

PRELIMINARY REPORT FOR THE PILOT SOIL SURVEY

PROCEEDINGS OF AN INTERPRETIVE WORKSHOP

Corvallis, Oregon

January 21-25, 1985

Environmental Research Laboratory -- Corvallis

200 S.W. 35th Street

Corvallis, Oregon 97333

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1.0 SUMMARY OF MEETING AND STATUS OF PILOT SOIL SURVEY

Jeffrey Lee

1.1 THE PILOT SOIL SURVEY: HISTORY AND OBJECTIVES

In the spring of 1985, EPA will initiate a Soil Survey as part of its responsibilities under the National Acid Precipitation Assessment Program. The purpose of the Soil Survey will be to provide regional data on soils and other watershed characteristics that are hypothesized to be important factors determining the response of surface waters to acidic deposition. This project is a part of EPA's Direct/Delayed Response Program which will (1) estimate the number of direct (rapid), delayed (slow), and non (very slow) response aquatic systems in selected regions of the eastern U.S.; (2) predict the time courses of changes in response to acidic deposition for key selected geographic subregions.

To assist in designing the Soil Survey, EPA conducted a Pilot Soil Survey in Maine, New York, and Virginia. The objectives of the Pilot Soil Survey were:

1. determine the reliability of existing state soil association maps (i.e., generalized state soil maps) in predicting what soils occur at specific National Surface Water Survey (NSWS) sites;
2. determine the homogeneity of soil associations on generalized state soil maps with respect to soil characteristics that control the sensitivity of surface water to acidic deposition;
3. determine whether the special soil characterization performed in the pilot study (i.e., analyses not done in standard NCSS surveys) can be related to

the standard NCSS characterization, so that existing data bases can be used for extrapolation; and

4. develop and test the organizational structure, field procedures, and laboratory capability required to carry out an expanded survey in 1985.

The Pilot was planned at a workshop in late July 1984 ("Summary of Planning Meeting; Soil/Water Pilot Survey; Orono, Maine; July 23-24, 1984," attached as Appendix 4). Vegetation mapping, soil mapping, and soil sampling were done by National Cooperative Soil Survey (NCSS) personnel (USDA-SCS and cooperators at land-grant universities) in Maine and New York and by the University of Virginia in Virginia. Watersheds in New York (32) and Maine (25) were randomly selected from NSWS watersheds with area less than 25 km², after stratification by the generalized state soil map "soil associations"; 3 "associations" were sampled in each state. Watersheds in Virginia (6) were selected to represent 3 "soil associations" found in the Shenandoah National Park. Laboratory analyses were done by Cornell University, University of Maine at Orono, and the National Soil Survey Laboratory (USDA-SCS) in Lincoln, Nebraska.

An interpretive workshop was held in Corvallis, Oregon, January 21-25, 1985. The purpose of the workshop was to evaluate the objectives, approaches, experiences, and available results of the Pilot as a basis for planning the Soil Survey. This was accomplished through vigorous discussions at the Plenary Sessions and in the Working Groups dedicated to specific topics.

1.2 CONCLUSIONS REGARDING PILOT OBJECTIVES

The overall conclusion from the Workshop was that the approach of the Pilot was generally valid for the objectives of the Soil Survey, but the plan for the Soil Survey must be substantially tighter and more specific than the

plan for the Pilot. Preliminary conclusions regarding the objectives of the Pilot Soil Survey were as follows:

Pilot Objective 1: Every watershed visited in the Pilot had soils consistent with the generalized state soil maps. These maps, however, are at scales of 1:500,000 to 1:750,000, and do not provide sufficient resolution to characterize individual watersheds. This creates the need to map individual watersheds. The generalized state soil maps might, however, be useful for regionalization of results.

Pilot Objective 2: The delineations of the generalized state soil maps encompass a variety of soils of differing characteristics. Chemical/physical data are needed for the map units used to map watersheds, i.e., for soil series (Section 3).

Pilot Objective 3: Initial regression analyses indicate that neutral salt CEC (a "special" variable) can be predicted from "standard" variables (Section 6). Analyses for relationships of other special variables (e.g., sulfate adsorption isotherms) to standard variables are continuing. Based on the success of the Pilot for neutral salt CEC, and of earlier, published, studies for other variables, it seems likely that existing data bases can be used for extrapolation.

Pilot Objective 4: Results from the Pilot Soil Survey have been used to show (Section 7) that mean neutral salt base saturation is generally about twice as high (0.22 to 0.27) for the soils collected from Maine as for those from New York (0.09-0.12). This result demonstrates the ability of

the approach used in the Pilot (and planned, with modifications, for the Soil Survey) to make distinctions among soils that are highly relevant to predicting watershed response to acidic deposition. Analyses are continuing for other important variables.

The Pilot also demonstrated that the standard NCSS field procedures and most, but not all, laboratory protocols are satisfactory; i.e., they can be used to produce data of sufficiently high quality within the constraints on time and resources. Watershed mapping and sampling approaches, laboratory protocols, QA/QC, and data management procedures will incorporate modifications based on the experiences of the Pilot Survey.

1.3 GENERAL POINTS OF CONSENSUS

Points of consensus at the meeting included the following:

1. The approach used in the Pilot Soil Survey, with some modifications, can be used to make distinctions among soils that are highly relevant to the objective of the Direct/Delayed Response Project (Sections 6, 7).
2. With one exception, outputs from the Soil Survey will provide the required soil-based inputs of the models to be used by the Direct/Delayed Response Program (Section 3). The Soil Survey can provide information on mineralogy, but not on weathering rates; these must come from other sources, including other Direct/Delayed Tasks.
3. As in the Pilot, watersheds should be selected in a stratified, random way from the watersheds of the National Surface Water Survey (NSWS) (Section 2).

4. The use of soil associations of the state generalized (schematic) soil maps for selection of watersheds, as in the Pilot, is an unnecessary layer of stratification, and is not recommended (Section 2).
5. Soil, vegetation, and depth-to-bedrock maps will be provided for each NSW watershed visited. These will be at a scale of 1:24,000. The basic mapping unit for soils will be the consociation, rather than the 1:65,000 map units used in the Pilot (Sections 2 and 4).
6. Standard National Cooperative Soil Survey (NCSS) procedures will be used for mapping, sampling, and quality control of field procedures. These procedures are described in detail in the National Soil Handbook (with Appendices) (Section 4).
7. Important soil units will be determined from the watershed maps. These soil units (i.e., phases of soil series) will be sampled and characterized in a statistically valid way. It is anticipated that 60 soil units will each be sampled 5 times, with an average of 6 horizons (Sections 2, 4). This data base will be used to characterize watersheds, including watersheds where the soil units have been identified but not sampled (Section 3).
8. Most laboratory protocols can be based on existing, published, methods; an important exception is the determination of the sulfate adsorption isotherm (Section 5).
9. Quality control/quality assurance and data mangement will need to be much more rigorous for the full Soil Survey than they were for the Pilot Soil Survey (Sections 5, 6).

These points are discussed in more detail in the reports of the individual Workshop Groups. These reports also indicate issues which need to be resolved.

1.4 STATUS OF UNRESOLVED ISSUES FROM WORKSHOP

From Section 2. Survey Design Issues

1. Stratify/select NSW watersheds for mapping. Analysis proceeding. Needed by April 15.
2. Define how the soil data are to be applied to the policy questions. Planning for Direct/Delayed Project is continuing. John Reuss is using a prototype aggregation procedure on soil and watershed data from the Pilot Soil Survey, and linking the results to aquatic chemistry data from NSW. Final report due May 1.
3. Select soil series for sampling. This will be done at mini workshop (mid-June) after maps are available.

From Section 5. Lab Analysis/Quality Assurance Issues

1. Sulfate adsorption isotherms. Development of procedure is being actively pursued. Question of whether to use air-dried or field-moist samples is being addressed through an experimental study.
2. Mineralogy. During a conference call with the modelers subsequent to the workshop, it was decided that, for the most important soils (approximately 10% of the pedons), the major primary and clay minerals will be determined for 4 horizons.
3. Development of QA/QC Protocols. The modelers agreed that, for their purposes, knowledge of soil parameters to $\pm 50\%$ would be adequate. This means that the routine procedures of soil laboratories (typically $\pm 10\%$) will be adequate. EMSL-LV will provide the following: a critical path analysis for developing QA/QC by March 8; draft protocols for lab analysis by March 22; draft protocols for field sampling by April 5. Mapping protocols will be those specified in the National Soils Handbook.

From Sections 6, 7. Analysis of Pilot Data

1. Completion of Pilot data bases. The data bases have been updated and are in quasi-final form.
2. Completion of analysis of data from pilot. John Reuss has responsibility for completing the analyses of Pilot Data (including linkage to NSWS data) to the extent necessary for designing the Soil Survey. An interim report from this effort is included as Section 7 (Addendum) of this workshop report. Final report is due May 1.

NOTE: THIS IS A REPORT FROM AN INTERPRETIVE/PLANNING WORKSHOP. THUS, IT IS A SNAPSHOT OF THE PLANNING PROCESS AS OF THE TIME OF THE WORKSHOP. ALL DECISIONS AND RECOMMENDATIONS ARE PRELIMINARY, AND SUBJECT TO CHANGE BASED ON FURTHER DISCUSSION AND CONSIDERATION.

2.0 SURVEY DESIGN GROUP

Compiled by Don Stevens and Dave Marmorek

2.1 SITE SELECTION

The NSWS sampled approximately 900 lakes in the Northeast (Figure 2.1), and will sample approximately 60 stream reaches in the Southern Blue Ridge Province. The sample sites for the Soil Survey will be selected in the watersheds of some of these lakes and streams. The sites will be selected in a multistage process:

1. For the Northeast, post-sample stratify the lakes in Region I of the NSWS using a cluster analysis on the variables alkalinity, sum of base cations, SiO_2 , $\text{SO}_4^{=}$, Al, ratio of watershed area to lake area, and relative flushing index. The clustering will be terminated at 3-5 clusters.
2. Select about 150 (exact number is budget dependent) watersheds from these clusters. This will be done at random; however, some clusters may be sampled less intensively, e.g., clusters corresponding to high alkalinity lakes (Figure 2.2).
3. Randomly select 30-50 watersheds from those of the National Stream Survey.
4. Map the watersheds with respect to: (a) vegetation (b) soil series, slope, and soil depth. As watershed maps are completed, they will be sent to Corvallis to be compiled into a list of occurrence of mapping units. Definitions of the mapping units to be field-sampled (e.g., which soil series can be lumped together?) will be specified during a several day miniworkshop. Participants will use their own professional judgment and published information on soil physical characteristics, data from the

NSWS LAKE LOCATIONS (ORNL: 9/06/84) VERIFIED REGION 1

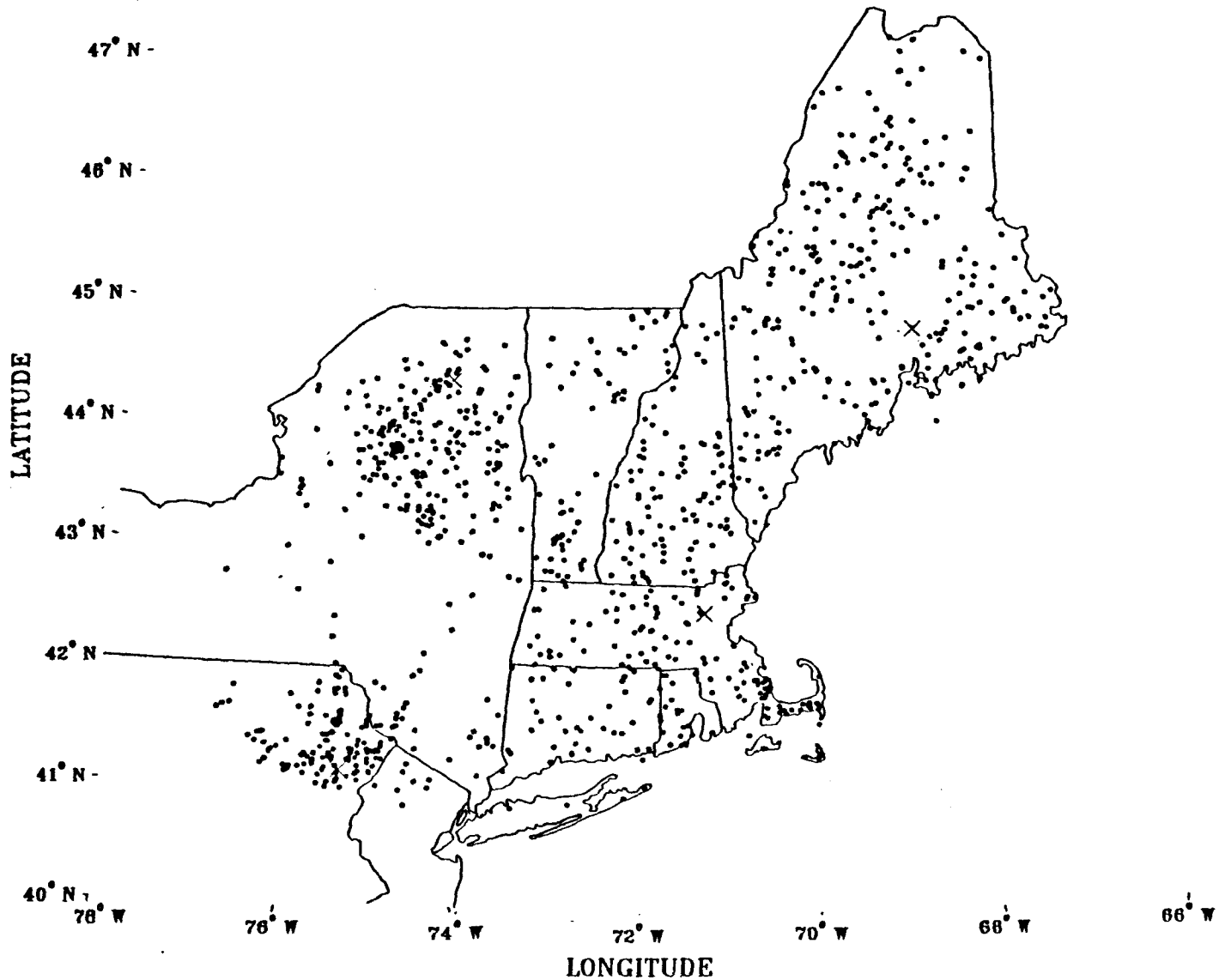


Figure 2.1 National Lake Survey Watersheds

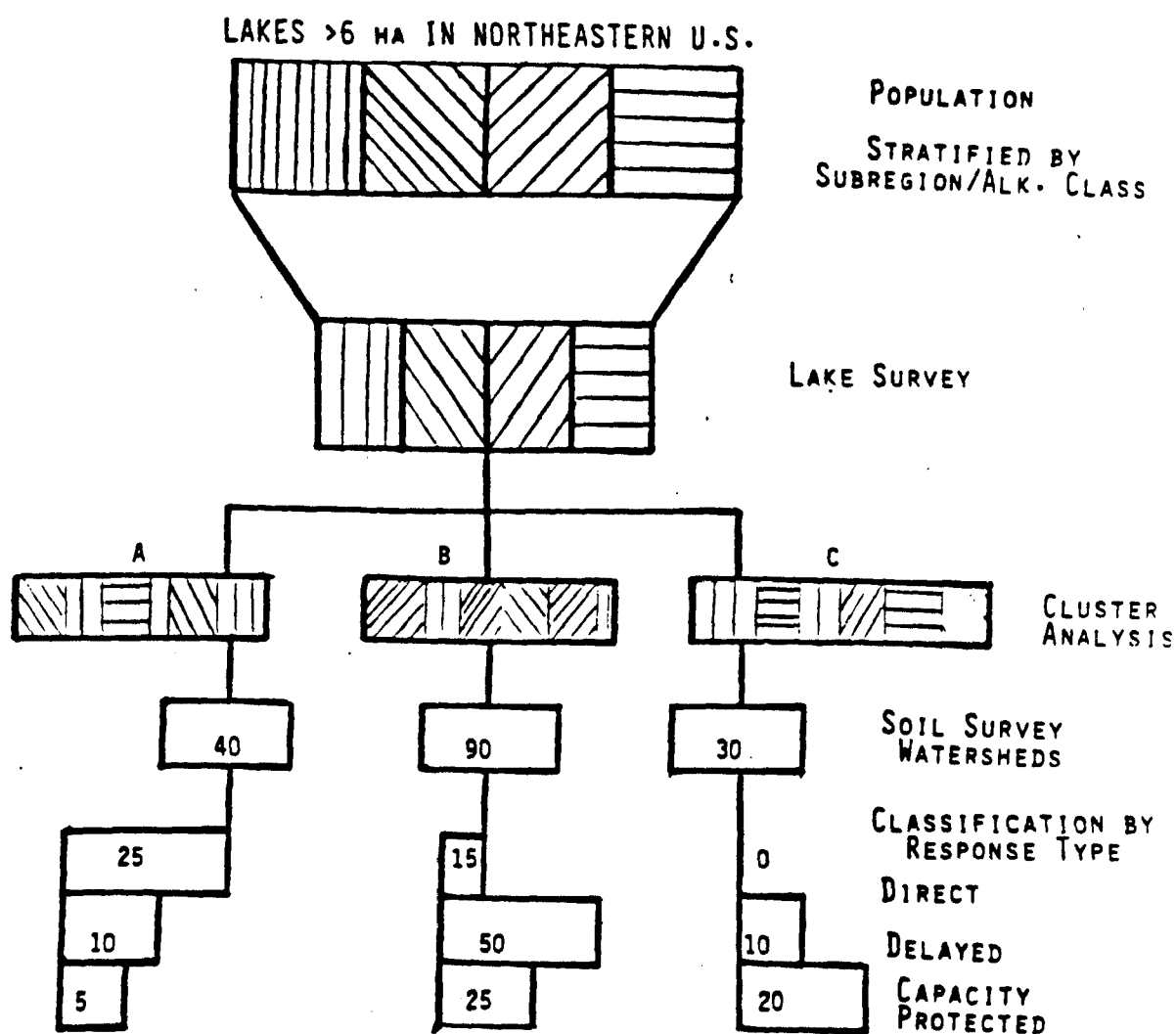


Figure 2.2

Proposed method of selection of Northeastern watersheds (Region I) for the Direct/Delayed Response Project. The figure assumes 160 watersheds were sampled in the Project.

pilot study, and existing soil chemistry data bases (available at Oak Ridge National Laboratory).

5. Select sample sites within watersheds so that characteristics and variability of the mapping units are adequately defined. This is shown schematically in the attached Figure 2.3.

The tasks for the Soil Survey are summarized in Figure 2.4. The uses of the two data bases (soils, watersheds) developed by the Soil Survey are indicated in Figure 2.5.

2.2 UNRESOLVED ISSUES

Several points still need to be resolved (see Section 1.4):

1. Should lakes with alkalinity $> 200 \mu\text{eq/l}$ be eliminated from the sample? Some pros and cons:

Pro: 1. There is "no" chance that such a lake will acidify within 50 years.

Con: 1. Dropping such lakes from the sample also drops them from the population of inference; no inference can be drawn about the soil properties that are associated with such lakes.

2. Dropping such lakes limits the range of response of watershed models, such as ILWAS or MAGIC. It would be impossible to determine what soil properties are associated with highly alkaline lakes.

3. Dropping such lakes may be unnecessarily drastic. As an alternative, instead of omitting highly alkaline lakes, they could be sampled less intensively.

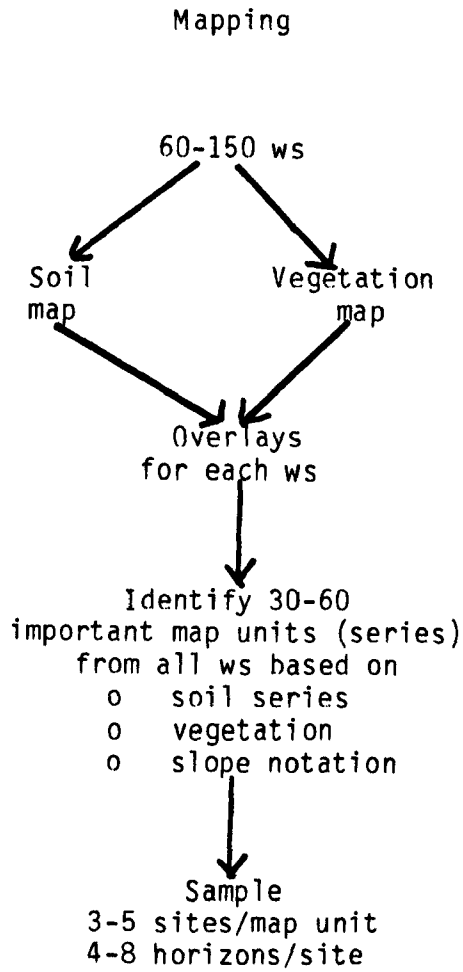


Figure 2.3. Watershed sampling procedure.

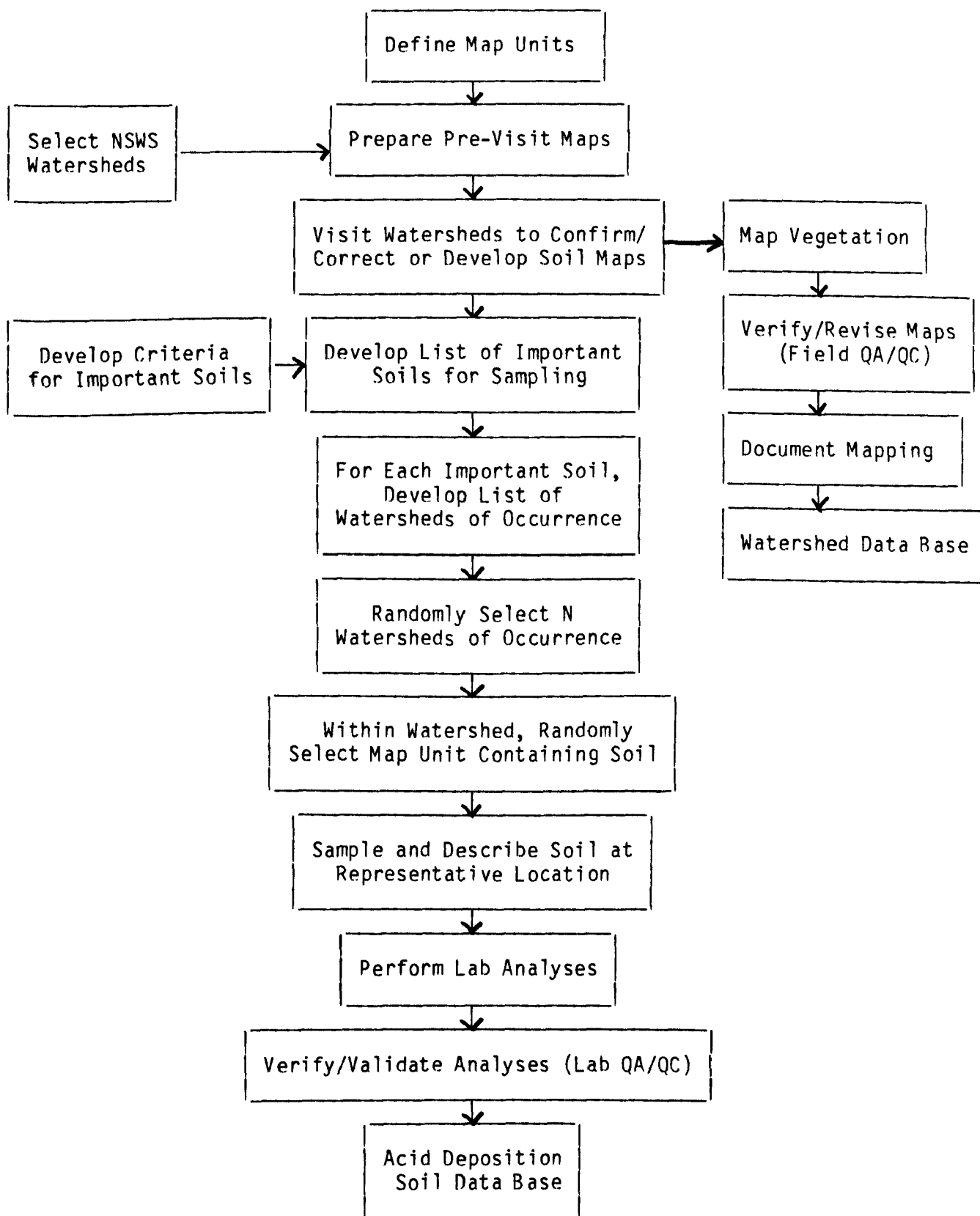


Figure 2.4. Task-flow for Soil Survey.

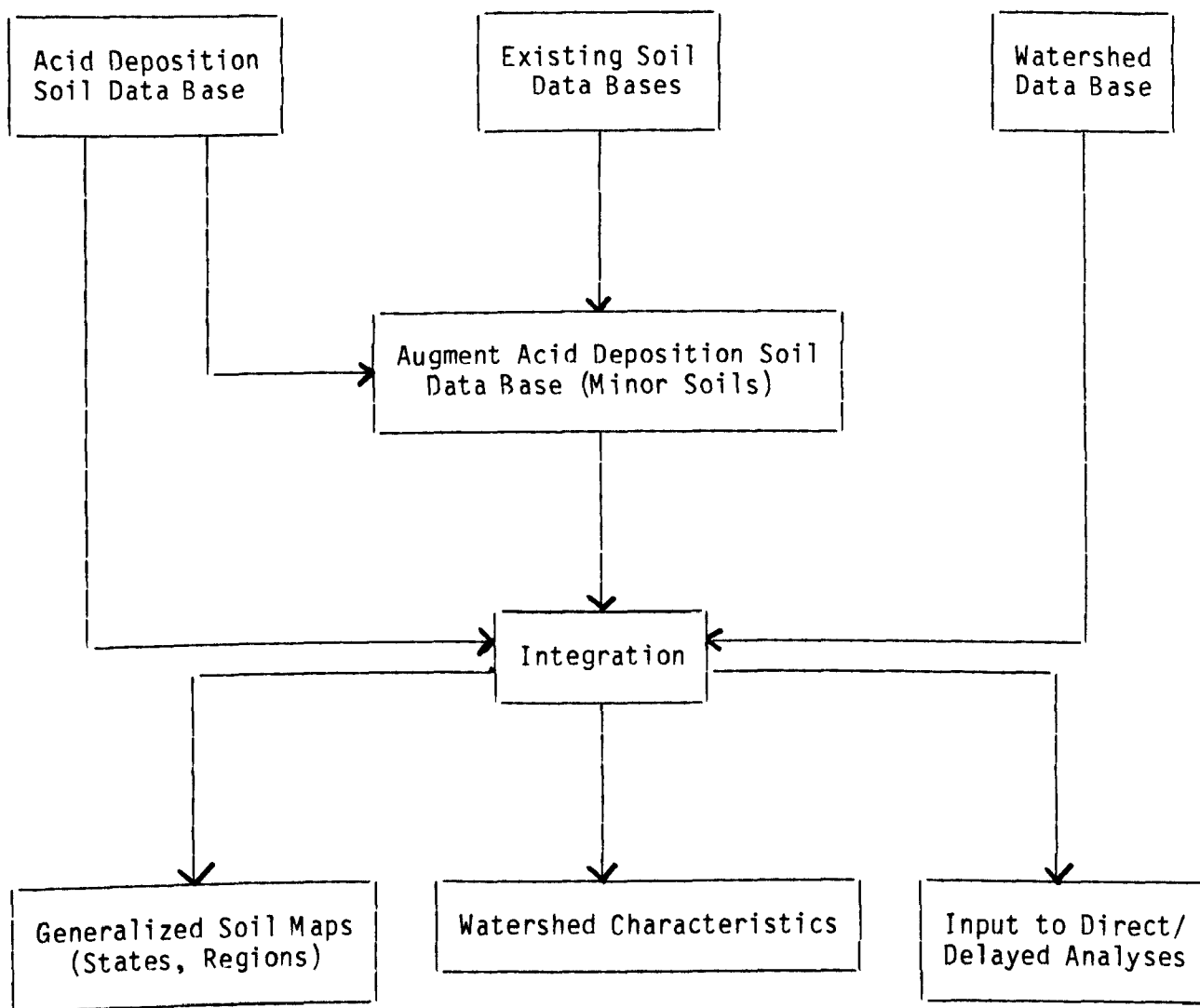


Figure 2.5. Use of data bases from Soil Survey.

2. It is not yet clear how the soil data are to be applied to the policy question. The flow of data analysis needs to be defined. The following should be specified:
 1. the data and format needed by the modelers;
 2. method for using sample data to arrive at a watershed description;
 3. quantities to be calculated from the data and the levels of aggregation at which they are to be calculated. Are means and variances needed? Or are statistical distributions needed? Should these be calculated at the watershed level? Mapping unit? Cluster? Subregion? Region?
3. The details of sample selection after definition of mapping units need to be worked out. These details will be specified at the mini workshop referenced in Section 2.1 (Site Selection). It is anticipated that 60 mapping units (series) will be sampled at 5 locations. Possibilities:
 1. Select (randomly) several watersheds from each cluster. Sample these watersheds intensively. Use a less intensive sampling on remaining watersheds.
 2. Select same number of samples for each mapping unit, with sampling sites on watersheds selected randomly. The sampling rate would be sufficient to assess the variability within mapping units (series).
 3. Select watersheds so that more frequently occurring mapping units are sampled more frequently.
 4. Can "access" be included as a criteria for selection of watersheds? Should large watersheds be included? These decisions involve similar problems as in unresolved issue 1. Dropping large or inaccessible watersheds simply excludes them from the population of inference.

3.0 MODELING GROUP

Compiled by Kent Thornton

This group addressed the following issue: What approaches can be used to assess direct, delayed, or no response systems based on: (a) existing data; and (b) data collected during the Soil Survey?

3.1 LEVELS OF ANALYSIS

Three levels of analysis were identified. Level I analyses use existing lake survey data while Level II and III analyses require supplemental information provided by the Soil Survey. These analyses may provide regional estimates.

3.1.1 Level I Analysis

1. The National Lake Survey (NLS, a component of NSWS) data can be used to determine the number of presently acid lakes and to estimate the number of direct response lakes. It can also be used to determine the number of capacity protected lakes with alkalinities greater than some value (perhaps 200 $\mu\text{eq/l}$). Lakes with pH greater than some value (such as 5.0) but with alkalinities less than some value (e.g., 200 $\mu\text{eq/l}$) may be delayed systems. The number of delayed systems, therefore, can be estimated using the NLS data base.
2. Level I analyses also include annual SO_4 or S budgets computed based on present deposition levels and lake SO_4 concentrations. These budgets can be computed for NLS lakes, ILWAS/RILWAS lakes, or other

lakes with available SO_4 data (i.e., Norton, Schofield, etc.). Correcting for runoff and ET (evapotranspiration) can estimate if these lakes are in steady state with respect to SO_4 . This estimate does not necessarily indicate a direct or delayed system, but is useful in assessing whether or not watersheds are accumulating sulfate through either $\text{SO}_4^{=}$ adsorption or other means.

3.1.2 Level II Analyses

Level II analyses represent order of magnitude estimates for determining the potential number of delayed systems. These analyses can provide time-varying estimates but require the type of data to be collected in the Soil Survey.

1. SO_4 adsorption. SO_4 adsorption isotherms will be determined for various soils throughout the Northeast using the Soil Survey data. Assuming present SO_4 deposition rates, those soils associated with delayed lakes (identified in Level I) can be theoretically titrated to determine the time until breakthrough. This can be done using both wet SO_4 deposition rate and an estimate of total SO_4 deposition rate as a multiple of wet [$\text{total } \text{SO}_4 = (1 + x) * \text{wet } \text{SO}_4$]. If the time to breakthrough is quite long (e.g., 500 years), these systems may be considered to be capacity protected. However, if the time is quite short, this does not necessarily imply that the system is likely to acidify; other watershed properties might prevent this.
2. CEC and percent base saturation. CEC and percent base saturation (BS) by neutral salts will be determined during the Soil Survey. Assuming: (a) present deposition levels, and (b) no (zero) weathering contributions to the base supply, the CEC and percent BS can be

titrated theoretically to estimate the time until base cations are depleted to some critical level. The endpoint will not be complete depletion since Al buffering will occur prior to complete depletion. One rule of thumb may be to deplete half (0.5) of the existing CEC (suggested by one group member but not universally endorsed). Another option is to titrate to a base saturation such as 15% as an estimate of the Al buffering threshold. If this time is quite long (e.g., 500 years), these systems may be considered to be capacity protected. This approach can be expanded to other systems by developing a regression approach to predict CEC and % BS by neutral salts based on the CEC and % BS at buffered pH 7, organic carbon, and other factors generally available in published information (see Section 6).

3.1.3 Level III Analysis

Level III analyses use dynamic modeling approaches to provide approximate time estimates for delayed systems. Three models exist that may be applied to a selected number (i.e., 10-15) of intensively studied Northeast lakes: ILWAS (Chen, Gherini et al.), MAGIC (Cosby et al.), and Trickle-Down (Schnoor). These models should be calibrated on several Northeast lakes and used to predict the rate of change of representative chemical variables (e.g., pH) important to aquatic systems. These models integrate mineral weathering, base cation exchange, sulfate adsorption, and soil contact. Multiple simulations can be conducted to look at the effect on lake chemistry response times of a wide range of combinations of key parameters (soil depth, $\text{SO}_4^{=}$ adsorption capacity, % base saturation, etc.). The results of these simulations could be expressed as tables or nomograms that estimate a watershed's response time

(plus or minus so many years) based on surveyed soil and hydrological parameters. An approximate estimate of the results for watersheds studied in the soil survey can be developed with these approaches. These estimates would still be "hypotheses," since the models that would create them have not been tested on independent time series data.

3.2 REQUIRED MODELING PARAMETERS

The modeling parameters required for Level II and III analyses are listed in the attached table. These have been delineated by hydrologic and chemical categories. While not all these parameters are required for each model, this list will permit the application of all three models to soil survey watersheds.

Table 3.1. Modeling parameters.

Deposition:

NADP type data

Air temperature, other meteorological data

Hydrology:

Catchment slopes

Depth of permeable media

Permeability

Chemistry:

Cation Exchange

CEC

Base saturation

Sorbed bases

Lime potential

Al potential

Soil Solution

pH

Alkalinity

Major cations and anions

Sulfate Adsorption

Isotherm parameters

Weathering

Carbonates

Weatherable minerals: heavies, plag

Vegetation

Percent coniferous

Percent deciduous

Percent open

4.0 MAPPING AND SAMPLING GROUP

Compiled by Fred Gilbert and Oliver Rice

4.1 SAMPLING PROTOCOL

The selection of sample sites within the watershed is critical to the ultimate use and value of the data for watershed and regional analysis. Soil scientists have the capability of recognizing the typical landscape position of the various taxa within a mapped area. Sample site selection will be formulated after completion of soil mapping. A listing of frequency and extent of soil series by state will be made from a compilation of the soil maps. At that time a minimum number (tentatively, 5) of sampling sites for each soil series will be determined to be in identified watersheds. Laboratory analysis of soil samples from these sites will characterize the properties and variability of the most important soil series (tentatively, 60) by horizon (average of 6 anticipated).

4.1.1 Soil Sampling and Description Procedure

- Soil profiles and sampling sites will be described using SCS-232 according to Chapter 4, Soil Survey Manual.
- Typifying pedon(s) for that named map unit will be sampled as specified in Chapter 8, Soil Survey Manual.
- Pedon sampling will include the C horizon (if present); sampling horizons as specified below.
- Samples will be taken from all continuous horizons > 3 cm thick (1 gallon of bulk sample from each horizon will be removed for lab analyses).

- In-place bulk density by Grossman method will be determined for all horizons except Oi.
- Each mineral horizon will be field tested for inorganic carbon (carbonates), using method given in Section 5.2.
- At each site a checklist will be completed.

4.1.2 Cost Estimate per Pedon

4 person sampling team requires:

Salary 2 - GS11 @ \$25.63/hr x 8 hr = \$205 x 2 =	\$410
2 - GS04 @ \$6.50/hr x 8 hr = \$52 x 2 =	104
per diem \$50 x 4	200
Supplies and Transportation	<u>90</u>
Subtotal	804
Overhead 26%	<u>209</u>
Total	\$1013

4.2 SOIL MAPPING -- ASSUMPTIONS, PROCEDURES, COSTS

The relative value and costs of soil mapping at two different scales was discussed by the field soil sampling group on Tuesday, 1/22/85. Specifically, the group considered soil mapping at a scale of 1:24,000 and at a scale of 1:62,500. The question considered was whether the data transfer value of one kind of map was better than the other. There was a consensus that we could make similar regional generalizations of data for a soil taxa (series, family, etc.) from maps made at both scales.

After we had this discussion, Rick Linthurst pointed out that those involved in formulating policy statement materials will feel more secure if they have soil maps available at a scale of 1:24,000. There will be many

places where the relationships of the suite of soils and the water chemistry will be unclear. Mapping at a scale of 1:24,000 may help clarify these relationships for a moderate increase in cost (Tables 4.1, 4.2). Therefore, it is recommended that watersheds be mapped at a scale of 1:24,000, and that the mapping units be consociations (soil series), as practical.

4.2.1 Procedure Guidelines

The soil survey will be completed using the specified guidelines of the National Cooperative Soil Survey (Soil Survey Manual, National Soils Handbook). The soil mapping units will be designed according to the needs of this study. They will be presented to EPA on USGS topographic sheets at a scale of 1:24,000. The soils will be classified according to Soil Taxonomy (Agriculture Handbook 436).

The soil scientists will make a vegetative map for the watershed during the soil mapping visit. The vegetation map will be made on a Mylar overlay of the soil map. The vegetative units will be those described in "Forest Cover Types of the United States and Canada" by F. H. Eyre, 1980, Society of American Foresters.

There will be a second overlay made during the soil mapping visit showing depth to bedrock classes. They will be shown as depth classes as follows:

<u>Class</u>	<u>Depth</u>	<u>Confidence Level</u>
I	< 20" (< 0.5 m)	High
II	20- 40" (0.5-1 m)	High
III	40-100" (1-2 m)	High
IV	100"-20' (2-5 m)	Moderate
V	20-100' (5-30 m)	Low
VI	> 100' (> 30 m)	Low

Table 4.1. Soil mapping at 1:62,500 scale.

Activity	Assumptions	Costs
Field mapping (soils and vegetation)	150 watersheds, 1000 acres/ws, 500 acres/day, \$25.63/hr, 8 hrs/day	\$61,512
Travel (field mapping)	300 days, \$50.00/day	15,000
Map preparations	1 day/ws, \$20.35/hr, 8 hrs/day	24,420
Photos	3 photos/ws, \$6/photo	2,700
Statistical analysis	1 day transect/ws, 1 day write up/ws, 1 day carto work/ws, \$25.63/hr, 8 hrs/day	92,268
Coordination activities	8 hrs/ws, \$35.00/hr	42,000
Planning meetings	4 meetings, 7 states, 1 person/state, 40 hr/meeting, \$35.00/hr	39,200
Travel (meetings)	\$1000/meeting/person	28,000
Plane rental (field mapping)	20 hrs/\$100/hr	<u>2,000</u>
Subtotal		307,100
Overhead	26%	<u>79,846</u>
Total		\$385,946
Average cost/watershed		\$2,580

Table 2. Soil mapping at 1:24,000 scale.

Activity	Assumptions	Costs
Field mapping (soils and vegetation)	150 watersheds, 1000 acres/ws, 200 acres/day, \$25.63/hr, 8 hrs/day	\$153,780
Travel (field mapping)	750 days, \$50.00/day	37,500
Map preparations	1 day/ws, \$20.35/hr, 8 hrs/day	24,420
Photos	5 photos/ws, \$6/photo	4,500
Statistical analysis	1 day transect/ws, 2 day write up/ws, 1 day carto work/ws, \$25.63/hr, 8 hrs/day	123,000
Coordination activities	8 hrs/ws, \$35.00/hr	42,000
Planning meetings	4 meetings, 7 states, 1 person/state, 40 hr/meeting, \$35.00/hr	39,200
Travel (meetings)	\$1000/meeting/person	28,000
Plane rental (field mapping)	20 hrs/\$100/hr	<u>2,000</u>
Subtotal		434,400
Overhead	26%	<u>118,144</u>
Total		\$562,544
Average cost/watershed		\$3,750

4.2.2 Costs

The estimated costs for making soil surveys, on maps with scales of 1:24,000 and 1:62,500, are attached as Tables 4.1 and 4.2. The assumptions used in deriving these costs were that none of the watersheds have been mapped in the past, and most will be difficult to access and difficult to traverse. Calculations are based upon the assumption that there are 150 watersheds to be mapped and that the average size of each watershed is 1000 acres. This allows some manipulation of the cost estimate of any number of watersheds.

4.3 EVALUATE SOIL MAP BY TRANSECT

Transect 10% of watershed chosen randomly. Randomly assign transect line across watershed and evaluate mapping by methods in Northeastern Soil Survey Work Planning Conference Report 1982.

4.4 INTERSTATE TECHNICAL COORDINATION -- WATERSHED MAPPING

4.4.1 Purpose

The primary purpose of interstate technical coordination is to insure that field mapping, map preparation, sampling, describing of soils, soil identification, and interpreting laboratory data to classify soils is done in a technically sound, standard, uniform manner in all watersheds, and that there is close adherence to mapping and sampling protocol by all involved field parties.

This becomes a large job because of the number of concurrent field operations and time constraints. The general standards for quality evaluation and control are those contained in the National Soils Handbook and Soil Survey Manual. Within these are additional ones identified as special needs of the Soil Survey for the NAPAP, covered in detail in the section on mapping and sampling.

4.4.2 Responsibilities

An outline of the responsibilities of interstate technical coordination are:

1. For study-specified standards, obtain adherence to:
 - mapping and sampling protocol
 - mapping intensity
 - map preparation (cartographic standards)
 - identification of soil qualifiers
 - standards for locating pedons to sample
 - standards for sample taking, field processing, storage, etc.
 - standards for describing soils
2. To resolve unforeseen technical problems in a uniform manner.
3. To exercise National Cooperative Soil Survey standards or quality control of soil mapping through:
 - coordination/correlation of series concepts
 - coordination/correlation of map unit concepts
 - application of identification legend
 - coordination of preparation of soil descriptions
4. To be involved as an advisor in all training, planning, and evaluation meetings.
5. To evaluate proposed mapping protocol for practical and technical soundness (can it be implemented and can results be satisfactory).

4.4.3 Operating Procedures

The proposed operating procedure involves:

1. Coordinator/correlator will participate in planning, training, and evaluation activities.

2. With state staff counterparts, coordinator/coorelator will participate in field (watershed) reviews of work in progress. Each state will be visited at least once and states containing several watersheds should be visited up to 3 times.
3. These visits will be to review all activities for technical adequacy to meet standards of the NSH and the specific needs of the surveys as contained in the mapping and sampling protocol.
4. A sample of maps and descriptions will be reviewed for completeness and quality, including series identification and classification in Soil Taxonomy before they are transmitted to EPA.
5. When laboratory data become available, these data and the field descriptions will be reviewed for accuracy of classification of the pedons sampled and the final correlation of the map units.

4.2.4 Cost for Interstate Technical Coordination

Cost estimate is salary at GM-14 plus overhead, plus travel for the full period of preparation, training, mapping, and follow-up.

Salary + benefits	= \$24,000
Per diem	= 5,000
Transportation to states	= 5,000
Transportation to EPA meetings (2)	= <u>1,800</u>
Subtotal	\$35,800
Overhead at 26%	<u>9,308</u>
Total	\$45,108
Average cost per watershed	\$300

4.5 REFERENCES

- Arnold, R. W. 1980. Development and use of Graphical Solution of Binomial Confidence Limits in Soil Survey. (Attached as Appendix 3.)
- Eyre, E. J. Forest Cover Types of the United States and Canada. Society of American Foresters.
- Hanna, W. E. 1982. Committee Report: Evaluating Soil Map Quality. In Proceedings of the Northeast Cooperative Soil Survey Conference.
- United States Department of Agriculture, Soil Conservation Staff. 1980-1984. Soil Survey Manual. Appendix to National Soils Handbook. Agric. Handbook 430.
- United States Department of Agriculture, Soil Conservation Staff. 1975. Taxonomy: A Basic System for Making and Interpreting Soil Surveys. Agric. Handbook 436, 654 pp.

5.0 LAB ANALYSIS/QUALITY ASSURANCE GROUP

Compiled by Paul Shaffer

5.1 LAB ANALYSES REQUIRED FOR SOIL SURVEY

1. pH -- distilled water, 0.01M CaCl_2
2. Test for inorganic carbon
3. Total organic carbon
4. Total organic nitrogen
5. Total sulfur
6. Cation exchange capacity
 - a. 1.0N NH_4OAc , pH = 7.0
 - b. 1.0N NH_4Cl , unbuffered
7. Exchangeable bases (Na, K, Mg, Ca)
 - a. extraction by 1.0N NH_4OAc , pH = 7.0
 - b. extraction by 1.0N NH_4Cl , unbuffered
8. Exchangeable acidity
 - a. BaCl_2 -- TEA method @ pH 8.2
 - b. 1.0N KCl -- total acidity, exchangeable Al
9. Extractable iron and aluminum
 - a. sodium pyrophosphate
 - b. ammonium oxalate
 - c. citrate-dithionite
10. Extractable sulfate
 - a. water soluble
 - b. phosphate extractable

11. Sulfate adsorption isotherms
12. Mineralogy on selected pedons and horizons
 - a. x-ray diffraction
 - b. thin sections
13. Lime potential
14. Particle size distribution

5.2 LABORATORY METHODS FOR SOIL SURVEY

1. pH (reference: Kaisaki, pers. comm., 1985)

pH will be measured using both deionized water and 0.01M CaCl_2 . For mineral soil horizons, a 2:1 solution:soil ratio will be used; for organic horizons, a 5:1 ratio soil. Soil-solution slurries will be mixed and allowed to equilibrate for one hour, with occasional stirring. After one hour, the sample will be stirred continuously for one minute, let stand for one minute, then pH measured potentiometrically in the liquid phase.

2. Test for inorganic carbon (carbonate) (reference: NCASI, page A-25; Kaisaki, pers. comm., 1985)

Place ground soil on a spot plate, moisten, and add several drops of 4N HCl. Look for effervescence, which would indicate dissolution of carbonates and release of CO_2 .

Comment: This test will be done in both field and laboratory; in the lab the spot plate will be examined under a binocular microscope. It is assumed that this test will show no carbonate in most samples; for those with a positive test for carbonate, inorganic carbon must be quantified.

3. Total organic carbon automated analysis, e.g.,
4. Total organic nitrogen LECO, Perkin-Elmer C-N
5. Total sulfur analyzer, etc.

6. Cation exchange capacity
 - a. NH_4OAc , 1.0N, pH 7.0 (reference: SSIR method F5A8)
 - b. NH_4Cl , 1.0N, unbuffered (reference: SSIR method F5A9)

Comment: Automated extraction is recommended, if available, for improved reproducibility.

7. Exchangeable bases (Mg, Ca, Na, K)
 - a. extraction by 1.0N NH_4OAc , pH = 7.0
 - b. extraction by 1.0N NH_4Cl , unbuffered

Comment: Procedure is analysis of leachates (from 6a, 6b above) for individual base cations. Analysis may be by atomic absorption/flame emission/ICP.

8. Exchangeable acidity
 - a. BaCl_2 -- TEA, pH 8.2 (reference: NCASI, page A-30)

Comment: Several variations of this method are possible. We are not sure whether any version is better than the others, but we need to specify one method.

 - b. KCl (1.0N) extraction (reference: Thomas, 1982; also cited in NCASI, page A-32)

Comment: This method will be used to quantify both total acidity and aluminum acidity. Al acidity can be measured by titra-

tion as described in the method citation listed above, or by Al analysis (AA/ICP) of the KCl extract.

Note: Base saturation is not listed as an analytical measurement. Base saturation is derived from analyses in #6-8, and the data user can compute it in any of several ways.

9. Extractable iron and aluminum

- a. sodium pyrophosphate extraction (organic Fe, Al) (reference: Bascomb, 1968; McKeague et al., 1971; SSIR method GC8)

Comment: pH of pyrophosphate extract should be adjusted to 10.0.

- b. ammonium oxalate (organic plus amorphous hydrous oxides) (reference: McKeague and Day, 1966; modified in NCASI, page A-38)

- c. citrate-dithionite (non-silicate Fe and Al) (reference: NCASI, page A-36)

Comment: Bicarbonate buffer may or may not be used in the extraction; recommendations for and against it have been given, so it will be used only if there are clear analytical advantages.

Iron and aluminum analyses for all fractions should be done by AA and/or ICP.

Comment: Based on differences in Fe and Al content of the procedures cited above, several Fe and Al fractions can be defined -- see Johnson and Todd, 1983. These extractions are generally very specific for iron fractions, but less specific for Al.

10. Extractable sulfate

- a. water soluble (reference: NCASI, page A-38)

- b. phosphate extractable (reference: modified from Ensminger, 1954)

Procedure: Sequential extractions of soil (4:1 solution:soil ratio), using 500 mg P/l (as NaH_2PO_4), instead of 1000 mg P/l as in Pilot; 4 extractions, with extracts pooled for analysis.

Comment: Sulfate by ion chromatography. Reduced concentration of PO_4 facilitates analysis by ion chromatography; use of multiple extractions insures quantitative recovery of sulfate from soils.

11. Sulfate adsorption isotherms

Procedural details are still under discussion. There is a consensus to do only B and C soil horizons, and to run only 5 point isotherms (0, 4, 8, 16, 32 mg S/l, or 0, 250, 500, 1000, 2000 meq SO_4 /l) using K_2SO_4 .

Still to be determined is the question of which soil preparation to use -- air dried, or field moist.

Sulfate will be by ion chromatography.

12. Mineralogy on selected pedons and horizons

No consensus was reached on what types of mineralogy-soil analyses should be performed, or for how many soils/depths per pedon (see Section 1.4).

The lack of a consensus stemmed largely from an uncertainty over end uses of data.

13. Lime potential (reference: Reuss, pers. comm., 1985)

Equilibrate soil with 0.002 M CaCl_2 . Measure pH, Al, Ca, Mg, Na, K.

14. Particle size distribution (reference: SSIR 3A1)

After removal of organic matter the percent sand, silt, and clay will be determined by the standard pipette method.

Note: Bulk density will be measured in the field using the Grossman method.

5.3 REFERENCES FOR LAB METHODS

- SSIR. Procedures for Collecting Soil Samples and Methods of Analysis for Soil Survey. USDA, Soil Survey Investigations Report #1, revised July 1984.
- NCASI, NCASI, 1983. Field Study Program Elements to Assess the Sensitivity of Soils to Acidic Deposition Induced Alterations in Forest Productivity. National Council of the Paper Industry for Air and Stream Improvement, Inc., Technical Bulletin No. 404. 35 p. plus appendices.
- Thomas, G. W. 1982. Exchangeable Cations. Chapter 9, pp. 159-166 in: Page, A. L. (ed.). Methods of Soil Analysis -- Part 2. American Society of Agronomy, Madison, Wisconsin.
- Johnson, D. W., and D. E. Todd. 1983. Some Relationships Among Fe, Al, C, and SO_4 in a Variety of Forest Soils. Soil Sci. Soc. Am. J.

5.4 ISSUES RELATED TO SOIL SAMPLE COLLECTION, ANALYSIS, AND DATA REPORTING

5.4.1 Sample ID Numbers

What ID numbers are necessary? It was suggested that samples be assigned two ID numbers -- a number compatible with NCSS ID system, since they will collect and may process samples/perform some analyses. The second number would be for survey use and would identify the sample by NSWWS watershed ID. States may also want special sample numbers for their own use. In any case, samples will be assigned a unique ID number for the purposes of this survey. This will be the controlling number, with any others carried as secondary identifiers.

5.4.2 Data Values

It was strongly recommended that significant figures not be truncated from the data set except by final data users. As an example., many of the base cation analyses reported for Pilot Survey listed 0.0 as concentrations, because of rounding to one decimal place. This was done even though analyses were reliable to two decimal places.

This should not be a problem, as long as data reporting protocols are specified in advance.

5.4.3 Choice of Analytical Lab

There was an assumption at the meeting that one lab would be selected, with several contractors. It was suggested that one lab should perform one (or a few) analysis for the entire sample set (e.g., CEC and extractable bases), in order to avoid interlaboratory variability. The lead laboratory would be responsible for receiving and logging samples, making and sending splits to subcontract labs, and tracking progress of subcontract labs in terms of timelines and QA requirements.

5.4.4 QA/QC Protocols

QA/QC protocols will be developed by EPA Las Vegas (Lou Blume of LEMSCO and Phil Arberg of EPA). They will work from procedures outlined above, and will use estimates of detection limit/precision/etc. supplied by Kaisaki, Shaffer, and others. Such information is needed ASAP, at the latest by the end of February. In the absence of guidance on specific analyses, their thinking will be a clone of lake survey methods and QA requirements (see Section 1.4).

6.0 DATA ANALYSIS GROUP

Compiled by Ray Brant and William Waltman

6.1 STATUS OF LAB AND DATA ANALYSIS

At the Corvallis meeting, the lab data from Maine, Cornell, and the NSSL were merged into one data base using R-base 4000. Included with the lab data were SAF (Society of American Foresters) cover types, soil series and associations, taxonomic classification, watershed name, and the percent acreages of the various associations. From this data base, R-base 4000 permits searches and sorting of any attribute (107 variables) into SAS files or files for Minitab. Basic summary statistics were computed on an IBM-PC-XT using Minitab and SAS was used for cluster analysis and various regressions. The total data base equaled 400K.

The pyrophosphate, dithionite-citrate, and NH_4 -oxalate extractions for Fe and Al were not completed by Cornell at the time of the meeting. In addition, the data base lacked particle size analysis for the Maine soils. Thus, the data base was not complete at this time, but would be following the workshop (see Section 1.4).

The sulfate adsorption isotherms, and water and sodium phosphate extractable sulfate analyses were also not completed by the NSSL, although some regressions and clustering were run on a limited data set.

Soil differences have already been examined by preparation of tables of means and variances of soil characteristics by soil series. These tables can be summarized using a 1-way analysis of variance. This would identify series effect, and would be an aid in grouping series. As a first cut, the analyses

could be done separately for each parameter measured. Since some of the parameters are highly correlated, multivariate analysis of variance should also be considered. (Section 7, "Addendum," is an interim report from a continuing analysis of Pilot data.)

It might also be worthwhile to make a preliminary examination of the relation between lake chemistry and soil properties. One thing that could be done fairly easily is to do an analysis of variance of alkalinity. A first pass would look for differences in alkalinity that could be explained by the dominant series in the watershed. A further refinement would be to carry out a canonical regression between a multivariate lake chemistry parameter (e.g., Alk, SiO₂, Al) and a multivariate average soil parameter (see Section 1.4).

6.2 RESULTS FROM DATA ANALYSIS

The primary objectives of the laboratory analysis portion of the pilot study were: (1) to determine whether existing state soil association maps, and other soil groupings, reflect differences in chemical and physical properties of soils that are of significance to acidification of a watershed; and (2) to determine whether standard tests used for soil characterization can be used to predict special analyses that are of importance as inputs to models of watershed acidification. Secondary objectives of the laboratory analysis portion of the pilot study were: (1) to assess inter- and intra-lab variability; and (2) to test laboratory methods and operations and recommend laboratory protocols for the 1985 soil survey project.

6.2.1 Soil Differences

Chemical -- Summary statistics were generated for the New York data stratified by major horizon designation (i.e., O, A, E, B, C). Means and

standard deviations were calculated for all horizons and were presented graphically for CEC-pH 7, CEC-neutral salt, Al-KCl extractable, and percent base saturation by sum of extractable cations-pH 7 buffered (Figures 6.1, 6.2, and 6.3). The results indicate that there are major differences among these horizons that are of significance to the acidification process when flow path is taken into consideration.

Summary statistics were generated for the aggregate data from New York State and Maine, stratified by major horizon and grouped according to great group classification. Means and standard deviations were calculated for all horizons and were presented graphically for the same properties as before (Figures 6.4, 6.5, and 6.6). The results indicate that there are differences in some of the chemical characteristics between Haplorthods and Aquepts. These two great groups are differentiated taxonomically primarily on the basis of wetness characteristics; therefore the data show significant differences in chemical properties associated with wetness. This is of particular significance to the question of acidification because of the implied differences in flow paths and retention time in these two groups of soils.

Summary statistics were generated for the chemical data for both the Chesuncook soil from Maine (3 sites) and the Becket soil from New York (5 sites). Means and standard deviations were calculated for all horizons and were presented graphically for the same properties as before (Figures 7-11). Both of these series are Haplorthods developed in glacial till deposits. The data show differences in means between these series but the standard deviations are large and the differences are not statistically significant based on such low numbers of observations. The data also show a high degree of variability within series as reflected by high CV values. This is interpreted as inherent variability in the natural soil system.

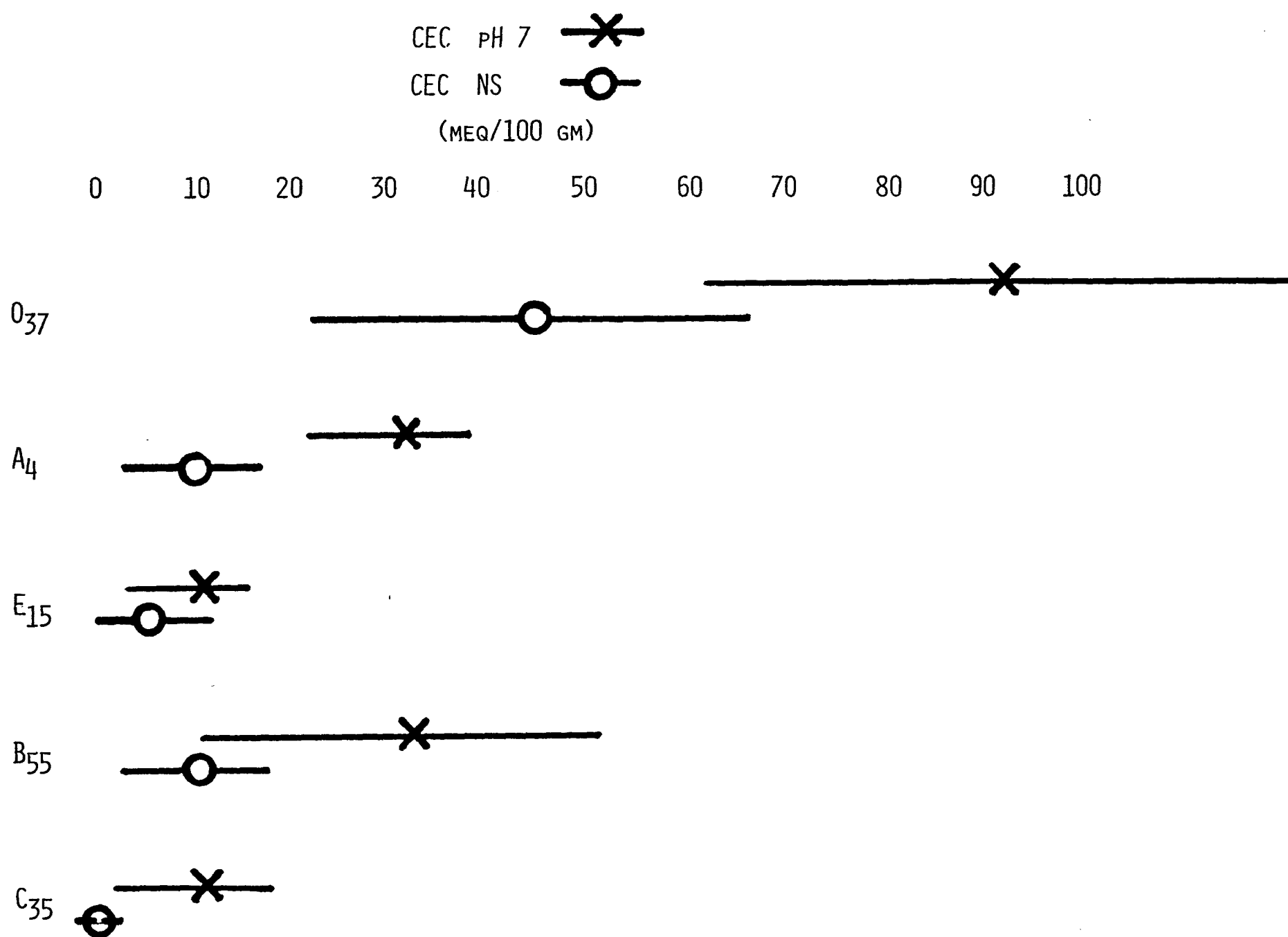


FIGURE 1. NYS DATA

AL KCL
(MEQ/100 GM)

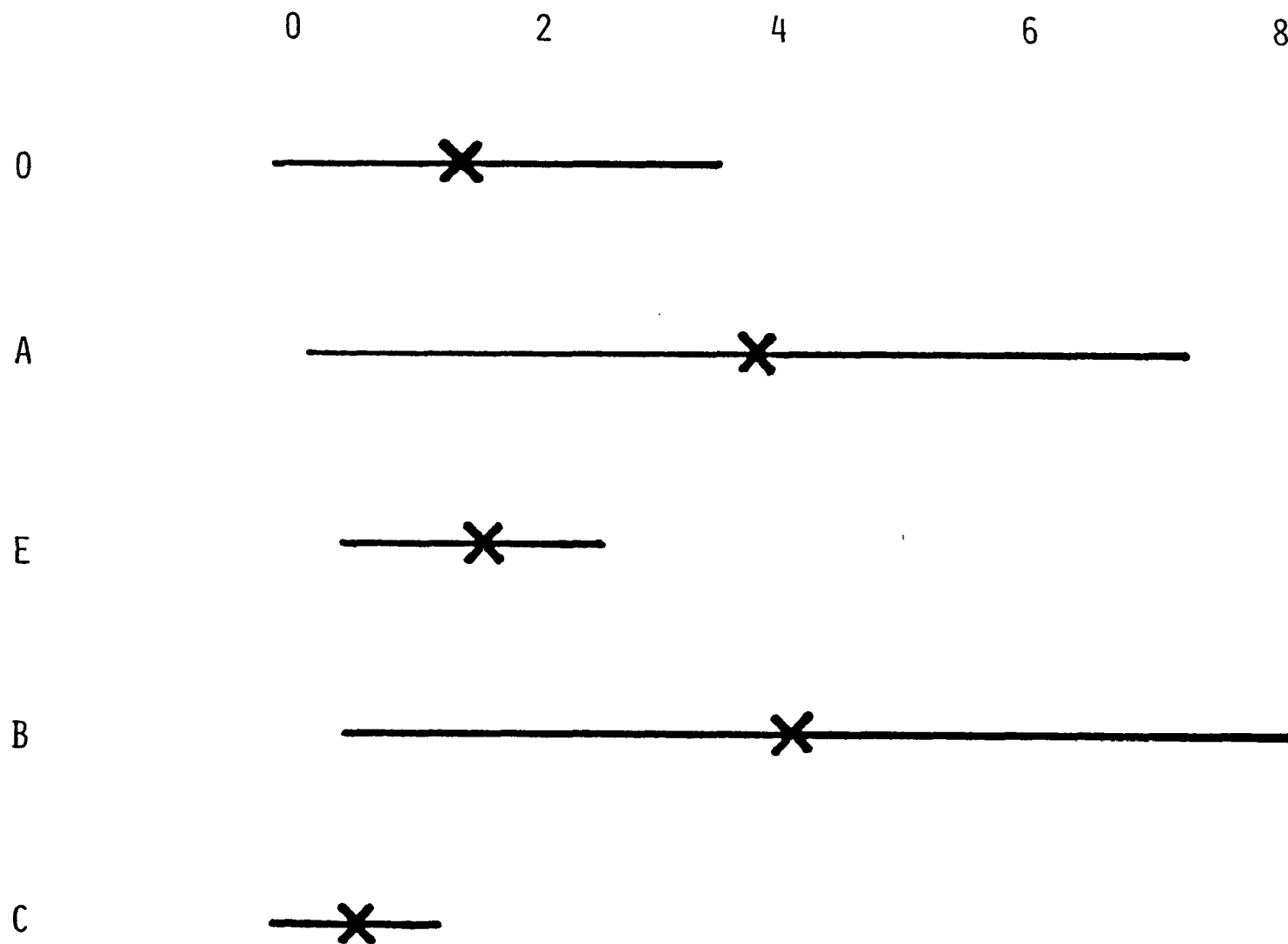


FIGURE 2. NYS DATA

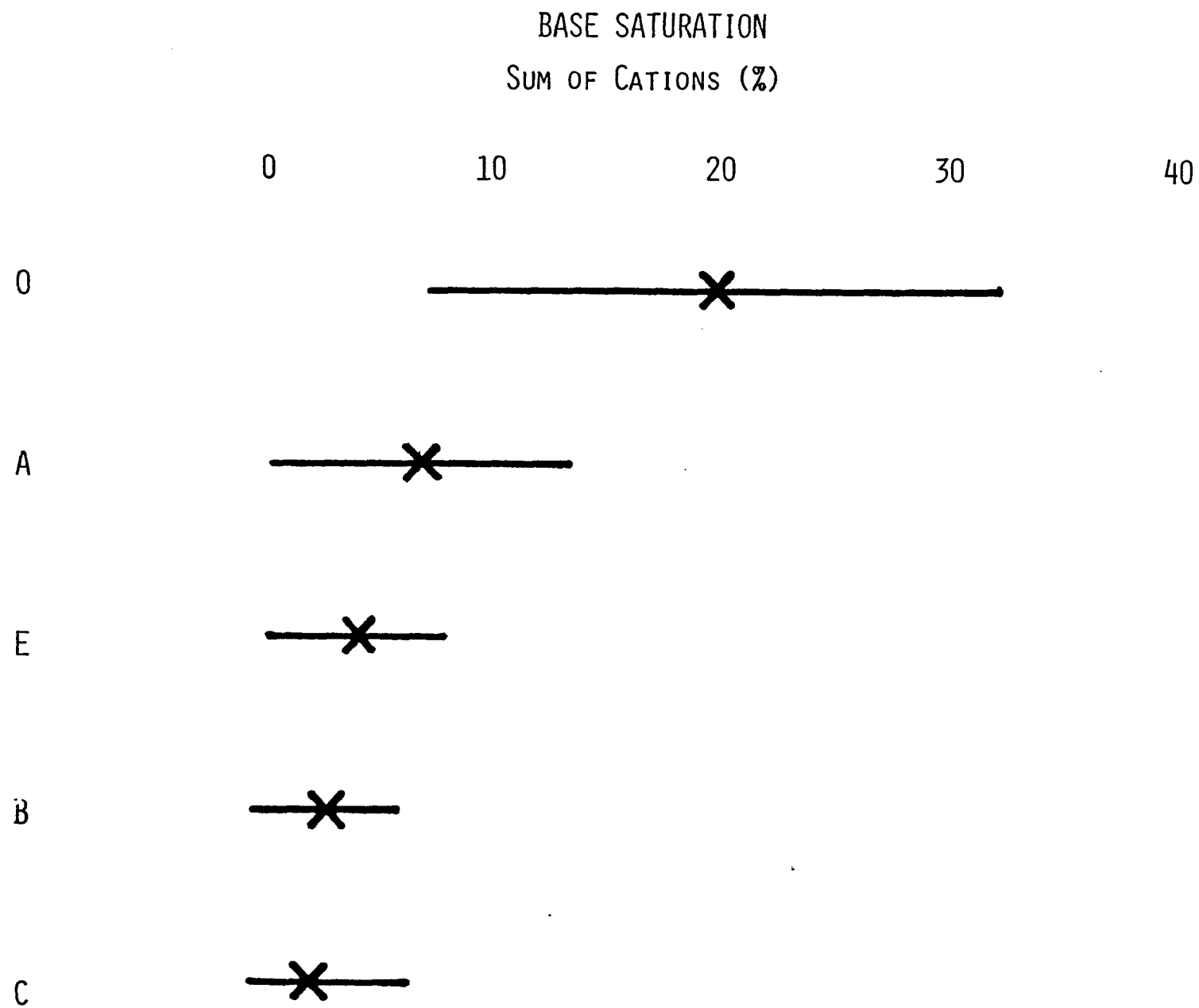


FIGURE 3. NYS DATA



FIGURE 4. NYS AND MAINE

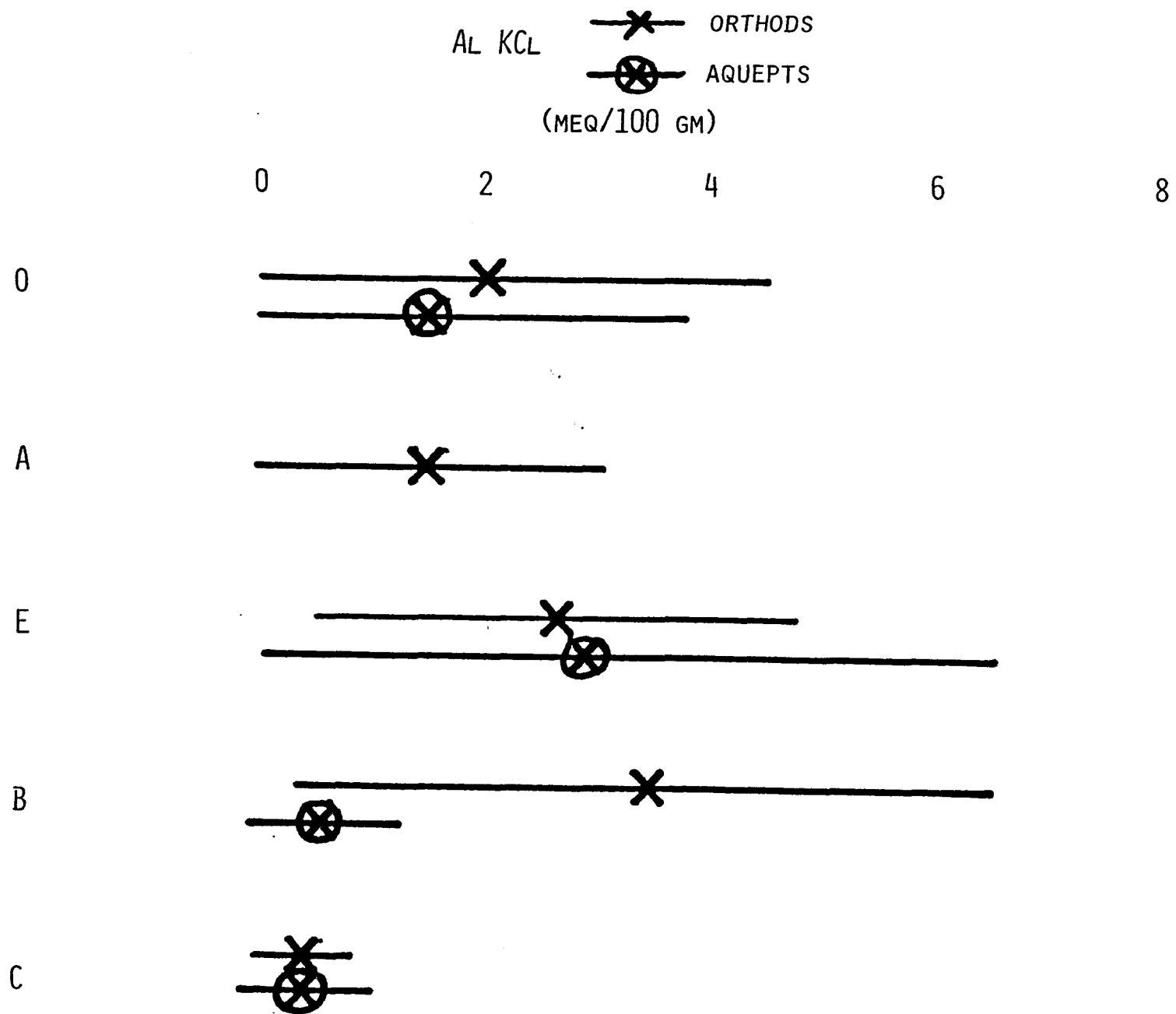


FIGURE 5. NYS AND MAINE

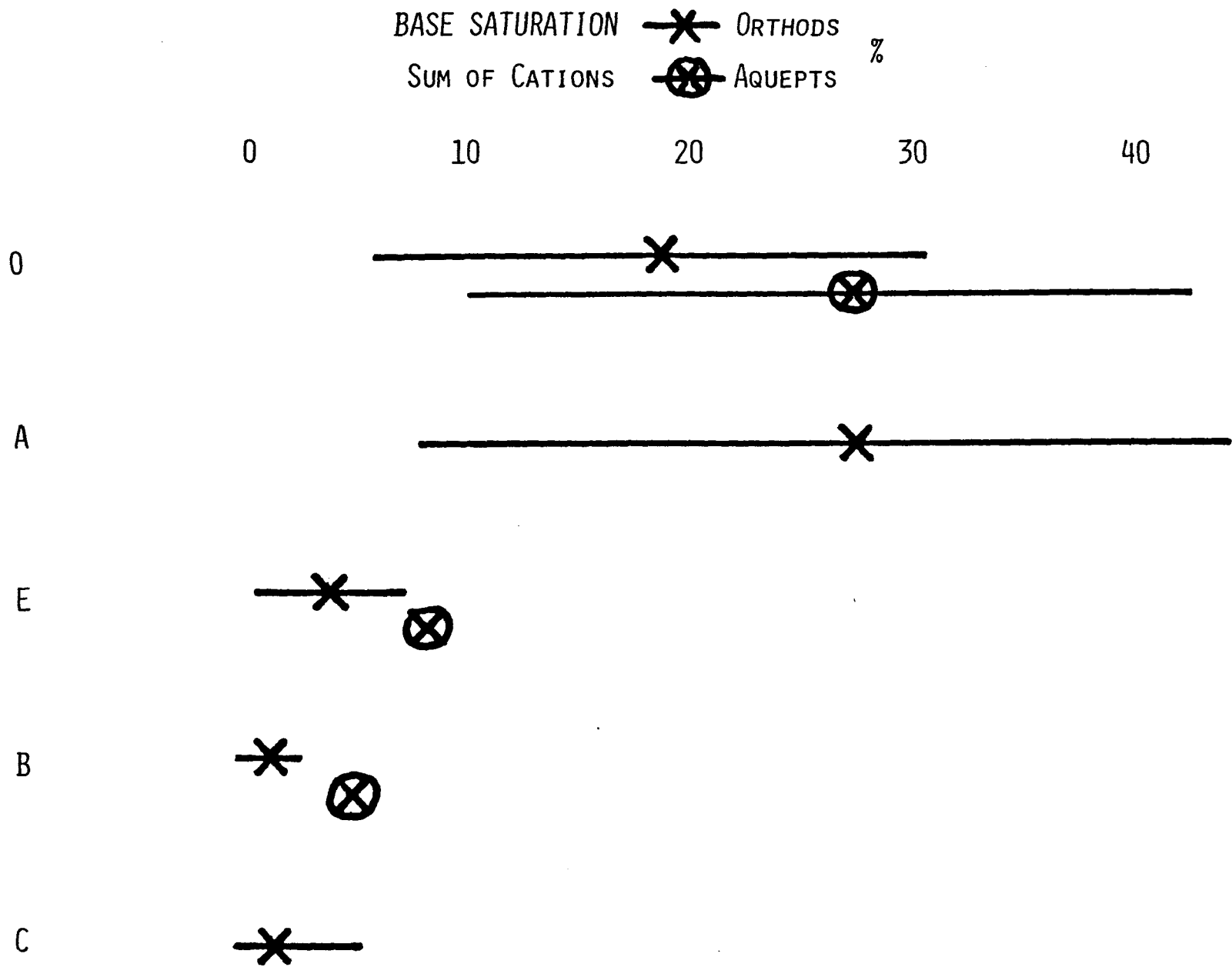


FIGURE 6. NYS AND MAINE

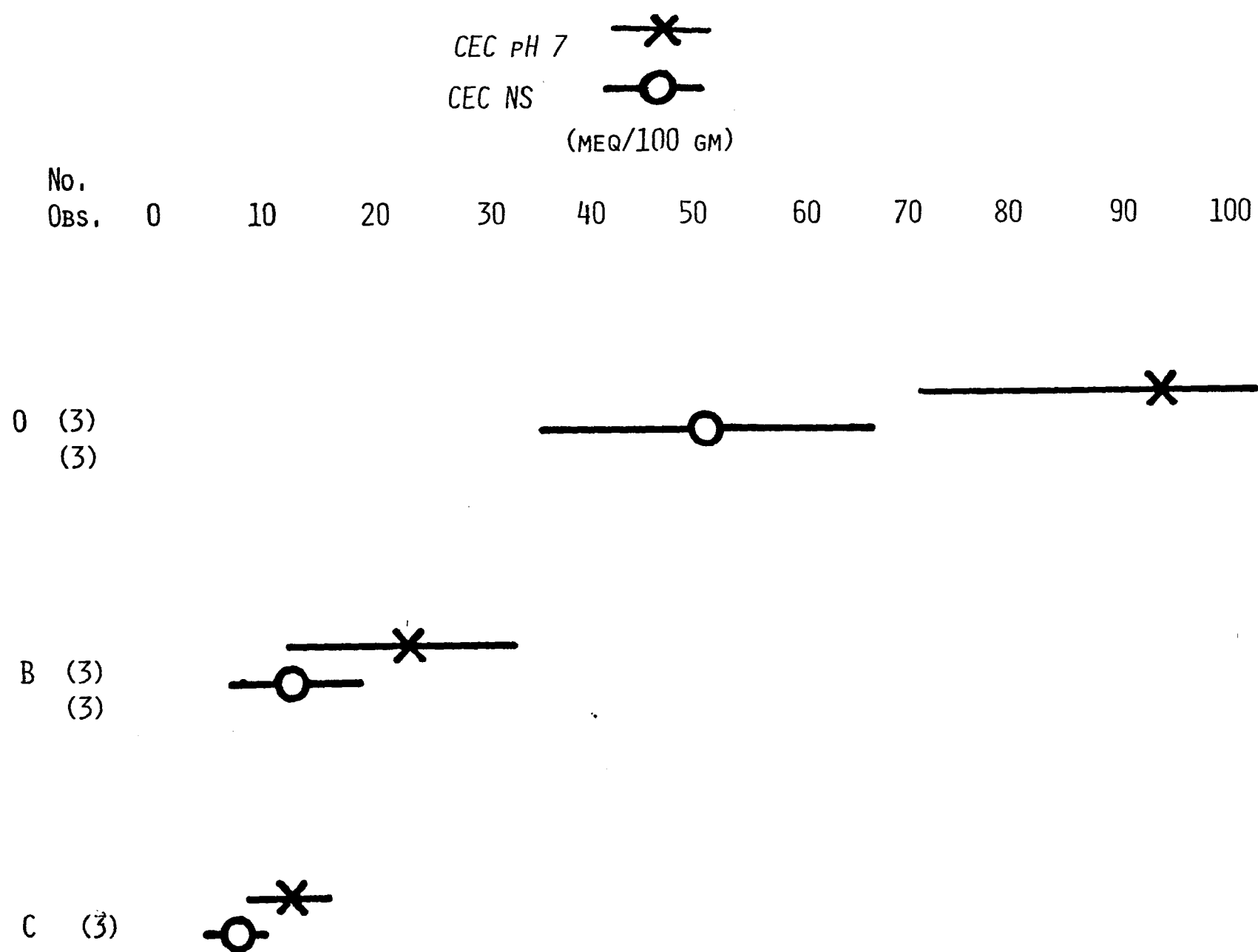


FIGURE 7. MAINE CHESUNCOOK




		AL KCL (MEQ/100 GM)				c.v.
No. OBS.		0	2	4	6	
0	(3)					(37)
B	(3)					(54)
C	(3)					(58)

FIGURE 8. MAINE CHESUNCOOK

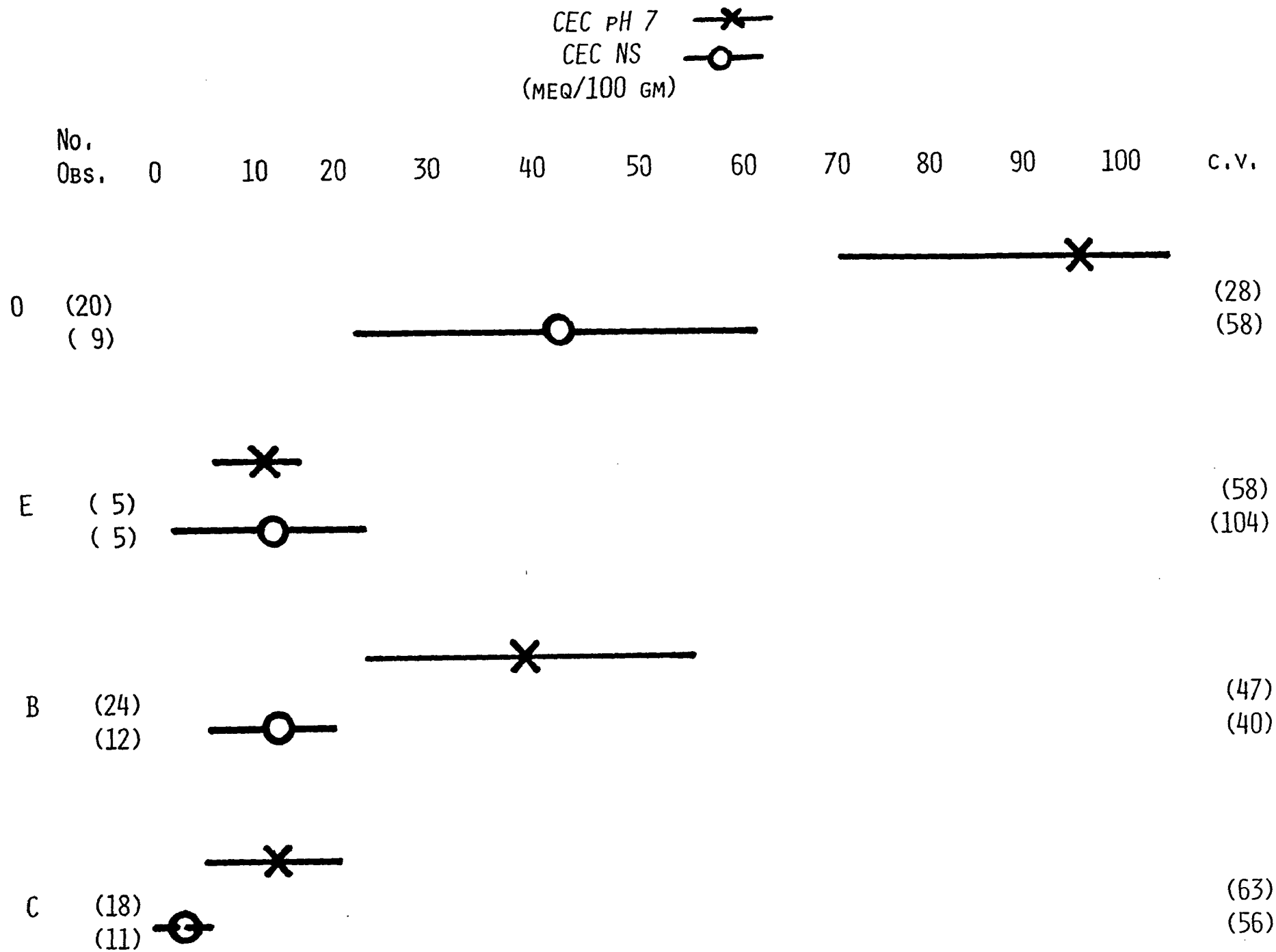


FIGURE 9. NYS BECKET

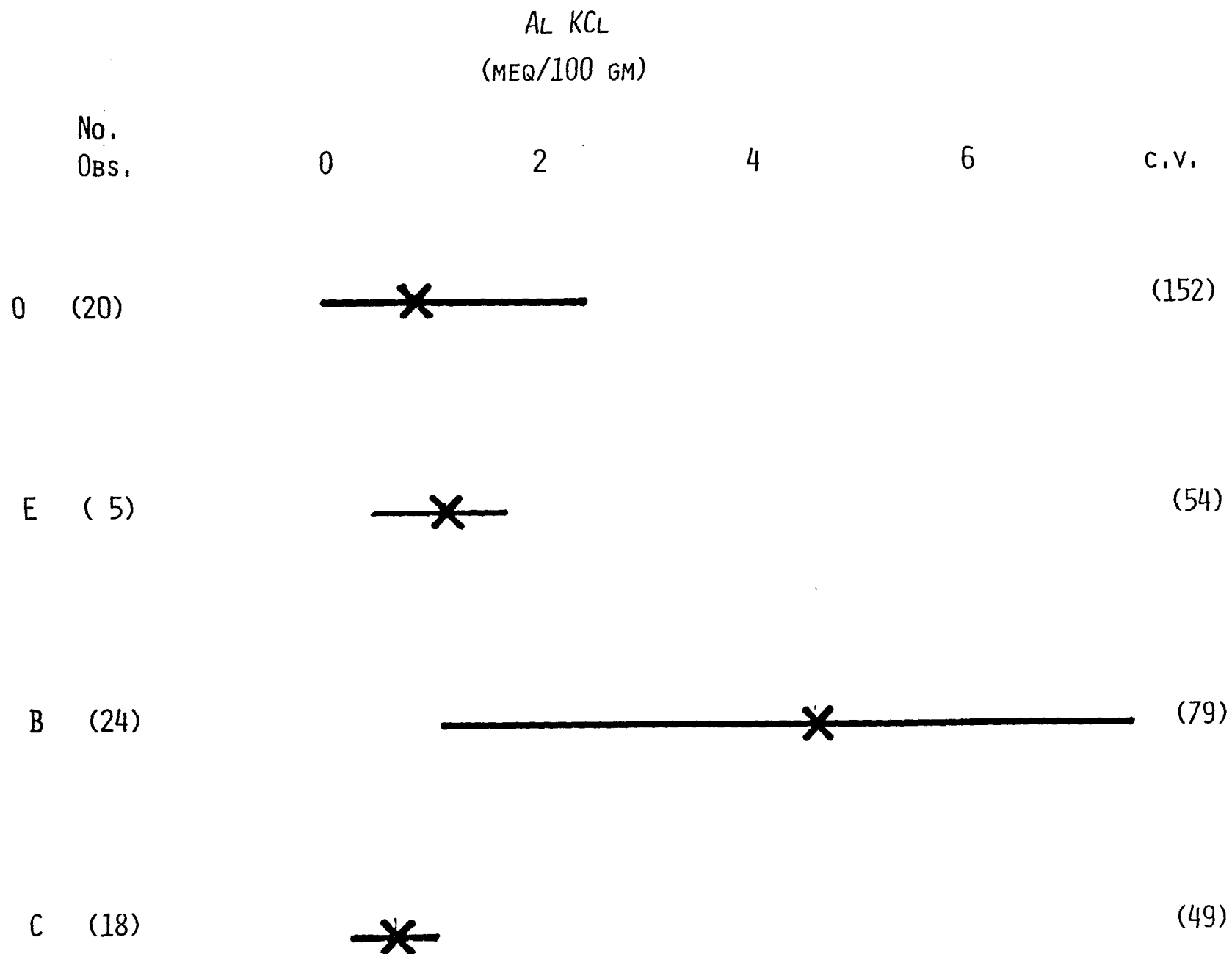


FIGURE 10. NYS BECKET

BASE SATURATION
SUM OF CATIONS (%)

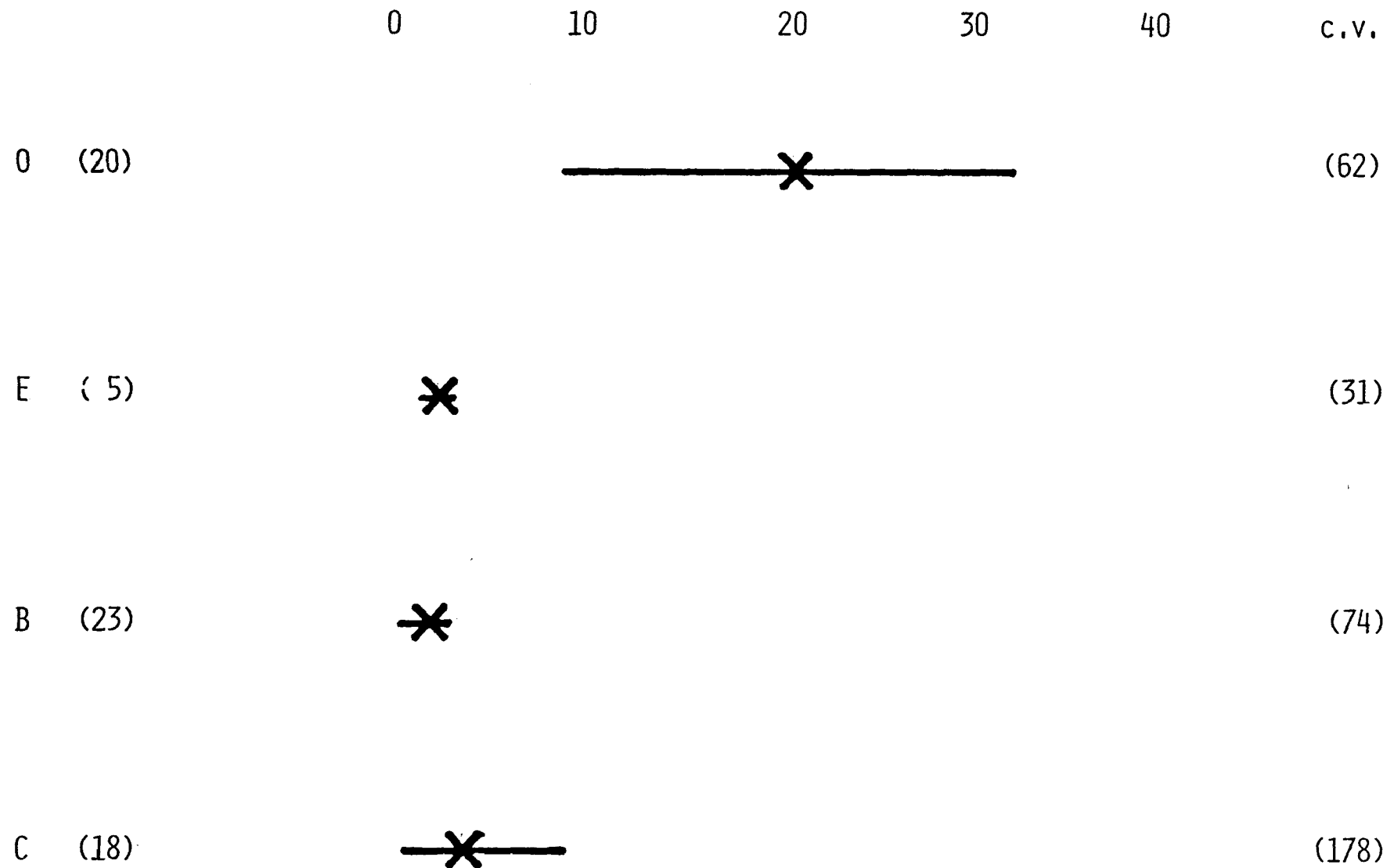


FIGURE 11. NYS BECKET

Cluster analyses of the B horizons of all soils based on 10 common soil chemical characteristics showed 3 major groupings of soils. With the exception of a few outliers, the data clustered by state (i.e., Maine, New York, and Virginia). This probably reflects regional differences in soils but may also reflect lab differences. Within the major clusters for New York state, the Becket, Adams, and Canaan series clustered separately.

Physical -- Physical properties of soils are of significance to hydrologic flow paths and retention times in these soils. Series criteria (i.e., taxonomic definitions) carry information relative to depth of bedrock, fragipans, dense basal till, or gravelly/sandy substratums where these characteristics occur. Soil associations in the pilot study vary with respect to relative composition and spatial distribution of soils and these characteristics. This data as it determines flow path coupled with measured differences in chemical properties in these soils should relate to acidification processes in the watersheds.

6.2.2 Predicting Special Tests

Of primary concern were the special tests: neutral salt CEC and sulfate adsorption.

Neutral salt CEC was successfully predicted by standard characterization tests. The regression equations are as follows:

For E, B, and C horizons (mineral horizons) from New York, Maine, and Virginia where clay and spodic extraction analyses were not included, stepwise regression showed correlations with R-squared values of up to 64.5.

$$CEC_{NS} = 0.48 (\text{Organic Carbon}) - 2.18 (\text{pH water}) + 0.73 (\text{Sum Bases} - \text{NHOAc}) + 0.175 (CEC - \text{NHOAc}) + 11.97 \text{ [R-squared} = 64.15]$$

and

$$\text{CEC}_{\text{NS}} = -2.17 (\text{pH-water}) + 0.79 (\text{Sum Bases-NHOAc}) + 0.175 (\text{CEC-NHOAc}) + 11.027$$

[R-squared = 64.59]

For E, B, and C horizons (mineral horizons) from Maine where spodic extraction analyses were included, stepwise regression showed a correlation with an R-squared value of 72.21.

$$\text{CEC}_{\text{NS}} = 10.25 (\text{CEC-NHOAc}) - 7.0 (\text{Al extract pyrophosphate}) + 1.424$$

[R-squared = 72.21]

For all O horizons (organic horizons) from New York, Maine, and Virginia, stepwise regression showed a correlation with an R-squared value of 69.82.

$$\text{CEC}_{\text{NS}} = 0.86 (\text{Sum Bases-NHOAc}) + 0.49 (\text{Organic Carbon}) + 0.150 (\text{Exchangeable Acidity BaCl}) - 5.866$$

[R squared = 69.82]

For available total sulfate data (water extractable S plus phosphate extractable S), there were very low correlations with clay, organic matter, CEC, extractable Fe and Al by pyrophosphate and CBD. R-squares were less than 10 percent. The available data base was very small and further statistical analysis is needed when lab analyses are completed.

6.2.3 Laboratory Variability in the Pilot Study

In the pilot survey, laboratory variability was compared between the National Soil Survey Laboratory (NSSL, Lincoln, Nebraska; Nebraska), Cornell Soil Characterization Laboratory (New York), and the University of Maine (Maine). As part of the laboratory comparisons, the Maine and Cornell labora-

tories exchanged standard samples of Ca, E, Bhsm, and Bs horizons. Each of these four standards was replicated 10 times and randomly interspersed among field samples for analysis. This interlaboratory comparison provides a good estimate of the precision in soil characterization analyses and also indicates the inherent variability for particular soil horizons (O, E, Bhs, and Bs).

Comparisons between the NSSL and the state laboratories are based upon 9-12 samples which were replicated twice. For example, from the samples sent for special analyses, 10% of the samples were replicated two times for standard characterization analyses. Thus, the statistical comparisons between the NSSL and the state laboratories are rather weak.

Table 6.1 presents the summary statistics for previous analyses of laboratories standards used at the Cornell SCL. The standards selected closely approximate the types of horizons encountered in the pilot survey. From these standards, it is apparent that the lab variability is not uniform across the different horizons. For Oa, Bhs, and Bs horizons, the coefficient of variation is < 20% for most of the characterization analyses. However, in Oi and E horizons (the extremes of % organic carbon), the CV values are considerably greater and largely reflect the inherent variability of the soil material rather than an analytical problem. Thus, the reproducibility or precision of these soil characterization analyses is largely a function of the types of soil horizon and the heterogeneity of the soil material (percent carbon and clay).

Table 6.2 provides the comparisons of Cornell and Maine for the E and Bhsm laboratory standards. In this study, there is a significant difference in the characterization data between the state laboratories. For example, the means for CEC at pH 7.0 on the Bhsm are 18.1 meq/100 g (Cornell) and 8.9 meq/100 g (Maine). Similarly, the exchangeable Ca, exchangeable Mg, KCl-Al, and organic carbon analyses were found to be significantly different between the two state

Table 6.1 Summary statistics for laboratory standards used at Cornell Soil Characterization Laboratory.

Standard		Exchangeable Bases				Exch. Acidity BaCl ₂ -TEA	1N KCl Extr. Al	Sum of Bases	CEC (Sum of cations)	PCT Base Sat	PCT Organic Carbon	PCT Nitrogen	
		Ca	Mg	K	Na								
-----meq/100 g-----													
S84NY 065-01-01 Oi	$\bar{x} \pm$ Std. Dev.	11.2±1.2	0.95±0.22	0.74±0.10	0.09±0.02	97.0±9.5	0.73±0.40	13.0±1.4	110.3±6.9	12.1±1.1	44.9±3.9	1.48±0.1	
	C.V.(%)	10.7	23.7	14.1	18.2	9.8	55.6	10.5	6.3	8.8	8.8	7.2	
S89ME 01-06-02 Oa	$\bar{x} \pm$ Std. Dev.	14.0±1.3	2.58±0.13	0.63±0.11	0.05±0.01	110.3±8.2	1.19±0.19	17.2±1.3	127.5±9.1	13.5±0.8	37.5±3.5	1.22±0.13	
	C.V.(%)	9.1	5.0	17.5	20.0	7.4	15.8	7.3	7.1	5.6	9.2	10.7	
S84Pa 053-07-01 E	$\bar{x} \pm$ Std. Dev.	0.05±0.01	0.02±0.01	0.014±0.01	0.01±0.00	2.6±0.7	0.20±0.03	0.1±0.00	2.7±0.7	3.9±1.1	0.24±0.10	0.01±0.01	
	C.V.(%)	13.9	40.8	36.9	0.00	27.0	16.7	0.0	24.4	26.7	41.6	-	
S84NY 019-01-04 Bhsm	$\bar{x} \pm$ Std. Dev.	0.98±0.03	0.06±0.01	0.02±0.00	0.01±0.00	21.0±1.6	0.69±0.04	1.1±0.0	22.1±1.6	5.0±0.5	1.5±0.1	0.05±0.01	
	C.V.(%)	3.1	16.7	0.0	0.00	7.8	5.9	-	7.4	9.2	6.7	20.0	
S84ME 01-06-04 Bs	$\bar{x} \pm$ Std. Dev.	0.30±0.03	0.07±0.004	0.09±0.004	0.01±0.004	37.9±4.2	3.52±0.33	0.5±0.0	38.9±4.1	1.3±0.1	5.1±0.7	0.18±0.01	
	C.V.(%)	9.3	5.7	4.4	25.8	11.2	9.4	-	10.5	10.3	15.5	6.3	

TABLE 6.2 Comparison of Laboratory Standards used at Cornell and Maine for the Pilot Survey.

Laboratory	Standard		Exch. Bases (meq/100 g soil)			Exch. Acidity BaCl ₂ -TEA (meq/100g)	CEC pH 7.0 (meq/100 g)	PCT Organic Carbon	PCT Total Nitrogen	1N KCl-Al (meq/100 g)
			Ca	Mg	K					
Cornell	S84 Pa 53-07 E	\bar{x}	0.048	n.c.	n.c.	2.60*	1.52*	0.24*	0.012*	n.c.
		CV(%)	4.2%	n.c.	n.c.	27.0%	25.7 %	40.2 %	35.2 %	
	S84 NY 19-01-04 Bhsm	\bar{x}	0.99*	0.06*	0.02 ^{ns}	21.00 ^{ns}	18.1 *	1.51*	0.051 ^{ns}	0.69*
		CV(%)	3.2	8.3	0.0 %	8.2 %	4.4 %	6.6 %	12.5 %	4.8 %
Maine	S84 Pa 53-07 E	\bar{x}	0.068	n.c.	n.c.	3.39*	1.27*	0.37*	0.03*	n.c.
		CV(%)	13.5 %	n.c.	n.c.	51.9 %	57.6 %	18.2 %	106 %	
	S84 NY 19-01-04 Bhsm	\bar{x}	0.88*	0.04*	0.04 ^{ns}	20.20 ^{ns}	8.87*	1.39*	0.051 ^{ns}	0.55*
		CV(%)	9.0	9.5	154 %	5.6 %	56.3 %	2.3 %	87.4 %	15.0

n.c. = not calculated; values were exceeding low for comparison.

* - indicates a significant difference between Cornell and Maine at $\alpha = 0.05$ level.

laboratories. In most of the wet chemical methods, the Cornell SCL had higher values across all the extractions than Maine. Additionally, the coefficients of variation are inflated in the E horizons where the low organic carbon and clay contents result in very little exchange capacity. Therefore, very minor differences between the laboratories appear significant in the E horizon standards.

Comparisons of the state laboratories (New York, Maine) with NSSL (Nebraska) are given in Table 6.3. All analyses performed by New York and Nebraska were highly correlated ($r \geq 0.93$). With the exception of Ca, results from Maine and Nebraska were also highly correlated. The results of regression analysis suggest that values from Nebraska tended to be higher than those from Maine for Ca, CEC-pH 7, and Fe, and lower for organic C. Values for organic C from Nebraska tended to be higher than those from new York. For many regressions, the intercept was consistent with zero, suggesting that a simple proportionality might be an adequate descriptor of inter-laboratory relationships. Statistical analyses of inter- and intra-laboratory comparisons are continuing.

6.2.4 Summary and Recommendations from Laboratory Variability

1. The CV values for the characterization methods vary with the type of soil horizon. E and O horizons present the greatest problems in terms of reproducibility or precision.
2. For many of the wet chemical procedures, the Cornell and Maine laboratory data are significantly different at the 0.05 probability level. However, the differences may be significant for one type of horizon and nonsignificant for another (e.g., E vs. Bhs).

Table 6.3. Comparison of results from state laboratories (New York, Maine) and National Soil Survey laboratory (Nebraska).

Analysis	Correlation (r)		Regression Analysis					
	New York- Maine	Nebraska- New York	Nebraska-Maine			Nebraska-New York		
			a	b	r ²	a	b	r ²
Exch. Ca	0.88		2.5 (2.8)	1.23 (0.25)	0.78			
Exch. Mg	1.00							
Exch. K	0.93							
Exch. Acidity	0.97	0.93				0.95 (7.2)	1.00 (0.13)	0.86
CEC-pH 7		0.98	-9.9 (9.3)	1.15 (0.10)	0.95			
CEC-Cation Sum	0.90	0.96						
Sum of Bases	0.86	0.98						
Base Saturation		0.96	3.4 (2.3)	1.08 (0.25)	0.73			
pH-H ₂ O		0.96						
pH-CaCl ₂	0.98	0.98						
Al-KCl		0.97	0.18 (0.30)	0.95 (0.08)	0.95			
Al-Oxalate			-0.03 (0.04)	1.07 (0.11)	0.93			
Fe-Dithionite- Citrate			0.13 (0.03)	1.88 (0.07)	0.99			
Fe-Oxalate			0.06 (0.02)	1.28 (0.05)	0.99			
Organic-C		1.00	0.20 (0.62)	0.91 (0.02)	1.00	-0.47 (0.52)	1.15 (0.02)	1.00
Total-N		1.00						

* Regressions are of the form $X_{NE} = a + bX_{ME, NY}$. Values in parentheses are standard deviations of estimates of a and b.

3. A major source of laboratory variability is probably associated with the heterogeneity of the soil materials rather than with the laboratory method.
4. In establishing QA/QC levels of precision, a "sliding" window is needed for the different types of soil horizons (e.g., < 20% precision window for the Bhs horizon versus ~ 20-50% precision window for E horizons.)
5. In future projects, choose appropriate internal standards that resemble the types of horizons to be analyzed (if sampling spodosols, use O, E, Bhs, C standards for comparison).
6. In the pilot project, Cornell used 5 standards replicated 10 times each and randomly interspersed with the field samples. The QA/QC standards represented 20% of the total number of samples analyzed. This provided a reasonable estimate of within-laboratory and between-laboratory variability.

7.0 ADDENDUM: INTERPRETATION OF RESULTS FROM PILOT SOIL SURVEY

John Reuss

7.1 PRELIMINARY RESULTS

(Note: This section was prepared after the workshop, and represents an interim report from a continuing analysis of Pilot data; see Section 1.4.)

Initial results from the Pilot Soil Survey are now available. These must be interpreted with caution as data are still being entered and files edited. Patterns discernible at this time appear to be highly relevant to water acidification due to acid deposition. It seems highly likely that these patterns will persist when all data have been entered and edited.

Parameters related to the ability of soils to buffer the system in such a manner that input acidity will not be passed onto the surface waters can be divided into three general classes, i.e.: (1) anion adsorption buffering mechanisms (sulfate adsorption); (2) ion exchange buffering; and (3) replenishment of bases through weathering of primary minerals. The discussion here relates largely to parameters that determine the capability of the watershed to buffer through ion exchange processes. A preliminary discussion of sulfate adsorption measurements is also reported. No mineralogical analyses were included in the Pilot effort.

Early work on "soil sensitivity" tended to focus on "soil pH," cation exchange capacity (CEC), total exchangeable bases (SB), and base saturation (BS). These parameters are interdependent, i.e., $BS = (SB) / (CEC)$, and pH has been proposed as a proxy for base saturation (McFee, 1980). Later workers using mechanistic models (e.g., Reuss and Johnson, 1985) have suggested

modifications and/or additions to the list of parameters. In this modified list base saturation is highly important. Total exchangeable bases and CEC are important as factors that determine base saturation, and also in determining the capacity to delay acidification. As used in these models, however, the CEC used in calculating base saturation must represent the charge at soil pH (neutral salt CEC) rather than that measured using solutions buffered at pH 7.0 or higher, as is common for agricultural or soil survey purposes. Additional parameters that such models have shown to be important are the characteristic relationships of pH to solution Al^{3+} levels (expressed as $3pH - pAl$ designated here as K_A), and relative affinity of the ion exchange for Ca^{2+} or Al^{3+} [this affinity may be expressed by the selectivity coefficient of Gaines and Thomas (1953)], designated here as K_S . Some models (Chen et al., 1984; Christophersen and Wright, 1980; Reuss, 1978) use the lime potential ($pH - 1/2 pCa$) as an input rather than base saturation and the selectivity coefficient. This is not an independent parameter, as it can be shown to be functionally related to the base saturation, pAl , and K_S . It is, however, relatively easy to determine experimentally whereas most experimental methods for determining K_S are very difficult. For this reason, in the Pilot Survey, lime potential, K_A and base saturation were determined experimentally, and the selectivity coefficient (K_S) has been calculated using the relationship of Reuss (1983).

The results reported here are from the "pedon analysis." These are profiles sampled in or near the various NLS watersheds selected for the Pilot Soil Survey. A sampled pedon is not necessarily intended to represent the watershed from which is selected. Rather, it is intended to represent the soil series as determined by the field surveyor. Soil series that are very common on the watersheds are represented in the Pilot Survey by as many as 10 pedons, whereas minor series are likely to be represented by only a single pedon.

Samples from New York were all from NLS watersheds in the Adirondacks. Samples from Maine were from watersheds sampled by the NLS and falling within their specific mapping units as shown on the large scale state "soil association" (schematic) mapping units. Watersheds $> 25 \text{ km}^2$ or those including cropland or housing developments were excluded.

The results reported here are from the mineral soil horizons. As expected, we have found little indication of differences among organic horizons attributed to regions or taxonomic groupings. Furthermore, it is likely that these sensitivity parameters cannot be meaningfully applied to organic horizons.

Mean values for New York and Maine for the mineral horizons are shown in Table 7.1. The CEC values are slightly higher in New York than in Maine, but the differences are not significant nor are they likely to be important in terms of acid deposition effects. The mean neutral salt base saturation, however, is generally about twice as high (0.22 to 0.27) in Maine as in New York (0.09-0.12). This effect appears to be real, although refinements in the test of significance may be required due to an obvious non-homogeneity of variance.

This result is important as the lower base saturation values should be associated with drainage water acidity at lower values of input acidity. One would expect that drainage waters from the watersheds in New York would become acid at a lower deposition level than those in Maine. It is not possible to discern whether this is due to an original lower base saturation level in the New York soils or whether the original levels were similar and the differences developed from greater cation losses due to acid deposition. Rough calculations suggest such differences could develop due to deposition over a couple of decades if bases exported are not replaced.

Table 7.1. Comparison of sensitivity parameter means from mineral soil horizons sampled in New York and Maine. Data are preliminary and means and tests of significance (t tests) must be regarded as approximate.

	Horizon					
	E		B		C	
	NY 16	ME 13	NY 37	ME 22	NY 12	ME 9
CEC (Neutral Salt)	6.38 ns	7.89	11.2 ns	8.8	2.57 ns	2.20
Base Saturation (Neutral Salt CEC)	0.11 *	0.25	0.12 *	0.22	0.09 *	0.27
pH - 1/2 pCa (Lime Potential)	1.83 ns	2.04	2.60 **	2.92	3.05 ns	3.24
3pH - pAl (K_A)	6.06 ns	6.71	8.45 **	9.30	9.23 **	10.17
Log Selectivity coefficient (K_S)	2.25 ns	1.79	1.70 ns	1.97	3.01 **	1.01
pH (Water)	3.82	3.49	3.43	4.20	5.01	4.60

* Significant at 5% level.

** Significant at 1% level.

ns = Not significant.

Both the lime potential and the K_A values tend to be lower in New York and the differences appear highly significant in the B horizon, and in the case of K_A in the C horizon as well. Lower values of either of these parameters would be associated with a greater sensitivity to acid deposition (i.e., alkalinity loss would occur at a lower level of deposition). These sensitivity parameters should not be regarded as independent, as intercorrelation may be expected. For example, the lime potential should be related to both the base saturation and K_A , and these parameters are both used in the calculation of K_S . It would probably be inappropriate to attempt any interpretation of the K_S values at this time.

No tests were made to compare values of pH (determined in soil-water suspensions) between the samples from different states. These analyses were done in different laboratories and such comparisons probably are not justified until interlaboratory comparisons of check samples are available.

Another tendency apparent from Table 7.1 is that K_A and lime potential tend to increase deeper in the profile. This would suggest that water passing through C horizons might regain alkalinity, whereas those draining directly from E or B horizons might remain acid. This tendency is also reflected in pH of soil-water suspensions and is consistent with current thinking as well. The low base saturation and higher pH and K_A values in the C may reflect a higher content of unweathered primary minerals.

One point of considerable importance for the larger survey being planned is the variability of sensitivity parameters within and among mapping units. The basic mapping unit for the standard Order 2 National Cooperative Soil Survey is the consociation (essentially, soil series). In the Pilot Survey, three series (Becket, Canaan, and Adams) were represented by five or more pedons. The means and standard deviations for a selected set of parameters for

all New York samples and for these three series (with the exception of one Becket in Maine, these pedons were all from New York) are shown in Table 7.2. With the exception of CEC, the means and standard deviations among these parameters for the Becket B horizon are about the same as those for all New York pedons. Thus, knowing that the soil belongs to the Becket series seems to give little or no more information concerning these particular parameters than knowing that the pedon came from the New York population. The standard deviation for the Adams and Canaan series, however, are generally well below those for all New York pedons. Thus, knowing the soils are Canaan or Adams series seems to place considerably tighter bounds than simply knowing that they are from New York. These results suggest the variance of these parameters within different series may be quite different. It is entirely possible that as other parameters are considered (e.g., sulfate adsorption), we may find that series that are highly variable in certain parameters may be quite homogeneous in others.

Preliminary analysis of sulfate adsorption data is summarized in Tables 7.3 and 7.4. The first table describes distribution of total extractable sulfate by horizon in soils from the three states, and indicates significant differences among the states and between soil horizons. Adsorbed sulfate concentrations are higher in Virginia soils than in Maine or, particularly, New York soils -- concentrations are 1.5 to 3.5 fold higher in Virginia B horizons, and 5 to 10 fold higher in the A/E and C horizons. Variability within states has received only very preliminary analysis, but there appear to be significant differences among soils from different series and associations in New York and Maine. Note, however, that inasmuch as those analyses were based on unverified data and small sample sizes, the finding of intra-state variability must be regarded as tentative.

Table 7.2

		<u>New York</u>	<u>Becket</u>	<u>Canaan</u>	<u>Adams</u>
	(n)	All (37)	(12)	(10)	(5)
CEC meq/100 g	\bar{x}	11.22	11.08	11.67	2.32
Neutral Salt	sd	7.44	4.65	5.02	2.06
Base Saturation	\bar{x}	0.12	0.14	0.12	0.13
Neutral Salt CEC	sd	0.07	0.07	0.10	0.04
pH - 1/2 pCa	\bar{x}	2.60	2.54	2.64	3.19
Lime Potential	sd	0.48	0.60	0.18	0.09
3pH - pAl	\bar{x}	8.45	8.19	8.71	9.41
K _A	sd	0.93	1.14	0.26	0.25
Log Selectivity	\bar{x}	1.70	1.60	1.55	3.00
Coefficient K _S	sd	0.63	0.50	0.23	0.19

Table 7.3. Total extractable sulfate (water plus phosphate extractable) in soils from Maine, New York, and Virginia soils sampled during EPA's pilot survey in autumn 1984. Values are expressed as mg S.kg⁻¹ soil, the number in parentheses represents one standard deviation.

Horizon	Maine		New York		Virginia	
	n	Total SO ₄	n	Total SO ₄	n	Total SO ₄
A		---			6	65.8 (<u>±</u> 45.0)
E	8	6.5 (<u>±</u> 1.3)				
B	27	55.9 (<u>±</u> 42.6)	38	24.7 (<u>±</u> 24.8)	5	87.1 (<u>±</u> 66.8)
C	19	18.5 (<u>±</u> 12.7)	25	11.1 (<u>±</u> 3.4)	5	62.8 (<u>±</u> 39.3)

Table 7.4. Sulfate adsorption capacity of soils from Maine, New York, and Virginia during EPA's pilot soil survey. Adsorption capacity was determined using a Langmuir isotherm fit of adsorbed sulfate and experimental isotherm data for each horizon sampled. Values are reported in mg S.kg⁻¹ soil; the value in parentheses is one standard deviation.

Horizon	Maine		New York		Virginia	
	n	SAC	n	SAC	n	SAC
A		NA ²		NA	6	83 (+ 43)
B ³	22	130 (+ 45)	46	91 (+ 54)	5	121 (+ 64)
C ³	18	36 (+ 22)	14	27 (+ 10)	5	98 (+ 39)

¹ SAC = sulfate adsorption capacity.

² NA = data not yet available.

³ Samples for Maine and Virginia used a pooled sample from all subhorizons of the B and C horizon; New York samples had up to 5 samples from subhorizons of the B horizon; the value reported is an ameliorated average of all B horizon samples.

Data analyses are incomplete, but a somewhat different relationship exists for sulfate adsorption capacity of soils from the EPA pilot Survey (Table 7.4). Maximum adsorption capacities (from a Langmuir isotherm fit of data) are comparable for B horizon soils from the three states (Maine, New York, Virginia), but the adsorption capacity of C horizon soils is substantially higher for Virginia soils. This is consistent with findings of Johnson and Todd (1983) who found relatively small differences in B horizon adsorption capacity of Spodosols and Ultisols, but large differences for A and C horizon soils, with markedly higher sorption capacity for southern Ultisols. The implication of these findings is that although B horizon adsorption behavior may be similar in the two regions, integrated adsorption capacity of the pedon is higher for southern soils. Although this may be true on broad regional scales, spatial heterogeneity within the regions is significant and localized sulfate mobility may vary widely. There is a critical need for data on variability within all the regions of interest as well as characterization of sulfate adsorption by soils that have been poorly studied.

7.2 PRELIMINARY INTERPRETIVE SUMMARY -- PEDON ANALYSIS

Soil parameters in the watersheds sampled in Maine, New York, and Virginia were generally within the expected range. One exception is the low neutral salt base saturation in New York (mean for the mineral horizons in the range of 0.09-0.12). The indication that these New York base saturations are substantially lower than those in the Maine watersheds (means 0.22-0.27) was unexpected.

A similar pattern seems to be present for other sensitivity indicators, that is, drainage waters from New York pedons might be expected to develop

negative alkalinity (net acidity) at lower deposition levels than those in Maine.

It is not possible to determine whether the difference in base status reflects inherent differences in the soil or is due to greater cation export due to (possible) heavier acid deposition loading in New York. Rough calculations suggest the differences are of a magnitude that could develop due to differential loading over a few decades unless compensated by accelerated weathering. This needs to be examined much more carefully, both in the pilot data and in the larger survey.

On balance, there are few "surprises" in the adsorbed sulfate data from the pilot survey. The current sulfate loading is higher in Virginia soils than in the soils from New York and Maine, particularly in the A/E and C horizons. Sulfate adsorption capacity is similar in B horizon soils from the three states, but substantially higher in C horizon soils in Virginia. There also appear to be significant differences in sulfate adsorption characteristics among soil series in Maine and New York; future efforts in interpreting Pilot data will be oriented toward correlating those differences with other soil properties.

The implications of current results for estimating sensitivity from standard soil survey taxonomic groupings are mixed. For parameters examined to date, variability within some series is substantially less than overall variation, whereas within other series this is not the case.

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Appendix 1

PHYSICAL PARAMETERS REQUESTED FROM SOIL SURVEY BY NSW

[with comments from Pilot Soil Survey Workshop]

A. Geology

1. Type of bedrock [From bedrock map, unless exposed]
2. Percent of bedrock exposed [Primarily from air photos; classes to be differentiated?]
3. Degree of fractionation [Can't do with any accuracy; probably simple yes/no designation]
4. Parent material (type of material, i.e., glacial till, outwash, alluvium, collovium, residual, lacustrine, marine sediments, eolian sands and beaches, etc.)

B. Site Description

1. Site position (i.e., upland, flood plain, stream terrace, moraine, depression, kame terrace, etc.) [Need to use standard terminology]
2. Percent slope [Classes to be differentiated?]
3. Average slope length and configuration [Length classes? Whose configuration convention?]
4. Stream type and density [Maps will indicate location; need geomorphologist or hydrologist to define classes of type]
5. Vegetation type (major timber types and ground cover species)
[Society of American Foresters classification]

C. Soil Morphology (by horizon)

1. Horizon designation
2. Horizon depth (upper and lower boundaries)
3. Type of boundary
4. Color
5. Structure
6. Consistence
7. Drainage class
8. Mottles (where, color, distinctness, frequency)
9. Root distribution
10. Presence of impermeable layers [estimation of permeable class by horizon]
11. Field textures (including coarse fragments, types, and classes)

D. Physical Laboratory Parameters

1. Bulk density
2. Mineral soil texture
3. Percent coarse fragments

UNDERSTANDING SOIL MAPS

J. A. Ferwerda

A soil map is a convenient way of showing the location and extent of the kinds of soil of an area. Many kinds of soil maps are being made throughout the world today. They fit into three broad classes:

1. Soil Survey Maps
2. Generalized Soil Maps
3. Schematic Soil Maps

Soil survey maps are made by field methods and require field investigations of the soils. Generalized soil maps are made by combining the delineations of pre-existing soil survey maps to form larger areas. Schematic soil maps are made by predicting the geographic distribution of different kinds of soil from many sources of information other than from existing soil survey maps. Schematic maps are generally small scale maps--1:1,000,000 or smaller--and often serve as preliminary maps for locating areas that need further investigation.

Like other maps, soil maps have their merits and limitations, generally governed by map scale and projected use. For example, a traveler about to make an automobile trip from Bangor, Maine, to San Francisco, California, to visit a friend does not select a map scale of 1" = 1 mile to plan his trip. He generally will sketch out his trip on a map of 1:7,500,000 scale or smaller to determine which states to travel through. As he travels through each state he will select a state map of about 1:500,000 scale that shows the major roads and highways. When he reaches the city of San Francisco, he will need a still more detailed city map at a scale of 1:7,000 or so that will show the individual streets of San Francisco, and finally he will consult a sketch map at 1:500 scale that will show the exact location of the house he is looking for.

The same principle of credibility applies to soil maps. What can be shown on a soil map depends primarily on its scale. In designing soil surveys the projected use of the survey and the complexity of the soil patterns on the ground largely determine the scale of the soil map. One must always keep in mind that the soil pattern on the ground is fixed--it does not change. What one sketches on a piece of paper (air photo) does not change the soil pattern on the ground. What one can show on the soil map is determined by the scale of the map, the skills of the mapper, and the complexity of the soil pattern on the ground.

A soil map should be designed to provide the necessary information and accuracy needed for a particular use. A 1:15,840 (4" = 1 mile) soil map does not provide enough information for all uses but it does provide soil information for many planning uses.

If soil information down to 0.5 acre is needed, the area should be mapped at 1:7,920 (8" = 1 mile) or larger scale. If 40 acre differences in soil are needed, a soil map at 1:62,500 may suffice.

When using soil maps, one must remember that scale, accuracy and detail are not the same thing.

Map scale is the relationship between corresponding distance on a map (a piece of paper) and the actual distance on the ground.

Map accuracy is the degree or precision with which map information is obtained, measured, and recorded.

Map detail is the amount of information shown on a map. The more information, the more detailed the map.

Obtaining map information that provides sufficient data for the purpose of making the map is generally more important than accuracy or scale. However, map scale, map accuracy, and map detail are interrelated. Their degree of refinement depends on the objective or purpose for making the soil survey map and the complexity of the soils on the ground. A large-scale map is not necessarily more accurate or more detailed than a small-scale map. Generally, a large-scale map can and does show more detail than a small-scale map. As stated earlier, soil survey maps are made by field investigation methods. The accuracy of the maps is determined largely by the complexity of the soils and the skills of the mapper. In the United States, the National Cooperative Soil Survey makes five kinds of soil survey maps designated Orders 1 through 5. Order 1 maps provide the most detail (or information) and Order 5 the least detail.

Order 1 soil survey maps are generally at a scale larger than 1:12,000 (1" = 1,000'). At 1:12,000 scale the minimum size delineation is about 1.5 acres. Order 1 soil maps are made for purposes that require appraisal of the soil resources of areas as small as a building site or an experimental plot. Mapping scale can be as large as 1:1. The soils in each delineation in Order 1 soil survey maps are identified by transacting and traversing by a soil scientist or mapper. Soil boundaries are observed

throughout their length. Any soils that affect potential use but are too small to be delineated are shown by defined spot symbols. Mapping is generally done on a recent air photo base.

Order 2 soil survey maps are generally at a scale of 1:12,000 to 1:31,680 (1" = 2,640' or 2" per mile). At these scales the minimum size delineation is 1.5 to 10 acres. Order 2 soil survey maps are made for purposes that require soil resource information for planning use of fields, farms, and other land areas that require intensive management. The soils in each delineation are identified by transecting and traversing by a soil scientist. Soil boundaries are plotted by observation and interpretation of air photos; these boundaries are verified at closely spaced intervals. Small areas of unlike soils are shown by defined spot symbols.

Order 3 soil survey maps are generally at a scale of 1:24,000 to 1:250,000 (1" = 20,833' or 0.25 inches per mile). At these scales the minimum size delineation ranges from 6 to 640 acres. These soil maps are useful for planning: soil resources of large forested tracts, watersheds, wildlife refuges, counties and other land areas that have projected extensive land uses such as rangeland, woodland, county, and multi-county planning. The soils in each delineation are identified by transecting, traversing, and some field investigations. Boundaries are plotted by observation and interpretation of remotely sensed data (air photos mostly) and verified with some field observations.

Order 4 soil survey maps are made at scales of 1:100,000 to 1:300,000 (0.21" = 1 mile). At these scales minimum soil delineations range from 100 to 1,000 acres. These maps are generally useful for planning the soil resource of large areas such as counties. The soils in each delineation are identified and their patterns and composition determined by transecting. Subsequent delineations are mapped by some traversing, by some observation, and by interpretation of remotely sensed data verified by occasional ground truth observations. Soil boundaries are plotted by air photo interpretations.

Order 5 soil survey maps are generally at a scale of 1:250,000 to 1:1,000,000 (0.063" per mile). Minimum size delineation ranges from 640 to 10,000 acres. These maps are made when information about the kind and distribution of soils is needed quickly for areas with limited soil data and for areas with difficult access. They are also made to locate large areas of soils for planning the soil resources of states and nations. The soils, their patterns, and the composition of each map unit are identified by mapping selected areas (15 to 25 sq. miles) with

Order 1 or Order 2 surveys or, alternatively, by transecting. Mapping is by widely spaced observations or by remotely sensed data with occasional verification by observation or traversing.

Soil maps can be a very useful tool in planning the use or development of a tract of land. Soil maps, however, must be used within the purposes for which they were designed.

A generalized soil map of a state at 1:750,000 scale should not be used to locate soils or soil suitability of individual fields or house lots. It is useful for planning the broad use of a state's soil resources. A 1:20,000 soil survey map is useful for planning fields, farms, and communities. It is not useful for planning 0.1 acre research plots.

In many places the pattern of soils is very complex, and in some places soils grade imperceptibly to other soils. Because of this, the soil units, even on a large-scale soil survey map, may not be absolutely homogenous or pure; thus on-site investigations are needed for specific small land area uses. For example, on-site investigations are needed to determine the suitability of a 0.1 acre plot for a septic tank installation for mapping units on Order 2 soil survey maps.

A common misuse of soil maps is to "blow them up" to a larger scale. This does not result in a more detailed or accurate map. In fact, the "blown up" map is misleading because if the mapping was made at the larger ("blown up") scale, more detail could be shown. Soil survey maps at 1:20,000 scale "blown up" to 1:12,000 are no more accurate or detailed than the original 1:20,000 map.

Many times the information on soil maps is transferred to other base maps, often at different scales. This diminishes the new map's accuracy, especially if the base map is not planimetrically correct, and more so if the scale is larger than the soil survey map.

An example is transferring a 1:20,000 soil survey map to a larger scale, 1:12,000 town map. When the soil survey map information (1:20 scale) is transferred to a smaller scale map, i.e., 1:50,000, accuracy is generally maintained but the detail of the soil map is less.

It is common practice to use soil maps as a basis for making soil suitability or soil interpretation maps for a specific use. Technically, these suitability maps are not "soil maps" but are single purpose "soil use potential" maps. These maps are generally colored green, yellow and red to show good, fair and poor suitability for a given use, or some other scheme is used to combine like soils for a given use. These soil suitability maps are very useful to planners when making decisions for land use. These soil suitability maps have the same credibility and limitations of the soil maps from which they are made. In addition, it must be borne in mind that soil suitability maps are made only on the basis of soil properties which affect that particular use. Soil suitability maps do not take into account such things as present land use, size of area, location, markets, roads, water bodies, accessibility; and other economic, esthetic, and environmental factors not tied directly to soil properties. These non-soil factors also affect the use and potential of a parcel of land. In some cases the non-soil factors may make it feasible and desirable to develop a piece of land for a particular use that has poor soil suitability for that use.

It is important to recognize the different kinds of soil maps, to know their merits and limitations and to understand the relationship of map scale, map accuracy, and map detail. With these principles in mind, a soil map can be a useful tool for the planner of small tracts of land, farms, communities, states, nations, and even the world.

GUIDE TO MAP SCALES AND MINIMUM SIZE DELINEATIONS

Map Scale	Inches Per Mile	Minimum Size Delineation ¹	
		Acres	Hectares
1:500	126.7	0.0025	0.001
1:2,000	31.7	0.040	0.016
1:5,000	12.7	0.25	0.10
1:7,920	8.00	0.62	0.25
1:10,000	6.34	1.00	0.41
1:12,000	5.28	1.43	0.57
1:15,840	4.00	2.5	1.0
1:20,000	3.17	4.0	1.6
1:24,000	2.64	5.7	2.3
1:31,680	2.00	10.0	4.1
1:62,500	1.01	39	15.8
1:63,360	1.00	40	16.2
1:100,000	0.63	100	40.5
1:125,000	0.51	156	63
1:250,000	0.25	623	252
1:300,000	0.21	897	363
1:500,000	0.127	2,500	1,000
1:750,000	0.084	5,600	2,270
1:1,000,000	0.063	10,000	4,000
1:5,000,000	0.013	249,000	101,000
1:7,500,000	0.0084	560,000	227,000
1:15,000,000	0.0042	2,240,000	907,000
1:30,000,000	0.0021	9,000,000	3,650,000
1:88,000,000	0.0007	77,000,000	31,200,000

¹The "minimum size delineation" is taken as a 1/4 x 1/4 inch square area (1/16 sq. in.). Cartographically, this is about the smallest area in which a symbol can be printed readily. Smaller areas can be delineated, and the symbol lined in from outside, but such very small delineations drastically reduce map legibility.

A soil survey is a field investigation of the soils of a specific area, supported by information from other sources. The kinds of soil in the survey area are identified and their extent shown on a map, and an accompanying report describes, defines, classifies, and interprets the soils. Interpretations predict the behavior of the soils under different uses and the soils' responses to management. Predictions are made for areas of soil at specific places. Soils information collected in a soil survey is useful in developing land-use plans and alternatives involving soil management systems and in evaluating and predicting the effects of land use.

A map unit is a collection of soil areas or miscellaneous areas delineated in mapping. A map unit description is generally an aggregate description of the delineation of many different bodies of a kind of soil or miscellaneous area but could conceivably consist of one delineated body. Map units are usually named for taxonomic units.

Depending on the complexity of the soils, the purpose for which the survey is made and the scale of mapping, the map units may be simple or complex.

Map units in Maine for this project are associations of soil series. The soil maps were made at 1:62,500 scale USGS-topographic base. The maps were made by using existing soil maps if available, air photo interpretation and traversing part of the watershed to confirm map units.

Map units can be interpreted by the soil series components of the association. Confidence of interpretations, of course, depends on the purpose for which the survey is made. At this intensity of mapping the minimum size delineation can be as small as 40 acres. These maps can be interpreted for planning: management of forests, watersheds, wildlife refuges, rangeland and other extensive uses. Broad or general relationships between soils and their use or reaction to inputs can be made.

The hydrology of the watersheds can be related to SCS hydrologic groups for each series in the watershed and can be generalized for each map unit or for the whole watershed.

DEVELOPMENT AND USE OF GRAPHICAL SOLUTION OF BINOMIAL
CONFIDENCE LIMITS IN SOIL SURVEY

Richard W. Arnold
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INTRODUCTION AND BACKGROUND

The Soil Resource Inventory Group (1978) at Cornell University had been looking for methods to estimate the minimum number of observations required to check the accuracy of an existing soil survey map. Dos Santos (1978) and Perez-Oraa (1979) used a cluster analysis equation and worksheet developed by the group for analyzing map unit composition. The cluster analysis approach was based on the brief discussion by Cochran (page 500) in Snedecor's (1956) book, STATISTICAL METHODS. It is a method for calculating the standard deviation of a sample proportion of a binomial distribution where clusters are of unequal size. Random transects of varying lengths crossing delineations of a map unit were considered to be clusters of unequal size. Having determined the standard deviation it was possible to calculate the standard error, confidence limits for a given probability level, and even estimate the number of average-length transects required to obtain a state degree of accuracy of the population mean. Although the calculations are not difficult, they are time-consuming and seem to command too much effort by field men for the results.

The work by Dos Santos (1978) indicated that sampling strategies for various types of landscapes could be developed. In some areas closely spaced point transects were most efficient, while in others it might be line transects, or points spaced farther apart. In none of his instances did pilot area mapping show to be as efficient in determining composition at the same level of accuracy.

Several papers came to our attention that provided ideas for a quicker solution. Van Gendersen et al. (1978) presented a method for allocating a number of sample points in a class of interpreted land use to estimate the classification accuracy. The concept incorporates the probability of making incorrect interpretations at prescribed accuracy levels of interpretation. To us this sounded similar to inclusions in soil map units. Their method indicates the number of errors for a particular sample size using the binomial expansion and is useful for determining the minimum number of randomly selected ground truth points for an α level of 0.05 (1 in 20 chance of being wrong). I think it was their discussion of having errors that motivated us to keep trying until we could reproduce their answers. We eventually realized that the errors are simply (1-number observed) listed in Snedecor's tables of confidence intervals for binomial distributions (1956, pages 4 and 5).

A paper by Hord and Brooner (1976) demonstrated how to determine the accuracy of classification using a quadratic equation to estimate confidence intervals for a binomial probability function. They prepared tables for sample numbers

from 50 to 200 in 50 unit intervals which gave limits of accuracy from .8 to 1.0. We eventually learned how to solve the quadratic equation on a hand calculator. The two roots of the equation are the upper and lower confidence limits for a given sample size with a certain error and at a particular probability level. This meant we could reconstruct the tables shown by Snedecor.

Graphs of accuracy or confidence limits versus sample sizes are exponential, clumsy to use, and hard to read. What we wanted was a way to relate the number of errors (inclusions) to the total sample and estimate the accuracy. The trick is to take a particular sample size, say 40, and for each error from 0 to 40, calculate the confidence limits using the quadratic equation approach described by Hord and Brooner. Then you interpolate between values to obtain the error term associated with a particular accuracy. For example, with a 1 in 10 chance of being wrong (90% probability level) an accuracy of 80% corresponds to about 12.3 errors and an accuracy of 60% corresponds to about 20.8 errors. We kept doing this until we could draw lines connecting the same levels of accuracy and they turn out to be straight lines. How convenient!

The graphs we have produced use the number of ground truth observations on the Y axis and the number of "other than" class members on the X axis. Previously, we called the X axis the errors but realized that inclusions are not really errors, they are simply observations that belong to classes other than the one we have called the delineation. The levels of accuracy (maximum = upper confidence limit and minimum = lower confidence limit) are shown as straight lines and interpolations can be made between them. The estimates obtained by this graphical solution are more than adequate for our purposes in soil survey. In fact, they are adequate for much of our research as well.

USE OF CONFIDENCE LIMITS

When we use classes that are mutually exclusive the decisions about any one class membership constitute a binomial experiment. We note that an observation either belongs to the class of interest, or it belongs to some other class. It is included or excluded; it is a yes or no decision.

In making probability statements you have trade-offs. For any set of observations, you can vary the chances of being wrong (probability level) or you can vary the limits of accuracy (degree of correctness). It is always a compromise. If you want to be really confident of your statement (say only 1 chance in 100 of being wrong) the limits will be very wide. On the other hand, if you like to gamble (1 chance in 5 of being wrong), then the stated limits will be very narrow. If a sample is truly representative of a larger population about which one wants to say something, then by increasing the number of samples the limits will become narrower. This is easy to understand when you consider that if we measured all pedons in a map unit we would have a perfect fit and the answer would be absolutely correct. And if we do that there is no need for statistics!

In the graphs presented there are only two levels of probability. One set is for 1 in 10 chances of being wrong (90% probability level) and the other set is for 1 in 20 chances of being wrong (95% probability level). For each probability level there are 4 graphs; 2 giving confidence limits for samples up

to 350. Thus, you have some flexibility in the size of your sample and in the probability level.

A lower confidence limit lets you make an at least statement. When you make 40 observations and 10 belong to other classes, the measured percent is 75% and graphically you note that at least 62% is estimated to be the same class (1 in 10 chance of error).

An upper confidence limit lets you make an at most statement. With the previous example you note that at most 83% is estimated to be the same class.

All too often we report only our guesstimate of the proportion found in a sample or suspected of being found. It is more realistic to give ranges based on the sample data at our disposal. Every decision we make is based on our perception of the correctness of the information and on our perception of the risk or expected consequence of making this decision versus an alternative decision.

How Many Samples to Take

The minimum number of observations to make varies with the chances of being wrong (probability level) and the level of accuracy (degree of correctness) desired.

The graphs for the lower confidence limit can be used to estimate how many samples will be needed. Set probability at 90% and assume you want your estimate to be at least 80% accurate when applying the sample results to the rest of the map unit. Follow the 80% line for minimum level of classification accuracy down to the Y axis where there are 0 "other than" class members and you note 14. This means you need 14 random observations all belonging to the same class, that is 14 out of 14. If you expect, or find, 3 observations that belong to other classes, then go to 3 on the X axis and vertical till you cross the 80% accuracy level and over on the Y axis where it indicates a need for about 38 observations. That is with 35 out of 38 observations belonging to the same class, you will expect an 80% accuracy of the major component.

Another way to think about samples is when you plan to take 200 samples (observations) then you must not have more than about 27 observations in other classes if you hope to at least achieve 80% accuracy.

The graphs for upper confidence limits are not applicable to estimate sample numbers. By looking at one of the upper limit graphs, you can see that the lines do not intercept the Y axis above zero, and we do not know what a negative sample is.

Estimating Composition

Based on the proportion you find in a sample, you are trying to estimate what the proportion will be in a larger population. You extrapolate from measurements made in a few delineations to what may be true for the whole map unit.

Assume you made 4 transects having 3, 9, 7, and 11 observations for a total of 40. Out of that 40 only 30 belonged to the same class. The predicted max-

imum accuracy would be about 83% and the minimum accuracy would be about 62%. You, therefore, are estimating that the map unit will have between 62 and 83% of the major component based on your set of observations and assuming a 1 in 10 chance of being wrong.

Estimates of each component can be obtained from the graph, or if necessary, by extending the graph if you maintain the same intervals on both the X and Y axes.

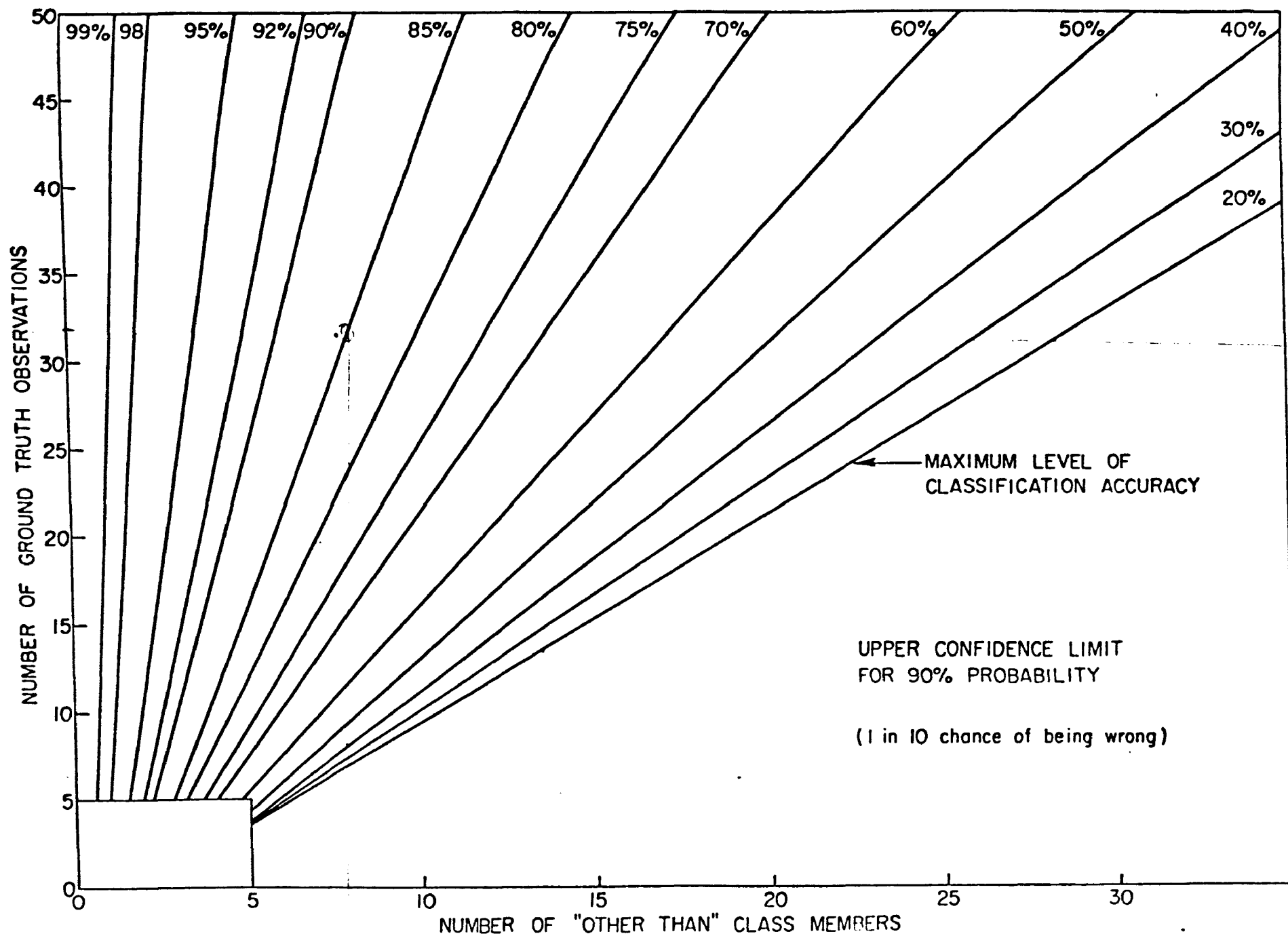
This same procedure applies to consociations, complexes, and associations. It also applies to other features such as stoniness, rock outcrop, and in as many ways as your mind decides to try.

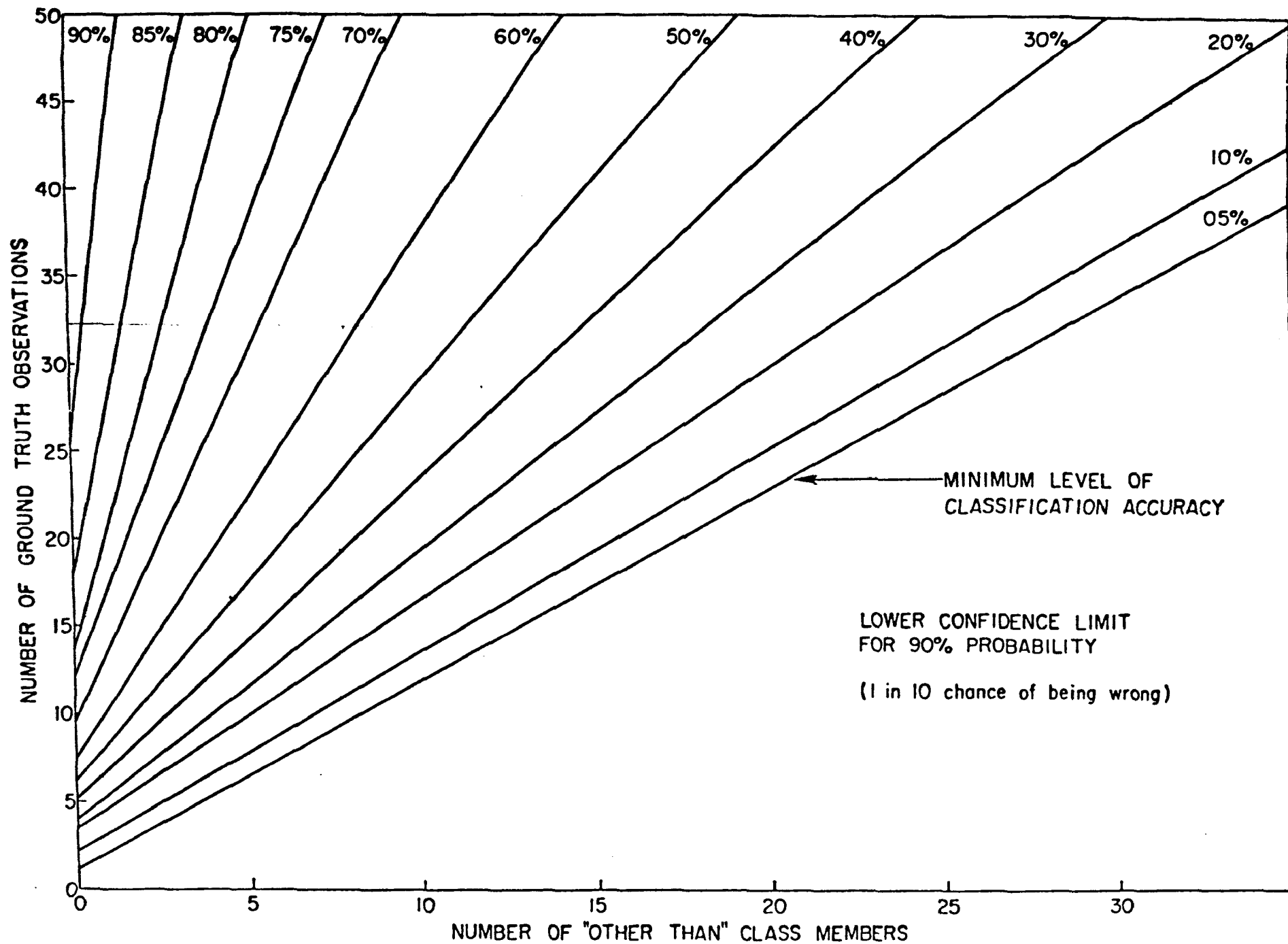
SOME COMMENTS

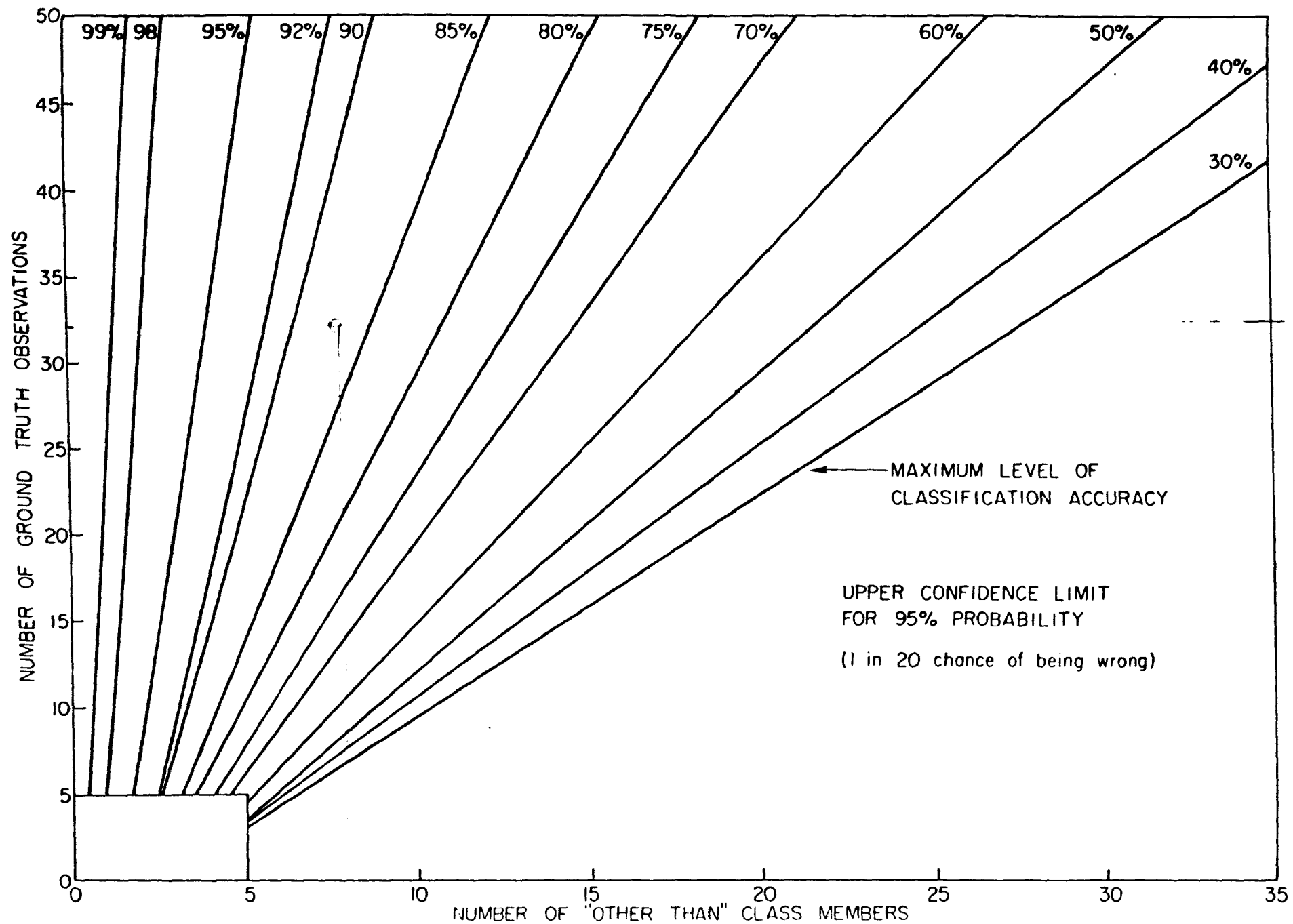
1. We live with risk and assessment of correctness of information, but we are not used to seeing it quantified. This is a matter of training in the acquisition and interpretation of such data.
2. Binomial experiments and decision-making based on such experiments are the basis for most activities in soil survey.
3. Graphical solutions permit us to concentrate on the nature and precision of our observations rather than worry about statistical calculations.
4. As field men become familiar with doing data collection as part of their mapping operations, they will have immediate feedback about the degree of variability they are observing and it will be in a numerical format.
5. Good data collection eases the strain of soil correlation. The facts will stand up and logical solutions will be more evident.
6. Map unit composition is nothing more than a measure of the correspondence of two or more sets of features. Composition can be in terms of interpretations just as it can be in terms of taxonomy.
7. Statements of probability with their associated limits on accuracy are the results of testing the models and hypotheses we use to segment the earth's surface. They are the tests of taxonomy and they are tests of interpretations.
8. We have a long way to go in telling others what we do, how we do it, and how to convey our findings. But do not forget, we have come a long way, Baby!

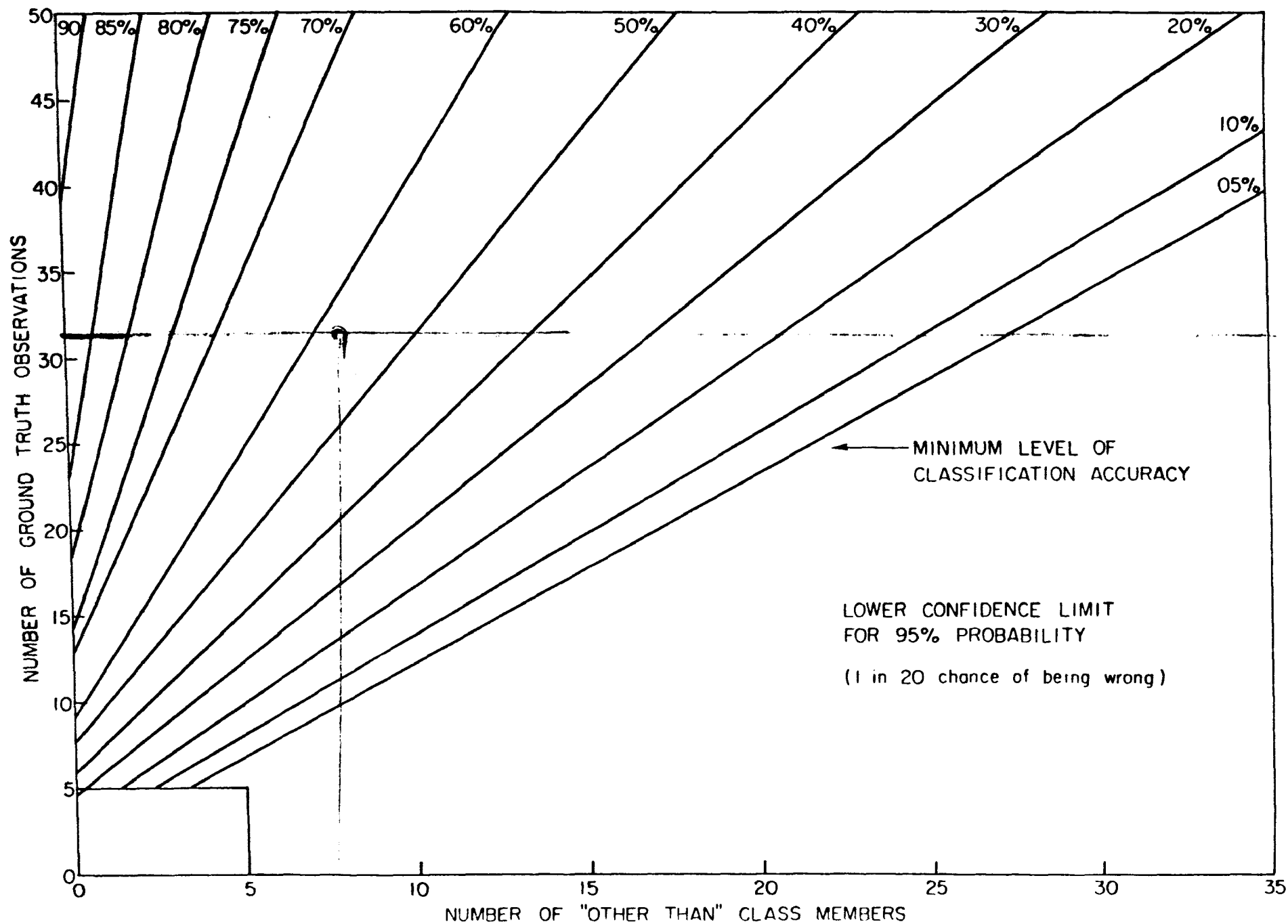
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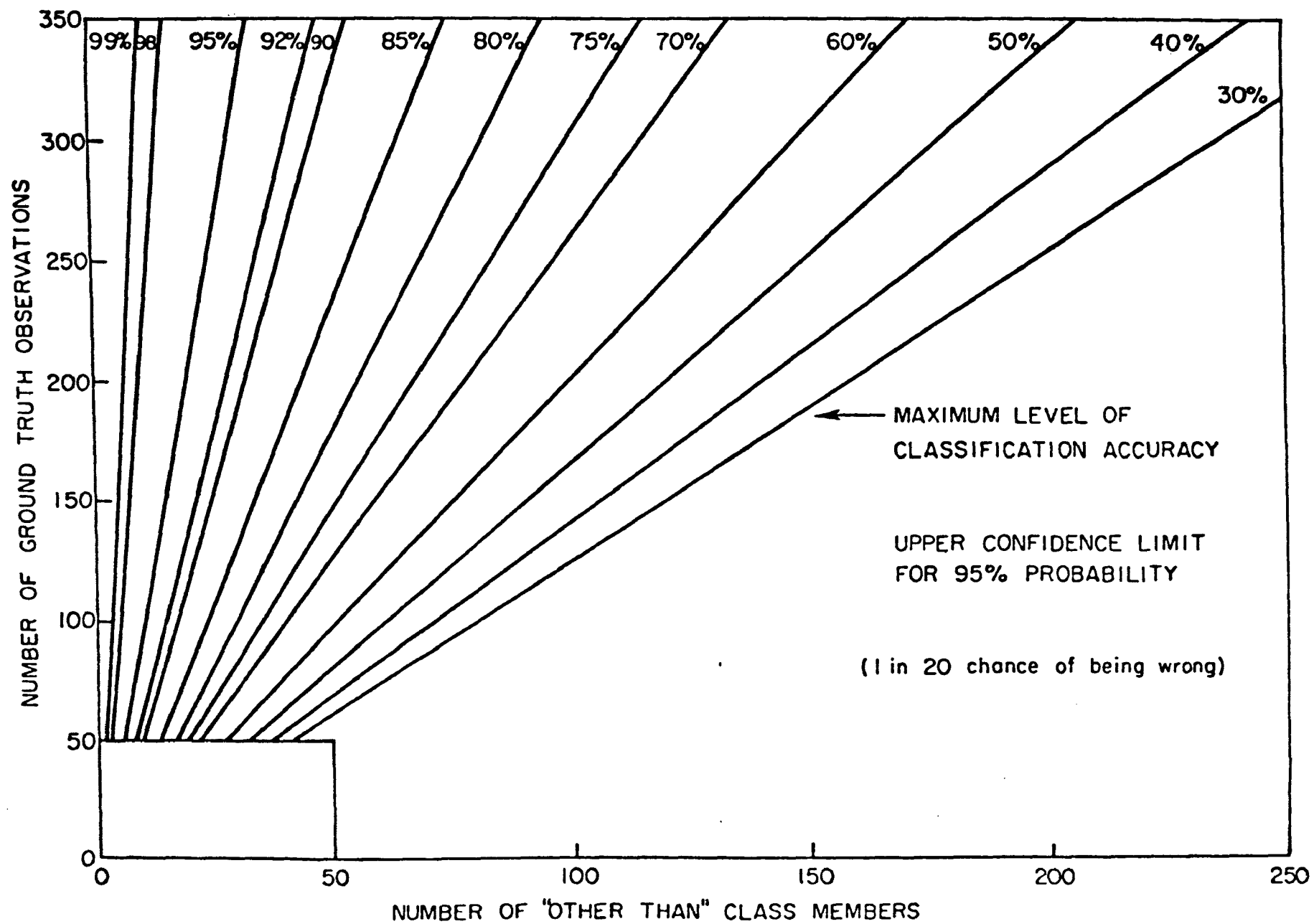
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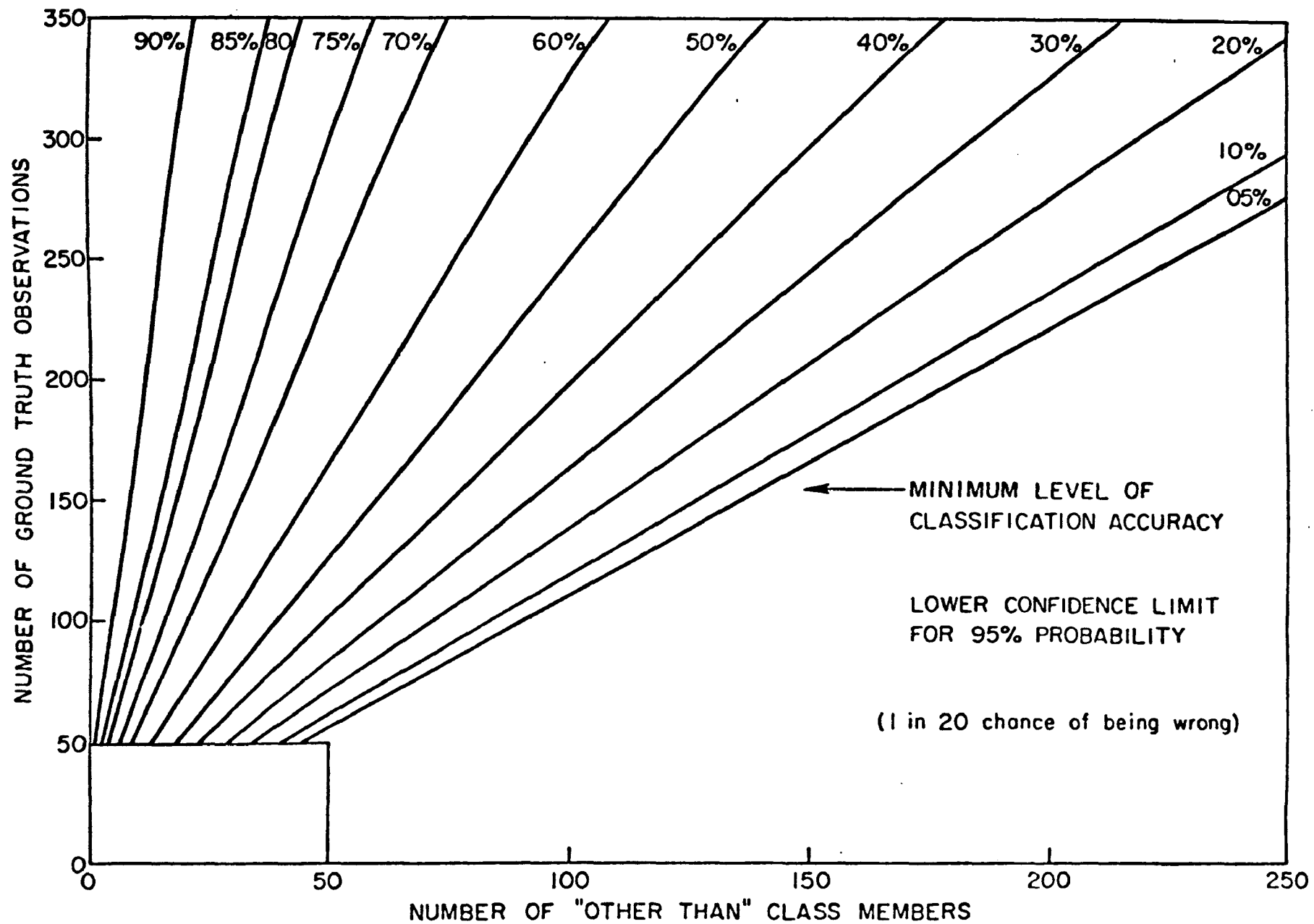


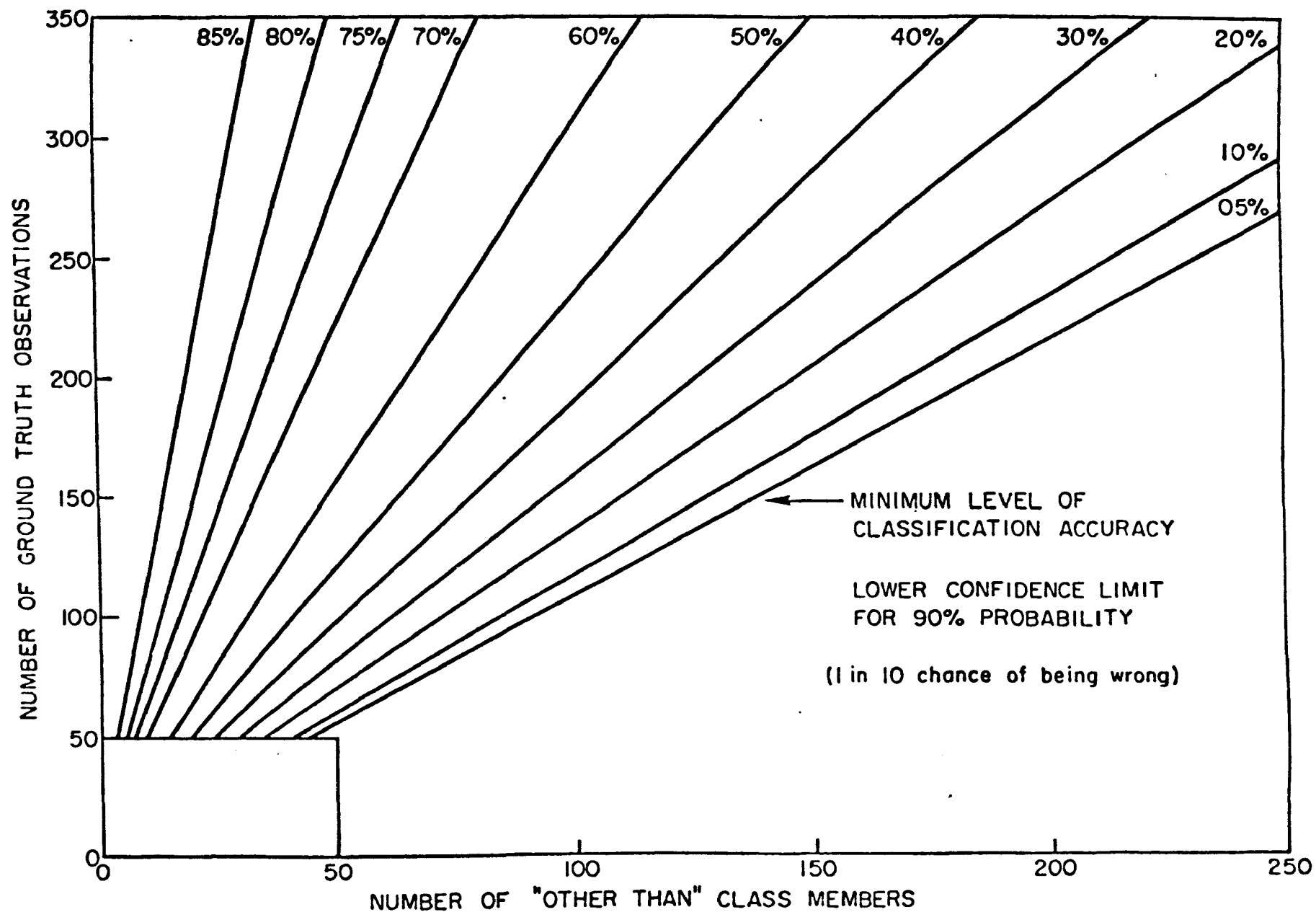


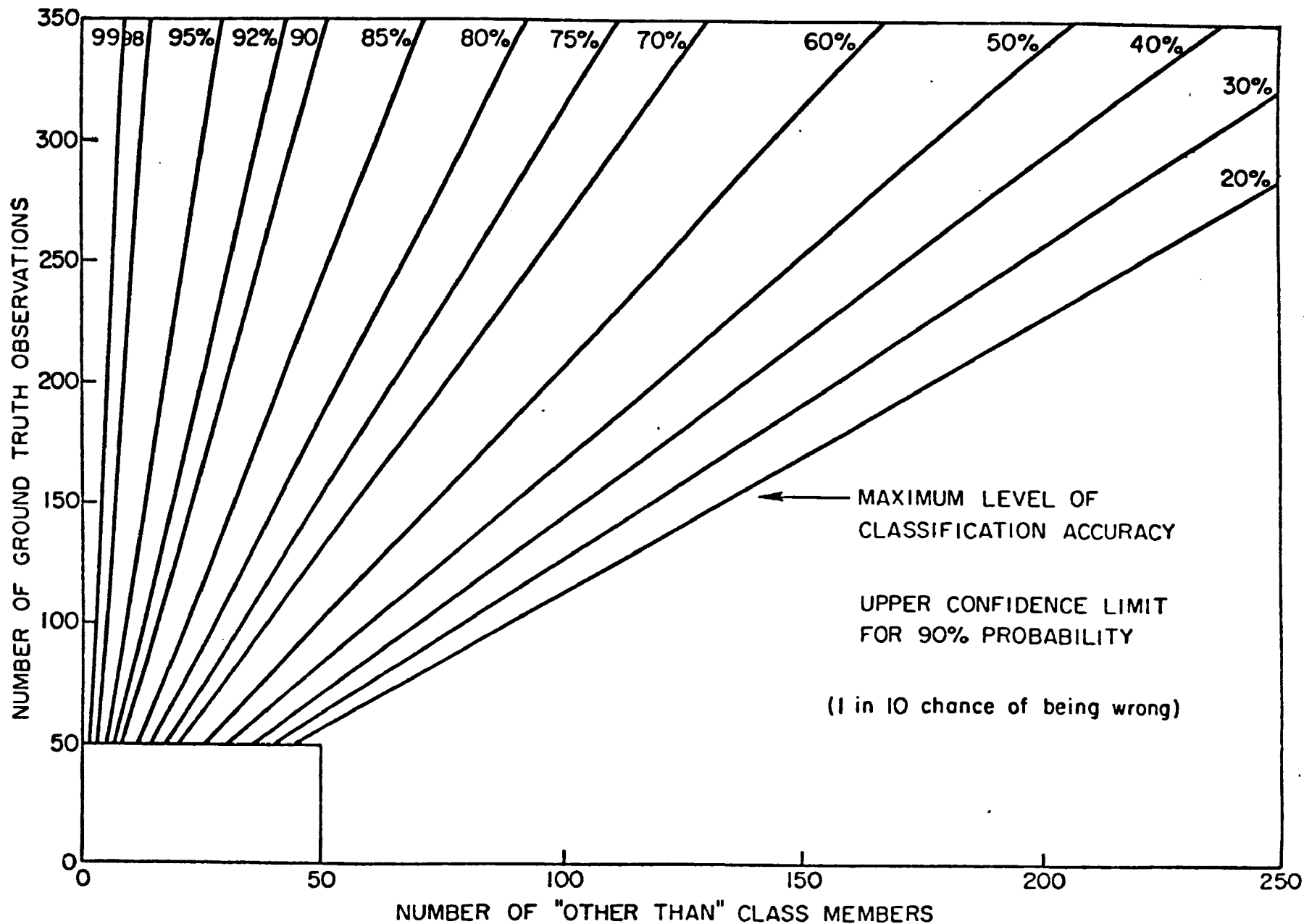












Appendix 4

SUMMARY OF PLANNING MEETING

SOIL/WATER PILOT SURVEY

Orono, Maine

July 23-24, 1984

I. INTRODUCTION

The following institutions (or agencies) were represented:

EPA -- ERL-Corvallis

University of Maine

Cornell University

USDA-SCS -- Washington, D.C.

USDA-SCS -- Maine

USDA-SCS -- New York

See attached list for names and addresses of participants.

The group engaged in extensive discussions of various aspects of the program, including the objectives and the various aspects of the approach, including site selection, field data collection, field sampling, and analytical methods. This summary presents the conclusions of the group concerning the approach and the methods to be used. It is not intended to be a recapitulation of the discussions.

II. OBJECTIVES

A. General Objectives

The general objectives of the pilot program, as presented to the group, are:

1. Conduct pilot survey (including laboratory analyses) to determine feasibility of using currently available soil association maps for regional generalization of soil properties relevant to surface water acidification.
2. Develop and test the organizational structure, field procedures, and laboratory capability required to carry out an expanded survey activity in 1985 for the purpose of regional generalization of soil characteristics that control the sensitivity of surface water to acid deposition.

There was no change in the objectives per se as a result of the discussion. However, the need for some clarification concerning the use of the term "soil association" became apparent. Soil associations may be defined at various levels of aggregation or detail. While soil association maps at a scale of 1:750,000 are apparently available for all states, in many of the areas of interest more detailed association maps are also available. It became apparent from the discussion that the divisions set forth on the statewide 1:750,000 maps may not always be those best suited to the present purpose. For instance, in the Adirondack area of New York the associations as delineated on the 1:750,000 map are aggregated to the point that the relationships of interest likely would not be discernible. As more detailed maps (1:62,500) are available for this area, associations to be tested will be selected from those. It should also be understood

that, while aggregation from greater to lesser detail is always possible, dis-aggregation is not.

B. Specific Objectives

As a result of the discussion at the meeting, a set of more specific objectives for the Pilot Soil Survey emerged. These may be summarized as follows.

For each of three or four major soil associations in each of the states of Maine and New York:

1. Determine the reliability of existing soil association maps in predicting what soils occur at specific National Surface Water Survey sites.
2. Determine the homogeneity of soil associations with respect to soil characteristics that control the sensitivity of surface water to acid deposition.
3. Determine whether the acid deposition characterizations can be related to the standard SCS characterization, so that existing data bases can be used for extrapolation.

III. SITE SELECTION

Approximately 25 small (generally < 30 km²) watersheds containing lakes to be sampled in the National Surface Water Survey (NSWS) will be selected in each state. These watersheds will represent three or four major soil associations. While the ideal would be an equal number of sites in each association, on a practical basis this may not always be possible. However, any soil association selected should be represented by at least 5 sites.

A. Soil Associations

Factors to be considered in selection of associations include:

1. Number of lakes of appropriate size in NSWS sample within the area represented by the soil associations. ERL-Corvallis will furnish a list of lakes within each state selected for the NSWS sample. The list includes lake name, coordinates, and identification of USGS maps showing the lake. An estimate of watershed size (either by area or size class) will also be furnished.

2. Range of Soil Properties

Within the constraints imposed by (1) above the associations should represent as wide a range of soil properties as possible. Differences may be due to factors such as bedrock type, surficial geology (parent material), topography, etc. Because the factors that will determine the available range of properties among soil associations will differ in each situation, no set protocol will be defined for selection of associations. The selection of associations will be left to the judgment of the individual state groups.

State groups will clearly identify the criteria used in selection of associations. A copy of the soil association maps used for this purpose will be furnished to ERL-Corvallis along with a list of the mapping units that fall within each association.

B. Watershed Selection (Within Associations)

1. Using the appropriate soil association map and the list (III.A.1, above), furnished by ERL-Corvallis, plus any other available information on watershed size, prepare a list of watersheds less than 50 km² in area that fall within each of the selected soil associations. If sufficient candidate watersheds are available, those larger than 30 km² may be deleted.
2. Pick random samples (including alternates) from each association.
3. Check watershed size on 7-1/2' or 15' maps. Drop those that are too large, replacing with alternates (note, watersheds may also be replaced by alternates at later stages if watersheds should prove unsuitable due to agricultural or urban usage, access unobtainable, etc.).

C. Watershed Data -- Pre-visit

1. Check available surveys.
2. Locate and sketch watershed on aerial photos, or on topographical maps if photos are not available. Preferred scale is 1:62,500.
3. If survey is available, sketch in soils. If survey not available, make predictions on soils using photo-interpretation and/or available maps.
4. Justify sampling sites.

Approximately 25 sites representing the major soil series encountered in the survey will be sampled. While these should be

drawn from as wide a distribution of the sampled watersheds as possible, the sampling sites will not necessarily be on a 1 watershed:1 sample basis. In some cases a site selected for sampling a particular series may not actually be within a watershed (avoid if possible). Number of sampled sites/series will roughly reflect the occurrence of the series on the selected watersheds. Potentially important groups such as histosols will be represented in the sample, even though they may not be dominant in any particular watershed. In order to minimize travel and sampling time, a preliminary selection of sampling sites should be made during the pre-visit stage.

D. Site Visit

1. Verify previously prepared sketch, modifying as necessary.
2. Sample and describe profile.

At each site selected for sampling, the profile will be described (form 232A) at one sample point. Analytical samples will be composited from the sample point and 9 satellites. Approximately 2 quarts of sample will be collected from each horizon as follows:

O -- Scrape off litter.

A or E -- Sample only if sufficiently thick so that 2 quarts can be collected.

B -- Sample top one half.

C -- If C not present, sample lower B.

Samples will be air dried, crushed, and split (standard SCS methods) (Soil Survey Investigations Report #1). One half of

each will be retained at the state level, the remainder submitted to a laboratory designated by ERL-Corvallis.

3. Describe watershed.

- a. Percent of each major (3-5) series.
- b. Vegetation types -- Use current SAF descriptors.
- c. Topography -- Percent slope, average length, configuration, stream type (i.e., dendritic, etc.) and density.
- d. Geology -- Type of bedrock, fractioning (Y/N), percent exposed, type of sampling material (till, outwash, etc.).
Locate site on bedrock and surficial geologic maps (if available).

IV. ANALYSIS

A. Introduction

The standard procedures referred to below are drawn from four major sources as follows:

SSIR, Soil Survey Laboratory Methods and Procedures for Soil Samples.

Soil Survey Investigations Report No. 1. USDA Soil Conservation Service. Washington, D.C. (1972).

MSA 1965, Methods of Analysis. C. A. Black (ed.). American Society of Agronomy. Madison, WI. Parts 1 and 2 (1965).

MSA 1982, Methods of Soil Analysis. A. L. Page (ed.). American Society of Agronomy. Madison, WI. Parts 1 and 2 (1982).

NCASI, Field Study Program to Assess the Sensitivity of Soils to Acidic Deposition Induced Alterations in Soil Productivity.

Technical Bull. No. 104. National Council of the Paper Industry
for Air and Stream Improvement (1983).

Many of the procedures in these references are similar or identical. In particular, a number of the NCASI procedures are drawn from the other sources. Procedures recommended in this paper were selected by ERL-Corvallis on the basis of suitability for the needs of the program and compatibility with procedures presently in use at the laboratories in the states that will be participating in the 1984 pilot program. Prior to final selection, procedures were discussed with participating scientists at the Orono, Maine, workshop, July 23-24, and in some cases with outside scientists.

B. Sampling

1. Field Sampling

For this study a small sampling area (one half ha or less) representative of the site and series to be sampled will be selected. One sampling point will be selected for profile description (form 232A). However, the samples collected for analytical purposes will be composites from the described sampling point and the 9-10 satellite points (in difficult sampling situations the number may be reduced but should not be less than 5). Samples will be collected from the O horizon (after removal of loose litter), the A or E horizon if the horizon is sufficiently thick so that adequate sampling volume can be collected, the top half of the B horizon, and the C horizon. If no C horizon is present the lower half of the B

will be sampled. Two quarts of soil will be collected from each horizon.

2. Sample Preparation

Follow SSIR procedures 1B1-1B4 (these are apparently the same or very similar to those in NCASI). Do not grind. After drying and thorough mixing, one quart will be retained at the state level for characterization analysis and one quart submitted to a central laboratory designated by ERL-Corvallis.

C. Physical Analysis

1. Particle Size Distribution

After removal of organic matter the percent sand, silt, and clay will be determined by the standard pipette method (SSIR 3A1). Fraction sizes (mm) to be recorded are: sand 2-0.50, silt 0.50-0.002, clay < 0.002. Separation of sand fractions by sieving is not necessary. If the particle size distribution is available from other sources, it will not be necessary to perform this measurement.

2. Bulk Density

Bulk density information is needed by horizons. If adequate BD information on the series in question is not available from other sources, we would suggest that the clod method, using either the paraffin coating (MSA 1965, page 381; NCASI, page 10) or the Saran coating (SSIR 41Ab, page 15) applied to air dry clods would be most appropriate.

3. Water Content (Desorption Curves)

These are not a high priority item. However, the 15 bar desorption curve might be useful if equipment is set up for this purpose.

D. Chemical Analysis

1. Standard Characterization

a. Organic Carbon

The preferred method is a dry combustion such as that given in MSA 1965 (page 543). The procedure in NCASI is identical. The procedures given in SSIR (6A1a or 6A2, pages 26-27) should also be satisfactory. However, the two state groups involved in the 1984 pilot program are using wet combustion procedures. It does not appear feasible for the state labs to utilize a dry combustion for this purpose. They should utilize their present procedures, clearly identifying the method and source. Organic carbon should also be run by the central lab, using either a dry combustion or an instrumental combustion method (see below).

Ordinarily, we would not expect removal of inorganic carbon to be necessary for samples from the regions selected for the pilot survey. However, in any areas where carbonates might possibly be encountered, a test for inorganic carbon should be made (MSA 1982, page 563; or NCASI, page A25). If carbonates are present they should be removed (MSA 1982, page 565; NCASI page A25).

NOTE: Some laboratories may be equipped with instruments that simultaneously measure total C and total N. These instruments can be successfully used on soils if experienced operators are available and appropriate precautions are taken. If instruments of this type are to be used (for example, the Perkin-Elmer 240), the laboratory should submit detailed procedures along with information on calibration against dry combustion methods to the EPA Project Officer for review.

b. Total Nitrogen

The Kjeldahl method is most widely used. The version given by Bremner (MSA 1982, page 610; NCASI, page A29) is suggested. However, most of the results available in the current data base have probably been obtained by either the macro- or semi-micro method given in SSIR (6B, page 29). Either should be satisfactory. Also, see note on Instrumental Methods under Organic Carbon, above).

c. pH

For this survey pH should be measured in both water and 0.01 M CaCl_2 . The procedures used for pH determinations can vary quite substantially. One of the most significant differences is whether the reading is taken on a suspension while it is being stirred (MSA 1982, page 20; SSIR 8C1, 8C13, pages 58-59), or taken in a partially settled suspension with the glass electrode immersed in the

sediment while the reference electrode is in contact only with the supernatant liquid (MSA 1965, page 902; NCASI, page A26).

There probably is no satisfactory answer. The most extensive analytical data base available for survey interpretation is that of USDS-SCS, apparently on stirred suspensions. The state labs are currently using measurements on settled systems. As the lab operators report that the correspondence of pH measurements made by this method with the SCS national lab results has been good, use of the sediment measurement is considered satisfactory. Therefore, pH will be measured on 1:1 soil:water and 1:1 0.01 M CaCl_2 solutions using current laboratory methods. Again the exact procedure followed will be reported.

d. Fe and Al

Both Fe and Al will be determined on three extracts, i.e., sodium pyrophosphate (SSIR 6C5, page 32), ammonium oxalate (SSIR 6C6, page 32), and dithionite-citrate-bicarbonate (SSIR 6C2, page 31; NCASI, page A36). Determination of the Fe and Al concentrations in the extracts will be by atomic absorption, flame photometry or ICP emission spectroscopy.

Al will also be determined on a 1 N KCl extract using a 30 minute extraction time (SSIR 6G1, page 36). NOTE: see Extractable Acidity, below.

e. Exchangeable (Extractable) Acidity

Undoubtedly the most common determination for exchange acidity is the barium chloride-triethanolamine (pH 8.2) method. This method probably gives less information relative to the acid deposition problem than does a non-buffered extraction such as KCl. However, since results from analysis by this method are most likely to be available in current data bases, it should be included in the characterization. The SSIR method (6H1, page 38) seems to be essentially the same as that given in MSA 1982 (page 163) and by NCASI (page A30). Either should be satisfactory.

A measure of neutral salt extractable acidity is essential for the present purpose. The 30 min KCl extract seems appropriate. NCASI recommends the titration method (MSA 1982, page 163; NCASI, page A32) giving a measure of total extractable acidity. The most closely corresponding measurement in the USDA data base would be KCl extractable A1. As the extraction appears virtually identical, we recommend determining A1 by AA or ICP on the extract prior to titration, so that both measures are available.

f. CEC and Extractable Base Cations

For our present purpose the most useful estimates of CEC would appear to be either derived from saturation with a neutral salt (e.g., NH_4Cl) or from a summation of extractable bases and a neutral salt exchange acidity.

Again, we are faced with the problem of compatibility with currently available data. For the pilot survey it would seem prudent to include the more commonly available NH_4NO_3 (pH 7.0) measurement of CEC (SSIR 5A1, page 22 or 5A6 page 24; MSA 1965, page 894). The extractable bases, i.e., Na, K, Ca, and Mg should also be determined on the NH_4OAc extract either by a combination of flame emission (Na and K) and AA (Ca and Mg), by AA alone, or by ICP.

2. Special Analysis (Central Laboratory)

It is contemplated that a variety of special analyses will be conducted on a split sample submitted to a central laboratory. In addition, at least part of the standard characterization analyses will be repeated at this laboratory. Due to the fact that organic carbon will be determined at the state level by the use of a wet combustion method, it should definitely be determined by the central laboratory using either a dry combustion or an instrumental method (see IV.A.6 above).

Special analyses currently under consideration include:

a. Neutral Salt CEC and Extractable Bases

The 1 NH_4Cl extraction will most likely be used (SSIR 5A7 included in the "addendum"; NCASI, page A29).

b. Lime Potential

While in some soils the pH as measured in 0.01 M CaCl_2 may be used to estimate the lime potential (pH - 1/2 pCa)

or the H-Ca activity ratio ($H/(Ca)^{1/2}$), in acid soils with low permanent charge the amount of Ca-Al exchange that would take place in this comparatively high Ca environment is likely to substantially modify the Al-Ca ratios on the exchange complex. Lime potential should therefore be measured by equilibrating with a more dilute solution of $CaCl_2$ (possibly 0.002 M), followed by measurement of both pH and Ca^{2+} concentration. Determination of monomeric Al on this solution could also give an estimate of the H- Al^{3+} activity ratio, providing that the inorganic monomeric Al can be satisfactorily separated from organically bound Al.

c. Extractable Sulfate

Both water and sodium phosphate extractable sulfate will be determined on all samples. The procedure will most likely be that given by NCASI. Ion chromatography will be required for all sulfate determinations.

d. Sulfate Adsorption Isotherms

Sulfate adsorption isotherms will be determined on all samples. Tentative plans are to use a series of 6 solutions with 0, 2, 4, 8, 16, and 32 ppm-S (0, 62.5, 125, 250, 500, and 1000 $\mu eq\ l^{-1}$, respectively), as calcium sulfate, and a 1:5 soil solution ratio. These will be shaken, followed by either filtration or centrifugation, and sulfate determined with by ion chromatography.

V. FUNDING MECHANISM

Cooperation with the EPA and the existing soil survey community is essential for both the 1984 Pilot Soil Survey and 1985 Soil Survey. Thus, the Pilot Soil Survey will proceed through Interagency Agreements (IAG's) with the state SCS offices in New York and Maine. In turn, these offices will enter into agreements with cooperators at the corresponding land-grant universities, Cornell and University of Maine. Also, an IAG with the SCS in Lincoln, Nebraska, will provide soil analyses by the National Soil Survey Laboratory. This laboratory will serve as the central laboratory for the Pilot Soil Survey.

VI. REPORTS AND MILESTONES

Field work begins	09/10/84
Field data sheets, including sketch maps (each state)	11/30/84
Soil sample analysis data (each state and central lab)	12/31/84
Interpretive workshop	01/15/85
Final reports (each state and central lab)	01/31/85
Final report for Pilot Survey	03/30/85

PLANNING MEETING
SOIL/WATER PILOT SURVEY
Orono, Maine
July 23-24, 1984

Attendees

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DRAFT AGENDA TOPICS
PILOT SOIL SURVEY INTERPRETIVE WORKSHOP
Environmental Research Laboratory
Corvallis, Oregon
January 21-25, 1985

I. Overview

- A. Soil survey as part of Direct/Delayed Response Project: What is EPA trying to accomplish? Where? When? Why? Exactly what data are needed - how will they be used?
- B. Proposed statistical structure and analysis; relationship to National Surface Water Survey.
- C. Resources available at ERL-C.
- D. List of completed analyses; preliminary list of analyses to be completed during workshop (iterative).

II. Discussion -- Overview

- A. Conclusion on data requirements.
- B. Preliminary discussion on statistical structure.
- C. Written Summary: Data requirements; statistical structure.

III. PI reports -- field operations: What was done? How? Why? What problems/opportunities were identified? (Discussion at this time limited to points of clarification.)

- A. Selection of soil associations, watersheds, soil series to be sampled:
How were these chosen? By what criteria?
- B. Pre-visit predictions: What resources were available? How useful were they?
- C. Site Visit: How were soil, vegetation sketch maps done? How difficult, time-consuming? Did you find what you expected to find; i.e. were pre-visit predictions confirmed? Conclusion on reliability and utility of existing resources.
- D. Soil Sampling: What criteria did you use to choose exact sampling locations? Exactly how were samples obtained? Labeled? Documented? Stored? Prepared for analysis? Split? Bring sample of shipping container.

IV. Discussion -- field operations

- A. Pilot protocol: Was it followed? Ambiguous? Logistically manageable?
- B. Survey protocol: Changes from approach of pilot? What needs to be made more specific? Implications for QA of field operations?
- C. Written Summary: Conclusions on adequacy of pilot protocol and reliability of existing resources. Specific recommendations for survey protocol for field operations.

V. Reports -- Lab operations

- A. PI reports: What was done? How? Any deviations from pilot protocol? Problems? How time-consuming?
- B. Data management for pilot: What? How? What statistical analyses have been done and are available? Which statistical analyses can and should be done during this meeting?

- C. Data reports: Inter- and intra-lab comparisons; frequency distributions of parameters for each soil association; relationships between parameters; other available analyses.
- D. Reports on data analyses performed during this meeting (iterative).

VI. Discussion -- Lab operations

- A. Pilot protocol: Was it followed? Ambiguous? Other problems?
- B. Inter and intra -- lab comparisons: Implications for QA of lab operations.
- C. Parameter distributions: Implications for use of soil associations as mapping units for soil survey.
- D. Parameter relationships: Implications for linking to existing data bases.
- E. Soil survey protocols: Are there parameters which can or should be eliminated from list of planned analyses? Added to this list? Should pilot protocols be modified? Made more specific?
- F. Written Summary: Conclusions on adequacy of pilot protocols. Conclusions on use of soil associations as mapping units, and on linking to existing data bases. Specific recommendations for parameters and protocols for survey.

VII. Organizational Issues

- A. Statistical structure and analysis revisited: Mechanism for site selection; proposed analyses.
- B. Quality Assurance: Management; information flow; field operations; data quality objectives; replication; reports.

- C. Analytical Lab(s): One or several labs; criteria for selection; mechanism for selection.
- D. Responsibilities: Role of EPA, SCS, Universities; efficient funding mechanisms; potential cooperators.
- E. Written Summary: Conclusions on approaches to statistical structure and analyses; site selection; QA; selection of analytical labs; responsibilities of participants.

VIII. Draft Workshop Report: An integrated document synthesized and expanded from the written summaries produced during the week, and incorporating the data analyses performed during the week and any additional discussions on each topic.

Appendix 6

PARTICIPANTS

PILOT SOIL SURVEY INTERPRETIVE WORKSHOP

Corvallis, Oregon
January 21-25, 1984

Cooperators in Pilot Soil Survey:

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Appendix 7

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January 21-25, 1985

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