense of other species, in an organically enriched stream section (e.g., from sewage input).

1.4 Information Sources

Contact local EC specialists and the regional EC coordinator for initial information needs. The Environmental Protection Agency (EPA), National Forest Service (NFS), Bureau of Land Management (BLM), National Park Service (NPS), as well as state agencies (e.g., Fish and Game, or Water Quality) have ecologists that might be helpful. Fish and Wildlife Service Cooperative Research Units should also be contacted for their expertise, particularly if taxonomic classification is necessary for monitoring activities.

2. MONITORING CONSIDERATIONS

2.1 Presampling Considerations

It is assumed that the goals of the contaminant monitoring activities have been defined and that sampling of benthos has been determined to be necessary to accomplish these goals. Advantages of including benthic macroinvertebrates in contaminant monitoring activities include:

- They are well suited for assessing site-specific impacts because many species have limited migration patterns or have a sessile mode of life.
- The recent history of water quality events can be detected through periodic sampling of the benthos because affected communities may require weeks or months to recover (whereas periodic physical/chemical monitoring of water alone could easily miss short-duration contamination events).
- Many macroinvertebrates bioconcentrate contaminants, enhancing the probability of detecting a given contaminant over water analysis alone.
- They are sensitive in varying degrees to most types of contaminants.

Some considerations in planning benthos monitoring activities include evaluating benthos characteristics such as behavior, trophic level, and spatial/temporal variations of invertebrate abundance.

2.1.1 Habits/Behavior

In running water, morphological and/or behavioral adaptations of benthos allow them to remain relatively sessile in a moving medium. An example of a morphological adaptation is the very flattened profile of stoneflies, which inhabit areas with a swift current. Many common stream organisms, for example, flatworms, annelids, crustaceans, and many of the insects, have no special morphological advantages over nonstream-dwelling members of their groups. They simply avoid the current by living under stones or in the dead water downstream of obstructions. Others live along the sides and avoid the swifter current toward the middle of larger streams (e.g., Gammarus species). Still others, such as the stoneflies (Plecoptera), are strictly confined to swift currents because of the need for highly oxygenated water. Therefore, in sampling the stream environment, particularly when comparing upstream to downstream diversity or diversity among streams, one needs to pay close attention to ensure that similar habitats are being sampled. Factors that should be considered are substrate type (sand, gravel, rock, or mud), depth, presence of riffles and pools, stream width, flow velocity, and bank cover.

2.1.2 Trophic Level

Most benthic macroinvertebrates are important as prey species to predators such as fish, birds, and mammals. Because many macroinvertebrates bioaccumulate contaminants, they contribute to the uptake of these contaminants by predators. The trophic level and specific habitat utilized can influence the availability of contaminants to various species. For example, many metals accumulate

in sediments. Those organisms inhabiting sediments are much more likely to uptake metals by virtue of their greater exposure than organisms occupying other habitats. Likewise, in this aquatic pathway example, biota that consume sediment-dwelling organisms (such as waterfowl consuming Chironomids or midges) are at greater risk of exposure to metals than biota that consume, for example, grain. Less subtle are the impacts of declining invertebrate populations on the populations of species that depend on them. For example, Paparo and Sparks (1977) report on the decline of diving ducks such as lesser scaups and canvasbacks, using the Illinois River during migration corresponding to the virtual disappearance of the birds' primary food item, fingernail clams. This disappearance was linked to high potassium levels in the Illinois River.

2.1.3 Spatial/Temporal Variation

The inherently heterogeneous nature of streams and the patchy distribution of the organisms over the substrate can result in highly variable data. Needham and Usinger (1956) analyzed benthic data from 100, 1-ft^2 Surber samples taken from a highly uniform riffle of a mountain stream. The samples yielded invertebrate weights of 0.015 to 2.31 grams, and it was calculated that 73 samples would be required to obtain a 5% error for mean weight at the 95% confidence interval. This sampling intensity is clearly prohibitive for routine sampling programs. However, if this inherent natural variability of benthic invertebrate distribution is recognized and an allowance for error of about 50 or 100% is accepted, then three to five replicates should normally be adequate. Because the collection of benthic samples takes only a fraction of the time and effort involved in processing these samples, a safeguard strategy to assure that even this error (50 to 100%) is reached would be to collect a larger number of samples (e.g., 5 to 10) and then process and analyze the replicates only until the desired level of error is obtained. This method ensures the desired level of error is reached with the minimum amount of processing effort.

Consideration should be given to the variability of stream invertebrate biomass over time. Life-cycle characteristics of the dominant insect species present in a reach of stream can greatly influence the amount of biomass in the stream at any given time as described by Hynes (1970). For example, in a stream dominated by spring mayflies, invertebrate biomass can fall sharply during late spring as many of the mature individuals emerge. Streams dominated by summer species of black flies and midges or by amphipods (which breed and grow during the summer months) may reach their peak in biomass during late summer. Thus, investigations that require invertebrate biomass data should take these large seasonal fluctuations into account. This requires that benthic samples be taken from the stream reach in question on a seasonal basis to determine the amplitude and duration of the seasonal variations.

In addition to seasonal changes of biomass, less predictable but substantial changes occur on an annual basis. Hynes (1970) presents invertebrate data taken from a river station during the same season over a 9-year period that show the total number of organisms changed as much as threefold from year to year. These changes are probably in part the result of annual differences in intensity and timing of climatic events. Periods of high water often have an especially drastic effect on biomass, reducing it by several-fold. In the semiarid western United States, localized summer thunderstorms can produce extremely severe floods that result in substrate scouring that reduces the invertebrate populations from thousands per square meter to close to zero.

In estuaries, studies of species diversity should be made in late summer when stresses on aquatic ecosystems are usually greatest and in spring when spawning occurs (Patrick and Kiry 1976).

Biomonitor organism collections, on the other hand, may require different timing. In one biomonitor organism study, oysters and clams were shown to have higher levels of polynuclear aromatic hydrocarbons (PAH) and pesticides (e.g., Kepone) in the fall, than in the spring. This was believed to result from the fact that oysters build up food reserves of lipids and glycogen during the fall. Clams in the study were in peak spawning condition at the time of the sampling (Bender et al. 1986). In the Mussel Watch program, which monitors contaminants in mussels and oysters in U.S. coastal waters, 4 years of data on mussels from Narragansett Bay, Rhode Island, showed a consistent trend of higher PCB levels in the spring compared to the rest of the year (Farrington et al. 1987). This was also believed to be related to spawning. Currently the program conducts all sampling from January to March to avoid the spawning period. Additional recommendations on seasonality of sampling with respect to rapid bioassessment are presented in Section 2.7.1.

2.2 Monitoring the Community

Monitoring the benthic community may be included as part of baseline monitoring activities in aquatic systems. Most aquatic habitats with acceptable water quality and substrate conditions support diverse macroinvertebrate communities. Such communities respond to changes in habitat quality by adjustments in community structure. This may include examining community biointegrity when a community is under contaminant stress to assess the degree and any progression or regression of the contaminant problem. Indices such as abundance (numbers or biomass of each taxon), richness (number of taxa), similarity, and diversity have been used for many years to describe and compare benthic communities. Recently, EPA has published "Rapid Bioassessment Protocols for Use in Streams and Rivers" (Plafkin et al., 1989) which incorporate various components of community structure as well as habitat evaluation. These protocols are discussed in Section 2.2.3.

2.2.1 Abundance

Abundance is the number and/or biomass of each taxon in a sample and can be related to sampling effort (pounds per square foot or per grab sample). This provides a basis for comparisons between sampling stations, different times, other water bodies, or published works. Caution is advised, however, that benthos samples are typically quite variable both spatially and temporally as a result of natural variability in habitat and cycles (Section 2.1.3).

2.2.2 Richness

Richness is the number of taxa (usually species) present at a specific site on a given sampling date or on an annual basis. Because of the variable sensitivity of species to contaminant stress, one can expect richness to decrease with increasing contamination. This is probably a good index for baseline contaminant monitoring; however, the same caution stated for abundance also applies to this index.

2.2.3 Diversity

The concept of diversity has two components: a) the number of species present (species variety or richness) and b) the distribution of all individuals among these species (evenness or equitability). Diversity indices have been widely used in the assessment of contaminant effects on community structure. However, other factors besides contaminant stress affect diversity, including

seasonal variation and physical condition of the habitat. Some diversity and similarity indices are presented in Table 4 of Appendix D.

2.2.4 Similarity

Similarity indices generally compare numbers of species as well as numbers of species in common between two or more communities. Similarity indices have been shown in many cases to be more sensitive to low levels of stress than diversity indices.

2.2.5 Rapid Bioassessment

The EPA has developed "Rapid Bioassessment Protocols (RBPs) for Use in Rivers and Streams" (Plafkin et al. 1989); these are recommended for use by Service personnel. The RBPs were developed by EPA for use by state agencies in conducting cost-effective biological assessments of lotic (flowing water) systems (note that as of December 1989, no analogous protocols have been developed for lentic, or nonflowing systems). Some stated applications of RBPs are initial screening, priority setting, point and nonpoint source evaluations, use attainability analyses, and trend monitoring. There are five RBPs: RBPs I through III are the benthic macroinvertebrate protocols, while RBPs IV and V apply to fish (see Fish Sampling RFM). RBPs I through III consist of three basic components: water quality/physical characteristics, habitat assessment, and a biosurvey. The protocols are summarized in the following subsections and are completely described in Plafkin et al. (1989). That reference will need to be obtained by Service personnel wishing to apply the protocols. The reference is available, free of charge, from

Office of Water
AWPD (WH-553)
U.S. Environmental Protection Agency
401 M St., S.W.
Washington, D.C. 20460

It is further recommended that Service personnel who intend to utilize the protocols take the 2 1/2-day RBP workshop. The Office of Water can provide information on that workshop.

2.2.5.1 RBP I. RBP I is a screening or reconnaissance assessment used to discriminate obviously impacted and nonimpacted areas from potentially affected areas requiring further investigation. Areas identified for further study can then be rigorously evaluated using RBPs II, III, and/or V, other quantitative fish or benthic surveys, or ambient toxicity studies. Although RBP I is simple and quick relative to the other RBPs, judgement of an experienced professional is required in determining impairment.

For RBP I, qualitative benthic samples are collected from all available habitats using a dipnet or kicknet, or by hand. Macroinvertebrate orders/families collected are listed on the Biosurvey Field Data Sheet (Figure 1) with an estimate of their relative abundance in the sampling area. Impairment may be indicated by absence of pollution-sensitive benthic macroinvertebrate taxa such as Ephemeroptera, Plecoptera, or Trichoptera (EPT); dominance of generally pollution-tolerant groups such as Oligochaeta or Chironomidae; or overall low benthic abundance or taxa richness. If impairment is detected, the investigator provides an estimate of the probable cause and source on the Impairment Assessment Sheet (Figure 2).

Rapid Bioassessment Protocol I

Biosurvey Field Data Sheet

RELATIVE ABUNDANCE OF AQUATIC BIOTA

Periphyton	0	1	2	3	4	Slimes	0	1	2	3	4
Filamentous Algae	0	1	2	3	4	Macroinvertebrates	0	1	2	3	4
Macrophytes	0	1	2	3	4	Fish	0	1	2	3	4

0 = Absent/Not Observed 1 = Rare 2 = Common 3 = Abundant 4 = Dominant

MACROBENTHOS QUALITATIVE SAMPLE LIST (Indicate Relative Abundance R = Rare, C = Common, A = Abundant, D = Dominant)

Porifera	Anisoptera	Chironomidae
Hydrozoa	Zygoptera	Plecoptera
Platyhelminthes	Hemiptera	Ephemeroptera
Turbellaria	Coleoptera	Trichoptera
Hirudinea	Lepidoptera	Other
Oligochaeta	Sialidae	
Isopoda	Corydalidae	
Amphipoda	Tipulidae	
Decapoda	Empididae	
Gastropoda	Simuliidae	
Bivalvia	Tabanidae	
	Culicidae	

Rare < 3 Common 3-9 Abundant > 10 Dominant > 50 (Estimate)

Observations

Figure 1. Biosurvey Field Data Sheet for use with Rapid Bioassessment Protocol I (Plafkin et al., 1989).

IMPAIRMENT ASSESSMENT SHEET

1. Detection of impairment: Impairment detected (Complete items 2-6) No impairment detected (Stop here)

2. Biological impairment indicator:

Benthic macroinvertebrates	Other aquatic communities
____ absence of EPT taxa	____ Periphyton
____ dominance of tolerant groups	____ filamentous
____ low benthic abundance	____ other
____ low taxa richness	____ Macrophytes
____ other	____ Slimes
	____ Fish

3. Brief description of problem: _____

Year and date of previous surveys: _____

Survey data available in: _____

4. Cause: (indicate major cause) organic enrichment toxicants flow habitat limitations other _____

5. Estimated areal extent of problem (m^2) and length of stream reach affected (m), where applicable: _____

6. Suspected source(s) of problem:

____ point source discharge (name, type of facility, location)
____ construction site runoff
____ combined sewer outfall
____ silviculture runoff
____ animal feedlot
____ agricultural runoff
____ urban runoff
____ ground water
____ other
____ unknown

Briefly explain:

Figure 2. Impairment Assessment Sheet for use with macroinvertebrate Rapid Bioassessment Protocols (Plafkin et al., 1989).

2.2.5.2 RBP II. RBP II is more thorough than RBP I, using quantitative sampling and analysis at the family taxonomic level. RBP II can be used to prioritize sites for more intensive evaluation (e.g., RBP III, replicate sampling, ambient toxicity testing, and chemical characterization) or can be used instead of RBP I for screening. RBP II is focused on the riffle/run habitat because it is the most productive habitat available in stream systems and includes many pollution-sensitive taxa of the Scraper and Filtering Collector functional feeding groups. Supplemental sampling of Coarse Particulate Organic Matter (CPOM) (Section 3.1.1.1) provides a measure of effects (particularly toxicity effects) on a third trophic component of the benthos, the Shredders.

A flowchart of the entire RBP II process is presented in Figure 3. For RBP II, two 1 m^2 riffle areas, one from an area of fast current and one from an area of slower current, are sampled at each station using a kick-net (Section 3.1.1.1) and the two samples are composited. In streams without riffles, run areas with cobble or gravel substrates will also suffice for kick-net sampling. Where neither riffle nor run communities with rock substrate are available, other submerged structures such as boulders, logs, bridge abutments, or pier pilings should be sampled by hand picking. These structures provide suitable habitat for Scrapers and Filtering Collectors, enabling RBP II to be used for a wider range of regions and stream orders.

For RBP II, field sorting and enumeration to obtain a 100-count subsample is recommended for the riffle/run sample (Section 3.4.1.2). In the field, all organisms in the subsample are then identified by family and classified by functional feeding group using Cummins and Wilzbach (1985). Organisms in CPOM samples are classified as Shredders or Nonshredders; if there are a large number of organisms in the sample, classifying a representative subsample of 20-60 organisms is acceptable. Results are recorded on the RBP II field data sheet (Figure 4).

Data interpretation is too complex to adequately summarize here; Section 6.2.2 and supporting appendices of Plafkin et al. (1989) provide the necessary guidance. Note that data interpretation relies on the availability of data from a suitable control station on the same stream, a reference site within the same ecoregion, or a reference database applicable to the region.

2.2.5.3 RBP III. RBP III is more rigorous than RBP II and can be used for monitoring trends in community structure that might be attributable to improvement or worsening of conditions over time. A flowchart of the RBP III process is presented in Figure 5. The process is very similar to that of RBP II, except that four levels of impairment can be distinguished.

Sampling of the riffle community is done the same way as for RBP II, with the two samples from each station composited and subsampled to obtain 100 organisms. Classification of macroinvertebrates is taken to the lowest level possible, usually to genus or species, in the lab. Where differences among stations are subtle, more detailed analyses such as larger subsamples, or processing a greater number of samples, may be required to resolve differences. CPOM samples are treated the same as for RBP II, i.e., organisms are classified as Shredders or Nonshredders in the field. Field data are recorded on the RBP III Field Data Sheet (Figure 6).

As for RBP II, data analysis is too complex to attempt to summarize here. Section 6.3.3 and supporting appendices of Plafkin et al. (1989) provide the necessary guidance. As for RBP II, data interpretation relies on a suitable control station, reference site, or reference database.

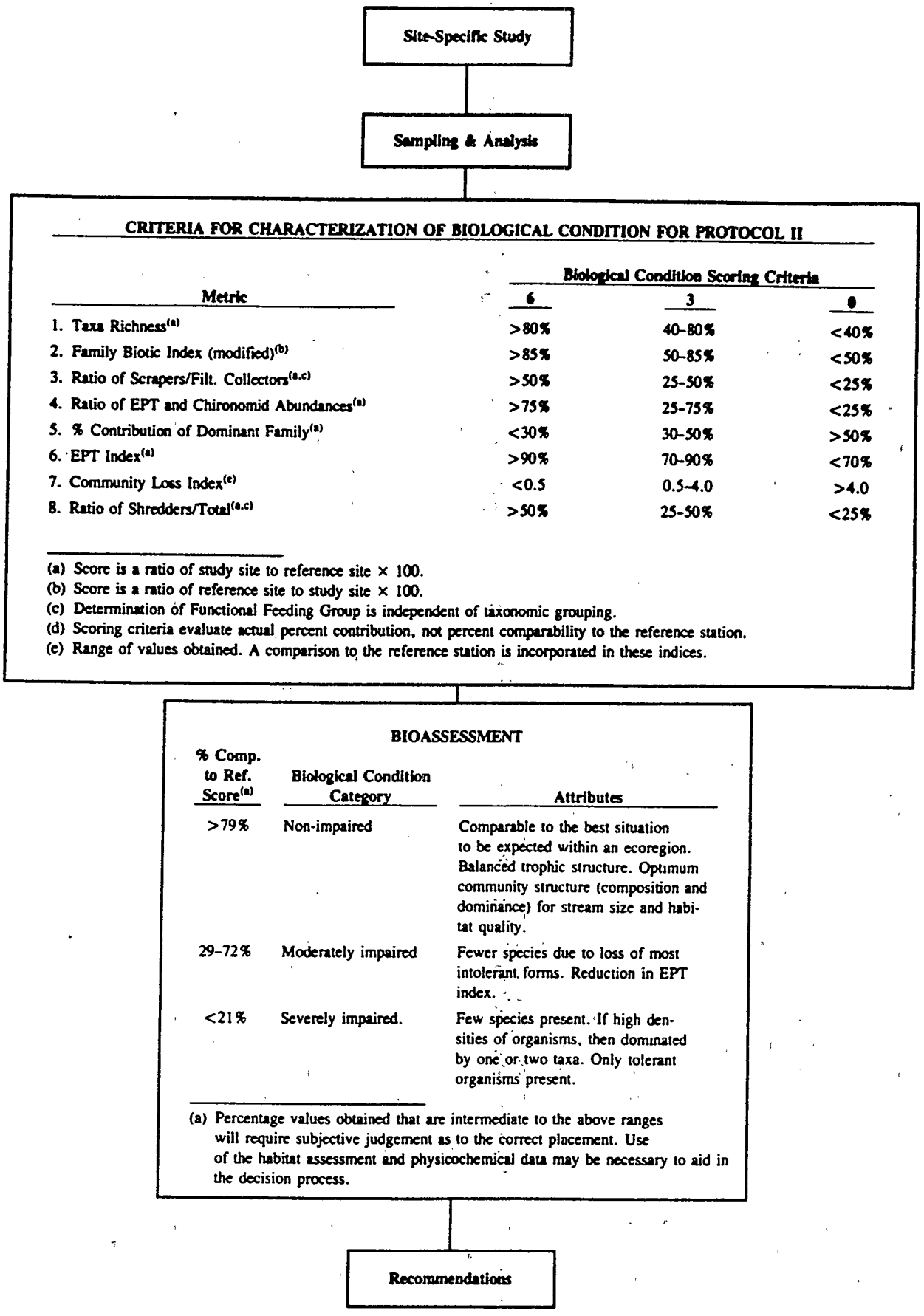


Figure 3. Flowchart of bioassessment approach advocated for Rapid Bioassessment Protocol II (Plafkin et al., 1989).

Rapid Bioassessment Protocol II

Biosurvey Field Data Sheet

RELATIVE ABUNDANCE OF AQUATIC BIOTA

Periphyton	0	1	2	3	4	Slimes	0	1	2	3	4
Filamentous Algae	0	1	2	3	4	Macroinvertebrates	0	1	2	3	4
Macrophytes	0	1	2	3	4	Fish	0	1	2	3	4

0 = Absent/Not Observed 1 = Rare 2 = Common 3 = Abundant 4 = Dominant

MACROBENTHOS QUALITATIVE SAMPLE LIST		List Families Present/Indicate Abundance
Oligochaeta		
	Anisoptera	
Gastropoda		Coleoptera
	Zygoptera	
Bivalvia		Diptera
	Plecoptera	
Ephemeroptera		
	Trichoptera	

Other

RIFFLE SAMPLE
FUNCTIONAL FEEDING GROUPS (Indicate No. of Individuals Representing Group)

Scrapers	Filtering Collectors

CPOM SAMPLE FUNCTIONAL FEEDING GROUPS (Indicate No. of Individuals Representing Group)

Shredders	Total Org. in Sample

Observations

Figure 4. Biosurvey Field Data Sheet for use with Rapid Bioassessment Protocol II (Plafkin et al., 1989).

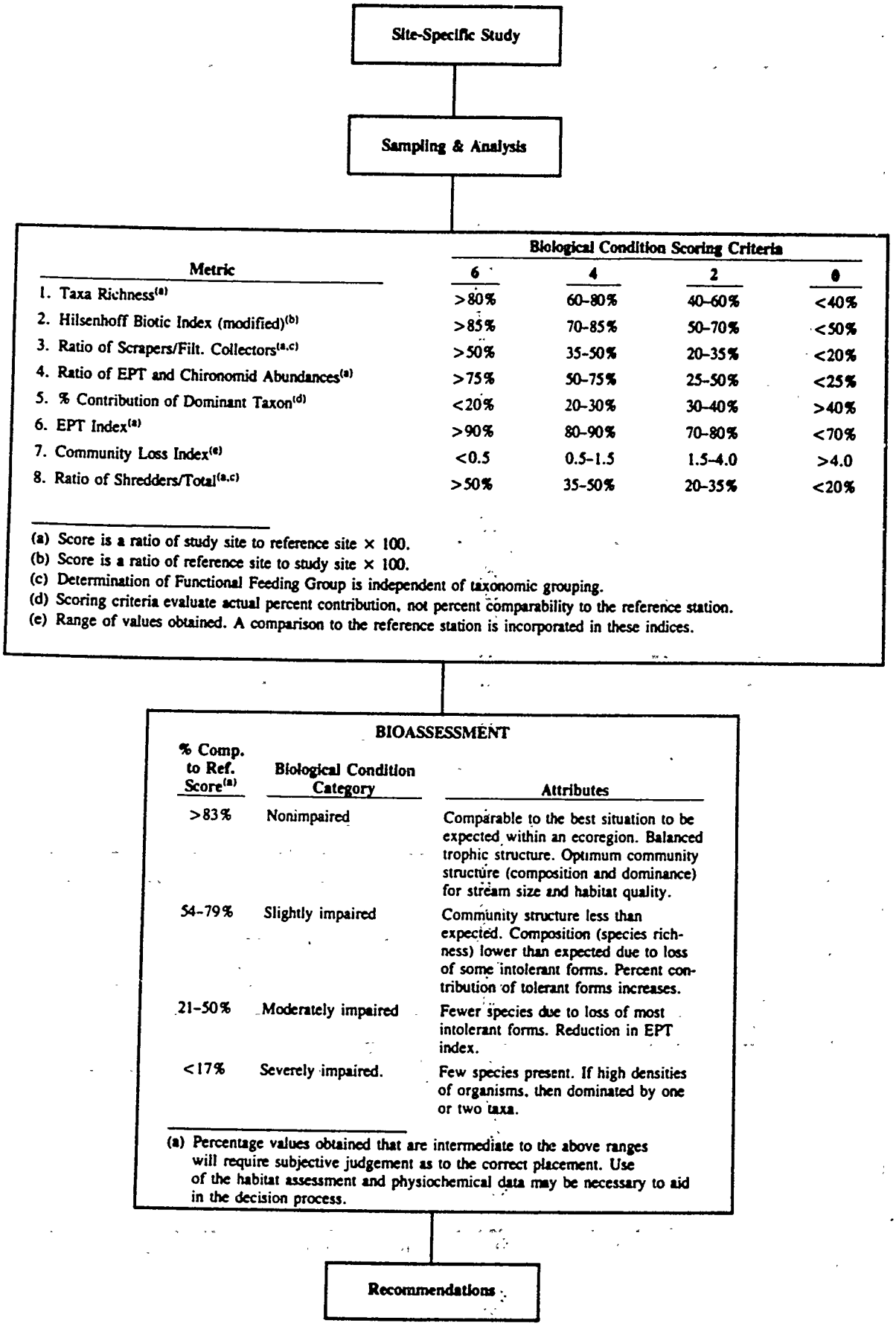


Figure 5. Flowchart of bioassessment approach advocated for Rapid Bioassessment Protocol III (Plafkin et al., 1989).

Rapid Bioassessment Protocol III

Biosurvey Field Data Sheet

RELATIVE ABUNDANCE OF AQUATIC BIOTA

Periphyton	0	1	2	3	4	Slimes	0	1	2	3	4
Filamentous Algae	0	1	2	3	4	Macroinvertebrates	0	1	2	3	4
Macrophytes	0	1	2	3	4	Fish	0	1	2	3	4

0 = Absent/Not Observed 1 = Rare 2 = Common 3 = Abundant 4 = Dominant

MACROBENTHOS QUALITATIVE SAMPLE LIST (Indicate Relative Abundance R = Rare, C = Common, A = Abundant, D = Dominant)

Porifera	Anisoptera	Chironomidae
Hydrozoa	Zygoptera	Plecoptera
Platyhelminthes	Hemiptera	Ephemeroptera
Turbellaria	Coleoptera	Trichoptera
Hirudinea	Lepidoptera	Other
Oligochaeta	Sialidae	
Isopoda	Corydalidae	
Amphipoda	Tipulidae	
Decapoda	Empididae	
Gastropoda	Simuliidae	
Bivalvia	Tabanidae	
	Culicidae	

Rare < 3 Common 3-9 Abundant > 10 Dominant > 50 (Estimate)

CPOM SAMPLE FUNCTIONAL FEEDING GROUPS (Indicate No. of Individuals Representing Group)

Shredders	Total Org. in Sample

Observations

Figure 6. Biosurvey Field Data Sheet for use with Rapid Bioassessment Protocol III (Plafkin et al., 1989).

2.3 Monitoring Selected Species

Monitoring at the species level consists of two subcomponents: (a) monitoring of selected biomonitor invertebrates for tissue contaminant levels and (b) monitoring of sensitive or bioindicator species for their presence/absence or for histopathological symptoms of contaminant stress.

2.3.1 Biomonitors

Many aquatic invertebrates bioconcentrate contaminants to levels far greater than the surrounding water. For this reason, they are useful for detecting the presence of contaminants that might otherwise go undetected in water samples alone. Examples of macroinvertebrates that have been used as biomonitors are bivalve mollusks, including the marine genera Mytilus, Ostrea, and Crassostrea and the freshwater genera Anodonta, Fusconala, and Corbicula; caddis flies (Trichoptera), mayflies (Ephemeroptera), dragonflies (Odonata), and midge larvae (Chironomus), and crustaceans such as crabs and crayfish.

Of these groups, bivalve mollusks are the preferred organism, if present. The U.S. "Mussel Watch" program uses mussels and oysters to monitor some 145 sites on the east, west, and Gulf coasts of the United States and two sites in Alaska. Farrington et al. (1987) list the following reasons that bivalves are good biomonitors in marine systems:

1. Bivalves are cosmopolitan (widely distributed geographically). This characteristic minimizes the problems inherent in comparing data for markedly different species.

2. They are sedentary through most of their life cycle and are thus better than mobile species as integrators of chemical pollution for a specific area.

3. Compared to fish and crustacea, bivalves are reasonably tolerant of many types of pollution. There are cases, however, where bivalve populations have been eliminated by certain types of pollutants.

4. They concentrate many chemicals by factors of 10^2 to 10^5 compared to seawater in their habitat. This often makes trace constituent measurements easier to accomplish in their tissues than in seawater.

5. Because the chemicals are measured in the bivalves, an assessment of biological availability of chemicals is obtained.

6. In comparison to fish and crustacea, bivalves exhibit low or undetectable activity of those enzyme systems that metabolize many xenobiotics such as aromatic hydrocarbons and PCBs. Thus, a more accurate assessment of the magnitude of xenobiotic contamination in the habitat of the bivalves can be made.

7. They have many relatively stable, local populations that are extensive enough to be sampled repeatedly, providing data on short- and long-term temporal changes in the concentrations of contaminants.

8. They survive under contaminated conditions that often severely reduce or eliminate other species. Although there are cases where bivalve populations have been eliminated by certain types of pollutants.

9. They can be successfully transplanted and maintained on subtidal moorings or on intertidal shore areas where populations normally do not grow--most often because of a lack of a suitable substrate--thereby allowing expansion of areas to be investigated.

10. Many are commercially valuable food species on a worldwide basis. Therefore, measurement of chemical contamination is of interest for public health considerations.

2.3.2 Bioindicators

Indicator species, or bioindicators, have been defined as those species that are either very sensitive to, or tolerant of environmental contaminants. Sensitivity can be expressed over a range of responses, from biochemical, physiological, or morphological, to avoidance or death (acute toxicity). Criteria for selecting indicator species are provided in Section 2.2 of the Introduction to Flora and Fauna RFMs (Appendix D).

Much of the indicator species concept has been based on organic domestic wastewater pollution studies (Sheehan et al., 1984). Components of sewage generally have a stimulatory effect on certain species by increasing food supplies and/or reducing numbers of competitors or predators. Sludgeworms and bloodworms (both Tubifex), for example, are known to favor heavy loads of organic material from sewage outfalls. Toxic chemical generally adversely affect most species to varying degrees.

Mayflies (Tephemeroptera), stoneflies (Plecoptera), and caddis flies (Trichoptera), together abbreviated EPT, are known to be sensitive to most environmental perturbations. Therefore, the absence of one or more of these groups from otherwise suitable habitat, when they exist in similar habitat in the same ecoregion, may indicate a contaminant problem. Ecoregions can be defined as regions of relative homogeneity in ecological systems or in relationships between organisms and their environment. In estuaries, it has been noted that, given sufficient salinity, the reduced growth of barnacles on buoys and wharves is indicative of the presence of toxic substances in the water (Patrick and Kiry, 1976).

Responses of given taxa to contaminants can vary regionally and according to contaminant type. Therefore, any universal tolerance classification system will have to be refined to fit a given area. The Rapid Bioassessment Protocols (Plafkin et al., 1989) use Hilsenhoff tolerance values. It is recommended that these values be used as a starting point. Consult with local and regional universities and state water quality and fish and game agencies to tailor these values to the specific study site.

For purposes of monitoring for histological responses to contamination, bivalve mollusks are recommended. Mollusks have been widely studied in this regard and exhibit various proliferative disorders related to organic and inorganic contaminants in their environment. All the advantages of using bivalves as biomonitors apply to their use as bioindicators. They are sedentary and long-lived, inhabit waters with nearly every conceivable type of contaminant, and are reasonably easy to locate and sample.

3. COLLECTION METHODS

The specific methods selected for collecting and preserving benthos samples depend on the type of habitat and the objective of the sampling/monitoring activities. With respect to contaminant monitoring, there are three possible objectives in collecting benthic macroinvertebrates:

1. To compare community indices at locations upstream and downstream of the contaminant source, or between contaminated and uncontaminated water bodies.

2. To determine the presence/absence or health of indicator organisms.

3. To measure contaminant residues in selected benthic macroinvertebrate biomonitors.

Site selection is important for all three objectives. In addition, the first and second objectives require careful attention to sampling methods and organism identification. For the third objective listed above, sample handling and preservation are of special concern to avoid cross-contamination. Sample collecting methods are not particularly critical; and since only one or two species are typically targeted, organism identification usually is not difficult.

3.1 Collection in Shallow Water

3.1.1 Collection in Streams

3.1.1.1 Collection for Rapid Bioassessment Protocols. The sampling method recommended for use with RBPs II and III is the kick-net. The kick-net is a piece of nylon window screen attached between two 1.3 m-long poles (the screen material may be doubled for extra strength) and forming a 1 m^2 area (width, i.e., from pole to pole, is the critical dimension). While the screen mesh size is larger than most netting used in collecting benthic macroinvertebrates, it is adequate for purposes of the RBPs. The net is used as follows: One person holds the net at the downstream edge of a selected 1 m^2 riffle area in contact with the bottom, stretched out perpendicular to the current, and angled with the top downstream of the bottom, while a second person kicks up the substrate in that 1 m^2 area. It may be necessary to use your hands to stir the substrate. The sample is then transferred by picking and washing to a gridded enamel pan for subsampling and sorting (Section 3.1.1.5).

It will also be necessary, when using the RBP's, to collect a separate CPOM sample to be used for enumerating the shredder functional feeding group. This is a qualitative sample, obtained by collecting several handfuls of submerged plant with half decayed parts such as leaves, needles, twigs, or bark. Greater detail on CPOM collection is provided in Section 6 of Plafkin et al. (1989). Material collected may be washed in a dip net or sieve bucket and processed similarly to portable invertebrate box sampler (PIBS) or standardized traveling kick method (STKM) samples described below.

3.1.1.2 Collection for Detailed Characterization of Community Structure. Monitoring community structure involves the sampling, identification, and counting of "representative" samples of the benthic community. Unfortunately, as is the case for sampling rocky-bottom stream substrates (EPA, 1979), it is difficult, if not impossible, to obtain unbiased estimates of benthic standing crop or

community composition. However, if one uses consistent methods that are well documented, the data among sampling locations can be compared. Of primary importance is choosing a method that yields the lowest possible replicate variability and the highest capture efficiency. This will vary with the sampling conditions and will require assessment by the investigator.

In streams, sampling riffle habitats will provide the richest benthic communities and may be the preferred habitat for this reason. Two methods have been found to provide adequate community data from riffles:

1. The box sampler (e.g., the Ellis-Rutter Portable Invertebrate Box Sampler or PIBS) (Figure 7) provides reasonable unit-area collection data where there is a relatively rich fauna (approximately 1000 animals/sample).

2. The Standardized Traveling Kick Method (STKM) (Hornig and Pollard, 1978) provides samples with low variability and generally will collect a large enough number of animals for extensive community analysis. This method is especially applicable in fauna-poor streams.

Generally, the PIBS is more useful in smaller streams, and the STKM is more useful in larger, wadable rivers. The PIBS is limited to water depths $\leq$ 30 cm, while the STKM may be used in depths up to 1-m.

A third method, the Surber sampler (Figure 8), has been used for many years in invertebrate studies. The original sampler design has been shown to have various problems, such as giving biased estimates of standing crop (Kroeger, 1972; cited in Pollard and Kinney, 1979) and low reproducibility among replicates in terms of total counts and total taxa (Pollard and Kinney, 1979). The modified Surber sampler reduces the backwash problem experienced with the original design and is, therefore, preferred over the standard Surber sampler (USDA, 1985).

For all methods, "uniform riffles" should be selected for sampling (unless one is sampling for RBP's--see guidance on site selection in Section 2.2.3.2). These are riffles determined by the investigator to have the least variability between available sampling sites in terms of substrate composition, water depth, and current velocity. When collecting replicate samples, always collect downstream samples first, as activity upstream can disturb the downstream fauna.

PIBS and Surber Sampler. The PIBS (Figure 7) and the Surber sampler (Figure 8) are operated in the same way. Place the sampler over rocky substrate in a shallow ($\leq$30 cm) riffle area, taking care not to disturb the substrate upstream of the sampler. Leave no gaps under the edges of the frame that would allow water to wash under the net. Fill gaps that may occur along the back edge of the sampler by carefully shifting rocks and gravel along the outside edge. When the sampler is in place (it may be necessary to hold it in place with one hand in a strong current), carefully turn over and lightly rub each enclosed large stone with the hands to dislodge organisms clinging to it before discarding. Scrape attached algae, insect cases, etc., from the stones into the sampler net. Stir remaining gravel and sand with the hands or a stick to a depth of 5 to 10 cm, depending on the substrate, to dislodge bottom-dwelling organisms. It may be necessary to hand-pick some mussels and snails that are not carried into the net by the current.

STKM. The following description is from Pollard and Kinney (1979). Traveling kick samples are collected with a triangular (or rectangular) dip net (Figure 9) with a mouth opening of 28

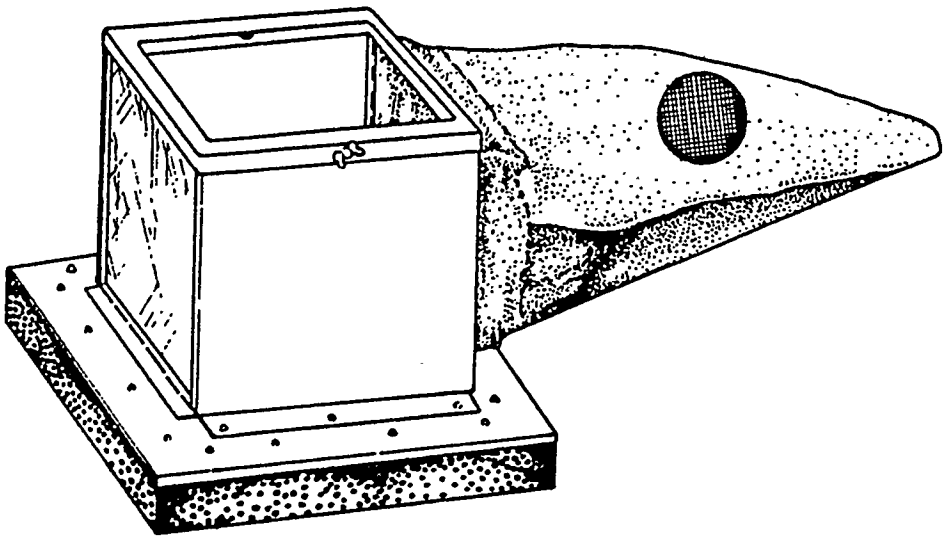


Figure 7. Portable invertebrate box sampler (Merritt and Cummings, 1978).

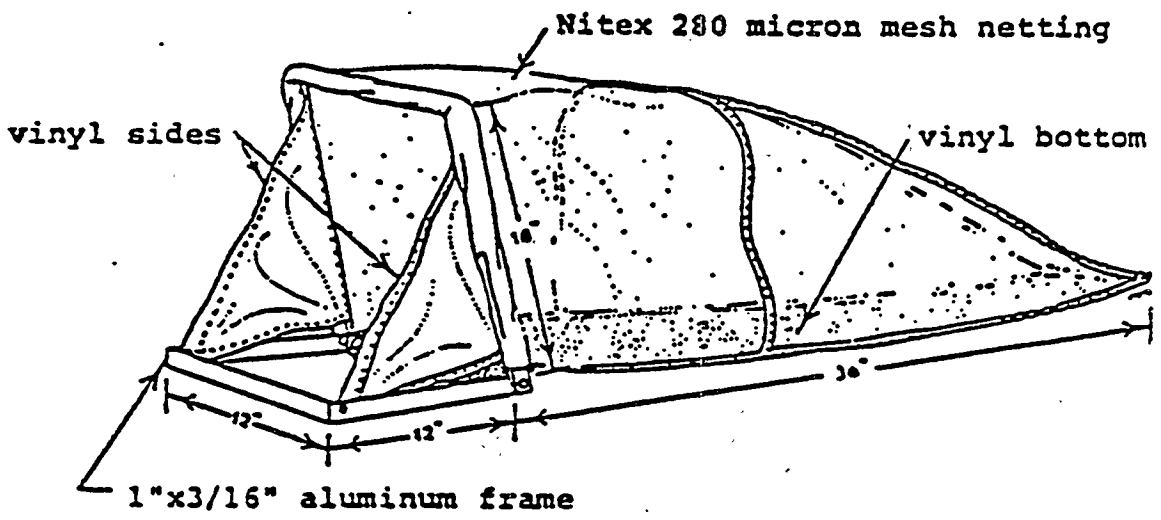


Figure 8. Modified Surber sampler (Fox et al., 1987).

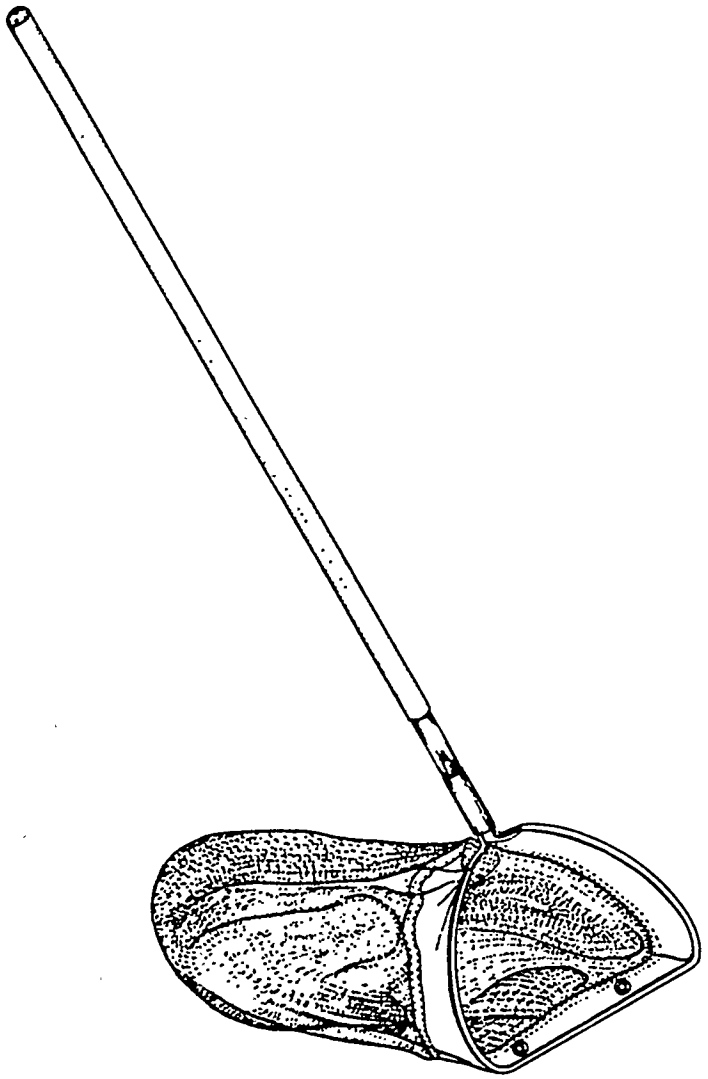


Figure 9. Dip net (Merritt and Cummings, 1978).

by 28 by 24 cm and fitted with a conical or pyramid-shaped 76-cm long nylon net with 16 strands per cm (40 mesh). Samples are collected by holding the net in front of the operator with the opening facing upstream while traveling downstream for 4 m in 30 s and vigorously kicking up the substrate in about a 0.75-m-wide swath (yielding 3 m^2 bottom area sampled). Markers set up at streamside will allow one to gauge the 4 m distance. A second investigator to time and spot the distance traveled is desirable. (Note that in fauna-rich streams the bottom area sampled should be reduced to about 1 m^2.) Note the kicking conditions in the field notes. Maintaining similar "kickability" between replicates and sample sites is important. For example, if the first two replicates are easily kicked up, but for the third replicate, one encounters embedded material that the boots just slide over, discard the material from the third replicate and start over in a more suitable location.

GENERAL EQUIPMENT LIST FOR BENTHIC MACROINVERTEBRATES

Chest waders
Aquatic kick-net (45x20 cm, 1 mm mesh)
Latex gloves
3.8-L acid washed (10% nitric acid) plastic container
20-L acid washed plastic container
Flagging (3 ft)
Microforceps (stainless steel)
Vacuum aspirator (attachments including Erlenmeyer flask, Nalgene tubing and Pasteur pipettes)
Sorting trays (40 x 30 x 8 cm)
2-oz acid washed (10% nitric acid) glass jars
Labels
Parafilm
Deionized water

3.1.1.3 ***Drift Nets.***. In some cases it might be desirable to sample drifting invertebrates, i.e., those invertebrates that migrate or are dislodged from the substrate. Using drift nets (Figure 10), thousands of organisms including larvae of stoneflies, mayflies, caddis flies, and midges and other Diptera may be collected in only a few hours (Weber, 1973). Maximum drift intensity occurs between sunset and midnight.

One obvious problem with using driftnets is that one does not know where captured invertebrates originated upstream. Thus, driftnet sampling at a single location will provide little meaningful data from a contaminant perspective. One can, however, compare drift data (e.g., species diversity, biomass, and contaminant residue) upstream and downstream of a point source (organisms cannot drift upstream), or between similar, impacted and unimpacted streams in the same region.

In small, swift streams, drift nets having a 15 x 30-cm (0.045 m^2) opening, 1.3 m bag length and No. 40 mesh are recommended (Weber, 1973).

Anchor the nets in flowing water for the desired time period (note that nets may need to be emptied frequently to avoid clogging). In large, deep rivers with lower current velocity, nets with larger openings (0.093 m^2) are recommended. In large rivers, maximum catches are achieved in the shoreline zone at depths less than 3 m with the net placed at 0.3 to 0.6 m above the bottom (Weber

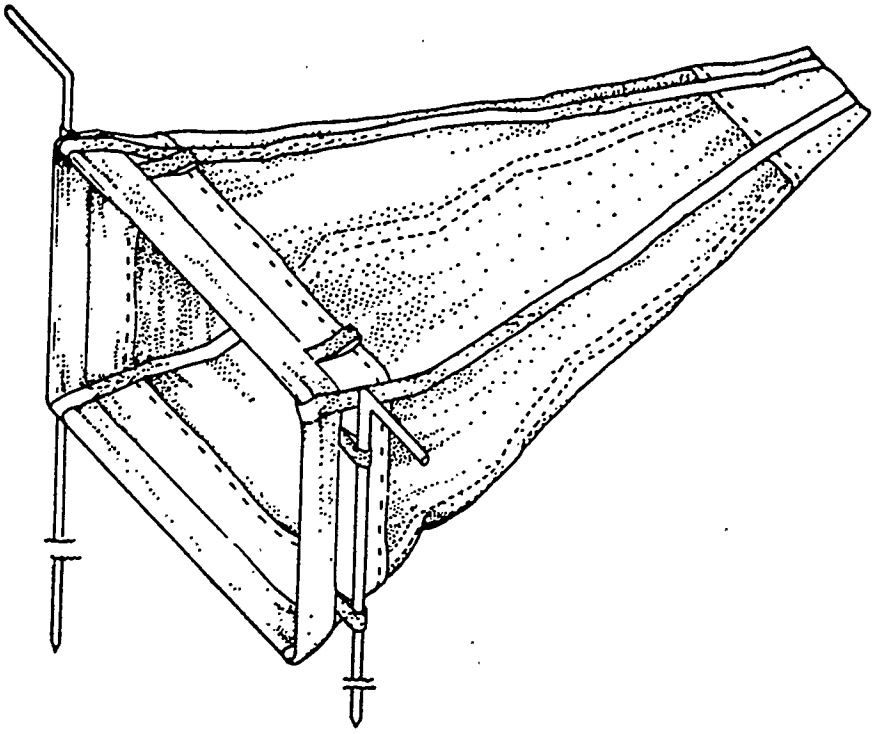


Figure 10. Drift Net Sampler (Merritt and Cummings, 1978).

1973). To lessen the chance of catching floating terrestrial insects, the top of the net should be placed below the water surface. Samples can be quantified (e.g., organisms/m^3 water) by placing a flowmeter in the mouth of the net.

3.1.1.4 ***Artificial Substrates.*** Artificial substrate samplers (Figure 11) can be used in either shallow or deep water habitats and are usually used in combination with other types of sampling. Organisms that colonize artificial substrates are primarily drift organisms such as larval aquatic insects, crustaceans, coelenterates, bryozoans, and possibly some worms and mollusks. Artificial substrates can be quite useful in contaminant investigations because they can isolate water quality effects from substrate and other micro-habitat effects (by providing a uniform substrate). Other advantages and disadvantages of artificial substrates are presented in Section 2.7.2.1 of the Rapid Bioassessment Protocols (Plafkin et al. 1989). Artificial substrates should be positioned at a depth of 0.3 m in deep waters ($\geq$1.2 m) or at middepth of low flow levels in shallow waters ($\leq$1.2 m) (APHA, 1985). Samplers can be suspended between a float and anchor or attached to steel reinforcing bar driven into the substrate. In any case, all samplers should be positioned for the same exposure to sunlight, current velocity, and habitat type. Samplers should be left in place for 6 weeks (Weber, 1973), though this is a general recommendation and time may need to be adjusted for a particular region. Note that data are only comparable among samplers left in the water for the same amount of time.

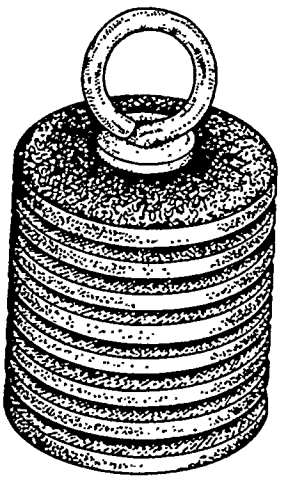
Before removing artificial substrate samplers from the water, enclose the sampler with a dip net (U.S. Standard No. 30 mesh) or plastic bags (double wrapping) to prevent loss of organisms. Once out of the water, the sampler can be disassembled and brushed in a pan of water to remove organisms. Preserve organisms as explained in Section 4.

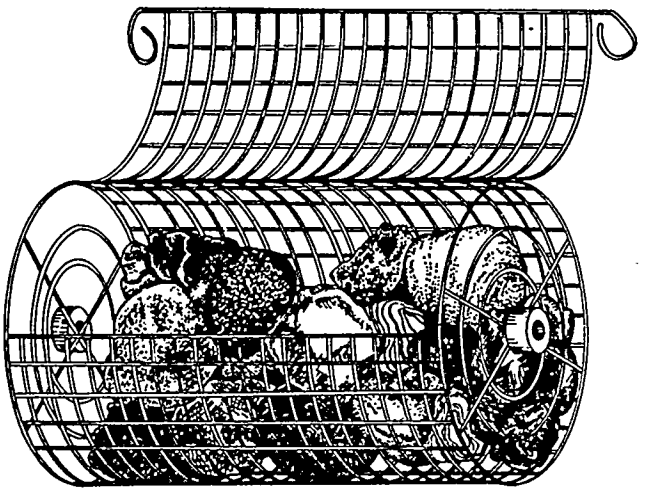
There are two types of artificial substrate samplers widely used: the Hester-Dendy multiplate (with Fullner modification) and the basket sampler (Figure 11a). The multiplate sampler is constructed of 0.3 cm (0.125 in.) tempered hardboard circles, 7.6 cm (3 in.) in diameter with 2.5 cm (1 in.) diameter spacers of the same material. There are 14 plates and 24 spacers drilled in the center and assembled as shown in Figure 11a. These are held together with a 0.63 x 15.2 cm (0.25 x 6 in.) threaded eyebolt with nuts at either end. Assembly and disassembly is facilitated by using a wingnut at the lower end. The assembled sampler exposes about 1160 cm^2 (180 $in.^2$) of surface area for attachment of organisms and weighs about 0.45 kg (1 lb). This configuration will fit into a 1-quart wide mouth canning jar. Multiplate samplers should not be reused if they have been subjected to contamination such as oils that may swab to the hardboard.

The basket sampler (Figure 11b) consists of a cylindrical "barbecue" basket, 28-cm (11-in.) long and 17.8-cm (7-in.) in diameter, filled with approximately thirty 5 cm (2 in.) diameter rocks (Figure 11b). This provides a surface area of about 2430 cm^2 (377 $in.^2$) for colonization. The complete sampler weighs about 8 kg (18 lb). If the sample contains gravel and sand (in most cases, it will), place it in a round-bottom container with water, agitate the sample, and pour off the debris and organisms into a screened bucket. Repeat until no organisms can be found in the gravel and sand.

Considerable laboratory processing time can be saved if samples are sorted from debris in the field while animals are alive and moving. This will work well if there are less than 500 animals in the sample, and the animals are fairly slow moving. It is not feasible to field sort samples with large numbers of highly mobile forms (e.g., baetid mayflies) due to the difficulty of capturing the animals. Samples with large amounts of debris (e.g., filamentous algae) are extremely difficult to field sort.

a.





b.

Figure 11. Artificial substrate samplers: (a) The Fullner-modified Hester-Dendy multiplate sampler and (b) basket sampler (Merritt and Cummings, 1978).

Samples such as these should be preserved (Section 4.1) and taken to the laboratory.

In the lab, preservatives are washed from unsorted samples by covering the sample jar with a screen of 571 μm netting (the sample jar itself can be used for this purpose--also, canning jars work well), pouring off the preservative, and rinsing the sample repeatedly with water. After removing the preservative, the sample should be transferred to a white enameled pan for sorting.

Sorting, whether in field or laboratory, is performed until no organisms are found for a 1-min continuous examination. The remaining debris is then checked by a different investigator, as part of the quality assurance procedure, until no animals are found for a 1-min continuous examination. If trained Service personnel are not available, taxonomic identification should be contracted to authorities in benthic taxonomy, such as local universities or consultants.

3.1.1.5 ***Subsampling Considerations.*** Subsampling methods and the number of subsampling repetitions, is always an issue when faced with a pan full of worms and midges. In order for benthos sampling to be cost-effective, it is unrealistic to spend an average of more than one person day per sample including sorting and counting. Often the only way to get the samples into this sort of time frame is to subsample them. The method of quartering the sample in a white enameled pan with dividers (Weber, 1973) is one method that can be used:

1. Place sample in white pan with approximately 3 cm of water. Examine all the contents of the pan and estimate the number of animals in the sample. If there are less than 500 animals sort the whole sample. If there are >500 animals, the sample can be halved, >1000 animals, the sample can be quartered. Do not subsample into less than quarters. This ensures that at least 250 animals are removed from any sample (assuming there are that many in it).

2. Disperse sample in pan until debris and organisms are evenly distributed (best visual distribution). Place a divider into the pan which quarters the pan and seals off all four quarters (use plexiglass dividers and cut to the shape of the pan with foam linings).

3. Some debris and animals will be trapped under the dividers when they are put into the pan. Be sure to distribute this material into the respective quarters as equitably as possible before the next step.

4. Select which quarter or two quarters are to be sorted. This can be accomplished by flipping a coin two times or with a random numbers table.

   For example:

   Toss 1 = heads
   = 1 or 3
   Toss 2 = tails
   = 3
   Sort 3rd quarter.

5. Remove indicated quarter from pan (a turkey baster works well) and place in another pan with an appropriate amount of water.

6. Process the portion of the sample as described above.

Figures 12, 13, and 14 are examples of field and laboratory data sheets that could be used with these methods.

The RPBs utilize a different subsampling method than presented here. See Appendix B of Plafkin et al. (1989) for a description of that methodology.

3.1.2 Collection in Standing Water

The characterization of benthic fauna in shallow standing water such as marshes, bogs, or swamps is considerably more difficult than for streams owing to the diversity of habitats. Several collection methods are generally needed to sample all taxa, including grab samples, core samples, emergence traps, kick-nets, and sweep nets. The nature of several of these methods (e.g., sweep nets and traps) precludes the quantitative description of communities. Thus, the usefulness of these methods is probably limited to describing species richness (numbers of species), collecting selected biomonitoring species, or noting the condition or presence/absence of indicator species. Grab samplers and core samplers, which sample a measurable surface area and volume of sediment, are appropriate for measuring benthic macroinvertebrates. However, the variability among such small area samples can be quite high; the sampling effort involved to reduce the variation (i.e., many samples) may be beyond the available budget and manpower.

3.1.2.1 ***Grab Samplers.*** The most commonly used grab samplers for benthic invertebrate studies are the Ponar [and petite Ponar (Figure 15a)], Peterson (Figure 15b) and Ekman dredges (Figure 15c). These and other grab samplers and their applicability and advantages/disadvantages are summarized in Table 2. Tables 1 and 4 of the Sediment Sampling RFM, Appendix I, also discuss these samplers. These samplers can be used in deep water, as they are deployed by lowering with a rope.

The Ekman and petite Ponar are the only dredges light enough for hand use from a small boat. Because of their light weight they are useful only for soft sediments. Sampling harder sediments requires heavier dredges and winches to retrieve them. Operating grab samplers is described in Section 2.1.3 of the Sediment Sampling RFM. The sample is transferred from the dredge to a calibrated pail for volume measurement, then washed through a 595 μm, U.S. Standard No. 30 (or smaller mesh, if desired) sieve for freshwater benthos, or a 1.0 mm, U.S. Standard No. 18 sieve for marine benthos. Preserve and handle samples according to their intended use (Section 4).

3.1.2.2 ***Core Samplers.*** Core samplers (Figure 16) are useful for sampling invertebrates that live deeper in the sediments, such as worms. One drawback of cores is that the surface area sampled is relatively small. Operation of coring devices is described in Section 2.1.2 of the Sediment Sampling RFM, Appendix I. Samples are processed as described above in Section 3.1.2.1.

3.1.2.3 ***Emergence Traps.*** Emergence traps, as the name implies, sample the adult stages of aquatic insects as they emerge from the water. This method is most useful in the analysis of complex communities. Collection of adult insects can facilitate identification and provide information on life cycles. There are various designs of emergence traps (Figure 17); Edmondson and Winberg (1971) lists two basic types: (a) floating boxes or tents that catch adults after they emerge from the water;

Station #_____ Date_____ Time_____	Verbal Site Location Description and Comments:	Nutrient #_____ Weather_____ Air Temperature_____ SP. Conductance_____ pH_____ H_2O Temperature_____
Water Samples		Miscellaneous Information
Flow	Phytoplankton	
Macrobenthos	Periphyton	

Figure 12. Field data sheet for use in macroinvertebrate sampling (Pollard 1981).

MACROINVERTEBRATE DATA - BENCH SHEET

1. Project: __ __
2. Area: __ __
3. Station: __ __ __ __ __ __
4. Substation: __ __ __
5.1 Month: __ __
5.2 Day: __ __
5.3 Year: __ __
6. Sampler: __ __
7. Field Biol.: __ __
8. Note: __ __
9. Replicate: __ __ of __ __

1. Lab Analysis: __ __ __ __ __ __
2. Sorter: __ __
3. Short Time: __ __ __ __
4. Counter: __ __
5. Count Time: __ __ __ __
6. Notes: __ __ __ __ __ __

Species #	Species Name	Rough Count	Whole Sample Count
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	
: : : :		: : : : :	

Total # of Taxa =

Total Count for Replicate =

Comments

Figure 13. Macroinvertebrate Data - Bench Sheet (Pollard 1981).

BIOLOGICAL SAMPLE STATUS - LABORATORY LOG

Complete Sample Identification (copy of sampling label)	Sampling Date	Date Arrived Lab	Date Sorting Complete	Date Counting Complete	Date Entered Into Computer	Notes

Figure 14. Biological sample status - Laboratory Log (Pollard 1981).

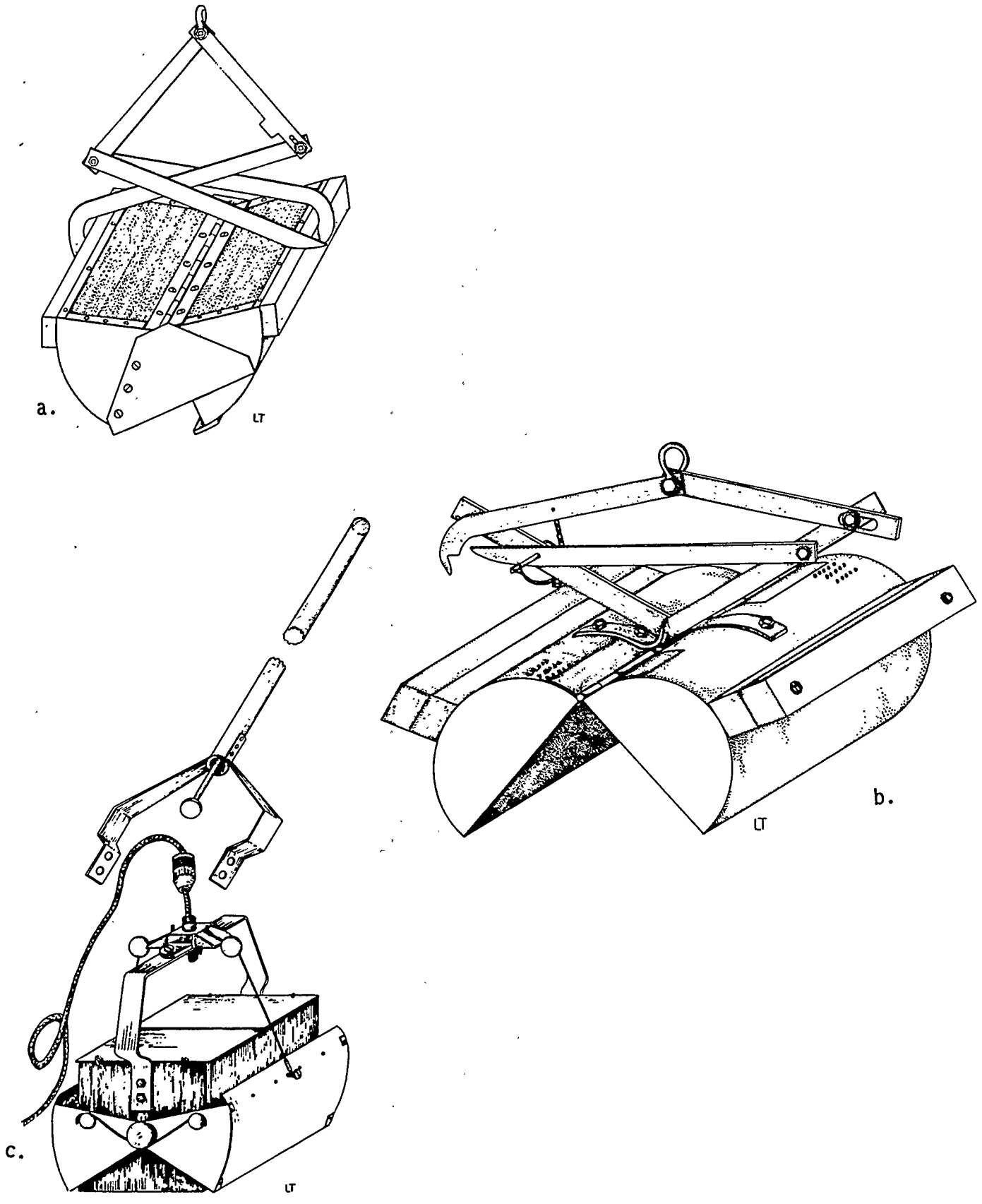


Figure 15. Grab samplers: (a) Ponar, (b) Peterson, and (c) Ekman (Merritt and Cummings, 1978)

Table 2. Relative efficacy and efficiency of selected macroinvertebrate sampling devices.

SAMPLING DEVICE	SUBSTRATE TYPE	HABITAT	EFFICIENCY	ADVANTAGES	DISADVANTAGES
Ponar	Hard and soft sediments (clay, hardpan, sand, gravel, muck)	Lakes, reservoirs, large rivers, estuaries	Not totally adequate for use in soft sediments; very efficient for hard sediments	Good penetration; little substrate disturbance	Requires boat with winch; jaws can be held open by pebbles
Petersen	Hard and soft substrates (clay, hardpan, sand, gravel, muck	lakes, reservoirs, large rivers, estuaries	Limited penetration	Substitute for Ponar; reasonable good on soft sediments without deep burrowing organisms	Requires boat with winch; disturbs substrate without modification
Ekman	Soft sediments	Freshwater lakes or large rivers with little current, reservoirs	Efficient in soft sediments	Excellent for soft sediments; good penetration	Jaws easily blocked
Orange-peel	Sandy	Deep lakes and marine waters		Useful in deep water; closes relatively well	Produces shock waves like other grabs
Smith-McIntyre	Clay, gravel, sand, mud	Estuaries, marine, and large rivers and deep water	Penetration limited	Reasonable quantitative	Heavy; need boat with winch, hazardous because of spring loading
Shipek	Clay, sand, gravel	Deep fresh waters, large rivers, estuaries	Samples relatively quantitative	Good for small samples	Heavy; need boat with winch
Modified Hester-Dendy Multiplate	Artificial	All types except wetlands; usually requires additional weight for stability	Two replicates considered adequate	Excellent for water quality monitoring purposes	Special care needed for installation on and collection, biased for aquatic insects. Hardboard construction.
Basket	Artificial	All types except wetlands; does not require additional weight for stability	Two replicates considered adequate	Excellent for water quality monitoring purposes	Materials used inside basked (usually limestone); may vary in size and texture

SOURCE: Modified from ISOM, 1978.

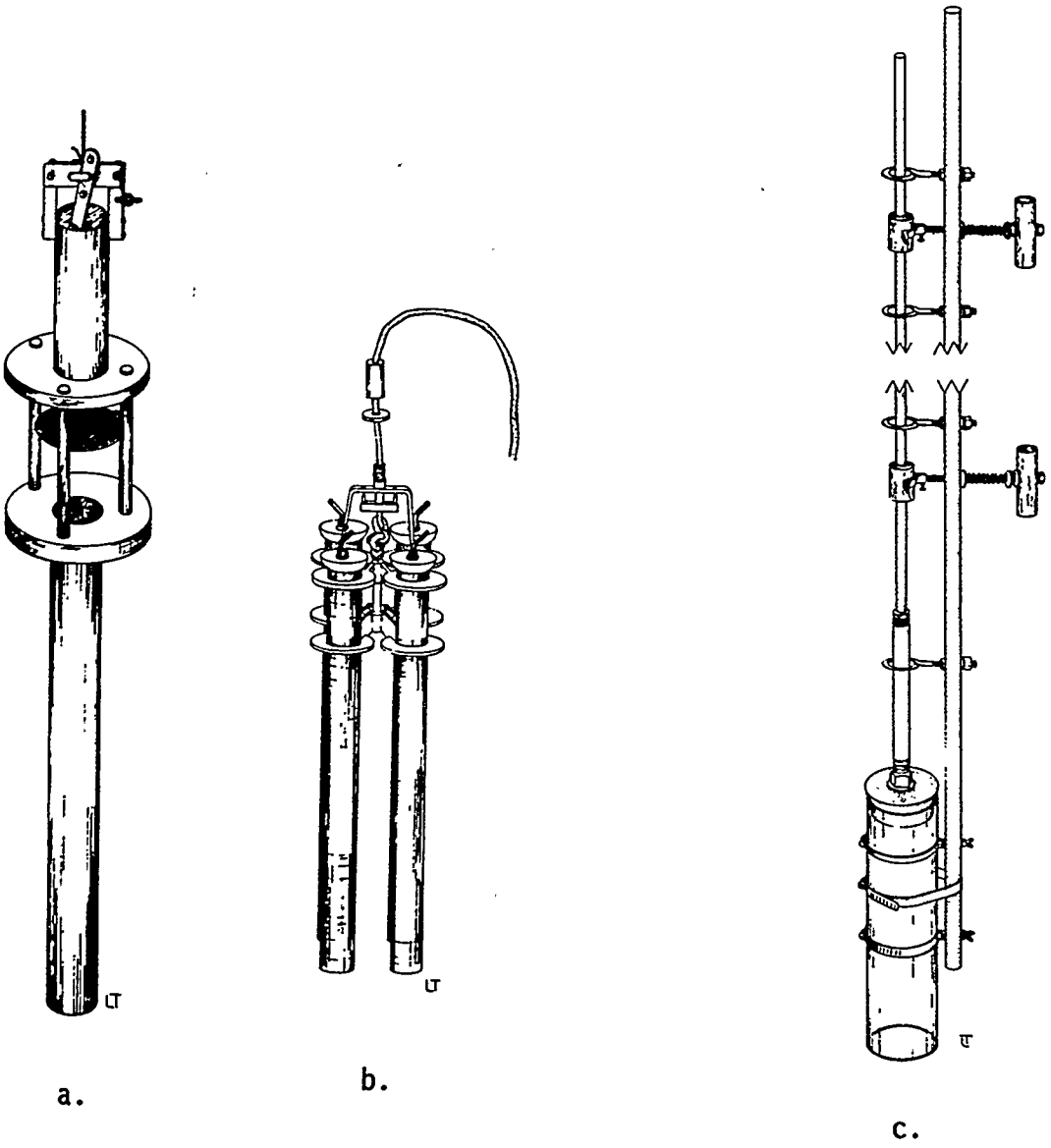


Figure 16. Core samplers: (a) Single core sampler, (b) Multiple core sampler, and (c) Core sampler with extension pole (Merritt and Cummings, 1978).

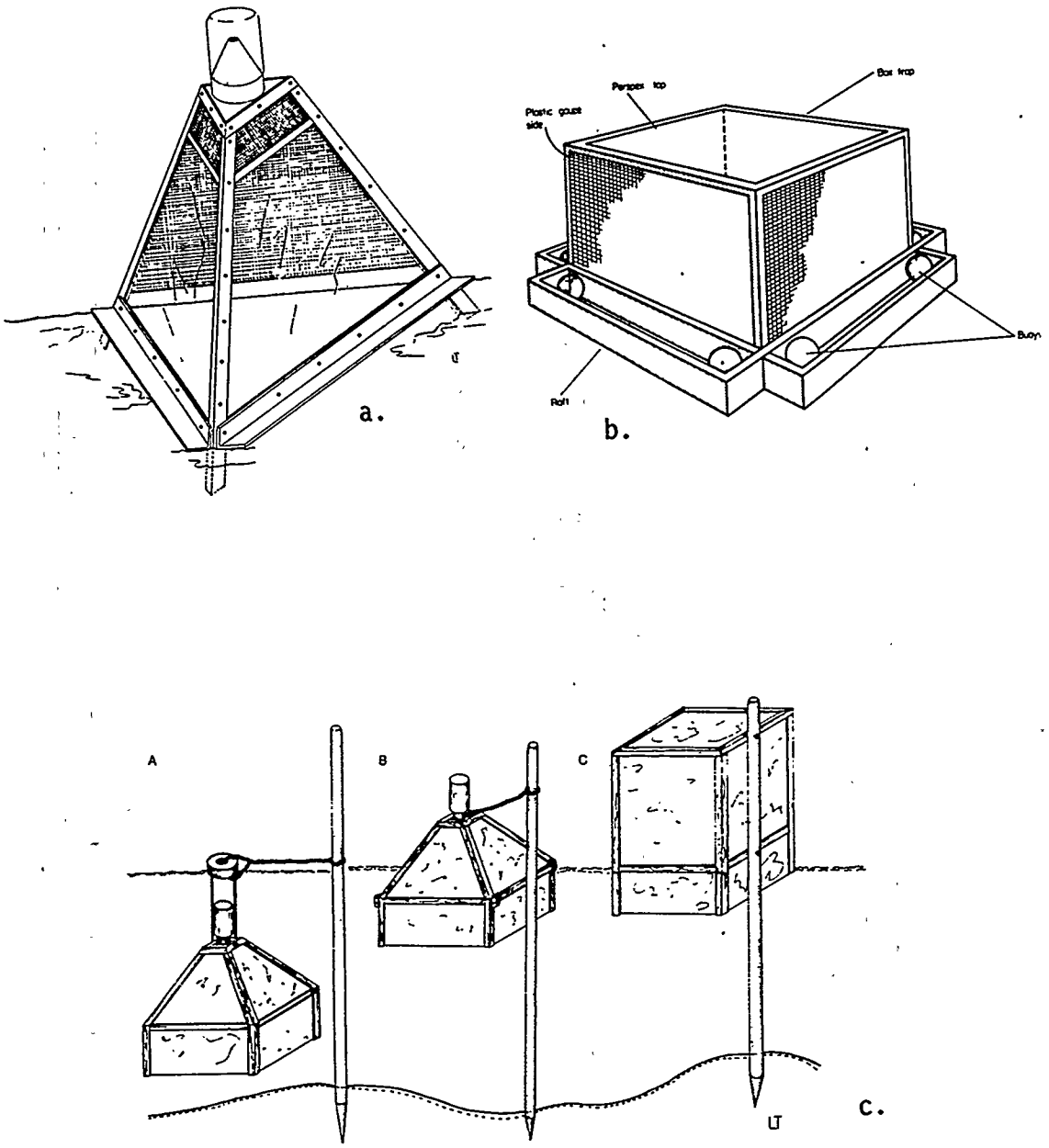


Figure 17. Emergence traps: (a) Mundie pyramid trap (submerged), (b) Floating box trap (floating), (c) Mounting options (stacked-box) (Merritt and Cummings, 1978).

and (b) partially or totally submerged funnels or pyramids (sometimes called submerged traps) which guide emerging pupae into a jar at the apex. Edmondson and Winberg (1971) provides adequate descriptions of various traps as well as their application and limitations.

3.1.2.4 Traveling Kick Method. A sampling method that works well for collecting specific organisms (such as Chironomidae larvae) for contaminant residue analysis or for benthos community characterization in wadable standing water, such as ponds, is the traveling kick method. The following description applies to the former purpose, though many steps would be the same if the purpose was to characterize the community.

1. Locate sampling area.

a. Collect sediment for benthic invertebrate removal using a rectangular aquatic kick-net. Latex gloves are worn throughout entire process to avoid contamination of samples. While standing in water, move backwards by quickly shuffling feet; this stirs up top sediment layers where benthic invertebrates occur. While moving backwards, sweep kick-net through stirred up sediments at pond bottom. Sweep for 10-15 seconds then lift net to surface.

b. Quickly examine net contents for Chironomidae larvae [because of its dominance in the benthic community and its importance as a food for wintering waterfowl in the grasslands (Connelly and Chesemore 1980)], this will be the only Family sorted from sediment. To select a site, there must be enough larvae present to ensure a 5 g sample. Normally, a single net containing 20 large larvae is a good indication of a site that can yield 5 g. Continue sampling from starting point in an outwardly spiralling pattern throughout subunit until locating the first concentration of larvae.

c. After locating such an area, flag off a small plot nearby that was not disturbed during search for larvae and which will remain undisturbed for other sampling regimes.

d. Process samples as described in Section 4.1.3.

3.2 Collection in Deeper Water

The characterization of benthic fauna in deeper (nonwadable) water is considerably more difficult than in shallow water. Collection methods are generally confined to grab samplers, core samplers, or artificial substrate samplers previously described. The applicability and advantages/ disadvantages of grab samplers and artificial substrate samplers are summarized in Table 2 and Table 3 of the Sediment Sampling RFM.

3.3 Collection of Selected Invertebrate Species

As discussed in Section 2.3.1, certain invertebrate species are useful as biomonitors. Bivalves are the preferred organism for this purpose if they are present. Some aquatic invertebrate biomonitors and methods of capture are presented in Table 3.

Table 3. Various benthic invertebrate bioconcentrators and sampling techniques.

Invertebrate	Contaminant Type Bioconcentrated	Sampling Technique	Notes
Bivalve molluscs	Metals, hydrocarbons, halogenated hydrocarbons, PAHs	Dredge (>2-3 m depth) Tongs (2-2.5 m depth) Sampling fork (≤1 m depth) Hand	Bivalves do not bioconcentrate more water-soluble chlorinated pesticides (e.g., hexachloro-cyclo-hexane, toxaphene)
Aquatic insects:			–
Caddisflies	Cd, Cu, Pb, Zn, PCBs	Aquatic net samplers (larvae, pupae); sweep net, light trap (with blue or neon light)	
Dragonflies	Cu, Pb, Zn	Aquatic net samplers, aerial net, light trap	–
Midge larvae (Chironomidae)	Phthalates, Zn	Aquatic net samplers, grab samplers	Sample mucky bottoms
Crabs, Crayfish	Halogenated hydro-carbons (PCBs, etc.)	Baited traps, trot lines (crabs)	–

Several methods for collecting benthos have been discussed previously. Numerous other methods exist for collecting selected benthic invertebrates (and the flying adult stages of some), some of which are presented here. Additional references include Edmondson and Winberg (1971), Usinger (1974), and Weber (1973). In most cases, the collector is limited only by the imagination.

3.3.1 Hand Picking, Aerial Nets, and Sweep Nets

Both freshwater and marine bivalve species can be collected by hand in shallow water or at low tide. Adult aquatic insects such as the dragonflies (Odonata) can be hand picked relatively easily from emergent vegetation in the early morning. Flying dragonflies can be captured with an aerial net by approaching from below and behind them.

Sweep nets, as the name implies, are swept through heavy vegetation (near the shoreline or emergent through vegetation) to capture attached aquatic insects.

3.3.2 Dredge, Tongs, and Sampling Fork

Oysters can be collected in deeper water using a commercial oyster dredge (Figure 18a) towed by a boat or in shallow water using oyster tongs (Figure 18b) or a sampling fork (potato fork).

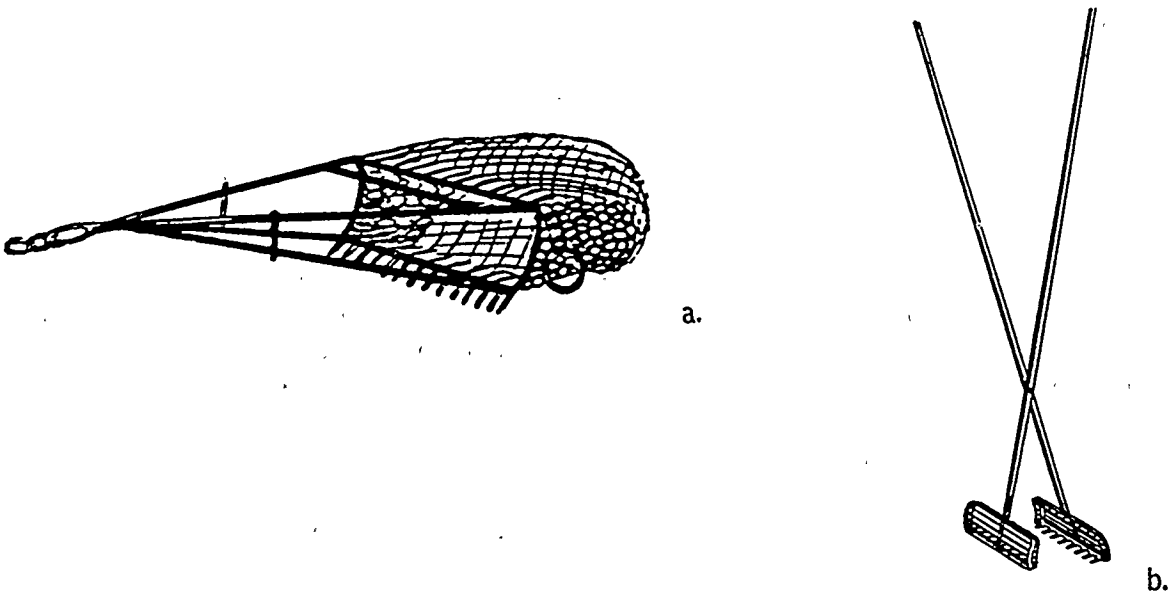


Figure 18. Oyster Dredge (a) (Stansbury, 1963); North American Shelfish Tong (b) (Von Brandt, 1972).

3.3.3 Light Traps

Light traps are useful for collecting most species of flying, adult insects. Generally, light traps consist of a light source to attract insects, and some method of capturing and/or killing the specimens. Light traps can be as simple as a Coleman lantern placed on a white sheet (though care must be taken not to contaminate the sheet or specimens with fuel if collecting for chemical analysis). More complicated traps utilize an electric light and fan, such as that described in Usinger (1974) (Figure 19). With this type of trap there may be potential for metal contamination of specimens from the electric motor.

A submersible light trap that has been useful for sampling at Kesterson is illustrated in Figure 20. This trap consists of a 4 L (1 gal) jar, a 14-cm diameter funnel, a 6 or 9 volt waterproof flashlight, some wire, PVC pipe (about 1 in.) and "T" fitting and a stake or metal fence post. This

submersible light trap was used successfully by Kesterson Wildlife Refuge personnel[1] using the following steps:

1. Nektonic invertebrates will be collected with modified light traps mounted on steel fence posts. Traps consist of 4-L clear plastic containers with 1 cm diameter funnels at open end. A 6-volt flashlight provides necessary light.

2. Before placement, rinse light traps three times each with pond water. Place two traps 3 m apart at each sampling plot. Invert and lower trap apparatus so that container is half submerged and attach to fence post with hose clamps. Both ends of funnel should have at least 3 cm of unobstructed water to ensure trap success. Turn on lights at dusk and check following morning.

3. Wear latex gloves during collection of trap contents to avoid contamination of samples. Remove trap from fence post. Hold finger over air hole at top of trap and invert. Rinse all invertebrates from funnel. Visually estimate percent composition of the various taxa (Family or Order). Record estimates. Remove funnel. Rinse brine shrimp net in water at site. Pour contents of trap into brine shrimp net in water at site. Place invertebrates into a 2-oz acid washed (10% nitric acid) glass sample jar.

4. Repeat Step 3 with other trap until sample jar is almost full (leave some space for ice expansion). Collect a minimum of 5 g of nektonic invertebrates at each sampling station.

5. Weigh sample and record weight on label and on data sheet. Label sample and seal tightly with parafilm. Freeze for storage and shipment.

EQUIPMENT LIST FOR COLLECTION USING LIGHT TRAPS

Chest waders
Light traps
  3.8-L clear plastic jug
  PVC pipe
  14-cm diameter funnel
  Flashlight
  6-volt batteries
  Attachment wires
  Hose clamps
  Metal t-fence posts
Brine shrimp net
Socket driver (size of hose clamps)
2-oz acid washed (10% nitric acid) glass jars
Latex gloves

---

[1]Paveglio, Fred, Fish and Wildlife Service, Kesterson, California, March 3, 1989, personal communication.

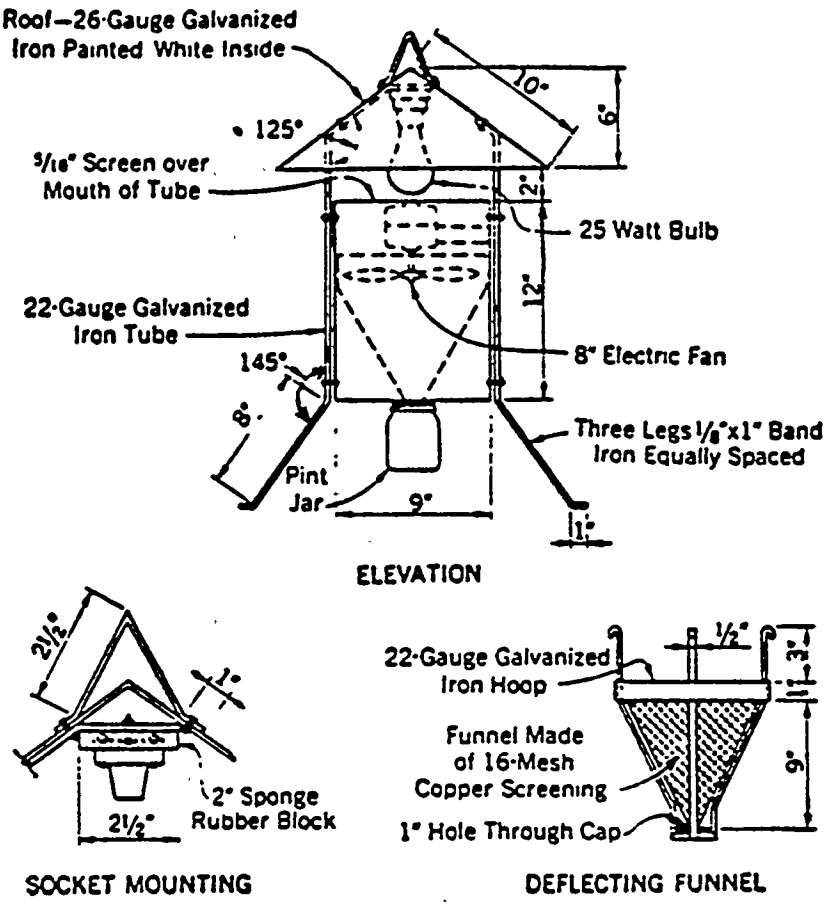


Figure 19. Structural details of the New Jersey light trap (Usinger, 1974).

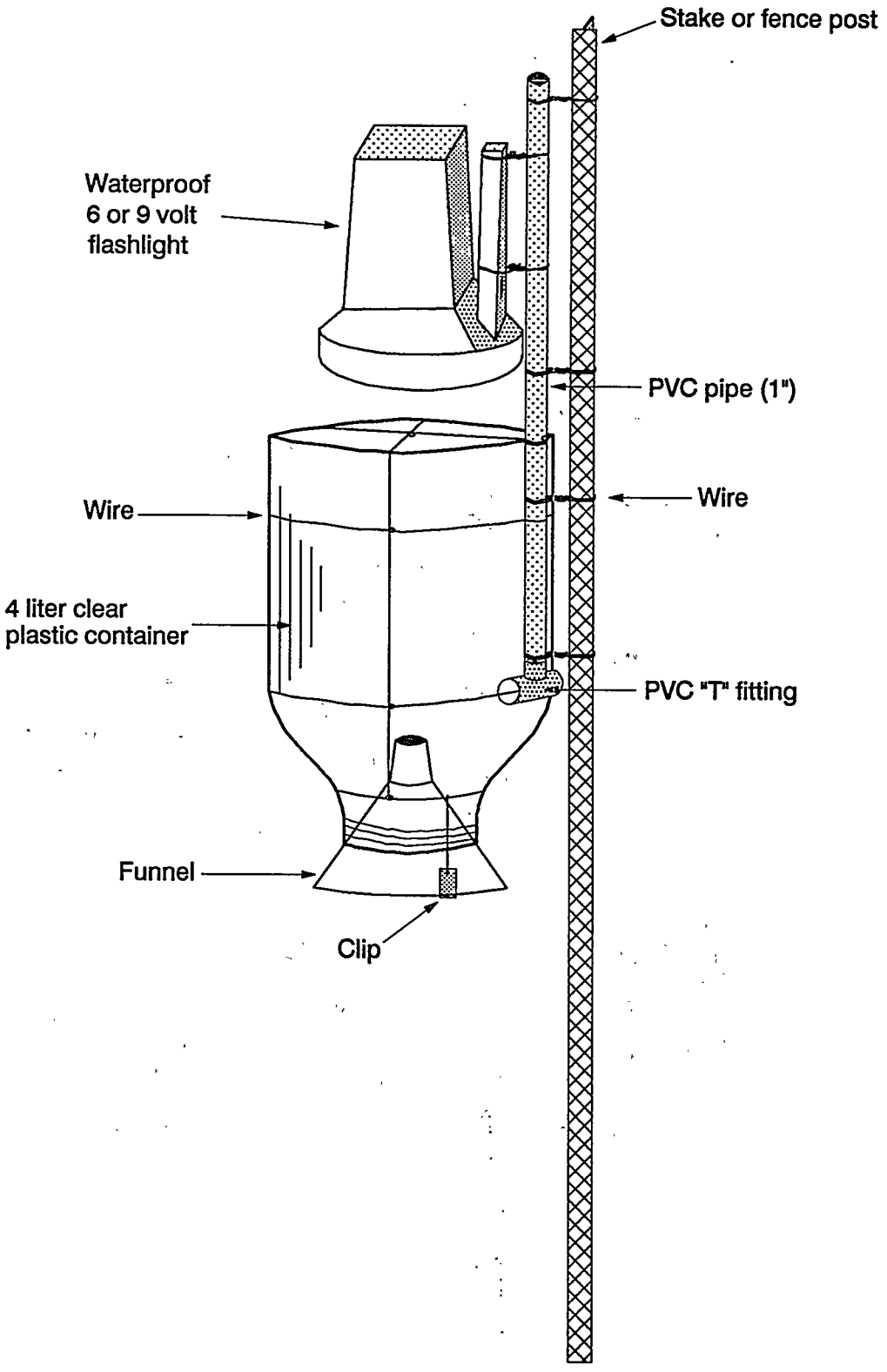


Figure 20. Partially submersible light trap.

Sorting trays (40 x 30 x 8 cm)

3.3.4 Baited Traps and Trot Lines

Crabs may be captured using baited crab pots or trot lines. Commercial crab pots consist of 1-1/2 in. mesh wire and generally capture crabs larger than 3 to 3-1/2 in. Smaller mesh will capture smaller crabs. Crayfish can be captured in baited crayfish traps. Trot lines are long lines, baited at intervals. The lines are checked frequently.

With all baited traps, care must be taken that the bait (usually fish) is not contaminated during handling, cutting, etc. For instance, fish should not be placed in the bottom of the boat, where they can come in contact with gasoline or oil. Similar precautions apply for captured specimens.

3.3.5 Incidental Capture

Larger benthic macroinvertebrates are often captured by various fish sampling devices. Trawling for bottom fish is known to capture crabs and shrimp. In fresh water, gill nets often entangle crayfish, and freshwater bivalves are sometimes brought up in seine hauls.

4. SAMPLE PROCESSING, PRESERVATION, AND HANDLING

4.1 Sample Processing

4.1.1 Sample Processing for Generalized Taxonomic/Community Characterization.

The generalized procedure for processing samples for taxonomic/community characterization purposes is illustrated in Figure 21. Processing samples for RBPs differs in some ways from procedures described here. Processing for RBPs is described in Section 4.1.2.

Samples are initially washed out of the sampler nets (use deionized water if for chemical analysis) into a bucket with a 16-strand-per-cm (40 mesh) screen (or other mesh size, as long as it is consistent with the mesh size of the sampling net) on the bottom to avoid accidental loss of organisms, and to remove fine debris. The sample is then transferred to a shallow white enamel pan. A wash bottle can be used to facilitate this process.

4.1.2 Sample Processing for RBPs II and III.

Sample processing for RBPs II and III is greatly simplified compared to the procedures described above, principally because of differences in data objectives. For both RBPs, riffle samples are transferred from the net, by washing and picking, to a gridded enamel pan and a 100-count subsample is removed. Alternately, subsampling for RBP III can be done in the lab. Subsampling of live invertebrates is greatly facilitated by narcotizing them in the pan with club soda or tobacco. The gridded pan subsampling procedure is completely described in Appendix B of Plafkin et al. (1989). For RBP II, the subsample is processed in the field with identification performed to the family level. For RBP III, the 100-count subsample is processed in the lab (alive) for identification to the lowest level possible, usually genus or species.

4.1.3 Sample Processing for Contaminant Residue Analysis.

Sample processing for contaminant residue analysis will usually involve removing from the sample a specified mass of individuals of a given species (the amount of biomass required will likely be determined by the analytical laboratory). This may be done in the field or in the lab, depending on conditions and preference. Either way, the sample should be cleaned as much as possible of detritus and sediments in the field. For samples collected from sediment, such as with a traveling kick-net or with dredges, some sort of sieving will be necessary. Standard metal sieve sets can be used if metals are not the contaminant of concern. If metals are of concern, the following method is recommended using the same dipnet used for the traveling kick method of collection:

1. Rapidly sweep partially submerged net from side to side churning sediments in net. One hand may be used to break up any large clods and also to help churn sediments (wear gloves throughout sieving process). Continue for 3-5 minutes.

2. The final step of sieving is accomplished using a panning technique. Rinse remaining sediments into a bottom corner of kick-net. Dip this corner beneath surface and use hand to "pan" floating and suspended material to opposite corner of the net. This panned material contains larvae. Use hand to work heavier sediments into sides of net then pan again.

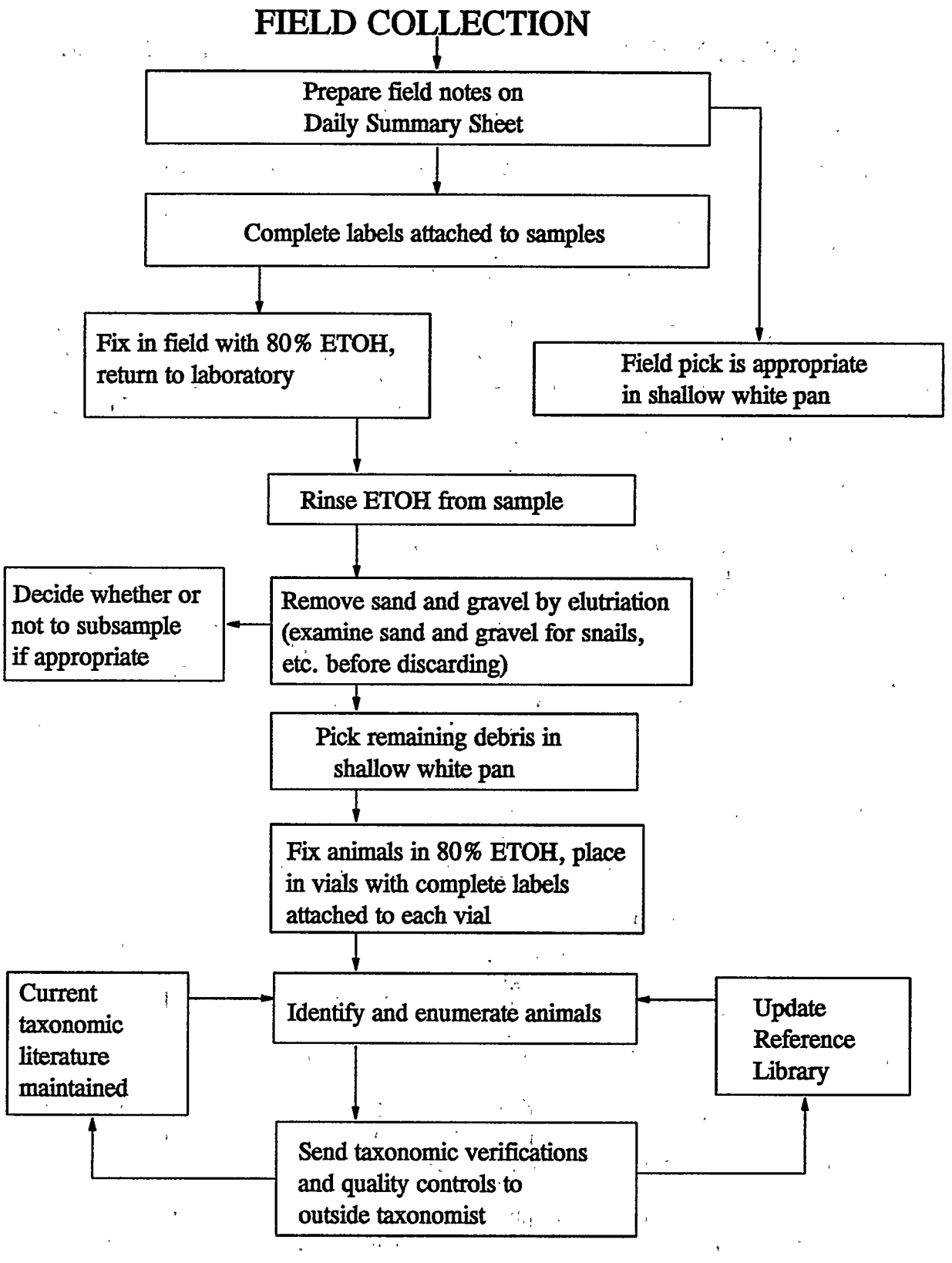


Figure 21. Flow diagram of field and laboratory processing steps for macroinvertebrate samples intended for taxonomic or community characterization studies (Pollard, 1981).

Continue process while saving panned material. Panned material is placed in an appropriate container and frozen.

On occasion, water under pressure may be needed in the field to wash samples or individuals such as bivalves. The following system (Figure 22) works well for that purpose. The system uses a 12-volt recreational vehicle water pump with an automatic pressure sensitive shut-off switch hooked up to a garden hose with a sprayer on one end[2]. Another hose, the feed line, goes from the pump to the water supply. The end has a standard garden bubbler on it surrounded by a fine mesh bag to strain the water. A trolling motor battery is used for power supply. Before using this system, check to see if cross-contamination of the sample from the equipment will occur. For most contaminants, this should not be a problem, however, the EC specialist or analytical chemists should be consulted.

4.2 Sample Preservation

Methods of preserving benthic samples will vary with the intended use of the samples. Generally, there will be three possible end uses of the samples, each with its own preservation requirements: (a) taxonomic evaluation, (b) chemical analyses, and (c) histological examination.

4.2.1 Preservation for Taxonomic Evaluation.

In the past, invertebrate samples for taxonomic evaluation and/or abundance/biomass measures were often fixed in the field with formalin Formalin has recently been listed by the EPA as a hazardous material, and as such, must be disposed of as a hazardous waste. Because of the inconvenience and expense of this special handling, it is best to avoid the use of formalin Eighty percent ethyl alcohol (ETOH) is a satisfactory alternative. If there is a large amount of organic matter in the sample, the ETOH should be changed one to two days after sample collection (drain off old and add new). As much of the original alcohol will have been absorbed by the organic matter, as well as diluted by sample moisture.

4.2.2 Preservation/Handling for Chemical Analyses.

Preservation of samples for chemical analyses is straightforward and simply involves chilling and freezing the sample as soon as possible after collection. No chemical preservatives should be used for these samples. Table 3 of the Documentation Guidance RFM, Appendix F provides information on preservation and handling of samples for chemical analysis. The following steps are written for preservation and handling of bivalve mollusks.

1. Clean specimens, if necessary, of detritus and mud by rinsing in water in which they were captured. For bivalve mollusks, a nylon or natural fiber brush works well for scrubbing.

2. Double wrap each individual in aluminum foil (if aluminum is a contaminant of concern, skip this step).

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[2]Paveglio, Fred Paveglio, Fish and Wildlife Service, Kesterson, California, March 3, 1989, personal communication.

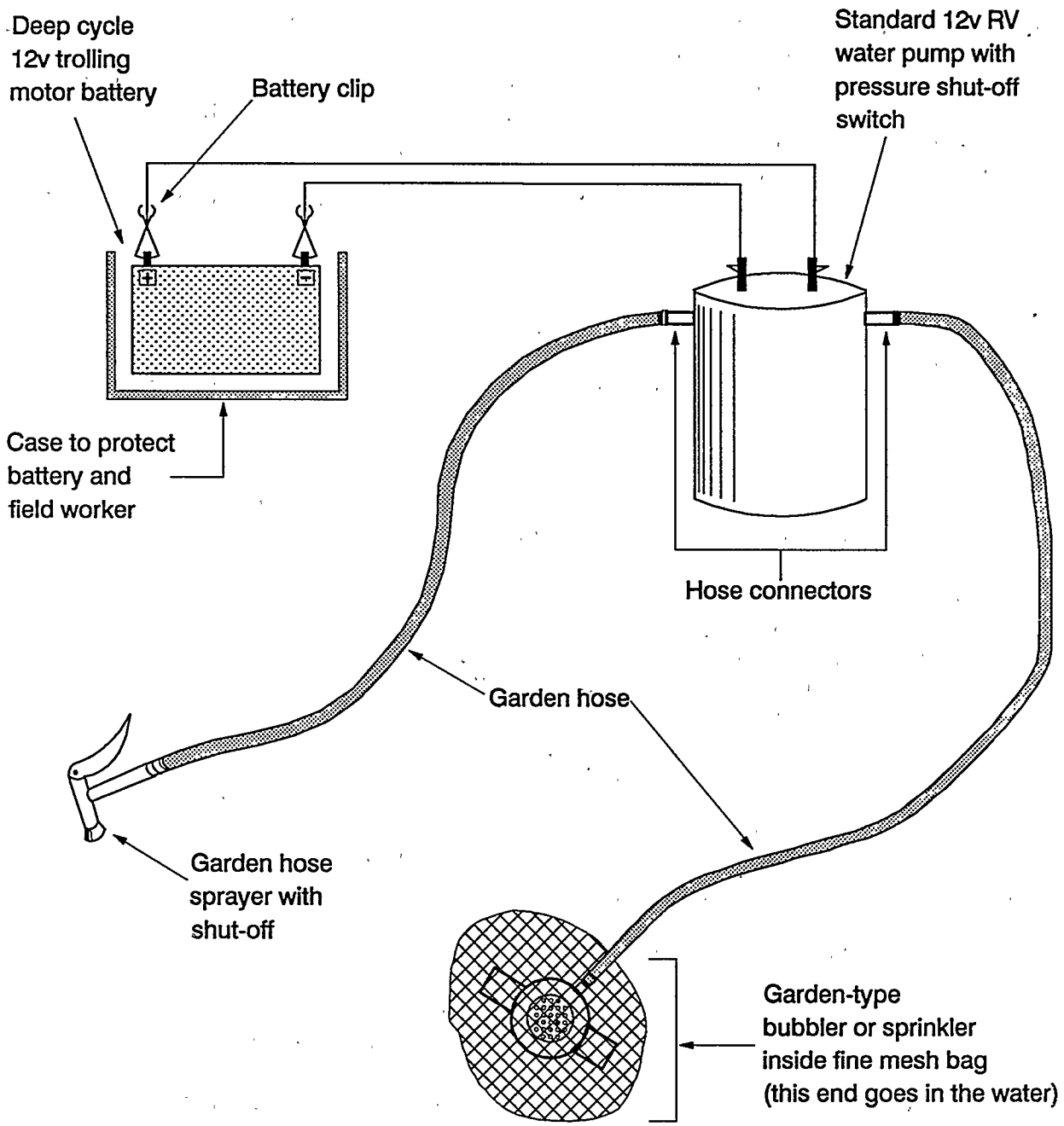

Figure 22. Battery-operated water pump for washing samples in the field.

3. Attach sample label to foil.

4. Place sample in Whirlpak or food quality plastic bag.

5. Attach sample tag to plastic bag (sample labels and tags are discussed in Section 2.6 of the Documentation Guidance SOP).

6. Place on dry ice (wet ice will suffice if dry ice is unavailable) in field; transfer to freezer upon return from field (holding times are presented Section 4 of the Documentation Guidance SOP, Appendix F).

7. Chain-of-custody (COC) is mandatory in all contaminant investigations involving litigation. Because the refuge manager may not know if or when analytical results will be used for litigation purposes, it is recommended that COC records be kept for all such samples. COC procedures are outlined in Section 2.7 of the Documentation Guidance SOP.

4.2.3 Preservation/Handling for Histological Examination

The following procedures apply to bivalve mollusks, which, if present, are the invertebrate group of choice for histopathological examination.

1. Clean specimens, if necessary, of detritus and mud by rinsing in water in which they were captured. A nylon or natural fiber brush works well for scrubbing.

2. For larger specimens or genera, such as Margaritifera, Mytilus, Crassostrea, etc., shuck (remove shell) in the field. For smaller genera, open shell. Care should be taken to avoid mutilating tissue; cutting the adductor muscle is recommended.

3. Attach sample label to individual specimens if large enough (string ties are recommended). If compositing small specimens, place sample label inside container with the composite sample.

4. Place sample in container of choice and add Deitrich's fixative in a volume at least 2x that of the tissue volume. Deitrich's solution is prepared as follows:

   2400 mL distilled water
   1200 mL 95% ETOH
   400 mL 37% Formalin
   80 mL glacial acetic acid.

   This makes slightly over 4 L of fixative.

5. Attach sample tag to outside of container (sample labels and tags are discussed in Section 2.6 of the Documentation Guidance SOP, Appendix F).

6. The COC is mandatory in all contaminant investigations involving litigation. Because the refuge manager may not know if or when histological results will be used for litigation purposes, it is recommended that COC records be kept for all such samples. COC procedures are outlined in Section 2.7 of the Documentation Guidance SOP.

7. From 2 days to 1 week following fixation in Deitrich's fixative, the solution should be changed to ETOH as follows:

   a. Pour off Deitrich's fixative to a container marked for hazardous waste disposal (because the fixative contains Formalin, an EPA-listed hazardous substance).

   b. Rinse sample several times with small volumes of tap water, pouring off rinsate to an approved hazardous waste container (the use of large volumes of water increases the volume of hazardous waste to be disposed).

   c. Refill container with 80% ETOH.

5. GLOSSARY

Benthic	Bottom-dwelling invertebrates large enough to be Macroinvertebrates seen without magnification
Benthos	The benthic macroinvertebrate community
Bioindicator	A species that is affected, either negatively or positively, by a contaminant. Negative effects can range from pathological symptoms in individuals to extirpation of the species. An example of a positive response is an increase in a population of a species, usually at the expense of other species, in an organically enriched stream section.
Biointegrity	the ability of a system to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region
Biomonitor	A species that accumulates or concentrates a contaminant in tissues to measurable levels. Ideally, the organism is not affected by the contaminant.
Diversity	a) the number of species present (species variety or richness); and b) the distribution of all individuals among these species (evenness or equitability)
Ecoregion	Regions of relative homogeneity in ecological systems or in relationships between organisms and their environment.
Ecosystem Stress	A perturbation of an ecosystem, either in terms of functional or structural attributes.
Histopathological	pertaining to diseased (pathos) tissues (histo)
Relative Abundance	Abundance in relation to sampling effort or, alternately, abundance of one species relative to abundance of all species in a sample
Substratum	The base or material on which an organism lives

6. REFERENCES

APHA (American Public Health Association), 1985. Standard Methods for the Examination of Water and Wastewater, 16th edition.

Bender, M. E., P. O. deFur, and R. J. Huggett, 1986. "Polynuclear Aromatic Hydrocarbon Monitoring in Estuaries Utilizing: Oysters, Brackish Water Clams, and Sediments," Oceans 86, 3, Proceedings Monitoring Strategies Symposium, Marine Technology Society, Washington, D.C., 1986, pp. 791-796.

Edmondson W. T. and G. G. Winberg (eds.), 1971. A Manual on Methods for the Assessment of Secondary Productivity in Fresh Waters, IBP (International Biological Program) Handbook No. 17, Oxford: Blackwell Scientific Publications.

EPA, Environmental Protection Agency, 1979. Assessment of Macroinvertebrate Monitoring Techniques in an Energy Development Area, A Test of the Efficiency of Three Macrobenthic Sampling Methods in the White River, EPA-600/7-79-163, U.S. Environmental Protection Agency, Las Vegas, Nevada.

Farrington, J. W. et al., 1987. "'Mussel Watch', Measurements of Chemical Pollutants in Bivalves as One Indicator of Coastal Environmental Quality," New Approaches to Monitoring Aquatic Ecosystems, ASTM STP 940, T. P. Boyle (ed.), America Society for Testing and Materials, Philadelphia, Pennsylvania.

Fox, D. G., J. C. Bernabo, and B. Hood, 1987. Guidelines for Measuring the Physical, Chemical, and Biological Condition of Wilderness Ecosystems, USDA Forest Service General Technical Report RM-146.

Greeson, P. E. et al. (eds.), 1977. Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples: Techniques of Water-Resources Investigations, Washington, DC: U.S. Department of the Interior, Geological Survey.

Hornig, C. E. and J. E. Pollard, 1978. Macroinvertebrate Sampling Techniques for Streams in Semi-Arid Regions, Comparison of the Surber Method and a Unit-Effort Traveling Kick Method, U.S. EPA, Las Vegas, Nevada.

Hynes, H. B. N., 1970. The Ecology of Running Waters, University of Toronto Press, Toronto, Ontario, Canada.

Isom, B. G., "Benthic Macroinvertebrates," W. T. Mason, Jr. (ed.), 1978. Methods for the Assessment and Prediction of Mineral Mining Impacts on Aquatic Communities: A Review and Analysis, FWS/OBS-79-30, U.S. Fish and Wildlife Service.

Needham, P. R. and R. L. Usinger, 1956. "Variability in the Macrofauna of a Single Riffle in Prosser Creek, California, as indicated by the Surber Sampler," Hilgardia, 24, pp. 383-409.

Omernik, J. M. and A. L. Gallant, 1986. Ecoregions of the Pacific Northwest, EPA-600/3-86/033, U.S. EPA, Corvallis, Oregon.

Paparo, A. A. and R. E. Sparks, 1977. Rapid Assessment of Water Quality Using the Fingernail Clam, Musculium Transversum, Biological Monitoring of Water and Effluent Quality, ASTM STP 607, J. Cairns, Jr., K. L. Dickson, and G. F. Westlake (eds.), American Society for Testing and Materials, Philadelphia.

Patrick, R. and P. R. Kiry, 1976. "Estuarine Surveys, Biomonitoring and Bioassays" Contributions from the Department of Limnology, Academy of Natural Sciences of Philadelphia, No. 6.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes, 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish, EPA/444/4-89-001, Environmental Protection Agency, Washington, D.C.

Pollard, J. E., 1981. Appendices, Field and Laboratory Manual for Collection and Analysis of Aquatic Biological Samples, UNLV/EMSL-LV, Cooperative Agreement No. CR 808529, EPA, Las Vegas, Nevada.

Pollard, J. E. and W. L. Kinney, 1978. Assessment of Macroinvertebrate Monitoring Techniques in an Energy Development Area, A Test of the Efficiency of Three Macrobenthic Sampling Methods in the White River, EPA-600/7-79-163, USEPA, Las Vegas, Nevada.

Sheehan, P. J. (eds.), 1984. "Effects of Pollutants at the Ecosystem Level," Scope 22, John Wiley and Sons, New York, New York.

Usinger, R. L.,1974. Aquatic Insects of California University of California Press, Berkeley, California.

Weber, C. I., 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents, EPA-670/4-73-001, Environmental Protection Agency, Cincinnati, Ohio.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D.2 BIRD SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix D.2 of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   D.2 Bird Sampling Reference Field Methods
   D.3 Fish Sampling Reference Field Methods
   D.4 Flora Sampling Reference Field Methods
   D.5 Reptiles and Amphibians Sampling Reference Field Methods
   D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

U.S. Fish and Wildlife Service
Division of Environmental Contaminants
4401 North Fairfax Drive, Room 330
Arlington, VA 22201

Commentor's Name_____ Phone_____

Address_____City_____State___Zip_____

Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

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ACRONYMS

BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
DOE	Department of Energy
EC	Environmental Contaminant
EPA	Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FWS	Fish and Wildlife Service
QA	Quality Assurance
QC	Quality Control
QAPjP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFM	Reference Field Methods
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act
TOC	Total Organic Carbon
TSCA	Toxic Substances Control Act
USDA	United States Department of Agriculture
USGS	United States Geological Survey

U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D.2

BIRD SAMPLING REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of these Reference Field Methods (RFM) is to provide field personnel of the U.S. Fish and Wildlife Service (FWS) with guidance in the collection, handling, and preservation of bird samples. This RFM is not intended to be an exhaustive presentation of all available field sampling methodologies.

1.2 Scope

The first section of this document and Table 1 serve as an introduction to bird collection methods. Section 2 contains presampling considerations such as Federal and state regulations, and the behavioral, morphological, and toxicological effects induced by various contaminants. Section 3 describes some of the trapping techniques used to collect birds, and details the procedures for the design, construction, and use of the traps. Section 4 outlines the procedures for the proper handling, preservation, dissection, and shipment of bird samples.

The document includes information such as how to collect, prepare, and submit wildlife specimens for postmortem examination; the common names of each disease, what caused the disease, relative susceptibility of various animals, where the disease is most common as well as general occurrence; when the disease is most likely to occur, how to recognize the disease, what to look for when examining the carcasses; what specimens to collect and how to preserve them for examination by diagnostic laboratories; what can be done to combat each disease; and hazards to man associated with handling diseased animals. Additionally, the document's appendices include sources of supplies used in collecting, preserving, and shipping specimens.

1.3 Background

Birds can provide useful information when testing for contaminants. Longer lived birds are valuable for assessing the long-term accumulation of contaminants. Lead poisoning has affected every major species of waterfowl in North America and has been documented in most other species of birds. Lead toxicity whether from lead shot, fishing sinkers, or other lead objects is intensified by the consumption of corn or other cereal grains and accumulates in soft tissues, such as liver, kidneys, and gizzards (Friend, 1987).

Oil toxicosis has become more widespread due to both natural oil seeps and human caused oil spills. Petroleum products cause hypothermia in birds because of damage to the feather waterproofing and insulating properties. Oil ingested, inhaled, or absorbed accumulates in the trachea, lungs, digestive tract, and around the vent.

1.4 Information Resources

Agencies that can provide additional information and assistance exist at the Federal, regional, state, and local level.

National Agencies:

- FWS National Wildlife Health Center
- National Forest Service
- Bureau of Land Management
- National Park Service
- U.S. Department of Agriculture, Veterinary Services Laboratory, Ames, Iowa

Regional Agencies:

- Southeastern Cooperative Wildlife Disease Study, University of Georgia-Athens
- Northeastern Center for Wildlife Disease, University of Connecticut-Storrs
- Colorado Wild Animal Disease Center, Colorado State University-Fort Collins

State Agencies:

- Wildlife Disease Programs

-Fairbanks, Alaska	-Fargo, North Dakota
-Sacramento, California	-Madison, Wisconsin
-Fort Collins, Colorado	-Laramie, Wyoming
-Rose Lake, Michigan	-Hampton, New Jersey

- State Departments of Agriculture

Local Agencies and Resources:

- Local University Programs
- Private Sector (Consultants, Veterinarians)
- Local hunters and trappers

The following is an excellent illustrated guide to bird sampling techniques, handling procedures, and control of avian diseases:

> Field Guide to Wildlife Diseases, Resource Publication 167, (Friend, Laitman, Kampen, 1987), published by the U.S. Department of the Interior and Fish and Wildlife Service.

For preservation and shipping requirements for particular samples, the Patuxent analytical lab should be consulted. The National Wildlife Health Research Center should be consulted if infectious disease is a potential hazard to human health and safety.

Table 1. Key to bird sampling methods

SAMPLING PROCEDURES	LOCATION IN RFM	GENERAL COMMENTS
Drop Trap	3.2.1	- Simple construction and easy to use - Useful for smaller birds - Low efficiency
Funnel Trap	3.2.2	- Easily constructed, transported, set-up, and dismantled
Sparrow Trap	3.2.3	- Effective for many seed-eating species - Low selectivity
SETH Low Cloverleaf Trap	3.2.4	- Most effective of the baited walk-in cloverleaf traps - Easily transported, set-up, and dismantled
Australian Crow Trap	3.2.5	- Effective for baited birds - Requires constant attendance
Cannon Net or Rocket Trap	3.2.6	- High selectivity and efficiency. Useful for gregarious feeders - Potentially hazardous and requires training (See FWS transmittal sheets - 24 AM 5) - Relatively expensive and labor intensive
Padded leg-hold or Lockhart trap	3.2.7	- Effective for capturing raptors - May cause leg injury to bird
Bal-Chatri trap	3.2.8	- Effective for capturing raptors - Adaptable to various habitats - Requires frequent attendance
Bow Net Trap	3.2.9	- Easily transported, set-up, and dismantled - Can be triggered automatically or manually
Mist Nets	3.3.1	- Useful for birds which do not take bait or with predictable flight patterns - Requires constant attention
Spotlighting	3.4.1	- Useful for ground-nesting birds and for waterbirds - High selectivity
Net-Firing Gun	3.4.2	- High selectivity - Useful in variety of habitats - Requires training
Drive Trap	3.4.3	- Useful for birds that can be herded - Moderate efficiency
Simple Noose Carpet	3.4.4	- Easily constructed, transported, set-up, and dismantled
Pit Trap	3.4.5	- High selectivity, useful for capturing raptors - Extensive construction - Potential injuries to handler and bird
Shooting	3.4.6	- High selectivity - Possible cross-contamination due to specimen damage

To contact the National Wildlife Health Center, telephone,
(608) 271-4640

To contact the National Wildlife Health Center Resource Team, telephone,
(608) 264-5422 or (608) 271-4640

Address: National Wildlife Health Center
6006 Schroeder Road
Madison, Wisconsin 53711

2. PRESAMPLING CONSIDERATIONS

2.1 Permits

Field personnel should have a full knowledge of both Federal and state regulations that apply to species collection. Certain techniques may require special permits or may be prohibited. With few exceptions, scientific collecting requires a federal permit. Field personnel planning to work with raptors, threatened and endangered species, and migratory waterfowl, should anticipate the requirements of Federal and state permits. When working with other species or when uncertain about the law, contact the FWS Division of Law Enforcement Special Agent in Charge (SAC) for the FWS Region in which the sampling will occur (see Attachment 1).

2.2 Morphological and/or Behavioral Changes

The observation of behavioral change or structural malformation can help identify possible contaminants. However, the correlation between exposure to contaminants and behavioral, morphological, and toxicological effects on many bird species are relatively unknown.

Exposure to contaminants may induce behavioral changes:

- Weakened condition and abnormal coordination
- Birds breaking their own eggs
- Birds dropping their live young from the nest
- Cannibalism at nest sites
- Failure to breed
- Abandonment of eggs and young

Malformations attributed to contaminants have been reported in gulls, terns, heron, cormorants, coots, ducks and other waterfowl, grebes, stilts, passerines, and birds of prey.

Exposure to contaminants may induce morphological abnormalities:

- Embryo deformities and mortality
- Weight loss in adult birds
- Reduced weight gain in hatchlings
- Malformation of eyes, beaks, legs, and/or wings
- Egg shell thinning
- Loss of plumage luster
- Skeletal deformity

Laboratory studies have shown that contaminants responsible for malformations include pesticides, heavy metals, selenium, organochlorines, industrial solvents, petroleum hydrocarbons, complex effluents, air pollutants, acids and bases, and various drugs.

Contaminant effects will vary depending upon:

- Species of bird
- Type of contaminant
- Species ability to detoxify the contaminant
- Degree of exposure
- Amount of contaminant absorbed or ingested
- Sex and age of the bird
- Stressful environmental conditions
- Presence/absence of synergistic, protective or additive contaminants

Histopathological changes induced by various contaminants include:

- Pulmonary diseases, e.g., malfunctions or deformity
- Renal tubular nephrosis
- Enteritis
- Ulceration of intestinal mucosa
- Death by dehydration, hypothermia
- Alteration of enzymes or enzyme activity (blood samples)
- Reproductive failure

Research referenced in Injury to Fish and Wildlife Species (DOI, 1987a, CERCLA 301 Project) identifies contaminants responsible for behavioral, morphological, and/or toxicological changes listed above.

2.3 General Field Precautions

As always, the safety of sampling personnel is the primary consideration when collecting samples. Birds exposed to environmental contaminants may develop weakened immune systems and be more susceptible to disease. These avian diseases can be transmissible to humans through live or dead birds. Personnel should wear rubber or plastic gloves, coverall, rubber boots, and breathing mask (surgical mask). The Field Guide to Wildlife Diseases (DOI, 1987a) details the procedures and precautions that should be completed before leaving a diseased site; i.e., double-bag gloves and coveralls, disinfect boots and the outside of plastic bags with a commercial disinfectant or chlorine bleach, and disinfect motor vehicles (especially wheel-wells and underside). These procedures help protect the collector and minimize the transmission of disease to unaffected wildlife populations. Attachment 2 of this RFM outlines procedures for disease control operations, equipment, and supplies used in disease control operations and station disease contingency plans.

3. COLLECTION TECHNIQUES

Field sampling personnel must be familiar with the bird population (resident and transient) of the refuge and carefully consider collection methods for the species to be sampled.

There will be occasions when trapping and/or netting techniques will best meet the needs of the sampling program. The information provided in Section 3.1 from "North American Bird Banding Techniques" (Keyes and Grue, 1982) provides useful information on traps and is presented here for the convenience of field personnel.

3.1 Hints On Traps

The ability of field personnel to innovate, improvise, and develop traps will contribute greatly to the efficiency of the sampling program. The traps mentioned and illustrated can be modified in many ways. Anyone with moderate skills in the use of hand-tools can develop a satisfactory trap from the suggested information and specifications that follow.

Construction Materials and Tools

Wire-mesh:

- Hardware cloth (approximately 0.5 and 1.25 cm mesh)-- soft-tempered, galvanized wire of approximately 18-gauge. This wire is easily shaped, but when used for larger traps, it must be reinforced at the corners and openings with 8- or 10-gauge galvanized wire.

- Welded mesh (approximately 1.25 cm)-- hard-tempered, galvanized wire approximately 18-gauge. The wires are parallel in both directions and spot-welded at each point of contact. This wire-mesh is best shaped over a straight edge using a wooden or rawhide mallet.

- Welded mesh (approximately 1.25 x 2.5 cm)-- hard-tempered, galvanized wire of approximately 16-gauge. The wires are spot-welded and parallel in both directions. This mesh is also shaped over a straight edge.

- Welded mesh (approximately 1.25 x 5 cm)-- this has the same general characteristics as the 1.25 x 2.5 cm welded mesh, but when used with the 5 cm mesh in vertical dimension may reduce damage to bills.

- All welded wire-meshes usually require additional rust-proofing after years of use. A penetrating, fish-oil-based paint provides the best rust-proof protection.

- Novices should use soft woven hardware cloth with appropriate mesh in their first efforts at trap construction. This material shapes easily and the corners can be secured by soldering, lacing with soft copper wire, or bending raw ends of the mesh to form a clip at the seam. The experienced trapper should then shift to welded wire-mesh for trap durability.

Miscellaneous Materials:

- Aluminum or hog-nosed clips for assembling welded wire traps
- Galvanized flux or tinner's acid (when solder is used for joint assembly)
- Screw-eyes can be used as ring guides secured to doors to guide descent
- Solid 50% tin and 50% lead solder
- Soft copper wire, 18- to 20-gauge, for lacing corners or joint assemblies
- Galvanized wire (10-, 12-, or 14-gauge) for reinforcing openings, handles, door guides
- Tempered pressed fibre-board or exterior laminated wood sheet for floors or use on snow

Tools:

- Bench-type vise
- Home-made anvil of 5 x 10 x 45 cm oak, cold-rolled steel, or section of railroad track
- Alligator clips
- Hand or approximately 5 mm electric drill
- Straight shank drills, approximately 0.5 to 5.0 mm
- Three-cornered and flat files
- Rawhide or wooden mallet
- Ball-peen hammer
- Diagonal-cutting, long-nose, squeeze-clip, and/or slip-joint pliers
- Tin snips
- Electric iron (approximately 15 g) or propane torch soldering device
- Abrasive (approximately 5 or 7.5 cm) fine-grit wheel

Much of the information in Sections 3.2 through 3.5 is from the Raptor Management Techniques Manual (Pendleton, 1987) and Wildlife Management Technique Manual (Schemnitz, 1980). Personnel are encouraged to refer to these resources for more detailed information. See Attachment 3 for sources of additional information about traps and trapping techniques and a summary of traps commonly used to capture birds within the groups identified.

For convenience, the following sections divide bird traps into three categories:

- Bait traps
- Accidental traps
- Miscellaneous

3.2 Bait Traps

Bait traps lure birds into the particular trap with a bait (such as grain, seeds, fruit, sunflowers, or suet-soaked cornmeal). Next to shooting, bait traps are probably the cheapest method of bird sampling. Bait trapping can frequently be undertaken as a one-man project. Pre-baiting an area is the process of baiting an area several times before actually trapping. This allows birds to become familiar with the location and will provide a better return when trapping begins. If possible, allowing the chosen trap to remain at the area for several days will allow birds to become accustomed to its presence.

There are many designs for bait traps and trap methods can be adapted or modified to fit most situations. Many species of birds, especially the gregarious seed-eaters, can be captured in these traps. Other species easily captured include but are not limited to grouse, pigeons, quail, pheasants, falcons, merlins, and vultures. They are also widely used for capturing ducks and mourning doves (USDI Wildlife Leaflet No.117).

3.2.1 Drop Trap

The simplest trap, often used for small birds, is a box constructed of wooden or 8- or 10-gauge wire frame and covered with wire mesh cloth. The trap is set by supporting one end of the box with a stick with a string attached (Figure 1). When the birds begin feeding on the bait, the trapper, hidden at a distance, pulls the string imprisoning them. Worten (1955) used this method to catch band-tailed pigeons. He used a 4.8 m square wooden frame, tightly covered with 3.8 cm mesh net, supported on 1 side by a 2.1 m pole.

3.2.2 Funnel Trap

Funnel traps consist of two chicken wire wings that funnel birds into an enclosed cage. These traps can be built large enough to capture vultures or scaled down to catch smaller birds such as grouse, quail, and pheasants. Meredith (1943) reports that funnel traps will catch migrating falcons and merlins when baited with a tethered lure bird such as a starling or pigeon. Cages are usually circular but may also be square or rectangular. Traps are constructed from 12½-gauge welded mesh wire attached to tubular or wooden frames with large hog rings. Wire bales can be cut into the lengths desired. Five or six lengths, cut equally, can be attached to each other (hog rings) in such a manner to form a cube so that the sides fold easily without binding. The sixth length can be used to make a bottom.

Traps can easily be dismantled by first removing the entrance structure and then the hog rings from three sides of the top and bottom. The traps can then be folded flat for easy handling and transport. In funnel traps, the entrance hole in located in the middle of the trap. The widest portion of the funnel is flush with the outer side of the trap. The narrow inner opening projects well into the interior of the trap. The funnel should be constructed of stout wire so that it will hold its shape. Captured birds find the narrowing funnel difficult to exit.

3.2.3 Sparrow Trap

The sparrow trap (Figure 2) is an effective trap for many species of birds including finches, grosbeaks, buntings, and other seed-eaters that come readily to feeding stations.

The trap dimensions are about 2 x 4 x 1.5 ft. The first entrance is sized about 3 x 3 in. and is flush with the bottom of the cage. The first chamber can be bottomless or floored. The second entrance should have a similar opening several inches above the floor of the cage. The appropriate bait is put in both chambers; the second chamber acts as a holding cage, preventing the birds from finding their way out again. A small door at the rear allows for collecting the catch.

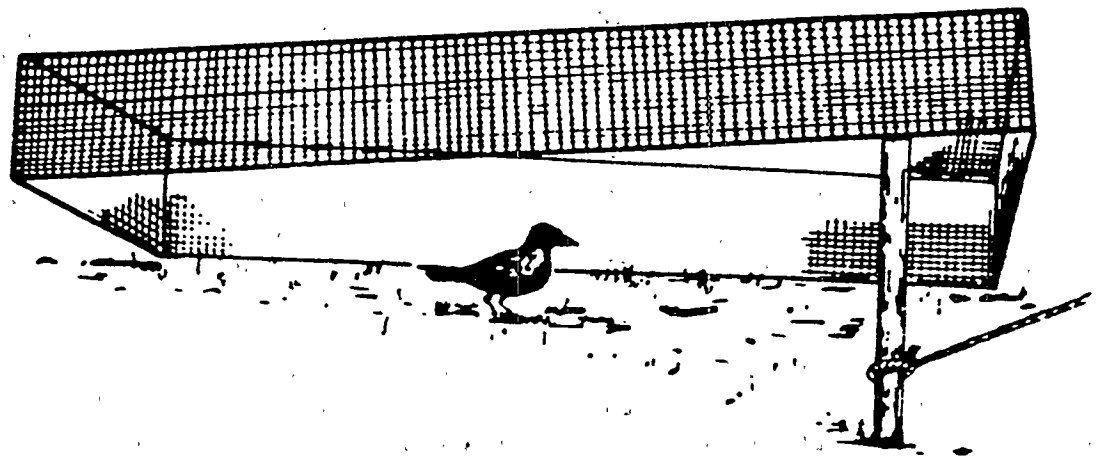


Figure 1. Drop Trap (Migratory Animal Pathological Survey, 1966).

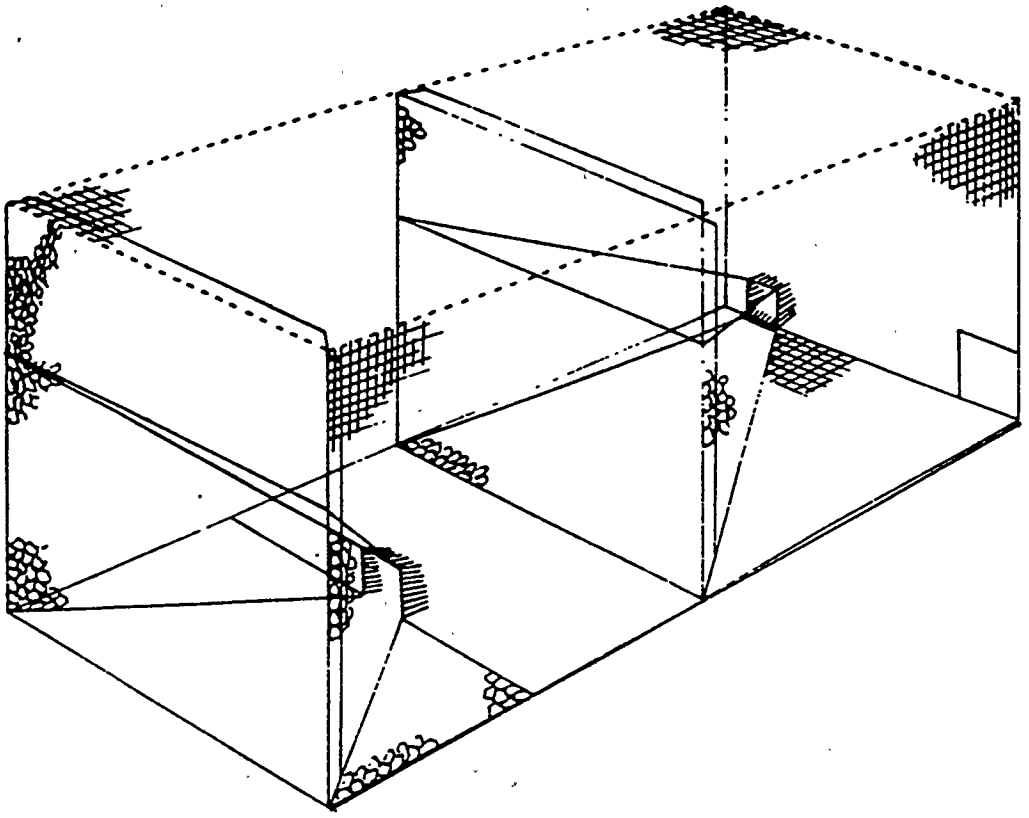


Figure 2. Sparrow Trap (Migratory Animal Pathological Survey, 1966).

3.2.4 Cloverleaf Trap

The all-purpose Seth Low Trap is one of the most useful of the baited walk-in cloverleaf traps (Figure 3). This trap is easy to set up and disassemble. The cage is shaped to the desired "cloverleaf" shape and held in place by stakes. The top (wire or preferably ½-in. fish netting) can be sewed in place or attached by hog nose clamps, and a hole for a door to the gathering cage can be cut at one end. The trap is then appropriately baited and left open.

Figure 4 shows details of the three-leaved clover trap. This design requires about a 50 ft strip of rolled chicken wire, with interior chambers more than 4 ft in diameter. The cage is shaped and held in place by stakes and hog nose clamps. Entrances can be made by simply cutting the wire and bending it back. The gathering cage may not be necessary and can be easily eliminated during construction of the trap. This type of trap is effective on mud flats for capturing shorebirds and will capture ducks when baited with corn or grain. Larger traps built in shallow water will capture ducks when baited.

3.2.5 House Trap or Modified Australian Crow Trap

The crow trap (Figure 5) is a square or rectangular cage 5 to 10 ft on one side and 5 to 6 ft high. This trap requires constant attendance but is one of the most productive traps for birds such as crows, ravens, magpies, and starlings, which will come to bait. Ground-feeding birds are permitted through entrances on the top of the trap. A slot in the sloping roof permits birds to fly down to bait yet discourages their escape. Ladder rungs across the slots are spaced to coincide with the size of birds desired for trapping. A door at one side permits entry to capture the birds or drive them into a holding pen.

3.2.6 Cannon Net or Rocket Trap

The cannon net or rocket trap consists of a large, light net that is carried by mortar projectiles over concentrated birds. The cannon net has been used to capture many species of birds including waterfowl, seabirds, shorebirds, passerines, cranes, and grouse (Dill and Thornsberry, 1950; Thompson and DeLong, 1967; Arnold and Coon, 1972). Raptors have been successfully captured, including black vultures and turkey vultures, California condors, and bald and golden eagles. The cannon net is one of the best traps available for these species; since most are somewhat gregarious, several individuals can be captured at a time.

Although cannon nets are selective, efficient, and can capture many birds at a single firing; they are potentially hazardous, relatively expensive and labor intensive. The initial cannon and net installation, plus site preparation, takes about 3 hours. Each subsequent test firing or preparation for firing takes about 1 hour. A crew of four people is required to stretch and fold the net after each firing (Pendleton, 1987). Test-firings are necessary to determine whether cannons are wired and angled correctly and to be certain that the net ejects properly. Because these traps involve explosives, they have an element of danger not present in most other traps.

NOTE: To comply with service policy concerning the safe and effective use of explosives only trained personnel should use this type equipment. Field personnel are referred to U.S. Fish and Wildlife Service transmittal sheets - 24 AM 5, "Explosives," for references on explosives handling and for specific references on use of the rocket net systems. The Office of Migratory Bird

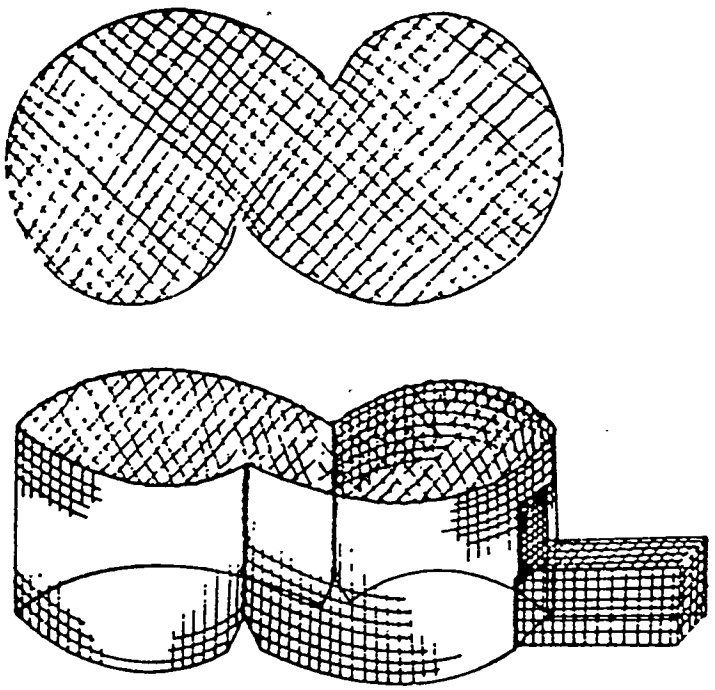


Figure 3. Cloverleaf trap; Seth Low trap (Migratory Animal Pathological Survey, 1966).

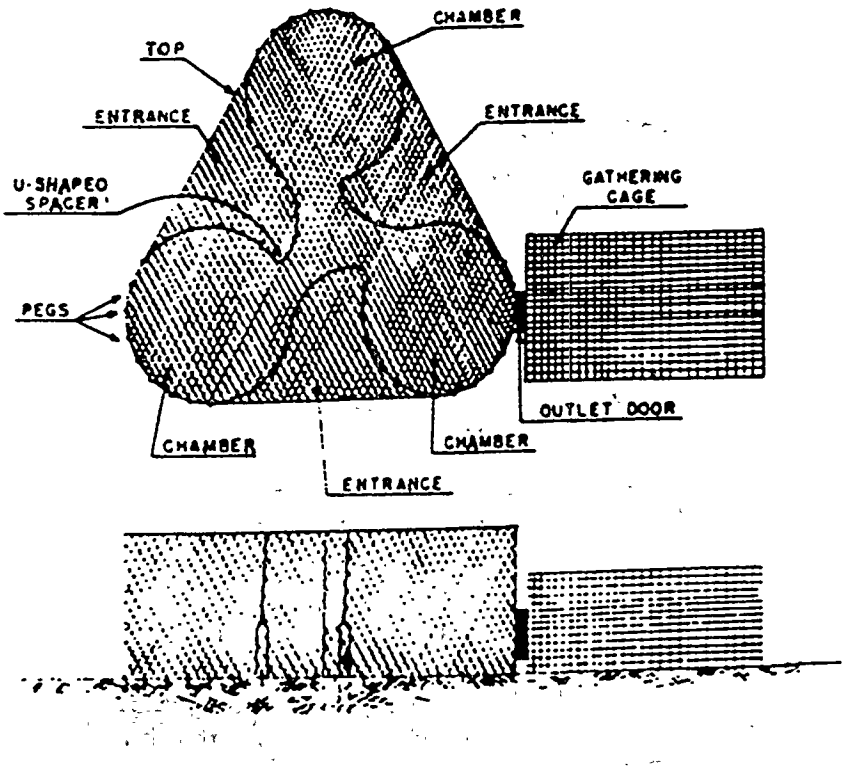


Figure 4. Cloverleaf trap; three-leaved (Migratory Animal Pathological Survey, 1966).

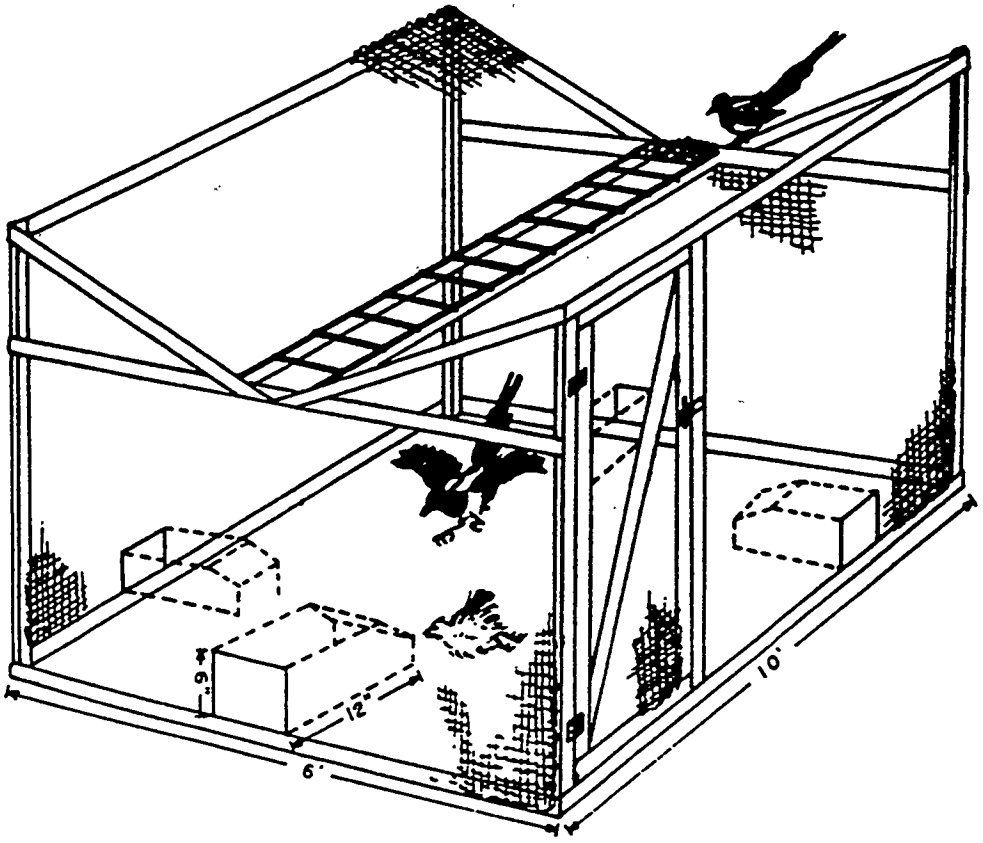


Figure 5. Australian crow trap (DOI, 1944).

Management, can be consulted for additional questions concerning the transmittal sheets or Supervisory Information Bulletins 86-6 and SSA-87-1.

These bulletins contain preliminary safety information of interest to rocket net users. Design specifications for one of the safest and simplest versions are described by Mundy and Choate (1973).

3.2.7 Padded Leg-hold or Lockhart Trap

This trap is used primarily for capturing raptors, especially eagles. The method consists of placing several padded leg-hold traps with weakened springs and padded jaws in the vicinity of an animal carcass. The jaws on new traps are powerful enough to break the toes of eagles and must therefore be weakened and/or padded. Springs can be weakened by striking both springs near the bend with a heavy hammer. Each jaw of the trap is padded by wrapping with neoprene or leather to a thickness of about 2½ in. and securing the padding with friction tape. The recommended trap for eagle capture is a No. 3 double long spring leg-hold. Leg-hold traps are not recommended for smaller species because of occasional bone breakage. Imler (1937) had success with red-tailed hawks, rough-legged hawks, prairie falcons, and great-horned owls using a No. 1 trap placed on poles or around rabbit carcasses, but found that species such as the Northern harrier, Swainson's hawk, and American kestrel sustained severe injuries. Smaller traps (No.1, No.2) may be adjusted for smaller species without causing injury.

Lockhart traps are used in conjunction with bait in areas frequented by the desired raptors. Animal carcasses such as calves, deer, rabbits, and waterfowl are most frequently used as bait. At the trapping site, the carcass is split open and pieces of fur or plucked feathers are spread around to make it appear as if it had been previously fed upon. Traps should be placed 10 to 20 in. from the bait in depressions dug in the soil. Four to eight traps usually are sufficient depending upon the size of the bait animal. Traps should be set with 5 x 5 in. piece of cloth under the jaws and over the trigger pan. The cloth will prevent soil used to camouflage the trap from falling in under the trigger pan. The trigger should be set for maximum pressure in order to avoid capturing small, nontarget carrion feeders that are attracted to the bait. A piece of 3-in. building insulation placed under the pan will also help reduce the number of small, nontarget species caught in the trap. Attach each trap to a 2-lb weight via a 5-ft line and shock absorber, then lightly bury each. Two traps connected together by their stake chains may eliminate the need for a separate weight.

3.2.8 Bal-Chatri Trap

The Bal-Chatri (Figure 6) is a wire cage with monofilament nooses tied to the top and/or sides and a lure animal inside. The lure animal is used to attract a bird, which alights and entangles its feet in slip knot nooses attached to the trap. The Bal-Chatri trap used to capture raptors is very effective and versatile. The Bal-Chatri can be used during all seasons, is portable, and has a good success rate for most species that take the trap.

North American species that have been captured on a Bal-Chatri include hawks such as sharp-shinned, Coopers', northern, Harris', gray, roadside, red-shouldered, broad-winged, Swainson's, red-tailed, ferruginous, and rough-legged hawks. Bal-chatris have also been used successfully on black-shouldered kites, northern harriers, American kestrels, merlins, aplomado falcons, prairie falcons, common barn-owls, eastern and western screech-owls, burrowing owls, spotted owls, barred owls, great gray owls, and long- and short-eared owls.

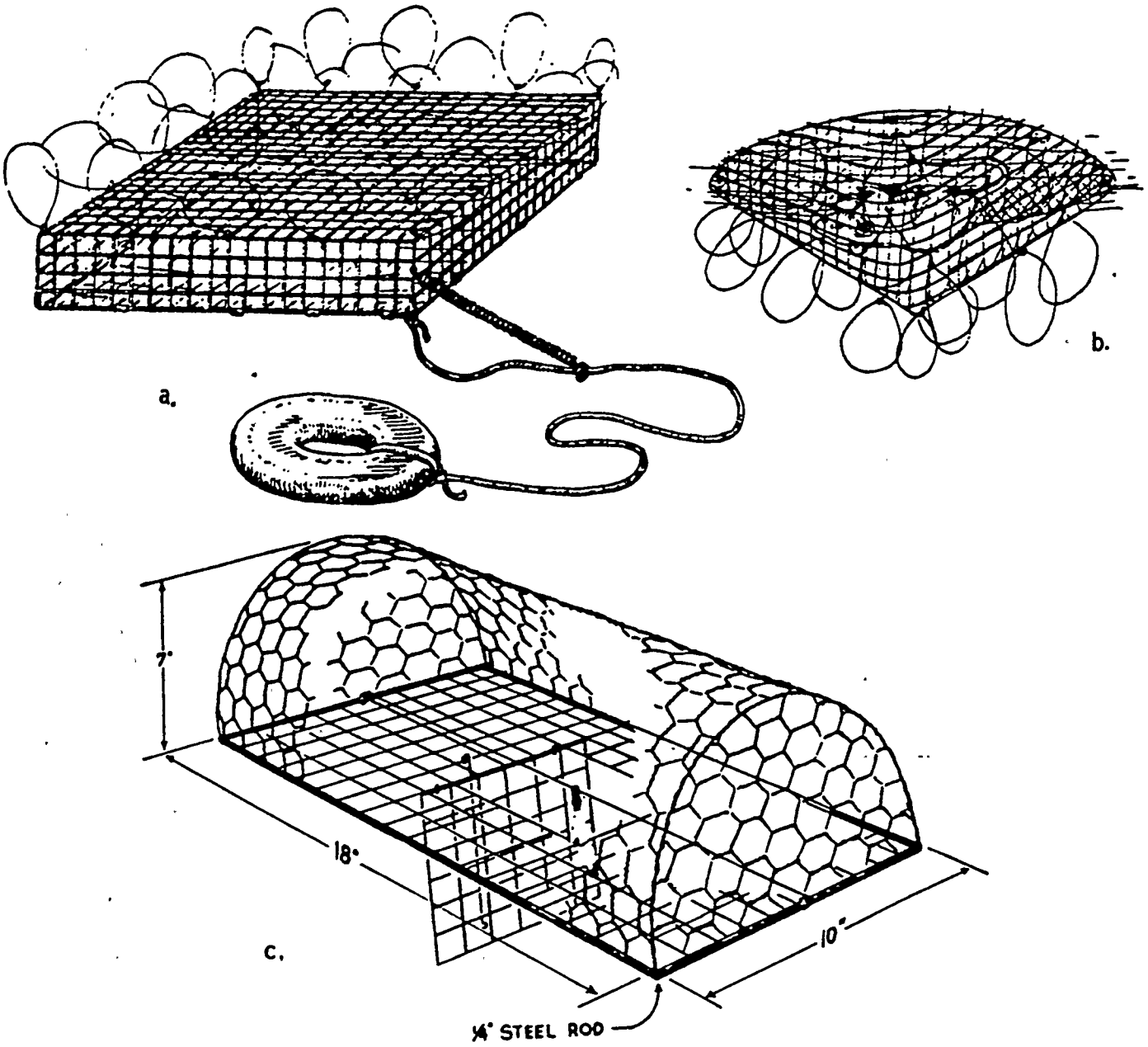


Figure 6. Bal-Chatri traps (Pendleton and Giron, 1987 and Berger and Hammerstrom, 1962)

Sampling personnel may find techniques by Berger and Hammerstrom (1962) especially useful. The trap they used was quonset-shaped with the top and side made of 1-in. chicken wire and the floor of 1-in. mesh welded wire. The top was covered with about eighty 40-lb test monofilament nylon nooses about 3-in. in diameter. Several noose knot tying techniques are presented by Jenkins and Collister (Pendeleton et al., 1967). Jenkins (1979) found that a running slip knot increased trapping success. The trap was constructed with a 4 x 5 in. door in the bottom for inserting the lure and where it will not interfere with the nooses. The cage must be large enough for the lure animals to run or fly within, so that the raptor can detect the activity. Construction of the cage may be accomplished with a single section of hardware cloth or several sections in which the sides, bottom, and top are fastened together. The different flaps or sections of the cage are most efficiently fastened with ring clips (Wiseman, 1979) or wires.

The trap is weighted, usually with an iron rod around the edge. A finished Bal-Chatri, for raptors up to the size of great-horned owls, should weigh about 2 lb 6 oz. Bal-chatris are relatively light weight traps and usually must be weighted to prevent the birds from becoming airborne with them. Once caught, the raptor should be able to drag the trap a short distance, because he may snap the noose holding him if the trap is too heavy.

3.2.9 Bow Net Trap

The bow net (Figure 7) consists of two semicircular bows of light metal with gill netting strung loosely between them. A lure animal, usually a bird, is placed in the center of the trap. Bow nets may be triggered automatically by a raptor or corvid, or manually from a blind. Bow nets may be more effective than Bal-Chatri in some instances because a tethered lure animal walking about with only a single trigger wire above may appear less intimidating than an animal in a Bal-Chatri cage.

Automatic models are described by Tordoff (1954) and Kenward and Marcstrom (1983). Hawks were regularly caught when the traps were set with a fresh kill. Clark (1970, 1976) describes one of the more typical manually operated models. One of the finer attributes of the manually operated models is its selectivity. This type of bow net has been used to capture bald eagles, sharp-shinned hawks, Cooper's hawks, red-tailed hawks, red-shouldered hawks, northern goshawks, broad-winged hawks, golden eagles, American kestrels, merlins, peregrine falcons, gray falcons, and prairie falcons. A major improvement in the typical design of the manually operated bow net (Clark, 1970; Field, 1970) is the use of garage door springs to power the bow.

3.3 Accidental Traps

Accidental traps are un-baited devices that birds accidently enter in the course of their travels.

3.3.1 Mist Nets

Mist nets are large, nearly invisible nets that are secured between poles and placed in appropriate habitat to entangle and capture birds. Mist nets require skill and constant observance but are particularly useful for species that will not come to bait or which use certain flight patterns along streams, etc. Use of mist nets for capturing morning dove is described by Harris and Morse (1958). Waterfowl have been readily captured at night with mist nets (Briggs, 1977). Mist nets work well on

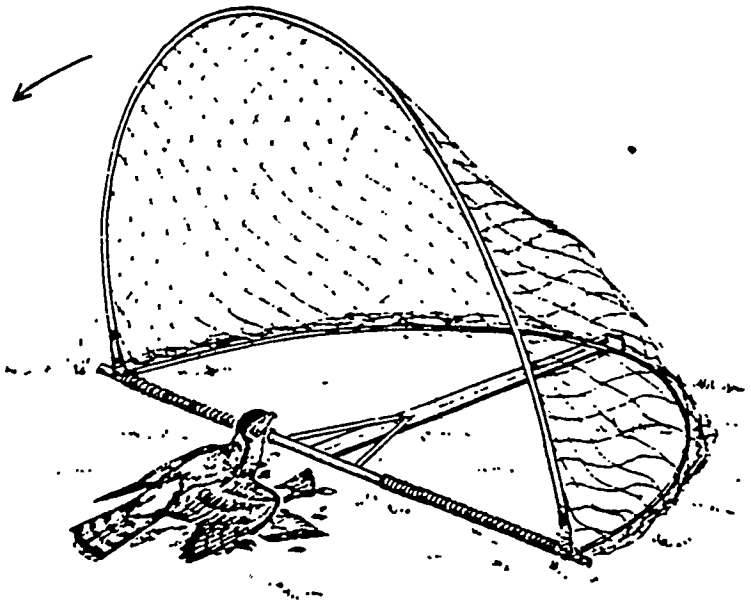


Figure 7. Bow Net trap (Pendleton and Giron, 1987).

a variety of raptors, especially small- to medium-sized owls. Mist nets have proven effective for the capture of northern saw-whet owls (Mueller and Berger, 1967; Walkimshaw, 1965) and long-eared owls (Smith et al., 1983). Mist nets have also been used effectively for capture of hawks, American kestrels, merlins, and common barn owls during migration (Clark, 1970). The nets are used as backups to bow nets, which attract the birds with live bait. Attacking raptors frequently will make a pass at the lure animal in a bow net and be caught in a mist net.

Mist nets are relatively inexpensive and are much easier to purchase than they are to build. The mesh size selected will vary according to the species being collected. A combination of 30- and 36-mm mesh sizes are best for capturing land birds weighing up to 100 grams, while larger mesh sizes perform well for birds such as Cooper's and red-tailed hawks, ducks, and ring-necked pheasants. Mist nets can be obtained from:

Bleitz Wildlife Foundation
5334 Hollywood Blvd.
Hollywood, CA

For further information see Bleitz, 1970. "Mist Nets and Their Use," Inland Bird-Banding Association News.

3.4 Miscellaneous

There are a number of miscellaneous capturing methods, some suited to only a particular species. Methods include using a spotlight, net-firing gun, hand net, etc.

3.4.1 Spotlighting

This technique involves immobilization of animals at night with light and sound. Labisky (1968) reports success with this technique in catching ground-nesting birds, primarily ring-necked pheasants and sage grouse. Other birds that can be captured by spotlighting, include sora rails, Virginia rails, barn owls, screech owls, bobwhite quail, greater prairie chickens, and woodcocks. Cummings and Hewitt (1964) describe the use of nightlighting for capturing waterbirds by net from a boat.

The basic equipment consists of a gasoline-powered generator; tape player; recording of chainsaw or other noise, hand-held spotlight; long-handled net; and floodlight cluster attached to a vehicle. Nightlighting is more effective if a loud, steady noise is broadcast throughout the operation. The AC power source provides better illumination than that produced by DC power. Once immobilized by light and sound, the birds are captured with long-handled nets.

The spotlighting technique can be modified for terrain not easily accessed by motor vehicle. A spotlight can be attached to a car battery carried in a backpack, maintenance free batteries are recommended to minimize the problem of acid leakage. This method has proven effective for capturing various species of birds, such as sage grouse, roosting starlings, and blackbirds.

3.4.2 Net-Firing Gun

The Net-Firing Gun consists of a hand-held, 3-barrel gun that uses explosives to propel a net. The gun net can project a variety of triangular or square nets, ranging from mist nets to heavy tensile-strength nets. Depending upon the size and mesh, the net can be projected 15-22 m. The gun can also be fired by remote control. It is a safe, effective, versatile tool for capturing breeding waterfowl and shows considerable promise for other wildlife species. Mechlin and Shaiffer (1980) describe the net-gun's operation, cost, suppliers, etc.

3.4.3 Drive Trap

Drive traps (Figure 8) are essentially funnel traps with long chicken wire leads directed into the funnel openings. These funnels face in both directions and lead into a holding pen or tubular-enclosed cage. Drive traps are not the most effective for capturing birds but have been used to successfully capture birds that tend to run when herded, i.e., quail, sage grouse, molting ducks, and geese. Drive traps (and baited funnel traps) have been used to capture waterfowl during large scale banding operations. Flightless (molting) geese may be taken by herding into a similar trap (Cooch, 1953).

3.4.4 Simple Noose Carpet

This trap is adapted from the Bal-Chatri and consists of a flat section of hardware cloth of any size with nooses of 2 kg test nylon attached about 5 cm apart and covering one side (Collister, 1967). It may be pressed into loose soil, covered with fine dirt, or set in shallow water. Suitable bait must be scattered on the trap. It can be used for taking ptarmigan, shorebirds, gulls, nuthatches, and jays, as well as woodpeckers. A modification of this device is a dome of wire netting to which nylon slip-nooses are attached. This domed noose carpet is placed over a nest and secured by a rope or strap. This method can be used to capture osprey or other nesting raptors.

3.4.5 Pit Trap

The pit trap is a deep hole large enough for a person to maneuver inside. Eagles and other raptors, attracted by nearby bait, are then grabbed by the person inside the pit.

Pit trapping is an ancient and well tested technique used by Native Americans but is seldom used today, probably because of the ease and effectiveness of trapping with leg-hold traps. Personnel at the FWS Condor Research Center in California have used this technique for studies with California condors.

Due to dangers when using pit traps, eye, hand, and arm protection is needed. While being handled, raptors may struggle, bite, and grab their captors. Most raptors are capable of inflicting painful wounds with their bills and talons; and in the cases of large hawks, large owls, eagles, and condors, these wounds can be serious. In most species, particularly eagles, the talons have the greatest potential for causing serious injury. When using this technique, it is important to restrain the bird as quickly as possible.

When removing blood or fat sample it may be necessary to hood and/or wrap the bird securely. As soon as the bird is grabbed, the talons and feet should be wrapped with strapping tape

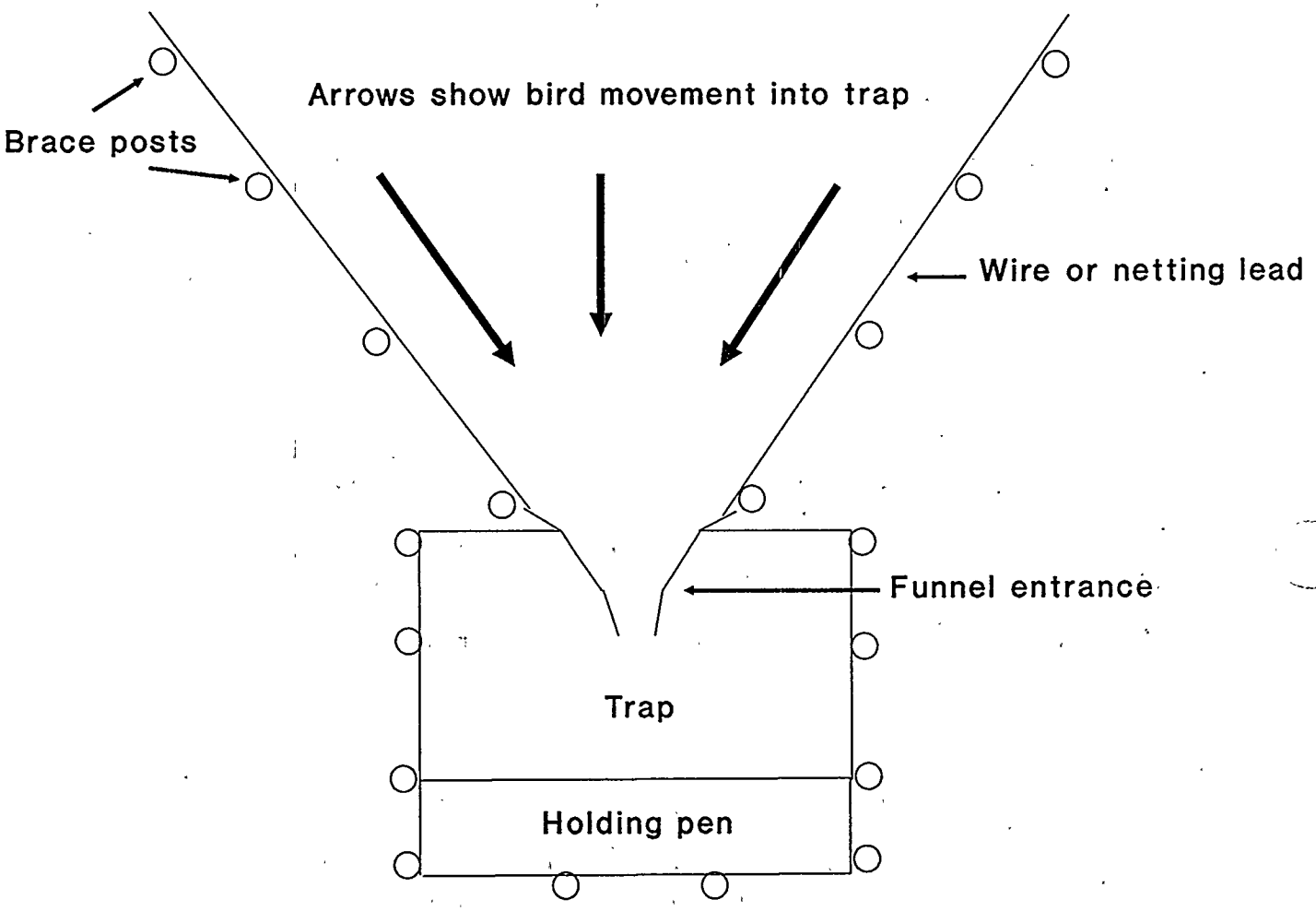


Figure 8. Drive Traps

and the wings folded together and a hood secured. Care should be taken to ensure that the hood is not too tight or touching the eyes. Methods of restraint include simply holding the bird; hooding the head; wrapping the wings close to the body with elastic bandaging tape, adjustable plastic belts (Evans and Kear, 1972) feet and legs can be controlled by wrapping them with nylon-reinforced strapping tape.

Once made, a pit trap is operational as soon as an animal carcass is positioned in front of the opening and the pit is manned. To construct a pit trap, a hole 0.9-m wide, 1.8-m long, and 1-m deep is dug in firm soil. A sheet (1.2 x 2.4 m) of 1.9-cm marine varnished, outdoor plywood is used to cover the pit. The walls of the pit are supported by 1-cm outdoor plywood, and braced with 5.1- x 10.2-cm x 0.9-m wooden beams nailed vertically in the corners to prevent earth slippage. One 2 x 4 beam is jammed and nailed between the vertical 2 x 4's at the front and back of the pit and a pair of 10.2- x 10.2-cm cross beams should be used to strengthen the roof when used in cattle country or where vehicles might be driven over it. A door approximately the width of the pit is cut at the end of the plywood cover. A rim of 2 x 4's is then nailed around the edge of the door on the roof to prevent debris from falling in when the door is opened. The door is hinged at the rear and a 25-cm diameter hole is cut in the middle of the door. A basket measuring about 35 cm in diameter and 30-cm high is then secured upside down by wire over this hole. A 15- to 20-cm x 0.8-m opening between the door and the top of the forward wall of plywood is the capture space through which the birds are grabbed. Carcasses of rabbits, calves, deer, etc., used as bait are placed in a small depression about 1 ft out from the capture space.

3.4.6 Shooting

Birds are easily collected by shooting them with a rifle. The drawbacks of this method is possible specimen damage and the cross contamination of organs and tissues. The size shot will depend upon the species of bird being collected. The 12-, 16-, and 20-gauge shotguns are used for larger birds, with shot sizes ranging from No.9 to No.2, depending on the size of and distance of the target specimen. The .410 shotgun is effective up to intermediate sized birds. Table 2 is a general guide to shot size versus species.

It is best to kill the bird(s) with the least amount of shot perforating the body as possible. In long-range shooting, the entire load should be directed toward the specimen; however, when shooting birds at close range, aim to one side of the bird rather than directly at the bird to ensure only a few of the shot will penetrate the bird.

Table 3 summarizes which traps are likely to be useful for capturing various bird species.

Table 2. Guide to shot size versus species

TYPE BIRD	TYPE SHELL	LEAD SHOT SIZE
Ducks	Magnum or classic hi-brass	4, 5, 6
Geese	Magnum or classic hi-brass	BB, 2, 4
Pheasants	Magnum or classic hi-brass	4, 5, 6, 7½
Quail	Classic hi-brass or field load	7½, 8, 9
Grouse and Partridge	Classic hi-brass or field load	5, 6, 7½, 8
Doves and Pigeons	Classic hi-brass or field load	6, 7½, 8, 9
Crows	Classic hi-brass or field load	4, 5, 6, 7½

Table 3. Traps considered effective for capturing representative species from the groups identified.

TYPE OF TRAP (Section)	SONG-BIRDS	UPLAND GAME BIRDS	MARSH/ SHORE BIRDS	WATER-FOWL	COLONIAL WATER BIRD	RAPTORS	CORVIDS
1. Bait traps							
Drop trap (3.2.1)	X						
Funnel trap (3.2.2)		X					
Sparrow trap (3.3.3)	X						
Cloverleaf trap (3.2.4)		X	X	X			
House trap or Australian Crow Trap (3.2.5)	X						X
Cannon net or rocket trap (3.2.6)		X	X	X	X		
Padded leg-hold or Lockhart Trap (3.2.7)						X	
Bal-Chatri Trap (3.2.8)						X	
Bow Net Trap (3.2.9)						X	
2. Accidental traps							
Mist Nets (3.3.1)	X		X	X		X	
3. Miscellaneous							
Spotlighting (3.4.1)		X	X	X			
Net-firing Gun (3.4.2)		X		X	X	X	X
Drive Trap (3.4.3)		X		X	X	X	X
Simple Noose Carpet (3.4.4)				X over nest		X	
Pit Trap (3.4.5)						X	

4. SAMPLE HANDLING, DISSECTING, AND PRESERVATION

4.1 Euthanasia

Birds captured alive should be euthanized in a humane manner. The following factors should be considered when choosing a technique:

- Does it present a risk to human health and safety?
- Does it induce immediate central nervous system depression?
- Does it require stressful capture and restraint?
- Is it appropriate for the size of bird?
- Will it interfere with diagnostic tests?
- Is specialized equipment or training required?
- Will this technique offend the casual observer?

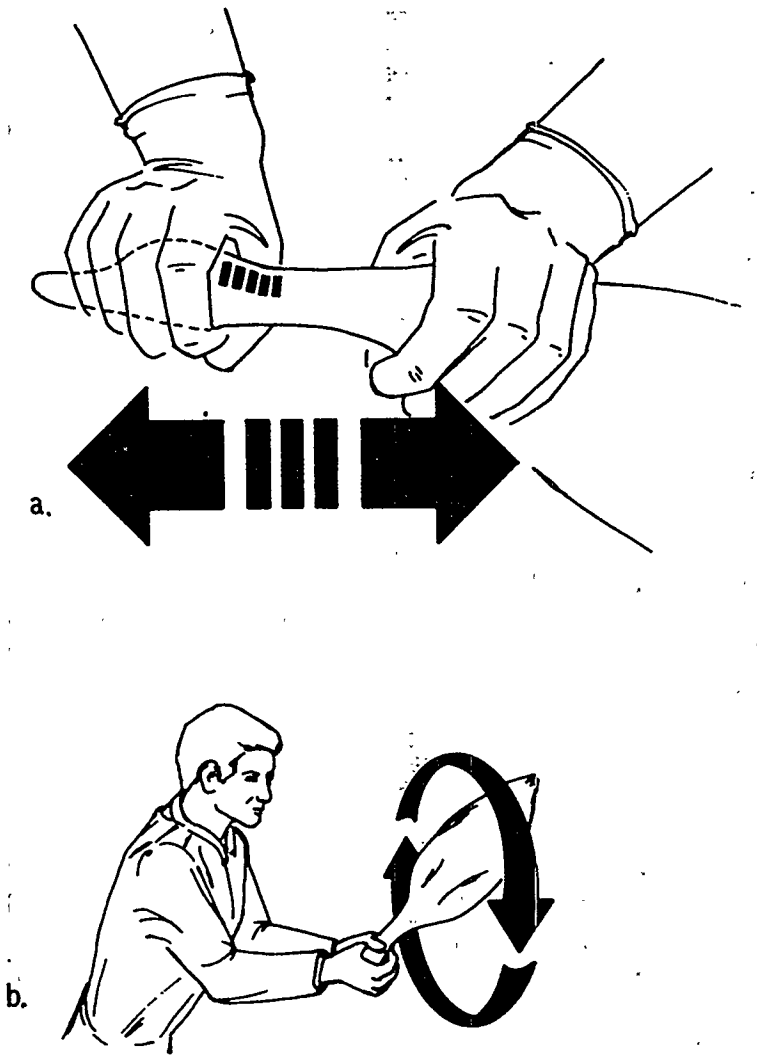
The Field Guide to Wildlife Diseases (DOI, 1987b) suggests several methods to euthanize samples. Physical euthanasia is preferred when monitoring for contaminants. Techniques include cervical dislocation [breaking the neck (Figure 9)], stunning and exsanguination (bleeding out) and shooting. Chemical euthanasia techniques include lethal injection, anesthetic gas (halothane, methoxyflurane, and nitrous oxide), and toxic gas (CO_2). Drawbacks of chemical euthanasia are specimen contamination, extra cost and time, and safety precautions for field personnel.

4.2 Handling and Preservation Procedures

When working with specimens that may be diseased or contaminated, personnel should wear disposable rubber or plastic gloves, coveralls, and rubber boots or waders. Before leaving an area where diseased birds have been collected, double-bag gloves and coveralls. Disinfect the outside of bags, boots, and waders with commercial disinfectant or chlorine bleach. Specimens should also be double-bagged in plastic before removal from the area to minimize transmission of disease to other wildlife populations.

Birds can be analyzed whole-body or by specific organ (e.g., remove brain, liver, blood, kidneys, etc.). The best specimen for submission is an entire bird. This allows the diagnostician to make an assessment of all the organ systems and to use the appropriate organs/tissues for diagnostic tests. If it is not possible to submit an entire bird, appropriate organs must be removed and submitted (see subsection 4.2.1 for details on conducting field necropsies). Carcasses should not be dissected in the field without first consulting disease specialist regarding methods of dissection and preservation of tissues and parasites. Help is available from a variety of sources e.g., Wildlife Management Techniques Manual Schemnitz (1980), and Field Guide to Wildlife Diseases (DOI, 1987). Field necropsies are at times of value for documenting the basic health, body condition, and obvious pathological conditions that could be associated with contaminants and for relating the reproductive state of birds undergoing chemical analysis.

It is best if carcasses are examined and dissected before freezing. However, this may not be possible in all cases and whole birds may have to be frozen before examination. Carcasses should not be bagged together before freezing. The high natural body temperatures of birds, small surface area, and the insulating qualities of the feathers combine to retard heat dissipation. Thus, to avoid



(a) The brain can be separated from the spine in small- to medium-sized animals by grasping the animal at the base of the skull with one hand, at the base of the neck with the other, and pulling rapidly and firmly in opposite directions with a strong snapping action. (b) For larger birds (duck and goose size), the spinal cord can be more easily separated by grasping the bird at the base of the skull and swinging or twirling the bird in a circular, snapping motion (DOI, 1987).

Figure 9. Cervical dislocation procedures.

decomposition, individual carcasses should be completely frozen before bagging.

Either chill or freeze all specimens (use refrigeration, dry ice, and/or blue ice packs), depending on how long shipping to the diagnostic laboratory will take (see Section 4.2.3). For dissection or necropsy, frozen carcasses should be thawed without heating. A running water bath may be helpful in some cases. Carcasses should not be thawed more than necessary to complete dissections or examinations. Because birds of variable sizes and plumages thaw at various rates, carcasses should be monitored continuously until the limbs are limber enough to be moved by hand. If analyses are not considered "routine," an analyst should be consulted to determine what special handling procedures may be necessary for the analysis to be performed.

Special precautions must be taken before sending birds into the Patuxent facility for analyses. Dr. Louis N. Locke, with the Madison Disease Control Center for the Service feels the preferred method of handling birds is that all birds should be sent through the Madison facility before going to Patuxent. This is because the potential exists for disease transmittal to birds in the holding pens, to the research specimens, or the threatened and endangered species kept at Patuxent. Birds that have diseases that can be transmitted to domestic fowl or are dangerous to humans are under the authority of the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA) and may need to be disposed.

4.2.1 Whole Carcass Submission

1. Wet the feathers with ASTM Type II distilled, deionized (DDI) water to facilitate feather removal.

2. Remove, by plucking, as many feathers as possible. This is best done by grabbing only a few at time and pulling in the direction opposite the lay of the feathers. Try not to tear the skin excessively.

3. Cut the beak off flush with the face.

4. Cut the legs off at the feather line.

5. Place bird in the dorsal position and open the abdominal cavity. Cut through the breast plate and remove both the upper and lower Gastrointestinal (GI) tract. Cut as close as possible to the mouth and cloaca. The GI tract should be saved in a decontaminated specimen jar, properly labelled, frozen, and stored for future analysis.

6. Tare specimen jar for carcass on a laboratory balance. Place the specimen in the specimen jar and record the weight. If the carcass is too large for a jar, it may be wrapped in clean aluminum foil (rinsed with hexane if hydrocarbons are to be analyzed) and then double-sealed in plastic bags. Label both the foil and the bag.

7. Samples should be properly wrapped, labeled, and preserved into appropriate sample containers (see BD-4.2.3).

8. Record the information in the field logbook and complete the chain-of-custody documents if required (see DOC-3.6-3.6.2)

9. Document all sampling activities as required (see DOC-3.0-3.1).

4.2.2 Dissection (Field Guide to Wildlife Diseases).

1. Tare a chemically cleaned specimen jar of appropriate size on a laboratory balance.

2. Place specimen in the dorsal position. Wet the feathers with ASTM Type II (DDI) water for better visualization of the incision.

3. Make a midline incision over the keel (Figure 10a), peel the skin back, cut through the ribs, and lift the breast muscle and sternum to expose the viscera (Figure 10b). You will be able to see the esophagus, heart, liver, and gizzard (Figure 10c-f).

4. Remove GI tract:

   a. Cut the esophagus as close to the mouth as possible, being careful not to spill any of the contents as they are required for analysis.

   b. Lift the upper tract and cut away any connective tissue holding it in place. Use forceps to hold the organs. Make an incision just below the stomach being careful not to spill any of the contents.

   c. Place the upper GI tract in the specimen jar and record the weight.

5. Remove any abnormal-appearing tissues or organs, and submit for examination. In general, heart, liver, GI tract, and brain should be collected.

6. Keeping tissues as clean as possible, place specimens in individual Whirl-Pak or clean plastic bags (if chemical assessments do not include organic analysis).

NOTE: When analyzed for organics, place specimens in rinsed aluminum foil. Acid rinsed or chemically cleaned glass jars may also be appropriate containers. It is generally recommended that samples collected for organic analysis not come in contact with plastic.

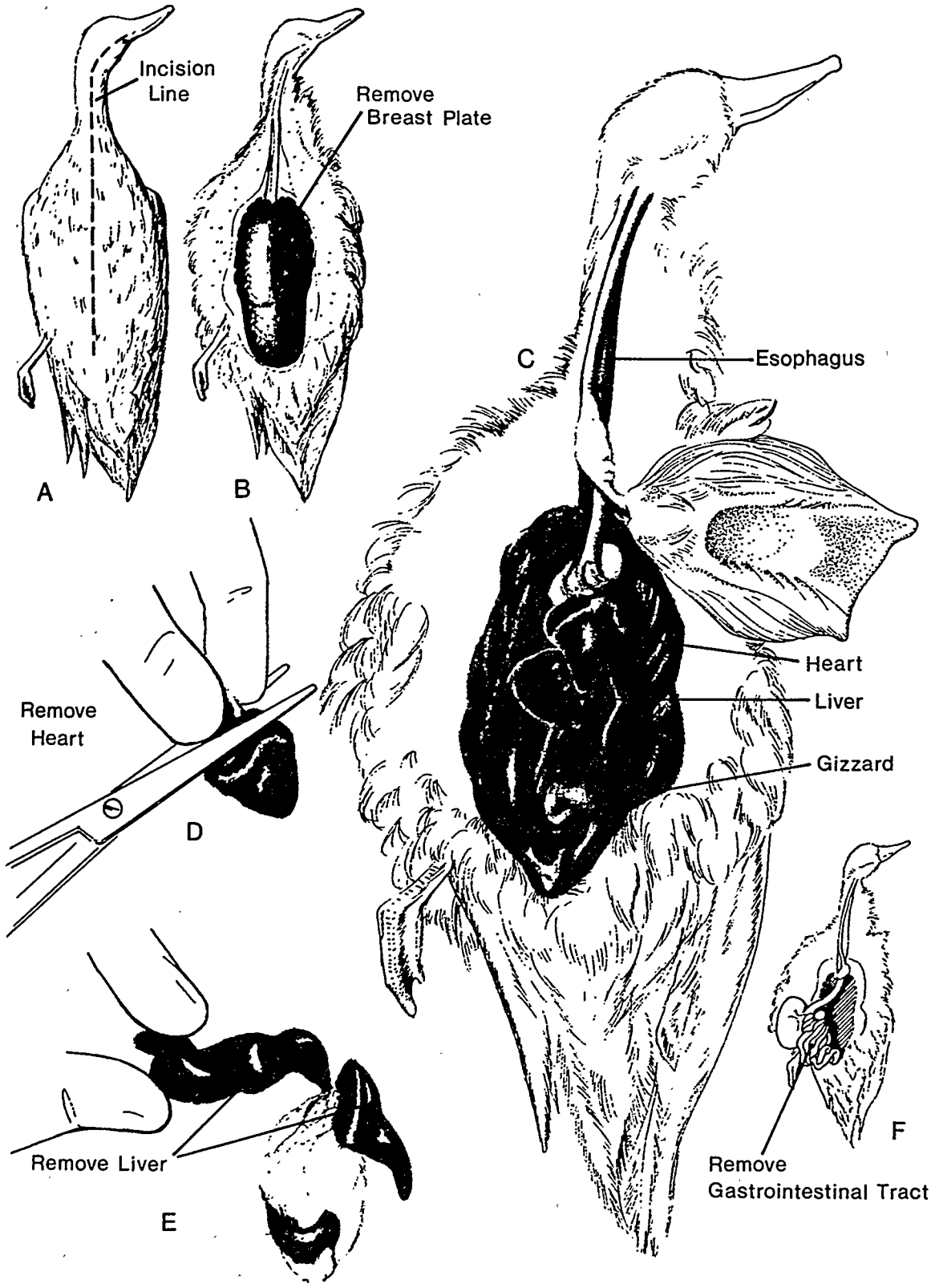
7. Samples should be properly wrapped, labeled, and preserved into appropriate sample containers (see BD-4.2.3).

8. Record the information in the field logbook and complete the chain-of-custody documents if required (see DOC-3.6-3.6.2)

9. Document all sampling activities as required (see DOC-3.0-3.1).

4.2.3 Labeling and Packing of Frozen Specimens.

Supplies: Insulated shipping container, dry ice (1 pound for each pound of material to be shipped, 5 pounds minimum), packing material (bubble wrap), strapping tape, sample labels and tags, and marking pens.



(a) incision line; (b) expose organs under breast muscle and sternum; (c) esophagus, heart, liver, and gizzard; (d) dissect out heart; (e) remove liver; and (f) tie-off and remove the gastrointestinal tract (DOI, 1987).

Figure 10. Dissecting a duck carcass.

1. Shipping container should be sized to contain samples, dry ice and a small amount of packing material.

2. Place a layer of dry ice on the bottom of the insulated shipping container.

3. Place a layer of packing material on the dry ice.

4. Identify each carcass separately with a sample tag fastened by a wire to a leg. Address all categories and parameters identified in the Documentation Guidance RFM, using indelible marker.

5. Place each specimen in an appropriate container.

6. Attach sample labels and tags to containers, addressing all the categories, and parameters identified in the Documentation Guidance RFM.

7. Wrap each sample container in packing material and place in shipping container.

8. Place a layer of packing material on top of the sample.

9. Place a layer of dry ice on top.

10. Repeat steps 4-7 until all the samples are packed.

11. Fill remainder of container with packing material.

12. Place the lid on the container.

13. Tape the lid in place, wrapping the entire perimeter of each individual container with the strapping tape. Use an indelible marker to write on the tape, listing the type of bird, the kind of tissue, and date the sample was taken.

14. Complete all chain-of-custody records as required (Documentation RFM, Section 3.6).

4.3 Egg Sampling, Handling, and Storage

The methods employed in preparing eggs for shipment will depend upon whether egg shell measurements will be made in the field. If egg shell measurements are needed, field personnel should take the measurements, then pour the egg contents into chemically cleaned jars. The contents can be frozen and shipped for analysis as with any other tissue stored in jars.

4.3.1 Egg Measurements

Supplies Vernier Caliper, forceps, scalpel, spatula (rounded tip), Starrett Dial Indicator Pocket Gage (0.01 mm graduations and with rounded contacts), and laboratory balance.

Methods

External Measurements and Egg Preparations

1. Record general egg condition and any obvious gross abnormalities. If egg is dirty, clean it using a soft bristle brush and ASTM Type II (DDI) water that is at or near the temperature of the egg.

2. If any cracks in the shell are present the egg should not be rinsed or immersed in water as this may compromise the sample. If there is significant leakage of contents from the egg, the contents probably should not be retained for analysis because of residue concentrations lost.

3. Calibrate calipers (Vernier Caliper and Starrett Pocket Gage).

NOTE: Make sure the substrate you work on when opening eggs is compatible with the contaminants that you will be looking for (aluminum is allowable for organochlorines and mercury). Use clean instruments scalpel, spatula, and forceps between eggs.

4. Measure egg length and breadth at the widest point before the egg is opened using a vernier caliper.

5. Tare a laboratory balance. Measure and record the whole weight of the egg.

6. Cut the egg in half at the equator by using the tip of the scalpel to etch the surface of the egg. Repeat several times until you have cut through the shell. While holding the egg over sample container to catch contents, insert the scalpel into the cut and twist . Use scalpel to cut through membranes if needed.

Caution: If the egg appears to be rotten, put it in a container (wrap completely in foil if compatible with contaminants to be analyzed for) and use the scalpel blade to poke to release pressure.

7. Empty contents of the egg into sample container and use the spatula to scrape the remaining residue if adhering to membranes being careful not to damage the membranes if possible. Gently rinse the inside and outside of the shell with water.

NOTE: When dumping egg contents in sample container note if the inner membrane is lost with contents. This information is helpful later when measuring shell thickness.

8. Weigh the sample container with egg contents, then subtract the weight of the container to get the weight of the contents.

9. If requested, you may need to examine the egg contents (using forceps) to determine if an embryo is present and general stage of development.

Egg Shell Thickness Measurements

1. Check the egg shell for (a) clean, smooth surfaces and (b) all three parts of the shell (egg shell, outer and inner membranes) are together and not separated (to be sure the inner membrane is present, look for a glossy appearance and smooth feel).

2. Take three or four measurements by placing the gage on selected measuring points with one hand and hold the shell in the other. Move the shell back and forth and from side to side to achieve the smallest reading (smaller shells may be light enough to naturally achieve the smallest reading without holding the shell). (Note: Take more measurements if you feel it is necessary or fewer readings if unable to find four good measuring points.)

If Patuxent Analytical Control Facility personnel are measuring the egg shells, the field biologist must keep the eggs as cool as possible without freezing the contents until the egg shells are measured.

To prepare whole eggs for shipment, individual eggs should be wrapped in either plastic sheeting with air bubbles, several layers of soft paper, or in a one-fourth to one-half inch thick layer of excelsior or similar wrapping material. Wrapped eggs are then packed firmly in cans (such as empty paint cans) or jars. Several eggs should be packed in each container firmly enough to prevent movement if the container is shaken. Keep the small end of the egg pointed downwards to lessen the potential for breakage. Eggs should not be packed so firmly that the eggs are cracked. Pack groups of containers in insulated boxes with sufficient packing material to prevent shifting. Dry-ice or blue-ice should be packed with the containers to keep the eggs cool during shipment. Identify the shipping container with the appropriate sample labels and tags identified in the Documentation Guidance RFM. Further information on egg handling and shipping procedures can be obtained from the Patuxent Analytical Control Facility.

4.4 Blood Samples

Blood sampling methods may vary according to analytical requirements. The analytical laboratory must be consulted if analyses are needed for non-routine chemicals. Specifics that should be addressed include (a) quantity, (b) handling procedure, (c) glassware, and (d) chemicals for blood chemistry. The general procedure is given as follows:

- After the capture of a bird, put a sack, tunic or hood over its head to calm and sedate the bird.

- Lay the bird on its back and secure the legs with leather strips, cord, or rubber banding. This is especially important when working with raptors.

- Sterilize the patagium (expandable, membranous fold of skin between the wing and the body of the bird) by soaking it with alcohol until feathers are wet. The vein should be plainly visible.

- Take a blood sample using a 20 to 25 gauge stainless steel needle for raptors (10 ml is the usual amount required, however, the sample volume and needle gauge will vary according to

the size of the bird. For example, 1 ml is generally taken from birds the size of kestrels). Even small amounts of blood removed from small birds can result in hematoma.

- The needle and syringe should be heparinized (to prevent clotting). This is done by drawing sodium heparin into the needle and syringe, then expelling it. The procedure can be performed in the laboratory or the field. Pre-heparinized needles and syringes can be purchased.

- Blood should be split into equal amounts. One half is frozen for heavy metal analysis. The remaining half is mixed with formalin for organochlorine analysis. Stan Wiemeyer (Patuxent) recommends a ratio of 5 ml formalin to 10 ml blood for organochlorine samples.

- Some laboratory analyst require that two slide smears be taken at the time of collection.

- Centrifuging may or may not be required before shipping. Contact the analytical laboratory for specific requirements.

5. REFERENCES

Arnold, K. A. and D. W. Coon, 1972. "Modification of the Cannon Net for Use With Cow Bird Studies," Journal of Wildlife Management 36:153-155.

Berger, D. D. and F. Hammerstrom, 1962. "Protecting a Trapping Station from Raptor Predation," Journal of Wildlife Management 26, pp. 203-206.

Bleitz, D., 1970. "Mist Nets and their Use," Inland Bird-Banding Association News 42(2):43-56.

Briggs, R. L., 1977. "Mist Netting Waterfowl," North American Bird Bander 2(2):61-63.

Clark, W. S., 1970. "Migration Trapping of Hawks and Owls at Cape May, N.J. - Third Year EBBA News 33:181-189.

Clark, W. S., 1976. "Cape May Point Raptor Banding Station: 1974 Results," North American Bird Bander 1:5-13.

Collister, A., 1967. "Simple Noose Trap," West Bird Bander 42:4.

Cooch, G., 1983. "Techniques for Mass Capture of Flightless Blue and Lesser Snow Geese," Journal of Wildlife Management 17(4):460-465.

Cummings, G. E. and O. H. Hewitt, 1964. "Capturing Waterfowl and Marsh Birds at Night With Light and Sound," Journal of Wildlife Management 28, 1.

Dietrich, R. (ed.), 1978. Diseases of Wildlife in Alaska, Institute of Arctic Wildlife Research, University of Alaska.

Dill, H. H. and W. H. Thornsberry, 1950. "A Cannon-Projected Net Trap for Capturing Waterfowl," Journal of Wildlife Management 14:132-137.

DOI, United States Department of the Interior, 1987. Injury to Fish and Wildlife Species, No. PB88-100169.

Evans, M. and J. Kear, 1972. "A Jacket for Holding Large Birds for Banding," Journal of Wildlife Management 36:1265-1267.

Field, M., 1970. "Hawk-Banding on the Northern Shore of Lake Erie, Ont.," Bird-Bander 6:52-69.

Harris, S. W. and M. A. Morse, 1958. "The Use of Mist Nets for Capturing Nesting Mourning Doves," Journal of Wildlife Management 22(3):306-309.

Heimerdinger, M. A. and R. C. Leberman, 1966. "The Comparative Efficiency of 30 and 36 mm Mesh Nets," Bird-Banding 37(4):280-285.

Imler, R. H., 1937. "Methods for Taking Birds of Prey for Banding," Bird-Banding 8:156-161.

Jenkins, M. A., 1979. "Tips on Constructing Monofilament Nylon Nooses for Raptor Traps," North American Bird-Bander 4:108-109.

Kenward, R. E. and V. Marcstrom, 1983. "The Price of Success in Goshawk Trapping," Raptor Res. 17:84-91.

Labisky, R. F., 1968. "Night Lighting: Its Use in Capturing Pheasants, Prairie Chickens, Bobwhites, and Cottontails," Illinois Natural History Survey Biological Notes, No. 62.

Mechlin, L. M. and C. W. Shaiffer, 1980. "Net-firing Gun for Capturing Breeding Waterfowl," Journal of Wildlife Management, 44, 4.

Meredith, R. L., 1943. "Methods, ancient, medieval, and modern, for the capture of falcons and other birds of prey," The Art of Falconry, Stanford University Press, Stanford, California. pp. 433-449.

Migratory Animal Pathological Survey, 1966. "An Asian Bird-Bander's Manual," P.O. Box 3443, Hong Kong.

Mueller, H. C. and D. D. Berger, 1967. "Observations on Migratory Saw-Whet Owls," Bird-Banding, 38:120-125.

Pendleton, B. A. Giron, 1987c. Raptor Management Techniques Manual, National Wildlife Federation.

Schemnitz, S. D. 1980. Wildlife Management Techniques Manual, 4th ed., The Wildlife Society, Washington, DC 686 p.

Tordoff, H. B., 1954. "An Automatic Live-trap for Raptorial Birds," Journal of Wildlife Management, 18:281-284.

Walkimshaw, L. H., 1965. "Mist-netting Saw-whet Owls," Bird-Banding, 36:116-118.

Wiseman, A. J., 1979. "On Building a Better Bird Trap," Bird-Banding, 51:30-41.

Worten, W. A., 1955. "A Trapping Technique for Band-Tailed Pigeons," Journal of Wildlife Management, 19(3):411-412.

6. BIBLIOGRAPHY

Berger, D. D. and H. C. Mueller, 1959. "The Bal-Chatri: A Trap for the Birds of Prey," Bird-Banding, 30:18-26.

Colorado Division of Wildlife, 1981. Manual of Communicable Wildlife Diseases in Colorado, W. Aldren (ed.), Colorado Division of Wildlife, Fort Collins, CO.

Cooperrider, A. Y., R. J. Boyd, and H. R. Stuart (eds.), 1986 Inventory and Monitoring of Wildlife Habitat, XVIII, U.S. Department of Interior, Bureau of Land Management, Service Center, Denver, Colorado, p. 858.

Davidson, W. R. and V. F. Nettles, Field Manual for Wildlife Diseases in Southeastern United States, Athens, GA, 209 pages.

Davis, D. E., 1987. Handbook of Census Methods for Terrestrial Vertebrates, CRC Press, 1987.

DOI, United States Department of the Interior, 1987b. Field Guide to Wildlife Disease - General Field Procedures and Diseases of Migratory Birds, Fish and Wildlife Service, Resource Publication No. 167, Washington, DC.

DOI, United States Department of the Interior, 1967. Live-Trapping North American Upland Game Birds, Bureau of Sport Fisheries and Wildlife, Washington, DC.

DOI, United States Department of the Interior, 1968. Mourning Dove Capture and Banding, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, No. 117.

DOI, United States Department of the Interior, 1944. Local Control of Magpies Through Destroying Nest and Roosts and Through Trapping, Fish and Wildlife Service, Wildlife Leaflet 252, Chicago, Illinois.

DOI, United States Department of the Interior, 1978. Exposure of Marine Birds to Environmental Pollutants, Fish and Wildlife Service No. 9, Washington DC.

DOI, United States Department of the Interior, 1967. A Field Guide to Cannon Net Trapping, Bureau of Sport Fisheries and Wildlife, Washington, DC.

Haramis, G. M., et al., 1982. "Techniques for Trapping, Aging and Banding Wintering Canvasbacks," Journal of Field Ornithology 53, 4, pp. 342-351.

Keyes, B. E. and C. E. Grue, 1982. Capturing birds with mist nets: A review. North American Bird Banding 7(1):2-14.

Lincoln and Baldwin, 1929. The Manual for Bird Banders, U.S. Fish and Wildlife Service.

McClure, H. E., 1984. Bird Banding. The Boxwood Press, Pacific Grove, CA, p. 341.

Smith, J. C., M. J. Smith, B. L. Hilliard, and L. R. Powers, 1983. "Trapping Techniques, Handling Methods and Equipment Use in Bio-telemetry Studies of Long-eared Owls," North American Bird-Bander, 8:46-47.

Thompson, M. C. and R. L. DeLong, 1967. "The Use of Cannon and Rocket-Projected Nets for Trapping Shorebirds," Bird-Banding, 38:2124-2128.

ATTACHMENT 1

ADDRESSES OF U.S. FISH AND WILDLIFE SERVICE, DIVISION OF LAW ENFORCEMENT REGIONAL OFFICES THAT ISSUE PERMITS

BIRD SAMPLING
REFERENCE FIELD METHODS

Regional Offices--Special Agents in Charge

Region 1 (Calif., Hawaii, Idaho, Nev., Oreg., Wash.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
847 N.E. 19th Avenue
Suite 225
Portland, OR 97232
(503) 231-6125

Region 2 (Ariz., N.M., Okla., Tex.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 329
Albuquerque, NM 87103
(505) 766-2091

Region 3 (Ill, Indiana, Iowa, Mich., Minn., Mo., Ohio, Wisc.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 45
Federal Building, Fort Snelling
Twin Cities, MN 55111
(612) 725-3530

Region 4 (Ala., Arkansas, Fla., Ga., Ky., La., Miss., N.C., S. C., Tenn.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 439
Richland B. Russell Federal Building
Atlanta, GA 30302
(404) 221-5872

Region 5 (Conn., Del., Maine, Md., Mass., N.H., N.J., N.Y., Pa., R.I., Vt., Va., W. Va.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 129, New Town Branch
Boston, MA 02258
(617) 965-2298

Region 6 (Colo., Kans., Mont., Nebr., N.D., S.D., Utah, Wyo.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 25486
Denver Federal Center
Denver, CO 80225
(303) 236-7540

Region 7 (Alaska)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 4-2597
Anchorage, AK 99509-2597
(907) 786-3311

Bird Banding Laboratory - U.S.
Chief
Bird Banding Laboratory
Office of Migratory Bird Management
U.S. Fish and Wildlife Service
Laurel, MD 20708

Bird Banding Laboratory - Canada
Canadian Bird Banding Office
Canadian Wildlife Service
Environment Canada
Ottawa, Ontario K1A 0E7

Office of Management Authority
U.S. Fish and Wildlife Service
18th & C Street, NW
Washington, DC 20240

ATTACHMENT 2

OUTLINE OF DISEASE CONTROL OPERATIONS

EQUIPMENT AND SUPPLIES USED
IN DISEASE CONTROL OPERATIONS

STATION DISEASE CONTINGENCY PLAN

BIRD SAMPLING
REFERENCE FIELD METHODS

OUTLINE OF DISEASE CONTROL OPERATIONS
Taken from "Field Guide to Wildlife Diseases" (DOI, 1987b)

I. PLANNING

A. IDENTIFY NEEDS

1. Sources of additional personnel to help during disease emergencies.
   a. state and federal agencies
   b. active military and National Guard
   c. private conservation agencies
   d. local sportsmen clubs
   e. local universities

2. Sources and availability of equipment and supplies for disease control operations

3. Special needs
   a. burning permits
   b. Section 7 consultations
   c. lodging and meal facilities for work crews
   d. ability to attract and hold animals on site-specific areas by providing food, water, refuge, or other means
   e. ability to deny animal use by specific areas by scaring devices and other means
   f. ability to capture animals for sampling, immunization, or other needs

B. RECORD BIOLOGICAL INFORMATION

1. Daily and seasonal animal movement patterns within general area

2. Migration patterns and population peaks for major and endangered species

3. Past history of diseases

II. INITIAL RESPONSE

A. IDENTIFY PROBLEMS

1. Obtain diagnosis by submitting carcasses to a qualified diagnostic laboratory as soon as mortality or morbidity is evident

2. Conduct field investigation to determine extent of problem (i.e., species, number of animals, and geographic area involved

3. Identify special biological, political, or physical considerations associated with problem. Before proceeding further with II. B and C, consult a specialist.

B. ESTABLISH CONTROL OF AREA

1. Close affected area, when warranted, to all but authorized personnel.

2. Identify special work areas for disease control activities.
   a. carcass disposal sites
   b. laboratory investigations area
   c. briefing area for news media and staff
   d. vehicle parking
   e. assembly areas for arriving workers
   f. command post

3. Initiate carcass cleanup, but do not dispose of carcasses without guidance from disease control specialists.

C. COMMUNICATIONS

Notify appropriate agency and nonagency personnel of die-off.

III. DISEASE CONTROL

A. RESPONSE

1. Disease control actions are dictated by the type of disease, environmental factors, species involved, and other circumstances. Typically, actions associated with major die-offs require:
   a. bringing personnel, equipment, an supplies on-site
   b. organizing work force, briefing workers about the problem, and assigning duties
   c. carcass pickup and disposal
   d. monitoring cause of mortality to detect changes in the cause of the problem (die-offs often involve more than a single cause and different control actions may be required for these different causes)
   e. decontamination of personnel and equipment
   f. news media briefing sessions and "show-me" trips

B. MANAGEMENT

1. Disease management activities often involve:
   a. population manipulation such as removal, controlled movement including relocation and local concentration of animal populations, and population dispersal
   b. habitat manipulation to prevent, attract, or maintain animal use of an area

2. Decontamination of the infected environment, such as:
   a. chemical treatment of land, water, and structures
   b. vegetation and water removal (desiccation) to allow air and sunlight (ultraviolet) to destroy microorganisms
   c. controlled burning to remove vegetation and dispose of mechanical structures

IV. SURVEILLANCE

A. MONITORING

After disease control operations have ended, the area should be kept under surveillance for 10 to 30 days to watch for additional flare-ups.

B. INVESTIGATIONS

This stage is also an appropriate time to conduct follow-up investigations of factors that helped cause and sustain the problem, and to carry out animal population and environmental sampling to discern disease exposure patterns and environmental reservoirs of disease agents.

V. ANALYSIS

Each disease control operation provides a learning experience. It is important to the success of future operations to evaluate what was done, the degree of success achieved, problems encountered, and what should have been done differently.

EQUIPMENT AND SUPPLIES USED IN DISEASE CONTROL OPERATIONS.

ACTIVITY	EQUIPMENT AND SUPPLIES
A. CARCASS COLLECTION	
1. Transportation of personnel	a. all-terrain and four-wheel vehicles, snowmobiles b. airboats, canoes, other boats c. helicopter d. waders, snowshoes
2. Transportation of carcasses	a. large, heavy-duty plastic bags b. plastic trash cans with lids c. sleighs and trailers d. trucks, boats e. strapping tape, duct tape
B. CARCASS DISPOSAL 1. Burial	a. earth-moving equipment for digging trenches or pits (bulldozer, backhoe) b. shovels c. lime or fuel oil to spread on carcasses d. trucks, boats
2. Incineration	a. portable incinerators and fuel b. local permanent incinerator c. earth-moving equipment for digging trenches or pits (bulldozer, backhoe) d. burning permits e. shovels f. metal grates and cinder blocks for building burning platforms sheet metal or metal roofing for heat reflectors h. fuel for burning carcasses (wood, coal, rubber tires, fuel oil, napalm) i. fire suppression equipment
C. SANITATION PROCEDURES 1. Decontamination of environment and structures	a. chemicals such as Environ, chlorine bleach b. pumps and suction apparatus for water drainage c. buckets, brushes d. spray application by aircraft, power systems mounted in trucks and boats, and hand-carried spray units
2. Protection of personnel and prevention of mechanical movement of disease agents to secondary locations by people and equipment	a. rain-gear, coveralls, rubber gloves/boots, hats b. spray units and chemical disinfectants such as Environ and chlorine bleach people and equipment c. plastic bags for transportation of field clothes to laundry, brushes, buckets

D. FIELD COMMUNICATIONS 1. Field activities	a. portable radios for communication between field personnel b. radios in vehicles for communication between field units and between units and command post
2. Information activities	a. typewriter for preparing briefing documents b. maps, acetate, and other supplies for overlays depicting die-off and control activity information c. telephone lines for communication with others, supply operations d. transportation for news media "show-me" trips
E. SURVEILLANCE/OBSERVATION 1. Field activities	a. aircraft and pilots certified for low-level flights (500 feet and below) for monitoring animal populations and environmental conditions b. binoculars and spotting scopes
2. Office activities	a. maps, acetate, and other supplies for tracking the progress of events and animal populations associated with die-off b. telephone for contacting others to trace movement of migrant animal populations that might enter problem area or that have departed problem area
F. ANIMAL POPULATION AND HABITAT MANIPULATION 1. Denying animal use of a specific area	a. aircraft, boats, snowmobiles, and other motorized means of hazing animal populations b. propane exploders c. crackers shell, break-open shotguns, and protective face shield d. audio systems and other scare devices e. pumps for draining water or adding water to areas
2. Concentration and maintenance of animals in a specific area	a. grain and other sources of food b. pumps and water to provide habitat c. Hunting" and "Area Closed" signs to provide temporary refuge area
G. ANIMAL SAMPLING AND MONITORING 1. Animal capture	a. cannon nets and other capture equipment b. grain and other baits to lure animals to capture site
2. Animal marking	a. visible marking devices such as paint, neck collars, and other devices b. permanent marking devices (leg bands, ear tags) c. temporary marking devices such as radio transmitters

STATION DISEASE CONTINGENCY PLAN

INTRO-DUCTION

I. Size, configuration, and other important characteristics of station area conveyed with help of tables, maps, photographs, station brochures, public use maps, and similar documents.

II. Record of previous disease outbreaks, including nature of disease, species involved, magnitude of die-off, and season and year.

DISEASE

I. Brief outline of current surveillance activities on station and adjacent Surveillance areas-State, Federal, and private.

II. Identify disease reporting and notification procedures (names, titles, organization, and telephone numbers of persons to be contacted).

DISEASE RESPONSE

I. Logistical considerations

A. Personnel sources (telephone numbers, addresses, names of contact persons).

B. Equipment (types and numbers on-site, and sources off-site).
1. Vehicles (conventional and all-terrain)
2. Aircraft (fixed-wing and rotary)
3. Earth-moving equipment (backhoe, bulldozer)
4. Pumps (for flooding or draining marshes)
5. Boats (motor, self-propelled, air boats)
6. Radios (portable and fixed); during nonfire seasons the Boise Interagency Fire Center, 3905 Vista Avenue, Boise, Idaho 83704, is a potential source for obtaining assistance
7. Incinerators
8. Decontamination units (sprayers)
9. Scaring devices (propane exploders, sirens)
10. Freezers
11. Portable toilets (construction site type).

C. Supply Sources (identify sources, addresses, and telephone numbers of local or closest sources)
1. Disinfect and chemicals
2. Plastic bags
3. Fuel for carcass burning
4. Field clothes (gloves, rainwear, coveralls, boots)
5. Plastic trash barrels, tubs, scrub brushes
6. Scaring devices (cracker shells, fireworks); provide contact telephone number and address for local animal damage control office
7. Dry ice and liquid nitrogen
8. Grain and other wildlife foods
9. Nearest shipping address for air and ground receipt of goods and supplies

D. Lodging for Temporary Personnel Assigned to Disease Control Operation

E. Food
   1. On-site capabilities
   2. Off-site capabilities (give consideration to early and late hours).

F. Identify Working Areas (diagrams, limited narrative)
   1. Clean areas
      a. command post (must have adequate telephones)
      b. news media briefing room
      c. parking
      d. eating areas
      e. staff assembly and rest areas
      f. equipment and supply receipt
      g. other
   2. Transition areas
      a. decontamination of personnel
      b. decontamination of equipment
   3. Contaminated areas
      a. carcass disposal
      b. laboratory investigations
      c. animal holding

II. Biological considerations (Provide data in charts, figures, photographs, maps)

A. Species and Population Data Major species (identify by season of presence, relative abundance, and peak population periods)

B. Animal Movement Patterns
   1. Daily
   2. Seasonal
   3. Production and dispersal patterns

C. Weather Patterns
   1. Freeze-up and ice-put periods
   2. Major periods of precipitation and drought
   3. Other (temperature profiles, haze, fog, high winds)

D. Habitat and Population Manipulation Potential
   1. Methods (water manipulation capability, feeding)
   2. Anticipated population response to habitat (movement, concentration, dispersal)

III. Communications (Provide lists of local/regional personnel and phone numbers)

A. State Agencies
   1. Conservation
   2. Agriculture

3. Health Department
4. University diagnostic laboratories

B. Federal Agencies
1. Environmental Protection Agency
2. U.S. Department of Agriculture
3. Public Health Service

C. Other Organizations
1. Cooperating organizations
2. Local sportsman clubs
3. Private wildlife area managers
4. Local game breeder organizations
5. Local domestic animal husbandry and production operations

D. Media
1. Television
2. Radio
3. Newspapers

OTHER INFORMATION

I. Location of nearby laboratories (hospitals, universities, count and State facilities).

II. Federal and state permit status for biological collections.

III. Burning permits

IV. Regulatory requirements

V. Background information (e.g., water sources, water quality data, potential sources of disease transmission between wildlife and domestic animals).

VI. Identification and location of adjacent or nearby wildlife refuges, management areas, and private preserves.

VII. Identification of unusual or politically sensitive aspects of area.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D.3 FISH SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix D.3 of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
   - D.3 Fish Sampling Reference Field Methods
   - D.4 Flora Sampling Reference Field Methods
   - D.5 Reptiles and Amphibians Sampling Reference Field Methods
   - D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
0	10/2/91	2.1	2-4	2-4c	5
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

U.S. Fish and Wildlife Service
Division of Environmental Contaminants
4401 North Fairfax Drive, Room 330
Arlington, VA 22201

Commentor's Name_____ Phone_____

Address_____City_____State___Zip_____

Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

References (if applicable):

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ACRONYMS

BLM	Bureau of Land Management
COC	chain of custody
DDT	dichlorodiphenyltrichloroethane
EC	Environmental Contaminant
EPA	Environmental Protection Agency
ETOH	ethyl alcohol
FDA	Food and Drug Administration
NCBP	National Contaminant Biomonitoring Program
NFS	National Fishery Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzoparadioxins
PCDFs	polychlorinated dibenzofurans
RBP V	Rapid Bioassessment Protocol
RFM	Reference Field Methods
SOP	Standard Operating Procedures
USGS	U.S. Geological Service

U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D.3

FISH SAMPLING REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of this Reference Field Methods (RFM) document is to provide guidance to Fish and Wildlife Service (FWS) personnel for monitoring the fish community and obtaining selected fish samples for physical and chemical analysis. Data generated from fish samples can be used by refuge personnel and Environmental Contaminant (EC) specialists to establish baseline data for a site or to help monitor the effects from current or historic contaminant exposure to the site.

1.2 Scope

This RFM is intended to guide Service personnel in collecting fish and in making appropriate use of associated data for contaminant monitoring activities. This document is not intended to provide guidance in sampling design or to include all the procedures for collecting these organisms. There are situations that may require collection devices and procedures other than those presented here. The methods provided here should be acceptable for most field contaminant studies. In special situations, EC specialists and experts in the field should be consulted for additional guidance. If methods other than those discussed in this document are used, they should be well documented so they can be duplicated, and future sampling efforts can easily follow the same procedures.

Section 1 provides a brief background discussion on the use of fish for contaminant monitoring activities. Additional information sources are included that may be useful when planning and implementing these activities.

Table 1 provides an overview of the sampling methods presented in this document. Section 2 discusses the collection of fish and the rationale for monitoring their community structure; community indices and their usefulness for field contaminant studies; and items that should be considered before sampling. Section 3 details the collection and handling of fish for various sampling situations; sampling devices and procedures; and sample preservation and handling techniques.

1.3 Background

Fish should be included in any contaminant monitoring program involving aquatic ecosystems. Fish generally occupy the upper levels of the aquatic food chain and are directly and/or indirectly affected by chemical and physical changes in the environment. Water quality conditions that impact

Table 1. Key to Fish Sampling Methods

Sampling Procedure	Location in RFM	Type of Monitoring*	Advantages	Disadvantages	May Need Assistance
ELECTROSHOCKING shallow river, lakes and streams	Section 3.1.1	A,B,C	Most efficient and nonselective Relatively mobile Adaptability to many habitats and conditions Immediate results Useful at sites with irregular bottom contours and around snags	Nonselective - can stun or kill most fish Equipment costs Can be hazardous if not used properly Requires operator Requires three or more people	FWS training and certification required State Fish and Game Local university or cooperative research unit
SEINING shallow river, lakes and streams shoreline areas of estuaries	Section 3.1.2	A,B,C	Relatively inexpensive and easy to operate Mesh size selection available for target species	Cannot be used in deep water Lower efficiency in deep water as fish can escape during operation Substrates should be clear of rocks and submerged vegetation Somewhat selective	State Fish and Game FWS
TRAWLING (Used from boat(s) in deep, open, low flow velocity bodies of water)	Section 3.1.3	A,B,C	Effective in deep water Allows collection of large numbers and diversity of samples and conditions	Not effective for flowing systems Requires boat and personnel with operator training	Local fishermen State Fish and Game Local University cooperative
ANGLING Species selective, involving use of hook and line	Section 3.1.4	C	Most selective method Does not require large numbers of personnel or equipment	Too selective Inefficient and time consuming	Local fisherman or guides
PASSIVE Gill nets, low-flow velocity lakes, rivers, and estuaries, used where fish movement is expected or anticipated	Section 3.2.1	A,B,C	Effective for collecting pelagic species Easy to operate Selectivity can be controlled by varying mesh size	Not effective for fish populations that do not exhibit movement patterns Selective for size Nets prone to tangling and clogging	State Fish and Gam Local University cooperative research units

* A = Initial Screening/Characterization
B = General Monitoring
C = Special Case Monitoring

Table 1. (continued)

Sampling Procedure	Location in RFM	Type of Monitoring*	Advantages	Disadvantages	May Need Assistance
TRAMMEL NETS Used in streams, lakes, and estuaries, frequently used where fish may be scared into the net	Section 3.2.1	A,C	Mesh size enables selectability Unattended operations Useful in areas where active methods are impractical	Nets prone to tangling and clogging Selective for size Not effective for bottom dwelling fish or populations that do not exhibit movement patterns	State Fish and Game Local university cooperative research units
ENTRAPMENT DEVICES Hoop Nets Used in fast moving deep waters	Section 3.2.2	A,C	High efficiency (effort vs. return) Unattended operations Useful for bottom-feeders and fish exhibiting movement patterns	Extensive set-up and maintenance time required Inefficient for short-term	State Fish and Game Local University cooperative research units
FYKE NETS Best used in shallow waters with low-flow velocity	Section 3.2.2	A,C	Unattended operation Can be serviced by single individual Useful for cover-seeking, mobile species (perch, sunfish)	Can be clogged by various debris Extensive set-up, inefficient for short-term	State Fish and Game Local University cooperative research units
TRAP NETS Used in water up to 12 m deep with clean, firm bottom	Section 3.2.2	A,C	Effective for migratory species that follow shorelines	Anchors fail to hold in soft bottoms Extensive set-up time	State Fish and Game Local University cooperative research units
POT GEARS Used in shallow to deep water	Section 3.2.2	A,C	Portable Does not require extensive manpower to fish	Not efficient for estimating relative abundance	Local University cooperative research Units Local fishermen
EXPLOSIVES Shallow lakes and streams	Section 3.2.4	C	Nonselective Useful for dense cover (weedbeds, snag pockets)	Safety and possible legal concerns High fish mortality Public concern	Check FWS policy State Fish and Game
POISON	Section 3.2.4	C	Nonselective	Not useful for contaminant residue analysis Safety and legal concerns Public concern	Check FWS policy State Fish and Game

* A = Initial Screening/Characterization
B = General Monitoring
C = Special Case Monitoring

the lower levels of the food chain may affect the abundance, species composition, and condition of fish populations. There may be cases where fish are more sensitive to the contaminant(s) than animals and plants in lower trophic levels (APHA, 1985). For certain contaminants (e.g., suspended sediment and certain metals), fish and other gill breathing organisms may be more affected by damage to gill membranes than by tissue accumulation of the contaminant. Because fish bioconcentrate some contaminants, tissue concentrations of these contaminants frequently exceed the concentrations in ambient waters and in lower trophic level food organisms by several orders of magnitude. The natural life histories of most fish species span several years; thus, sufficient time is available for fish to accumulate high residue levels through continuous, low-level exposure. In these situations, identification and chemical analysis of these "biomonitor" species may provide valuable information regarding the exposure of the ecosystem to contaminants.

Monitoring the fish community structure may also be a useful method to assess potential chronic or acute contaminant exposure. Contaminant impacts on a species may range from the elimination of the population to a slight reduction in reproductive capacity, growth, or resistance to disease and parasitism. Significant changes in community structure indices may indicate a potential contaminant problem and warrant the initiation of additional studies.

Massive fish kills are dramatic signs of abrupt changes in environmental conditions. However, because fish can repopulate an area rapidly if the niche is not destroyed, the cause of the kill may be difficult to detect by examination of the fish community after it has recovered from the effects of the perturbation. Chronic pollution is more selective in its effects and exerts its influence over a long period of time, perhaps causing recognizable changes in the species composition and relative abundance of the fish. For example, many species of fish have strict dissolved oxygen and temperature requirements, and are intolerant of chemical and physical contaminants resulting from agricultural, industrial, or mining operations. The discharge of moderate amounts of degradable organic wastes can increase the nutrient levels in the habitat and result in an increase in the standing crop of fish. However, this increase usually occurs in only one or a few tolerant species, while sensitive species may be eliminated. Measurement of this type of potential change should be considered as a component of contaminant field studies that can link biological (ecosystem) change and contaminant (chemical) analysis.

One possible indication of the relative severity of a contaminant impact is the absence of one or more fish species in aquatic habitats otherwise well suited for habitation. Total absence of fish in a particular habitat, significant reductions in total densities, or a substantial decrease in the number of species present may be attributable to acute lethal effects, chronic reproductive failures, or voluntary (behavioral) avoidance of an area as a result of contamination or lack of sufficient prey or suitable habitat (which also may be a result of contamination).

1.4 Information Sources

Contact local EC specialists and regional EC Coordinator for initial information needs. The Environmental Protection Agency (EPA), National Forest Service (NFS), Bureau of Land Management (BLM), National Park Service (NPS), as well as state agencies (e.g., Fish and Game or Water Quality) have fisheries biologists and ecologists that might be helpful. Cooperative fishery research units at local universities should also be used for their expertise and cost-effectiveness,

particularly if taxonomic classification is necessary for monitoring activities. Additional references can be found in this RFM.

2. MONITORING CONSIDERATIONS

2.1 Presampling Considerations

Before initiating a fish sampling program, the overall objectives of the contaminant monitoring program must be established. The objectives will be largely determined by the goals of the Service, the potential risk to important resources at the site, and the physical characteristics of the site. It is assumed that the objectives of the contaminant field studies have been defined and that sampling of fish has been determined to be necessary to accomplish them. The following items should be considered before including fish as a part of your monitoring activities:

- Goals/objectives of the overall contaminant study
- Appropriateness of this medium to meet the goals/objectives of the monitoring activity
- Contaminant:
  - source(s)
  - type(s)
  - transport pathways
  - receptors
  - sinks
  - physical characteristics
- How this medium fits into the ecological (source-receptor) relationship for the site
- Whether sampling some other medium will satisfy the monitoring objectives more efficiently or effectively.

The specific methods selected for collecting fish samples depend on the type of habitat and the objectives of the sampling/monitoring activities. With respect to contaminant monitoring, there are three possible objectives in collecting fish:

1. To compare community indices at locations upstream and downstream of the contaminant source, or between contaminated and uncontaminated water bodies.

2. To determine the presence/absence or health of bioindicator species.

3. To measure contaminant residues in selected fish biomonitors.

Site selection is important for all three objectives. In addition, the first and second objectives require careful attention to sampling methods. Sample handling and preservation are important for all three objectives. However, in order to measure contaminant residues (third objective), sample handling and preservation are of special concern to minimize cross-contamination and/or otherwise affect (e.g., contaminant degradation due to improper storage of sample) the contaminant concentrations in the tissues. Sample collecting methods are less critical as long as cross-contamination is avoided.

Additional considerations in planning fish monitoring activities include evaluating characteristics such as behavior, trophic level, and spatial/temporal variations of abundance.

There are generally two broad categories of monitoring activities involving fish: (a) monitoring the community; and (b) monitoring selected species.

Monitoring the community involves an intensive effort to collect representative samples of the entire fish community in order to assess and monitor the biointegrity of the ecosystem. Community monitoring may be appropriate, depending on the purpose of the study, for baseline monitoring activities. This would also be useful for more intensive monitoring efforts to quantify the degree of damage to the community from contaminant inputs; however, this requires that baseline values for the site, or a suitable control site be available for comparison.

Monitoring selected species (b) can be divided into two subcategories. The first subcategory involves the direct measurement of chemicals bioaccumulated by individuals of a selected species (biomonitors); ideally, species used for this purpose should tolerate contaminant presence in the environment without suffering injury and population losses. The second subcategory involves examining the frequency of one or more biological responses in a fish population exposed to contaminants (bioindicators). In this case, the species selected should be quite sensitive to contaminant presence, expressing exposure as some type of injury (lesions, eroded fins, etc.), reduced growth, and/or weight loss. In some cases, a bioindicator species may be sufficiently injured or sensitive that it disappears from the community (either through avoidance or death); that in itself can be valuable information.

2.2 Monitoring the Community

For baseline monitoring, Service personnel will likely be monitoring the entire fish community for changes in "biotic integrity." Biotic integrity is defined as "the ability of a system to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of natural habitat of the region" (Karr et al., 1986). Systems possessing biotic integrity are resilient with respect to most naturally-caused perturbations as well as to many major disruptions caused by humans. Biotic integrity is not necessarily correlated with harvestable products (such as desirable sport fish) or species of economic value. In fact, in some systems the presence of harvestable products in large amounts may indicate a loss of integrity.

It is recognized that many Service lands consist of highly modified habitat such as diked wetland pools and other shallow water bodies. Biotic integrity may already be compromised because of habitat alteration and manipulation. For these systems it may be difficult to find control areas with which to compare community composition, and high biotic integrity may be unattainable because of habitat limitations. Nevertheless, it is worthwhile to perform at least an initial analysis of the fish community asa starting point, using the methodology described below. If the community is found, for example, to consist of only tolerant species, then monitoring selected bioindicator species for several parameters (Section 2.3.2) may be the optimal strategy.

Impacts of contaminants on the biotic integrity of running waters can be assessed using the EPA's Rapid Bioassessment Protocol V [RBP V (Plafkin et al., 1989)]. RBP V employs Karr's Index of Biotic Integrity (IBI), which is described in Karr et al., 1986. The IBI has been endorsed by the EPA for use in ecological assessment of hazardous waste sites (Warren-Hicks et al., 1989). Generally, the IBI incorporates data from the study of entire fish communities in twelve "metrics" [a

metric is a measure, such as total number of species, that provides information about a specific attribute of the sampling site (Karr et al., 1986)].

The RBPs were developed by EPA for use by state agencies in conducting cost-effective biological assessments of lotic (flowing water) systems (note that as of December 1989, no analogous protocols have been developed for lentic, or nonflowing systems). Some stated applications of RBPs are initial screening, priority setting, point and nonpoint source evaluations, use of attainability analyses, and trend monitoring. There are five RBPs: RBPs I through III are the benthic macroinvertebrate protocols (see Appendix D.1, Benthic Macroinvertebrate RFM), while RBPs IV and V apply to fish.

RBP IV is a survey questionnaire (Figure 1) for polling state fishbiologists and university ichthyologists believed knowledgeable about fish assemblages in stream reaches of concern. The RBP IV may be useful in the initial stages of contaminant studies if the investigator is unfamiliar with the history of the stream and local fish fauna. More detail on RBP IV is described in Plafkin et al. (1989). That reference will need to be obtained by Service personnel wishing to apply the protocols. The reference is available, free of charge, from

Office of Water
AWPD (WH-553)
U.S.Environmental Protection Agency
401 M St., S.W.
Washington, D.C. 20460

RBP V consists of three basic components: water quality/physical characteristics, habitat assessment, and a biosurvey. The RBP V is summarized below and all RBPs are completely described in Plafkin et al. (1989). Figure 2 is a flowchart of the entire approach to using RBP V. The steps are as follows:

1. Select a site. Sampling stations should be representative of the water body as a whole. For example, in streams, sampling should include at least one (preferably two) riffle(s), run(s), and pool(s) if these habitats are typical of the stream in question. Midchannel and wetland areas of large rivers, which are difficult to sample effectively, may be avoided. This may result in some species being undersampled, but data should be adequate for the objective of RBP V.

2. Identify regional fish fauna. This information should be readily available from state fish and game agencies, local universities, and regional literature. Appendix D.2 of Plafkin et al. (1989) lists some regional references.

3. Assign species to trophic, tolerance, and origin guilds. Appendix D of Plafkin et al. (1989) lists these classifications for many western and midwestern species. Appendix II of Karr et al. (1986) lists classifications for north-central species.

4. Assess available data for metric suitability and stream size patterns. For example, if no sunfishes inhabit small streams in a region, a metric rating of 5 is arbitrarily assigned to metric 3 for small stream sites because the absence of sunfishes does not indicate a degraded

FISH ASSEMBLAGE QUESTIONNAIRE

INTRODUCTION

This questionnaire is part of an effort to assess the biological health or integrity of the flowing waters of this state. Our principle focus is on the biotic health of the designated waterbody as indicated by its fish community. You were selected to participate in the study because of your expertise in fish biology and your knowledge of the waterbody identified in this questionnaire.

Using the scale below, please circle the rank (at left) corresponding to the explanation (at right) that best describes your impression of the condition of the waterbody. Please complete all statements. If you feel that you cannot complete the questionnaire, check here [ ] and return it. If you are unable to complete the questionnaire but are aware of someone who is familiar with the waterbody, please give this person's name, address, and telephone number in the space provided below.

_____

_____

_____

Waterbody code _____

Waterbody name _____

Waterbody location (also see map)

State _____ County _____ Long/Lat_____

Ecoregion _____

Waterbody size

Stream (<1 cfs, 1-10 cfs, >10 cfs)

(Answer questions 1-4 using the scale below.)

5 Species composition, age classes, and trophic structure comparable to non (or minimally) impacted sites of similar waterbody size in that ecoregion.

4 Species richness somewhat reduced by loss of some intolerant species; young of the year of top carnivores rare; less than optimal abundances, age distributions, and trophic structure for waterbody size and ecoregion.

3 Intolerant species absent, considerably fewer species and individuals than expected for that waterbody size and ecoregion, older age classes of top carnivores rare, trophic structure skewed toward omnivory.

Figure 1. Fish assemblage questionnaire for use with Rapid Bioassessment Protocol IV (source: Plafkin et al., 1989).

2 Dominated by highly tolerant species, omnivores, and habitat generalists; top carnivores rare or absent; older age classes of all but tolerant species rare; diseased fish and anomalies relatively common for that waterbody size and ecoregion.

1 Few individuals and species present, mostly tolerant species and small individuals, diseased fish and anomalies abundant compared to other similar-sized waterbodies in the ecoregion.

0 No fish

(Circle one number using the scale above.)

1. Rank the current conditions of the reach

5 4 3 2 1 0

2. Rank the conditions of the reach 10 years ago

5 4 3 2 1 0

3. Given present trends, how will the reach rank 10 years from now?

5 4 3 2 1 0

4. If the major human-caused limiting factors were eliminated, how would the reach rank 10 years from now?

5 4 3 2 1 0

(Complete each subsection by circling the single most appropriate limiting factor and probable cause.)

Subsection 1--Water Quality

Limiting factor		Probable cause	
5	Temperature too high	18	Primarily upstream
6	Temperature too low	19	Within reach
7	Turbidity	20	Point source discharge
8	Salinity	21	Industrial
9	Dissolved oxygen	22	Municipal
10	Gas supersaturation	23	Combined sewer
11	pH too acidic	24	Mining
12	pH too basic	25	Dam release
13	Nutrient deficiency	26	Nonpoint source discharge
14	Nutrient surplus	27	Individual sewage
15	Toxic substances	28	Urban runoff
16	Other (specify below)	29	Landfill leachate
	_____	30	Construction
17	Not limiting	31	Agriculture
		32	Feedlot
		33	Grazing
		34	Silviculture
		35	Mining
		36	Natural
		37	Unknown
		38	Other (specify below)
			_____

Figure 1. (continued)

Subsection 2--Water Quantity

Limiting factor	Probable source
39 Below optimum flows	45 Dam
40 Above optimum flows	46 Diversion
41 Loss of flushing flows	47 Watershed conversion
42 Excessive flow fluctuation	48 Agriculture
43 Other (specify below)	49 Silviculture
_____	50 Grazing
44 Not limiting	51 Urbanization
	52 Mining
	53 Natural
	54 Unknown
	55 Other (specify below)
	_____

Subsection 3--Habitat Structure

Limiting factor	Probable cause
56 Excessive siltation	64 Agriculture
57 Insufficient pools	65 Silviculture
58 Insufficient riffles	66 Mining
59 Insufficient shallows	67 Grazing
60 Insufficient concealment	68 Dam
61 Insufficient reproductive habitat	69 Diversion
62 Other (specify below)	70 Channelization
_____	71 Snagging
63 Not limiting	72 Other channel modifications
	73 Natural
	74 Unknown
	75 Other (specify below)
	_____

Subsection 4--Fish Community

Limiting factor	Probable source
76 Overharvest	84 Fishermen
77 Underharvest	85 Aquarists
78 Fish stocking	86 State agency
79 Non-native species	87 Federal agency
80 Migration barrier	88 Point source
81 Tainting	89 Nonpoint source
82 Other (specify below)	90 Natural
_____	91 Unknown
83 Not limiting	92 Other (specify below)
	_____

Subsection 5--Major Limiting Factor

93 Water quality
94 Water quantity
95 Habitat structure
96 Fish community
97 Other (specify)
_____

Your name (please print)_____

Figure 1. (continued)

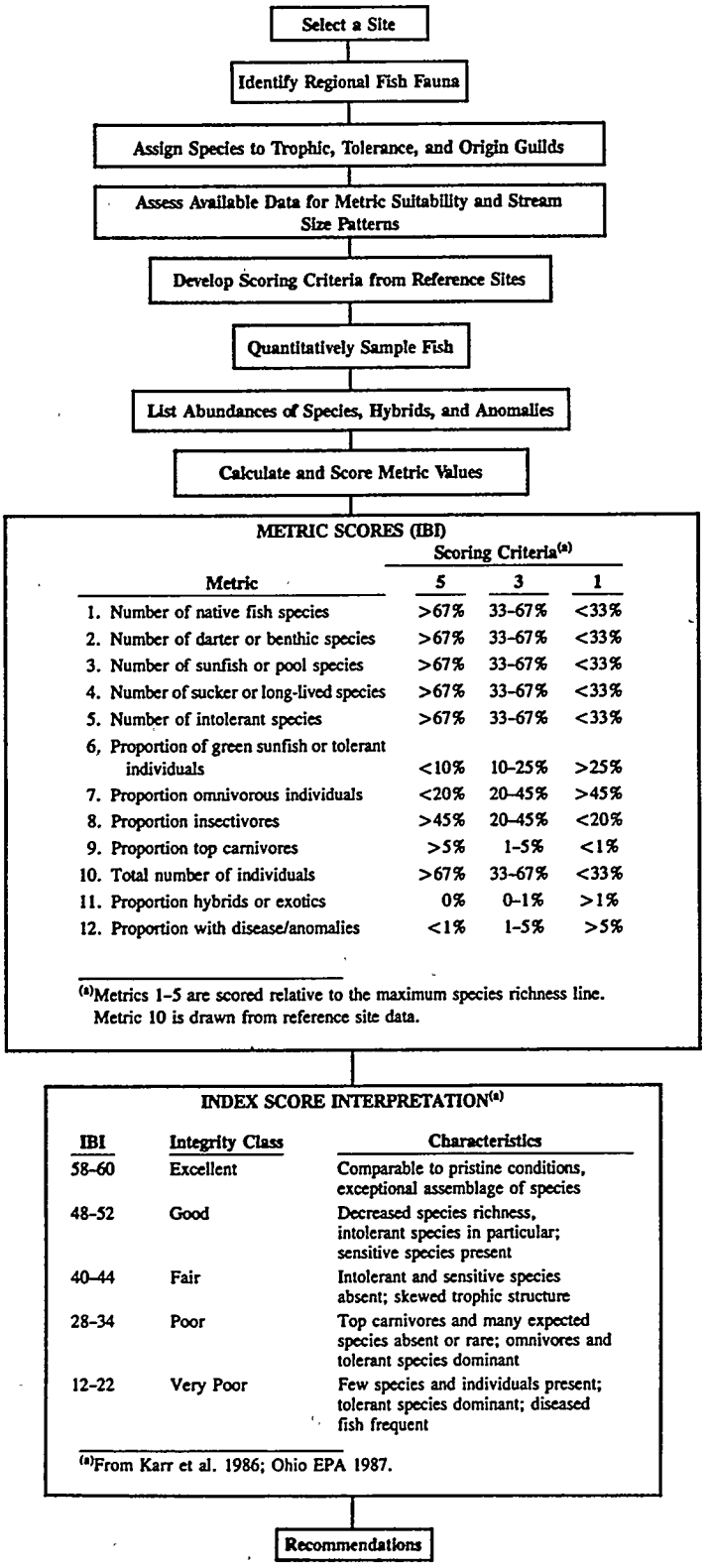


Figure 2. Flowchart of bioassessment approach advocated for Rapid Bioassessment Protocol V (Plafkin et al., 1989)

condition. More discussion of the tailoring of individual metrics is provided in Section 7 of Plafkin et al. (1989).

5. Develop scoring criteria from reference sites. Data from unperturbed sites on a stream of similar size in the same geographic region are used to develop scoring criteria. Detailed discussion of how this is done is provided in Plafkin et al. (1989) and Karr et al. (1986).

6. Quantitatively sample fish. Electrofishing (see Section 3.1.1) is the sampling technique recommended for use with RBP V. However, pilot studies may indicate the need for different or multiple gear. At least 100 individuals should be collected, if possible. The goal is to obtain a representative estimate of the species present and their abundances, for a reasonable amount of effort (generally 1 to 2 hours of actual sampling time, depending on gear used and complexity of the site). To assure comparability of fish community status among sites, sampling technique and effort should be standardized.

7. List abundances of species, hybrids, and anomalies. A field collection data sheet (Figure 3) should be completed for each sample. If retained in a live car, most fish can be identified, counted and weighed, and returned to the water alive. For purposes of this protocol, it is only necessary to separate each species into juveniles and adults (based on size and coloration) and record total numbers and weights (optional) and incidence of external anomalies (Figure 3). Weights are not used for the 12 IBI metrics, but it has been suggested (Plafkin et al., 1989) that a "Metric 13, Total Fish Biomass" may be appropriate in areas where fish size may vary by orders of magnitude.

   Weights can also be used for computing Gammon's "Index of Well-Being" (IWB). The IWB is not part of RBP V but is presented here as an index that may be useful in certain situations. The IWB was developed for use in large rivers, where it may be difficult or impossible to sample the entire fish community. The IWB is calculated as

$$IWB = 0.5 \ln N + 0.5 \ln B + H'_N + H'_B$$

   where

   N = number of individuals caught per kilometer
   B = biomass of individuals caught per kilometer
   H'= Shannon diversity index, calculated as

$$H' = -\sum p_i \log p_i$$

   where $p_i = n_i / N$ = proportion of individuals (or proportion of biomass) in the species

   Omitting highly tolerant species from the number and biomass variables may increase sensitivity of the IWB in highly degraded environments (EPA, 1987).

8. Calculate and score metric values (Figure 4). Although the metric scores add to a single "index score", one should not neglect the importance of individual metric scores in data interpretation. This is especially important when an index score falls between classes. For example, an index score of 55 falls between integrity classes "good" and "excellent". In this case, one would need to look at the metric scores that were used to derive the index score. Consistently low metric scores (for example, 34% would be a low 3 in metrics 1-5) would

page___ of___

FISH FIELD COLLECTION DATA SHEET

Drainage _____ Date _____
Sampling Duration (min) _____
Sampling Distance (m) _____ Sampling Area (m^2) _____ Crew _____
Habitat Complexity/Quality (excellent good fair poor very poor)
Weather _____ Flow (flood bankfull moderate low)
Gear Used _____ Gear/Crew Performance _____
Comments _____
Fish (preserved) Number of Individuals ____ Number of Anomalies _____

Genus/Species	Adults		Juveniles		Anomalies(*)
	No.	Wt.	No.	Wt.	No.

(*) Discoloration, deformities, eroded fins, excessive mucus, excessive external parasites, fungus, poor condition, reddening, tumors, and ulcers

Figure 3. Fish Field Collection Data Sheet for use with Rapid Bioassessment Protocol V (Plafkin et al., 1989)

indicate the integrity class should be the lower of the two classes, or "good" in this example.

If RBP V detects impairment at a study site, then the problem becomes one of separating habitat effects from water quality effects. Assessment of habitat quality is not addressed here but is adequately treated in Section 5 of Plafkin et al. (1989). Measurement of water quality is described in the Water Quality RFM.

2.3 Monitoring Selected Species

2.3.1 Biomonitors

In some cases, one may be interested only in whether contaminants are present in a system, and what the potential is for impacting higher trophic level organisms. Fish bioaccumulate contaminants to varying degrees, depending on the contaminant, fish species, temperature, and salinity to name a few variables.

The degree that fish bioaccumulate most metals is highly variable; for this reason, fish are not usually the first choice for biomonitoring of metals. However, mercury, arsenic, and cesium may bioaccumulate in edible fish tissues. Fish organs, especially livers and kidneys, accumulate a greater variety and higher levels of metals (e.g., mercury, cadmium, nickel, selenium and tin) than edible fish tissues. Secretion of metals also varies among organs. Bluegills and largemouth bass, for example, exposed to 10 ppb selenium for 120 days showed no elimination of the selenium after 30 days in clean water from spleen, liver, kidney and muscle. Gills and erythrocytes of these fish, however, showed 50% excretion after 15 days (Eisler, 1985). May et al., (1981) showed similar loss from gills and retention by kidneys and livers of brook trout exposed to cadmium. Hunn (1989) suggests that ovaries are a good organ to monitor for mercury and selenium, while testes accumulate cadmium.

Fish are excellent biomonitors for organic contaminants such as polychlorinated biphenyls (PCBs), polychlorinated dibenzo paradioxins (PCDDs), and polychlorinated dibenzo furans (PCDFs). PCDDs and PCDFs are largely insoluble and difficult to detect at low concentrations in water; therefore, the EPA and many state environmental agencies use fish tissue to identify the relative concentrations of dioxins or furans in aquatic habitats. Organic contaminants often accumulate in fish livers, while metabolites can be found in the gall bladder and bile (Hunn, 1989). The National Contaminant Biomonitoring Program (NCBP) measured some 25 organochlorine compounds in fish samples collected in 1980-81 (Schmitt et al., 1985). This monitoring network has documented the nationwide decline of DDT, PCBs, and dieldrin since a previous sampling effort in the mid 1970's.

When monitoring trends or comparing different locations, it is very important to use consistent species of the same age class for residue analyses. Species differences exist in the uptake of and tolerance to metals, as with other contaminants. Northern squawfish, for example, have been shown to accumulate significantly higher concentrations of mercury, arsenic, and zinc than other species in the same waters (Lowe et al., 1985). The Mosquito fish accumulates and can tolerate high levels of selenium (Eisler, 1985).

For contaminant monitoring in fresh water, it is recommended that the refuge manager collect fish species in accordance with the NCBP. The NCBP maintains a large database on contaminant

Station No. _____

Site _____

Metrics[a]	Scoring Criteria[b] 5 (%)	3 (%)	1 (%)	Metric Value	Metric Score
1. Number of Native Fish Species	>67	33-67	<33		
2. Number of Darter or Benthic Species	>67	33-67	<33		
3. Number of Sunfish or Pool Species	>67	33-67	<33		
4. Number of Sucker or Long-Lived Species	>67	33-67	<33		
5. Number of Intolerant Species	>67	33-67	<33		
6. % Green Sunfish or Tolerant Individuals	<10	10-25	>25		
7. % Omnivores	<20	20-45	>45		
8. % Insectivores or Invertivores	>45	20-45	<20		
9. % Top Carnivores	>5	1-5	<1		
10. Total Number of Individuals	>67	33-67	<33		
11. % Hybrids or Exotics	0	0-1	>1		
12. % Anomalies	<1	1-5	>5		

Scorer _____ IBI Score _____

Comments: _____

(a) Karr's original metrics or commonly used substitutes. See text and Table 7.2-1 for other possibilities.

(b) Karr's original scoring criteria or commonly used substitutes. These may require refinement in other ecoregions.

Figure 4. Data Summary Sheet for Rapid Bioassessment Protocol V (Plafkin et al, 1989).

residues in fish; by collecting similar species as the NCBP, one can utilize that database for comparison purposes. To be sure the most current techniques and species are being used, the EC Specialist should be contacted. The species currently recommended are

1. Bottom dwellers (preferably commercially or recreationally significant)

    a. Carp (*Cyprinus carpio*)
    b. White sucker (*Catostomus commersoni*) or other member of the sucker family
    c. Channel catfish (*Ictalurus punctatus*) or other member of the catfish family
    d. Other, with justification (document in writing)

2. Other species (preferably an important sport fish)

    a. Cold water environments: rainbow trout (*Onchorynchus mykiss*); brown trout (*Salmo trutta*); brook trout (*Salvelinus frontinalis*); lake trout (*S. namaycush*)
    b. Warm water environments: large mouth bass (*Micropterus salmoides*) or other member of the sunfish family such as crappie (*Pomoxis sp.*), bluegill (*Lepomis macrochirus*), etc.
    c. Cool water environments: walleye (*Stizostedion vitreum*), or other members of the perch family
    d. Other with justification--but must be representative of the drainage system.

In bays and estuaries, one should collect species consistent with the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program (NOAA, 1986). Target species by geographic area for this program are presented in Table 2. These species are collected with otter trawls (Section 3.1.3).

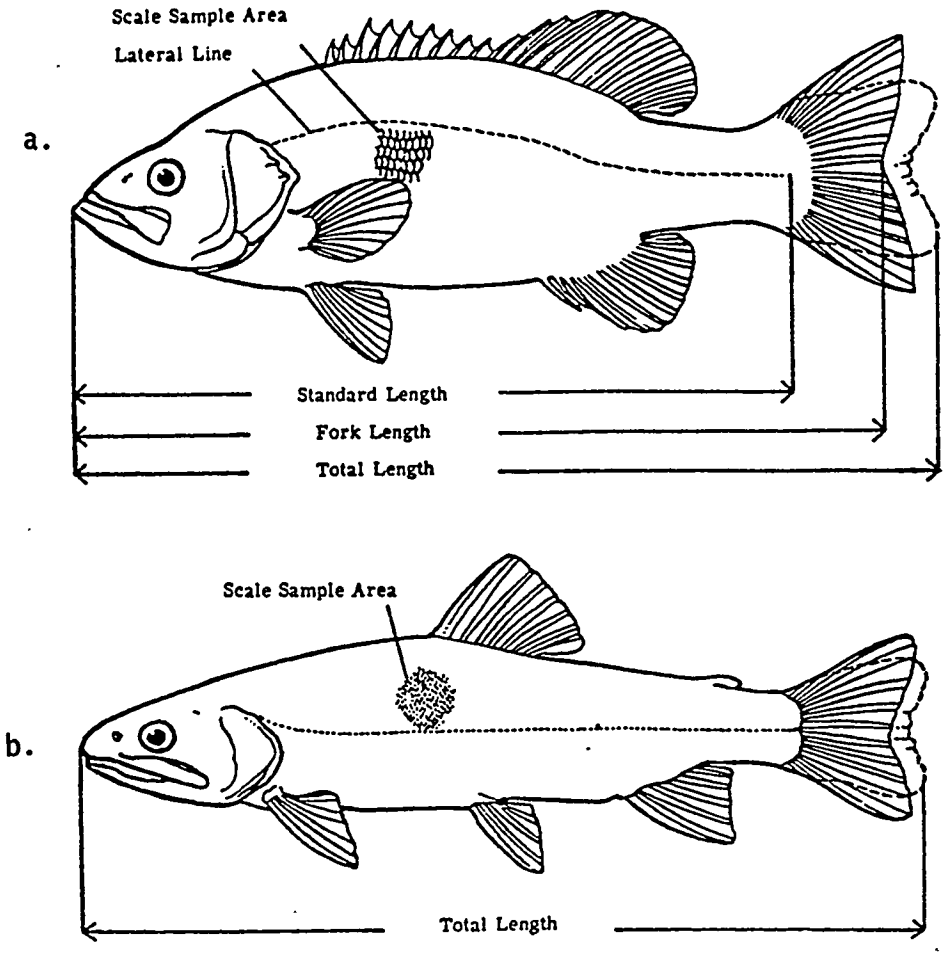
At a minimum, lengths, weights and structures for age determination should be collected from each fish sent for residue analysis (Figure 5).

Field sampling personnel can perform an important monitoring function by observing and collecting distressed or dead fish as part of routine reconnaissance of the sampling site. Pathological examination (Section 2.2.5) of such fish may disclose the cause of death. Documentation of on-the-spot observations of existing conditions such as color of the water, floating material, effluent discharge, and immediate collection of a water sample (See Surface Water RFM) are vital for a true explanation of the mortality (APHA et al., 1983). If field instrumentation is at hand, pH, dissolved oxygen, conductivity, and salinity (if applicable) measurements should also be made.

2.3.2 Bioindicators

A bioindicator (or indicator) has been defined as a species that is either very sensitive to or very tolerant of a contaminant (see Introduction to the Use of Flora and Fauna RFM, Appendix D). A contaminant's effect on a fish species ranges from avoidance of the contaminant to chronic biochemical, physiological, or morphological responses, to acute toxicity. Manifestations of these responses may include changes in one or more of the following:

- Relative abundance



Note: that total length measurement requires a compressed tail to give maximum length (Lagler, 1956).

Figure 5. Fish Length Measurements and scale sampling areas commonly used. (a) Spiny-rayed fish and (b) soft-rayed fish.

- Size distribution
- Growth rate
- Condition (length/weight relationship)
- Physical appearance
- Incidence of disease and parasitism
- Behavior (e.g., rapid ventilation or erratic movements)

Table 2. Target Fish Species for the National Status and Trends Program, NOAA.

Northeast Coast

Longhorn sculpin (*Myoxocephalus octodecemspinosus*)
Shorthorn sculpin (*M. scorpius*)
Winter flounder (*Pseudopleuronectes americanus*)
Window pane flounder (*Scophthalmus aquosus*)
Yellowtail flounder (*Limanda ferruginea*)
Hogchoker (*Trinectes maculatus*)
Atlantic croaker (*Micropogon undulatus*)
Spot (*Leiostomus xanthurus*)

Southeast Coast and Gulf of Mexico

Atlantic croaker (*Micropogon undulatus*)
Spot (*Leiostomus xanthurus*)

West Coast

Barred sand bass (*Paralabrux nebulifer*)
White croaker (*Genyonemus lineatus*)
Hornyhead turbot (*Pleuronichthys verticalis*)
Diamond turbot (*Hypsopsetta guttulata*)
Spotted turbot (*Pleuronichthys ritteri*)
Yellowfin sole (*Limanda aspera*)
Flathead sole (*Hippoglossoides elassodon*)
English sole (*Parophrys vetulus*)
Starry flounder (*Platichthys stellatus*)
Pacific staghorn sculpin (*Leptocottus armatus*)

Source: NOAA, 1986

*2.3.2.1 **Relative Abundance.*** Generally, it is impractical or impossible to obtain absolute measures of fish abundance or biomass in a given water body or stream section. Estimates can be made using mark/recapture methods but these require considerable effort to reduce the associated error of estimation. Relative abundance, i.e., abundance in relation to sampling effort (e.g., catch per unit effort) may be a useful index for a contaminant monitoring program. Although the index is subject to much natural variation, gradual or sudden declines in the index may signal a response to a contaminant. The index should be calculated for each fish species; sensitive species (by definition) will decline in abundance before other species.

Sampling fish communities for the purpose of computing relative abundance can be accomplished using a variety of methods. The method chosen should be capable of catching most or all species present. Alternately, if one or more sensitive species has been identified, the method should be effective for that species. Relative abundance data can only be compared among samples collected with the same kind of gear and at the same sampling site. "Unit effort" is expressed as per net hours (i.e., hours net is fished) for passive nets, per tow length for trawls, per area for seines, and per time (minutes or hours) for electroshocking.

Frequency of sampling should be tailored to each case. For long-term trend monitoring, annual sampling will be adequate (note that sampling should be conducted at the same time each year). Before and after samples are needed for monitoring effects of specific events (i.e., such as runoff following a rainstorm). One may wish to sample at intervals after the event (monthly, for example) to monitor recovery, if impacts are detected.

2.3.2.2 Size-Frequency Distribution. A plot of the size frequency distribution of a fish population will often exhibit modes among the smaller fish, which correspond to the youngest age groups (Bagenal, 1978). Missing or weak year classes would likely be a response to some environmental perturbation. It is important to select gear that is appropriate for the size of fish you desire; for example, very small fish often are not captured in gill nets or by electroshocking.

2.3.2.3 Growth Rate. The most common means of determining growth rates of fish is by back-calculating lengths at earlier ages from the body scale relationship (Bagenal, 1978). By comparison of growth rates over several years, trends can be detected which may be in response to contamination. For some species (e.g., catfish, which don't have scales) it may be necessary or preferable to determine age using other bony structures, such as otoliths or spines. However, collection and preparation of otoliths, and preparation of spines requires considerably more experience, skill, and special equipment than for scales. Chapter 16 of Nielson and Johnson (1983) provides an excellent discussion of the methodology of age determination. Nevertheless, Service personnel are advised to consult with experts from within the Service, or from local universities or state fish and game departments, before undertaking age determination with these methods. In addition, for quality assurance purposes it will be necessary to have a second individual independently "read" a proportion (10 to 15%) of the tissues to validate the results of the first person.

2.3.2.4 Condition. Condition factors, or coefficients of condition, are calculated from the length-weight relationship:

$$K = W/L^3$$

where

K = condition factor,
W = weight in grams, and
L = length in millimeters.

Condition factors may be employed to compare "condition" of fish of a given species between years or between locations. However, caution must be exercised in that K may vary with age or sex of the fish, or with season. One should avoid examining a fish population for condition during its spawning season, as weight is highly variable depending on spawning stage (especially true for females). Sampling gear selectivity must also be accounted for, e.g., a given mesh size of a gill net will catch the fattest of small fish and the thinnest of large fish. Generally, comparisons of condition

factors of given species are only valid among fish of the same length and sex, collected at the same time of year and with the same type of gear (Bagenal 1978; Lagler 1956).

2.3.2.5 Physical Appearance. No single pathological condition can serve as a universal indicator of contaminant stress in fishes. There are, however, certain pathological conditions, e.g., ulceration of the skin, fin erosion, skeletal anomalies and tumors, that serve as anatomical, biochemical, and physiological indicators of environmental pollution. In addition, scale disorientation may also be of value in assessing the incidence of early developmental abnormalities. The use of a checklist (Figure 6) in evaluating the health status of fish populations is a good screening tool for identifying a possible contaminant problem. In addition to the checklist, color photographs may considerably enhance the description of the abnormality.

Whether or not external abnormalities are detected, if there is cause to suspect contaminant exposure, the investigator may wish to examine or have examined the internal anatomies of a sample. A methodology developed over the past 20 years at Utah State University has been used successfully by nonpathologists in field contaminant investigations. Referred to as the "Autopsy Based Fish/Condition Assessment," it is specially designed as a practical field system that does not require expensive, sophisticated equipment. This method relies on the physical appearance of organs and some external features of affected fish in relation to those of control fish of the same species. The methodology can be easily learned in a 2-day classroom/lab course. The Service is already using this methodology in hatchery applications, and it shows great promise as a screening tool for contaminant studies on refuges. For more information on the methodology and training course, contact

Dr. Ron Goede
Utah State University
Fisheries Experiment Station
1465 West 200 North
Logan, Utah, 84321
(801) 752-1066

Visual examination of the body cavity and internal organs of the fish will require additional time and some familiarity with the internal anatomy of the species under study (Figure 7). A sharp scalpel or a good pair of dissecting scissors will be needed to make the incision through the body wall. The incision should start at the base of the opercle and end at the anus. A second incision should be made from the base of the opercle to the spinal column, creating a flap of tissue that can be raised to reveal the internal organs in place.

A blunt probe can be used to separate the internal organs for better visibility. If desired, the entire gastrointestinal tract can be dissected by cutting the esophagus and slowly lifting and cutting the gastrointestinal tract free, severing the tract at the anus. In this way, the organs associated with the gastrointestinal tract can be more easily examined.

If specimens are to be saved for histopathological examination at a later time, they should be preserved in 10% phosphate buffered (pH 7.00) formalin together with a few apparently normal specimens from the same catch (Mearns and Allen, 1978).

Establishing that a population may be experiencing stress from an external cause, such as contaminant exposure, can be inferred only if (1) the frequency of the abnormality changes with age,

Date: _____ Sampling method: _____ Control No.: _____
Location: _____ Length (mm): _____
Recorder: _____ Species: _____ Weight (g): _____
Other: _____ Sex: _____
Tissue samples: Frozen for residues: _____ Fixed for pathology: _____

SAMPLE CHECK LIST FOR EXTERNAL EXAMINATION OF FISHES

NOTE: Circle the most appropriate condition under each heading for each individual.

BODY FORM
- Normal
- Emaciated
- Truncate
- Scoliosis
- Lordosis
- Kyphosis

BODY SURFACE
- Normal
- Raised scales
- Swollen
- Lesions
- Excess mucus
- Reoriented scales
- Growths
- Parasites
- Wound(s) - lamprey
- Color pattern

LIPS AND JAWS
- Normal
- Deformed
- Growths

SNOUT
- Normal
- Pugnose (Pughead)
- Growths
- Abrasion(s)

BARBELS
- Normal
- Deformed
- Missing

OPERCLE
- Normal
- Incomplete

ISTHMUS
- Normal
- Enlarged
- Hemorrhagic

EYES
- Normal
- Popeye
- Cloudy cornea
- Missing
- Lens deformed
- Lens parasites
- Lens cataract

FINS
- Normal
- Frayed - eroded
- Parasites
- Hemorrhagic
- Gas bubbles

FINS - ERODED
- Dorsal
- Pectoral
- Pelvic
- Anal
- Adipose
- Caudal

GILLS
- Normal
- Bright red
- Brown
- Gas bubbles
- Parasites

PSEUDOBRANCH
- Normal
- Enlarged

BRONCHIAL CAVITY
- Normal
- Growths
- Parasites

UROGENITAL OPENING
- Normal
- Inflamed

ANUS
- Normal
- Inflamed

LESION - LOCATION & TYPE
- Fins
- Head
- Eyes
- Mouth
- Peduncle
- Ventral
- Dorsal
- Lateral

BEHAVIOR
- Gasping
- Flashing
- Lethargic
- Fintwitching
- Convulsions
- Headup-taildown
- Head-tail whirling
- Pectoral fins folded forward
- Belly up
- Loss of balance
- Long axis whirling

OTHER OBSERVATIONS

Figure 6. Sample check list for external and internal examination of fishes (FWS, 1987). (cont.)

SAMPLE CHECK LIST FOR GROSS INTERNAL EXAMINATION OF FISHES

NOTE: Circle the most appropriate condition under each heading for each individual.

BODY CAVITY
- Normal
- Fluid-clear
- Fluid-bloody
- Fluid-cloudy
- Adhesions

MESENTERIC FAT
- Normal
- None
- Excessive

LIVER
- Normal
- Discolored
- Yellowish
- Pale
- Enlarged
- Parasites

GALL BLADDER
- Empty
- Full
- Yellow
- Green
- Enlarged
- Parasites

STOMACH
- Normal
- Empty
- Food
- Mucus
- Fluid
- Hemorrhagic

PYLORIC CAECA
- Normal
- Parasites

INTESTINES
- Normal
- Flacid
- Mucus
- Feces
- Fluid
- Hemorrhagic
- Parasites

SPLEEN
- Normal
- Enlarged
- Shrunken
- Discolored

GAS BLADDER
- Normal
- Fluid
- Growths

KIDNEY
- Normal
- Pale
- Swollen
- Soft
- Hemorrhagic
- Stones
- Growths
- Cysts
- Parasites
- (urinary bladder)

TESTIS
- Immature
- Mature
- Ripe
- Constricted
- Growth

OVARIES
- Immature
- Mature
- Ripe
- Reabsorbing
- Growth

MUSCLE
- Normal
- Soft
- Parasites

TUMORS
- Liver
- Liver wt(g)___
- Tumors - other

OTHER OBSERVATIONS

Figure 6. (continued)

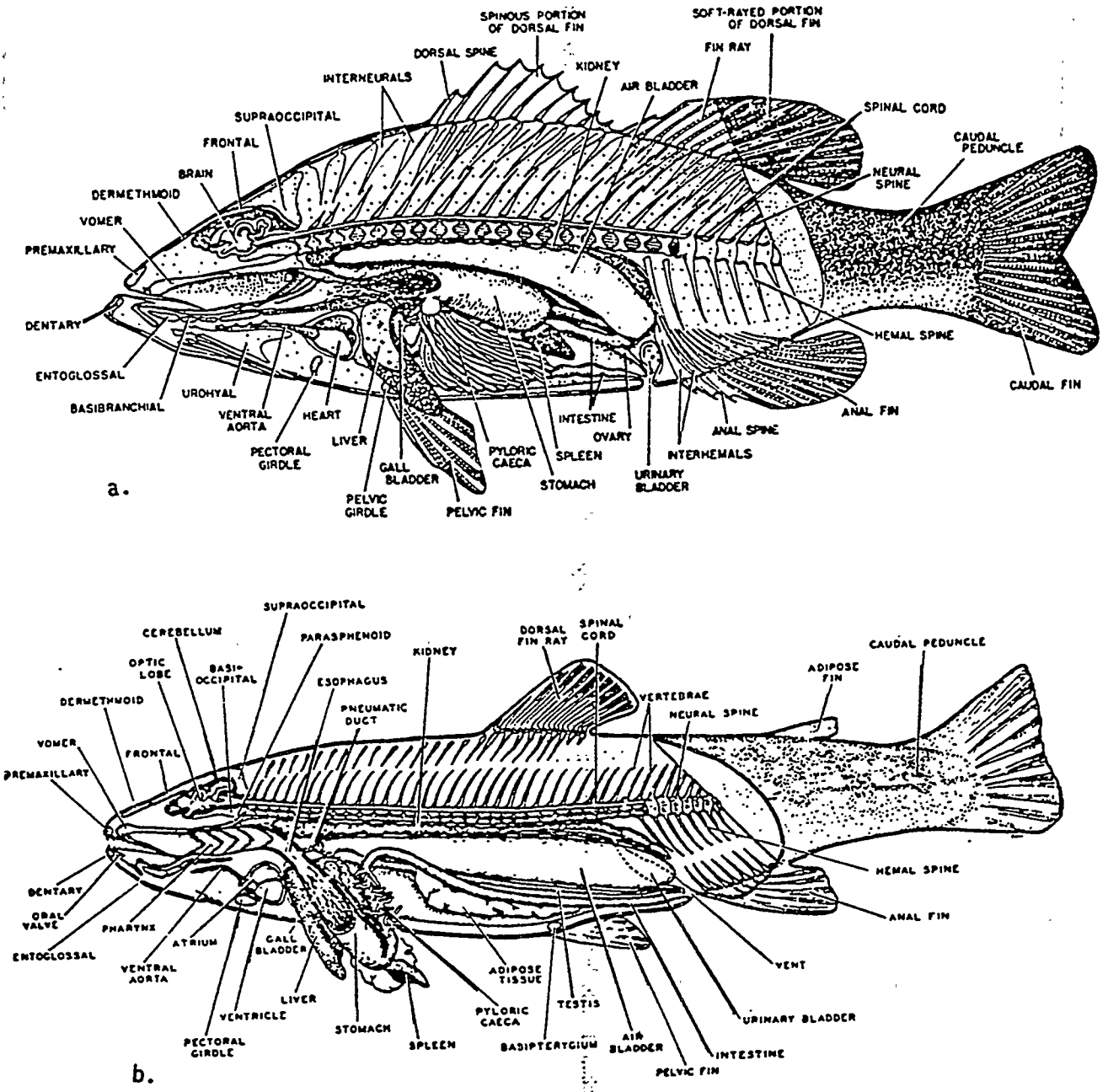


Figure 7. Anatomy of a spiny-rayed fish (a) largemouth bass and a soft-rayed fish (b) brook trout. (Lagler, 1956).

(2) the frequency changes with time (later samplings), or (3) the frequency is greater compared to baseline frequencies in control populations. The number of individuals from the population that will be required to accurately estimate the frequency of an abnormality will depend on the level of sensitivity required for the study. If, for example, the investigator wishes to detect the difference between a 1% baseline frequency and a 20% frequency, the number of fish required from each population will be much less than if one must detect the difference between a 1% baseline and a 5% frequency. The investigator should consult with a statistician to determine sample size. If the frequency of abnormalities exceeds background levels, histopathological examination of a sample should be sought.

*2.3.2.6 **Incidence of Disease and Parasitism.*** Useful information can be collected readily from diseased or parasitized fish. Diseases include those caused by infectious agents such as parasites, bacteria, viruses, and fungi. When possible, fish should be examined fresh and immediately after death. If this is not possible, preserve fish in 5% formaldehyde or freeze them. After being systematically examined by an analytical laboratory, it should be possible to say with certainty what the fish has <u>not</u> died from, and it may be possible to draw definite conclusions as to the actual cause of death.

*2.3.2.7 **Behavior.*** "Behavioral toxicity occurs when the introduction of a chemical or other stressful condition induces a behavioral change that exceeds the normal range of variability" (Marcucella and Abramson 1978; cited in FWS, 1986). Oil or hazardous substances can alter a variety of behaviors such as locomotor activity, ventilation frequency, learning ability, swimming performance, and avoidance response. These alterations can result in a series of events that can ultimately reduce survival of individuals in natural environments.

Behavioral responses to contamination vary with species, contaminant type and contaminant concentration, and can be influenced by various water quality parameters (e.g., pH, temperature, etc.). Many responses to sublethal contaminant concentrations are difficult to observe in the field. Other than fish kills, behavioral avoidance is one of the easiest responses to detect. Lack of fish or species composition shifts may be an indication of a contaminant problem. Between the extremes of avoidance and death, some gross responses can be observed in the field. These include whirling, flashing, gasping, and loss of swimming equilibrium. These behaviors should be noted on the "Sample check list for external examination of fishes" (Figure 6).

3. FISH COLLECTION METHODS

This section identifies methodologies for fish sampling for the situations likely to be encountered in fisheries surveys. The advantages, disadvantages, limitations, and uses of each of the various techniques and sampling devices are addressed.

Fish collection devices are in one of two categories: active and passive. Active methods include electroshockers, seines, trawls, poisons, and angling gear. Passive methods include gill nets, Fyke nets, trammel nets, hoop and pound nets, and D-traps. Descriptions of the various fish sampling and inventory approaches, methods, and equipment are provided in Table 3 and the following sections. Other useful sources for this information include Bagenal (1978), EPA (1979), Weber (1973), and Nielson and Johnson (1983).

3.1 Active Collection

3.1.1 Electroshocking

3.1.1.1 Discussion. Electroshocking is one of the most efficient and least selective of the active fish sampling methods. It involves passing an electric current between two submerged electrodes or between one electrode and a ground. When an alternating current (AC) is passed between two submerged electrodes, fish present in the field are temporarily stunned. Fish lose equilibrium and are easily removed from the water by a dip net. A direct current (DC) passed between a submerged electrode and a ground causes fish to move toward the anode ("galvanotaxis") where they can be dipped from the water.

Electroshocking units are available as backpack shockers (Figure 8), shore or pram-mounted units, and units mounted on boats (Figure 9). The boat-mount, shore, and some backpack shockers use a 110-V, 60 cycle generator run by an air-cooled gasoline engine. Backpack shockers are also available that operate from battery power, rather than a generator.

The entire motor/generator assembly for a boat weighs approximately 70 lbs. Voltage can be varied by a variable voltage pulsator, between 50 and 700 volts AC and between 25 and 350 volts DC. Three operators are required to operate the boat-mount shocker; one is responsible for operation of the generator and boat while the others are responsible for keeping the probes in position and collecting the stunned fish. It is also desirable from a safety standpoint to have three persons on board. If one person falls overboard, the boat operator can maintain control of the boat while the third person assists the person in the water. On occasion, it may be desirable to have a second boat with three personnel following the electroshocking boat to collect those fish that are slow to surface. Efficiency of boat-mounted shockers is enhanced by use at night, with appropriate underwater lights.

Shore or pram-mounted electroshocker units consist of gasoline-powered generators with long cords extending to hand held electrodes. Backpack units can either be powered by a small gasoline engine/generator, or a storage battery.

3.1.1.2 Application. Electroshocking is suited for sampling a variety of aquatic habitats (Table 3). Its success varies with certain environmental parameters, such as conductivity, salinity, temperature, water flow, etc. Electrofishing is less effective in brackish and salt water, and may be

Table 3. Some principal methods of fish capture according to habitat type.

System	Subsystem												
		Trap	Fyke	Gill	Trammel	Pound	Boat	Wading	Straight/Bag	Beach	Purse	Trawl	Poisons
	Pelagic						X			X	X	X	
	Profundal									X	X	X	
Marine	Littoral												
	Subtidal			X	X		X				X		
	Intertidal			X	X		X						
	Pelagic						X				X	X	
	Profundal										X		
Estuarine	Littoral												
	Subtidal		X	X	X	X	X		X		X	X	
	Intertidal		X			X	X	X	X			X	
	Tidal			X	X		X			X	X	X	
Riverine	Lower Perennial			X	X		X	X	X	X	X	X	
	Upper Perennial	X	X	X	X	X	X	X	X	X			X
	Intermittent							X	X				X
	Limnetic						X			X	X	X	
Lacustrine	Profundal			X	X					X	X	X	
	Littoral	X	X	X	X	X	X	X	X	X			X
	Marsh							X	X				X
Palustrine	Bog							X	X				
	Swamp	X		X	X	X	X	X	X				X
	Ditch							X	X				X

Source: Modified from Mason, 1978.

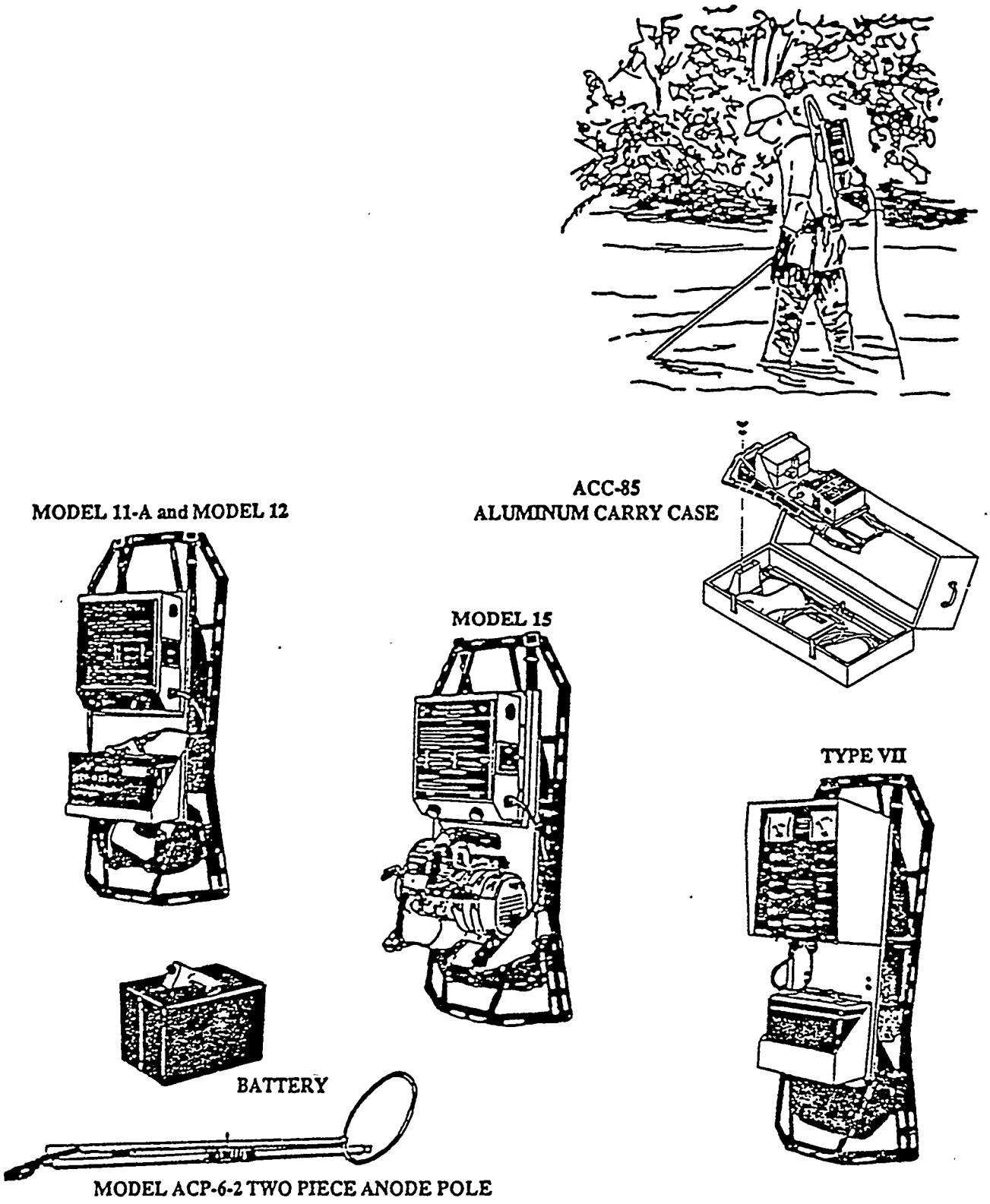


Figure 8. Backpack mounted electroshocking devices. (From Smith-Root, Inc., Vancouver, Washington)

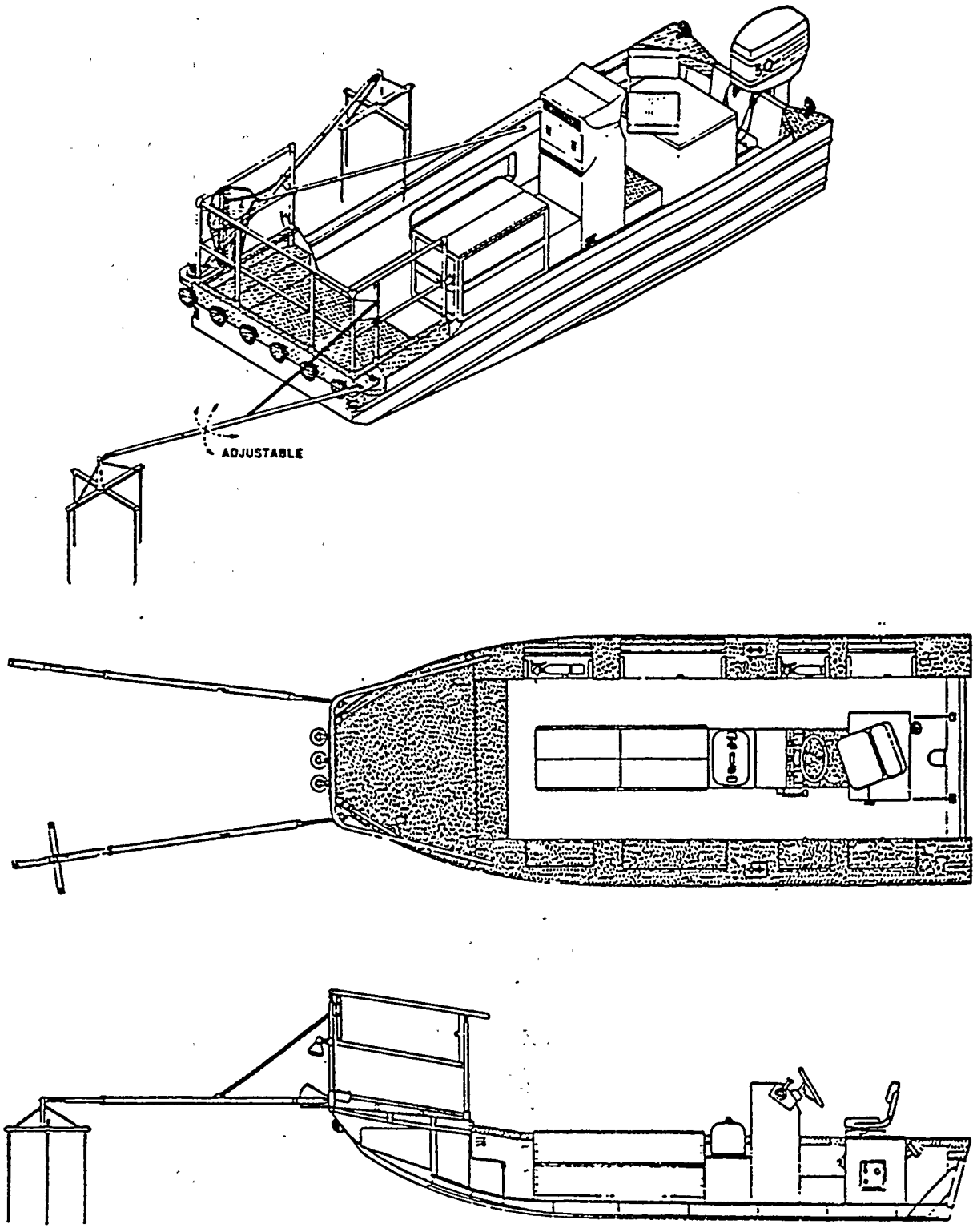


Figure 9. Boat-mounted Electroshocking device. (From Smith-Root, Inc., Vancouver, Washington)

ineffective in extremely soft waters (<25 mg/L as $CaCO^3$). In brackish or salt water, a high-powered (at least 7.5 W) generator is required, as well as modified electrodes and electrode configuration (consult manufacturer). In fresh water, DC or pulsed DC is usually used. Pulsed DC reportedly is more effective in leading fish to the anode when used properly. However, in soft waters, AC may be more effective than DC or pulsed DC. Boat-mounted shockers can be used effectively in shallow rivers, ponds, and lakes but special modifications are needed in order to be effective in waters deeper than 5 m. Backpack and shore or pram-mounted shockers are designed for use in marshes or small, wadable streams. Shore shockers have greater power capabilities (such as may be needed in brackish water) but are less mobile than backpack units. However, by mounting the generator unit on a towed pram or raft, mobility is greatly enhanced. After selecting a suitable site (i.e., wadable with minimal emergent vegetation) follow the manufacturer's instructions for the instrument, voltage type, and type of water being sampled. For optimum results, the technique and type of current employed should be adapted to local conditions.

3.1.1.3 Safety. Part 24 (Safety) of the FWS Administrative Manual provides detailed guidance on the safety aspects of electroshocking (24 AM 13) and watercraft (24 AM 2). All FWS personnel engaged in electroshocking activities should be familiar with these and other appropriate sections of the Administrative Manual. Among the requirements of 24 AM 13 is that electrofishing team leaders "demonstrate knowledge of the principles and techniques of electrofishing." In order to meet that requirement, a person must satisfactorily complete either the National Fisheries Academy course, "Principles and Techniques of Electrofishing," or a certifying examination by the Superintendent, National Fisheries Academy.

Safety equipment required by 24 AM 13 includes rubber footwear (usually hip boots or waders) and rubber linesman's gloves (rated above the voltage used for electroshocking) to protect the wearer from electrical shock, and personal flotation devices (life vests) when operating in waters that are deep, high velocity, or turbid.

Procedure For Alternating Current Backpack Shocker.

1. Two persons, each holding the nonconductive handle of a submerged electrode and carrying the shocker, walk upstream a predetermined distance (usually determined by previous experience), or until a number of fish sufficient for the purpose of the study are captured.

2. A third (and possible forth) sampler follows them with a dip net and containment vessel.

3. As the two samplers walk upstream, no more than 5 m apart, the third sampler collects the stunned fish and places them in the containment vessel.

Procedure for Direct Current Backpack Shocker.

1. One person holds the cathode (ground) suspended in the water.

2. The second person moves the submerged anode plate through the water leading fish to a hand-held dip net for capture.

3. A third person holds the dip net and collects the fish.

4. Fish are placed in the containment vessel.

A variation on this procedure is to use combination dip net/electrodes (netting is simply sewn onto the circular or diamond-shaped electrodes). With this method, two people can easily electroshock a stream, both serving as collectors. When electroshocking streams, the upper and lower ends of the area to be sampled should be blocked with seine nets to prevent fish from escaping. This is especially important for quantitative sampling.

Procedure for Boat-Mount Shocker.

1. Operating a boat-mounted shocker requires three people: one to operate the boat and generator and two to collect the stunned fish.

2. Electrodes are extended from bars in front of the boat, or the boat itself (if aluminum) can serve as one electrode. Electrodes may be wire, chain, or free-swinging metal rods.

3. A second boat may follow the first to collect any late-rising fish.

The voltage, pulse width, pulse frequency, and time elapsed for the sampling effort, as well as location and length of stream or shoreline, should be recorded in a field logbook. Markers such as survey stakes or floats should be used to mark the sample area. This ensures that, for future sampling, data are comparable.

Minimum Equipment for Any Electroshocking Effort

1. Electroshocking unit
2. Dipnets
3. Buckets or tubs for fish
4. Waders or hip boots, rubber gloves, personal flotation devices
5. Data forms

The central source for electroshocking information for the Service is the Superintendent of the National Fisheries Academy, Kearneysville, West Virginia, 25430.

3.1.2 Seining

3.1.2.1 Discussion. The general principle of seining is to encircle the fish with the shore usually acting as part of the "circle." Seines are constructed of strips of strong netting with floats attached to the top and heavily weighted line at the bottom. Seine nets work best where the substrate is clear of debris or rocks large enough to snag the net and are inefficient in the presence of submerged vegetation. Two basic types of seines are in common use, bag seines and straight seines.

Bag seines are somewhat bag-shaped in the center to aid in confining the fish. The wings of bag seines may be of coarser mesh than the center portion and may be tapered toward the ends where they are attached to stout poles. Hauling lines should be attached to the top and bottom of the poles. Deep water seining requires the use of a boat and operator, as well as someone to remain on shore. Seining is less effective in deep water because fish can escape over the floats and under the weighted line.

There are two common sizes of bag seines (APHA, 1985):

1. 7.5-m long by 1.8-m deep, with the main portion constructed of 12.6 mm square-mesh netting, and the bag (1.8-m long) constructed of 6-mm square-mesh netting
2. (For larger fish) 30-m long by 1.8- or 2.4-m deep with 2.5- to 5-cm square-mesh netting in the main body and 12- to 25-mm square-mesh netting in the bag.

The smaller bag can be handled by two people in shallow water. The larger bag seine is very useful in near-shore lake waters too deep to wade.

Straight seines are constructed of rectangular-shaped netting with no bag. They are available in various lengths, 1.2 m and longer, with square-mesh sizes of 3, 6, or 12 mm. Hocutt (1978) and Mason (1978) recommend the 1.5 m long straight seine with 3 mm mesh for all-around seining in streams and shallow rivers. They can be used by two people in shallow water. The nets have stout poles attached to each end for the operators to use in manipulating and positioning the forward edge of the net. Nylon seines are recommended because of the ease of maintenance.

3.1.2.2 Application. In small, shallow, slow-moving streams or shallow lakeshores with relatively smooth bottoms and few obstructions, two-man seining operations can be very effective. Seining can also be effective in near shore waters too deep to wade, but shallower than the depth of the net. When used in waters no deeper than two-thirds the height of the seine, all fish within the seined area that are large enough to be retained by the mesh are subject to capture.

In practice, seining is somewhat selective in that some fish avoid the net. It is not effective in removing all the fish in waters deeper than two-thirds the height of the net, because fish will pass over or under the net. Obstructions in the stream and irregular bottoms interfere with seining operations and allow fish to escape.

Procedure (small bag seine and straight seine):

1. Two persons hold opposite ends of the seine and stretch the net out perpendicular to the shore.
2. Haul the seine a predetermined distance parallel to shore, keeping the lead line in contact with the substrate. The near shore end should be kept as close to the shore as possible, avoiding obstacles. The offshore end should slightly proceed the near shore end during the haul.
3. After hauling the seine the desired distance along the shore, pivot the offshore end in an arc around the near shore end as rapidly as possible and bring the seine to shore.
4. Slowly pull the seine onto shore, keeping the lead line in contact with the substrate. Do not pull the lead line in too rapidly as the float line will submerge, allowing fish to escape.
5. Pull the seine onto shore, allowing for a pocket to remain in the center of the seine; shake fish into the pocket.
6. Remove the desired number and types of fish, returning other fish to the water.

Procedure [large (30-m long) bag seine]:

1. Tie off or hold one end of the seine on the shore. A line attached from the shore to the shore end of the seine can be used when deploying the seine offshore.

2. Using a boat, tow the opposite end offshore the desired distance with the seine perpendicular to the shoreline.

3. Slowly tow the offshore end of the seine back toward the shore, with the boat transcribing an arc with a radius slightly shorter than the length of the seine.

4. After the boat reaches the shore, slowly pull both ends of the lead line onto shore, keeping the lead line in contact with the substrate. Do not pull the lead line in too rapidly and cause the float line to submerge, allowing fish to escape.
5. As float line and seine become slack, pull the seine into shore allowing a pocket to remain in the center of the seine; shake fish into the pocket.

6. Remove the desired number and types of fish, returning other fish to the water.

3.1.3 Trawling

Discussion and Application: A trawl is a cone-shaped bag of netting towed through the water column or along the bottom by one or two vessels. Trawls are useful for sampling rivers with low flow velocities, lakes, bays, estuaries, and open ocean waters. They have little application in most flowing systems except in very large rivers. Trawl surveys are useful for assessing, in a standardized fashion, the relative abundance, diversity, and health of all available fish (and the larger invertebrates) (Mearns and Allen, 1978), as well as for collecting specimens for contaminant residue analyses. Three basic types of trawls are (1) the beam trawl used to capture bottom fish (Figure 10), (2) the otter trawl used to capture bottom and near-bottom fish (Figure 10), and (3) the open water trawl used to capture schooling fish. Of these types, the small otter trawl (10 to 40 ft openings) is the most frequently used for coastal biological surveys (Mearns and Allen, 1978). The beam trawl and open-water trawl are both too cumbersome to handle from small boats.

Small otter trawls can be used from small boats manned by an experienced crew. They are useful in water depths down to 5 m. Single-warp (i.e., towed by a single cable) otter trawls ranging in headrope length from 10 to 16 ft are recommended for shallow waters, estuaries, and lagoons, and can be towed by small boats (14 to 25 ft); 25 ft nets are recommended for deeper open coastal waters. Body mesh of the nets should not exceed 1.5 to 2.0 in. stretch mesh and the cod-end should be fitted with fine-mesh liners (0.25 or 0.5 in. stretch measurement) to retain juvenile fishes. Trawls should be fitted with chain or lead weights on the foot rope, attached to a pair of doors or otter boards fitted with steel shoes and towed by a pair of swivel-mounted bridles that are three times the headrope length. Towing time and rate should be standardized, e.g., 10 min on bottom at 2.5 knots along isobaths.

Recommendations for setting gear, hauling, retrieval, and trouble-shooting as well as methods for quickly sorting and measuring catches and summarizing data are provided in Mearns and Allen (1978). Additional sources of trawling methods are Bagenal (1978), and Nielson and Johnson (1983). Service personnel are advised to seek assistance from local universities and state fish and game

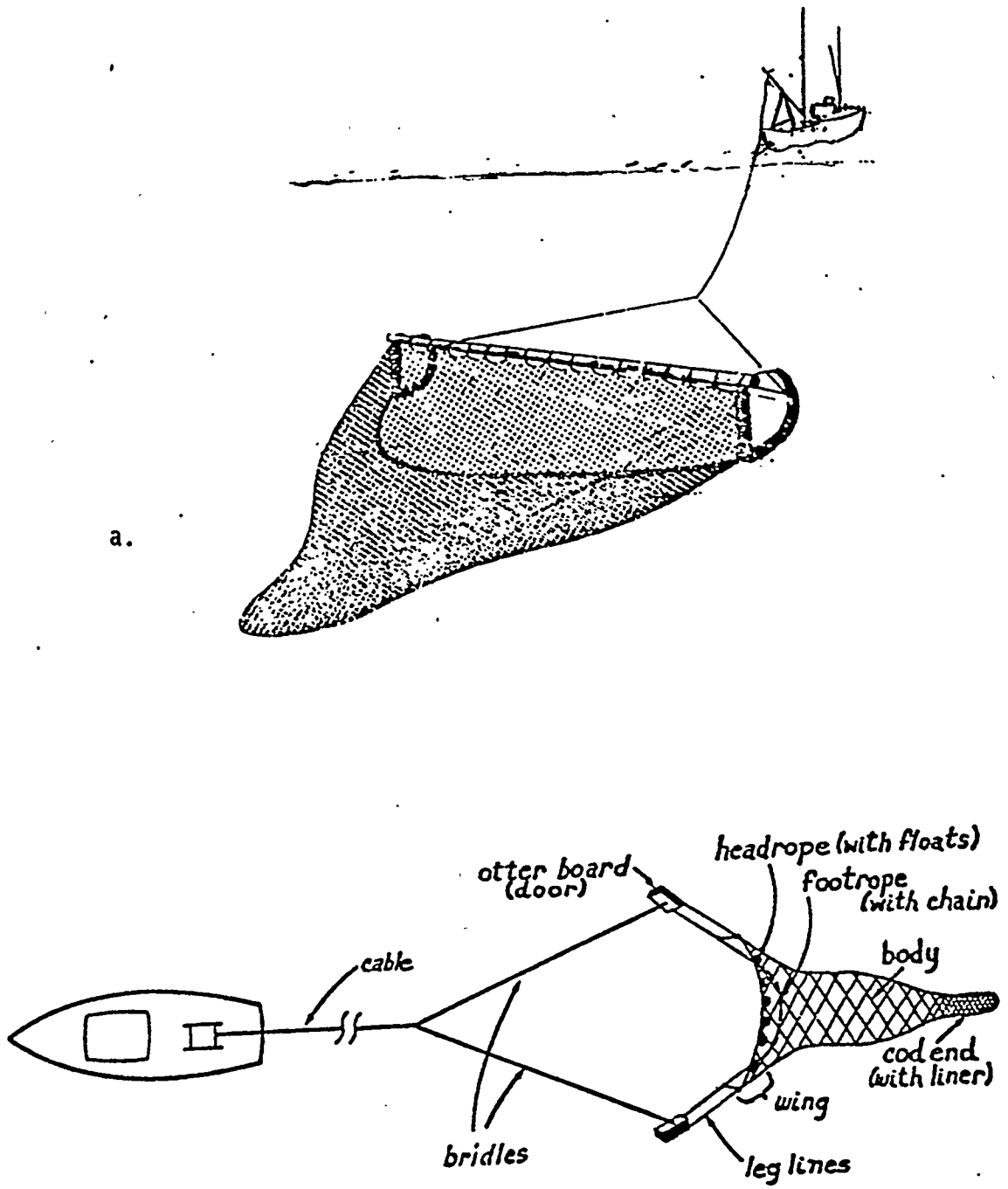


Figure 10. The beam trawl (a) (Dumont, 1961); and the otter trawl (b) (Mearns and Allen, 1978).

agencies regarding exact specifications for such things as winches and davits to haul various size trawls aboard. It may be necessary to charter the services of commercial trawlers in most estuaries and marine habitats.

3.1.4 Angling

3.1.4.1 Application. The "hook and line" approach is one of the most selective forms of fish collection. It can be as simple as still-fishing using a hand-held rod, trolling lures, or baited hooks, or it may involve the use of trot lines with several baited hooks. The most effective procedure for a given area is often learned from local fishermen or guides.

This method is generally unsuitable for detailed survey work because it is too selective in sizes and species caught, and the catch per unit effort is generally low. However, there may be instances, such as sampling larger trout streams, when this technique is the best and most effective one (other than poisons) to use. Otherwise, it cannot be considered as anything more than a supportive technique or a method for obtaining a few adult specimens when other techniques are inappropriate. For example, it would be an appropriate method for obtaining a few specimens for tissue analysis.

3.2 Passive Collection

Passive techniques generally require less effort than active techniques, but they are also usually less suitable for shallow water collecting because many species evade entanglement and entrapment devices. In general, the catch efficiency of passive techniques is a function of the size of the population being sampled and movement of the fish population.

3.2.1 Entanglement Nets

3.2.1.1 Application. Gill and trammel nets (Figure 11) are commonly used to sample fish populations in lakes, reservoirs, estuaries, and large rivers. They can be fished at the bottom (sinking nets), at mid-depth or at the surface (floating nets) and can be operated as stationary or movable gear. They are not well suited to fast-moving rivers because they are nearly impossible to hold in place and tend to become clogged with debris. (Clogging is also a serious problem in slow-moving rivers that carry a lot of debris). When used as movable gear in rivers, the netting operation is hindered by the snagging of rocks and debris.

Gillnets are considered to be species and size selective because the mesh size determines the catch. Gillnets can be constructed of several sections, each of different mesh size (usually called "experimental" gillnets). This provides a greater range of sizes and species collected. They can be constructed of multifilament or monofilament nylon. The monofilament nets are more expensive and more difficult to use than multifilament nets, but they usually capture more fish.

Nets with float lines and solid-core lead lines are less likely to become tangled than those with individual floats and lead weights. At least two individuals working from a boat are required to set and retrieve gillnets. They are effective in collecting pelagic fish, but can be severely tangled when catching species with large or barbed spines such as catfish. Crayfish can cause similar tangling problems. Diving ducks are also very vulnerable to capture and subsequent drowning. Nets set at

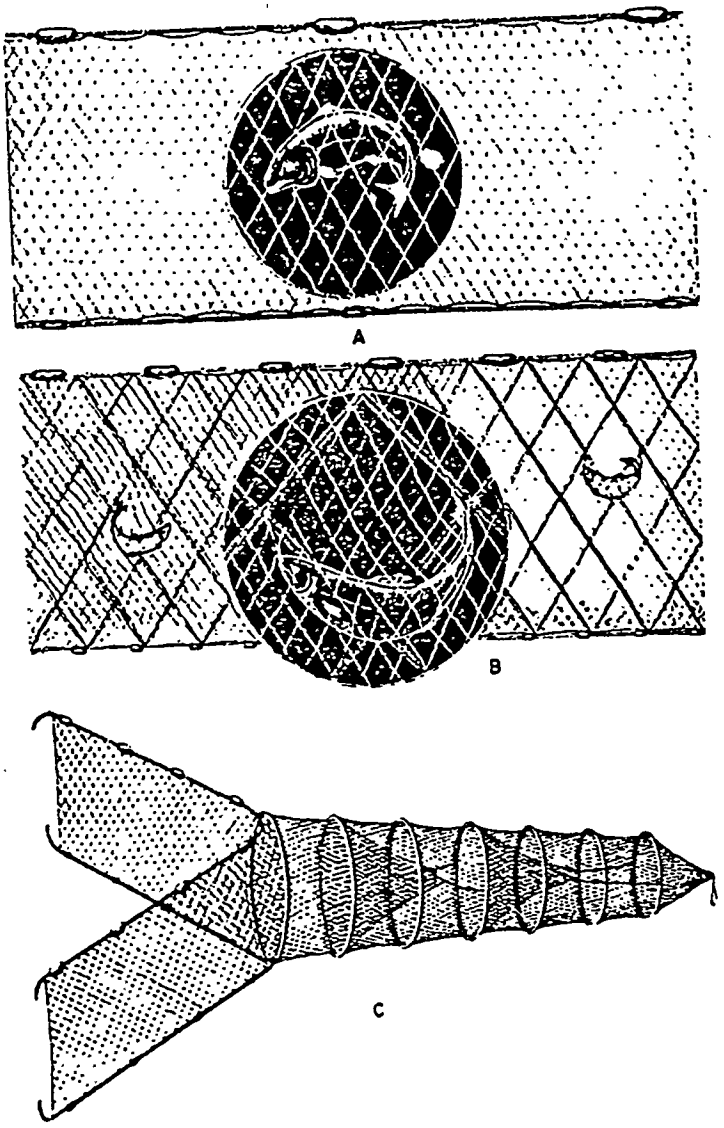


Figure 11. Examples of passive nets: (a) gillnet; (b) trammel net; (c) fyke or hoop net. (APHA, 1985)

the surface may entangle the feet of surface swimming ducks. These factors should be considered when using gillnets in waterfowl areas.

Trammel nets (Figure 11) are constructed of a layer of large-mesh netting on each side of loosely hung smaller gillnetting. Small fish are collected in the gillnetting and larger fish are captured in the pocket of the gillnetting that is formed as the smaller meshed netting is forced through an opening of the larger meshed netting.

Trammel nets are used in the same manner as gillnets, i.e., across the anticipated path of movement of the fish, or they are placed to encircle a visible school. As with gillnets, at least two people are required to set the nets, but because of the severe entanglement problem associated with removal of the catch, additional help is desirable when retrieving the nets. Trammel nets also are hazardous to diving and surface swimming ducks.

Procedure:

1. Tie off float line to shore so that the beginning of the gillnet is in at least 0.5 to 1.0 m of water. When using experimental gillnets, set the smallest mesh size closest to shore.

2. Stretch out gillnet perpendicular to shore. Attach anchor to lead line and marker float to float line. Make sure net is as taut as possible.

3. Leave net in water the predetermined length of time. Often, nets are set in early evening and retrieved the following morning; however, if fresh specimens are required, one should check nets at shorter intervals depending on water temperature.

4. Retrieve net, removing fish as it is retrieved. In many cases, especially for fish with spiny rays (e.g., bass and other sunfish), it may be easier to slip the fish on through the netting, rather than attempt to "back" the fish out. For catfish, removal is greatly facilitated by clipping off the pectoral spines with a pair of diagonal cutters, or pulling them off with pliers (see Chapter 16 of Nielson and Johnson, 1983) if they are needed for age determination.

5. Stretch out net to dry (not necessary for monofilament nets).

A galvanized laundry tub works well for storing, transporting, deploying, and retrieving gillnets. During retrieval, the tub catches much of the water from the net, keeping the boat drier.

3.2.2 Entrapment Devices

3.2.2.1 Application. Traps are considered to be the best all-around method of taking samples of fish in large streams. Traps can be useful for sampling fish in fast-moving, deep waters where other methods are not effective. They are most efficient in turbid water and are especially wellsuited to taking bottom feeders. Like most passive techniques, traps are most effective during periods of extensive fish movement. The trap design and netting mesh size can be selected to meet the needs of the survey. Traps include hoop nets, fyke nets, trap nets, and pot gears.

Hoop nets (Figure 11) are most often used in channel habitats of rivers because they can be set in strong currents without being washed away or clogged with debris. The nets are set with the

mouth opening downstream, at depths sufficient to entirely cover the hoops, by attaching a rope to an anchor or stake at the stream bottom. By using landmarks, nets can be set without buoys and retrieved with a grappling hook, thus minimizing potential for vandalism or theft. Baiting the nets with cheese or pressed soybean cake enhances their effectiveness. Generally, nets are left for 24-hour periods. Hoop nets are selective for species attracted by cover, bait, or other fish. In the Mississippi River basin, hoop nets are especially selective for catfish, buffalo, and carp; other species such as smallmouth bass and gizzard shad rarely enter hoop nets.

The construction of the net facilitates easy handling and it can be stored or carried on, and deployed from, a small boat. Hoop nets 2 to 6 ft in diameter can be purchased commercially (Section 3.3).

The Fyke net (Figures 11 and 12) is a hoop net with wings or leads attached to the first frame to funnel the fish toward the enclosure. Fyke nets can be used in nonflowing waters where the movement of fish is random. The efficiency of Fyke nets may be impaired in streams by trash and debris lodging against the wings. The Fyke net is best used in fairly shallow waters, as deep as the height of the wings. It can be deployed from a small boat. The Fyke net is a more permanent structure than the hoop net because of the posts and anchors required to secure the leads. Two people can easily deploy the device, and thereafter it can be serviced by one person.

Fyke nets can be set in several different ways. Nets with a single leader are often set perpendicular to the shoreline. The leader is anchored to shore and the net let out while backing away. Fyke nets can also be deployed in pairs with a single leader between them. This type of set is usually made parallel to the shoreline, for example, along weed beds. Generally, fyke nets are selective for cover seeking, mobile species; such as esoscids (perch) and centrarchids (sunfish).

Trap nets (Figure 13) are based on much the same principle as hoop nets, but they are more complex. Floats and weights give the devices their shape. Traps can be fished very effectively for slow-moving sunfish, perch, and catfish, when baited with cheese, cottonseed cake, etc. However, considerable experience is required to use them successfully. Because of this factor, they probably will not be useful for most Service purposes.

Pot gears are portable, rigid traps, such as the common minnow trap and lobster pot, which are generally constructed of wire mesh, plastic, wood, or glass. Pot gears are effective at capturing bottom dwelling species seeking food or shelter. The small size of pot gears makes them very portable and easily deployable by one person. As with other types of traps, pot gears are usually baited with cheese, cottonseed, or soybean cake.

Additional information for the use and deployment of entrapment devices can be found in Bagenal (1978) and Nielson and Johnson (1984).

3.2.3 Purchasing Fish from Fishermen

Fish can sometimes be purchased from commercial or sport fishermen. When obtaining fish in this manner for analyses of priority pollutants, it is imperative that specimens be preserved immediately and that handling be kept to a minimum. To ensure that the fish are handled properly, a member of the sampling team should accompany the fishermen during the operation.

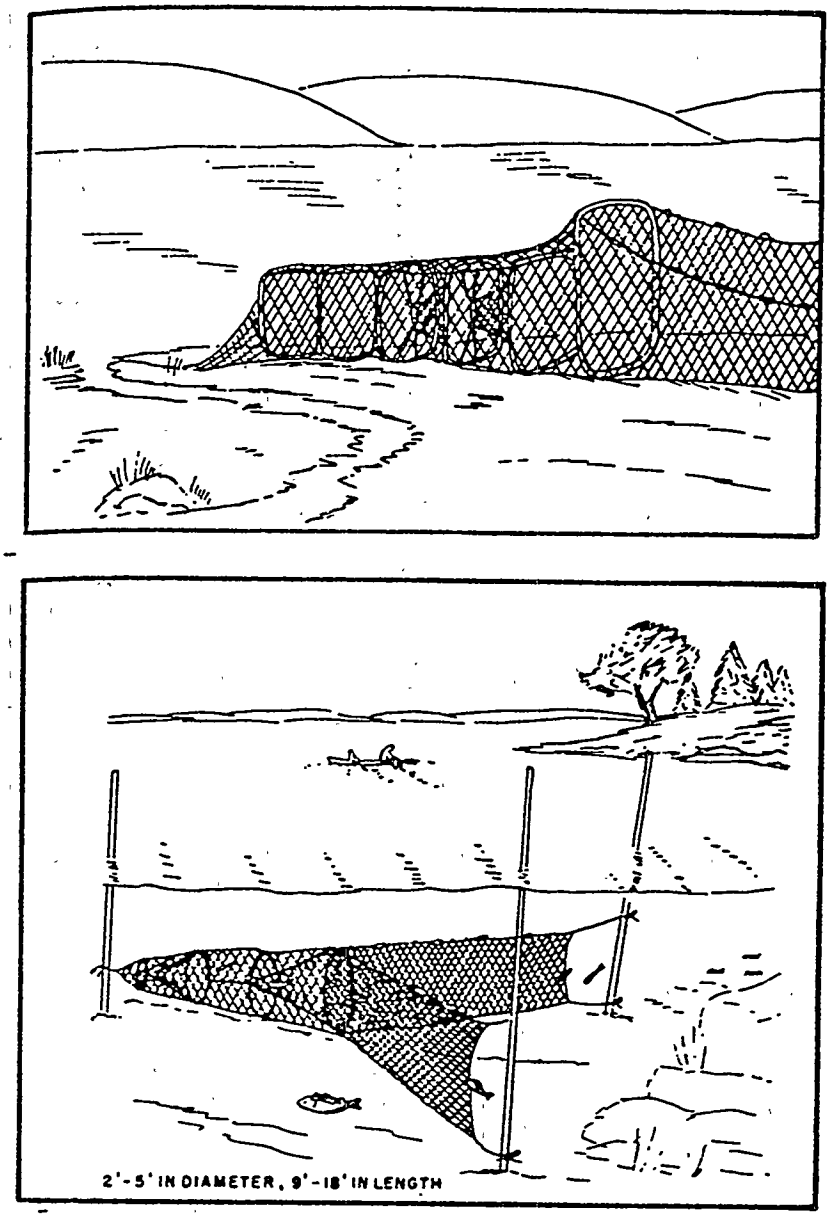
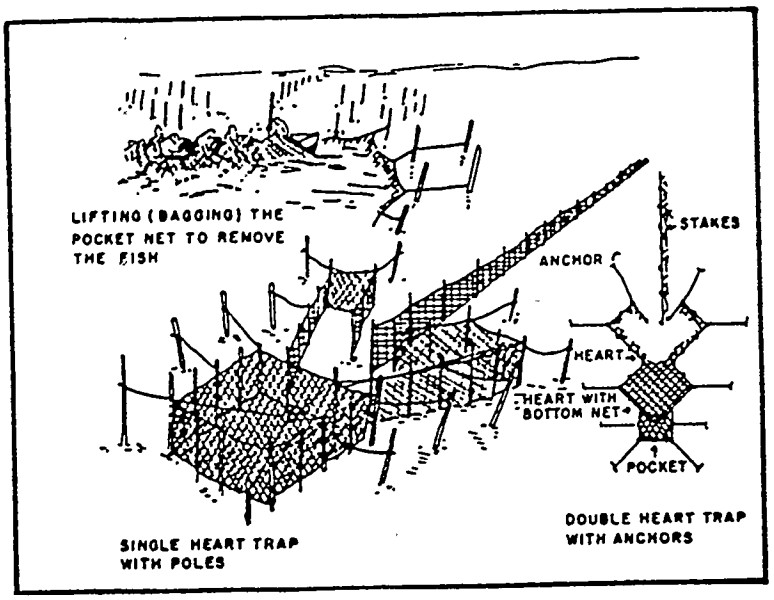


Figure 12. Fyke nets. (Everhart et al., 1975)



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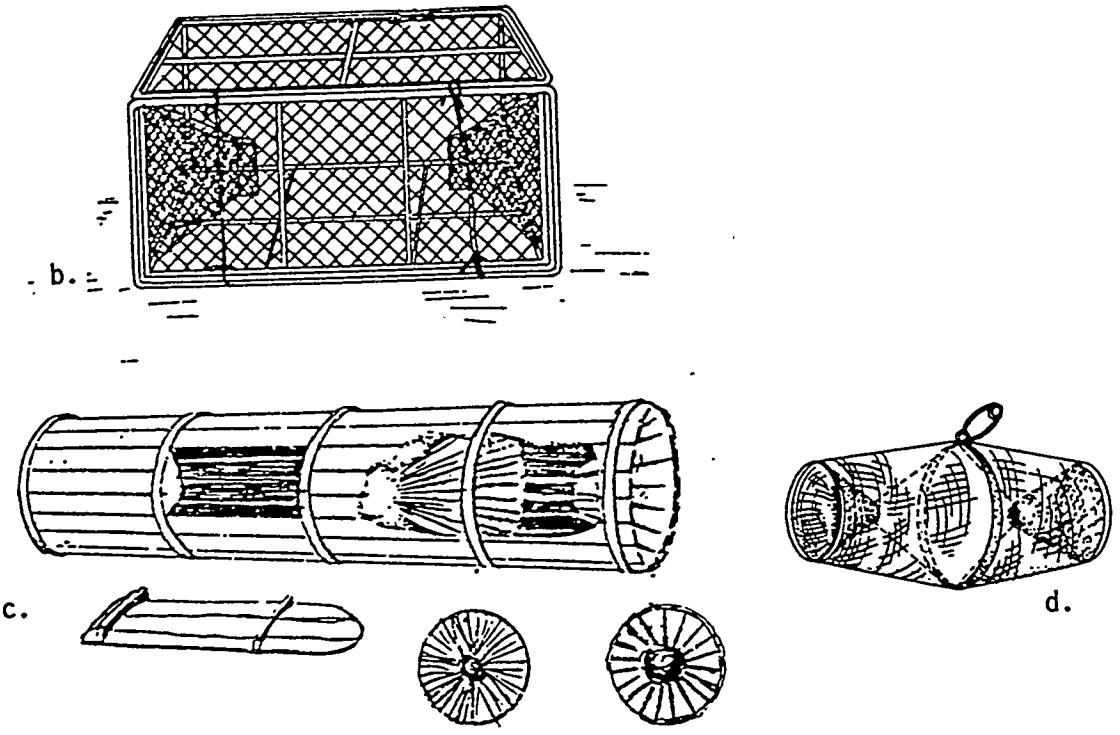

Figure 13. Trap nets: (a) Maze (pound net) gear; (b) king crab crab pot; (c) slat trap; and (d) minnow trap. (Everhart et al., 1975 and Nielson and Johnson, 1983).

If fishermen are to be used on a regular basis, it would be useful to selection a person(s) that is willing to be trained in the proper procedures and/or provide written procedures and materials for him/her.

3.2.4 Explosives and Poisons

Explosives, including primachord and M-80 firecrackers, have been used to stun and collect fish in certain situations. Obvious disadvantages include safety risks, possible legal concerns, and nontarget species killed. These methods can also be offensive to the casual observer. An advantage of this collection method is its nonselectivity; all fish within range of the explosion are likely to be stunned or killed (this may also be a disadvantage, if one desires minimal impacts on the fish community from sampling activities). This methodology is mentioned here to make Service personnel aware of its existence. Further information and guidance should be sought from local universities and state fish and game agencies.

Poisons have similar disadvantages and advantages to explosives. The most common poison used in fisheries work is rotenone. Generally, poisons are not advocated for collecting fish for contaminant residue analyses, but may be useful for other purposes such as species composition and growth studies. As with explosives, it is recommended that Service personnel seek assistance from universities or state fish and game agencies.

3.3 Optional Equipment

The following equipment may be used in a fish sampling effort:

1. Measuring board
2. Weight scale(s)
3. Envelopes for fish scales or spines (coin envelopes work well) and knife to remove scales
4. Dissecting kit, if field dissection is required
5. Containers and preservative
6. Ice chest and ice, if nonpreserved specimens are required, or if preservation is to be done in lab
7. Block nets (to block off stream segments)
8. Foil and plastic bags (for fish needed for organics and metals analysis, respectively)
9. Live car and/or buckets/tubs
10. Species list, key, and/or pictures
11. Camera and tape recorder (e.g., to document fish kills, or abnormalities)
12. Stakes and hammer, surveyor's tape to mark sampling areas
13. Basic tool kit including screw drivers, pliers, diagonal cutters, crescent wrenches, knife, hammer, electrical and duct tape, bailing wire, and other items required to perform maintenance on equipment being used.

3.4 Equipment Suppliers

Suppliers of fish collecting equipment include:

Nets (dip, gill, trammel, hoop), Seines, Traps, Trawls

Duraframe Dipnet
Viola, WI
(608) 538-3140

Memphis Net and Twine Co., Inc.
Memphis, TN
(901) 458-2656

Nylon Net Company
Memphis, TN
(901) 774-1500

Research Nets, Inc.
Bothell, WA
(206) 821-7345

Electrofishing Equipment

Coffelt Electronics
Englewood, CO
(303) 761-3505

Smith-Root, Inc.
Vancouver, WA
(206) 573-0202

4. SAMPLE HANDLING AND PRESERVATION

4.1 Preservation and Handling for Contaminant Analysis

4.1.1 Discussion

The methods of preservation and handling of fish depend upon the size of the individuals collected and the contaminant(s) being studied. All individuals should be adult fish and preferably of uniform size (i.e., same size class). For larger catches, Lauenstein and Young (1986) recommend plotting length-frequency distribution as fish are caught to identify the prevalent size class or preferred size class for the composite sample. Because of practical limitations in homogenizing samples in preparation for analysis, no composite sample should contain individual fish over five lbs., and total weight of a composite sample should not be less than 0.5 lbs. or greater than twenty-five lbs. Species should not be mixed within any composite sample.

Maximum effort should be made to collect the preferred species from the designated groups (Section 2.2.1). If after substantial effort, one or more of the preferred species are determined to be unavailable, alternate species may be collected. Alternate species should be closely related to the preferred species, preferably of the same genus. Note that caution should be exercised when deciding whether an alternative species can be substituted for the species called for in the study plan. In structured studies, assumptions for many statistical tests can tolerate missing data but do not allow for substitutions. Alternative species are useful if there is a data set for the species to which the sample can be compared; but data from one species cannot be plugged into the data set of another without ignoring accepted statistical practices.

Analytical results for contaminants can vary depending upon how the sample material is handled and prepared. PCBs and other lipophilic compound concentrations are generally higher in whole fish than in edible portions. Often, whole fish analyses will be performed on samples collected on refuges because the results will more closely reflect the impacts on predators consuming the entire fish. However, there may be occasions when fish samples should be analyzed along public health guidelines. Public health officials usually analyze only the edible portions of fish (e.g., fish fillets) since they are interested in quantifying the contaminant concentration that will be passed on to the human consumer. The Food and Drug Administration (FDA) and respective state health agencies have their own guidelines concerning what constitutes an edible portion and how samples should be prepared for analysis. All fish species are not treated alike. For example, skin-on fillets are analyzed in carp, while catfish are skinned and the head and internal organs removed before analysis. Specific procedures for preparing fish fillets according to FDA guidelines can be found in FDA (1988). Service biologists should have copies of FDA regulations, action levels, and respective state standards available if they are concerned about contaminant levels in fish or other foods.

Section 4.2 provides information regarding sample preparation, preservation, and shipping requirements for chemical analysis. Table 3 of the Documentation Guidance RFM also contains information on these requirements.

4.1.2 Contaminant Analysis Procedures

1. Collect the number of fish necessary for analysis from each collecting site.

2. Wash each fish in water from which it is collected; wash off detritus, vegetation, sediment, and soil. Take care that fish do not contact potentially contaminated surfaces (plastics, identifying labels, printed papers, metal, mud or sediment, boat bottom, etc.). Place fish in acetone- or hexane-rinsed stainless steel pan.

3. Weigh each fish to the nearest gram, then measure length (usually total length) to nearest 0.5 centimeter. Record in Field Logbook. Collect scales (or other bony structures, if necessary) according to Bagenal (1978) or Nielson and Johnson (1983) for subsequent age determination.

4. Record (date, location, habitat type, collection method, fish species, comments, and other pertinent information in field logbook. (Section 3.4, Documentation Guidance RFM).

5. If required for the desired analysis, remove internal organs by splitting from vent, anteriorally, to the pectoral girdle. Fish should be weighed before and after removal of organs.

6. Unless compositing samples, label each fish with a sample label (Section 3.5.1, Documentation Guidance RFM).

7. Place fish in appropriate container. For analysis of organics and metals (other than aluminum), wrap in clean aluminum foil (dull side toward fish), then double bag in plastic bags. Composite samples can be combined in bags.

8. Securely attach a serialized sample tag to each sample container (Section 3.5.2, Documentation Guidance RFM). Put fish on ice and freeze them upon return to the laboratory. Samples should be stored at -30#C until they are shipped for analysis.

9. Complete all chain-of-custody documents and record them in the Field Logbook (Section 3.6. Documentation Guidance RFM).

Each composite sample must be provided with the sample tag firmly tied on the outside of the plastic bag. Individual lengths and weights should be recorded only on the Field Data Record in the Field Logbook (Section 3.4, Documentation Guidance RFM).

4.2 Preservation and Handling for Purposes Other Than Contaminant Analysis

4.2.1 Histological Examination

In the field, fish collected for the purpose of histological examination should be placed in plastic bags labeled with all pertinent information (date, location, sample number, etc.) and

put on ice (but not frozen). Weighing and measuring can be done in the lab or in the field, as desired.

In the lab, and as soon as possible after collection, the appropriate tissues (as recommended by the histopathologist who will perform the examination--usually liver, kidneys, spleen, gills and skin) should be excised and placed in labeled bottles in preservative (again, according to the preference of the histopathologist--usually formalin, Deitrich's fixative, or Bouin's solution). If preferred, or if fish cannot be brought to a lab within a reasonable period, e.g., 24 hours, these steps can or should be carried out in the field.

4.2.2 Taxonomic Verification

In the field, fish collected for taxonomic verification or archiving can either be placed directly in 5% formalin for small fish and 10-20% formalin for large fish (after weighing and measuring, if desired), or placed on ice and preserved later in the lab. Fish larger than a few inches long should be slit along the belly, right of the mid-line, to allow preservative to enter the body cavity. The right side is preferred because the left is usually used for scale samples and taxonomic purposes, such as scale counts along, above, and below the lateral line. Fish should remain in formalin for several days, after which they should be soaked and washed thoroughly in water, transfered to 50% ethanol for a 2-5 days, and finally stored in 70% ethanol. All containers should carry appropriate collection data inside and outside the container.

Note that formalin is an EPA-listed hazardous substance and as such, must be disposed of as hazardous waste. This includes the rinsate when transferring fish from formalin to alcohol. Because of this, it is important to reuse formalin to the extent practical, and to use nonhazardous substitutes if available (Note: for most applications formalin is the only satisfactory preservative).

Another note of caution regarding formalin has been provided by John Hickey, Service EC Specialist in New York. Scented formalin is now available, and while the scent eliminates the objectionable odor of formalin, it does not reduce the hazard posed by extended inhalation of the chemical. That is, you may not be aware of inhalation until symptoms common to formalin inhalation, such as headaches, occur. Because of its hazardous properties, precautions should be taken such as wearing gloves and working in a well-ventilated area.

5. GLOSSARY

Bioindicator	A species that is either very sensitive to, or very tolerant of a contaminant.
Biointegrity	Also biotic integrity. The ability of a system to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region.
Biomonitor	A species that accumulates or concentrates a contaminant to measurable levels in tissues. Ideally, the organism remains unaffected by the contaminant.
Diversity	The number of species present (species variety or richness); and b) the distribution of all individuals among these species (evenness or equitably).
Ecoregion	Regions of relative homogeneity in ecological systems or in relationship between organisms and their environments.
Ecosystem Stress	A perturbation of an ecosystem, either in terms of functional or structual attributes.
Histopathological	(Histopathology) The study of diseased tissues.
Lipophilic compounds	Compounds having a strong affinity for lipids or fats.
Live car	A submerged cage of wire or nylon mesh sides for keeping captured fish alive.
Metric(s)	In the context of the Index of Biotic Integrity (IBI), a metric is a measure, such as total number of species, that provides information about a specific species attribute of a sampling site.
Pelagic	Ocean surface waters
Relative Abundance	Abundance in relation to sampling effort or, alternately, abundance of one species relative to abundance of all species in a sample.

6. REFERENCES

APHA (American Public Health Association) et al. 1985. Standard Methods for the Examination of Water and Wastewater, 16th edition. APHA, Washington, D.C.

Bagenal, T. B: 1978. "Methods for Assessment of Fish Production in Fresh Waters," T. B. Bagenal (ed.), IBP Handbook No. 3, 3rd edition, Blackwell, Scientific Publication, Oxford.

Dumont, W. H. and G. T. Sundstrom. 1961. "Commercial Fishing Gear of the United States". US Fish and Wildlife Circular No. 109. U. S. Printing Office, Washington, D. C.

Eisler, R. 1985. Selenium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review, U.S. Fish and Wildlife Service Biological Report 85(1.5), October 1985, Laurel, Maryland.

EPA, 1979. Sampling Protocols for Analysis of Toxic Pollutants in Ambient Water, Bed Sediment and Fish. U.S. Environmental Protection AgencyContract No. 68-01-3852, Washington D.C..

Everhart, W. H., A. W. Eipper, W. D. Youngs. 1975. Principles of Fishery Science. Cornell University Press, Ithica and London.

FDA, 1988. Pesticide Analytical Manual, 2, FDA/OMO-88/17B, Food and Drug Administration, Center for Food Safety and Applied Nutrition.

FWS, 1986. Field Operations Manual for Resource Contaminant Assessment. U.S. Fish and Wildlife Service, Contaminant Assessment Division, Washington, D.C..

FWS, 1987. "A Checklist for Use in the Physical Examination of Fishes." U.S. Fish and Wildlife Service, Research Information Bulletin No. 65-87, June 1987.

Karr, J. R., K. D, Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. "Assessing Biological Integrity in Running Waters - A Method and Its Rationale," Illinois National History Survey Special Publication 5.

Lagler, K. F. 1956. Freshwater Fishery Biology, 2nd edition, Wm. C. Brown Company Publishers, Dubuque, Iowa.

Lauenstein, G. G., and D. R. Young. 1986. "National Status and Trends Program for Marine Environmental Quality--Bethic Surveillance Project: Cycle III Field Manual," NOAA Technical Memorandum NOS OMA 28, Rockville, Maryland.

Lowe, T. P., T. W. May, W. G. Brumbaugh, and D. A. Kane. 1985. National Contaminant Biomonitoring Program; Concentrations of Seven Elements in Freshwater Fish, 1978-1981," Arch. Environ. Contam. Toxicol., 14, pp. 363-388.

Mason, W. T., Jr. 1978. "Methods for the Assessment and Prediction of Mineral Mining Impacts on Aquatic Communities: A Review and Analysis." USFWS Workshop Proceedings, Harper's Ferry, West Virginia.

Mearns, H.J. and M.J. Allen. 1978. Use of Small Otter Trawls for Coastal Biological Surveys, EPA-600/3-78-083.

Nielson, L.A. and D.L. Johnson (eds.). 1983. Fisheries Techniques. A Comprehensive Survey of

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D.4 FLORA SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix D.4 of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   D.2 Bird Sampling Reference Field Methods
   D.3 Fish Sampling Reference Field Methods
   D.4 Flora Sampling Reference Field Methods
   D.5 Reptiles and Amphibians Sampling Reference Field Methods
   D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

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Section to be Revised_____ Page(s)_____

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Suggested Revision (attach additional pages if more space is needed):

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ACRONYMS

BLM	Bureau of Land Management
COC	Chain-of-Custody
EC	Environmental Contaminant
EPA	Environmental Protection Agency
ETOH	Ethyl Alcohol
NPS	National Park Service
PAH	Polynuclear Aromatic Hydrocarbons
PCBs	Poly-chlorinated biphenyls
RFM	Reference Field Method
SOP	Standard Operating Procedure
USGS	U.S. Geological Service

U.S. FISH AND WILDLIFE SERVICE LANDS
BIOMONITORING OPERATIONS MANUAL

APPENDIX D.4
FLORA SAMPLING
REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of these Reference Field Methods (RFM) is to provide field personnel of the U.S. Fish and Wildlife Service (FWS) with guidance in the collection, handling, and preservation of flora samples. This RFM is not intended to be an exhaustive presentation of all available field sampling methodologies.

1.2 Scope

The first portion of this RFM contains information and sources that can help refuge personnel identify potential contaminant problems by the symptomatic response of flora. This information may be used by refuge personnel as guidance regarding what plant symptoms may be indicators of contamination problems. Refuge personnel can incorporate reconnaissance observations as a part of their routine field work particularly in areas that have been identified as potential contaminant transport pathways. There are numerous reasons why the responses to stress discussed in this document may occur, many of which are not contaminant oriented. If these conditions do exist in some plants at a particular site, refuge personnel should contact an environmental contaminants (EC) specialist and/or a local plant pathologist to help diagnose the cause. Sources of additional information and guidance are discussed in Section 1.4.

It is not the intent of this document to provide specific information regarding physiological and morphological responses to contaminants by various plant species; rather, its purpose is to provide general monitoring information that can direct the need for further investigation should conditions exist that warrant such action.

The second portion of this RFM contains methods for the collection and storage of plant samples for contaminant analysis. Information regarding the rationale for collecting the sample is also included. There are numerous methods for collecting flora samples; those selected have proven to be relatively simple and straightforward. Table 1 provides some advantages and disadvantages to the collection a particular flora medias.

Situations that require special studies are not specifically addressed by this document. Special studies are contaminant problems that require detailed studies and the assistance of EC specialist to assess their extent and the proper action for correction. These studies may require modification to the methods included or completely different procedures. If other methods are used, they should be documented in writing to the extent that they differ from those contained within this RFM.

1.3 Background

1.3.1 Contaminant-Induced Symptoms

Biological samples, such as plants, have a distinct advantage over abiotic media in that they will exhibit symptoms of stress resulting from some contaminants. It should be emphasized, however, that diagnosis of the nature and causes of suspected contaminant injury to vegetation is usually a complicated process. It is difficult to determine if observable effects are resulting from a specific contaminant or to other stresses associated with the physical environment, e.g., soil variability, water excess, or deficiency. Additionally, many biological agents cause symptoms on vegetation (primarily the leaves) that mimic those caused by various contaminants (see Section 1.4 of this RFM (EPA, 1978) for applied resource information). Symptoms induced by contaminants are

Table 1. Key to Flora Sampling

SAMPLING MEDIA	LOCATION IN RFM	TYPE OF MONITORING	GENERAL COMMENTS
Litter	3.1	A,C	Important collection media for atmospheric depostiion contaminants and for examining nutrient cycling Minimum equipment requirements
Trees, shrubs, and forbs	3.2	C	Physical (symptomatic damage) malformations readily observable
Mosses and lichens	3.3	A,C	Good H_2SO_4 and trace metals concentrators and indicators Not available at all sites
Phytoplankton	3.4.1	A,B,C	Good indicator of aquatic contaminants
Periphyton	3.4.2	A,B,C	Artificial substrates may take 14+ days for periphyton colonization
Macrophyton	3.4.3	A,B,C	High species diversity requires different methods

A = Initial Screening/Characterization
B = General Monitoring
C = Special Case Monitoring

highly variable depending upon the contaminant(s), its concentration, means of exposure, the plant species, its age or stage of development, and plant vigor.

Refuge personnel must consider all the symptoms that are present, separate relevant from irrelevant data, and determine the role of each possible causal factor. It is also important to be aware that contaminants do not always induce a visible response by the vegetation. Therefore, areas with a

potential contaminant source should not be overlooked when taking samples even if the vegetation appears normal.

1.3.2 Factors Affecting Plant Response

Plants vary considerably in their morphological and physiological response to a contaminant. Certain species may be quite sensitive, while others may be very tolerant. The relative sensitivity of plants to SO_2 that might be found on or around a refuge are presented in Table 2. Factors associated with vegetation sensitivity to specific contaminants include

1. Light (quality and quantity)
2. Soil moisture
3. Humidity
4. Temperature
5. Nutrition
6. Plant and tissue age
7. Biological induced stresses
8. Other contaminants present

Information pertinent to some of the above factors is provided for each contaminant addressed in Section 1.4 (EPA, 1978) of this RFM. In general, the conditions that tend to favor the growth of a plant also tend to increase their sensitivity to contaminants.

1.4 Information Resources

In addition to consultations with the EC specialists, local university, Bureau of Land Management (BLM), National Forest Service (NFS), National Park Service (NPS), Environmental Protection Agency (EPA), and county extension office personnel are good sources for relevant information. The resources provided below may also be useful to obtain additional information.

Scientific and government resources are recommended and include the following:

1. EPA, 1978. "Diagnosing Vegetation Injury Caused by Air Pollution," EPA-450/3-78-005, Applied Science Associates, Inc., Valencia, Pennsylvania 16059.

This document is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20102, Stock No. 055-003-00088-2. The phone number for the Government Printing Office main order desk in Washington, D.C. is (202) 783-3238.

A Self-Instruction Training Course #SI:448, Air Pollution Effects on Vegetation," has been developed by EPA and complements this document. The training course consists of 35-mm slides, booklets, audio cassette tapes, and quizzes with answers at the end of each unit. Information concerning the handbook and training course can be obtained from the Senior Environmental Specialist, Phone--(919) 541-2355.

The following sequence of questions can be used to help diagnose suspected contaminant injury to vegetation:

Table 2. Relative sensitivity of plants to SO_2[a]

Sensitive		Tolerant
	CROPS	
Alfalfa	Sweet Potatoes	Celery
Buckwheat	Lettuce	Corn
Barley	Beans	Onion
Cotton	Broccoli	Potato
Red Clover	Squash	Cabbage
Oats	Wheat	
Peas	Carrot	
Spinach	Tomato	
	FLOWERS	
Sweet Pea	Sweet William	
Four O-Clock	Gladiola	
Cosmos	Tulip	
Bachelor Button	Violet	
Aster	Zinnia	
	TREES	
Quaking Aspen	Alder	Cedar
Jack Pine	Red Pine	Citrus
White Pine	Austrian Pine	Maple
White Birch	Hazel	Linden
Larch	Apple	
Large-Toothed Aspen	Douglas Fir	
Willow	Ponderosa Pine	
	GARDEN PLANTS	
Peas	Cucumber	Muskmelon
Rhubarb	Lettuce	Corn
Spinach	Radish	Onion
Swiss Chard	Squash	Potato
Beans	Tomato	Cabbage
Beets	Cultivated Mustard	Broccoli
Turnips	Kohlrabi	Turnips
Carrot		

a. EPA PB82-238924, February 1978. "Vegetation Injury Caused by Air Pollution."

a. Is there a contaminant source nearby capable of causing injury, e.g., mode of contaminant transport, such as air or water?

b. What are the characteristics of the terrain or location?

c. What are the symptoms of injury and what part of the plant is affected?

d. What is the distribution of the affected plants?

e. Are biological agents present?

f. Is more than one species of plant affected?

g. What is the crop history of the affected area?

The document describes a systematic step-by-step method of obtaining and handling the pertinent information in such a way as to increase the probability of reaching a correct diagnosis of the cause of plant injury. The method presented utilizes a branching key that leads through a series of steps to a final conclusion for a particular set of circumstances. Each step of the method contains a description of what to look for, or some other discussion, and is usually followed by a question that must be answered in order to be directed to the next step.

The diagnostic routine is designed to do one of two things: (1) lead to a conclusion that the observed injury was in all likelihood caused by air pollution, in which case the routine will often indicate the causal contaminant and its source; or (2) eliminate contamination as the cause of injury either because of a lack of conclusive information or because of a determination that another factor is a more likely cause.

It should be pointed out that the above reference and its diagnostic routine deal primarily with physiological and developmental responses by plants to specific airborne contaminants. Contaminants addressed include ozone, peroxyacetyl nitrate (PAN), oxides of nitrogen (NO_x), sulfur dioxide, fluorides, chlorine, hydrogen chloride, ethylene, ammonia, hydrogen sulfide, carbon monoxide, heavy metals, particulate matter, and pesticides. Many of the plants are identified as sensitive, intermediate, or tolerant to contaminant exposure and are primarily agricultural and ornamental species or cultivars (see Appendix C of the EPA reference).

If these species are not located on service lands, it might be possible to locate them just outside the refuge (i.e., in a grain field) and use them as a monitoring location.

2. APCA, 1970. Recognition of Pollution Injury To Vegetation, Air Pollution Control Association, Pittsburgh, Pennsylvania.

This resource is a 1970 pictorial atlas, which contains a concise and accurate text giving sources of contaminants, symptoms on plants, and tables of plant susceptibility for each contaminant. It also contains photos of markings often confused with each type of air contaminant injury. The cost is approximately $20.00.

3. U.S. FWS. Habitat Evaluation Procedures, Project Impact Evaluation Team, Division of Ecological Services, Fort Collins, Colorado 80526.

This is a FWS resource well recognized for its vegetative sampling methods and habitat evaluation procedures.

4. USDA, 1983. United States Department of Agriculture (USDA), Methods of Vegetation Sampling and Analysis on Revegetated Mined Lands, General Technical Report INT-151, Intermountain Forest and Range Experiment Station, Ogden, Utah 84401, October 1983.

This handbook is intended as an introduction to some of the major vegetation sampling methods that have been useful for evaluating revegetation success. Although the emphasize is on revegetation of mined lands, the various components of vegetation sampling are discussed in detail.

5. Donald J. Lisk, 1972. Trace Metal In Soils, Plants, and Animals, Academic Press, New York, New York, pp. 267-325.

This resource gives the ratio of contaminant concentrations in soils to those in plants for 29 metals.

6. Dale W. Jenkins, 1981. Biological Monitoring of Toxic Trace Elements, EPA-60S3-80-090, U.S. EPA.

This resource gives the relative toxicity of 14 metals to higher plants, mosses, lichens, and algae. It also provides other useful information on metal toxicity to plants.

7. U.S. Fish and Wildlife Service
Lloyd 500 Bldg., 500 NE Multnomah Street
Portland, Oregon 97232
Phone 503/231-6154

RESEARCH: Wetlands classification, mapping, and remote sensing in Region 1-USFWS (OR, WA, ID, NV, CA, Pacific Islands).

8. U.S. Fish and Wildlife Service
National Wetlands Inventory, Suite 101
Monroe Bldg., 9720 Executive Center Drive
St. Petersburg, Florida 33702
Phone 813/893-3867

RESEARCH: Development of wetland plant data base. Experience in wetland flora and wetland identification and delineation. Have published national, regional, and state wetland plant lists and created annotated national wetland plant species data base.

9. G. Bruce Wiersma, 1985. Recommended Integrated Monitoring System For Pollutants on U.S. National Parks Designated As Biosphere Reserves, EG&G-PBS-6721, Idaho National Engineering Laboratory, U.S. Department of Energy, January 1985.

This report addresses pollutant monitoring in remote biosphere reserves, e.g., what pollutants should be monitored, types of samples that should be collected, and how samples should be collected.

2. PRESAMPLING CONSIDERATIONS

Refuge personnel should include a preliminary reconnaissance of the study area to familiarize themselves with the study site and gather plant community characteristics information (e.g. dominance and distribution of plants) and evidence, or lack of evidence, of contaminant induced symptoms. The reconnaissance should include:

1. A search for damaged plants, i.e., dead or dying leaves; misshapen leaves, flowers, or fruits; yellowing vegetation; or stunted growth. Note these data in the field logbook with as much detail as possible. Include drawings, sketches, or preferably photographs. Cameras that produce "instant" pictures are particularly useful. Several shots should be taken to provide the site in proper perspective. These not only aid in site documentation but can provide evidence of symptomatic damage to plants. Pictures can be stapled into the field logbook as part of the permanent record. A tape recorder may also be helpful for describing the site.

2. The use of maps, aerial photographs, survey stakes, measurement tapes, and landmarks to document the boundaries of the monitoring area, and the locations of the sampling points.

3. A compiled list of local sources for needed equipment (Table 3).

4. A characterization of the plant community. This should provide refuge managers with an information base about the basic ecology of a refuge (see Section 1.4 of this RFM, U.S. FWS (Resource No. 3), for applied resource information). The "habitat type" section is a method of site classification that uses the plant community as an integrated indicator of environmental factors. "Habitat type" classification is also valuable for the classification and mapping of vegetation.

   These data are useful since change in the types and abundance of species composing the community may indicate the presence of contamination.

   Components that are typically used to characterize the plant community include frequency, density, cover measurements, and production. These various vegetation sampling methodologies are in some detail in the following reference (see Section 1.4 of this RFM, Resource Nos. 4, 7, and 8, for applied resource information).

5. A collection of control samples (selected species) analyzed for contaminant baseline values (see Section 3 for guidance). This is especially important when evaluating inorganic contamination. Species and symptom identification can often be accomplished in the field at the time of sampling.

6. A survey of nearby events that may result in contaminant exposure. Such things as airborne drift of aerially applied insecticides and herbicides that could cause damage to plant communities or organisms in the food chain on the refuge.

Table 3. Equipment for flora collection

	Litter	Trees/Shrubs	Forbs	Mosses/Lichens	Phytoplankton	Periphyton	Macrophyton
Aluminum Foil (acid-rinsed)	X	X	X	X	PA	PA	PA
Camera ("instant pictures")		X	X	X	X	X	X
Camera film		X	X	X	X	X	X
Clipboard	X	X	X	X	X	X	X
Compass	PA	PA	PA	PA			
Dredge (Ekman)							PA
Envelopes	PA	PA	PA	PA			
Gloves (leather, latex	X	X	X	X	X	X	X
Grappling device					PA	PA	PA
Ice chest	X	X	X	X	X	X	X
Ice/Blue Ice/Dry Ice	X	X	X	X	X	X	X
Labels	X	X	X	X	X	X	X
Maps (local topographic)	PA	PA	PA	PA	PA	PA	PA
Meter stick/tape measure	PA	PA	PA	PA	PA	PA	PA
Metric rules	PA	PA	PA	PA	PA	PA	PA
Pens (indelible ink)	X	X	X	X	X	X	X
Plastic bags	X	X	X	X	PA	PA	PA
Rakes					PA	PA	PA
Rope					PA	PA	PA
Record book (logbook)					PA	PA	PA

Table 3. (continued)

Slides (Microscope and tray)						X	
Solvents (acetone, hexane)		X	X	X	X	X	X
Spray tank (pressurized) disilled water			X	X	PA	PA	PA
Stapler		X	X	X	PA	PA	PA
String/baling twine		X	X		PA	PA	PA
Survey stakes	X	X	X			PA	PA
Tags	X	X	X	X	X	X	X
Tape (masking, etc.)	X	X	X	X	PA	PA	PA
Teflon pan (decontamination)		X	X	X	X	X	X
Tools (hammer, shovel, pole shears, screwdriver, trowel, pruners)	X	X	X	X		PA	PA
Tweezers (forceps)	X			X	X	X	X
Vials (assortment of acid-cleaned wtih Teflon caps, if required)	X	X	X	X	X	X	X
Waders (chest or hip)			X		X	X	X
Water sampler (Kemmerer)					X	PA	PA

PA = possible application

3. VEGETATION COLLECTION

Sampling procedures for different vegetation groups share many common elements, e.g. equipment requirements, documentation, and decontamination. Table 2 identifies equipment for vegetation collection. It should be modified as necessary, and equipment selection must reflect sampling requirements and specific needs. Before sample collection, refer to the Documentation Guidance Standard Operating Procedure (SOP) for specifics regarding handling, shipping, preservation, and holding time requirements. The field sampling methods, handling procedures, preservation techniques, and transportation procedures all affect final data quality and must be conducted properly to preserve sample integrity.

Samples collected for contaminant analysis should be representative of the entire impact area. Therefore, the collector may want to concentrate on collecting samples from the worst area if the purpose is to show the greatest impact. Representative composite samples should not be collected from the same square meter or confined area. Do not mix plant species unless composite samples are desired for analytical purposes.

Selection of the plant part as well as the age of the plant and/or plant organ may influence its desirability for contaminant study (see Symptomatology and Factors Affecting Plant Response for specific contaminants addressed in Resource No. 1, Section 1.4 this RFM).

Samples of vegetation can be cross-contaminated by associated soil and unclean tools and containers. Any soil must be removed thoroughly and not allowed to contact the plant part to be analyzed. When entire plants or roots are collected, soil should be removed by rinsing the root mass in a Teflon pan or stainless steel tub of distilled water, followed by squirting distilled water from a stainless steel pressurized sprayer to remove tenacious soil materials. This also applies to lichens and mosses, which can usually be handled much like vascular plants.

Sampling tools (scissors, knives, trowels, pruners) should be washed with water between samples and, if the chemical of interest is organic, with solvents such as acetone or hexane. Disposable gloves should be worn and changed between samples (see Appendix F, Decontamination Guidance RFM). Subsamples taken at equidistant points should result in a larger sample than is necessary for most chemical analysis. The sample can then be divided into several replicates and/or splits to satisfy quality assurance requirements.

Sample containers are usually plastic bags or jars of Teflon or glass, depending on the chemical analysis desired. Samples for trace metal analysis can simply be collected in plastic bags. Normally, those to be analyzed for organic contaminants must be collected in Teflon or glass containers. The most practical method to preserve vegetation samples is to keep them cold and in tightly sealed sample containers with minimum exposure to light. A recommended container for transport and storage of vegetation samples is a large ice chest. Dry ice is the preferred cooling agent.

Sampling methods for aquatic plants will vary according to the type of plants being sampled and the needs of the sampling program. Aquatic vegetation is especially susceptible to heat and light-mediated degradation processes; therefore, particular attention must be given to preservation, holding time, etc., to minimize or avoid sample alteration.

3.1 Litter Sampling

Litter serves as an important collection point for many potential contaminants, primarily from dry and wet deposition. The guidance which follows is further addressed in Resource No. 9, Section 1.4 this RFM.

Normally litter is composed of three layers:

1. Fresh litter (recently fallen), which is called the L layer

2. Partially decayed litter, which is called the F or fermentation layer

3. Decomposed litter, partially incorporated with soil, which is called the humus layer.

This sampling procedure includes only the L and F layers.

Procedures for sampling litter:

1. Locate monitoring station and mark or verify position on map.

2. At each plot lay out a circle of 10 m diameter (Figure 1). This circle does not have to be marked on the ground.

3. Take care not to walk on the litter before sampling.

4. To ensure "representative sampling," 10 litter samples should be collected at approximately equally spaced distances around the circumference of the circle.

5. Put on disposable latex gloves. Change gloves between samples, but not between subplots.

6. Remove about 25 to 50 g of the L and F layers (Figure 2) at the first soil pit. Be careful not to include any soil from the soil pit. Do not sample the humus layer. Collect sufficient samples to satisfy QA/QC requirements (see Sampling QA/QC RFM).

7. Place the litter in a clean, unused plastic bag or in jars of Teflon or glass, depending upon the chemical analysis required. When using a plastic bag as the container, roll the bag around the litter and seal with tape around the middle.

8. Check that a Teflon liner, if required, is present in the vessel cap. Secure the plastic bag or vessel cap tightly.

9. Repeat the process at each of the 10 subplots.

10. When all subplot locations are sampled, identify the sample container with the appropriate sample label and sample tag.

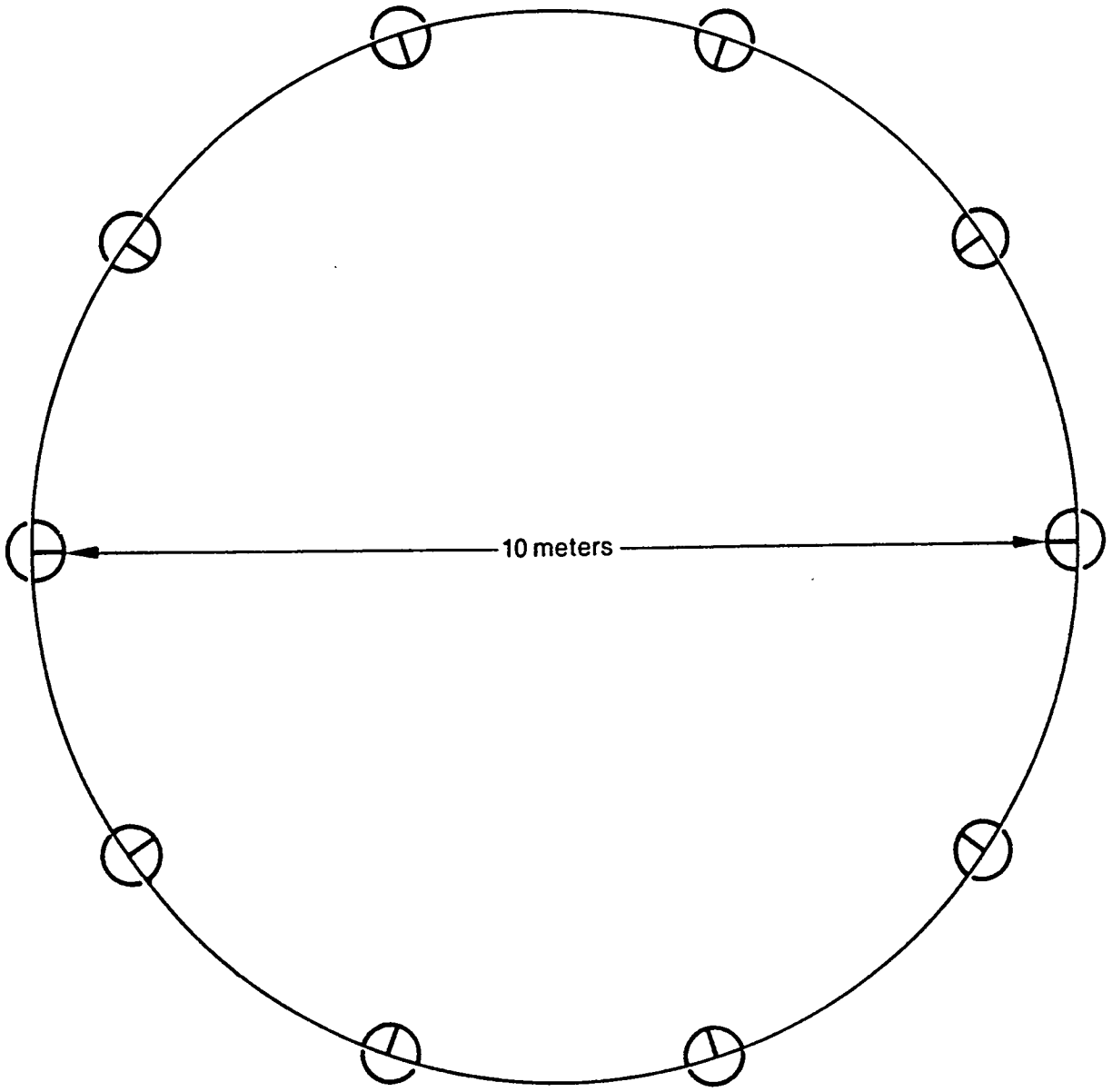

Figure 1. Illustration of how subplots are laid out in the field (Wiersma, 1985.)

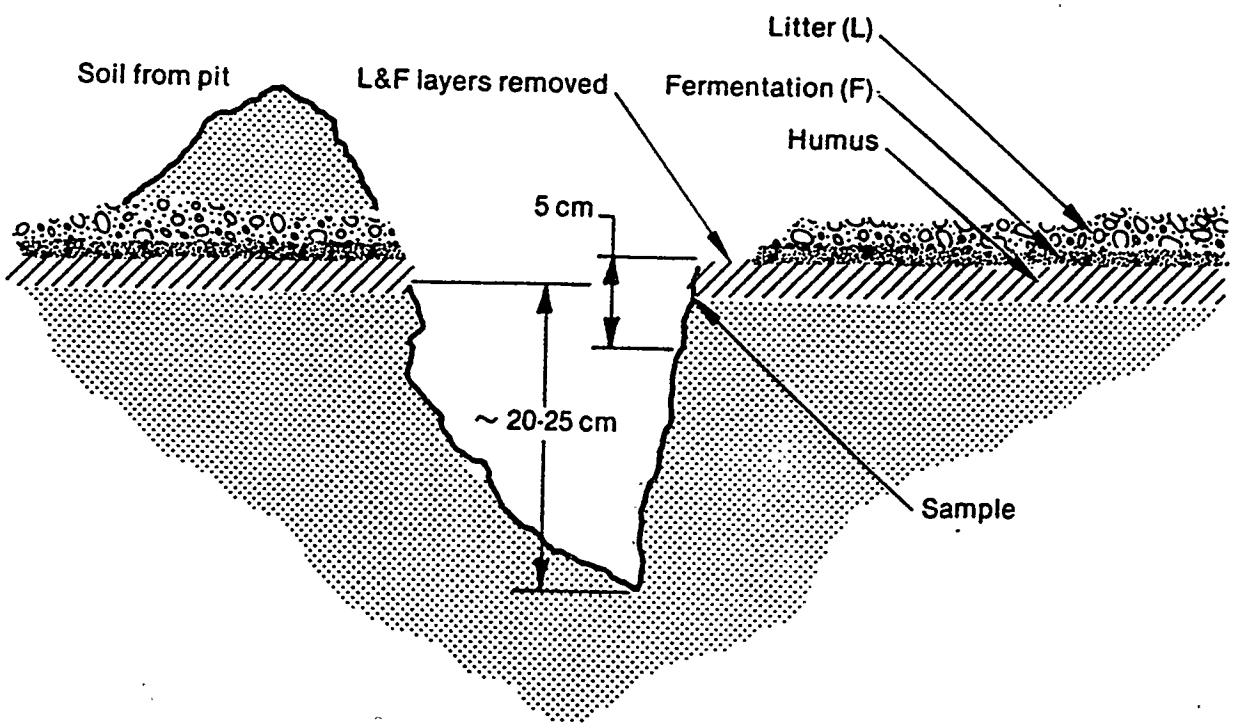

Figure 2. Side view of a soil pit (Wiersma, 1985.)

3.2 Procedure for Sampling Trees, Shrubs, and Forbs

1. Locate monitoring station and mark or verify position on map.

2. Sample can usually be stripped or broken from the plant manually, but if cutting tools (pruners, etc.) are used, care must be taken to avoid contamination during sampling. Use of metallic cutting tools should be avoided when taking samples for trace metals (see Decontamination Guidance RFM).

3. Collect sufficient plant material to satisfy QA/QC and analytical requirements (approximately 50 g dry weight equivalent or more depending on what contaminant is to be analyzed and the moisture content of the species, see Documentation SOP).

4. Transfer sample(s) to containment vessels, usually plastic bags or jars made of Teflon or glass, depending upon the chemical analysis required.

5. Check that a Teflon liner, if required, is present in the vessel cap. Secure the cap tightly.

6. Identify the sample container with the appropriate sample label and sample tag.

3.3 Procedure for Sampling Mosses/Lichens

1. Locate monitoring station and mark or verify position on map.

2. In general, sampling will be conducted at each plot and associated subplots as described for litter. However, some adjustments will have to be made in the event the appropriate species of vegetation is not readily available.

3. Put on a pair of new latex disposable gloves.

4. Pick a moss sample from a log, tree trunk, or rock near each subplot. Place this in a new plastic bag.

5. Try to avoid collecting moss or lichen samples directly from the soil surface. The soil can contaminate the moss or lichen sample and also cause interferences in the chemical analyses.

6. Continue around the circumference of the plot until you have collected about 50 to 75 g for the sample. Collect sufficient samples to satisfy QA/QC requirements (see Appendix F, Documentation SOP). Collect sufficient samples to satisfy QA/QC requirements (see Appendix F, Documentation SOP).

7. Transfer samples to containment vessels, usually plastic bags or jars made of Teflon or glass, depending upon the chemical analysis required. (For specific guidance, see Appendix F, Documentation Guidance SOP, Table 2c.)

8. Never mix species in the same container

9. Always change the plastic gloves between plots and when a new species is being collected at the same plot.

10. Check that a Teflon liner, if required, is present in the vessel cap. Secure the cap tightly.

11. Identify the sample container with the appropriate sample label and sample tag.

3.4 Sampling Aquatic Plants - Phytoplankton, Periphyton, and Macrophyton

3.4.1 Phytoplankton (microscopic, free-floating plants)

A "skimmed" surface sample (sample collected as near the water surface as possible) ordinarily reveals a disproportionate sample because plankton are often trapped at the surface film. Subsurface sampling is often adequate for collection of a representative sample in the main channel of rivers/streams because their waters are usually well mixed vertically. When stream water is mixed vertically and horizontally, periodic samples collected at midstream 0.5- to 1-m below the surface should yield representative planktonic populations, depending upon the maximum depth of the stream. Vertical and horizontal movements of phytoplankton are common in lakes and reservoirs. The depth distribution of phytoplankton in lakes and reservoirs is principally determined by the dynamic processes in the water, e.g., penetration of light and depth of the thermocline.

Preparation for field sampling can proceed as soon as sampling locations, depths, and frequency have been determined. A phytoplankton sample consists of a volume of water, usually 1 L. The procedures that follow (phytoplankton and periphyton) may not work for direct chemical analysis because of the small biomass of phytoplankton per unit volume of water. Sample collection with a plankton net will concentrate the biomass. Visible invertebrates can then be removed with forceps and/or fingers.

The following procedures may be used to sample phytoplankton:

1. To collect a sample representative of the entire flow of the stream, use a depth-integrated sampler, such as the Kemmerer bottle. Note, however, the incompatibility of various bottle construction materials with some analytical techniques (see Surface Water RFM, Section 4.1.4, for definitive guidance). Another method is to use the sample container as the sampling device (see Surface Water RFM, Section 4.1.1).

2. Collect sufficient samples to satisfy QA/QC requirements (see Documentation SOP).

3. Check that a Teflon liner, if required, is present in the vessel cap.

4. Secure the cap tightly after transferring the sample to the appropriate container (acid-cleaned glass jars are recommended).

5. Identify the sample container with the appropriate sample label and tag. Be sure to label the tag clearly with indelible ink, addressing all the categories and parameters. Place the label in the appropriate carrying container and preserve, as required.

3.4.2 Periphyton

Periphyton refers to communities of plants and other microorganisms that are attached to or live upon submerged solid surfaces. Periphyton are greatly influenced by water quality and are useful in assessing the effects of pollutants on lakes and streams. Samples are often difficult to obtain from natural substrates (submerged stones, pilings, sticks, etc.) because of a lack of appropriate natural features at desired sampling locations. Artificial substrates (glass slides or other materials) provide uniform, controlled samples and are more commonly used. However, samples may not be representative of the natural habitat, and contaminant assessment data may reflect this.

A widely used artificial substrate is a 25 x 75 mm (1 x 3 in.) standard glass microscope slide. Several slides are exposed to submerged trees, stumps, logs, and boulders at each sampling location. Slides may also be attached to stakes driven into the bottom or put on a slide tray and suspended from a float. The substrates must be submerged but may be near the surface of the water or at any other appropriate depth.

The length of time required for colonization of the substrates by periphyton will depend upon the season, water temperature, light, nutrient availability, and other factors. Exposure probably should be at least 14 days but will vary and must be determined for each season and water type. After sufficient colonization of periphyton indicated by visible green or brown growth on the artificial substrate, proceed with sample collection.

The following procedures should be used to sample periphyton from an artificial substrate:

1. Remove the substrate from the water.

2. Scrape the periphyton from the substrate into an appropriate precleaned sample container (acid-cleaned glass jars are recommended). A glass slide works well as a scraping device.

3. Check that a Teflon liner, if required, is present in the vessel cap.

4. Secure the cap tightly and minimize exposure to light.

5. Identify the sample container with the appropriate sample label and tag. Be sure to label the tag clearly, addressing all the categories for the parameters. Place the labeled container in an appropriate carrying container and preserve, as required.

3.4.3 Macrophyton

Macrophyton refers primarily to aquatic flowering plants but also includes aquatic mosses, liverworts, ferns, various algal group including large marine algae. Extensive areas of shallow lakes, marshes, and canals are often covered with large numbers of higher aquatic plants.

No single standard operating procedure can be recommended because of the species diversity of macrophyton and wide range of conditions that exist in the refuge system. Therefore, general guidance is provided and must be adapted to meet sampling needs.

1. Select the sampling site.

2. Equipment selected must be compatible with the species sampled. The choice usually depends upon the water depth. For instance, communities of plants that live unattached in the water, such as duckweed or algae, can be collected by using the container immersion method (see Surface Water RFM, Section 4.1.1).

   Immersed rooted aquatics, such as water lily or cattail, can be collected with a variety of tools such as a rake, shovel, or grappling hook. In deep water, grabs such as the Ekman may be employed to collect submerged types.

   Marshgrass and similar wetland forbs can be collected using lawn shears and/or a shovel.

3. Samples should include entire plants, if possible, e.g., flowers, seed pods, roots, rhizomes, tubers, etc.

4. Select the appropriate sized, precleaned, sampling container (see Appendix F, Documentation Guidance SOP).

5. Check that a Teflon liner, if required, is present in the vessel cap.

6. Transfer the sample to the appropriate sample container and secure the cap tightly (acid-cleaned jars are recommended).

7. Identify the sample container with the appropriate sample label and tag. Be sure to label the tag clearly, addressing all the categories and parameters. Place the label in the appropriate carrying container and preserve, as required.

4. SAMPLE HANDLING AND PRESERVATION

4.1 Sample Handling

Vegetation samples can be contaminated or cross-contaminated by associated soils or unclean tools and containers. All soil must be removed from samples. Soil should not be allowed to contact plant parts to be analyzed or the inside of the sample container. Disposable gloves should be worn when handling samples.

Sample containers can be plastic bags and jars of teflon or glass, depending on the chemical analysis desired. For example, samples for trace metal analysis can be collected in plastic bags, while samples to be analyzed for organic pollutants must be collected in teflon or glass containers.

Seeds can be collected in envelopes that allow drying and have an inherent labeling surface. Alternatively, seeds can be placed in glass or plastic vials.

Label all sample tags carefully and clearly, addressing all the categories and parameters. Ensure that the sample label is attached to the sample container, then placed in the appropriate carrying container, and preserved as required. Complete all chain-of-custody documents and record in the field logbook. Consult Appendix F, Documentation Guidance SOP for more information on the handling, shipping, preservation, and holding time requirements of samples.

4.2 Sample Preservation

Sample preservation is important because samples can change chemically and/or physically in the time between collection and analysis. Prolonged storage will lead to mold or spotting of a specimen. Also, vegetation is very susceptible to heat and light-mediated degradation processes and to fungal and bacterial growth.

The most practical method of preserving vegetative samples is to keep them cold in a tightly sealed sample container with a minimum exposure to light. The use of metal ice chests with dry ice is recommended. Artificial "blue ice" packages can also be used to store samples. Samples for symptom examination should be preserved in a commercially available vegetation preservative.

5. GLOSSARY

Bioindicator	A species that is affected, either negatively or positively, by a contaminant. Negative effects can range from pathological symptoms in individuals to extirpation of the species. An example of a positive response is an increase in a population of a species, usually at the expense of other species, in an organically enriched stream section (e.g., from sewage input).
Biointegrity	the ability of a system to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region
Biomonitor	A species that accumulates or concentrates a contaminant in tissues to measurable levels. Ideally, the organism is not affected by the contaminant.
Ecoregion	Regions of relative homogeneity in ecological systems or in relationships between organisms and their environment.

6. REFERENCES

Wiersma, G. Bruce, 1985. Recommended Integrated Monitoring System for Pollutants on U.S. National Parks Designated as Biosphere Reserves, EG&G-PBS-6721, U.S. Department of Energy, January 1985.

U.S. Environmental Protection Agency, 1978. Diagnosing Vegetation Injury Caused by Air Pollution, EPA-450/3-78-005, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20102, Stock No. 055-003-00088-2, 315p.

7. BIBLIOGRAPHY

American Public Health Association, "Standard Methods for the Examination of Water and Wastewater," 15th edition, 1015 Eighteenth Street, NW, Washington, D.C. 20036.

Clark, T. et al., 1988. "Wildlife Monitoring, Modeling, and Fugacity," Environmental Science Tech., 22, 2.

Cooperrider, A. Y., Boyd, R. J., Stuart, H. R. (eds.), 1987. 1986 Inventory and Monitoring of Wildlife Habitat, xviii, U.S. Department of Interior, Bureau of Land Management Service Center, Denver, CO, 858p.

Davis, D. E., 1987. "Handbook of Census Methods for Terrestrial Vertebrates," S. H. Anderson, Comments on Measurement of Habitat, CRC Press, Inc., pp. 278-280

Fuller, H. J. et al., 1971. The Plant World, 5th edition, Holt-Rinehart-Winston.

Gleason, H. A. and Cronquist, A., 1964. The Natural Geography of Plants, Columbia University Press.

Odum, E. P., 1968. Fundamentals of Ecology, 2nd edition, W. B. Saunders Company.

Oosting, H. J., 1956. The Study of Plant Communities, 2nd edition, W. H. Freeman and Company.

Schemnitz, S. D., 1980. Wildlife Management Techniques Manual, 4th edition, The Wildlife Society, Washington, D.C.

U.S. Department of Agriculture (USDA), 1983. Methods of Vegetation Sampling and Analysis on Revegetated Mined Lands, General Technical Report INT-51, Intermountain Forest and Range Experiment Station, Ogden, UT 84401.

U.S. Environmental Protection Agency, 1984. "Vegetation Sampling--Techniques and Strategies," Environmental Monitoring Systems Laboratory, P.O. Box 15027, Las Vegas, NV 89114-5027

U.S. Fish and Wildlife Service, 1979. "Classification of Wetlands and Deepwater Habitats of the United States".

U.S. Fish and Wildlife Service, 1986. "Field Operations Manual for Resource Contaminant Assessment," Resource Containment Assessment Division.

U.S. Fish and Wildlife Service, 1979. "Habitat Evaluation Procedures," Project Impact Evaluation Team, Division of Ecological Services, Fort Collins, Colorado 80526.

Ward's Natural Science Establishment, Inc., "How to Make a Plant Collection," A Ward's Curriculum Aid, P.O. Box 1712, Rochester, NY 14603.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D.5 REPTILES AND AMPHIBIANS SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix D.5 of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
   - D.3 Fish Sampling Reference Field Methods
   - D.4 Flora Sampling Reference Field Methods
   - D.5 Reptiles and Amphibians Sampling Reference Field Methods
   - D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
0	10/2/91	2.1	2-4	2-4c	5
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

U.S. Fish and Wildlife Service
Division of Environmental Contaminants
4401 North Fairfax Drive, Room 330
Arlington, VA 22201

Commentor's Name_____ Phone_____

Address_____ City_____ State___ Zip_____

Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____ Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

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ACRONYMS

BLM	Bureau of Land Management
COC	Chain-of-Custody
DDT	Dichlorodiphenyltrichloroethane
EC	Environmental Contaminant
EPA	Environmental Protection Agency
ETOH	Ethyl alcohol
FDA	Food and Drug Administration
NCBP	National Contaminant Biomonitoring Program
NPS	National Park Service
PCBs	poly-chlorinated biphenyls
PCDDs	poly-chlorinated dibenzo paradioxins
PCDFs	poly-chlorinated dibenzo furans
RFM	Reference Field Methods
SOP	Standard Operating Procedures
USGS	U.S. Geological Service

U.S. FISH AND WILDLIFE SERVICE LANDS
BIOMONITORING OPERATIONS MANUAL

APPENDIX D.5
HERPETILE SAMPLING
REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of these Reference Field Methods (RFM) is to provide field personnel of the U.S. Fish and Wildlife Service (Service) with guidance in the collection, handling, and preservation of reptile samples. This RFM is not intended to be an exhaustive presentation of all available field sampling methodologies.

1.2 Scope

This RFM is intended to guide refuge biologists and Environmental Contaminant (EC) specialists in collecting amphibians and reptiles for contaminant monitoring. This document is not intended to address toxicological effects, provide instructions in sampling design, or to include all the procedures for collecting these organisms. There are situations that will require collection devices and procedures other than those presented in this Appendix. The methods provided should be acceptable for general contaminant monitoring activities. In special situations experts in the field should be consulted for additional guidance. If methods other than those discussed in this document are used, they should be documented to enable future sampling efforts to follow the same procedures.

This introductory section provides a background discussion on the collection of herpetiles for contaminant monitoring activities. It also suggests additional information sources that might be useful when planning and implementing these activities. Table 1 describes some of the advantages and disadvantages of using particular types of collection methods.

The second portion of this RFM addresses presampling considerations (e.g., seasonal variation, food habits, selection of indicator species, etc.) for the collection of herpetiles prior to going into the field.

The third portion of this RFM details the collection techniques for specific amphibians and reptiles. This section includes methods, equipment, bait, and precautions needed to successfully collect samples.

Section 4 outlines the proper handling, preservation, and shipping procedures of samples.

Attachment 1 lists addresses of Service regional offices and divisions of law enforcement that issue permits.

1.3 Background

Knowledge of the effects of environmental contaminants on herpetofaunal communities is fragmentary because only a few comprehensive studies have been performed to establish toxic levels contaminant exposure. However, there are a few reports that provide indications of herpetological sensitivity to environmental contaminants such as pesticides. Hall (1980) found reptiles to be more sensitive to the effects of pesticides than warm-blooded vertebrates, and reptilian mortality was observed at dose levels generally considered safe for birds and mammals.

Objectives for sampling and monitoring the herpetofaunal community include:

- To identify specific contaminants that may be adversely impacting herpetofaunal populations or associated habitat and measure contaminant residues in selected herpetofauna biomonitors
- Assess the importance of certain species as conveyers of contaminants to predators higher in the food web
- To determine the presence, absence, or health of indicator organisms and establish certain species as biological indicators of contaminants present.

1.4 Information Resources

Agencies that can provide additional information and assistance include:

- FWS National Wildlife Health Center
- National Forest Service
- Bureau of Land Management
- National Park Service.

Regional Agencies:

- Southeastern Cooperative Wildlife Disease Study, University of Georgia-Athens
- Northeastern Center for Wildlife Disease, University of Connecticut-Storrs
- Colorado Wild Animal Disease Center, Colorado State University-Fort Collins.

State Agencies:

- Wildlife Disease Programs

Fairbanks, Alaska	Fargo, North Dakota
Sacramento, California	Madison, Wisconsin
Fort Collins, Colorado	Laramie, Wyoming
Rose Lake, Michigan	Hampton, New Jersey

- State Departments of Agriculture.

Table 1. Key to Herpetile Collection Methods

Collection Method	Location in RFM	Applicable Herpetile	Advantages	Disadvantages
.22 caliber rifle with bird shot	3.1, 3.2, 3.3	Snakes, lizards, large frogs, and salamanders	Low cost Quick	Destroys sampling tissue May introduce contaminants or cross-contaminate tissues and organs
Snares	3.2, 3.3	Snakes, lizards	Live capture Easy to transport and set-up	Requires some training Possible injury to reptile
Pit traps and drift fences	3.2, 3.2, 3.3	Snakes, lizards, frogs, salamanders	Equipment is inexpensive Non-destructive	Preparation of traps and subsequent waiting period is extensive Samples exposed to carnivores
Road running	3.1, 3.2, 3.3	Snakes, lizards	Can cover a large area quickly	Samples usually damaged and/or contaminated
Minnow seine or minnow trap	3.1	Frogs, salamanders	Non-destructive Easy to transport and set-up	Non-target species captured
Treble hooks	3.4	Turtles	Easy to transport and set-up	Destructive Possible cross-contamination
Barrel trap	3.4	Turtles	Allows for live-capture Equipment is inexpensive	Barrel itself may contain contaminants (metals, oils)

Local Agencies and Resources:

- Local University Programs
- Private Sector (Consultants, Veterinarians)
- Local hunters and trappers.

The Patuxent analytical lab should be consulted regarding requirements for sample preservation and shipping requirements for particular samples. The National Wildlife Health Research Center should be consulted if infectious disease is a potential hazard to human health and safety or if the spread of disease is a concern.

To contact the National Wildlife Health Center, telephone,
(608) 271-4640

To contact the National Wildlife Health Center Resource Team, telephone, FTS: 364-5422 or (608) 264-5422 or (608) 271-4640

Address: National Wildlife Health Center
6006 Schroeder Road
Madison, Wisconsin 53711

2. MONITORING CONSIDERATIONS

2.1 Presampling Considerations

Prior to initiating a herpetofauna sampling program, the overall objectives of the contaminant monitoring program must be established. The objectives will be largely determined by the goals of the refuge, the potential risk to important receptors at the site, and the physical characteristics of the site. It is assumed that the objectives of the contaminant monitoring activities have been defined and that sampling herpetiles has been determined to be necessary to accomplish them.

Field personnel should have a full knowledge of both federal and state regulations applicable to species collection. Certain techniques may require special permits or may be prohibited. Usually there are few laws pertaining to the collection of amphibians; however, some states (such as California) protect all plants and animals, and permits must be obtained prior to proceeding with any collection. For instance, most crocodilians and several snakes and turtles are protected by Federal and/or state laws. If uncertain about the laws in specific regions, contact the Service Division of Law Enforcement Special Agent in Charge (SAC) for the region in which the collecting is to be conducted. Also, Czajka and Nickerson (1977) summarize pertinent state laws.

2.1.1 Habits/Behavior

Sampling personnel should be conscious of species habits, food preferences, and population densities. Observed differences in animals activity and reproduction habits vary with natural environmental factors, such as temperature and precipitation and may be the result of natural variability in weather rather than contaminant induced changes. Sampling personnel must be careful when interpreting amphibian and reptile population data. Sampling personnel should be careful not to overcollect in areas of low population density.

Feeding habits among reptiles and amphibians is governed by life stage and the relative abundance of potential prey species. Understanding basic herpetofaunal food habits will assist personnel in determining:

- What species to sample
- What time to sample
- Where to sample
- Which sampling techniques to use.

The degree of success in the collection of herpetiles is tied to knowing the appropriate bait, equipment, and optimum time and place to sample.

2.1.2 Spatial/Temporal Variation

The peak period of activity among North American amphibians is in the spring. Spring and fall rains frequently initiate heavy frog and salamander activity. Many species spend most of their time in terrestrial habitats under rotten logs, bark, leaf litter, and roadside seeps. Increased metabolic activity during the breeding/migration period increases predator-prey activity and should provide sampling personnel with good opportunity to obtain representative sample populations.

Because ontogenetic or individual age differences in feeding habits may affect contaminant concentration and transport within food webs, consistency in sampling individuals is recommended. For example, young rattlesnakes feed on mice, lizards, and spadefoot toads, while older rattlers feed on larger mammals, such as ground squirrels, cottontail rabbits, kangaroo rats, pocket gophers, and wood rats. This dietary change is more frequently absent in turtles because of their more piecemeal method of feeding.

A seasonal change of habitat will frequently initiate a corresponding change in the feeding habits of certain predators. Generally, this is related to the abundance of food in the respective habitat.

2.1.3 Physiology

Amphibians and reptiles are known to accumulate various contaminants; however, the significance of these residues to herpetofaunal communities is poorly understood. For pesticides and environmental contaminants there is only limited knowledge about the types and quantities that are particularly hazardous to reptiles and amphibians (Hall, 1980).

Physiological studies indicate that acutely toxic amounts of organochlorines probably inhibit nerve transmission, resulting in tremors, paralysis, and loss of motor control. PCBs, which are known to inhibit reproduction in some mammals, may interfere with reproduction in amphibians and/or reptiles, such as oviparous snakes. Neurotoxicity and resultant nerve demyelination has been associated with various organophosphates. Organophosphates and carbamate insecticides have also been shown to affect nerve synapse by blocking impulse transmission through inhibition of the enzyme acetylcholinesterase.

Literature reviewed by Hall (1980) indicates that the following generalizations may apply to amphibians and reptiles:

1. A given toxicant may cause different effects at different stages of the life cycle and among closely related species.

2. Persistent contaminants that cannot readily be detoxified or excreted tend to be more damaging to species at higher trophic levels within the same food web.

3. Contaminant-induced effects vary considerably depending upon the physiological state of the animal, e.g., hibernation, estivation, prolonged breeding activity, or seasonal change of habitat.

4. Metabolites of pesticides and contaminants may be more or less toxic and subject to storage than the parent compound. Animal toxicity, therefore, depends upon the form of the contaminant to which the animal is exposed.
5. Many contaminants appear to affect specific enzyme systems at the cellular level and appear to produce a variety of sublethal effects in different organisms.

6. Long-lived species are more likely to be affected by persistent contaminants than the short-lived species. For instance, snapping turtles can be exposed to persistent contaminants for a number of years and tend to accumulate significant concentrations. Turtle fat is literally

a sink for organic contaminants such as PCBs, PCDDs, PCDFs, DDE, and dieldrin. Organic contaminants bioaccumulate in turtle livers but not to the same extent that they do in turtle fat. Snake fat is also a good tissue for monitoring contaminant concentrations.

2.2 Monitoring the Community

An intensive effort is required to collect representative samples of the entire herpetofauna community in order to assess and monitor the biointegrity of the ecosystem. Community monitoring is recommended for baseline monitoring activities. This recommendation would be useful for enacting intensive monitoring efforts to quantify the degree of damage to the community from contaminant inputs; however, this requires that baseline values for the site, or a suitable control site be available for comparison.

2.3 Monitoring Selected Species

Monitoring selected species will include collection of biomonitors for contaminant residue analyses, monitoring the presence/absence of bioindicators, or examination of bioindicators for condition, growth rate, histopathology, and other indices. This monitoring activity would be conducted for contaminant screening and/or more intensive investigations at the site. The following sections provide some discussion regarding these monitoring activities.

2.3.1 Biomonitor

In some cases, sampling may be specific as to whether contaminants are present in a system and what the potential is for impacting higher trophic level organisms.

2.3.2 Bioindicators

A bioindicator (or indicator) has been defined as a species that is either very sensitive to or very tolerant of a contaminant (see Introduction to Flora and Fauna, Appendix D). Limited understanding of the effects of contaminant residues upon herpetofaunal populations makes the selection of an indicator species difficult at best. Sampling personnel must observe contaminant episodes involving amphibians and reptiles to identify the most sensitive species .

Guidance for the selection of indicator species for birds may permit a few generalizations concerning selection of indicator species for amphibians and reptiles, because they may be close relatives. Consider the following when selecting indicator species:

- Species that suffer a considerable population decline may suggest a narrow range of tolerance, thereby qualifying as an indicator species of refuge habitat quality.

- Carrion eaters tend to bioaccumulate contaminants at higher levels than herbivores or omnivores.

- High order consumers generally make better indicators than herbivores and low order consumers.

- Eggs tend to bioaccumulate contaminants and may therefore be acceptable contaminant indicators.

Hall (1980) cites a study wherein various pesticide residues in three species of female whiptail lizards declined from June to August. This loss was attributed to egg laying and supported by the finding that eggs contained five times the residue levels of adult females.

The snake-eating habit of king snakes and their habitat diversity should make them prime candidates as contaminant indicators. King snakes are found in a variety of habitats--grassland, woodland, cultivated fields, coniferous forests, desert, and tropical scrub.

Bullfrogs may qualify as an indicator species by virtue of their voracious feeding habits. Turtles, especially carrion feeders such as snapping turtles, are excellent indicator organisms. Carnivorous salamanders qualify as excellent indicator species.

3. COLLECTION METHODS

Sampling methods for amphibians and reptiles will vary according to the species and habitat sampled. With herpetiles, collection should also include turning over rocks, logs, and debris. Because most amphibians and reptiles seek shelter when not active, netting and sifting through piles of dead leaves in springs, ponds, or streams should produce good results. Use caution because unwanted specimens (e.g. scorpions) may also be present.

Personnel should ensure that baits and constructed materials for the traps are not contaminated. For example, barrel traps may be coated with tar or other materials that contain polynuclear aromatic hydrocarbons. Care should be taken selecting materials for bait that do not readily disintegrate. For example, liver submerged in water will not stay on a hook very long and will need frequent baiting.

3.1 Frogs and Salamanders

Salamanders may be carnivorous or scavengers. These aquatic or semiaquatic animals have limited tolerance to conditions of low humidity and, therefore, rarely move far from moist areas. Salamanders feed primarily on insects, although aquatic species augment their diet with fish, earthworms, other amphibians, and reptiles. Semiaquatic species supplement their diet with spiders, sowbugs, and earthworms.

Mature frogs are primarily carnivorous. They are among the most voracious feeders of the amphibians and reptiles. Generally the bulk of their prey consists of insects, but supplements include fish, crayfish, spiders, and earthworms. Bullfrogs have been known to consume young blackbirds that fall from nests.

Methods/Equipment - Options

- A .22 caliber rifle with bird shot for large specimens. May introduce contaminants and affect analytical results.
- Minnow seine
- A coarse-meshed dip net or hand net with a long handle coupled with a head lamp works well in for frogs and salamanders in ponds and streams.
- A minnow-trap baited with fresh, uncontaminated liver works well for aquatic salamanders.
- During the mating season, placing an unmated female salamander inside a small screen cage inside a minnow trap will attract both male and female salamanders.
- Electrofishing is reported to be effective for aquatic salamanders (See Fauna Sampling "Fish" RFM).

- Various configurations of pit traps and drift fences (especially on rainy nights) will trap amphibians. When using pit traps, an inch or more of water should be added to each trap to drown shrews that might be captured.

- A hoop net or frame net with or without bait can be used to capture salamanders.

3.2 Snakes

Snakes are carnivores, egg eaters, or scavengers. Some species feed primarily on rodents or lizards, while some species are highly selective. The King snake, for instance, consumes large numbers of snakes of other species.

Methods/Equipment - Options

- A .22 caliber rifle with bird shot, is especially recommended for venomous snakes. However, lead shot may contaminate the sample.

- Snare (use 1/8 in. sash cord) (Figure 1f).

- Snake stick (Figure 1c, d, e) is used to pin down the animal. Then the snake can be picked up by the back of the head, close enough so it cannot turn and bite. High-top leather boots and heavy leather gloves are recommended if working near venomous snakes.

- Road running at night works well many amphibians and reptiles are nocturnal.

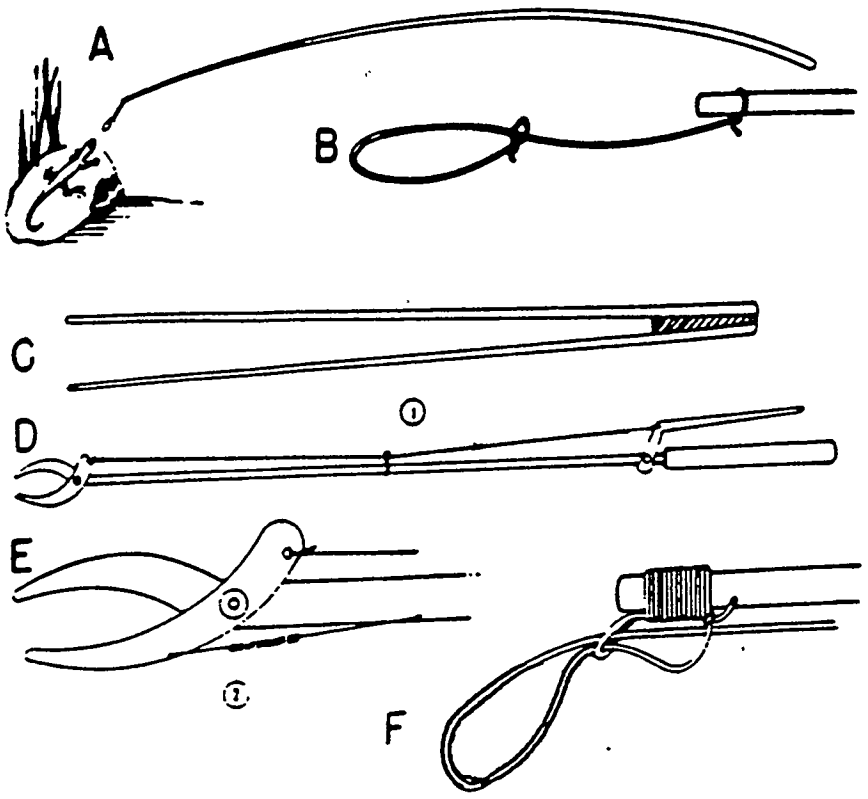
Place large lizards or non-venomous snakes in a bag (Figure 2). Canvas, flour, or seed bags work well (coarse weave burlap or jute bags are not to be trusted as snakes can squeeze through a surprisingly small hole). An assistant should hold the bag open, using both hands. As soon as the snake is dropped into the bottom of the bag, the bag is immediately twisted in a clockwise or counterclockwise manner. The twisted neck of the bag is then folded double and tightly secured. Mixing venomous with non-venomous snakes should be avoided. Snakes rarely bite through sacks; however, do not take chances. Sacks should not be allowed to dangle against one's body when being carried.

3.3 Lizards

Lizards are mostly carnivorous, feeding primarily on insects, spiders, and millipedes.
Methods/Equipment - Options

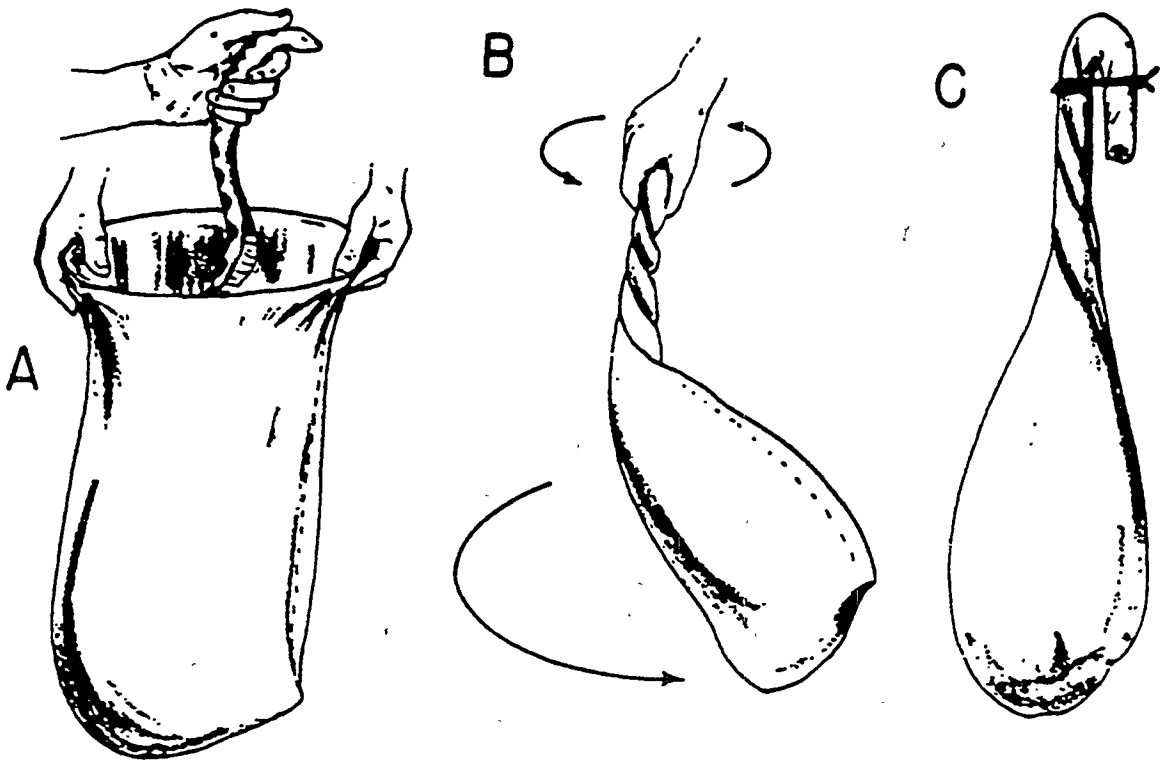
- A .22 caliber rifle with bird shot. However, lead shot may contaminate sample.

- Snare (hangman's noose). A telescoping fishing pole works well for a snare rod (Figure 1a, b). Use 0.5 to 1.0 lb monofilament nylon leader. Most lizards are very tolerant of the snare loop. Approach the lizard cautiously and quietly until it can be reached by the noose. Carefully work the noose over the lizard's head. A slight upward jerk will pull the noose closed.



Use and detail of the lizard snare (C) Wooden tongs for picking up poisonous reptiles (D-E) Details of a snake stick (F) Details of a heavy-duty snare for capturing very large snakes (1) Guide, (2) spring. (Knudsen, 1966).

Figure 1. Reptile-catching devices (A-B).



First drop the specimen in the bag, twist the bag, and finally tie the neck.

Figure 2. Method of holding a snake and placing reptiles in a snake bag (Knudsen, 1966).

- Drift fences using aluminum flashing and 20-L plastic buckets may be employed as successful pitfall traps (Gibbons and Semlitsch, 1981) (Figure 3). Note: stainless steel buckets are recommended for samples that are to be analyzed for organic contaminants.

- Road running occasionally works well for nocturnal lizards.

3.4 Turtles

As a group, turtles have the most varied diets of any of the amphibians and reptiles. Some are herbivores, others are carnivores, while others are omnivores. Several species feed primarily on fish and eggs. Carrion or omnivorous feeders such as the snapping turtle may be better contaminant indicators than herbivorous species.

In northern climates, turtles should be collected during the warmest time of the year. They generally are not active during cool periods when overnight temperatures fall below freezing.

Methods/Equipment - Options

Terrestrial: Terrestrial turtles can be picked up by hand.

Aquatic: Legler (1960) presents information on a portable hoopnet used successfully. The snapping turtle, Chelydra, is successfully collected using a trot line as described below:

1. Use treble hooks (usually 2/0 or larger depending on the size) on about 6 in. drops.

2. Space the hooks approximately 8 ft apart. (Line length will vary according to the size of the stream or lake sampled.)

3. Bait the hooks with a generous amount of contaminant free liver or other meat.

4. Distribute baited hooks, from the deepest part of the pool, upstream so the scent will carry downstream to turtles in all areas of the pool.

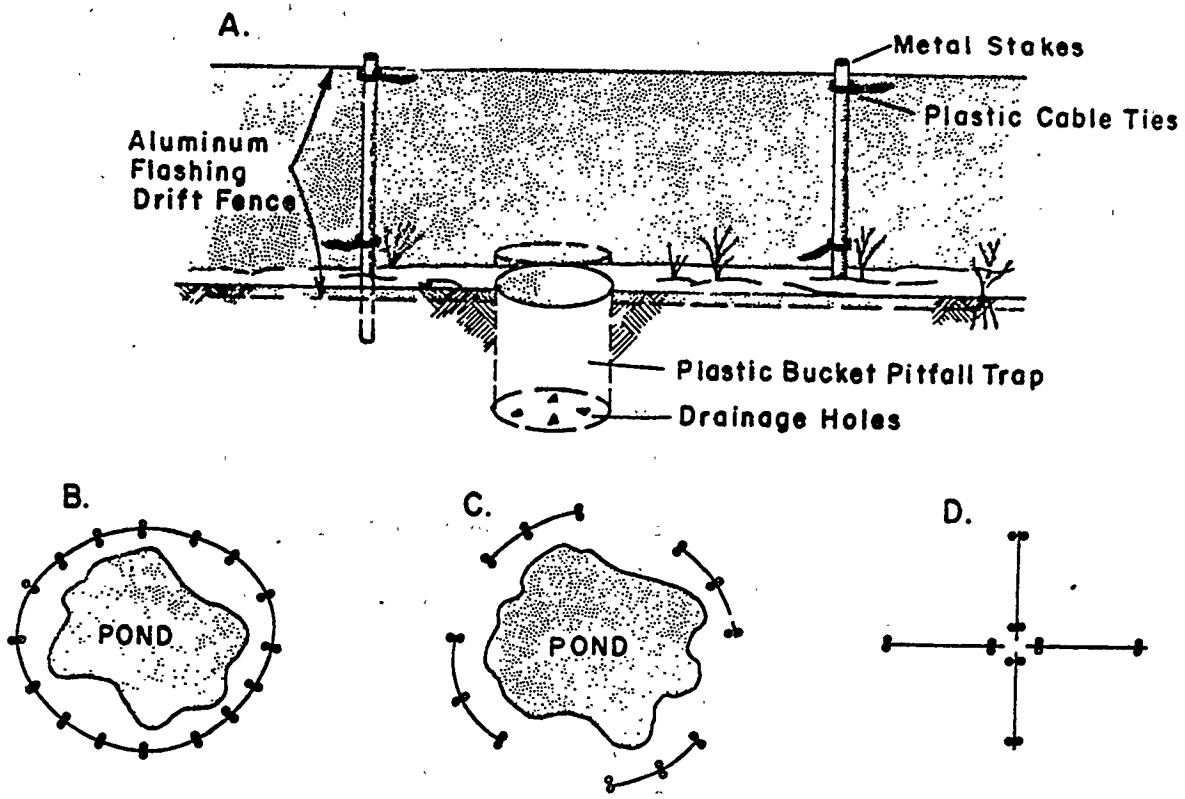
Many aquatic turtles are attracted to meat baits and can be collected in a half-submerged barrel trap (Figure 4) described below.

1. Drill several 1/2- to 1-in. diameter holes in a wooden barrel or metal drum.

2. Secure barrel to a stake, then drive the stake into a shallow region of a pond where turtles occur.

3. Submerge the drum so that the top protrudes 5 or 6 in. out of the water.

4. Using a standard gate hinge, attach a roughened, wooden plank to the upper rim of the drum. Position the fulcrum so that the tripping mechanism operates in a "teeter-totter" manner.



(A) cross section (B) top view of a continuous fence (C) top view of a partial fence (D) top view of a plus-shaped fence array

Figure 3. The basic design for a terrestrial drift fence with pitfall traps, and spatial arrangements. (Gibbons and Semlitsch, 1981).

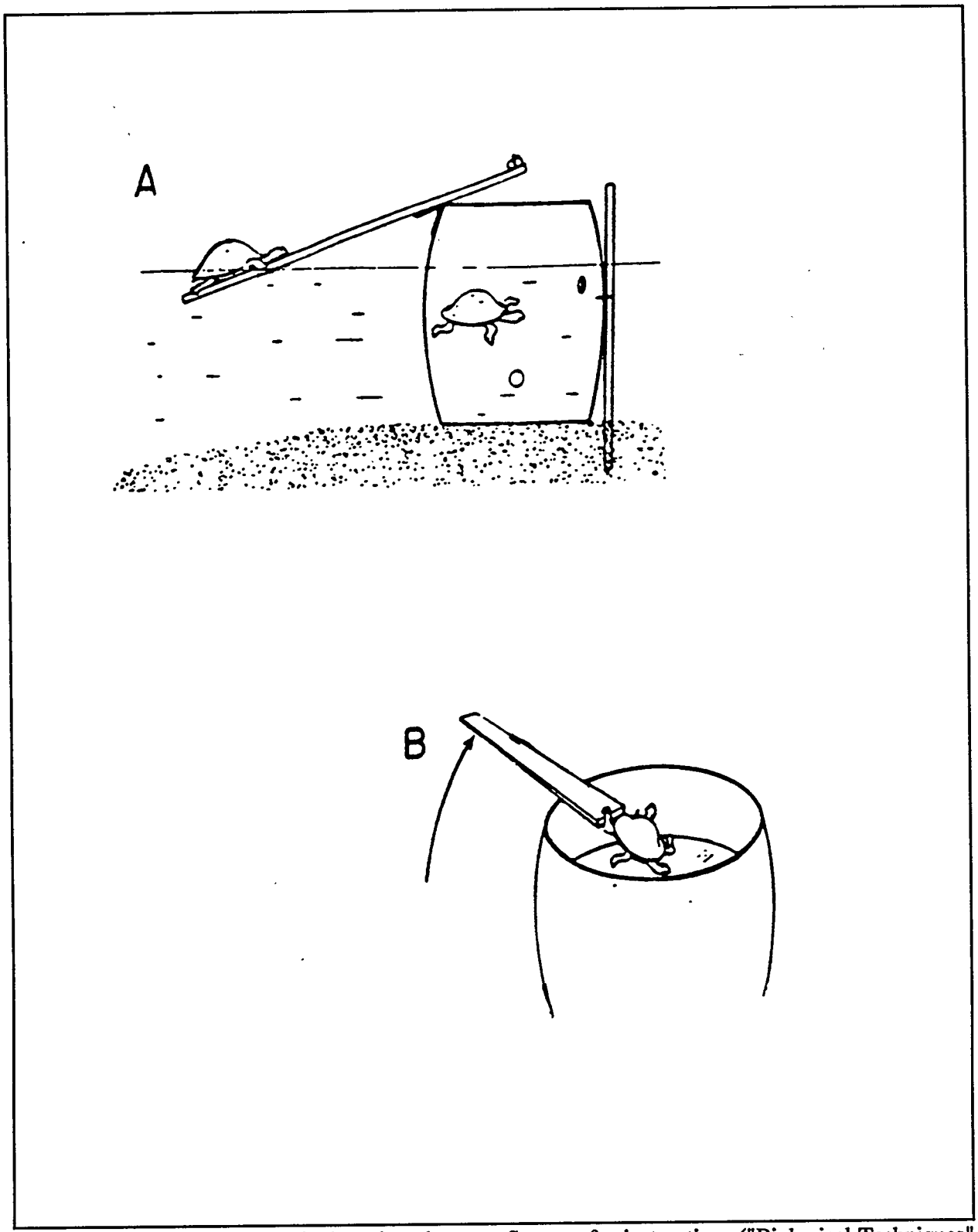


Figure 4. Diagram and use of a barrel turtle trap. See text for instructions ("Biological Techniques" - Kundsen, 1966).

5. Attach bait to the plank end positioned directly over the open drum. A fresh piece of meat makes an ideal general purpose bait. Additional meat should be placed inside the partially submerged barrel. The juices will diffuse through the barrel and help attract turtles.

Baits effective for snapping turtles are generally attractive for other species. Soft-shells are particularly attracted to unspoiled watermelon rind. Fresh fish or fresh entrails of fowl work well for several species. Lagler (1943) presents information on the following methods of collecting freshwater turtles: shooting, gaffing, spearing, set-lining, and trapping.

Turtles can also be trapped in still open water with baited nylon turtle traps. The traps should be set partially submerged overnight to prevent drowning of captured turtles. A sardine can punched with holes and suspended inside the trap near the closed end will work as bait. To remove the turtles, the trap is taken to shore and the funnel rope loosened. Turtles can be transported in heavy bags with care taken to ensure they do not bite through the bag.

4. SAMPLE--HANDLING AND PRESERVATION

4.1 Euthanasia

Frogs, salamanders, snakes, lizards, and turtles are easily euthanized by freezing, either on dry ice, in an ice chest, or in an electric freezer. If immediate freezing is not possible, a small strike on the head will usually dispatch them.

Turtles can also be euthanized by cutting their throats. If necessary, snakes, lizards, and turtles can be euthanized by drowning in weighted net sacks; however, this is a slow process.

4.2 Procedures for Storing and Shipping Samples

Place specimens in burlap bags, attach field data tag, and place in an ice chest or freezer overnight. Note: It is generally recommended that samples collected for organic analysis not come in contact with plastic. Frozen tails, legs, or bodies, may break if bumped or dropped. Careful handling after freezing will minimize or prevent breaking the specimens before they are thawed. Field data should accompany the specimen bags.

1. Label the sample tag carefully and clearly, addressing all the categories and parameters, (see Appendix F, Documentation Guidance RFM for guidance), then attach around the neck of snakes or around the hind leg or waist of salamanders, lizards, and frogs. If the legs or head of turtles is not accessible, drill a small hole in the edge of the shell for threaded or wired tag attachment.

2. If chemical assessments do not include organic analysis, place frogs, salamanders, and lizards in labeled Whirl-pak bags or food quality plastic bags. As previously stated, it is recommended that samples collected for organic analysis not come in contact with plastic. All specimens (especially large snakes and turtles) can be wrapped in properly labeled aluminum foil, which can then serve as the sample container.

3. Ensure that the sample label is attached to the sample container, then place in an appropriate carrying container and preserve as required. Samples should be frozen as soon as possible (see Appendix F, Documentation Guidance RFM).

4. Complete all chain-of-custody documents and record in the field logbook. (See Appendix F, Documentation Guidance RFM for handling, shipping, preservation, and holding time requirements.)

5. REFERENCES

Czajka, A. F. and M. A. Nickerson, 1977. "State Regulations For Collecting Reptiles and Amphibians In The Fifty United States," Spec. Publ. in Biol., Geol., Milwaukee Publ. Mus., No. 1:1-79.

Gibbons, J. W. and Semlitsch, R. D., 1981. "Terrestrial Drift Fences With Pitfall Traps: An Effective Technique for Quantitative Sampling of Animal Populations," Brimleyana, 7, pp. 11-16.

Hall, R. J., 1980. Effects of Environmental Contaminants on Reptiles: A Review, Fish and Wildlife Service, Report No. 228, Washington, D.C.

Knudsen, J. W., 1966. Biological Techniques - Collecting, Preserving, and Illustrating Plants and Animals, Harper and Row, New York, New York, p. 525.

Lagler, K. F., 1943. Methods of Collecting Freshwater Turtles, Copeia, No. 1, pp. 21-25.

Legler, J. M., 1960. "A Simple and Inexpensive Device For Trapping Aquatic Turtles," Utah Academy Proceedings, 37, pp. 63-66.

6. BIBLIOGRAPHY

Campbell, H. W., 1977. "Reviews and Comments," Copeia, pp. 605-606.

Davis, D. E., 1987. Handbook of Census Methods for Terrestrial Vertebrates, CRC Press, Inc., Boca Raton, FL.

Klauber, L. M., 1982. Rattlesnakes - Their Habits, Life Histories, and Influence on Mankind, University of California Press.

Oliver, J. A., 1965. The National History of North American Amphibians and Reptiles, Princeton, New Jersey: D. Van Nostrand Company, Inc., p. 359.

Stebbins, R. C., 1966. A Field Guide To Western Reptiles and Amphibians, Boston: Houghton Mifflin Company, p. 279.

ATTACHMENT 1

ADDRESSES OF FWS REGIONAL OFFICES, DIVISION OF LAW ENFORCEMENT THAT ISSUE PERMITS

ATTACHMENT 1

ADDRESSES OF FWS REGIONAL OFFICES, DIVISION OF LAW ENFORCEMENT THAT ISSUE PERMITS

Regional Offices--Special Agents in Charge

Region 1 (Calif., Hawaii, Idaho, Nev., Oreg., Wash.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
847 N.E. 19th Avenue
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Portland, OR 97232
(503) 231-6125

Region 2 (Ariz., N.M., Okla., Tex.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 329
Albuquerque, NM 87103
(505) 766-2091

Region 3 (Ill., Indiana, Iowa, Mich., Minn., Mo., Ohio, Wis.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
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Federal Building, Fort Snelling
Twin Cities, MN 55111
(612) 725-3530

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Atlanta, GA 30302
(404) 221-5872

Region 5 (Conn., Del., Maine, Md., Mass., N.H., N.J., N.Y., Pa., R.I., Vt., Va., W. Va.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 129, New Town Branch
Boston, MA 02258
(617) 965-2298

Region 6 (Colo., Kans., Mont., Nebr., N.D., S.D., Utah, Wyo.)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 25486
Denver Federal Center
Denver, CO 80225
(303) 236-7540

Region 7 (Alaska)
U.S. Fish and Wildlife Service
Division of Law Enforcement
Special Agent in Charge
P.O. Box 4-2597
Anchorage, AK 99509-2597
(907) 786-3311

Federal Wildlife Permit Office
Office of Management Authority
U.S. Fish and Wildlife Service
18th and C Street, N.W.
Washington, DC 20240

EGG-EST-9222
April 1993

U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX D.6 MAMMALS SAMPLING REFERENCE FIELD METHODS

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The opinions, findings, conclusions or recommendations expressed in this document are those of the authors and do not necessarily reflect the views of Research and Development, Fish and Wildlife Service, U.S. Department of the Interior. The mention of trade names or commercial products is for illustrative purposes only and does not constitute endorsement or recommendation for use by the Federal Government.

PREFACE

This is Appendix D.6 of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
   - D.3 Fish Sampling Reference Field Methods
   - D.4 Flora Sampling Reference Field Methods
   - D.5 Reptiles and Amphibians Sampling Reference Field Methods
   - D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

U.S. Fish and Wildlife Service
Division of Environmental Contaminants
4401 North Fairfax Drive, Room 330
Arlington, VA 22201

Commentor's Name_____ Phone_____

Address_____City_____State___Zip_____

Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

References (if applicable):

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U.S. FISH AND WILDLIFE SERVICE LANDS
BIOMONITORING OPERATIONS MANUAL

APPENDIX D.6
MAMMAL SAMPLING
REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of this Reference Field Methods (RFM) document is to help refuge biologists and Environmental Contaminant (EC) Specialists in selecting an appropriate mammal species for contaminant monitoring purposes and to suggest methods for sample collection. Data generated from monitoring mammals can be used to help determine if and where contamination problems exist and to develop and implement contaminant monitoring activities.

1.2 Scope

This RFM is intended to guide refuge biologists and EC specialists in collecting mammals for contaminant monitoring. This document is not intended to address toxicological effects on mammals, provide instructions in sampling design, or to include all the procedures for collecting these organisms. There are situations that will require collection devices and procedures other than those presented here. The methods provided here should be acceptable for most contaminant monitoring activities. In special situations, experts should be consulted for additional guidance. If methods other than those discussed in this document are used, they should be well documented such that future sampling efforts can easily follow the same procedures.

This introduction provides a background discussion on mammal collection for field contaminant studies and suggests additional information sources that might be useful when planning and implementing these activities.

The second section of this RFM describes collection methods for contaminant monitoring and information concerning mammals (morphology, physiology, longevity, etc.) that should be considered before going into the field.

The third section of this RFM contains collection techniques that describe the methods and hardware used to trap mammals. It is divided into three sections based on the relative size (small, medium, and large) of the mammals to be collected. Each section also contains information (diets, habitats, behaviors, etc.) pertinent to individual species, which may apply to other mammals not discussed.

Table 1 provides a list of collection methods discussed in this RFM and the associated advantages/disadvantages. Table 2 provides some representative mammals and associated collection techniques.

Table 1. Key to Mammal Collection Methods in This Document

Type of Mammals	Collection Technique	Advantages	Disadvantages	Additional Information
SMALL		Similar species in most habitats Small mammals are usually abundant in numbers	Small amounts of sampling material for contaminant analysis	Contact local University Mammology Experts
Shrews, mice, and other small rodents	Mouse traps and snap-traps	Traps are small, inexpensive and easy to operation	May destroy animal's tissues and organs	
	Pitfalls and Trenches	Equipment is inexpensive Can be used as a live-trap and as a kill-trap Non-destructive	Preparation of traps and subsequent waiting period is extensive Animals exposed to carnivores	
Medium		Sufficient amount of material for analysis		Fish and Game, Universities
Skunks, squirrels, raccoons, badgers	Box traps; HavaHart, Tomahawk	Animal is taken alive and without damage Traps are easy to operate Various trigger mechanisms, sizes, and styles	Traps are expensive and easily damaged Populations may be sparse	
Muskat, nutria, beaver		Provide infomraiton on waterborne contaminants		
	Conibears	Kills animal quickly	Cause damage to animal's tissue and organs	
	Steel leg hold traps	Reliable, easy to operation, and effective in most habitats	Often causes foot injury or possible death of animal	Fish and Game, local trappers, Universities
	Rope and wire snares	Wide variety of sizes an dstyles Small snares are lightweight, easy to transport, and quickly set-up	Less effective than otehr types of traps Possible injury or death to animal and is less human Illegal in some areas	Fish and Game, local trappers, Universities
LARGE		Deer will accumulate certain metallic elements in their livers Sufficient amount of material for analysis	Wide variety of diet makes them poor sampling subjects Dispersed populations in summer	Fish and Game, Universities, local hunters and trappers
Deer, elk, antelope	Clover trap	East to set-up adn operate	High initial dollar investment	
	Net traps	Effective for most trapping situations Moderate costs	Requires extensive manpower Frequently in need or repair	
	Corral traps	Effective for trapping and safe for the animal	Extensive costs, construction, and preparation	
	Shooting	Quick, easy, and inexpensive	Destroy tissue and organs, possible tissue cross-contamination	
	Drugs	Non-destructive; reduces damage to animal from forced restraint Eliminates mental distress Easier to sample and measure	Initial investment expensive Possible side effects and/or overdose Requires extensive training and licensing	

Table 2. Representative Mammals and Collection Methods

MAMMAL	TYPE OF DEVICE	BAIT	NOTES
Shrew	Snap type mouse trap	Fresh and bloody meat, mussels, baby mice	Set traps in a 1-in runway (e.g. vole)
	live-pitfall trap	Smear blood or oil on side of trap	Check traps frequently; shrews are cannibalistic and short lived in traps
Mole	Digging, hose with water from burrows		
Harvest mouse	Snap trap, revolving live trap, Havahart box trap	Peanut butter and oatmeal w/drop of anise or a freshly killed or live grasshopper	
Grasshopper mouse	Snap trap	Fresh grasshoppers, crickets, vole/mouse meat	
Ground squirrel	Box traps, .22 rifle, or #1 leghold	Peanut butter w/oatmeal, nuts, fruit	
Skunks	#1 or #1 1/2 baited leghold trap, box trap, or .22 Hornet rifle	Canned cat food or sardines w/few drops of anise	
Badger	#1 or 2 baited leghold trap; .22 rifle	Fresh killed squirrel or jackrabbit	
Muskrat, nutria, beaver	Conibears, steel legholds		
Mink	#1-1/2 steel leghold trap	Fresh skinned muskrat or fish	
Raccoon	#1-1/2 or #2 steel leghold	Shiny circular object	Double jaw trap to prevent chewing off foot
	Box trap box	canned salmon, fish, poultry, fruit	
Foxes and Coyotes	Snare, #1-1/2 or #2 leghold trap for foxes, #3 or #4 for coyotes Flush from den with tear gas .30-30 rifle	Carrion or fresh meat	Conceal traps well
Opossums	#1 or #1-1/2 leghold trap Box trap	Rancid lard, can fish, rotten fruit	Cover traps with grass
Deer	Corral and chute, clover trap .30-30 or larger	Leafy alfalfa, apples	
Elk	Clover traps M-99 tranquilizer	Apples	
Caribou	Drop net	Salt	
Pronghorn	.25.06, .257 or .30.06 rifle		Extremely difficult to trap or net

1.3 Background

Mammals can provide useful information for assessing the presence of contaminants in an area. Because of their size and relatively long lives, some species are valuable for assessing long-term exposure of an area to contaminants. Some species ingest large amounts of contaminated fauna and flora and will retain some contaminants or their metabolites in organs, tissues, and body fluids.

Other advantages of using mammals in a contaminant monitoring program include:

- High metabolic rate may increase contaminant exposure from food and water because of activity and food requirements.
- Many small mammals are easily captured.
- Medium and large species are easily identified in the field.
- Mammals occupy several trophic levels and diverse habitats.
- Hair and nails may be collected for non-destructive analysis of many species.
- Evidence of their presence may be noted by tracks, scats or other signs of activity.
- Larger, less secretive species display obvious visual symptoms of stress and/or mortality.
- Information from routinely assessed species can be utilized. Parts from hunters/trappers may also be used for some contaminant analyses.

Mammals do present some disadvantages as biomonitors or indicator organisms. Many species range widely, seasonally, and even daily, over such large areas that it would be difficult to determine the contaminant source. Mortality may be unobserved because of the small size and/or secretive nature of a species, making detection of population trends difficult to determine without an extensive trapping effort. Also, because of low populations and/or public concern, destructive sampling may not be desirable for some species.

Mammals are generally characterized as poor indicator species in furnishing initial evidence of contamination from behavioral or physical effects. Their size alone tends to increase their resistance to the toxic effects of many contaminants. Reduced populations might be a result of habitat loss rather than contaminant effects. However, in some circumstances are useful as biomonitors of contaminant presence and may furnish useful information about the extent of a contaminant's migration in the food chain.

1.4 Information Resources

The following wildlife disease programs may offer information and assistance when developing a monitoring program using mammals:

U.S. Fish and Wildlife Service, National Wildlife Health Center, Madison, Wisconsin.

State fish and game agencies located at Fairbanks, Alaska; Sacramento, California; Fort Collins, Colorado; Rose Lake, Michigan; Hampton, New Jersey; Delmar, New York; Fargo, North Dakota; Madison, Wisconsin; and Laramie, Wyoming.

Regional wildlife disease programs:

Southeastern Cooperative Wildlife Diseases Study, University of Georgia-Athens.
Northeastern Center for Wildlife Disease, University of Connecticut-Storrs.
Colorado Wild Animal Disease Center, Colorado State University-Fort Collins.

Bureau of Land Management, National Park Service, departments of agriculture.

Local universities are often involved in wildlife disease programs and can be used for their expertise and cost effectiveness.
Private consultants can provide useful information regarding wildlife disease problems.

Three books used widely in the area of wildlife sampling are:

Cooperrider, Boyd, and Stuart, 1986. Inventory and Monitoring of Wildlife Habitat, published by the U.S. Department of Interior, Bureau of Land Management.

Giles, ed. 1971. Wildlife Management Techniques Manual 3rd edition, published by The Wildlife Society.

Schemitz, ed. 1980. Wildlife Management Techniques Manual 4th edition, published by The Wildlife Society.

2. SELECTING SPECIFIC MAMMALS FOR MONITORING

2.1 General Considerations

The objectives for a contaminant study will influence the types of animals to be collected and the methods used for collection. Service objectives are generally concerned with determining either (1) the level and geographic extent to which a managed area is being exposed to contaminants or (2) the level and extent that particular populations are being exposed to contaminants. The following are brief discussions of items to be considered prior to selecting a mammal for contaminant monitoring purposes.

Safety

The collection and handling of mammals (especially live-trapping) requires safety precautions by the collector. Mammals may carry rabies or other diseases that could infect an individual if scratched or bitten by the mammal. Leather gloves and boots, long-sleeved shirts, long pants, and possibly eye-protection should be used for mammal collection. Individuals should also consider being appropriately immunized before mammal collection if potential hazards warrant.

Biomonitor and Indicator Species

The biomonitor and indicator species concepts are important in contaminant monitoring. A biomonitor is a species that accumulates or concentrates a contaminant to measurable levels in tissues. Ideally, the mammal remains unaffected by the contaminant. These species might be collected to analyze selected tissues or contaminants. An indicator species is a species that is either very sensitive to or very tolerant of a contaminant. The presence or absence of these species might be monitored as an indication of contaminant exposure. Effects shown by indicator species can range from sublethal biochemical and physiological effects, to avoidance of the contaminant or acute toxicity (death).

Additional considerations for selecting biomonitor and indicator species are discussed in the Introduction to Flora and Fauna Sampling RFM (Appendix D) of this OM.

Diet

Diet is an important criterion for evaluation of a given species for monitoring. Species selection depends on the the objectives of the study, contaminant(s) of concern, and the transport pathways involved. Generally, it is more useful to collect a strict carnivore, herbivore, or one that preys upon a few select species because it is very difficult to assess the source of a contaminant in a mammal that has a varied diet.

Number of Individuals Collected

If the study design requires a set number of samples for statistical considerations or to cover a large enough area, these factors will dictate the minimum number of individuals required. If this number will not provide the quantity of sample required for chemical analysis, additional individuals will need to be collected to meet the needs of the analytical labs. Consult both a statistician and the lab conducting the analysis to ensure the statistical design and sample quantity is appropriate.

Abundance

Population abundance is an important consideration when concerned with sampling costs and logistics. An abundant population will more easily provide a statistically significant number of samples. In many cases, results obtained from sparse populations will be inconclusive. Destructive sampling of an abundant species will also have less impact on the local population and associated predators or prey.

Feeding Patterns

The daily and seasonal feeding behavior is also important. The range and amount of time spent feeding should be considered. Rapidly metabolizing species may process contaminants more rapidly. A species feeding frequently every day has a greater chance of being exposed to a contaminant than an organism that is inactive for long periods of time. If the contaminant problem is localized, it is better to choose an organism with a small home range that coincides or overlaps the contaminated area. Again, the objectives of the study, contaminant(s) of concern, and transport pathways are considered when determining the indicator organism.

Home Range

Home range is the area traversed by the individual in its normal activities of food gathering, resting, mating, and caring for young. Species used for investigating the geographical extent to which an area has been exposed to a contaminant should have restricted home ranges. Widely ranging species, such as ungulates, would probably be inappropriate for most studies but could be used to determine the level and extent of contaminant exposure by specific populations or provide an integrated measurement over a large area. Widely ranging species may be useful in the initial stages of monitoring when determining if a contaminant is present.

Behavior/Habits

Seasonal activities (migration, hibernation, reproduction, etc.) are an important consideration. Migratory species will have large home ranges and are not always available for collection. Although it is possible that these organisms have accumulated contaminants from other areas along their migratory routes, this information is still useful in assessing contaminant effects on the species.

Individuals that hibernate experience major metabolic reductions during the hibernating seasons. Also, a mammal that spends a portion or an entire season in a dormant or resting state would not be a useful organism for monitoring contaminants during that season. Diurnal and yearly cycles of behavior and/or physiology should also be taken into consideration. For example, major metabolic changes occur in females during estrous cycles, which may affect contaminant uptake and metabolism. Increased uptake can be useful if the organism is a biomonitor and can be sacrificed. Increased contaminant uptake also can be important in that it could increase the potential of a contaminant affecting the population.

Longevity

Longevity of an organism should be considered. If the animal is short-lived, the potential for contaminant accumulation may be reduced. This effect can be offset (e.g., shrews) by a high

metabolic rate. Longer lived animals can accumulate contaminants over a longer period of time, potentially providing samples with measurable quantities of the contaminant.

Ease of Capture

The ease of capture can significantly impact the costs associated with sample collection. The collection method and associated time required should be considered. Smaller organisms are usually more easily captured; however, more individuals are required to provide enough material for analysis. Body parts from game animals can usually be obtained at hunting checkpoint stations, but this makes locating a contaminant source difficult. Use of sample material from local trappers should also be considered. Arrangements can be made to have trappers mark their sites on a map and to take special care in handling the sample. The potential for cross-contamination is a disadvantage of using these organisms for contaminant analysis, but this will depend on the contaminant being measured.

Human Consumption

Biomagnification may occur throughout the food chain. Therefore, there is a possible exposure pathway to humans should bioaccumulation occur in game animals. From a public health perspective, it may be necessary for game animals to be part of any monitoring program. Sampling protocols established by local agencies may need to be used to address their concerns. However, these methods may not be appropriate for contaminant monitoring studies. Consult with the local public health office if this is a relevant concern.

Local Restrictions and Required Permits

Before collecting samples it is necessary to research any methods or materials that are restricted or require special authorization. For instance, the use of certain traps and ammunition may be illegal in some states or areas. Also, Federal and state licenses are required to obtain many of the drugs used for drugging mammals. The species for which collection permits are required can also vary from among states. Local, state, and Federal enforcement officers should be notified before collecting managed species.

2.2 Recommendations

Some general recommendations can be made about the selection of mammals for monitoring. No single mammal species has been universally used or recommended for use in national monitoring programs. The FWS Resource Contaminant Assessment (RCA) manual (FWS, 1986) recommends several species. In addition, Eisler (1985a through 1988b) has reviewed laboratory and field data on various contaminants. These documents may provide information useful for selecting a species for monitoring.

Shrews meet most criteria for a biomonitor species. Shrews are known to accumulate metals and organochlorine compounds such as pesticides, polychloronated biphenyls (PCBs), polychlorinated dibenzoparadioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) and other lipophilic organic compounds. However, there is little information available about the toxicity or residual effects on shrews to determine the extent of a contaminant problem. Since there is extensive toxicity data for rats and mice, it may be more useful to use a species closer to rats or mice.

Harvest mice (genus Reithrodontomysç) have been recommended as alternatives to shrews (FWS, 1986). Harvest mice are found in a variety of habitats in most areas of the United States. They are generally omnivorous, taking about 50% vegetation and 50% insects and larvae. Grasshopper mice (genus Onchomysç) may be useful as biomonitors, although there is little literature on such use. Their chief value may be that they occur in habitat too dry to support many shrews or harvest mice.

Eisler (1986a) reported high chromium levels in the hair of the western jumping mouse, an herbivore (though field conditions and possible sources of chromium were not noted). Voles and rabbits also are herbivores and are also suited as biomonitors when contaminated vegetation is present.

Mink have been shown to biomagnify waterborne mercury from pulp and paper mills. Levels were 10 times higher in these mammals than in predatory fishes in the same area (Sheffy and St. Amant 1982; cited in Eisler 1987a). Fur contained the highest mercury levels, followed by the liver and kidney. Piscivorous furbearers appear to accumulate higher levels of waterborne mercury than herbivorous species such as the muskrat or beaver. The biggest drawback of mink and river otters as biomonitors is their low population densities. They may be quite useful, however, in initial screening for contaminants in aquatic systems. In areas where they are trapped, tissues for residue analysis might be available. If trappers' catches are to be used, instructions should be provided to the trappers regarding sample cross-contamination precautions and preservation procedures.

Among large mammals, grazers and browsers such as deer and elk can be expected to encounter large amounts of contaminants from atmospheric inputs such as pesticides, arsenic and other metals. Hair appears to accumulate the highest levels of metals such as mercury, chromium, and arsenic. This allows for non-destructive sampling of these larger animals.

3. COLLECTION METHODS FOR SMALL SIZED ANIMALS

3.1 Collection Techniques

NOTE: The first step in any sampling episode should be to obtain any licenses or permits required for mammal collection.

3.1.1 Snap Traps

Commercial snap traps are used to kill-trap small sized mammal populations. Snap traps (Figure 1) come in different sizes (dependent upon the species) and different brand types such as Museum Special, McGill, and Victor. Museum Specials are reported to be more efficient than other snap traps because of their more sensitive trigger mechanism (Johnson and Keller, 1983). Snap traps can be fitted with rubber tubing over the striking-bar to minimize damage to the sample.

The traps should be inspected to ensure they are working properly and numbered with a marking pen for easier tracking. A mixture of peanut butter and oatmeal or granola works well for many animals. This mixture gives off a luring order and is effective in most weather conditions. The type of contaminant being monitored and the tissues being analyzed should be considered when selecting a bait.

After the proper bait has been chosen, the trapper places the bait on the trap and then sets the trap at each appropriate location. The traps are checked as necessary, to prevent sample degradation or predation by other organisms.

3.1.2 Pitfalls and Trenches

Pitfalls (Figure 2) are cans or buckets buried in the ground so the top rims are flush with the substrate (Cooperrider et al., 1986). The cans should be round and gallon size or larger. After installation the pitfall should be covered with a lid and a layer of dirt to allow resident animals to become accustomed to its presence. When tracks are noted in the dirt on the can lid, the trapper can remove the lid, bait the can, and check the trap as necessary.

For some small animals (such as shrews), trenches will increase potential success. For best results, the trenches should be 1 in. both deep and wide and laid out in a grid pattern (Figure 2). It is best to lay the grid adjacent to small streams or other moist areas. The trench should also be kept moist and bait placed along the bottom.

3.1.3 Bat Traps

Mist nets and harp-type traps (Figures 3 and 4), are effective for live-trapping bats. Mist nets are commercially available in various sizes, colors, and construction material. A good mist trap for bats is typically 9 m (30 ft) long, 2 m (7 ft) high, and constructed of fine black nylon mesh of about 36 mm (1.5 in.) squares. The cross lines in the net, called trammels, are looped at each end and attached to both poles. The poles may be made of bamboo or electrical conduit and are secured in the ground and stabilized with a guy cord and/or rocks.

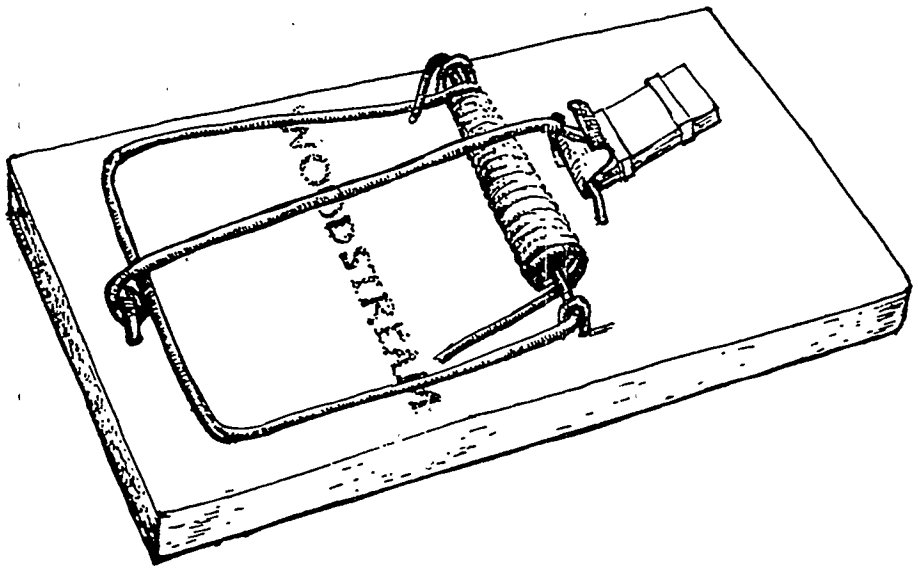

Figure 1. Museum Special snap trap shown in set position. (Nagorsen and Peterson, 1980).

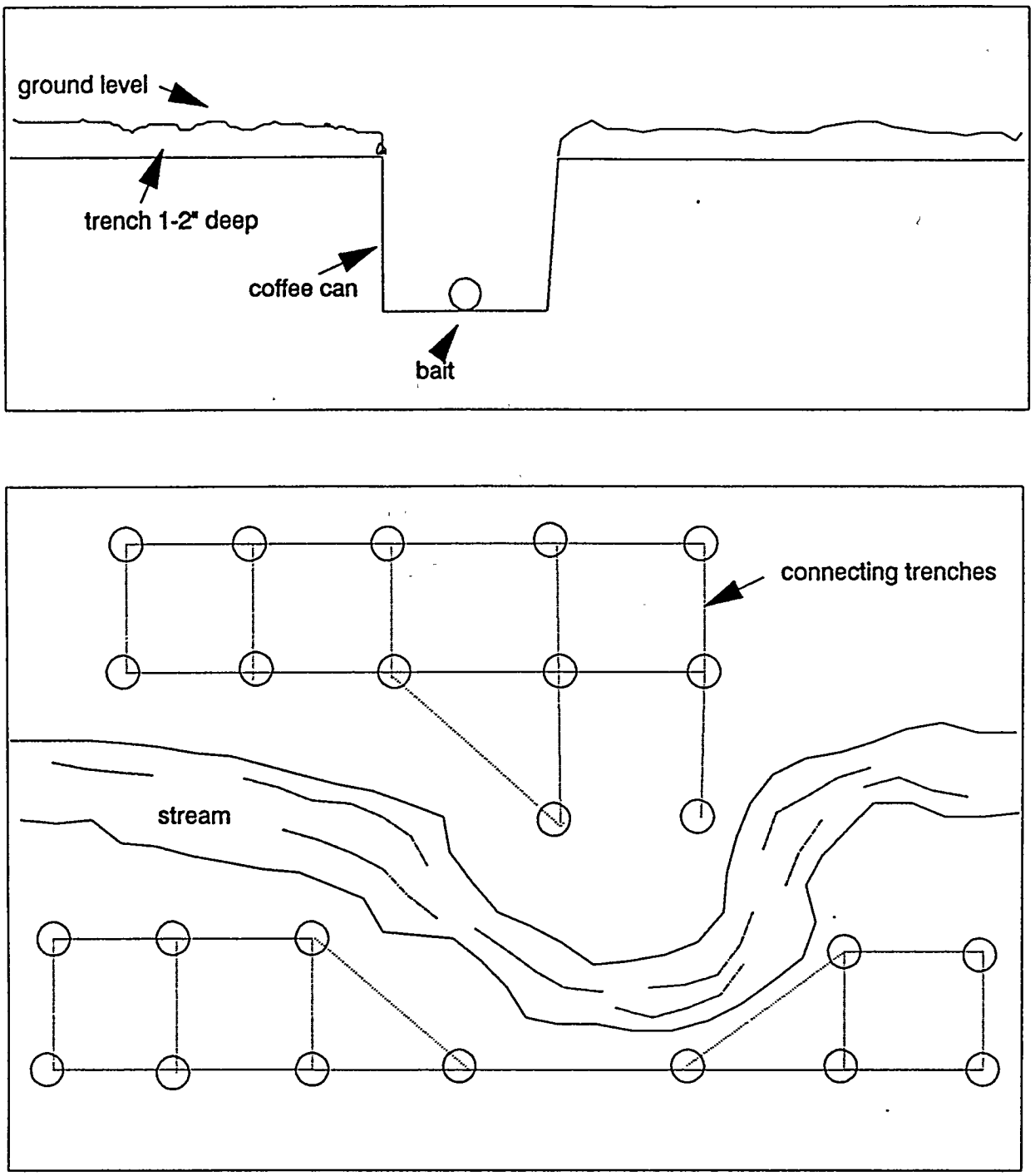

Figure 2. Diagram of pitfalls and associated trenches for shrews and mice (Cooperrider et al., 1986).

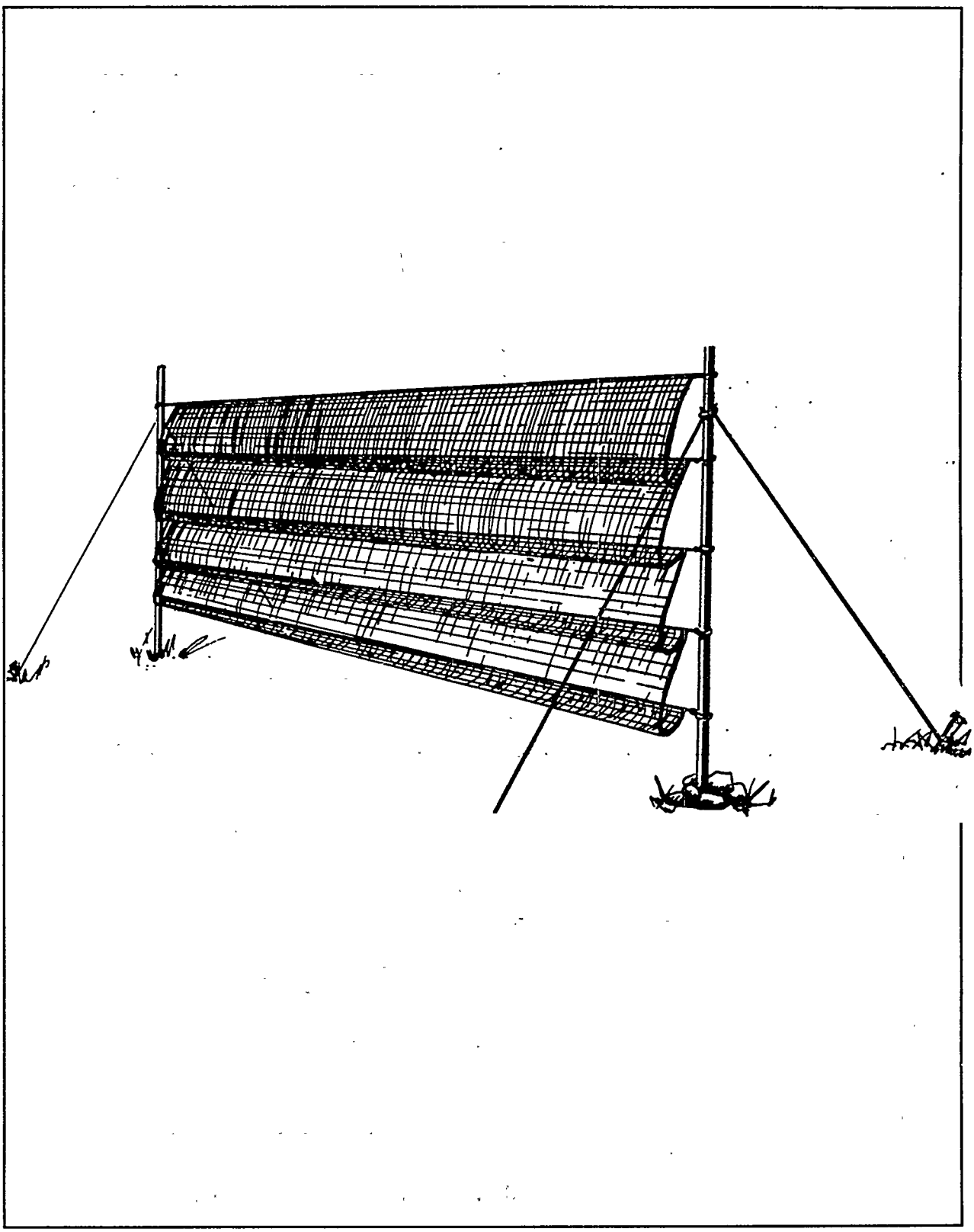

Figure 3. Mist net setup (Cooperrider et al., 1986).

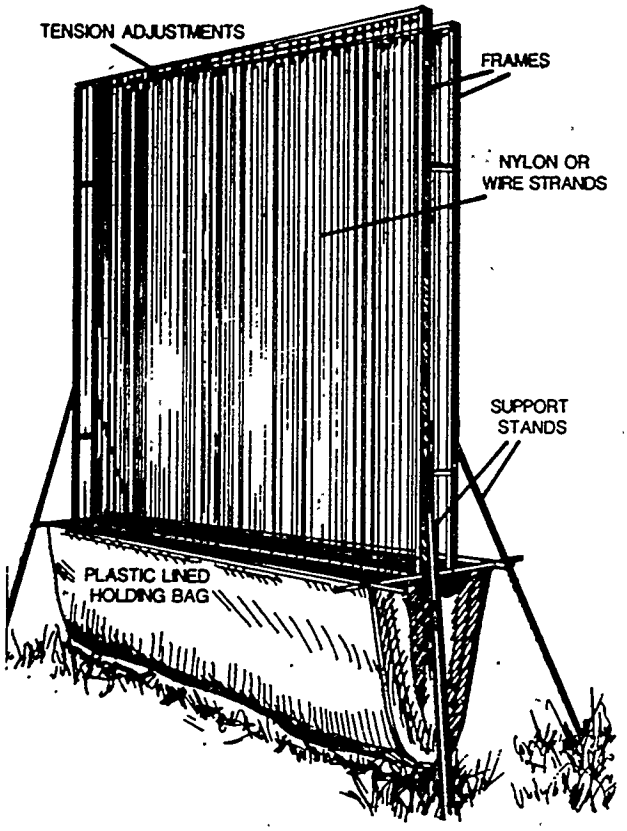

Figure 4. Harp-type trap (Cooperrider et al., 1986).

The trammels are looped around the poles and set at intervals which allow for pockets to form in the netting. The trapper should wait until twilight or darkness to raise the net to avoid trapping birds that are active in the evening. Remove any debris that may have been entangled in the net (bats may sense it). Nets should be checked at least every 15 min to prevent trapped bats from chewing holes in the net and escaping or injuring themselves.

The types, designs, and construction of harp traps are described in Constantine (1958), Greenhall and Paradiso (1968), and Tuttle (1974). Tuttle's version (Figure 4) consists of two adjacent aluminum frames about 1.5 m (6 ft) square and spaced about 8 cm (3 in.) apart. The strings, strung vertically in the frame, are usually 0.2-mm (0.008-in.) stainless steel wire or 5- to 20-lb (3- to 9-kg) monofilament nylon line. At the bottom is a canvas holding bag lined with a slick, plastic covering. The plastic is attached to the top of the canvas bag, but is allowed to hang free to the bottom of the canvas bag. The metal frame, wire strands, and holding bag can be made adjustable.

The harp trap is designed so that when a bat collides with the vertical wire it is stopped, slides down the wires, and drops into the holding bag. Once inside the holding bag the bat climbs up the canvas bag to escape, and is trapped between the attached plastic and canvas. Once there, they remain docile until collected by the trapper.

Another technique to trap bats is the use of a hand net. Wide mouth insect nets with a long or extendible handle work best. Hand nets are useful when working in a confined space such as caves, mines, or buildings. The hand net can capture bats in flight (usually from behind) or is used to cover openings where bats are roosting.

In arid regions with restricted water, one or two strands of fine piano wire can be stretched across a pond about 20 cm (6 in.) above the water. Bats striking the wire will fall into the water. As bats swim to shore, they can then be captured with a hand net (Nagorsen and Peterson, 1980).

Bats that forage above the tree canopy or roost in caves with high ceilings can be shot. A good combination is a small shot (no. 10 or higher) loaded in .22 or.32 caliber shells. A .410 gauge shotgun with light shot is an alternative. This method has the obvious drawbacks of specimen damage, cross-contamination and the danger of hunting at night.

3.2 Biological Considerations

3.2.1 Shrews

Shrews (genera Sorex, Notosorex, Blarina) are most effectively trapped by pitfall traps and trenches. It is recommended to start with a 1-meter interval between traps and then extend the intervals to the least distance noted between successful traps. Shrews will follow mouse or vole runways; thus, a small channelling trench in imitation of a runway should be dug between traps with a garden trowel. A bare trench is not as attractive to shrew as one rescreened with grasses and/or sedge to furnish a partial cover. When preparing the pitfall, smearing blood or oil from fish or oysters around the rim of the can will enhance the attractiveness of the can to shrews. Shrews can also be kill-trapped with a standard snap-trap. The same runway and interval patterns used for pitfall traps apply.

Because of their high metabolic rate, shrews must be provided food when captured in live traps. Fresh and bloody meat, sardines, or earthworms will suffice for shrew bait. However, precautions should be taken to prevent introducing contamination to study subjects via bait. The trapper is also advised to check his traps frequently since shrews are cannibalistic (Collins, 1967).

3.2.2 Mice

Harvest mice are primarily nocturnal, omnivorous, and are found in overgrown fields, marsh edges, and woodland savannahs. They do not generally eat carrion or other mice; although they have been observed feeding on fresh carcasses of road-killed ground squirrels.

The metabolic rate of harvest mice is lower than shrews and their diet is not as varied. Harvest mice seldom reach the density of most shrew species, but they are fairly common in prime habitat areas. Their presence is indicated by distinctive nests, built of leaves and cottonwood fluff, either on the ground or in multiple-forked branches of shrubs. Tracks and scats also assist in locating harvest mouse habitats and populations.

Harvest mice are most easily trapped by a standard snap-trap. Box traps (Section 4) work well for collecting live harvest mice. There are several baits they respond to fairly well. A mixture of clover leaves, oatmeal, and peanut butter with a drop of anise works well and live or freshly killed grasshoppers tied to the trigger will attract harvest mice. Trappers should start with a trapping grid interval of 3 m and adjust as necessary. Harvest mice respond to trenches between traps and thus may be channeled into trap sites.

Grasshopper mice (genus Onchonomys) are small, mostly nocturnal, short-tailed mice. Their diet includes seeds, vegetation, adult and larvae insects, and they prefer voles and vegetarian mice when available. They are a useful biomonitor in that they may be found in areas where harvest mice and shrews are scarce or nonexistent and can be used as a substitute.

The grasshopper mouse is more trap-shy than most mice. A standard snap trap set in a 4- to 5-m grid is a good starting interval for trapping. Bait is critical; fresh grasshoppers and mormon crickets are good bait in season. Mouse meat, from peromyscus or voles, is also good bait. Box traps with live prey mice or smeared blood will sometimes prove effective in capturing them.

3.2.3 Gophers and Moles

Moles spend most their lives underground (fossorial) in search of worms and earth-deposited insect larvae. The worms they feed on may contain metallic elements from contaminated soil, and the moles may then accumulate them. Their presence is indicated by earth mounds as they dig for food or push up dirt from a burrow. Mole tunnels and mounds have a more rounded contour than gopher mounds and also lack a burrow entrance in the center of the mound surface (Schemnitz, 1980). Gophers have similar habits to moles, but may be vegetarians (pocket gophers).

Trapping methods to obtain gophers and moles are limited because they are not easily baited and are rarely visible. They can be captured with gopher traps or harpoon mole traps (Figures 5 and 6); however, impaling type traps may introduce contaminants. The traps should be set in the tunnels leading between their mounds and secured to prevent them from pulling the traps into their burrows (Cooperrider et al., 1986). Since they do not normally dig their tunnels very deep, moles and

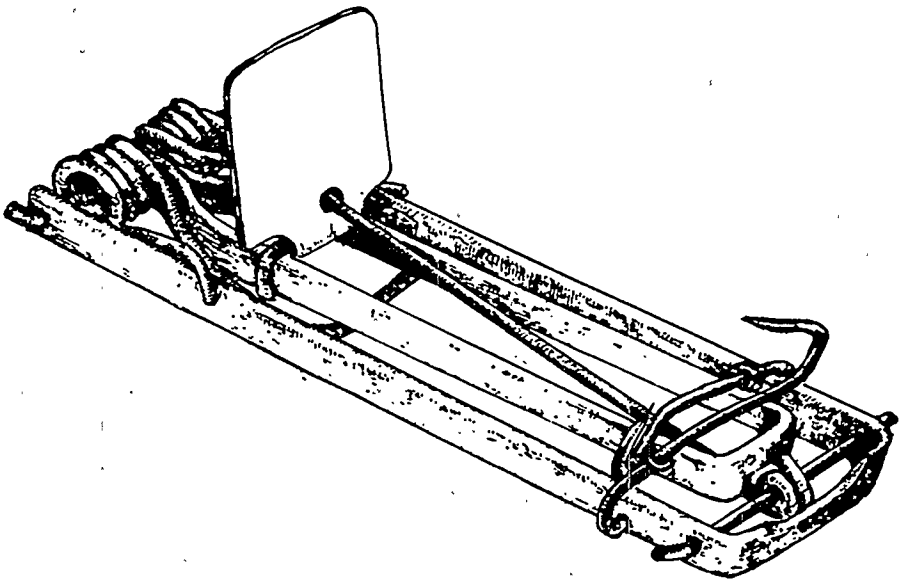

Figure 5. Gopher trap in the set position. Trap size is 15 x 5 cm (6 x 2 in.) (Nagorsen and Peterson, 1980).

gophers may be captured by digging up selected areas where their tunnels end. Noisome gasses can also be sprayed into burrows and tunnels to force them from their tunnels. There is again the possibility of introducing contaminants. Finally, each may be flushed from burrows by means of a high pressure water hose.

3.2.4 Bats

As the only truly flying mammals, bats (Chiroptera) should not be overlooked when monitoring contaminants. Most species of bats found in north America are nocturnal and eat insects, although some feed on plant pollen and nectar. Their roost sites can be both natural (caves, tree foliage, or hollow trees) and man made structures (buildings, abandoned mines, and under bridges). Bats may use different roost sites at different times of day or season. Evidence of used roost sites are urine stains, bat droppings, or chewed insects. Local hunters and farmers can also aid in locating roost sites.

It has been demonstrated that mother bats can accumulate organochlorines in their milk and subsequently pass lethal concentrations to their young when nursing (Geluso et al., 1976). Grey bat die-offs have been reported due to the accumulation of dieldrin and heptachlor in the brains of bats (Clark, 1988). Diagnosis of heavy metal contamination in bats requires analyzing liver and kidney tissue along with a histological examination. Analysis of bat guano as a first step may indicate whether organochlorines or metal are involved (Clark, 1988).

Positioning of nets or traps is critical to capture success. At a roost site, nets should be set blocking the exits the bats are likely to use. At drinking or foraging sites, the trapper should use several traps at locations that block the likely flight patterns of the bats (Figure 7).

Handling bats requires gentle care for the bat and caution for the handler. Because bats may bite and a small percentage of bats carry rabies, leather gloves should always be worn. Persons expecting to collect bats should be immunized against rabies before trapping bats. A good way to hold a bat is to grasp it with the thumb placed under the bat's mouth with the remaining fingers on top, restraining the body and wings. If holding a bat by the wings, use care not to break the delicate wing bones.

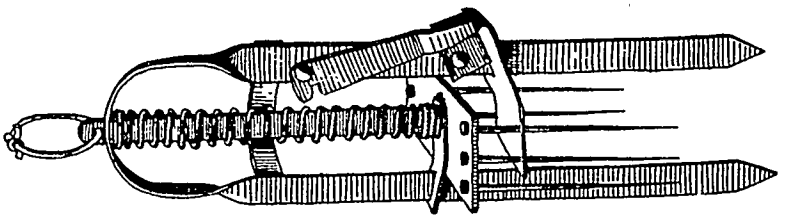

Figure 6. Harpoon type of mole trap is 40 cm (16 in.) in length (Nagorsen and Peterson, 1980).

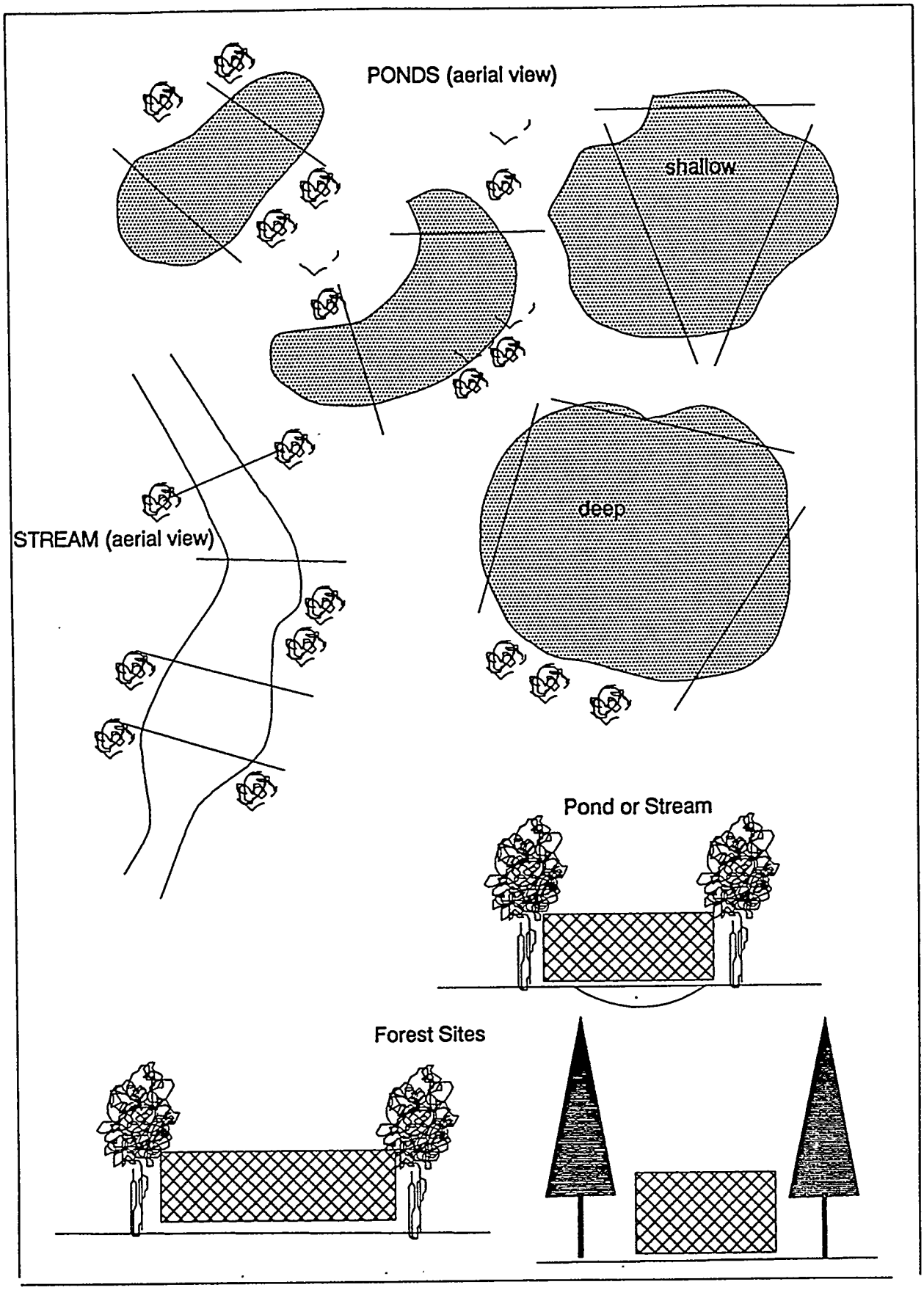

Figure 7. Possible placements for mist nets (Cooperrider et al., 1986).

4. COLLECTION METHODS FOR MEDIUM-SIZED MAMMALS

4.1 Collection Techniques

Medium-sized mammals are usually collected using live-trapping techniques. Shooting the animal is a viable option but cross-contamination of tissues and organs should be considered prior to using this method.

4.1.1 Box Traps

Box traps (Figure 8) are most effective for trapping medium size mammals but are also used to trap small- and large-sized mammals. They have a variety of names (Hava-hart, Longworth, National, Sherman, Victor, Tomahawk) and come in a variety of sizes. Their construction usually consists of wood, wire, aluminum, plastic, or a combination of these. Most traps are either spring loaded or work off gravity and have a locking mechanism to prevent escape. Enclosed traps (wood, aluminum) contain the trapped animal in the dark and generally keep them more docile. Wire box traps provide for an easy visual inspection of the trapped animal. Because of costs or to increase efficiency, some field workers design and construct their own traps.

Once baited, the trap should be secured, given some vegetational cover, and finally set. Nesting material such as cotton or wool should be included in the trap during cool weather. Traps should be kept out of direct sunlight if possible and checked at least daily.

4.1.2 Snares

Snares are often illegal and local restrictions should be checked. They are best suited for areas where the animal crawls under a fence or travels along regularly used trails or narrow passageways (Giles, 1971). They are made up of varying lengths and sizes of wire looped through a locking device (Schemnitz, 1980; Lensing and Roux, 1975). When the snare is triggered, it tightens around the foot or body of the animal. There are two basic types of snares: body snares and activated snares (also called foot or trip snares). The design of a snare will vary for the type of animal being trapped. A body snare (Figure 9) consists of a loop with a locking device tied to a tree or branch that tightens around the neck or body of an animal when triggered. As the animal tries to escape, its forward momentum tightens the loop around its body. A trip or activated snare (Figure 10) is one that, when sprung, self tightens on the animal. Its principle elements are the trigger mechanism and the spring.

Live specimens can be obtained with snares if they are closely attended by the trapper or if there is a "stop" on the snare to prevent it from closing too tightly around the animal. Attaching a bell to the snare can alert the nearby trapper that the snare has been sprung.

4.1.3 Leg-hold and Conibears

Leg-hold traps or steel traps come in a variety of types and sizes. The following sizes are suggested guidelines:

No. 0 and 1 for weasels

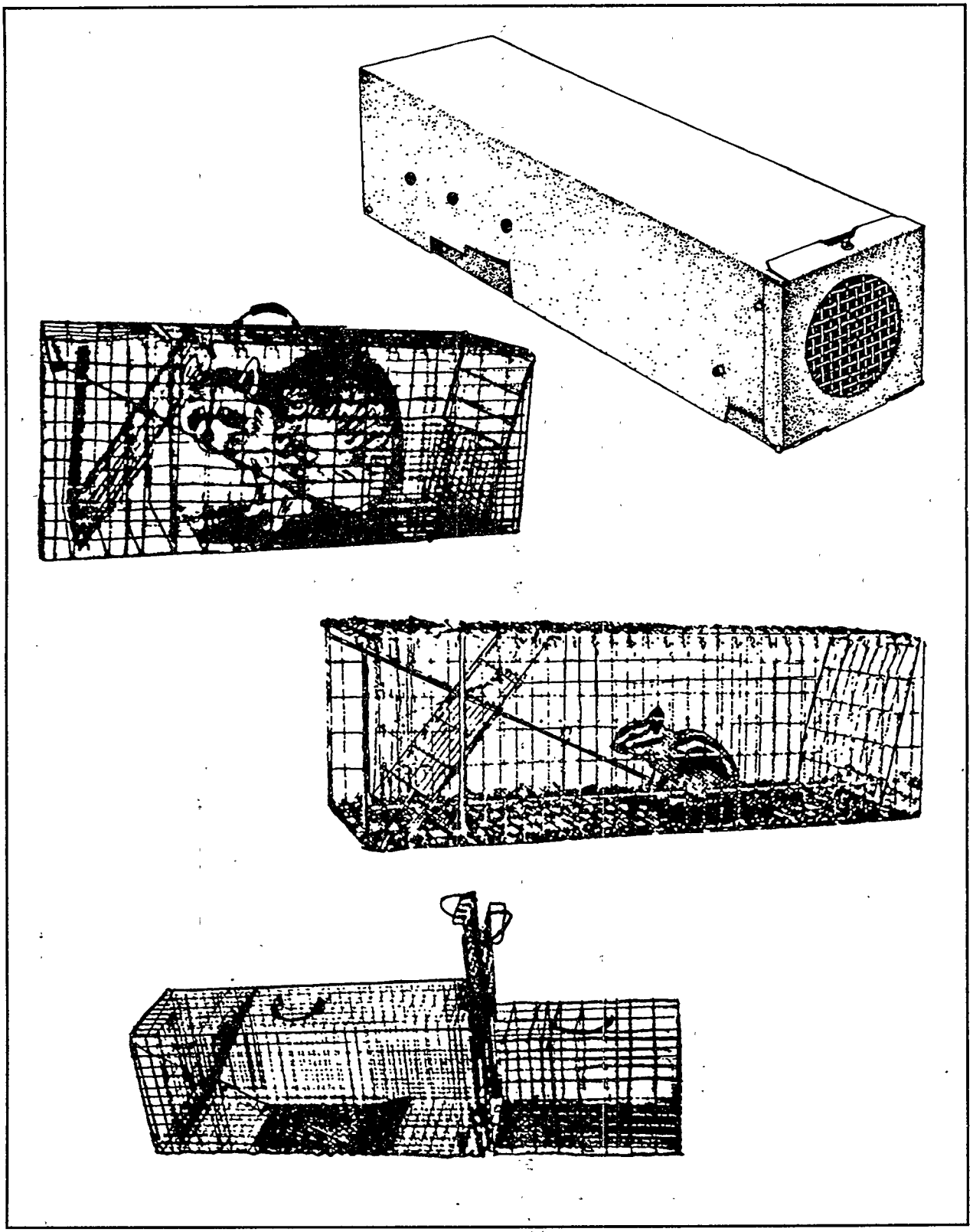

Figure 8. Various types of box traps (Nagorsen and Peterson, 1980).

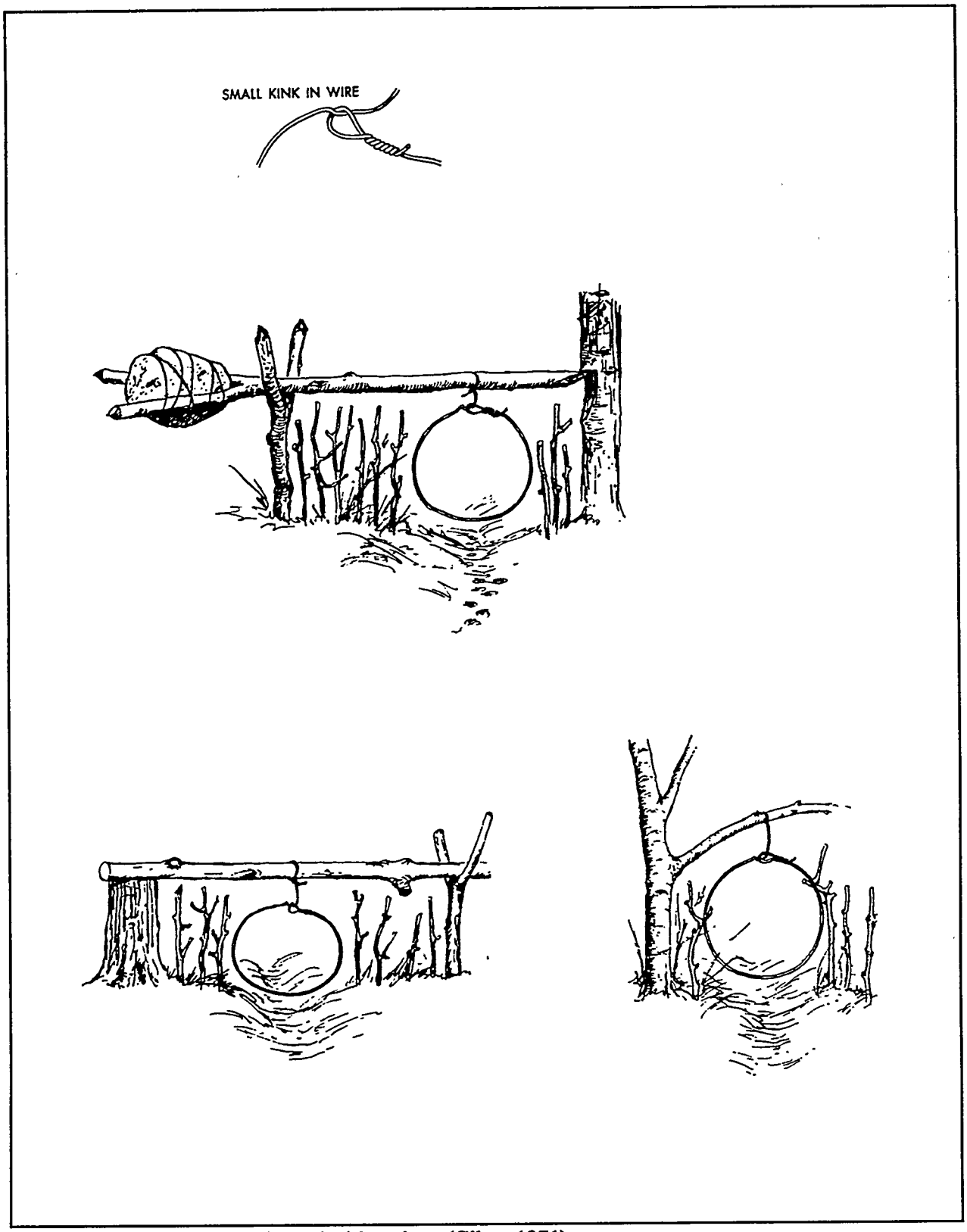

Figure 9. Body snares set in typical locations (Giles, 1971).

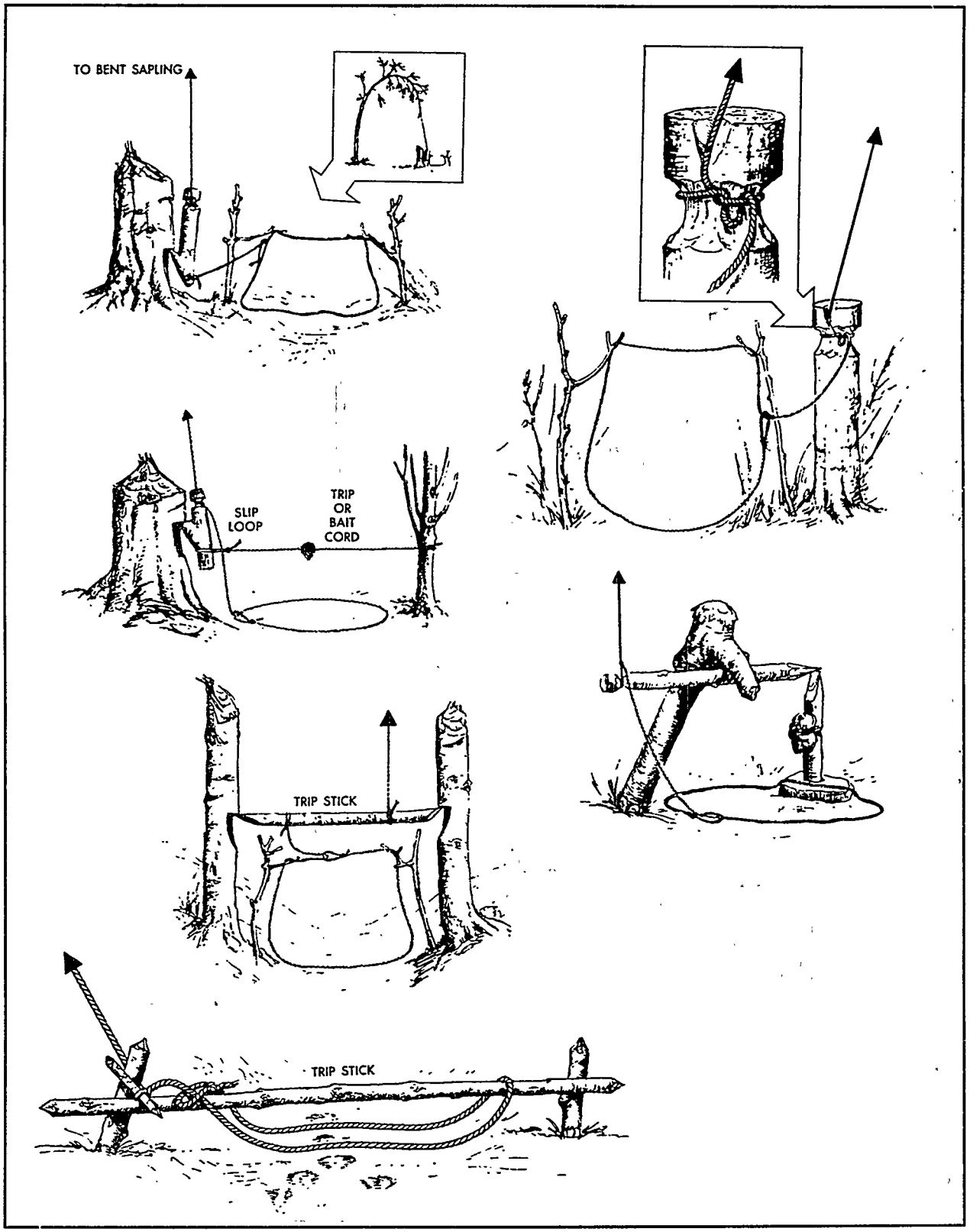

Figure 10. Activated snares and trigger mechanisms (Giles, 1971).

No. 1 and 1-1/2 for skunks, opossums, minks
No. 1-1/2 and 2 for foxes, raccoons
No. 3 and 4 for bobcats, coyotes
No. 4 and 4-1/2 for wolves

A drawback of the leg-hold trap is that they may cause foot and leg damage if used improperly. They can be padded to prevent such damage. As with all trapping techniques, local laws and regulations should be checked before using leg-holds.

A Conibear (Figure 11) trap is an alternative to leg-hold traps if live specimens are not required. It is a spring activated mechanism that has a pair of rectangular wires that close like scissors when tripped. They can be set in runways, water, and entrances to burrows and lodges. The Conibear trap captures the victim around its neck or chest and will usually kill the animal quickly without causing extensive suffering.

4.2 Biological Considerations

4.2.1 Squirrels

Ground squirrels are found throughout the United States. They have a varied diet, eating roots, tubers, green vegetation, seeds, insects, and eggs of ground nesting birds. They have been observed eating fresh meat from road-killed ground squirrels, chipmunks, jackrabbits, and sage grouse. They are hibernators and most species spend the hottest and driest period of the year in underground estivations. Murie (1954) provides information about ground squirrel tracks and scats.

Ground squirrels can be trapped with live traps such as a Hava-Hart that is baited with pieces of apple or carrot. Following capture, ground squirrels should not be caged together because they can be aggressive toward one another when confined together. Another method of capture is a #1 leghold trap. Since most species of ground squirrel are not trapwise, an exposed trap placed in the entrance to the burrow will usually work.

Another method to quickly collect squirrels with a minimum of effort is by shooting. An accurate shot is required or else the animal will escape into burrows and die. A chest-section hit with a .22 rimfire rifle loaded with a hardnosed or slow-expanding bullet will kill them without extensive tissue damage. A .410 shotgun loaded with #8 shot is also suitable. Safety precautions and cross-contamination must be considered.

4.2.2 Skunks

Skunks are omnivorous, opportunistic feeders, and mostly nocturnal. They have a varied diet that includes insects, mice, voles, young ground roosting birds, fruit, berries, mushrooms, some vegetation and tubers. Although they do not capture fish, fish oil is used as an ingredient of trapping scent lures for skunks. They may achieve high population densities in certain lowland areas where food is abundant and varied.

There are four species of skunks in the United States: hognosed, spotted, hooded, and common (or striped). Skunks are den-dwellers and will use a burrow dug by another species if

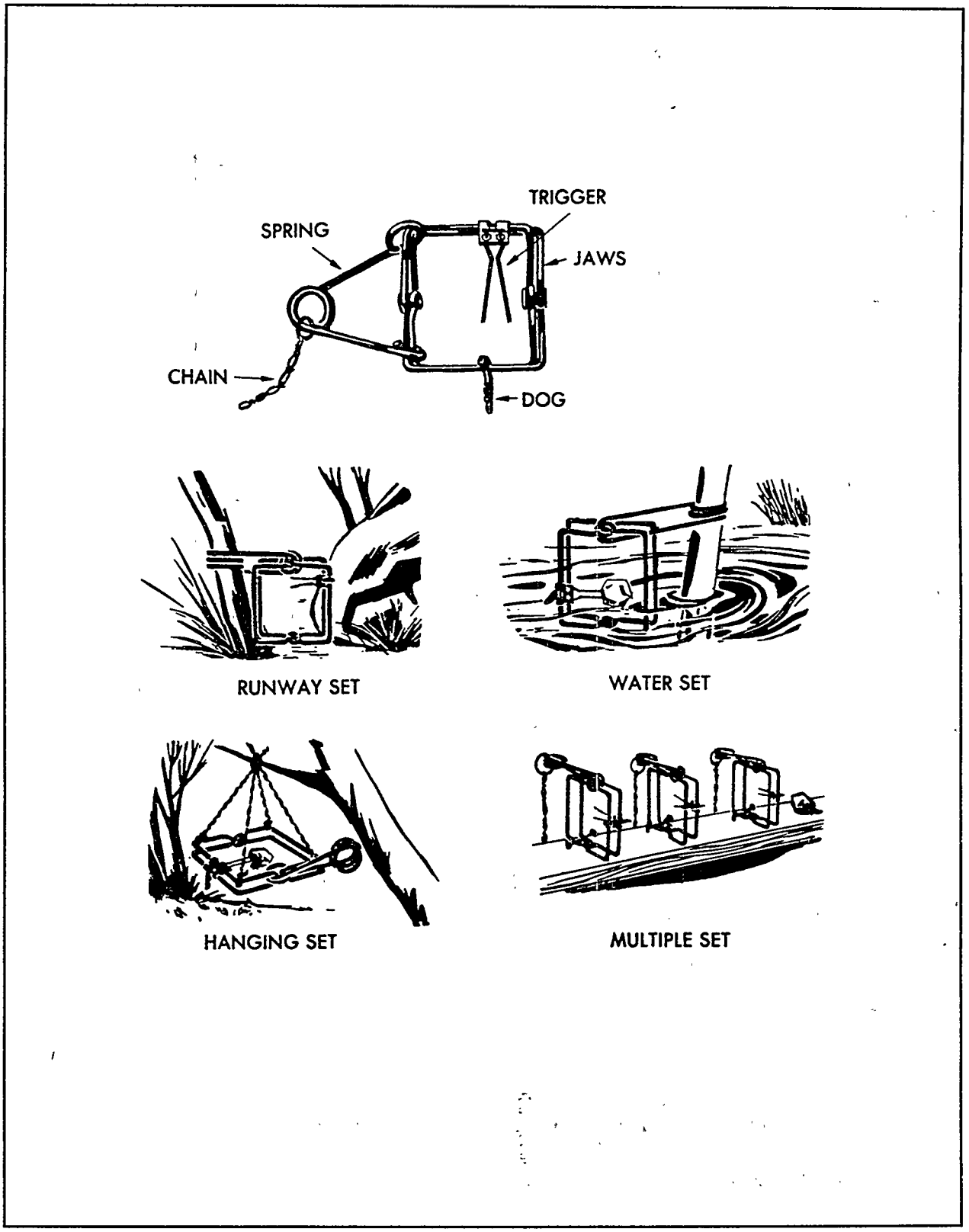

Figure 11. Conibear traps (Giles, 1971).

available. Skunks may be live trapped using a Hava-Hart or other such box trap. To trap skunks, locate their burrows and travel lanes by noting tracks and scats. A #1-1/2 or #2 leghold set in front of the den, lightly covered with a sprinkling of grass or straw is effective. Smelly-meat or fishy bait works for skunks, and commercial scents are available. Trappers also can make bait from a mixture of rancid goose or chicken grease, anise extract and sardine oil. A tablespoonful of scent at each set shielded from rain or snow is sufficient. If sampling considerations allow, skunks may also be collected with a .22 rimfire.

4.2.3 Raccoons

Raccoons are mostly nocturnal, nonhibernators, and have a varied diet. They feed heavily on fish, freshwater molluscs and snails. They will eat bird eggs and will prey on young birds. Raccoons consume many domestic crops, such as sweet corn, berries, fruits, and are fond of some roots, tubers and mushrooms, and sometimes prey on domestic chickens and ducks.

Freshwater mussel shells along waterways are evidence of raccoon feeding. Their tracks are distinctive (Murie 1954); and can be found in tidal flats, muddy streams, and shorelines.

The raccoon's value as a biomonitor is limited by its frequent wide-ranging habits, and by long periods of near-dormancy in winter. This could be of value when conducting an initial screening of an area or if looking at several potential pathway/exposure routes. Some contaminant information can be obtained from raccoons when no other species can furnish conclusive evidence of the contaminant in question in a given area.

Raccoons are easily live trapped in large Hava-Hart type traps. Raccoons are also trapped using a #1-1/2 or #2 leghold trap. It is important to check raccoon traps frequently as they may escape, given enough time. Many trappers use double-jawed traps with a drag or trap stake that the raccoon cannot chew off. A cubby set using canned salmon or comb honey for bait is very effective on raccoons. Canned or frozen shrimp are also a good bait, and raccoon scent is commercially available.

4.2.4 Rabbits, Hares, and Pikas

Lagomorphs are useful as pesticide contaminant monitors because of their strict vegetation diet. They feed on various grasses, herbs, plants, and shrubs in season and turn to twigs, buds, and barks in winter.

Common species of rabbits and hares (Leporidae) in the continental United States are blacktailed and whitetailed jackrabbits, snowshoe hares, and cottontails. Antelope jackrabbits are found in Arizona, White-sided jackrabbits in New Mexico, and Tundra hares in Alaska. They use heavy brush, grassland, or low growing trees for cover.

Pikas (Ochotonidae) are smaller than rabbits with short rounded ears and no visible tail. Pikas are found in rockslides of mountain areas. Active by day, they store food in small piles beneath boulders.

The presence of rabbits and hares can usually be determined by direct observation. Activity signs, such as fecal pellets, tracks in runways and snow, or even skeletal remains can help locate

them. They can be detected at night by their "eye shine" from a spotlight.

Wooden or wire box traps are effective for live trapping lagomorphs. The traps should be baited with apples, alfalfa, or their preferred vegetation. Snares set in trails or runways, or a baited #1 leghold trap can also be used to trap rabbits and hares.

Shooting rabbits and hares is a viable option because of their abundance. Pikas are not as abundant and are preferably live trapped. Shooting may destroy tissue for examination and cross-contamination between tissues and organs may occur. A .22 caliber rifle or a shotgun with a light shot (No. 7 shot or greater) may be used. Since most species can carry tularemia, or "rabbit disease," gloves should be worn when handling.

4.2.5 Badgers

Badgers (Taxidea taxus) can be found in open country or large forest clearings. They are carnivorous, eat carrion, and commonly scavenge highways for road-kill. They prey primarily on ground-squirrels and other open-country rodents, and eat eggs of ground nesting birds. They will eat grasshoppers, crickets, and larvae when preferred food is scarce. They are predators of opportunity with great digging ability. They are primarily nocturnal, although they may be seen at any time of day. Badgers do not hibernate, but spend long periods underground at temperatures below 20# in a semidormant state.

Badgers are difficult to collect in either leghold or live traps. A carefully concealed #1-1/2 or #2 leghold trap will hold a badger. A fresh-killed ground squirrel or jackrabbit can be used for bait. Badgers have been observed to be trapwise by turning the trap upside down to spring it, or piling dirt on top of the trap to avoid capture. The trap pan should be about 3 in. to the left or right of the line of approach to the bait.

When shooting a badger, a medium-to-larger caliber rifle and expanding bullet load should be used. It should be noted that wounded badgers will retreat into burrows and be lost to the collector.

4.2.6 Mink

The Service may have to collect samples of mink to determine the spread and concentration of water-borne contaminants when no other study subject is adequate or when a fish feeding species is required for a study. Mink are found in varied wetland habitats throughout North America south of Alaska's Brooks Range. They are solitary and generally nocturnal and their populations are normally sparse. Mink prey on fish, shellfish, mice, muskrats, and small birds. Their metabolic rate is high and they spend only very short periods of time resting. Mink tracks and scats may be found along streamside silt bars and mud flats.

Mink are not easy to trap, but can sometimes be obtained from trappers. They may be caught in muskrat sets or submerged leghold or conibear traps. A fresh muskrat or fish carcass can be used for bait. Scent is commercially available or can be made from mink or muskrat scent glands.

A #1 or #1-1/2 leghold trap is commonly used for mink and should be staked in deep water. Live traps for mink should be approximately 75 x 18 x 18 cm. The trapper will have to check these traps frequently. Heavy leather gloves should be worn when handling live mink.

4.2.7 Foxes

Foxes are active throughout the year, are generally nocturnal, and have a large home range. They have varied feeding habits, with preference governed more by availability. Mice and other small rodents form an important part of the diet for red and gray foxes. They also feed on fruit, birds, rabbits, and carrion when available. The Arctic fox eats lemmings and other small mammals, ground nesting birds, marine mammals, and caribou carrion.

State wildlife agencies and local trappers may be the best source of fox specimens. They are occasionally trapped by state officers in response to complaints and state officers will usually collect and care for specimens as prescribed by the manager or researcher.

Foxes readily respond to a call imitating a wounded rabbit distress call. They are most easily collected by shooting. A .22 hornet or .222 caliber work well. Care should be taken in the selection of bullets because those expanding too fast will tend to destroy more tissue than necessary or desirable.

Before attempting to trap foxes the researcher must locate travel lanes and hunting areas. These are evidenced by tracks and scats or occasional kills. Night surveys with spotlights are also effective for locating areas that foxes frequent. The finding of a den may furnish the only means of live-trapping foxes. Current use is evidenced by remains of birds and/or rabbits around the main entrance. When all entrances to a den are plugged, or capped with nets, tear gas may be used to flush the foxes into traps.

A staked #1-1/2 or #2 leghold trap set for foxes should be carefully covered and the chain and drag concealed. The site should be reconstructed as it was before the trap emplacement. The trap should be placed in a slight depression, about as deep as the height of the set trap, with a bit of cotton or cattail fluff under the pan. A trap cloth should be fitted over the trap and camouflaged with dirt, duff, and finally grass. The trapper should also know how to use the fire set. One should dig a hole about 6-in. deep and perhaps 10 by 10-in. square. Burn a mixture of hardwood, such as birch or mahogany, and bits of bone and meat in the hole. In the resulting fine ashes, set the trap and cover it with a cloth and about an inch of fine ashes. Foxes will dig in the ashes and become trapped by the front foot. Foxes are also trapped with the aid of commercial scent attractions.

4.2.8 Opossum

Opossums (Didelphis virginiana) have a varied diet of eggs, rodents, carrion, insects, fruits, berries, and mushrooms. They have small home ranges and may be nocturnal or diurnal in habit. Opossums do not reach very high population densities though they are fairly common in hardwood forest habitat. They are not very secretive and may be easily shot or trapped.

Opossums are trapped with the aid of a scent bait. A mixture of rancid lard or bacon grease, cod liver oil, and rotten fruit suspended about a foot off the ground and set over a concealed #1 or #1-1/2 leghold trap is an effective method of trapping opossums. A handful of grass should be used to cover the trap from view.

4.2.9 Armadillos

The nine-banded armadillo (Dasypus novemcinctus) is found throughout most of Texas and the southeastern United States. Armadillos are insectivorous but will eat worms, grubs, and carrion. They are diurnal feeders that prefer moist areas vegetated with shrubs, mesquite, or scrub oak. Their presence is detected by tracks and scats (Murie, 1954) and by scratches and furrows left after they claw the ground seeking insects. Although their armor protects them to some degree from windborne contaminants, they are good specimens for ingested contaminants.

Armadillos dig burrows that usually can be observed parallel to the ground surface about a foot below. If the collector can determine where the burrow ends, an armadillo can be extracted from its burrow by using a shovel to dig a hole. They are often observed foraging for worms and grubs in the litter and duff of mesquite and blackjack groves. When approached by the collector they will either attempt to escape or curl into an armored ball. In either case they may be picked up and put into a sack. They should be handled with leather gloves and may urinate on the collector if precautions are not taken.

4.2.10 Coyotes and Wolves

Both coyotes and wolves are particularly hard to trap and are considered unsuitable as sampling subjects. Wolves are also unsuitable because they are extinct or endangered everywhere in the United States but Alaska. Coyotes are versatile opportunistic scavengers and have a widely varied diet from shrews and mice to fish and the young of big game animals. Wolf prey mostly upon ungulates. Coyotes have been live trapped with leghold traps, and have been killed by den hunters, aerial hunting, dogs, and poison baits. If a coyote or wolf sample is needed, it can often be obtained from animal control agents or trappers who regularly collect these animals. They retrieve the carcasses for the hides and could supply tissue or organ specimens.

5. COLLECTION OF LARGE-SIZED ANIMALS

5.1 Collection Techniques

5.1.1 Net Traps

The various types of net traps used to trap large-sized mammals include tangle nets, drive nets, drift nets and funnel net traps. They are usually constructed of nylon-mesh. Tangle nets and drive nets are placed along likely escape routes. These devices tangle the animals after being driven into the nets by ground crews or aircraft. Net traps are often used as the wings and fencing in conjunction with a corral trap. Cannon nets have also been used successfully to project a net over white-tailed deer.

5.1.2 Corral Traps

Corral traps are used primarily for the collection of big game animals. Giles (1971) and Schemnitz (1980) describe the construction and precautions necessary when using corral traps. Construction is both extensive and expensive but can yield a high return. When animals are trapped using a corral trap, they are either netted in the corral trap or shunted into a handling chute that opens off to one side.

5.1.3 Clover Trap

The Clover trap has proven to be effective for trapping deer. It consists of a collapsible metal frame with the top and sides covered by a nylon net. It may be used in conjunction with a bag-shaped catch-net. The opening of the catch-net is hooked around the opening of the trap along with a purse-line. When the gate is lifted, the deer runs into the catch-net and pulls the purse-line closed.

5.1.4 Injected Drugs

The use of drugs is a very effective method for capturing large animals. However, this usually requires Federal licensing or the presence of a veterinarian and extensive training is required in the use of drugs, equipment, appropriate dosages, and the proper care and handling of drugged animals. Schemnitz (1980) gives extensive information describing each of these concerns. As always, the contamination of tissues or organs from injected drugs must be considered.

Various brands and types of equipment have been developed to administer drugs into animals. Brands of guns and darts include CAP-CHUR, Paxarms, and Pneu-Dart. Other types of equipment include Pole Syringes or Jab-Sticks, crossbow and bow-and-arrow syringe, and even Blowguns and Blowpipes. The use of oral drugs through feed can also be considered. Table 3 presents a summary of commercial equipment available to administer drugs into animals.

New types of drugs and drug combinations continue to be developed. Some of the drugs currently being used include Etorphine hydrochloride (M-99), Succinylcholine chloride (Anectine and Sucostrin), Phencyclidine hydrochloride (Sernylan), Ketamine hydrochloride (Vetalar), Tiletamine hydrochloride (CI-744), and Xylazine hydrochloride (Rompun). Table 4 provides a summary of

Table 3. Commercial Equipment Used to Inject Drugs into Animals (adapted from Schemnitz, 1980)

Manufacturer	Name	Propellent	Optimum Range (m)	Features
Palmer Chemical Equipment Co., Douglasville, GA	CAP-CHUR Extra long-range rifle Long-range rifle Short-range pistol Projectile syringe	 ..22 blank CO2 CO2 Drug injected by powder charge	 70 23 14 ---	 4 power loads 2 CO2 cylinders 1 CO2 cylinder Sizes: 1-15 ml (aluminum)
Paxarms Ltd, Timaru, New Zealand, US Dist-Quinn Zool. Assoc., Beverly Hills, CA	Paxarms Mark 21 rifle Mark 15 pistol Projectile syringe	 .22 blank .22 blank Drug injected by compressed air	 80 25 ---	 Velocity control, 4 barrel sizes Velocity control, 4 barrel sizes 4 calibers; sizes 1 ml-20 ml (plastic)
Pneu-Dart, Inc., Williamsport, PA	Pneu-Dart Model 175-close range Model 170,171-long range Model # unknown being revised P&C darts CL & PL darts	 Compressed air pump gun .22 blank CO2 Drug deposited in powder form Drug injected by explosive cap	 4-36 91 ? 	 3-8 pumps Powder control valve & slide lever action Succinylcholine loads, 1-32 mg Succinylcholine loads, 1-200 mg
Ideal Instrument, Chicago	Simmons Pole syringe	 Manual	 1-3	 Aluminum poles, 2 lengths, uses disp. syringes

Table 4. Drugs and dosages used for Capturing and Handling Mammals (adapted from Schemnitz, 1980)[a]

Genus	Common Name	Dosages	Remarks
Etorphine hydrochloride (M-99)			
Ursus americanus	Black bear	1.6 mg/100 g	
Cervus elaphus	Elk	7 mg (Ad. cows) 4-5 mg (Yl. cows) 5 mg (Yl. bulls)	Combined with 20 mg Vesprin
Odocoileus virginianus	White-tailed deer	2 mg/deer 5-6 mg	Added 20-30 mg Azaperone Used alone
Alces alces var. americana	Moose	4-5 mg/moose	Used alone
Ovis canadensis	Desert bighorn	2-2.5 mg/bighorn 2.5-3.75 mg (female) 3.5-3.75 mg (male)	Added 15 mg Haloanisone or 20 mg Azaperone 3-5 mg Acetylpromazine or 20-25 mg Zylazine 5-8 mg Acetylpromazine or 30-50 mg Zylazine
Succinylcholine Chloride (Anectine and Sucostrin)			
Cervus elaphus	Elk	27.0 mg/Ad. (Male) 24.4 mg/Ad. (Female)	Immobilization 9-12 min. 24% mortality
Odocoileus virginianus	White-tailed deer	0.07-0.10 mg/kg 0.05-0.09 mg/kg 0.08-0.26 mg/kg	Reaction: 5.1 min. Hyaluronidase added; reaction 2-3 min. Powder form-mortality; 9% adult, 14% fawns
Odocoileus hemionus	Black-tailed deer	0.15-0.31 mg/kg	10% mortality
Antilocapra americanus	Pronghorn antelope	0.13-2.20 mg/kg	Captive-no deaths
Alces alces var. americanus	Moose	15-17 mg/adult 12-14 mg/subadult 9-11 mg/calf	Dosages for late spring and mid-winter Dosages reduced 20-30% late winter and early spring
Ovis canadensis	Bighorn sheep	0.44-1.45 mg/kg	Lower dose for late winter
Mirounga angustirostris	Elephant seal	2.5 mg/kg	Apnea periods 4-9 minutes
Ursus maritimus	Polar bear	3.6 mg/kg 3.3 mg/kg	Cubs and yearling Adult and subadult
Felis concolor	Mountain lion	1.1 mg/kg 1.86-1.96 mg/kg	Adults Juveniles
Lynx rufus	Bobcat	2.2 mg/kg	Used on trapped animals
Taxidea taxus	Badger	3.5 mg/kg	Trapped animals
Dicotyles tajacu	Peccary (Javelina)	60-75 mg 25-35 mg	Free-ranging Trapped animal
Odocoileus virginianus, hemionus	White-tailed deer Mule/Black-tailed	1.5 mg/kg 0.5-1.5 mg/kg	Added Sparine 0.5 mg/kg Wild and captive deer

Table 4. (continued)

Genus	Common Name	Dosages	Remarks
Ovis canadensis	Bighorn sheep	2.35 mg/kg (male) 1.89 mg/kg (female)	Added Sparine or Anatran
Ketamine hydrochloride (Vetalar)			
Procyon lotor	Raccoon	8-10 mg/kg	Collapsed in 2-5 min.
Lynx rufus	Bobcat	11 mg/kg	Restraint dosage
Mirounga angustirostris	Elephant seal	1.4-6.9 mg/kg	
Tiletamine hydrochloride (Cl-744)			
Ursus americanus	Black bear	4.0 mg/kg	Free-ranging
Odocoileus virginianus	White-tailed deer	9.9 mg/kg	Captive (749 tests)
Xylazine hydrochloride (Rompun)			
Cervus elaphus	Elk	0.55 mg/kg 180 mg/elk	Captive Added 65 mg Ketamine
Odocoileus	White-tailed deer	0.89-8.00 mg/kg	Used alone, captive (68)
Antilocapra americanus	Pronghorn antelope	30 mg/antelope	Added 20 mg Ketamine
Bison bison	Buffalo	125 mg/bison	Added 100 mg Ketamine
Ammotragus lervia	Aoudad	0.46 mg/kg	Added 1.6 mg/kg Ketamine

[a] Additional information on drugs and drug dosages may be obtained from local Departments of Fish and Game, zoos, and veterinarian colleges.

drugs and dosages that have been used for capturing and handling mammals. This table is for reference only. Specific drugs and dosages for a study should be selected based on information specific to the species selected, general health characteristics of the population, time of year, and any existing data for the area.

Additional information concerning drugs and the associated equipment can be obtained from local Departments of Fish & Game, zoos, veterinarians, and universities with veterinarian and wildlife management programs.

5.2 Biological Considerations

5.2.1 Deer

White-tailed deer (*Odocoileus virginianus*), Mule deer (*Odocoileus hemionus*), and Black-tailed deer (*Odocoileus hemionus* var. *Columbianus*) are the most common North American artiodactyls. They are closely related and have somewhat similar habits.

Both black-tailed deer and white-tailed deer have smaller home ranges than mule deer and are not normally migratory. They may shift to favorable elevations and different ranges seasonally, but seldom do they migrate the distance normally traveled by mule deer and their movements are not as predictable as those of the mule deer. Both mule deer and white-tailed deer tend to form close herds during winter; black-tailed deer do not exhibit this behavior to the same extent. The primary food of the black-tail throughout most of its range is Gaultheria shallon, the coastal salal and various Madronas and Ceanothus species.

Mule deer are found in a variety of habitats throughout the mountain West, Great Basin, and the southwestern and Sonoran deserts. They are fond of old burn sites and like to feed on south-facing slopes and on ridgetops during the dawn and dusk hours. In the west and northwest their favorite foods are bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata* var. *Wyomingensis*), mahogany (*Cercocarpus spp.*) and various saltbushes (*Atriplex spp.*) In the Southwest, the California coffee-berry (*Rhamnus crocea*) and buckbrush (*Ceanothus integerrimus*) are major parts of a mule deer diet. During summer and fall mule deer eat forbs and grass. They are all fond of salt from both natural and artificial licks.

The white-tailed deer diet is varied and includes the plant genus Ceanothus, mast, and mesquite beans. In the Southwest they can be found in forest, brushland, and scrub cover. They prefer burns and logging sites when vegetational cover following forest disturbances reaches the maximum deer food potential. Black-tailed deer use similar habitat in this range.

Because of their feeding behavior and wide home ranges, deer are generally poor study subjects for many contaminants. However, they have a tendency to accumulate certain metallic elements (mercury, chromium, arsenic) in their livers, and their hair and blood sometimes can furnish contamination evidence.

Deer are relatively easy to collect. Noting fresh dung, tracks, or watching downwind from feeding areas will usually furnish a shooting opportunity. A large caliber (.270 to .308) rifle or

shotgun with buckshot is required for effective and humane collection of these animals.

Seasonally, there are instances when deer samples may be collected by other means. If a hunting season is in progress, state personnel can usually be employed to collect hair and some tissue samples at check stations (liver, kidney and other organs are usually absent because of field dressing). The investigator can arrange with local hunters so samples may be collected from their kills; however, the potential for cross-contamination and difficulties obtaining accurate information from hunters are its disadvantages. Fresh roadkills can also be used for sample collection.

Live trapping can provide samples of known quality. Most deer are fairly easy to trap by means of the Clover trap. Net traps with aircraft have also been successfully used to live trap deer. Although more expensive, more deer may be taken quickly with the corral-and-chute type trap (Giles, 1971).

Hay is the preferred bait during the winter. Apples are good bait for warmer areas and for summer. Southwestern deer are easily baited with a mixture of cracked corn and stock molasses. A livestock salt lick is also useful as bait. In areas where livestock salt is not available, a bucket of rocksalt in campfire ashes will attract deer as will the burning of licorice in the campfire and with scattered pieces of apple. Before using baits, consideration should be given to whether the bait may be contaminated or how it otherwise might affect the tissue being sampled.

In open country, mule deer can be immobilized by shooting from a helicopter with a Capchur-gun loaded with a tranquilizing dart. This is an expensive procedure, but it ensures that samples are taken from the area of the contamination (if known), and can be accomplished quickly with trained personnel. Deer shot with a dart may run a mile or two before the drug immobilizes them.

The most effective trapping methods for the immediate area may often be obtained from local state game managers and biologists. Often they have conducted extensive trapping and marking operations on local deer populations over a period of years and have worked out relatively good trapping systems.

5.2.2 Elk

Elk (*Cervus elaphus*) are herbivorous and migratory in most areas. Their diet consists primarily of grass and browse. They are not a very good study subject for local contaminant assessments because they tend to range over wide areas. They may, however, be a good biomonitor of trace elements resulting from atmospheric deposition. Their livers will accumulate metal contaminants. Like deer, their blood may also furnish evidence of a contaminant.

Trapping elk with corral traps is most effective in fall and winter when they form compact herds. Calves and adults may be trapped in Clover traps of sufficient size. This can cause a great degree of stress to the animal and is undesirable. Bull elk confined in a corral trap with antlerless elk may accidently kill them when excited by the approach of trappers. Generally, bulls should be shuttled out of the trap and released as quickly as possible since ordinarily they do not frequent cow herds. Careful reconnaissance before locating traps can be used to reduce the likelihood of taking bulls.

Elk may be hunted with a helicopter and shot with a tranquilizing dart to immobilize them for sample collection. This is only practical in open country and is best conducted in spring, when elk are bunched and moving off winter ranges. M-99 is a good tranquilizer, but legislation requires the presence of a veterinarian when this chemical is used. Elk shot with succhinal chloride may escape the tranquilizing crew and hide in heavy cover before being immobilized.

Elk are hunted extensively throughout most of their range so hunters and state-operated checking stations are a possible source of samples. Also, in some areas, outfitters and guides may be contacted for cooperation in obtaining specimens.

5.2.3 Caribou

Caribou (Rangifer spp.) are extremely long ranging, sometimes migrating hundreds of miles, and it is unlikely in most situations that they will be considered useful as biomonitors for a localized contaminant. They are useful as biomonitors for atmospheric deposition of trace elements. Caribou are generally lichen feeders, although they browse on willow occasionally. The lichens that provide most of their diet tend to concentrate airborne trace elements.

Caribou are extremely fond of salt and can be attracted to a lick and then trapped using a drop net. They are found in open country (with the exception of woodland caribou) and are easy to immobilize with darts fired from a helicopter. They are hunted extensively during the late summer and early fall, thus, samples should be easy to obtain from state Fish & Game personnel, hunters, and from cooperative outfitters and guides.

5.2.4 Antelope

American Pronghorn Antelope (*Antilocapra americanus*) are diurnal and tend to feed and rest for 30- to 40-min intervals around the clock. Often they are migratory, traveling hundreds of miles between summer and winter ranges. To meet daily water requirements, they remain within a day travel to waterholes or streams. They are not easily trapped but have been captured with coral traps. Because their range is usually saturated with an ample supply of livestock salt blocks they are are not easily baited. Their diet is primarily sagebrush of Tridentata and Nova species. Droppings and tracks and the open country they live in make them easy to locate.

Antelope are highly excitable and mortality resulting from being chased in a helicopter can be high. State personnel have conducted extensive trapping operations by running herds of pronghorn into wing traps with teams of aircraft and horsemen. Extra care must be taken with this method because of the high rate of antelope mortality. Appropriate calibers for killing antelope are .25.06, .257, or a .30.06 calibers.

Antelope are hunted extensively, and the hunts are often checked by state wildlife personnel. Samples can usually be obtained at check stations or from cooperative biologists, wardens or conservation officers. Hunter cooperation is often easily obtained.

5.2.5 Hogs and Boars

Wild hogs have highly varied diets and are likely to feed at any time of day or night. They eat insects, fruit, nuts and mast, berries, grain, vegetation, snakes, lizards and rodents, calves, fawns,

lambs, carrion, and spawned out fish. They are fairly good sampling subjects for looking at an integrated diet, but not too useful if trying to assess a particular pathway.

Hogs are drawn to odorous baits such as grain mixed with whey or sour milk, or a mixture of apples and potatoes. They can be baited into clover traps or driven into corral traps. Clover traps should be constructed of woven wire to prevent them from chewing their way out. When using a corral trap, a smaller chute than is required for deer should be used. Hogs are quick and potentially vicious and should be handled with care using leather gloves and boots. Hogs can be collected by shooting with a medium caliber shot or with a shotgun loaded with buckshot. Outfitters guiding hog hunts may be a good source of specimens.

5.2.6 Cattle and Sheep

Domestic cattle and sheep are fair subjects for sampling, especially on refuges that allow grazing. Their grazing area and potential contact with contaminated herds can be fairly well identified. Refuges with managed grazing programs and livestock operations may consider these animals for sampling. Though domestic stock are not necessarily representative in their response to contaminants, they may play a useful role in a monitoring program.

Sampling programs must be negotiated with the livestock owner; usually blood, milk, and hair samples are relatively easy to obtain. If processed locally, samples from specific animals may be obtained at the slaughter house.

5.2.7 Horses and Burros

Wild horses and burros are wide ranging diurnal feeders. They feed mostly on grass and forbs. Consequently, their effectiveness as biomonitors is similar to other wide ranging animals.

Collecting live horses is usually accomplished by chasing them on horseback or with aircraft into a corral with wing traps. It is more expensive to trap them and they are not easy to bait. If necessary, equines can easily be shot from horseback or aircraft with a dart gun or a deer rifle.

Wild burros are somewhat more difficult to hunt than wild horses. They can be located by observing droppings or by locating their water source and waiting downwind and out of sight of the water source. Since their hide is tough a .30-06 or equivalent caliber is required to kill them.

6. SAMPLE PRESERVATION AND SHIPPING

NOTE: When working with specimens that may be diseased or contaminated, personnel should wear disposable rubber or plastic gloves, coveralls, and rubber boots or waders.

Mammals can be analyzed whole-body or by specific organ. The best specimen for submission is an entire animal. This allows the diagnostician to make an assessment of all the organ systems and to use the appropriate organs/tissues for diagnostic tests. If it is not possible to submit the entire specimen, appropriate organs must be removed and submitted. Carcasses should not be dissected in the field without first consulting a disease specialist regarding methods of dissection and preservation of tissues and parasites. Field necropsies are at times of value for documenting the basic health, body condition, and obvious pathological conditions that could be associated with contaminants, and for relating the reproductive state of specimens undergoing chemical analysis.

It is best if carcasses are examined and dissected before freezing because the freezing process can alter some tissues. However, this may not be possible in all cases and whole specimens may have to be frozen before examination. To avoid decomposition, individual carcasses should be completely frozen before bagging.

Either chill or freeze all specimens (use refrigeration, dry ice, and/or blue ice packs), depending on how long shipping to the diagnostic laboratory will take. If analyses are not considered "routine", an analyst should be consulted to determine what special handling procedures may be necessary for the analysis to be performed. For additional information consult the appropriate EC Specialist, Regional EC Coordinator, and/or analytical lab personnel.

6.1 Whole Carcass Submission

1. Tare specimen jar for carcass on a laboratory balance. Place the specimen in the specimen jar and record the weight. If the carcass is too large for a jar, it may be wrapped in clean aluminum foil (rinsed with hexane if hydrocarbons are to be analyzed) and then double-sealed in plastic bags. Label both the foil and the bag.

2. Samples should be properly wrapped, labeled, and preserved into appropriate sample containers.

3. Record the information in the field logbook and complete the chain-of-custody documents if required.

4. Document all sampling activities as required.

6.2 Dissection

1. Remove any abnormal-appearing tissues or organs, and submit for examination.

2. Keeping tissues as clean as possible, place specimens in individual Whirl-Pak or clean plastic

bags (if chemical assessments do not include organic analysis).

NOTE: When analyzed for organics, place specimens in rinsed aluminum foil. Acid rinsed or chemically cleaned glass jars may also be appropriate containers. It is recommended that samples collected for organic analysis not come in contact with plastic.

3. Samples should be properly wrapped, labeled, and preserved into appropriate sample containers.

4. Record the information in the field logbook and complete the chain-of-custody documents if required.

5. Document all sampling activities as required.

6.3 Labeling and Packing of Frozen Specimens

Supplies: Insulated shipping container, dry ice (1 lb for each lb of material to be shipped, 5 lbs minimum), packing material (bubble wrap), and strapping tape, sample labels and tags, marking pens.

STOP: Notify personnel or laboratory receiving the shipment and provide them details as to the shipment contents, arrival time, etc.

1. Shipping container should be sized to contain samples, dry ice, and a small amount of packing material.

2. Place a layer of dry ice on the bottom of the insulated shipping container.

3. Place a layer of packing material on the dry ice.

4. Identify each carcass separately with a sample tag fastened by a wire to a leg. Address all categories and parameters identified in the Documentation Guidance SOP, using indelible marker.

5. Place each specimen in an appropriate container.

6. Attach sample labels and tags to containers, addressing all the categories, and parameters identified in the Documentation Guidance RFM.

7. Wrap each sample container in packing material and place in shipping container.

8. Place a layer of packing material on top of the sample.

9. Place a layer of dry ice on top.

10. Repeat steps 4 through 9 until all the samples are packed.

11. Fill remainder of container with packing material.

12. Place the lid on the container.

13. Tape the lid in place, wrapping the entire perimeter of each individual container with the strapping tape. Use an indelible marker to write on the tape, listing the type of specimen, the kind of tissue, and date the sample was taken.

14. Complete all chain-of-custody records as required (see Documentation SOP).

6.4 Blood Samples

Blood sampling methods may vary according to analytical requirements. The analytical laboratory must be consulted if analyses are needed for nonroutine chemicals. Specifics that should be addressed include (a) quantity, (b) handling procedure, (c) glassware, and (d) chemicals for blood chemistry.

The needle and syringe should be heparinized (to prevent clotting). This is done by drawing sodium heparine into the needle and syringe, then expelling it. The procedure can be performed in the laboratory or the field. Preheparinzed needles and syringes can be purchased. Blood should be split into equal amounts. One half is frozen for heavy metal analysis. The remaining half is mixed with formaline for organochlorine analysis in a ratio of 5 ml formaline to 10 ml blood for organochlorine samples. Some laboratory analysts require that two slide smears be taken at the time of collection. Centrifuging may or may not be required before shipping. Contact the analytical laboratory for specific requirements.

7. REFERENCES

Clark, D. R. Jr., 1988. "Environmental Contaminants and the Management of Bat populations in the United States." Symposium Management of Amphibians, Reptiles, and Small Mammals in North America. Flagstaff, Arizona.

Collins, H. H. Jr., 1967. Complete Field Guide to American Wildlifeç, East, Central, and North, Harper & Bros, New York, New York.

Constantine, D. G., 1958. "An automatic bat-collecting device." Journal of Wildlife Management, 22, pp. 17-22.

Cooperrider, A. Y., R. J. Boyd, and H. R. Stuart, 1986. Inventory and Monitoring of Wildlife Habitat, U.S. Department of Interior, Bureau of Land Management Service Center, Denver, Colorado.

Eisler, R., 1987. Mercury Hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.10).

Eisler, R., 1986. Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.6).

Eisler, R., 1985-1990. Contaminant Hazards Reviews. U.S. Fish and Wildlife Service Biological Report 85(1.1 - 1.20).

FWS, 1986, Fish and Wildlife Service. Field Operations Manual for Resource Contaminant Assessment.

Geluso, K. N., S. Allentrack and D. E. Wilson, 1976. "Bat Mortality, Pesticide Poisoning and Migratory Stress." Science, 194, pp. 184-186.

Giles, R. H. (ed.), 1971. Wildlife Management Techniques, 3rd edition, The Wildlife Society, Washington DC.

Greenhall, A. M. and J. L. Paradiso, 1968. "Bats and bat banding." U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife.

Johnson, W. C. and B. L. Keller, 1983. "An Examination of Snap-Trapping Techniques for Estimating Rodent Density in High Desert," Northwest Science,57, pp. 194-204.

Lensing, J. E., and T. F. Roux, 1975. "A Capture Snare for the Smaller Mammal Predators and Scavengers." Madoqua, 9(1), pp. 57-61.

Murie, Olaus J., 1954. A Field Guide to Animal Tracks, Houghton Mifflin Company, Boston, Massachusetts.

Nagorsen, D. W. and R. L. Peterson, 1980. A Mammal Collectors' Manual, The Royal Ontario Museum, Toronto, Cananda.

Schemnitz, S. D. (ed.), 1980. Wildlife Management Techniques Manual, 4th edition, The Wildlife Society, Washington DC.

Tuttle, M. D., 1974. An improved trap for bats. Journal of Mammalogy, 55, pp. 475-477.

8. BIBLIOGRAPHY

Burt, W. H. and R. P. Grossenheider, 1952. Field Guide to the Mammals, Boston, Massachusetts: Houghton Mifflin Company.

McCracken, H. J. and H. Van Cleve, 1947. Trapping, the Craft and Science of Catching Furbearing Animals, A. S. Barnes & Co., New York, New York

Musgrove and Blair. 1979. Fur Trapping. Winchester Press.

Novak, Baker, Obbard and Mallock (eds). 1987. Wild Furbearer Management and Conservation in North America. Ontario Ministry of Natural Resources.

Taylor, W. P., 1956. The Deer of North America, Stackpole Company, Harrisburg, Pennsylvania, and The Wildlife Management Institute, Washington, D.C.

Timm. 1983. Prevention and Control of Wildlife Damage. Great Plains Agricultural Council-Wildlife Resources Committee and Nebraska Cooperative Extension Service. Institute of Agricultural and Natural Resources, University of Nebraska - Lincoln.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX E
DECONTAMINATION GUIDANCE
REFERENCE FIELD METHODS

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PREFACE

This is Appendix E of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   D.2 Bird Sampling Reference Field Methods
   D.3 Fish Sampling Reference Field Methods
   D.4 Flora Sampling Reference Field Methods
   D.5 Reptiles and Amphibians Sampling Reference Field Methods
   D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
0	10/2/91	2.1	2-4	2-4c	5
1					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

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Commentor's Name_____ Phone_____

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Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

References (if applicable):

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ACRONYMS

ASTM	American Society for Testing and Materials
DDI	distilled-deionized water
DHHS	U.S. Department of Health and Human Services
DOE	U.S. Department of Energy
ECS	Environmental Contaminant Specialist
EPA	U.S. Environmental Protection Agency
FWS	U.S. Fish and Wildlife Service
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PVC	polyvinyl chloride
RFM	Reference Field Method
Service	U.S. Fish and Wildlife Service
USCG	U.S. Coast Guard
VOA	volatile organics analysis

U.S. FISH AND WILDLIFE SERVICE LANDS
BIOMONITORING OPERATIONS MANUAL
APPENDIX E
DECONTAMINATION GUIDANCE
REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of this Reference Field Methods (RFM) document is to provide guidance for decontaminating personnel and sampling equipment after sampling contaminated environmental media. Sampling episodes will contaminate personnel and equipment, such as personnel attire, sampling devices, and sampling tools, and must be decontaminated for health and safety measures, and for maintaining sample and data quality integrity by eliminating sample to sample cross contamination.

Depending upon the circumstances, some equipment (e.g. housings for some air collecting and automatic water collecting equipment) may not become contaminated during sampling. As such, the responsibility and decision to decontaminate sampling gear and equipment must be made on a case by case basis by field personnel.

1.2 Scope

This RFM identifies methods and techniques that have been successfully used by numerous state, local, and Federal agencies to clean sampling tools, equipment, and personnel attire following an exposure to environmental contaminants. In addition to the contamination procedures presented, commonly used cleaning and neutralizing solutions are identified.

Some decontamination procedures are more suited to specific equipment and some may be easier to implement because of existing and available facilities. This RFM provides general guidance for personnel decontamination. However, it is recommended that field personnel exposed to contaminants follow definitive decontamination procedures presented in health and safety plans and in contaminant Sampling and Analysis Plans such as the Standard Operating Safety Guidelines (EPA 1986).

1.3 Background

There are two important questions that must be answered when decontamination is addressed in the design and execution of a sampling program. These questions are:

- Could contaminated sampling equipment pose a health threat to U.S. Fish and Wildlife Service (Service) personnel who use the equipment?
- Will the sampling equipment cause contamination of any subsequent samples that must be collected?

Equipment must be decontaminated if a remote possibility exists that the answer is yes to one or both of these questions. It is obvious that contaminated sampling equipment, as addressed in the first question, could be detrimental to the health and safety of sampling personnel. Question 2 addresses the fact that data obtained from a contaminant sampling effort will be used to identify and make decisions concerning environmental contaminant trends, and perhaps, used in the development and implementation of remedial measures to abate any detrimental contaminant influences. If sample integrity cannot be ensured, as suggested by the second question, improper decisions and consequences could result from using the data from these samples.

It is recommended that decontamination procedures for personnel and personnel protective attire be definitively addressed by health and safety personnel before sampling is initiated. The extent of personnel decontamination procedures depends on a number of factors, the most important being the type and level of contaminants involved. The more harmful the contaminant, the more extensive the decontamination procedures must be. Whenever it is possible for personnel to become contaminated with a highly toxic or skin-destructive substance, an extensive decontamination procedure must be implemented.

Decontamination is time consuming, costly, and may generate waste that requires packaging for proper disposal. Also, decontamination procedures for sampling equipment must be developed in conjunction with analytical laboratory personnel to ensure that there is no analytical interference caused by any decontaminating wash or rinse solutions during sample analysis. To eliminate potential solution interferences it is recommended that disposable sampling equipment be used when applicable, available, and acceptable from an economic standpoint. Disposable equipment can save time and money and, most importantly ensure that no cross contamination occurs. The use of the following disposable sampling/handling equipment is suggested:

- Stainless steel spoons and screens
- Sampling containers
- Teflon and silicone tubing
- Aluminum pans when appropriate for mixing and compositing samples.

Special consideration is generally required when both radioactive and chemical contaminants are present. At times, the presence of contamination on equipment can be ascertained in the field using organic vapor analyzers for chemical contaminants and radiation monitoring equipment for radioactive contaminants. See Appendix G, Field Measurements RFM, for operational guidance. For many contaminants, there is no method to immediately determine how effective decontamination is.

Extreme care should be taken to prevent contamination of field measurement instrumentation. Under most circumstances, field instruments will not become contaminated unless they are used in a careless manner. If contamination occurs, it is difficult to clean most measurement instruments without damaging them. Any instrument(s) that cannot be decontaminated easily should be protected while being used. General precautions include placing each instrument inside a clear plastic bag with the bag taped and secured around the instrument. Openings can be made in the bag for sample intake and probe connections.

1.4 Information Resources

The U.S. Environmental Protection Agency (EPA), the National Institute for Occupational Safety and Health (NIOSH), and the U.S. Department of Energy (DOE) can provide information concerning recommended techniques and procedures for decontaminating personnel and equipment. Several excellent documents exist that identify these techniques and procedures including:

- Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, NIOSH, Occupational Safety and Health Administration (OSHA), U.S. Coast Guard (USCG), and EPA, Department of Health and Human Services (DHHS), Publication No. 85-115.

- Standard Operating Safety Guidelines, Environmental Protection Agency, Environmental Response Team, Washington, D.C., 1986.

- Criteria for a Recommended Standard ... Occupational Exposure to Hot Environments, Department of Health and Human Services, Revised Criteria, 1986.

- The Environmental Survey Manual, Department of Energy, DOE/EH-0053, Second Edition, January 1989.

Service personnel should be cognizant of any Service policies regarding the types and levels of permissible contaminant exposures. In cases where unacceptable exposures may occur, the EPA should be consulted. Appropriate training in personnel protection and in handling and sampling contaminated media can also be obtained from the EPA.

The potential use and decontamination of drilling and heavy equipment is addressed in this RFM. In cases where heavy equipment is used, their operation and decontamination may require expertise from experienced contractors and/or state and Federal agency personnel.

2. SAMPLING EQUIPMENT

Sampling equipment and tools that cannot be satisfactorily decontaminated in the field must be shipped to a suitable facility for decontamination. Physical removal of contamination using brushes should be followed by a wash/rinse process using appropriate decontamination solutions. The recommended decontamination procedures for sampling equipment that has been used for collecting media contaminated with both organic and metal contaminants is as follows:

1. Check for adhered material; use a suitable brush to dislodge and physically remove any large particles.

2. Wash and scrub thoroughly with a nonphosphate laboratory glassware detergent (e.g., Alconox).

3. Wash and scrub thoroughly with tap water.

4. Rinse thoroughly with 10 N nitric acid.

5. Rinse thoroughly with tap water.

6. Double rinse with American Society for Testing and Materials (ASTM) Type II distilled-deionized (DDI) water.

7. Spray rinse all equipment surfaces with pesticide-grade methanol or pesticide-grade hexane using Teflon wash bottles. Collect the solution (methanol or hexane) in a suitable container for disposal. One effective collection technique is to place a large glass or stainless steel funnel below the tools during rinsing. A mixing bowl can be used as a collection vessel and then become the last item cleaned in the sequence of operations. If a rinsate sample is required, make an additional final rinse of the item, using ASTM Type II (DDI) water, and collect it for analysis. Allow equipment to air dry. Do not air dry the equipment in areas where airborne dust will recontaminate the equipment.

8. Collect a swipe sample for radioactive analysis if the item is known or suspected of being radioactively contaminated (see Section 2.2 for additional information).

9. After cleaning, equipment used to collect samples for organic analysis should be wrapped in aluminum foil; equipment used to collect samples for inorganic analysis should be wrapped in plastic wrap or plastic bags.

NOTE: An item can be steam cleaned between Steps 6 and 7 if a steam cleaner is available and the equipment is not heat or steam sensitive.

An abbreviated decontamination procedure may occasionally be required for cleaning sediment and soil sampling devices between grab samples when making up a single composite. This procedure consists of brushing off visible material with a wire brush. A wire bottle brush works well for cleaning core samplers. All surfaces should be scrubbed, washed, and rinsed with tap water and then rinsed with ASTM Type II (DDI) water. A small amount of cross contamination between grab

samples may occur using this technique in lieu of a full decontamination procedure; however, the amount of carry-over contamination may be insignificant when compared to the total mass of the sample obtained for compositing.

When sample containers are submersed for sample collection [i.e., when collecting samples for volatile organic analysis (VOA)], the external container surface can be decontaminated after capping the container with a thorough tap water rinse. The container can then be dried with a paper towel (e.g., Kimwipe) before labeling. In the event the sample is suspected of containing high pollutant concentrations, especially organics, the external container surface should be rinsed with methanol or hexane.

Teflon sample tubing and medical grade silicone peristaltic pump tubing can be precleaned in a laboratory, using an ethanol rinse followed by a hexane rinse. The tubing is then dried in a low temperature vacuum oven. Teflon sample tubing and peristaltic pump tubing may not require decontamination during field use if they are dedicated to a specific sampling location requiring a composite sample. The tubing should be decontaminated after sampling and before initiation of the next composite.

All materials and equipment used for decontamination must be disposed of properly. The final disposition of rinse water and material dislodged from sampling equipment will depend on the known or suspected contaminant levels. In certain instances, following definitive identification of the contaminants decontamination rinse water may be disposed of directly on the ground, while in other instances it may have to be collected and properly packaged for disposal. All solvents used for decontamination must be collected for proper disposal. Service environmental contaminant specialists (ECS) should determine appropriate disposition of decontamination wash and rinse water. For large scale decontamination programs polyvinyl (PVC) or Hypalon decontamination pads with built-in sumps are commercially available for preventing the spread of contaminants that are dislodged or rinsed off. Materials collected in the sump can be pumped into drums for proper disposal by Service personnel.

In some air sampling procedures (See Air Monitoring-Appendix C) decontamination of equipment is not a separate activity but an inherent part of sample recovery. Results from air samples are presented in terms related to total sample mass collected per unit volume of sampled air. Therefore, the results are valid only if every trace of the sample mass (e.g., particulates) is recovered from the entire sampling system. To ensure complete recovery, it is recommended that the sampling system be cleaned and flushed. Inside surfaces of the particulate probe assembly should be cleaned by rinsing it with acetone from a wash bottle while simultaneously scrubbing it with a nylon bristle brush that matches the diameter of the probe. All the acetone rinse must be collected. A brush should be run through the probe several times and the probe and brush rinsed each time with acetone. The filter holder and other components must be cleaned and rinsed with acetone in a similar manner. The acetone rinse is then transferred to a beaker or other suitable container and evaporated to recover particulate matter. The particulate material recovered from the cleanup decontamination procedure and particulates collected during the sampling episode can be confined and analyzed together as a single sample.

2.1 Sample Containers

Ensuring the integrity of collected samples is enhanced by using clean containers. It is recommended that clean containers be purchased and the reuse of containers be prohibited or minimized. In cases where commercially cleaned containers are not cleaned satisfactorily and the reuse of containers is unavoidable, the cleaning procedures presented below can be used.

2.1.1 Polyethylene bottles and polyethylene caps

- Rinse bottles and lids with 5% sodium hydroxide
- Rinse with deionized water
- Rinse with 5% Ultrex (or equivalent) nitric acid in deionized water
- Rinse with deionized water
- Drain and air dry

2.1.2 Amber-glass bottles or 40-mL vials

- Scrub and wash bottles in a detergent (e.g., Alconox)
- Rinse with copious amounts of distilled water
- Rinse with acetone
- Rinse with methylene chloride (Nanograde or equivalent)
- Rinse with hexane (Nanograde or equivalent)
- Air dry
- Heat to 200°C
- Allow to cool
- Cap with clean caps with Teflon liners

2.1.3 Bottle caps (paper and Teflon liners)

- Paper liners
  - Remove paper liners from caps
  - Wash with detergent
  - Rinse with distilled water
  - Dry at 40°C

- Teflon liners (avoid contact with fingers)
  - Wash with detergent
  - Rinse with distilled water
  - Rinse with acetone
  - Rinse with hexane (Nanograde or equivalent)
  - Air dry
  - Place liners in cleaned caps
  - Heat to 40°C for 2 hours
  - Allow to cool
  - Cap cleaned bottles.

NOTE: All solvents used must be disposed of properly.

2.2 Heavy Equipment

There may be times when bulldozers, trucks, backhoes, and drill rigs are required in a sampling program. These items and other heavy equipment are difficult to decontaminate. The method generally used is to wash them using high pressure steam, and scrub accessible parts with a suitable detergent and water solution under pressure. A decontamination station may be required. Decontamination should be conducted on a wash pad constructed so that cleaning solutions and wash water can be recycled or collected for later disposal. Decontamination operations should start with the easiest procedure first. For example, a general spraying to remove the bulk of material would be followed by steam cleaning and scrubbing difficult areas.

Components in direct contact with contaminated media, such as scoops and wheels, must be given particular care. The cleaning procedure described below, followed by swiping can be used.

- Using wire brushes or scrapers, physically remove any bulk material adhering to the equipment that requires decontamination. If necessary, use water under pressure and a nonphosphate detergent to help dislodge contaminated material.

- Steam clean the equipment at 350-375°F if possible.

- Rinse twice with hexane. Discard the solvent into a waste container for later disposal.

- Collect a swipe sample for immediate radioactive analysis if the item is known or suspected of being radioactively contaminated. Swipe the equipment (about 100 cm^2 of surface area) with a filter paper measuring 47 mm in diameter.

NOTE: Swipe testing is a method for determining the effectiveness of surface decontamination of radioactivity. For chemical and radioactive contaminants, filter paper swipes (47 mm diameter) are wiped over selected surfaces of the equipment and analyzed in the laboratory. However, for some radioactive contaminants, the swipes can be analyzed by a hand-held radiation detector. Swipes analyzed by a hand-held radiation detector provide real-time information; swipes analyzed by the laboratory provide after-the-fact information (See Appendix G, FIM RFM, Section 8.1.5).

If laboratory radiation detection equipment is available, survey or analyze the swipe. For radiation levels the following criteria are used by DOE (1987): The sampling equipment is considered clean and suitable for use if there are <50 dpm/100 cm^2 (beta, gamma) and/or $<10^{-5}$ Ci/100 cm^2 of ^{238}Pu, $^{239,240}Pu$, or ^{241}Am.

- Rinse the decontaminated item (part) with ASTM Type II (DDI) water and collect a rinsate blank if required.

NOTE: Physical scrubbing with brushes may be necessary to loosen materials. In most instances, hot water is more effective than cold. When flushing equipment under high pressure, take care not to damage items such as dials, gauges, and loosely hanging wires or hoses.

Dry removal of contaminants can be accomplished by brushing, vacuum cleaning, vacuum blasting, and sandblasting. Vacuum cleaning with high efficiency units mounted over 55-gal recovery drums provides the greatest control of fugitive emissions. It is recommended that porous items such as wooden truck beds, cloth hoses, and wooden handles not be used because, in many cases, they cannot be properly cleaned.

It is extremely important to control the volume of waste water used during equipment decontamination because these liquids must be contained for disposal.

2.2.1 Drilling equipment

When drilling equipment is used during sampling, the drill rig and its tools must be decontaminated. Decontaminate the drill rig and tools before starting drilling operations to prevent carry-over contamination from a previous borehole. Take swipes, if possible, to verify the effectiveness of the decontamination operation. Whenever drilling operations are suspended (e.g., at the end of the workday) and the tools are removed from the borehole or well, the tools must either be decontaminated before reinsertion into the borehole or well, or they must be adequately protected from accidental contamination by dust and other matter. Periodically decontaminate the tools to minimize the probability of cross contamination within the borehole or well. Because it is often difficult to determine the degree of contamination by organic compounds, frequent (daily) decontamination of the tools will help minimize accidental contamination. The drilling tools used in the borehole also need to be decontaminated when progressing from contaminated to uncontaminated geologic material. Once contaminated material is encountered, decontaminate the drilling tools, especially if drill cuttings are used to determine the presence of contaminants. Decontaminate the drill tools just before drilling into the section of the borehole that will be within the well intake. This will minimize the possibility of contaminating the potential producing zone. Also, during well development, all equipment, such as pumps, logging tools, and drilling tools must be decontaminated before insertion into the borehole or well. A cable tool rig and its tools should be decontaminated on a routine basis to minimize contamination of the potential production zone by contaminants originating from another site, surface soils surrounding the wellhead, or overlying contaminated zones with the borehole.

Once drilling is under way, decontamination of continuous flight augers is not practical because it would require the withdrawal of augers from the borehole. Cross contamination within a wellbore does not generally pose a problem for auger drilling methods. However, rotary drilling methods do pose contamination problems involving drill cuttings that adhere to the wellbore wall and contaminate the drilling fluids.

Well completion materials, such as removable casing, screen, casing sand for the filter pack, bentonite, cement, and concrete, should also be free of contaminants. Both materials and services should be specified contaminant-free when purchasing or contracting for them. Sampling and analyzing samples of well completion materials actually used are recommended as an additional check. Temporary casings removed from the borehole should be steam cleaned both inside and out before use. Screen and well casings should be obtained from the manufacturer in a cleaned condition whenever possible. These materials must be sealed to prevent contamination during transportation and when in on-site storage before use. Casing joint lubricant(s) should be limited to essentially inert material, such as Teflon tape, which does not contain the monitored contaminants. Materials (sand and gravel) for the well screen filter, bentonite and cement used to seal the annulus around the well

casing, and concrete in the upper portion of the annulus around the well casing should all be free of monitored contaminants. At a minimum, the well completion materials should not contain any constituents that will interfere with analysis.

3. PERSONNEL ATTIRE

Most decontamination plans assume all personnel and their attire leaving an area of potential contamination are grossly contaminated. A system is generally established to wash and rinse, at least once, all articles worn by personnel. This is usually done in combination with the sequential doffing of attire, starting with the most heavily contaminated item and progressing to the least contaminated article. From a personnel safety and decontamination perspective, specific conditions at a site should be evaluated before sampling. These conditions include

- Types of contaminants
- Levels of contaminants
- Media or materials contaminated

If site conditions warrant (see EPA, 1986 for guidance) or if there is a probability of contact with hazardous materials, levels of protection must be identified. Attire or equipment to protect the body against contact with known or anticipated toxic materials is divided into four categories according to the degree or level of protection afforded. These levels include

- Level A Should be worn when the highest level of respiratory, skin, and eye protection is needed.

- Level B Should be worn when the highest level of respiratory protection is needed, but a lesser degree of skin protection is needed.

- Level C Should be worn when a lesser level of respiratory protection is needed than Level B. Skin protection criteria are similar to Level B.

- Level D Should be worn only as a work uniform and not on any site with respiratory or skin hazards. It provides no protection against chemical hazards.

Consult EPA (1986) for the identity of attire that is commensurate with the identified protection levels.

In the event that Service personnel are or could become contaminated by hazardous wastes (see FWS, 1986 for definition and guidance), a contamination reduction zone should be established. The contamination reduction zone confines personnel decontamination activities to a limited area and controls access into and out of an exclusion zone. If a contamination reduction zone is required, consult DHHS (1985) for specifications and operational requirements.

Anyone in a contamination reduction zone should wear the level of protection designated for decontamination. Specific areas are identified for the decontamination of sampling tools, portable field equipment, removed clothing, and other safety and sampling equipment. These areas are restricted to personnel wearing the appropriate level of protection. All activities within the zone should be confined to decontamination.

Certain parts of contaminated respirators, such as the harness assembly and leather or cloth components, are difficult to decontaminate. If grossly contaminated, they may have to be discarded. Rubber components can be soaked in soap and water and scrubbed with a brush. Regulators must be

treated and maintained according to manufacturer's recommendations. Persons responsible for decontaminating respirators must be thoroughly trained (Consult local DOE or EPA for guidance).

Respirators, reusable protective clothing, and other personal articles must also be sanitized before reuse. The insides of masks and clothing become soiled from exhalation, body oils, and perspiration. If practical, protective clothing should be machine washed. In some cases, normal decontamination procedures cannot remove contaminated substances from protective clothing or sampling devices. If persistent contamination is expected, disposable garments should be worn (consult EPA, 1986 and DHHS, 1985 for guidance).

In some cases, contamination can be removed by physical means involving dislodging or displacement, rinsing, blowing or wiping-off, and evaporation. The use of a disposable outer garment, such as a Tyvek suit often can be used to keep gross contamination from reaching protective clothing and thus reduce the required decontamination of protective clothing. Contaminants that can be removed by physical means are identified as

- Loose materials
- Adhering materials
- Volatile liquids
- Entrapped or permeated wastes

Removal of contamination by physical means should be followed by a wash/rinse process that involves the use of solutions to augment physical cleaning methods.

To choose the appropriate wash and rinse solutions for decontamination, one must take into account the following factors:

- Solubility behavior of contaminant (Table 1)
- Compatibility of choice solutions with contaminant and equipment
- Accessibility of solutions
- Effectiveness of solutions and methods
- Storage, handling, and disposal requirements of solutions
- Hazards associated with cleaning solutions (i.e., flammability and toxicity).

In general, the more common solvents and the compounds they work best on are presented below:

- Water
  - Dissolves low chain hydrocarbons, inorganics, salts, some organic acids, and other polar compounds.
- Dilute Acid
  - Dissolves caustic (basic) compounds, amines, and hydrazines.
- Dilute Base:
  - Dissolves acidic compounds, phenols, thiols, and some nitro and sulfonic compounds.
- Organic Solvents:
  - Dissolve nonpolar compounds such as other organics; can also dissolve fabrics of protective clothing.

Table 1. General guide to solubility of contaminants in four solvent types[a]

Solvent	Soluble Contaminants
Water	Low-chain hydrocarbons Inorganic compounds Salts Some organic acids and other polar compounds
Dilute Acids	Basic (caustic) compounds Amines Hydrazines
Dilute Bases For example: - detergent - soap	Acidic compounds Phenols Thiols Some nitro and sulfonic compounds
Organic Solvents For example: - alcohols - ethers - ketones - aromatics - straight-chain alkanes (e.g., hexane) - common petroleum products (e.g., fuel oil, kerosene)	Nonpolar compounds (e.g., some organic compounds)

a. DHHS, 1985.

Choice of solvent wash and rinse solutions will depend on their compatibility with the equipment material being decontaminated. For example, most of the fabrics of protective clothing are made of polymer organics that can be dissolved or destroyed by organic solvents. The metals and gaskets of tools and equipment can be damaged by overly acidic or caustic compounds. Also, it is important that the chemical waste and the cleaning solution be compatible. Consult local EPA, Health and Safety Personnel and EPA (1986) for information concerning solution factors and solution-fabric compatibility.

4. DECONTAMINATION AND DECONTAMINATION EQUIPMENT

If available, steam or hot water with detergent is generally the decontaminant agent of choice. However, in some cases it may be necessary to use specific solutions, chemicals, or combinations of solutions and chemicals to ensure thorough decontamination. Whatever solution is used, its possible reactivity and suitability for the contaminants and the material to be cleaned must be carefully evaluated. Some commonly used decontamination (cleaning and neutralizing) solutions are identified in Table 2.

Table 2. Cleaning and neutralizing solutions

Decontamination Solution	Remarks
Sodium Carbonate (Washing Soda)	5 to 10% aqueous solution, good water softening agent, effective for inorganic acids, strongly alkaline
Sodium Bicarbonate (Baking Soda)	5 to 10% aqueous solution, amphoteric --effective with most acids and bases
Trisodium Phosphate[a] (TSP, Oakite)	5% aqueous solution, good water softening agent/detergent, general rinse solution, strongly alkaline
Combination	An aqueous solution of 5% sodium carbonate and 5% trisodium phosphate
Calcium Hypochlorite (HTH)	10% solution, disinfectant, bleaching, and oxidizing agent; care required in storage, mixing, and application

a. Use of phosphates should be avoided whenever feasible.

Biological contaminants have been decontaminated using: betapropiolactone, formaldehyde solution, ethylene oxide-fluorinated hydrocarbon mixture, peracetic acid, and strong bleaches and caustics. These decontaminants require special care during handling and use, and they may degrade rubber products found on some sampling devices. Consult local EPA personnel for specific guidance.

Most decontamination equipment and solutions can be easily procured. For example, soft-bristle scrub brushes or long-handle brushes are excellent for decontaminating equipment. Water dispensed from buckets or garden sprayers can be used for rinsing and large galvanized washtubs or

stock tanks can hold wash and rinse solutions. Most contaminated liquids can be stored temporarily in metal or plastic cans or drums, and in large plastic garbage cans or similar containers lined with plastic bags. Paper or cloth towels for drying equipment are also easily obtained.

If equipment decontamination is required and a definitive decontamination/disposal procedure has been selected, all personnel must follow that procedure. A decontamination record (Figure 1) should be maintained and placed in the field logbook by the sampling team leader. This record should describe and document the decontamination episodes of tools, equipment, clothing, and/or personnel. Compliance in maintaining these records should be frequently checked by appropriate Service personnel.

For each sampling effort, the potential hazards that Service personnel may be exposed to should be described and documented in the field logbook. Health and safety considerations must be foremost in conducting all decontamination procedures.

SAMPLING TEAM LEADER
SAMPLING/MONITORING PROGRAM NAME
EQUIPMENT USED
POSSIBLE HAZARDS
PROTECTIVE EQUIPMENT NEEDED
SPECIAL PROCEDURES, PRECAUTIONS
DECONTAMINATION PROCEDURES AND DECONTAMINANT SOLUTIONS USED
WASTE DISPOSAL PROCEDURES USED

Figure 1. Decontamination record.

5. GLOSSARY

Blanks	Prepared samples used to measure various cross-contamination sources
Heavy metals	Metals having a specific gravity of 5.0 or over
Pollutant	Any introduced substance that limits a resource use for a specific purpose
Rinsate sample	A sample usually consisting of ASTM Type II (DDI) water that was passed over (last rinse) a sampling device. Used to measure residual contamination after device was decontaminated.
Semivolatiles	A group of organic compounds consisting of base/neutrals, acids, and pesticides that are identified in and analyzed by Method 625 in 40 CFR 136
Volatile	Solids or liquids that are relatively unstable at standard temperature and pressure, and undergo spontaneous phase change to a gaseous state

6. REFERENCES

DHHS, 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities Department of Health and Human Services, U.S. Public Health Service Centers for Disease Control Pub. No. 85-115.

EPA, 1986. Standard Operating Safety Guidelines, Environmental Protection Agency, Emergency Response Team. Office of Emergency and Remedial Response, Washington, D.C..

DOE, 1987. The Environmental Survey Manual, Department of Energy, DOE/EH-0053, Washington, D.C..

7. BIBLIOGRAPHY

DHHS, 1986. Criteria for a Recommended Standard, Department of Health and Human Services, National Institute for Occupational Safety and Health, Washington, DC.

EPA, 1984. Characterization of Hazardous Waste Sites--A Methods Manual, 2, Environmental Protection Agency, 2nd edition, EPA-600/4-84-076.

EPA, 1984a. User's Guide to the Contract Laboratory Program, Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1983. Preparation of Soil Sampling Protocol--Techniques and Strategies, Environmental Protection Agency, EPA-600/4-83/020.

FWS, 1986. Field Operations Manual for Resource Contaminant Assessment, U. S. Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C.

Levine, S. P. and W. F. Martin, 1985. Protecting Personnel at Hazardous Waste Sites, Butterworth Publishers, Steneham, MA.

McElroy, D. L., 1987. Quality Assurance Program, Plan for Area "C" Interim Extraction Project McClellan Air Force Base, Idaho National Engineering Laboratory, EG&G Idaho, ST-ES-09-87.

U.S. Army Toxic and Hazardous Materials Agency, 1987. USATHAMA QA Program, U.S. Army Aberdeen Proving Ground, MD.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX F
DOCUMENTATION GUIDANCE, SAMPLE HANDLING, AND QUALITY ASSURANCE/QUALITY CONTROL STANDARD OPERATING PROCEDURES

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PREFACE

This is Appendix F of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   D.2 Bird Sampling Reference Field Methods
   D.3 Fish Sampling Reference Field Methods
   D.4 Flora Sampling Reference Field Methods
   D.5 Reptiles and Amphibians Sampling Reference Field Methods
   D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM Benthic Macroinvertebrates
BRD Birds
FSH Fish
FL Flora
HPT Herpetiles
MAM Mammals
DEC Decontamination
DOC Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM Field Instrument Measurements
GW Ground Water Sampling
SED Sediment Sampling
SO Soil Sampling
SW Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

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Example					
0	10/2/91	2.1	2-4	2-4c	5
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

U.S. Fish and Wildlife Service
Division of Environmental Contaminants
4401 North Fairfax Drive, Room 330
Arlington, VA 22201

Commentor's Name_____ Phone_____

Address_____City_____State___Zip_____

Section to be Revised_____ Page(s)_____

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ASTM	American Society for Testing and Materials
BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
COC	Chain-of-Custody
DOE	Department of Energy
DOT	Department of Transportation
DQO	Data Quality Objectives
EC	Environmental Contaminant
ECC	Environmental Contaminant Coordinator
EPA	United States Environmental Protection Agency
FWS	United States Fish and Wildlife Service
LCS	Laboratory Control Samples
MDL	Method Detection Limit
NEIC	National Enforcement Investigation Center
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RFM	Reference Field Methods
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act
SOP	Standard Operating Procedures
SRM	Standard Reference Material
USGS	United States Geological Survey
VOC	Volatile Organic Compounds

U.S. FISH AND WILDLIFE SERVICE LANDS
BIOMONITORING OPERATIONS MANUAL

APPENDIX F
DOCUMENTATION GUIDANCE, SAMPLE HANDLING, AND QUALITY ASSURANCE/QUALITY CONTROL STANDARD OPERATING PROCEDURES

1. INTRODUCTION

1.1 Purpose

This Standard Operating Procedure (SOP) identifies requirements for Quality Assurance/Quality Control (QA/QC) and the documentation of field sampling activities. Refuge protection and management activities must be based on an understanding of the state of and man's effect on the environment. This understanding is based upon collected environmental data. As a result, it is imperative that all environmental data collected, generated and used to make decisions are scientifically valid, of known quality, thoroughly documented, and legally defendable.

1.2 Scope

The importance of data quality in environmental sampling effects conducted by the U.S. Fish and Wildlife Service (Service) is emphasized by the requirement to provide a Quality Assurance Project Plan (QAPP) and to identify data and sample collection activities and procedures. Critical elements of a QAPP are presented, along with a developmental process for systematically identifying data quality requirements and producing the QAPP.

The requirements and importance of maintaining sample integrity from a physical and evidence perspective are provided. Information addressing these critical aspects include: documentation requirements for individual samples, site descriptions, sample handling, and sample preparation procedures. In addition, shipping and log book entry requirements are identified, and detailed step-by-step procedures necessary for maintaining sample custody are provided.

1.3 Background

The need for QA/QC and documentation procedures is justified by the following rationales:

- Provides data of known quality for use in decision making
- Enhances and facilitates sample tracking and the interpretation of sampling and analytical data
- Standardizes data entries for input into data management systems for efficient retrieval and data manipulation

- Identifies and establishes the authenticity of data collected for possible remedial measures.

The first parameter addresses the importance of collecting data of a specified and known quality that allows for making sound and appropriate decisions. The second parameter addresses the need to view sampling and analysis results as a function of data quality and data application. Knowledge of the circumstances under which the samples were collected, handled, preserved, transported, and analyzed will play an important role in how data are used and interpreted.

The third parameter addresses the need for uniformity in data gathering and data recording among refuges. A consistent, standardized documentation program is essential for developing an effective and efficient data management system and for comparing data in a complex or region.

The fourth parameter addresses the potential for the adjudication of sampling and analysis results and the associated role that evidentiary proceedings may play in remedial measures. Contaminant monitoring from an enforcement and remedial action perspective may involve information gathering procedures that are more restrictive on personnel, materials, and methods than those procedures previously used for ecological research and/or environmental surveys. As a result, some protocols previously used for collecting, handling, documenting, and shipping samples may fail to meet the demands required for contaminant sampling situations.

For the refuge contaminant monitoring program, record keeping, QA/QC and documenting field activities are essential elements of a thorough investigation. A written record of all field data, samples, observations, and events provide the following:

- Ensures that all essential and required information is consistently acquired and preserved for current use and future reference
- Helps streamline collection procedures
- Ensures timely, correct, and complete analysis for all parameters being requested
- Satisfies quality assurance requirements
- Establishes a chain-of-custody record for samples
- Provides evidence in court proceedings.

Maintaining standardized records enhances the usability of data necessary to conduct and implement refuge management programs. Using standard forms also ensures that the same types of information will be recorded consistently. These records will document and support decisions regarding the existence and abatement of contaminant problems at refuges.

1.4 Information Resources

A number of Federal and state agencies are involved in the development of contaminant sampling methods. These agencies, which include the Environmental Protection Agency (EPA), the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, and state departments of environmental quality should be consulted as required for state-of-the-art assistance.

2. QUALITY ASSURANCE/QUALITY CONTROL

2.1 Introduction

Obtaining adequate environmental data for decision making requires that QA/QC requirements be identified and implemented. QA and QC are defined as follows:

> QA is a set of coordinated actions such as plans, specifications, and policies used to ensure that a monitoring program can be quantifiable and produce data of known quality. QA integrates SOPs, Data Quality Objectives (DQOs), and approved methodology [e.g., Reference Field Methods (RFMs)]. QA starts at the conception of a project or process and extends through to the final product.
>
> QC is the systematic use of procedures to achieve and maintain a specified level of quality for a measurement collecting system. QC is and consists of system checks and measurement processes such as the use of quality assessment samples.

The identity and accumulation of QA/QC requirements and the processes necessary to meet these requirements for all refuge contamination sampling efforts must be presented in a QAPP.

2.2 Quality Assurance Project Plan

The QAPP is a formatted document that aids management, field, and laboratory personnel in planning and executing specific environmental data collection and data generation projects. The QAPP should be written by the individual(s) responsible for the sampling project [e.g., refuge personnel and environmental contaminants (EC) specialist]. It is a valuable document before the project begins (to allow all interested parties an opportunity to review the plan from a QA perspective); during the project (as a guide for QA reviews and audits); and after the project (as a basis for judging whether the projects goals and objectives were obtained). IT MUST BE WRITTEN AND APPROVED BY THE RESPONSIBLE INDIVIDUAL (e.g., REFUGE MANAGER) BEFORE ANY SAMPLING BEGINS. A QAPP helps ensure consistency in data for long-term comparison even when personnel at a refuge changes.

The QAPP does not need to be long, but should be precise and complete in its purpose. A QAPP has sixteen sections that need to be addressed, however for a small sampling project, certain sections can be combined (e.g., 6, 8, and 9).

1. Title Page
2. Table of Contents
3. Project Description
4. Project Organization and Responsibility
5. QA Objectives for Measurement Data
6. Sampling Procedures
7. Sample Custody and Documentation
8. Calibration Procedures and Frequency
9. Analytical Procedures
10. Data Reduction, Validation and Reporting

11. Internal Quality Control Checks
12. Performance and System Audits
13. Preventive Maintenance
14. Routine Procedures Used to Assess Data
15. Corrective Action
16. QA Reports to Management

The Title Page cites the project title, and the name(s) of the individual(s) requesting and/or overseeing the project, including the EC specialist. Signatures and date of signing on the title page denotes project approval.

A Table of Contents is necessary for large sampling projects but is discretionary for small sampling projects.

The Project Description provides a general description of the project: e.g., a map of the location, a list of the study objectives, data usage, experimental design, monitoring parameters, frequency of collection, and anticipated start and completion dates.

The Project Organization lists the personnel involved with the project and their corresponding responsibilities. An organizational chart should be supplied with lines of authority duly noted.

In the QA Objectives for Measurement Data, DQOs (Section 2.3) for Precision, Accuracy, Representativeness, Completeness, Comparability, and Detection Limit are addressed.

- Precision - measures the reproducibility of measurements compared to their average value. Precision is usually stated as the variance, the standard deviation, relative standard deviation, range, or relative range. Precision measures the variability among measurements. The smaller the variability, the greater confidence you have that a given measurement falls close to the average value. Precision is measured by the use of splits or collocated (duplication) samples and field evaluation samples.

- Accuracy - measures the bias in a measurement system. It compares the measured value to a true or standard value. Accuracy can be expressed as percent recovery, which is the measured value divided by the true value (times 100). The smaller the bias is or the closer the recovery is to 100% the more accurate the measurement. Accuracy is measured by the use of standards, spiked samples, and field evaluation samples.

- Representativeness - is a qualitative statement of the degree to which a sample represents the characteristic of the population being measured. Representativeness is controlled by defining sample protocols, SOPs, or RFMs and sticking to them throughout the study.

- Completeness - is the percentage of total measurements made which are judged to be valid measurements. Judgments of validity are based by experts on historical performance records of the methods, calibration data, other internal control checks, and the use for which the data are intended. Lost or contaminated samples or missing data obviously degrade completeness. As a rule of thumb, the completeness should be at least 90 percent.

- Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. Sample data should be comparable with other measurement data for similar samples and sample conditions. This goal is achieved through using standard techniques and SOPs to collect and analyze representative samples and reporting analytical results in appropriate units.

- Detection Limit - The difference between a signal and the mean noise signal of the analytical method at a given confidence level and power. The noise results from random electronic currents in the detector when no sample is being measured.

The Sampling Procedures section describes the details of sampling based on the predetermined understanding of the site and the requirements of the collected data. Decontamination and preparation of sampling containers and sampling equipment must be defined or referenced. The type and frequency of QA for field samples must be identified. It is permissible for sampling protocols, RFMs and/or other specific sampling procedures to be attached to the QAPP.

In the Sample Custody and Documentation section, samples must be identified or tagged and, for legal purposes, a written log of physical sample possession must be maintained. Sample transfer documentation must be addressed. A few of the items to be noted are identity of sampler, date, time, type of containers, and preservation methods (Sections 3, 4, 5, and 6).

Calibration Procedures and Frequency must be duly noted in this section. They may be included by citation of manufacturer's instruction and operation manuals or to established SOPs. Unless written down, these are easily dismissed as unnecessary, but are critical. The frequency of cleaning and calibration should be identified and followed rigorously. Considering the sensitivity of modern analytical methods and the extremely low levels of detection sought for some contaminants, the analysis actually starts with the rigorous cleaning of sample containers and sampling equipment.

The Analytical Procedures section references the SOPs or provides a written description. As mentioned previously, this section and the calibration procedures can be combined with the sampling procedures. Whether separate or combined, all of the sampling and analytical procedures must be documented in detail and/or cited.

The Data Reduction, Validation, and Reporting section should detail for each measurement parameter the calculation methods used, the means used to validate the data during collection and reporting, and the treatment of data outliers when reporting the data. Consistent data reporting is necessary. The criteria used to accept, qualify, or reject data should be documented as well.

The Internal Quality Control Checks section states how data will be validated through a system of internal checks and balances such as duplicate samples, spiked samples, split samples, blanks, and control samples.

The Performance and Systems Audits section addresses inspections that are performed to monitor the ongoing project. These are checks that verify procedures are being followed. An audit may be requested for reasonable cause by any involved party in the data generation administrative, field, or laboratory staff.

The Preventive Maintenance section should list the routine and documented care of field equipment and materials used in the sampling or analyses of samples. This information may be covered by RFMs or be available in manufacturer supplied manuals and procedures.

The Routine Procedures Used to Assess Data section should address the specific procedures (e.g. statistical) used to assess data precision and accuracy.

The Corrective Action section identifies the procedure and methods that will be used and/or actions that will be taken to correct any identified deviation from the plan. It designates the individual to contact if something goes wrong. It includes planned activities and/or procedures that will be implemented in the event that equipment failure, weather conditions, or personnel illnesses should interfere with the project.

The QA Reports to Management section addresses the types and disposition of project reports. These reports include data quality progress and/or final summation reports. Project reports emphasizing QA should include results of audits along with any significant QA problems, and what was done to address them.

The QAPP, along with sampling and analysis protocols and logbooks, act as historical documents denoting the details of the project that may not be noted in the final report. These details are essential for comparison of data collected at different times and/or at different locations. They are also required for defensibility of data in matters of litigation.

2.3 Data Quality Objectives

Basically, the DQO process consists of determining what information is needed, why it is needed, and how it will be acquired and used. Developing DQOs should not place additional requirements on management personnel and the EC specialist, but should be integrated into the documentation of normal thought processes of planning, designing and carrying out environmental data generation projects. DQOs are analogous to the first steps in the "Scientific Method," starting with problem identification and suggesting possible solutions. Scientifically valid approaches (statistically analyzed, and thorough) are then designed and implemented.

DQOs are quantitative and qualitative statements describing the quality of data needed to support a specific environmental decision or action. These descriptors must be considered and identified by decision makers for each sampling effort in order to determine if the data are or will be appropriate for a particular application. Data quality definitions may be specified in the requirements of a federal or state act, regulation, and/or order and require only administrative interpretation for a clear definition.

DQOs as previously identified (Section 2.2) include: Precision, Accuracy, Representativeness, Comparability, Completeness and Detection Limit that are used to evaluate and validate data. Correctly documented, they are the attributes of the data produced that make it suitable for reiterating into the decision making and planning process and provide for defensibility if challenged either in litigation or as to professional credibility.

The development of DQOs and the QAPP can be a time consuming and difficult task. Therefore, a developmental process used by EPA personnel is presented in Attachment 1 along with checklists to guide individuals through the DQO thought process.

2.4 Key Quality Assurance Components

A rigorous program to identify, assess, and assure data quality cannot be developed and implemented if key components of a sampling effort are neglected. Those components include training, preliminary study, audits, documentation, and sampling methods.

2.4.1 Training

Training is an integral part of an effective quality assurance program. It should furnish the essential knowledge needed by all project participants to assure that plans, methods, and procedures are implemented and accomplished as designed. The training program should identify key principles and point out any changes to the plan and/or protocols to project personnel. At the same time it should orient new employees to project methods and procedures. Training should begin before a project is started to allow personnel time to develop and perfect the techniques needed to conduct the study. Training may be formal, or informal, in the classroom, or on the job. A practical way to implement a training program is to integrate it into a preliminary screening.

2.4.2 Preliminary Screening

The purpose of a preliminary screening is to obtain initial data for monitoring design purposes, to test and evaluate the logistics plan, equipment, and sampling and analytical protocols prior to implementation of a full-scale program. It will also provide input into the quality assurance design, and data interpretation approach. Preliminary screenings are recommended for all projects that need initial data to finalize a project's approach. To maximize usefulness, the preliminary screening should employ all available plans and protocols, including the same personnel, equipment, and procedures that will be used for subsequent efforts. After the preliminary screening is complete, the methodologies can be carefully evaluated to determine whether or not changes need to be made before initiating the full-scale monitoring program.

2.4.3 Audits

Audits are an integral part of the QA process and are vital for assuring that program procedures are being implemented.

Audits are performed to document the implementation of the QAPP and/or associated operational protocols. Three specific kinds of audits can be used to determine the status of the measurement system, the adequacy of the data collection systems, the completeness of documentation of data collection activities, and the abilities of the program to meet the mandated data collection and data quality objectives. These three types of audits are Performance Audits, Technical System Audits and Data Quality Audits, respectively (See EPA, 1985 for specific procedures).

- Performance Audits are used to determine objectively whether an analytical measurement system used by a laboratory is operating within established control limits. They are generally

based on samples having known concentrations of the analytes of concern These audits are performed by Patuxent.

- Technical System Audits are qualitative on-site audits that evaluate the technical aspects of the field operation against the requirements of approved protocols and/or QAPP. Audit reports will note any problems, and identify corrective action to be taken to protect the validity of future data.

- Data Quality Audits are performed to verify that data generated are of known and documentable quality. Evaluation of documentation associated with measurement data are the principal means for performing these audits. This is an important part of the validation of data reports. Data quality audits document that methods and SOPs designated in the QAPPs were followed, and that the resulting data set is a functional part of satisfying the established DQOs. The audit results are vital to decisions regarding the legal defensibility of the data should it be challenged in litigation proceedings.

2.4.4 Documentation

Errors can increase and occur in any measurement program through inadequately prepared and reviewed documentation. Documentation procedures must be developed prior to a study. Measures to assess and minimize errors, as described, are not going to be effective without adequate documentation.

It is important that field personnel follow specified, documented procedures. If changes in program execution and design (e.g., sample location selection, number of samples to be collected, sampling intervals, and tools) are required, these changes must be documented with appropriate rationale.

2.4.5 Sampling Methods

The sample collector must select methods that best accommodate specific sampling needs, and that satisfy the stated sampling objectives. Improper use and selection of sampling tools may result in data that are not representative of the environment being sampled. Measurement errors can result from using improper tools. Results based on previous experience or from an equivalency test may be used to evaluate and select the proper tool for a specific sampling objective. Sampling personnel are also responsible for providing the appropriate sample for laboratory analysis. See media specific RFM for guidance.

2.5 Measurement Errors

During the total measurement process errors will be induced from sampling, handling, transportation, preparation of the samples for shipment to the laboratory, preparing the sample for analysis at the laboratory, analysis of the samples at the laboratory, and interpretation and analysis of the data. The magnitude of these errors will depend upon the precision of the particular phase of the measurement process. An objective of the QA program is to assess, report, and minimize the errors from individual measurement phases.

To identify and address errors in the measurement processes, the types and amounts of quality assessment samples to adequately characterize error must be determined. The timing and type of quality assessment samples in the measurement process determines the type of information that should be obtained. The number and type of quality assessment samples is determined by available resources and the degree that the measurement process needs to be characterized. The simplest case for determining quality assessment sample types and numbers is when one sampling method, one sampling crew, and one laboratory are used to analyze samples. A more difficult, and probably more typical, case is when more than one batch of samples are either collected or analyzed by various crews at either various times or by various laboratories.

2.6 Quality Assessment Samples

Quality assessment samples are used to evaluate the quality of the measurement system. These samples are used to assess the quality of the data to assure that it meets the original objectives.

Quality assessment samples include samples from three groups, based upon whether they are double-blind, single-blind, or non-blind to the analytical laboratory. Double-blind samples are samples that cannot be distinguished from routine samples by the analytical laboratory. Single-blind samples are samples that can be distinguished from routine samples but are of unknown concentration. Non-blind samples are samples that have a concentration and origin that are known to the analytical laboratory. Each of these samples are used to assess the quality of the measurement system.

The following outlines how these samples are used in the control of the measurement process. To obtain an unbiased measure of the internal consistency of the samples and their analyses, the individual quality assessment samples must be double-blind and should be labeled as routine samples so that the analyst (and also laboratory management) does not know the relationship between these and field samples. This reduces the chances of conscious or unconscious efforts to improve the apparent consistency of the analyses.

DOUBLE-BLIND SAMPLES

1. Field Evaluation Samples

These samples are of known concentration, subjected to the same manipulations as routine samples and introduced in the field at the earliest stage possible. They can be used to estimate total measurement bias and, if used in duplicate, precision estimates can be made.

2. Low Level Field Evaluation Samples

These samples are essentially the same as field evaluation samples, but they have very low or nonexistent concentrations of the contaminant. They are used for determination of contamination in the sample collection, transport, and analysis processes. They can also be used for determination of the system detection limit.

3. External Laboratory Evaluation Samples

This sample is similar to the field evaluation sample except it is sent directly to the analytical laboratory without undergoing any field manipulations. It can be used to determine laboratory bias and precision if used in duplicate. Spiked samples have been used as external laboratory evaluation samples in past studies for dioxin, pesticides, and organics.

4. Low Level External Laboratory Evaluation Samples

This sample is similar to the low level field evaluation samples except it is sent directly to the analytical laboratory without undergoing any field manipulations. It is used to determine method detection limit, and the presence or absence of laboratory contamination.

5. Field Matrix Spike

This is a routine sample spiked with the contaminant of interest in the field. Because of the inherent problems associated with the spiking and recovery procedure for a media such as soil, a field matrix spike is not recommended for field studies (consult analyst for media specific guidance).

6. Field Duplicate

An additional sample taken near a field sample to determine variability.

7. Field Split

This is a sample that is homogenized and split into two or more samples of theoretically equal concentration at the sampling site. It is used to indicate the within-batch measurement error. Samples are sent to the same laboratory. With relatively homogenous material, this sample will yield the same error component as the field duplicate. This sample can also be used for across-batch variability when sent to different laboratories and sampled by one crew.

SINGLE-BLIND SAMPLES

1. Field Rinsate Blanks

These samples, also called field blanks, decontamination blank and equipment blanks are obtained by running ASTM Type II water [distilled, deionized water (DDI)] over and through the sampling equipment after decontamination to test for any residual contamination.

2. Preparation Rinsate Blank

These samples are obtained by passing ASTM Type II (DDI) water through the sample preparation apparatus after cleaning in order to check for residual contamination.

3. Trip Blank

These samples are most often used when volatile organics are sampled, and consist of actual sample containers filled with ASTM Type II (DDI) water, and are kept with the field samples throughout the

sampling event. They are then packaged for shipment with the field samples and sent with each shipping container to the laboratory. This sample is used to determine the presence or absence of contamination during shipment.

NON-BLIND SAMPLES

These samples [e.g., Laboratory Control Samples (LCS)] are used to assess bias and precision. For convenience, these samples are described in Attachment 2 with the definitions being adapted from the Contract Laboratory Program (CLP) Inorganic Statement of Work #788 (EPA, 1988).

2.6.1 Split Samples

Samples can be split to provide:

- Samples for both parties in a litigation or potential litigation situation
- A measure of the within-sample variability
- Samples for spiking in order to test recovery
- To measure analytical and extraction errors.

The location of the sample splitting determines the components of variance that are measured by the split. A split made at a sample preparation facility to which samples are sent from the field measures error introduced from that point onward. A split made in the field includes errors associated with field handling. A split or series of subsamples made in the laboratory for extraction purposes measures the extraction error and subsequent analytical errors.

2.6.2 Spiked Samples

Spiked samples are prepared by adding a known amount of reference chemical to one of a pair of split samples. Comparing the results of the analysis of a spiked member to that of the non-spiked member of the split measures spike recovery and provides a measure of the analytical bias. Spiked samples are difficult to prepare with some media. Frequently the spike solution is added to the extract of a field sample. This minimizes the problem of mixing, but does not provide a measure of the interaction of the chemicals in a field sample with the spike; neither does it provide an evaluation of the extraction efficiency. A predigest spike, as utilized in the CLP, Attachment 2, would allow a check of the extraction or digestion efficiency. In addition, if the laboratory does the spiking, it would then be a non-blind sample.

2.6.3 Blanks

Blanks provide a measure of various cross-contamination sources, background levels in the reagents, decontamination efficiency, and other potential error that can be introduced from sources other than the sample. For example, a blank introduced at the earliest point in the field can measure input from contaminated dust or air into the sample. A rinsate blank (i.e., decontamination sample) measures any chemical that may have been on the sampling and sample preparation tools after the decontamination process is completed.

2.7 Quality Assessment Sample Design

An effective quality assurance program should ensure that the uncertainty associated with the measurement system should be insignificant when compared to the uncertainty allowed for the population of interest.

It is critical that a quality assurance system provide for quantification of total measurement error. Measurement error involves three major sampling effort phases; i.e., sample collection, sample preparation, and sample analysis. Each of these phases can be divided into smaller components depending on the specific design of the sampling effort.

It is important to realize that if the error associated with the sample collection or preparation phase is large, then the best laboratory quality assurance program may be insignificant. The EC specialist and refuge manager should apply the greatest amount of emphasis to that phase that contributes the largest component of error; this will not be possible if the quality assurance design does not provide for error evaluation of all individual measurement phases.

The diagram in Figure 1 shows a suggested quality assurance design that will allow determination of various components of measurement bias and precision. The quality assessment samples, discussed in the diagram, were defined previously in Section 2.6.

Figure 1 depicts how quality assessment samples of several types can be injected and treated at the sample collection, preparation, and analysis stages. Starting at the left of the diagram, the collection of a field duplicate is shown. At the location selected for the duplicate, two co-located samples are collected. One is designated as the routine sample the other as the field duplicate. During the preparation phase, before the samples are shipped to the laboratory, a routine field sample may be split into two subsamples. The second sample is designated the preparation split. A subsample is also prepared from a field duplicate. These samples are then forwarded to the analytical laboratory for analysis.

Moving to the middle of the diagram, paired field evaluation (audit) samples are shown entering the process at two stages. Field evaluation samples are introduced as early in the collection and packaging process as possible. These samples are then subjected to the same handling and analysis procedures as the other samples. The external laboratory evaluation samples are introduced after the preparation stage in such a way that they cannot be identified as QC samples by the laboratory and thereby serve as double-blind samples. These samples are then subjected to the same analytical procedures as routine field samples.

On the right side of Figure 1, two types of rinsate blanks are shown. The field rinsate blank is used to check for sample-collection equipment contamination, and the preparation rinsate blank is used to check for preparation equipment contamination.

2.8 Number of Quality Assessment Samples

Suggested rules for the number of quality assessment samples are presented in Table 1. This rule of thumb guidance can be and is used for environmental data collection projects (EPA, 1987a and b, 1989; and DOE 1987).

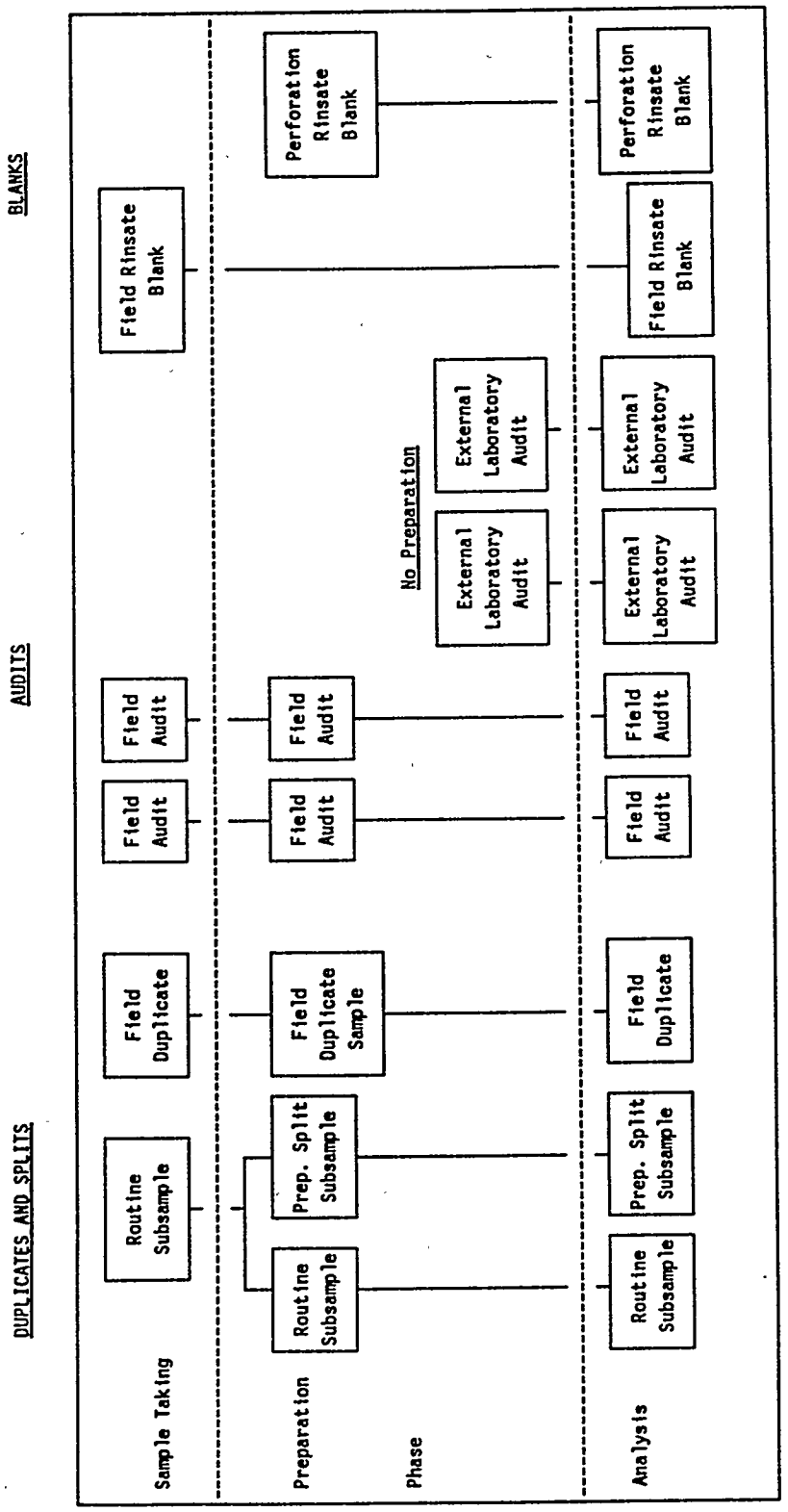

Figure 1. Quality Assessment Samples

These rules of thumb suggestions; however, are not always appropriate and should be treated with caution. A better approach is to determine how each type of quality assessment sample is to be employed and then determine the number for that type based on the use. For example, field duplicates can be used to estimate media variation. Hence, the number of field duplicates to be collected in the sampling effort should be dictated by how precise one wants that estimate of the variance to be.

Some types of quality assessment samples, such as the calibration samples, are used to provide a quality instrument control function. That is, if measurements of these standards differ too much from their reference values, the instrument is declared out of control and will have to be adjusted. Depending on a specific circumstance, it may be necessary to go back and re-analyze all samples between the last in-control reading and the out-of-control reading. The frequency of use of samples of this type can be based on costs of the analyses of these samples versus the costs of re-analyzing field samples in out-of-control situations.

The percentage of the total monitoring effort allocated to QA/QC activities will depend on many factors including the size of the project, the available knowledge concerning sampling and analytical procedures, and the relationship of environmental risk to a pollutant's concentration. If the concentration is near the method detection limit, there will be little room for error in the measurements, and the QA/QC effort may have to be large to assure that measurement errors are kept small. Initially, one should not specify a certain percentage of the project's costs be allocated to QA/QC without considering the above factors. Each project will have its own specific DQOs thereby requiring different approaches and levels of QA/QC.

Table 1. General guidelines for minimum QA samples for field sample programs

Media	Field Collocated or Replicate	Field Blank	Trip Blank	Background Sample	Inter-lab Split-Sample
Aqueous	one in twenty	one in twenty	one per day of sampling VOAs one per shipping container	min. of two per sampling event-media	when required to meet objectives
Soil, sediment	one in twenty	one in twenty	(VOAs) one per shipping container	min. of two per sampling event-media	when required to meet objectives
Air	one in twenty	not available	one per day of sampling (VOAs) one per shipping container	min. of two per sampling event-media	when required to meet objectives

NOTE: This table is provided to serve as general guidance only; quality assessment sample requirements must be developed on a media and site-specific basis. Laboratory blanks and spikes are method specific and are not included.

Sources for statistical considerations that must be used in the process for systematically determining the types and numbers of quality assessment samples are presented in Section 2.9. Service personnel are encouraged to use other QA/QC guidance that is available addressing specific media (e.g., biota). Consult and incorporate Service QA/QC requirements as needed (FWS, 1986).

2.9 Data Quality Objectives Development Process

It is required for the Refuge Contaminant Monitoring Program that DQOs be developed and incorporated into a QAPP. If necessary, the developmental process (Attachment 1) as presented can be used to assist in the development of DQOs. It is encouraged that refuge managers and EC specialists use additional references and documents as required for assistance in DQO development. References that are particularly useful for this purpose include:

A Rationale for the Assessment of Errors in the Sampling of Soils. U.S. EPA. 1989. EPA/X-89/203. Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

Data Quality Objectives for Remedial Response Activities - Development Process. U.S. EPA. 1987. EPA/540/G-87/003. OSWER, Washington, DC.

Data Quality Objectives for Remedial Response Activities - Example Scenario. U.S. EPA. 1987. EPA/540/G-87/004. OSWER, Washington, DC.

Soil Sampling Quality Assurance Users Guide, Second Edition. U.S. EPA. 1989. EPA 600/8/89/046. Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

3. DOCUMENT CONTROL

Document control is a systematic procedure for ensuring that all study documents used are properly identified and accounted for during and when the study is completed. Document control addresses the following:

- Document inventory
- Document accountability
- Permanent project files

Presented in Table 2 are study documents that are commonly used and maintained in a permanent project file. Also identified are those documents that are commonly numbered (serialized) for traceability.

Table 2. Study documents

Document Control Identifiers and Headers	Serialized
Sampling plan	
Quality assurance project plan	Sample tags
Sample catalog	Chain-of-Custody documents
Analytical forms	
Log books	
Field data records and forms	
Shipping forms	
Correspondence	
Photographs, maps, drawings, etc.	
Litigation documents	
Final report	

Because of the importance of proper document control it is advisable to select a specific person (preferably not seasonal) to oversee and coordinate all document control responsibilities. The size and magnitude of the sampling effort will be a factor in the selection of a document coordinator and in the type and numbers of documents required.

A number of documents identified in Table 2 require only the proper identifier and header (e.g., photographs, correspondence). Others, such as project logbooks, chain-of-custody forms, field data forms, and sample identification documents need to be filled out as descriptive and inclusive as possible. Only those documents requiring detailed entries will be discussed in detail.

An identifier can be used to identify project documents, such as sampling plans and quality assurance plans, and used on title pages or covers of project logbooks and field data record files. The approval blocks are not required for logbooks or files but should be used for QAPP plans and sampling/monitoring plans. The header, identified above in the upper right-hand corner, should be

An example of an identifier and document header:

Study ID Code:
Section:
Revision:
Date:
Page:___of___

U.S. Fish and Wildlife Service
Region 7
Anchorage Fish and Wildlife Enhancement

Arctic-Nesting Geese Contaminant Study
General Study Plan

Principal Investigator

_____ _____
Fish and Wildlife Biologist Date
Anchorage Fish and Wildlife Enhancement

Approvals:

_____ _____
Anchorage Fish and Wildlife Enhancement Date

_____ _____
Yukon Delta National Wildlife Refuge Date

_____ _____
Environmental Contaminants Coordinator Date

placed on each page of project documents, e.g., sampling, analysis, and QAPP plans.

Document inventory will provide document accountability to those who will use the data to make decisions concerning management practices and for remedial measures. All documents should be cataloged, categorized, and have a unique study code number that identifies the region, specific refuge or geographic location where the study is carried out. For example, a suggested study code may incorporate a portion of the sample catalog coding requirements as follows:

010-92-R1-14550	010 -	Study number
	92 -	Year program was conducted
	R1 -	Region 1
	14550	Desert NWF[1]

[1] See Attachment 3, Section H for the National Wildlife Refuge organizational codes.

After a study has been completed, all documents generated should be assembled and stored in a permanent project file. Refuge managers or their designees are responsible for ensuring that the collection, assembly, and inventory of all program documents are completed This document file repository should have an index identifying all program documents and a system that identifies the disposition of and location of all original and copied documents. This file is considered accountable; therefore, any documents leaving the repository must be signed out.

3.1 General Documentation Procedures

The following guidance applies to all documents for the study:

- Entries made in logbooks, field records and forms, sample labels and tags, and chain-of-custody documents should be made only with waterproof ink. If lead pencils or other writing instruments are used, note the reason in the logbook.
- Correct errors by drawing a single line through the error and enter the correct information.
- Initial and date all corrections.
- Enter in the logbook the location and disposition of voided documents by recording their serial number (serialized documents) and/or program header and identifier information.
- Place prenumbered (serialized) and voided documents in the program file for accountability.
- Use only bound logbooks (no spiral notebooks).

3.2 Sample Catalog

A sample catalog and the appropriate analytical forms must be filled out before samples can be submitted for analysis. The catalog and analytical forms are filled out by the principal investigator and/or the EC specialist and submitted by the regional Environmental Contaminants Coordinator (ECC). The elements of a sample catalog consist of the following:

- Cover Memorandum: Memorandum explaining the study and requesting analytical assistance.
- Catalog Number: Assigned by the Patuxent Analytical Control Facility.
- Project Title: An informative description of the study.
- Study ID No.: This identifier is assigned by the Division of Environmental Contaminants.
- Objective: Purpose of the study including the intended use of the data.
- Background: Historical information concerning the site, potential contamination and a rationale for why the study should be conducted.

- Instruction: General description identifying how the study is to be conducted and the samples that are to be submitted for analysis.
- Sensitivity and Non-Routine Analysis: Chemical and physical analysis required. Identify analytical methods and any necessary special tests or analyses.
- Analytical Priority: Analytical priority for contaminants.
- Sample Final Disposition: Individual(s) to whom samples are to be returned.
- Data Recipients: Individual(s) that will receive data.
- Charge Account Number: Number for accounting purposes.
- Study Funding Cap: Maximum amount available for conducting the study.
- Principle Contact: Persons responsible for conducting study.
- Chain-of-custody: Identifies if study is operated under chain-of-custody.
- Catalog: Listing of sample number, sample type, and matrix and analysis required.
- Submitted by approval and concurrence: ECC and Supervisors.

Attached to the sample catalog are sample ID numbers, matrix, sample types, and selected biological and physical parameters. See current FWS Sample Catalog requirements before addressing this requirement.

3.3 Analytical Form

An analytical form (Attachment 3) must be filled out and accompany the sample catalog. The analytical form does not include sample ID numbers, but is cross-referenced with the sample catalog by the regional and/or the study ID number. In addition, the geographical area or refuge organizational codes and collection dates are identified.

3.4 Logbooks

Logbooks provide the basis for project reports. Therefore, they must contain only factual sampling/monitoring activity observations. Entries must be made in a bound book, be objective, and free of personal feelings and/or other terminology that might prove inappropriate. All entries should be dated and signed immediately after the entry by the individual making the record. Because logbooks are part of the permanent project file, they should be in the custody of the refuge manager or his/her designee. It should contain and identify pertinent activities and the names of individuals performing audits (Section 2.4.3). It is recommended that all involved personnel sign the logbook for future use in identifying dated entries.

Logbooks must have consecutively numbered pages and display the following identifier and headers on the front cover:

- Project Title
- The name of the logbook (e.g., Field Logbook)
- Name and address of refuge and field station conducting the sampling/monitoring activity
- Name of the Refuge Manager, Sampling Leader, or the appointed designee responsible for data entries
- Catalog Number
- Logbook Number (e.g., 1 of 1, 1 of 2)

All logbooks should be maintained in a secured area when not in use, and placed in the permanent project file upon completion.

3.4.1 Field Logbook

All information pertinent to field activities should be entered in a bound book with consecutively numbered pages. At a minimum, logbook entries must include:

- WHEN (date, time)
- WHERE (county, state, site address, sample location)
- WHO (those present, directly involved)
- HOW (equipment used, or procedures followed)

Additional entries of a why and what nature must also be included. Such entries include:

- Name and address of field contacts (federal, state and local representation present but not directly involved in sampling study).
- Type of media sampled (soil, sediment, biota, etc.). References such as maps or photographs taken or acquired of the sampling site.
- Any field measurements such as pH, soil texture, temperature, egg shell dimension and carcass weight.
- All sample ID numbers, and descriptions of observation and actions.

Because sampling studies vary widely, logbook entries should be as descriptive and precise as possible. Those reading the entries should be able to reconstruct the sampling situation from the recorded information. Language must be objective and factual. If anyone other than the person to

whom the logbook was assigned makes an entry, they must date and sign it. Errors should be corrected with a single line drawn through the error; the correct data filled in, and the correction entry initialed and dated. If warranted, state why the entry was corrected.

It is recommended that logbook entries be as uniform and systematic as possible for comparability in data assessments and data reporting. However, because of the multitude of sampling and data measurement and collection situations that will be addressed by Service personnel, it is not possible to identify and present standardized data entry formats for all sampling situations. Attachment 4 identifies suggested field activity and sampling data logbook entry formats. As this SOP is intended to be a working document, additional and/or updated field logbook formats will be incorporated when appropriate.

A field logbook Contents page may be useful if the study is extensive. Figure 2 shows a suggested Contents page format with the appropriate headings.

FIELD LOGBOOK CONTENTS				
Sampling Location/Matrix	Date Sampled	Sample ID Number(s)	Sample Log Sheet	Page #

Figure 2. Field Logbook Contents page.

As presented below, the contents page headings should be filled out as definitive as possible.

- Sampling location--Indicate location of sampling area by site code and identify matrix if possible (e.g., soil).
- Date sample collected--Indicate date (dd/mmm/yy) of sample collection.
- Sample ID number(s)--Indicate ID (code) number(s) of the physical sample(s) collected (see Section 4).
- Sample log sheet--Include page number of sample log sheet within the Field Logbook where quantitative information and measurements were recorded for a given location or sample ID number(s).

3.5 Sample Labels and Tags

Samples must be identified with a sample label and a sample tag. Both sample labels and sample tags must be attached and accompany samples to the analytical laboratory. The sample label is permanently attached to the sample container and will be disposed of with the sample. The sample tag, attached to the container by string or wire tie, becomes part of the permanent record in the project files when the disposition of the sample is complete. The sample tag should be returned to the originator and/or the custodian of the project files as physical evidence of sample receipt and analysis, and, if required, may later be introduced as evidence in litigation proceedings.

3.5.1 Sample Labels

Use standard I-CHEM or equivalent labels (see Figure 3). Record the following information on each label:

- Refuge (site) identification--Refuge name or refuge organizational code or field station code (see Attachment 3, Section D and H).
- Date--Record the date (dd/mmm/yy) of sample collection (e.g., 27/JUL/92).
- Time--Record the time, based on a 24-hour clock (e.g., 0900, 1450), when the sample material was collected. If the sample was put in its container at a time different than when it was collected, this should be noted in the field logbook and on the sample label.
- Preservative (type/volume)--Indicate the type and volume of preservative(s) added (e.g., 5 mL $HN0_3$) and/or the conditions under which the sample is stored (e.g., 4°C).
- Study ID Code--Record study ID Code No. (see Section 4).
- Analysis--Indicate the analysis that will be performed by the laboratory.
- Sample ID number--Place sample ID number in blank space above "Specially cleaned container".

3.5.2 Sample Tag

The purpose of sample tags is to maintain sample identity and to identify aspects (e.g., hazards) associated with the sample that may require special handling procedures. A suitable sample tag is shown in Figure 4.

Affix a serialized sample tag by wire ties, tape, or other secure methods to each sample container that contains the following information:

- Refuge ID--Record Refuge organizational code (see Attachment 3, Sections D and H).
- Study ID--Record Study ID number (see Section 3).

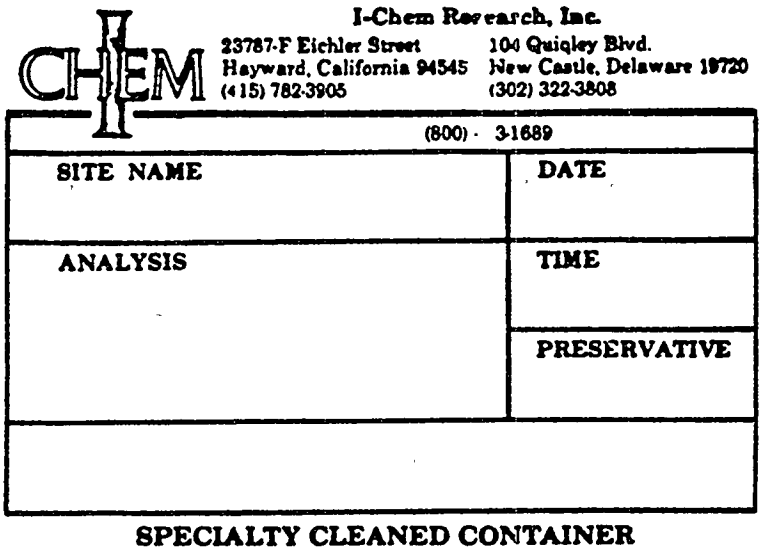

Figure 3. Sample label.

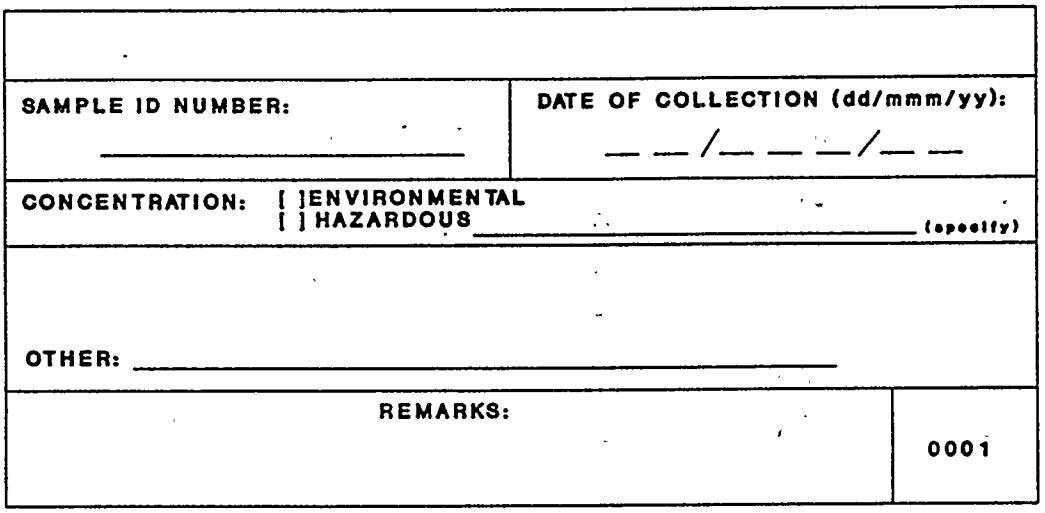

Figure 4. Sample Tag

- Sample ID Code--Record the ID number of the sample.

- Date of collection--Record date (dd/mmm/yy) of sample collection (e.g., 27/JUL/92).

- Concentration--Taking into consideration previous information and knowledge gathered about the sampling site and based on any sample screening (e.g., pH), sampling personnel will indicate, to the best of their knowledge, whether the sample is hazardous.

- Remarks--Record study ID number and any additional information regarding any hazards associated with the sample that would require special handling procedures. Time of collection and sampling location should also be recorded.

3.6 Chain-of-Custody

With increasing frequency, many biologists are involved in contaminant studies which are either potential Law Enforcement cases or may eventually lead to some type of litigation. Due to the sensitivity of these studies, additional precautions are often required to ensure that residue data generated from a sample collection are submittable evidence in a court of law. Any studies involving litigation (e.g., bird die-offs, possible poisoning cases) will require detailed documentation of the handling and transporting of samples. From the initial collection in the field to their final laboratory destination, samples will require a Chain-of-custody (COC) Record to document the integrity of the samples. COC Records perform four functions: (a) they record who has custody of a sample, (b) who takes possession of a sample when it is transferred, (c) substantiate that a sample was constantly under custody between sample collection and laboratory analysis, and (d) acts as an inventory of the samples inside the shipping container.

3.6.1 Sample Custody

According to the EPA National Enforcement Investigation Centers (NEIC) Policies and Procedures (1986), in-situ measurements can be considered and will constitute evidence. A sample collected from a national wildlife refuge for the determination of contaminants can be considered as physical evidence.

A sample is under custody if:

- It is in your possession.
- It is in your view, after being in your possession.
- It was in your possession and you locked it up.
- It is in a designated secure area.

To establish the integrity of samples, it may be necessary to demonstrate that the samples were maintained under custody from the time they were collected in the field to the time they were analyzed in the laboratory.

3.6.2 Chain-Of-Custody Documentation

COC Records will be carbonless and serialized (Figure 5). A number of acceptable COC Records are available for use but must at least contain the following information:

- Date and Time of collection--Record date (dd/mmm/yy) and time of sample collection (e.g., 27/JUL/92 11:00 am).
- Site name--Refuge name or refuge organizational code or field station code (see Attachment 3, Sections D and H).
- Samplers--Whomever initiated the COC Record must sign their name in the space provided.
- Sample ID code--Indicate the ID code number(s) of physical sample(s).
- Analysis--Indicate the analysis that will be performed on the samples.
- Inventory/Description--all samples are clearly described and listed, including the sample ID number. Special attention should be applied to this section as only the samples that are accurately described are considered to be valid for litigation purposes.
- Relinquished by/received by (From:/To:)--Indicate the individual who relinquishes possession of the samples and the individual accepting possession of the samples. Record the date and time of the transfer. Note that the first person to relinquish the samples must be one of the individuals who collected the samples.
- Package received with custody seals intact--When samples arrive at the lab, record the condition of the custody seals.
- Sample labels, sample tags, and chain-of-custody agree--Indicate that all the contents of the package are in order by checking the appropriate space.

3.6.2.1 Chain-of-Custody Record. The COC Record lists all transfers in the possession of samples. This piece of documentary evidence attests that the sample was constantly under custody between sample collection and laboratory analysis.

All sections of the COC Record should be filled in (typed) with specific information pertaining to the sample collection. If samples were collected from different sites or on several dates, multiple COC Records will be necessary. If more than one container is required to ship the samples, a separate COC Record for each container will list the samples actually held in each container. An indication of the total number of containers (i.e. 1 of 3) should be noted on each COC Record. The COC Record should be placed in a clear plastic shipping window and securely attached to the outside of the container with the words "Chain-Of-Custody Record" clearly visible.

The COC Record will be initiated by the sampler, reviewed and signed during any change in custody and QA reviewed and signed by the shipping personnel. A copy of the COC Record will be held in a temporary field file until the original is received at the analytical laboratory. The original COC Record will be shipped with the samples to the laboratory where it will be QA reviewed and

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U. S. FISH AND WILDLIFE SERVICE
DIVISION OF LAW ENFORCEMENT

CHAIN OF CUSTODY RECORD

FILE NO.
INV-

DATE AND TIME OF SEIZURE:	DISTRICT:	EVIDENCE/PROPERTY SEIZED BY:

SOURCE OF EVIDENCE/PROPERTY (person and/or location):	CASE TITLE AND REMARKS:
☐ TAKEN FROM: ☐ RECEIVED FROM: ☐ FOUND AT:	

ITEM NO.	DESCRIPTION OF EVIDENCE/PROPERTY (include Seizure Tag Numbers and any serial numbers):

ITEM NO.				
	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
ITEM NO.				
	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
ITEM NO.				
	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	

☐ ADDITIONAL TRANSFERS ON REVERSE SIDE

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Figure 5. Chain-of-Custody Record.

FILE NO.

INV.

CHAIN OF CUSTODY RECORD (continued)

ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA: ☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	

GPO 888-333

Figure 5. (continued)

signed by the laboratory sample custodian. An indication as to the completeness of the COC Record ["Y" (Yes) or "N" (No)] will be entered. The original copy of the COC Record will remain with the samples. Following the destruction and/or final disposition of the samples as stated on the catalog, the original COC Record will be sent to the location of the permanent project file and filed with the other project documents. This process is illustrated in Figure 6.

Figure 7 is an example of a COC Record starting with the initial transfer of bird carcasses from the field sampling personnel to the contaminant specialist, then to the National Wildlife Health Research Lab (NWHR) for diagnostic necropsy and pathology work up. Note that each carcass has been assigned a unique sample ID number which should be attached to both the outside of the bag or container as well as the carcass itself. All sample ID tags should be written in waterproof ink. Each sample is listed as a separate item under the description section and should be listed sequentially under the item number column. When using a commercial courier, the airbill number should be clearly documented under the "DELIVERED TO" notation. A copy of the COC Record and the airbill should be retained by the submitter.

In the second example (Figure 8), the same hypothetical samples are shipped from NWHR to two different laboratories for analysis. The sample description now includes the case number ID assigned by NWHR, as well as the original sample ID tag number. This is required to cross-reference the two numbering schemes and allow proper identification of the samples. Note that the three red-winged blackbird GI tracts have been pooled into one sample, while two distinct tissues (2 Samples) have been remove from one eagle carcass. This leaves a total of five samples from the original six carcasses collected. Since the catalog is to be split between the two labs, a photocopy of the COC Record should be forwarded to each lab with the samples. A solid line should be placed directly under the last entry in the Description section with a notation indicating the total number of samples. Any changes to the typed information should be initialed by the individual making the changes.

3.6.2.2 Custody Seals/Evidence Tape The NEIC procedure requires that a custody seal (Figure 9) be affixed (taped) to the shipping container in such a manner that the cooler cannot be opened without breaking the seal. To accomplish this, secure the container with filament tape and attach a custody seal across the top and bottom of the container. Evidence tape that wraps completely around the container can also be used. As an added precaution, the sender signs and dates the custody seal or evidence tape. These precautions ensure that the integrity of the samples can be demonstrated.

While being shipped from the field to the laboratory, samples pass through the hands of postal clerks, couriers, and others who are unidentified. The samples, however, are effectively in a secure area and therefore, signatures from these intermediary "couriers" are not required.

3.6.2.3 Disposal of Samples or Other Physical Evidence. Before any sample or other physical evidence is disposed of, the refuge manager or his/her designee must be contacted in writing by the person requesting permission to dispose of the samples. The samples will not be disposed of until a written form of communication is returned to the appropriate person, specifically giving permission to dispose of the samples. After the samples are disposed of the sample tags will be sent to the refuge for inclusion in the project file.

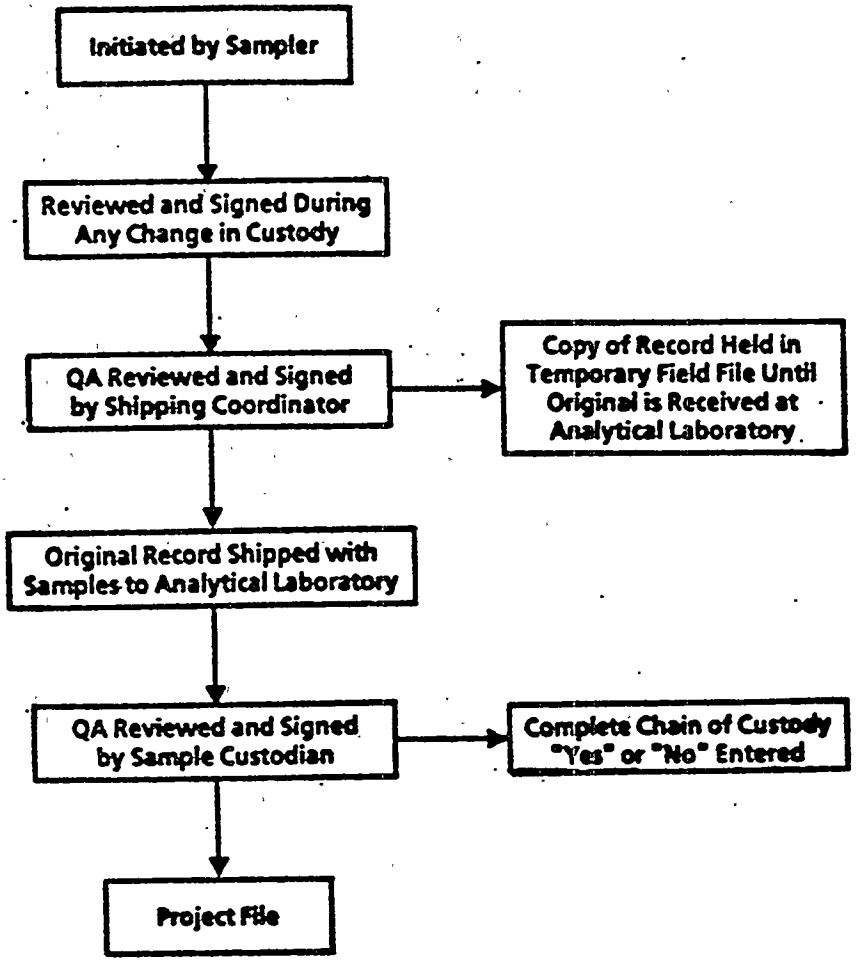

Figure 6. Documentation process for Chain-of-Custody Record.

DEPARTMENT OF THE INTERIOR
U. S. FISH AND WILDLIFE SERVICE
DIVISION OF LAW ENFORCEMENT

CHAIN OF CUSTODY RECORD

FILE NO.
INV.

DATE AND TIME OF SEIZURE:	DISTRICT:	EVIDENCE/PROPERTY SEIZED BY:
4/15/89 11:00 a.m.		John Law, Special Agent

SOURCE OF EVIDENCE/PROPERTY (person and/or location):
☐ TAKEN FROM:
☐ RECEIVED FROM:
☐ FOUND AT:
Dismal Gulch Country Club
Rt 245 Box-T
Carbamate County
East Famphur, GA

CASE TITLE AND REMARKS:
Dismal Gulch Bird Die-off
Suspected pesticide poisoning

ITEM NO.	DESCRIPTION OF EVIDENCE/PROPERTY (include Seizure Tag Numbers and any serial numbers):
1	Canada Goose (Adult) -- Carcass Tag# DG01
2	Canada Goose (Juvenile) -- Carcass Tag# DG02
3	Red-Winged Blackbird (Adult) -- Carcass Tag# DG03
4	Red-Winged Blackbird (Adult) -- Carcass Tag# DG04
5	Red-Winged Blackbird (Adult) -- Carcass Tag# DG05
6	Bald Eagle (Immature) -- Carcass Tag# DG06
	Total (6) samples

ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA:
1-6	SA John Law FWS-LE		4/15/89	☐ U.S. MAIL ☒ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	
	Ernie C. Specialist FWS-ES		4/15/89	
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA:
1-6	Ernie C. Specialist FWS-ES		4/16/89	☐ U.S. MAIL ☐ IN PERSON ☒ OTHER: Airborne Express
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	airbill# 602298034
	Dr. Nancy Thomas FWS-NWHR		4/17/89	
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA:
				☐ U.S. MAIL ☐ IN PERSON ☐ OTHER:
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	

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☐ ADDITIONAL TRANSFERS ON REVERSE SIDE

Figure 7. Chain-of-Custody Record Example 1.

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
DIVISION OF LAW ENFORCEMENT

CHAIN OF CUSTODY RECORD

FILE NO.
INV.

DATE AND TIME OF SEIZURE:	DISTRICT:	EVIDENCE/PROPERTY SEIZED BY:
4/15/89 11:00 a.m.		John Law, Special Agent

SOURCE OF EVIDENCE/PROPERTY (person and/or location):
☐ TAKEN FROM: Dismal Gulch Country Club
☐ RECEIVED FROM: Rt 245 Box T
☐ FOUND AT: Carbamate County
East Famphur, GA

CASE TITLE AND REMARKS:
Dismal Gulch Bird Die-off
Suspected pesticide poisoning

ITEM NO.	DESCRIPTION OF EVIDENCE/PROPERTY (include Seizure Tag Numbers and any serial numbers):
	NWHR Case #
1	8403-001 Canada Goose -- G.I. Tract (1) Tag# DG01
2	8403-002 Canada Goose -- Stomach content (1) Tag# DG02
3	8403-003 Red-Winged Blackbird -- Pooled G.I. Tract (3) Tag# DG03
	8403-004 DG04
	8403-005 DG05
4	8403-006 Bald Eagle -- Upper G.I. Tract and crop content (1) Tag# DG06
5	8403-007 Bald Eagle -- Liver (1) Tag# DG06
	Total (5) Samples

ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA:
1-4	Dr. Nancy Thomas FWS-NWHR		5/1/89	☐ U.S. MAIL ☐ IN PERSON
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	☒ OTHER: Airborne Express
	Dr. Greg Smith FWS-PWRC		5/2/89 airb	11# 603578124
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA:
5	Dr. Nancy Thomas FWS-NWHR		5/1/89	☐ U.S. MAIL ☐ IN PERSON
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	☒ OTHER: Airborne Express
	Edward Hinderberger Environmental Trace Substances Research Center		5/3/89 airb	11# 603729413
ITEM NO.	FROM: (PRINT NAME, AGENCY)	RELEASE SIGNATURE:	RELEASE DATE	DELIVERED VIA:
				☐ U.S. MAIL ☐ IN PERSON
	TO: (PRINT NAME, AGENCY)	RECEIPT SIGNATURE:	RECEIPT DATE	☐ OTHER:

☐ ADDITIONAL TRANSFERS ON REVERSE SIDE

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Figure 8. Chain-of-Custody Record Example 2.

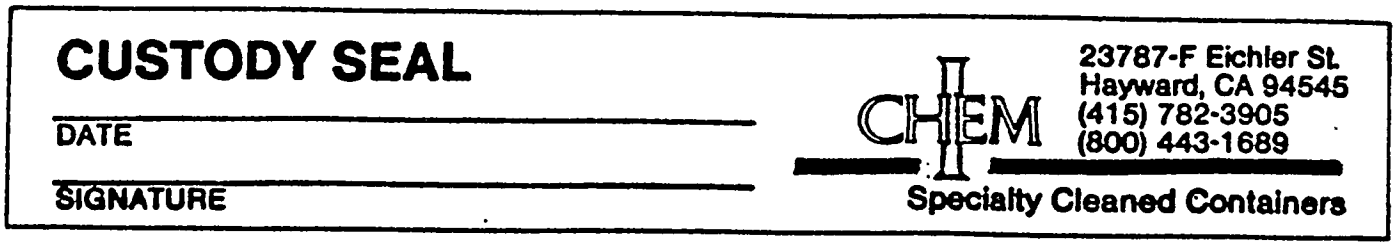


Figure 9. Custody Seal

4. SAMPLE IDENTIFICATION CODE

A unique sample identification code must be assigned to each physical sample. The requirements of the sample code are a) the code be unique and distinguish the sample from other similar samples, and b) the code be traceable throughout the sampling, analytical, and data reporting process. The sample code number also serves to reference each sample that is collected from a designated site under a General Study Plan or QAPP. The sample ID code used must be identified in the project's QAPP Plan and in the General Study Plan. Cross referencing and identifying samples collected for a specific sampling study can be accomplished by the study code number identified in Section 3. Once the sample ID code is assigned it must be identifiable in the data entry and data retrieval process. To meet these two requirements the sample ID number will contain the following information as part of an eight character code:

Character(s)	Define	Code
1 and 2	Matrix/Sample type	ALPHA (see Attachment 3, Section Q)
3, 4, 5, 6 and 7	Site Specific Identification Code	ALPHA or Numeric

The refuge organizational designation on the sample tag will identify the region in which the sample originated and/or was submitted for analysis. The purpose of the matrix code is to identify the sample type (e.g., soil, bird, water).

The site specific identification code serves to identify sampling location, (e.g., well sites, nests, stream sites). The site specific code must be identified in the General Study Plan as to what each character signifies.

The site specific identification code can also be used to identify quality control samples that are submitted for analysis, e.g., rinsates, splits, and/or duplicates.

In summary, a sample ID code such as SE101409 may indicate the following:

- Sediment sample
- Collected from Pond Number 10, Sampling Site 14, at a water depth of 9 ft

5. SAMPLE HANDLING

5.1 Container Types

It is recommended that sample containers be obtained from a commercial source that provides clean containers. The cleaning procedures used should be EPA approved if possible. Container sources are listed in Attachment 6.

Personnel can clean their own containers if cost effective. See Decontamination Guidance RFM and/or FWS (1986) for procedures. The recommended containers and sample volumes are identified in Tables 3, 4, and 5 by media and analytical requirements.

When collecting samples where the outside of the container could get wet or muddy it is advisable to attach the ID label to the container prior to sample collection. The sample labels should not be filled out unless at the sampling site.

5.2 Sample Size

Sample sizes are specified in Tables 3, 4, and 5 as a function of the desired analytical parameter(s). Fill sample containers to approximately 80% capacity to allow for outage (except those samples specifying "no headspace" or "minimal headspace").

5.3 Sample Preservation

Use the preservation requirements specified in Tables 3, 4, and 5 to retard chemical and/or biological changes that may occur after sample collection. If a delay between sample collection and analyses is expected, some samples (e.g., soil and sediment) may be frozen (see FWS, 1986 for guidance).

5.4 Sample Holding Times

Sample holding times as used by EPA (1983) and DOE (1987), are listed in Tables 3, 4, and 5 by analytical parameter(s).

Table 3. Sample container, preservation, and holding time requirements--aqueous samples

Analytical Parameter(s)	I-Chem Container Type/No.[a]	Container Size[b]	Recommended Sample Size[b]	Preservation	Recommended Holding Time	Comments
Inorganics						
Metals (except mercury)	HDPE (C) 313-0500 or 319-1000	500 mL	500 mL	HNO_3 to ph<2	6 months[b] 180 days[c]	For Ag analysis. Protect from light.
Mercury	HDPE (C) 313-0500 or 319-0500	500 mL	500 mL	HNO^3 to pH<2	28 days[b]	—
Hexavalent chromium	HDPE (C) 313-0500 or 319-0500	500 mL	500 mL	4°C	24 hours[b]	
Anions--NO_3^-, PO^{4-3}, F-,Cl-, SO^{4-2},Br-	HDPE (B) 313-0500 or 319-1000	500 mL	500 mL	4°C	48 hours[b] 28 days[b]	—
Cyanide--total	HDPE (B or C) 313-1000 or 319-1000	1000 mL	1000 mL	10 N NaOH to pH>12, 4°C	14 days[b,c] (24 hours[b] if sulfides are present)	Protect from light. Test for oxidizing agent and sulfides prior to preservation with NaOH
Sulfide	HDPE (B or C) 313-0250 or 319-0250	250 mL	250 mL acetate per 250 mL, 4°C	0.5 mL 2N Zn	28 days[b]	—
Cations--K^+,Na^+, Ca+2, Mg^{+2}	HDPE (C) 313-0500 or 319-0500	500 mL	500 mL	HNO_3 to pH<2	6 months[b]	May be determined on same sample as metals.
Dissolved oxygen	HDPE or glass	500 mL	500 mL	None	None--perform in field	—
Organics						
Total organic carbon	Borosilicate Glass (B) 349-0125	125 mL	125 mL	H_2SO_4 or HCl to pH<2, 4°C	28 days[b]	No headspace.
Oil and grease	Glass, wide mouth 341-950 or 321-1000	1000 mL	1000 mL	H_2SO_4 to pH<2, 4°C	28 days	—

Table 3. (Continued)

Analytical Parameter(s)	I-Chem Container Type/No.[a]	Container Size[b]	Recommended Sample Size[b]	Preservation	Recommended Holding Time	Comments
Organics (cont.)						
Volatile organics (VOAs)	Borosilicate vial with Teflon-silicone septa (B) S336-0040	40 mL	4 vials (160 mL total)	4°C, when Cl is present 0.008% Na_2SO_3	14 days[b] 10 days[c]	No headspace. Protect from light.
Semivolatile organics (extractable and pesticides/PCBs)	Glass jar, Teflon-lined cap, amber (A) 349-1000 or 345-2360	3 x 1 L or 2 x 2360 mL	3 L	4°C, when Cl is present 0.008% Na_2SO_3	Extract– 7 days[c] 5 days[c] Analyze– 40 days[e,f]	Protect from light.
Ammonia	HDPE(B or C) 313-0500 or 319-0500	500 mL	500 mL	H_2SO_4 to pH<2, 4°C	28 days[b]	
Hydrazine	HDPE (C)	500 mL	500 mL	HCl to pH<2	14 days	Minimal headspace.
Miscellaneous						
Total Dissolved Solids	HDPE(B or C) 313-0250 or 319-0250	250 mL	250 mL	4°C	48 hours[b]	–
Total Suspended Solids	HDPE(B or C)	250 mL	250 mL	4°C	7 days[b]	
Biochemical Oxygen Demand (BOD)	HDPE (B)	1000 mL	1000 mL	4°C	48 hours[b] No headspace.	Protect from light.
pH	HDPE or glass			none	none-perform field	Must be measured within 2 hrs, if not taken in situ.
Conductivity	HDPE or glass	100 mL	100 mL	none	none-perform in field	–

Table 3. (Continued)

Analytical Parameter(s)	I-Chem Container Type/No.[a]	Container Size[b]	Recommended Sample Size[b]	Preservation	Recommended Holding Time	Comments
Pesticides/PCBs	Glass, amber Teflon-lined cap (A) 349-1000 or 345-2360	3 x 1 L or 2 x 2360 mL	3L	4°C	extract--7 days[b] 5 days[c] analyze 40 days[e,f]	Protect from light.
Total Organic Halogens	Borosilicate Glass (A)349-0250	250 mL	250 mL	0.25 mL 0.1 N Na_2SO_3	28 days	No headspace. Protect from light.

a. HDPE--High Density Polyethylene Bottles
(A)--I-Chem Cleaning Protocol A
(B)--I-Chem Cleaning Protocol B
(C)--I-Chem Cleaning Protocol C.

b. Maximum holding time per Federal Register, Vol. 59, No. 209, Oct. 26, 1984, pp. 43260-43261. Samples should be analyzed as soon as possible after collection. Maximum times are the total time samples may be held after collection and before analysis and still be considered valid.

c. Holding time allowable per CLP Inorganic SOW 787. Samples must be analyzed within the time indicated from the validated time of sample receipt.

d. Holding time allowable per DOE Environmental Survey Organic Chemists Meeting, December 1987.

e. Holding time allowable per CLP Organic SOW 10/86 (Rev 7/87). Samples must be extracted and/or analyzed within the time indicated from the validated time of sample receipt.

f. Holding time allowable per Federal Register after extraction until analysis.

Table 4. Sample container, preservation, and holding time requirements--soil sediment samples

Analytical Parameter(s)	I-Chem Container Type/No.[a]	Container Size[b]	Recommended Sample Size[b]	Preservation	Recommended Holding Time	Comments
Inorganics						
Metals	HDPE (C) wide mouth 311-0250	250 mL	100 g	4°C	6 months[b] 180 days[c]	—
Mercury	HDPE (C) wide mouth 211-0250	250 mL	100 g	4°C	28 days[b] 28 days[c]	—
Cyanide	HDPE,wide mouth, (B or C) 311-0250	250 mL	100 g	4°C	14 days[b,c]	—
Organics						
Volatile organics	Glass jar, with Teflon-faced cap, (B) wide mouth 3241-0120 or 320-0125	125 mL	100 g	4°C	14 days[c] 10 days[c]	Minimize headspace.
Priority pollutants	Borosilicate vial with Teflon-Silicone Septa (b) 5336-0040	40 mL	3 vials 120 mL total	4°C	10 days from receipt	—
Semivolatile organics (Extractables pesticides/PCBs)	Glass with Teflon-lined cap, wide mouth (A) 341-0250 or 320-0250	250 mL	100 g	4°C	Extract--7 days[b] 5 days[d] Analyze 40 days[d,e]	—

a. HDPE--High Density Polyethylene Bottles
(A)--I-Chem Cleaning Protocol A
(B)--I-Chem Cleaning Protocol B
(C)--I-Chem Cleaning Protocol C
b. See FWS 1986 for specific requirements.
c. For specific species, refer to FWS 1986.
d. Require separate vials for each.
e. Use chemically pure ACS grade 37% formaldehyde.
(Note: Formaldehyde may be considered a hazardous waste depending on concentration at the time of disposal.)

Table 5. Sample container, preservation, and holding time requirements--biota samples

Analytical Parameter(s)	Container Type[a]	Sample Size Fauna	Flora	Preservation[a]	Holding Time	Comments
Inorganics						
Metals	Food quality plastic bag/ acid cleaned jar	50 g	50 g	Refrigerate/ freeze	6 months	See Table 3 "Aqueous Samples" for liquid biota samples; Follow specific inorganics requirements
Organics						
Volatile organics	Double wrap in aluminum foil and place in plastic bag	50 g	50 g	Refrigerate/ freeze	7 to 10 days from receipt	See Table 3 "Aqueous Samples" for liquid biota samples and "Soil/Sediment" for solid biota sample; follow specific volatile requirements.
Semivolatile organics (Extractables and Pesticides/PCBs)	Double wrap in aluminum foil and place in plastic bag	50 g	50 g	Refrigerate/ freeze	Extract 5 to 10 days analyze 30 days from receipt	Same comment as but follow specific volatile organics requirements.
Blood samples (organocholorine/ metal)[b]	Septum vial	3-10 mL		Add 1 part formaldehyde to 20 parts blood (0.05 mL formaldehyde to 1 mL blood) Refrigerate[c]	---	---
Necropsy	Food quality plastic bag/ acid cleaned jar	---	---	Refrigerate	---	---

a. For specific species, refer to FWS 1986.
b. Require separate vials for each.
c. Use chemically pure ACS grade 37% formaldehyde.

(Note: Formaldehyde may be considered a hazardous waste depending on concentration at the time of disposal.)

6. TRANSPORTATION/SHIPMENT OF SAMPLES

All sample shipments must be made in compliance with the U.S. Department of Transportation (DOT) and the EPA regulations governing shipment of hazardous materials and substances as required. In addition, all samples that may be used as evidence must be transported so that their integrity, including the physical integrity of the samples (Section 5) and their authenticity as real evidence (Section 3.6) is preserved.

After collection and before packaging and shipping, each sample must undergo an identification and classification process to identify the proper shipping method (see DOT, 1983). A review of the Field Logbook must be conducted by the sampling personnel. Specifically, any recorded field measurements (e.g., radioactivity, pH, organic vapors), and other relevant information concerning the material within the sample container must be reviewed.

Samples of substances listed in the Hazardous Materials [49 Code of Federal Regulations (CFR) 172.101] must be identified, packaged, marked, labeled, documented, and transported according to the regulations listed for that material (see DOT 1983). A letter of understanding between the EPA and the DOT states that preservatives in water samples are exempt, provided that the reagents do not exceed the concentrations specified in Table 6.

However, when the chemical composition of the sample is unknown, an appropriate transportation category should be selected in accordance with 49 CFR 172.402(h). This code pertains to the shipment of packages containing samples that fall within the following:

> If doubt exists as to the class or labeling requirements of a material that is to be transported for laboratory analysis, the material may be labeled according to the shipper's tentative class assignment based upon:

- Defining criteria (i.e., definitions of the hazard classes).
- The hazard precedence prescribed in 49 CFR 173.2 as shown in Table 7.
- The shipper's knowledge of the material.

Table 6. Concentration of hazardous materials used as preservatives in water samples that are exempt from DOT hazardous materials regulations

1. HCl in water solutions at concentrations of 0.4% by weight or less.
2. $HgCl_2$ in water solutions at concentrations of 0.004% by weight or less.
3. $HN0_3$ in water solutions at concentrations of 0.15% by weight or less.
4. H_2S0_4 in water solutions at concentrations of 0.35% by weight or less.
5. NaOH in water solutions at concentrations of 0.08% by weight or less.
6. H_3P0_4 in water solutions at concentrations yielding a pH range between 4 and 2.

(From Letter of Understanding between EPA and DOT, 11 April 1979).

Table 7. DOT priority ranking of hazardous materials

Radioactive Material
Poison A
Flammable Gas
Nonflammable Gas
Flammable Liquid
Oxidizer
Flammable Solid
Corrosive Material (Liquid)
Poison B
Corrosive Material (Solid)
Irritating Materials
Combustible Liquid (in containers exceeding 110-gal capacity)
ORM-B
ORM-A
Combustible Liquid (in containers having capacities of 110-gal or less)
ORM-E

In most instances, samples of hazardous material will, by definition, fall into one or more of five classes: (a) radioactive, (b) flammable liquid, (c) oxidizer, (d) flammable solid, and (e) corrosive.

6.1 Procedure for Packaging, Marking, and Documenting Transport of Samples

Attachment 5 describes acceptable procedures for shipping the following types of material for analysis: (a) samples containing nonhazardous material samples, (b) samples containing nonradioactive hazardous material, (c) samples containing limited quantities of radioactive material, and (d) samples containing radioactive material not exempted as "limited quantity" and not exceeding DOT A_2 limits.

Similarly classed materials (chemically compatible) may be packed in the same shipping container, yet care must be taken to prevent mixed or consolidated packaging of noncompatible hazardous material.

7. GLOSSARY

Background Level	Amount of pollutants present in an ambient matrix due to natural sources.
Batch	Group of samples which are collected, shipped, and analyzed under similar conditions.
Pollutant	Any introduced substance that limits a resource use for a specific purpose.
Semivolatiles	A group of organic compounds consisting of base/neutrals, acids, and pesticides that are identified in and analyzed by Method 625 in 40 CFR Part 136.
Volatile	Solids or liquids which are relatively unstable at standard temperature and pressure and undergo spontaneous phase change to a gaseous state.

8. REFERENCES

DOE, 1987. United States Department of Energy, DOE Environmental Survey Manual, Vol. 1-4, "Field Sampling Protocols and Guidance," DOE/EH-0053 U.S. DOE Office of Environmental Audit and Compliance, Washington, D.C.

DOT, 1983. United States Department of Transportation, Requirements for Transportation of Radioactive Materials. Part II, Vol. 48, No. 48, 49 CFR Parts 171-178.

EPA, 1983. United States Environmental Protection Agency, Characterization of Hazardous Waste Sites--A Method Manual; Volume II, Available Sampling Methods. USEPA Environmental Monitoring Systems Laboratory, P.O. Box 15027, Las Vegas, NV 89193, EPA-600/4-83-040.

EPA,1985. United States Environmental Protection Agency. Standard Operating Procedures for Conducting Sampling and Sample Bank Audits. EPA 600/ 4-85-003 EMSL-LV, Las Vegas, NV 89193.

EPA, 1986a. United States Environmental Protection Agency, National Enforcement Investigations Center (NEIC) Policies and Procedure. NEIC, Denver, Colorado, EPA-330/9-78-001-R (revised May 1986).

EPA, 1986b. Code of Federal Regulations, Environment Protection Agency - Title 40, Part 50.

EPA, 1986c. United States Environmental Protection Agency, Soil Sampling Quality Assurance User's Guide--Second Edition, EPA 600/8-89/046, 1989. EMSL-LV. Las Vegas, NV 89193.

EPA, 1987a. United States Environmental Protection Agency. Data Quality Objectives for Remedial Response Activities: Development Process. EPA/540/G-87/003. March, 1987. U.S. Environmental Protection Agency, Washington, D.C..

EPA, 1987b. United States Environmental Protection Agency. Data Quality Objectives for Remedial Response Activities: Example Scenario. EPA/540/G-87/004. March 1987. U.S. Environmental Protection Agency, Washington, D.C..

EPA, 1988. United States Environmental Protection Agency. Contract Laboratory Program-Statement of Work for Inorganic Analysis, Multi-Media Multi-Concentrations. SOW No. 788.

EPA, 1989. United States Environmental Protection Agency. A Rationale for the Assessment of Errors in the Sampling of Soils for Inorganic Contaminants. EPA/X-89/203 EMSL-LV, Las Vegas, NV 89193. In review.

FWS, 1986. United States Fish and Wildlife Services, Field Operations Manual for Resource Contaminant Assessment Resource Contaminant Assessment Division, U.S. Department of Interior, Washington D.C..

ATTACHMENT 1

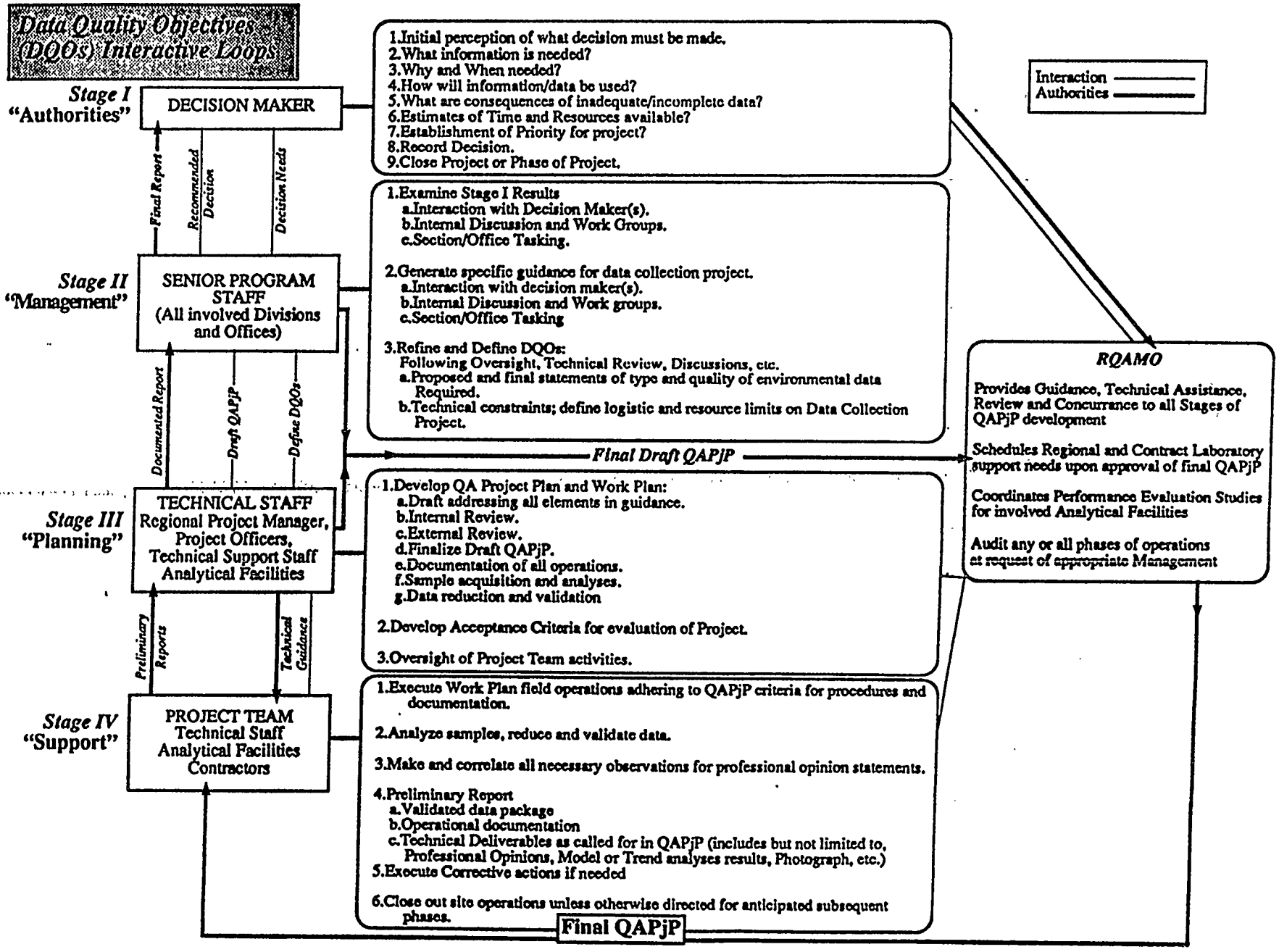
DATA QUALITY OBJECTIVE AND QUALITY ASSURANCE PROJECT PLAN DEVELOPMENTAL PROCESS

Appendix F
Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control
Standard Operating Procedures

ATTACHMENT 1

Contents

1. Diagram of DQOs Interactive Loops 1-3
2. DQOs Checklist for Decision Makers 1-4
3. DQOs Checklist for Senior Program Staff 1-5
4. DQOs Checklist for Technical Staff 1-6
5. DQOs Checklist for Project Team 1-7
6. Example of Quality Assurance Plan 1-8


Data Quality Objectives (DQOs) Interactive Loops
Stage I
"Authorities"
DECISION MAKER
1.Initial perception of what decision must be made.
2.What information is needed?
3.Why and When needed?
4.How will information/data be used?
5.What are consequences of inadequate/incomplete data?
6.Estimates of Time and Resources available?
7.Establishment of Priority for project?
8.Record Decision.
9.Close Project or Phase of Project.
Interaction
Authorities
Final Report
Recommended Decision
Decision Needs
Stage II
"Management"
SENIOR PROGRAM STAFF
(All involved Divisions and Offices)
1.Examine Stage I Results
a.Interaction with Decision Maker(s).
b.Internal Discussion and Work Groups.
c.Section/Office Tasking.
2.Generate specific guidance for data collection project.
a.Interaction with decision maker(s).
b.Internal Discussion and Work groups.
c.Section/Office Tasking
3.Refine and Define DQOs:
Following Oversight, Technical Review, Discussions, etc.
a.Proposed and final statements of type and quality of environmental data Required.
b.Technical constraints; define logistic and resource limits on Data Collection Project.
Documented Report
Draft QAPjP
Define DQOs
Final Draft QAPjP
RQAMO
Provides Guidance, Technical Assistance, Review and Concurrance to all Stages of QAPjP development
Schedules Regional and Contract Laboratory support needs upon approval of final QAPjP
Coordinates Performance Evaluation Studies for involved Analytical Facilities
Audit any or all phases of operations at request of appropriate Management
Stage III
"Planning"
TECHNICAL STAFF
Regional Project Manager,
Project Officers,
Technical Support Staff
Analytical Facilities
1.Develop QA Project Plan and Work Plan:
a.Draft addressing all elements in guidance.
b.Internal Review.
c.External Review.
d.Finalize Draft QAPjP.
e.Documentation of all operations.
f.Sample acquisition and analyses.
g.Data reduction and validation
2.Develop Acceptance Criteria for evaluation of Project.
3.Oversight of Project Team activities.
Preliminary Reports
Technical Guidance
Stage IV
"Support"
PROJECT TEAM
Technical Staff
Analytical Facilities
Contractors
1.Execute Work Plan field operations adhering to QAPjP criteria for procedures and documentation.
2.Analyze samples, reduce and validate data.
3.Make and correlate all necessary observations for professional opinion statements.
4.Preliminary Report
a.Validated data package
b.Operational documentation
c.Technical Deliverables as called for in QAPjP (includes but not limited to, Professional Opinions, Model or Trend analyses results, Photograph, etc.)
5.Execute Corrective actions if needed
6.Close out site operations unless otherwise directed for anticipated subsequent phases.
Final QAPjP

DATA QUALITY OBJECTIVES DEVELOPMENT CHECKLIST

FOR STAGE I (DECISION MAKERS)

"AUTHORITIES"

1. Initial Perception of what decision must be made. Complete? ☐

   Comment: _____

2. What information is needed? Complete? ☐

   Comment: _____

3. Why and when needed? Complete? ☐

   Comment: _____

4. How will information/data be used? Complete? ☐

   Comment: _____

5. What are the consequences of inadequate/incomplete data? Complete? ☐

   Comment: _____

6. Estimates of time and resources available. Complete? ☐

   Comment: _____

7. Estimates of priority for project. Complete? ☐

   Comment: _____

8. Record decision. Complete? ☐

   Comment: _____

9. Close project or phase of project. Complete? ☐

   Comment: _____

DATA QUALITY OBJECTIVES DEVELOPMENT CHECKLIST

FOR STAGE II (SENIOR PROGRAM STAFF)

"MANAGEMENT"

1. Examine Stage I results. Complete? ☐

   a. Interaction with Decision Maker(s). ☐

   b. Internal discussion and work groups. ☐

   c. Section/office tasking. ☐

   Comment: _____

2. Generate specific guidance for data collection project. Complete? ☐

   a. Interaction with Decision Maker(s). ☐

   b. Internal discussion and work groups. ☐

   c. Section/office tasking. ☐

   Comment: _____

3. Define and Refine DQOs. Complete? ☐

   a. Proposed and final statement of type and quality of environmental data required. ☐

   b. Technical constraints; define logistic and resource limits on Data Collection Project. ☐

   Comment: _____

DATA QUALITY OBJECTIVES DEVELOPMENT CHECKLIST

FOR STAGE III (TECHNICAL STAFF)

"PLANNING"

1. Develop QA Project Plan and Work Plan: Complete? ☐

   a. Draft addressing all elements in guidance. ☐

   b. Internal Review. ☐

   c. External Review. ☐

   d. Finalize QAPP. ☐

   e. Documentation of all operations. ☐

   f. Sample acquisition and analyses. ☐

   Comment: _____

2. Develop acceptance criteria for evaluation of project. Complete? ☐

   Comment: _____

3. Oversight of Project Team activities. Complete? ☐

   Comment: _____

DATA QUALITY OBJECTIVES DEVELOPMENT CHECKLIST

FOR STAGE IV (PROJECT TEAM)

"SUPPORT"

1. Execute Work Plan field operations adhering to QAPP criteria for procedures and documentation. Complete? ☐

   Comment: _____

2. Analyze samples, reduce and validate data. Complete? ☐

   Comment: _____

3. Make and correlate all necessary observations for professional opinion statements. Complete? ☐

   Comment: _____

4. Preliminary Report. Complete? ☐

   a. Validated data package. ☐

   b. Operational documentation. ☐

   c. Technical deliverables as called for in QAPP (includes, but not limited to, professional opinions, model or trend analyses results, photographs, etc.). ☐

   Comment: _____

5. Execute corrective actions if needed. Complete? ☐

   Comment: _____

6. Close out site operations unless otherwise directed for anticipated subsequent phases. Complete? ☐

   Comment: _____

EXAMPLE FORMAT AND CRITICAL ELEMENTS

OF QUALITY ASSURANCE PLAN

PROJECT NAME: _____

PROJECT CODE: _____

ADDRESS: _____

_____

RESPONSIBLE ORGANIZATION: _____

_____

APPROVALS:

Project Officer: _____ Date:_____

QA Officer:_____ Date:_____

ESD Peer Review: _____ Date:_____

Regional Sample Control Center: _____ Date:_____

Supervisor: _____ Date:_____

I. PROJECT ORGANIZATION AND RESPONSIBILITY

The following is a list of key project personnel and their responsibilities:

Organization Manager:_____
Project Officer:_____
QA Officer:_____
Field Operations:_____
Laboratory Operations:_____
Data Quality Review:_____
System/Performance Audit:_____

II. PROJECT CODES AND SAMPLE NUMBERS

Project No.:_____ Account No.:_____
Laboratory Designated:_____ EPA:_____ CLP:_____ Private:_____
Sample Numbers Assigned: from_____ to _____

III. PROJECT DESCRIPTION

1. Objective and Scope:_____

2. Schedule and Tasks of Milestones:

Tasks/Subtasks	Dates

3. Data Usage:_____

4. Monitoring network/sample collection design and rationale:_____

5. Sample Handling:

# of samples	Sample Matrix	Collection Frequency	Analytical Parameter	Type of Sample Container	Sample Preservation	Holding Time	Analytical Detection Limit	Quality Control Samples

IV. DATA QUALITY OBJECTIVES

1. Precision and accuracy protocols/limits:_____

_____

2. Data Representativeness:_____

_____

3. Data Comparability:_____

_____

4. Data Completeness:_____

_____

V. SAMPLING PROCEDURES (including QC checks):_____

_____

VI. SAMPLE CUSTODY PROCEDURES:_____

_____

VII. CALIBRATION PROCEDURES AND PREVENTATIVE MAINTENANCE:_____

_____

_____

VIII. **ANALYTICAL METHODS (including QC checks):**

IX. **DOCUMENTATION, DATA REDUCTION, AND REPORTING**

1. Documentation:

2. Data Reduction and Reporting:

X. **DATA ASSESSMENT:**

XI. **PERFORMANCE/SYSTEM AUDITS:**

XII. **CORRECTIVE ACTION:**

XIII. **REPORTS:**

XIV. INSTRUMENT CALIBRATION AND TEST LOG

Instrument Name and Model #:_____

Serial Number:_____

Date of calibration and/or test (dd/mmm/yy)	Time of calibration and/or test	Methods and types of standards used for calibration and/or test	Calibration and/or test performed by (Signature)	Calibration results

ATTACHMENT 2

QUALITY ASSESSMENT SAMPLES IN THE CONTRACT LABORATORY PROGRAM

Appendix F
Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control
Standard Operating Procedures

NON-BLIND SAMPLES

1. Laboratory Control Sample (LCS) - A well-characterized sample whose analyte concentrations are known to the laboratory, is used for internal laboratory control. This sample is also called a quality control audit sample.

2. Pre-digest Spike Sample - A routine sample in which a known quantity of analyte is added to an aliquot of the sample. It is used to determine bias from the digestion and analysis of components.

3. Post-digest Spike Sample - A routine sample in which a known quantity of analyte is added to an aliquot after the digestion process is completed. It is used to determine bias from the analytical or detection phase. When used in combination with a pre-digest spike sample, the bias from the digestion phase may be determined by difference.

4. Analytical Laboratory Duplicate (ALD) - This sample is a subsample of a routine sample which is analyzed by the same method. It is used to determine method precision, but because it is a non-blind sample, or known to the analyst, it can only be used by the analyst as an internal control tool and not as an unbiased estimate of analytical precision.

5. Initial Calibration Verification (ICV) and Continuing Calibration Verification (CCV) Solutions - These are prepared solutions containing known concentrations of analytes that originated from a different source as the calibration standards. They are used as an independent check of the instrument calibration accuracy. The CCV samples are normally run in an ordered fashion after a specified number of routine samples.

6. Initial Calibration Blank (ICB) and Continuing Calibration Blank (CCB) Solution - These are blank samples run at the same frequency as the ICV and CCV, and they are used to check for instrument baseline drift.

7. CRDL Standard for ICP and AA - This is a solution standard at a concentration of two times the CRDL, or two times the IDL, whichever is greater. It is used during each run in place of a formal instrumental detection limit determination to assure the instrument is running properly.

8. Linear Range Verification Check Standard - This standard is a solution of known analyte at concentrations within the upper limit of the linear range. Above this range, the samples must be diluted.

9. ICP Interference Check Sample - This sample contains two parts. Part A contains the potential interfering analytes, and Part B contains both the potential interfering analytes and the target analytes. Parts A and B are analyzed separately to determine the potential for interferences.

ATTACHMENT 3

INSTRUCTIONS FOR COMPLETING ANALYTICAL FORMS

PATUXENT WILDLIFE RESEARCH CENTER
U. S. FISH AND WILDLIFE SERVICE

Appendix F
Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control
Standard Operating Procedures

ATTACHMENT 3

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INSTRUCTION MANUAL FOR COMPLETING ANALYTICAL FORMS

PATUXENT WILDLIFE RESEARCH CENTER
U. S. FISH AND WILDLIFE SERVICE

The following pages present instructions for completing analytical forms for submitting materials for chemical residue analyses. A complete catalog of the samples, with all relevant information about the samples, must also be submitted in addition to the analytical form.

The instruction pages are organized alphabetically from A through Q, and each page corresponds to an information block on the analytical form that the submitter should complete. The forms can be completed by either typing or printing neatly.

Instruction pages should be kept in a notebook which permits substitution of individual pages as revisions are made. Each page is dated in the lower right corner.

ANALYTICAL FORM

PATUXENT WILDLIFE RESEARCH CENTER

This form must be included with a catalog of samples.

FOR LABORATORY USE

CN

DSC

AL C SRL

(A) SUBMITTER (last name, first initial)

(B) REGION (1-7, R&D=8, WO=9)

(C) REGIONAL REQUEST NO. (samples from EC Coordinators only)

(D) FIELD STATION CODE

(E) DATE MO DAY YR

(F) YEAR COLLECTED

(G) STATE COLLECTED (00 if > 1 state)

(H) GEOGRAPHIC AREA OR REFUGE ORGANIZATION CODE

WORK ELEMENT/UNIT (FWS research samples)

LAB USE ONLY

(I) COST CODE

(J) PURPOSE

(K) NO. OF CONTAINERS SHIPPED

(L) FINAL DISPOSAL OF SAMPLES

COMMENTS: _____

COMPLETE LEFT HALF OF REVERSE SIDE FOR ANALYSES

Analytical Codes:

For Laboratory Use Only

	(M) Analysis Type	(N) Sample Type	(O) Species		(P) Number	(Q) Matrix	R	C	AL	DA/DPO	DRS	SC
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

Use additional analytical code sheets if necessary.

A. SUBMITTER (alpha)

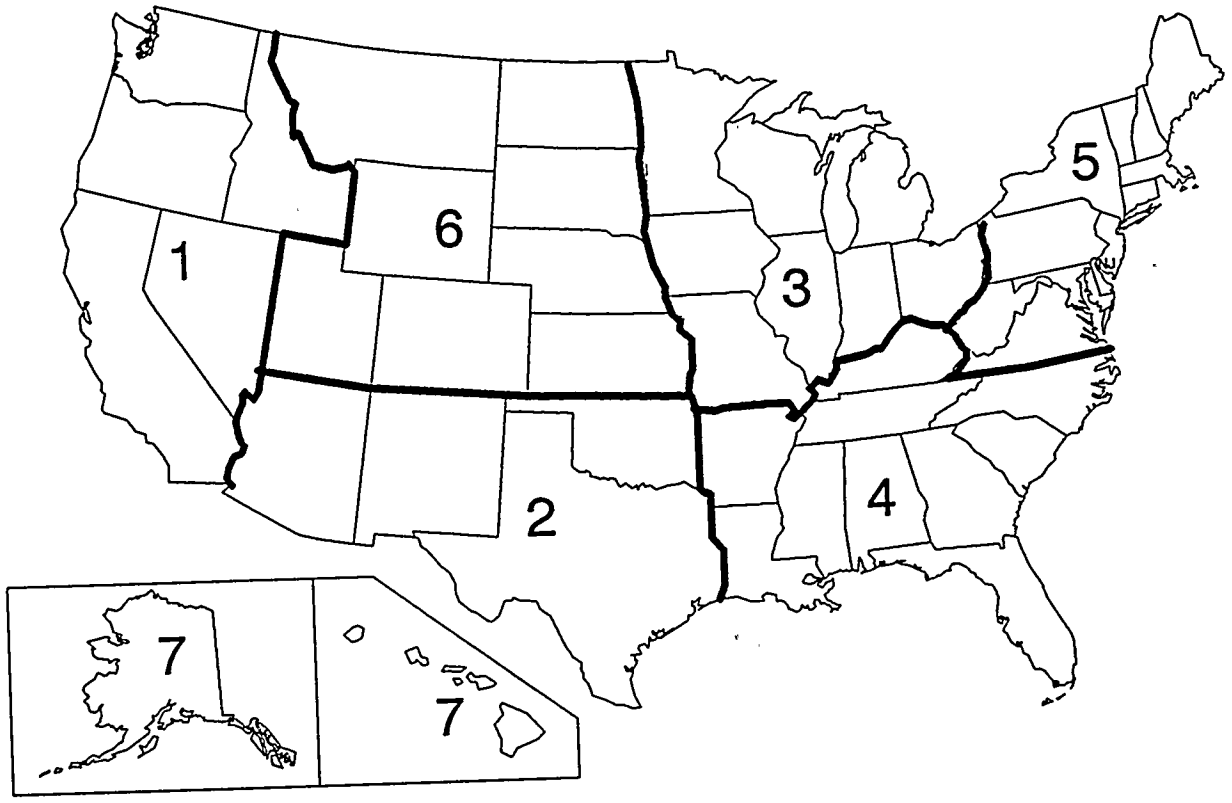
Up to nine characters for the last name, and one block for the first initial of the person who completes the catalog.

B. REGION (numeric)

FWS regions 1 through 7 (see regional map), Region 8 is Research (R&D), and Region 9 is the Washington office.

C. REGIONAL REQUEST NUMBER (alpha and/or numeric)

A unique code which is assigned to the catalog by the Regional Coordinator -- Environmental Contaminants. This can consist of any string of numbers and/or letters that the Regional Coordinator selects. For Research samples, this will be assigned at the laboratory.



Jurisdictional Map of the U.S. Fish and Wildlife Service

D. FIELD STATION CODES (alpha)

1. FWS Research Laboratories
   PWRC -- Patuxent Wildlife Research Center
   NFCR -- National Fisheries Contaminant Research Center
   GLFC -- Great Lakes Fisheries Research Center
   NPWR -- Northern Prairie Wildlife Research Center
   NWHC -- National Wildlife Health Center
   NEC -- National Ecology Center
   AFWC -- Alaskan Fisheries and Wildlife Research Center
   NFRS -- Seattle National Fishery Research Center
   NWRC -- National Wetlands Research Center
   NFRG -- National Fisheries Research Center -- Gainesville
   NFLT -- National Fisheries Center -- Leetown
   NFLC -- National Fisheries Research Center -- LaCrosse

2. Ecological Services Field Stations

   Enter the 3-digit number following the FWS in your dialcom electronic mailbox code.

E. DATE SUBMITTED

MONTH/DAY/YEAR

F. YEAR COLLECTED (numeric)

The calendar year in which the samples are collected. Enter the last year if the sample collection spans more than one year.

G. STATE COLLECTED (alpha)

Use postal code 2-letter abbreviation. If samples are collected in more than one state enter 00.

STATE	CODE	STATE	CODE
Alabama	AL	New Mexico	NM
Alaska	AK	New York	NY
Arizona	AZ	N. Carolina	NC
Arkansas	AR	North Dakota	ND
California	CA	Ohio	OH
Colorado	CO	Oklahoma	OK
Connecticut	CT	Oregon	OR
Delaware	DE	Pennsylvania	PA
Florida	FL	Rhode Island	RI
Georgia	GA	South Carolina	SC
Hawaii	HI	South Dakota	SD
Idaho	ID	Tennessee	TN
Illinois	IL	Texas	TX
Indiana	IN	Utah	UT

Iowa	IA	Vermont	VT
Kansas	KS	Virginia	VA
Kentucky	KY	Washington	WA
Louisiana	LA	West Virginia	WV
Maine	ME	Wisconsin	WI
Maryland	MD	Wyoming	WY
Massachusetts	MA		
Michigan	MI	District of Columbia	DC
Minnesota	MN	Guam	GM
Mississippi	MS	Puerto Rico	PR
Missouri	MO	Virgin Islands	VI
Montana	MT		
Nebraska	NE		
Nevada	NV		
N. Hampshire	NH		
New Jersey	NJ		

H. GEOGRAPHIC AREA OR NATIONAL WILDLIFE REFUGE (alpha/numeric)

If samples were collected in an area or refuge not on the list (OTHER) enter zeros. If samples were collected in more than one area or refuge enter Z's. Describe location in comments.

1. GEOGRAPHIC AREA CODES (alpha)

AKCST -- Alaskan Coast
AKINT -- Alaska, Interior
AKNSL -- Alaska, North Slope
CHBAY -- Chesapeake Bay Estuarine Areas
FLCST -- Florida Coast (Atlantic and Gulf)
GRLKS -- Great Lakes
LOMIS -- Lower Mississippi River
NECST -- Northeastern U.S. Coast
PACNW -- Pacific Northwest Coast
PRPOT -- Prairie Potholes
SECST -- Southeastern U.S. Coast
SFBAY -- San Francisco Bay
SJVAL -- San Joaquin Valley, CA
TULBS -- Tulare Lake Basin, CA
TXGUL -- Texas Gulf Coast
UPMIS -- Upper Mississippi River
ZZZZZ -- More than one area
OOOOO -- Other

2. NATIONAL WILDLIFE REFUGE ORGANIZATIONAL CODES (numeric)

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Agassiz NWR	MN	32510
Alamosa NWR	CO	65510
Alaska Maritime NWR	AK	74500
Alaska Peninsula NWR	AK	74510
Alligator River NWR	NC	41630
Amagansett NWR	NY	52562
Anaho Island NWR	NV	14591
Anahuac NWR	TX	21520
Ankeny NWR	OR	13591
Antioch Dunes NWR	CA	11646
Appert Lake NWR	ND	62511
Aransas	TX	21530
Arapaho NWR	CO	65520
Arctic NWR	AK	75600
Ardoch NWR	ND	62525
Arrowwood NWR	ND	62510
Ash Meadows NWR	NV	14554
Attwater Prairie Chicken NWR	TX	21560
Audubon NWR	ND	62540
Back Bay NWR	VA	51310
Baker Island NWR	TT	12511
Bamforth NWR	WY	65521
Bandon Marsh NWR	OR	13500
Banks Lake NWR	GA	41591
Baskett Slough NWR	OR	13592
Bear Butte NWR	SD	645

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Bear Lake NWR	ID	14613
Bear River Migra Bird Refuge	UT	65530
Bear Valley NWR	OR	11666
Becharof NWR	AK	74515
Benton Lake NWR	MT	61510
Big Boggy NWR	TX	21542
Big Lake NWR	AR	43515
Big Stone NWR	MN	32640
Bitter Creek NWR	CA	10000
Bitter Lake NWR	NM	22510
Black Coulee NWR	MT	61521
Blackbeard Island NWR	GA	41626
Blackwater NWR	MD	51530
Block Island NWR	RI	53541
Blowing Wind Cave NWR	AL	43661
Blue Ridge NWR	CA	116
Bogue Chitto NWR	LA	43616
Bombay Hook NWR	DE	51550
Bon Secour NWR	AL	43630
Bone Hill NWR	ND	62632
Bosque Del Apache NWR	NM	22520
Bowdoin NWR	MT	61580
Brazoria NWR	TX	21540
Breton NWR	LA	43556
Browns Park NWR	CO	65550
Brumba NWR	ND	62582
Buck Island NWR	TT	41524

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Buenos Aires NWR	AZ	22530
Buffalo Lake NWR	TX	21570
Buffalo Lake NWR	ND	62662
Butte Sink NWR	CA	11624
Cabeza Prieta NWR	AZ	22571
Cabo Rojo NWR	TT	41521
Cache River NWR	AR	40000
Caloosahatchee NWR	FL	40000
Camas NWR	ID	14611
Camp Lake NWR	ND	62543
Canfield Lake NWR	ND	62513
Cape Meares NWR	OR	13593
Cape Romain NWR	SC	42510
Carolina Sandhills NWR	SC	42520
Castle Rock NWR	CA	11647
Catahoula NWR	LA	43525
Cedar Island NWR	NC	42531
Cedar Keys NWR	FL	41511
Cedar Point NWR	OH	31541
Charles M. Russell NWR	MT	61520
Chase Lake NWR	ND	62514
Chassahowitzka NWR	FL	41510
Chautauqua NWR	IL	33650
Chickasaw NWR	TN	40000
Chincoteague NWR	VA	51570
Choctaw NWR	AL	53535
Cibola NWR	AZ	22540

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Clarence Cannon NWR	MO	33640
Clear Lake NWR	CA	11661
Coachella Valley NWR	CA	10000
Cold Springs NWR	OR	13581
Columbia NWR	WA	12510
Columbian Whitetailed Deer NWR	WA	13554
Colusa NWR	CA	11621
Conboy Lake NWR	WA	13522
Connecticut Coastal NWR	CT	53546
Conscience Point NWR	NY	52564
Copalis NWR	WA	135
Cottonwood NWR	ND	62623
Crae Orchard NWR	IL	33610
Creedman Coulee NWR	MT	61582
Crescent Lake NWR	NE	64510
Crocodile Lake NWR	FL	41580
Cross Creeks NWR	TN	42515
Cross Island NWR	ME	53335
Crystal River NWR	FL	41516
Culebra NWR	TT	41522
Currituck NWR	NC	41631
D'Arbonne NWR	LA	43545
Dakota Lake NWR	ND	62633
Deer Flat NWR	ID	14560
Delevan NWR	CA	11622
Delta NWR	LA	43555
Des Lacs NWR	ND	62570

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Deseched NWR	TT	41523
Desert NWR	NV	14550
Desoto NWR	IA	33510
Dungeness NWR	WA	13331
Eastern Neck NWR	MD	51590
Eastern Shore of Virginia NWR	VA	51650
Edwin B. Forsythe NWR	NJ	52510
Egmont Key NWR	FL	415
Elizabeth A. Morton NWR	NY	52566
Ellicott Slough NWR	CA	44643
Erie NWR	PA	41420
Eufaula NWR	AL	43560
Fallon NWR	NV	14592
Farallon NWR	CA	11641
Featherstone NWR	VA	51612
Felsenthal NWR	AR	43570
Fern Cave NWR	AL	40000
Fish Springs NWR	UT	65540
Fisherman Island NWR	VA	51511
Flattery Rocks NWR	WA	135
Flint Hills NWR	KS	64520
Florence Lake NWR	ND	61516
Fox River NWR	WI	32524
Franklin Island NWR	ME	53532
FT. Niobrara NWR	NE	64520
Gravel Island NWR	WI	32521
Grays Lake NWR	ID	14612

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Great Dismal Swamp NWR	VA	51520
Great Meadows NWR	MA	53310
Great Swamp NWR	NJ	51530
Great White Heron NWR	FL	40000
Green Bay NWR	WI	32522
Green Cay NWR	TT	41525
Grulla NWR	NM	21591
Hagerman NWR	TX	21580
Hailstone NWR	MT	61521
Hakalau Forest NWR	HI	125
Half-Way Lake NWR	ND	62517
Halfbreed Lake NWR	MT	61522
Hanalei NWR	HI	12522
Harbor Island NWR	MI	61512
Harris Neck NWR	GA	41617
Hart Mt. Natl Antelope Range	OR	14622
Hatchie NWR	TN	51525
Havasu NWR	AZ	22510
Hawaiian Islands NWR	HI	12521
Hewitt Lake	MT	61522
Hiddenwood NWR	ND	61544
Hillside NWR	MS	43580
Hobart Lake NWR	ND	61513
Hobe Sound NWR	FL	41561
Holla Bend NWR	AR	43590
Hopper Mt. NWR	CA	11611
Horicon NWR	WI	32520

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Howland Island NWR	TT	12512
Huleia NWR	HI	12523
Humboldt Bay NWR	CA	11590
Huron NWR	MI	31511
Hutchinson Lake NWR	ND	61519
Hutton Lake NWR	WY	65522
Imperial NWR	AZ	22560
Innoko NWR	AK	75605
Iroquois NWR	NY	52540
Island Bay NWR	FL	40000
Izembek NWR	AK	74520
J. Clark Salyer NWR	ND	61620
J. N. "Ding Darling" NWR	FL	41540
James C. Campbell NWR	HI	12527
Jarvis Island NWR	TT	12513
Johnson Lake NWR	ND	61520
Johnston Island NWR	TT	12515
Kakahaia NWR	HI	12525
Kanuti NWR	AK	75610
Karl E. Mundt NWR	SD	64532
Kealia Pond NWR	HI	12500
Kelleys Slough NWR	ND	61583
Kenai NWR	AK	74525
Kern NWR	CA	11610
Kesterson NWR	CA	11651
Key West NWR	FL	41500
Kilauea Point NWR	HI	12529

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Kirtland Warbler WMA	MI	31500
Kirwin NWR	KS	64610
Klamath Forest NWR	OR	11662
Kodiak NWR	AK	74530
Kofa NWR	AZ	22570
Kootenai NWR	ID	14580
Koykuk NWR	AK	75615
Lacassine NWR	LA	42610
Lacreek NWR	SD	64540
Laguna Atascosa NWR	TX	21550
Lake Alice NWR	ND	62584
Lake Andes NWR	SD	64550
Lake Elsie NWR	ND	62661
Lake George NWR	ND	62521
Lake Ilo NWR	ND	62571
Lake Isom NWR	TN	42576
Lake Mason NWR	MT	61523
Lake Nettie NWR	ND	62546
Lake Otis NWR	ND	62547
Lake Thibadeau NWR	MT	61584
Lake Woodruff NWR	FL	41550
Lake Zahl NWR	ND	52561
Lames Lake NWR	ND	62586
Lamesteer NWR	MT	61531
Las Vegas NWR	NM	22580
Lee Metcalf NWR	MT	61560
Lewis and Clark NWR	OR	13555

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Little Goose Lake NWR	ND	62587
Little Peno Oreille NWR	WA	13561
Long Lake NWR	ND	62622
Lords Lake NWR	ND	62624
Lost Lake NWR	ND	62548
Lostwood NWR	ND	62572
Lower Hatchee NWR	TN	
Lower Klamath NWR	CA	11663
Lower Rio Grange Valley	TX	21552
Lower Suwannee NWR	FL	41515
Loxahachee NWR	FL	41560
Mackay Island NWR	VA	51520
Malheur NWR	OR	13570
Maple River NWR	ND	62634
Mark Twain NWR	MO	33620
Martin NWR	MD	51540
Marumsco NWR	VA	51611
Mason Neck NWR	VA	51610
Massasoit NWR	MA	53557
Mathews Brake NWR	MS	53583
Matlacha Pass NWR	FL	41500
Mattamuskeet NWR	NC	42530
Maxwell NWR	NM	22581
McFaddin NWR	TX	21525
McKay Creek NWR	OR	13582
McLean NWR	ND	62549
McNary NWR	WA	13520

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Medicine Lake NWR	MT	61530
Merced NWR	CA	11652
Meredosia NWR	IL	33652
Merritt Island NWR	FL	41570
Michigan Islands NWR	MI	31522
Mille Lacs NWR	MN	32541
Mingo NWR	MO	33540
Minidoka NWR	ID	14614
Minnesota Valley NWR	MN	32590
Missisquoi NWR	VT	53520
Mississippi River NWR	IL	32570
Mississippi Sandhill Crane NWR	MS	43615
Moapa Valley NWR	NV	14553
Modoc NWR	CA	11690
Monomoy NWR	MA	53551
Monte Vista NWR	CO	63560
Montezuma NWR	NY	52550
Moody NWR	TX	215
Moosehorn NWR	ME	53530
Morgan Brake NWR	MS	43582
Muleshoe NWR	TX	21590
Muscatuck NWR	IN	31530
Nansemond NWR	VA	51581
Nantucket NWR	MA	53555
National Bison Range NWR	MT	61540
National Elk Refuge	WY	61530
National Key Deer Refuge	FL	41580

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Necedah NWR	WI	32530
Nine-Pipe NWR	MT	61541
Ninigret NWR	RI	53540
Nisqually NWR	WA	13530
Nomans Land Island NWR	MA	53556
North Flatte NWR	NE	64311
Nowitna NWR	AK	75620
Noxubee NWR	MS	43620
Okefenokee NWR	GA	41590
Optima NWR	OK	21620
Oregon Islands NWR	OR	13594
Ottawa NWR	OH	31540
Ouray NWR	UT	65570
Overflow NWR	AR	43571
Oxbow NWR	MA	53512
Oyster Bay NWR	NY	52563
Pablo NWR	MT	61542
Pahranagat NWR	NV	14551
Panther Swamp NWR	MS	43581
Parker River NWR	MA	53550
Passage Key NWR	FL	40000
Pathfinder NWR	WY	65523
Patuxent Wildlife NWR	MD	83800
Pea Island NWR	NC	42540
Pearl Harbor NWR	HI	12524
Pee Dee NWR	NC	42550
Pelican Island NWR	FL	41572

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Petit Manan NWR	ME	53533
Piedmont NWR	GA	41580
Pierce NWR	WA	10000
Pinckney Island NWR	SC	41629
Pine Island NWR	FL	415
Pinellas NWR	FL	40000
Pixley NWR	CA	11612
Pleasant Lake NWR	ND	62588
Plum Tree Island NWR	VA	51512
Pocasse NWR	SD	64571
Pond Island NWR	ME	53552
Presquile NWR	VA	51620
Pretty Rock NWR	ND	62585
Prime Hood NWR	DE	51560
Protection Island NWR	WA	135
Pungo NWR	NC	42560
Quillayute Needles NWR	WA	
Quivira NWR	KS	64620
Rabb Lake NWR	ND	62625
Rachel Carson NWR	ME	53553
Red Rock Lakes NWR	MT	61570
Reelfoot NWR	TN	42575
Rice Lake NWR	MN	32540
Ridgefield NWR	WA	13551
Rock Lake NWR	ND	62589
Rose Atoll NWR	TT	12514
Rose Lake NWR	ND	62590

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Ruby Lake NWR	NV	14370
Sabine NWR	LA	43640
Sachuest Point NWR	RI	53543
Sacramento NWR	CA	11620
Saddle Mountain NWR	WA	13511
Salt Meadow NWR	CT	53544
Salt Plains NWR	OK	21630
Salton Sea NWR	CA	11630
San Andres NWR	NM	22521
San Bernard NWR	TX	21541
San Bernardino NWR	AZ	22523
San Francisco Bay NWR	CA	11640
San Juan Islands NWR	WA	13532
San Luis NWR	CA	11650
San Pablo Bay NWR	CA	11644
Sand Lake NWR	SD	64570
Sandy Point NWR	TT	41526
Santa Ana NWR	TX	21551
Santee NWR	SC	42570
Savannah NWR	GA	41625
Schooi Section Lake NWR	ND	62626
Seal Beach NWR	CA	11613
Seal Island NWR	ME	53534
Seatuck NWR	NY	52565
Seedskadee NWR	WY	65580
Selawik NWR	AK	75625
Seney NWR	MI	31510

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Sequoyah NWR	OK	21640
Sevilleta NWR	NM	22522
Sheldon NWR	NV	14621
Shell Keys NWR	LA	435
Shell Lake NWR	ND	62574
Sherburne NWR	MN	32550
Sheyenne Lake NWR	ND	62551
Shiawassee NWR	MI	31520
Sibley Lake NWR	ND	62523
Silver Lake NWR	ND	62591
Slade NWR	ND	62524
Snyder Lake NWR	ND	62592
Springwater NWR	ND	62526
Squaw Creek NWR	MO	33560
St. Johns NWR	FL	41573
St. Marks NWR	FL	41640
St. Vincent NWR	FL	41650
Stewart Lake NWR	ND	62576
Stillwater NWR	NV	14590
Stoney Slough NWR	ND	62527
Storm Lake NWR	ND	62662
Stump Lake NWR	ND	62593
Sully's Hill Nat'l GM Pres.	ND	62594
Sunburst NWR	ND	62525
Supawna Meadows NWR	NJ	52572
Susquehanna NWR	MD	51531
Sutter NWR	CA	11623

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Swan Lake NWR	MO	33570
Swan River NWR	MT	61543
Swanquarter NWR	NC	42532
Tamarac NWR	MN	32560
Target Rock NWR	NY	52560
Tennessee NWR	TN	42620
Tensas River NWR	LA	43690
Tetlin NWR	AK	75630
Tewaukon NWR	ND	62660
Texas Point NWR	TX	21526
Thacher Island NWR	MA	53554
Three Arch Rocks NWR	OR	13595
Tijuana Slough NWR	CA	11631
Tinioum Nat'l Environmental Ct.	PA	52570
Tishomingo NWR	OK	21650
Togiak NWR	AK	74535
Tomahawk NWR	ND	62529
Toppenish NWR	WA	13521
Trempealeau NWR	WI	32578
Trustom Pond NWR	RI	53545
Tule Lake NWR	CA	11664
Turnbull NWR	WA	13560
Tybee NWR	GA	41624
Ul Bend NWR	MT	61529
Umantilla NWR	OR	13560
Union Slough NWR	IA	33580
Upper Klamath NWR	OR	11665

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Upper Miss River Nat'l W&FR	IL	32579
Upper Ouachita NWR	LA	43546
Upper Souris NWR	ND	62680
Valentine NWR	NE	64521
Wallops Island NWR	VA	51571
Wapack NWR	NH	53513
Wapanossa NWR	AR	43650
War Horse NWR	MT	61524
Wasita NWR	OK	21660
Wassaw NWR	GA	41627
Watercress Darter NWR	AL	40000
Waubay NWR	SD	64590
Wertheim NWR	NY	51461
West Sister Island NWR	OH	31542
Wheeler NWR	AL	43660
White Lake NWR	ND	62553
White River NWR	AR	43670
Wichita Mts. Wildlife Refuge	OK	21670
Wild Rice Lake NWR	ND	62663
Willapa NWR	WA	13552
William L. Finley NWR	OR	13590
Willow Creek/Lurline	CA	10000
Willow Lake NWR	ND	52527
Wintering River NWR	ND	62628
Wolf Island NWR	GA	41623
Wood Lake NWR	ND	62595
Wyandotte NWR	MI	31525

REFUGE NAME	STATE	ORGANIZATIONAL CODE
Yazoo NWR	MS	43680
Yukon Delta NWR	AK	74540
Yukon Flats NWR	AK	75638

I. COST CODES (numeric)

Enter cost code only if cost of analysis is supported by funds other than the regional analytical funds.

J. PURPOSE CODES (alpha)

RES -- Research
MON -- Monitoring (over a number of years)
SUR -- Survey (initial site survey)
TAO -- Technical Assistance, General
TA1 -- Technical Assistance, Bureau of Reclamation
TA2 -- Technical Assistance, Army Corps of Engineers
TA3 -- Technical Assistance, Environmental Protection Agency
TA4 -- Technical Assistance, Law Enforcement
WDO -- Wildlife Die-off
OPR -- Operations/Refuge
OOO -- Other

K. NUMBER OF CONTAINERS SHIPPED (numeric)

The total number of jars, bags, etc. that are included in the shipment. This number will be used at the laboratory to verify the number of jars (or other containers) sent. This number should be the total for all coolers or boxes sent in this shipment (the total for the catalog).

Example: If five mallards are collected and the livers are pooled into one jar and the kidneys are to be analyzed individually and are placed in five separate plastic bags, the number entered would be six.

L. FINAL DISPOSAL OF UNUSED SAMPLE

I -- Incinerate
R -- Return to submitter

M. ANALYSIS TYPE CODES (numeric)

Code Number	ANALYSIS TYPE
Organics	
1000	Organochlorine Scan (including total PCBs)
1100	Aliphatic hydrocarbons
1200	PAHs (polynuclear aromatic hydrocarbons)
1300	Organophosphate pesticide(s)
1500	Carbamate pesticide(s)
1600	Dioxins
1620	Furans
1700	Other Organics (use comments section)
Inorganics	
5000	Metal Scan (includes Se, As, Hg, and ICP scan with no preconcentration)
5100	Selenium only
5110	Arsenic only
5120	Mercury only
6000	Other metal(s) (specify in comments section)
6100	Lead only
7000	Cations
7010	Anions
8000	Boron
9000	Other Inorganics (use comments section)

To determine the appropriate code number to enter, refer to the analytical sheets included in this section. A catalog of the specific analyses requested must be included.

N. SAMPLE TYPE CODES (alpha)

BRD -- Bird (including eggs)
MAM -- Mammal
REP -- Reptile
AMP -- Amphibian
FSH -- Fish
INV -- Invertebrate
VEG -- Vegetation
SED -- Sediments
SOL -- Soils
WAT -- Water
FED -- Feed samples from toxicity studies
OTH -- Other

O. SPECIES CODES

The species code consists of two blocks of three letters each. In the first block enter the first three letters of the Genus name of the organism. In the second block enter the first three letters of the species name. Do not enter the common name. The species codes should be entered for birds, mammals, fish, plants, etc. If the species is not known, the sample consists of abiotic material (e.g. water), or is a composite of several species (e.g. a variety of aquatic invertebrates), then enter zeros in all six blocks.

P. NUMBER

The number of containers of that particular species/matrix to be analyzed for the analysis type code specified.

Q. MATRIX CODES (alpha)

EG -- egg
CR -- carcass (without tissues, skin/feathers, feet, etc.)
BR -- brain
LV -- liver
KD -- kidney
GI -- gastrointestinal tract or gut contents
MS -- muscle
WA -- water
SE -- sediments
VG -- vegetation
SO -- soils/sediments
BL -- blood
WB -- whole body (nothing removed)
GD -- gonads
FD -- feed, prepared diet
OT -- other

ATTACHMENT 4

SUGGESTED FIELD ACTIVITY AND SAMPLING DATA LOGBOOK/LOGSHEET ENTRY FORMATS

Appendix F
Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control
Standard Operating Procedures

ATTACHMENT 4

SUGGESTED FIELD ACTIVITY AND SAMPLING DATA LOGBOOK/LOGSHEET ENTRY FORMATS

Contents

1. Activity Log 4-3
2. Sample Log 4-5
3. Specialized Field Data Recording Format 4-10
   - 3.1 Groundwater Sample Log 4-10
   - 3.2 Well Drilling Log 4-14
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   - 3.8 Soil Data Collection Log 4-23

1. ACTIVITY LOG

The Activity log is used to document the sampling team's daily activities and should contain the following information.

- Date--Record the date (dd/mmm/yy) (e.g., 27/JUN/92). Record the day and year using two numeric digits each. Use 01 through 09 for the first nine days of the month. Follow this procedure whenever a date is recorded.

- Page ____ of ____ --Indicate how many pages were used to record the team's activities for a given day.

- Sampling Members--List all the members on the sampling team involved in the field activities that day.

- Narrative (include time and location)--Create a chronological record of the team's activities throughout the day, including the time and location of each activity. Include descriptions of any general problems encountered and names of personnel contacted for permits, logistics, security, technical or other information, and general observations of the weather.

- Recorded by (signature)/QA checked by (signature)--Persons performing these tasks must sign their names in the appropriate spaces provided. The recorded by (signature) should be the individual making the entry. The QA check signature is the individual checking the entry. The QA check is always recommended when litigation is possible.

ACTIVITY LOG

Date (dd/mmm/yy): ___/___/___ Page ____ of____

Sampling Members:

_____ _____

_____ _____

_____ _____

Chronological record of sample collection activities (including permits, logistics, gear, procedures, weather, time, location):

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Recorded By: _____(signature)

QA Check By: _____(signature)

2. SAMPLE LOG

The sample log sheet is used to record the following information :

PAGE 1

- Sample ID number--Indicate the characters of the sample ID number assigned to the physical sample.
- Date of collection--Record the date (dd/mmm/yy) of sample collection (e.g., 27/JUL/92).
- Time of collection--Record the time' based on a 24-hour clock (e.g., 0900, 1450), when the sample material was contained.
- Sampling location--Indicate the location of sampled area e.g., New Hope Pond, Ruby Lake, or use refuge organizational code (see Attachment A).
- Sampling point--Indicate the exact point where the sample was collected as indicated by description and/or coordinates (e.g., 01, 02, 03; or N end of lake, approximately 100 ft from culvert drainage, or N28,661 E65,146).
- Sample depth (below surface)--Indicate the depth below the surface level where the sample was collected and record the appropriate units.
- Sample matrix--Indicate the matrix identifier (see Attachment A, Section Q) that most appropriately describes the sample material.
- Field observation--Record any observations relevant to the sampling area, contaminant source, or the sample itself. For example:
  - Soil--color, texture, moisture, cohesiveness, odor
  - Sediment--exposed or underlying water, texture, color, cohesiveness, viscosity
  - Water--turbidity, water level, direction of flow, flow rate
  - Sampling site--terrain, topography, landforms
- Field measurements--Record results of any quantitative measurements that are made at the sampling site or pertain to the sample (e.g., pH, conductivity, and temperature).
- Sample type--Indicate type of sample collected (e.g., grab, composite, see Section 2
- Procedure followed--Indicate the Sampling procedure used and whether the sampling procedure was identified in the study plan. Describe all changes in sample procedures. Also include reasons for moving a sampling site if that occurred, in the space provided and on additional sheets if needed.
- Recorded by (signature)/QA checked by (signature)--Persons performing these tasks must sign their names in the appropriate spaces provided.

SAMPLE LOG (PAGE 1)

SAMPLE ID NUMBER _____ **Date of Collection (dd/mmm/yy)**_____
Sampling Location:_____
Description:_____

Sampling Point Description:_____
Sample Depth: _____ **to** _____ _____**(units) below surface**

Sample Matrix (insert appropriate identifier): _____ **(See Attachment 3 Section Q)**

SOLID MATRICES	LIQUID MATRICES
Soil (1) Surface (-0-3') (2) Subsurface Sediment (3) Lake/Pond (4) River/Stream (5) Impoundment Pond (6) Spring (7) Other _____ Air Sample (8) Filter (Charcoals) (9) Sorbent (10) Other _____ Biota (1) Flora Species_____ (2) Fauna Species_____ (3) Other_____	Surface Water (14) Lake/Pond (15) River/Stream (16) Spring/Seaps (17) Domestic (18) Other_____ Ground Water (19) Well (20) Vadose (21) Other_____

Field Observations

_____
_____
_____

Field Measurements:

	Reading	Units	Inst. Number
Radioactivity			
Temperature			
pH			
Conductivity			
Turbidity			
DO			
FID/PID			

Sample Type: _____ Grab _____ Spatial Composite _____ Time Composite _____
Other _____ QC Trip Blank _____ QC Rinsate _____

Procedure Followed _____Yes _____No. If no is checked, specify deviations below:

_____

Recorded By; _____ QA Check By; _____
(signature) (signature)

SAMPLE LOG (PAGE 2)

SAMPLE NUMBER	CONTAINER		ANALYSIS	PRESERVATIVES
	VOLUME (ml)	TYPE		

Received By: _____ QA Check By: _____

Signature Signature

SAMPLE LOG (PAGE 3)

SKETCH OF SOURCE LOCATION AND SAMPLING POINTS

Recorded by:_____ QA Check by:_____
Signature Signature

PAGE 2

- Sample number--Indicate ID number assigned to the physical sample.
- Container volume--Indicate the total volume of the sample container in which the sample is placed (e.g., 1000 mL).
- Container type--Describe the sample container in which the sample is placed (e.g., amber glass, high-density polyethylene (HDPE), or cubitainer).
- Analysis--Indicate the analysis that will be performed by the analytical chemistry laboratory.
- Preservatives (type/volume)--Indicate the type and volume of preservative(s) added (e.g., 5 mL $HN0_3$) and/or conditions under which the sample was stored (e.g., 4°3).

PAGE 3

- Sketch--Draw a map indicating location of sampling points, distances between points, and any other pertinent information. Be as specific as possible. Include north direction and scale or dimensions. Considerations should be given to the permanence of any landmarks that are referenced.

3. SPECIALIZED FIELD DATA RECORDING FORMATS

A number of sampling/monitoring situations may require the collection of field data that necessitates the use of a specialized format (e.g., groundwater). When separate specialized forms are used, they must be included and bound in the Field Logbook or, if more convenient, bound in a separate Field Data Logbook. If a specialized Field Data Records and Forms Logbook is used, it must have the appropriate identifier and header (see Section 3 and 3.4).

This logbook becomes part of the project file and must be filled out and handled as previously identified for all program documents.

3.1 GROUNDWATER SAMPLE LOG

PAGE 1

- Sample ID number--Indicate the characters of the sample ID number assigned to the sample.
- Date of collection--Indicate date (dd/mmm/yy) of sample collection (e.g., 27/JUL/92).
- Time of collection--Record the time, based on 24-hour clock (e.g., 0900, 1450), at which the sample material was collected.
- Well ID number or description--Indicate the identification number of the well. If no number is associated with the well (e.g., a domestic well), provide a sufficient description of the well.
- Well coordinates or sampling location--Indicate the coordinates of the well based on a coordinate system or identify by other means the exact location that would allow the well to be located at a later date.
- Depth of screen section from top of inner casing (see Groundwater RFM)--Obtain this information from the original well construction logbook. Record information in feet or meters from top of inner casing.
- Type of inner casing--Describe the physical makeup of the inner casing [e.g., steel, stainless steel, polyvinyl chloride (PVC)].
- Bore volume calculation--Base this calculation on field measurements (depth to water from top of inner casing and well diameter) and information obtained from the original well construction logbook (depth of well from tip of inner casing) in order to calculate the purge volume. Note that all units used in the bore volume calculation are in feet (also see Groundwater RFM).
- Purge method--Indicate the method implemented in purging the existing well.
- Purge volume (gal)--enter the actual volume purged.

- Sample method--Indicate the method implemented in obtaining a sample(s) from the existing well.

- Field observations--Record any visual or otherwise sensed observations relevant to the sampling area, contaminant source, or the sample itself (e.g., turbidity, terrain, topography).

- Field measurements--Record results of any quantitative measurements that are made of the sampling area or the sample; e.g., pH, conductivity, salinity. Results of any field screening will also be entered under field measurements.

- Procedure followed--Indicate whether the sampling procedure identified in the general study plan was followed. If not, specify the deviations in the space provided.

- Recorded by (signature)/QA Check by (signature)--Persons performing these tasks must sign their names in the appropriate spaces provided.

GROUNDWATER SAMPLE LOG (PAGE 1)

Date of Collection (DD/MMM/YY): __/__/__
Time of Collection: __/__/__

Sample ID Number _____

Well ID Number of Description: _____

Coordinates of Well Location: _____

Depth of Screen Section: (from top of inner casing): _____ ft to _____ft

Type of Inner Casing: _____

Depth of Well from Top of Inner Casing (H2) _____ft.
Depth to Water from Top of Inner Casing (H1) _____ft.
Depth of Water Column H2 - H1 = _____ft.
Well Diameter (diam.): _____ in.
Bore Volume: (H2-H1) x 3.14r2m _____ cu. ft. x 7.48m _____gal.
Purge Method: _____ Bailer _____ Bladder Pump _____ Purge Vol.:_____Other _____

Sample Method: _____
Field Observation: _____

Field Instrument Measurements:

	Measurement	Unit	Instrument Number
Radioactivity:	_____	_____	_____
Temperature:	_____	_____	_____
pH:	_____	_____	_____
Conductivity:	_____	_____	_____
Other (specify):	_____	_____	_____

HACH or other Kits	Parameter	Measurement	Unit
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Procedure Followed: _____ Yes _____ No. If no specify deviations:

_____
_____
_____

Recorded By: _____ Checked By: _____
signature signature

GROUNDWATER SAMPLE LOG (PAGE 2)

CONTAINER					FILTERED		
Sample Number	Volume	Type	Analysis	Preservative	Yes	No	Size

Purge Water Measurements:

Time	Temperature	pH	D.O.	Conductivity	ORP

Recorded by _____ Checked by _____

Signature Signature

PAGE 2

- Sample number--Record ID number assigned to the physical sample.
- Container volume--Record the total volume of the sample container in which the sample is placed (e.g., 500 mL).
- Container type--Describe the sample container in which the sample is placed (e.g., amber glass, cubitainer).
- Analysis--Indicate the analysis that will be performed by the analytical laboratory.
- Preservatives (type/volume)--Indicate the type and volume of preservative(s) added (e.g., 5 mL $HN0_3$) and/or conditions under which the sample was kept (e.g., 4°3).
- Filtered--Was sample filtered, if yes, record size of filter.
- Purge water measurements--Record measurements:(ORP) oxidation reduction potential.

3.2 WELL DRILLING LOG

The well drilling log is used when new wells are being constructed. The following data is recorded on this form:

- Date--Indicate date (dd/mmm/yy) when form was initiated (e.g., 27/JUL/92) and date well started (constructed) and date well was completed.
- Page _ of _ Indicate how many drilling report forms were used to record the activities for a given day.
- Well ID Number--Identification number assigned to the new well (if available; otherwise indicate temporary ID number).
- Well coordinates--Indicate the coordinates of the well, or identify the exact well location that would allow the well to be located at a later date and time.
- Drilling company--Indicate the firm contracted to conduct the actual well drilling.
- Drill crew/media team--Record the names of all the members on the drilling crew and the sampling team involved in field activities that day.
- Type of rig--Indicate the type of drilling rig used in the construction of the well.
- Drill method--Indicate the drilling method used in the construction of the well.
- Drill fluid--Indicate the type of drilling fluid(s) if used in the construction of the well.
- Depth of well--Record the well depth feet below ground surface at the start and end of each day.

WELL DRILLING LOG

Date (dd/mmm/yy): ___/___/___ Page ____ of ____

Date Well Started: ___/___/___

Date Well Completed: ___/___/___

Well ID Number: _____ Sample ID Number: _____

Well Coordinates or Drilling Location: _____

Drilling Company: _____

Drilling Team:

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

Type of Rig: _____

Drill Method: _____

Drill Fluid: _____

Depth of Well Start: _____ft. End: _____ft.

Narrative:

Recorded By: _____ QA Checked By: _____
(signature) (signature)

- Narrative (include time and location)--Create a chronological record of activities throughout the day including the time of each activity. Include descriptions of any general problems encountered and names of personnel contacted by the team for permits, logistics, security, technical, or other information, and observations of the weather.

- Recorded by (signature)/QA check by (signature)--Persons who perform these tasks must sign their names in the appropriate spaces provided.

3.3 WELL DRILLING SUBSURFACE DATA LOG

Geologic characteristics of the subsurface profile at drilling sites should be recorded as drilling proceeds. Data which identifies and describes the subsurface profile should be recorded on a well drilling subsurface data log.

- Drilling location--Indicate the well coordinates (based on a coordinate system recognized by the refuge) or identify in some manner the exact well location that would allow for the well to be located at a later date and time.

- Date--Record start and end dates of form completion (dd/mmm/yy).

- Page __ of __--Indicate how may sheets were used to complete the Record of Subsurface Exploration.

- Well ID number--Record identification number assigned to the well (if available, otherwise indicate temporary) that is recognized by the site (see Figure 5).

- Groundwater first encountered at (ft)--Record the depth at which groundwater is first encountered during the drilling procedure feet below ground surface.

- Depth--Indicate the respective depth of observation and/or sample collection feet below ground surface.

- Number--Indicate the sample number: If samples are for profile description, describe sample ID code used in field logbook. If samples are for chemical analysis, complete sample log sheet (Figure 3).

- Interval and type--Record depth interval (ft) at which samples were collected (e.g., 5 to 6 ft) and the sampling device used (e.g., split spoon).

- Advanced/recovery--Record distance (ft) the driller advanced and amount of sample recovered (ft).

- Blows (Per 6 in.)--Indicate number of blows required to advance the sampler 6 in. (based on a 140-lb hammer falling 30 in.).

- Description of materials--Provide a brief description of the types of materials encountered during the drilling procedures. Water-bearing zones should also be identified (see Tables 2, 3, and 4 in Soil Sampling RFM for description assistance).

- Recorded by (signature)/QA check by (signature)--Persons performing these tasks must sign their names in the appropriate spaces provided.

WELL DRILLING SUBSURFACE LOG

Page _____ of _____

Drilling Location or Well Coordinate: _____ Date (dd/mmm/yy) ___/___/___

Well ID Number: _____ Start: ___/___/___

Groundwater first encountered at _____ ft. End: ___/___/___

Sample					Description of Materials (color, modifier, material) Classification, indicate on water bearing zones)
depth (ft)	Number	Interval	Advanced Recovery (in.)	Blows (per 6 in.)	
5-					
0-					
5-					
0-					
5-					
0-					
5-					

Recorded By: _____ QA Check by _____

Signature Signature

3.4 WELL COMPLETION LOG

The well completion log must be filled out after the well is completed. The information on this log must identify well engineering aspects that may be necessary for designing and implementing future sampling/monitoring programs. The well completion log, as shown, is used to record the following data:

- Well location--Indicate the coordinates of the well or identify the exact well location that would allow for the well to be located at a later date and time.
- Well ID number--Record the identification number assigned to the well.
- Drilling company--Indicate the firm subcontracted to conduct the actual well drilling.
- Type of rig--Indicate the type of drilling rig used in the construction of the well.
- Date installation completed--Record date (dd/mmm/yy) well is completely installed.
- Total depth--Record the depth of the well (ft) from the top of the casing.
- Development method--Indicate the method used to develop the well.
- Development end--Record date (dd/mmm/yy) and time (based on a 24-hour clock) development ended (see Groundwater RFM).
- Total water removed during development--Indicate the amount of water (gal), removed from the well during development.
- Description of turbidity at end of development--Describe the turbidity of the groundwater at end of development.
- Additional comments--Record any additional information relative to the contaminant source. Sample or the sampling activity that may be of importance.
- Well construction summary--Complete the information referred to by the diagram that summarizes specific information and measurements that describe the completed well.
- Recorded by (signature)/QA check by (signature)--Persons performing these tasks must sign their names in the appropriate spaces provided.

WELL COMPLETION LOG

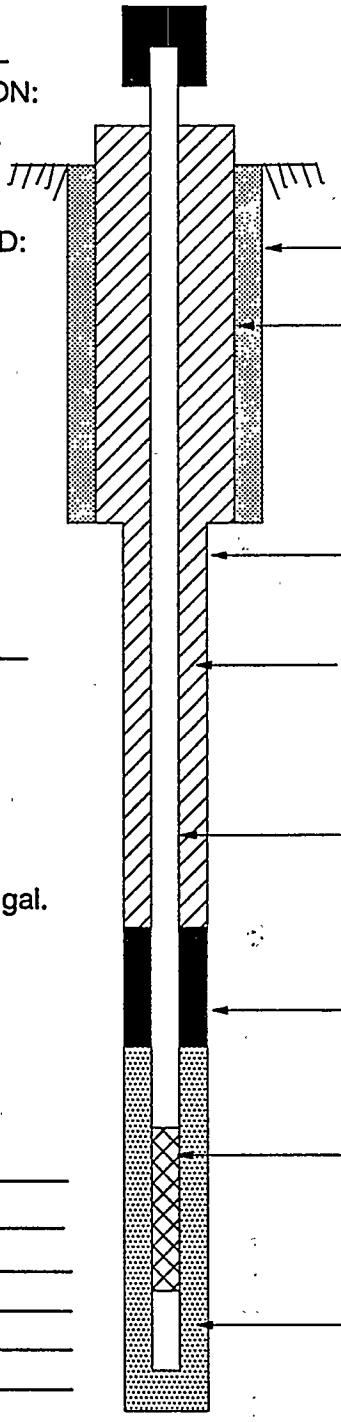
SITE NAME: _____

WELL ID NUMBER:_____
WELL COORDINATES or LOCATION:
_____
DRILLING Co._____
TYPE OF RIG:_____
DATE INSTALLATION COMPLETED:
_____
TOTAL DEPTH:_____ft.
_____
DEVELOPMENT
METHOD:_____
_____
_____
_____
START DATE: __ __ / __ __ __ / __ __
TIME: _____
END DATE:__ __ / __ __ __ / __ __
TIME: _____

TOTAL WATER REMOVED
DURING DEVELOPMENT:_____ gal.

DESCRIPTION OF TURBIDITY
AT END OF DEVELOPMENT:
[ ] Clear [ ] Slightly Cloudy
[ ] Med. turbid [ ] Very Cloudy

_____
ADDITIONAL COMMENTS:_____
_____
_____
_____
_____



WELL CAP ELEVATION:_____ ft.

GROUND SURFACE
ELEVATION:_____ ft.

CONDUCTOR HOLE DIA.:_____ in.

SURFACE CONDUCTOR
TYPE:_____
ID:___ in. OD:____ in.
_____ to _____ ft.

BOREHOLE DIA.:_____ in.
_____ to _____ ft.

FILLER
TYPE:_____
_____ to _____ ft.

CASING (with screen)
TYPE:_____
ID:_____ in. OD:_____ in.
_____ to _____ ft.

SEAL
TYPE:_____
_____ to _____ ft.

SCREEN
TYPE:_____
ID:_____ in. OD:_____ in.
_____ to _____ ft.

PACK
TYPE:_____
_____ to _____ ft.

RECORDED BY:_____(Signature) QA CHECK BY:_____(Signature)

3.5 FIELD INSTRUMENT CALIBRATION AND TEST LOG

The Instrument Calibration and Test Log is used to document instrument calibration and/or test results. Use one log for each instrument and record the following:

- Instrument name, model, and serial number
- Date and time of calibration and/or test
- Methods and types of standards used for calibration and/or test (see manufacturer instructions)
- Signature of individuals performing the calibration and/or test
- Calibration results

NOTE: Consult manufacturer operational instructions for definitive guidance on calibrating and using field instruments.

For the calibration of certain instruments (e.g., hydrolab pH meter), specific calibration form may be needed. It is good practice to use the Instrument Calibration and Test Log in addition to instrument specific calibration forms.

3.6 MEDIA SPECIFIC DATA LOGS

Media specific data logs that are identified in the sampling RFMs (e.g., soil, surface water) can be used. A soil data collection log form is shown on page 4-23 for illustrative purposes.

INSTRUMENT CALIBRATION AND TEST LOG

INSTRUMENT NAME _____ INSTRUMENT MODEL_____

SERIAL NUMBER _____

Date of Calibration and/or Test (dd/mmm/yy)	Time of Calibration and/or Test	Method and Types of Standards Used for Calibration and/or Test	Calibration and/or Test Performed by (signature)	Calibration Results

HYDROLAB CALIBRATION

Hydrolab:	SOND#:	Date (dd/mmm/yy):	Time:

	INITIAL CALIBRATION	POST-CALIBRATION
Temperature:	_____ °C	_____ °C
Barometric Pressure:	_____ mmHg	_____ mmHg
Dissolved Oxygen:	_____ ppm	_____ ppm
Conductivity:		
_____ MKCL	_____ mmho/cm	_____ mmho/cm
pH:	_____	_____
	_____	_____
	_____	_____
ORP: pH4	_____ Volts	pH4 _____ Volts
pH7	_____ Volts	pH7 _____ Volts
Battery Check:	_____	_____

Comments:

Signature of Calibrator:

SOIL DATA COLLECTION LOG

SAMPLE NO.:		REFUGE:	DATE:
SAMPLING LOCATION:			
SANDS AND GRAVELS			
1. Test 1			
2. Test 2			
3. Test 3			
4. Test 3A			
5. Test 4			
Comments			
SILTS AND CLAYS			
6. Test 5			
7. Test 6			
8. Test 7			
9. Test 8			
10. Test 9			
11. Test 9A			
12. Test 10			
13. Test 11			
Comments			
OTHER PARAMETERS			
14. Consistency			
15. Permeability			
16. Organic Matter			
17. Inorganic Matter			
18. Clay Minerals			
19. pH			
Comments			

ATTACHMENT 5

SAMPLE SHIPPING PROCEDURES

Appendix F
Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control
Standard Operating Procedures

ATTACHMENT 5

Sample Shipping Procedures

Contents

1. Nonhazardous Material 5-3
2. Nonradioactive Hazardous Material 5-4
3 Method of Shipment 5-5
4. Table 5-1 Marking Requirements for Dangerous Goods 5-5

ATTACHMENT 5

The following procedures have been used by U.S. Government agencies for the shipment of samples to analytical Laboratories IT IS RECOMMENDED THAT CURRENT DOT REGULATIONS BE CONSULTED PRIOR TO SHIPMENT.

1. Packages of Samples Containing Nonhazardous Material

Procedures for packaging, marking, labeling, and documenting packages containing nonhazardous sample material are as follows:

- A sturdy Coleman "Steelbelted" ice chest or equivalent brand ice chest (cooler) should be selected as the shipping container. Tape the drain plug shut on the inside and outside. Line the inside of the cooler with a heavy-duty plastic trash bag. Puncture the bag with small holes near the top to prevent build-up of CO_2. Put an initial layer of vermiculite in the bottom of the lined cooler to cushion the samples during transportation

- Place enough dry ice in the center of the cooler to keep samples frozen 36-48 hours. Use at least a 1:1 sample to dry ice weight ratio. The dry ice should be wrapped in newspaper and placed in a box to keep it from coming into direct contact with glass containers. The box will ensure the original dry ice volume is maintained inside the cooler even though it will sublime during shipment (without a box to maintain the volume, the samples will shift and break).

NOTE: Blue Ice can be used as a substitute for dry ice but is not highly recommended. The drawback of Blue Ice is the possible puncture and leakage of the Blue Ice container and subsequent contamination of samples.

- Each sample container and its attached sample tag will be put inside a sealed ziplock bag. Either position the same tag so that it may be read through the bag, or attach a second sample tag directly to the ziplock bag. The samples will be placed upright in the lined cooler and packed in such a way as to prevent them from tipping over, breaking, and spilling. To do this, wrap each individual jar with bubble wrap plastic cut to the proper size, or place the jars in their original box and wrap in bubble wrap plastic. Retighten all jar lids before packing. Any jars that have developed cracks should be replaced at this time.

- The remaining space inside the cooler will be filled with vermiculite, which serves as a packaging material and as an absorbent should any of the sample bottles leak or break. The cooler shall contain enough vermiculite to absorb all the sample material contained within the cooler in case of an accident. The liner will then be sealed with tape or a twist-tie.

- Two completed Chain-of-Custody Records or packing lists inventorying the contents of the cooler, and any other required shipping papers accompanying the samples to the laboratory, will be placed inside plastic bags which are taped to the inside lid of the cooler and to the outside of the container. A copy of the Chain-of-Custody Record will be held in a temporary field file until the shipment and accompanying Chain-of-Custody Record is received at the analytical chemistry laboratory.

- The cooler will be latched closed and taped securely with fiber filament tape.

- At least one Chain-of-Custody seal, signed and dated by shipping personnel, must be affixed to the cooler in such a manner that the cooler cannot be opened without breaking the seal. This can be accomplished by wrapping the filament tape--which secures the lid of the cooler--around an open custody seal at least twice, and affixing the custody seal to itself.

- The outside of each shipping container will display the submitter's name and address (From:) and the name and address of the analytical laboratory (To:).

- Package orientation labels will be placed on all four sides of the shipping container.

The outside of the cooler should be labeled with the following warning that the contents includes dry ice:

Dry Ice ORM-A 1845

- Fill out the appropriate air carrier information (with an up to date address for the recipient) and retain a copy in a temporary field file until shipment is received at the analytical laboratory. Do not ship to a P.O. Box.

- Always call the receiving laboratory BEFORE shipping and inform them of the container's contents, when to expect the container, and what analysis is to be performed on the samples.

2. Packages of Samples Containing Nonradioactive Hazardous Material

Procedures for packaging, labeling, and documenting packages containing hazardous, nonradioactive sample material are identical to those for packages containing nonhazardous sample material, with the following additional requirements:

- Each package will be checked to make sure the hazardous material does not exceed the quantity levels specified in 49 CFR 172.101. Note that in most instances the hazardous material must be packaged, marked, labeled, and documented as "limited quantity" because sample coolers are not DOT-specified packages.

- Each sample--except volatile organic analysis vials which may be grouped in fours--will be placed inside a metal paint can. The remaining space in the can will be filled with vermiculite. The lid of the paint will be shut and secured with tape or paint can clips.

- Each package will be appropriately marked (Table C-1) and labeled as specified in 49 CFR 172.101 and as required for mixed and/or consolidated packaging, as applicable.

- Each paint can containing a hazardous sample will bear the following information on the external surface: (1) a sample identification number, (2) a label for the appropriate hazard, and (3) a package orientation label.

- A Federal Express Restricted-Articles Airbill for "limited quantity" hazardous material will be completed and a copy will be held in a temporary field file until shipment is received at the analytical laboratory.

3. Method of Shipment

All samples bound for the analytical chemistry laboratory should be shipped via Federal Express Priority One Overnight Delivery or equivalent.

Table 5-1. Marking requirements for packages containing dangerous goods (49 cfr 172.300)

1. Proper shipping name and identification number.
2. Name and address of shipper or consignee (FEC prefers both).
3. If liquid, "This Side Up" or "This End Up".
4. If required, the box specification (DOT, IATA, or ICAO box specifications).
5. Hidden marking requirements, usually found in explosive packaging notes Example: "Handle Carefully," "Keep Fire Away."
6. If a DOT cylinder or box is overpacked, the DOT number cannot be seen. The words "Inside Packages (container) comply with Prescribed Specification" must be marked on the outside package.
7. "Limited quantity" and ORMDs need not be marked with the identification number.
8. Packages containing a hazardous substance must be marked with the letters RQ (not the weights).
9. All constituents of the hazardous substances must be marked in association with the basic description if the proper shipping name fails to include them.

All markings must be durable, in English, printed unobscured on a contrasting background, and located away from similar markings.

ATTACHMENT 6

BIOLOGICAL SUPPLIES AND VENDORS

Appendix F
Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control
Standard Operating Procedures

ATTACHMENT 6

Biological Supplies

Chemically Clean Jars
- I-Chem Research
- Scientific Specialties Service, Inc.

Dissection Kits
- Health Resources and Services Administration
- Ace Scientific
- Curtin Matheson Scientific
- PGC Scientifics
- Thomas Scientific

Polyethylene Bottles
- Health Resources and Services Administration
- Ace Scientific
- Thomas Scientific

Whirl-Paks
- Ace Scientific
- Curtin Matheson Scientific
- PGC Scientifics

Teflon Spatula
- Curtin Matheson Scientific
- PGC Scientifics
- Thomas Scientific

Insulated Boxes
- Polyform Packers Corp.

Calipers
- VWR Scientific
- Ace Scientific
- Curtin Matheson Scientific

Micrometer
- Ace Scientific
- Curtin Matheson Scientific
- L.S. Starret Co.

Laboratory Balances
- Ohaus Scale Corp.
- VWR Scientific
- Ace Scientific
- Curtin Matheson Scientific
- PGC Scientifics
- Thomas Scientific

Candlers
- G.Q.F. Manufacturing Co.

Egg Volume Device
- Carolina Biological Supply Co.

Bubble Wrap
- GSA contract pending
- Local building supply houses
- Post Office

Styrofoam Sheets
- GSA contract pending
- Local building supply houses

Coolers
- The Coleman Co.
- Igloo Corp.
- Estca Corp.

Marking Pens
- PGC Scientifics
- Local stationary store

Nitric Acid
- North Strong Scientific

Pesticide Grade Hexane and Acetone
- ACE Scientific Supply Co., Inc.

Vendor List

ACE Scientific
40-A Cotters Lane 800-631-5602
East Brunswick, NJ 08816

Carolina Biological Supply Co.
Burlington, NC 27215 800-334-5551
Gladstone, OR 97027 800-547-1733

Curtain Matheson Scientific
8291 Patuxent Range Rd. 301-498-5210
Suite F
Jessup, MD 20794

The Coleman Co.
P.O. Box 1762 316-261-3211
Wichita, KS 67201-1762

Dept. Of Health and Human Services
Public Health Service 301-642-2247
Health Resources and Services Administration
Supply Service Center
Perry Point, MD 21902

Estca Corp.
P.O. Box 1082 206-453-9998
Bellevue, WA 98009

G.Q.F. Manufacturing Co.
P.O. Box 1552 912-236-0651
Savannah, GA 31402

I-Chem Research
23787-F Eichler Street 800-443-1689
Hayward, CA 94545

The Igloo Corp.
2166 Wisconsin Ave. N.W. 202-265-0246
Washington, D.C. 20007

L.S. Starret Co.
Athol, MA 01331 508-249-3551

North Strong Scientific
7322 Westmore Road 301-762-2121
Rockville, MD 20850

Ohaus Scale Corp.
29 Hanover Rd. 800-672-7722
Florham Park, NJ 07932

PGC Scientifics
9161 Industrial Ct. 800-424-3300
Gaitherburg, MD 20877

Polyfoam Packers Corp.
2320 South Foster Ave. 800-323-7442
Wheeling, IL 60090

Scientific Specialties Service, Inc.
P.O. Box 352 301-644-6200
Randallstown, MD

Thomas Scientific
99 High Hill Rd.
P.O. Box 99 609-467-2000
Swedesboro, NJ 08014

VWR Scientific
P.O. Box 626 800-257-8407
Bridgeport, NJ 08014

EGG-EST-9222
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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX G
FIELD INSTRUMENT MEASUREMENTS REFERENCE FIELD METHODS

K. W. Brown
R. C. Rope
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PREFACE

This is Appendix G of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   D.2 Bird Sampling Reference Field Methods
   D.3 Fish Sampling Reference Field Methods
   D.4 Flora Sampling Reference Field Methods
   D.5 Reptiles and Amphibians Sampling Reference Field Methods
   D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

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Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

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ACRONYMS

AM	Administrative Manual
AMC	Aerojet Manufacturing Company
ANC	Acid Neutralizing Capacity
ASTM	American Society of Testing and Materials
ATC	Automatic Thermocompensator
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
EPA	United States Environmental Protection Agency
FID	Flame Ionization Detector
GM	Geiger-Muller
N	Normality
NIST	National Institute of Standards and Technology
PCB	Polychlorinated Biphenyl
PID	Photoionization Detector
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
QCC	Quality Control Check
RCRA	Resource Conservation and Recovery Act
RFM	Reference Field Methods
TOC	Total Organic Carbon
UV	Ultraviolet
YSI	Yellow Springs Instrument Company

U.S. FISH AND WILDLIFE SERVICE
BIOMONITORING OPERATIONS MANUAL

APPENDIX G
FIELD INSTRUMENT MEASUREMENTS
REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of this Reference Field Methods (RFM) document is to provide guidance in obtaining selected on-site measurements using portable field instrumentation. The information obtained by U. S. Fish and Wildlife Service (Service) personnel using field instrumentation can be used to augment the interpretation of laboratory analytical results of collected samples. For example, in many cases the extent of contamination and the behavior of a chemical contaminant(s) will be affected not only by environmental media but also by existing physical and chemical parameters (e.g., pH, temperature).

1.2 Scope

This RFM identifies field instruments used to collect environmental data that can be used for making on-site decisions concerning environmental contamination. General guidance addressing the operational aspects of each instrument is also provided. To ensure satisfactory performance, however, personnel must be familiar with the detailed operation and maintenance found in the manufacturer's operating instructions for each specific instrument. Field personnel instrument users must realize that the directions identified in this RFM are intended to emphasize the importance of following detailed procedures necessary for collecting environmental data of known quality. The procedures identified may supplement but are not a substitute for an instrument's operating instruction manual. Because of the rapidly changing technology and the advanced development of field instruments, it is neither practical nor cost-effective to include and describe all available field instrumentation in this RFM. Some of the instruments are routinely used by Service personnel, while others (e.g., radiation instruments) may be used only on rare occasions. Also, there are some measurement methods described that may require assistance from other federal agency personnel or contractors. These instruments and methods are included to provide Service personnel with the information and background that will enable informed discussion with appropriate experts in the field of environmental contamination.

1.3 Background

Depending upon the objective(s) and/or available resources for the sampling effort, it may be necessary to obtain some specific field measurements. The collection of these field measurements may include data from field instrumentation but are not limited to the following uses:

- To indicate the presence of organics and dissolved total organic carbon (TOC)

- To assess the potential for chemical change as a function of temperature
- To determine if there is a presence of radioactive materials
- To use as a screening aid to detect the presence of organic vapors
- To measure suspended material in liquid media for assessing the degradation of habitat and biological life
- To determine dissolved oxygen content for assessing water quality and its impact on biological life
- To determine hydrogen ion concentration.

The parameters that are most critical to measure in the field are those that may change during the actual collection, handling, and transport of samples to a laboratory (e.g., temperature). In addition to obtaining data immediately, and in many cases from minimally disturbed environmental media, advantages of collecting data with field instrumentation include

- Cost - Most field instruments are relatively inexpensive to purchase and operate. Data obtained are generally inexpensive compared to laboratory analytical costs.
- Maintenance - Instruments, if used properly, can be maintained, calibrated and stored with minimal resources and time requirements.
- Operation - Most field instruments are simple to operate and provide reliable data.
- Screening - Immediate data retrieval allows for on-site decision making (e.g., site selection, sample handling and sample preservation).

Critical elements that must be addressed when using field instruments are calibration and documentation. All equipment with mechanical metering devices and electronic components must be calibrated regularly to ensure the accuracy and data quality. Calibration and documentation guidance is presented for each instrument described. Manufacturer's calibration instructions should be followed in all cases. It is also recommended that standards, such as National Institute of Standards and Technology (NIST) Certified Thermometers for temperature-measuring devices, Class 5 weights for balances, and absorption filters for spectrophotometers be obtained for calibrating instruments. Also, documentation for each instrument is required that identifies calibration results, personnel making calibration, dates and time of calibration, reagents used in calibration(s), and all repair and maintenance information.

From the perspective of identifying and measuring physical and chemical parameters, the instruments and procedures presented in this document can provide adequate data. If increased accuracy is required, samples should be collected according to procedures in the appropriate RFM and analyzed under laboratory conditions. As previously stated, some parameters may be changed or altered during physical collecting, handling, preservation and/or shipment of samples; as a result, collecting some measurements may only be obtained by field instrumentation.

1.4 Information Resources

When considering the purchase and use of field instrumentation use only U.S. Environmental Protection Agency (EPA) approved or validated equipment and/or methods. Field instruments must

be constructed to withstand environmental exposure, be reliable, be easy to operate, and preferably provide immediate data.

Today, field personnel can select from a large number of available field measurement and testing kits that will provide measurements of meteorological parameters, metals, pesticides, and other organic contaminants in most environmental media (see Section 1).

It is the responsibility of the instrument user to correctly operate and use an instrument for its intended use. The user is also responsible for knowing an instrument's limitations. For example, specialized equipment or special adaptations or components to existing equipment may be necessary for the correct operation in extreme environments (e.g., temperatures, salinity). Instrument limitations can be obtained from the manufacturer or they may be identified as "special condition" in EPA-approved or validated methods.

2. HYDROGEN ION (pH)

2.1 General Procedures

The pH of an aquatic environment is regulated by abiotic (inorganic CO_2 equilibria, surficial geology, and anthropogenic pollutants) and biotic factors (photosynthesis, respiration, and decomposition). A pH balance is usually maintained by the presence of buffering reactions within the aquatic system. A shift in this balance can cause chemical and biotic repercussions.

The pH is defined as the negative logarithm of the activity of hydrogen ions (H+). The H+ activity is a measure of the "effective" concentration of hydrogen ions in solution; it is always equal to or less than the true concentration of hydrogen ions in solution. Values usually range from pH 1 to pH 14, with pH 1 most acidic, 7 neutral (at 25°C), and pH 14 most alkaline. Each pH unit represents a tenfold change in H+ activity (i.e., a pH 4 solution is 10 times as acidic as a pH 5 solution).

When the pH of a sample solution is measured, the hydrogen ions come into equilibrium with the ion exchange surface (glass) of a calibrated pH electrode, which creates an electrical potential. This voltage difference is measured by the pH meter in millivolts, then is converted and displayed as pH units.

2.1.1 Scope and Application Summary

This method is taken from EPA (1989) for illustrative purposes and is applicable for determining pH in samples from flowing waters of low ionic strength. The Aquatic Effects Research Program utilized a Beckman model 121 meter and Orion-Ross model BNC-8104 glass electrodes to measure the pH of stream waters. The method described assumes that the Beckman meter and Ross electrode are used. This method however, can be used with modification with other portable instrumentation meeting equivalent specifications. This method is also applicable to systems other than lotic systems.

The applicable pH range is 3.0 to 8.0 units. The range may be extended with use of a wider range of pH calibration standards and pH quality control check (QCC) solutions. The calibration standards and reagents used in this method pose no health hazard to the samplers.

It is recommended that the meter and electrode be calibrated at a Service lands facility. At the sampling location the meter is checked against a pH 4.00 QCC solution and a pH 7.00 buffer standard. If the meter does not fall within specified limits for each check, it should be recalibrated.

Water samples for pH determinations are collected with a peristaltic pump and food-grade Tygon tubing. The tubing is attached to the end of an extension pole and placed in the stream. After the tubing is purged for two minutes, a 250-mL sample beaker is rinsed three times with stream water. A sample of 150 to 200 mL is then pumped into the beaker. A second sample is collected in the same manner. These samples are used to determine pH. A glass electrode and an automatic thermocompensator (ATC) are placed into the sample, and its pH is displayed on the meter's digital readout.

2.1.2 Equipment and Supplies

- Beckman 121 portable pH meter or equivalent
- Meter operation manual
- ATC probe
- Orion-Ross model BNC-8104 combination glass electrode
- Peristaltic pump
- Wash bottle (1 L)
- Extension pole
- Six 250-mL bottles for field rinse, pH 4.00 QCC solutions, and pH 4.00 and 7.00 buffer standards
- NIST-traceable thermometer
- Tygon tubing
- Watch or stopwatch
- Syringe
- Calibration and field data forms (field logbook)
- Deionized water--used in all preparations, should conform to American Society of Testing and Materials (ASTM) specifications for Type I reagent grade water (ASTM, 1984)
- pH calibration standards--commercially available pH buffers (NIST traceable values of pH 4.00 and pH 7.00 at 25°C)
- pH 4.00 QCC solution; 0.0001 N (1 mL of 0.1 N H_2SO_4 diluted to 1 L with deionized water). Prepare daily
- Six 250-mL disposable beakers
- Electrode filling solution (3 mol KCl)

2.1.3 Meter and Electrode Preparation

NOTE: It is recommended that all personnel operating pH meters be familiar with operating procedures. The pH meter must remain dry, enclosed in plastic with desiccant packets, and checked for moisture.

NOTE: The Orion-Ross pH electrode has a glass bulb. Care should be taken in handling the electrode to prevent shock to the bulb. The electrode should always be carried upright in a padded case or vest pocket.

1. Lower the pH electrode's fill hole collar to uncover the opening.

2. Make sure the pH electrode is properly conditioned for use. Refer to the electrode instruction manual. If response time is unacceptable, recondition the electrode as described in Section 2.1.7.

2.1.4 Calibration

2.1.4.1. pH Meter. Use NIST traceable buffers-meters should be calibrated to pH 4.00 and pH 7.00. Calibration should be checked, first by reading the pH 4.00 and pH 7.00 buffers, then by reading the lower ionic strength pH 4.00 QCC solution (see Figure 1).

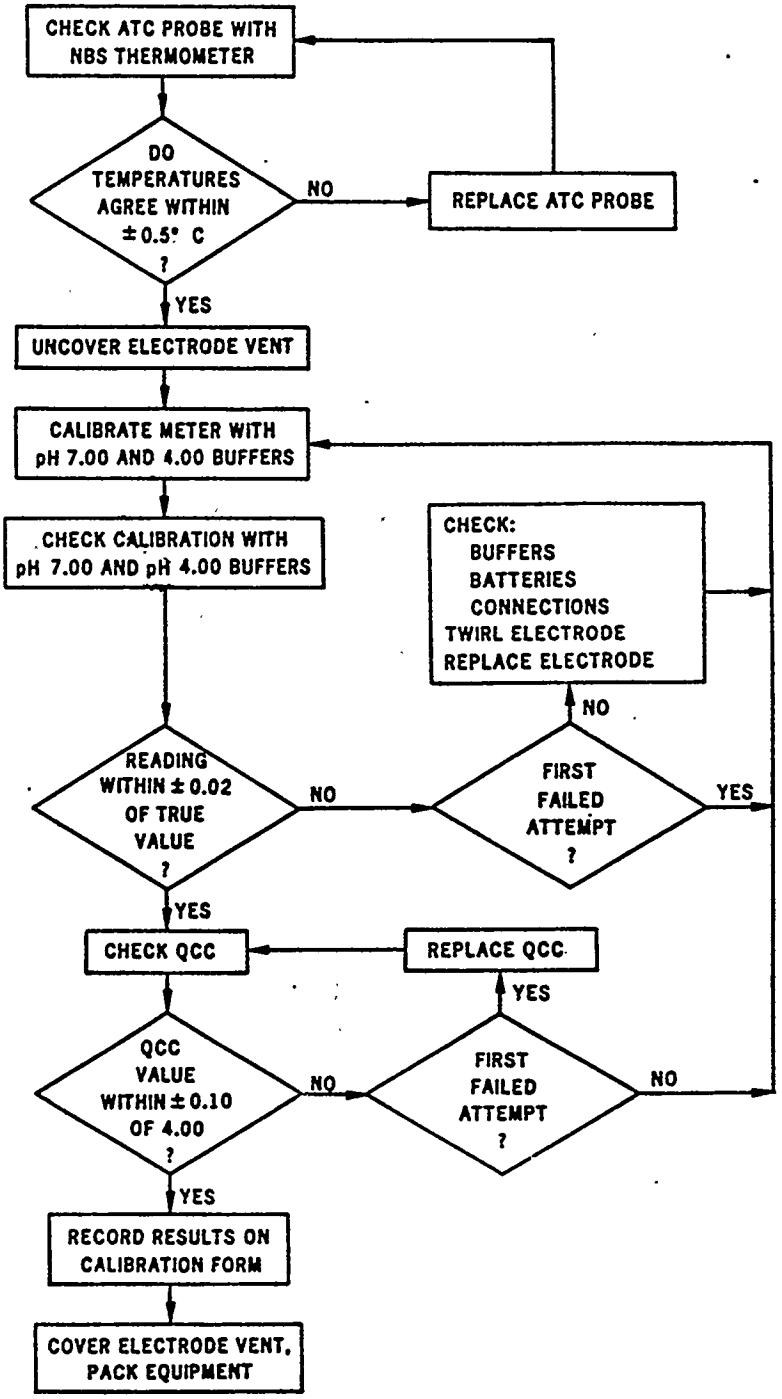

Figure 1. Flowchart for pH meter calibration.

Time for equilibration of the pH electrode varies depending on the ionic strength of the solution being measured. The criterion for a stable reading is no change of more than 0.01 pH unit during a 60-s period. All measurements of pH during calibration, calibration checks, quality control (QC) checks, and sample measurement use this criterion for a stable reading.

The pH meter switches off automatically after a period during which no buttons are pressed. If the display switches off, press the "pH" key to restart the display.

2.1.4.2 ATC Probe Check.

1. Immerse the electrode, ATC probe, and NIST-traceable thermometer into the rinse beaker of pH 7.00 buffer.

2. Press the "pH" key and read the temperature on the display. The two temperature readings should agree to within 0.5°C.

3. If they do not agree, stir the solution and check the temperature again after a short pause for equilibration.

4. If they still do not agree, either the ATC probe or the meter is malfunctioning. Replace the ATC sensor and check the temperature again.

5. If this does not result in agreement with the NIST-traceable thermometer, refer to the instrument manual for troubleshooting guidance.

2.1.4.3 NIST-Traceable Buffers.

NOTE: The "Auto-lock" key on the pH meter is used only during standardization, and then only after a stable reading is attained. All measurements of samples, calibration checks, and QC checks must be made with the "Auto-lock" OFF.

NOTE: In the field, buffer solutions are carried in two 125-mL bottles. To avoid cross-contamination, clearly mark "rinse" on one bottle and its cap. Mark "test" on the other bottle. Use 250-mL plastic beakers for initial standardization. These beakers should also be clearly marked "rinse" and "test".

1. Press the "Clear" key on the pH meter.

2. Rinse the electrode and probe with deionized water and immerse the electrode and ATC probe in the "rinse" beaker of pH 7.00 buffer.

3. Gently swirl the electrode and ATC probe in the buffer for 30 s.

4. Move the electrode and ATC probe to the "test" beaker of the same buffer. Do not swirl.

5. Press the "Standard" key.

6. Turn the "Auto-lock" feature OFF.

7. Observe the pH display. When the display is stable (see second paragraph of Section 2.1.4.1) for 60 s, turn "Auto-lock" ON. When the reading locks, the standard has been stored in memory.

8. Rinse the electrode and ATC probe in deionized water.

9. Place the electrode and ATC probe in the rinse beaker of pH 4.00 buffer.

10. Repeat Steps 3-8 above.

11. Complete a Quality Assessment/Quality Control (QA/QC) calibration (Section 2.1.6.1) and pH (Section 2.1.6.2) check before going to the field.

2.1.4.4 Field QC Check.

NOTE: Performed in the field before sampling. Leave the "Auto-lock" OFF during this entire procedure.

1. Check the connection of the electrode and ATC probe. Twirl the electrode gently to remove bubbles. Remove the KCl-filled storage cap and lower the collar on the reference solution fill hole.

2. Rinse the electrode with deionized water.

3. Conduct an initial QC check by using pH 4.00 QCC solution. If the QC check is unacceptable, recalibrate, then recheck the QC. If it is still unacceptable, calibrate and use the spare electrode. If the spare electrode will not meet standards, the data must be qualified.

4. Rinse the electrode and ATC probe with deionized water.

5. Record QCC pH and temperature readings in the field logbook. Also record the pH reading.

2.1.5 Field Sample pH Measurement

1. Perform initial field QCC (see Section 2.1.4.4).

2. After purging the tubing and rinsing the beaker three times, pump a 150-200-mL sample of stream water into a 250-mL beaker.

3. Press the "pH" key and swirl the electrode and ATC probe in the sample for 3 min.

4. Collect a fresh sample and transfer the electrode and ATC probe. Let it sit, unswirled, for 2 min, then begin watching for a stable reading ($\pm$0.01 pH units for one minute). Record the pH, temperature and time required for stabilization.

5. Remove the electrode and ATC probe in such a way as to prevent them from touching the ground or other surfaces and discard the sample. Collect a fresh 150-mL sample.

6. Immerse the electrode and ATC probe in a fresh sample. When the reading is stable, record the pH, temperature, and time required for stabilization.

7. Repeat Steps 4 and 5 until two successive pH readings agree within 0.03 pH units. The first reading is not used for successive comparisons, thus, there are at least 3 sample readings and stabilization times recorded. Record final pH and temperature readings.

8. If a duplicate sample is to be taken at this site, repeat Steps 1-6. Record duplicate pH and temperature readings.

NOTE: See Figure 2, flow chart for field sample pH measurement.

2.1.6 Quality Assurance and Quality Control

2.1.6.1 Calibration Check. A calibration check should be conducted immediately following the initial calibration to verify the accuracy of the calibration values stored in the memory.

NOTE: Turn "Auto-Lock" OFF during this entire procedure.

1. Swirl the electrode and ATC probe in the "rinse" beaker of pH 7.00 buffer for 30 s.

2. Move to the "test" beaker. Do not swirl.

3. Press the "pH" key on the meter and observe the pH display. When the reading is stable for 60 s, record the pH and temperature.

NOTE: If recalibrating in the field, record the pH and temperature.

4. If the displayed reading differs from the theoretical value at the measured temperature (see Table 1) by greater than 0.02 pH units, recalibrate using both buffers.

5. Rinse the electrode and ATC probe in deionized water and proceed.

6. Repeat Steps 1-5 for the pH 4.00 buffer.

2.1.6.2 pH QC Check.

NOTE: This procedure can be conducted immediately following a successful initial calibration check to ensure the accuracy of the calibration for relatively low ionic strength, unbuffered solutions.

NOTE: QC solution has a theoretical pH of 4.00 at 25°C (see Section 2.1.2).

NOTE: Beakers marked "QCC solution rinse" and "QCC solution standard" are used for calibrations.

NOTE: Leave the "Auto-lock" OFF during this entire procedure.

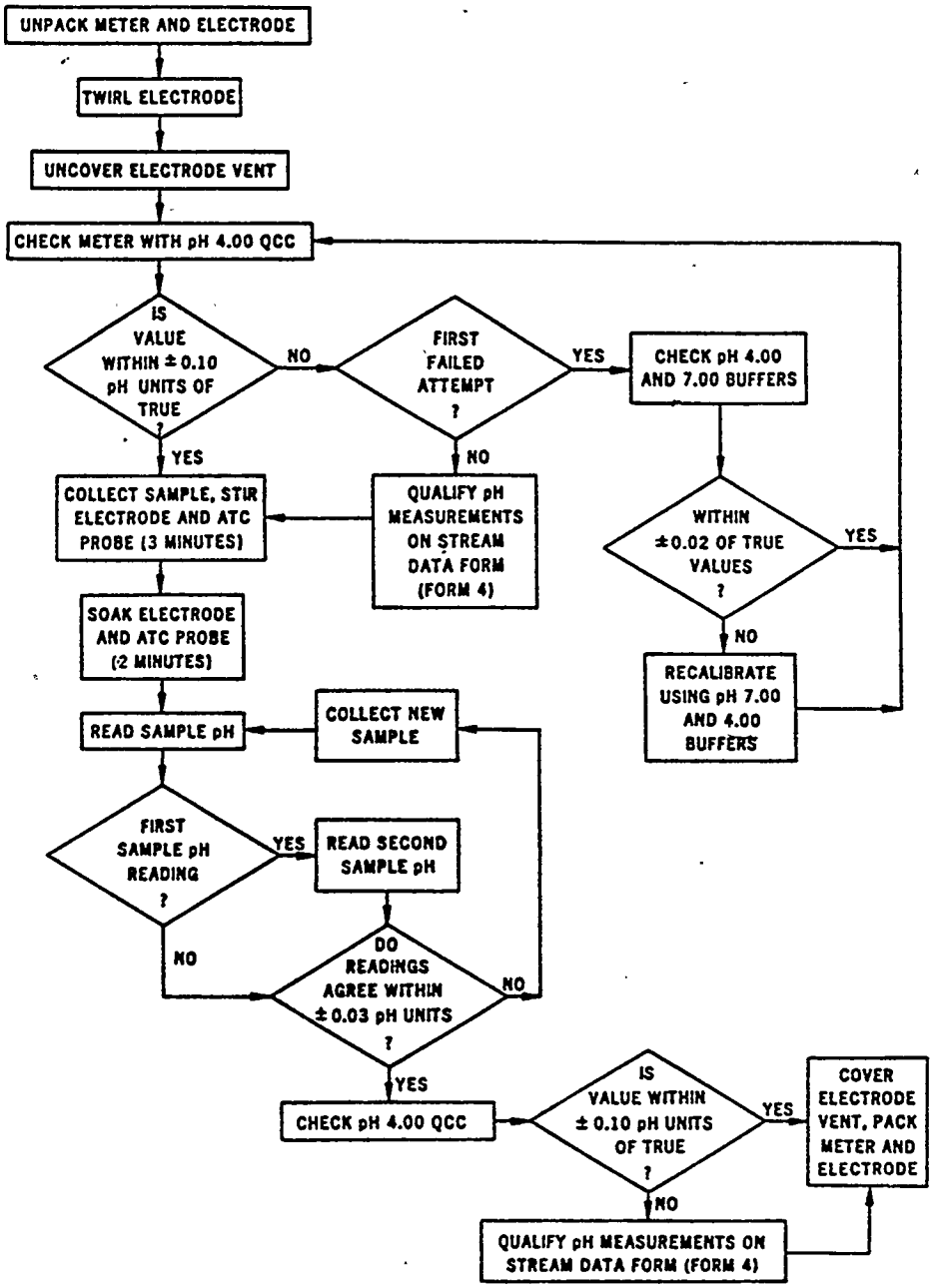

Figure 2. Flowchart for field sample pH measurement.

Table 1. Temperature correction factors for pH buffers[a]

Temp. °C	pH 4.00 Buffer	pH 7.00 Buffer	pH 10.00 Buffer	Temp. °C	pH 4.00 Buffer	pH 7.00 Buffer	pH 10.00 Buffer
0	4.01	7.12	10.34	30	4.01	6.99	9.94
5	4.01	7.09	10.26	35	4.02	6.98	9.90
10	4.00	7.06	10.19	40	4.03	6.98	9.85
15	4.00	7.04	10.12	45	4.04	6.97	9.78
20	4.00	7.02	10.06	50	4.06	6.97	9.70
25	4.00	7.00	10.00				

a. Values given are for pH 4 reference buffer solution (NIST-Traceable, SRM 185e) and pH 7 reference buffer solution (NIST-Traceable, SRM 186-1 and 186-11-c), prepared by American Scientific Products, McGaw Park, IL 60085 (Source: EPA 1989)

1. Swirl the electrode and ATC probe in the "QCC solution rinse" beaker for 3 min.

2. Move to the "QCC solution test" beaker. Do not swirl.

3. Press the "pH" key on the meter.

4. Observe the pH display. Wait two min, then begin timing the stability of the reading. When the reading is stable for 60 s ($\pm$0.01 pH units), record the pH and temperature.

5. If the displayed reading differs from pH 4.00 by greater than 0.10 pH units, rinse the probe and check again with a fresh beaker of QCC solution.

6. If the value is still unacceptable, prepare a fresh QCC solution and begin again.

7. If the value is still unacceptable, clear and recalibrate using both buffers.

8. When an acceptable QCC solution value has been obtained, push the "OFF" key on the meter and pack for transport.

   NOTE: Calibration data are retained by the meter. Do not press the "Clear" key or calibration data will be erased. To restart pH measurements when the instrument is off, press the "pH" key.

2.1.7 Maintenance

1. The meter should be sealed in a plastic bag containing a desiccant package (e.g., silica gel). The bag should be placed in a second sealable plastic bag for transport.

2. The meter should be stored so as to minimize physical shock during transport.

3. Avoid exposing the meter and electrodes to extremes of temperature or to direct sunlight.

4. Electrodes should be kept upright as much as possible, especially during transport.

5. The electrode and ATC probe should be carried wrapped in a plastic bag.

6. Keep the electrode filled with 3 mol KCl.

7. Always carry a spare electrode which is known to be fully functional.

8. If the meter will not standardize using a specific electrode, the following procedure is recommended:

   a. Carefully drain the filling solution from the outer chamber of the electrode through the vent using a syringe equipped with a small diameter tube.
   b. Using the syringe, the small diameter tubing, and deionized water, rinse and then drain the chamber thoroughly.
   c. Rinse the chamber by filling, agitating, and draining it with fresh 3 mol KCl through the vent.

9. It the electrode response does not improve after completion of Step 8, electrode etching is recommended. Electrodes should be returned to the laboratory for etching. If this is not possible, they may be etched in the field by using the following process:

   a. Drain the filling solution from the electrodes.
   b. Rinse the filling chambers with deionized water and drain.
   c. Refill with deionized water.
   d. Prepare a 50% NaOH solution by slowly adding 30 g NaOH to 30 mL deionized water.
   e. Stir the solution with the electrodes to dissolve the NaOH.
   f. Stir the solution another 2 min with the electrodes.
   g. Rinse the electrodes with deionized water.
   h. Rinse the electrodes in pH 7.00 buffer for 2 min.
   i. Drain the deionized water from the filling chamber.
   j. Refill with 3 mol KCl, agitate the electrodes and drain.
   k. Refill with 3 mol KCl, and twirl the electrodes overhead by their leaders to remove bubbles.

NOTE: Etch electrodes in groups of three. Prepare a fresh NaOH solution for each group of electrodes.

CAUTION: NaOH is extremely caustic. The solution is exothermic and the solution will become very hot. Prepare the etching solution in a well ventilated area. Avoid breathing the fumes, and exercise extreme caution.

3. DISSOLVED OXYGEN

3.1 General Procedures

Dissolved oxygen (DO) is a measure of the amount of oxygen concentration dissolved in solution. In natural waters, concentrations of oxygen are essential for survival of most aquatic organisms. Measures of DO and temperature are used to assess water quality and the potential for healthy aerobic organism populations.

3.1.1 Scope and Application Summary

Moving waters are generally considered essential for accurate DO determinations. For this reason, stream water measurements are usually taken in situ. Measurements of DO from beakers, biological oxygen demand (BOD) bottles, or lake strata can be accomplished with various probe attachments and/or manual stirring procedures. Portable DO meters are commonly used in stream studies. The DO measurement method described here for illustrative purposes utilizes the Yellow Springs Instrument Co. (YSI) Model 54A oxygen meter and Model S739 dissolved oxygen and temperature probes. The method can also be modified and used for other instrumentation meeting equivalent specifications. The method is not limited to lotic systems. In situ DO measurements in lake waters can be taken with minor changes in the procedure. Refer to operations manual for modification.

The applicable range of measurements taken with the YSI DO meter is 9-20 mg/L (ppm O_2) (YSI, 1980). Because calibration is relatively simple, the meter can be calibrated at the sampling site.

It is recommended that the DO meter and probe be air calibrated prior to field activities, on-site, and upon return. After each calibration, the quality of DO and temperature measurements is determined by comparing readings to theoretical concentrations of air saturated deionized water. At the sampling site, the meter is recalibrated at ambient temperatures. The probe is placed into the stream and the DO values are displayed on the meter analog readout. DO readings are adjusted to compensate for temperature and pressure (depth).

Sources of potential error in DO determinations include low battery voltage, changing instrument position after on-site calibration, lack of water flow across the membrane, loss of probe membrane integrity (bacterial colonization or punctures), improper calibration, storage of probe in deionized water, and poor membrane replacement techniques. Proper measurement and maintenance procedures should alleviate these problems.

Natural surface waters contain gases which may contaminate and tarnish the gold cathode, causing erroneous measurements. If the probe is used for long periods with a loose fitting membrane, silver may plate the cathode. These buildups can interfere with the operation of the sensor and should be removed according to the manufacturer's instructions (YSI, 1980).

3.1.2 Equipment and Supplies

YSI model 54A portable meter or equivalent
YSI model 4739 probe with cable or equivalent

Meter operation manual
NIST-traceable thermometer
Probe calibration chamber
1-gallon plastic bottle
3-gallon bucket
Aquarium pump, air stone, and air tubing
Calculator
Watch
Replacement membranes
Probe electrolyte
Tap water
Field logbooks

3.1.3 Meter and Electrode Preparation

The DO meter is prepared for use prior to calibration and conducting on-site measurements. The probe is always stored in tap water between uses. Stream water may be used, but should be replaced with tap water when available. If the instrument is subjected to physical shock, repeat the following preparation process:

1. Adjust the zero, using the screw on the meter face with the selector switch in "OFF" position.

2. Turn the selector to "REDLINE". Adjust the "REDLINE" knob to align the needle with the red line on the meter panel.

3. Turn the selector to "ZERO". Adjust the needle to the "0" value with the "ZERO" control knob.

4. Check the membrane on the probe for air bubbles.

3.1.4 Calibration

Zero and redline adjustments to the meter should be made prior to calibration and field measurements as noted in Section 3.1.3. Perform calibration prior to departure for the field site(s), prior to sample measurement, and again upon return to the Service lands. All DO readings and calculated intermediate values should be recorded. Calibration procedures utilize temperature and altitude to calculate theoretical DO in water-saturated air.

1. Attach the moist air calibration chamber to the probe, release and clamp, and immerse the probe in a water bath (bucket or stream). Turn the meter to "REDLINE." Equilibrate the probe for 15 minutes.

2. Turn the selector switch to "TEMP", read the temperature of the chamber, and determine the saturation value from Table 2 and on the back of meter.

3. Multiply the saturation value by the altitude correction factor (Table 3 and on back of meter) to obtain a theoretical calibration value.

Table 2. Solubility of oxygen in fresh water at zero chlorinity

Temp °C	DO (mg/L)	Temp. °C	DO (mg/L)	Temp. °C	DO (mg/L)	Temp. °C	DO (mg/L)
0	14.62	8	11.84	16	9.87	24	8.42
1	14.22	9	11.58	17	9.66	25	8.26
2	13.83	10	11.29	18	9.47	26	8.11
3	13.46	11	11.03	19	9.28	27	7.97
4	13.11	12	10.78	20	9.09	28	7.83
5	12.77	13	10.54	21	8.91	29	7.69
6	12.45	14	10.31	22	8.74	30	7.56
7	12.14	15	10.08	23	8.58	31	7.43

From Standard Methods for the Examination of Water and Wastewater. 16th Edition, p.413 (American Public Health Association).

Table 3. Altitude correction factors for dissolved oxygen measurements.

Atmospheric Pressure (mmHg)	Equivalent Altitude (ft)	Equivalent Altitude (m)	Correction Factor	Atmospheric Pressure (mmHg)	Equivalent Altitude (ft)	Equivalent Altitude (m)	Correction Factor
775	-540	-165	1.02	638	4756	1450	0.84
760	0	0	1.00	623	5403	1647	0.82
745	542	165	0.98	608	6065	1849	0.80
730	1094	333	0.96	593	6744	2056	0.78
714	1388	423	0.94	578	7440	2268	0.76
699	2274	693	0.92	562	8204	2500	0.74
684	2864	873	0.90	547	8939	2725	0.72
669	3466	1056	0.88	532	8694	2955	0.70
654	4082	1244	0.86	517	10472	3192	0.68

4. Turn the selector switch to the appropriate range position.

5. Adjust the "CALIBRATE" knob until the meter reads the theoretical calibration value determined in Step 3 above. Allow two minutes to verify the stability of the reading. Readjust if necessary.

6. Perform calibration check as described in Section 3.1.6.1.

NOTE: Calibration can be disturbed by physical shock, touching the membrane, or drying out of the electrolyte.

Prior to on-site measurements, the meter should be recalibrated. The probe is placed into the calibration chamber (water removed), sealed and placed into the stream for equilibration.

NOTE: See flowchart diagram for dissolved oxygen meter calibration (Figure 3).

3.1.5 Field Sample DO Measurement

The probe end should be protected by the screw cap and fully submerged in the water. The membrane end should not come in contact with the bottom, although the probe may lay on its side, with the end elevated off the substrate. See Figure 4 for DO field measurement flowchart.

1. Calibrate the meter using the air calibration procedure (Section 3.1.4).

2. Attach the probe to the sampling boom.

3. Immerse the probe in flowing stream water at selected sampling depth.

4. Turn selector to "TEMP". Allow the reading to stabilize. Record water temperature.

5. Turn the selector to the appropriate DO range. Allow the reading to stabilize. Record the DO reading.

3.1.6 Quality Assurance and Quality Control

3.1.6.1 Calibration Check. This QCC is conducted after calibration at the Service lands, both before and following field activities. The QCC consists of comparing calibrated meter readings to the calculated DO of air-saturated deionized water, based on temperature and altitude. If measurements do not fall within limits for a QCC, recalibrate the meter (before field use) or qualify field DO measurements. If the meter cannot be calibrated so that it meets the QCC and a backup meter is not available, either qualify field data collected with the meter or correct the problem as described in Section 3.1.7.

NOTE: Also refer to operator's manual.

1. Air-saturate a bucket of deionized water by bubbling air through the water with an aquarium pump and air stone for a minimum of one hour (preferably several hours).

   NOTE: Avoid large changes in ambient temperature during saturation.

2. Place the probe in the sample and stir gently. Set the selector to "TEMP," read the temperature of the bath, and determine the saturation value from the O_2 solubility table (Table 2 and on back of meter).

3. Check the temperature reading using the following procedure:

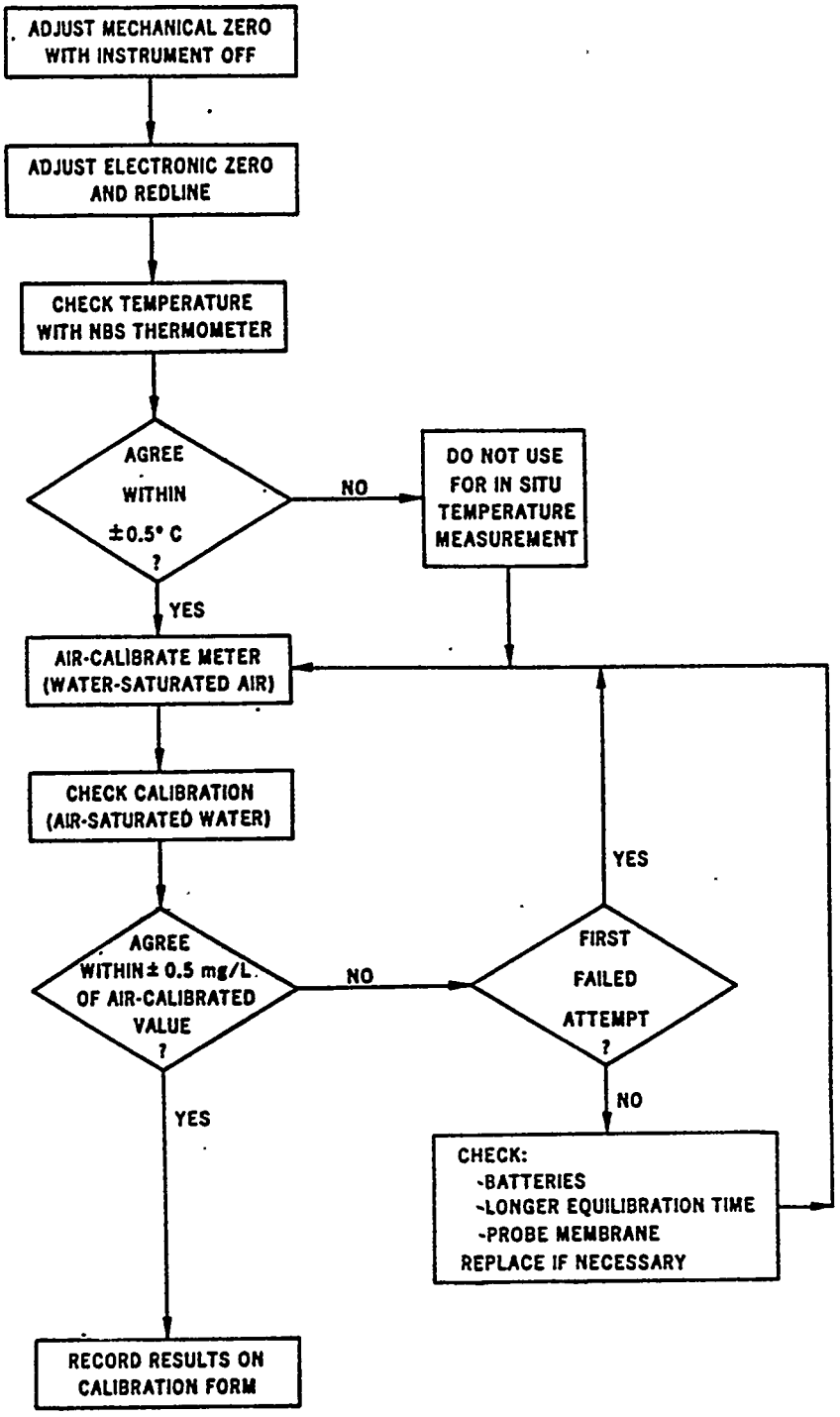

Figure 3. Flowchart for dissolved oxygen meter calibration.

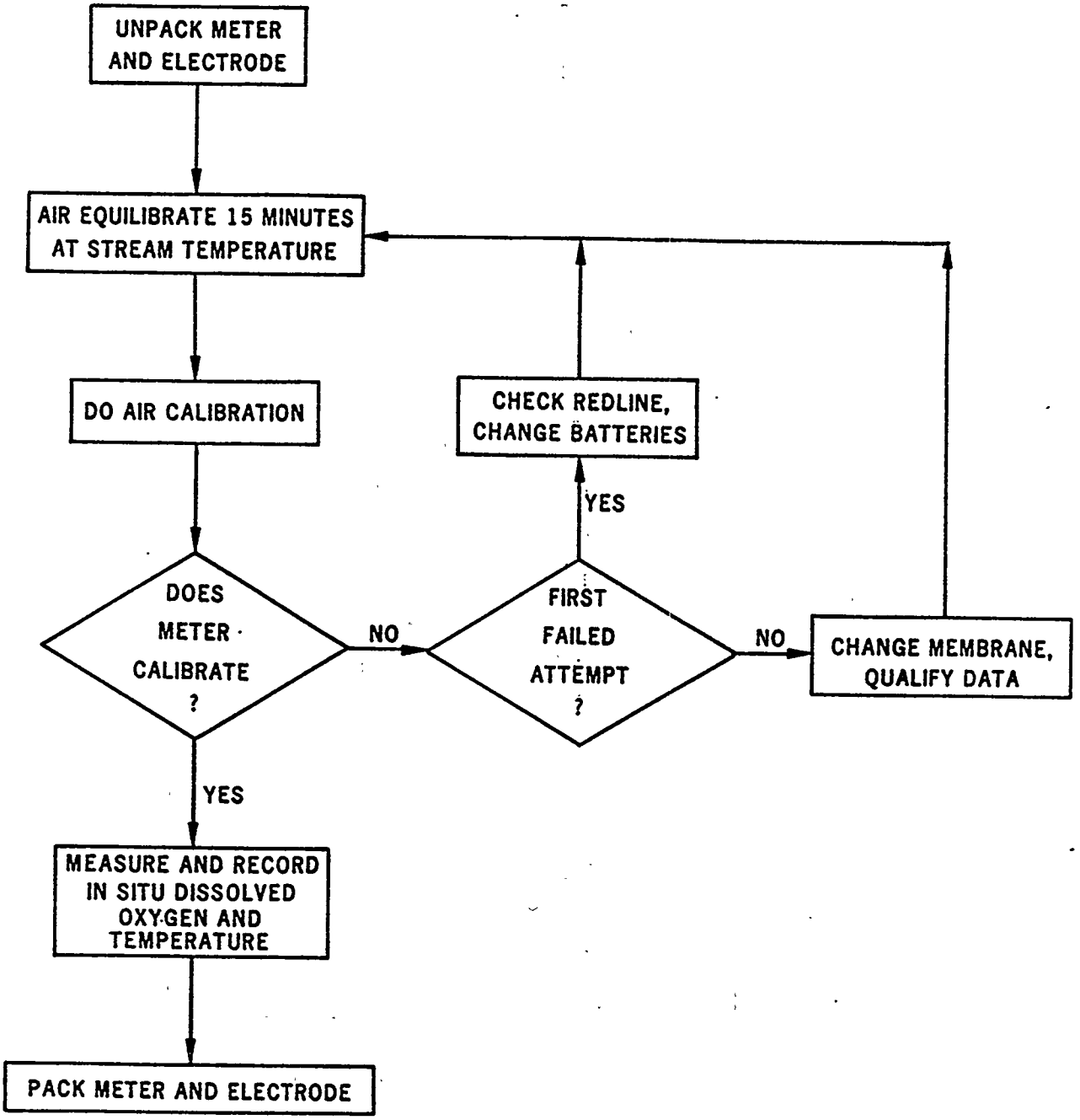

Figure 4. Flowchart for field dissolved oxygen measurement.

a. Immerse the probe in a bucket of water.
b. Turn the selector knob to "TEMP." Check the real temperature on the meter against the temperature obtained by using an NIST-traceable thermometer. Readings should agree within 0.5°C.
c. If the readings do not agree within 0.5°C, do not use the probe to measure stream temperature. Instead, use a conductivity meter or an alternate method. This method should be recorded.

4. Determine the local altitude from a topographic map or obtain atmospheric pressure from a mercury barometer. Determine the atmospheric correction factor (Table 3 and on back of meter).

5. Multiply the saturation value by the atmospheric correction factor to obtain the theoretical dissolved oxygen concentration of the water.

6. Turn the selector to the appropriate DO range and take the DO reading while stirring the probe in the bucket. Calculate the difference between the calculated theoretical value and the measured values. The measured readings should be within ± 0.5 mg/L O_2 of the calculated value. Record values.

   a. If the reading is outside the acceptance limits, recalibrate with water-saturated air (Section 3.1.4) and repeat this calibration check.

   b. If the reading is still not acceptable, check the probe and meter for malfunction.

3.1.7 Maintenance

Refer to the instrument manual for membrane replacement instructions.

1. Replace the membrane and electrolyte (or entire probe) if erratic readings are observed, if calibration is not stable, if bubbles form under the membrane, or if bacterial growth is observed on the membrane. Note especially the instructions concerning the pressure compensation diaphragm and removal of hidden bubbles.

2. If calibration is unstable after membrane replacement, let the membrane equilibrate for 24 hours. If the meter must be used during this period, data may have to be qualified with a comment such as "new membrane installed at site."

3. Check the meter and meter case frequently for moisture. The meter must be kept dry. Open the meter back and allow it to dry overnight if the meter is moist.

4. SPECIFIC CONDUCTANCE

4.1 General Procedures

Conductivity, as related to water analysis, is a measurement of water's capacity for conveying electrical current and is directly related to the concentration of ionized substances in the water. It is a measure which often can be linearly correlated with the ionic strength of a solution. Specific conductance can also be used to generate a synthetic ionic balance of a solution. This balance can be used as a check of measured cation and anion concentrations. A number of considerations should be given to ensure sample integrity when collecting samples and making conductivity measurements. For example, if measuring very low levels of conductivity, it may be necessary to protect the sample(s) from atmospheric gases such as carbon dioxide or ammonia.

4.1.1 Scope and Application Summary

The method described for illustrative purposes is applicable for determining specific conductance in samples of water of low ionic strength. This method utilizes a Yellow Springs Instrument Co. (YSI) Model 33 S-C-T meter and Model 3310 conductivity/temperature probes to measure specific conductance.

Moving water potential is generally not a problem during conductivity measurements. For this reason, water measurements usually are taken in situ, but also may be obtained from open beakers. Portable conductivity meters are most commonly used. This method can be modified and used with other instrumentation that meets equipment specifications. The applicable range of measurements taken with this YSI unit is 2.5 to 50,000 MS/cm (μmhos/cm at 25°C) The meter and probe are calibrated at the factory. The quality of specific conductance and temperature measurements is determined with low-range, mid-range, and high-range QCC solutions prior to sampling. There is no true meter calibration for this method. At the sampling site, the meter is checked against a single, low-range QCC solution. A probe is placed into the stream and conductance values are displayed on the meter's analog readout. Conductance readings are not temperature compensated. All values are adjusted (based on sample temperature and a correction table) to specific conductance at a reference temperature of 25°C.

Temperature variations represent the major source of potential error in specific conductance determinations. To minimize this error, meter quality control checks are conducted under controlled temperatures, readings are adjusted relative to 25°C, and temperature measurements are checked against an NIST-traceable thermometer.

Natural surface waters contain substances (oils, humic and fulvic acids, suspended solids) that may build up on metal surfaces of the conductivity probe. Such a buildup interferes with the operation of the electrode and should be removed periodically, following the manufacturer's instructions.

Measurements with the conductivity/temperature probe can be affected by objects in close proximity. The manufacturer recommends that metal and nonmetal materials (including the stream or lake bottom) be kept at least 6 and 2 inches, respectively, away from the probe during all readings.

Generally, conductance is determined in situ, therefore sample collection, preservation and storage are not applicable. Water samples may be collected from streams and lakes with a peristaltic pump and Tygon tubing. A water volume of at least 200 mL is required to measure specific conductance in a beaker. After the meter is prepared, the probe is placed into the sample, and electronic and thermal equilibria are established. Measurements are then taken.

4.1.2 Equipment and Supplies

- YSI model 33 S-C-T portable meter, or equivalent
- YSI model 3310 probe with cable, or equivalent
- Meter operation manual
- NIST-traceable thermometer
- Two 250-mL bottles for field rinse and test QCC (74 μS/cm) solutions
- Wash bottle (1L)
- Field logbook
- Six 250-mL disposable beakers for rinse at test QCC (74, 174 and 718 μS/cm) solutions
- Deionized water (used in all preparations) should conform to ASTM specifications for Type 1 reagent grade water (ASTM, 1984)
- 74 μS/cm specific conductance calibration check solution (0.0005 N KCl)--0.5 mL of 1 N KCl diluted to 1 L with deionized water
- 147 μS/cm specific conductance calibration check solution (0.001 N KCl)--1 mL of 1 N KCl diluted to 1 L with deionized water
- 718 μS/cm specific conductance calibration check solution (0.005 N KCl)--5 mL of 1 N KCl diluted to 1 L with deionized water

4.1.3 Meter and Electrode Preparation

Following meter preparation, if the instrument is subjected to physical shock, repeat preparation process. Note that the probe should always be stored in deionized water between uses.

1. Check probes for outward signs of fouling. Do not touch the electrodes inside the probe with any object.

2. Plug the probe securely into the instrument jack.

3. Adjust the meter to "ZERO" with the set screw on the meter face so the needle coincides with "0" on the scale.

4. Turn the mode control to "REDLINE." Adjust the redline control so that the needle will line up with the red line on the meter scale. If alignment cannot be achieved, replace the batteries.

4.1.4 Calibration

Because the YSI conductivity meter is calibrated at the factory, temperature and specific conductance measurements can only be compared to known standards to determine accuracy. This is really a QCC and is termed meter calibration check. It should not be confused with true calibration

procedures. Meter zero and redline adjustments are made, but they do not relate to any standard or known solution values.

Perform initial temperature and calibration checks prior to departure to the sampling site(s) (if possible). All specific conductance readings should be recorded. This documentation procedure will ensure that both temperature-uncompensated and temperature-compensated specific conductance values will be recorded. This practice reduces the probability of calculation errors resulting in unrecoverable losses of data. Temperature correction factors (at 25°C) used for calculation of theoretical specific conductance values are listed in Table 4. Refer to Figure 5, flowchart for conductivity meter calibration.

When making measurements, the entire electrode and thermistor (located on top of the electrode) should be fully submerged, but the electrode should not rest on the bottom of the beaker or stream channel.

Table 4. Factors for Converting Specific Conductance of Water to Values at 25°C (Based on 0.1 N KCl AND 0.01 N NaNO3 Solutions)*

Temp °C	Factor	Temp °C	Factor	Temp °C	Factor	Temp °C	Factor	Temp °C	Factor
3	1.62	9	1.39	15	1.21	21	1.08	27	0.97
4	1.58	10	1.38	16	1.19	22	1.06	28	0.95
5	1.54	11	1.33	17	1.16	23	1.04	29	0.93
6	1.50	12	1.30	18	1.14	24	1.02	30	0.92
7	1.46	13	1.27	19	1.12	25	1.00	31	0.90
8	1.42	14	1.24	20	1.10	26	0.98	32	0.89

* Wetzel, R. G. and G. E. Likens, 1979. Limnological Analyses. W. B. Saunders Co., Philadelphia

4.1.4.1 Temperature Check.

1. Rinse the probe and NIST-traceable thermometer with deionized water before and after submersion in QCC solutions.

2. Immerse the probe in the rinse beaker of the 74 μS/cm standard. Be certain that the thermistor is fully submerged.

3. Set the mode switch to "TEMP".

4. Compare the meter reading with that obtained by using an NIST-traceable thermometer. The readings should agree within 0.5°C of each other. Record values.

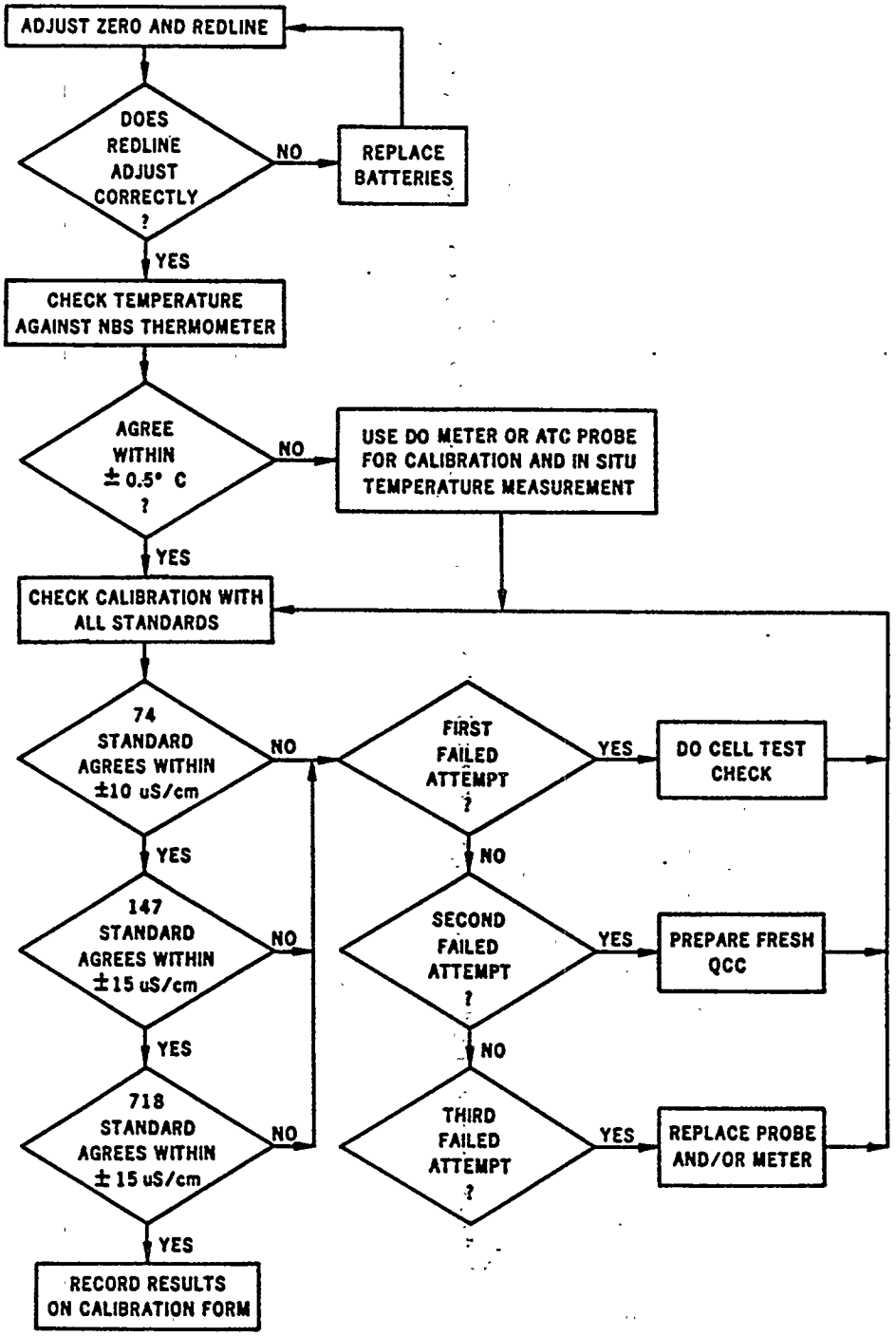

Figure 5. Flowchart for conductivity meter calibration.

5. If temperature readings do not agree, do not use the conductivity probe to measure QCC solution temperatures or in situ temperature at the sample site. Use an alternate method for temperature measurements. Make note of this change in field logbook.

4.1.4.2 Calibration Check. The initial calibration check consists of comparing specific conductance values of the three QCC solutions to theoretical values that have been corrected for temperature. If measurements do not fall within prescribed limits for each QCC solution, compare the meter values to another meter and probe if possible. If readings are unacceptable with the second meter, replace check solutions and check again. If readings for the two meters are still unacceptable, troubleshoot one or both as described in Section 4.1.7.2.

1. Rinse the probe with deionized water.

2. Immerse the probe in the rinse beaker containing 74 μS/cm QCC solution. Agitate the probe slightly. Remove the probe from the rinse beaker.

3. Immerse the probe in the standard beaker containing fresh solution. Determine the temperature and record. Set the mode selector to the "X1" scale.

4. Read the conductivity and record it as uncompensated conductivity in the field logbook. Calculate the temperature-compensated specific conductance and record. The temperature compensated value should be 74 μS/cm $\pm$ 7 μS/cm.

5. Repeat Steps 1-4, using the 147 μS/cm specific conductance standard solution. The temperature corrected value should be 147 μS/cm $\pm$ 15 μS/cm.

6. Repeat Steps 1-4, using the 718 μS/cm specific conductance standard solution. The temperature corrected value should be 718 μS/cm $\pm$ 72 μS/cm.

4.1.5 Field Sample Specific Conductance Measurement

The probe should be fully submerged in the stream/lake water and should not contact the bottom. Note, in coastal areas some fresh water sampling sites may be influenced by tidal influences. If this occurs, see operators manual for guidance.

Refer to Figure 6, flowchart for field sample specific conductance measurement.

1. Perform initial field QCC (see Section 4.1.6.1).

2. Immerse the probe in the flowing portion of the stream, downstream from the pump intake tubing.

NOTE: The probe should be fully immersed in the stream flow but should not be touching bottom. This can be accomplished by placing it across the sampling boom.

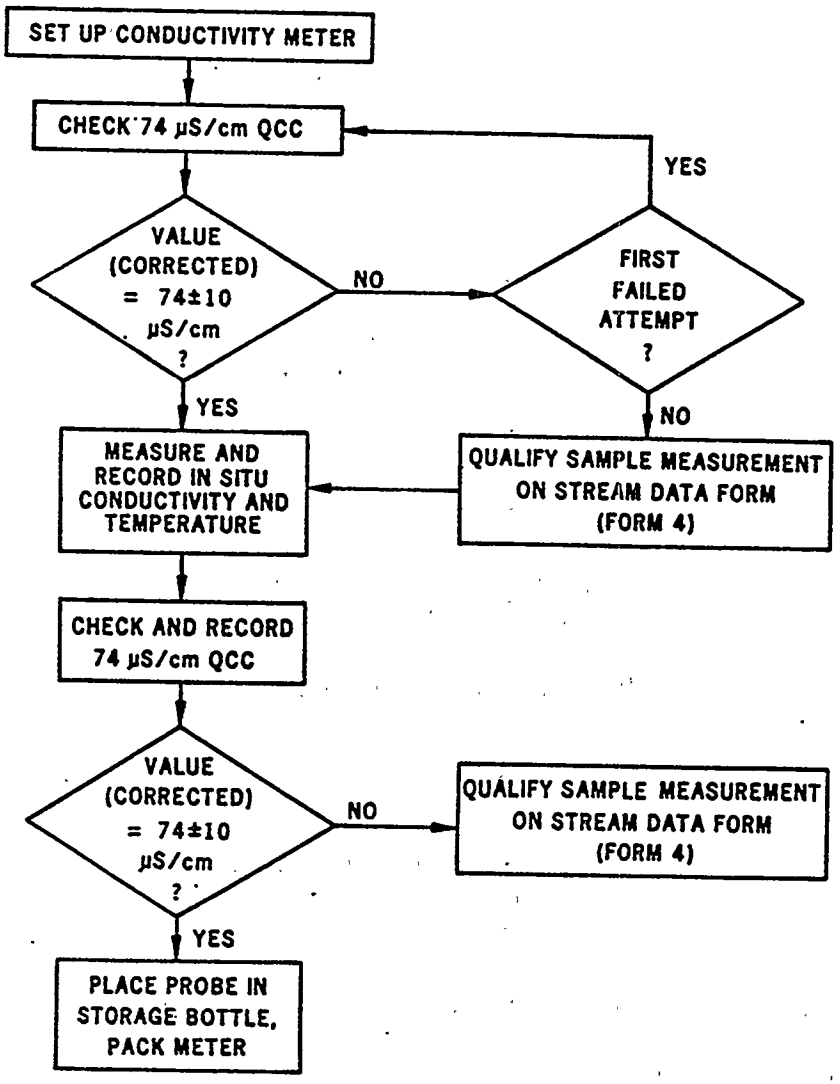

Figure 6. Flowchart for field sample specific conductance measurement.

3. Set "MODE" selector to "X1" scale and read specific conductance. Record the value on the field data form. Calculate the temperature compensated value, or, the conversion may be done at a later date.

4. Between sampling sites, perform an additional field QCC.

4.1.6 Quality Assurance and Quality Control

4.1.6.1 Field Quality Control Check. Perform the QCC at each sampling site before and after in situ specific conductance determinations. Record uncompensated and compensated QCC solution measurements.

1. Follow the procedure in Section 4.1.4.2, Steps 1-4 for Calibration Check, using the 74 μS/cm QCC solution carried into the field in two 250-mL plastic bottles, one labeled "rinse" and one labeled "test." Record uncompensated QCC solution conductivity and temperature values in the field logbook.

2. Calculate the compensated QCC solution specific conductance (see operation manual) and record.

   a. Compensated QCC solution reading must be 74 $\pm$ 10 μS/cm. If not, repeat QCC solution check.
   b. If an acceptable value is not obtained for the second QCC solution, proceed with the in situ determination and final QCC.
   c. If either the initial or the final QCC solution measurement does not fall within acceptable limits, qualify all specific conductance values in the field logbook associated with the unacceptable QCC solution value(s).

After returning from the field, if any QCC solution measurements made during site sampling operations were outside specified limits, repeat the calibration and QCC solution procedures (Section 4.1.4), perform maintenance, or troubleshoot the meter according to Section 4.1.7.2 and the manufacturer's operation manual.

4.1.7 Maintenance

4.1.7.1 Instrument. Refer to the instrument manual for probe cleaning instructions.

1. Store the probe in deionized water.

2. Before using a probe which has been stored dry, soak the probe in deionized water for 24 hours.

3. Always turn off the meter after use.

4. Keep the meter dry.

4.1.7.2 Troubleshooting. If acceptable QCC solution values are not obtained, replace the QCC solution. If required, troubleshoot the meter and probe as follows:

1. Rinse the probe well and recheck the solution.

2. Recheck "REDLINE" and replace the batteries, if necessary.

3. Using the 718 μS/cm with the meter set to the "X10" scale, press the "CELL TEST" button. If the reading falls more than two percent, the probe is fouled. Clean the probe according to the manufacturer's instructions.

4. If these measures do not remedy the problem, replace the meter or probe, or both. To determine whether it is the meter or the probe that is malfunctioning, switch probes with another meter for which acceptable QCC readings have been obtained. If values obtained are still unacceptable, the meter is malfunctioning. If acceptable readings are obtained, the original probe is malfunctioning.

5. If the meter will not meet QCC for the 147 or 718 μS/cm standards and if no replacement meter/probe is available, include this information in the field logbook.

5. TURBIDITY

5.1 General Procedures

Turbidity in most waters results from suspended clay, silt, finely divided organic and inorganic matter, plankton, and other microorganisms. Instruments that measure turbidity measure the optical property of a water sample which results from the scattering and absorbing of light by the particulate matter present. The amount of turbidity is dependent upon variables such as the size, shape and refractive indices of the particles. It must be noted that no direct relationship exists between the turbidity of a water sample and the weight concentration of the matter present. The clarity of a natural body of water can be an indicator of its condition and productivity.

5.1.1 Scope and Application Summary

Two turbidity measurement methods will be described for illustrative purposes. The first of these is the Monitek™ instrument Model 21 digital nephelometer, and the second is the Secchi Disk which is visually operated.

If possible, it is recommended that the nephelometric method be used instead of visual methods because of its greater precision and sensitivity. Determine turbidity on the day the sample is taken if possible. If storage is unavoidable, store samples in the dark for up to 24 hours. Do not store for long periods because irreversible changes in turbidity may occur. The nephelometer should be kept, and the samples analyzed at the refuge facility.

When using instrumentation such as the Monitek instrument, it is recommended that samples with less than 40 nephelometric turbidity units (NTU) be shaken to disperse the solids before being analyzed. After shaking, wait until air bubbles disappear before measurements are taken. Read the turbidity measurement directly from the instrument scale. For turbidity readings exceeding 200 NTU, dilute the sample with turbidity free water, shake and then analyze.

The Secchi Disk transparency measurement provides an in situ estimate of water clarity. This procedure requires no calibration and no quality assurance or quality control checks. Maintenance is limited to visual inspection for damage to the disk and calibrated line.

5.1.2 Equipment and Supplies

5.1.2.1 Nephelometer.

Monitek Model 21 digital nephelometer
Meter operation manual
Field logbook
Cuvette(s)
Parafilm
Kimwipes
Cubitainer (1 gallon)
Disposable gloves
Syringe and syringe filter

Standards

1. Standards recommended are AMCO turbidity standards with values of 5.0, 10.0 and 20.0 NTU (AMCO-AEPA-1) standard AMCO Polymetrics, 2696 Naven Avenue, Redwood City, California).

2. The 1.7 NTU standard supplied with the Monitek nephelometer can be used for daily checks. In addition, two linear calibration sets can be used to standardize the nephelometer over two ranges: 5, 10, and 20 NTU and 50, 100, 200 NTU.

NOTE: Standards must not be diluted.

Turbidity Free Water

Turbidity free water satisfactory for measuring turbidity as low as 0.02 NTU can be obtained by passing distilled water through a membrane filter having precision-sized holes of 0.2 μm. Rinse collecting flask at least twice with filtered water before using.
5.1.2.2 Secchi Disk.

Secchi Disk
Operation instructions
Calibrated line (refers to depth markings made against a standard tape measure)
Field logbook

5.1.3 Calibration

5.1.3.1 Nephelometer. The following calibration procedure is for the 0-200 NTU range.

1. Turn the instrument on and allow it to warm up for at least 15 minutes.

2. With the lamp on and cuvette well empty, set the range switch to 2 NTU.

3. Zero the instrument by adjusting the zero control knob. The display will read 0.00 with the minus sign flashing on and off.

4. Make an index mark on the top of a scratch-free cuvette and on the cuvette well of the instrument so that alignment is easily achieved.

5. Rinse the cuvette twice with 5 mL of the 10.0 NTU standard. Seal with parafilm and gently invert so that all the surfaces are contacted.

6. Fill the cuvette with approximately 25 mL of the 10.0 NTU standard. Dry the exterior with a Kimwipe, removing fingerprints, liquid, etc. Insert the cuvette and align the index marks.

7. Set the instrument on the 20 NTU range and adjust the "standardize" control knob so the instrument reads the true value of the standard printed on standard bottle (10.0 NTU).

8. Repeat Steps 4-6 for 1.7, 5.0, and 20.0 NTU standards. Record readings in field logbook. Measure the 1.7 and 5.0 NTU standards on range 20, and the 20 NTU standard on range 200.

9. It is recommended that the measured values be 1.7 $\pm$ 0.3, 5.0 $\pm$ 0.5, and 20.0 $\pm$ 2.0 NTU. If the measured values are unacceptable, repeat all steps.

NOTE: Be sure that the cuvettes are clean. Acceptable values must be obtained prior to sample analysis.

Routine Quality Control Check (0 to 20 NTU Range)

NOTE: If the number of samples in a batch is less than 16, measure a 5.0 NTU standard halfway through the batch. If the number of samples is greater than 16, measure a 5.0 NTU standard after every 8 samples. The standard must always be measured again after the last sample in a batch.

1. Using the 5.0 NTU standard, repeat Steps 4-6.

2. Record values in field logbook.

3. Measured value should be 5.0 $\pm$ 0.5 NTU. Record acceptable values in field logbook and continue with sample measurement.

If values are not acceptable, repeat Steps 1-9.

5.1.3.2 Secchi Disk. There are no special calibration requirements.

NOTE: The disk should be clean and a calibrated line must be used when making measurements.

5.1.4 Field Sample Turbidity Measurement

5.1.4.1 Nephelometer.

1. Collect sample(s) in a suitable container (e.g., cubitainer).

2. Store samples in a dark environment and transport to refuge facility.

3. At refuge facility, gently swirl sample container to evenly distribute any settled particles.

NOTE: Avoid rigorous agitation to minimize introduction of air bubbles which can interfere with measurement. Allow sample container to come to room temperature prior to turbidity measurement.

4. Wearing disposable gloves, rinse a cuvette with two 5-mL sample portions and discard rinses.

5. Cap sample container and swirl as described above. After swirling, immediately fill cuvette.

6. Wipe exterior of cuvette with Kimwipe, and place into nephelometer. Measure the turbidity on range 20. Record results in field logbook.

7. After 8 samples repeat routine QCC (0 to 20 NTU Range) measurement procedures. If it is within the control limits, record in logbook and continue sample analysis. If not, then recalibrate and reanalyze samples.

8. If sample readings are greater than 20 NTU, measure on range 200. Immediately analyze a standard with a concentration higher than the sample (50 or 100 NTU). If the observed value for the standard is not within $\pm 5\%$ of the actual value (100 ± 5) then recalibrate the instrument on range 200 using the 20, 50, and 100 NTU standards and remeasure the sample.

9. If a sample turbidity exceeds 200 NTU, dilute 1:10 and remeasure as in Step 8 above. A syringe equipped with a syringe filter may be used to obtain a portion of filtered sample.

10. Duplicate: one sample per batch (or 2 for every 10 samples) is analyzed in duplicate (2 cuvettes drawn from same sample container). Results should agree within 10% or reanalysis is recommended.

11. Record sample and standard results.

5.1.4.2 Secchi Disk.

NOTE: The sampler must not wear sunglasses. Photogray prescription lenses are permissible. Use of glasses should be noted. Disk operation should be performed in the shade, note if this is not possible.

1. Lower the Secchi Disk on a calibrated line until it disappears from view. Record the depth.

2. Raise the disk until it reappears, record the depth.

3. The average of these depths is the Secchi Disk transparency.

5.1.5 Maintenance

1. Follow manufacturer's instructions for nephelometer care.

2. Clean cuvettes by rinsing with deionized water. Make sure cuvettes are clean and free of fingerprints, smudges, etc. Avoid handling cuvettes in region of light path. Do not handle cuvettes unless wearing gloves. Optical comparability of cuvettes can be made by comparing nephelometer readings using 10 NTU standard. Cuvettes are considered equivalent if readings differ by less than 0.2 NTU's.

6. TEMPERATURE

6.1 General Procedures

Temperature measurements are commonly used during calculation of alkalinity and pH, in studies of saturation and stability with respect to calcium carbonate, and in the calculation of salinity. Elevated temperatures resulting from discharges of heated water may have significant ecological impact.

Temperature measurements can be made with thermistors, or with any good mercury-filled Celsius thermometer. As a minimum, a thermometer should have a scale marked for every 0.1°C with markings etched on the capillary glass. Thermometers should have a minimal thermal capacity to permit rapid equilibration. For field use, thermometers with metal cases are recommended.

6.2 Temperature Determination

Inspect thermometer before each sampling episode to ensure that there are neither cracks in the glass, nor air spaces or bubbles in the mercury. If a dial-type thermometer is used, the face cover must not be broken or damaged. All thermometers should be initially calibrated against an NIST-certified thermometer, and then cross-checked against a calibrated NIST-certified thermometer at least quarterly. Calibrate thermistors and electronic readout units in the same manner. Check recording thermometers for recording accuracy before each use; the accuracy of the recorder time scale must be checked quarterly. In the field, thermistors should be checked against a thermometer before use.

Record calibration information, names of persons making the calibrations, and dates and times of calibration in the field logbook. Note and record each field calibration in the field logbook with the observed temperature readings reported to the nearest 1°C.

Temperature measurements can be obtained from solids (e.g., soils), liquids and gases. Various continuous recording devices are also available. After collecting temperature measurements, record sampling location, media, time, and date in field logbook.

7. ORGANIC VAPORS

7.1 General Procedures

Monitoring organic vapors can be useful as an indicator of airborne contaminants that may pose potential safety hazards. In addition, organic vapor monitoring can be used to determine the identity and concentration of organic compounds and the extent of their distribution.

An important criteria in selecting an organic vapor measurement instrument is that it must be proven safe when used in hazardous environments. Electrical devices and instruments which use flame or combustion principles must be of a type that will not ignite in combustible atmospheres.

As safe equipment operation is an important consideration, the user must become familiar with the detailed operation and maintenance procedures found in a specific instrument's operating manual. Sampling personnel must also familiarize themselves with the limitations of each instrument. Inability to detect certain compounds, slow response time, pump rate capacity, etc. are all factors which may affect the safety of the operator and the quality of the data. The measurement and assessment of organic vapors in some cases may require a trained environmental specialist. If refuge personnel are not familiar with the operation and data assessment of organic vapor contamination, assistance should be obtained from Regional EPA offices.

7.1.1 Scope and Application Summary

Two types of organic vapor measurement instruments are identified for illustrative purposes; however, equivalent instruments are available. The two types include the flame ionization detector (FID) and the photoionization detector (PID).

7.1.1.1 Flame Ionization Detector.. The FID instruments respond to most organic vapors as they form positively charged ions when combusted in a hydrogen flame. The magnitude of the response is a function of the detector sensitivity, the ionization properties and the concentration of a particular compound. The signal must be comparable to that generated by a known concentration of a standard gas during calibration. The sample concentration is then reported as the ppm equivalent of the calibration compound. Most instruments are calibrated with a known concentration of methane; however, almost any gaseous hydrocarbon that produces a response can be used.

Most portable FIDs rely on the sample gas to supply the combustion air to the detector flame, so they are designed to operate in ambient atmospheres with relatively normal oxygen concentrations (21%). This design precludes the sampling of process vents, poorly ventilated or sealed containers, or any sample gas hydrocarbon concentration sufficient to reduce the available oxygen or otherwise saturate the detector. In such instances, adaptations are available to supply a source of oxygen.

FIDs are useful as a general screening tool however, they will not respond to particulate hydrocarbons such as pesticides, PNAs and PCBs.

7.1.1.2 Photoionization Detector. The PID instruments are designed to detect, measure and record levels of many organic and inorganic vapors in air. They will respond to most vaporous

compounds that have an ionization potential less than or equal to that supplied by the ionizing source in the detector.

Though they can be calibrated to a particular compound, the PID instruments cannot distinguish between detectable compounds in a gaseous mixture. In this situation, they indicate an integrated response in relation to the response factors of all ionizable species present. The PID sensor consists of a sealed ultraviolet (UV) light source that emits photons that are energetic enough to ionize many trace species but do not ionize the major components of air such as O_2, N_2, CO, CO_2, or H_2O. A chamber adjacent to the UV source contains a pair of electrodes. When a positive potential is applied to one electrode, the field created drives any ions formed by absorption of UV light to the collector electrode, where the current (proportional to concentration) is measured. This signal is amplified and conditioned and then sent to the output display.

The portable PID is useful as a general survey instrument. It is similar to the FID in application; however, its capabilities are somewhat broader in that it can detect certain inorganic vapors. Conversely, the PID is unable to respond to certain low molecular weight hydrocarbons (e.g., methane and ethane) that are readily detected by the FID.

7.1.2 Equipment and Supplies

Portable organic vapor analyzer Model OVA-108
Photoionization analyzer Model PI 101
Field logbook
Operator's manual

7.1.3 Calibration

Refer to operations manual for detailed calibration requirements.

7.1.4 Field Sample Organic Vapor Measurement

Because of the complexity of properly using these field instruments, field personnel should consult the operations manual and available trained personnel.

8. RADIATION

8.1 General Procedures

Environmentally high levels of radioactive contamination generally result from military or industrial activities. These sources will include products from nuclear fuel cycle operation, mining and processing ores, and medical uses of radioisotopes.

Perhaps the most important aspect of detecting radioactive contamination at sampling sites will be for screening purposes, and to obtain preliminary data for designing definitive monitoring programs. In either case, meaningful measurements require careful application of good scientific techniques. Most field radiation measurements are relatively inexpensive to obtain, can be completed quickly, and are useful for determining whether further analysis for specific radionuclides is merited.

8.1.1 Scope and Application Summary

The most commonly used radiation detectors are those that respond to ionizing particles by producing electrical pulses. The pulses are initiated by the imparting of energy by the ionizing particles to electrons in the sensitive volume of the counter. Two modes of signal production are used in radiation counter design. In the first, the energy serves as a trigger to produce an output electrical pulse of constant form every time an interaction occurs in the detector. The output pulse is constant regardless of the amount of energy deposited in the detector. In the second mode, the magnitude of the output pulse is proportional to the amount of energy deposited in the detector; that is, the greater the energy deposited, the larger the output pulse.

A number of radiation instruments are identified for illustrative purposes; however, many equivalent instruments are available. It is recommended that refuge and contaminant specialists be familiar with the capabilities of portable radiation instruments. In many circumstances, refuge personnel will need the assistance of radiation specialists for calibrating instruments and conducting surveys. This assistance is available from state and federal environmental agencies.

For the proper calibration techniques and the operational use of the instruments identified below see EPA (1983).

8.1.2 Instruments

8.1.2.1 Survey Meter E-500B/E520 GM (Eberline). These instruments are perhaps the most commonly used field detectors. They are popular because they are simple in principle, easy to operate, sensitive, reliable, and very versatile as a detector of ionizing radiation. Using an end window GM counter, the operator can distinguish beta particles from gamma photons by covering the window with the beta shield.

It is recommended that this instrument be calibrated with a 10-millicuries (mCi) and a 100-mCi low-level cesium-137 source and a 1-Ci and a 10-Ci high level cesium-137 source prior to its use. Calibration should be completed by trained personnel and at a site that has adequate facilities for proper handling and storage of the cesium-137 sources.

8.1.2.2 Scintillators. Scintillators are available in a variety of materials and in many sizes and shapes. The larger and heavier scintillators are used to detect gamma photons, since their greater mass gives them a higher detection efficiency.

Before this instrument is used, it should be calibrated with a 1-mCi and a 10-mCi cesium-137 source. Also, see Section 8.1.3 for additional calibration recommendations.

8.1.2.3 LSI Gamma Rate Recorder (Continuous Recorder).. These instruments are continuous radiation recording devices that have their own power supply, provide a permanent record of radiation levels and can be placed in the field and run for a sufficient length of time without daily maintenance. One such field instrument that meets these criteria and is utilized to a great extent for measuring radiation levels is the LSI Gamma Rate Recorder (EPA, 1983).

8.1.3 Calibration

See EPA (1983) for correct methodology.

8.1.4 Field Sample Measurements

See EPA (1983) for recommended measurement procedures.

8.1.5 Taking a Swipe Sample

Swipe samples are taken to determine radioactive contamination of surfaces. The following is the procedure to collect a swipe sample:

> Using Whatman filter paper (47 mm dia.) wipe a known area of the surface (usually 100 sq. cm). This is so any contamination can be related to a certain area. Usually a tight S pattern or square pattern is used, but this is not necessary. Place the filter paper between two index cards in an envelope or a ziplock bag. Mark the container, indicating a sample #, the date, what the swipe was taken from, the amount of surface area swiped, and your name. Do not fold the filter paper as it may make it more difficult to be properly aligned in the detector. Document information in a log book and send sample for analysis.

9. GENERAL FIELD EQUIPMENT LIST

pH Measurement
- pH meter/case
- Electrodes
- ATC probe
- 250-mL beakers
- pH 7.00 buffer (250 mL bottle)
- pH 4.00 buffer (250 mL bottle)
- H_2SO_4 solution 0.0001N (250-mL bottle)
- Electrode filling solution
- Instruction manual
- Stopwatch
- Extra batteries

Conductivity
- Meter and case
- Extra batteries
- Probe and storage bottle
- 74 uS QCCS (250 mL bottle)
- Instruction manual

Dissolved Oxygen
- Meter and case
- Extra batteries
- Probe and bottle
- Calibration chamber
- Membrane kit/filling solution
- Instruction manual

Team Gear
- Maps
- Field logbook
- Forms
- Pump
- Batteries and cable
- Sample kits (Cubitainers, syringes, labels)
- Syringe protective cases
- Sampling boom
- Extra sample labels
- Sealable plastic bags
- Pens, pencils, marker
- Deionized water for blanks (when applicable)

Team Gear (continued)
- Deionized water for rinsing
- Calculator
- Cooler
- Frozen gel packs
- Latex surgical gloves
- Kimwipes (box)
- Camera, film, batteries
- Clipboard
- Compass
- Knife
- Correction factor tables
- Steel rod
- Mallet
- Flow meter, batteries
- Waders
- Tarp
- Ductape
- Strapping tape
- Emergency phone numbers
- Sunscreen
- Drinking water
- Insect repellent

Personal Gear (per person)
- Rain gear (coat and pants)
- Snake guards or gaiters
- Flashlight
- Nylon line
- Space blanket
- First aid kit
- Emergency rations
- Matches (waterproofed)

Vehicle Equipment
- Spare tire, lug wrench, jack
- Jumper cables
- Tool kit
- Spare fuses
- Flares
- Fire extinguisher
- Axe/machete
- Shovel
- First aid kit
- Spare keys/magnetic case

10. GLOSSARY

Absorption	The penetration of a substance into or through another.
Anion	A negatively charged ion.
Background level	Amount of a naturally occurring chemical present in soil which has not been exposed to human activities involving the chemical.
Bulk density	The mass of dry soil per unit bulk volume, determined before drying to a constant weight at 105°C.
Cation	A positively charged ion.
Cation-exchange	The total of exchangeable cations that a soil can absorb, expressed in milliequivalents per gram or 100 grams of soil.
Composite samples	Combinations of more than one sample collected at various sampling locations and/or different points of time.
Compositing	The act of bringing or being together.
Grab Sample	A single sample representative of a specific location at a given point in time. Its representativeness will decrease as sources vary over time and distance.
Heavy Metals	Metals having a specific gravity of 5.0 or more.
Ionic	Containing or involving ions.
In situ	In the original place.
Mixing	The act of blending together in a single mass.
Lotic	Pertaining to moving water.
Pollutant	Any introduced substance that limits a resource use for a specific purpose.
Semivolatiles	A group of organic compounds consisting of base/neutrals, acids, and pesticides that are identified in and analyzed by Method 625 in 40 CFR Part 136 (see FWS 1986 for chemical list).
Volatile	Solids or liquids which are relatively unstable at standard temperature and pressure and undergo spontaneous phase change to a gaseous state (see FWS 1986 for chemical list).

11. INSTRUMENT SOURCES

1. Hydrolab Corporation, Austin, Texas
2. Yellow Springs Instrument Company - P.O. Box 279, Yellow Springs, Ohio 45387
3. Weathertronics, P.O. Box 41039, Sacramento, California
4. Hach Company, P.O. Box 389, Loveland, Colorado 80539
5. Lidlum Measurements, Inc., Sweetwater, Texas

12. REFERENCES

American Public Health Association, 1985. Standard Methods for Examination of Water and Waste Water, 16th edition, 1015 Fifteenth Street N.W., Washington, DC.

ASTM, 1984. Annual Book of ASTM Standards, Volume 11.01, Standard Specification for Reagent Water, D 1193-77 (reapproved 1983). Philadelphia, Pennsylvania.

EPA, 1989. U.S. Environmental Protection Agency, Handbook of Methods for Acid Deposition Studies Field Operations for Surface Water Chemistry. USEPA Environmental Monitoring and Support Laboratory - Las Vegas, Nevada 89193 and Environmental Research Laboratory, Corvallis, Oregon 97333. EPA-600/4-89-028.

EPA, 1983a. U.S. Environmental Protection Agency, Field Monitoring Standard Operating Procedures, USEPA Offsite Radiological Safety Program, Environmental Monitoring Systems Laboratory, P.O. Box 93478, Las Vegas, NV 89193-3478.

EPA, 1983b. U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes, USEPA Environmental Monitoring and Support Laboratory, EPA 600/4-79-020, Cincinnati, OH.

EPA, 1983c. U.S. Environmental Protection Agency, Characterization of Hazardous Waste Sites - A Methods Manual: Volume II, Available Sampling Methods, USEPA Environmental Monitoring Systems Laboratory, Las Vegas, EPA-600/4-83-040.

FWS, 1986. United States Fish and Wildlife Service, Field Operations Manual for Resource Contaminant Assessment, Resource Contaminant Assessment Division, U.S. Department of the Interior, Washington, DC.

Yellow Springs Instrument Company, 1980. Instructions for YSI Model 54A Meters. Yellow Springs, Ohio.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX H
GROUNDWATER SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix H of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
   - D.3 Fish Sampling Reference Field Methods
   - D.4 Flora Sampling Reference Field Methods
   - D.5 Reptiles and Amphibians Sampling Reference Field Methods
   - D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

U.S. Fish and Wildlife Service
Division of Environmental Contaminants
4401 North Fairfax Drive, Room 330
Arlington, VA 22201

Commentor's Name_____ Phone_____

Address_____City_____State___Zip_____

Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

References (if applicable):

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ACRONYMS

CWA	Clean Water Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
EC	Environmental Contaminants
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FWCA	Fish and Wildlife Coordination Act
PARCE	Precision, Accuracy, Representativeness, Completeness and Comparability
QAPP	Quality Assurance Project Plan
QA	Quality Assurance
QC	Quality Control
RFM	Reference Field Method
TOC	total organic carbon
TOX	total organic halogens
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX H GROUNDWATER SAMPLING REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of these Reference Field Methods (RFM) is to identify procedures for the collection of groundwater samples from the saturated and vadose (unsaturated) zones of the geological profile for physical and chemical analyses. Data on chemical contamination obtained from groundwater monitoring can be used by Service personnel and Environmental Contaminant (EC) specialists to manage groundwater resources to protect fish and wildlife species and habitat.

1.2 Scope

Because of the complexity of identifying and adequately selecting well locations, the initial portion of the RFM presents a discussion of the hydrogeologic setting and provides general guidance in well construction and well placement requirements. It is not the intent to provide definitive direction for these elements, but to provide Service personnel with adequate information to consult with qualified construction and sampling contractors as required.

The second portion of this RFM identifies methods appropriate for sampling groundwater in the saturated and vadose zones for contaminant analysis. Generally, the sampling techniques and the sampling devices described can be used by Service personnel; however, there are some sampling methods and devices described that would likely require assistance from other Federal agency personnel or contractors. These methods are included to provide Service personnel with information that may enable informal discussion with appropriate experts.

1.3 Background

Obtaining representative groundwater data for assessing the extent and magnitude of contamination in an aquifer (a rock formation containing water) is extremely complex, and in most cases, expensive. For example, a sample from a monitoring well may represent a very small portion of the horizontal and vertical component of an aquifer. Unlike surface water sampling, where samples can be collected easily at several locations, obtaining information on the spatial differences of groundwater quality requires the installation of monitoring wells. Because of the complexity and expense of well development, it is essential that sampling objectives and methodology be defined before sample collection. The methodology must address the parameters to be measured, the data quality required, the sampling methods, and be compatible with analytical methods necessary to meet monitoring objectives.

The collection of available data during a preliminary planning phase, such as the aquifer's volume and the rate and direction of flow, is essential for the design and implementation of a groundwater monitoring program. Figure 1 presents the many facets of the hydrologic cycle that must be considered during this planning phase. Consultation with a qualified groundwater hydrologist (such as U.S. Geological Survey personnel) before initiating of groundwater sampling activities is also advised.

Groundwater sampling is conducted to

- Determine the presence and concentration of contaminants in comparison to background levels.
- Determine if contaminated groundwater may be a source of contamination to other areas of Service lands.
- Determine the potential risk to flora and fauna from specific groundwater contaminants.
- Determine if contaminant concentrations exceed regulatory limits or action levels and warrant remediation.
- Meet the provisions and intent of environmental laws such as the Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act (TSCA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Factors to consider when designing groundwater monitoring/sampling activities include:

- Hydrogeologic setting
- Data quality requirements
- Well construction and well placement
- Sample collection procedures.

Addressing the above factors will aid in proper interpretation of groundwater data for decision making purposes, which can be extremely complex.

Maintaining the integrity of well samples is complex. For example, as reported by Scalf et al. (1981), groundwater is usually well insulated, therefore, temperature fluctuations of groundwater are minimal in its natural environment. However once transported to the surface, sample temperature may change very rapidly. Temperature fluctuations will influence waterborne contaminants. Processes such as gas exchange or solid/solution reactions may be affected, as many reaction rates double with each 10°C rise in temperature. Also, ions normally present in groundwater in trace amounts may be altered when sampled because of processes such as oxidation, precipitation, ion exchange, and adsorption.

Analytical methods that will be used to examine groundwater samples have been validated with prescribed sample volumes. The analyst must be provided with a sample that is commensurate

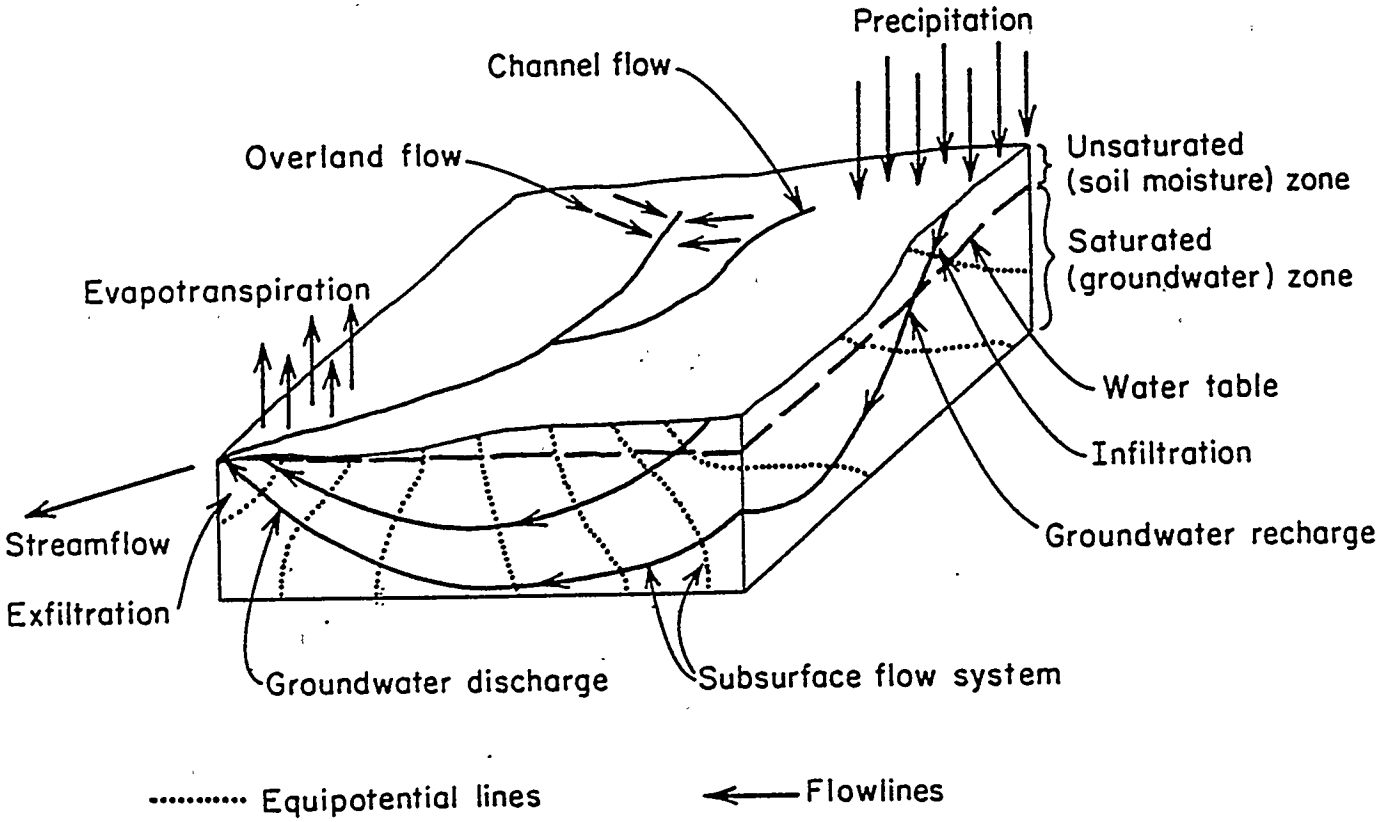


Figure 1. Schematic representation of the hydrologic cycle (Freeze and Cherry 1979).

with the analytical requirements, or the validity of the analysis may be compromised. The responsibility for providing the appropriate sample for analysis lies with sampling personnel.

Because of the difficulties in assessing groundwater data, the analyst and sampling personnel should discuss the sampling and sample handling methods to be used. The importance of sampler-analyst cooperation cannot be over emphasized when collecting samples from wells.

1.3.1 Hydrogeological Setting

Geologic factors relate to geological formations and their water-bearing properties, whereas hydrologic factors relate to the movement of water in these formations. The combination of these factors is referred to as the hydrogeologic setting.

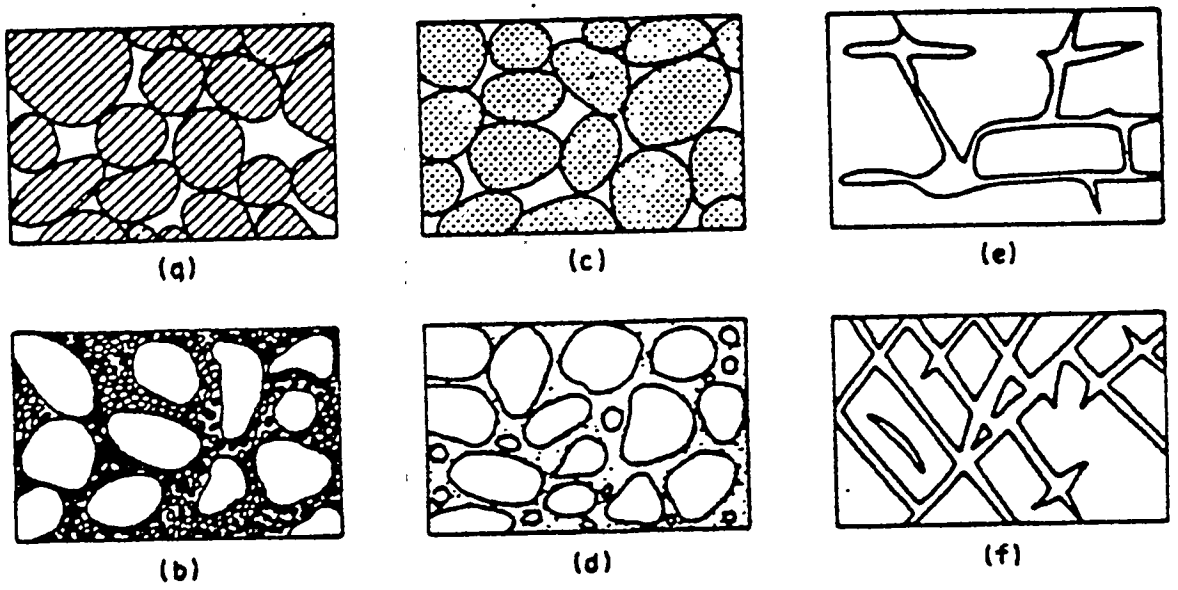
The geologic framework includes lithology (study of rock formations), texture, structure, and mineralogy, and the distribution of the materials through which groundwater flows. The hydraulic properties of earth materials depend upon their origin and lithology, as well as the subsequent stresses to which the materials have been subjected. Groundwater movement depends upon the effective permeability and the hydraulic gradient within an aquifer. Permeability is related to the nature, size, and degree of interconnection of pores, fissures, joints, and other openings.

Three types of geological formations are commonly encountered in groundwater sampling programs: (1) porous material, (2) fractured material, and (3) fractured porous material. In porous material, water and contaminants move through the pore spaces between individual grains. This material consists of sand and gravel, silt, loess, clay, till, and sandstone. In fractured material, water and contaminants move through cracks or solution crevices in otherwise relatively impermeable rock. Fractured media include dolomite, limestones, some shales, granites, and crystalline rocks (e.g., quartz). In fractured porous material, water and contaminants move through both the intergranular pore spaces and cracks or crevices (Figure 2). The movement of water through the pores and cracks or solution crevices will depend on the relative porosity and degree of channeling from cracks or crevices.

The makeup of these basic types of geological materials is seldom homogeneous. Being aware of these conditions is critical as the consistency of the geologic material will play a role in the behavior and rate of water movement and associated contaminant transport. Table 1 shows the water-bearing properties of some commonly encountered geological materials.

A number of hydrologic parameters at sampling sites within a regional groundwater flow system should be determined. For example, water level data from each geologic formation at properly selected vertical and horizontal locations at prospective sampling sites is necessary for determining the horizontal and vertical groundwater flow paths. In addition, it is important to determine the approximate rates of groundwater movement. Hydraulic conductivity data (from pump tests) are necessary for estimating the flow rates of groundwater. Figure 3 presents a subsurface water classification scheme. For additional information, the movement and behavior of water in the vadose and saturated zones see EPA 1983a and 1985, or contact a local hydrologist at the U.S. Geological Survey.

The effective porosity of geologic materials influences their capacity to transmit water. Not all the pore spaces in geologic materials permit flow. Dead end pore spaces and pore space occupied



Texture and porosity: (a) Well-sorted sedimentary deposit having high porosity; (b) poorly sorted sedimentary deposit having low porosity; (c) well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity; (d) well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; (e) rock rendered porous by solution; (f) rock rendered porous by fracturing.

Figure 2. Texture and porosity of geological materials.

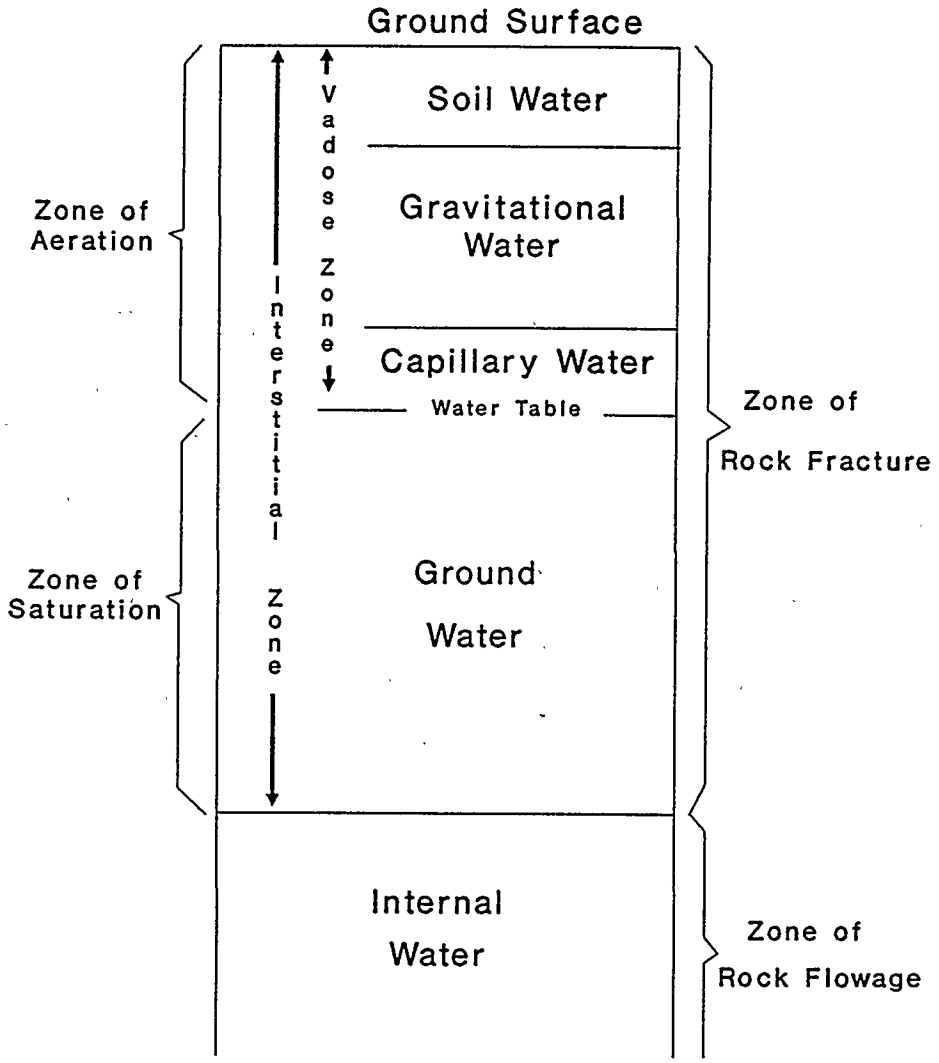


Figure 3. Diagram of a subsurface water classification scheme.

by water held by surface tension to particles are not available for groundwater movement. If porosity values for a site are not available, drainable porosity can be used to approximate effective porosity.

Knowledge of the rates and direction of groundwater flow is essential to determine if the locations of the monitoring wells are or will be in the right direction and within reasonable flow distances of a potential pollution source. The rate of flow data can also be used to calculate reasonable sampling frequencies.

The geochemical and biological properties of the groundwater should be identified in terms of their potential interference with the objectives of the sampling/monitoring activities. For example, chemical reactions or organism transformations of chemicals may influence the analytical results. If the potential for these reactions or transformations exists, consideration should be given to identifying likely transformation products. For definitive guidance if these conditions are likely, consult an analyst before collecting samples.

1.4 Information Resources

Groundwater monitoring is conducted to enable Service personnel to make assessments of groundwater movement, identify groundwater pollutants, and recognize geochemical considerations that affect the quality of groundwater. However, before initiating any specific groundwater field work, all pertinent geologic, hydrologic, geochemical, and subsurface biological data should be compiled by sampling personnel and interpreted by a qualified hydrogeologist. Data that may be available include: geologic maps, profile cross-sections, aerial photographs, and an array of water-well data including well location, date drilled, depth, name of driller, water level and date measured, well completion methods, geophysical logs, formation samples, pumping test(s) and water quality data.

Hydrological expertise and state-of-the-art methodologies are available through a number of U.S. Government agencies including the U.S. Geological Survey (USGS), U.S. Bureau of Reclamation (BOR), and the U.S. Environmental Protection Agency (EPA). Other resources include consultants on the private sector, local drillers and local and state universities.

Table 1. Relative permeability and porosity properties of common geological materials (Davis and DeWiest, 1966).

HIGHEST PERMEABILITY	HIGHEST POROSITY
Well-sorted gravel	Soft clay
Porous basalt	Silt
Cavernous limestone	Tuff
Well-sorted sand	Well-sorted sand
Poorly sorted sand and gravel	Poorly sorted sand and gravel
Sandstone	Gravel
Fractured crystalline rock	Sandstone
Silt and tuff	Porous basalt
Clay	Cavernous crystalline rock
Dense crystalline rock	Fractured crystalline rock
	Dense crystalline rock
LOWEST PERMEABILITY	**LOWEST POROSITY**

2. MONITORING WELL CONSTRUCTION AND WELL PLACEMENT

Factors to consider in developing an effective groundwater monitoring program are proper site selection, appropriate drilling techniques, and monitoring well construction. Methods of well construction and the materials used for the casing and screen may affect the quality of the well and its utility for the collection of groundwater. Components of monitoring well construction presented below serve as general guidance. For definitive guidance, see EPA (1985). Also, see Table 2 for recommended well-construction information for specific pollutants. Documentation requirements as identified in Appendix F, Documentation Guidance and Quality Assurance/Quality Control Standard Operating Procedure (SOP) should be followed.

2.1 Well Depth

Wells should be constructed to allow sampling at specific depths. This requires provisions for grouting above, and if necessary, below the well screen on the outside of the casing (see Figure 4). The location, depth, and type of the screen are important as they will impact sampling of immiscible organics. For example, sampling for less or more dense organics, which float or sink, will require that the screen be set at different depths.

2.2 Well Diameter

Diameter of well casings should be held to the minimum practical size that meets both the strength requirements for the well depth and the size of the sampling device required to deliver water samples to the surface. Water held in the well casing undergoes chemical changes. During sample collection, some chemically altered water will be brought to the surface with water from the formation being sampled (see Section 3.1.2, Well Purging to address this situation). The relative quantity of water is related to the permeability of the formation being sampled, the rate at which the well is sampled, and the diameter of the well casing. The amount of water removed from the well casing is a function of the formation's hydraulic properties and the pumping rate. As the diameter of the well increases, larger portions of altered, nonrepresentative water are initially delivered to the surface.

Based on the necessity of groundwater sampling, pumps capable of lifting water from depths as great as 166 to 250 m (500 to 750 ft), and as small as a 5.1 cm (2 in.) diameter well can be used. If pumping tests require the removal of large water volumes, a 10.2-cm (4-in.) diameter or larger well is recommended.

2.3 Well Casings/Screens

Well casings and screens (Table 3) should be constructed of materials with little or no potential for affecting the quality of the sample. Monitoring well screens should be long enough to permit entry of water from the vertical zone of interest, but held to a minimum in length so that water level data obtained from the well will represent discrete depth information. In wells where the length of the screen is long (5 ft or more), the resulting water level and sample will be an integrated value representing the part of the aquifer at the same level or higher then the screen.

Table 2. Recommended well construction and sampling procedures based on pollutant of interest.

MEASUREMENT	WELL-CONSTRUCTION	SAMPLING METHOD
Physical Properties Temp., pH, Hardness Conductivity, Dissolved O_2 Turbidity Odor, color Settleable matter Residue Filterable Nonfilterable Total Volatile	All drilling and construction methods described are acceptable. The use of water or drilling mud will not significantly affect the samples if the well is pumped before sampling for a sufficient time to clear the well of drilling fluids. This can be determined in the field using a conductivity meter.	All methods described are acceptable (see Table 5 for additional information). The easiest method should be used providing the sampling device is rinsed thoroughly between sampling events.
Metals Dissolved Suspended Total	All drilling and construction methods described are acceptable except bentonite clays or other clay-based drilling muds and should not be used if possible. Plastic casing is preferable to metal casing.	All methods are acceptable provided the groundwater is not aerated during the sampling. The sampling device should be metal-free and should be rinsed thoroughly between sampling events.
Inorganics, Nonmetallics Acidity Iodine Alkalinity Nitrogen Bromide Phosphorus Chloride Silica Chlorine Sulfate Cyanide Sulfide Fluoride Sulfite	All drilling and construction methods described are acceptable. The use of water or drilling mud will not significantly affect the samples if the well is pumped before sampling for a sufficient time to clear the well of drilling fluids. This can be determined in the field using a conductivity meter.	All methods are acceptable although methods such as bailers and pumps which minimize changes in dissolved gas composition of the sample, are preferable if the parameters being measured are affected by pH or dissolved gas changes.
Organics - Routine Analyses	All drilling and construction methods described are acceptable with exceptions noted below.	All methods are acceptable providing the sampling device is rinsed thoroughly between sampling events with exceptions noted below.
Exceptions: Consult with EPA and/or USGS when sampling for "Oil and Grease" when a separate organic phase is present in the aquifer. For high sensitivity "Organic Carbon" analyses methods for "Organics" by chromatographic methods, presented below, are preferable.		
Organics - Determined with high sensitivity analyses by chromatographic methods Purgeable (VOA) Nonpurgeable	Desirable for wells to be constructed without the use of contaminating drilling fluids, muds, and casings. Casing in order of preference should be Teflon, stainless steel, steel. If possible, plastic casing should not be used.	Samples analyzed for purgeable volatile organics (VOA) should be collected by a glass or Teflon bailer after the well is thoroughly flushed with non aerating pump. Vacuum and air-lift pumps should not be used. Samples to be analyzed for trace levels of organics should be collected with Teflon or glass systems.
Microorganisms	All of the methods described are acceptable with the exception that biodegradable drilling muds such as Revert should not be used. All components of a well-casing, sandpack pump should be chlorinated after completion and then thoroughly pumped to remove any residual chlorine.	All of the methods described are acceptable if the sampling device can be sterilized before use.

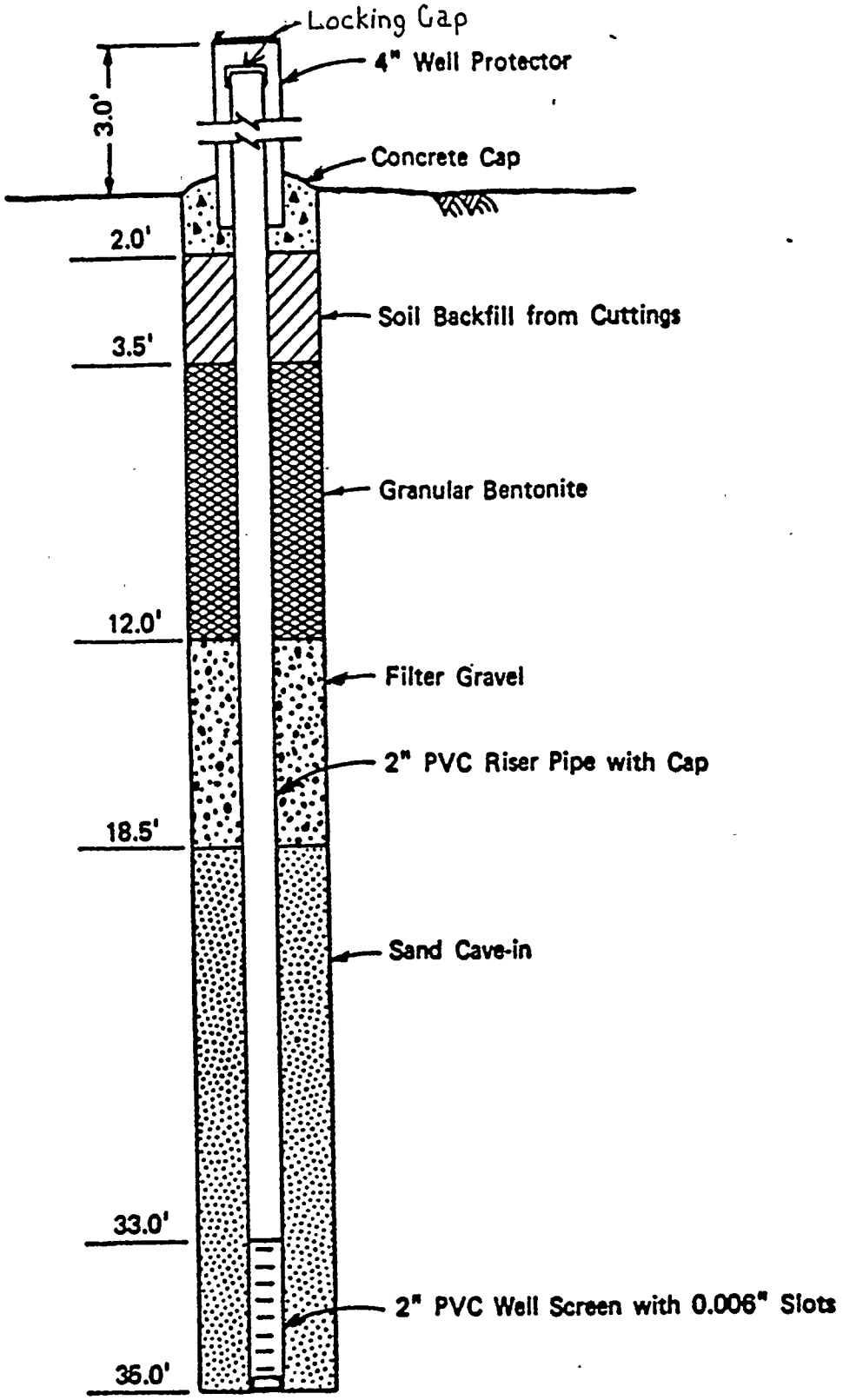


Figure 4. Monitoring well construction diagram. (EPA, 1988)

Table 3. Advantages and disadvantages of different well casing and screen materials.

TYPE	ADVANTAGES	DISADVANTAGES
PVC (polyvinyl chloride)	Excellent chemical resistance to weak alkalies, alcohols, aliphatic hydrocarbons, and oils Good chemical resistance to strong mineral acids, concentrated oxidizing acids, and strong alkalies	May absorb constituents from groundwater May react with (e.g. ketones, esters, and aromatic hydrocarbons) and leach constituents into groundwater
Polypropylene	Excellent chemical resistance to mineral acids Good to excellent chemical resistance to alkalies, alcohols, ketones, and esters Good chemical resistance to oils Fair chemical resistance to concentrated oxidizing acids, aliphatic hydrocarbons, and aromatic hydrocarbons	May react with (e.g. oxidizing acids and aliphatic hydrocarbons) and leach constituents into groundwater
Teflon™	Outstanding resistance to chemical attack; insoluble in all organics except a few exotic fluorinated solvents	High cost relative to other materials
Mild steel	Strong and rigid, temperature sensitivity not a problem	May react with corrosive materials and leach constituents into groundwater Not as chemically resistant as stainless steel
Stainless steel	Excellent resistance to corrosion and oxidation	Heavier than plastics May corrode and leach some chromium in very acidic waters May act as a catalyst in some organic reactions

Source: DOE 1987.

2.4 Well Drilling

Selection of drilling and well completion methods should be based on the minimization both of disturbance to the geologic materials and introduction of air, fluids, and muds. The use of organic drilling muds or additives should be avoided; in most cases, it is best to use air. The introduction of any foreign material has the potential to interfere with the chemical quality of water obtained from the monitoring wells. Table 4 presents popular monitoring well drilling methods.

Suitable (e.g., chemically inert) filter pack material for use around the well screen and for sealing the annulus around the well casing should be selected. The material for the filter pack must be chemically inert and dimensionally stable. The material in the annular space around the casing must prevent fluid migration within this space. Materials such as sodium bentonite are chemically compatible with many contaminants and are chemically inert. Concrete can be used in the annular space around the well casing from the land surface to below the frost line, and for an apron around the well casing at the land surface. The completed well should also be protected by a locking cap.

2.5 Well Development

After drilling is completed, wells must be developed to restore the natural permeability of the formation adjacent to the borehole. Proper development of monitoring wells is required for the successful collection of water samples. During the drilling process, fines are forced through the sides of the bore hole into the formation, forming a mud cake that reduces the hydraulic conductivity of the materials in the immediate area of the well bore. If water from the formation being monitored can not freely enter into the monitoring well, the mud cake must be broken down in the screened portion of the well and the fines removed from the well. The removal of these fines will enhance the yield of the monitoring well. Improperly developed monitoring wells will produce samples containing suspended sediments that will both bias the chemical analysis of the collected samples and cause frequent clogging of field filtering and collection equipment.

The first step in well development involves the movement of water at alternately high and low velocity into and out of the well-screened gravel pack to break down the mud pack on the well bore and loosen fines in the materials being monitored. This step is followed by pumping to remove these materials from the well and the immediate area outside the well screen. This procedure should be continued until the water pumped from the well is visually free of suspended materials or sediments. For definitive guidance, see EPA (1985).

Table 4. Drilling methods for monitoring wells.

TYPE	ADVANTAGES	DISADVANTAGES
Air rotary	No drilling fluid used, minimizing contamination Used in unconsolidated and consolidated formations, capable of drilling to any depth Formation sampling ranges from hard, dry formations to nothing when circulation is lost in formations Formation water is blown out of hole along with cuttings, making it possible to determine when the first water-bearing zone is encountered Collection and field analysis of water blown from the hole can provide enough information regarding changes in water quality for parameters such as chlorides.	Casing is required to keep the hole open when drilling in soft, caving formations below the water table When more than one water-bearing zone is encountered and hydrostatic pressures are different, flow between zones may occur between the time drilling is completed and the hole can be properly cased and grouted off
Cable tool	Only small amounts of drilling fluid (generally water with no additives) are required Can be used in both unconsolidated and consolidated formations; well suited for caving, large gravel type formations with large cavities above the water table Excellent formation samples, when water is encountered, changes in potentiometric levels are observable Relative permeability and water quality data from different zones can be obtained by skilled operators Good seal between casing and formation if flush jointed casing is used	Potential contamination by drilling fluid Relatively large diameters are required minimum 10,2 cm (4 in.) casing Steel drive pipe must be used Usually a screen must be set before a water sample can be taken
Hollow stem auger	No drilling fluid used, minimizing contaminant problems Formation waters are sampled using a screened lead auger or advancing a well point ahead of the augers Hole caving can be overcome by implacing screen casing before augers are removed Drive cores or split-spoon samplers can be used to collect core samples ahead of drill bit	Only used for unconsolidated materials Limited to depths of 100 to 150 ft, formation samples may not be completely accurate depending on how they are taken
Mud Rotary	Can be used in both unconsolidated and consolidated formations, core samples can be collected Capable of drilling to any depth Casing not required during drilling Flexibility in well construction	Drilling fluid required Little information on location of water table, limited information on water producing zones is directly available during drilling Formation samples may not be accurate

3. SAMPLE COLLECTION METHODS

No single sampling method can be recommended for all sites and conditions. However a number of sampling devices and measurement methods are identified in this RFM. Sampling personnel will have to select the device or method that will best satisfy his/her sampling needs and monitoring objectives. Tables 5 and 6 provide sampling methods and information concerning their application that may be useful in selecting a sampling/purging device. Proper conclusions made from groundwater chemical data for designing additional definitive monitoring/sampling programs or in support of remedial measures can be extremely difficult. Therefore, it is important that field or contractor personnel follow the procedures and directions provided in site specific study plans and in the QA/QC plan.

3.1 Saturated Zone Monitoring

At the wellhead, the condition of the surface seal and well cap protector should be examined for evidence of frost-heaving, cracks, or vandalism. Observations should be recorded in the field logbook. The area around the well may have to be physically cleared of weeds (do not use chemical sprays) or other materials before sampling. A clean drop cloth can be placed around the wellhead, particularly if the land surface is disturbed or potentially contaminated (if it is windy, spray with water to settle dust). The use of a drop cloth may save time and the work of cleaning equipment or tubing should they fall on the ground during sampling. The well protector should then be unlocked and the cap removed.

3.1.1 Water Level Measurement

Prior to purging (see Section 3.1.2), it is extremely important to measure and record the water level in the well. Water level measurements are used to calculate the liquid bore volume for pre-purging and are also important for interpreting hydrological and groundwater analytical data. Depths to the water level are normally measured with respect to the top of the well casing and should be recorded to the nearest 0.01 ft. To avoid contamination, gloves (i.e., latex) should be worn at all times during water level measurements and sampling. Equipment decontamination is required after water level measurements (see Decontamination Guidance RFM - Appendix E).

Three commonly used water level measurement devices are steel tapes, electric drop lines, and pressure transducers.

3.1.1.1 Steel Tapes. The use of a narrow 6 to 10 mm (1/4 to 3/8 in.) wide steel tape is perhaps the most accurate and straightforward method for making water level measurements. Tapes that are graduated throughout their entire length in meters, centimeters, feet, tenths of a foot, and hundredths of a foot with raised lettering and divisions are preferable. The bottom few feet of the tape is covered with an indicator chalk (usually fine marking carpenters chalk) so that the raised surface of the tape will permit the observation of color change when the chalk is wet. The tape is lowered into the well to the anticipated water level depth so that the chalked portion of the tape is in the water. Note depth of the tape when held at an even foot mark. It is important to make sure that the tape has been continuously lowered into the water and not raised back to an even foot mark. The tape is then withdrawn and the reading from the wetted portion of the tape subtracted from the

Table 5. Criteria for selecting groundwater sampling/purging equipment

Sampler	Type	Purge	Maximum Sample Depth	Minimum Well Depth	Sample Delivery rate/vol.	Parameters*													
						1	2	3	4	5	6	7	8	9	10	11	12	13	14
Open Bailer	Grab	Yes	No Limit	½ in	Variable	X			X	X	X		X				X		X
Point-source	Grab	Yes	No Limit	½ in	Variable	X	X	X	X	X	X		X	X	X	X	X		X
Syringe	Grab	No	No Limit	1½ in	0.01-0.2 gpm	X	X	X	X	X	X		X				X	X	X
Gear-drive	Submersible	Yes	200 ft	2 in	0-0.5 gpm									X					
Bladder pump	Submersible	Yes	400 ft	1½ in	0-2 gpm	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Helical rotor	Submersible	Yes	160 ft	2 in	0-1.2 gpm	X	X	X	X	X	X	X	X	X	X	X	X	X	
Centrifugal	Submersible	Yes	Variable	3 in	Variable	X			X		X						X	X	
Peristaltic	Suct. Lift	Yes	26 ft	½ in	.01-0.3 gpm	X			X		X		X				X		
Gas-lift	Gas contact	Yes	Variable	1 in	Variable								X						
Gas drive	Gas contact	Yes	150 ft	1 in	0.2 gpm	X			X		X		X				X		X

* 1. Conductivity
2. pH
3. Redox
4. Major Ions
5. Trace Metals
6. Nitrate, fluoride
7. Dissolved gasses
8. Non-volatiles
9. Volatiles
10. Total Organic Halogens
11. Total Organic Carbon
12. Radium
13. Gross alpha/beta
14. Coliform bacteria

Source: Adapted from Pohlmann and Hess (1988)

Table 6. Comparative Evaluation of Groundwater Purging and Sampling Devices

Type	Advantages	Disadvantages
Submersible pumps (gear-drive, helical rotor, centrifugal)	Wide range of diameters. Constructed from various materials 12-V pump is highly portable; other units are fairly portable. Depending on size of pump and pumping depths, relatively large pumping rates are possible for wells larger than 2-in. (51-mm) diameter. Readily available; 1 3/4 in. (44.5-mm) helical screw pump has rotor construction that permits pumping fine-grained materials without damage to the pump	With one exception, submersible pumps are too large for 2-in. (51-mm) diameter pumps. Conventional units are unable to pump sediment-laden water without incurring damage to the pump. 1 3/4-in. (44.5-mm) pump delivers low pumping rates at high heads. Smaller diameter pump is relatively expensive.
Gas pressure displacement	Relatively portable. Readily available. Inexpensive. Suitable for well development	Causes changes in carbon dioxide concentrations, therefore, is unsuitable for sampling for pH-sensitive parameters. In general, not an appropriate method for acquisition of water samples for detailed chemical analyses because of degassing effect on sample. Oxygenation is impossible to avoid unless elaborate precautions are taken. Cannot be used for sampling.
Open bailer	Constructed in a wide variety of diameters and materials. No external power source is required. Extremely portable. Low surface-area-to-volume ration, resulting in a very small amount of volatile organics while sample is contained in bailer. Easy to clean. Readily available. Inexpensive	Sampling procedure is time consuming; sometimes impractical to properly evacuate casing before taking samples. Aeration may result when transferring water to the sample bottle; requires careful operation and sample handling precautions under field conditions
Point-source bailer	Seals off sample in the bailer as it is retrieved. Prevents contamination of sample from well casing particulates. Extremely portable.	Sampling procedure is time consuming; sometimes impractical to properly evacuate casing before taking samples. Aeration may result when transferring water to the sample bottle; requires careful operation and sample handling precautions under field conditions
Positive displacement (bladder pump)	Can be constructed in diameters as small as 1 in. (25.4 mm). Can be constructed from a wide variety of materials. Relatively portable. Reasonable range of pumping rates. Driving gas does not contact water sample, eliminating possible contamination or gas stripping. Expected to provide both efficient well purging and representative samples over a range of conditions with minimal difficulty in field operations	Gas source required. Large gas volumes and long cycles are necessary when pumping from deep wells. Pumping rates are lower than those of suction on jet pumps. Commercial units are relatively expensive.
Suction-life (peristaltic pump)	Relatively portable. Readily available. Inexpensive	Sampling is limited to situations where water levels are within about 20 ft. of ground surface. Vacuum effect results in significantly lower recoveries of purgeable organic compounds and dissolved gases

Table 6. (continued)

Type	Advantages	Disadvantages
Gas drive	Isolates sample from the operating gas. Requires no electrical power source. Operates continuously over extended periods of time. Can be operated at pumping heads in excess of 500 m	Particulate matter may damage or inactive the pump unless the suction line is filtered. Low pumping rates are experienced.
Gas lift	Can be used as a portable or permanently installed sampling system. Used to flush the well and to sample	Not suitable for pH-sensitive parameters such as metals. Can damage filter pack around well screen if the well is evacuated under high pressure and if the intake of the sample line is located within the screened interval. If air or O_2 gas is used, oxidation may occur. Gas stripping of volatile compounds may occur

foot reading held at the measuring point. The resulting value is the depth to water from the measuring point.

Measurements taken in this manner, if carefully done, are accurate to the nearest 0.30 cm (0.01 ft). Three readings should be taken to ensure that reproducible results are obtained.

3.1.1.2 Electric Drop Line. Commercially purchased drop lines are generally battery powered and equipped with a milliammeter. The drop line is lowered into the well until the probe contacts the water, closing the circuit between the two wires. The meter indicates a current flow. A point above the well head is identified as the measuring point (the measuring point should stay consistent for all measurements). A ruler is used to measure the distance from the nearest reference point (a graduation mark on the drop line) to the selected measuring point. Subtract this amount if the reference point is above the measuring point. Add this amount if the reference point is below the measuring point. See manufacturer's instructions for definitive guidance.

After repeated use, the markings on drop lines often have a tendency to become loose and slide along the wires. Drop lines may also become kinked so they do not hang straight in the well. These, among other potential problems, can limit the accuracy of drop lines to about 3 cm (1/10 of a foot). It is important to check the condition of the drop line after each use. Drop lines are very convenient to use, particularly in deep wells, and they do not need to be totally reeled out of the well between multiple readings.

3.1.1.3 Pressure Transducers. Pressure transducers offer advantages over the steel tape and electric drop line. A pressure transducer is lowered into a well below the water level. The transducer indicates the amount of pressure exerted on it, thus measuring the height of water above the transducer. To obtain the actual depth to the water, subtract the amount of "submergence" of the transducer from the reading at the measuring point. Transducers are useful for taking water level measurements in a well during pump tests. The transducer is left in the well and transmits a continuous record of water level data to a strip chart or digital recording device during the course of the test.

The accuracy of transducers depends on the type and sensitivity of a particular device. Most transducers are rated in terms of a percent of their full scale capability. For example, a 0 to 5 psi (pounds per square inch) transducer rated at 0.01% will provide readings to the nearest 0.30 cm (0.01 foot). A 0 to 25 psi transducer rated at 0.01% will provide reading to the nearest 1.52 cm (0.05 foot).

3.1.2 Well Purging

The composition of water within the well casing and annular space is not representative of the surrounding aquifer. To obtain a representative sample, the well must be purged.

The recommended amount of purging before sampling is dependent on the characteristics of the well, the hydrogeological nature of the aquifer, the type of sampling equipment being used, and the contaminant parameters being sampled. A recommended procedure is to pump or bail the well until a minimum of three to five bore-volumes have been removed.

To find the volume of standing water in the well, use the following calculations:

$V = \pi r^2 h$

where

V = volume in cubic feet

$\pi \cong 3.14$

r = inside radius of monitoring well casing (ft)

h = height of standing water in well from bottom (ft)

Example: a 4-inch well at 150 ft.

$r = 2$ in. $\cong 0.167$ ft.

$r^2 \cong 0.028$ ft^2

$V = (3.14)(0.028 \text{ ft}^2)(150 \text{ ft})$

$\cong 13.2$ ft^3

x 5 volumes

$= 66$ ft^3

x 7.54 gals/ft^3

$\cong$ 500 gallons of water to purge

Completely purging a well is only possible if the well is pumped dry. If this is not possible two alternative approaches are (1) record the water level in the well while pumping (when the water level has stabilized, most if not all of the water being pumped is coming from the aquifer) and (2) monitor the temperature, conductivity, or pH of the water while pumping (when these parameters stabilize, it is probable that little or no water is being pumped from casing storage). These parameters can be determined using field instrumentation from in-line sensors or from small aliquots collected from the purged water.

Environmental contamination is possible when disposing of purged water. Disposal practices range from simply dumping the purged water on the ground (not down the well), to implementing a full containment, and disposal program. The best disposal practice is to contain the purged water and store it until the water samples have been analyzed. Once the contaminants are identified, appropriate disposal procedures can be determined.

The following provides step-by-step guidance for purging wells:

1. Use clean, non-contaminating equipment. Determine the water level in the well (see Section 3.1.1), then calculate the fluid volume in the casing.

2. Select purging device (see Table 5 for guidance).

3. Lower the precleaned purging device just below the water level and begin purging. Collect or dispose of purged water in an acceptable manner. Keep lowering the device below the water level as necessary (keep submerged).

4. Measure rate of purge discharge using a bucket and stopwatch.

5. Purge a minimum of three (preferably five) casing volumes or until discharge pH, conductivity, or temperature stabilizes to $\pm 10\%$ over at least two successive well volumes pumped. Note also that all down-hole and potentially wetted surfaces must also be non-contaminating/noncontributing. This includes power and suspension cables and compressed gas or sample tubing.

3.1.3 Sample Collection

Once the well has been purged and the water level is at its pre-purged level, sampling can begin. Sampling for VOCs should be initiated as soon as possible before substantial volatilization occurs. If well recovery is slow, it may be necessary to wait several hours or even until the following day before sufficient water volume is available for all the required samples. When a pump is used for sample collection, its pumping rate must be controlled to match the transmissivity (rate of flow) of the formation and the capacity of the well screen. Excessive drawdown of the well during sampling could result in the collection of nonrepresentative samples because of changes in groundwater flow. Figure 5 provides schematic diagrams of commonly used groundwater sampling devices.

The following characteristics should be considered when selecting groundwater sampling devices:

- The device should be simple to operate to minimize the possibility of operator error.

- The device should be durable, portable, easily decontaminated, and repairable in the field.

- The device should have good flow controllability to permit low flow rates (100 mL/min) for sampling volatile chemical constituents, as well as high flow rates (1 L/min) for large-volume samples and for purging stored water from monitoring wells.

- The device, when in use, should create little physical and chemical disturbance of groundwater solution composition to avoid bias or imprecision in analytical results.

Samples should be placed in decontaminated containers and taken in a prearranged priority so that all sample handling and preservation takes place as rapidly as possible. Although no significant error has been reported for gas-sensitive constituents pumped with a positive displacement bladder device when air is used as the drive gas, it may be prudent to switch the drive gas from air to

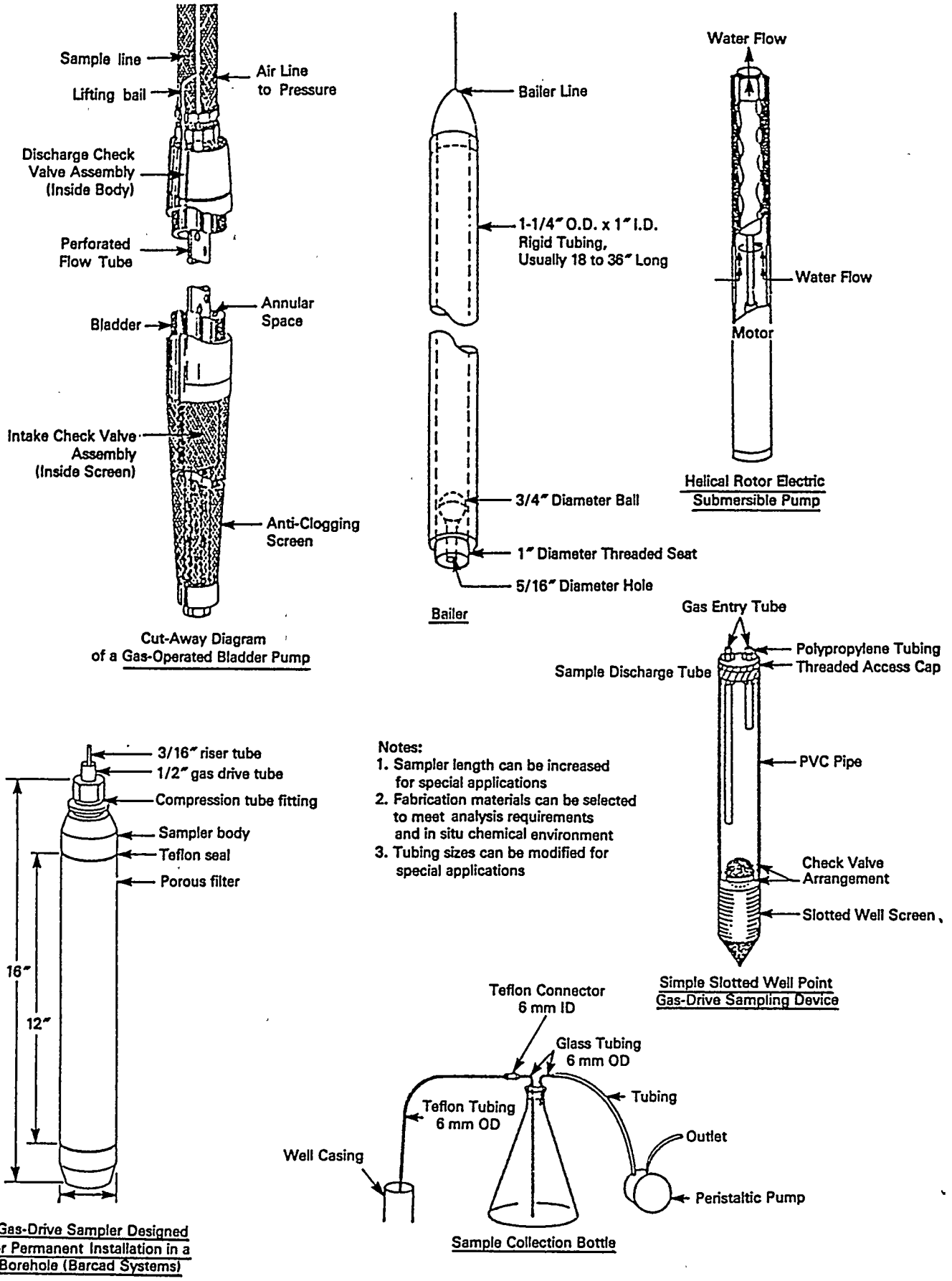


Figure 5. Schematic diagram of common groundwater sampling devices (EPA, 1987).

nitrogen. Samples for dissolved gases should be taken in-line ahead of the flow-through electrode cell at a flow rate of less than 100 mL/min. See the manufacturer instructions for definitive guidance when operating these devices. See Table 5 for guidance in selecting the appropriate sampling device and Table 6 for a comparative evaluation of some groundwater sampling and purging sampling devices.

To collect samples for dissolved gases, volatile organic constituents, total organic carbon (TOC), and total organic halide (TOX), carefully slow the delivery rate to 100 mL/min or less and allow the pump discharge to flow gently down the side of the container with minimal entry turbulence. Allow the container to overflow at least 1.5 volumes. The samples should be rapidly capped, excluding any headspace and preserved as soon as possible (a cooler with ice should be taken to the field). Samples for extractable organic compounds and metals can then be collected. When filling the large volume bottles, the flow rate can be increased. Document all sampling activities as required and record the cumulative water volume pumped during sampling. Additional guidance includes

1. Collect split and duplicate samples as required. (DOC 2.6, 2.7).

2. Check that a Teflon liner is present in container cap as required. Secure the cap tightly. See Table 7 for container information.

3. Identify the sample container with the appropriate sample label and tag. Be sure to label the tag carefully and clearly, addressing all the categories or parameters. Place the labeled sample container in an appropriate carrying container and preserve, as required. Complete all chain-of-custody documents
(if required) and record in the field logbook. (DOC - 3.3-3.6, 5.0, 5.0-5.4, 6.0)

4. Decontaminate sampling equipment after use and between sample locations and collect blanks as required (DEC-2.0,2.1,2.2).

3.1.3.1 Sampling for Low Density, Immiscible Organics.. Low- density, immiscible organics include gasoline and other chemicals and petrochemicals have specific gravities less than water and are likely to be present in water as a separate phase because of low solubility. These chemicals tend to float on the water surface and commonly occupy the capillary fringe zone above the water table. In a confined aquifer, these chemicals are found along the upper surface of the permeable material and also within the overlying confining layer.

Sampling procedures for low density, immiscible organics differ substantially from those for other pollutants. It is necessary to sample at least two and sometimes three distinct layers or depths within the well.

After the well is initially constructed, it should be developed and pumped to remove invaded water, and then it should sit idle until the water level and the floating layer of petrochemicals fully stabilize.

Measurement of the thickness of the petrochemical layer may then be accomplished by using a water-level indicator gel with a steel tape to determine the depth to the water surface. A weighted float may be used to determine the depth to the top of the petrochemical layer. The difference

between these two readings is the thickness of the petrochemical layer. Electric water-level sounders will not work properly for these determinations.

A sample of the floating petrochemicals can then be taken using a bailer that fills from the bottom. Care should be taken to lower the bailer just through the petrochemical layer, but not significantly down into the underlying groundwater.

Samples of the groundwater at the bottom of the screen and at some intermediate location, such as the mid-point of the screen, may also be obtained with a bailer. However, in order to avoid mixing the waters, a separate casing is temporarily lowered inside the permanent well casing. This casing is equipped with an easily removed cap on the bottom so that no fluid enters the casing until it has reached the desired depth for sampling. The cap is then knocked free of the bottom of the casing, allowing water to enter from that specific depth to be sampled by the bailer. At significant depths below the petrochemicals, several full bailers of water may be withdrawn and discarded before the sample is taken to obtain a fresh formation sample. Thorough cleaning of the bailer is required between sampling events.

3.1.4 Sample Filtration

Filtration of groundwater samples is recommended for some soluble constituents as a form of sample preservation. Samples collected for TOC, TOX, and VOCs should not be filtered, as any increased handling may result in the loss of these chemical constituents. Allowing these samples to settle prior to analysis, followed by sample decanting, is preferable to filtration in these cases. If filtration is necessary for the determination of extractable organic compounds, the filtration should be performed in the laboratory. It may be necessary to run parallel sets of filtered and unfiltered samples with standards to establish the recovery of hydrophobic compounds (consult with analyst for recommendations).

Water samples collected for dissolved inorganic chemical constituents (e.g., metals, alkalinity, and anionic species) should be filtered in the field immediately after collection. The recommended method is an in-line filtration module that operates from sampling pump pressure. These modules, which are commercially available, have tubing connectors on the inlet and outlet parts and range in diameter from 2.5 to 15 cm. Large diameter filter holders that can be rapidly disassembled for filter pad replacement are the most convenient and efficient. Gravity type filtering procedures can also be used.

Choice of filter media must be made on the basis of the analytical methods required for those samples (consult with an analyst before filtering). It is recommended that a 0.45-mm nominal-sized filter be used. Sampling personnel must be trained in proper procedures for replacing these filters since fine particles can easily be transferred to the outlet side of a disassembled filter module. Sloppy technique may result in contaminated samples. After a filter pad is changed, the initial 100 mL of fluid should be discarded as a rinse. Even if very careful procedures are followed, clogging and small particle breakthrough are problems that must be noted and addressed on a case-by-case basis.

As previously mentioned, filtering may be done by an in-line system. In this case, the pump discharge is connected to an in-line filter apparatus and the samples for alkalinity, dissolved metals, and other inorganic constituents are collected. When the filtered samples have been collected, the time and cumulative volume pumped should be recorded in the field logbook. Document samples and

sampling procedures used (see Documentation Guidance and Quality Assurance/Quality Control SOP - Appendix F for requirements).

3.1.5 Sampling Equipment

The following is a suggested list of groundwater sampling equipment:

- Compressed N_2 cylinder for bladder pump
- Compressed air tanks for bladder pump
- Alkalinity field instrument [pH meter (see Field Instrument Measurements RFM) with temperature compensation, electrode, battery-operated magnetic stirrer, burette, titrant, beakers]
- Flow through cell in box with 3-way valve system to route pump output to cell (e.g., pH, 2 redox, temperature electrodes and conductivity cell) or to sample/waste
- Regulators for gas cylinder
- Buckets (15 L) and graduated cylinder (5 L) to measure purge volume and sample waste
- Dissolved oxygen field instrument
- Shovel
- Water level equipment (e.g., steel tape)
- Precleaned filter membranes, inline filters and filter holders
- 5-gal water jugs of deionized water
- Sampling pumps (e.g., bladder)
- Pump tubing sets (Teflon) 1 air, 1 water. Tubing diameter should be no less than 6 mm (1/4 in.) o.d. and the larger diameter sizes will minimize tubing material effects if they are anticipated)
- Gas manifold (to operate multiple pumps from same compressed gas supply)
- Insulated coolers for sample storage and preservation
- Toolboxes
- Precleaned and labeled sample containers
- Documentation notebook.

3.2 Vadose Zone

The vadose zone is in the unsaturated state, but contains water that can be collected for analysis. Collection of samples from the vadose zone are usually done after groundwater or soil samples indicate a potential problem or when a contaminant has been spilled or disposed of in the vadose zone. This is a difficult sampling procedure and assistance from a consultant may be required.

The recommended collecting devices for vadose zone sampling are suction samplers. The two commonly used sampling devices include

- Ceramic samplers (suction lysimeters)
- Membrane samplers.

These two samplers work on the same principle. When placed in the soil, the pores of the sampler become an extension of the pore space of the soil. Consequently, the water content of the

soil and collection cup become equilibrated at the existing soil-water pressure. By applying a vacuum to the interior of the cup that the pressure is slightly less inside the cup than in the soil, solution slowly flows into the cup. The water sample can then be pumped to the surface and collected for analysis. At the present time, these devices are the best available for direct sampling above the water table.

3.2.1 Ceramic Samplers

Ceramic cups may be subdivided into two categories: (1) vacuum operated soil-water samplers and (2) vacuum-pressure samplers. Vacuum operated soil-water samplers consist of a ceramic cup mounted on the end of a small diameter Teflon or PVC tube. The upper end of the tubing projects above the soil surface as shown in Figure 6. A rubber stopper and outlet tubing are inserted into the upper end. Vacuum is applied to the system and soil water, if available, moves into the cup. To extract a sample, a small diameter tube is inserted into the outlet tubing and extended to the base of the cup. The small diameter tubing is connected to a sample-collection flask. A vacuum is applied via a hand vacuum-pressure pump and the sample is sucked into a sample container. These devices can be used to sample to depths of 2 m. They can be placed at shallow depths using a shovel; at greater depths, power driven excavation devices would have to be used (see Soil RFM - Appendix J for information). The space between the sampler and undisturbed soil should be filled with silica sand to enhance contact.

To extract water samples from greater depths, the vacuum-pressure sampler can be used (Figure 7). These units were developed for sampling soil water to a maximum depth of 16 m. The body tube of this device is about 61 cm long, holding about 1 L of water. Two stainless steel copper lines are forced through a two-hole rubber stopper sealed into the tube body. One line extends to the base of the ceramic cup, and the other terminates a short distance below the rubber stopper. The longer line connects to a sample bottle and the shorter line connects to a vacuum-pressure pump. All lines and connections are sealed.

To operate, a vacuum is applied to the system (the longer tube to the sample bottle is clamped shut). When sufficient time has been allowed for the unit to fill with solution, the vacuum is released and the clamp on the outlet line is opened. Air pressure is then applied to the system, forcing the sample up and into a collection container. A basic problem with this unit is that when air pressure is applied, some of the solution in the cup may be forced back through the cup into the surrounding pore-water system.

3.2.2 Membrane Samplers

The construction of this device (Figure 8) includes a membrane filter and a glass fiber prefilter mounted in a "Swinnex" (Millipore Corporation) type filter holder. The membrane filters commonly used are made of polycarbonate or cellulose acetate.

This sampler can be used by following these steps:

- Dig a hole to the selected sampling depth
- Place two small glass fiber "wick" discs in the filter holder next to and in front of the prefilter
- Place two sheets of glass fiber in the bottom of the hole

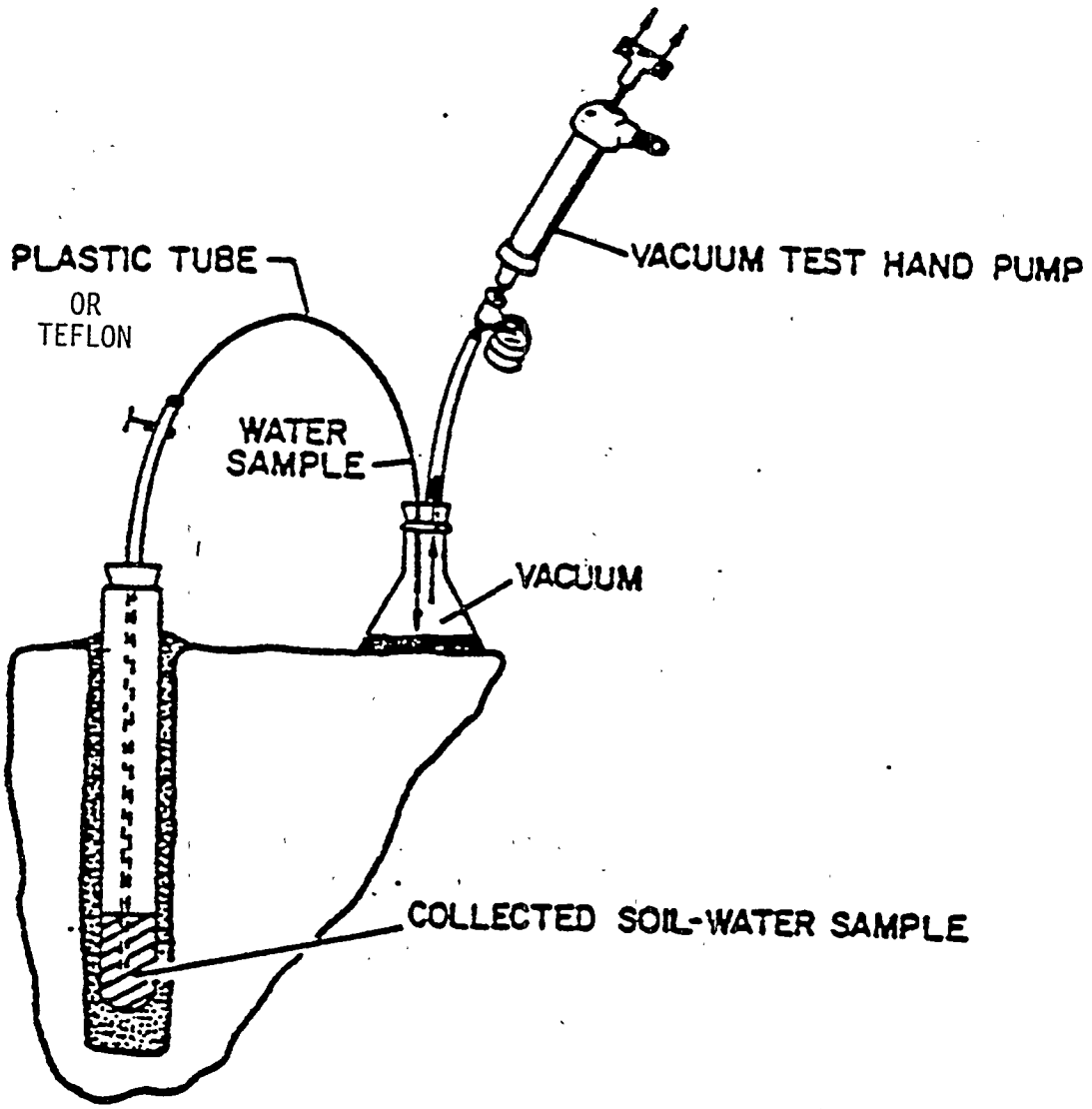


Figure 6. Vacuum operated soil-water sampler (EPAb, 1983).

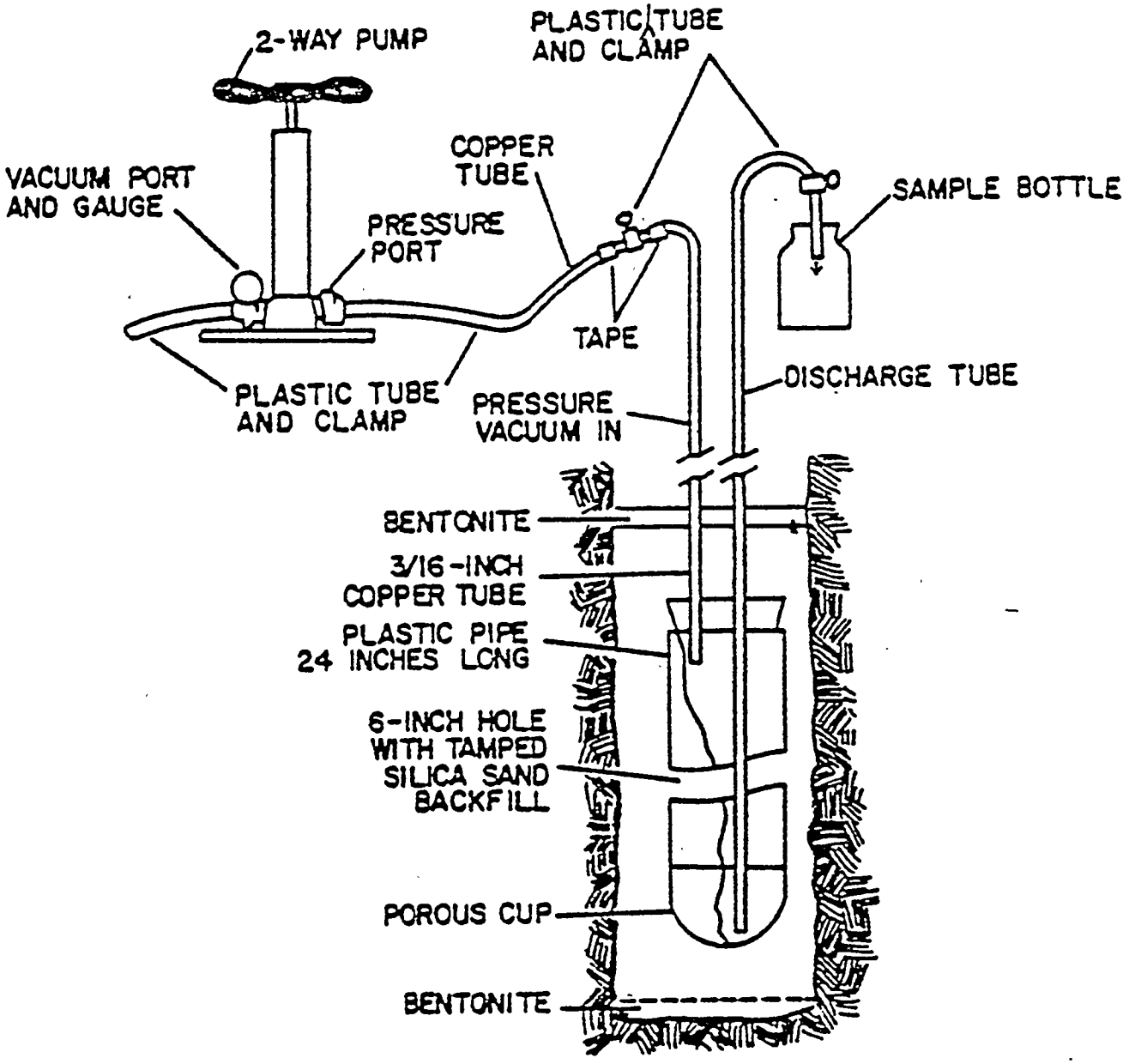


Figure 7. Vacuum-pressure sampler (EPAb, 1983).

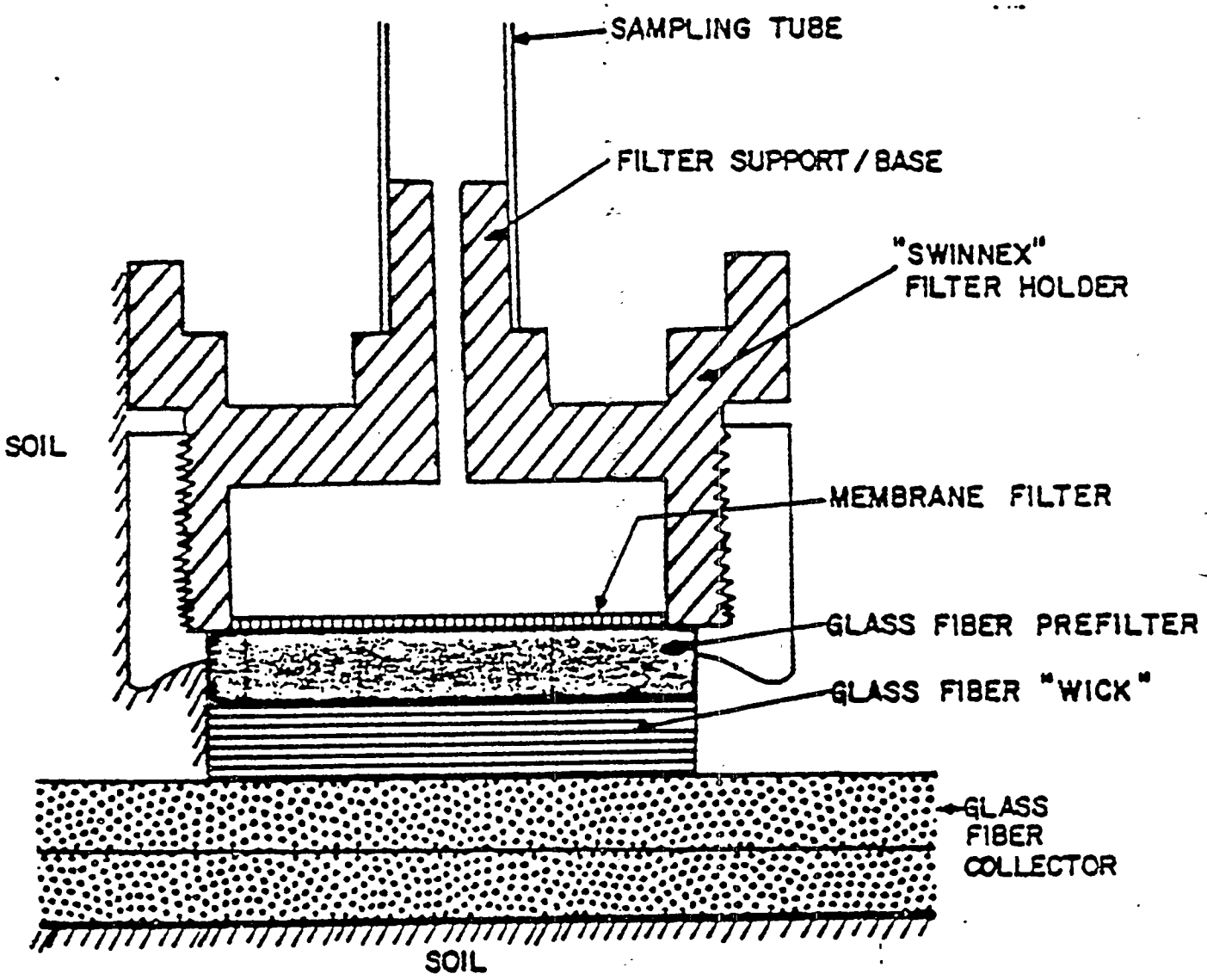


Figure 8. Cutaway view of Membrane Filter sampler (EPAb, 1983).

- Attach sampling tube to the filter holder
- Backfill the hole with soil.

Soil water migrates toward the sampler by capillary action. Water flows into the glass fiber sheets toward the glass fiber wicks by applying suction to the filter holder. Samples are collected by filling sample containers with soil water brought to the surface by suction.

For both the Ceramic and Membrane samplers, follow the sample handling, preservation, and documentation guidance as identified in Section 3.1.3, Numbers 1 through 4.

The glass fiber sheet and wick collector system provides contact with a relatively large area of soil, and a favorable sampling rate can be maintained at depths to 4 m. Follow sample handling, preservation, and documentation guidance as identified in Section 3.1.3, Numbers 1 through 4.

4. GLOSSARY

Annular Space	The open space formed between the bore hole and the well casing.
Aquifer	A geologic formation or structure that transmits water in sufficient quantity to supply the needs for an economic development, usually saturated sands, gravel, fractures, and cavernous and vesicular rock.
Aquitard	A geologic formation of low permeability which stores a transient groundwater in significant quantities but typically at a very slow rate.
Bentonite	A sedimentary rock largely comprised of clay minerals that have a great ability to absorb water and swell in volume.
Capillary Water	A term used to describe interstices with such small openings that they can retain fluids by capillarity. Confined
Aquifer	An aquifer under greater than atmospheric pressure bounded above and below by impermeable layer or layers of distinctly lower permeability than the aquifer itself.
Hydraulic	A coefficient of proportionality which describes the rate Conductivity at which a fluid can move through a permeable medium. It is a function of this medium and of the fluid flowing through it.
Measuring Point	The above ground point from which measurements will be referenced.
Messenger	A weight which slides down the drop-line to trigger the sampling device.
Piezometers	Generally a small diameter, non-pumping well used to measure the elevation of the water table or potentiometric surface.
Permeability	Capacity for transmitting a fluid, measured by the rate at which a fluid of standard viscosity can move through material in a given interval of time under a given hydraulic gradient.
Porosity	The degree to which the total volume of a soil, sediment or rock is permeated with pores or cavities, generally exposed as a percentage of the whole volume unoccupied by solid particles.
Reference Points	The graduation marks on a tape or drop-line used for determining depth.
Saturated Zone	That portion of the geological profile in which the pores or openings of the strata are filled with water.

Transmissivity	The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width under a unit hydraulic gradient.
Vadose Zone	That portion of the geological profile extending from the lower limit of the soil column to the upper surface of the saturated zone.
Water Table	The water level surface below the ground at which the vadose zone ends and the phreatic zone begins. It is the level to which a well screened in the unconfined aquifer would fill with water.

5. REFERENCES

Davis, S. N. and R. J. M. DeWiest, 1986. Hydrogeology, John Wiley and Sons, Inc., New York.

DOE, 1987. The Environmental Survey Manual, U. S. Department of Energy, DOE/EH-0053, Office of Environmental Audit.

Freeze, R. A., and J. A. Cherry, 1979. Groundwater, New Jersey: Prentice Hall Inc.

EPA 1988. Generalized Ground-Water Sampling Device Matrix. Coop CR812713-01-5 USEPA, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

EPA, 1987. Groundwater Handbook EPA/625/6-87/016. Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma 74820.

EPA, 1985. Practical Guide for Ground-Water Sampling, EPA 600/2-85-104, Environmental Research Laboratory, Ada, Oklahoma, 1985.

EPA, 1983a. Vadose Zone Monitoring for Hazardous Waste Sites, EPA 600/X-83-064, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, 1983.

EPA 1983b. Characterization of Hazardous Waste Sites - A Methods Manual: Volume II, Available Sampling Methods, 600/4-83-040, USEPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, EPA.

6. BIBLIOGRAPHY

Campbell, M. D. and J. H. Lehr 1977. Water Well Technology, New York: McGraw-Hill Book Company.

Driscoll, F. G. 1986. Groundwater and Wells, 2nd Edition, Johnson Division, St. Paul, Minnesota.

EPA, 1987. Ground-Water Monitoring Quality Assurance for RCRA, EPA 600/X-87-035, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

EPA, 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, Office of Solid Waste and Emergency Response.

EPA, 1986. Data Quality Objectives Development Guidance for Remedial Investigation/Feasibility Study Activities.

EPA, 1981. Manual of Ground-Water Quality Sampling Procedures, EPA 600/2-81-160, Environmental Research Laboratory, Ada, Oklahoma.

EPA, 1980. "Water Quality Criteria Documents," Federal Register, Washington, D.C.

FWS, 1986. United States Fish and Wildlife Service, Field Operations Manual for Resource Contaminant Assessment, Resource Contaminant Assessment Division, U.S. Department of the Interior.

Johnson, E. E., 1966. Ground Water and Wells, A Reference Book for the Water-Well Industry, St. Paul, Minnesota.

Keely, J. F. and K. Boateng, 1987. Maintaining Well Installation, Purging and Sampling Techniques - Part 1 Conceptualizations, Ground Water, 25, 3.

U.S. Government Printing Office, Protection of Environment, 1985. Code of Federal Regulations, CFR 40 Parts 190 to 399, Washington, D.C.

U.S. Government Printing Office, 1977. "The Clean Water Act Showing Changes Made by the 1977 Amendments," 95th Congress, Washington, D.C., No. 95-12.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX I
SEDIMENT SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix I of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   D.2 Bird Sampling Reference Field Methods
   D.3 Fish Sampling Reference Field Methods
   D.4 Flora Sampling Reference Field Methods
   D.5 Reptiles and Amphibians Sampling Reference Field Methods
   D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

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Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

References (if applicable):

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ACRONYMS

BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
DOE	Department of Energy
EC	Environmental Contaminant
EPA	Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FWS	Fish and Wildlife Service
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RFM	Reference Field Methods
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act
TOC	Total Organic Carbon
TSCA	Toxic Substances Control Act
USDA	United States Department of Agriculture
USGS	United States Geological Survey

U.S. FISH AND WILDLIFE SERVICE LANDS
BIOMONITORING OPERATIONS MANUAL

APPENDIX I
SEDIMENT SAMPLING
REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of these Reference Field Methods (RFM) is to identify procedures in collecting sediment samples for physical and chemical analysis. Data generated from sediment sampling/monitoring activities relating to sediment contamination can be used by refuge personnel and Environmental Contaminant (EC) specialists to develop and implement contaminant management activities.

Sediment sampling/monitoring is conducted to

- Determine risk to the environment from sediment contamination.
- Determine the extent to which sediments serve as either sources or sinks for pollutants.
- Determine the presence and distribution of pollutants in sediments as a function of both time and space.
- Obtain measurements for validating sediment transport and distribution models.
- Meet the provisions and intent of environmental laws such as the Fish and Wildlife Coordination Act (FWCA), the Clean Water Act (CWA), the Comprehensive Environment Response, Compensation, and Liability Act (CERCLA), and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

1.2 Scope

Both the physical and the chemical characteristics of the sediment system will influence the transformation, retention, and movement of pollutants through the sediment matrix. The physical parameters should not be ignored. Procedures identified in the Soil Sampling and in the Field Instrument Measurements RFMs can be used to obtain some physical field measurements. Depending upon the objectives of the sediment sampling/monitoring effort, identifying some of the physical characteristics of the sediment may be necessary to enhance sediment chemical data. To obtain definitive physical data, it may be necessary to collect samples and have them analyzed under laboratory conditions. The techniques described may be conducted by refuge personnel; however, some methods may require assistance from other Federal agency personnel or private contractors (Table 1).

Table 1. Key to sediment sampling procedures.

Sediment Collection Methods	Location in RFM	Type of Monitoring*	Advantages	Disadvantages	May Need Assistance
Spoons, Scoops, and Trowels (Volatile and Metal Analysis)	2.1.1	A, B, C	Inexpensive and easy to carry and use.	Requires manual power—not the best for volatile samples. Can bias the sample by not collecting all fines.	Could get equipment from USGS. If area is contaminated, requires special protective gear. Ask EC specialist for assistance. Also, if contaminated, USEPA can provide assistance from a Remedial Project Manager.
Coring Devices	2.1.2	A, B, C	Easy to carry. Good for sampling shallow marsh deposits and peag bogs with fines.	Difficult to use in swift current. Some limitation on sampling depth.	
Grab and dredge samples	2.1.3	B, C	Most can be used from small boats. Good in soft sediments.	Influenced by bottom hardness and strong currents, may leak, and may need a winch.	
Cable and Reel	2.2.2	B, C	Good for composites. Can sample in deep water.	May have some difficulty in high velocity flows.	
Bed-Load Samplers	2.3.1	A, B, C	Good in compacted material.	Not good in high velocity flows.	

* A = Initial Screening/Characterization
B = General Monitoring
C = Special Case Monitoring

The analytical methods for contaminant determination that will be used to examine the sediments collected for this program have been validated with a prescribed sample volume and a specified particle size. The analyst must be provided with a sample that is commensurate with the analytical requirements. The sampling personnel also must prepare and ship sediment samples in a prescribed manner to provide a representative sample from the total material collected. For example, if multiple samples are collected from a single sampling site for compositing, it is required (in most cases) that the samples be prepared in the field before shipping them to the analytical laboratory. Preparation of single samples may also be required. Soil sample preparation procedures that may be adapted for sediment by field personnel are presented in the Soil Sampling RFM. Section 3 of this RFM identifies commonly used sediment preparation and handling procedures. These procedures must at a minimum satisfy the following requirements:

- Provide an adequate sample having sufficient volume to satisfy the analytical requirements.
- Provide a sample with appropriate particle size to obtain meaningful data.
- Provide a representative sample of the total material collected.

Methods selected to sample sediments will depend on the sampling/monitoring objectives, the monitoring design, and the conditions for which the sampling device was designed. There are additional factors that must be addressed and considered when collecting sediment samples. Streams, estuaries, lakes, and impoundments, for example, will most likely demonstrate significant variation over time in sediment composition with respect to distance from inflows, discharges, outflows, or other disturbances. It is important, especially when sampling is to be conducted over a specified time period, to document exact sampling location by using fixed reference points on the banks of bodies of water, e.g., estuaries or lakes. A compass is usually adequate for identifying location. If required, highly accurate positioning guidance for large bodies of water is identified in EPA (1986). Table 2 lists the advantages and disadvantages of these positioning methods.

Because of the complexities of assessing sediment data, strict observance to the monitoring design is required. Changing sampling site locations and sample collection handling methods without appropriate documentation could result in unreliable data.

No single sampling method can be recommended for all sampling conditions. However, a number of sampling methods are identified in this RFM and appropriate instructions are provided. Refuge personnel should select the method that is most appropriate for their sampling needs.

1.3 Background

The sediment matrix discussed herein is defined as any particulate matter that is moved by water to or from a land surface and into or through the waterways of a river basin, a lake system, or an estuary. Generally sediments consist of both mineral particles and organic material. The organic fraction commonly consists of material that is in various degrees of decomposition with particle sizes ranging from colloidal humus to large pieces of material. The inorganic fraction consists of particulate matter from one or a combination of the three major rock groups: igneous, metamorphic, or sedimentary. The size of the mineral particles can range from that of colloids clays through silts

Table 2. Summary of acceptable positioning methods.

Category	Achievable Accuracy	Maximum Range	Advantages	Disadvantages
Higher Accuracy Group				
Theodolite	10 to 30 ±1 m and up	<5 km	Traditional method. Inexpensive. High accuracy. Successfully applied. Restricted areas.	Line of sight. Two manned shore stations. Simultaneous measurements. Limits on intersection angles. Area coverage; station movement.
EDMI	1.5 to 3.0 cm	3 km without multiple prisms	Extremely accurate. Usable for other surveying projects. Cost. Compact, portable, rugged.	Motion and directionality of reflectors. Line of sight. Visibility, unless microwave. Two shore stations. Ground wave reflection.
Total Stations	5 to 7 cm	<5 km	Single onshore station. Other uses. Minimum logistics.	Reflector movement and directionality. Prism costs. Line of sight. Optical or infrared range limitations.
Microwave Navigation System	+1 to 3 m	25 km	No visibility restrictions. Multiple users. Highly accurate. Radio line-of-sight	Cost. Multiple onshore stations. Logistics. Security. Signal reflective nulls.
Range-Azimuth Systems	0.01 and 0.5 m	<5 km (optical) 30 km (elec)	High accuracy. Minimum logistics. Use in restricted/ congested areas. Future cost. No shore stations.	Current coverage. Initial development cost.
Lower Accuracy Group				
Sextant[a]	+10 s	<5 km ±2 m and up	Rapid. Easy to implement. Common equipment. Low cost. No shore party. High accuracy closer to shore.	Simultaneous measurement of two angles. Target visibilities, location, maintenance. Line of sight. Best in calm conditions. Limits on acceptable angles.
Loran-C	+15 m and up	none	No visibility or range restrictions. No additional personnel. Low cost, existing equipment.	Interference in some areas. Used only for repositioning except in limited areas, need to locate station initially with another system.
Variable Range Radar	+0.5 +25 m	16 72 km	No visibility restrictions. No additional personnel. Low cost, existing equipment.	Line-of-sight. Relies on map accuracies of targets. Accuracy decreases with range scale.

a. Accuracies greater than +20 m are not common farther than 1 km from shore under normal operating conditions, as such, this method is considered in the lower accuracy group. Data from USEPA, 1986.

Table 3. Size classification and characteristics.

Inorganic	
Type	**Size and Characteristics**
Boulders	>256 mm (10 in.) in diameter
Rubble	64 to 256 mm (2-1/2 to 10 in.) in diameter
Gravel	2 to 64 mm (1/12 to 2-1/2 in.) in diameter
Sand	0.06 to 2.0 mm in diameter; gritty texture when rubbed between fingers
Silt	0.004 to 0.06 mm in diameter
Colloids	<0.00024 Particulates that remained suspended in solution
Marl	Calcium carbonate; usually gray; often contains fragments of mollusk shells or CHARA; effervesces freely with hydrochloric acid
Organic	
Detritus	Accumulated wood, sticks, and other undecayed coarse plant materials
Fibrous peat	Partially decomposed plant remains; parts of plants readily distinguishable
Pulpy peat	Very finely divided plant remains; parts of plants not distinguishable; varies in color from green to brown; varies greatly in consistency, often being semifluid
Muck	Black, finely divided organic matter; completely decomposed

Source: USEPA 1978 and USACE 1981.

and sands to gravel and boulders. Table 3 presents a commonly used size classification scheme and identifies various inorganic and organic characteristics of sediments.

The size distribution of sediments is important because it may affect the distribution of chemicals in the aquatic environment. Specifically, sediments can remove chemical contaminants from water by the process of sorption. Also, as sorption is a surface phenomena, the smaller particle sizes generally have a higher concentration of chemical contaminants on a weight to weight basis.

Risk to the environment from contaminated sediments alone is possible but sometimes difficult to determine. Important factors that must be considered include identifying exposure pathways to the most sensitive receptors of concern. It is generally the water in contact with the sediments that leads ultimately to the exposure of a receptor. Therefore, it may be important to measure the extent to which sediments act as a contaminant source to contacting waters. For example, if significant quantities of a pollutant are found to be associated with sediments initially and then released over

time, the sediments act as a pollutant source. As a result, just knowing the concentration of pollutants in water originating from contaminated sediments is not sufficient for estimating exposure.

The commonly used descriptor, "total sediments," can be characterized as being the sum of bed material, suspended-load, bed-load. Bed material (See glossary) is the sediment mixture of which the bed is composed. Suspended-load sediments are defined as that material moving in suspension in a fluid, being maintained by the upward components of the turbulent currents or by colloidal suspension. Bed-load is defined as sediment that moves by sliding, rolling, or bouncing along on/or near the stream bed.

Sediments, and those contaminated with pollutants, can produce varied effects on aquatic ecosystems. Suspended sediments can decrease light penetration, reducing the depth of photosynthetic activity. A reduction of photosynthetic activity and consequently food web efficiency can upset population balances. Other potential detrimental effects on aquatic organisms by the total sediment matrix include

1. Creating conditions conducive to the entry and persistence of disease-related organisms
2. Altering water chemistry by the adsorption and/or absorption of contaminants
3. Clogging and abrasion of gills and other respiratory surfaces
4. Affecting usable habitat by the scouring and filling of pools and riffles and the changing of bed composition
5. Affecting intragravel permeability and dissolved oxygen levels
6. Entombing life stages of biotic organisms
7. Adhering to the chorion of eggs.

1.4 Information Resources

The U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers (USACE) can provide local information concerning sediments or provide the necessary guidance to acquire the needed information. A number of excellent guidance documents exist addressing the behavior, characteristics, sampling and quality assurance aspects for sediment sampling. Those guidance documents include

Procedures for Handling and Chemical Analysis of Sediment and Water Samples. USACE, Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi, 1981.

Sediment Sampling Quality Assurance User's Guide. U.S. Environmental Protection Agency (EPA) Environment Monitoring Systems Laboratory, Las Vegas, Nevada, 1985.

Puget Sound Estuary Program--Puget Sound Protocols. EPA Region 10, Seattle, Washington and USACE, Seattle Washington, 1986.

Field Methods for Measurement of Fluvial Sediments. USGS, Reston, Virginia, 1988.

Below are recommended steps to follow to obtain available information/expertise regarding the site's sediment characteristics.

1. Contact the USGA or the USACE to determine if sediment characteristics and parent material have been identified. If so, request this information and information concerning stream flow rates and sediment quantities transported by flowing bodies of water.

2. If #1 is not a viable option, contact a local university, U.S. Forest Service, U.S. Bureau of Land Management, or State Conservation or extension Service personnel to determine if they have specialists that can provide assistance.

3. If assistance is available, review the RFM to become familiar with sampling procedures. Request that a sediment specialist visit the refuge and discuss available data and sampling/monitoring approaches.

4. If assistance is not available when needed, use the RFM and conduct necessary sediment sampling/monitoring procedures. Document the approach and results obtained for your specific monitoring objectives. Consult regional EC specialists as necessary.

2. SEDIMENT COLLECTION METHODS

It may be somewhat arbitrary to address sampling bed material, suspended-load and bed-load sediments separately because during the process of sediment transport, an exchange of the three sediment fractions may occur. However, to better define the three different sampling approaches, the following discussion presents these three components separately.

Important criteria to consider when selecting sediment sampling tools include

- Material used in the construction of the tool is noncontaminating
- Capability for obtaining a specific sample
- Suitability for sampling various sized sediments
- Suitability for sampling sediments under various water/environmental conditions
- Relative sample size required
- Labor and training requirements
- Cost.

Penetration of bed material by sediment samplers can be impeded by gravelly or stony substrates. This problem is generally accented by smaller diameter tools such as coring devices and jaw type grab samplers. Alternate tools include hand scoops and dredging equipment. Another important consideration is water depth and accessibility to a selected sampling site. For example, hand-held equipment is generally suited to small and intermediate sized streams and small bodies of water. When streams and lakes cannot be waded, the use of a boat with a cable and reel is usually necessary. Also, the material used in the construction of sampling equipment may contaminate the collected sample. The identity of the construction material as a function of the contaminant of concern is critical.

It is good practice for at least two individuals to work together in the field to obtain samples; this is especially true when safety is a concern. Also, sediment sampling is often tedious, and two individuals can take turns operating the sampling tool. In addition, sampling/monitoring documentation is facilitated when two individuals work together. In some cases, especially when sediments are dry, soil sampling equipment may be appropriate for collecting sediment samples. See the Soil Sampling RFM for equipment descriptions.

The sampling methods described herein are for the collection of sediment samples only. Frequently, it is desirable to collect samples of surface and subsurface water to complement sediment chemical data. The collection of surface waters is described in the Surface Water RFM.

2.1 Bed Material Sediment Sample Collection Methods

Bed material samplers have been difficult to design and use because of the wide range of particle sizes that can be encountered. During use, bed material sampling equipment may change the flow characteristics of a body of water. Such a hydraulic change will normally affect the behavior of the sediment on or near the sampling site. When this condition occurs, it becomes more difficult to obtain a truly representative sample.

There are three broad classifications of bed material sediment sampling devices. These are shoveling devices, coring devices, and grab and dredge samplers. Shoveling devices are generally suited for shallow areas; corers produce the least disturbed samples; and grab and dredge samplers collect large surface area samples that become mixed. Because there have been concerns about the samples collected by grab and dredge samplers, they should only be used where other sediment samplers will not work.

The choice between sampling equipment should always be based on the sampling objectives and conditions. Shovels are hand held devices that are suitable for collecting surface materials that are within the actual reach of sampling personnel. Corers function by driving a tube into the sediments, usually through the use of gravity, hydrostatic pressure, vibration, or by hand. The length of core that can be collected generally is limited to 10 core diameters in sand substrate and 20 core diameters in clay substrate. When using a core liner, care must be taken as substantial sample disturbance may result from the internal friction between the coring device and the liner.

Free-fall coring devices are often difficult to use in swift currents and can cause compaction of the vertical structure of sediment samples. Therefore, if the vertical stratification in a core sample is of importance or interest, a piston or vibration corer should be used. These devices use both gravity and hydrostatic pressure. As the cutting edge penetrates the sediments, an internal piston remains at the level of the sediment-water interface, minimizing sediment compression and internal friction. If samples will not be sectioned before analysis, compaction is an academic problem, and free-fall corers are a suitable alternative.

Grab and dredge samplers are designed primarily to retrieve surface sediments, and some are useful for collecting substrates dominated by gravel layers. A problem identified with the use of these samplers is that shock waves are generated ahead of the descending samplers, and these waves can wash away light, unconsolidated sediments and unattached benthic organisms. This effect is minimized with samplers that have flaps, screens, or valves to create a flow-through system during descent. An added benefit of flaps is that sample washout protection is provided by the flaps during sample recovery.

Grab and dredge samplers are influenced by bottom hardness, depth to sample, currents and fall rates and angles as well as lateral boat motion. These factors can contribute to sample composition variability where sediment concentrations vary vertically. Therefore, it is recommended that the use of grab and dredge samplers be limited to areas of vertically homogeneous sediments. Unless preliminary data are available, knowledge of sediment structure would be unknown.

A number of bed material sediment samplers have been evaluated for sampling characteristics. These observations and evaluations are presented in Table 4.

As previously stated, a number of the soil sampling tools, e.g., shovel type devices, and the procedures for their use in collecting soil samples may be applicable for the collection of some sediment samples. Some of these tools and the procedures for their use are repeated in this RFM for convenience.

2.1.1 Spoons, Scoops, Trowels

Spoons, scoops, and trowels are used almost exclusively for the collection of shallow surface samples. These devices are considered by many scientists to be somewhat undesirable as sampling tools because the reproducibility of sampling area, depth, and volume from one sampling site to another is poor. However, if sampling inconsistencies (e.g., area, volume and/or depth, and core descriptions) are not critical to the sampling objective, then the use of these devices is acceptable.

Care should be exercised when using spoons, scoops, and trowels to collect sediment as these tools can be very disruptive to the water/sediment interface and may cause substantial alterations in sample integrity if care is not exercised.

2.1.1.1 Spoons. The simplest, most direct method of collecting sediment samples is to use stainless steel spoons. The common spoon size referred to here varies from the teaspoon size of about 10-g capacity to the tablespoon and mixing spoon sizes that vary from 30 g to about a 100-g capacity.

2.1.1.2 Scoops. The recommended device is a stainless steel or Teflon scoop similar or identical to ice scoops. Scoops that vary in capacity from less than 300 g to more than 2000 g can be purchased. The advantages of spoons and scoops include

- Inexpensive--Numerous spoons and scoops can be purchased with limited resources.
- Availability--Stainless steel spoons and scoops are readily available. Time constraints in obtaining these tools are minimal.
- Decontamination--These tools can be easily decontaminated with water and/or appropriate solvents. Because of the cost involved in the decontamination procedure, it is generally recommended to discard used spoons instead of decontaminating them. (See Decontamination Guidance RFM for suggested methods.) The cost of some scoops would also prevent the discarding of this device.
- Remote area sampling--Spoons and scoops can be carried to remote areas.
- Screening--Fast and inexpensive method for collecting sediment samples for initial screening purposes.

Table 4. Operational Aspects of Bed Material Sediment Sampling Equipment

Sampler	Characteristics	Trigger System Reliability	Jaw Shape, Design and Cut	Preservation and Protection from Sample Washout	Stability in Current
Shovels, i.e., spoons, scoops, trowels	Surface layers are easily collected in shallow waters. Undesirable for sampling reproducibility. Suitable for soft or hard materials. Usually disturbs bottom material.	—	—	Material can be dislodged from surface of sampling device if care is not taken especially when sample is being brought to the surface	Fair, depends on the sampling personnel use and direct handling of the sampling device
Hand corer with removable teflon or glass liners	Shallow wadable waters, deep waters if scuba available. Hand use extended to waters of 10 ft by the use of extension rods	—	—	Requires removal of lines before repetitive sampling. Risk of metal contamination from barrel and core cutter.	Fair, handles may provide for greater stability and ease of substrate penetration
US BMH-53	Length--46 in. Made of corrosion-resistant materials. Sample container-stainless steel. Piston mechanism	Piston creates a partial vacuum. Piston serves to help remove sample.	—	—	Hand-held for use in wadable streams--for sampling bed material finer than medium gravel
Benthos gravity corer	Cores of 3 m or less in soft clays, muds or sandy silts. Particularly suitable for studies of the sediment/water interface, for studies on depositional sediment structures	—	—	—	—
Alpine Gravity Corer	Cores of 2 m or less in almost all sediment types. The rugged nature of this corer lends itself to general usage. For studies involving sediment structure or large volumes of material, the corer is unsuitable	—	—	—	—
Gravity corers, i.e., Phleger corer	Cores of 0.5 m or less, in almost all sediment types. Particularly suited to bottom materials containing a high percentage of fibrous organic material. The low cutter angle, the narrow wall thickness and high point loading, and the extremely sharp cutter, make it very suitable for sampling shallow lacustrine and estuarine deposits, marsh deposits, and thin peat beds.	—	—	Low risk of sample contamination	Small sample, requires repetitive operation and removal of liner, time consuming

Table 4. (continued)

Sampler	Characteristics	Trigger System Reliability	Jaw Shape, Design and Cut	Preservation and Protection from Sample Washout	Stability in Current
Franklin-Anderson Grab	Suitable for obtaining material for bulk sample analysis. Works best in soft clays, muds, silts, and sands. Will occasionally obtain a good gravel sample.	Good, but perhaps too sensitive on hard sand and gravel bottom.	Poor. During the first stages of closure and when under the greatest pressure of springs and weight, the jaw shape loosely follows the arc or cut. However, the degree of fit becomes progressively worse as the closing pressure is reduced. Because each jaw is semicylindrical in shape, sample displacement is necessary within it if anything near maximum capacity is to be achieved.	Fair, but the tightness of closure is largely dependent upon the lack of grains trapped between the edges of the jaws. Providing a tight fit between the two jaws is obtained, the sample is well shielded against washout. If the jaws are kept open by material trapped between the jaws, washout can be severe or total.	Fair, despite the weight of this grab, it tends to "stream" at an inclined angle under conditions of rapid ship drift or fast water flow. Provided lowering and conditions are calm and stable, the sampler will hold upright during the initial sampling process; if, however, the line is allowed to slack, the sampler will fall over.
Dietz-LaFond grab	Can be used for general sampling but not recommended for any particular use. Of all the samplers tested, this pattern proved to be the least suitable.	Poor, unless area of trigger foot is increased to at least 50 cm^2. Triggering may often be impossible in very soft mud unless the foot has been modified.	Poor, as for Franklin-Anderson	Fair, comments as for Franklin-Anderson	Poor. This sampler is very sensitive to "streaming" and will rarely operate in the vertical position unless used in ideal conditions. Its tendency to maintain an inclined attitude during descent sometimes results in a failure to trigger.

Table 4. (continued)

Sampler	Characteristics	Trigger System Reliability	Jaw Shape, Design and Cut	Preservation and Protection from Sample Washout	Stability in Current
Birge-Ekman dredge	Suitable for soft clays, muds, silts, and silty sands. This sampler should be used under calm water conditions, typically in small lakes or restricted areas. The lack of sample disturbance, square cross section, and moderate penetration make this sampler suitable for detailed studies (i.e., biological and geochemical) of the top 2 to 3 cm of bottom sediment. Because of its light weight and easy handling, it is well suited to small boat operations.	Good. Triggered by messenger weight dropped from surface, normally consistent but can be affected on soft bottoms if sampler is allowed to settle for too long before dropping the messenger.	Excellent. Jaw shape exactly follows arc of cut and almost no sample displacement occurs.	Good, except when the sampler is used in very coarse or shelly sediment. Under these conditions, material may be trapped between the jaws, preventing their closure. In this case, washout may be severe. The jaws are so designed that they slightly overlap one another, thus a slight imperfection of closure can be tolerated.	Fair, despite the light weight of this sampler and its tendency to "stream", its wide base gives good stability and stance once it has come to rest on the sediment floor. Under poor sampling conditions, however, it becomes impossible to operate because: (a) the sampler, due to its light weight, is continually being lifted and dropped and "streamed" along the bottom, and (b) any slack in the line, particularly near the sampler, is likely to impede the proper function of the triggers' messenger weight. It tends to roll over after triggering on all but soft bottoms.
US BMM-60	A scoop/bucket device. Will penetrate bed to about 1.7 in. Hold about 175 cc of material.	Constant, torque spring activated by release of hanger rod tension.	—	Gasket on closure plate prevents sampled material from being washed out.	Hand-held, hanger rod/handline operated. Weighted sampler nose aids in sampler penetration
US BMM-80	A scoop/bucket device. Will penetrate bed to about 1.7 in. Hold about 175 cc of material.	Lever on handle to open or close bucket assembly	—	Closure is sufficiently sealed to prevent washout.	Effective where sediments consist of consolidated fines with no armoring present

Table 4. (continued)

Sampler	Characteristics	Trigger System Reliability	Jaw Shape, Design and Cut	Preservation and Protection from Sample Washout	Stability in Current
Pattersen Grau	This sampler, like the Franklin-Anderson, is suitable for taking bulk sample material in most types of sediment. It is quite unsuited for studies of detailed and specific sediment properties, thought it is perhaps a little more successful in taking gravel samples (Either of these two samplers (Peterson or Franklin-Anderson) will go well as a general purpose bulk sampler.	Fair to good, thought tends to be a little oversensitive on hard sand and gravel bottoms.	Poor. Comments as for Franklin-Anderson, except that, instead of the reduction in closure pressure being produced by slackening of tensional springs, the same result is proceeded by reduced leverage on the scissor arms mounted across the hinge line.	Good, comments as for Birge-Ekman. Can collect a large sample: Can penetrate most substrates	Good. This is a heavy sampler (may require a winch) with a wide base lien (when the jaws are open). It maintains a near vertical descent under all conditions, but after sampling it tends to fall over (unless on a soft bottom).
Ponar grab	An excellent general purpose bottom sampler. In practice, it operates better than either the Petersen or Franklin-Anderson over the full range of bottom types. It can also obtain bottom samples with little or no disturbance and with the protecting screens removed or folded back, direct access can be had to the sediment surface of the sample. Such access to an undisturbed sample makes is suitable for geochemical, sedimentological, and biological studies. Because of the large sample volume and its relatively undisturbed state, this sampler is very suitable for population studies of the bottom sediment fauna	Good, though like the Petersen, tends to be a little oversensitive on gravel bottoms. May not function well on heavy gravel.	Excellent. Jaw shape exactly follows arc of cut and almost no sample displacement occurs. Useful on soil, silt and clay.	Good, comments as for Birge-Ekman. In addition to the overlap jaws, this sampler has a pair of metal side plates, mounted close to the moving side faces of the jaws. These plates further reduce the possibility of washout. Large sample can be obtained, permitting subsampling.	Very good, comments as for Petersen; because of its weight and wide baseline (when jaws are open) this grab has a good vertical descent under most conditions and has a stable stance on the bottom. The presence of the fixed side plates prevents the grab from falling over after jaw closure and helps in preserving a near perfect bottom sample.
Van Veen grab	Open upper face with rubber flaps. Penetration in sediment is by weight of sampler	Good, but free fall to bed may trigger unit prematurely	---	Sampler should be checked prior to use. Closure is sufficiently sealed to prevent washout.	Effective in marine environments. Supported by hydrowire on a ball bearing swivel. Swivel minimizes twisting during deployment.

Table 4. (continued)

Sampler	Characteristics	Trigger System Reliability	Jaw Shape, Design and Cut	Preservation and Protection from Sample Washout	Stability in Current
Shipek Bucket Sampler	An excellent general purpose sampler, though perhaps a little heavy for small boat operation. This sampler is capable of working with almost equal success on all types of bottom material. It provides a sample even less disturbed than the Ponar, making it the most suitable sampler for detailed geological studies of the sediment surface. The sampler volume is significantly less than that of the Ponar, and the quantity of material sampled at maximum cutting depth is also less than the Ponar. These two points may, therefore, favor the Ponar for certain biological (population) studies. On the other hand, the rapid rotation of the Shipek bucket, as opposed to the much slower closure of the Ponar's jaws, may make it more suitable for sampling sediment containing a significant population of nonsessile forms.	Good, though some slight settlement may occur before triggering on very soft materials. Sampler may fail to trigger when lowered gently on soft bottoms. By lifting and dropping the trigger weight a few centimeters after bottom contact, abortive casts may be avoided. The slight movement of the inertial trigger weight has no other effect on the sampler.	Excellent, as for Ponar. In addition, the rotation of the bucket is extremely rapid. In most cases the rotational shear is far greater than the sediment shear strength, thus the cutting action is very clean (producing minimal disturbance), particularly in soft clays, muds, silts, and sands.	Excellent. The great advantage of the Shipek, over all of the other samplers described, is that the bucket closes with its separation plane aligned in the horizontal rather than int he vertical. Good samples can be retrieved even when bucket closure is prevented by pebbles or similar material, even 2 to 5 cm across. With the bucket properly rotated, washout is completely avoided.	Excellent. Despite the large size of this sampler, its weight ensures a near perfect vertical descent even under conditions of rapid drift or fast water flow. The sampler is also very stable even on bottom slopes 20 degrees or more. This stability ensures the minimum possible disturbance of the sample material.
US BM-54	Length 22 in. with tail vanes made of cast steel. Weighs about 100 lb.	Driving force provided by a constant-torque spring.	—	—	Not good in high velocity flows. Good in compacted material

2.1.1.3 Trowels. Trowels are shovel-like instruments similar in use to spoons and scoops. The sampling advantages are identical to spoons and scoops except for the cost. The cost of discarding some trowels instead of decontaminating them would probably become prohibitive, especially during long-term repetitive sampling programs.

Using spoons, scoops, and/or trowels, single or multiple samples can be collected by the following procedures:

1. Insert clean scoop, spoon, or trowel into sediment and carefully remove sample.

2. If compositing a series of grab samples, use a stainless steel or glass mixing bowl or Teflon tray for mixing. Sieve, mix, and collect appropriate sample. (See Section 3 and the Soil Sampling RFM, Section 5, for additional guidance.)

   NOTE: Do not mix sediment that will be analyzed for volatile organics.

3. Transfer sample into an appropriate sample container with a stainless steel laboratory spoon or equivalent. (See Documentation Guidance SOP for container requirements.)

4. Collect split and duplicate samples if required. (See Documentation Guidance SOP).

5. Check that a Teflon liner is present in container cap if required. Secure the cap tightly. The chemical preservation of solids is generally not recommended. Refrigeration is usually the best approach, supplemented by a minimal holding time. (See Documentation Guidance SOP for definitive requirements.)

6. Identify the sample container with the appropriate sample label and tag. Be sure to label the tag carefully and clearly, addressing all the categories or parameters. Place the labeled sample container in an appropriate carrying container and preserve as required. Complete all chain-of-custody documents and record in the field logbook. (See Documentation Guidance SOP for definitive requirements.)

7. Decontaminate sampling equipment after use and between sample locations, and collect rinsate blanks as required. (See Documentation Guidance SOP).

2.1.2 Coring Devices

As identified in Table 4, a number of coring devices can be selected. Select the device that will best meet the sediment conditions and satisfy the specific sampling requirements. When sediments are to be analyzed for volatiles, it is advantageous to use Teflon or glass liners in the corer to minimize handling. Under some conditions, the liner may be an acceptable container to ship samples to the laboratory. When selecting liners, care should be taken to choose a liner material that does not contaminate the sample.

Coring devices are the most suitable sediment sampling instruments for collecting undisturbed samples that can be sectioned and used for profile descriptions. Many hand-held corers can be fitted with extensions that allow the collection of sediment samples underlying various liquid depths.

Some corers have flaps that are clipped open during descent and snapped shut by a triggering mechanism after the sample has been collected. These triggering mechanisms and the various closing devices must be checked and maintained on a routine basis to prevent unacceptable performance and sample leakage. For deep sediment sampling, cables, reels, and winches can be used to raise, lower, and operate coring sampling devices.

The procedures that are identified below for coring devices provide general guidance. It is recommended that personnel consult and follow the manufacturer's instructions pertaining to the proper use of any sampling equipment.

2.1.2.1 Nongravity hand-operated corers.. For most nongravity hand-operated corers, the following procedures should be used:

1. Document that the corer was properly precleaned.

2. Force the corer into the sediment with a smooth, continuous motion.

3. Twist the corer, then withdraw it in a single smooth motion.

4. Remove the nosepiece, withdraw the sample from the corer, and place the sample in a stainless steel bowl, glass bowl, or Teflon tray. Describe core and sieve and mix as required. Do not withdraw the sample if a liner is used in the corer and the liner is to be used as a container.

5. Transfer the sample into an appropriate sample container with a clear stainless steel laboratory spoon or equivalent.

6. Follow guidance as identified on page 17 numbers 4, 5, 6 and 7.

2.1.2.2 Gravity type corers. For gravity type corers, the following procedures should be used:

1. Attach a precleaned corer to the required length of sample line. Solid braided 5-mm (3/16-in.) nylon line is sufficient; however, 20-mm (3/4-in.) nylon is easier to grasp during hand hoisting.

2. Secure the free end of the line to a fixed support to prevent accidental loss of the corer.

3. Allow the corer to free fall through water to the bottom with minimal winnowing and surface disturbance.

4. Retrieve the corer with a smooth, continuous lifting motion. Do not bump the corer, as this may result in some sample loss.

5. Remove the nosepiece from the corer (e.g., eggshell core retainer) and slide the sample out of corer into a stainless steel or glass bowl or Teflon pan. Describe core and sieve and mix if required. Do not mix if samples are for volatile analysis. (See Section 3 for sample handling recommendations.)

6. Transfer the sample into an appropriate sample container with a stainless steel laboratory spoon or equivalent.

7. Follow guidance as identified in section 2.1.1.3 steps 4, 5, 6 and 7.

2.1.3 Grab and Dredge Samplers

One criterion for an adequate grab and dredge sampler is that it consistently collects samples to the required depth below the sediment surface. An additional requirement is that the sampler can be handled properly and efficiently onboard a boat if required. It is always recommended that personnel consult and follow the manufacturer's instructions on the correct use and operation of specific samplers.

Collection of sediment samples by these samplers requires that the sampler

- Create a minimal bow wake when descending
- Form a leakproof seal when the sediment sample is taken
- Prevent winnowing and excessive sample disturbance when ascending.

Most grab samplers have open upper faces that are fitted with flaps. Upon descent, the flaps are forced open to minimize the bow wake, whereas upon ascent, the flaps are forced closed to prevent sample winnowing. Although most samplers seal adequately when purchased, the wear and tear of repeated field use eventually reduces this sealing efficiency. Personnel should routinely monitor the sampling instrument for sample leakage. If a sampler is to be borrowed or leased for a project, its sealing ability should be confirmed before sampling. Also, it is prudent to have a backup sampler on board in case the primary sampler begins leaking during use.

As shown in Table 4, a number of grab and dredge samplers are available. For illustrative purposes, the use of the Ponar grab sampler is described. As previously stated, it is recommended that personnel consult and follow the manufacturer's instructions pertaining to the correct use of any sampling equipment.

The Ponar grab sampler is a clamshell type device that can be used for deep-water sampling in sand, clay, and other soft sediments. Grab samplers are not capable of collecting undisturbed samples. Material in the first centimeter of sediment cannot be separated from that at lower depths. The sampling action of these devices causes agitation currents that may temporarily resuspend some settled solids. This disturbance can be minimized by slowly lowering the sampler the last half meter and allowing a very slow contact with the bottom. If water samples are to be collected also, it is recommended that they be collected before the sediments are collected.

To operate a Ponar sampler, the shell is opened and latched in place and slowly lowered to the bottom. It trips on bottom contact, but to operate effectively, the grab sampler must bite vertically. This requirement poses little problem in lakes with little current, but in river work, bottom sampling is especially difficult because the sampler frequently fails to contact the bottom perpendicularly. Because of the sampler's weight, it is advisable to operate this device with a winch on a boat or from some other supporting structure. The weight of some Ponar samplers is 23 kg

(45 lb) without weights and about 32 kg (70 lb) with weights. However, samplers are available in lighter weights. A Ponar having a 232 cm^2 sample area is available that is light enough to be operated without a winch. Sediment penetration depth with this device, however, will usually not exceed several centimeters.

Procedures for use

1. Tie a weight to the sample line and measure and mark the distance to the bottom on a sample line. A secondary mark, 1-m shallower, will indicate

   better proximity so that the lowering rate can be reduced when the sampler is 1-m above the bottom and prevent unnecessary bottom disturbance.

2. Attach a precleaned ponar sampler to the sample line. Solid braided 5-mm (3/16-in.) nylon line is usually of sufficient strength; however, 20-mm (3/4-in.) or greater nylon line allows easier hoisting.

3. Open the sampler jaws until they latch. From this point on, support the sampler by its lift line, or the sampler will be tripped and the jaws will close.

4. Tie the free end of the sample line to a fixed support to prevent accidental loss of the sampler.

5. Begin lowering the sampler until the proximity mark is reached.

6. Slow the rate of descent through the last meter until contact is felt.

7. Allow the sample line to slack several centimeters. In strong currents, more slack may be necessary to release the mechanism.

8. Slowly raise the sampler clear of the water surface.

9. Empty the sampler by placing it in a stainless steel or glass bowl or Teflon tray and open. Lift the sampler clear of the bowl or tray.

10. Sieve and mix, if required, and collect a suitable sample with a stainless steel spoon or equivalent. Place the sample into an appropriate container. Do not mix or sieve if collecting sediments for volatile analysis.

11. Follow guidance identified on page 17 numbers 4, 5, 6 and 7.

2.2 Suspended Sediment Sample Collection Methods

The ideal procedure for sampling a flowing body of water to determine the sediment discharge and contaminant levels would be to collect the entire flow of the stream over a given time period, remove the water, and analyze the sediment. Obviously, this method is a physical

impossibility. Instead, the sediment concentration of the flow can be determined by (a) collecting depth-integrated samples and (b) collecting point integrated samples.

The depth integrated sample provides an integrated sediment sample collected from a vertical column originating from the surface and ending at the bottom of a water body. Whereas, a point integrated sample represents a number of sediment samples collected at different locations on a given cross section of a water body. Table 5 identifies the dimensions and specifications of a number of suspended-sediment sampling devices that can be used for the collection of sediments.

Suspended-sediment samplers are used to obtain a sample of the sediment moving or temporarily suspended in the fluid stream. Criteria used in the design and construction of suspended-sediment samplers are as follows:

1. Allow water to enter the inlet (nozzle) isokinetically. (In isokinetic sampling, water approaching the nozzle undergoes no change in speed or direction as it enters the orifice.)

2. Permit the sampler inlet to reach a point as close to the stream bed as physically possible. [This may vary from approximately 9 cm to 18 cm (3-1/2 in. to 7 in.), depending on the sampler].

3. Minimize disturbance to the flow pattern of the stream, especially at the nozzle.

4. Be as simple and maintenance-free as possible.

When a suspended-sediment sampler is submerged with the inlet pointing directly into the flow, a part of the streamflow enters the sampler container through the sampler nozzle as air in the container exhausts under the combined effect of the following three forces:

1. The positive dynamic head at the nozzle entrance, caused by the flow

2. A negative head at the end of the air-exhaust tube, caused by flow separation

3. A positive pressure caused by a difference in elevation between the nozzle entrance and the air-exhaust tube.

When the sample in the container reaches the level of the air exhaust, the flow rate drops and circulation of the streamflow in through the nozzle and out through the air-exhaust tube occurs. Because the velocity of the water flowing through the bottle is less than the stream velocity, the coarser particles settle out, causing the concentration of coarse particles in the sample container to gradually increase.

The depth-integrating sampler is designed to isokinetically and continuously accumulate a sample from a liquid vertical column while transiting the vertical at a uniform rate. This sampler collects and accumulates a sediment sample as it is lowered to the bed and is raised back to the surface. Whereas, the point-integrating sampler uses an electrically activated solenoid valve, enabling sampling personnel to isokinetically sample selected points or portions of a given cross section.

Table 5. Dimensions and specifications of suspended sediment sampling equipment

		Sampler Dimensions					
Sampler Designation US	Construction Material	Length (in.)	Weight (in.)	Weight (lb)	Suspension Type	Maximum Depth (ft)	Intake Size (in.)
DH-48	Aluminum	13	3.2	4.5	Rod	8.86	1/4
DH-75P	Cd-plated	9.25	4.25	1.5	Rod	16.0	3/16
DH-75Q	Cd-plated	9.25	4.25	1.5	Rod	16.0	3/16
DH-75H	Cd-plated	9.25	4.25	1.5	Rod	–	3/16
DH-59	Bronze	15	3.5	22.0	Handline	19.0	1/8
DH-59	Bronze	15	3.5	22.0	Handline	16.0	3/16
DH-59	Bronze	15	3.5	22.0	Handline	9.0	1/4
DH-76	Bronze	17	4.5	22.0	Handline	16.0	1/8
DH-76	Bronze	17	4.5	22.0	Handline	16.0	3/16
DH-76	Bronze	17	4.5	22.0	Handline	16.0	1/4
DH-81	Plastic	7.5	4.0	0.5	Rod	–	3/16
DH-81	Plastic	7.5	4.0	0.5	Rod	9.0	1/4
DH-81	Plastic	7.5	4.0	0.5	Rod	9.0	5/16
D-49	Bronze	24	5.25	62.0	Cable reel	19.0	1/8
D-49	Bronze	24	5.25	62.0	Cable reel	16.0	3/16
D-49	Bronze	24	5.25	62.0	Cable reel	9.0	1/4
D-74	Bronze	24	5.25	62.0	Cable reel	19.0	1/8
D-74	Bronze	24	5.25	62.0	Cable reel	19.0	3/16
D-74	Bronze	24	5.25	62.0	Cable reel	19.0	1/4
D-74	Aluminum	24	5.25	42.0	Cable reel	19.0	1/8
D-74	Aluminum	24	5.25	42.0	Cable reel	19.0	3/16
D-74	Aluminum	24	5.25	42.0	Cable reel	19.0	1/4
D-77	Bronze	29	9.0	75.0	Cable reel	15.0	5/16
P-61	Bronze	28	7.34	105.0	Cable reel	180.0.	3/16
P-63	Bronze	37	9.0	200.0	Cable reel	180.0	3/16
P-72	Aluminum	28	7.34	41.0	Cable reel	72.2	3/16

US - United States Standard Sampler
D - Depth Integrating
H - Hand held Rod or Line
P - Point Integrating.

SOURCE: USGS (1987).

It is generally concluded (USGS, 1988) that point-integrating samplers are more versatile than the depth-integrating samplers. For example, they can be used to collect an integrated sample representing the mean sediment concentration in a vertical column, or they can be used to collect a sample at any given point from the surface to within a few centimeters of the bed.

When using the point-integrating sampler, the nozzle should be parallel to the stream flow with the cross-sectional area exposed to approaching particles. The air is exhausted from the sample container and directed downstream away from the nozzle area as the sample enters. The intake and exhaust passages are controlled by the solenoid valve, which can be activated on demand. When the valve is activated (open to the sampling position), the sampling procedure is identical to that used for depth-integrating samplers.

2.2.1 Hand-Held Samplers

For situations involving the collection of sediment in shallow wadable bodies of water or where access to a sampling site can be obtained from a low bridge span or cableway, a number of lightweight samplers are suggested. These samplers include the USDH-48 (United States Standard Sampler Depth Integrating Hand-Held), the USDH-59, USDH-75, USDH-76, and USDH-81. All of these samplers are described in detail in USGS (1988).

For illustrative purposes, the USDH-75H is described here. The following information provides only general guidance. It is recommended that personnel consult and follow the manufacturer's instructions pertaining to the correct use of any sampling equipment.

The DH-75H weighs 0.9 lb and is available in two versions, the DH-75P and DH-75Q, which accept plastic containers of pint and quart volumes respectively. The sampler consists of a cadmium-plated sheet-steel body 9-1/4-in. long, excluding the nozzle and sample container, with a retainer piece and shock cord assembly to hold the sample container against a cast silicone stopper through which the 3/16-in. nozzle and 180-degree air exhaust tube pass to the mouth of the bottle. The DH-75H can be used in wadable bodies of water as a general purpose depth-integrating suspended-sediment sampler. This sampler is recommended for use when the flow velocity is from 2 to 12 ft/s, and the water depth is less than 15 ft.

To use this sampler:

1. Preclean the nozzle and associated parts. Preclean the sample collecting containers and lids. (see Decontamination Guidance RFM for recommendations.)

2. Insert a clean sample collecting container into the sampler and check for obstructions in the nozzle or air exhaust tube.

3. Place the sampler into the water so that the nozzle is above the water and the lower tail vane is in the water for proper upstream-downstream orientation.

4. Lower the sampler at a constant rate until the sampler touches the streambed, then immediately reverse the sampler direction and raise the sampler at a constant rate until it clears the surface. If the sampler is not raised immediately, the sample will be biased to the collection of larger sized particles (bed-load sediments) near the bed. The transit rate used in raising the sampler need not be the same as the one used in lowering, but both rates must be constant to obtain a velocity- or discharge-weighted sample. The rates should be such that the bottle fills to near its optimum level (approximately 3 in. below the top or 350 to 420 mL for the pint bottle, or 2 in. below the top or 650 to 800 mL for the quart bottle).

For streams that transport heavy loads of sediment and/or to satisfy quality control requirements, at least two complete depth samplings of the vertical should be made as close together in time as possible, one sample for each sampling episode. Each container then constitutes a sample and can be analyzed separately or two or more containers can be composited. Sample analyses from two or more individual containers for a given period is useful for identifying contaminant variation.

5. Immediately after collection, inspect the sample collecting container and note sample quantity. Sieve and mix the sample if required. After required preparation, place in appropriate container, secure container cap, label, and preserve as required. If the sample is inadequate, resample.

6. Follow guidance identified in section 2.1.1.3 steps 4, 5, 6 and 7.

2.2.2 Cable and Reel Samplers

For situations involving the collection of sediment in bodies of water that are not shallow or wadable, the following suspended sediment samplers are suggested: the USD-74, USD-77, USP-61 (United States Standard Sampler Point Integrating), USP-63, and USP-72.

For illustrative purposes, the USP-61 is described. The following information provides only general guidance. It is recommended that personnel consult and follow the manufacturer's instructions pertaining to the correct use of any sampling equipment.

The USP-61 weighs about 105 lb and can be used for depth integrated as well as point integrated sample collection to a maximum depth of 180 ft. The sampler valve for this sampler has two positions. When the solenoid is not energized, the valve is in the nonsampling position, in which the intake and air exhaust passages are closed; the air chamber in the body is connected to the cavity in the sampler head; and the head cavity is connected through the valve to the sample container.

When the solenoid is energized, the valve is in the sampling position, in which the intake and air exhaust are open, and the connection from the sample container to the head cavity is closed.

The USP-61 can be used in flow velocities of 2.0 to 12.0 ft/s.

To use this sampler

1. Preclean the nozzle and associated parts. Preclean containers and lids.

2. Insert a clean sample container in the sampler and close the sampler head.

3. Lower the sampler to the streambed, keeping the solenoid closed and note the depth to the bed.

4. Start raising the sampler to the surface, using a constant transit rate. Open the solenoid at the same time the sampler begins the upward transit.

5. Keep the solenoid open until after the sampler has cleared the water surface. Close the solenoid.

6. Remove and inspect the bottle containing the sample, check the volume of the sample and, if adequate, label appropriately. Resample if sample is inadequate.

7. Insert another clean bottle into the sampler and close the sampler head.

8. Lower the sampler until the lower tail vane is touching the water, allowing the sampler to align itself with the flow.

9. Open the solenoid and lower the sampler at a constant transit rate until the sampler touches the bed.

10. Close the solenoid the instant the sampler touches the bed. (By noting the depth to the streambed in Step 3 above, the operator will know when the sampler is approaching the bed.)

11. Raise the sampler and remove the sample container.

12. Follow guidance identified in section 2.1.1.3 steps 2, 3, 4, 5, 6 and 7.

The transit rate used when collecting the sample in the upward direction need not be the same as that used in the downward direction. If the depth is greater than 30 ft, it is recommended that the upward and downward integrations be broken into segments no greater than 30 ft. It is important that samples be obtained at a given vertical for both the downward and upward directions. Also, previous tests (USGS, 1988) have shown an increase in the uptake ratio of about 4% when descending versus a decrease in the uptake ratio of about 4% on ascent.

If samples are not composited, documentation should be adequate to identify the segment or range of depth sampled and whether it was taken on the descending or ascending trip.

Point samples can also be collected using the same procedures described above. The point sample is a sample of the water-sediment mixture collected from a single point in the cross section. Data obtained in this manner may be used to define the distribution of sediment at a single point, such as an observer's fixed station.

If samples are collected for the purpose of defining and identifying the horizontal and vertical distribution of contaminant concentrations and/or particle size, the samples collected at points in the cross section, with any of the point integrating type samplers, will be satisfactory. Normally, 5 to 10 point samples are adequate to identify the horizontal distribution. Vertical distribution can be adequately defined by obtaining point integrating samples from a number of points between the water surface and the streambed. It is generally recommended that samples be taken at the surface, from 1 ft above the bed, and from 6 to 10 additional points in the vertical above the 1-ft above bed point. At each point, a sample should be collected and analyzed separately. The results can then be plotted on a cross section relative to the samples' locations in the water column. Sampling personnel should check with the monitoring design requirements for definitive program direction before initiating sampling strategy.

The selection of sampling sites and the media to sample is best determined on a site-by-site basis as a number of local parameters must be considered. However, information concerning suggested sediment data interpretation and sample site selection criteria can be obtained from USGS (1988).

2.3 Bed-Load Sediment Sample Collection Methods

As previously identified, bed-load sediment is that material that moves by sliding, rolling, or bouncing along on/or very near the bed. These sediments that can contribute to the dispersion of contaminants and detrimentally affect exposed biota are generally the most difficult to collect. For example, any device placed on or near the bed may disturb the flow and rate of bed-load movement. More importantly, bed-load transport rate and the velocity of water close to the bed vary considerably with respect to both space and time. Therefore, any sample obtained at a given point may not be representative of the mean transport rate for a reasonable interval of time, because the bed particles move intermittently at a mean velocity much less than that of the water. Bed-load discharge cannot be determined in the same manner as suspended-sediment loads, that is, by use of water-discharge data. As such, a bed-load sampler must be able to representatively sample, directly or indirectly, the mass or volume of particles moving along the bed through a given width in a specified period of time.

The recommended devices for collecting bed-load sediments are the pressure-difference samplers. These samplers are designed to create a pressure drop at the sampler's exit and thus maintain entrance velocities approximately equal to the ambient stream velocity.

2.3.1 Pressure Difference Bed-Load Sampler

For illustrative purposes, the Helley-Smith bed-load sampler is described. The following information provides only general guidance; it is recommended that personnel consult and follow the manufacturer's instructions pertaining to the correct use of any sampling equipment.

The Helley-Smith sampler consists of an expanding nozzle, sample bag, and frame. The sampler design enables collection of particle sizes less than 76 mm at mean velocities to 9.8 ft/s. The sampler has a 3 x 3-in. square entrance nozzle, an area ratio (ratio of nozzle exit to entrance area) of 3.22, and a 295-in^2 polyester mesh sample bag that is 18-in. long with mesh openings, usually either 0.2 or 0.25 mm, attached to the rear of the nozzle assembly with a rubber o-ring. The total weight of this sampler is 66 lb, requiring the use of a cable-reel suspension system. However, a lighter version incorporating a wading rod assembly is also available. Heavier versions, weighing from 99 to 550 lbs, have been used and are available.

To use this sampler

1. Lower a clean sampler to the streambed. Use a stopwatch to measure the time interval during which the sampler is on the streambed. The sampling time interval should be the same for each site sampled. The time required to collect a sample can vary from 5 seconds or less to several hours or more. Generally a sampling time of 30 to 60 seconds is preferred, and 60 seconds should be considered a maximum time. Because of the temporal variations in

bed-load transport rates, there is no easy way to determine the appropriate sampling time. Several test samples, as many as 10 or more collected sequentially at a location with a suspected high transport rate, may be needed in order to estimate the proper sampling time interval to be used. It is recommended (USGS, 1988) that the sample time be short enough to allow for the collection of a sample from a section with the highest transport rate, without filling the sample bag more than about 40% full.

2. If channel cross section sampling is necessary, one sample should be collected at each preselected vertical location, starting at one bank and proceeding to the other. The samples can be placed in separate containers for individual analysis and labeled with the vertical locations sampling site number, or they may be composited.

3. Raise the sampler and place sediment samples in an appropriate container for preparation.

4. Follow guidance identified in sction 2.1.1.3 steps 2, 3, 4, 5, 6, and 7.

3. SAMPLE PREPARATION AND HANDLING METHODS

Methods for sample preparation and handling after collection and before analysis are determined by the type of test to be run and the specific parameter being quantified. There are three general types of chemical tests addressed in this section. The guidance identified is general and may not be applicable to some specific contaminants. If there is a question as to the proper preparation and handling procedures for a specific analysis, it is recommended that a qualified Service chemist be consulted. Also, decisions and criteria regarding nonsediment material that should be removed from the sample (e.g., twigs, leaves, shells, rocks) should be identified in the site specific study plan before sampling.

All samples that are to be analyzed must be protected from contamination during sample preparation and handling. For example, all sampling and handling equipment (i.e., scoops, sample containers, mixing containers, collection equipment) should be made of noncontaminating material and should be decontaminated before use. Samples should not be touched with ungloved fingers. In addition, potential airborne contamination (e.g., exhaust gases, cigarette smoke) should be avoided.

After a sample is collected, the following observations should be documented:

- Sampling site location
- Depth
- Characteristics of the surficial sediment
  - Texture
  - Color
  - Biological structures (e.g., shells, tubes, macrophytes)
  - Presence of debris (e.g., wood chips, wood fibers, human artifacts)
  - Presence of oily sheen
  - Odor (e.g., hydrogen sulfide, oil, creosote)
- Characteristics of the core's profile
  - Changes in sediment characteristics
- Characteristics of sampler
  - Penetration depth
  - Leakage
  - Winnowing
  - Disturbance.

Before collecting sample for analysis, the overlying water must be removed. The preferred method of removing this water is by slowly siphoning it off near one side of the sampler. Methods such as decanting the water are not preferred as unacceptable disturbance or loss of fine-grained sediment and organic matter may result.

Once the overlying water has been removed, the sediment can be prepared and sampled. Sieving and a thorough mixing or homogenizing of the initial sample is recommended when preparing

Table 6. Sediment container preservation and archiving information.

Contaminant Type	Size and Type of Container	Sample Size	Preservative	Holding Time[a]
		INORGANICS		
Metals	1-L wide mouth glass with Teflon- or Al foil-lined cap 250 mL glass with Teflon-lined or Al foil-lined cap	1 L	4°C (recommended)	6 months
Mercury	Same as above	250 mL	4°C (recommended)	6 months
Cyanide	Same as above	250 mL	4°C	28 days
		ORGANICS		
TOC	250 mL glass with Teflon or foil lined lid	250 mL	4°C	10 days
Volatiles	40 mL (glass with septa) 1 L glass with Teflon lined cap 125 mL glass with Teflon lined cap	(3) 40 mL vials[b] 1 L 125 mL	4°C	10 days 10 days 10 days
Semivolatiles	1 L glass with Teflon lined cap wide mouth 250 mL glass with Teflon lined cap wide mouth	250 mL	4°C	Extract in 20 days Analyze extract by 30 days
Priority Pollutants	Same as for valatiles above	Same as for volatiles above	Same as for volatiles above	Same as for volatiles above

a. May be held longer if only collecting for elemental analysis, i.e., not concerned with ionic state of the element.
b. FWS requirements.

aliquots for different chemical analyses (DO NOT SIEVE OR MIX SAMPLES FOR VOLATILE ANALYSIS). Homogenization is important when the combined contents of several sediment grab samples are required to provide sufficient material for analysis. Compositing can be performed by first sieving sediment through a Number 10 sieve (2.0 mm) if possible. After sieving, transfer the sieved sediment to a dry, cleaned stainless steel or glass bowl and then stir with a clean stainless steel spoon or spatula until textural and color homogeneity are achieved. After mixing, collect the required aliquots. The recommended sample quantity as identified by FWS (1986) is as follows: for priority pollutant analysis, a 1-L and three 40-mL vials should be collected. For routine contaminant analysis, a 1-L sample is sufficient (Table 6). A sample of the material greater than 2.0 mm should be sampled and archived for possible future analysis.

The mixing container and all utensils should be decontaminated between uses and kept covered to prevent airborne or other contamination. Because of the cost and time required for decontamination, it may be more cost effective to use disposable preparation equipment. Sample containers must be carefully cleaned before sample collection. Separate samples are typically required for the determination of volatile and semivolatile organic compounds and metals. Container preparation techniques may differ for these chemical groups. See FWS (1986) and Decontamination RFM for recommendations.

Samples for the analysis of volatile organic compounds should be taken before any compositing for other analyses. Many of the volatile compounds of interest would be lost during compositing. Containers should be filled with no headspace left. It is recommended that three samples be collected to ensure that an acceptable sample with no headspace is submitted to the laboratory for analysis. Sample containers can be filled without leaving headspace in one of two ways, depending on the water content of the sediment. If there is adequate water in the sediment, the vial should be filled to overflowing so that a convex meniscus forms at the top. If there is little or no water in the sediment, containers should be filled as tightly as possible, eliminating obvious air pockets. With the liner's Teflon side down, the cap should be carefully replaced.

Sediment samples for analysis of semivolatile compounds should be collected after mixing and stored in containers with Teflon-lined screw lids. If precleaned containers cannot be purchased, then the containers should be washed thoroughly. For guidance, see FWS 1986 and the Decontamination Guidance RFM.

Sediment samples for the analysis of metals should be collected after mixing in clean wide mouth, high density polyethylene or glass bottles. The containers and lids should be precleaned.

Samples should be stored in the dark at 4°C, on ice, until extraction. Analyses for all contaminants should be performed within the holding time requirements. Freezing is preferred for samples to be analyzed for semivolatile organic compounds if the analysis cannot be performed within the allotted holding time. Care must be taken with frozen samples to prevent container breakage by leaving headspace for the interstitial water to expand and by freezing containers at an angle rather than in an upright position. See the Documentation Guidance SOP for recommended guidance concerning proper sample containers, preservation, and holding time requirements.

4. ARCHIVING SAMPLES

A number of sampling/monitoring circumstances may require the archiving or storing of portions of collected samples that have been submitted for analysis. For example, the design of a monitoring program may require a large number of samples be collected. If there is uncertainty as to the definitive identity of a contaminant(s) or cost of analysis is a concern, an alternative for analyzing all of the samples collected is to select only a small number of them for analysis. Following the analysis and data assessment of these initial samples, a decision to analyze additional samples can be made. Additional reasons for archiving samples is to provide a "backup" if a sample is lost or spilled, and/or when additional analysis is necessary for validating an unexpected or unusual (exceedingly high or low) result. Losing or spilling a sample that has cost significant money and/or time to collect can also be extremely detrimental to a sampling/monitoring program.

Archived samples should be stored in containers and under the preservation requirements presented on Table 6 and/or in the Documentation SOP. If samples are stored for a period longer than the stated holding time, a decision concerning the use and utility of the data obtained from their analysis must be made. This decision would have to be made by the data user on a case-by-case basis as a function of the intended end use of that particular data and should be documented as necessary.

5. GLOSSARY

Absorption	The penetration of a substance into or through another.
Anion	A negatively charged ion.
Background Level	Amount of a naturally occurring chemical present in soil which has not been exposed to human activities involving the chemical.
Bed Material	Composed of two elements; the first consisting of particles frequently transported as part of the suspended load or bedload, but considered as bedload even at rest. The second element consists of particles and aggregates of particles which compose definite structures on the stream bed and reside there indefinitely.
Cation	A positively charged ion.
Colloidal-Suspension	Particles so small that in water they will not settle out under the action of gravity but will stay suspended even in quiet water due to Brownian motion. Particle sizes range from one micron to one millimicron.
Composite Samples	Combinations of more than one sample collected at various sampling locations and/or different points in time.
Estuary	That portion of a coastal stream influenced by the tide of the body of water into which it flows. For example, the point at which a bay or mouth of a river meets the tide water; an area where fresh and marine water mix.
Fines	Very small particles; fraction passing a No. 200 sieve.
Grab Sample	A single sample representative of a specific location at at given point in time. Its representativeness will decrease as sources vary over time and distance.
Heavy metals	Metals having a specific gravity of 5.0 or more.
Pollutant	Any introduced substance that limits a resource use for a specific purpose.
Semivolatiles	A group of organic compounds consisting of base/neutrals, acids, and pesticides that are identified in and analyzed by Method 625 in 40 CFR Part 136 (See USFWS 1986 for chemical list).
Volatile	Solids or liquids which are relatively unstable at standard temperature and pressure and undergo spontaneous phase change to a gaseous state (See USFWS 1986 for chemical list).

6. REFERENCES

EPA, 1985. United States Environmental Protection Agency. Sediment Sampling Quality Assurance User's Guide, USEPA Environmental Monitoring Systems Laboratory, P.O. Box 15027, Las Vegas, NV 89114-5027, EPA-600/4-85-048.

EPA, 1986. United States Environmental Protection Agency. Puget Sound Estuary Program--Puget Sound Protocols, USEPA Region 10 Office of Puget Sound and U.S. Army Corps of Engineers, Seattle, Washington, Final Report TC-3991-04.

FWS, 1986. United States Fish and Wildlife Service. Field Operations Manual for Resource Contaminant Assessment, U.S. Fish and Wildlife Service, Washington, D.C.

USACE, United States Army Corps of Engineers, 1981. Procedures for Handling and Chemical Analysis of Sediment and Water Samples, U.S. Corps of Engineers Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi.

USGS, 1973. United States Geological Survey. Techniques of Water-Resources Investigations of the United States Geological Survey: Chapter A4, Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples. U.S. Government Printing Office, Washington, D.C. 20402, Stock Number 2401-00326.

7. BIBLIOGRAPHY

American Public Health Association, 1985. Standard Methods for the Examination of Water and Wastewater, 16th Edition, American Public Health Association, Washington, D.C.

DOE, 1987. United States Department of Energy. The Environmental Survey Manual, USDOE DOE/EH-0053, Washington, D.C.

EPA, 1973. United States Environmental Protection Agency. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents, EPA-670/4-73-00, National Environmental Research Center, Cincinnati, Ohio.

EPA, 1978. United States Environmental Protection Agency. Sediment and Water Quality: A Review of the Literature Including a Suggested Approach for Water Quality Criteria, USEPA, Region X, 1200 Sixth Avenue, Seattle, WA 98101, EPA 910/9-78-048.

EPA, 1983. United States Environmental Protection Agency. Characterization of Hazardous Waste Sites--A Method Manual: Volume II, Available Sampling Methods, USEPA Environmental Monitoring Systems Laboratory, P.O. Box 15027, Las Vegas, NV 89114-5027, EPA-600/4-83-040.

EPA, 1984. United States Environmental Protection Agency. USEPA Contract Laboratory Program Statement of Work for Organics Analysis Multi-Media, Multi-Concentration, IFB WA 85-T176, T177, T178, USEPA Washington, D.C.

Lind, O. T., 1974. Handbook of Common Methods in Limnology, St. Louis: C. V. Mosby Company.

USGS, 1988. United States Geological Survey. Field Methods for Measurement of Fluvial Sediments, U.S. Department of the Interior, USGS open-file report 86-531, Reston Virginia.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX J
SOIL SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix J of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
   - D.3 Fish Sampling Reference Field Methods
   - D.4 Flora Sampling Reference Field Methods
   - D.5 Reptiles and Amphibians Sampling Reference Field Methods
   - D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
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0	10/2/91	2.1	2-4	2-4c	5
1					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

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Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

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ACRONYMS

BLM	Bureau of Land Management
CEC	Cation-exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
EC	Environmental Contaminant
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RFM	Reference Field Methods
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act
SCS	Soil Conservation Service
TOC	Total Organic Carbon
TSCA	Toxic Substances Control Act
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USEPA/EPA	United States Environmental Protection Agency
USFWS/FWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

U.S. FISH AND WILDLIFE SERVICE
BIOMONITORING OPERATIONS MANUAL

APPENDIX J
SOIL SAMPLING
REFERENCE FIELD METHODS

1. INTRODUCTION

1.1 Purpose

The purpose of this Reference Field Methods (RFM) document is to provide guidance for obtaining selected onsite physical soil measurements and collecting surface and subsurface soil samples for physical and chemical analysis. Data generated from soil sampling/monitoring activities relating to soil contamination can be used by refuge personnel and Environmental Contaminant (EC) specialists to determine areas of contaminated soil, and to develop and implement contaminant management activities.

1.2 Scope

The first portion of this RFM contains field tests to aid in classifying soils for the site. The information obtained may be useful for initial assessment of the potential for contaminant retention and migration through the soil at the site. These tests are subjective and may produce variable results when performed by inexperienced personnel. However, the information gained may still be useful if historical information is unavailable or inadequate. Prior to initiating these tests it is advisable to contact a local United States Department of Agriculture Soil Conservation Service (SCS) office to determine what information and expertise are available.

The second portion of this RFM contains methods appropriate for sampling soils for contaminant analysis and monitoring activities. Generally, the techniques described may be conducted by refuge personnel; however, there are some sampling methods described that would likely require assistance from other Federal agency personnel or contractors (see Table 1). These methods are included to provide refuge personnel with information that may enable informed discussion with the appropriate experts.

1.3 Background

Soil sampling/monitoring is conducted to

- Determine the presence and concentration of specified pollutants.
- Determine spatial and temporal distribution of pollutants.

- Determine whether contaminated soils may be a source of contamination to other areas of a refuge.

- Determine the potential risk to flora and fauna from specific soil contaminants.

- Identify contaminant sources, transport mechanisms or routes, and potential receptors.

- Determine if contaminant concentrations exceed regulatory limits or action levels and warrant remediation.

- Meet the provisions and intent of environmental laws such as the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Toxic Substances Control Act (TSCA).

- Contribute to a research technology transfer or other environmental studies.

The soil referred to in this manual is a portion of the mass (surface and subsurface) of unconsolidated mantle of weathered rock and loose material lying above solid rock. For this document, the soil component is defined as all mineral material located within 150 cm (60 in.) of the surface and is 2 mm or less in size. This is the size normally used to distinguish between soils (consisting of sands, silts, and clays) and gravels. In addition, the 2-mm size is generally compatible with the analytical laboratory methods/capabilities. Organic matter is also commonly found in many soils and is considered an integral part of the soil matrix. Organic matter that meets the 2-mm size requirement should be included.

The behavior of contaminants in the soil environment is a function of the contaminant's and soil's physical and chemical properties. Soil sorption (the retention of substances by adsorption or absorption) is related to properties of the contaminant (e.g., solubilities, heats of solution, viscosity, and vapor pressure) and to properties of soils (e.g., clay content, organic content, texture, permeability, pH, particle size, specific surface area, ion exchange capacity, water content, and temperature).

Clay and organic matter generally show greater contaminant concentrations than other components. The clay minerals are the major constituent of the soil structure that influences the retention of chemicals and under some circumstances, can control the rate of chemical migration through the soil. The basic crystalline structure of the clays are layered aluminosilicates.

The aluminosilicates form three main groups of minerals--kaolinate, illite (or hydrous micas), and montmorillonite (or smectite). These clay minerals are formed either as a stack of mineral sheets formed from octahedral and tetrahedral crystal structures. The kaolinite mineral is classed as a 1:1 clay mineral because there is one sheet of each type of crystal layer.

The illite and montmorillonite minerals are formed from two sheets of the tetrahedral layer and one sheet of the octahedral layer. The layers are bonded together by different means in each of the minerals found in nature. For example, the layers in kaolinite are connected by hydrogen bonds located between the mineral layers. The size and reactivity of the mineral depends upon the

chemicals that saturate the exchange sites located on the edges of the mineral and on the interior surfaces of the mineral sheets. The 2:1 minerals are more reactive because of the greater surface area and the higher surface charge.

The exchange or charge sites on the minerals are available for binding with chemicals. The more reactive the chemical, the greater the potential for it to be bound to the soil or changed by the surface reaction with clay minerals. When the sites are saturated with one chemical (such as calcium), it can be replaced by a more reactive chemical. The chemicals can move through the soil by exchanging on and off sites. This exchange process is the means whereby a chemical may form a plume with a sharp leading edge and a long trailing edge of concentration. Some chemicals such as 2, 3, 7, 8-tetrachlorodibenzo-para-dioxion (TCDD) are so reactive with the soil that it is essentially impossible to remove the chemical once it has moved below the zone where the ultraviolet rays from sunlight can react with it. Other chemicals such as the acids may react with the minerals and be neutralized. The resulting hydrogen ions on the surface of the clays may decompose the mineral, or they may simply occupy the exchange sites to be replaced later by other materials leaching to the soil.

Soils are extremely complex and variable, which necessitates a multitude of sampling approaches throughout the refuge system. The sample collector must select methods that best accommodate specific sampling needs, and satisfy the stated sampling objectives. Table 1 provides a matrix of the sampling methods included in this RFM and information concerning their appropriate use and complexity.

Both field and laboratory tests are necessary to understand the presence and movement of contaminants in the soil. Field tests supply information for soil classification and its relation to onsite environmental conditions. Laboratory tests supply analytical data beyond the capabilities of field testing, such as the type and quantity of a contaminant. Laboratory tests can also provide definitive data concerning soil parameters such as organic carbon.

The sample collector is responsible for providing the appropriate sample for laboratory analysis. Field sample preparation procedures are included in this RFM. A soil sample must satisfy the following requirements:

1. Provide sufficient volume of soil material ≤ 2 mm in size to satisfy the analytical requirements,

2. Provide a sample representative of the site to be evaluated.

It is important that field personnel follow the Quality Assurance/Quality Control (QA/QC) procedures and directions provided in Section 2 of the Documentation SOP. If changes in program execution and design (e.g., sample site selection, number of samples to be collected, sampling intervals, and specific media collected) are required, these changes, with appropriate rationale, must be documented in the field notebook (see Section 3 Documentation SOP).

Assistance in proper sampling, sample preparation, and laboratory analyses for classifying soils can be obtained from local SCS offices and soil scientists in other Federal and non-Federal agencies. Also, private contractors may be consulted for assistance with specialized equipment or testing procedures. Finally, it is imperative to know and understand what is required by the lab doing the analysis. The EC specialist associated with the refuge should be able to provide this information.

1.4 Information Resources

The SCS can provide information concerning local soils or provide the necessary guidance to acquire the needed information. An excellent primary source of information is the SCS Soil Survey, which describes physical and chemical properties of soils nationwide. This information may be obtained from a local SCS office. The soil survey includes such information as soil maps of the area, soil classifications and characteristics, and information regarding the use and management of the soils. The SCS office personnel will be able to assist in the application of this information for refuge contaminant studies. They may also be able to demonstrate particular sampling/testing techniques and provide necessary equipment for initial sampling activities.

Below are recommended steps to follow to obtain available information/expertise regarding the site's soil characteristics:

1. Contact SCS to determine if refuge soils have been mapped. If so, obtain soil survey (free of charge) and locate specific sites on the soil survey map. Consult SCS personnel to help interpret soil survey information. If refuge is not mapped, ask soil scientist from SCS to visit refuge and characterize the soils of concern.

2. If #1 is not a viable option, contact the Bureau of Land Management (BLM), Forest Service, Land Grant University, or County Extension Office personnel to determine if they have a soil scientist available to assist in characterizing the soils.

3. If assistance is available, review the RFM to become familiar with the required tests and procedures before the arrival of the soil scientist. This will aid in directing appropriate questions to the expert while at the site.

4. If assistance is not available when needed, use the RFM (Table 1) and conduct the soil assessment following the procedures provided and document the results for your specific monitoring objectives. Consult regional EC specialist as necessary.

Table 1. Key to soil sampling procedures

Sampling Procedure	Location in RFM	Type of Monitoring[1]	Advantages	Disadvantages	May Need Assistance
Course Grained Test (Soil Texture)	2.1.1	A,B,C	Gives indication of soil's ability to trap contaminants. Easy to do in field. Only takes a few minutes.	Must be done in series of steps from gravel to fine grained soils to get proper texture classification.	Check with soil scientist in Agronomy department of local university or ask SCS or BLM for assistance.
Gravel Test (Soil Texture)	2.1.2	A,B,C			
Fine Grained Test (Soil Texture)	2.1.3	A,B,C			
Ribbon Test (Soil Texture)	2.1.4	A,B,C	Used to determine specific types of fine grained soil. Can be done quickly in the field. Helps to provide additional information on contaminant sorption and/or best location to sample.	May need to seek assistance to obtain accurate results. Might need to air dry and/or take soils back to the office. Requires some advanced planning	
Clod Strength Test (Soil Texture)	2.1.5	A,B,C			
Plasticity Test (Soil Texture)	2.1.6	A,B,C			
Stickiness Test (Soil Texture)	2.1.7	A,B,C			
Odor Test (Organic Matter)	2.2	A,B,C	Easy to conduct, gives information on soils affinity for contaminants.	Difficult to smell on cold (32-40°) days.	
Permeability	2.3	A,B	Uses texture data to estimate how fast contaminants move.	Provides only crude estimate.	Ask SCS or local university soil scientist
Organic Matter	2.4	A,B,C	Helps to assess potential for contaminant retention in soil.	Requires lab analysis.	
Calcium Carbonate	2.5	A,B,C	Helps assess potential impact from acid deposition. Easy to conduct.	Requires safe use of some acids in the field	Ask SCS to set up acid solution.
Mica Content (Clay Minerals)	2.6.1	A,B,C	Indicates if organic contaminants will be retained in the soil.	Need to air dry soil.	
Clay Content (Clay Minerals)	2.6.2	A,B,C		Requires additional chemicals, but may be obtained already mixed.	Ask SCS or local universities.
SOIL pH					
- Paper		A,B	Inexpensive, easy to carry. Determines degree of acidity or alkalinity, instant results. Provides quick indication of a problem.	Accurate data requires use of dyes or pH meter.	Need pH strips from supplier.
- Dyes		A,B,C	More accurate than pH paper, easy to use in the field	Requires carrying additional supplies	Need test kits from supplier.

1. A = Initial Screening/Characterization
   B = General Monitoring
   C = Special Case Monitoring (to be conducted if a routine general monitoring effort identified a potential problem. Could require assistance from an EC specialist and special monitoring tools.)

Table 1 (continued)

Sampling Procedure	Location in RFM	Type of Monitoring[1]	Advantages	Disadvantages	May Need Assistance
- pH Meter		B,C	Provides most accurate results	Need special equipment that requires calibration	Ask chemist for operating assistance.
Spoons, Scoops, and Shovels (Semi-volatiles and Metal Analysis)	3.1.1.1	A,B,C	Inexpensive and easy to carry and use.	Requires manual power--not the best for volatile samples	Could get equipment from SCS. If area is contaminated, requires special protective gear. Ask EC specialist for assistance. Also if contaminated, EPA can provide assistance from a Remedial Project Manager.
Screw-type Augers (Semi-volatiles and Metal Analysis)	3.1.1.2	B,C	Easy to carry and use; readily available. Easy to sample in moist soils. Good for vertical composite samples.	Not recommended for volatile samples; not good for rocky or dry sandy soils. Requires more manual power; harder to decontaminate.	
Barrel Augers (Semi-volatiles and Metal Analysis)	3.1.1.3	B,C			
Tube-Type Samples (Volatile, Semi-volatile and metal)	3.1.1.4	B,C	Provides cores for volatile samples. Can sample at a discrete depth.	Requires 2 or more people. Not good in stony soil.	
Augers (Power Driven)	3.1.2.1	C	Provides deep large samples	Need special power source and 2 or more people.	Could get equipment from SCS. If area is contaminated, requires special protective gear. Ask EC specialist for assistance. Also if contaminated, EPA can provide assistance from a Remedial Project Manager.
Split Spoons (Power Driven)	3.1.2.2	C			
Soil Gas Sampling	4.0	--	Good for assessment of organic vapor.	Various levels of complexity; some require special skills and equipment.	
- Passive Devices	4.1	A,B,C	Good for organic vapor screening; easy to use. Good to assess hydrocarbon and other gases.	Doesn't provide specific chemical species data. Requires special tools and procedures. Seek assistance from EC specialists.	
- Drive Tubes	4.2	C			
- Wells	4.3	C			

1. A = Initial Screening/Characterization
   B = General Monitoring
   C = Special Case Monitoring (to be conducted if a routine general monitoring effort identified a potential problem. Could require assistance from an EC specialist and special monitoring tools.)

2. FIELD TESTS AND DATA COLLECTION

The following tests will aid in classifying soils at a sampling site. In some cases, verification of results may require two or more tests. Because these tests are general in nature, recommendations regarding which test would yield the most definitive data were not made; this decision must be made by refuge personnel based on their knowledge of the individual site. Field tests should not be used to replace laboratory tests, but provide an onsite tool to assist the sampler in determining where contaminants may concentrate.

Equipment requirements for conducting these field tests are minimal. Except for some reagents (identified in text or included in sample kits), equipment needs consist of common laboratory spatulas, pans, and trays. Definitive reagent and equipment requirements are identified in the text within the corresponding section.

All data collected from a field sampling/monitoring program must be documented. The results of each test should be noted in the field logbook and on the soil data collection form shown on Figure 1.

2.1 Soil Texture

Soil texture refers to the relative proportions of the various size groups of individual soil grains in a mass of soil. Specifically, it refers to the proportions of clay, silt, and sand and is usually based upon one of several systems of classification. The Unified Soil Classification System (USCS) is very useful to field sampling personnel in their effort to obtain field data. As shown on Table 2, the USCS system identifies soils according to their textural and plasticity qualities. The soils are identified and classified as being (a) coarse grained, (b) fine grained, or (c) highly organic with descriptive names and a letter symbol indicating principal characteristics.

The following tests describe procedures to obtain soil texture data for the USCS system. Table 3 is provided to identify specific tests for definitive texture parameters. Figure 2 identifies soil classes in graphic form.

2.1.1 Coarse-grained Test (Table 3, Test 1)

Part 1:

a. Spread a sample of soil on a flat surface (clip board) and examine the particles.

b. Approximate the grain size by visual inspection.

c. If more than 50% of the grains are easily distinguished by the unaided eye, the material is a coarse soil.

d. If less than 50%, it is a fine soil (Section 2.1.3).

e. Record observations.

SAMPLE NO: _____ **REFUGE:** _____ **DATE:** _____

SAMPLING LOCATION: _____

_____

PERSON PERFORMING TEST: _____

SANDS AND GRAVELS

1. Test 1 (coarse grained) _____
2. Test 2 (gravel) _____
3. Test 3 (fine grained) _____

COMMENTS:

SILTS AND CLAYS

4. Test 4 (ribbon) _____
5. Test 5 (liquid limit) _____
6. Test 6 (clod strength) _____
7. Test 7 (plasticity) _____
8. Test 8 (stickiness) _____
9. Test 9 (odor) _____

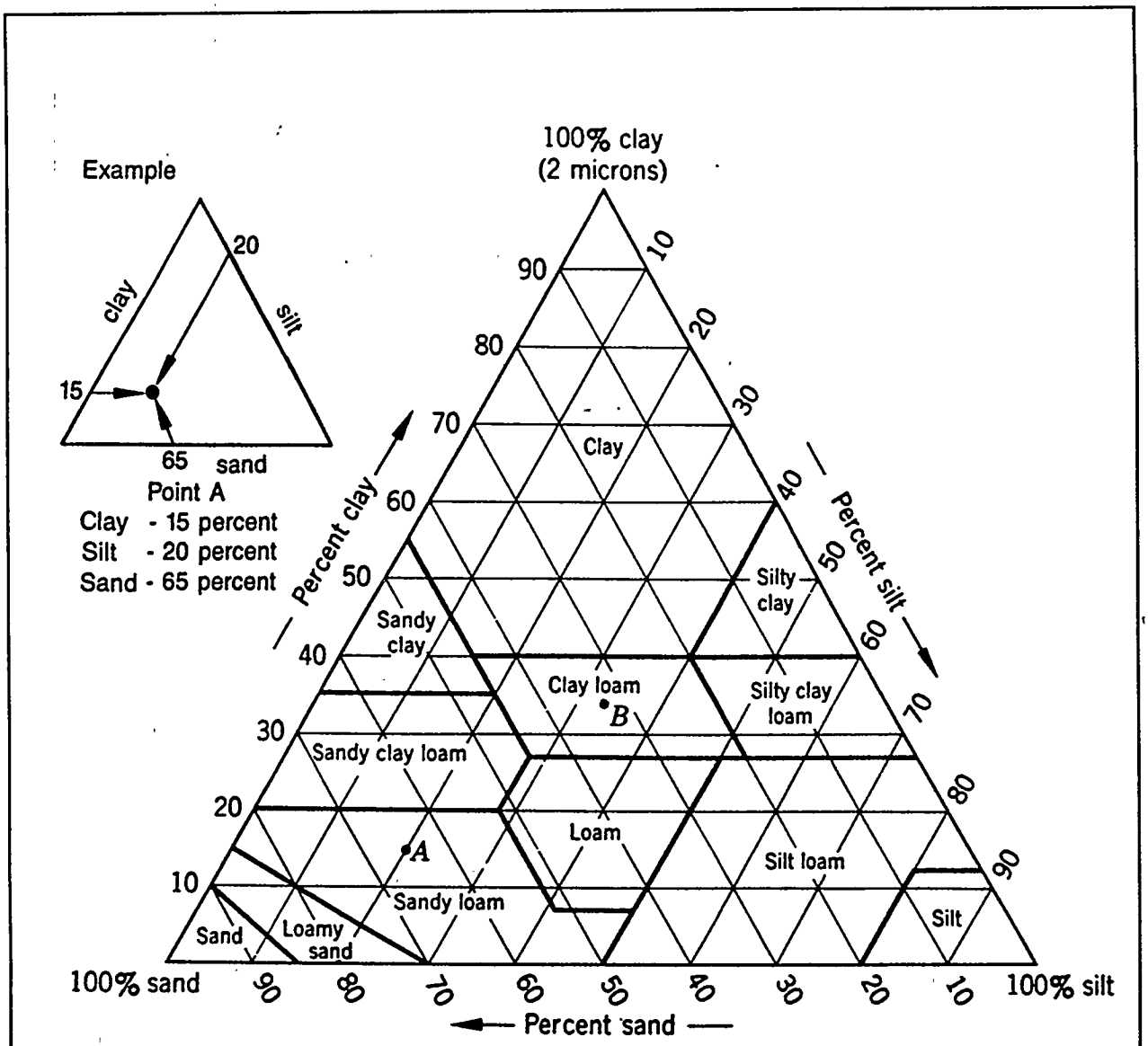
COMMENTS:

OTHER PARAMETERS

10. Permeability _____
11. Organic Matter _____
12. Inorganic Matter _____
13. Clay Minerals _____
14. pH _____

COMMENTS:

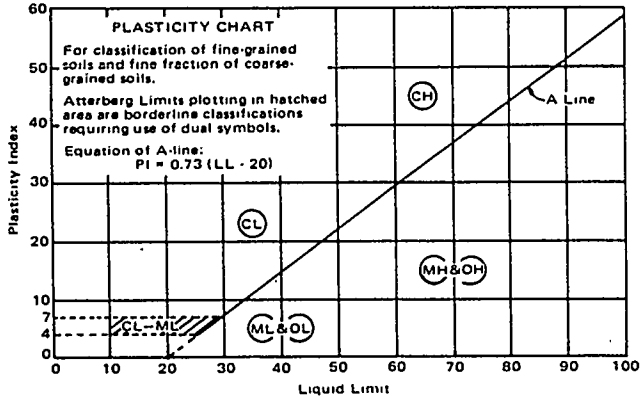
Figure 1. Soil data collection form.



The sum of the percentages of sand, silt, and clay at any point in the triangle is 100. Point A represents 15 percent clay, 65 percent sand, and 20 percent silt; the textural class name for this sample is *sandy loam*. A soil containing equal amounts of the three separates is a *clay loam* (point *B* in Fig. 2). The various soil classes are separated from one another by definite lines of division in Fig. 2. Their properties do not change abruptly at these boundary lines, however, but one class grades into the adjoining classes of coarser or finer texture. *(H.D. Foth, 1972).*

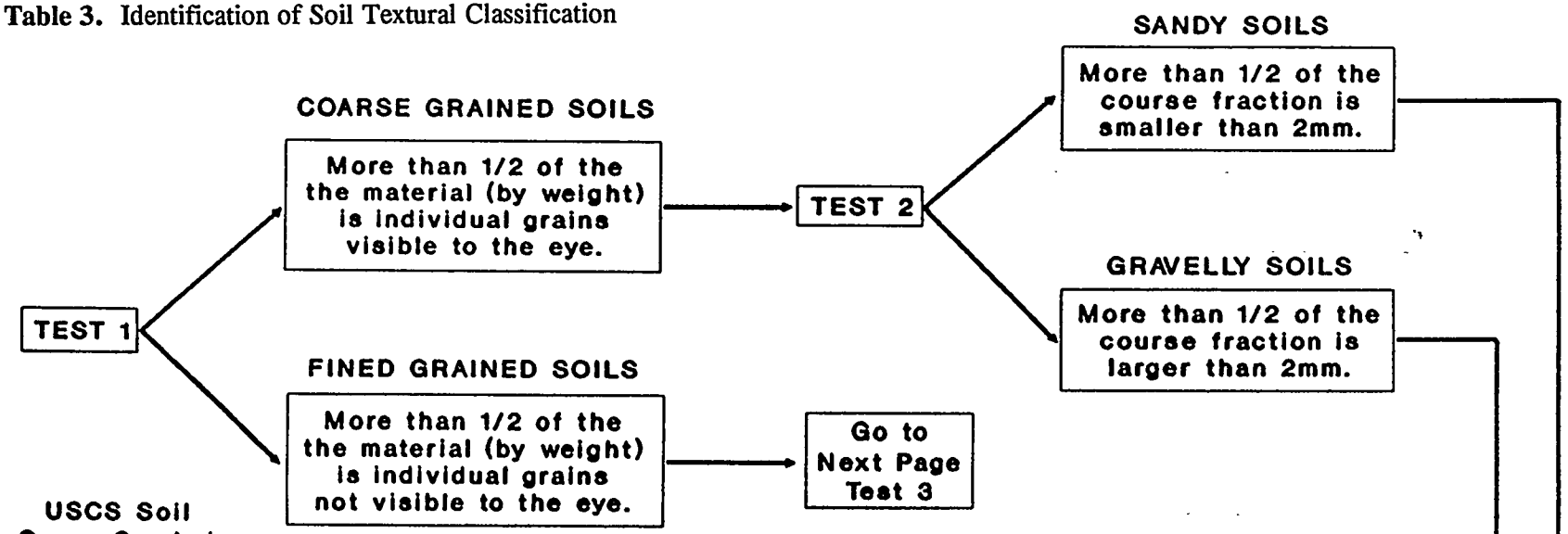
Figure 2. Soil classes as a function of particle size composition.

Table 2. Unified soil classification system (PCA, 1973)

Major Divisions			Group Symbols	Typical Names	Classification Criteria	
Coarse-Grained Soils More than 50% retained on No. 200 sieve*	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines Less than 5% pass No. 200 sieve GW, GP, SW, SP More than 12% pass No. 200 sieve GM, GC, SM, SC 5% to 12% pass No. 200 sieve Borderline classification requiring use of dual symbols	$C_u = D_{60}/D_{10}$ Greater than 4; $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW
		Gravels with Fines	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4 / Atterberg limits plot above "A" line and plasticity index greater than 7 — Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean Sands	SW	Well-graded sands and gravelly sands, little or no fines		$C_u = D_{60}/D_{10}$ Greater than 6; $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			SP	Poorly graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW
		Sands with Fines	SM	Silty sands, sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4 / Atterberg limits plot above "A" line and plasticity index greater than 7 — Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		
Fine-Grained Soils 50% or more passes No. 200 sieve*	Silts and Clays Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			OL	Organic silts and organic silty clays of low plasticity		
	Silts and Clays Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts		
			CH	Inorganic clays of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity		
Highly Organic Soils			PT	Peat, muck, and other highly organic soils	Visual-Manual Identification, see ASTM Designation D2488.	

*Based on the material passing the 3-in. (75-mm.)sieve.

Table 3. Identification of Soil Textural Classification



USCS Soil Group Symbol		
GW	Substantial amounts of all grain sizes	CLEAN GRAVELS Will not leave stain on wet palm
GP	Predominantly one size or range of sizes with intermediate sizes missing	
GM	Nonplastic fines	DIRTY GRAVELS Will leave stain on wet palm
GC	Plastic fines	
SW	Wide range of grain sizes with a substantial amount of each size	CLEAN SANDS Will not leave stain on wet palm
SP	Predominantly one size or range of sizes with intermediate sizes missing	
SM	Nonplastic fines	DIRTY SANDS Will leave stain on wet palm
SC	Plastic fines	

Table 3. Identification of Soil Textural Classification (continued)

FINED GRAINED SOILS

TEST 3 → More than 1/2 of the the material (by weight) is individual grains not visible to the eye.

RIBBON TEST (Test 4)	CLOD STRENGTH TEST (Test 5)	PLASTICITY TEST (Test 6)	STICKINESS TEST (Test 7)	USCS Soil Group Symbol
Weak Ribbon	Easily Crushed	Thread Easily Pulled Apart, Low Plasticity	Brushes off Easily when Dry	ML
Flexible Medium-strength	Medium-hard to Break	Thread Hard to Pull Apart, High Plasticity	Rubs off with Moderate Effort when Dry	CL
Hard Ribbon	Medium-hard to Break	Moderately Hard to Pull Apart	Rubs off with Moderate Effort when Dry	MH
Flexible Strong Ribbon	Almost Impossible to Break	Thread Hard to Pull Apart, High Plasticity	Must Rewet to Completely Remove	CH

HIGHLY ORGANIC SOILS Odor/Texture Tests (Test 8)		
Readily Identified by Dark Color, Musty Odor, and Frequently by Fibrous Texture	Musty Odor, Dark Color, Non-fibrous, Low Plasticity	OL
	Musty Odor, Dark Color, Non-fibrous, High Plasticity	OH
	Musty Odor, Medium to Dark Color, Fibrous, No Plasticity	PT

Part 2:

a. Saturate a small sample of the soil with water.

b. Rub a large marble-sized sample between the thumb and forefinger. Sand grains (coarse material) will feel rough and gritty, whereas aggregates of fine-grained materials will break down and feel silky.

c. Record observations.

2.1.2 Gravel Test (Table 3, Test 2)

Part 1:

a. Spread a representative sample of the soil on a flat surface.

b. Determine if more than one-half of the visible grains are greater than 2 mm.

c. If they are, the material is a gravel. If they are not, it is a sand.

d. Record observations.

Part 2:

a. Remove the coarse materials (greater than 2 mm in diameter) by either rolling the coarse grains off the flat surface with your hand or by tapping the coarse materials off the edge of the surface.

b. Saturate the remaining materials with water and work it with your hands.

c. The hands will not be stained if there is less than 5% fines.

d. The texture code will be a GW or a GP if the material is a gravel, or SW or SP if the material is a sand. (Table 2 provides letter Code Descriptions.)

e. The hands will be stained when there is more than 12% fines. Weak casts can be formed for the moist soil.

f. The soil will be GM or a GC if the material is a gravel, or SM or SC if it is a sand (Table 2).

g. Dual symbol materials (5 to 12% fines) cannot be classified by field methods.

h. Record observations.

Part 3:

a. Take a second sample of soil and place it on a flat surface. Spread it out and observe the grain size distribution.

b. If coarse materials consist of evenly distributed particle sizes, the material is a well graded gravel (GW) or sand (SW).

c. If coarse materials consist chiefly of one size particle or of large and small particles without intermediate sizes, the material is a poorly graded gravel (GP) or sand (SP).

d. Record observations.

NOTE: Practice with samples of known particle sizes will aid in field testing. If particle size tests are not routinely done, it is recommended that practice with blind samples be initiated. These samples could be obtained from a local SCS agent, or by contacting the agronomy department at a local university.

2.1.3 Fine-grained Test (Table 3, Test 3)

a. Spread a sample of soil on a flat surface (clip board) and examine the particles.

b. Approximate the grain size by visual inspection.

c. If more than 50% of the grains are easily distinguished by the unaided eye, the material is a coarse soil.

d. If less than 50%, it is a fine soil (Section 2.1.3).

e. Record observations.

f. Complete Test 1 (Section 2.1.1)

g. Use tests 4-8 to determine the type of fine-grained soils.

h. When there is more than 12% fines in a coarse-grained material, complete the tests for fine-grained materials (Tests 4 through 8) to determine if the material is clayey or silty. The soil will be GC if clayey and GM or SM if silty. (Table 2 provides Letter Code Descriptions.)

i. Record observations.

2.1.4 Ribbon Test

Test 4:

a. Take a quantity of soil measuring at least 2 x 2 x 2 cm (3 teaspoons) and wet it with water until a plastic state occurs. (This condition prevails when the soil contains just enough moisture that it can be rolled into 3-mm diameter threads.) These threads or ribbons are formed by squeezing and working the sample between the thumb and forefinger. Plastic limit is governed by clay content.

b. A weak ribbon (one which breaks easily) indicates a silty loam (ML) soil.

c. A hard ribbon (one which does not break easily) indicates a nonorganic silty (MH) soil. A flexible ribbon with medium strength indicates a silty clay loam (CL) soil. A strong, flexible ribbon indicates a silty clay (CH) soil.

d. Record observations.

2.1.5 Clod Strength Test

Test 5:

a. Clod strength is estimated by crushing a dry clod (lump or mass) of soil between the thumb and finger. Drying soil under laboratory conditions is not required. Select a clod that appears to be dry or collect a small amount and let air dry for 24 to 48 hours.

b. A block of soil at least 2 cm in its smallest dimension should be used since smaller samples can give erroneous results.

c. Easily crushed material of low strength is an ML. Medium strength material is either a CL or MH. CH material is almost impossible to break.

d. Record observations.

2.1.6 Plasticity Test

Test 6:

a. Wet and mold a small 2 x 2 x 2 cm (3 teaspoons) soil sample so that it can be rolled into a thread without crumbling. The material will not stick to the hands if the correct amount of water is added.

b. Roll the moist soil with the palm of the hand on any clean, smooth surface such as a piece of paper or glass plate to form a coarse thread and pull it apart.

c. A tough thread (hard to pull apart) indicates high plasticity (CH or CL).

d. A medium tough thread indicates an MH material and a weak thread (easily pulled apart) indicates an ML material.

e. Record observations.

2.1.7 Stickiness Test

Test 7:

a. Saturate a pea size sample of the soil and let it dry on the hands.

b. An ML soil will brush off with little effort.

c. A CL or MH soil rubs off with moderate effort when dry.

d. A CH soil requires rewetting to completely remove it from the hands.

e. Record observations.

2.2 Odor Test

The test for odor provides an indication of organic soils.

Test 8:

a. A fresh damp organic soil will have a distinctive, pungent, musty odor [A peat soil (PT) will also have a spongy or fibrous texture].

b. Record observations.

2.3 Permeability

Permeability is a measure of the ability of soil to conduct water and is expressed in cm/s. Determining the relative permeability of soil for general screening purposes is useful since permeability influences the transformation, retention, and movement of contaminants through the soil matrix. It is important to note that other factors, such as degree of saturation, soil chemistry and contaminant chemistry, strongly influence the ability of the contaminant to move through the soil. The use of Figure 3 and Table 4 eliminates the necessity to conduct actual permeability field tests for general screening purposes. The use of this information does require identification of the soil type being sampled (see Section 2 for guidance).

Procedure:

To determine relative permeability, compare the permeability values for the specific soil type identified in Table 4 with its corresponding value in Figure 3. This procedure will help determine general relative permeability classes for representative soils, e.g., very high, high moderate, low, and very low. The estimates can be used to provide an indication of the potential for water and water soluble contaminants to penetrate and move through soils. However, the permeability of specific contaminants will have to be considered on a case-by-case basis as some contaminants i.e. oils, can not be directly correlated with water permeability ratio. Record observations on the soil data collection form (Figure 1).

Certain soil types are considered permeable or semipermeable.

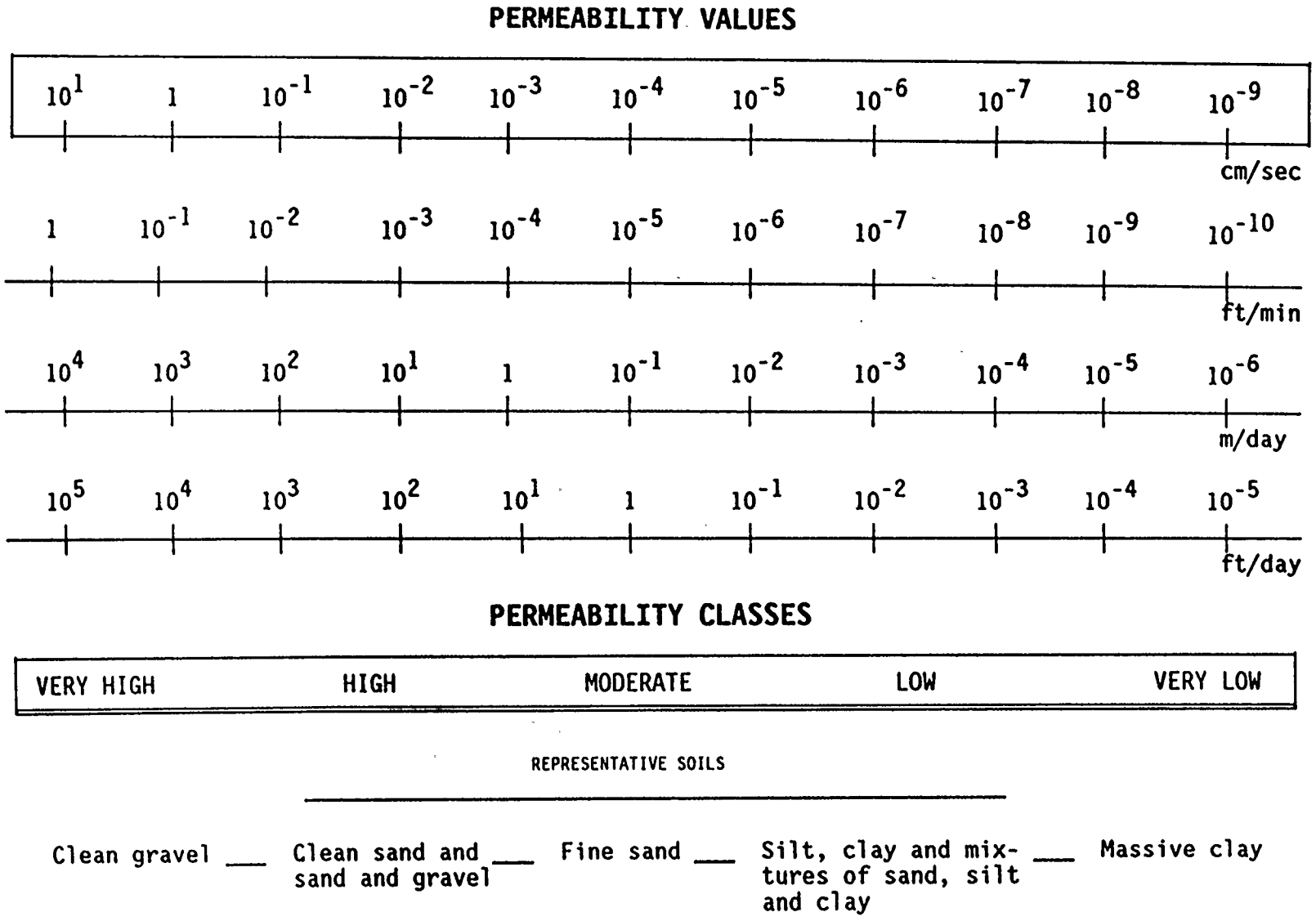


Figure 3. Permeability of representative soil materials (from Water and Power Resources Service, 1981).

Table 4. Representative values for permeability (K_a) of soils classified by the Unified Soil Classification System

SOIL TYPE	USCS SOIL GROUP SYMBOLS	PERMEABILITY VALUES K (cm/s)
Well graded gravels, gravel-sands mixtures, little or no fines	GW	10^{-2}
Poorly graded gravels, gravel-sand mixtures, little or no fines	GP	10^{-2}
Silty gravels, gravel-sand-silt mixtures	GM	10^{-3} to 10^{-6}
Clayey gravels, gravel-sand-clay mixtures	GC	10^{-6} to 10^{-8}
Well graded sands, gravelly sands, little or no fines	SW	10^{-3}
Poorly graded sands, gravelly sands, little or no fines	SP	10^{-3}
Silty sands, sand-silt mixtures	SM	10^{-3} to 10^{-6}
Clayey sands, sand-clay mixtures	SC	10^{-6} to 10^{-8}
Inorganic silts and fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	ML	10^{-3} to 10^{-6}
Inorganic clays or low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays	CL	10^{-6} to 10^{-8}
Organic silts and organic silty clays or low plasticity	OL	10^{-4} to 10^{-6}
Inorganic silts, micaceous or diatomaceous fine sandy or sity soils, elastic silts	MH	10^{-4} to 10^{-6}
Inorganic clays of high plasticity, fat clays	CH	10^{-6} to 10^{-8}
Organic clays of medium to high plasticity, organic silts	OH	10^{-6} to 10^{-8}
Peat and other highly organic soils	Pt	Not classified

SCS, 1979. Engineering Manual

Permeable soils include

- GW, GP, SW
- SM or SC with less than 15% fines[a] (see Section 2.1.2, Part 2 Procedures c, and e)
- GM or GC with less than 20% fines.

Semipermeable soils include

- CL, CH, ML, and MH
- SM or SC with more than 15% fines
- GC or GM with more than 20% fines

2.4 Organic Matter

Soil organic matter is an important parameter for estimating the potential retention of chemical contaminants in the soil. In general, the retention time of certain metals and nonpolar organic compounds is greater in soils with high organic content than in those with low organic content. To determine the percentage of organic matter in soil, it is recommended that samples be sent to an appropriate laboratory for analysis. Field techniques are not adequate for definitive organic matter determinations. For guidance in collecting samples for organic matter analysis, refer to the collection procedures, containers, and preservation requirements identified for semivolatile contaminants in Section 3.1.1.1, "Procedures for Collecting Soil Using Spoons, Scoops, and Shovels." Local SCS personnel and the USDA (1975), may also provide useful guidance. The following information is used to categorize percent organic matter concentrations.

Organic Matter Content Class	Percent
(VL) Very Low	<0.5
(LL) Low	0.5-1.0
(ML) Moderately Low	1.0-2.0
(MM) Medium	2.0-4.0
(HH) High	>4.0

Source: USDA, 1951

2.5 Calcium Carbonate

Calcium carbonate ($CaCO_3$) may provide a buffering capacity for acidic contaminants. For example, limestone is readily soluble and will buffer acid deposition effects. For this test, it is recommended that material be used that is less than 2 mm in size. Results identify carbonate minerals present in the soil at levels of about 1.0% or higher. Effervescence is observed after the addition of

[a] "Fines" are defined as soil particles that pass through a No. 200 sieve screen. There are two types of fines--silt and clay, the clay being the smallest (0.002 mm or 2 microns). Permeability is reduced with increasing proportions of fines.

4 N HCl. This solution is made by adding 1 part concentrated HCl into 10 parts water. NOTE: Always add acid to water and use safety equipment when mixing (gloves, eye protection, apron).

NOTE: In testing very dry soils, the emission of air bubbles should not be confused with slight effervescence. Quality control support may be required (see EPA, 1987).

Test 1:

a. Place 1 g (about the size of a large marble) of less than 2 mm sized soil material in the well of a porcelain spot plate. Thoroughly moisten the soil with a few drops of deionized water; stir with a clean glass rod to remove entrapped air.

b. Add three drops of 4 N HCl from a plastic squeeze bottle and immediately observe the treated sample under a hand lens.

c. Record presence or absence of effervescence for each sample.

d. Repeat the treatment and the observation with a second 1 g sample.

e. Record observation.

Effervescence is commonly coded and described as follows:

(EE) Slightly effervescent - (bubbles are readily observed)
(ES) Strongly effervescent - (bubbles form a low foam)
(EV) Violently effervescent - (thick foam "jumps up")

For more detail on this and approximate concentration of $CaC0_3$, contact your local SCS agent.

2.6 Clay Minerals

Clay minerals are the major constituents of the soil structure that influence the retention of contaminants and may control the rate of contaminant migration through the soil. The basic crystalline structure of the clays is layered aluminosilicates. The aluminosilicates in soils form three main groups of clay minerals: kaolinite, illite (or hydrous micas), and montmorillonite.

The ion exchange or charge sites on the clay minerals are available for binding with contaminants. The more reactive the contaminant, the greater is the potential for it to be bound to the soil, or changed by the surface reaction with the clay minerals. After a contaminant has saturated all of the ion exchange sites, it may be replaced by other contaminants having greater sorption potential. Sorption depends on the charge, polarity, etc., of the contaminant, on its concentration, on the presence of competing contaminants, and on the sorption characteristics of the clay.

The following tests provide field procedures for obtaining clay mineral data.

2.6.1 Test 1: Mica Test

a. Select a 2-g clod of air-dry soil.

b. Rub the clod with a knife blade.

c. A shiny surface indicates high plasticity. You are seeing the shine of the dry highly plastic fines (i.e., the clay minerals).

d. Record observations.

2.6.2 Test 2: Clay Test

a. Prepare a saturated solution of malachite green in nitrobenzene to use as an indicator solution (follow prescribed safety procedures when handling nitrobenzene). Chemicals can be obtained from Fisher Scientific, Faden Road, Springfield, N.J. and guidance for preparing the solution can be obtained from a local university. To determine quantitative amounts of clay, laboratory tests should be completed.

b. Add several drops of the indicator to a small sample (1 g) of soil.

c. If the wetted soil remains blue or green-blue, the soil contains minerals of the kaolinite group.

d. A yellow-red color indicates montmorillonite.

e. A purple-red purple color indicates illite.

f. Record observations.

2.7 Soil pH

The intensity of soil acidity or alkalinity is expressed in pH. Soil pH is a critical parameter that should be measured on a routine basis. Field measurement of pH using field test kits, e.g., indicator dyes, provides an indication of soil contamination. Soil pH can be determined either by colorimetric or by electrometric methods. The colorimetric uses color indicators. The electrometric method generally uses a pH meter with a glass electrode (see Section 11 Field Instrument Measurements RFM). The electrometric tests are usually conducted in a laboratory, but they can be completed in the field. Whenever precise measurements are needed, a pH meter must be used. The procedures for proper preparation of soil for these pH determinations are presented below (Palmer and Troeh, 1980).

For colorimetric field use, test kits are available from most scientific supply companies (see Field Instrument Measurements RFM, for suggested sources) and provide easy, inexpensive, and relatively accurate results. The dyes are mixed with small amounts of soil and indicate pH by the resulting color. The color is matched and identified by standardized color coding charts. Record observations in the field log book and soil data collection form.

The following codes, notations, and descriptions are used to identify pH:

		pH
(EA)	Extremely acid	Below 4.5
(VS)	Very strongly acid	4.5 - 5.0
(SA)	Strongly acid	5.1 - 5.5
(MA)	Medium acid	5.6 - 6.0
(SA)	Slightly acid	6.1 - 6.5
(NA)	Neutral[b]	6.6 - 7.3
(MA)	Mildly alkaline	7.4 - 7.8
(MO)	Moderately alkaline	7.9 - 8.4
(SA)	Strongly alkaline	8.5 - 9.0
(VA)	Very strongly alkaline	9.1 and higher

pH Test Procedures:

A. Electrometric Method:

1. Weigh out two 10 g quantities of a soil sample that has been passed through a 2-mm sieve and put each in a small, clean 30-50 mL beaker.

2. Add about 20 mL of distilled water to each beaker and mix well with a clean glass or plastic rod or spoon.

3. Let stand about 15 minutes. Stir several times during the 15 minutes.

4. Carefully insert the pH meter electrodes into each sample and determine the pH according to the instructions for the particular machine being used.

B. Colored Indicator (Colorimetric) Method:

1. Thoroughly clean the depressions in a pH spot plate (available with pH kits) by washing with water and drying with a clean cloth or tissue. No trace of acid, base, oil, or perspiration from fingers, etc. should be present.

2. Place a sample of soil about the size of a pea in one or more of the depressions. The soil should cover about half of the area of the depression.

3. Choose an indicator that is likely to include the soil pH in its range. This will usually be Brom Cresol Purple or Brom Thymol Blue. The pH ranges of four common indicators are

[b]Strict neutrality is pH 7.0, but in field work those soils between pH 6.6 and 7.3 are called neutral.

	pH
Brom Cresol Green	4.0 - 5.2
Brom Cresol Purple	5.4 - 6.6
Brom Thymol Blue	6.0 - 7.2
Cresol Red	7.2 - 8.4

4. Add enough pH indicator to saturate the soil plus enough excess to see the color of the indicator. Do not flood the soil with a large excess of indicator.

5. Mix the soil and indicator thoroughly either by shaking (works well with sandy soils) or by stirring with a clean rod.

6. Compare the color of the excess indicator (clear of soil particles) to the color chart for that indicator. If the color viewed against the white background of the spot plate matches near the central region of the color chart, the pH indicated for the matching color should be recorded as the pH of the soil.

7. If the color of the indicator is approximately that of one end of the pH range of that indicator, repeat the test with another indicator. If after repeating the test and a definitive result is not evident, the electrometric method will have to be used.

3. SOIL COLLECTION METHODS

Exposure to airborne contaminants, especially those recently deposited, is often evident in the surface layer of the soil. Contaminants that have been deposited by liquid spills or by water soluble materials may be found at depths up to several meters. Plumes emanating from hazardous waste dumps or leaking storage tanks may be found at considerable depths depending on the soil and type of contaminants (ie., water soluble pesticides in sandy soil can travel to the groundwater). Cores should be checked with portable radiation detection and organic vapor equipment if necessary (See Section 7 and 8, Field Instrument Measurements). The methods of sampling each of these conditions are slightly different, but all make use of one of three basic sampling tools. Samples can be collected with some form of (1) scoop, (2) corer, or (3) augering device (Section 3.1.1).

Important criteria to consider when selecting soil-sampling tools include

- Compatibility with the objectives of the monitoring effort
- Capability for obtaining a specific sample of known size from a known location in the soil profile
- Suitability for collecting samples exposed to a specific contaminant group
- Suitability of the tool for sampling a specific soil type to a certain depth
- Suitability of the sampling tools construction material and mode of operation to prevent cross contamination of the sample
- Suitability for sampling soils under various moisture conditions
    - Accessibility of the sampling site
    - Relative sample size required
    - Labor requirements
    - Cost,

Sites located on soils of intermediate texture (i.e., loams) may require the use of regular augers. For cohesionless and cohesive soil conditions, some tools are more effective than others for obtaining and retaining samples. For example, sand augers are better for sampling in cohesionless soils that are a variation of the standard barrel auger. Dutch augers and mud augers are best suited for cohesive soils.

It may be difficult to retain samples of wet soils in a sampler. Hand-held samplers that are particularly suited for wet soils include both the Dutch and mud augers, and special soil sampling tubes. Thin-walled drive samplers with built-in sampler retainers (often called eggshells) are also used. Peat samplers are designed for sampling in wet organic soils.

As with saturated samples, it may be difficult to retain samples of very dry, cohesionless soils with some sampling tools. Sand augers and specially designed soil-sampling tubes are useful for sampling in these types of soils. Also, thin-walled drive samplers with sample retainers or "core catchers" can be used. Drive samplers can have two types of sample retainers, a one-way solid flap valve, or a segmented, spring-type basket retainer. Core catchers are inserted inside the sampler between the shoe and the sample barrel.

Rocky or stoney soils generally impede the progress of most tools. The problem will be accentuated with small diameter tools, such as soil corers or probes. Larger diameter barrel augers may be necessary and will guarantee adequate soil sample size after the rocks have been discarded.

The size of samples that can be taken varies with different sampling devices. For example, the borehole of most hand-driven screw-type augers generally is less than 5 cm in diameter; barrel augers are available for obtaining 13-cm cores. The choice of a sampling tool may be based on sample size requirements, e.g., the number or kinds of analyses to be done on the soil sample. In addition, the sampling design and the analytical requirements will help define sample size.

Site accessibility also can influence the selection of sampling devices of a study. Sampling sites located in rugged terrain or in marshy areas may be inaccessible by vehicle. Other areas may be temporarily inaccessible following heavy rains. For such conditions, power-driven units mounted on trucks may not be usable, and personnel may need to take portable sampling equipment to the site on foot. Table 5 provides a matrix of soil sampling equipment and selected soil parameters that may be useful in selecting sampling tools.

It is good practice for at least two individuals to work together in the field to obtain samples. Hand-sampling is often tedious, and two individuals can take turns operating the sampling tool. Sampling/monitoring documentation can be facilitated when two individuals are involved. Safety concerns are also better addressed with two or more individuals.

The methods described in this document are for the collection of soil samples only. At times, it is desirable to collect samples of soil water. Groundwater analysis provides a good indication of soluble chemicals that may be moving through the soil system. The collection of soil water is addressed in sampling methods for groundwater (see Section 3.2, Groundwater RFM).

3.1 Equipment

Soil sampling equipment can be divided into two general groups: (a) hand-held samplers and (b) power-driven samplers. The procedures presented are general in nature. It is recommended that manufacturer instructions be followed when using sampling equipment.

3.1.1 Hand-held Samplers

Hand-held samplers include all devices that use manual power to collect soil samples. Historically, these devices were developed to obtain soil samples for agricultural investigations (e.g., determining soil salinity and soil fertility, characterizing soil texture, determining soil-water content), and for engineering studies (e.g., determining bearing capacity). These sampling devices will usually meet the needs of the FWS in monitoring and are categorized as follows:

.ble 5. Criteria for Selecting Soil Sampling Equipment

Type of Sampler	Obtains Core Sample		Most Suitable Soil Types		Operation in Stoney Soils		Most Suitable Soil Moisture Conditions		Access to Sampling Site During Poor Soil Conditions		Relative Sample Size		Sampling Depth		Labor Requirements		Cost	
	Yes	No	Cohesive	Coh-less	Fav	Unfav	Wet	Dry	Yes	No	Small	Large	Shallow	Deep	One	Two/more	Small	Large
HAND-HELD																		
Spoons		X	X	X	X		X	X	X			X	X		X		X	
Scoops		X	X	X	X		X	X	X			X	X		X		X	
Shovels		X	X	X	X		X	X	X			X	X		X	X	X	
AUGERS																		
Screw-Type		X	X	X		X	X		X		X		X	X	X		X	
Barrel																		
Post-hole		X	X		X	X	X		X			X	X	X	X		X	
Dutch		X	X		X		X				X		X	X	X		X	
Regular		X	X		X		X		X		X		X	X	X		X	
Sand		X		X	X		X		X			X	X	X	X		X	
Mud		X	X		X		X		X			X	X	X	X		X	
TUBE-TYPE SAMPLERS																		
Soil probes Wet tips Dry tips	X X		X X			X X	X X		X X		X X		X X	X X	X X	X	X X	
Veihmayer Tubes	X		X			X	X		X		X		X	X	X		X	
Thin-walled Tube Samplers	X		X			X	X		X			X	X	X	X	X	X	
Peat Samplers	X		X			X	X		X			X	X	X	X	X	X	
POWER DRIVEN																		
Hand-held Screw-type Power Auger		X	X	X		X	X	X	X			X	X	X	X	X		X
Truck Mounted Auger		X	X	X		X	X	X		X		X		X		X		X
Tripod Mounted Drive Auger	X		X			X	X	X		X		X		X		X		X
Split Spoons	X		X			X	X	X		X		X	X	X		X		X

1. Spoons, scoops, and shovels
2. Screw-type augers
3. Barrel augers
4. Tube-type samplers.

Most of these devices can be used to obtain both surface and subsurface soil samples; however, it must be emphasized that some methods are better suited for collecting a soil sample if there is suspicion of a particular type of soil contaminant. For example, many devices (e.g., augers) are not appropriate for collecting soils for volatile organic analysis.

3.1.1.1 Spoons, Scoops, and Shovels.

Spoons: The simplest, most direct method of collecting soil samples is to use stainless steel spoons. Plastic- or Teflon-coated spoons are also available. The common spoon size referred to here varies from the teaspoon size of about 10 g capacity, to the tablespoon and mixing spoon sizes that vary from 30 g to about a 100 g capacity.

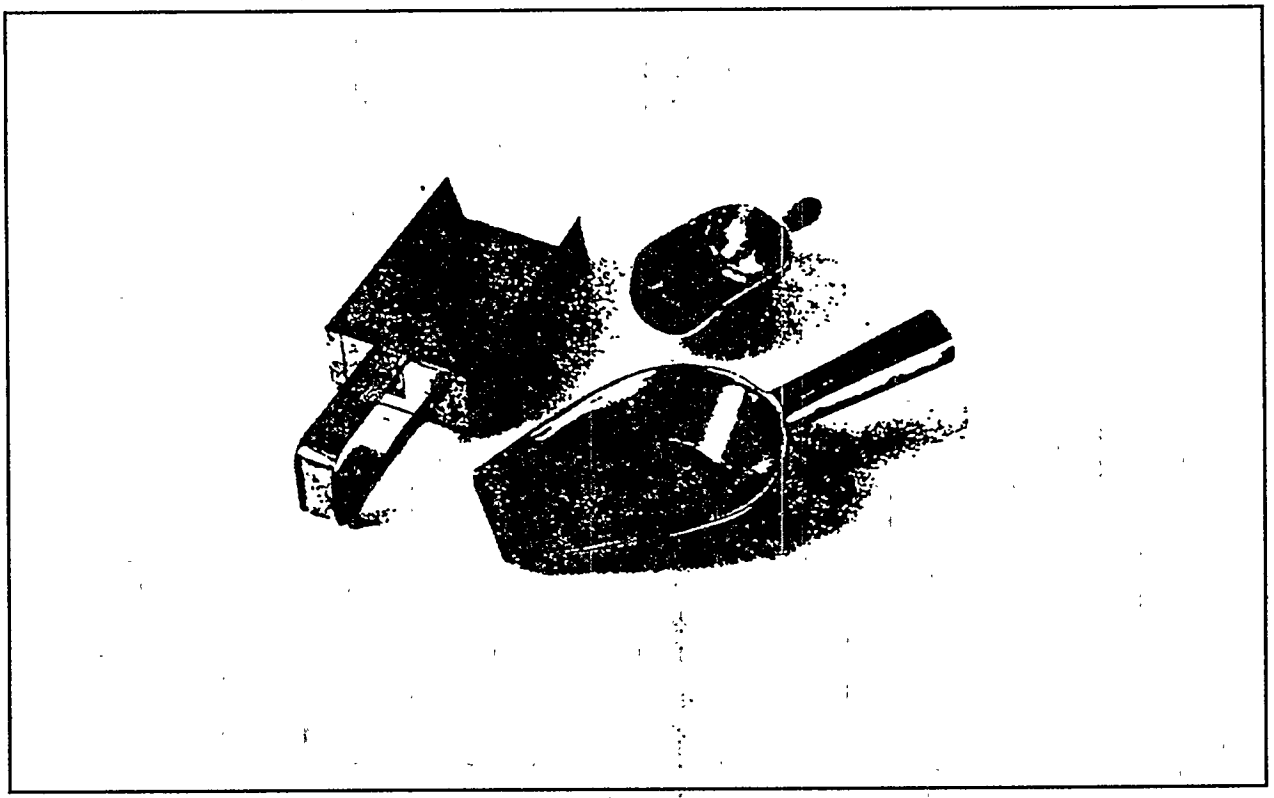


Figure 4. Scoops (Soil Test, Inc. catalog, 1983).

Scoops: The recommended device is a stainless steel scoop similar or identical to ice machine scoops (Figure 4). Scoops that vary in capacity from less than 300 g to more than 2000 g can be purchased.

Spoons and scoops are used almost exclusively for the collection of surface samples. However, these devices are considered by many soil scientists to be undesirable, as the reproducibility of area sampled, depth, and volume from one sampling site to another is poor. If sampling consistencies are not critical to the sampling objective, then the use of these devices is recommended. The advantages of using spoons and scoops include

- Inexpensive--numerous spoons and scoops can be purchased with limited resources.
- Availability--stainless steel spoons and scoops are readily available. Time constraints in obtaining these tools are almost nonexistent.
- Decontamination--spoons and scoops can be easily decontaminated with water and/or appropriate solvents. It is recommended to use a clean spoon for each sample. Spoons can either be decontaminated or discarded, considering the costs and time involved in the decontamination procedure.
- Screening--spoons and scoops provide a fast and inexpensive method for collecting soils for initial screening purposes.
- Remote area sampling--spoons and scoops can be carried and packed to remote areas.

Shovels: Shovels and shovel-like instruments (e.g., trowels) are similar in their use to spoons and scoops. The sampling advantages are identical to those of spoons and scoops except for the cost. The cost of discarding most shovels, instead of decontaminating them, would probably become prohibitive, especially during long-term repetitive monitoring programs.

3.1.1.1.1 Procedure for Collecting Soil Using Spoons, Scoops, and Shovels--

Volatiles: When collecting soils for volatile analysis, place the first adequate grab sample (enough to fill the collection jars) in 40-mL septum vials and in a 1-L glass wide mouth bottle with a Teflon-lined cap (See specific contaminant requirement, FWS, 1986). Maintain and handle this sample in as undisturbed a state as possible and make sure the 40 mL containers are completely filled to the top to minimize volatile loss. It is critical that the containers be properly sealed, labeled, and preserved [see Sections 3, 5, and 6 of Documentation SOP, and FWS (1986) for definitive requirements]. Also, do not attempt to mix or sieve these soil samples in the field. Document sample depth, location, and other required field information.

Semivolatiles: If required, composite the collected grab samples and, if possible, screen the soils in the field through a precleaned 0-mesh (No. 10, 2-mm) disposable stainless steel screen. Use the collecting instrument to mix the screened material in a suitable disposable tray, stainless steel mixing bowl, or a sheet and then place an adequate sample (enough to fill sample containers) in the appropriately labeled container, seal, and preserve [see Sections 3, 5, and 6 of Documentation SOP and FWS (1986) for definitive requirements]. Discrete grab samples must also be screened and mixed.

NOTE: For recommended and definitive field soil preparation methods see Section 5, Preparation Procedures. Wet soils are difficult to screen and mix adequately. If the proper field facilities and equipment are not available for sample preparation, send the sample to the analytical laboratory for preparation.

Metals: The procedures for collecting soils for metal analysis using spoons, scoops, and shovels are identical to those procedures described above for semivolatile analysis. However, two different considerations are required: (1) check Section 5 Documentation SOP for different container and preservation requirements and (2) stainless steel collecting and sample preparation devices contain certain metals (e.g., chromium) that could contaminate the sample. Teflon-lined or plastic sampling equipment is an alternative. Document sample depth, location, and other required field information. Decontaminate sampling equipment after use and between sampling locations. See Section 2 Decontamination Guidance RFM, for procedures. Collect decontamination blank, if required (see QA/QC Section 2, Documentation SOP).

Field Equipment & Supplies

Sampling devices: spoons, scoops, shovels

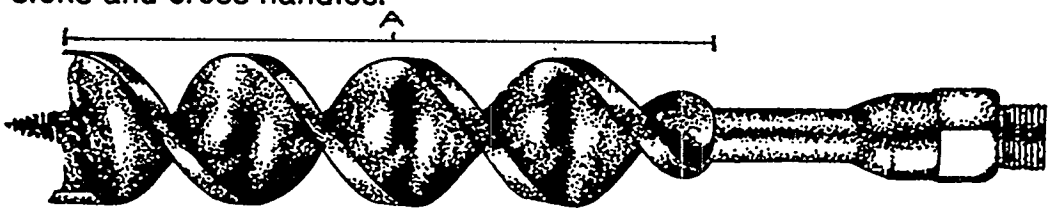
Item	Contaminant Being Sampled For
No. 10 mesh stainless steel screen	For metals, organic matter (TOC), and semivolatiles
Mixing Containers	
Stainless steel, glass, Teflon	For all contaminants
Aluminum pans	For all contaminants except aluminum
Plastic	For metal analysis only
Appropriate sample containers (Section 5 Documentation SOP Table 6 and FWS, 1986)	All contaminants
Field logbook	All contaminants
Chain-of-custody materials	All contaminants
Map(s) of sampling location(s)	All contaminants
Plastic bags for waste	All contaminants
Plastic bags for sample containers (Glass sample containers are to be placed in plastic bags)	All contaminants
Freeze packs	All contaminants
Ice chest	All contaminants
Field survey instruments (e.g., radiation detector, etc.	All contaminants

3.1.1.2 Screw-type Augers. Screw-type augers (Figure 5) are used to collect samples primarily from the upper 2 m of the soil profile. They consist of an auger bit, a series of drill rods or tubing, and a "T" handle. Augers can be obtained in a variety of sizes ranging from 3 cm to more than 15 cm in diameter. The soil auger bit is similar in appearance to a wood auger with the cutting side flanges and tip removed.

Samples obtained using screw-type augers are collected directly off the flights (Figure 5) when the auger is removed from the soil. Augers disturb the integrety of samples rendering them unsuitable for volatile analysis, and they do not provide a suitable sample for profile description. A completely representative sample may not be possible because of the difficulty in identifying the exact sampling depth.

Screw Auger

The extra heavy-duty screw type auger is used for taking smaller soil samples. Diameter sizes are 1⅓" and 1¾". The flighting is a double twist for easier penetration. Screw augers can be used with our extensions and cross handles.



(Source: Art's Manufacturing & Supply, American Falls, ID, aka Art's Machine Shop)

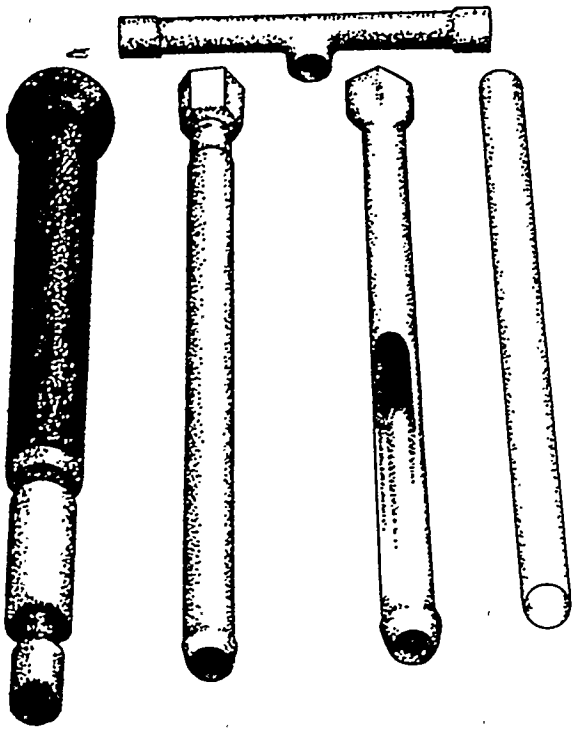
Figure 5. Screw-type auger (A = one flight).

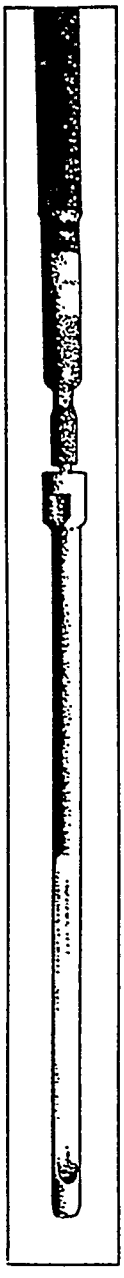
The primary advantages of screw-type augers include

- Open thread face provides easy access to sample
- Fairly easy to decontaminate
- Operates well in moist soils
- Satisfactory when a composite of the soil column is required
- Fairly inexpensive
- Readily available.

The primary disadvantages include

- Not effective in some soils (e.g., hard pans, rocky soils, dry sand)
- Tends to contaminate lower depths with material from upper depths because of cave-in and/or sloughing
- Disturbed sample (i.e. mixed to some degree)
- Sampling depth is limited to about 60 in.





Soil Recovery Probe

The AMS patent pending soil recovery probe is a dual purpose probe. When using this probe with liners, you can obtain exact depth samples. Samples can be retained in plastic teflon or stainless liners. The S.R.P. is ideal for dissipation studies. By removing the liners you have a regular soil probe. Two diameters of probes are available, 1 1/8" or 7/8". The 1 1/8" uses a 1" diameter liner and the 7/8" uses a 3/4" diameter liner. Stock production lengths are 6", 12", 18", and 24". These probes come in chrome plated, or by special order are available in all stainless . The hammer attachment is suggested for use with soil recovery probes.

(Source: Art's Manufacturing & Supply, American Falls, ID, aka, Art's Machine Shop)

Figure 6. Thin-wall tube sampler.

3.1.1.2.1 Screw-type Auger and Thin-wall Tube Combination---For most sampling situations involving a screw auger, the thin-wall tube sampler (Figure 6) is used as the actual sampling instrument. These tools complement one another; the auger is used to bore a hole to a point just above the required sampling depth. At this point, the auger is slowly pulled out (some twisting may be required). The auger tip is replaced by the thin-wall tube sampler lowered down the borehole and forced into the soil to the required depth. The tube sampler is then withdrawn containing the sample.

The thin-wall tube sampler does provide a relatively undisturbed sample that is more suited to volatile analysis than soils collected from auger flights. A number of disadvantages include

- Difficult to extract soil from the tube
- Difficult to decontaminate without long bore brushes
- Not suitable for rocky soils
- Not suitable for dry fine soils
- Not suitable for extremely wet soils
- Sampling depth is limited.

3.1.1.2.2 Procedures for Collecting Soil Using Screw-Type Augers with Thin-walled Tubes--The general sampling procedures described previously under "Procedures for Collecting Soil Using Spoons, Scoops, and Shovels" should be followed. The collection of soil from screw auger flights is not recommended for the analysis of volatile compounds because this sampling method disturbs the soil matrix. The specific sampling procedures for screw-type augers are

1. Attach the auger bit to a drill rod extension and attach the "T" handle to the drill rod.

2. Clear the area to be sampled of any surface debris (twigs, rocks, litter).

3. Begin drilling, periodically removing accumulated soils. This prevents accidentally brushing loose material back down the borehole when removing the auger or adding drill rods.

4. After reaching desired depth, slowly and carefully remove auger from boring. (Note: When sampling directly from auger flights, collect sample after auger is removed from boring and proceed to Step 10).

5. Remove auger tip from drill rods and replace with precleaned thin-wall tube sampler. Install proper cutting tip.

6. Carefully lower thin-wall tube sampler down borehole. Gradually force sampler into soil. Take care to avoid scraping the borehole sides. Do not hammer the drill rods to facilitate coring, as the vibrations may cause the boring walls to collapse.

7. Remove sampler and unscrew drill rods.

8. Remove cutting tip and remove soil core from thin-wall tube sampler.

9. Discard top of soil core (approximately 2.5 cm), which should represent material collected by the sampler before penetrating the desired sampling layer. Field judgment is required in

determining how much of the sample to discard. Place remaining core into sample container by pushing it out with a wooden dowel, or the liner can be used as a sample container if end caps are available.

10. Verify that a Teflon liner is in the sample container cap if required. Secure the cap tightly. The chemical preservation of solids is generally not recommended. Refrigeration is usually the best approach supplemented by a minimal holding time. Consult Table 6 of this RFM or Section 5 of the Documentation SOP for containerization and preservation guidelines.

11. Label the sample bottle with the appropriate sample tag. Label the tag carefully and clearly, addressing all the categories or parameters. Complete all documentation requirements and record in the field logbook.

12. Decontaminate sampling equipment after use and between sampling locations. See Section 2 Decontamination Guidance RFM for procedures. Collect decontamination blank if required (see QA/QC Section 2, Documentation SOP).

3.1.1.3 Barrel Augers. Barrel augers consist of a short tube or cylinder in which the soil sample is retained. Components of this sampler consist of (a) a penetrating bit with cutting edges, (b) the barrel, and (c) two shanks welded to the barrel at one end and a screwed section at the other end (Figure 7). Extension rods are screwed on as necessary to reach the required sampling depth. The uppermost extension rod contains a tee-type coupling for attachment of a handle. The extensions are marked in even depth-wise increments above the base of the tool.

A number of barrel augers are available and include the following types:

- Post-hole Auger. The simplest and most available barrel auger is the common post-hole auger (Figure 7) (also called the Iwan-type auger). The barrel part of this auger is not completely solid, and the barrel is slightly tapered toward the cutting bit. The tapered barrel together with the taper on the cutting bit helps to retain the sample within the barrel.

- Dutch Auger. The Dutch-type auger (Figure 8) is a smaller variation of the post-hole auger. The pointed bit is attached to two narrow, curved body segments, welded onto the shanks. The outside diameter of the barrel is generally only 8 cm (3 in.). These tools are best suited for sampling in heavy (e.g., clay) wet soils.

- Regular Barrel Auger. The barrel portion of this general purpose auger (Figure 9) is completely enclosed. As with the post-hole auger, the cutting blades are arranged so that the soil is loosened and forced into the barrel as the unit is rotated and pushed into the soil. Each filling of the barrel corresponds to a depth of penetration of about 8 cm to 13 cm (3 to 5 in.). The most popular barrel diameter is 8 cm (3 in.), but sizes ranging from 4 cm to 15 cm (1.5 to 6 in.) are available. The cutting blades are arranged to aid retention of the sample in the barrel. Extension rods can be made from either standard black pipe or from lightweight conduit or seamless steel tubing. The extensions are circumscribed by evenly spaced marks to facilitate determining sampling depth.

- Sand Augers. This type of auger (Figure 10) is similar in design to the barrel auger. However, it has a specially formed penetrating bit to retain dry and loose material in the

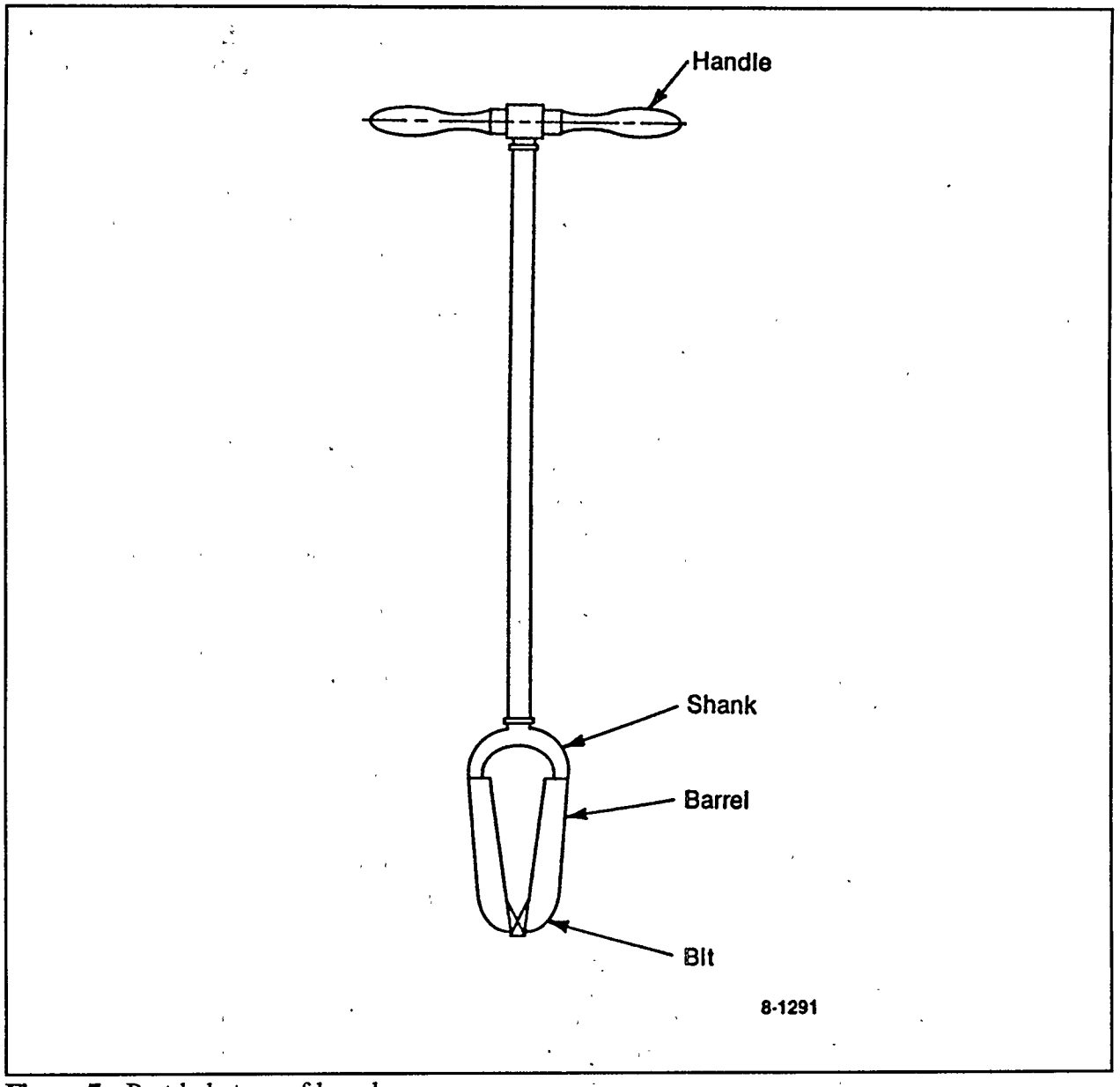


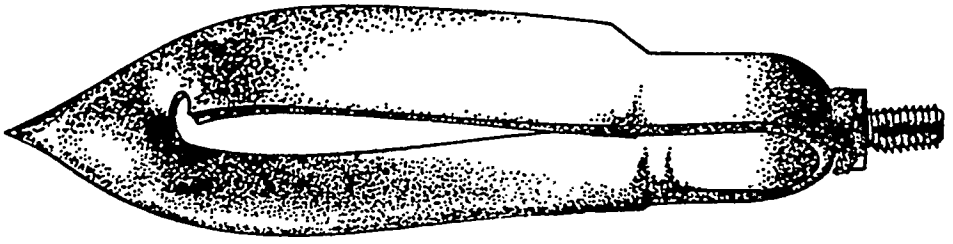
Figure 7. Post-hole type of barrel auger.

barrel.

- Mud Augers. This type of auger (Figure 11) is also similar to the barrel auger but is designed for sampling heavy, wet soils or clay soils. The barrel is constructed with open sides to facilitate the extraction of the sample.

To operate barrel augers, the auger bit is placed on the soil surface and turned to advance the tool into the ground. When the barrel is filled, the unit is withdrawn from the cavity, and the soil is removed from the barrel. Barrel augers generally provide a larger sample size than the screw-type augers.

The Dutch type auger is excellent for drilling extremely wet, boggy soil. It is also useful in very fiberous, heavily rooted, and swampy areas. This auger is hand-forged from high carbon spring steel. This is available in three inch diameter only. Use the Dutch auger with AMS standard extensions and cross handles.



Source: Art's Manufacturing and Supply, American Falls, ID, aka Art's Machine Shop.

Figure 8. Dutch-type post-hole auger.

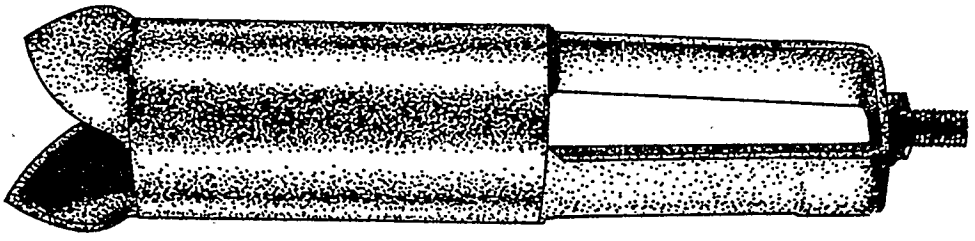
The advantages, disadvantages, and utility of these augers are the same as the screw augers. They are similar to the screw augers in that they are excellent for sampling a given soil column when a composite aliquot is required, but they can be difficult to decontaminate and cumbersome to extract samples from. They are not recommended for the collection of soils for analysis of volatile compounds.

Decontaminate sampling equipment after use and between sampling locations. See Section 2, Decontamination Guidance RFM for procedures. Collect decontamination blank if required (see QA/QC Section, Documentation SOP).

3.1.1.3.1 Procedures for Collecting Soils Using Barrel Augers--The general sampling preparation requirements and procedure for volatiles, semivolatiles, and metals previously described in the "Procedures for Soil Using Spoons, Scoops, and Shovels" section should be followed. The use of augers for the collection of soil for the analysis of volatile compounds is not recommended, as they disturb the soil matrix.

3.1.1.4 Tube-type Samplers. Tube-type samplers are tubes sharpened on one end and fitted with a "T" shaped handle on the other end. They are usually constructed of stainless steel or brass and commonly measure 45 cm (18 in.) in length and about 2.5 cm (1 in.) in diameter. However, tube samplers are available in various lengths and diameters.

The regular auger is used for ordinary soil sampling. Specially designed bits guarantee easy penetration even in the hardest soils. AMS augers are extendable and come in various diameters, 1⅓", 1¾", 2", 2¼", 2¾", 3¼", 4", 5", 6" and 7". All AMS augers are constructed from high quality stainless tubing and stellite hard surfaced high carbon steel bits.



Source: Art's Manufacturing and Supply, American Falls, ID, aka Art's Machine Shop.

Figure 9. Regular barrel auger.

This type of sampler is not suitable for sampling in dense, stony soils. They are, however, the preferred sampling instrument to use if an undisturbed soil core is required, e.g., for obtaining a sample for the analysis of volatile compounds.

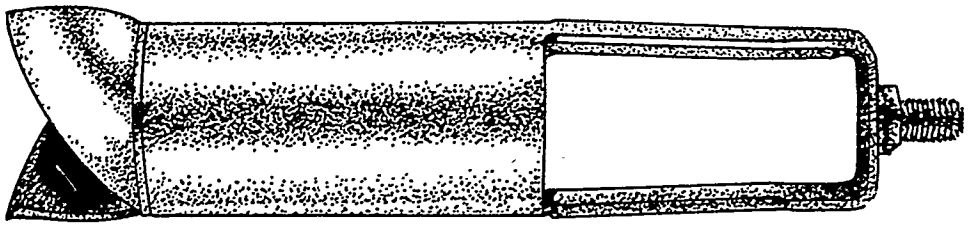
A number of these devices are available with slightly differing designs. Some of the more common include

- Soil sampling tubes/probes. These tools (Figure 12) consist of a hardened cutting tip, a cut-away barrel, and an uppermost threaded segment.

  The cut-away barrel is designed to facilitate examining soil layering and to allow for the easy removal of soil samples. Generally, the tubes are constructed from high strength alloy steel. The sampler is available in three common lengths--30 cm, 38 cm, and 45 cm (12, 15, and 18 in.). Two modified versions of the tip are available for sampling either in wet or dry soils. Commonly used tube samplers obtain samples of 2 cm in diameter.

  Sampling with these devices requires forcing the tube vertically into the soil. When the tube is filled to the appropriate depth, the handle is twisted and the assembly is pulled to the surface. These devices units are available with attachments which allow foot pressure to be applied to force the sampler into the ground. A commonly used variety of theis design is the Shelby tube, which has proven to be an excellent sampling instrument.

"The AMS sand auger was especially designed for use in extremely dry sandy soils. Bits are especially formed to retain dry sand samples. The sand augers are available in various diameters, 1½", 1⅓", 2", 2¼", 2¾", 3¼", 4", 5", 6", and 7". Sand augers are also available in all stainless for ease of decontamination.



Source: Art's Manufacturing and Supply, American Falls, ID, aka Art's Machine Shop.

Figure 10. Sand auger.

- Veihmeyer Tube. The Veihmeyer sampler (Figure 13) consists of four basic parts: a tube, a head, a point, and a drive hammer. The tube is constructed of chromium-molybdenum steel and comes in various standard lengths from 0.91 to 4.9 m (3 to 16 ft). This tube is calibrated every 30.5 cm (12 in.). The head is attached to the upper end of the tube and acts to protect the top of the tube from deforming when the tube is driven into the ground. Interchangeable points, which provide the cutting action, can be attached to the bottom of the tube. A variety of pointsare available for different types of soil and sampling situations. Each point is shaped to penetrate specific types of soil without pushing the soil ahead of it, thus preventing the core from compacting in the tube, and also to keep the sample from being "sucked" out of the tube as it is pulled from the ground. The drive hammer is constructed of cast iron and its heavy weight (15 lbs) is used to drive the tube into the ground. It also doubles as a handle when pulling the sampler from soft ground. An optional puller jack can be used to pull the tube out of hard soils or from greater sampling depths.

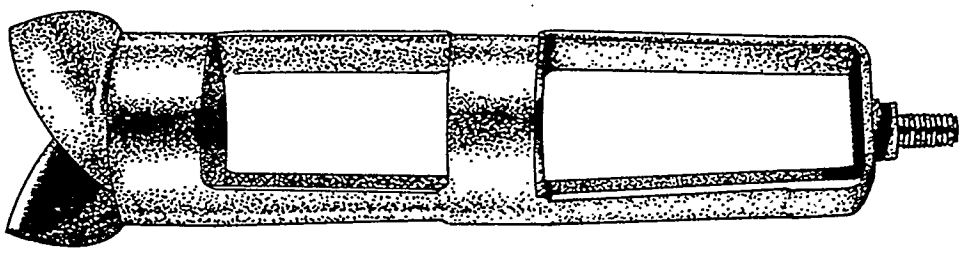
  The Veihmeyer sampler can be used for core sampling of most types of soil to a maximum depth of 4.9 m (16 ft). It may not be applicable to sampling stony, rocky, or very wet soils.

Procedures for Use

1. Assemble the Veihmeyer sampler by screwing the point and the head onto the tube.

2. Insert the tapered handle (drive guide) of the hammer through the head.

The mud auger features an opening cut out of the cylinder for the easy removal of heavy, wet soil and clay samples. Bits are similar to the regular augers but are spaced further apart. The mud head is available in all stainless construction and is available in 1⅓", 1¾", 2", 2¼", 2¾", 3¼", 4", 5", 6" and 7" diameters.



Source: Art's Manufacturing and Supply, American Falls, ID, aka Art's Machine Shop.

Figure 11. Mud auger.

3. Place the sampler in a perpendicular position on the soil to be sampled.

4. With left hand holding the tube, drive the sampler into the ground to the desired sampling depth by pounding the head with the drive hammer. Do not drive the tube further than the tip of the hammer's drive guide.

5. Record the length of the tube that penetrated the ground.

6. Remove the drive hammer and fit the keyhole-like opening on the flat side of the hammer onto the head. In this position, the hammer serves as a handle for the sampler.

7. Rotate the sampler at least two revolutions to shear off the sample at the bottom.

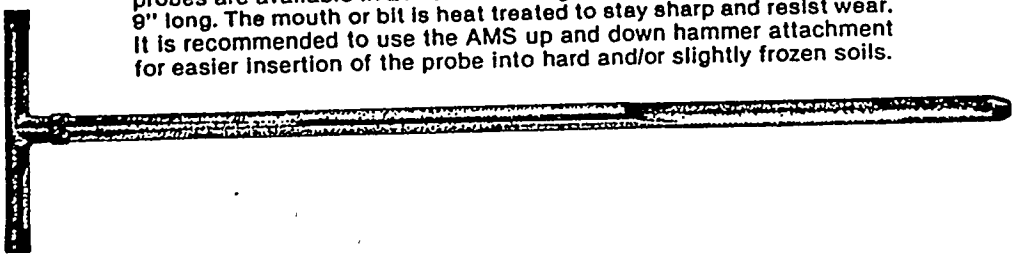
8. Lower the sampler handle (hammer) until it just clears the two ear-like protrusions on the drive head and rotate about 90-degree angle.

9. Withdraw the sampler from the ground by pulling the handle (hammer) upwards. When the sampler cannot be withdrawn by hand, as in deep soil sampling, use the puller jack and grip.

10. Dislodge the hammer from the sampler; turn the tube upside down; tap the head gently against the hammer; and carefully recover the sample from the tube. The sample should slip out easily. (Removing soil samples from solid, seamless tubes or sleeve sampling devices

Soil Probes

AMS soil probes are the best and easiest way to sample top soil. The probes are available in 21" and 33" lengths and the cross handles are 9" long. The mouth or bit is heat treated to stay sharp and resist wear. It is recommended to use the AMS up and down hammer attachment for easier insertion of the probe into hard and/or slightly frozen soils.



Extensions and Cross Handles

AMS extensions and cross handles are made from the highest quality alloy available. Extensions come in various lengths, but can also be made to your specific lengths. These extensions fit all of the AMS equipment. Cross handles are now available with a rubber coating which enhances comfort and could help eliminate shock from underground power lines.

(Source: Art's Manufacturing & Supply, American Falls, ID, aka Art's Machine Shop)

Figure 12. Soil sampling tubes/probes.

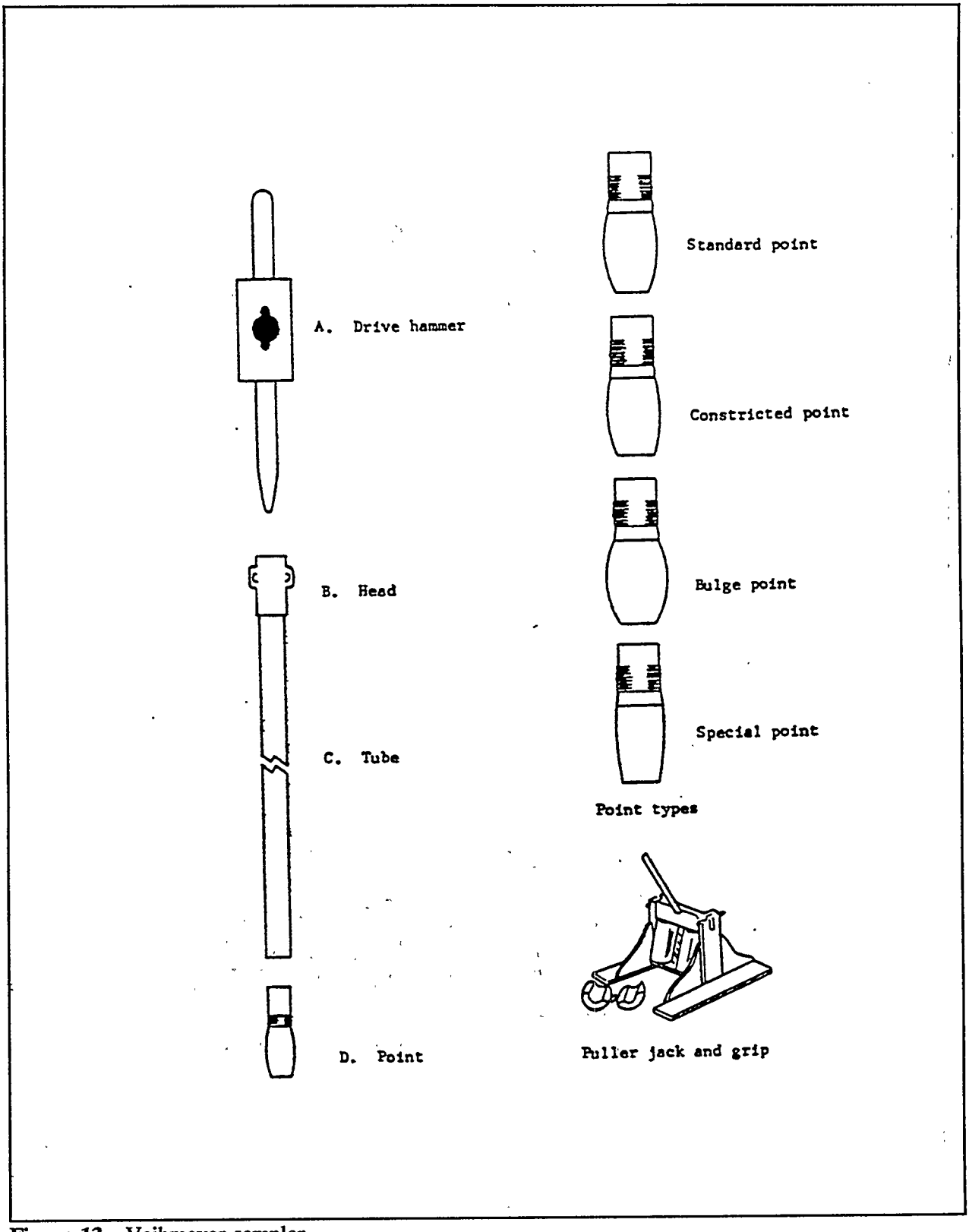


Figure 13. Veihmeyer sampler.

may require a sample ejection device because of soil compaction. These devices are generally piston operated and can be obtained from soil sampling equipment vendors.)

11. Store the core sample, preferably, in a rigid, transparent, or translucent plastic tube when observation of soil layers is to be made. The use of the tube will keep the sample relatively undisturbed. In other cases, use a 1000-mL or 2000-mL (1-qt or 1/2-gal) sample container to store the sample.

12. Label the samples; affix the seals; record in the field logbook; complete analysis request sheet and chain of custody record; and deliver the sampler to the laboratory for analysis.

Tube components of this sampler are constructed from hardened metal. The tube is generally marked in even depth increments.

- Thin-walled Drive Sampler. Commonly used with the screw auger, the thin-wall drive sampler (Figure 6) can, however, be used as a single sampling tool. This instrument consists of a thin-walled seamless steel tube with a beveled cutting tip and a head unit threaded to fit a standard drill rod. The head contains a ball check valve for releasing air from the cylinder during sampling.

  The tubes are available in diameters of 2.2 cm and 2.28 cm (7/8 and 1-1/8 in.). Commonly used tube lengths are 15.2 cm, 30.5 cm, 45.7 cm, and 61.0 cm (6, 12, 18, and 24 in.).

  As previously described, these samplers are commonly attached to a drill rod, and the assembly is lowered into a cavity excavated by an auger. The tube is then forced into the undisturbed soil. This can be accomplished by hand. The thin-walled sampler is then withdrawn from the auger hole.

- Peat Sampler. This tool consists of a sampling tube and an internal plunger containing a cone-shaped point, which extends beyond the sample tube, and spring catch at the upper end. Prior to sampling, the unit is forced into the soft ground to the required depth. The pronged plunger prevents soil from entering the tube. Then the spring catch is released via an actuating rod assembly to withdraw the internal plunger. The next step is to force the tube into the undisturbed soil to the required depth. The tube is then withdrawn containing the collected sample. The sample removed is about 2 cm (3/4 in.) in diameter and 12 cm (5 in.) in length. This tool is designed primarily for sampling soils high in organic matter. Figure 14 is an example of a type of silage sampler that may be also used in peat sampling.

The tube samplers are the preferred when collecting soils for analysis of volatiles. Care must be exercised when extracting the sample from the tube to minimize sample disturbance.

3.1.1.4.1 Procedures for Collecting Soils Using Tube-type Samplers--The general sampling preparation requirements and procedures for volatiles, semivolatiles, and metals previously described in the "Procedures for Collecting Soil Using Spoons, Scoops, and Shovels" section should be followed. The specific sampling procedures for tube-type samplers are

1. Locate and clear the area to be sampled of any surface debris (twigs, rocks, litter).

The silage auger is specifically designed to sample silage pits and peat bogs. It features a stainless steel cylinder designed with open sides for easy removal of silage. High carbon heat treated, razor sharp scallop knife edge for a clean cut. Use with standard extension and cross handle.

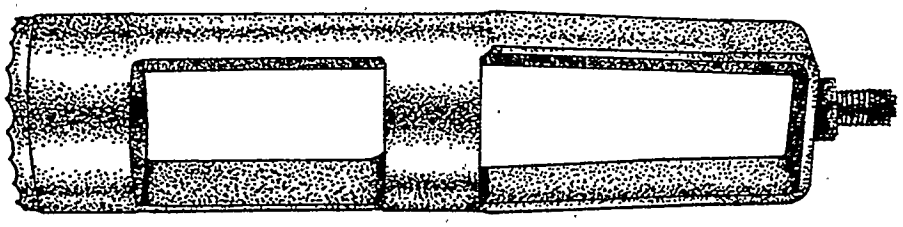


Figure 14. Peat/silage auger.

2. Drive core tube into the ground to the desired depth.

3. Retrieve core tube with sample, extract core, and place in aluminum trays or tin foil if aluminum is not to be analyzed.

4. Collect undisturbed sample for volatile organics, completely filling the appropriate labeled container with the sample.

5. For nonvolatile contaminants (semivolatile and metals), repeat the procedure until sufficient soil material has been collected.

6. Composite and screen cores through 0-mesh (No. 10) stainless steel screen, mix (see Preparation Procedures, Section 5), and place in appropriate labeled containers.

7. Complete documentation procedures and provide preservation requirements as needed. Refrigeration is recommended supplemented by a minimum holding time. See Documentation SOP and USFWS (1986), for containerization and preservation recommendations.

8. Process samples and decontaminate equipment as described in Section 2 Decontamination Guidance RFM. Collect decontamination blank if required (see QA/QC Section 2, Documentation SOP).

Field Equipment and Supplies

Field measurement instrumentation (e.g., radiation detectors)

Stainless steel spoons

No. 10 mesh stainless steel screen

Aluminum pans

Tube type samplers

Sample containers

Sample labels

Chain-of-custody materials (if required)

Location maps

Plastic bags

Decontamination equipment and supplies

Documentation materials (e.g., field logbook)

Freezer packs

Ice chest

Wooden dowel.

3.1.2 Power Driven Samplers

It is anticipated that the maximum depth required for soil sampling on refuges will be between 1 and 2 m. The hand-held samplers described previously will, in most cases, be adequate. For some special situations, it may be necessary to use power-driven samplers (e.g., augers, corers, or split spoons). Local drilling contractors and tool rental companies have power driven samplers that are available for use.

3.1.2.1 Augers. Two types of power augers are available. The first is the hand-held auger commonly driven by a small air-cooled engine. Two handles are attached to the head assembly that allows two operators to guide the auger into the soil. The throttle and clutch controls are integrated into grips on the handles. The second is the truck-mounted auger.

The sampling procedures as previously described for screw-type augers should be followed. If a thin-wall tube sampler or coring device is used with the auger, follow the sampling procedures as previously described for screw-type auger and thin-wall tube combination.

3.1.2.2 Split Spoons. To describe soil profiles without trenching and to obtain samples at substantial depths, the split spoon is the recommended sampling device. Split spoons are tubes constructed of high strength alloy steel in which the barrel of the sampler has a tongue and groove arrangement that runs the length of the tube (spoon). During sampling, the two halves are placed together and a hardened shoe with a beveled cutting tip is threaded onto one end of the tube and a drive head assembly is screwed onto the other end. After the sample is taken, the two halves of the tube can be separated exposing the enclosed soil core. These samplers are available with internal diameters ranging from 5 cm (2 in.) to about 15 cm (6 in.) and come in lengths up to about 65 cm (26 in.). Threaded collars are available for attaching two or more lengths.

The split spoon can be used with the auger by using the same procedures as identified with the thin-wall tube sampler. It can also be driven with a tripod-mounted power sampler. These tripod power units consist of an engine with a cathead assembly mounted near the base of one leg of the tripod. Manila rope is wound around the cathead and passed through a pulley attached to the top of the tripod. The upper rope end is attached to a hammer drive assembly. In many soils, the split spoon can also be forced into the ground by the hydraulic drawdown on a drill rig.

It is recommended that a 63.5-kg weight (resembling a pile driver) be used to drive the split spoon. The weight should be allowed to free fall 76 cm for each blow to the spoon. The number of blows required to drive the spoon 15.2 cm is counted and recorded. The blow counts are a reflection of the soil density. If hydraulic drawdown is used, information derived by blow counts cannot be obtained.

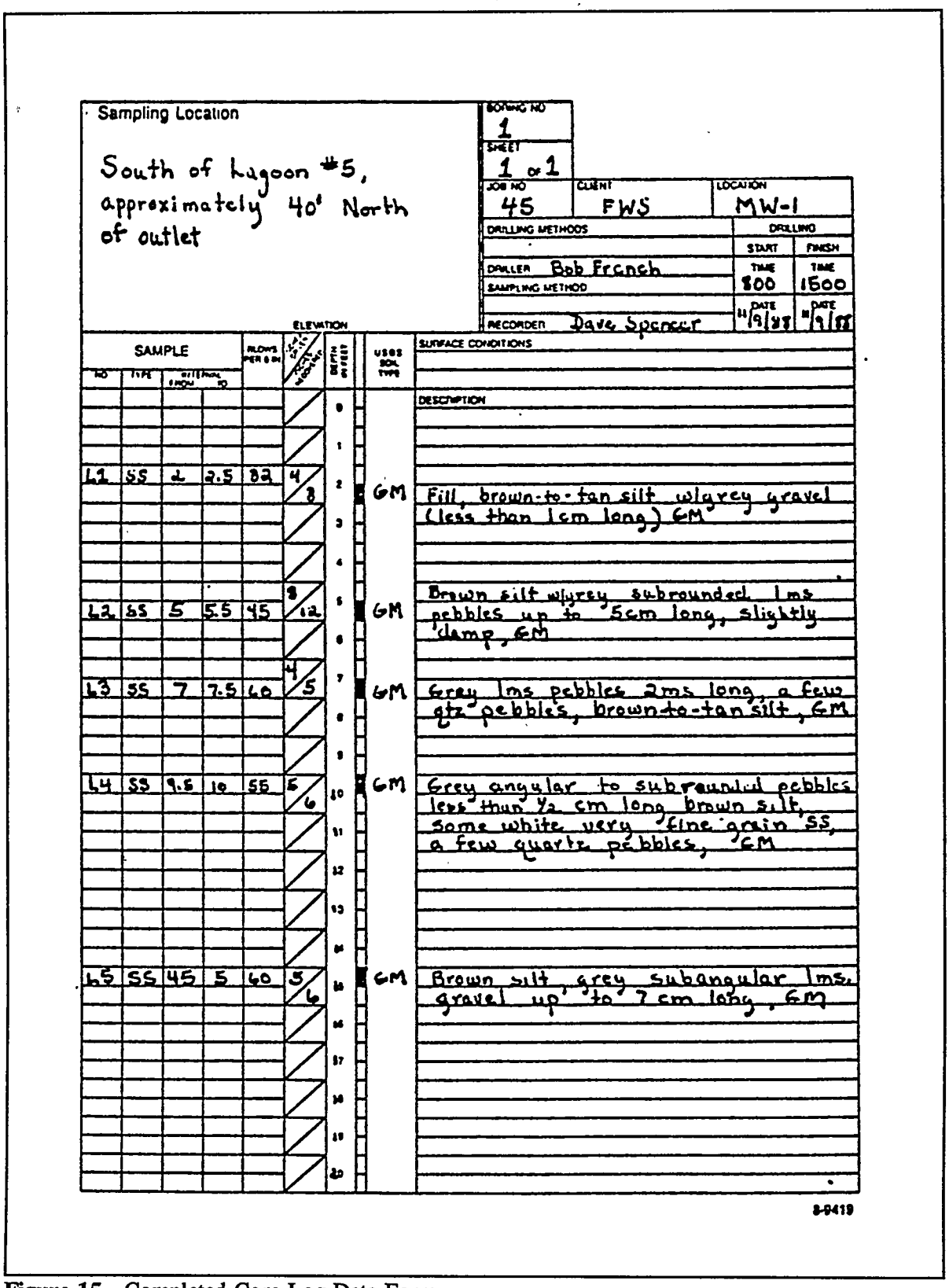
The procedure for using split spoons is as follows:

1. Identify sampling location and clear the area of any surface debris (twigs, rocks, litter).

2. Drive the split spoon into the ground to the desired sampling depth. Count driving blows if required.

3. Retrieve the split spoon; unscrew the shoe, cutting tip, and the upper collar. Break the spoon apart. If samples are to be collected for volatiles, examine the core and remove the core section to be sampled as soon as possible. Use sampling procedures previously described. Place the sampled core in the appropriate container and preserve as specified in the Documentation SOP.

4. The operator should prepare core logs while operating the sampler. These logs should note the depth of sample, the length of the core, and the depth of any features of the soil such as changes in physical properties, color changes, the presence of roots, rodent channels, etc. If chemical odors are noted or unusual color patterns are detected, these should be noted also. The soil horizons or strata are the avenues through which contaminants are likely to migrate. Some are more permeable than others and are thus more likely to contain traces of the contaminants if they are moving through the soil. Generally, the sands and gravels are more prone to contamination than are the clays because of increased permeability. For



Sampling Location

South of Lagoon #5, approximately 40' North of outlet

BORING NO: 1
SHEET: 1 of 1
JOB NO: 45
CLIENT: FWS
LOCATION: MW-1
DRILLING METHODS
DRILLING START: 800
DRILLING FINISH: 1500
DRILLER: Bob French
SAMPLING METHOD
RECORDER: Dave Spencer
DATE: 11/9/88
DATE: 11/9/88

SAMPLE NO	SAMPLE TYPE	SAMPLE WITH FROM	SAMPLE WITH TO	BLOWS PER 6 IN	ELEVATION / SAMPLE NUMBER	DEPTH IN FEET	USGS SOIL TYPE	SURFACE CONDITIONS / DESCRIPTION
						0		
						1		
L1	SS	2	2.5	82	4/8	2	GM	Fill, brown-to-tan silt w/grey gravel (less than 1cm long) GM
						3		
						4		
L2	SS	5	5.5	45	8/12	5	GM	Brown silt w/grey subrounded lms pebbles up to 5cm long, slightly damp, GM
						6		
L3	SS	7	7.5	60	4/5	7	GM	Grey lms pebbles 2ms long, a few qtz pebbles, brown-to-tan silt, GM
						8		
						9		
L4	SS	9.5	10	55	5/6	10	GM	Grey angular to subrounded pebbles less than ½ cm long brown silt, some white very fine grain SS, a few quartz pebbles, GM
						11		
						12		
						13		
						14		
L5	SS	45	5	60	5/6	15	GM	Brown silt, grey subangular lms gravel up to 7 cm long, GM
						16		
						17		
						18		
						19		
						20		

8-8419

Figure 15. Completed Core Log Data Form.

documentation, use a Core Log Data Form. An example of a completed Core Log Data Form is provided (Figure 15).

5. Collect other sections of the core for nonvolatile contaminants as previously described. Composite the sample if required and screen samples through 0-mesh (No. 10) stainless steel screen, mix as described in Preparation Procedures (Section 5), and place in appropriate labeled containers.

6. Complete chain-of-custody forms if required. Complete documentation requirements (see Documentation SOP for guidance).

7. The operator should decontaminate sampling equipment each time after use. See Decontamination Guidance RFM, for procedures. Collect decontamination blank if required (see QA/QA Section 5, Documentation SOP).

3.2 Trenching

Detailed examinations of soil profiles with hand-held samplers is possible from trenches. However, it is not a cost-effective sampling method, unless the trenching could be done in conjunction with another activity such as laying a pipe or digging a basement. Procedures for collecting discrete soil samples from a trench are as follows

- A trench approximately 1-m wide is commonly dug to a depth approximately 30 cm below the desired sampling depth. The maximum effective depth for this method is about 2 m unless done in some stepwise fashion. Where a number of trenches are to be dug, it may be more expedient to use a backhoe. The sampler collects the desired volume and/or depth increment using a trowel by carefully excavating a slice of soil from the side of the trench. The soil can be treated as an individual sample or composited with other samples collected from a face, or faces of the trench. After the initial sample is taken, the first layer is completely cut back to expose clean soil at the top of the second layer to be sampled. Care must be exercised to ensure that the sampling area is clear of all material from the layers above. The trowel is then used to take samples from the shelf created by the excavation from the side of the trench. This process is repeated until all depth increments are sampled. The resulting aspect appears as a set of steps cut into the side of the trench. When depth increment sampling is required, the use of clean sampling equipment at each depth is mandatory.

- An alternate procedure is to use a punch or coring device to remove soil cores from the side of the trench at specified sampling depths. Care must be taken to guard against soil sloughing down the side of the hole. A shovel should be used to carefully clean the soil sampling area before driving the coring device into the trench side.

4. SOIL GAS COLLECTION METHODS

Soil organic vapor monitoring is a cost effective means of delineating the area and movement of organic contaminants in the soil subsurface. The sensing of soil gases is a relatively new technique and the assessment of soil gas data can be extremely complex. However, sampling of soil gases can serve as a quick screening tool.

Most soil properties (e.g., moisture content, organic matter, soil pore water vapor pressure) must be identified before assessment is possible. Information concerning important aspects of these and other soil properties and their relationship with soil gas data assessment is reported by Dewitt et al. (1987). Soil gas measurements are very complex and should not be attempted by most novice personal. A qualified contractor should be consulted to ensure results are accuate.

Field measurements of soil gases may involve one of the following four basic approaches:

- Measurement of emission fluxes collected at the soil surface.
- Measurement of soil pore space gases collected with subsurface probes.
- Measurement of well vapors collected by probes.
- Measurements of gases from passive collection devices buried at relatively shallow depths.

4.1 Passive Devices

This sampling device consists of an activated carbon organic vapor monitor placed in a manifold that is comprised of an open, inverted 1-qt metal container (Kerfoot, 1986). To implement and use this sampling device, the following procedures can be followed:

1. Select sampling site(s).
2. Invert container (Kerfoot, 1986) and bury at selected depth.
3. The length of exposure of the carbon vapor monitor is a function of the organic contaminants to be collected and measured (Consult with Service chemist to identify exposure length).
4. Retrieve carbon vapor monitor, properly document, package, and preserve sample for analysis (Section 5, Documentation Guidance SOP for requirements).

4.2 Drive Tubes

Soil gas samples can be collected from predeveloped test holes using solid sorbent tubes attached to personal monitoring pumps. The test holes are prepared by driving a metal rod (approximately 1 in. diameter) into the soil with a drive weight. Commercial bar hole-makers are available that combine the steel hole-making bar and drive weight in one unit (DOE, 1987).

The sampling device consists of a sampling cartridge packed with a solid sorbent and a pump system capable of maintaining a constant flow rate across the collection media for a specified period of time. In principle, organic vapors present in the drive tube air are adsorbed on the collection media and subsequently desorbed, thermally or chemically, in the laboratory.

Several sorbent combinations have been used for collection and concentration of volatile organic species. However, the porous polymer, Tenax-GC, is the preferred collection material for a wide variety of compounds at concentrations typically found in ambient air. The sorbent and/or prepacked tubes must be thoroughly precleaned (Section 2, Decontamination Guidance RFM) and checked for interferences before use.

This system is particularly adapted for rapid evaluation of soil gas generation. With a hydrocarbon analyzer or an explosimeter, this method can be used to quickly determine the areal extent of a waste site or the location of a particular emission source using the following procedures:

1. Select locations free from rocks and debris.

2. Place bar point on ground and drive bar into the ground until desired depth is reached. It is only necessary to guide the weight in its vertical travel.

3. Remove bar hole-maker.

4. Attach suitable length of stainless steel or Teflon tubing to Tenax tubes and personal monitoring pumps.

5. Lower tubes into test holes and turn on gas pump [see EPA (1983) for definitive directions for operating air pumps].

6. Remove sampling tubes, properly document, containerize, and pressurize for shipment to laboratory (Sections 2 through 6, Documentation Guidance SOP).

4.3 Wells

Existing groundwater monitoring wells can be used to check for the presence of those gases being released from the groundwater. In some cases, the groundwater level will be below the top of the screened portion of the well allowing free soil gases to enter the well casing.

Wells especially designed for soil-gas monitoring can be placed by conventional well placement techniques. However, the well casing should be perforated the entire distance; the annular space should be packed with gravel; and the top sealed with a grout (e.g., bentonite) cap. The top of the casing can be equipped with a sampling valve to allow easy coupling to the monitoring instruments.

Well gas sampling can be accomplished by lowering a sampling cartridge as identified in Section 4.1 through a cap on the top of a well. The sample collection apparatus should be constructed of nonpacking material that will minimize adsorption or desorption effects. Teflon or glass are preferable to steel or brass in this application. The sampling cartridge is then connected to

the gas pump. Gas sensing monitor probes can also be used in the well that provide immediate data for decision making purposes.

Well gas sampling involves the following procedures:

1. Sound the well for water level or bottom (see Section 2.1, Groundwater RFM for guidance).

2. Select the required length of Teflon tubing. It should be of sufficient length to approach the water level or well bottom, but not so long as to allow water or bottom sediments to enter probe inlet. An inside diameter of 3 mm (1/8 in.) is usually sufficient. However, because tubes of this diameter lack rigidity, a small weight should be secured to the inlet end to facilitate lowering.

3. Lower the tubing through an appropriate sized stopper on the top of the well casing. A wooden plug serves well. It is not critical to maintain an effective seal around the tubing.

4. Lower intake to near bottom and attach outlet tubing from well to gas monitor inlet port.

5. Turn gas sensing monitor on, observe reading, and record in field logbook. If sample is to be collected, turn pump on, and collect sample. (Air flow rate from pump and the volume of air sampled will vary with the efficiency of the trapping device by Tenax trap and the sensitivity of the analysis required. See EPA, 1984, Section 4.)

6. After collecting sample, gradually raise the intake tubing and probe while observing the gas sensing instrument readings.

7. Record readings, remove probe, sample, and close casing.

8. Properly document, containerize and preserve sample for analysis (Section 2 through 6, Documentation Guidance SOP).

9. If sensing instrument fails to return to background readings, replace sample inlet tube and recalibrate before proceeding to next well. (NOTE: Sometimes vapors may condense on the lower portion of the sample tube; merely cutting off the bottom several centimeters of the intake tube may remove the source of contamination and allow reuse of the remaining sample tube. An alternative procedure is to replace the sample tube.)

5. PREPARATION PROCEDURES

Handling and preparation of samples of moist soils is extremely difficult, and improper handling and preparation can seriously affect the analytical results and data interpretation. Sieve soil (if possible) through an 0-mesh (No. 10, 2-mm) disposable stainless steel or Teflon-coated screen, then mix, and air dry or composite the sample. (NOTE: This is not true if samples are for volatile contaminant analysis.)

5.1 Stainless Steel/Aluminum Container Mixing

Mixing a sample in the field or office before shipping to the lab should be done in either an aluminum (if appropriate), stainless steel, or glass mixing containers. Advantages of these containers include their ease of procurement, ease of cleaning and decontamination (or even sterilization), and sturdiness when subject to rough handling and transport. Another advantage is that whole samples can be easily handled, and clods broken up using the appropriate tool, e.g., stainless steel spoon, trowel, or pestle. After the sample is thoroughly mixed, the soil is spread evenly in the bowl or spread out on another surface (e.g., plastic sheet) and then quartered. Samples of the mixed soil are taken and placed in the appropriate containers [see Section 5, Documentation Guidance SOP and FWS, 1986 for requirements].

5.2 Air Drying

There is no requirement that samples be dried prior to shipment to the analytical laboratory. Check with the EC specialist for requirements for your particular situation before drying the sample; improper sample handling may destroy sample for chemical analysis.

The following technique is included as a field method; however, drying may require several days to complete.

For the purposes of some analyses for metals and most semivolatile pollutants, the procedure is as follows:

1. Weigh wet sample and record weight if percent moisture is required.

2. Spread out the soil sample on a stainless steel sheet and allow to air dry. This may take 3 days or more. Sample is air dry when it reaches a constant weight.

3. When dry, weigh and record weight if percent moisture is required.

4. Break up soil aggregates and pull apart the top soil plugs consisting of vegetation and root mat if present. With a pair of decontaminated scissors or another suitable instrument, cut off the vegetation label and archive.

5. Remove large rocks and dried vegetation. Weigh nonsoil fraction separately (e.g., vegetation, rocks). Archive nonsoil portion for possible future analysis if soil sample results indicate contaminantion.

6. Crush the entire soil sample with a rolling pin, stainless steel spoon, or some similar tool. Blend with a stainless steel spoon for 30 min.

7. Sieve through a 0-mesh (No. 10, 2-mm) disposable stainless steel or Teflon screen.

8. Spread out the sample, mark off quarters, and take samples from each quarter in a consecutive manner until appropriate sample volume is collected. Archive remaining sample for future analysis, if needed.

9. When ready for shipment to the analytical laboratory, shake the sample to mix thoroughly.

When air drying and mixing soils, the potential for cross-contamination can become a serious factor. Swipes, decontamination blanks, and splits of mixed soils will be required to identify cross-contamination possibilities and the homogeneity of the mixed soils (see QA/QC Section 2.6 Documentation SOP).

Field personnel preparing soils must take precautions by working in well ventilated areas.

5.3 Laboratory Preparation

Laboratory mixing of whole samples can be substituted for field mixing, with appropriate procedures for drying, sieving, and mixing for analytical purposes. For some difficult-to-manage soils or for particular purposes (e.g., volatiles), a more rigorously controlled and monitored environment may be required such as for controlled drying, reduced contamination procedures, and special preparation for analytical purposes, including sample grinding.

It is recommended that all soil preparation for volatile organic analysis be completed according to laboratory procedures. Obtain and consult Service laboratory procedures for recommended soil preparation methods.

6. ARCHIVING SAMPLES

A number of sampling/monitoring circumstances may require the archiving or storing of portions of collected samples that have been submitted for analysis. For example, the design of a monitoring program may require a large number of samples be collected. If there is uncertainty as to the definitive identity of a contaminant(s) or cost of analysis is a concern, an alternative for analyzing all of the samples collected is to select only a small number of them for analysis. Following the analysis and data assessment of these initial samples, a decision to analyze additional samples can be made. Additional reasons for archiving samples is to provide a "backup" if a sample is lost or spilled, and/or when additional analysis is necessary for validating an unexpected or unusual (exceedingly high or low) result. Losing or spilling a sample that has cost significant money and/or time to collect can also be extremely detrimental to a sampling/monitoring program.

Archived samples should be stored in containers and under the preservation requirements presented on Table 6 and/or in the Documentation SOP Section 5. If samples are stored for a period longer than the stated holding time, a decision concerning the use and utility of the data obtained from their analysis must be made. This decision would have to be made by the data user on a case-by-case basis as a function of the intended end use of that particular data and should be documented as necessary.

Table 6. Soil archiving information

Contaminant Type	Size and Type of Container	Sample Size	Preservative	Holding[a] Time
INORGANICS				
Metals	1-L wide mouth glass with Teflon™ or Al foil-lined cap 250 mL glass with Teflon™-lined or Al foil-lined cap	1 L	4°C (recommended)	6 months
Mercury	Same as above	250 mL	4°C	28 days
Cyanide	Same as above	250 mL	4°C	28 days
ORGANICS				
TOC	250 mL glass with Teflon™- or foil-lined lid	250 mL	4°C	10 days
Volatiles	40 mL (glass with septa	(3) 40 mL vials[b]	4°C	10 days
	1 L glass with Teflon™-lined cap	1 L	4°C	10 days
	125 mL glass with Teflon™-lined cap	125 mL	4°C	10 days
Semivolatiles	1 L glass with Teflon™-lined cap wide mouth	1 L	4°C	Extract in 10 days. Analyze extract by 30 days
Priority Pollutants	Same as for volatiles above	Same as for volatiles above	Same as for volatiles above	Same as for volatiles above

a. May be held longer if only collecting for elemental analysis, i.e. not concerned with ionic state of the element.
b. USFWS Requirements

7. GLOSSARY

Absorption	The penetration of a substance into or through another.
Anion	A negatively charged ion.
Background Level	Amount of a naturally occurring chemical present in soil which has not been exposed to human activities involving the chemical.
Bulk density	The mass of dry soil per unit bulk volume, determined before drying to a constant weight at 105°C.
Cation	A positively charged ion.
Cation-exchange	The total of exchangeable cations that a soil can absorb, expressed in milliequivalents per gram or 100 grams of soil.
Composite Samples	Combinations of more than one sample collected at various sampling locations and/or different points in time.
Compositing	The act of bringing or being together.
Fines	Very small particles; fraction passing a No. 200 sieve.
Flights	One section of a spiral drill pipe; usually 5 feet in length.
Grab Sample	A single sample representative of a specific location at at given point in time. Its representativeness will decrease as sources vary over time and distance.
Heavy metals	Metals having a specific gravity of 5.0 or more.
Mixing	The act of blending together in a single mass.
Pollutant	Any introduced substance that limits a resource use for a specific purpose.
Semivolatiles	A group of organic compounds consisting of base/neutrals, acids, and pesticides that are identified in and analyzed by Method 625 in 40 CFR Part 136 (See USFWS 1986 for chemical list).
Sieving	The act of separating by particle (soils) by a sieve or strainer.
Soil	The systematic arrangement of soils into groups or classification categories on the bases of their characteristics.
Soil Profile	A vertical section of the soil from the surface through all its horizons, including C horizons.

Tenax tubes	Air sampling equipment that holds tenax^{R} a high molecular weight sorbent material used for collecting airborne organic pollutants
Volatile	Solids or liquids which are relatively unstable at standard temperature and pressure and undergo spontaneous phase change to a gaseous state (See USFWS 1986 for chemical list).

8. REFERENCES

Dewitt, D. A., R. B. Evans, W. A. Jury, T. H. Statks, B. Eklund and A. Gnolson, 1987. Soil Gas Sensing for Detection and Mapping of Volatile Organics, National Well Water Association, EPA and Environmental Research Center, University of Nevada, Las Vegas.

DOE, 1987. United States Department of Energy, DOE Environmental Survey Manual, Vol. 1-4, "Field Sampling Protocols and Guidance," DOE/EH-0053, U.S. DOE Office of Environmental Audit and Compliance, Washington, D.C..

EPA, 1984. United States Environmental Protection Agency, Characterization of Hazardous Waste Sites--A Methods Manual: Volume II, Available Sampling Methods, 2nd edition, EPA-600/4-84-076.

EPA, 1987. United States Environmental Protection Agency, Direct/Delayed Response Project, Quality Assurance Plan for Soil Sampling, Preparation and Analysis, EPA/600/8-87/021, Office of Acid Deposition, Environmental Monitoring and Quality Assurance, Washington, D.C..

FWS, 1986. United States Fish and Wildlife Service, Field Operations Manual for Resource Contaminant Assessment, Resource Contaminant Assessment Division, U.S. Department of the Interior, Washington D.C.

Kerfoot, H. D. and C. L. Mayer, 1986. The Use of Industrial Hygiene Samplers for Soil-Gas Surveying, Groundwater Monitoring Review.

Palmer, R. G. and F. R. Troeh, 1980. Introductory Soil Science Laboratory Manual, 2nd edition, Ames: Iowa State University Press.

PCA, 1973. Soil Primer, (EB007.04S), Portland Cement Association.

USDA, 1951. United States Department of Agriculture - Soil Survey Manual, Handbook No. 18, USDA Agricultural Research Administration, Washington, D.C.

USDA, 1975. United States Department of Agriculture, Soil Toxonomy, U.S. Soil Conservation Service, USDA Agriculture Handbook No. 436.

Yang, J. T. and W. E. Bye, 1979. A Guidance for Protection of Groundwater Resources from the Effect of Accidental Spills of Hydrocarbons and Other Hazardous Substances, USEPA, EPA-570/9-79-017, U.S. Environmental Protection Agency, Washington, D.C..

9. BIBLIOGRAPHY

Brady, N. C., 1978. The Nature and Property of Soils, 8th edition, New York: Macmillan Publishing Company, Inc.

Brown, K. W. and Associates Inc., 1980. Hazardous Waste Land Treatment, Draft Edition SW-874, U.S. Environmental Protection Agency, Cincinnati, Ohio.

EPA, 1983. United States Environmental Protection Agency, Soils Data Collection in Support of Emergency Response Activities, EPA Environmental Monitoring Systems Laboratory, P.O. Box 93478, Las Vegas, Nevada 89193-3478, No. V-1027-NASX.

EPA, 1983. United States Environmental Protection Agency, Unsaturated Zone Monitoring for Hazardous Waste Land Treatment Units, EPA Environmental Monitoring Systems Laboratory, P.O. Box 93478, Las Vegas, Nevada 89193-3478, No. 68-03-3090.

EPA, 1986. United States Environmental Protection Agency, Soil Homogenization, EPA Environmental Monitoring Systems Laboratory, P.O. Box 93478, Las Vegas, Nevada 89193-3478, No. 68-03-3249.

EPA, 1984. United States Environmental Protection Agency, Soil Sampling Quality Assurance User's Guide, EPA 600/4-84-043, Environmental Monitoring Systems Laboratory, P.O. Box 93478, Las Vegas, Nevada 89114.

EPA, 1983. United States Environmental Protection Agency, Preparation of Soil Sampling Protocol: Techniques and Strategies, EPA/600/4-83/020, Environmental Monitoring Systems Laboratory, P.O. Box 93478, Las Vegas, Nevada 89114.

Fuller, W. H., 1978. Investigation of Landfill Leachate Pollutant Attenuation by Soils, EPA-600/2-7P-158, USEPA, Cincinnati, Ohio.

Sims, R., 1986. Contaminated Surface Soils In Waste Treatment Techniques, Pollution Technology Review No. 132, ISBN 0-8155-1085-3, Noyes Publications.

State of California, 1986. The California Site Mitigation Decision Tree Manual, Department of Health Services, Toxic Substances Control Division, Attentive Technology and Policy Development Section.

USDA, 1974. United States Department of Agriculture - Soil Conservation Service, Definitions and Abbreviation for Soil Descriptions, Portland, Oregon: West Technical Service Center.

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U.S. FISH AND WILDLIFE SERVICE LANDS BIOMONITORING OPERATIONS MANUAL

APPENDIX K
SURFACE WATER SAMPLING REFERENCE FIELD METHODS

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PREFACE

This is Appendix K of an operations manual designed to facilitate the development of biomonitoring strategies for U.S. Fish and Wildlife Service (FWS) lands. It is one component of the U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual (Manual). All the documents included in the Manual are listed below. This document may be updated in the future to accommodate changes in sampling and monitoring strategies. A page to document revisions to this Appendix and a sheet for suggested revisions is provided in the front of this Appendix.

Volume I

Introduction to the Manual, background information on monitoring, and procedures for developing a biomonitoring strategy for Service lands.

Volume II - Appendices and Summary Sheets

A. Legislative Background and Key to Relevant Legislation
B. Biomonitoring Operations Workbook
C. Air Monitoring - A Reference Manual
D. Introduction to the Flora and Fauna for Biomonitoring
   - D.1 Benthic Macroinvertebrate Sampling Reference Field Methods
   - D.2 Bird Sampling Reference Field Methods
   - D.3 Fish Sampling Reference Field Methods
   - D.4 Flora Sampling Reference Field Methods
   - D.5 Reptiles and Amphibians Sampling Reference Field Methods
   - D.6 Mammal Sampling Reference Field Methods
E. Decontamination Guidance Reference Field Methods
F. Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
G. Field Instrument Measurements Reference Field Methods
H. Ground Water Sampling Reference Field Methods
I. Sediment Sampling Reference Field Methods
J. Soil Sampling Reference Field Methods
K. Surface Water Reference Field Methods

Reference Field Method Summary Sheets

BM	Benthic Macroinvertebrates
BRD	Birds
FSH	Fish
FL	Flora
HPT	Herpetiles
MAM	Mammals
DEC	Decontamination
DOC	Documentation Guidance, Sample Handling, and Quality Assurance/Quality Control Standard Operating Procedures
FIM	Field Instrument Measurements
GW	Ground Water Sampling
SED	Sediment Sampling
SO	Soil Sampling
SW	Surface Water Sampling

The intention is to revise and update this document as methods and techniques are improved or as corrections are made. This page is provided to document the inclusion of revisions or inserts to this section of the Operations Manual.

Revision #	Date	Section(s)	Old Pages	New Pages	# of New Pages
Example					
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Document Revision Worksheet

Use this worksheet to document suggested revisions (make a copy for your files) and send it to:

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Section to be Revised_____ Page(s)_____

Paragraph number(s) (1 = paragraph at very top of page)_____Line number(s)_____

Suggested Revision (attach additional pages if more space is needed):

References (if applicable):

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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	Chain-of-Custody
CLP	Contract Laboratory Program
EC	Environmental Contaminant
EPA	Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FWS	U.S. Fish and Wildlife Service
NADP	National Atmosphere Deposition Program
NOAA	National Oceanic and Atmospheric Administration
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RFM	Reference Field Methods
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act
TOC	Total Organic Carbon
TOX	Total Organic Halogens
TSCA	Toxic Substances Control Act
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VOA	Volatile Organic Compounds

U.S. FISH AND WILDLIFE SERVICE LANDS
BIOMONITORING OPERATIONS MANUAL

APPENDIX K
SURFACE WATER SAMPLING

1. INTRODUCTION

1.1 Purpose

The purpose of these Reference Field Methods (RFM) is to identify procedures in collecting surface water samples for contaminant analysis. Surface waters addressed in this RFM include flowing and standing waters (whose surface is open to the atmosphere), snow, ice, and rain. Contaminated waters may be detrimental to organisms through direct alterations of the physical environment and by direct exposure of fish and wildlife resources to toxicants.

1.2 Scope

The collection of surface water samples in this RFM is presented in three separate subsections. The first subsection identifies the sampling devices, methods, and requirements necessary for collecting samples from standing or moving bodies of water such as rivers, impoundments, springs, and lakes. The second subsection addresses the methods and devices necessary for collecting precipitation samples, and the third subsection identifies the techniques, devices, and methods recommended for collecting ice and snow samples.

Field measurements of surface waters (e.g., pH, temperature, dissolved oxygen, turbidity) are not covered here, but are addressed in the Field Measurements RFM.

Information concerning the advantages and disadvantages of sampling devices are presented along with recommended sample preservation, holding times, and size requirements. Generally, the sampling techniques and the sampling devices described can be used by refuge personnel, however there are some sampling methods and devices described that may require assistance from other Federal agency, state, or contractor personnel.

1.3 Background

To protect aquatic environments that may be altered by industrial, mining, agricultural, and human activities, the U.S. Environmental Protection Agency (EPA) established standards to limit toxic materials in water. The Water Quality Act of 1965 requires states to set standards for limiting releases of materials into streams and lakes. The Federal Water Pollution Control Act and the amendments of 1972, as amended by the Clean Water Act of 1977, address the control of water pollution sources and the identification of activities that may contribute to stream sedimentation. The Water Quality Act of 1987 requires regulators and state officials to use a water quality-based approach to control persistent pollution problems (i.e., non-point pollution). Each state is required to establish its own water quality criteria. These criteria should specify concentrations of water

constituents from various uses, e.g., fish, wildlife, recreation, domestic water sources, and agriculture (Cooperrider, 1986). In addition, the Fish and Wildlife Coordination Act, the Marine Protection, Research, and Sanctuaries Act, and the Endangered Species Act, provide the impetus for initiating sampling/monitoring programs in aquatic habitats.

The collection and subsequent assessment of contaminant data from surface water are complex, as all water bodies are not homogeneous. For example, the stratum or depth can be a factor in the chemical composition of a habitat and, must therefore, be considered in the sampling design. In lake, pond, and reservoir water bodies shallower than 5 meters, neither chemical nor thermal stratification is likely to occur, because wind action is sufficient to mix the water (Cowgill, 1988). However, in relatively immobile waters deeper than 5 meters, chemical and thermal stratification commonly occurs. Surface waters collected at prescribed depths are under different pressure and temperature regimes than exist when the samples are transported to the surface. Temperature and pressure fluctuations may influence the behavior of waterborne contaminants.

Varying velocities and turbulences in water bodies result from channel construction, gradient, and flow of water. Maximum turbulence occurs at some point in the cross section and diminishes toward the surface or the bottom. The area of maximum flow velocity and the associated turbulent areas do not maintain a constant position within the channel. The actions of the maximum velocity coupled with those of the accompanying turbulent zones are equally important and must be addressed in the design and implementation of a monitoring program, as these processes will influence contaminant location, movement, and deposition.

Water quality measurements can be used to help assess the condition of a refuge's aquatic environment. Table 1 identifies some commonly measured water quality parameters. Because these measurements are relatively inexpensive to obtain, they can be useful for screening purposes and used for preliminary planning (EPA, 1985). However, because water systems are generally not homogeneous as previously stated, data from a single sampling episode may only represent water parameters for a specific time and place and may not be representative of the long-term situation at a given sampling location. If an initial field measurement indicates a problem, a systematic regimen of field data collecting over a specified time period should be implemented to identify trends and to obtain data for the development of a more definitive sampling effort.

1.4 Information Resources

Collection, evaluation, and use of available surface water data during the planning phase is essential for an adequate design and implementation of a surface water monitoring program. An important resource is a limnologist from the private sector or universities can be consulted before beginning surface water monitoring programs. In addition, limnological expertise is available in several government agencies, including the U.S. Geological Survey, U.S. Bureau of Reclamation, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, and the National Atmospheric Deposition Program/National Trends Network (NADP/NTN).

Table 1. Water quality measurements

Bacterial Indicators	Arsenic
Biochemical Oxygen Demand	Boron
Carbon Dioxide	Cadmium
Color	Calcium
Conductivity	Chlorine
Dissolved Oxygen	Chromium
Hardness	Cobalt
Inorganic Carbon	Copper
Organic Carbon	Cyanide
pH	Iron
Salinity	Lead
Specific Conductance	Manganese
Temperature	Mercury
Total Dissolved Solids	Nitrates
Turbidity	Nitrites
	Oil and grease
	Phosphates
	Polychlorinated Biphenyls
	Selenium
	Silver
	Strontium
	Sulfide
	Vanadium
	Zinc

Information resources on rainfall collection include the NADP/NTN. This network has over 200 monitoring stations throughout the United States. For a listing of these stations, and more extensive information about the NADP/NTN, refer to the Air Monitoring Reference Manual (Appendix C). The USGS has extensive information on surface water monitoring, including an acid rain program. Publications useful in the development of a surface water monitoring program include:

- Summary of Federal Contaminant Monitoring Programs and Related Databases: A Fish and Wildlife Perspective.
- Newsletters and Quarterly/Annual reports from the NADP/NTN.
- EPA Methods Manual for the National Surface Water Survey Project.

2. SAMPLING METHODS

The selection of appropriate sampling devices and sampling location is based upon the program's objectives. No single sampling method can be recommended because of the wide range of aquatic environments and conditions that exist in the refuge system. Several sampling methods are identified below with appropriate directions provided.

When selecting water sampling devices, the device should:

- Be simple to operate to minimize the possibility of operator error
- Be durable, portable, cleanable, and reparable in the field
- Cause little physical and chemical disturbance of water
- Be constructed of material that will not contaminate samples
- Be capable of collecting an adequate volume
- Be affordable.

2.1 Surface/Subsurface Waters

Surface/subsurface waters include springs, seeps, rivers, ponds, lakes, reservoirs, and estuary environments. It is recommended that the selected sampling container be disposable if possible, and constructed of nonreactive material such as glass, stainless steel, or Teflon and have at least 500 mL capacity. Commonly used water sampling devices are described in Table 2.

2.1.1 Sample Container Immersion

An efficient method of collecting water samples is to use the sample container as the sampling device. Container immersion is generally used in shallow or wadable water bodies; however, it can be used from fixed structures (e.g., bridges) and from floating devices.

Samples can be collected by wading to the sampling location. If in a current, face upstream and submerge the container to the appropriate depth and allow it to fill. When collecting water samples from still water, avoid disturbing sediments. If sediments or other materials are present in the sample, the analytical results may not accurately depict contaminant levels in the water. Sampling should be avoided when the wind is blowing excessively because wave action in shallow water bodies may stir up the bottom sediments. If debris or plants are floating on the surface, clear them away before submerging the sample container.

Surgical gloves should be worn at all times when sampling to prevent cross contamination and as protection from polluted waters.

Using sample containers, water samples can be collected by the following procedures:

Table 2. Water sampling devices

Device	Material	Advantages	Disadvantages
Sample container	Glass polyethylene	Inexpensive disposable	Surface only No depth control
Scoops	Stainless steel	Inexpensive	Surface only No depth control
Nansen sampler	Teflon lined	Able to use in series	Small volume
Kemmerer sampler	PVC	No metal contamination	Fixed capacity from 0.4-16 L
Weighted bottle sampler	glass	No metal contamination	Unsuitable for viscous liquids
Extended bottle sampler	glass	No metal contamination Minimized sample transfer	Unsuitable for viscous liquids Limited sampling depth
	Brass Acrylic plastic	Depth increments	Metal contamination
Van Dorn bottle	PVC	No metal contamination	Fixed capacity from 2-30 L
Pumps (ISCO)	Variety of materials	Large volume samples, continuous samples composite samples, discrete samples	Possible sample contamination

1. Select the appropriate sized precleaned sample container. Samples should be taken in a prearranged priority so that all sample handling and preservation can take place as rapidly as possible. Sample containers, sample size, and preservation requirements for water samples are presented in Table 3. For more definitive guidance see Documentation SOP.

2. Clear surface debris if present. Rinse sample containers with the water that is to be sampled three times prior to sampling.

3. Submerge the sample container below the water surface to the appropriate depth. If the water is flowing, point the container opening upstream.

Table 3. Containers, sample size, and preservation requirements for water samples

Analytical Parameter	Size and Type of Container	Sample Size	Preservative	Holding Time
Inorganic Metals	500 mL (HDPE)	500 mL	HNO_3 to pH<2 (for dissolved metals filter immediately)[a]	6 months
Organics TOC	125 mL (Glass)	125 mL	H_2SO_4 or HCl to pH<2 4°C	28 days
VOAs (Volatiles)	40 mL (Glass vial with septa)	4 vials	4°C or 4°C plus pH>2 with HCl No headspace Protect from light	7 days 30 days
Semivolatiles	1 liter (Glass-teflon™ lid)	3 l	4°C	Extract 5 days Analyze 30 days

a. See Section 2.1.6 for guidance. For additional information, see Documentation and Quality Assurance/Quality Control SOP and APHA 1985.

4. Allow the container to fill to desired volume (e.g., leave about 1% of the container's capacity to allow for expansion if samples are to be shipped). If samples are to be analyzed for volatiles, see the procedures listed in this RFM (page 9) for the collection of water samples for volatile organics prior to collection.

5. Remove the container from the water, preserve sample as required (see Table 3 and/or Documentation SOP), check that a Teflon liner is present in container cap if required. Secure the cap tightly.

6. Rinse the container's outside surface with clean water and dry with a paper towel. Verify the sample label is correct and complete.

7. Place the labeled sample container in an appropriate carrying container and preserve as required. Complete chain-of-custody documents if required and record them in the field logbook. Complete all documentation requirements. (See Documentation SOP for definitive requirements.)

8. Collect split and duplicate samples if required. [See Documentation SOP for requirements.]

9. Decontaminate sampling equipment after completing the sampling at each location, and collect rinsate blanks as required. Decontamination is minimized when using the container immersion method. However, if another sampling device is used, follow Procedures 1 through 3, fill the container to the required volume, cap appropriately, and follow Procedures 7 through 11.

10. Move to next sampling location and repeat procedures.

When collecting samples to determine the presence of volatile organic compounds, follow the procedures below:

1. Identify the sample container with an appropriate label and tag. Be sure to label the tag carefully and clearly with water proof ink, addressing all the categories or parameters.

2. Submerge a 40-mL sample vial upside down to the selected sampling depth. Minimal disturbance is required to protect the integrity of the sample's volatile constituents.

3. Turn the vial right side up and allow the vial to fill and reach equilibrium.

4. Place the cap over the mouth of the vial so that the Teflon-coated septum is down, and firmly screw down the cap while the sample is still underwater.

5. Remove the vial from water.

6. Invert the vial to verify that there are no entrapped air bubbles. If air bubbles are discovered within the sample, discard it and resample.

7. Collect the appropriate number of samples and QA/QC samples as required.

8. Rinse the vial's outside surface with clean water and dry with a paper towel. Verify the sample label is correct and complete.

9. Record the information in the field logbook and complete the chain-of-custody documents if required.

10. Maintain sample at 4°C or preserve with HCl as stated in Table 3. Fifteen minutes after the initial cooldown, check and retighten vial cap to prevent the infiltration of air and contaminants.

11. Decontaminate sampling device and collect rinsate blanks as required (see Decontamination Guidance RFM and Documentation SOP for requirements and procedures).

NOTE: If filling vials from another sampling device, completely fill the vial with minimal disturbance and follow Procedures 3 and 5 through 10.

2.1.2 Scoops

Scoops can be used to sample shallow water associated with seeps and springs where the surface contour intersects the water table. They can develop above the water table where infiltrated water percolates downward to a perching horizon and then migrates laterally to the intersection of that horizon and the surface contour. These areas usually have well-established microbiological populations marked by extensive moss and algal growths. Their effect on the oxygen content, pH, nutrient, and metals concentrations in this environment can be extensive. Thus, the water that seeps from these areas may be substantially altered and may not represent subsurface conditions. However, seeps and springs can yield some pertinent information if the data are properly interpreted. If the

sampling area is without developed wells, seeps and springs are certainly worth sampling, especially because of the ease with which they can be sampled.

A stainless steel scoop of the type found in ice machines is ideal for collecting samples from seeps. As the flat bottom is pressed against the ground water will flow into the scoop for transfer to sample containers. It is important to collect the sample as close to the actual seep or spring as possible to reduce contact time with the atmosphere. It must be noted that sample reproducibility is difficult with this sampling device. Follow the guidance presented in Section 2.1.1 of this RFM for sample collection, handling, documentation, and QA/QC procedures and requirements.

2.1.3 Pond Samplers

The pond sampler (Figure 1) consists of an adjustable clamp attached to the end of a two- or three-piece telescoping aluminum tube that serves as a handle. The clamp is used to secure a sampling container. The sampler may not be commercially available, but it is easily and inexpensively fabricated. The tubes can be readily purchased from most hardware supply stores. The adjustable clamp and sampling device can be obtained from most laboratory supply houses.

The pond sampler can be used to collect samples from ponds, lagoons, and reservoirs. Grab (individual) samples can be obtained at distances as far as 3.5 m from the edge of water bodies by following the procedures identified below:

1. Assemble the pond sampler. Make sure that the bolts and nuts that secure the clamp to the pole are tightened properly. Place a labeled sampling container (beaker) in the clamp and tighten clamp.

2. Collect grab samples by slowly submerging the precleaned sampling container with minimal surface disturbance.

3. Retrieve the sampling container from the surface water with minimal disturbance. Place sample in the appropriate sample container. Follow sample collection and handling procedures identified in Section 2.1.1.

2.1.4 Kemmerer Sampler

For collecting water samples at discrete depths, a number of devices are available. These include the Kemmerer, Nansen, and VanDorn samplers. In addition, several bottle collection devices are available and are illustrated in Sections 2.1.4.1 and 2.1.4.2.

NOTE: The plastic Kemmerer and Van Dorn water samplers can contaminate water samples with mercury concentrations well above the EPA ambient water quality criterion of 12 ng/L, depending on how rapidly the sample is taken, due to the blue plastic bands used as end seals or stoppers in Kemmerer style models in the No. 1200 and 1500 series and in the Van Dorn (Alpha) style model 1100 series. Replacement silicone rubber end seals and assemblies are available from William Phillips, President, Wildlife Supply Company, 301 Cass Street, Saginaw, MI 48602 (517-799-8100).

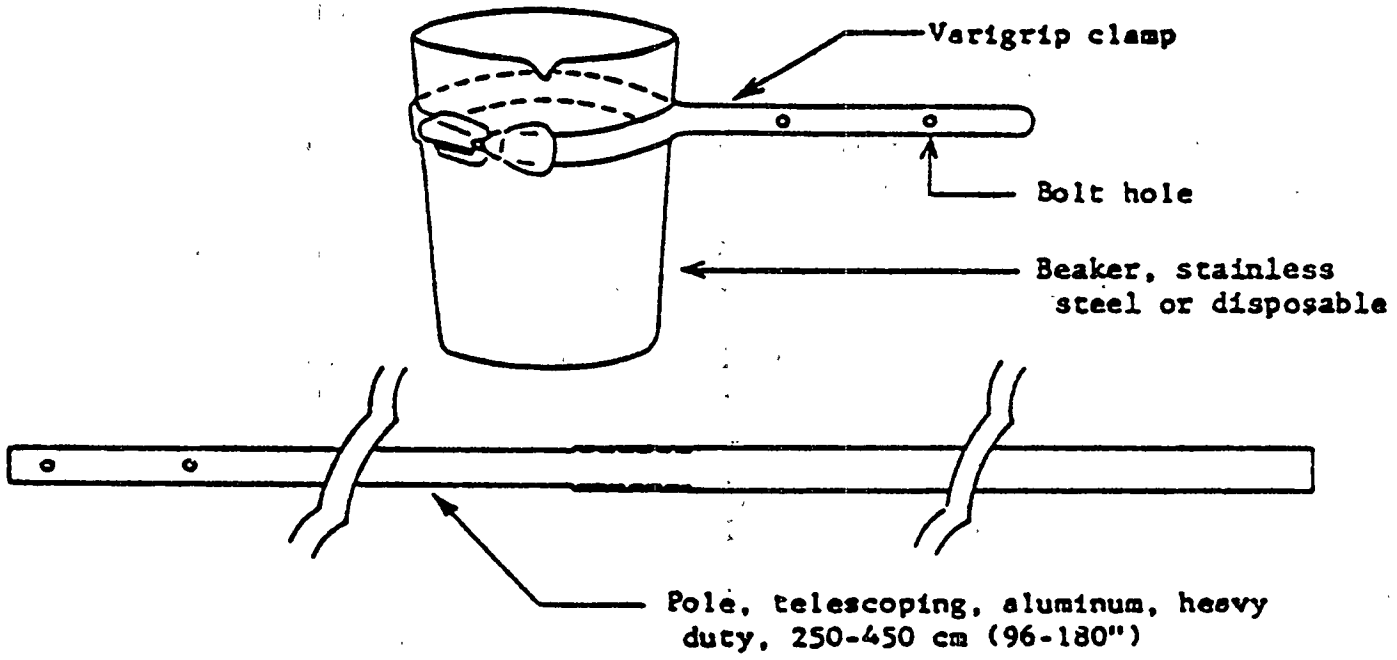


Figure 1. Pond sampler (USEPA 1988).

For illustrative purposes, the Kemmerer sampler is described. The following information provides only general guidance. It is recommended that personnel consult and follow the manufacturer's instructions pertaining to the correct use of any sampling equipment.

The Kemmerer sampler (Figure 2) is a messenger-activated water sampling device. In the open position, water flows easily through the device. Once the sampler is lowered to the desired depth, a messenger is dropped down the support line, tripping the release mechanism and closing the device. In the closed position, the device is sealed, both on top and bottom, sealing prevents any additional contact with the water column. After sealing, the Kemmerer sampler can be retrieved.

The Kemmerer sampler is a practical method of collecting discrete, at-depth samples from surface waters where the collection depth exceeds the lift capacity of pumps. The application can be

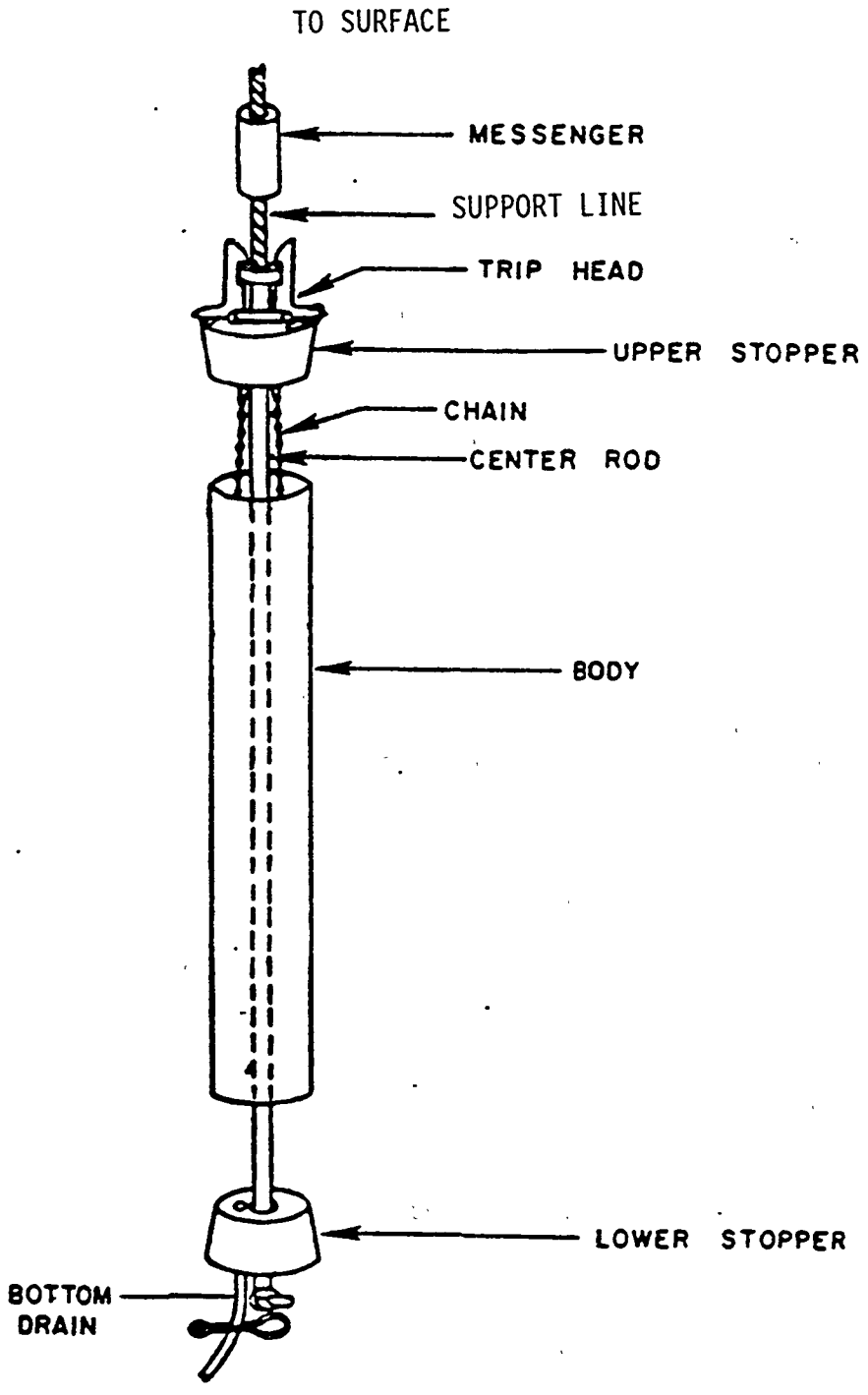


Figure 2. The Kemmerer Sampler.

limited, however, by the incompatibility of various sampler construction materials with some analytical techniques. Proper material selection, i.e., all metal assemblies for organic analysis or all plastic assemblies for trace element analysis, will overcome most of these deficiencies. To use this device, follow the procedures identified:

1. Read the manufacturer instructions.

2. Decontaminate the Kemmerer sampler (see Decontamination Guidance RFM), and check that sample drain valve is closed (if bottle is so equipped).

3. Measure and then mark the support line at the desired sampling depth.

4. Open the bottle by lifting the top stopper-trip head assembly.

5. Gradually lower bottle until desired sampling depth is reached.

6. Place a messenger on the sample line. Release the messenger.

7. Retrieve the sampler; hold sampler by center stem to prevent accidental opening of bottom stopper.

8. Rinse or wipe off exterior of sampler body.

9. Recover the sample by holding the lower stopper and sampler body with one hand. Transfer samples by either (a) opening the drain valve (if present) over sample bottle, or (b) lift the top stopper with other hand and carefully pour contents into sample bottles.

10. Allow sample to flow slowly down side of sample bottle with minimal disturbance.

11. Follow sample collection, handling, and documentation procedures identified in Section 2.1.1.

2.1.4.1 Weighted Bottle Sampler. This sampling bottle device is used to sample liquids at specified depths. The weighted bottle sampler (Figure 3) consists of a glass bottle, a weight sinker, a bottle stopper, and a line for opening the bottle and lowering and raising the sampler.

This sampler is commercially available or it can be easily fabricated. A disadvantage is that this sampler is undesirable for sampling very viscous liquids. Alternatives to the weighted bottle sampler include the Kemmerer sampler and the extended bottle sampler presented in Section 2.1.4.2. To use this sampler follow the procedures identified below:

1. Read the manufacturer instructions.

2. Decontaminate the sampler.

3. Measure and mark the support line at the desired sampling depth.

4. Gently lower the sampler into the liquid to the desired depth so as not to remove the stopper prematurely.

5. Pull out the stopper with a sharp jerk of the sampler line.

6. Allow the bottle to fill completely as evidenced by the cessation of air bubbles.

7. Raise the sampler, cap the bottle, and rinse or wipe off the exterior of bottle.

8. If appropriate, the bottle can be used as the sample container.

9. If the bottle is not to be used as the sample container, pour the collected sample into an appropriate container and allow the sample to flow slowly down the side of the sample container with minimal disturbance.

10. Follow sample collection, handling and documentation procedures identified in Section 2.1.1.

2.1.4.2 Extended Bottle Sampler. This device is a grab sampler designed to sample subsurface liquids to a maximum depth of 1.5 m (5 feet). It consists of a 1.8-m aluminum tube connected to a stainless steel clamp that can be adjusted to hold a multitude of different sized sample containers (Figure 4). The construction of this device allows the container cap to be remotely removed and replaced while submerged by turning the handle grip rod.

An advantage to this device is that sample transfer can be minimized by using a sample container as the collection device. Disadvantages include limited sampling depth and sampling very viscous liquids is difficult. To use this system, the sampler should follow the procedures outlined below:

1. Read the manufacturers instructions.

2. Select the appropriate sample container and container cap. Decontaminate them as required.

3. Attach the handle grip rod to the container cap.

4. Secure the sample container in the clamp and place cap over container mouth.

5. Lower the sampler into the water (liquid) to the desired depth.

6. Turn the handle grip rod to remove the cap.

7. Allow the bottle to fill and then replace the cap.

8. Raise the sampler and rinse or wipe off the exterior of the container.

9. If appropriate, use collection container as the sample container.

10. If the collection container is not to be used as the sample container, pour the collected sample into the appropriate sample container as previously described by allowing the sample to flow slowly down the side of the sample container with minimal disturbance.

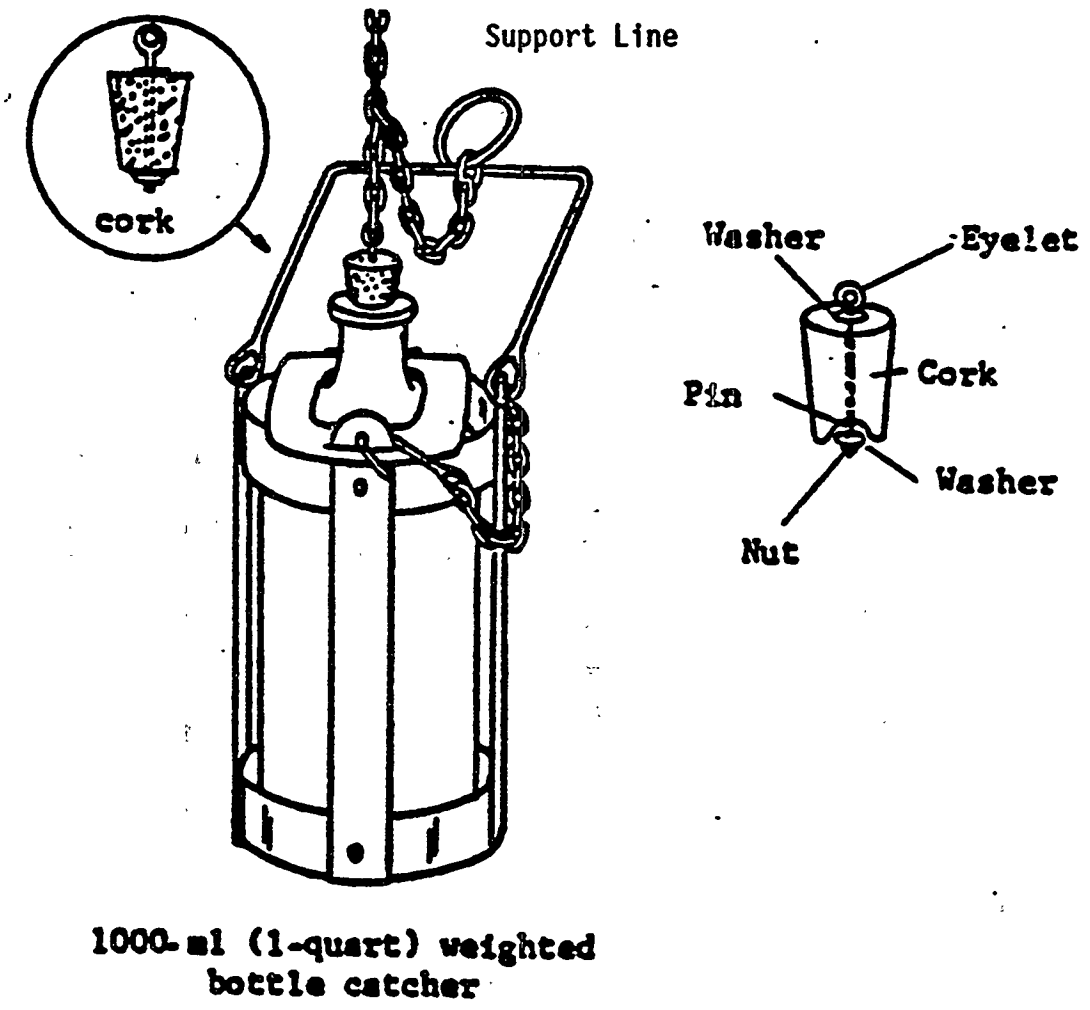


Figure 3. Weighted bottle sampler (USEPA 1988).

11. Follow sample collection, handling, and documentation procedures identified in section 2.1.1.

2.1.5 Pumps

A number of pump samplers are commercially available. Two commonly used pumps are the Peristaltic and the automatic composite samplers (a commonly used composite sampler is the ISCO). Peristaltic pumps can be obtained from most equipment supply outlets.

2.1.5.1 Peristaltic Pump. A peristaltic pump (Figure 5) should be capable of achieving a pump rate of at least 1 to 3 Lpm. A Teflon tubing for extending the suction intake should also be used. A portable battery-operated pump is preferable because it eliminates the need for dc generators or ac inverters. The samples are collected through an essentially nonreactive chemical material. The

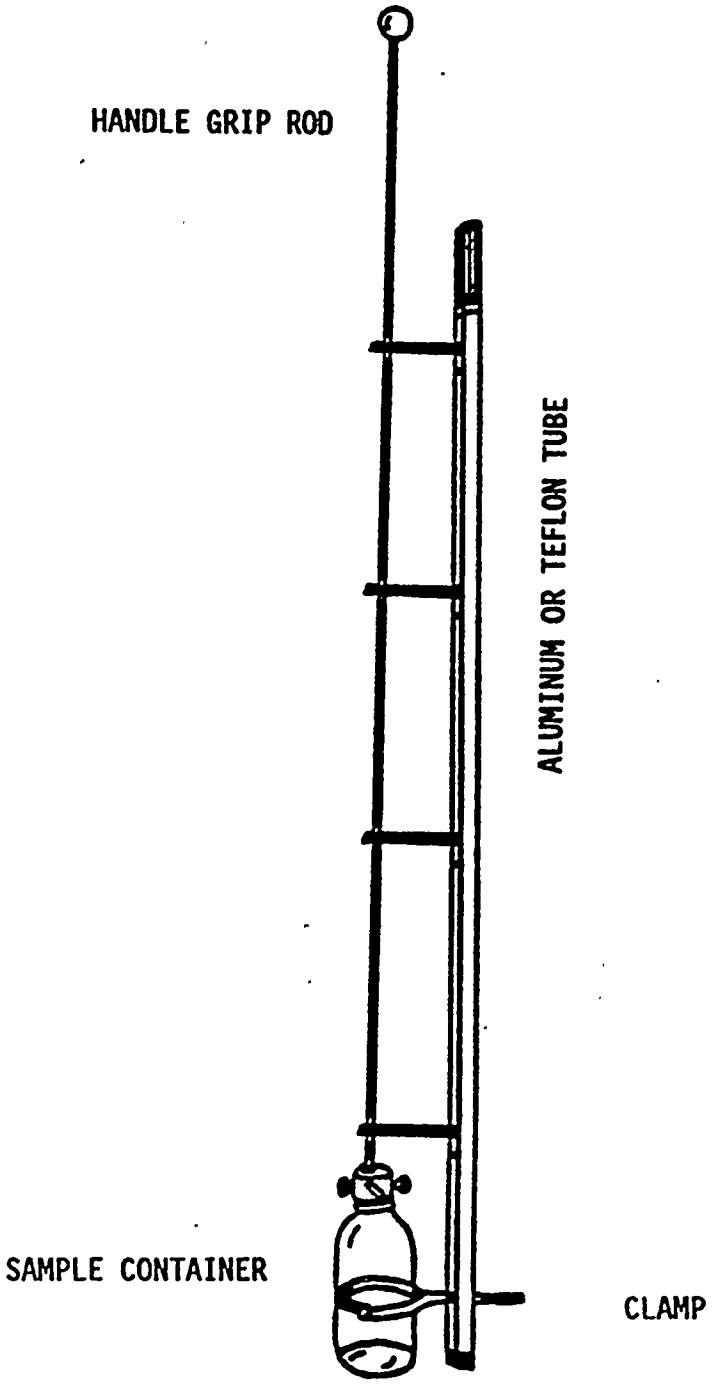


Figure 4. Extended bottle sampler (EPA 1988).

device is practical for a wide range of sampling applications including streams and ponds. The main disadvantage is that the lift capacity of the pump is about 8 m.

When using the peristaltic pump, the following procedures should be followed:

1. Install clean, medical-grade silicone tubing in the pump head, as per the manufacturer's instructions. Use minimally adequate tubing on the discharge side to facilitate convenient dispensation of the liquid into sample containers and only enough on the suction end for attachment to the intake line. This practice will minimize sample contact with the silicone pump tubing.

2. Select the length of suction intake tubing necessary to reach the required sample depth and attach to intake side of pump tubing. Heavy-wall Teflon, of a diameter equal to the required pump tubing (manufacturer's specifications), suits most applications. (Heavier wall tubing will allow for a slightly greater lateral reach.)

3. If possible, allow several liters of water to pass through the pump's system before actual sample collection.

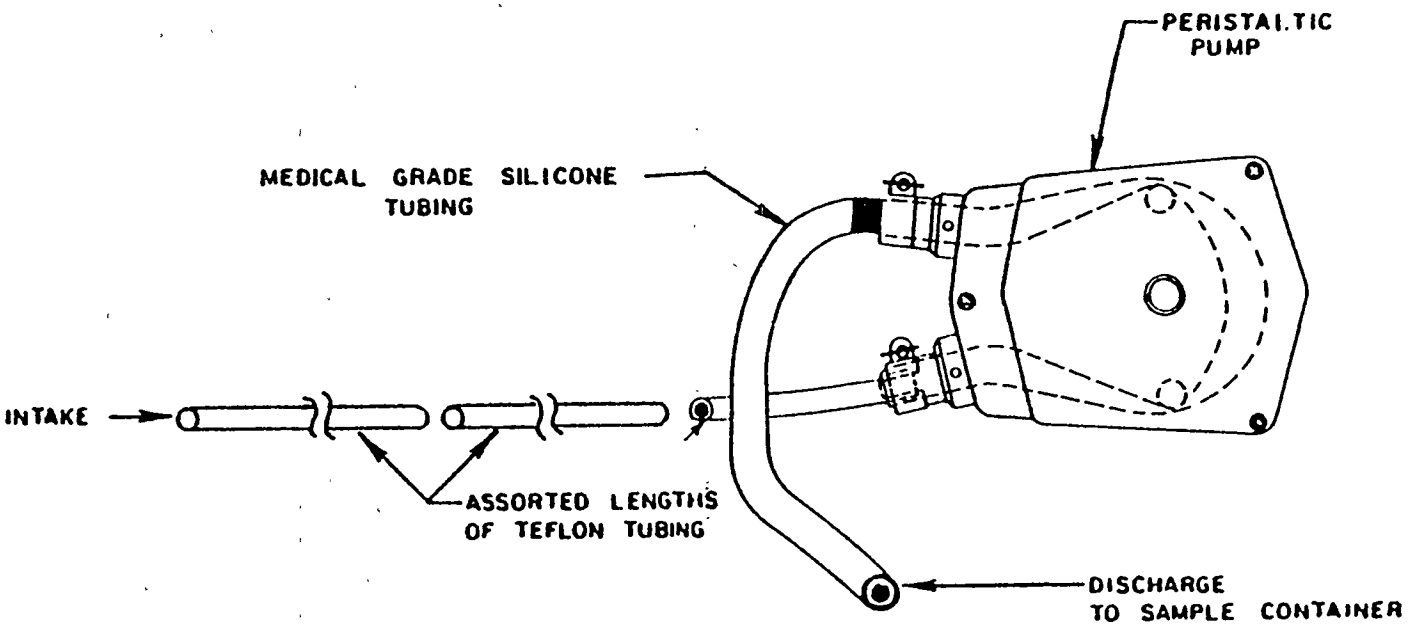


Figure 5. Peristaltic pump.

4. Fill required sample containers by allowing pump discharge to flow gently down the side of the container to minimize entry turbulence. Preserve and cap each container as required. Follow the sample collection and handling procedures identified in Section 2.1.1. Prior to the collection of additional samples, the tubing should be decontaminated or discarded and replaced with new tubing. (See Decontamination Guidance RFM for recommended tubing cleaning procedures.)

2.1.5.2 Automatic Composite Samplers. Composite sampling is used to determine average or mass per unit time concentrations and to identify any sporadically discharged contaminants that may be absent from grab samples. Commercially available automated samplers offer a variety of composite sample collection options, such as simple composites, flow proportional composites, and sequential composites. The sampling method described here is for a simple time composite.

A simple time composite sample is made up of a series of aliquots (smaller samples) of constant volume collected at regular time intervals and combined in a single sample. The procedures below should be followed:

1. Read manufacturer's instruction manual for specific operating procedures.

2. Sample bottles and tubing, intake strainer, and any portion of the sampler that contacts the sample must be cleaned prior to use. Place preservative, if required, into collecting container and ice (blue ice) into the sampler to maintain the proper temperature.

3. Position the sampling unit close to the sampling location. Consider the unit location's stability, ease of access, safety, and security.

4. Place the intake vertically or at a slope to ensure gravity drainage of the tubing between samples. Avoid loops or dips in the line.

5. Exercise care when placing the intake(s) in a water body, especially those containing suspended solids. Run the first aliquot of sample into a waste container (e.g., 500-mL beaker). Check that a sufficient flow velocity is maintained to prevent deposition of solids. The intake should be positioned facing upstream. Secure the intake with a line to eliminate drag on the sample intake tubing.

6. Inspect the intake after each setup and clean any debris from the strainer. If the setup is to be moved to a different location, the sample tubing (Teflon, if possible) must be rinsed with deionized-distilled water, removed from the sampler, capped at both ends with aluminum foil, and placed in a plastic zip-lock bag. These items may be reused for subsequent collections only at that same sample location. In this manner, the sampling unit can be used at various locations, while those components of it that become contaminated are dedicated to a specific sampling location over a specified time. This greatly reduces decontamination requirements and the margin for error. The strainer will also require appropriate decontamination.

7. After installation, run a trial sample to ensure proper operation and sample collection. Collect a sufficient volume to purge three intake line volumes through the unit.

8. Apply padlocks, custody tape and/or seals to the sampler lid and/or sample intake tubing to provide reasonable assurance of sample integrity during unmanned collection time.

After the composite sampling episode is completed, transfer the required sample volume from the collection containers to the appropriate sample containers and follow the sample collection and sample handling procedures identified in Section 2.1.1. This sampler can also be used to collect discrete samples at specific times.

2.1.6 Sample Filtration

Filtration of some water samples is recommended for some soluble constituents as a form of sample preservation. Samples collected for TOC, TOX and volatile organic compounds should not be filtered, because any increased handling may result in the loss of these chemical constituents. Allowing these samples to settle prior to analysis, followed by sample decanting, is preferable to filtration in these cases. If filtration is necessary for the determination of extractable organic compounds, the filtration should be performed in the laboratory.

Water samples collected for dissolved inorganic chemical constituents (e.g., metals, alkalinity, and anionic species) should be filtered in the field immediately after collection if possible. The recommended method is an in-line filtration module that operates from sampling pump pressure.

These modules, which are commercially available, have tubing connectors on the inlet and outlet parts and range in diameter from 2.5 to 15 cm. Large diameter filter holders that can be rapidly disassembled for filter pad replacement are the most convenient and efficient. Gravity type filtering procedures can also be used.

Choice of filter media must be made on the basis of the analytical methods required for those samples (consult with an analyst prior to filtering). It is recommended that a 0.45-mm nominal-sized filter be used. Sampling personnel must be trained in proper procedures for replacing these filters because fine particles can easily be transferred to the outlet side of a disassembled filter module. Sloppy technique may result in contaminated samples. After a filter pad is changed, the initial 100 mL of fluid should be discarded as a rinse. Even if very careful procedures are followed, clogging and small particle breakthrough are problems that must be addressed on a case-by-case basis.

As previously mentioned, filtering may be done by an inline system. In this case, the pump discharge is connected to an inline filter apparatus and the samples for alkalinity, dissolved metals, and other inorganic constituents are collected. When the filtered samples have been collected, the time and cumulative volume pumped should be recorded in the field logbook. Document samples and sampling procedures as required (see Documentation Guidance SOP).

2.1.6.1 Resin Samplers. Resins can be used to directly collect contaminants. The exchange material is generally placed in a column in which a predetermined volume of water is forced through by pumping or by gravity. The choice of exchange resins and the volume of throughput water as a function of its level of contamination are critical elements that must be addressed prior to using this technique. Consult with an analyst prior to using this method for definitive direction.

2.2 Rainfall Collection

The collection and analysis of liquid precipitation has been shown to be an important mechanism for identifying atmospheric contamination. Wet deposition refers to contaminant scavenging by rain and snow. The mechanisms of wet deposition and the categories encompassing precipitation scavenging are presented by Davidson et al. (1987).

A number of sampling problems are associated with the collection, analysis, and assessment of precipitation data. Some of these problems include contamination of the sample by the collection device, timely sample collection, and preservation to prevent absorption of contaminants on the walls of the collecting device. Sampling devices should be placed a minimum of 200 feet from any metal supports, wires, or probes and remote to any vehicular traffic. Additional considerations are security, accessibility, and surrounding land use. Quality assurance and quality control procedures are also essential for obtaining accurate, precise, and representative atmospheric samples and for demonstrating the integrity of the sample during collection, handling, and analysis (see Documentation SOP for recommendations).

2.2.1 Sampling Equipment

A number of precipitation sampling devices are available. However, the sampler currently used by the NADP/NTN is the wet/dry Aerochem Metrics Model 301. This sampler is designed to collect rain or snow in a bucket container, which is open only during precipitation events. A sensor

detects the occurrence of precipitation and activates a motor that removes a cover from the collection container. By using the same sampler, data can be compared to the extensive data being collected by the NADP/NTN.

Samples are collected in a standard high-density polyethylene vessel having a 13-L capacity. Additional information about alternate power sources (e.g., solar and batteries) and the size and construction of collection containers (e.g., Teflon and stainless steel) can be obtained from equipment suppliers or by contacting NOAA.

Before installing the bucket collection container, it must be decontaminated. Methods for decontaminating containers are identified in the Decontamination Guidance RFM.

Following a sampling episode, if sufficient precipitation is available, aliquots can be taken for selected field measurements, e.g., conductance and pH. See Field Instrument Measurements RFM or NADP (1984) for guidance in obtaining field measurements. Samples for chemical analysis should be containerized, handled, preserved, and documented as described in Section 2.1.1. Also, sampling personnel must complete the field precipitation documentation form (Figure 6) and place it in the field logbook.

2.3 Ice and Snow Collection

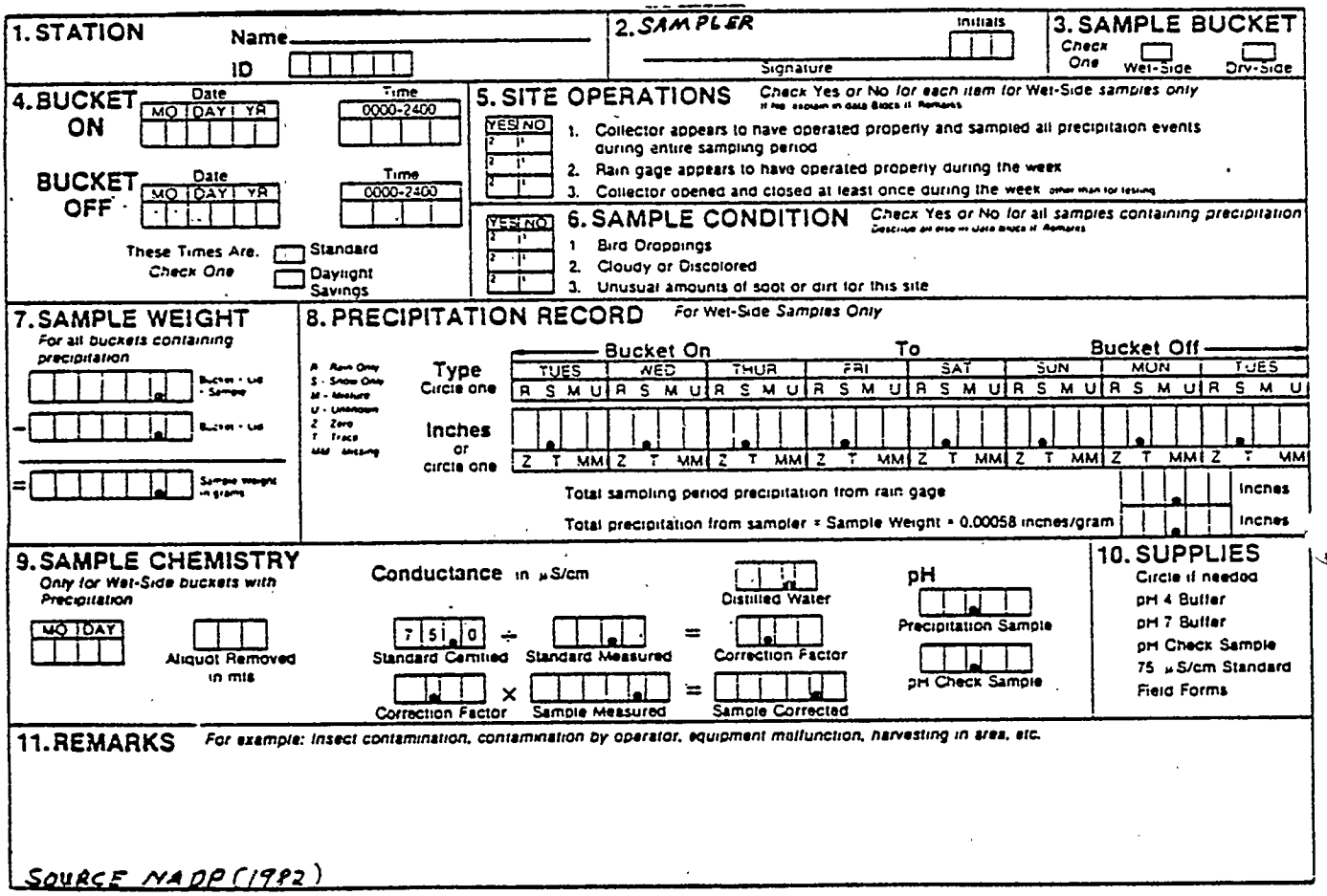
Assessing the contribution and distribution of contaminants from the air pathway to both aquatic and terrestrial ecosystems can be achieved by collecting and analyzing snowfall, snowpack, and ice core samples (Davidson 1987 and Boutron et al. 1987). Similar to rain samples, the analysis of snow and ice samples taken in recent years, has shown an increasing trend in the levels of a number of contaminants, including sulfates, nitrates, and a number of heavy metals.

The suggested parameters (e.g., remote to vehicular traffic) parameters presented in Section 2.2 for selecting sampling locations should be addressed when selecting sampling locations for snow and ice samples. In addition, sampling personnel must consider and identify appropriate quality assurance/quality control procedures prior to initiating sample collections. See Documentation SOP for recommendations.

2.3.1 Snowfall Sampling

A number of automatic snowfall samplers are available. Only two samplers are discussed for illustrative purposes. The first is the wet/dry Aerochem Metrics Model 301 identified in Section 2.2.1. In addition to the power requirements that can be a handicap for use in remote areas, this sampler may require substantial maintenance in cold environments (EPA 1988). For example, freezing temperatures may affect the operation of the collection container cover, and the moisture sensor may not detect dry snow, thereby resulting in a covered collection container during snowfall. If this sampler is used, follow the manufacturer's instructions, and follow the procedures for sample collection, preservation, and documentation as identified in Section 2.1.1.

Another automatic sampler is the U.S. Geological Survey designated 46-cm bulk sampler. This sampler is a 46 cm by 1.8 m metal cylinder. The top of the cylinder is open to the atmosphere, permitting the continuous collection of deposited material. The bottom of the sampler has a hose



1. STATION — Name ____ ID [ ]
2. SAMPLER — Initials [ ] Signature ____
3. SAMPLE BUCKET — Check One: Wet-Side ☐ Dry-Side ☐
4. BUCKET ON — Date MO DAY YR [ ] Time 0000-2400 [ ]
BUCKET OFF — Date MO DAY YR [ ] Time 0000-2400 [ ]
These Times Are. Check One: Standard ☐ Daylight Savings ☐
5. SITE OPERATIONS — Check Yes or No for each item for Wet-Side samples only
YES NO
1. Collector appears to have operated properly and sampled all precipitation events during entire sampling period
2. Rain gage appears to have operated properly during the week
3. Collector opened and closed at least once during the week
6. SAMPLE CONDITION — Check Yes or No for all samples containing precipitation
YES NO
1 Bird Droppings
2. Cloudy or Discolored
3. Unusual amounts of soot or dirt for this site
7. SAMPLE WEIGHT — For all buckets containing precipitation
Bucket + Lid + Sample
− Bucket + Lid
= Sample weight in grams
8. PRECIPITATION RECORD — For Wet-Side Samples Only
R - Rain Only; S - Snow Only; M - Mixture; U - Unknown; Z - Zero; T - Trace; MM - Missing
Type Circle one
Inches or circle one
Bucket On ____ To ____ Bucket Off ____
TUES WED THUR FRI SAT SUN MON TUES
R S M U | Z T MM
Total sampling period precipitation from rain gage ____ Inches
Total precipitation from sampler = Sample Weight × 0.00058 inches/gram ____ Inches
9. SAMPLE CHEMISTRY — Only for Wet-Side buckets with Precipitation
MO DAY [ ]
Aliquot Removed in mls [ ]
Conductance in µS/cm
Distilled Water [ ]
750 ÷ Standard Certified; Standard Measured [ ] = Correction Factor [ ]
Correction Factor [ ] × Sample Measured [ ] = Sample Corrected [ ]
pH
Precipitation Sample [ ]
pH Check Sample [ ]
10. SUPPLIES — Circle if needed
pH 4 Buffer
pH 7 Buffer
pH Check Sample
75 µS/cm Standard
Field Forms
11. REMARKS — For example: Insect contamination, contamination by operator, equipment malfunction, harvesting in area, etc.
SOURCE NADP (1982)

Figure 6. Precipitation Documentation Form.

clamp for attaching a sample collection bag after the snow melts. It may be advantageous to paint the outside of the bulk sampler black to facilitate melting.

As with the Model 301, the collection efficiency of the 46-cm bulk sampler is affected by wind direction and speed. The collected sample represents both wet and dry deposition, and sample contamination is likely because the sampler is not covered. The advantage of this sampler is that it can be placed in remote locations without power requirements.

The 46-cm bulk container construction material must be noncontaminating, and clean sample collection bags should be used for each sampling episode. After adequate sample material has been collected, preservation, handling, and documentation requirements should be followed. Decontamination of the bulk sampler must be completed before and after sampling episodes (see Decontamination Guidance RFM for recommendations).

2.3.2 Snowpack Sampling

*2.3.2.1 **Hand Held Samplers.*** A number of coring devices, similar to soil augering and coring devices, are available for collecting snowpack samples (See the Soil Sampling RFM Section 3.1.1.2 for detailed descriptions). They come with handle extensions for depth increment sampling.

Another useful sampler is the snow tube. This device has a beveled cutting edge to cut through snowpacks to the required depths. The sampled depth is identified by a scale on the outside of the tube. After sampling, remove the tube from the snowpack, and weigh the tube with an appropriately calibrated balance to determine water equivalent. Remove the core from the snow tube, place the sample in the sample container, preserve the sample, and complete the documentation as required (see Section 2.1.1 and Documentation Guidance and Quality Assurance/Quality Control SOP for requirements). Decontaminate the sampling device prior to subsequent sample collection.

Trowels and shovel-type sampling devices can also be used for sampling surface snow. These devices are commonly used when sample reproducibility is not required. The advantages and disadvantages of using these sampling tools are presented in Section 3 of the Soil Sampling RFM.

*2.3.2.2 **Trenching.*** This method of snowpack sampling can be used to make detailed examinations of snowpack profiles. Individual samples can also be collected using this method. Procedures for collecting discrete samples from a trench are as follows:

> A trench is commonly dug to a depth approximately 30 cm below the desired sampling depth. The maximum effective depth for this method is about 2 m unless done in some stepwise fashion. The sampler collects the desired volume and/or depth increment using, for example, a trowel to carefully excavate a slice of snow from the side of the trench. The snow can be treated as an individual sample or composited with other samples collected from a face or faces of the trench. After the initial sample is taken, the first layer is completely cut back to expose clean snow at the top of the second layer to be sampled. Care must be exercised to ensure that the area selected for sampling is clear of all material from the layers above. The trowel is then used to take samples from the shelf created by the excavation from the side of the trench. This process is repeated until all depth increments are taken. The resulting aspect appears as a set of steps cut into the side of the trench. When depth increment sampling is required, the use of clean sampling equipment at each depth is mandatory.

An alternate procedure is to use a coring device to remove snow cores from the side of the trench at specified sampling depths. Care must be taken to guard against snow sloughing down the side. A trowel (e.g., Teflon coated) can be used to carefully clean the snow sampling area prior to driving the coring device into the trench side.

Faces of snowbanks can also be sampled using the techniques described above. Follow the guidance presented in Section 2.1.1 and in the Documentation SOP for sample handling and documentation requirements.

2.3.3 Ice Sampling

Ice can be sampled using a number of methods. For surface and near surface samples, the simplest and most direct method is to use stainless steel picks or ice saws. These devices are convenient to transport and are easily decontaminated; however, they are not always recommended because reproducibility of sampling area, depth, and volume from one site to another is poor. If reproducibility is critical, select other sampling devices.

The screw-type auger is the most popular device for moderate depths. Both hand-operated and power augers with extensions are available for collecting deeper samples. Samples are collected off the auger flights; consequently, these devices are not suitable for profile description.

Thermal drills are recommended for collecting deep samples and obtaining cores for profile description. These devices provide an inner core that can be sectioned for increment sampling. However, more effort is required to decontaminate these ice sampling devices.

Ice samples can also be obtained from ice faces using techniques identified in Section 2.3.2.2. The preferred device for this situation, however, would be a pick instead of a trowel. Sample handling and documentation procedures identified in Section 2.1.1 should be followed.

3. GLOSSARY

Blanks	Prepared samples used to measure various cross-contamination sources.
Duplicate samples	A collocated sample, usually collected at some prescribed distance from a field sample. Provides short-range spatial variability.
Heavy metals	Metals having a specific gravity of 5.0 or over.
Limnology	The study of the biological, chemical, geographical, and physical features of fresh waters.
Measuring Point	The above ground point from which measurements will be referenced.
Messenger	A weight that slides down the drop-line to trigger the sampling device.
Pollutant	Any introduced substance that limits a resource use for a specific purpose.
Quality Control Samples	Also called quality assessment samples. Defined as those samples that allow statements to be made concerning the quality of the measurement system.
Reference Points	The graduation marks on a tape or drop-line used for determining depth.
Rinsate samples	A sample usually consisting of DDI water that was passed over (last rinse) the sampling device. To measure residual contamination after device is decontaminated.
Semivolatiles	A group of organic compounds consisting of base/neutrals, acids, and the pesticides that are identified in and analyzed by Method 625 in 40 CFR Part 136.
Split sample	A sample that is prepared for analysis and then split. It is used to measure homogeneity of prepared sample.
Volatile	Solids or liquids that are relatively unstable at standard temperature and pressure and undergo spontaneous phase change to a gaseous state

4. REFERENCES

Boutron, C. F., C. E. Patterson, V. N. Petrov and N. I. Barkov, 1987. "Preliminary Data on Charges of Lead Concentrations in Antarctic Ice from 155,000 to 26,000 Years BP," Atmospheric Environment, 21, 5, Great Britain.

Cooperrider, A. Y., R. J. Boyd, and H. R. Stuart (eds.), 1986. Inventory and Monitoring of Wildlife Habitat, U.S. Department Interior, Bureau of Land Management Service Center, Denver, CO.

Cowgill, V. M., 1988. "Sampling Waters: The Impact of Sample Variability on Planning and Confidence Levels," In Principles of Environmental Sampling, L. H. Keith (ed.) American Chemical Society.

Davidson, C. I., R. E. Honrath, J. B. Kadone, R. S. Tsay, P. A. Mayewski, W. B. Lyons, and N. Z. Heidan, 1987. "The Scavenging of Atmospheric Sulfate by Arctic Snow," Atmospheric Environment, 21, 4, Great Britain.

EPA, 1985. Methods Manual for the National Surface Water Survey Project, United States Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

EPA, 1988. Sampling for Hazardous Materials, United States Environmental Protection Agency, Environmental Response Team, OERR, Washington, D.C.

EPA, 1990. Quality Assurance Newsletter, United States Environmental Protection Agency, Environmental Monitoring Systems Laboratory, , Cincinnati, Ohio.

NADP, 1982. NADP Instruction Manual Site Operation, National Atmospheric Deposition Program, Colorado State University, Fort Collins, Colorado.

NADP, 1984. NADP Quality Assurance Plan Deposition Monitoring, National Atmospheric Deposition Program, Colorado State University, Colorado.