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PROJECT PLAN for the ACID DEPOSITION EULERIAN MODEL EVALUATION and FIELD STUDY

Prepared by
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Prepared for
THE PROJECT MANAGEMENT GROUP

February 1989

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PREFACE

The purpose of this project plan is twofold. The first component is to serve as a general source of guidance to the Project Management Group (PMG) and its technical oversight Teams in their quest for a successful evaluation -- an outcome that depends critically on the development or acquisition of well defined evaluation methods, observational data of known uncertainty, and the ability to interpret the results in a meaningful way. The second is to provide a framework for consolidating the activities of the individual participants in the bilateral acid deposition model evaluation study into a cohesive whole.

The field study components, in particular those relating to the surface network, of the overall model evaluation effort are more thoroughly described in this plan than are the procedures for evaluating the Eulerian models. This is a consequence of the fact that the evaluation procedures were still evolving from concepts to detailed implementation plans over the period this document was produced.

Representatives of the participating organizations* have agreed that the following principles should guide the PMG:

- Each measurement activity will be operated according to a comprehensive quality assurance plan.

* Atmospheric Environment Service of Environment Canada, Electric Power Research Institute, U.S. Environmental Protection Agency, Florida Electric Power Coordinating Group, Ontario Ministry of the Environment

- Procedures will be developed and adopted by the participants that will ensure to the extent practicable the comparability of measurement methods.
- All activities related to model evaluation will be coordinated among participants.

The framework will be assembled by describing the genesis of the model evaluation study, what data each of the participants are collecting to support the model evaluation, what the quality objectives are for the data, how those objectives will be achieved, where the data will reside, and how the model evaluation will be carried out.

It is hoped that implementation of this plan will contribute to achieving a scientifically credible and technically defensible model evaluation.

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Section 1

BACKGROUND

This section provides a brief history of the events that have culminated in the regional Eulerian model evaluation study described in this document. It begins with a description of why comprehensive acid deposition models have been developed. This is followed by a statement of the rationale underlying our conviction that it is necessary to thoroughly evaluate the performance of these models. Different approaches to model evaluation are then described. The section ends with a chronology of the more significant steps that have been taken in planning the study.

1.1 Development of ADOM and RADM

The atmospheric deposition of acidic materials in precipitation, gases and particles can damage sensitive components of terrestrial and aquatic ecosystems. The processes involved in converting gaseous emissions to acids and their salts, and in transporting and depositing them are so complex as to defy simple interpretation based on field measurements, no matter how carefully made. What it takes, in principle, to predict reliably how much emitted material will be deposited and where, is a thorough understanding of the relevant processes and their embodiment in computer simulation models. This predictive ability is necessary if cost effective measures are to be taken to protect sensitive ecosystems by selectively controlling the emission of acid precursors.

Mathematical models that incorporate our present understanding of the governing processes (e.g., horizontal and vertical transport, gas phase chemistry, scavenging and subsequent chemical reactions in clouds, and wet and dry deposition) have been, and continue to be, developed to fill this need. However, some of these models do not capture the higher order complexity of the chemical processes involved. Rather, they treat all processes in a simple first-order way. This type of model has been rejected by many acid deposition researchers as being an unreliable tool for predicting deposition fields from arbitrary emission fields because it does not capture the nonlinearities inherent in the natural system that can give deposition responses that are not proportional to emissions changes. Although it may do a reasonable job of reproducing present deposition patterns given present emissions, there is concern as to whether this type of model can produce realistic deposition patterns given different emissions.

What is needed are models that represent the higher order science in as complete a fashion as is practicable within the constraints of present knowledge and modeling resources. Two of these higher order, comprehensive models that are under development in North America are the Regional Acid Deposition Model (RADM) and the Acid Deposition and Oxidant Model (ADOM), respectively designated by the U.S. and Canadian governments as potential emission control policy assessment tools. RADM has been developed under the aegis of the American National Acid Precipitation Assessment Program (NAPAP). ADOM development was begun by the Ontario Ministry of

the Environment and the Atmospheric Environment Service, Environment Canada, with supplementary support subsequently provided by the Federal Republic of Germany's Umweltbundesamt and the Electric Power Research Institute.

These models are intended to provide a surrogate reality of such fidelity that legislators, regulators, and those whose discharges to the atmosphere are regulated will endorse their use for this purpose. Such acceptance by the community at large will make them credible tools for exploring emissions change scenarios and assessing source-receptor relationships.

1.2 Commitment to Model Evaluation

Although the RADM and the ADOM are the focus of the model evaluation effort described here, other models will almost certainly be evaluated once the proper tools (data and methods) are available. Model evaluation is viewed by the participants as an essential element in the process that begins with model development and ends with its application, because it is the step that demonstrates how well the model mirrors the natural system. Further, the economic and scientific motivations underlying this demonstration are substantial.

Managerial and technical approaches for the regional Eulerian model evaluation and field study have been proposed earlier (Durham et al., 1986) and serve as the basis for much of this plan.

1.3 Types of Model Evaluation

Although the lines of distinction are not always clearly drawn, four broad categories of model evaluation can be defined: mechanistic, diagnostic, operational, and comparative.

Mechanistic evaluations can be conducted by examining in detail the fidelity of process representations in the model code with respect to the best understanding available of the governing mechanisms. They can also involve an analysis of how well specific parameterizations represent more mathematically exact process representations. They answer the question, "Is the science correctly represented?"

Diagnostic evaluations would not normally involve the same level of detail as mechanistic ones. Rather, they examine the response of model outputs to a wide range of model inputs to see how well the model mimics perceived reality -- as represented by theory and careful observation. One subset of this type of evaluation is the familiar sensitivity analysis, wherein the relative response of a specific output to changes in different inputs, or combinations of inputs, is studied. Another would be comparison of the serial changes in species' compositions predicted by the gas phase chemistry module with those involved in smog chamber experiments. As used in the present context, diagnostic evaluations rely in large part on time-resolved (less than 24 hours), three-dimensional observational data. They answer the question, "Do the parts of the model appear to be working correctly?"

A model's performance is operationally evaluated on the basis of its ability to simulate observations of target variables (such as sulfate or nitrate deposition in precipitation) averaged over a given period -- generally several days to a year. (Because the models are not intended to capture the fine-scale spatial and temporal variability of rainfall and meteorological variables, there is little point in operationally evaluating the models on a shorter term). Measurement data from the monitoring networks described in this plan will be largely used for this type of evaluation. Over the range of conditions tested, operational evaluation answers the question, "Is the model giving the right answers?"

In a comparative evaluation the performance of a model or its parts is compared with that of another model for an identical set of inputs (to the degree allowable by the models' formulations). It answers the question, "If I use this model, will I get the same results as if I had used that model?"

The primary use of the data expected from the field study covered by this project plan is intended to be for operational and diagnostic evaluations.

1.4 Field Study Planning

A series of planning meetings and workshops, many of them jointly sponsored, has been conducted to define goals and methods for the model evaluation. They are listed in Table 1-1, together with

subsequent pertinent meetings.

At the Quality Assurance Workshop, held 11-13 June 1986 in Toronto, the attendees recommended the establishment of a Quality Assurance Management Committee, composed of a representative from each of the sponsoring organizations. This recommendation was implemented and a charter for the committee was subsequently drawn up and endorsed by each of the organizations.

After several meetings had been convened to coordinate preparations for the field study, it became apparent to the QAMC members that activities other than field measurements --in particular, emission inventories and model evaluation protocols-- were equally essential to the model evaluation process, but were not receiving the same level of coordinated attention. The QAMC asked the Eulerian Modeling Bilateral Steering Committee (EMBSC) to consider this problem and to make a recommendation for addressing it. Its recommendation was to rename the QAMC the Project Management Group (PMG), to reflect a broader set of responsibilities, and to set up three subsidiary teams to oversee activities on the topics of measurements, emissions, and model evaluation.

The recommendations of the EMBSC were adopted with slight modification: the Measurements Team was split into two, one each for operational measurements and diagnostic measurements. The PMG felt that the distinction between routine, surface-based

(operational) and research-grade, airborne and ground (diagnostic) measurements was sufficiently great to warrant separate teams. The initial meetings of these groups are listed in Table 1-1. The meetings will continue at approximately quarterly intervals until the group's component of the model evaluation effort is completed.

Table 1-1

PLANNING AND DESIGN MEETINGS FOR THE
MODEL EVALUATION EFFORT

DATE	TOPIC	LOCATION
30 OCT 84	EMBSC	Washington, D.C.
19 FEB 85	EMBSC	Toronto, Ont.
MAY 85	Technical Committee Workshop on Field Study Plan	RTP, NC
NOV 85	EPRI OEN Workshop	Seattle, WA
FEB 86	Workshop on Model Evaluation Protocol	Raleigh, NC
19 FEB 86	EMBSC	Toronto, Ont.
MAR 86	Workshop on Field Study Design	Seattle, WA
JUN 86	Workshop on Quality Assurance	Toronto, Ont.
25 AUG 86	EMBSC	Toronto, Ont.
OCT 86	Methods Reconciliation Workshop	Toronto, Ont.
MAY 87	RADM Peer Review	Raleigh, NC
JUL 87	QAMC	Chicago, IL
22 JUL 87	EMBSC	Washington, D.C.
AUG 87	Workshop on Diagnostic Evaluation	Raleigh, NC
OCT 87	PMG	Chicago, IL
NOV 87	PMG and Team Conveners	Chicago, IL
FEB 88	PMG and Teams	RTP, NC

Subsequent meetings of the PMG and teams have been convened approximately quarterly.

Section 2

ORGANIZATION

2.1 Overall Study Organization

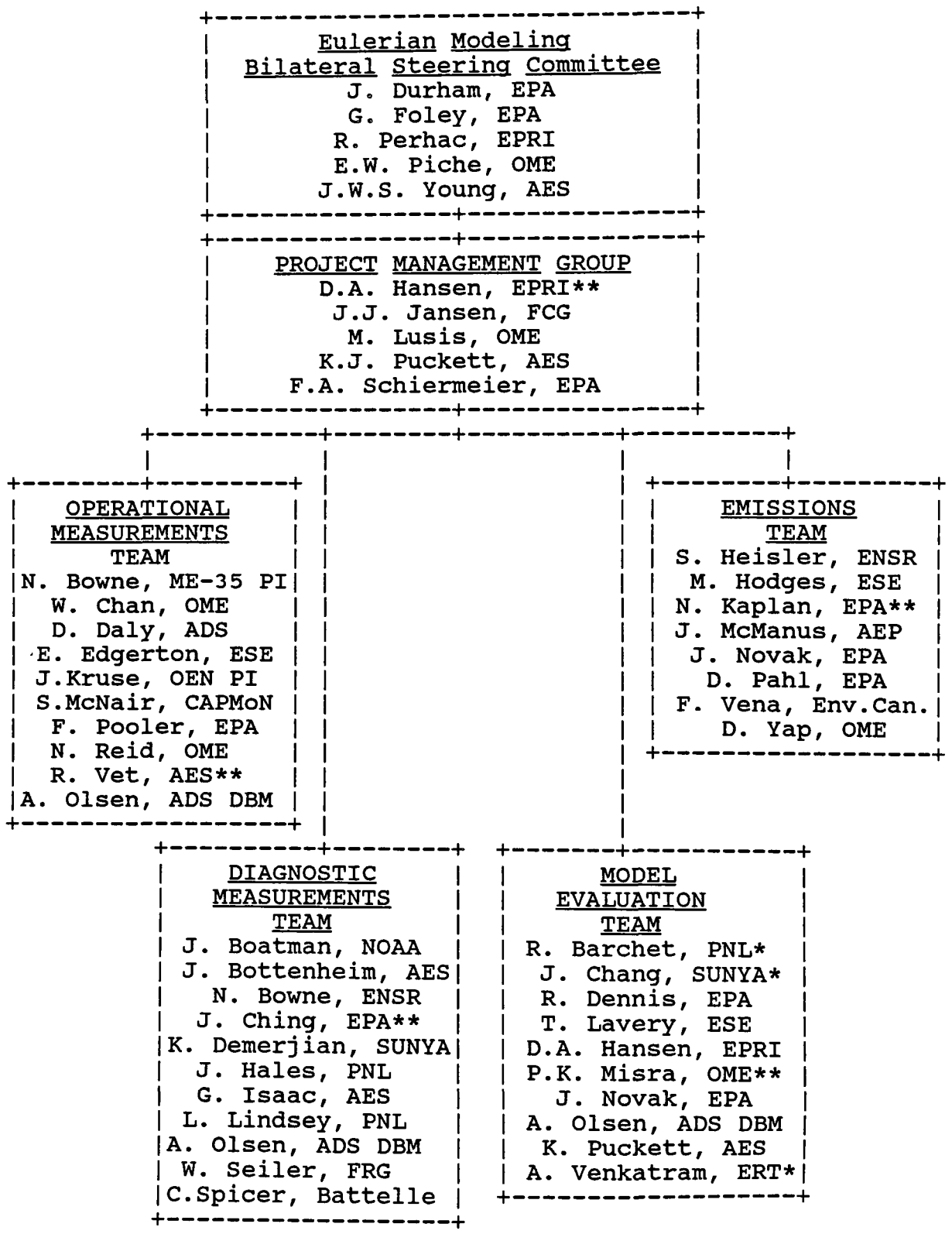
The organizational structure of the binational acid deposition model evaluation effort is shown in Figure 2-1. Top level guidance and liaison among high-level managers of the participating organizations is provided by the EMBSC. Reporting to the EMBSC, the members of the PMG are managers responsible within their organizations for the measurement networks and/or for their model evaluation efforts. The Team members, in turn, are managers within their organizations of, or individuals with expertise in, the appropriate program component.

The evolution of this organizational structure has been described in Section 1. The structure reflects the breadth and scope of the agencies and technical disciplines involved in planning, implementing, and completing this very complex undertaking.

The responsibilities of the PMG and the Teams are described in Sections 3 (objectives) and 5 (deliverables).

2.2 Model Evaluation Team Support Organization

The Model Evaluation Team has set up an organizational structure involving checks, feedbacks, high level oversight, and extensive interactive peer review for conducting the performance evaluations of the models. The structure is illustrated in Figure 2-2 and is



* Ex officio
** Chairman

Figure 2-1. Model Evaluation Organization

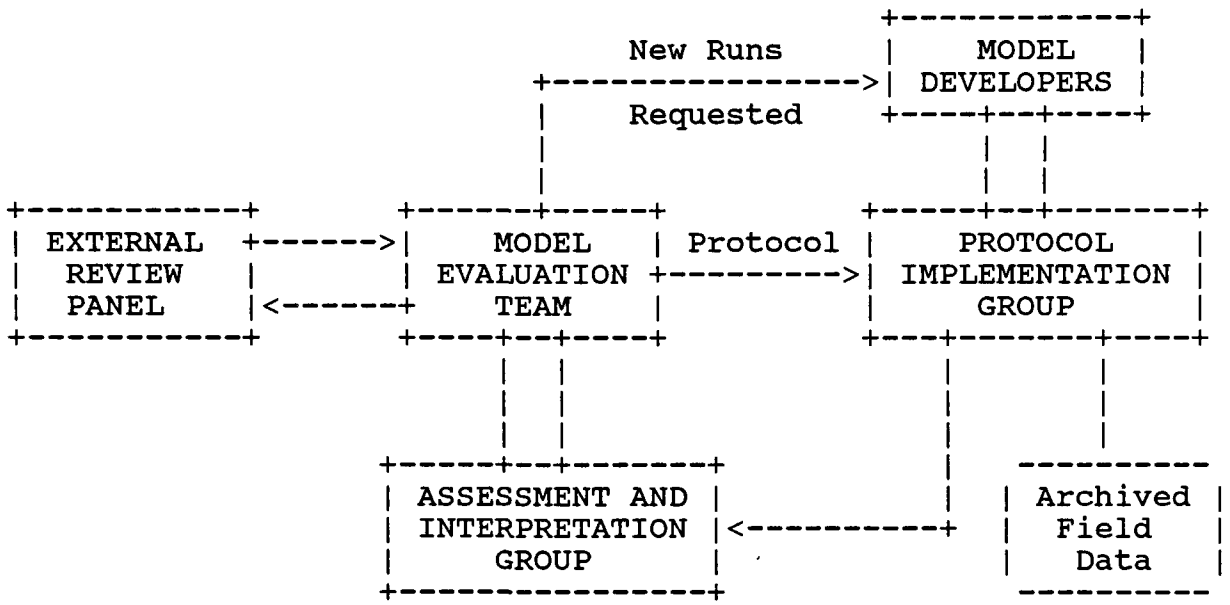


Figure 2-2. Model Evaluation Team Support Organization

designed to provide a highly visible, scientifically credible evaluation process, in which all sponsors can participate.

Once the model evaluation protocol(s) has been completed under the aegis of the Model Evaluation Team (MET), it will be implemented by the Protocol Implementation Group (PIG), which will most likely be made up of computationally oriented staff from a contractor. The PIG will treat the protocol as a set of instructions that will be carried out as written. It will draw on the field data archive as needed to meet the data requirements of the protocol. It will interact with the modelers to exercise the models as specified in the protocol. As the protocol itself is exercised, the results of the observations-predictions comparisons, sensitivity analyses and other possible activities specified by it will be fed by the PIG to the Assessment and Interpretation Group (AIG). The PIG is viewed as something of a buffer between the AIG and the model developers, reducing their interaction and the perception of those outside the process that the modelers are overly influencing any conclusions drawn by AIG.

The AIG will have the responsibility for interpreting the results and producing evaluation reports, initially, in a preliminary sense to NAPAP in time for incorporation in the 1990 final assessment report, and finally as a report on the completed operational and diagnostic evaluations. The composition of the AIG is not settled, but will probably be made up of contractor staff supported by external expert consultants. The AIG will

likely be funded and managed in large part by the U.S. EPA, the staff of which will frequently consult with the MET.

An international group of highly respected scientists (see Table 2-1), expert in various aspects of model evaluation, make up the External Review Panel (ERP). They have been invited by the EMBSC on behalf of the MET to serve on this panel. They will work closely with the MET not only reviewing the model evaluation protocol before its implementation, but reviewing the interim and final reports passed to it by the Team from the AIG. It is anticipated that the ERP will make recommendations from time to time for course corrections that may involve protocol modifications or additional model runs. These recommendations will be channelled through the MET.

Table 2-1

External Review Panel

Dr. Peter Bloomfield, North Carolina State University

Dr. William Chameides, Georgia Institute of Technology

Dr. Anton Eliassen, the Norwegian Meteorological Institute

Dr. Fred Fehsenfeld, NOAA Aeronomy Laboratory

Dr. Bernard Fisher, Central Electricity Research Laboratories, UK

Dr. Dean Hegg, University of Washington

Dr. Dieter Kley, Institut fur Chemie, Julich, FRG

Dr. Harold Schiff, York University, Canada

Dr. Ted Yamada, Los Alamos National Laboratory

Section 3

OBJECTIVES

3.1 Project Management Group

The objective of the PMG is to ensure that the Eulerian acid deposition models are evaluated:

- o according to a well-defined protocol,
- o using input and evaluative data of defined precision accuracy, representativeness, and comparability,
- o in such a way that uncertainties in model outputs can be distinguished from those in the input and evaluative data, and
- o in terms of established (to the degree possible) performance criteria.

The PMG will pursue this objective by:

- o coordinating activities of the member organizations related to model evaluation, partly through approximately quarterly meetings;
- o soliciting suggestions from the Eulerian Model Bilateral Steering Committee (EMBSC) when problems arise which are of interest to the PMG and require resolution at a higher management level;
- o establishing four teams to assist the PMG by providing technical oversight of Study-related activities on the topics of operational (routine monitoring) measurements, diagnostic (airborne and enhanced chemistry site)

measurements, emission inventories, and model evaluation;

- meeting approximately quarterly with the team chairs to be briefed on team activities;
- providing for the review and approval of the project quality assurance plans for each of the sponsor's' networks;
- encouraging standardization of methods and protocols;
- encouraging member agencies to practice active quality control; and
- specifying common data base characteristics and reporting protocols.

3.2 Technical Oversight Teams

The Teams will provide a broad base of technical expertise and management skill to assist in meeting the PMG's objective. They will also be guided by specific objectives developed by the PMG in consultation with each team.

3.2.1 Operational and diagnostic measurements teams. The objective of both of these teams will be to produce a standardized data set of defined precision, accuracy, representativeness, and comparability* for the model evaluation program through the coordination and oversight of the measurements, data management and quality assurance programs of the individual participating organizations.

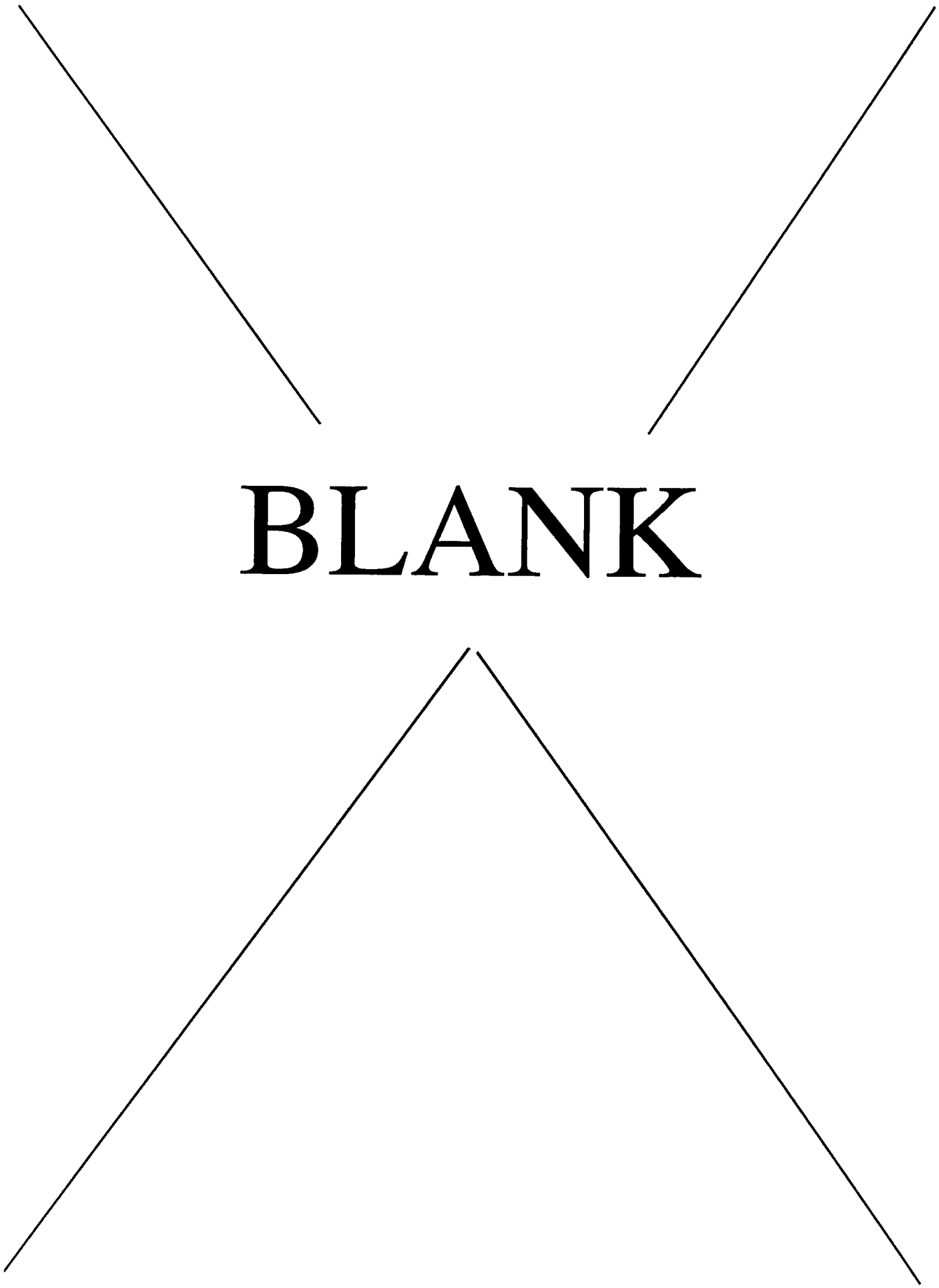
*The terms defining data quality are discussed in Section 4.

The Operational Measurements Team will pursue its objective by:

- ensuring that the results of quality control studies are assessed and that recommended corrective actions are taken;
- reviewing and recommending for diagnostic studies the methods of establishing estimates of bias and variance;
- reviewing and recommending quality assurance and quality control methods for model development and evaluation; and
- designing inter-network and inter-laboratory studies of uncertainties.

3.2.2 Emissions inventories. The objective of this team will be to produce a standardized data set of defined uncertainty through the coordination and oversight of NAPAP, EPRI, and Canadian emission inventory acquisition, data management and quality assurance programs.

3.2.3 Model evaluation. This team's objective is to ensure that the model evaluation methods are consistent with the model design characteristics and appropriate in the context of their application, that they can be objectively used and produce results that are scientifically defensible.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Section 4

DATA QUALITY OBJECTIVES

The data quality objectives stem directly from the PMG's objective. They will be achieved through implementation and execution of this plan and the QA plans of the participating organizations listed in the Appendix. These plans should be consulted for details.

Quantitative objectives may be stated for the precision, accuracy, lower quantifiable limits and completeness of each measured observable. Ideally these would be specified in advance by the model evaluators, based on their perception of the data quality required for them to do an adequate job. However, since no comparable specifications have ever been formulated, such an expectation is unrealistic. Therefore, these data quality objectives will be based instead on what are reasonable expectations for the selected measurement methods under carefully controlled field and laboratory conditions and on less quantitative judgements of the methods' ability to provide data with quality commensurate with that required by the evaluation protocol. They are given for precision, accuracy, lower quantifiable limit, and completeness in Table 4-1.

Although numerical measures of data comparability and representativeness may, in principle, be developed, to do so *a priori* appears to be impractical at this juncture. They will

Table 4-1

DATA QUALITY OBJECTIVES FOR
PRECISION, ACCURACY, LOWER QUANTIFIABLE LIMIT
AND COMPLETENESS

AIR QUALITY

Observable (Interval)	Method (Units)	Expec. Upper Range	Precision (The Larger of)	Accuracy	Lower Quantifiable limits 3 x SD	Lower Quantifiable limits 10 x SD	Completeness
Particulate Mass (24 Hr)	FP/G (ug/m^3)	50	+/-15% 3 ug/m^3	+/-10%	2 (ug/m^3)	6 (ug/m^3)	90%
	FPC/G (ug/m^3)	100	+/-15% 3 ug/m^3	+/-10%	2 (ug/m^3)	6 (ug/m^3)	90%
Particulate Sulfate (24 Hr)	FP/AC (ug/m^3) FP/IC (ug/m^3)	50	+/-15% 0.4 ug/m^3	+/-10%	0.3 (ug/m^3)	0.8 (ug/m^3)	90%
Particulate Nitrate (24 Hr)	FP/AC (ug/m^3) FP/IC (ug/m^3)	20	+/-15% 0.3 ug/m^3	+/-10%	0.2 (ug/m^3)	0.5 (ug/m^3)	90%
Particulate Ammonium (24 Hr)	FP/AC (ug/m^3)	20	+/-15% 0.03 ug/m^3	+/-10%	0.02 (ug/m^3)	0.05 (ug/m^3)	90%
Sulfur Dioxide (24 Hr)	FP/AC (ug/m^3) FP/IC (ug/m^3)	200	+/-15% 0.4 ug/m^3	+/-10%	0.3 (ug/m^3)	0.8 (ug/m^3)	90%
Nitric Acid (24 Hr)	TFR/IC (ug/m^3) TFR/AC (ug/m^3) FP/AC (ug/m3) FP/IC (ug/m^3)	20	+/-15% 0.4 ug/m^3	+/-10%	0.3 (ug/m^3)	0.8 (ug/m^3)	90%
Ammonia (24 Hr)	TFR/AC (ug/m^3) FP/AC (ug/m^3)	20	+/-15% 0.1 ug/m^3	+/-10%	0.07 (ug/m^3)	0.2 (ug/m^3)	90%
Ozone (1 Hr)	Photometry (ug/m^3)	1000	+/-10% or 10 ug/m^3	+/-10%	8 (ug/m^3)	25 (ug/m^3)	90%
Nitrogen Dioxide (1 Hr)	Luminol CL (ug/m^3)	100	+/-10% 0.2 ug/m^3	+/-10%	0.17 (ug/m^3)	0.5 (ug/m^3)	90%
(24 Hrs)	TEA FP/IC (ug/m^3)	20	+/-15% 0.4 ug/m^3	+/-10%	0.3 (ug/m^3)	0.8 (ug/m^3)	90%

Table 4-1 (Continued)

DATA QUALITY OBJECTIVES FOR
PRECISION, ACCURACY, LOWER QUANTIFIABLE LIMIT
AND COMPLETENESS

AIR QUALITY

Observable (Interval)	Method (Units)	Expec. Upper Range	Precision (The Larger of)	Accuracy	Lower Quantifiable Limits 3 x SD	10 x SD	Completeness
PAN (24 Hr)	FS/IC (ug/m^3)	40	+/-15% 4 ug/m^3	+/-10%	4 (ug/m^3)	14 (ug/m^3)	90%
Hydrogen Peroxide (1 Hr)	E/F (ppb)						
Hydrocarbons	GC/FID (ppbc)						
Aldehydes	Der/HPLC (ppb)						

FP/AC = Filter pack, automated colorimetric analysis
FP/IC = Filter pack, ion chromatographic analysis
Luminol CL = Luminol chemiluminescence
TFR/IC = Transition flow reactor, ion chromatographic analysis
TFR/AC = Transition flow reactor, automated colorimetric analysis
FS/IC = Filter sampler, ion chromatographic analysis
FP/G = Filter pack, gravimetry
FPC/G = Fine particle collector, gravimetry
PAN = Peroxyacetyl nitrate
GC/FID = Gas chromatography analysis with flame ionization detection
Der/HPLC = Derivatization with high performance liquid chromatograhic analysis

Table 4-1 (Continued)

DATA QUALITY OBJECTIVES FOR PRECISION, ACCURACY,
LOWER QUANTIFIABLE LIMIT AND COMPLETENESS

PRECIPITATION CHEMISTRY (24 Hrs)

Observable	Method (Units)	Expec. Upper Range	Precision (The Larger of)	Accuracy	Lower Quantifiable Limits 3 x SD	Lower Quantifiable Limits 10 x SD	Completeness
Precipitation Amount	Rain Collector (grams)	10,000	+/-10% 8 gm	+/-10%	8 (gm)	24 (gm)	90%
Field pH	pH Meter (pH units)	14	+/-0.04 pH units	+/-0.05 pH units	NA	NA	90%
Field Conductance	Cond. Mtr. (umho/cm)	NA	+/-10% 0.2 umho/cm	+/-10%	0.3 (umho/cm)	1 (umho/cm)	90%
Lab pH	pH Meter (pH units)	14	+/-0.04 pH units	+/-0.05 pH units	NA	NA	90%
Lab Conductance	Cond. Mtr. (umho/cm)	NA	+/-10% 0.2 umho/cm	+/-10%	0.3 (umho/cm)	1 (umho/cm)	90%
Sulfate	IC (umol/l)	100	+/-10% 0.2 umol/l	+/-10%	0.1 (umol/l)	0.4 (umol/l)	90%
Nitrate	IC (umol/l)	50	+/-10% 0.2 umol/l	+/-10%	0.1 (umol/l)	0.4 (umol/l)	90%
Chloride	IC (umol/l)	8	+/-15% 0.1 umol/l	+/-10%	0.1 (umol/l)	0.3 (umol/l)	90%
Ammonium	AC (umol/l)	10	+/-15% 0.6 umol/l	+/-10%	0.5 (umol/l)	1.4 (umol/l)	90%
Sodium	AA (umol/l)	8	+/-30% 0.5 umol/l	+/-10%	0.4 (umol/l)	1.1 (umol/l)	90%
Potassium	AA (umol/l)	4	+/-50% 0.3 umol/l	+/-10%	0.2 (umol/l)	0.6 (umol/l)	90%
Calcium	ICAPES (umol/l)	9	+/-20% 0.3 umol/l	+/-10%	0.2 (umol/l)	0.6 (umol/l)	90%
Magnesium	ICAPES (umol/l)	4	+/-15% 0.08 umol/l	+/-10%	0.07 (umol/l)	0.2 (umol/l)	90%

IC = Ion chromatography
AC = Automated colorimetry
AA = Atomic absorption spectroscopy
ICAPES = Inductively coupled argon plasma emission spectroscopy

Table 4-1 (Continued)

DATA QUALITY OBJECTIVES FOR
PRECISION, ACCURACY, LOWER QUANTIFIABLE LIMIT
AND COMPLETENESS

METEOROLOGY

Observable (Interval)	Method (Units)	Range Upper / Lower	Precision (The Larger of)	Accuracy	Lower Quantifiable Limits 3 x SD	Lower Quantifiable Limits 10 x SD	Completeness
Precipitation Amount (1 Hr)	Rain Gauge (cm)	NA	+/-10% 0.025cm	+/-0.13	0.025cm	0.076cm	90%
Wind Speed (1 Hr)	Anemometer (mph)	50	+/-10% 1 mph	+/-5%	1 mph	NA	90%
Wind Direction (1 Hr)	Wind Vane (deg)	540	+/-10^0	+/-10^0	NA	NA	90%
Temperature (1 Hr)	Thermistor (deg F)	122 / -40	+/-1^0 F	+/-1^0 F	NA	NA	90%
Dew Point (1 Hr)	LiCl (deg F)	104 / -22	+/-2^0 F	+/-2^0 F	NA	NA	90%
Barometric Pressure (1 Hr)	Capacit. (in Hg)	31 / 22	+/-0.05in	+/-0.1in	NA	NA	90%

probably be developed a posteriori based on analysis of field and laboratory measurement and quality control data. In the meantime, the PMG will attempt to ensure that the data are as comparable and representative as possible by taking the steps discussed below.

Representativeness will be judged both temporally and spatially. With only two years of data expected from the model evaluation field program a rigorous determination of temporal representativeness will probably not be possible for all measured observables. However, inferential determinations can be made by comparison with those observables for which longer term records exist, in particular meteorological variables. The actual comparison methods remain to be defined by the measurements teams.

Spatial representativeness can be assessed in at least two ways. One will be based on the data collected in the VAR network and will give insight into sub-grid cell variance. The other will be based on an analysis of paired-station covariance, using data from the combined networks. Higher covariance associated with stations having smaller separations would indicate lack of an overriding local source or topographical influence and therefore a higher probability of the stations' spatial representativeness.

Comparability will be established in several ways: by comparison of quality control data among networks, by inter-laboratory comparison studies involving the interchange of samples or the

challenging of samplers with common test atmospheres, by comparison of measurement data from the Egbert and Penn State inter-network colocation stations, and by comparison of standard operating procedures among networks. Development of procedures for implementing these comparisons will be the responsibility of the measurements teams.

Precision will be a measure of the reproducibility of measurements. Data from colocated samplers, replicate analyses, duplicate samples and repeated span checks can be used to measure reproducibility.

Accuracy will be determined by comparison of measurements against authoritative standards or, in their absence, against arbitrary standards. In the latter case, the determination will be referred to explicitly as "relative accuracy."

Lower quantifiable limit will be determined as the minimum concentration that a measurement process can distinguish at a specified confidence level above a background value. The procedure for determining an LQL may differ from observable to observable. It's value may vary with time, as the variables involved in its determination may not be constant.

Completeness will be determined as the percentage of the possible reported values that are actually validated and entered into the evaluation data sets. A common set of data validation criteria

will be established by the measurements Teams.

Section 5

DELIVERABLES AND SCHEDULE

5.1 PMG

Deliverables from the PMG include the Project Plan and semi-annual (or, as requested) briefings to the EMBSC on the project status. The project schedule is shown in Table 5-1.

5.2 Technical Oversight Teams

5.2.1 Operational measurements. The operational measurements team will be responsible for producing:

1. a standardized data set from the surface networks for use in the model evaluation;
2. evidence of the comparability of data sets from the contributing networks;
3. quality-assured data on a schedule commensurate with the needs of model evaluators and preliminary, screened data from intercomparison sites within 3 months so that the comparability of data among networks may be assessed;
4. a QA Plan for the operational networks and evidence of its application;
5. Quarterly reports to the PMG until approximately August 1988 and then Semi-annual reports thereafter.

5.2.2 Diagnostic measurements. The diagnostic measurements team will be responsible for producing:

1. a standardized data set from the airborne measurements,

Table 5-1

SCHEDULE

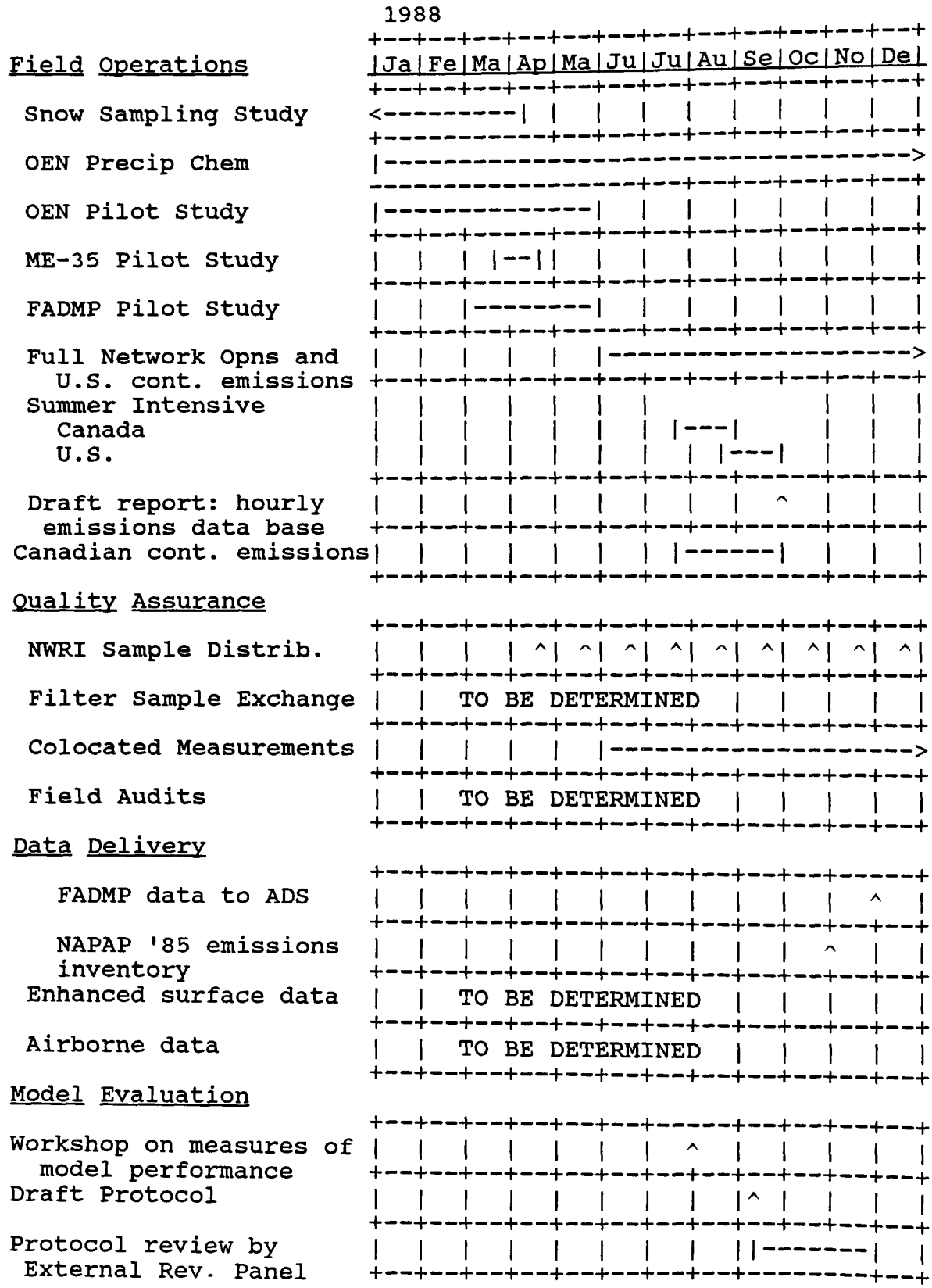


Table 5-1 (Continued)

SCHEDULE

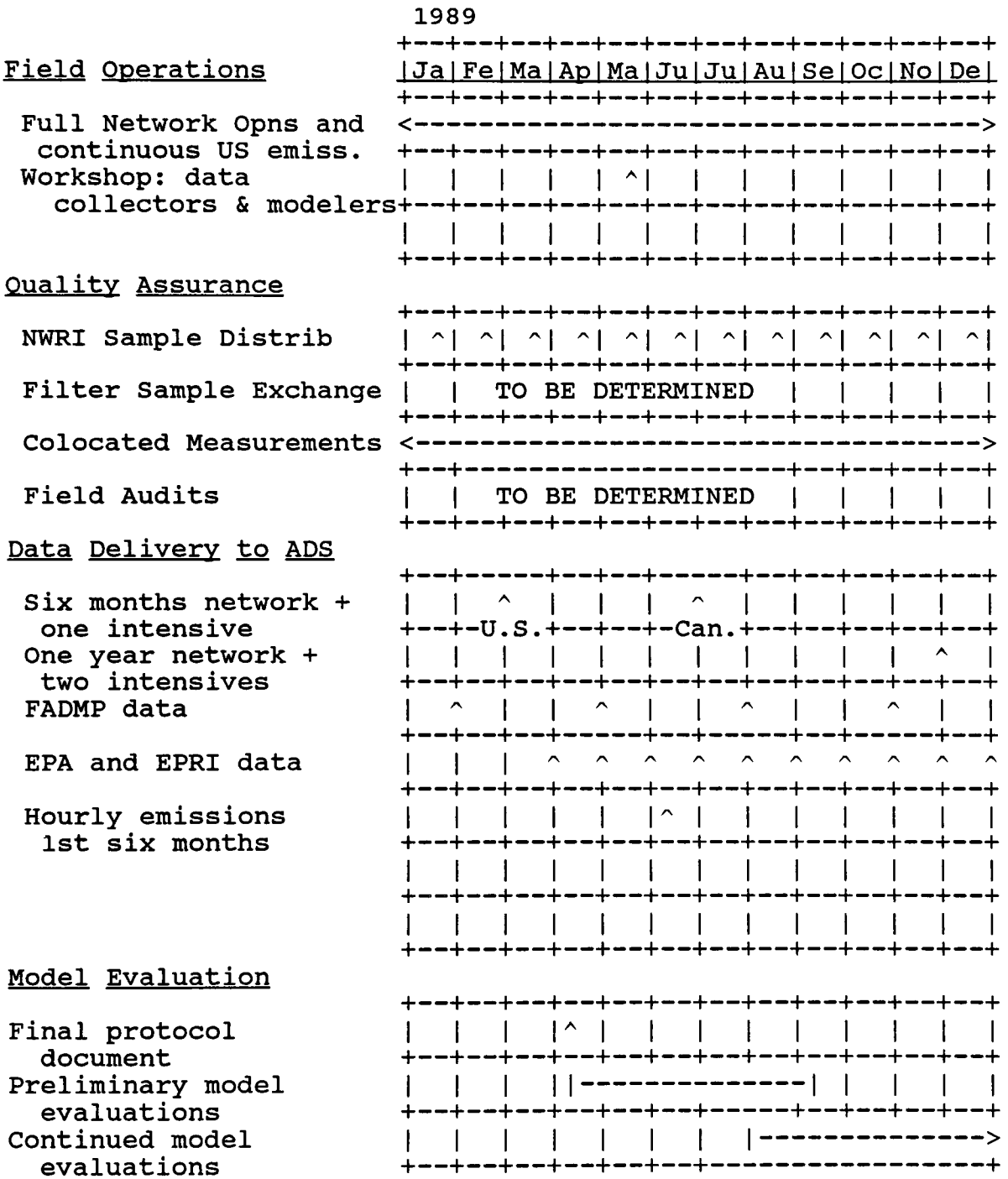
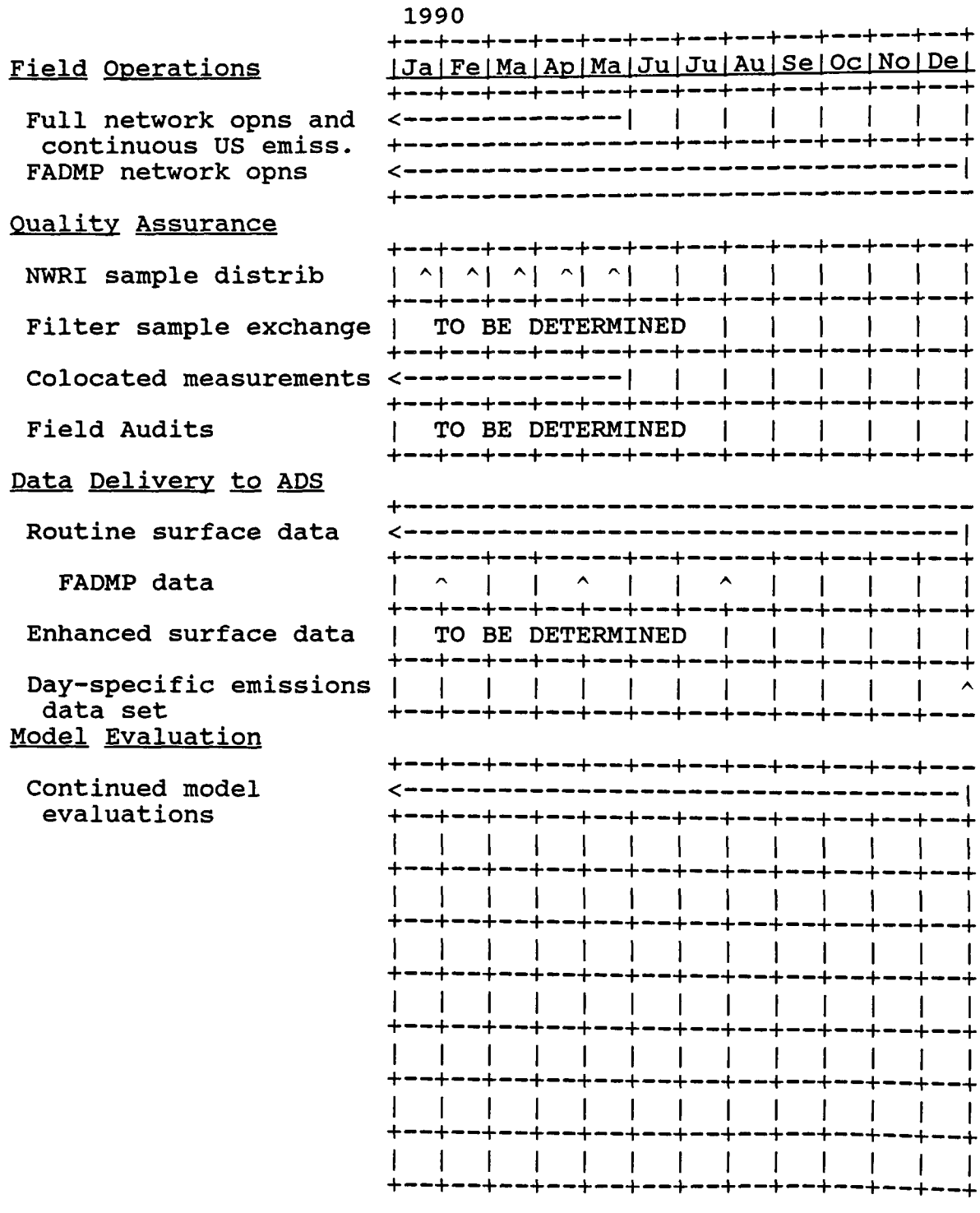


Table 5-1 (Continued)

SCHEDULE



VAR network, and enhanced chemistry stations;

2. evidence of the comparability of data sets from the contributing programs;
3. quality-assured data no longer than 6 months after completion of the measurements;
4. QA plan for the diagnostic measurements and evidence of its application; and
5. semi-annual reports to the PMG.

5.2.3 Emissions inventories. The emissions inventories team will be responsible for producing:

1. a standardized emissions data base for use in model evaluation;
2. evidence of the comparability of the constituent data sets;
3. quality assured data on a schedule that meets the needs of the model evaluation team;
4. QA plan for the emissions inventory and evidence of its application; and
5. semi-annual reports to the PMG.

5.2.4 Model evaluation. The model evaluation team will be responsible for producing:

1. scientifically defensible model evaluation protocols;
2. establishment of a model evaluation advisory committee;
3. QA plan for model evaluation process and evidence of its application as part of the final report on model

evaluation;

4. statement of requirements and schedules for data delivery for model evaluation; and

5. semi-annual reports to the PMG.

Section 6

AEROMETRIC AND PRECIPITATION MEASUREMENTS

This section describes what and where measurements will be made, what tests have been conducted to characterize their performance, what steps will be taken to achieve the data quality objectives, and how the data will be archived.

6.1 Field Measurements

Observational data are to be collected over a two-year period beginning in mid-1988 in at least five surface-based, cooperatively coordinated, measurement networks (see Figure 6-1). In the U.S.A., the Environmental Protection Agency (EPA), EPRI, and the Florida Electric Power Coordinating Group (FCG) will operate networks, while in Canada the Atmospheric Environment Service (AES) and the Ontario Ministry of the Environment (OME) will do likewise. (The door is being left open for participation by other organizations, providing they meet the standards specified for ensuring comparability of their measurements with those of the existing participants.) Participating sites and their locations are listed in Table 6-1. Sites have been selected with regard to their freedom from the influence of local emission sources, their placement with respect to one another to ensure that important spatial gradients in deposition predicted by the models can be resolved, and other criteria as enumerated in planning documents. (See, for example, Operational Evaluation Network Work Plan, ERT, 1987.)

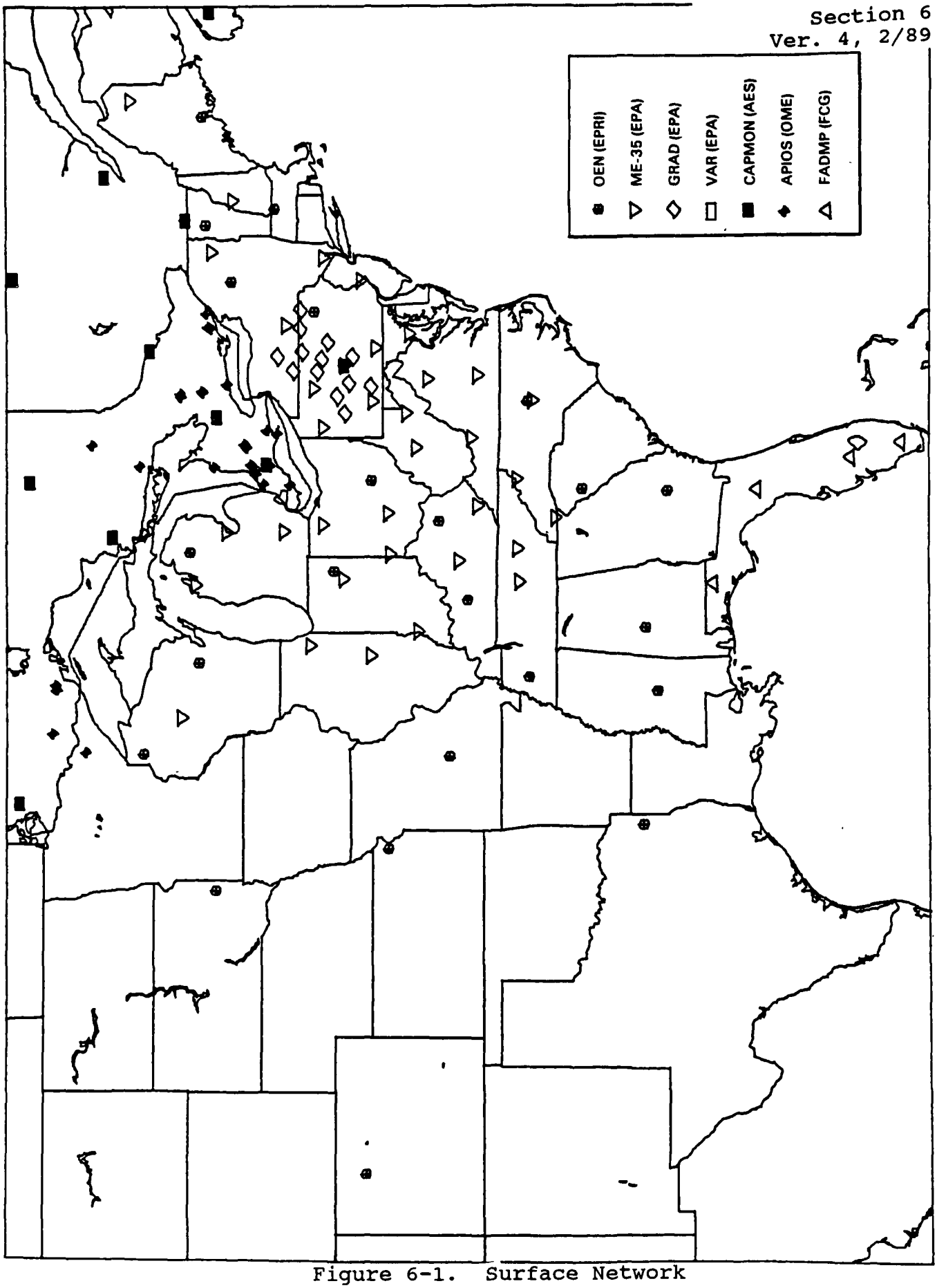


Figure 6-1. Surface Network

Table 6-1

MODEL EVALUATION FIELD STUDY
SITE LOCATIONS

APIOS (OME)

SITE NAME	NO.	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
Longwoods (with AES)	01	42 53	81 29	PC,SO2,SO4,tNO3,RG
Wellesley	02	43 28	80 46	PC,SO2,SO4,tNO3,RG
Balsam Lake	03	44 38	78 51	PC,SO2,SO4,tNO3,RG
Dorset	04	45 13	78 56	PC,SO2,SO4,tNO3,RG, O3,NOX,PAN
Charlston Lake	05	44 30	76 03	PC,SO2,SO4,tNO3,O3,RG
Fernberg	06	47 50	91 52	PC,SO2,SO4,tNO3,RG
Gowganda	07	47 39	80 47	PC,SO2,SO4,tNO3,RG
High Falls	08	46 20	81 33	PC,SO2,SO4,tNO3,O3,RG
Egbert (with AES, EPA, EPRI)	09	44 14	79 47	PC,SO2,SO4,tNO3,RG
State College, PA (with AES, EPA, EPRI)	10	40 47	77 56	PC,SO2,SO4,tNO3,O3,RG
Rural Ozone Only				
Hawkeye Lake	11	48 40	89 26	O3
Tiverton	12	44 18	81 35	O3
Huron Park	13	43 18	81 30	O3
Thedford	14	43 10	81 51	O3
Parkhill	15	43 10	81 41	O3
Mendaumin	16	42 57	82 12	O3
Merlin	17	42 15	82 13	O3
Long Point	18	42 35	80 23	O3
Simcoe	19	42 51	80 16	O3
Stouffville	20	43 57	78 36	O3

Table 6-1 (Continued)

MODEL EVALUATION FIELD STUDY
SITE LOCATIONS

APIOS (OME), Continued

Precipitation Chemistry Only*

SITE NAME	NO.	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
Melbourne	21	42 47	81 33	PC
N. Easthope	22	43 24	80 53	PC
Raven Lake	23	44 37	78 54	PC
Nithgrove	24	45 12	79 04	PC
Wilmer	25	44 27	76 32	PC
Railton	26	44 23	76 36	PC
Dawson	27	48 38	89 37	PC
Quetico Centre	28	48 45	91 12	PC

PC: Precipitation chemistry: pH, conductivity, sulfate, nitrate, chloride, ammonium, sodium, potassium, calcium, magnesium
SO2: Gaseous sulfur dioxide
SO4: Particulate sulfate
tNO3: Gaseous nitric acid plus particulate nitrate
O3: Gaseous ozone
PAN: Gaseous peroxyacetyl nitrate
RG: Weighing bucket rain gauge
* Data delivery on slower schedule than from sites 1-10.

Table 6-1 (Continued)

MODEL EVALUATION FIELD STUDY
SITE LOCATIONS

CAPMoN (AES)

SITE NAME	NO.	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
ELA	01	49 39	93 43	PC,SO2,SO4,tNO3,O3,RG
Algoma	02	47 06	84 06	PC,SO2,SO4,tNO3,O3,RG
Bonner Lake	03	49 23	82 07	PC,RG
Chalk River	04	46 04	77 24	PC,SO2,SO4,tNO3,O3,RG
Sutton	05	45 05	72 42	PC,SO2,SO4,tNO3,O3,RG
Montmorency	06	47 19	71 09	PC,SO2,SO4,tNO3,O3,RG
Kejimkujik	07	44 26	65 12	PC,SO2,SO4,tNO3,O3,PAN, RG
Chapais	08	49 49	74 49	PC,SO2,SO4,tNO3,O3,RG
Egbert (with EPA, EPRI, OME)	09	44 14	79 47	PC,SO2,SO4,tNO3,O3,RG
State College, PA (with EPA,EPRI, OME)	10	40 47	77 56	PC,SO2,SO4,tNO3,RG
Longwoods (with OME)	11	42 53	81 29	PC,SO2,SO4,tNO3,O3,RG

PC: Precipitation chemistry: pH, conductivity, sulfate, nitrate, chloride, ammonium, sodium, potassium, calcium, magnesium
SO2: Gaseous sulfur dioxide
SO4: Particulate sulfate
tNO3: Gaseous nitric acid plus particulate nitrate
O3: Gaseous ozone
PAN: Gaseous peroxyacetyl nitrate
RG: Rain gauge

Table 6-1 (Continued)

MODEL EVALUATION FIELD STUDY
SITE LOCATIONS

OEN (EPRI)

SITE NAME	NO.	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
Tunkhannock, PA	02[a]	41 34 30	75 59 40	PC, APC, gases, met
Ft. Wayne, IN	07	41 02 39	85 19 08	"
Gaylord, MI	10	44 56 58	84 38 30	"
Winterport, ME	13	44 37 05	68 58 30	"
Uvalda, GA	14	32 01 59	82 29 24	"
Marshall, TX	17	32 39 58	94 25 06	"
Lancaster, KS	18	39 34 10	95 18 17	"
Underhill, VT	20[a]	44 31 42	72 52 08	"
Big Moose, NY	21	43 49 03	74 54 08	"
Yampa, CO	23	40 09 54	106 54 49	"
Shawano, WI	24[a]	44 42 30	88 37 28	"
Round Lake, WI	25	46 14 09	91 55 40	"
Warwick, MA	26	42 39 00	72 18 10	"
Zanesville, OH	27	40 01 52	82 04 04	"
Leitchfield, KY	28	37 25 30	86 21 10	"
Pittsboro, NC	29	35 47 30	79 15 20	"
Moorhead, KY	30	38 12 10	83 31 20	"
Bells, TN	31	35 44 30	89 07 30	"
Marion, AL	32	32 36 45	87 21 30	"
Morton, MS	33	32 17 30	89 38 00	"
Due West, SC	34	34 19 30	82 23 10	"
State College, PA	36[b]	40 46 59	77 55 59	"
Brookings, SD	37	44 14 50	96 49 50	"
Jerome, MO	38	37 55 10	91 58 55	"
Egbert, Ont.	39[b]	44 14 00	79 47 00	PC,APC,SO2,HNO3,NH3

[a] With ME-35
[b] With APIOS, CAPMoN, ME-35
PC= Precipitation chemistry: pH, conductivity, sulfate, nitrate, chloride, ammonium, sodium, potassium, calcium, magnesium; APC= Aerosol particle chemistry: mass, sulfate, nitrate, ammonium; Gases: Ozone, nitrogen dioxide, sulfur dioxide, nitric acid, ammonia; Met: Precipitation amount, wind speed, wind direction, dew point, temperature, barometric pressure

Table 6-1 (Continued)

MODEL EVALUATION FIELD STUDY SITE LOCATIONS

ME-35 (EPA)

SITE NAME	NUMBER	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
Pittsboro, NC	301	35.67	79.23	PC*,PA, APC, FPM,gases
Wartburg, TN	302	36.08	84.54	PC, PA, APC, gases
West Pt, NY	303	41.35	74.05	PC, PA, APC, FPM,gases
Whiteface Mtn, NY	305	44.38	73.85	PC*,PA, APC, FPM,gases
State College, PA	306[a]	40.78	77.93	PC, PA, APC, FPM,gases
Parsons, WV	307	39.10	79.66	PC*,PA, APC, gases
Prince Ed. SF, VA	308	37.17	78.31	PC, PA, APC, FPM,gases
Hubbard Brook, NH	309	43.80	72.00	PC, PA, APC, FPM,gases
Ithaca/Danby, NY	310	42.35	76.49	PC*,PA, APC, FPM,gases
Kane Forest, PA	312	41.60	78.77	PC, PA, APC, FPM,gases
Goddard SP, PA	313	41.35	80.17	PC, PA, APC, FPM,gases
Deer Cr. Park, OH	314	39.64	83.22	PC, PA, APC, FPM,gases
Newcomb Tract, MI	315	42.42	83.90	PC*,PA, APC, gases
Beltsville, MD	316	39.03	76.82	PC*,PA, APC, FPM,gases
Laurel Hill SP, PA	317	40.01	79.23	PC, PA, APC, FPM,gases
Tanners Ridge, VA	318	38.52	78.48	PC*,PA, APC, gases
Cedar Creek SP, WV	319	38.88	80.85	PC, PA, APC, FPM,gases
Mountain Lake, VA	320	37.37	80.52	PC, PA, APC, FPM,gases
Lilley Cornett, KY	321	37.09	82.99	PC, PA, APC, FPM,gases
Oxford, OH	322	39.53	84.72	PC, PA, APC, gases
Brokensword, OH	323	40.92	83.00	PC, PA, APC, FPM,gases
Unionville, MI	324	43.63	83.38	PC, PA, APC, FPM,gases
Roaring Creek, NC	326	36.11	82.05	PC, PA, APC, gases
Edgar Evins SP, TN	327	36.04	85.73	PC, PA, APC, FPM,gases
Arendtsville, PA	328	39.92	77.31	PC, PA, APC, FPM,gases
Perryville, KY	329	37.68	84.97	PC*,PA, APC, FPM,gases
Bondville, IL	330	40.05	88.37	PC*,PA, APC, gases
Salimonie Lake, IN	333	40.80	85.60	PC, PA, APC, FPM,gases
Perkinstown, WI	334	45.20	90.60	PC*,PA, APC, FPM,gases
Ashland, ME	335	46.62	68.41	PC*,PA, APC, FPM,gases
Coweeta Forest, NC	337	35.05	83.43	PC*,PA, APC, FPM,gases
Vincennes, IN	340	38.78	87.49	PC, PA, APC, FPM,gases
Washington Cr. NJ	344	40.32	74.87	PC, PA, APC, FPM,gases
University Park,IL	346	41.45	87.72	PC, PA, APC, FPM,gases
Cadillac, MI	349	44.13	85.42	PC, PA, APC, gases
Underhill, VT	395[b]	44.53	72.87	PC, PA, APC, gases
Tunkhannock, PA	396[b]	41.58	75.99	PC, PA, APC, gases
Shawano, WI	397[b]	44.71	88.62	PC, PA, APC, gases
Egbert, Ont	398[a]	44.14	79.47	PC, PA, APC, gases

PC= Precipitation chemistry: pH, conductivity, sulfate, nitrate, chloride, ammonium, sodium, potassium, calcium, magnesium; PA= Precipitation amount; APC= Aerosol particle chemistry: sulfate, nitrate, ammonium; FPM= Fine particle mass; Gases= Sulfur dioxide, nitric acid, nitrogen dioxide, ammonia

[a] With APIOS, CAPMoN, OEN

[b] With OEN

* Includes S(IV)

Table 6-1 (Continued)

MODEL EVALUATION FIELD STUDY SITE LOCATIONS

EPA Optional (O), Supplementary (S), and TVA (T) Sites

NAME	SITE NUMBER	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
Grant Fork, IL	356(O)	38.92	89.73	PC, PA, APC, gases
Piseco, NY	357(O)	43.45	74.52	PC, PA, APC, gases
Belleayre, NY	358(O)	42.14	74.52	PC*,PA, APC, gases, FPM
Plainview, IL	359(S)	39.08	89.95	PC, PA, APC, gases, FPM
Breese, IL	360(S)	38.67	89.73	PC, PA, APC, gases
Quabbin Res.,MA	393(S)	42.30	72.34	PC, PA, APC, gases
Land Bet.Lakes, KY (LBL)	394(T)	36.79	88.07	PC, PA, APC, gases

EPA Gradient Resolution Network (GRAD)

NAME	SITE NUMBER	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
Ford City, PA	361	40.75	79.51	PC*,PA, APC, gases@
Hawthorne, PA	362	41.03	79.27	PC, PA, APC, FPM,gases@
Pr.Gallitzin, PA	363	40.63	78.56	PC*,PA, APC, gases@
Shawnee SF, PA	364	40.03	78.64	PC, PA, APC, gases@
Decatur, PA	365	40.71	77.40	PC*,PA, APC, gases@
Emporium, PA	366	41.50	78.15	PC ,PA, APC, gases@
Renovo, PA	367	41.37	77.53	PC*,PA, APC, FPM,gases@
Williamsport, PA	368	41.16	76.92	PC, PA, APC, FPM,gases@
Wirt, NY	369	42.15	78.11	PC, PA, APC, gases@
Little Marsh, PA	370	41.90	77.44	PC*,PA, APC, FPM,gases@
E. Smithfield,PA	371	41.95	76.66	PC, PA, APC, gases@
Wayland, NY	372	42.56	77.60	PC*,PA, APC, gases@
Brackney, PA	373	41.94	75.92	PC*,PA, APC, gases@
North Orwell, PA	374	41.90	76.28	PC, PA, APC, gases@

PC: Precipitation chemistry: pH, conductivity, sulfate, nitrate, chloride, sodium, potassium, calcium, magnesium
* Includes S(IV)
PA: Precipitation amount
APC: Aerosol particle chemistry: sulfate, nitrate
FPM: Fine particle mass
Gases: Sulfur dioxide, nitric acid, nitrogen dioxide, ammonia
@ Includes ozone

Table 6-1 (Continued)

MODEL EVALUATION FIELD STUDY SITE LOCATIONS

EPA Sub-grid Variability Network (VAR)

NAME	SITE NUMBER	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
Eddyville, Ky	381	37.07	88.03	PC, PA, APC, gases@
Cadiz, Ky	382	36.77	87.73	PC, PA, APC, gases@
New Concord,Ky	383	36.53	88.09	PC, PA, APC, gases@
Benton, Ky	384	36.82	88.405	PC, PA, APC, gases@

FADMP (FCG)

SITE NUMBER	LATITUDE	LONGITUDE	OBSERVABLES MEASURED
2	30 47 30	85 48 29	PC, PA, APC, gases@
5	29 38 40	82 28 34	PC, PA, APC*, gases*@
9**	27 10 41	81 21 30	PC, PA, APC, gases@
13	25 45 38	80 49 40	PC, PA, APC*, gases*@

PC: Precipitation chemistry: pH, conductivity, sulfate, nitrate, chloride, sodium, potassium, calcium, magnesium
PA: Precipitation amount
APC: Aerosol particle chemistry: sulfate, nitrate, ammonium
Gases: Sulfur dioxide, nitric acid, nitrogen dioxide, ammonia
* Samples collected as 3-day averages
** Present location; may be relocated within 1 km.
@ Includes ozone
TBD: To be determined

Embedded within these two years would be four periods in which more intensive (higher sampling frequency) and extensive (additional variables) measurements would be taken from aircraft and at special (enhanced) surface sites. These intensive measurement periods are planned to collect data for diagnostic evaluations since the surface network does not provide the relevant information. The intensive periods will be scheduled to sample important seasonal contrasts.

6.1.1 EPA: ACID-MODES. The EPA field measurement programs are collectively referred to as the ACID Model Operational/ Diagnostic Evaluation Study. Data for the operational aspect will come from a 35-station network called the ME-35, located in the eastern U.S. The variables that will be measured in this network, the measurement techniques, and the data averaging intervals are listed in Table 6-2.

The issue of how representative of the total area within a modeled grid cell are the measurements made at one station will be explored using three to five additional measurement stations clustered around three geographically dispersed ME-35 or TVA stations. As shown in Table 6-1, the exact locations of the stations comprising this sub-grid variability network (VAR) have yet to be determined. An additional set of 14 stations arrayed in three parallel linear chains in a southwest-northeast direction across Pennsylvania into New York will be operated by EPA in a effort to resolve the steep depositional gradient expected in that region. This set is called the GRAD network,

Table 6-2

ME-35 MEASUREMENT TECHNIQUES

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD (hrs)
Air Quality		
Particulate sulfate, nitrate, ammonium	FP/AC	24
Nitric acid, ammonia	TFR/AC	24
Ammonia, sulfur dioxide, nitrogen dioxide	FP/AC	24
Precipitation Chemistry		
Amount	WOC	24
pH	pH Meter	24
Conductivity	meter	24
Sulfate, nitrate, ammonium, chloride	AC	24
Sodium, potassium	AA	24
Calcium, magnesium	ICAPES	24
Dissolved sulfur dioxide	AC	24

FP/AC = Filter pack, automated colorimetric analysis
TFR/AC = Transition flow reactor, automated colorimetry
TEA FP/AC = Triethanolamine impregnated filter in filter pack, automated colorimetry analysis
WOC = Wet-only collector
AA = atomic absorption spectroscopy
ICAPES = Inductively coupled argon plasma emission spectroscopy

referring to its role in resolving depositional and concentration gradients. The locations of its stations are also given in Table 6-1. In addition to the same measurements made at ME-35 stations, ozone will be measured at GRAD network stations. Consideration is being given to the possibility of expanding the number of GRAD stations at a later date.

EPA is also funding the operation of additional stations cooperatively with state agencies in Illinois, New York, and Massachusetts, and with the Tennessee Valley Authority in Tennessee. These sites are also listed in Table 6-1.

Plans call for collection of the data for diagnostic evaluations primarily during 6-week-long intensive measurement periods at least during the summer of 1988 and possibly spring of 1990. The emphasis during these "intensives" will be on the collection of airborne measurement data to yield vertical profiles and horizontal transects at a higher spatial and temporal resolution than obtainable from the surface networks. These data will be supplemented with those from measurements taken at the less numerous enhanced chemistry stations (see Sections 6.1.2, 6.1.3 and 6.1.6) of a larger suite of variables at higher temporal resolution than those taken at the majority of surface stations. Descriptive information on the broad suite of variables to be measured during intensives appears in Table 6-3.

6.1.2 OME: APIOS. Eight stations of the existing Acid Precipitation in Ontario Study daily sampling network have been

Table 6-3

MEASUREMENT TECHNIQUES TO BE USED
DURING INTENSIVES

EPA

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD
Sulfur dioxide	Flame photometry	1 min (5 sec)
Sulfur dioxide, nitric acid	FP/IC	30 min
Ozone	Chemiluminescence	1 min (5 sec)
Ammonia	FP/AC	30 min
Nitrogen dioxide	Luminol chemiluminescence	1 min (5 sec)
Hydrogen peroxide	E/F	1 min
Hydrocarbons (speciated)	Capillary column GC	Integrated (5 to 30 min)
Light scattering coefficient	Nephelometer	1 min (5 sec)
Dew point	Chilled mirror	1 min
Broad band radiation	Pyranometer	1 min
Ultraviolet radiation	Photocell	1 min
Altitude	Absolute pressure transducer	Continuous
Position	Loran - C	Continuous
Particulate sulfate, nitrate chloride	FP/IC	30 min
Particulate ammonium	FP/AC	30 min

Table 6-3 (Continued)

MEASUREMENT TECHNIQUES TO BE USED
DURING INTENSIVES

AES Ground-based Measurements at Egbert

Same measurements shown in Table 6-5 plus:

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD
Sulfur dioxide	Pulsed fluorescence Filter pack	Continuous 6 hrs
Ozone	UV photometry	Continuous
NOy	Catalytic reduction, chemiluminescence	Continuous
Nitrogen dioxide	Luminol chemiluminescence	Semi-continuous
Nitric oxide	Chemiluminescence	Continuous
Ammonia	Filter pack Denuder	6 hrs 1 hr
PAN	GC/ECD	(48/day)
Nitric acid	Filter pack	6 hrs
Hydrogen peroxide	TDLAS Coulometric peroxidase Luminol chemiluminescence	5 min Continuous Continuous
Formaldehyde	TDLAS	5 min
Aldehydes	GC	1 hr
Hydrocarbons (speciated)	GC	(3/day)
Carbon monoxide	NDIR	Continuous
Aerosol particles	Filter pack	6 hrs

GC/ECD = Gas chromatography with electron capture detection
TDLAS = Tunable diode laser absorption spectroscopy
NDIR = Non-dispersive infrared

Table 6-3 (Continued)

MEASUREMENT TECHNIQUES TO BE USED
DURING INTENSIVES

Additional AES Measurements at Egbert

OBSERVABLE	TECHNIQUE	FREQUENCY OF MEASUREMENT
Ozone profile	Tethersonde	Periodically
Ozone/SO2 profile	DIAL	Periodically
Ozone profile	Beukersonde	2/day as appropriate
Temp., RH profile	Beukersonde	4/day as appropriate
Mixing depth	Acoustic sounder Mie lidar	Continuous Continuous
Micrometeorological variables	Standard met tower	Continuous

Table 6-3 (Continued)

MEASUREMENT TECHNIQUES TO BE USED
DURING INTENSIVES

OME Ground-based Measurements at Dorset

Same measurements shown in Table 6-4 plus:

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD
Ammonia	Filter pack	24 hrs
NOy	Catalytic reduction with chemiluminescence	Continuous
NO/NO2	Luminol chemiluminescence	Continuous
PAN	GC/ECD	(48/day)
Hydrogen peroxide	TDLAS	Continuous
Formaldehyde	TDLAS	Continuous
Aldehydes	TAGA 6000	Continuous
Hydrocarbons (speciated)	GC	(3/day)

GC/ECD = Gas chromatography with electron capture detection
TDLAS = Tunable diode laser absorption spectroscopy
TAGA 6000 = A system based on mass spectrometry

adapted for operational model evaluation data collection. OME will also support colocated measurements with AES, EPA, and EPRI at Egbert, Ontario and State College, PA. Measuring capabilities at these sites are summarized in Table 6-4. One OME site -- Dorset -- is being instrumented for intensive atmospheric chemistry measurements. The measurements to be made there are listed in Table 6-3.

6.1.3 AES: CAPMoN, enhanced chemistry sites and aircraft. A 10-station subset of the existing Canadian Air and Precipitation Monitoring Network has been designated for operational evaluation data collection. AES will also support colocated measurements with EPA, EPRI, and OME at the State College, PA site. Measurement attributes are shown in Table 6-5. The site at Egbert, Ontario, will not only serve as another location for colocating one sampling system each from AES, EPA, EPRI, and OME, but will also have enhanced measurement capabilities (listed in Table 6-3) to provide data for diagnostic evaluation.

AES also is planning an airborne measurement campaign to collect data for diagnostic evaluation as summarized in Table 6-6. To the extent possible, the AES measurement campaign will overlap with that of EPA.

Table 6-4

APIOS MEASUREMENT TECHNIQUES

OBSERVABLE	TECHNIQUE OR PROCEDURE	AVERAGING PERIOD (hrs)
Air Measurements		
Sulfate and Nitrate	Teflon filter, extract in DDW Ion chromatography	24
Ammonium	Teflon filter, extract in DDW Automated colorimetry	24
Nitric acid and Sulfur dioxide	Nylon Filter, extract in 0.003N NaOH, ion chromatography	24
Sulfur dioxide	Whatman 41 impregnated with K2CO3 Extract with H2O2, ion chromatog.	24
N.B. Sulfur dioxide is obtained as the sum of the nylon and Whatman 41 values.		
Precipitation Measurements		
pH	pH meter with low conductance combination electrode	24
Total acidity	Gran titration	24
Conductivity	Conductivity cell and meter	24
Sulfate, nitrate and chloride	Ion chromatography	24
Ammonium	Automated colorimetry	24
Sodium, potassium calcium and magnesium	Flame atomic absorption	24

Table 6-5

CAPMoN MEASUREMENT TECHNIQUES

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD (hrs)
Air Measurements		
Sulfate and nitrate	FP/IC	24
Sulfur dioxide and nitric acid	FP/IC	24
Ozone	UV Photometry	Continuous
Precipitation Chemistry		
pH	pH meter	24
Sulfate, nitrate, chloride	Ion chromatography	24
Ammonium	Automated colorimetry	24
Sodium, potassium	Flame photometry	24
Calcium, magnesium	Atomic absorption	24

FP/IC = Collection with filter pack, ion chromatographic analysis

Table 6-6

AIRBORNE MEASUREMENTS TO BE TAKEN BY AES

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD
Sulfur dioxide	Pulsed fluorescence	30 sec
Nitric oxide	Luminol chemiluminescence	20 sec
Nitrogen dioxide, ozone	Luminol chemiluminescence	1 sec
PAN	GC, luminol chemiluminescence	5 min
Hydrogen peroxide	Enzymatic fluorimetric	10 sec
Hydrocarbons (speciated)	Cannister samples analyzed by GC	5x2 min
Sulfate, nitrate, nitric acid, ammonia	Filter pack	50 min
Aldehydes	DNPH cartidges	50 min
Solar radiation	UV radiometer	30 sec
Cloud/precipitation water	ASRC collector	<20 min
Aerosol size distribution	PMS ASASP	<1 sec
Cloud droplet size distribution	PMS FSSP	<1 sec
Precipitation particle size distribution	2-D grey scale 2-D-P	<1 sec
Cloud liquid water content	PMS FSSP King probe	<1 sec

GC = Gas chromatography

6.1.4 EPRI: OEN. The Operational Evaluation Network will include 23 independent sites (exclusive of the 2 colocated with the other networks). These are largely at or nearby former sites in the Utility Acid Precipitation Study Program (UAPSP). A summary of OEN measurements is given in Table 6-7.

6.1.5 FCG: FADMP. Four sites will be operated in Florida using methods virtually identical to those used in the OEN (see Table 6-8). 24-hour precipitation samples will be collected at all four sites. 24-hour air quality samples will be collected every day at two of the sites and 72-hour samples every third day at the remaining two sites (see Table 6-1).

6.1.6 Complementary programs. Several studies of various aspects of the acidic deposition phenomenon will be taking place concurrently with the model evaluation field study. Results from some of these will be useful supplements for model evaluation. In addition, opportunities for collaboration with other organizations are being investigated.

Table 6-7

OEN MEASUREMENT TECHNIQUES

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD (hrs)
Air Quality		
Particulate mass, sulfate, nitrate ammonium	FP/AC	24
Sulfur dioxide	FP/AC	24
Nitric acid, ammonia	TFR/FP/AC	24
Ozone	UV Photometry	1
Nitrogen dioxide	Luminol chemiluminescence	1
Peroxyacetyl nitrate	Alkaline filter/IC	24
Hydrocarbons, speciated	Canister/CCGC	24
Carbonyls	DNPH/HPLC	24
Meteorology		
Wind speed	Cup anemometer	1
Wind direction	Wind vane	1
Temperature	Thermistor	1
Dew point	LiCl cell	1
Barometric pressure	Capacitance	1
Precipitation amount	Weighing bucket	1
Precipitation Chemistry		
pH, field and lab	pH meter	24
Conductivity, field and lab	Conductivity meter	24

Table 6-7 (continued)

OEN MEASUREMENT TECHNIQUES

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD (hrs)
Precipitation Chemistry (continued)		
Sulfate, nitrate, chloride	IC	24
Ammonium	AC	24
Sodium, potassium	AA	24
Calcium, magnesium	ICAPES	24
Precipitation amount	WOC	24

FP/AC = Filter pack collection, automated colorimetric analysis
TFR = Transition flow reactor
IC = Ion chromatographic analysis
Canister/CCGC = Collection in passivated canister, capillary column gas chromatographic analysis
DNPH/HPLC = Collection on dinitrophenylhydrazine cartridge, analysis by high performance liquid chromatography
AA = Atomic absorption spectroscopic analysis
ICAPES = Inductively coupled argon plasma emission spectroscopic analysis
WOC = Wet-only collector

Table 6-8

FADMP MEASUREMENT TECHNIQUES

OBSERVABLE	TECHNIQUE	AVERAGING PERIOD (hrs)
Air Quality		
Particulate sulfate nitrate, ammonium	FP/AC	24
Nitric acid	TFR/FP/AC	24
Ammonia, sulfur dioxide, nitrogen dioxide	FP/AC	24
Precipitation Chemistry		
Amount	WOC	24
pH	pH meter	24
Conductivity	conductivity meter	24
Sulfate, nitrate, chloride	IC	24
Sodium, calcium, magnesium	ICAPES	24
Ammonium	AC	24
Potassium	AE	24

FP = Filter pack
AC = Automated colorimetric analysis
TFR = Transition flow reactor
WOC = Wet-only collector
AE = Atomic emission spectroscopy
IC = Ion chromatography
ICAPES= Inductively coupled argon plasma emission spectroscopy

The Department of Energy's acid deposition research program is termed Processing of Emissions by Clouds and Precipitation (PRECP). Many of its researchers will have participated in a multi-agency field investigation of convective storms in the vicinity of Champaign, IL. Dubbed 3CPO (for Cloud Chemistry and Cloud Physics Organization) it was planned for May through July 1988 --coincident with the beginning of the model evaluation field study. The dynamics of convective storms and how they process atmospheric constituents were to be studied with an eye toward refining the parameterizations in the RADM scavenging module. The following year, in late Fall 1989, PRECP researchers plan to similarly study stratiform cloud systems. Although the results will be most useful to those developing models, they may also find model evaluation applications.

NOAA -- at the Scotia Range at Penn State; SUNY (Albany) -- at Whiteface Mountain, NY; TVA -- at Whitetop Mountain; and Georgia Tech -- at Brasstown Bald in north Georgia, operated specially equipped ground stations and an aircraft (NOAA) during the summer 1988 intensive measurement period. As an example of the types of measurements that are to be made at these locations, the measurements planned for the Georgia Tech site are shown in Table 6-9. Data will be used for diagnostic model evaluation and refining estimates of inflow boundary conditions for the modeling domain.

American Electric Power Service Corporation is sponsoring the collection of several hundred canister and sorbent samples at

Table 6-9

MEASUREMENTS PLANNED FOR GEORGIA TECH
SITE AT BRASSTOWN BALD DURING SUMMER 1988 INTENSIVE

OBSERVABLE	TECHNIQUE	SAMPLE PERIOD
O_3	UV Photometry	12 sec
SO_2	Pulsed Fluorescence	continuous
NO	Chemiluminescence	2 min
NO_2	Photolysis/chemiluminescence	2 min
NO_y	Au converter/chemiluminescence	2 min
CO	GC/HgO detection	4-5/hr
NMHC (speciated)	GC/FID	2/hr (max)
HNO_3	Nylon filter in filter pack IC analysis	30 min to 2 hrs
$SO_4^=$ (particulate)	Teflon filter in filter pack IC analysis	30 min to 2 hrs
NO_3^- (particulate)	Teflon filter in filter pack IC analysis	30 min to 2 hrs

NMHC = Non-methane hydrocarbons
GC = Gas chromatography
FID = Flame ionization detector
IC = Ion chromatography

five OEN stations during the Autumn 1988 and possibly the Spring 1990 U.S. intensives. Plans call for the canister samples to be collected over 24-hour period and analyzed by capillary column gas chromatography for C2 through C12 hydrocarbons. The sorbent samples are to be collected over 12-hour periods and analyzed for C1 through C5 carbonyl compounds. The data will be used for diagnostic model evaluation and for checks on the hydrocarbons emissions estimates.

6.2 Emission Inventories

A necessary input for exercising the models is the gridded emissions distribution. Inventories for the U.S. and Canada have been compiled for sulfur dioxide, nitrogen oxides, volatile organic compounds, soil dust, and ammonia separately by EPA and EPRI with assistance from AES and OME. EPRI's inventories are for the year 1982. EPA has compiled one set of inventories for 1980 and is in the process of developing another for 1985.

In addition, EPA plans to estimate the real-time SO2 and NOx emissions from over 200 of the largest stationary sulfur dioxide sources (comprising about 100 power plants) over the course of the field study to make this particular input to the model evaluation data set as realistic as possible. A similar activity is underway in Canada for the largest 15 sources east of Saskatchewan, but only during the intensive measurement periods.

6.3 Data Base Management

Each participating organization will maintain the data from its own network in its own data base. To facilitate easy access to the data for model evaluation, a composite archive of commonly formatted data will also be established within the Acid Deposition System (ADS), maintained at the Battelle Pacific Northwest Laboratory. Realizing the data's unique value to the model development community (because of their geographical coverage, number of measured variables, duration, and quality definition), the participants have agreed that data collected during the first year of the field study (June 1988 through May 1989) will be available for model development following their validation.

However, there may be some restrictions on the data's availability for the following reasons:

1. Much of the first six months' data will be used to conduct a preliminary evaluation of the RADM in time for the results to be included in the final assessment report from NAPAP (Fall 1990).
2. Some of the data generators would like to have the initial opportunity to analyze the data in preparing reports of findings for publication in the technical literature.

Therefore, potential data users should be aware that it may be necessary to gain approval from the data generators before the data can be released.

The second year's data are to be sequestered and used initially

solely for a comprehensive model evaluation, the conduct of which will probably extend beyond the lifetime of NAPAP.

6.4 Methods Characterization

Measurement methods used in the model evaluation field study must be fully characterized in terms of their sensitivity (LQL), precision, and accuracy -- commensurate with estimated model evaluation requirements -- and influence of potential interferences. Many of the planned methods had not been standardized at the time of their selection because no standard methods existed for the observables of interest that had the requisite characteristics: sensitivity, selectivity, simplicity, reliability, economy, etc. It was therefore necessary to conduct the necessary characterization tests prior to the method's adoption for use in the field study.

The sample collection or measurement systems that have been subjected to laboratory characterization tests specifically for the model evaluation field study are the filter packs, transition flow reactors (TFR), PAN filter sampler, Luminox LMA-3 NO_2 analyzer, and an automated colorimetry system. Filter packs, TFRs, the PAN filter sampler, and precipitation collectors have been tested under field conditions as well. The specific tests and pertinent references to them are listed in Table 6-10.

6.5 Quality Assurance Auditing and Corrective Action

Performance and systems audits of field, laboratory, and data management operations will be handled by a combination of

Table 6-10

METHODS PERFORMANCE CHARACTERIZATION

LABORATORY TESTS

System	Test	Reference
Filter Pack	Filter absorption capacity for impregnating solution	i
	SO_2 collection efficiency of carbonate impregnated filters as function of temperature, relative humidity, and concentration	i,x
	NH_3 collection efficiency of citric acid impregnated filters as function of temperature, concentration, and citric acid loading	i
	NO_2 collection efficiency of triethanol-amine impregnated filters as function of filter type and face velocity	i
	SO_2 collection efficiency of triethanol-amine impregnated filters as function of concentration	i
	HNO_3 collection efficiency of nylon filters	i,x
	Flow resistance of various 47-mm filter discs, wet and dry	i
Integrated PAN	Efficiency of chilled water scrubbers for acetic acid removal	i
	Chilled scrubber temperature dependence on flow rate	i
	Determining analytical conditions for acetate analysis on ion chromatograph	i
Transition Flow Reactor	HNO_3 collection efficiency by nylon inserts during dynamic sampling, dry air and 50% RH	i
	HNO_3 collection efficiency by nylon inserts during passive sampling	i
	HNO_3 collection efficiency, blank levels	v

Table 6-10 (Continued)

LABORATORY TESTS (Continued)

System	Test	Reference
Automated Colorimetry	Phosphoric acid interference with indol-phenol blue method	i
	Comparison with ion chromatographic nitrate analyses	i
	Sample processing rate for nitrate, ammonium, and sulfate analyses	i
	Analysis of TEA impregnated filter extracts	i
	Optimization of analytical conditions for sulfate, nitrate, and ammonium analyses	i
Luminox (LMA-3)	Linearity, range, lower detection limit, zero and span drift, interferences, RH and temperature response	ii
	Linearity, duplicate sampling, zero and calibration drift, interferences,	i

Table 6-10 (Continued)

FIELD TESTS

System	Test	Reference
TFR/Filter Pack	Check prototype performance and compare with other methods during SCAQS	i
	Duplicate sampling	vi
Filter Packs	Machined TFE vs injection molded PFA filter holders	iii,iv
	2-year comparison of AES and OME data at Longwoods	ix
	Methods characterization	x
	Comparison of HNO_3 nylon filter method with spectroscopic and other methods	xi,xiii xiv
	Comparison of NH_3 impregnated filter method with spectroscopic and other methods	xv
	Comparison of HNO_3, NO_3^- and NH_4^+ methods	xii
Precipitation Collectors	Snow sampling efficiency of different types of precipitation gauges and samplers; influence on composition	vii
Precipitation Chemistry and Deposition	Precision using Aerochem Metrics and MIC collectors. Examination of sources of error	viii

Table 6-10

References

i. Operational Evaluation Network Semi-Annual Progress Report, 1 January - 1 August 1987, ERT Doc. No. P-E292-710, Concord, MA. October 1987.

ii. D.W. Joseph, C.W. Spicer and G.M. Sverdrup. Evaluation of Luminox LMA-3 NO_2 Monitor for Acid Deposition Network Applications, Battelle Draft Topical Report, Columbus, Ohio. July 1986.

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ix. W. Fricke. A Preliminary Comparison of APN and APIOS Data at Longwoods/Ont. Internal AES memorandum, 23 December 1986.

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Table 6-10

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xiii. K.G. Anlauf, D.C. MacTavish, H.A. Wiebe, H.I. Schiff, and G.I. MacKay. Measurement of Atmospheric Nitric Acid by the Filter Method and Comparison with the Tunable Diode Laser and Other Methods. Accepted for publication, Atmospheric Environment, 1988.

xiv. K.G. Anlauf, et al. A Comparison of the Measurement of Atmospheric HNO3 at High Ambient Concetrations by Nylon Filter, Tunable Diode Laser, Transition Flow Reactor, and Fourier Transform Infrared Spectroscopy. In preparation, 1988.

xv. H.A. Wiebe et al. A Comparison of Atmospheric Ammonia by Filters, Transition Flow Reactor Tubes, Denuder Tubes, and Fourier Transform Infrared Spectroscopy. In preparation, 1988.

contractual and organizational arrangements. AES and OME will use their own staff members (not directly involved in operations) to conduct audits.

A subcontractor, Desert Research Institute (DRI), to EPA's prime contractor (ENSR), will conduct systems and performance audits of ENSR's and Combustion Engineering Environmental's activities in support of ME-35. DRI will also audit the airborne measurement systems operated by Battelle Columbus Laboratories during the intensives.

Within the OEN, the initial plan called for quality assurance staff from each of the two measurement contractors (ENSR as prime, CE Environmental as subcontractor) to audit the operations of the other. This has been superseded by the use of internal audits of each contractor's operations by members of its own staff, not directly involved in the the operations, and external systems audits by a QA contractor common to all participants. This use of a single contractor (REA) to audit all networks stems from an awareness that establishing and maintaining comparability of measurements among the networks over the course of the field study would be simplified if the quality assurace audit planning and execution were centralized. The nature of the external audit is described below.

EPA was the first to contract with Research & Evaluation Associates to perform management systems audits (MSA) and data

traceability audits on the prime contractor's activities. The MSAs will involve reviews of facilities, equipment, record keeping, data validation, data management and reporting for the entire QA system. Traceability audits involve reviews of operational, computational and recording activities of the measurements. Data points will be selected at random to trace back from the central data base through the laboratory to their origins in either the aircraft or field sampling sites.

The Diagnostic Measurements Team will assist in determining the type and extent of quality assurance applied to the aircraft and enhanced chemistry measurements.

Descriptions of the audit procedures are given in the respective network QA Plans (see Appendix).

The results of all audits will be reported through the responsible technical oversight team to the PMG. Deviations from standard operating procedures, results outside control limits, and other indications of procedural weaknesses or circumstances that could detract from measurement comparability among the various activities will be dealt with at the appropriate level required for corrective action at the earliest opportunity.

6.6 Inter-network Comparisons

These will be conducted by the participating organizations through the operation of colocated measurement systems and by interlaboratory comparisons. The FADMP will not participate in

the field comparisons, but will participate in the other activities designed to demonstrate or assess comparability of measurements. Having selected methods identical to those used in the OEN the FCG decided that colocating FADMP equipment with the other networks at State College and Egbert would be redundant (see below).

6.6.1 Colocation of field measurement systems. Two sites (Egbert, Ontario and State College, PA) will be equipped with measurement systems from AES, EPA, EPRI, and OME. At Egbert, each of these organizations will install one air quality sampler (filter pack or filter pack/TFR combination), one precipitation collector, and one rain gauge.

At State College, the complete suite of samplers and analyzers used by each of these organizations at its network sites will be installed in duplicate, exclusive of those instruments used by only one of the participants (such as analyzers for ozone, by EPRI, and, possibly, hydrogen peroxide, by EPA), of which only one will be installed. The colocation of duplicate measurement systems will allow the inter-network deviations to be distinguished from the intra-network measurement precision.

At Longwoods, Ontario, OME and AES will operate colocated sampling systems to provide a third site to allow possible bias between their air quality measurements to be assessed.

6.6.2 NWRI QC comparison on precipitation samples. The National Water Research Institute, Environment Canada, has been contracted to provide external quality assurance services by providing 10 certified precipitation test samples per month to each of the participating laboratories and to approximately six other laboratories shown to have performed reliably in previous inter-laboratory comparisons. NWRI will monitor the stability of the test samples.

The analytical results will be used to assess inter-laboratory bias. Inclusion of the other six high-performance laboratories is expected to provide a stable and reliable median for bias assessment. Two or three artificially prepared standard mixtures of known stability would also be distributed monthly to allow analytical accuracy also to be assessed.

Criteria will be established to define very good, average, and poor performance. Verified instances of poor performance by a participating laboratory will be communicated as soon as practical to the laboratory so that corrective action may be taken. Concurrently, the measurements team representative responsible for the laboratory will be notified so that he can ensure that corrective action has been taken. Such instances will be brought to the attention of the measurements team and the PMG so that further assurance is gained that measurement discrepancies are resolved.

Reports on the inter-comparison procedures and results will be issued annually by the NWRI and at the end of the study.

6.6.3 Filter pack testing on common test atmospheres. In addition to the comparisons conducted under field conditions at the colocated sites, the filter packs used by the participating networks are to be challenged under controlled conditions with test atmospheres containing nitric acid, sulfur dioxide, and ammonia (either in combination or individually) as a further test of their relative performance.

The protocol for testing the filter packs will be developed by ENSR in consultation with the Operational Measurements Team and the actual tests will be performed using the test atmosphere generation and exposure system at ENSR's Camarillo, CA laboratory. ENSR will provide a report of the test results to the Team through the Teams's OEN representative.

6.6.4 AES/EPA airborne measurements comparisons.
The airborne measurement systems used by the AES and EPA will be subjected to intercomparison testing according to a protocol to be developed under the auspices of the Diagnostic Measurements Team.

6.7 Intra-network Colocation
In addition to the data from the duplicate samplers at the State College inter-network comparison site, intra-network precision assessments will rely on data from 4 APIOS, 2 OEN, 6 EPA, and 1

FADMP colocated stations. The stations will be geographically dispersed and will be changed in the OEN after the first year and in the ME-35 every six months.

6.8 Common Filter and TFR Supplier

By agreement among participants, all Teflon, nylon, and impregnated filters used in the field study will be supplied by a common vendor. Following a competitive procurement, ENSR was selected as the filter supplier. Each participating organization will contract separately with ENSR for its supply of filters. Filter specifications are given in Table 6-11.

The Teflon and nylon filters will be shipped in yearly batches to each sponsor. Impregnated filters will be supplied in monthly batches because their greater propensity for contamination limits their shelf life. Nylon and Naphion filter-material inserts for the transition flow reactors will also be provided by ENSR to the ME-35, OEN, and FADMP. As the surface area of the inserts is 70% of that of the 47-mm filters, the blank levels for nitric acid (nylon inserts) and ammonia (Naphion inserts) will be proportionately smaller than the values shown in Table 6-11.

6.9 Composite Data Archive

Site descriptions, all measurement data taken during the model evaluation field study, and quality control data and sample status codes that support data quality estimates will be archived together in the Acid Deposition System (ADS) data base at Battelle Pacific Northwest Laboratory. This archive, compositing

Table 6-11

FILTER SPECIFICATIONS
(All 47-mm diameter)

Filter Type	Target Species	Blank Levels (ug/filter)	Recipe
Teflon Membrane 1 um Zefluor	Sulfate	1.1	NA
	Nitrate	1.3	NA
	Ammonium	1.0	NA
Nylon Membrane S&S 1 um Nylon 66	Nitric acid	1.0	NA
Whatman 41	Sulfur Dioxide	2.1	15% K_2CO_3 5% Glycerol
Whatman 41	Ammonia	1.0	25% Citric acid 5% Glycerol
Whatman 41	PAN	1.0	10% KOH 2% Glycerol

data from all participating networks and laboratories, will ensure common data formats for like variables, irrespective of source, and facilitate access by prospective data users. Data will be transmitted to ADS by each participating organization on differing schedules, but not to exceed quarterly for the preceding quarter. Thus, the longest time interval between sample collection and transmittal of its measurement data to ADS should be about 6 months.

The contents of the data archive are summarized in Table 6-12. Functional specifications for the data archive have been developed under contract from OME and are given by Daly and Olsen (1988) along with a detailed description of its contents. The archive will be established under contract from EPA and will be maintained for two years after the completion of the study. Thereafter, users may still obtain copies of the data on tape, but will probably have to sort it themselves to access specific subsets.

6.10 Individual Network Data Archives

Each of the data-generating organizations will maintain an archive of its own data. The archive will contain not only all the original validated data that the organization transfers to the ADS composite archive but also the quality control data (such as from analysis of blanks, replicates, spikes, and standards) and field logs and zero, span and calibration data that are used for the data quality assessments and for data validation. Also

Table 6-12

DATA ARCHIVE CONTENTS

- o Support Documentation
  - Program overview
  - Sampling platform descriptions
  - Data processing manual
  - Data transfer description
  - Quality control procedures manuals
  - Quality control reports
  - Quality Assurance reports
- o Site Data Base
  31 variables
- o Precipitation Chemistry Record Variables
  147 variables
- o Filter/Transition Flow Reactor Chemistry Record Variables
  97 variables
- o Continuous Gas Phase Chemistry Record Variables
  22 variables
- o Hourly Precipitation Record Variables
  12 variables
- o Hourly Meteorology Record Variables
  52 variables
- o Aircraft Filter Chemistry Record Variables
  53 variables
- o Aircraft Continuous Sampling Record Variables
  124 variables

archived will be the data from quality auditing of lab and field performance.

Section 7

EMISSIONS

Comprehensive emissions inventories have been, and are being compiled under programs distinct from the model evaluation program. As such they are not strictly under the aegis of the PMG. Nonetheless, these inventories will serve as the major basis for emissions data inputs to the models during their evaluation. For this reason, the PMG plans for the Emissions Inventory Team to ascertain the uncertainties associated with these emissions data to the extent possible and to work with the Model Evaluation Team to determine how the emissions uncertainties propagate through the models to influence the output uncertainties. Of course, these considerations also apply to the real-time emissions estimates, gathered over the duration of the field study by EPA in the U.S. and during the intensives by AES and OME in Canada (see Section 1.5).

The Team has been asked to determine to what extent quality control has been exercised in the compilation of the inventories in terms of checking for consistent application of emissions calculation procedures, for data entry errors, and for reasonableness of the values.

With respect to the volatile organic compounds, ammonia, and soil dust inventories there is little independent data available with which to gauge uncertainties. At a minimum, the relative magnitudes of the values in inventories of the same species,

compiled by different organizations, should be compared. When discrepancies judged to be significant are noted, their causes should be investigated and the discrepancies resolved, when possible. When unresolvable, the influence of using the different values as model inputs on the output uncertainty should be ascertained by the model evaluators.

Section 8

MODEL EVALUATION PROTOCOLS

RADM and ADOM may be evaluated in a number of ways, as outlined in Section 1.3. Their comparative evaluation is underway at Battelle Pacific Northwest Laboratory, with subcontracts to the model developers, SUNY Albany and ENSR. Protocols for evaluation of the gas phase chemistry, scavenging (including cloud physics and aqueous phase chemistry), and atmospheric transport modules are being developed.

The observational data collected in the model evaluation field study are to be used to operationally and diagnostically evaluate the models. These evaluations will involve in one way or another the comparison of model output with observational data.

Model evaluation is an important component of the NAPAP assessments. For model evaluation results to be incorporated into the 1990 NAPAP final assessment report, they should be received by NAPAP in October 1989 although some schedule slippage is possible. This schedule necessitates a "preliminary" evaluation of RADM and ADOM. Over the period April through June 1989 both models will undergo the same evaluation process, which will use data from the first six months of the field study, including those from the summer 1988 intensive measurement campaigns in Canada and the U.S. The nature of the preliminary evaluation will be specified in a model evaluation protocol document, which is scheduled for completion in April 1989.

The protocol for the more comprehensive evaluation that motivated the field study in the first place is only at a conceptual stage of development. Its completion will probably take place after gaining experience with the "preliminary" NAPAP evaluation.

It is the responsibility of the Model Evaluation Team to propose these protocols and then to expedite their implementation. In the meantime, the general aspects of the model evaluations, as described in this section, are sufficiently understood to help guide the design of the field study.

8.1 Operational Evaluation

Several approaches to operational evaluation have been considered: geographical pattern comparison, point-to-grid-cell comparison, and multivariate analysis. Condensed descriptions of these are provided below.

The first one, pattern recognition, involves use of an interpolation/extrapolation scheme to construct gridded data maps based on the time-averaged field measurements and then comparison of these gridded values with those calculated from the Eulerian model output. A presumed advantage of this approach is that the spatially interpolated patterns are better able to represent the actual deposition and air quality distributions than the discrete data from which they are derived. Seasonal or longer averages of observed and predicted precipitation constituents such as sulfate, nitrate, and ammonium, and air quality variables such as sulfur dioxide, nitric acid, nitrogen dioxide, ammonia and particulate

sulfate, nitrate, and ammonium would be compared.

An interpolation method under serious consideration for this application is kriging. (See, for example, Seilkop and Finkelstein, 1987, for a brief explanation of simple kriging and its application to precipitation data.) Although simple kriging has some restrictive assumptions (e.g., Philip and Watson, 1986) that detract from its utility for model evaluation, it has the advantage that it yields estimates of interpolation uncertainty for each interpolated value. This is an important attribute because, in principle, it allows this source of variance to be distinguished from others such as measurement uncertainty, "subgrid" variability, and meteorological stochasticity. An attempt to identify and use elaborations of the method that avoid the restrictive assumptions of simple kriging will be made. The Model Evaluation Team will decide what the preferred interpolation method or methods will be. It must also resolve the question of what statistical measures will be used for assessing spatial and temporal comparability between the observational and model output fields.

A more traditional approach to operational model evaluation is the so-called point-to-grid-cell (or "point-to-node") comparison in which averaged observational data at the measurement locations are compared with the averaged model predictions for the grid cell containing each location. Several performance measures based on this approach were recommended by an American Meteorological Society workshop in 1980 and are described by Fox (1981).

A third way that has been discussed is the use of principal component analysis of both the observational and model output data. (See Henry and Hidy, 1979, for an example of PCA application to environmental data.) This multivariate analysis approach takes a large number of variables, many of which may be temporally correlated, and groups them into a smaller number of uncorrelated variables (principal components). The correlations result from physical and chemical associations of the variables. Measurement data from two identical natural systems will yield identical variables and weights in their separately calculated principal components. Therefore, the similarity between the principal components calculated from the observational data and those calculated from the model output data should provide a measure of how well the model is capturing the physical and chemical essence of the natural system. How the degree of similarity would be judged and interpreted remains an unresolved issue.

These three general approaches to model evaluation should not be considered exhaustive. The Model Evaluation Team is considering a number of other statistical and subjective measures of model performance and will be receptive to any further suggestions that appear promising.

8.2 Diagnostic Evaluation

Diagnostic evaluations will rely principally on measurement data from the aircraft, VAR surface stations, continuous analyzers at surface network stations in the vicinity of measuring aircraft and

enhanced chemistry sites operated by cooperating agencies. Protocols for conducting the diagnostic evaluations have not been completed, but will almost certainly involve some form of point-to-grid-cell comparisons for vertically resolved data and line-to-linearly-grouped-grid-cells comparisons for horizontal transect data. Protocol completion will be the joint responsibility of Model Evaluation and Diagnostic Measurements Teams.

8.3 How Models Will be Run to Obtain Averages

Operational evaluations rely on comparing temporally averaged data. The methods for obtaining the observational averages are straightforward. Those for the model outputs are not, because of presumed modeling resource constraints.

Four techniques for obtaining long term averages are under consideration:

- direct simulation of seasonal and annual cycles using the models as presently configured,
- aggregation of episodic model runs to statistically represent average behavior,
- interactive use of a comprehensive model and a simpler, less computationally intensive model, whereby the comprehensive model establishes typical chemical environments across the modeling domain and the simpler model works within that framework to calculate the actual long-term averages, and
- reconfiguration of model architecture to run more speedily and

efficiently on a parallel processing machine. Each technique has its advantages and disadvantages.

Direct simulation is expected to be the most expensive and time consuming of the alternatives. The cost of supercomputer running time and the effort expended in compiling and manipulating the requisite input data would be relatively considerable. On the other side of the coin, no major new software development would be required and there is a current familiarity with running the models as presently configured.

EPA and OME have been funding examinations of the feasibility of breaking down the full range of meteorological variability into a set of meteorological classes, each of which contributes some characteristic fraction of the total wet and dry deposition to the ground and within which exist characteristic aerometric conditions. Feasibility would mean that by weighting the deposition and concentrations associated with each class by its frequency of occurrence, the long term totals and averages could be estimated. The disadvantages of this technique are that its feasibility has yet to be established and that because it is an indirect method of estimating averages, it lacks the credibility of the direct method. Its advantage is that it is less costly in terms of money and manpower than the direct method, because it requires less computing time and data assimilation effort.

The feasibility of interactively using comprehensive and simpler models to obtain long-term averages has not been explored in

depth. The approach was suggested by analogy to the solution to a related problem suggested by Kleinman (1988) whereby he would use RADM to establish a chemical environment and then a simpler model to evaluate SO_2 emissions change scenarios.

The possibility of running the models on a parallel processing machine has only recently been brought under consideration. Its feasibility is being explored by the RADM development staff in separate consultations with Argonne National Laboratory and with IBM.

This approach would require substantial modification of the computer code and the acquisition of an appropriate existing computer or the development of one custom-designed for this application. The expense and effort to meet these requirements are an obvious disadvantage, but its relative magnitude versus direct simulation remains to be determined.

On the positive side, the very nature of the Eulerian (gridded) approach and the processes being simulated in the models -- they are inherently multitudinous and parallel -- makes them ideal candidates for parallel processing. If appropriate hardware had been available at the inception of the models' development, it is likely they would have been written in parallel mode.

Section 9

REFERENCES

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APPENDICES

A. PMG Charter

B. List of pertinent quality assurance plans

CHARTER OF THE PROJECT MANAGEMENT GROUP FOR REGIONAL EULERIAN ACID DEPOSITION/OXIDANT MODEL EVALUATION STUDIES

SPONSORS

Atmospheric Environment Service, Environment Canada, Toronto, Ontario, Canada

Electric Power Research Institute, Palo Alto, CA

Environmental Protection Agency, Research Triangle Park, NC

Florida Electric Power Coordinating Group, Tampa, FL

Ontario Ministry of the Environment, Toronto, Ontario, Canada

BACKGROUND

Each of the sponsoring agencies and institutions is operating or plans to operate an acid deposition monitoring network and to make additional measurements for model evaluation. Each of these approaches has independent sampling procedures. For effective model evaluation against the common monitoring data, differences among methods applied by the various sponsors to measure the same variable must be defined and minimized.

The Regional Model Evaluation Quality Assurance Workshop (Toronto, 10-13 June 1986) recommended that the Sponsors establish a Quality Assurance Management Committee (QAMC) to function as described in the workshop report (Olsen, 1986) and proposed QA management approach (Cox, 1986). This QAMC was constituted immediately following the workshop and by October 1986, EPA, EPRI, and OME had become signatories to the QAMC charter. In 1987 AES became a signatory to the charter, bringing the committee to full membership.

In response to a recommendation solicited by the QAMC from the Eulerian Modeling Bilateral Steering Committee (EMBSC),

- the QAMC was renamed the Project Management Group (PMG);
- its purview enlarged from network monitoring to also encompass emissions inventories, measurements for diagnostic evaluations, and the model evaluation process itself; and
- four teams were established to assist the PMG in organizing, coordinating, and assuring the quality of operational measurement, diagnostic measurement, emissions estimation, and model evaluation activities as described in the Project Plan.

Subsequently, the Florida Electric Power Coordinating Group (FCG) adopted sampling methods identical to those used by EPRI and joined the model evaluation field study.

PURPOSE OF THIS CHARTER

The purpose of this Charter is to:

- o express the agreement of intent among Sponsoring Agencies and Institutions to establish the Project Management Group, and
- o express the extent of cooperation and obligations of the Sponsors and the members of the Group.

OBJECTIVES

With assistance from the Teams providing technical oversight of the Operational Measurements, Diagnostic Measurements, Emissions Inventories, and Model Evaluation, the Group shall act to provide a quality assured data set for model evaluation. It shall provide well documented, scientifically credible operational and diagnostic evaluations of RADM and ADOM.

FUNCTIONS

The Group shall:

- o constitute the four Teams described in the preceding background statement and convene them at periodic intervals;
- o receive status reports from the Teams and recommend corrective action as needed;
- o produce a Project Plan for the model evaluation studies;
- o direct the Teams in establishing mechanisms to:
  - review and approve Sponsors' Quality Assurance Plans for measurements and data reduction, validation, and management;
  - review and recommend the methods of establishing estimates of bias and precision;
  - encourage standardization of methods and protocols;
  - encourage member agencies to practice active quality control;

- design inter-network and inter-laboratory studies of uncertainties; and

- specify common data base characteristics and protocols.

MEMBERSHIP

The Group membership shall consist of one member from each Sponsoring agency who possesses these characteristics:

- o has a detailed knowledge of the monitoring and research tasks of the model evaluation project;
- o is not directly related to data generation from tasks; and
- o is knowledgeable in quality assurance or has support of a quality control staff or contractor.

It is desirable, but not essential, that each Sponsor's member be in a management position that is effective in recommending reprogramming of resources to bring about timely corrective action.

CHAIRMAN

The Group shall elect its chairman, who will serve a term as agreed upon by the Group members. The chairman's duties will be to:

- o schedule regular quarterly meetings;
- o prepare and provide an agenda in advance of each meeting;
- o moderate the meeting;
- o provide a written summary of the meeting; and
- o report on Group accomplishments and model evaluation study status to the EMBSC.

FINANCIAL SUPPORT

The Sponsoring agencies agree to support this Group in these ways:

- o Provide travel and per diem for their members of the Group and the Teams to attend four meetings per year. These meetings may be held at one of the agency's facilities or at a mutually convenient intermediate location such as Chicago, IL.
- o Provide 20% of their member's (or the equivalent in staff's

or contractor's) time for conducting the functions of a Group member.

- Provide internally a Quality Assurance Officer (staff or contractor) to assess their quality control data interactively with the appropriate Measurements Team.

The Group shall not request the Sponsoring agencies to provide any support or funds other than identified above. The Sponsoring agencies will fund and manage bias and precision data experiments, partitioning of precision experiments, and internal quality assurance and quality control within their respective programs.

DURATION

The Sponsoring agencies may withdraw membership at any time. This charter expires annually on 1 January, unless its Sponsors specifically approve its continuation. A record of such action will appear in the minutes of the fourth quarter's meeting.

APPROVAL

Designated and Approved by Agency's or Institution's Manager Responsible for the Model Evaluation Studies.

AES Member:

Approved by: Date:

EPA Member:

Approved by: Date:

EPRI Member:

Approved by: Date:

FCG Member:

Approved by: Date:

OME Member:

Approved by: Date:

Appendix B

QUALITY ASSURANCE-RELATED DOCUMENTS IN USE IN THE EULERIAN MODEL EVALUATION FIELD STUDY

Listed here are the quality assurance plans, work plans, operating (procedures) manuals, and other pertinent documents that dictate and describe how activities are to be conducted in support of the Eulerian Model Evaluation Field Study. They are listed by the organization to whose operations they apply.

1. Atmospheric Environment Service, Environment Canada

Quality Assurance Reports

The Canadian Air and Precipitation Monitoring Network (CAPMoN) Quality Assurance Plan for Precipitation Monitoring Systems. R.J. Vet and S.G. Onlock, Report CSC 110.194-3-1 Concord Scientific Corporation, 2 Tippett Road, Downsview, Ontario M3H 2V2, March 1983.

The Canadian Air and Precipitation Monitoring Network (CAPMoN) Quality Assurance Plan for Air Monitoring Systems. R.J. Vet, Atmospheric Environment Service. TO BE WRITTEN

The Canadian Aircraft Program Quality Assurance Plan. Atmospheric Environment Service. TO BE WRITTEN

Procedures Manuals

Canadian Air and Precipitation Monitoring Network (CAPMoN) Operator's Instruction Manual - Precipitation. Air Quality and Inter-Environmental Research Branch, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, April 1985.

Canadian Air and Precipitation Monitoring Network (CAPMoN) Operator's Reference Manual - Precipitation. Air Quality and Inter-Environmental Research Branch, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, April 1985.

Canadian Air and Precipitation Monitoring Network (CAPMoN) Precipitation Sampling Instruments Operation and Maintenance Manual - Operator's Edition. Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, April 1985.

Canadian Air and Precipitation Monitoring Network (CAPMoN) Inspector's Reference Manual - Precipitation. Air Quality and Inter-Environmental Research Branch, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, April 1985.

Canadian Air and Precipitation Monitoring Network (CAPMoN) Precipitation Sampling Instruments Operation and Maintenance Manual - Inspector's Edition. Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, April 1985.

Preliminary Draft - Canadian Air and Precipitation Monitoring Network (CAPMoN) Site Operator's Manual - Air and Ozone System, Belfort gauges. Atmospheric Environment Service, March 1988.

Preliminary Draft - Canadian Air and Precipitation Monitoring Network (CAPMoN) Inspector's Manual - Air and Ozone System, Belfort gauges. Atmospheric Environment Service, March 1988.

2. Electric Power Research Institute

EPRI-OEN Field Operation and Maintenance Manual. Document No. 2460-003-332, April 1988. ERT, Inc., Concord, MA and Environmental Monitoring and Services, Inc., Camarillo, CA.

Volume I: Training and Precipitation Measurements
Volume II: Meteorological Measurements
Volume III: Aerometric Measurements

Operational Evaluation Network Quality Control Procedure Manual (Draft). Document No. 2460-003-800, May 1988. ERT, Inc., Concord, MA.

Operational Evaluation Network Work Plan (Draft). Document No. P-E292-100, August 1986. ERT, Inc., Concord, MA.

Operational Evaluation Network Siting Manual. January 1987. ERT, Inc., Concord, MA.

3. Environmental Protection Agency

Quality Assurance Reports

Acid Model Operational Diagnostic Evaluation Study Quality Assurance Project Plan, Document No. 9100-014-800, June 1988. ERT, Inc., Concord, MA, and Environmental Monitoring and Services, Inc., Camarillo, CA.

Acid Model Operational Diagnostic Evaluation Study: Option XI - The Measurement of S(IV) in Precipitation Quality Assurance Project Plan (Draft), February 1988. Combustion Engineering, Environmental Monitoring and Services, Inc., Camarillo, CA.

Acid Model Operational Diagnostic Evaluation Study: Option XI - The Measurement of S(IV) in Precipitation Work Plan (Draft),

January 1988, Combustion Engineering, Environmental Monitoring and Services, Inc., Camarillo, CA.

Procedures Manuals

Acid MODES Network Siting Manual (Draft), October 1987. ERT, Inc., Concord, MA.

Acid MODES Field Operations and Maintenance Manual (Draft), February 1988. ERT, Inc., Concord, MA.

Acid Model Operational Diagnostic Evaluation Study Standard Operating Procedures Field Measurements (Draft), Document No. G418-800, February 1988. ERT, Inc., Concord, MA. (Revised version in preparation)

Acid Model Operational Diagnostic Evaluation Study Standard Operating Procedures Laboratory Analysis and Data Management (Draft), Document No. G418-800, February 1988. ERT, Inc., Concord, MA. (Revised version in preparation)

4. Florida Electric Power Coordinating Group

Laboratory Operations Manual. Florida Acid Deposition Study. ESE Document No. 006F/80-610-111. Environmental Science and Engineering, Inc., Gainesville, FL. September 1981.

Environmental Monitoring Project Quality Assurance Plan. Florida Acid Deposition Study. ESE Document No. 004F/80-610-111. Environmental Science and Engineering, Inc., Gainesville, FL. September 1981.

Field Operator's Instruction Manual (Phases I and II). Florida Acid Deposition Study. ESE Document No. 004F/80-610-600. Environmental Science and Engineering, Inc., Gainesville, FL. September 1981.

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Field Operator's Instruction Manual (Phase III). Florida Acid Precipitation Study. ESE Document No. 004FS/82-615-101. Environmental Science and Engineering, Inc., Gainesville, FL. October 1982.

5. National Water Research Institute, Environment Canada

External Quality Assurance. Cost Factors and Work Plans to Examine Specific Laboratory Performance of those Laboratories Providing Precipitation Data to Test the Eulerian Model (Aqueous Phase).

6. Ontario Ministry of the Environment

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Technical and Operating Manual APIOS Deposition Monitoring Program (1st Revised Edition). W.S. Bardswick. Report ARB-082-87-AQM. Ontario Ministry of the Environment, 1987.

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