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Office of Acid Deposition, Environmental
Monitoring and Quality Assurance
Washington DC 20460

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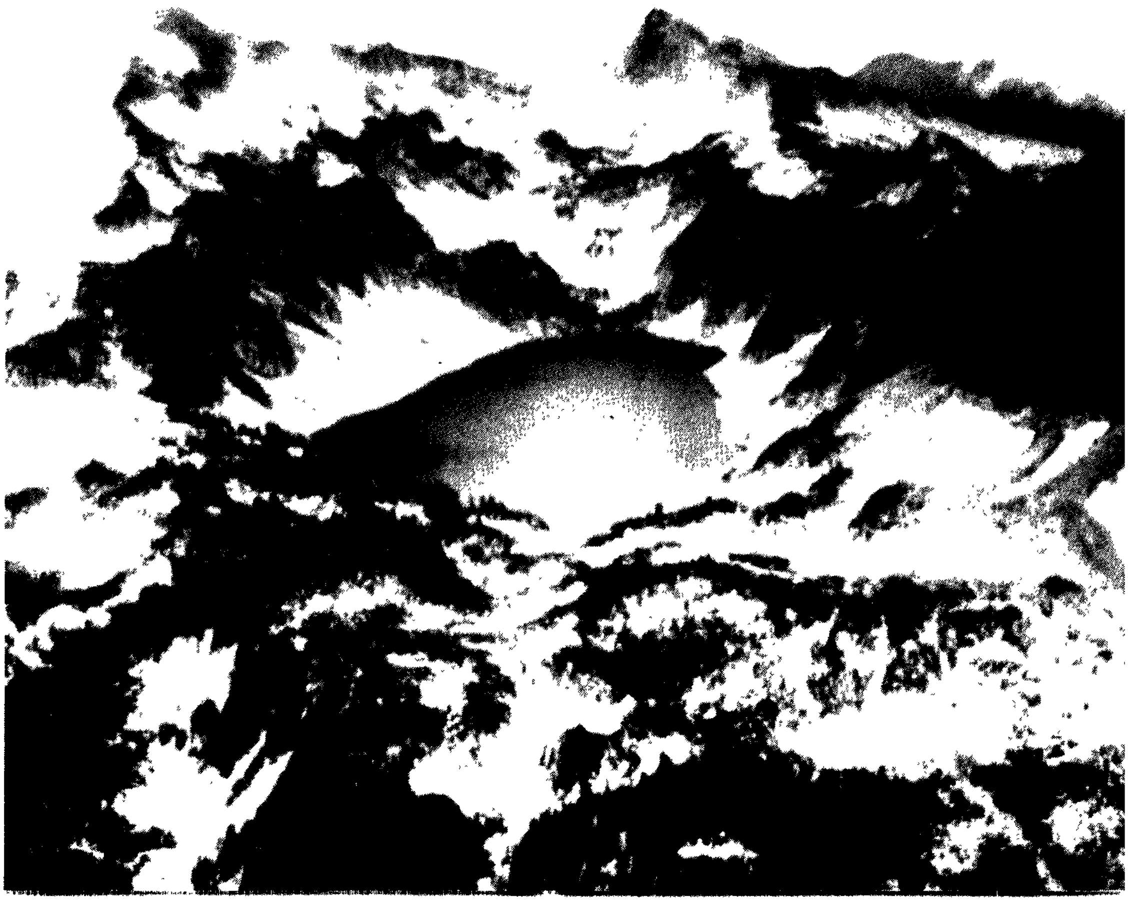
April 1987

Research and Development

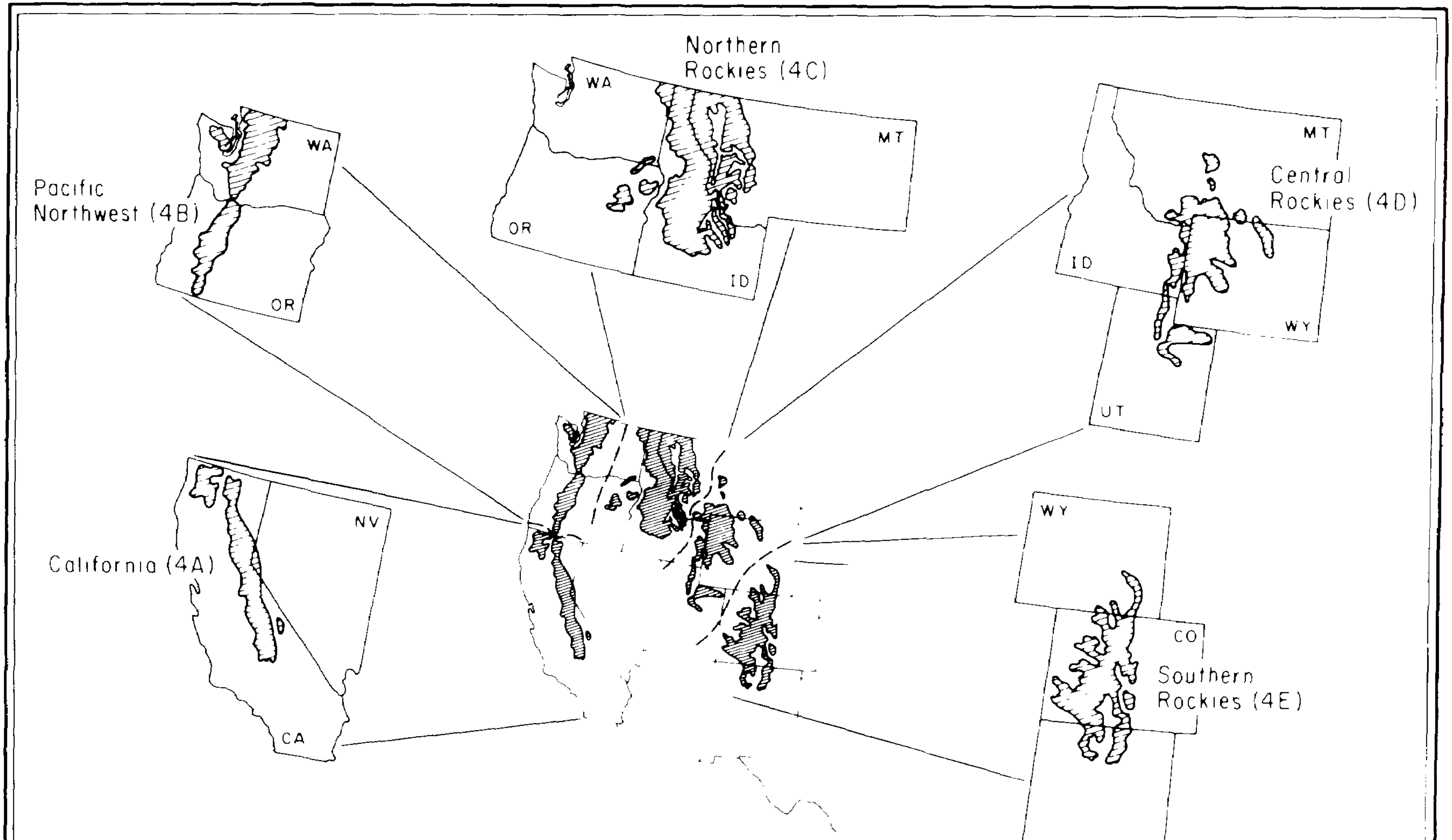
EPA

# Western Lake Survey Phase I

# Field Operations Report Field Operations Report



Aquatic Effects Research Program



Subregions of the Western Lake Survey - Phase I

EPA 600/8-87/018
April 1987

# Western Lake Survey
# Phase I

## Field Operations Report

A Contribution to the
National Acid Precipitation Assessment Program

Aquatic Effects Research Program

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

Environmental Monitoring Systems Laboratory - Las Vegas, NV 89119
Environmental Research Laboratory - Corvallis, OR 97333

## *NOTICE*

The information in this document has been funded by the U.S. Environmental Protection Agency under contract no. 68-03-3249 to Lockheed Engineering and Management Services Company, Inc. It has been subject to the Agency's peer and administrative review, and it has been approved for publication as an EPA document.

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## ABSTRACT

The Western Lake Survey-Phase I was conducted during the fall of 1985 as a synoptic chemical survey to characterize lakes located in regions of the western and northwestern United States thought to be potentially susceptible to the effects of acidic deposition. The Western Lake Survey is part of Phase I of the National Surface Water Survey which is designed to assess the problem of acidic deposition on a national scale. This document describes the planning and execution of the Western Lake Survey-Phase I field sampling and field laboratory operations.

To facilitate lake sampling, field stations were established in Missoula, Montana; Bozeman, Montana; Aspen, Colorado; Wenatchee, Washington; and Carson City, Nevada. Sampling crews deployed from these base sites sampled 757 lakes between September 11 and November 5, 1985. The lakes were sampled either by helicopter crews or, in the case of lakes located in designated National Forest wilderness areas, by Forest Service field ground crews. Helicopter crews collected 54 percent of the samples; ground crews collected 46 percent. Field protocols for both groups are described. To determine whether or not the two sampling methods provided data of comparable quality, 45 lakes in wilderness areas were sampled twice, once by a helicopter crew and once by a ground crew, during a special calibration study.

The water samples were delivered to mobile laboratories located at each field station. At the mobile laboratories, some analyses were conducted, and samples were processed into aliquots which were preserved. The samples were then shipped to contract. analytical laboratories for more detailed analyses.

At the close of the Western Lake Survey-Phase I, base site coordinators, field managers, and Survey management personnel met to discuss the field sampling and field laboratory operations and to make recommendations for future National Surface Water Survey activities and for similar surveys. The group noted that all sampling was completed within the scheduled sampling windows and that the safety record for the Survey was excellent. Communication between the helicopter crews and the field stations was good. The use of satellite remote sites (in conjunction with the field stations) improved the cost-effectiveness of helicopter sampling. Although modifications made to the field laboratory trailers improved laboratory operations, it was decided that locating the field laboratory in a warehouse would reduce the potential effects of temperature extremes, wind, and dust on the laboratory environment, instrumentation, and data quality. It was also decided that better communication to coordinate ground crew and helicopter crew sampling activities could minimize the problems encountered when unusually large numbers of samples arrived for processing at the field laboratory within a short time.


This report was submitted in partial fulfillment of Contract no. 68-03-3249 by Lockheed Engineering and Management Services Company, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from February 1985 to December 1985, and work was completed as of December 1986.

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# ACKNOWLEDGMENTS

Lockheed-EMSCO field operations were managed by S. L. Pierett and K. Asbury. K. Cabble (Lockheed-EMSCO) assisted with field station and base site selection. J. Baker, F. Morris, B. Baldigo, C. Hagley, J. Wilson, and C. Mayer (Lockheed-EMSCO) provided training for field samplers. D. Peck, L. Drewes, and M. Morison (Lockheed-EMSCO) organized the training program for field laboratory personnel.

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This document is a contribution to the National Acid Precipitation Assessment Program.

# INTRODUCTION

The Western Lake Survey Phase I (WLS-I), counterpart to the Eastern Lake Survey-Phase I (ELS-I) completed during the fall of 1984, is the second and final synoptic lake survey of the National Surface Water Survey (NSWS). The U.S. Environmental Protection Agency (EPA) implemented the NSWS in early 1984 as part of the National Acid Precipitation Assessment Program (NAPAP). A subset of regionally characteristic lakes identified during Phase I may be studied during Phase II to quantify biological resources and temporal variability. The design, results, and interpretation of the data from WLS-I are presented in Landers et al. (1987).

The regions of the western United States that contain the majority of low alkalinity waters were delineated by Omernik and Powers (1983) who developed a national surface water alkalinity map on the basis of historical data. From this map, five subregions of interest (Figure 1) were identified for WLS: (1) the Sierra Nevada and the Klamath Mountains (California [4A]), (2) the Cascade Mountains and the Olympic Mountains (Pacific Northwest [4B]) (3) the northern Rocky Mountains and the Blue Mountains (Northern Rockies [4C]), (4) the central Rocky Mountains [4D], and (5) the southern Rocky Mountains [4E]. To ensure that the maximum number of lakes could be sampled during a limited sampling season, a field station was established in each subregion. The field station served as a staging area for sampling activities and was the center for communication with the other WLS-I participants. A field laboratory trailer was also located at each field station.

Although the ELS Pilot Study and ELS-I both demonstrated that helicopters provide the most rapid and efficient means of sample collection, helicopters could not be used in the wilderness areas of the West. The use of helicopters (or other motorized vehicles) in wilderness areas is prohibited by the Wilderness Act of 1964. Consequently, the WLS-I wilderness area lakes had to be sampled by ground teams. Helicopters equipped with floats were used to sample lakes outside the wilderness areas. Helicopter sampling teams followed methodology and protocols established for ELS-I; ground sampling teams followed protocols designed specifically for WLS-I. To determine whether or not the method of sample collection affected sample characteristics and data comparability, a calibration study was conducted during which 45 WLS-I lakes were sampled both by helicopter teams and by ground teams.

# FIELD OPERATIONS

The activities that were required to carry out field sampling operations for WLSI included planning and implementing a logistical support capability, selecting field stations, developing field sampling protocols, and training personnel.

## Survey Planning

In addition to the expendable supplies and equipment necessary for WLS-I laboratory and helicopter operations, the inclusion of the ground sampling operation required a much larger procurement effort than was required for ELS-I. Coordination among the Environmental Monitoring Systems Laboratory (EMSL) of the EPA in Las Vegas, Nevada; the Environmental Research Center (ERL) of the EPA in Corvallis, Oregon; and the Forest Service was essential to all aspects of survey planning.

## Field Station Selection

Both field laboratory and helicopter operations were directed from the individual field stations. The primary concern in selecting a site for helicopter operations was that of finding a location that would allow the maximum number of lakes to be sampled within a 150-mile radius. When a group of target lakes was beyond normal helicopter sampling range, a remote base site was established. The criteria used to select the field stations are presented below.

### Field Station Requirements--

Airport access was the primary consideration. All field stations were located at or near airports to facilitate the landing, refueling, communications, and maintenance of the contract helicopters. Field sampling operations required a room near the helicopter landing area for storage of supplies and for calibration of instruments. A source of jet A fuel for the helicopters was also required at each field station.

### Field Laboratory Requirements--

Each field laboratory was located in a secure area near the helicopter landing area to facilitate the transfer of samples. The proper electrical service was required, as was a telephone line. A minimum water pressure of 50 psi and a sewer drain were also required for the proper operation of the field laboratory. Specific requirements for the operation of the trailers are described in Morris et al. (1986).

Full service overnight carrier pickup and delivery and major or commuter airline service were required at each field station. These services were also required for shipments of equipment and supplies to field stations from the Las Vegas warehouse. Charter airplane service or Forest Service aircraft at each field station were required so that samples and supplies could be transported between remote base sites and the field station. Aircraft were also used to deliver samples collected by some ground teams to some of the field stations.

### Personnel Support Requirements--

Suitable lodging and restaurant facilities near the field station were required. Paging systems were used at some sites to assure that key personnel could be called on a 24-hour basis. The field station had to be located near a hospital for safety purposes. Arrangements had to be established with a local bank to allow field personnel to cash out-of-town travel checks.

### Sites Selected--

The geographic distribution of lakes to be sampled (Figure 1) required five field stations to complete the WLS-I within the fall turnover period. The selected field stations and associated remote sites are shown in Table 1.

## *Procurement*

Many aspects of procurement, such as the computer based inventory system, a warehouse facility for storage and receipt of supplies and equipment, and inventory control forms were already in place because they had been implemented during ELS-I. Field equipment used by ground sampling crews, such as inflatable rafts and dry suits, was purchased by the Forest Service, and all sampling gear was provided by EPA.

## *Personnel Training Program*

Field personnel for WLS-I were recruited by Lockheed Engineering and Management Services Company, Inc. (Lockheed-EMSCO) or were provided by Forest Service or EPA regional offices. A number of the Lockheed-EMSCO field personnel involved in WLS-I had been directly involved in ELS-I. The additional personnel were hired by Lockheed-EMSCO as temporary employees; prior academic and professional experience was required for employment. All Lockheed-EMSCO personnel underwent an intensive technical and safety training program at the Las Vegas facility of Lockheed-EMSCO. Laboratory personnel were given medical surveillance physicals and were fitted for respirators. Training also included cardiopulmonary resuscitation, first aid, and defensive driving.

EPA and Forest Service personnel were trained at each field station over a 3-day period by Lockheed-EMSCO management and field sampling personnel. Training emphasized field protocol, safety, and the proper handling and transport of samples to minimize the potential for contamination. Hands-on training was given to helicopter crews and ground crews. Each person was individually tested on the use of all equipment and on the collection of each type of sample (blank, routine, syringe, and nitrate/sulfate aliquot). All helicopter sampling personnel were instructed in helicopter safety by a representative from the U.S. Department of the Interior, Office of Aircraft Services.

### *Field Station Organization*

The organizational structure of the field station was similar to that used during ELS-I (Morris et al., 1986), except that several staff positions were added for WLSI: Forest Service field manager, Lockheed-EMSCO logistics coordinator, and Forest Service ground sampling teams (Figure 2). Each field station was staffed by 12 to 14 scientists and technicians, 1 to 2 pilots, and a mechanic. The base coordinator, duty officer, and two to three members of the helicopter sampling crew were personnel from the regional EPA offices (Regions VIII, IX, and X). All field station personnel were accountable to the base coordinator who was responsible for the overall operation of the field station and remote base sites. The duties of the base coordinator included:

- coordinating daily sampling activities
- acting as on-site project officer for OAS helicopter contracts
- coordinating visits from the NSWS management team and the press
- scheduling fixed wing aircraft services
- obtaining permission to access privately owned lakes
- assigning helicopter sampling personnel daily
- debriefing helicopter crew members
- updating the master sampling plan
- initiating search and rescue operations
- maintaining a daily operations log with the duty officer
- preparing a final report on base site operations.

The duty officer was directly responsible to the base coordinator. Responsibilities of the duty officer included:

- planning daily sampling activities with base coordinator
- preparing lake coordinate lists
- receiving flight plans from pilots
- providing sampling teams with lake maps and data forms
- assisting base coordinator in updating master sampling plan
- debriefing helicopter sampling teams
- overseeing remote base site operations
- acting as base coordinator in the coordinator's absence.

The EPA field sampling personnel were rotated on a regular (approximately 2 week) basis. One or two Lockheed-EMSCO field personnel remained at the field station or associated remote site throughout the operation to provide continuity and to train incoming EPA field personnel when necessary.

The Forest Service field manager was responsible for the ground sampling operation and for coordinating the pickup from the field and the delivery to the field laboratory of samples collected by ground teams. The EPA base coordinator and the Forest Service field manager had several joint duties. These duties included:

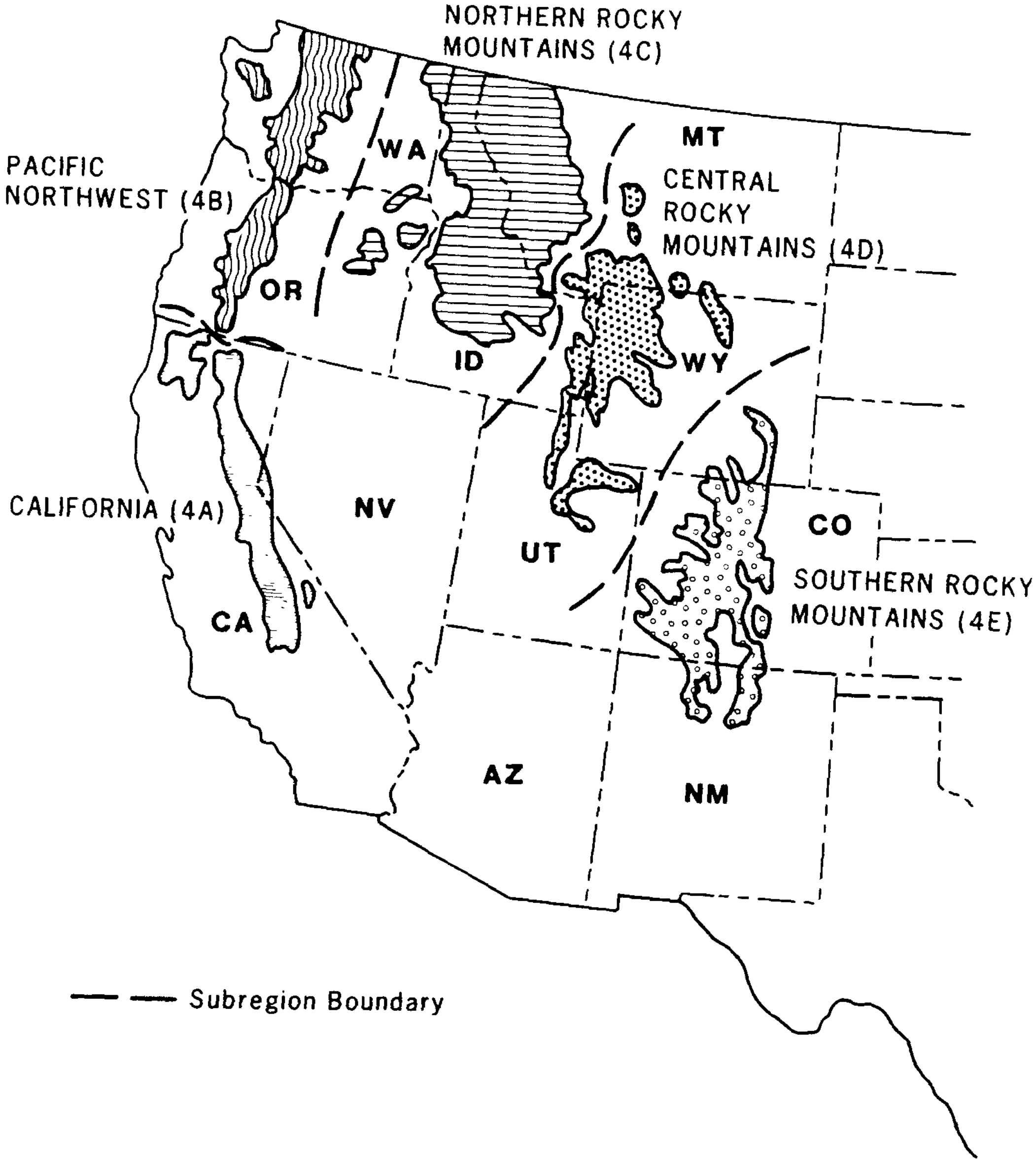


Figure 1. Subregions studied during the Western Lake Survey-Phase I.

TABLE 1. FIELD STATIONS AND REMOTE BASE SITES FOR WESTERN LAKE SURVEY - PHASE I

| Field Station | Subregion | Remote Base Sites |
|---|---|---|
| Carson City, Nevada | 4A | Bishop, California<br>Redding, California |
| Wenatchee, Washington | 4B | Everett, Washington<br>Bend, Oregon |
| Bozeman, Montana | 4C | Red Lodge, Montana<br>Evanston, Wyoming<br>Pinedale, Wyoming |
| Missoula, Montana | 4D | D'Alene, Idaho<br>McCall, Idaho |
| Aspen, Colorado | 4E | Saratoga, Wyoming<br>Granby, Colorado |

- coordinating the sampling efforts of the calibration study lakes
- tracking lakes sampled by helicopter and ground crews
- providing a daily summary of field sampling operations to the laboratory coordinator.

The logistics coordinator was responsible for disbursement of equipment and supplies to the ground sampling crews, as well as for maintaining an up-to-date inventory of all field equipment. The logistics coordinator was also trained as a laboratory analyst or a field sampler and in the shipment of samples to the contract laboratories. Laboratory personnel responsibilities were identical to those defined for ELS-I and are described in Morris et al. (1986).

The ground crew member of the helicopter crew was responsible for all post-flight activities. After the helicopter departed, the ground crew member assisted the duty officer in organizing lake maps, completing appropriate parts of the field data forms (lake name, coordinates, and lake sketch), and completing the lake coordinates form for the next day's sampling sites. Upon the return of a helicopter, the ground crew member received field samples, verified completeness of the lake data forms, conducted a quality control check on the Hydrolab units, and prepared supplies for the following day of sampling.

## *Field Laboratory Set up*

All five field laboratories used during WLS-I had been used previously for ELS-I. The trailers were towed to their respective field sites where they were positioned to minimize exposure to wind-borne particulates and were connected to utilities. Two to three days were required for the laboratory to become fully operational.

## *Communications*

The WLS-I communications center in Las Vegas functioned similarly to the one that had been established for ELS-I. Details of the operation and function of the WLS-I communications center can be found in Morris et al. (1986). Local communications centers were established at each field station to coordinate site activities with Las Vegas and with the other field stations. Coordination among base sites was necessary to ensure that samples were transferred correctly from the base sites to the contract analytical laboratories.

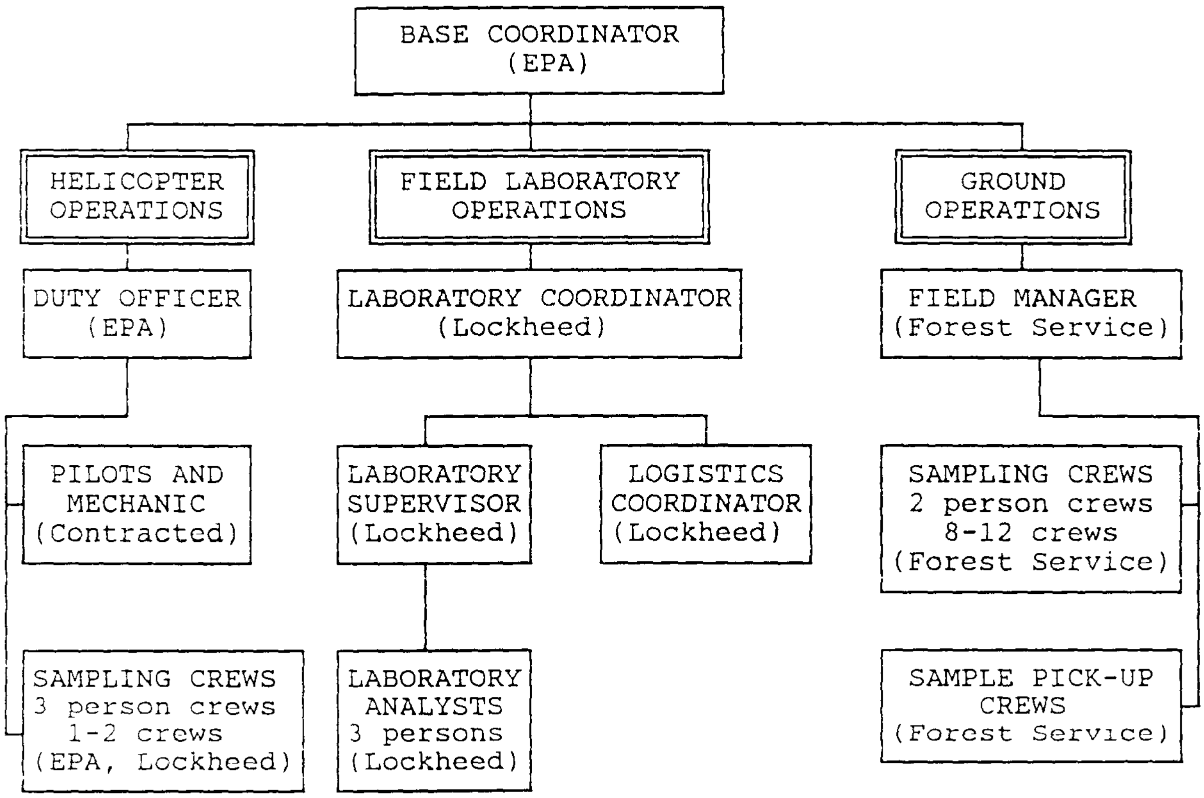


**Figure 2. Field station organization for Western Lake Survey-Phase I.**

# *FIELD SAMPLING OPERATIONS*

## *Field Sampling Equipment*

### Helicopter Sampling--

The mountainous terrain of the western United States required a helicopter capable of prolonged high altitude flying. The Aerospeciale Lama 315B fulfilled this need and was used at all sites with the exception of Wenatchee, Washington, where a Bell Long Ranger was used because the target lakes were located at lower elevations in this subregion. The helicopters used during WLS-I sampled an average of three to six lakes per day.

The field equipment used for helicopter sampling during WLS-I was identical to that used during ELS-I, except that the specifications of the Van Dorn sampler were different. The Van Dorn used during WLS-I was identical in volume (6.2 L) but measured 81.5 cm by 10 cm as opposed to 47 cm by 17 cm for the Van Dorn used during ELS-I. Both surveys used Van Dorn samplers that were equipped with LuerLok fittings to allow syringe samples to be taken without atmospheric contact.

A Hydrolab model 4041 with a 50-m cable was used for in situ measurement of pH, temperature, and conductance. A 20cm diameter black and white Secchi disk was used to measure lake transparency.

Site depth was measured with a Ray Jefferson model 220 electronic depth finder mounted on the helicopter float. Accuracy of the depth sounder was checked against a sounding line on the first lake sampled each day.

### Ground Sampling--

The Van Dorn sampler, Secchi disk, and sounding lines used by the ground teams were identical to those used by the helicopter crews. Temperature was measured with a YSI model 425C telethermometer with a YSI 400-series probe. A 30-m cable was used with the telethermometer. The pH was measured using ColorpHast indicator strips (pH ranges 4.0-7.0 and 6.5-10.0). Conductance was not measured by the ground sampling teams.

## *Field Quality Assurance*

A strict quality assurance (QA) program was required for WLS-I field sampling operations (Silverstein et al., 1987a, in preparation). QA protocols for helicopter sampling, including equipment calibration, collection of QA and field samples, and data recording were identical to those used during ELS (Drouse et al., 1986). The ground sampling QA protocols specific to WLS-I were designed to correspond as closely as possible to those followed by helicopter crews. Duplicate and blank samples were assigned in such a way that each field crew would collect at least one of each during the survey. Custody forms were employed to track ground samples from the time of collection to the time of analysis at the contract analytical laboratory.

### Field Instrument Calibration--

The Hydrolab and telethermometer required daily calibration or calibration checks. The Hydrolab was calibrated daily prior to use and was checked for drift after completion of the day's sampling. A National Bureau of Standards (NBS) traceable thermometer was used to check the accuracy of the temperature probe. Thermometer and meter values were required to agree within 2°C. NBS color-coded buffers (pH 4.01 and 7.00) were used as standards in calibration. The conductivity probe was standardized with a 0.001 M KCl solution that had a specific conductance of 147 ~S cm-1.

A quality control check sample (QCCS) was used to check the accuracy of calibration in the morning and to check the drift of the instrument after the day's sampling. The QCCS was prepared by bubbling $CO_2$ through deionized water at a rate of 1 to 2 L min-1 for 20 to 30 minutes. Meter values were compared to theoretical values of pH and specific conductance at given temperatures and barometric pressures. If the meter value differed by more than 0.15 pH units or 20 ~S cm-1, recalibration was performed by following procedures recommended by the manufacturer. Calibration data were recorded on a calibration form and were submitted to the field laboratory coordinator at the end of the day. The initial and final QCCS values for pH and specific conductance were entered on the lake data form.

The thermistor unit used by the ground sampling crews was checked and calibrated by measuring the temperature of an ice slurry (approximately 0°C) and a water sample (10 to 20°C) with the meter and with a thermometer. If the thermistor and thermometer readings differed by 0.5°C or more, the meter was not used.

### Quality Assurance Samples--

The QA plan (Silverstein et al., 1987a, in preparation) required that helicopter teams collect blank and duplicate samples each day. Each ground crew collected blank samples at two of their assigned lakes which were selected at random. Blank samples consisted of water from the field laboratory meeting Type I reagent grade specifications. Crews processed blank samples with the Van Dorn sampler at the first lake sampled each day. The blank samples were processed by the field laboratory by using the same sample protocol used for routine samples. Blank samples were used as a check for field and laboratory contamination.

A duplicate water sample was collected on one lake per day by one helicopter crew at each field station. Each ground team collected duplicate samples from two of their assigned lakes which were selected at random. The duplicates were samples collected with the Van Dorn sampler at the same location and depth as the routine samples., duplicates were used to check the replicability of sample collection and analysis. Quality assurance requirements for duplicate samples are described in detail in the QA plan (Silverstein et al., 1987a, in preparation).

### Data Recording--

Field observations and in situ measurements were recorded on multicopy forms (Appendix A) similar to those used during ELS-I. The forms were modified slightly so that they could be used by both ground sampling crews and helicopter crews. While on the lake, the ground crews recorded data on waterproof Nalgene copies of the data form contained in a field logbook; later they transcribed the data to the standard multicopy forms. A copy of each form was sent to Oak Ridge National Laboratory for entry into the WLS-I database. Quality assurance personnel in Las Vegas received a second copy.

## *Field Sampling Protocols*

Helicopter sampling protocols for WLS-I were identical to those used during ELS-I, these protocols are described in Morris et al. (1986). Ground sampling protocols were developed to follow as closely as possible those previously established for helicopter sampling and documented in a draft operations manual. Sampling protocols used by ground teams are described in the following sections.

Wilderness lakes were sampled by Forest Service personnel who hiked to the lakes or traveled to the lakes via pack animals. The Forest Service crew usually departed for the lake the day before it was to be sampled, spent the night at the lake, and sampled the lake on the following morning. Each crew carried a radio and kept in contact as much as possible with a local Forest Service district dispatcher. The dispatcher, in turn, communicated frequently with the Forest Service field manager at the field station. The field manager coordinated all ground sampling operations at a particular field station.

### Lake Shore Activities--

At the lake shore, ground sampling crews assembled equipment and supplies, and inflated the rafts that were used as sampling platforms. Rocks were gathered and cleaned and were placed in nylon mesh bags for use as an anchor if needed. The crew then completed labels for all samples to be collected and recorded site description information on the lake data form. They checked the operation of the thermistor by comparing the thermistor value to the temperature recorded by a thermometer. If the two values differed by 2°C or more, the in situ temperature data were qualified.

### Sampling Site Selection--

Shoreline topography was used to determine what part of the lake was deepest. The deepest spot was selected for sampling. For multilobed or dendritic lakes, the spot in the deepest, most downstream lobe was selected. In all sampling site selections, influences from major inflows or local disturbances were avoided. After the sampling site was selected, it was marked on a lake sketch.

An anchor was not used if local conditions were favorable (i.e., lack of wind or a shallow lake). If required, the anchor was slowly lowered to the bottom; care was taken to avoid disturbing the sediments.

### Lake Site Activities--

Once the raft was positioned at the sampling site, the following activities were performed sequentially.

*Site depth*--Depth at the sampling site was determined by using the anchor and calibrated line. Site depth was recorded in the field logbook.

*Stratification status*--Ground crews used the YSI telethermometers to determine temperature profiles at each lake. Thermal stratification status of a lake was determined by using the same criteria as those established for the helicopter crews (Morris et al., 1986). If the lake was found to be stratified and it was feasible for the crew to return at a later date, no sample was obtained.

*Secchi disk transparency*--The protocol for determining Secchi disk transparency was identical to that used by the helicopter crews (Morris et al., 1986).

*Sample collection*--Water samples were collected by the ground crews by following the protocol established for the helicopter crews (Morris et al., 1986) with the exception that ground crews (1) collected a 125-mL nitrate/ sulfate aliquot and (2) determined pH by using indicator strip.

The nitrate/sulfate aliquot was collected from the Van Dorn sampler after collection of the bulk water sample. Aliquots were also collected for blank and duplicate samples. The aliquot bottles were rinsed three times with 20-mL portions of sample, and the samples were preserved with three drops (0.1 mL) of 5 percent HgCl2.

*Field pH determination*--In addition to the nitrate/sulfate aliquots, two additional 10-mL borosilicate glass vials, rinsed three times with sample, were filled from the Van Dorn sampler for pH determination using ColorpHast indicator strips. A 4.0 to 7.0 pH test strip was placed in one of the vials and was allowed to develop for 10 minutes. The pH was then estimated to the nearest 0.1 pH unit by using the color chart provided by the manufacturer. If the pH was 6.2 or greater, the procedure was repeated by using the second vial and a pH 6.5-10.00 test. The pH value was then recorded in the field logbook. A duplicate measurement was obtained from all field duplicate samples.

*Data transcription*--Lake data were transcribed from the Nalgene field logbook to the multicopy lake data forms. To ensure that the data were recorded accurately, the crew member who had not recorded the data originally checked over both forms.

*Sample packing and transport*--All samples, including syringes and aliquots, were placed in ice chests and were maintained at 4°C during transport to the field laboratory. Syringes were placed in hard plastic containers with foam padding to minimize disturbance and leakage. Custody forms

(Appendix A) were signed by the field manager or by transfer personnel if crews did not return to the base site. The temperature of the coolers was recorded on the custody form if samples were transferred from a ground crew to a transport crew, and again upon arrival at a field station.

## Calibration Study

To determine whether it would be necessary to apply a calibration factor to data from water samples collected by ground crews, a calibration study was performed. The calibration factor derived was intended to be applied to data for a given parameter and would account for differences between samples collected by the ground method and those collected by the helicopter method. The likely causes for differences between these samples were thought to be temperature fluctuations in transportation containers, agitation of samples on the trail, airborne contaminants, and extended holding times. There were no a priori assumptions that a calibration factor would be necessary, i.e., the null hypothesis of the study was that there would be no difference between data obtained by ground and those obtained by helicopter for a given study lake. Fifty wilderness area lakes were selected for sampling by both helicopter and ground crews throughout the five regions. Results of the calibration study are presented in Landers et al. (1987).

There were no changes in field sampling protocol which distinguished calibration lakes from other lakes sampled, and the identity of calibration lakes was unknown to the ground sampling crews. Helicopter crews were aware that they were sampling calibration lakes, primarily because the maps indicated that the lakes were in wilderness areas and because the helicopter crews had to meet specific requirements in the sampling protocol (discussed below).

An effort was made to sample calibration lakes by helicopter as soon as possible after sampling by the ground crews. The base coordinator and Forest Service field manager worked together to coordinate timing of sampling operations.

*Helicopter Protocol--*

Three bulk water samples were collected by helicopter crews on calibration lakes. Two syringe samples were obtained for each bulk water sample. In addition to the syringe and Cubitainer samples, which were collected following standard survey protocols, a 125-mL nitrate/sulfate aliquot was collected for each bulk water sample. These aliquots were preserved with 0.1 mL of 5 percent $HgCl_2$. Blank nitrate/sulfate aliquots were obtained from selected calibration study lakes by rinsing the Van Dorn sampler three times and then by filling it with a 200- to 300-mL portion of deionized distilled water. The 125-mL blank nitrate/sulfate aliquot was collected from this "sample," and preservative was added.

### Ground Sampling Protocol--

Ground crews collected two bulk water samples on each calibration lake. The collection of a duplicate sample did not reveal to the crews that they were sampling a calibration lake, since these were lakes for which a duplicate was required based on the schedule given the crews by the field manager. Syringe samples and nitrate/sulfate aliquots were collected by following standard protocols.

### Laboratory Protocol--

The purpose of the third sample collected by helicopter crews was to provide data on extended holding times. This sample was to be randomly chosen and was held for processing at the field laboratory until arrival of the corresponding samples collected by the ground crew. For the remaining two samples collected by helicopter, a coin was tossed to determine which analytical laboratory would receive the routine sample and which would receive the duplicate. The same procedure was applied to the two samples collected by the ground crew. This provided a means to quantify laboratory bias for the WLS-I.

The majority of calibration samples arrived at the field laboratory on the same day, and all five samples were processed on the same day. Because this procedure provided no data on extended holding times, it was decided midway through the survey to randomly choose and hold one of the three helicopter samples for a period of 48 hours, regardless of whether or not the samples arrived at the field laboratory on the same day. The withheld samples were stored at 4°C until processing.

## FIELD LABORATORY OPERATIONS

Field laboratory operations for WLS-I were closely adapted from the procedures followed during ELS-I. Refinements based on experience gained during ELS-I field operations and the need to accommodate special requirements of the ground crews brought about some modifications in laboratory design.

A field laboratory was located at each base site during the survey because of concerns about sample stability and because of the desire to process and preserve samples in the field. The measurement requirements and data quality objectives (Drouse et - al., 1986; Silverstein et al., 1987a, in preparation) defined during ELS-I and followed during WLS-I required that processing and preservation of samples be done at the field station. Concerns about the stability of pH, dissolved inorganic carbon (DIC), true color, and turbidity after sample collection necessitated that these parameters be analyzed at the field station. Samples were processed and preserved as soon as possible after collection. The analytical methods and preservation procedures used at the field laboratory are summarized in the WLS-I methods manual (Kerfoot and Faber, 1987, in preparation) and are detailed in the ELS-I methods manual (Hillman et al., 1986)

The primary goals of field station operations were to collect representative lake samples without contamination, to obtain data at each lake site, to preserve sample integrity so that samples could be analyzed accurately at the contract analytical laboratories, and to perform limited analyses. During the development of the operational protocol, the objectives of the field laboratory were defined as follows:

- Receive lake and QA samples and field data from each sampling team, and verify sample condition upon receipt.
- Review field data forms for accuracy and completeness.
- Incorporate audit samples with each batch, and analyze the batch samples for pH, DIC, true color, and turbidity.
- Process, preserve, and ship samples to contract laboratories for detailed analysis, and ship the nitrate/sulfate splits collected by the ground crews to EMSL-Las Vegas for analysis.
- Coordinate sample shipment information with the sample management office and with EMSL.
- Distribute field station data forms to the appropriate offices.
- Provide high quality deionized water to ground crews and helicopter crews for use as QA blanks.

Modifications made to the laboratory for WLS-I included a larger reverse osmosis cartridge for increased output of deionized water, an adjustable induction blower for optimal operation of the laminar flow hood, and an improved sink drain design. A photoionization detector was placed in each laboratory to warn the laboratory crew when the air contained 50 percent of the chronic (8-hour) safety level of methylisobutyl ketone (MIBK).

## RESULTS

A total of 912 lakes were visited by ground crews and helicopter crews during WLS-I. Of these, 757 (83 percent) were

**Table 2. Period of Operation, Number Of Regular Lakes Visited, and Number of Regular Lakes Sampled by Helicopter (H) and Ground (G) Crews During the Lake Survey-Phase I**

| Field Station | Period of Operation | Number of Lakes Visited | | Number of Lakes Sampled | |
|---|---|---|---|---|---|
| | | H | G[a] | H | G[a] |
| Carson City, Nevada | 9/19/85 - 11/1/85 | 112 | 63 | 91 | 61 |
| Wenatchee, Washington | 9/20/85 - 11/5/85 | 103 | 81 | 86 | 78 |
| Bozeman, Montana | 9/11/85 - 10/19/85 | 98 | 82 | 73 | 78 |
| Missoula, Montana | 9/11/85 - 10/9/85 | 102 | 91 | 70 | 77 |
| Aspen, Colorado | 9/11/85 - 10/15/85 | 110 | 70 | 75 | 68 |
| | Totals | 525 | 387 | 395 | 362 |

[a] Calibration study lakes are included as lakes visited and sampled by ground crews only, even though helicopter crews also visited these lakes, because the lakes were located within wilderness areas.

actually sampled. The period of operation of each field station, the number of lakes visited, and the number of lakes sampled by helicopter crews and ground crews are shown in Table 2.

Ten lakes were visited for sampling a second time to avoid stratification or to replace lost or contaminated samples.

Some lakes that were originally selected for sampling were not sampled. Most of these lakes were frozen, thermally stratified, or too shallow. Some were lakes for which no access permission could be obtained or that had dried up since they were mapped (nonlakes). Local weather conditions prevented access to some lakes. In some cases, disturbances or hazardous conditions near the lake prevented the lake from being sampled. Table 3 summarizes the number of lakes selected but not sampled because of the conditions described.

Considerable effort on the part of the Forest Service ground sampling crews and field managers ensured that samples arrived at the field station as soon as possible after collection. Of the samples collected by ground teams, over 50 percent were delivered to the field laboratory on the day of collection, and almost two-thirds were delivered by the day after collection. The longest delay was 6 days (1 sample). Details of the effects of these extended holding times are reported in Landers et al. (1987) and Silverstein et al. (1987b, in preparation).

Of the 50 lakes originally designated as calibration study lakes, 45 were sampled by ground crews and by helicopter crews. The lakes that were not sampled were frozen; these were in the Northern Rockies subregion assigned to the Bozeman field station. Of the 45 lakes sampled, 25 were sampled by both types of crews on the same day (56 percent). Twelve lakes were sampled 1 day apart, and the other eight were sampled 2 to 9 days apart. The time difference in sampling was due to the inability of helicopter crews to reach the lakes during inclement weather. Often, this weather was

**Table 3. Summary, by Field Station, of Regular Lakes That Were Not Sampled During the Western Lake Survey-Phase I**
(NAP = No access permission, H = Helicopter crew, G = Ground crew)

| Field Station | | NAP | Inaccessible | Non-Lake | Too Shallow | Frozen | Other | Total |
|---|---|---|---|---|---|---|---|---|
| Carson City, | H | 2 | 0 | 6 | 8 | 1 | 1 | 18 |
| Nevada | G | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| Wenatchee, | H | 3 | 0 | 2 | 12 | 0 | 0 | 17 |
| Washington | G | 0 | 0 | 0 | 3 | 0 | 0 | 3 |
| Bozeman, | H | 1 | 3 | 2 | 13 | 12 | 1 | 32 |
| Montana | G | 0 | 0 | 1 | 0 | 12 | 0 | 13 |
| Missoula, | H | 0 | 0 | 4 | 15 | 7 | 0 | 26 |
| Montana | G | 0 | 0 | 1 | 3 | 0 | 0 | 4 |
| Aspen, | H | 0 | 0 | 3 | 8 | 21 | 1 | 33 |
| Colorado | G | 0 | 0 | 0 | 2 | 0 | 0 | 2 |

not severe enough to prevent ground crews from reaching the lake.

The numbers and types of samples processed by each field station are summarized in Table 4. Routine samples accounted for 49 percent of the samples processed, with duplicate, blank, and audit samples making up 21, 15, and 13 percent of the total, respectively.

## OBSERVATIONS AND RECOMMENDATIONS

In December 1985 after the completion of WLS-I field operations, a meeting was held in San Francisco, CA, for all base coordinators, Forest Service field managers, and members of the WLS project management team. The purpose of the meeting was to review WLS-I operations and to provide recommendations for future NSWS activities and for other similar surveys. The observations and recommendations developed during that meeting are described below.

Sampling at all five sites was completed by ground crews and by helicopter crews within the scheduled sampling windows. Although there were several frozen lakes encountered in the Rocky Mountains subregions, no field station was forced to end operations prematurely because of inclement weather.

Barring two instances in the Central Rockies subregion, the WLS-I was completed with an excellent safety record. In one instance, a Forest Service ground crew member was charged by a moose and suffered a broken rib. In another instance, a pack horse was killed in a fall while returning from a lake. Some survey participants suggested that helicopter training should have been more closely tailored to specifics of WLS-I helicopter sampling protocols, to include, for example, working safely on the pontoon platforms, working under icy conditions, and packing samples in the coolers on the outside of the helicopters. For any future surveys of this type, "on-board" field training to complement classroom presentations will be emphasized.

The overlapping sampling schedules of helicopter crews and ground crews made communication and planning a critical aspect of WLS-I field operations.

The addition of the logistics coordinator, whose primary duty was to keep Forest Service ground crews supplied with necessary field equipment and to maintain an inventory of field equipment, proved very

**Table 4. Summary, by Field Station, of Samples Processed During the Western Lake Survey-Phase I**
(H = Helicopter, G = Ground. TB = Trailer blank, when D.I. water was substituted for an audit sample. X = routine and blank samples from lakes that were sampled a second time.)

| | Routine | | Duplicate | | Blank | | Others | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H | G | H | G | H | G | Audit | TB | X | Total |
| Carson City, Nevada | 101 | 54 | 38 | 25 | 23 | 17 | 52 | 10 | 4 | 324 |
| Wenatchee, Washington | 95 | 77 | 42 | 31 | 30 | 20 | 42 | 1 | 3 | 341 |
| Bozeman, Montana | 73 | 78 | 31 | 37 | 24 | 28 | 32 | 2 | 0 | 305 |
| Missoula, Montana | 83 | 78 | 36 | 40 | 26 | 32 | 40 | 0 | 3 | 338 |
| Aspen, Colorado | 88 | 68 | 31 | 33 | 24 | 26 | 44 | 9 | 0 | 323 |
| Totals | 440 | 355 | 178 | 166 | 127 | 123 | 210 | 22 | 10 | 1631 |

successful. Supply shortages were experienced to some degree at all the sites but did not prevent sampling of any lakes.

Communication between helicopter crews and base sites was greatly improved over ELS-I. This was due to the flight-following program provided by the Forest Service. The base coordinator or duty officer could track the progress of the helicopters and could relay messages to the crews during flights through the local Forest Service dispatcher who was in continual radio contact. Similarly, the Forest Service field manager could communicate with the ground crews.

The use of remote base sites greatly improved the economy of using helicopters during the WLS-I. In terms of the helicopters used, the Aerospeciale Lamas provided the high altitude capability required for sampling in the mountainous western states.

As in ELS-I, field samplers trained in Las Vegas remained on-site throughout the project. EPA personnel rotated in as field samplers on a regular (approximately 2-week) basis. Having the trained field samplers on-site for the duration of the study provided continuity and ensured adherence to established protocols at all sites.

Laboratory operations generally proceeded smoothly during WLS-I. The physical changes to the laboratory trailers proved beneficial. The increased capacity for generating deionized water met the increased needs easily. The adjustable induction blower allowed the laminar-flow hood to have static flow while MIBK was in use and so that no vapors entered the laboratory. Centrifuging samples in the hood and using centrifuge tubes different from those used during ELS-I virtually eliminated any MIBK vapors in the laboratory.

Maintaining a comfortable temperature within the laboratory could only be achieved with extra space heaters on particularly cold nights (below freezing). The crew members working in the laminarflow hood were exposed to these cold temperatures no matter how comfortable the rest of the laboratory was, and some of the reagents froze when they were placed in the hood. Having a lab in a warehouse would reduce interferences from this problem and would reduce wind and possible airborne contamination.

At some sites, the combined total of samples delivered by the helicopter led to very long hours for the laboratory crew that had to process and analyze all samples before the next day's batch arrived. These high sample loads also exceeded the number of samples the contract laboratories were obligated to handle within specified times. Some of these problems were unavoidable: bad weather often required that sampling schedules be altered. The problem can be minimized in future operations by improved communication to coordinate ground and helicopter sampling.

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# APPENDIX A

## FIELD DATA FORMS USED DURING THE WESTERN LAKE SURVEY

**NATIONAL SURFACE WATER SURVEY**
**FORM 1 LAKE DATA**

☐ HELICOPTER ☐ GROUND TEAM

D D M M M Y Y
DATE
SAMPLING TIME h
METER ID

STATE | LAKE ID | LAKE NAME

INITIAL pH
FINAL pH
INITIAL μS
FINAL μS

MAP COORDINATES
LAT
LONG

LORAN READINGS
LAT
LONG

ALTIMETER

PHOTOGRAPHS
FRAME ID AZIMUTH
LAP CARD

DISTURBANCES WITHIN 100 METERS OF SHORE
☐ ROADS ☐ LIVESTOCK ☐ MINES/QUARRIES ☐ FIRE
☐ DWELLINGS ☐ INDUSTRY ☐ LOGGING ☐ OTHER

SECCHI DEPTH DISAPPEAR m REAPPEAR m

SITE DEPTH ft | SITE DEPTH (ft) × 0.3048 m/ft = m | AIR TEMP °C

**LAKE STRATIFICATION DATA**

DEPTH | T°C | μS | pH
1.5m
BOTTOM -1.5m

ΔT°C (1.5, B -1.5m)

IF Δ > 4° C PROCEED
IF NOT STOP HERE

0.6 SITE DEPTH | T°C | μS | pH

ΔT°C (1.5 0.6 DEPTH)

IF ΔT > 4°C FILL IN
FOLLOWING DATA BLOCK

LAKE DIAGRAM (from topographic map)

Elevation ft
Outlets (#)
Inlets (#)
Reservoir
N

Verified by

SITE DEPTH
CHECK ONE
☐ ≤20m ☐ >20m

| ≤20m | >20m | T°C | μS |
|---|---|---|---|
| 4 | 5 | | |
| 6 | 10 | | |
| 8 | 15 | | |
| 10 | 20 | | |
| 12 | 25 | | |
| 14 | 30 | | |
| 16 | 35 | | |
| 18 | 40 | | |
| 20 | 45 | | |
| | 50 | | |

COMMENTS ☐ NOT SAMPLED, SEE BELOW

DATA QUALIFIERS
(A) INSTRUMENT UNSTABLE
(B) REDONE FIRST READING NOT ACCEPTABLE
(C) INSTRUMENTS SAMPLING GEAR NOT VERTICAL IN WATER COLUMN
(D) SLOW STABILIZATION
(E) CABLE TOO SHORT
(Q) DID NOT MEET QCC
(<) SAMPLE COLLECTED AT 0.5m
(X)(Y)(Z) OTHER (explain in COMMENTS section)

REASON LAKE NOT SAMPLED (CHECK) ☐ FLOWING WATER ☐ INACCESSIBLE ☐ NO ACCESS PERMIT ☐ URBAN/INDUSTRIAL FROZEN
☐ HIGH COND (>1500μS) ☐ NON-LAKE ☐ TOO SHALLOW STOCK POND ☐ OTHER

FIELD LAB USE ONLY
TRAILER ID
BATCH ID
SAMPLE ID (ROUTINE)
DATE RECEIVED
TIME RECEIVED

FIELD CREW DATA
HELICOPTER ID CREW ID
OBSERVER (PRINT)
SAMPLER (PRINT)
OBS SIGN
GROUND CREW MEMBER
SIGN

FORM DISTRIBUTION
WHITE COPY—ORNL
PINK COPY—EMSL-LV
YELLOW COPY—FIELD

**Figure A-1. Lake data form for Western Lake Survey-Phase I.**

## NATIONAL SURFACE WATER SURVEY
### WESTERN LAKE SURVEY

SAMPLE TRACKING AND CUSTODY FORM

BASE SITE: ______________ DATE OUT: ________________

CREW ID: ______________ DATE RETURNED: ____________

NUMBER OF CONTAINERS

| LAKE ID | 4-L CUBITAINER | SYRINGES | NITRATE/SULFATE ALIQUOT | COMPLETED LAKE DATA FORM | COMMENTS |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| 1. Relinquished by: (Sampler) | Date | Time | Temps | 2. Received by: (Pick-up Crew) | Date | Time | Temps |
|---|---|---|---|---|---|---|---|
| 3. Received by: (Field Manager) | | | | 4. Received by: (Lab Coordinator) | | | |

COMMENTS: ________________________________________

COPIES: Base Coordinator, Field Manager, Field Lab, EMSL-LV (Comm. Ctr.)

Figure A-2. Sample custody form for Western Lake Survey-Phase I.



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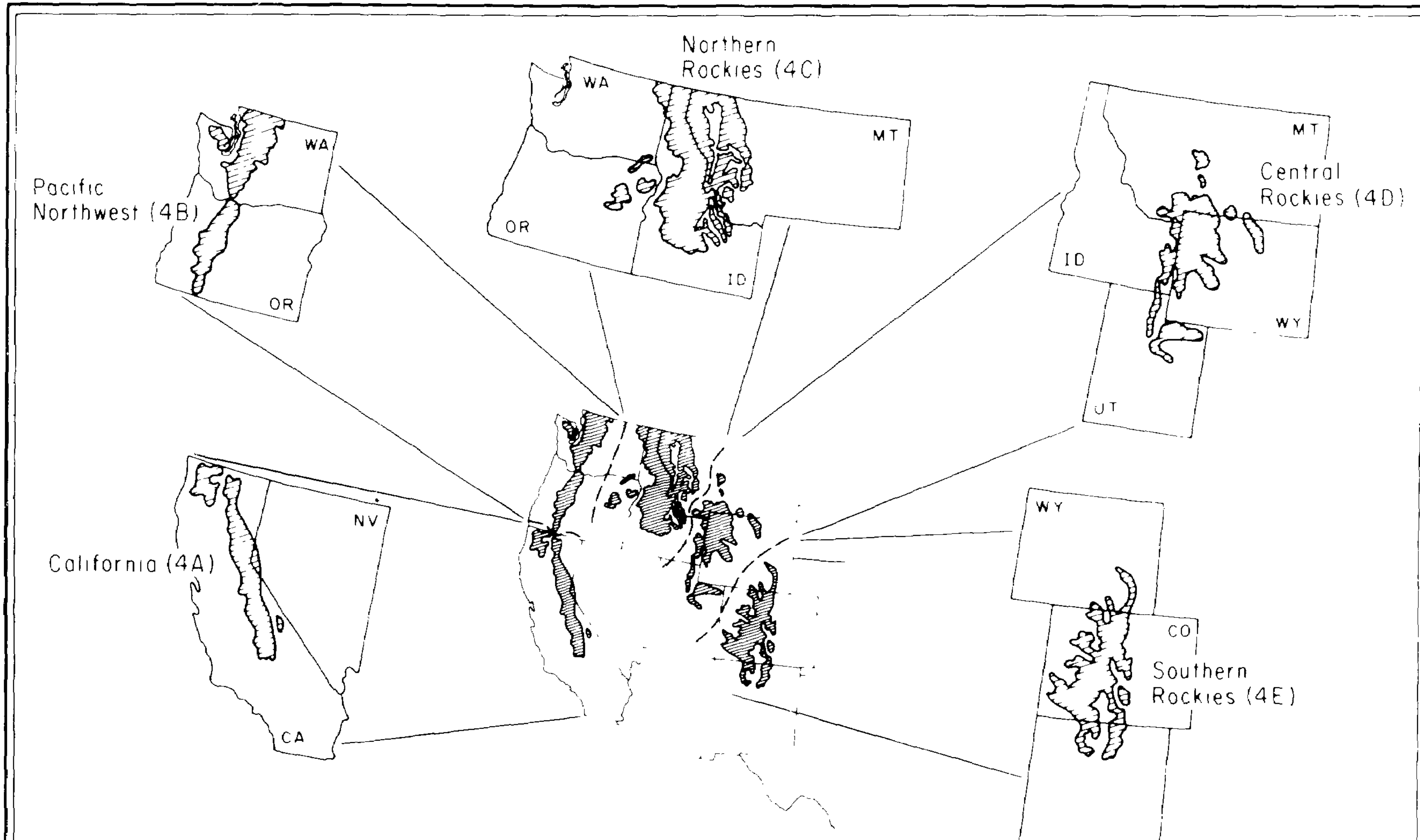


Subregions of the Western Lake Survey - Phase I