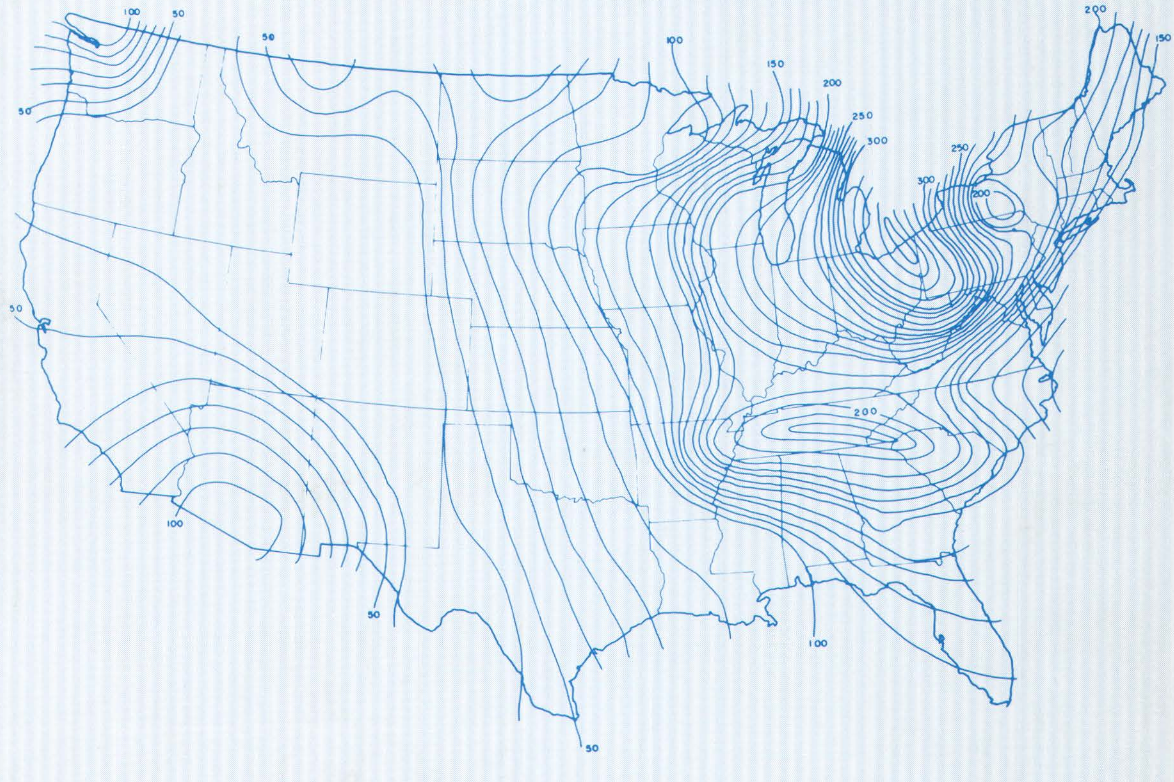
Design of the National Trends Network for Monitoring the Chemistry of Atmospheric Precipitation



U. S. Geological Survey Circular 964

ABOUT THE COVER: Average annual sulfate deposition in the United States, mg/m^2, July 1978–September 1980.

National Acid Precipitation
Assessment Program

Design
of the
National Trends Network for Monitoring the Chemistry of Atmospheric Precipitation

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West Point, New York

Prepared for the
Deposition Monitoring Task Group
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Preface:

This is a report of the Interagency Task Force on Acid Precipitation. The Task Force was created under the Acid Precipitation Act of 1980 (Title VII of P. L. 96-294) to conduct a comprehensive research program on the causes and effect of acid precipitation, and on means by which any adverse effects might be reduced.

The research program is managed through a series of task groups, each of which is responsible for planning and conducting a segment of the program. A lead agency has been assigned for each of the task groups as follows:

Task Group	**Lead Agency**
A. Natural Sources	Nat'l Oceanic & Atmospheric Administration
B. Man-made Sources	Department of Energy
C. Atmospheric Processes	Nat'l Oceanic & Atmospheric Administration
D. Deposition Monitoring	Department of the Interior
E. Aquatic Efferts	Environmental Protection Agency
F. Terrestrial Effects	Department of Agriculture
G. Effects on Materials & Cultural Resources	Department of the Interior
H. Control Technologies	Environmental Protection Agency
I. Assessments	Environmental Protection Agency
J. International Activities	Department of State

The National Acid Precipitation Assessment Program is intended to focus federally-funded research on the timely development of a firmer scientific basis for policy decisions related to acid precipitation. Reports are released both as Task Force reports on multi-agency efforts and as individual agency reports on single-agency projects.

This report is a product of the Deposition Monitoring Task Group. The members of the task group are as follows:

Members:

Lead agency: U.S. Geological Survey

U.S. Environmental Protection Agency
U.S. Department of Energy
Nat'l Oceanic & Atmospheric Administration
Cooperative State Research Service
U.S. Forest Service
National Park Service
U.S. Bureau of Land Management
Tennessee Valley Authority
Pacific Northwest National Laboratory
Brookhaven Nat'l Laboratory
National Bureau of Standards
U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service
U.S. Ofc. of Surface Mining & Reclamation

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Design of the National Trends Network for Monitoring the Chemistry of Atmospheric Precipitation

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ABSTRACT

Long-term monitoring (10 years minimum) of the chemistry of wet deposition will be conducted at National Trends Network (NTN) sites across the United States. Precipitation samples will be collected at sites that represent broad regional characteristics. Design of the NTN considered four basic elements during construction of a model to distribute 50, 75, 100, 125 or 150 sites. The modeling oriented design was supplemented with guidance developed during the course of the site selection process. Ultimately, a network of 151 sites was proposed.

The basic elements of the design are:

(1) Assurance that all areas of the country are represented in the network on the basis of regional ecological properties (96 sites);

(2) Placement of additional sites east of the Rocky Mountains to better define high deposition gradients (27 sites);

(3) Placement of sites to assure that potentially sensitive regions are represented (15 sites);

(4) Placement of sites to allow for other considerations, such as urban area effects (5 sites), intercomparison with Canada (3 sites), and apparent disparities in regional coverage (5 sites).

Site selection stressed areas away from urban centers, large point sources, or ocean influences. Local factors, such as stable land ownership, nearby small emission sources (about 10km), and close-by roads and fireplaces (about 0.5km) were also considered. All proposed sites will be visited as part of the second phase of the study.

INTRODUCTION

The Deposition Monitoring Task Group of the Interagency Task Force on Acid Precipitation is charged in the National Acid Precipitation Assessment Plan (Interagency Task Force on Acid Precipitation, 1982) with developing three types of precipitation monitoring networks: a Global Trends Network, a National Trends Network (NTN), and research support networks as needed.

This paper deals with the development of the NTN. The task group viewed the design of the network and selection of sites as comprising five distinct steps:

(1) Establishment of siting and operating criteria against which candidate sites would be judged for their acceptability for incorporation into the network.

(2) Development of a distribution model which would provide a basis for distributing sites across the conterminous United States.

(3) Evaluation of existing precipitation monitoring sites for acceptability in meeting the siting criteria and to see how well they satisfy the distribution established by the model.

(4) Identification of tentative new sites needed to fill voids in the distribution model.

(5) On-site evaluation of the suitability of each site.

The task group's concept of the NTN and its siting criteria used in this project (step 1) can be found in Appendix A. Steps 2, 3, and 4 are addressed in this paper.

On-site evaluation of site suitability will be performed at a later date and will be reported separately.

ACKNOWLEDGEMENTS

Site operators and supervisors in each of the networks provided much of the site information which made this analysis possible. We would particularly like to thank Mr. Richard Cram, National Oceanic and Atmospheric Administration; Dr. Leo Topol and Mr. George Kilby of Rockwell International; Dr. William Parkhurst of the Tennessee Valley Authority; and Dr. Paul Michael of Brookhaven National Laboratory for providing information or assisting in getting their networks' cooperation in providing information.

Many maps were needed to support this analysis. Mr. Richard Ipri, the U.S. Military Academy map librarian provided numerous U.S. Geological Survey guadrangle maps and base maps that were needed for the drawing. Dr. Frederick Lanery of the Fish and Wildlife Service, St. Petersburg, Florida, provided a complete set of the Ecoregion and Land-Surface Form maps for the United States. Without their help the analysis could not have been completed. Other valuable adminstrative support was provided by Miss Sue Romano, Mrs. Shirley Bonsell, and Mrs. Judi Dubaldi.

MODELS FOR DISTRIBUTION OF NETWORK SITES

The design of the NTN proceeded in several stages and involved the interaction of the authors with a panel of reviewers that met at Bear Mountain, New York, in March 1982, and interaction with the task group on numerous occasions. The resulting design is a product of the authors enhanced by input and direction from these groups. Two important phases of model development exist: pre-Bear Mountain and post-Bear Mountain. The pre-Bear Mountain material presented on the pages that follow represent several attempts at incorporating knowledge of atmospheric deposition chemistry and factors which control this chemistry into a relevant distribution approach. At the Bear Mountain workshop, the review panel and the task group discussed the various approaches. Some approaches were retained, some discarded, and others modified. The post-Bear Mountain model incorporates these changes and serves as a basis against which potential sites were evaluated. The model establishes the number of sites per region and does not deal in specific site locations. Evaluation of existing sites and selection of sites to fill voids in the design are discussed later under the section on Populating the Model.

PRE-BEAR MOUNTAIN MODELS

Wet deposition samples are collected in buckets having openings of approximately 678 cm^2 but the data are then extrapolated over areas of hundreds and thousands of km^2. The dilemma then becomes one of siting 50 to 150 samplers in regions of the country so that measurements from each are representative of large areas of the United States.

Uniform or Random Distribution

If nothing were known about emissions, ambient air data, precipitation chemistry, or sensitive ecosystems, one of two methods for designating sites would probably be tried. In the first method, a grid with the appropriate number of intersections would be laid over a map of the United States. At each intersection, or as close to each intersection as possible, a sampling site meeting the established criteria would be located. The product of this exercise would be a network of uniform distribution.

The second method is similar to the first in that the country be over-lain by a grid. With a grid of 150 boxes, one site would be placed within each of the 150 boxes. If a finer grid was used, such as a 470 grid resulting from use of the 1:250,000-scale series of topographic maps (U.S. Geological Survey, 1980) then a technique would be necessary to choose only 150 boxes. Each box could be assigned a non-repeating random number between 1 and 470. Many 150-site networks could be generated by this method. These networks could then be examined to search for one network where the sites best meet the established siting criteria.

The above techniques yield sampling locations unbiased by subjective criteria. But they suffer by not using information about emissions, potentially susceptible ecosystems, and existing wet deposition data.

A Regional Approach

The next level of complexity that one might like to incorporate into a site distribution model is some method of assuring that all areas of the country differing from each other by some property or properties are represented by a sampling site. A number of maps of the United States have been produced which divide the United States into regions based on different properties. Some of the more familiar are road atlases showing State and county boundaries. Most of these utilize political or other boundaries to divide the country and are not at all suited for this kind of analysis. In this study environmental properties of representation were sought because of their relevance to the potential effects of acid rain.

Many maps of the United States do exist which divide the country into regions based on physical, biological or other environmental relationships. Atwood's (1940) "Physiographic Provinces of North America" is one such division of the country using landforms as the basis of its division. Another is the soils map of the United States (U.S. Geological Survey, 1966), which displays the pattern of soil orders and suborders. Kuchler (1964) produced a map based on potential vegetation types. Hammond (1964) divided the country into classes of land-surface form. Thornthwaite (1931) produced a climatic map of North America. Garrison and others (1977) define 34 ecosystems into which all the land of the conterminous United States was classified. Bailey (1976, 1978, and 1980) described ecoregions of the United States based on climatic and vegetative factors.

Bailey's Ecoregions of the United States was chosen as the ideal regional discriminator for this network design. It combines biotic and abiotic factors into one classification system, and generalizes properties over broad areas (Bailey, 1978 and 1980, and Bailey and Cushwa 1981), thus producing a reasonable number of regions with which to work. Bailey's scheme is hierarchical with many levels of generalization. This allows aggregating of data at different levels as needed.

Bailey's scheme uses a four-digit code, sometimes preceded by an alphabetic character, to represent the ecoregion hierarchy. The first digit in the scheme represents the domain. Three are recognized in the conterminous United States--humid temperate domain (2000), dry domain (3000), and humid tropical domain (4000). A fourth domain, polar domain (1000), is found in Alaska and Canada. Domains are located on the basis of annual rainfall and mean temperature of the warmest month.

The second digit in the scheme represents a subdivision of the domains into divisions. The humid temperate domain (2000) is divided into six divisions —warm continental (2100); hot continental (2200); subtropical (2300); marine (2400); prairie (2500) ; and mediterranean (2600). The dry domain (3000) has steppe (3100) and desert (3200) divisions. The humid tropical domain (4000) has savanna (4100) and rain forest (4200) divisions, but only the savanna is exhibited in the conterminous United States. General environmental characteristics of the domains and divisions are shown in Table 1.

Divisions are then subdivided into provinces, the third digit in the scheme, based on uniform regional climate and the type or types of zonal soils.

Sections represent the fourth digit of the scheme. These indicate, where present, local climatic variations and areas which have a single vegetative climax type. Figure 1 summarizes Bailey's ecoregion breakdown.

Usually a single vegetative climax association is characterized by the province, but two or more climaxes may need to be represented, for example, on highlands. This often happens on mountains where each altitudinal zone may have a different climax. So, at the province level, highland provinces are distinguished by the use of an alphabetic modifier preceding the four-digit code. The three types of highland are: mountain (M), plateau (P), and altiplano (A). (Instead of further differentiating each of the altitudinal variations on each highland thus creating a multitude of small areas, these are categorized by the climatic regime of the lowlands in which they occur). A list of the area of each province and their composite sections are provided in Appendix B.

Not all of Bailey's provinces are subdivided into sections. For this reason the province level has been chosen as a benchmark for the analysis. To initially allocate network sites based on provinces, the ratio of the area of each province relative to the total area of the United States was calculated. This fraction was then multiplied by the desired number of sites (50, 75, 100, 125, or 150) in the network to yield the number of sites, by province, in the provisional network. Fractions greater than 0.5 were rounded up. Any province which did not receive a site based on area was given a site to ensure complete ecoregion representation in the network.

PROVINCES GIVEN ONE SITE TO ENSURE REPRESENTATION

NETWORK SIZE	50	75	100	125	150
Provinces	2410	2410	2410	4110	4110
	2610	3120	3120		
	3120	3140	4110		
	3140	4110			
	4110				

When provinces were subdivided and more than one site was allocated to the province, the fractional area relative to province area was used to distribute sites within the province. All sections were not allocated sites under this procedure, because design criteria ensured ecoregion representation at the province level, not the section level. For example, province 2110 has four sections. Based on a 50-site network, four sites should be in province 2110. The options were to place one site in each section, thereby allocating by section, or to allocate sites on an area basis, which is the method of choice, whereby section 2111 would get one site, section 2114 would get one site, section 2113 would get two sites, and section 2112 would get none. The area basis for section distribution was used throughout.

Table 2 shows results of provisional network selections based solely on equal area-weighting of ecoregions for five different network sizes. Also shown are existing monitoring sites by network within each ecoregion. (A description of each network is included in the section on Populating the Model.)

TABLE 1

General Environmental Characteristics of Domains and Divisions
(after Bailey 1976)

DOMAIN	DIVISION	TEMPERATURE	RAINFALL	VEGETATION	SOIL*
2000 Humid Temperate	2100 Warm Continental	Coldest month below 0°C warmest month <22°C	Adequate throughout the year	Seasonal forests, mixed coniferous	Gray-Brown Podzolic (Spodosols, Alfisols)
	2200 Hot Continental	Coldest month below 0°C warmest month >22°C	Summer maximum	Deciduous forests	Gray-Brown Podzolic (Alfisols)
	2300 Subtropical	Coldest month between 18°C and -3°C, warmest month >22°C	Adequate throughout the year	Coniferous and mixed coniferous - deciduous forest	Red and Yellow Podzolic (Ultisols)
	2400 Marine	Coldest month between 18°C and -3°C, warmest <22°C	Maximum in winter	Coniferous forest	Brown Forest and Gray-Brown Podzolic (Alfisols)
	2500 Prairie	Variable	Adequate all year, excepting dry years, maximum in summer	Tall grass, parklands	Prairie soils, Chernozems (Mollisols)
	2600 Mediterra-nean	Coldest month between 18°C and -3°C, warmest month >22°C	Dry summer, rainy winters	Evergreen woodlands and shrubs	Mostly immature soils
3000 Dry	3100 Steppe	Variable, winters cold	Rain <50 cm/yr.	Short grass, shrubs	Chestnut, Brown soils and Sterozems (Mollisols, Aridisols)
	3200 Desert	High summer temperature, mild winters	Very dry in all seasons	Shrubs or sparse grasses	Desert (Aridisols)
4000 Humid Tropical	4100 Savanna	Coldest month >18°C, annual variation < 12°C	Dry season with <6 cm/yr.	Open grassland, scattered trees	Latosols (Oxisols)

*** Names in parentheses are soil taxonomy orders**

Figure 1. - Ecoregions of the Conterminous United States (after Bailey, 1976).

TABLE 2

Ecoregion Distribution of Sites Based on Equal–Area Weighting

DIVISION	ECO-REGION	50	75	100	125	150	NADP SITES IN ECOREGION AS OF MAY 1982	OTHER SITES IN ECOREGION
2100 Warm Continental	2111	1	1	1	1	2	MI25, MN16, MN18, WI37	
	2112	0	0	1	1	1	MI22, WI36	R6
	2113	2	3	3	4	5	MI09, MI53, NY08, NY10, NY12, NY52, NY65, PA 29, WI28, WI36	M2, R10, U5, U15, CAN2, CAN3
	2114	1	2	2	3	3	MA08, ME00, ME02, ME09, ME99, NH02, NY20, VT01	M1, R16, U1, U2, U3, U14
	M2111	0.5	0.5	1	1	1		
	M2112	0.5	0.5	1	1	1	ID04, MT05	
2200 Hot Continental	2211	1	1	1	2	2	OH49	U4, U6
	2212	1	2	2	2	3	MI26, OH17, OH71	M8, R21, U18
	2213	1	1	2	2	2		R1
	2214	2	3	4	5	6	MA01, MA13, NC25, NJ99, NY51, PA42, TN00, TN11, VA13, VA28, WV18	M3, M6, M9, R4, R15, T3, U16
	2215	2	3	4	6	7	AR27, IL35, IL63, MO03, MO05	R13, T1, T2, U7, U17
2300 Subtropical	2311	2	3	4	5	6	FL00, FL03	R17, U8
	2312	1	1	1	2	2		
	2320	5	7	9	12	14	AR02, GA41, MD13, MS14, NC03, NC11, NC33, NC34, NC35, NC41, SC18, TX21, TX38	M4, M7, R5, R19, U9, U10, U11, U19
2400 Marine	2410	1	1	1	1	1	OR99	
	M2411		0	0	1	1	WA14	
	M2412		0	0	0	0		
	M2413	1	1	1	1	1	OR02	
	M2414		0	0	0	0	CA45	
	M2415		1	1	1	1	OR08, OR10	

TABLE 2
(Continued)

Ecoregion Distribution of Sites Based on Equal–Area Weighting

DIVISION	ECO-REGION	50	75	100	125	150	NADP SITES IN ECOREGION AS OF MAY 1982	OTHER SITES IN ECOREGION
2500 Prairie	2511	2	4	4	5	7	IL11, IL18, IL19, IL47, IN34	M5, U12
	2512	2	2	3	4	4	TX52, TX53	
	2521	1	1	1	2	2		
	2522	0	0	1	1	1		
	2523	1	1	1	1	2		R2
	2531	2	3	4	5	6	MN27, NE15	R8, U13
	2532	1	1	2	2	3	SD00	
	2533	1	2	2	3	3		
2600 Medi-terranean	2610	1	1	1	1	1	CA88	R9
	M2610	1	1	1	1	2	CA75, CA99	
	M2620	1	1	1	2	2	CA42, CA85	
3100 Steppe	3111	2	2	3	4	4		
	3112	2	3	4	4	6	ND07, WY99	R7, CAN1
	3113	2	4	5	6	7	CO22	R11
	M3111	1	1	1	1	2	ID15	R20
	M3112	1	2	4	4	5	WY08	R3, R14
	M3113	1	2	2	3	3	CO00, CO19, CO21, NM07	
	3120	1	1	1	1	1	OR17	
	M3120	1	1	1	2	2	AZ03	R12
	3131	2	3	3	4	5	ID03, OR11	
	3132	1	1	1	1	2	CA34	
	3133	1	1	2	2	2		
	3134	0	1	1	1	1		
	3135	0	0	0	1	1		

TABLE 2
(Continued)

Ecoregion Distribution of Sites Based on Equal-Area Weighting

DIVISION	ECO-REGION	50	75	100	125	150	NADP SITES IN ECOREGION AS OF MAY 1982	OTHER SITES IN ECOREGION
3100 Steppe (Cont'd)	P3131	1	1	1	2	2	UT02	
	P3132	1	2	2	2	3	CO99, NM09	
	3140	1	1	1	1	1	AZ01, AZ99	
	A3141	0.5	0.5	1	1	1		
	A3142	0.5	0.5	1	1	1	CO15, WY06	
3200 Desert	3211	0.5	1	1	1	1		R18
	3212	0.5	1	1	2	2	TX04	
	3221	0.5	1	1	2	2		
	3222	0.5	1	2	2	2	AZ06	
4100 Savanna	4110	1	1	1	1	1	FL11	
TOTAL		**57**	**80**	**100**	**127**	**149**		

Knowing how many sites were to be recommended in each ecoregion, the next step chosen was to overlay the index map for the 1:250,000-scale map series (U.S. Geological Survey, 1980) with Bailey's ecoregion map (see Figure 2). Each grid box of the index map then had associated with it the two most predominant ecoregion provinces present (or one, if only one was present). Boxes so designed were randomly sorted by computer until a solution for the ecoregion quota was met. One product from this sorting, satisfying the 100-site provisional network from Table 2, is shown in Figure 2. (Figure 2 is not a unique solution to the 100-site provisional network of Table 2.) When a grid box was selected for a particular ecoregion, only that area of the ecoregion in that grid box is filled in. Locations for sampling sites would then be restricted to the filled in portion of the grid boxes shown in Figure 2.

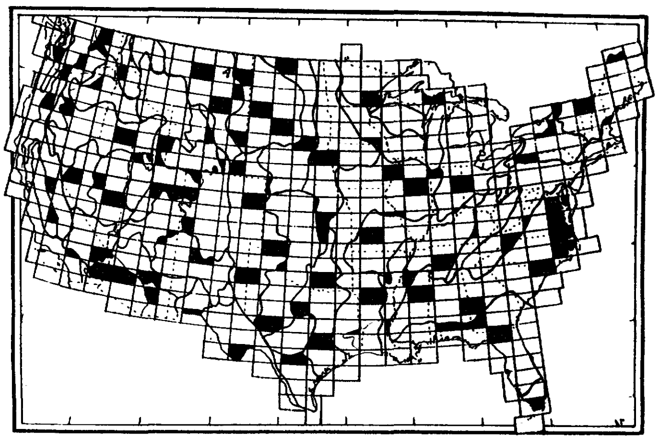


Figure 2 - Randomly Selected, Equal-Area Weighted Ecoregion Distribution for a 100 Site Network.

From Model to National Trends Network Recommendations

The model developed above was not the final distribution model. Based on guidance from the task group, additional factors were considered as explained later. However, the development of Figure 2 gives the opportunity to explain how the procedure for model building led to the final recommendation for the NTN.

Two lists were ultimately provided to the task group:

(a) Those existing precipitation monitoring sites that met the siting criteria and are in ecoregions designated by the distribution model.

(b) Ecoregions where the model calls for sites, but where current monitoring sites meeting the siting criteria do not exist.

The first list is easily derived. If, for example, the model designates a grid box in ecoregion 2111 then all the existing precipitation monitoring sites that fall in ecoregion 2111, and that meet the siting criteria, will be listed. For ecoregions with more existing monitoring sites meeting the siting criteria than sites called for in the final distribution model, recommendation for selection would be made on the basis of which sites would provide the broadest distribution within the ecoregion, and which would meet the greatest number of nice-to-have features in their siting criteria, for example, a colocated calibrated watershed, a colocated acid rain effects research study site, or a long-term observational record. The second list consists of recommended site locations for ecoregions with fewer existing monitoring sites meeting the siting criteria than called for in the distribution model.

Weighting Factors for Site Distribution

A number of factors which affect the distribution of acid deposition or in turn are affected by acid deposition were considered for use in weighting the initial distribution of recommended sites for the NTN. To clarify, it was agreed that all ecoregion provinces must be represented in the final network design. In addition, other factors than equal area-weighting alone were to be used. This section details the various weighting factors considered by the task group, most of which were later rejected as irrelevant or unworkable. But, their consideration provided valuable insights for the final design of the network.

Mean Annual Precipitation

Wilson and others (1982) have shown that, at least in the northeastern United States, wet deposition is roughly proportional to the amount of precipitation. This being the case, then some measure of rainfall is a natural candidate for a weighting factor. However, in Bailey's classification, the amount of precipitation is considered in the delineation of ecoregions at the domain level and at the division level. For this reason annual precipitation was not considered as a weighting factor, for to do so would have given double weighting to precipitation.

The possibility of using some level of annual precipitation as a cutoff below which a site would not be recommend was considered. This was discarded because it was likely that in some areas of low precipitation, much of the precipitation that did occcur, occurred in several large events, the chemistry of which could have important ecological effects on the ecoregion receiving it.

Precipitation Variability

Several measures of precipitation variability were examined: precipitation efficiency, thunderstorm and snowstorm frequency, and the coefficient of variation of annual precipitation (variability).

Precipitation efficiency, the percent of available moisture in the atmosphere which actually falls, has a small variability (2.5 to 12.5 percent) across the conterminous United States and was not used for this reason.

Thunderstorm and snowstorm frequency each depict a single part of precipitation variability. Although the two together provide a good approximation of precipitation variability, the coefficient of variation or variability (Hershfield, 1962) of annual precipitation, as estimated on 1:250,000-scale quadrangle sheets, was considered a better measure.

Figure 3 shows those quadrangles with high precipitation variability and those with low precipitation variability, i.e., where variability exceeds 25 percent of the mean annual precipitation.

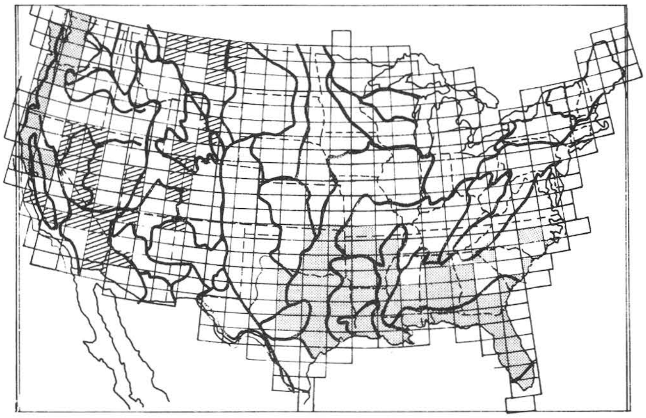


Figure 3 - Precipitation Variability in the Conterminous United States. Cross Hatch = low variability; Dot Pattern = high variability

The quadrangles identified in Figure 3 with high precipitation variability were doubly weighted in an ecoregion-coupled selection process to produce the provisional 100-site network shown in Figure 4. The effect of double-weighting can be seen by comparing Figure 4 with Figure 2. Ecoregions in the south and west in Figure 4 are more densely sited, while conversely, other ecoregions without double-weighting show fewer sites.

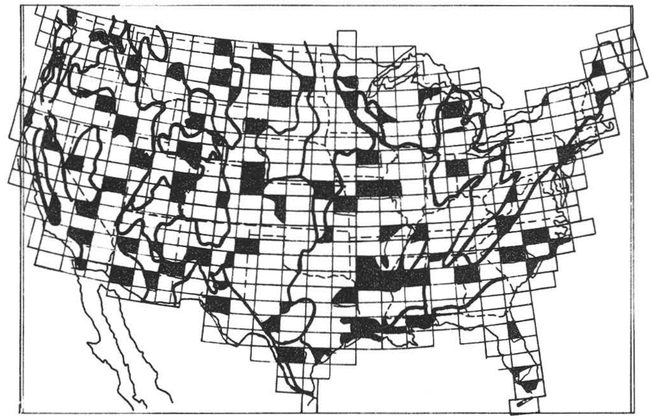


Figure 4 - Randomly Selected, Precipitation Variability Weighted Network of 100 Sites.

Ambient Concentrations of Air Pollutants

In locating sampling sites, the intention was to generally place sites away from point source pollutant concentrations to avoid skewing the data, i.e., hot spots were to be avoided.

Data from the National Air Monitoring Stations (NAMS) network which contains particulate data from 80, mostly urban, sites across the United States and data from the Storage and Retrieval of Aerometric Data (SAROAD) data base were examined for possible use in siting. Except for particulate data, there are not enough data available across the country to reasonably indicate background concentrations of pollutants.

Air Pollutant Emissions

Several data bases exist which contain data on pollutant emissions from point sources of pollution. The Multistate Atmospheric Power Production Pollution Study (MAP3S) Emissions Inventory (Benkovitz, 1980) was used in the analysis to compare one area against another. The MAP3S data base contains emissions data for particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, and hydrocarbons as well as information on stack height, plant operating characteristics, etc. The data base has a file of emissions by county. It also contains information on more than 50,000 stationary sources.

The data were summarized on 1:250,000-scale quadrangle maps. Only the data for sulfur dioxide, nitrogen oxides, and particulates were used as these have the most potential for influencing precipitation chemistry.

Based on an arbitrary division of the country into three regions (Northeast—north of latitude 38°N, east of longitude 94°W; Southeast—south of latitude 38°N, east of longitude 94°W; and West—west of longitude 94°W) regional means for each pollutant were calculated, as well as values one and two standard deviations from the mean. Values greater than two standard deviations above the mean were used to find grid boxes that had excessively high emissions. The intent was to exclude quadrangles with extremely high emissions, as opposed to hot spots, from the NTN. This approach was abandoned however, because this might seriously underestimate the background acid deposition across the United States. The approach was changed to favor the selection of grid boxes with the lowest 10 percent of emissions in each of the 3 regions defined above. This approach would underestimate deposition to some extent but this seemed more desirable than skewing the data because of high emission.The grid boxes representing the 10 percent of each region with lowest sulfur dioxide, nitrogen oxides and particulate emissions were identified. Any grid box which had low emissions in one or more species was double weighted. A quadrangle low in two or three emission types was not weighted more heavily than one that was low in only one emission type. This approach still allowed some regions to be chosen with moderately high background emissions, but the probability of being chosen was reduced.

As with the precipitation variability weighting process, Table 2 was then modified to reflect double weighting due to low emissions. This revised table was then used as the basis for another random computer selection of grid boxes. (Emissions weighting was later dropped from consideration in the post-Bear Mountain models, however, sites downwind of large point sources, within approximately 50km, were avoided in the final list of recommended sites.)

Topography

To ensure representativeness of the data accumulated by the NTN, it is important not to favor one climatic or meteorological regime over another. Bailey's ecoregions ensures that all regions of the country, both windward and leeward, are represented. It also identifies the high altitude regimes. Although no attempt was made early on to ensure representativeness of altitudinal variation, this was later attempted in the site selection process described in the section on Populating the Model.

Existing Wet Deposition Chemistry Data

Wet deposition data already collected from operational networks allows an opportunity to use these data for shaping site selection. Following a review of the summary isopleth maps available (Gibson, 1982; Semonin, 1981 and Work Group 1, 1983), Semonin's deposition-based maps were selected for use because they represent total and seasonal loading over several years, while the others confined their presentations to concentrations over single years. The main use of these maps was to place sites so as to better define areas with steep gradients of pollutant concentrations.

Because the goals of NTN are long-term trend delineation over years, rather than over seasons, Semonin's summary maps were used rather than his seasonal maps. His isopleth maps for calcium, magnesium, chloride, sulfate, nitrate, sodium, potassium and hydrogen ions were examined. For simplicity, only three of these maps were used to shape site selection. They were chosen to reflect an indication of a neutralizing constituent, calcium; the major acidifying constituent for most areas, sulfate; and hydrogen ion; which summarizes net acidic input.

Semonin's isopleth maps, a sample of which is given in Figure 5, used unequal intervals between isopleths for better resolution in the western United States. Therefore, to visually determine gradients on the same relative scale, the isopleth maps were replotted onto the 1:250,000-scale index map and isopleths for the missing increments were then interpolated by observation. An example of one of these maps is shown in Figure 6. (The pattern also suggests the sulfate maxima over the northeastern United States.) With equally separated isopleths now in place, it was a simple matter to estimate the gradient of each constituent in any 1:250,000-scale grid box. The number of isopleths passing through the grid box were counted. The steeper the gradient, the more isopleths that passed through the box. The quadrangles with a high number of calcium, sulfate or hydrogen ion isopleths passing through the box are shown in Figure 7.

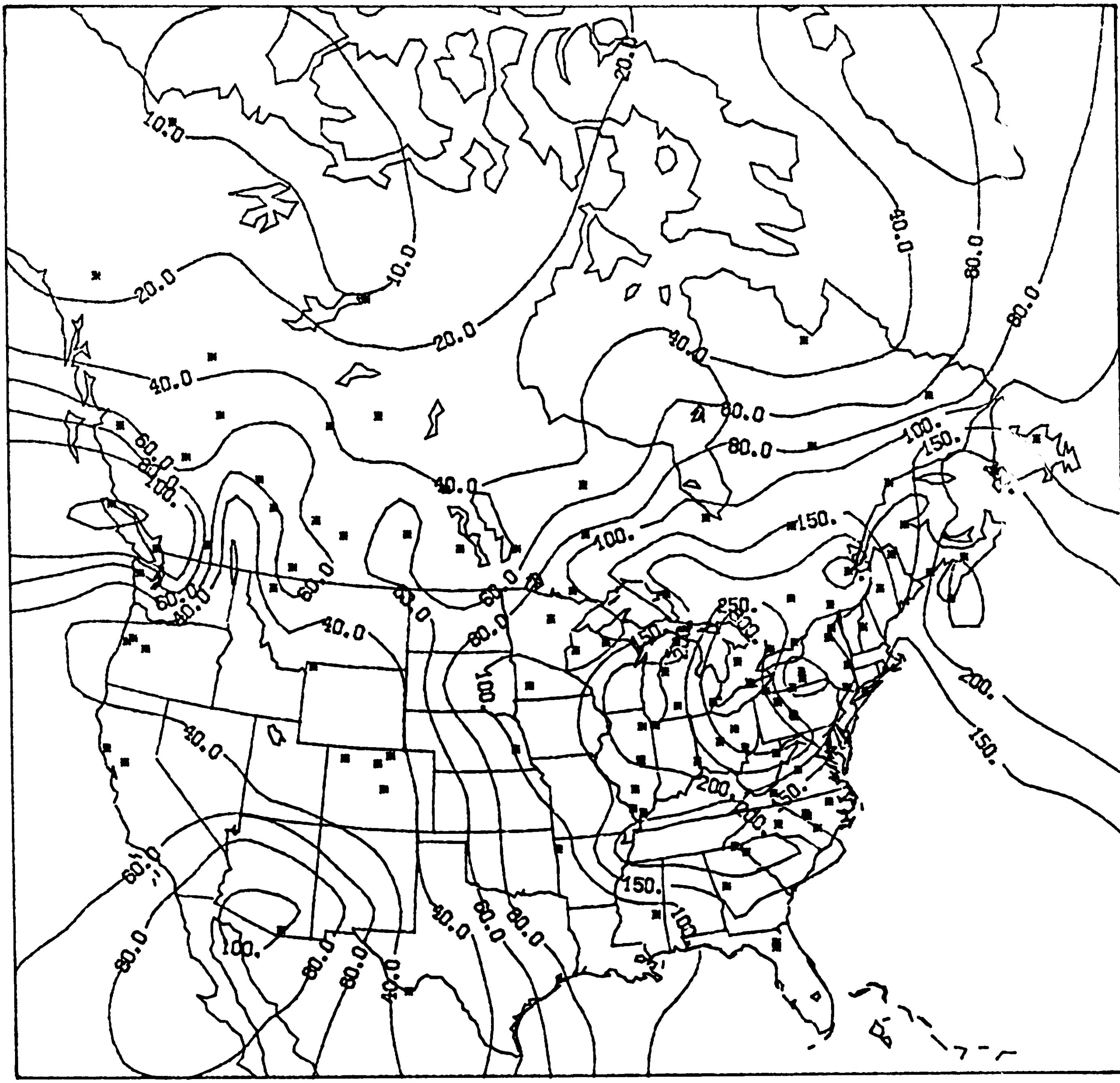


Figure 5. - Average Annual Sulfate Deposition (mg/m²) over North American, July 1978—September 1980. (Semonin, 1981.)

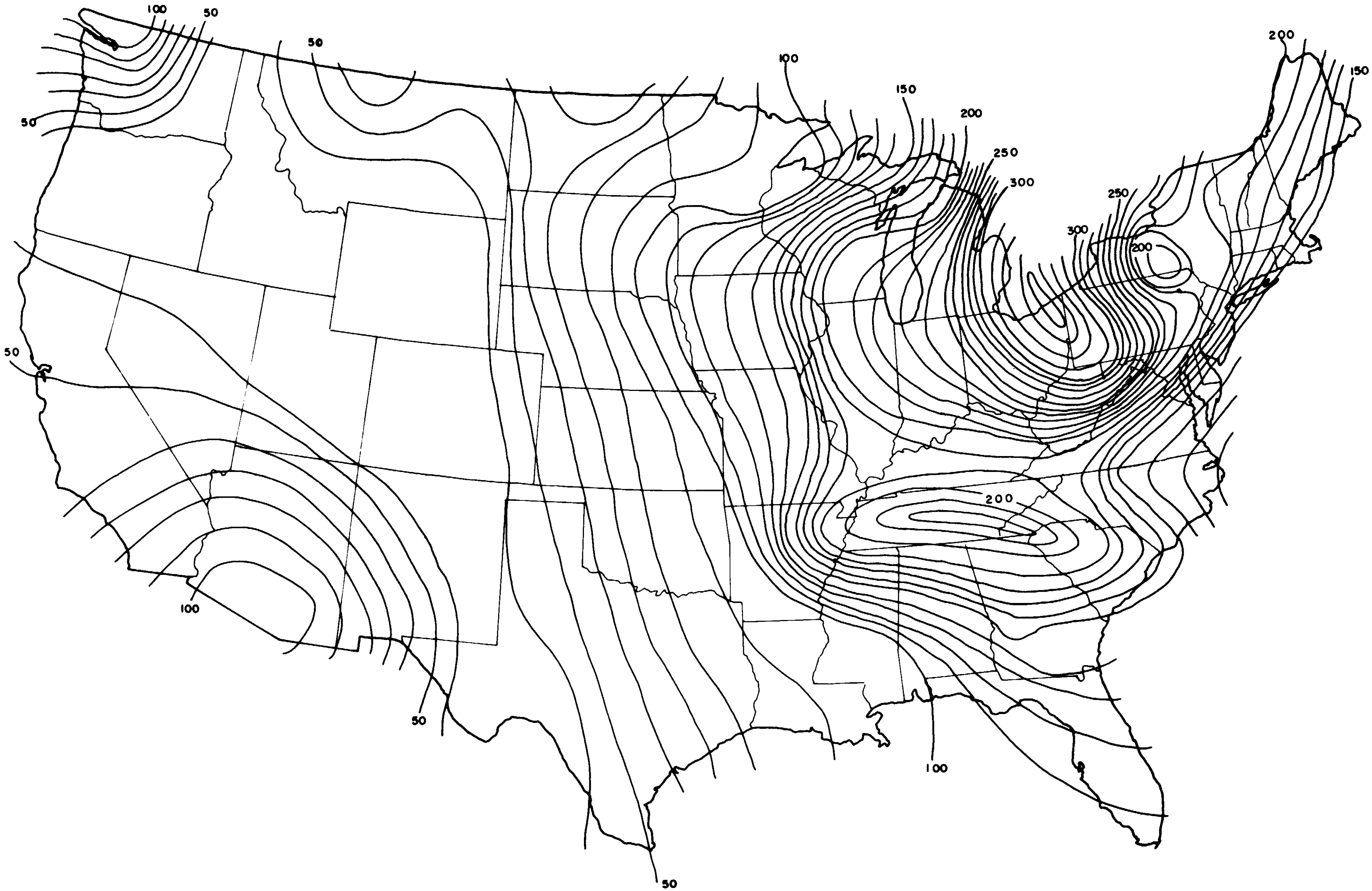


Figure 6. - Deposition Isopleths for Sulfate (mg/m^2) Redrawn with Missing Isopleths Interpolated. (Modified from Semonin, 1981.)

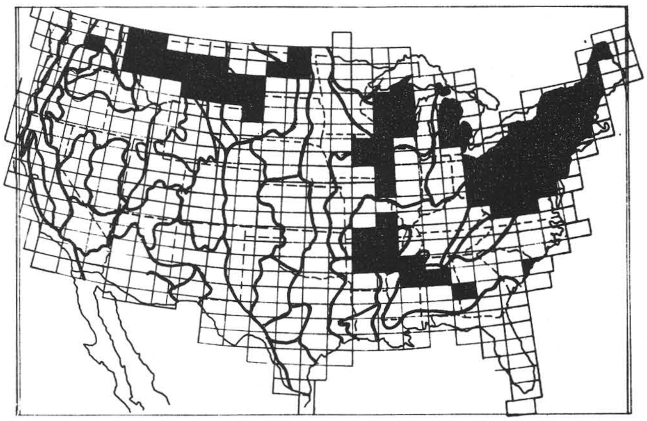


Figure 7 - Quadrangles with High Deposition Gradients for Calcium, Sulfate, or Hydrogen Ions.

Potential Sensitivity to Acid Deposition

Several maps of potential sensitivity of a region to the effects of acid deposition have been published. The map by McFee (1980) for the Eastern United States is based on soil types. The map by Hendrey and others (1980) is based on bedrock geology. A third map, by Omernik and Powers (1982), uses alkalinity as a measure of relative sensitivity to acidic deposition. Any of these might be used as a measure of potential susceptibility. Initially, the task group did not see a need for site selection based on potential susceptibility of a region. So, it was not used in the pre-Bear Mountain phase in determining recommended site locations.

Combination of Weighting Factors

In this section it is shown how the four parameters—ecoregion equal area distribution, high precipitation variability, low emissions, and high deposition gradients--are combined onto one weighting scheme. To derive Table 3, the random selection process by ecoregion was repeated with each 1:250,000 grid box favored by either high precipitation variability, low emissions or high deposition gradient given twice the opportunity for selection, and any grid box favored by more than one of these weighting factors given three times the chance of being selected. Figure 8 shows the 1:250,000-scale quadrangles favored by one or more of the weighting factors. Table 3 yields several possiblenetworks for the NTN. Each ensures that all ecoregion provinces of the United States are represented. Each favors placement of sites in: (1) areas of low pollutant emissions, (2) areas with highly variable precipitation and, (3) areas that present data indicate are transitional between areas of highly polluted precipitation and areas of relatively clean precipitation.

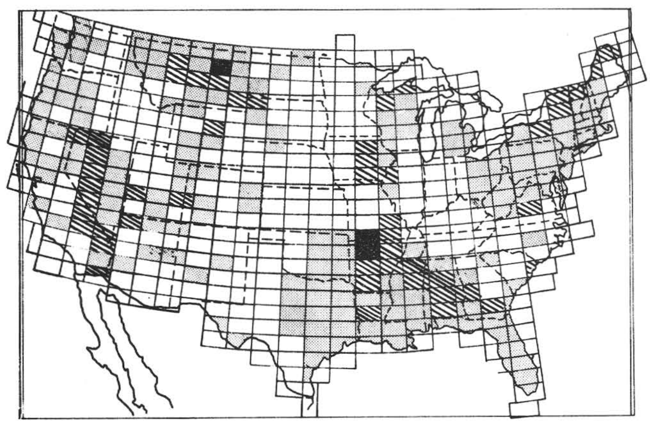


Figure 8 - Quadrangles with Weighting Due to High Precipitation Variability, Low Emissions, or High Deposition Gradients.
Dotted Pattern = one weighting factor;
Cross Hatch = two weighting factors;
Solid = three weighting factors

TABLE 3

Ecoregion Distribution of Sites Based on High Precipitation Variability, Low Emissions, and High Deposition Gradient Weighting Factors

DIVISION	ECOREGION	50	75	100	125	150
2100 Warm Continental	2111	1	1	1	1	2
	2112	1	1	1	1	1
	2113	2	3	4	5	7
	2114	1	3	3	4	2
	M2111	0.5	0.5	1	1	1
	M2112	0.5	0.5	1	1	1
2200 Hot Continental	2211	1	1	1	2	2
	2212	1	2	2	2	3
	2213	1	1	2	2	2
	2214	2	3	4	5	6
	2215	2	3	4	6	7
2300 Subtropical	2311	1	3	5	6	7
	2312	1	1	1	3	3
	2320	6	9	12	15	18
2400 Marine	2410	1	1	1	1	1
	M2411	0	0	0	1	1
	M2412	0	0	0	0	1
	M2413	1	1	1	1	1
	M2414	0	0	0	1	1
	M2415	1	1	1	1	1
2500 Prairie	2511	2	3	4	4	6
	2512	2	2	4	5	5
	2521	1	1	1	2	2
	2522	0	1	1	1	1
	2523	1	1	1	1	1
	2531	1	2	3	4	4
	2532	1	1	2	2	2
	2533	1	1	1	2	2

TABLE 3

(Continued)

Ecoregion Distribution of Sites Based on High Precipitation Variability, Low Emissions, and High Deposition Gradient Weighting Factors

DIVISION	ECOREGION	50	75	100	125	150
2600 Mediterranean	2610	1	1	1	1	1
	M2610	1	1	1	1	2
	M2620	1	1	1	1	1
3100 Steppe	3111	2	2	4	4	6
	3112	2	2	4	4	6
	3113	1	2	4	4	5
	M3111	1	1	1	1	2
	M3112	1	1	3	3	4
	M3113	1	2	2	2	2
	3120	1	1	1	1	1
	M3120	1	1	1	1	1
	3131	2	2	2	4	4
	3132	1	1	1	1	3
	3133	1	1	2	2	2
	3134	1	1	1	1	1
	3135	0	0	1	1	1
	P3131	1	1	1	2	2
	P3132	1	2	2	2	2
	3140	1	1	1	1	1
	A3141	0.5	1	1	1	1
	A3142	0.5	1	1	1	1
3200 Desert	3211	0.5	1	1	1	1
	3212	0.5	1	1	1	1
	3221	1	2	2	3	3
	3222	1	1	2	2	2
4110 Savanna	4110	1	1	1	1	1
TOTAL		**59**	**79**	**105**	**128**	**148**

DISCUSSION AT BEAR MOUNTAIN

A draft document consisting of the material reviewed above, plus some additional tables, similar to Table 2, detailing the effect of each weighting factor were distributed to a panel of nine reviewers knowledgeable in the workings of the task group. Each provided written comments which were summarized and then used at the Bear Mountain workshop for joint discussion with the reviewers and the task group.

The discussion covered two basic areas; (1) the framework of the design; and, (2) the use or abuse of weighting factors.

Framework for the Discussion

There was a discussion of the relationship of network goals to network size. Information from a paper by Haszpra (1980) showed that in a uniformly distributed network of 150 stations each station would represent a square 220 kilometers on a side. The relative error of which, for annual sulfate deposition, would be approximately 8 percent, while the seasonal error could be in excess of 30 percent. (Eight years of data from the European Atmospheric Chemistry Network were used in the statistical analysis.) Haszpra (1980) also showed that if a non-uniform or random grid is used, or if the deposition field has "hot spots," then an even denser network would be needed to keep the relative error the same as the uniformly distributed case. While agreeing in principle that more sites are desirable, the task group felt that they could not justify funding for sites in excess of 150.

Several additional considerations were suggested which might have given the siting model another dimension, for example; (1) energy development, such as, mine mouth powerplants, oil shale retorting, or coal gasification; (2) agricultural/forestry activities, such as stripping and clearing for grazeland; (3) changing demographic patterns; and (4) water utilization. There was general agreement that it would be impossible to know with certainty all these kinds of possible changes.

Flexibility of the Network

Several reviewers were concerned that the network design was not flexible enough. Items brought up for consideration included:

- Samplers should be colocated with samplers from other networks. (Because of the networks being considered in the second phase of this project, there was reason to believe this concern would be satisfied.)
- Some fraction of the network sites should be mobile stations to address changing network needs such as "hot spots" or unrepresentativeness of one or more chemicals. (The task group agreed that the network should be reevaluated periodically to optimize siting based on current knowledge.)
- That sites placed to better define the gradients be reevaluated periodically to see if they are needed or should be repositioned. (In response, the task group confirmed its commitment to periodic reevaluation of these sites.)
- That the design of the NTN was being separated from the National Acid Precipitation Assessment Program's study sites for streams and lakes and from long-term research on plants and soils. (In formulating the NTN, as many sites as possible will be established with these studies in mind.)

Weighting Factors for Site Distribution

Everyone accepted the ecoregion basis for distributing sites. There were some reservations. One reviewer was concerned that the inherent ecoregion weighting might lead to separating the collectors too far apart to provide statistically adequate coverage for ascertaining temporal trends. There was concern that by using other weighting factors the statistical objectivity of the study might be lost. The orginial design concept held that by using several factors, the weighting bias, if any, would eventually even out, and that in essence there would be a return to equal area distribution. As Figure 8 illustrates, this was not the case. A detailed discussion of each weighting factor follows:

Precipitation Variability

It was pointed out that Hershfield's map (1962) was too coarse for use in mountainous regions. It was thought to favor the West, South, and Midwest too much, and emphasize the arid parts of the country too much. After considerable discussion, precipitation variability was dropped as a weighting factor.

Air Pollutant Emissions

Comments in this area can be summarized best by quoting one of the reviewers: "Use of emissions weighting is questionable because by focusing on low emissions the NTN would monitor only background areas. The network should be designed to depict the real picture, not just where the sheep graze." Emissions as a weighting factor was subsequently discarded.

Existing Wet Deposition Chemistry Data

All participants favored incorporating these data somehow. Opinions on how to do it differed. One reviewer preferred using seasonal as opposed to annual gradients. Another preferred the use of precipitation concentration instead of deposition loading to avoid the effect of precipitation amount. Use of Semonin's maps was later decided as the best way to deal with these considerations.

Potential Sensitivity to Acid Deposition

Almost all reviewers wanted some measure of ecological sensitivity included in the weighting scheme. Typical comments ranged from: "Current concern with acid deposition has focused on sensitive areas; changes in these areas cannot be overlooked": to "Ecological sensitivity is a factor but not one which should dominate site selection." The group recommended incorporating potential sensitivity as a basic consideration in siting.

POST-BEAR MOUNTAIN MODEL

Following the workshop the task group met while still at Bear Mountain to decide which parts of the pre-Bear Mountain model to retain, and which to discard. The following guidance evolved:

- Place between 75 and 100 sites on the basis of equal area weighting by ecoregion.
- Place between 25 and 50 sites east of the Rocky Mountains on the basis of the known deposition gradients for hydrogen ion, nitrate, sulfate and ammonium.
- Place 15 sites in areas potentially susceptible to the effects of acid deposition, but not represented by either of the above placements.
- Place up to 10 sites allowing for other considerations, such as urban area effects, intercomparision with Canada and apparent disparities in regional coverage.

This guidance was based on the task group's view that weighting by formula was not particularly appropriate, and that the ecoregion concept took into account most of the climatic and meteorological characteristics proposed as weighting factors. Special attention to regions showing high susceptibility to acidification and abrupt increases in deposition loadings with distance could be provided by insightful addition of extra sites.

Two very different analytical tasks were involved in the final evaluation of potential sites for incorporation into the NTN: the first was that of looking at existing operating sites; the second was that of evaluating areas without existing stations. For the first, a wealth of information was available; maps, sketches, photographs, and precipitation-chemistry data. For these sites, data bases are often available which provide information on emissions and meteorological data in and around the sites. For the second task of siting in new locations, special maps, emissions data, and meteorological data, etc. are often unavailable.

Existing sites can be screened to distinguish between good sites and bad sites. This screening can be used with the information available from maps and from data on emissions and meteorology to project the suitability of potential sites for the NTN. In this section, the kinds of data available and the potential uses of this information in site analysis are examined.

EXISTING SITES TO BE CONSIDERED

From the outset it was agreed to limit consideration of candidate sites for the NTN to those operated by the Multistate Atmospheric Power Production Pollution Study (MAP3S), National Atmospheric Deposition Program (NADP), Tennessee Valley Authority (TVA), and the Utility Acid Precipitation Study Program (UAPSP). Meteorological stations of the NOAA Reference Climatological Station (RCS) Program were also considered.

Multistate Atmospheric Power Production Pollution Study

The MAP3S network consists of the nine stations tabulated in Appendix C and shown in Figure 9. Four of the stations (Whiteface, Ithaca, Penn State, and Virginia) began operation in 1976. A second group of four sites (Illinois, Brookhaven, Lewes, and Oxford) began operation in 1978. Oak Ridge was added in early 1981. Samples are wet-only collected on a modified-event basis defined by the operator. Analysis is done at Battelle's Pacific Northwest Laboratories. The network is funded by the U.S. Department of the Energy and the U.S. Environmental Protection Agency.

National Atmospheric Deposition Program

The NADP network, at the time of model preparation, consisted of the 101 sites operating on May 30, 1982, and an additional 7 sites that had been located, but had not yet collected any samples. These sites are listed in Appendix C and plotted in Figure 9. The network utilizes an Aerochem–Metrics 1/ wet/dry precipitation collector. Wet-only samples are collected weekly. A dry-deposition sample is collected every 8 weeks. Both are analyzed at the Central Analytical Laboratory at the Illinois State Water Survey. Each site in the network is funded by a sponsoring agency, either Federal, State, educational, or private sector. Coordination funds are provided by the U.S. Department of Agriculture and the U.S. Geological Survey. The U.S. Geological Survey and other agencies have contributed quality control/assurance services, and the time of their personnel for leadership roles.

Tennessee Valley Authority Trends Stations

The TVA network consists of the three sites listed in Appendix C and plotted in Figure 9. These sites are the remnants of a small network started in 1971 which grew to 11 stations by 1979 but reverted to its present size in 1982. The network uses wet/dry collectors of the Health and Safety Laboratory design (Volchok and Graveson, 1975). Sampling is biweekly on the wet-only side and bimonthly on the dry. Samples are analyzed in the Chattanooga Laboratory. Funding is by TVA and the Electric Power Research Institute (EPRI).

Utility Acid Precipitation Study Program

The UAPSP network consists of the 19 sites listed in Appendix C and plotted in Figure 9. The network started operation in October 1981, but six of the sites had prior history as part of the EPRI Eastern Regional Chemistry Network (EPRI, 1979). The network utilizes an Aerochem–Metrics sampler to collect a wet-only sample on a daily basis. Analyses are performed by Rockwell International. The network is funded by 34 electric utilities in the Eastern United States and receives technical guidance from EPRI.

NOAA Reference Climatological Station Program

The RCS network consists of 21 meteorological stations listed in Appendix C and plotted in Figure 9. The network is run by contractors, mostly State Agricultural Experiment Stations, under the supervision of the National Weather Service in Asheville, North Carolina. No wet deposition data were being collected at the time of model preparation.

1/ Use of trade name does not denote endorsement by the U.S. Goverment.

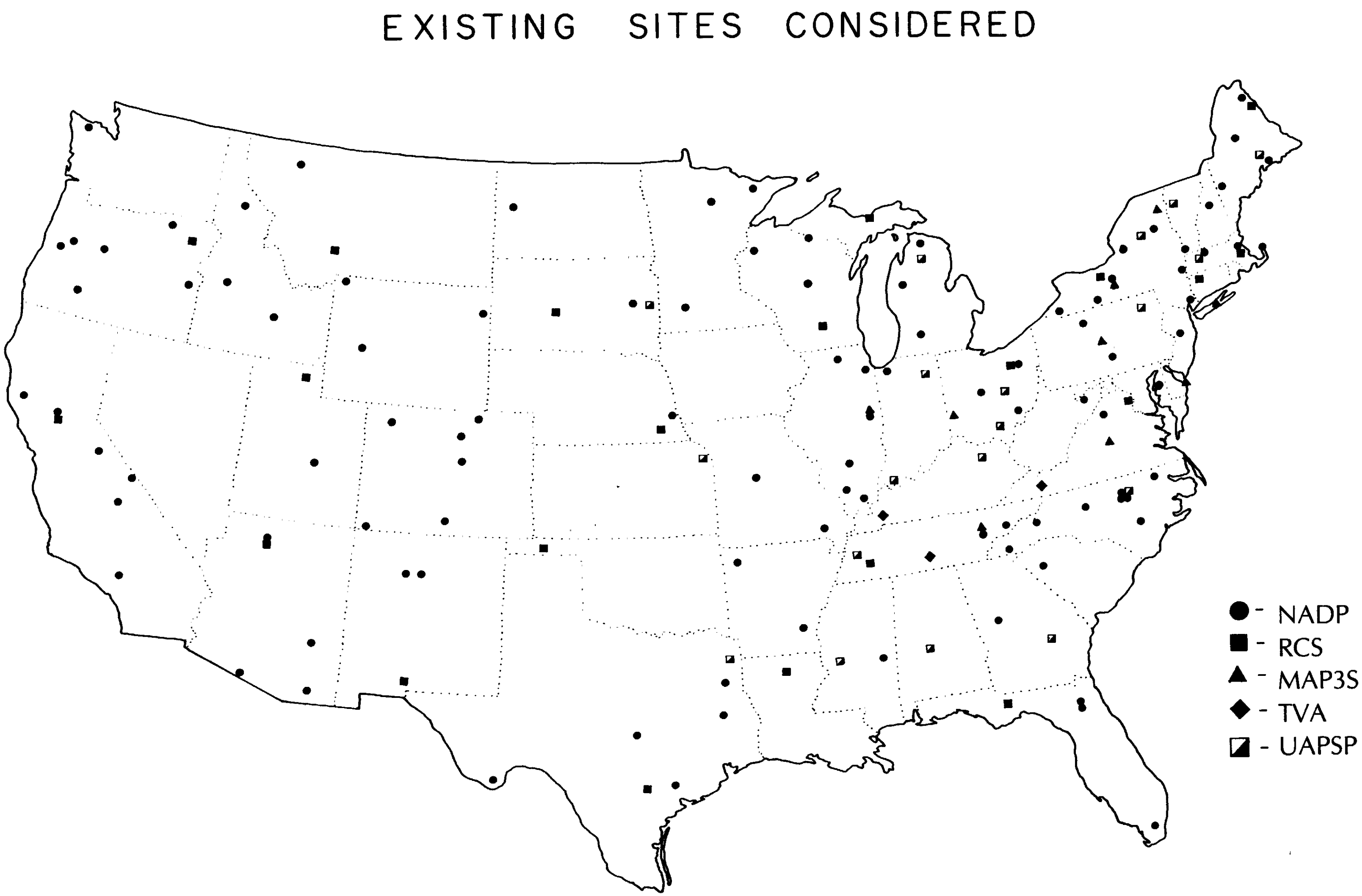


Figure 9 - Existing Precipitation Monitoring and Climate Monitoring Sites.

Because of their geographic spread and the level of training of their operators, these sites were thought to have potential for new sites.

Colocated Sites

Sites from several of the above networks are colocated. These sites are listed below:

- M5 - Illinois (MAP3S) colocated with IL11-Bondville (NADP)
- M9 - Oak Ridge (MAP3S) colocated with TN00-Walker Branch (NADP)
- R9 - Davis (RCS) colocated with CA88-Davis (NADP)
- R21 - Wooster (RCS) colocated with OH71-Wooster (NADP)
- U19 - Raleigh (UAPSP) colocated with NC41-Finley Farm (NADP)

AVAILABLE SITE DATA

Site Description Information

The Site Criteria and Standards Subcommittee of the NADP requires each NADP site to supply the following information. Comparable data was sought for each candidate NTN site:

- site location;
- site logistics information (accessibility, power, security, etc.);
- equipment on hand (raingage, wind instruments, pH and conductivity meters);
- information on period of operation of the site;
- topography, soil type, tall objects around the site;
- civilization around the site (roads, airfield, powerplants, industry, etc.);
- a listing of all meteorological instruments colocated;
- aerosol and gas samplers at the site;
- description of any nearby associated acid rain effects research;
- description of any nearby calibrated watershed;
- a sketch map of the site showing all objects over 4 feet in height within 100 feet of the site;
- a set of eight photographs in the principal compass directions with sampler in the foreground;
- a soils map and associated soil description for the area surrounding the site;
- maps: 1:250,000-scale and either the 7.5 or 15 minute topographic quadrangle.

Air Pollutant Emissions Data

As noted earlier, the MAP3S Emission Inventory was used as the data base for locating both point and area sources. This inventory was compiled from the National Emissions Data System, from information supplied by the Federal Power Commission, as updated during the MAP3S regional experiment studies (Benkovitz, 1980). In the inventory point sources are tabulated for all 48 conterminous States as well as Canada.

Area sources were available for the conterminous United States only. Emissions of particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide were also extracted from the MAP3S data base. Area sources for each county are listed in the MAP3S data base by the latitude and longitude of the county centroid.

To make the emissions data easy to use a computer graphics program was written. The output produces two plots; the first displays the area surrounding the site out to 20-km (Figure 10) and places a character where each emission source is located. The Standard Industry Code was used as a guide to display potentially heavy industrial sources as an alphabetic character, while all potentially low emitters (apartment houses, light industry, government complexes, etc.) were displayed as plus signs (+). A second plot with the same information for a 50-km radius was also generated.

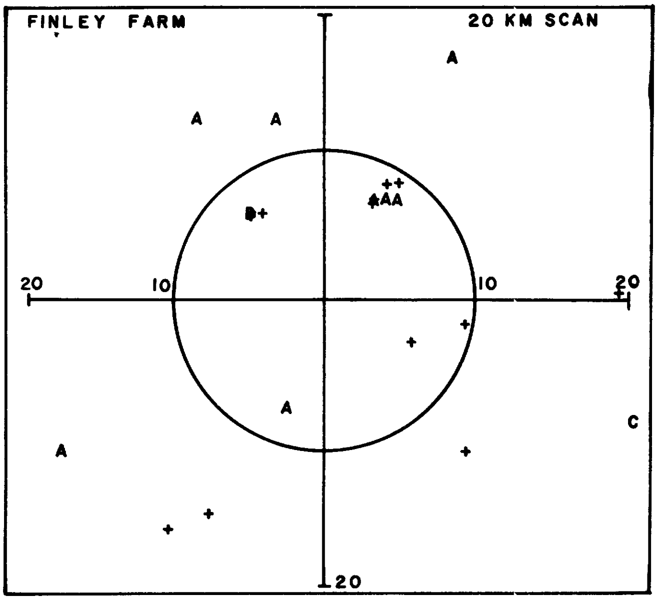


Figure 10 - Sample Plot of Emission Sources Within 20 km of a Proposed Site at Finley Farm, North Carolina.

NATIONAL TRENDS NETWORK SITE SUITABILITY ANALYSIS	DATE:	SITE CODE:
SITE NAME:	NETWORK AFFILIATION:	

DATA AVAILABLE

☐ 1:250,000 map ☐ 1:62,500 map ☐ 1:24,000 map
☐ site questionnaire ☐ supplemental questionnaire ☐ sketch map
☐ site photos ☐ Emissions plot ☐ wind rose
☐ other(*specify*)

SITE OWNERSHIP: ☐ federal ☐ state ☐ other(*specify*)

SITE MANAGER/INSTITUTION:

LOCAL CONDITIONS;

LONG RANGE CONDITIONS:

ANNUAL PRECIPITATION AMOUNT:	PRECIPITATION CHEMISTRY:

EQUIPMENT STATUS: (within 50 meters of sampler)

☐ Automatic Wet Precip Collector. ☐ Type__________ ☐ Lid Rcd__________
☐ Rcdg Rain Gage ☐ Conductivity meter ☐ Balance
☐ pH meter ☐ other instruments on site

ASSOCIATED RESEARCH/CALIBRATED WATERSHED

Figure 11 - Form for Site Suitability Analysis

The point source emission tabulation and the two emission plots for each potential NTN site were produced and added to the site description file for each site.

Wet Deposition Chemistry Data

At the time the site review was taking place (March–July 1982), wet-deposition data was not always available for a site being considered. To solve the problem of how to evaluate a site which had no data, it was decided not to consider any site-specific data thereby treating all sites equally.

PROCEDURE FOR EVALUATING EXISTING SITES

For comparison of sites, the form shown in Figure 11 was designed to answer the following questions:

(1) Who owns the land on which the site is situated?

(2) Who is managing/operating the site?

(3) What are local conditions (1–2-km radius) around the site?

(4) What are regional conditions like within a 50-km radius?

(5) What is the annual precipitation at the site?

(6) What equipment is on hand at the site?

(7) Is any acid rain effects research being performed at the site and/or does a calibrated watershed exist nearby?

Each site was given a subjective rating of good, marginal, or bad. The good sites were useable as they were, the marginal sites required some upgrading, and the bad sites were not considered useable even with upgrading. Insofar as possible the one-page form for site suitability analysis was filled out for each site. All ratings are based on an analysis of the form and the other information available for the site.

Some bias in how sites were pre-selected to fill out the recommended network was unavoidable. NADP sites would generally be given preference over sites of equal stature from other networks because the NADP sites followed the same operational protocal adopted for NTN and required no out-of-pocket expense to comply with the NTN protocol. (In no case was a lesser quality NADP site given preference over another site of better quality). UAPSP sites were at a disadvantage because they are almost exclusively on private land and could violate the long-term land use/ownership stability guideline. Other network sites, including RCS sites, were considered essentially equal because they all would require About the same expense in new equipment to join NTN.

PROCEDURE FOR EVALUATING AREAS WHERE NO STATION EXISTS (NEW SITES)

The main requirements in the selection process for new sites were: 1) to identify a location unaffected by local sources; 2) stable land ownership; and 3) ease of servicing.

Figure 9 shows that the majority of existing sites were located in the eastern half of the United States requiring new selections in the West, South, and Central sections of the country. Some existing sites did not meet the general siting criteria necessitating selection of replacement sites.

The MAP3S Emission Inventory (Benkovitz, 1980) was utilized to produce 470 plots of stationary emission sources for the conterminous United States, each equalivant to a 1:250,000 scale map sheet (USGS, 1980), (Figure 12). These plots were used to identify large areas that might be suitable for sites. Powerplants and large stationary emitters were identified on the plots so areas could be selected to minimize these influences.

Next the selected areas were closely examined, using the 1:250,000 scale map sheets equalivant to the emission plot to identify locations stable in land ownership and having personnel available for servicing the site. State and Federally controlled areas were prime candidates in this respect. National parks, national forests, national wildlife refuges, state parks, and agricultural experiment stations were selected most often. If a site was a candidate to

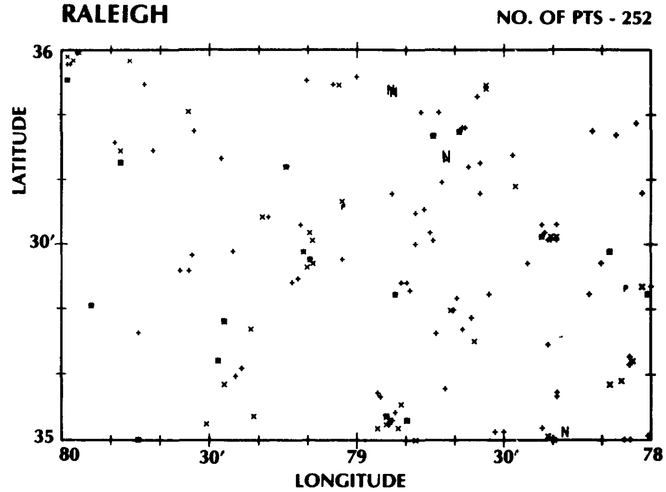


Figure 12 - Emission Plot for the Raleigh Quadrangle.

represent a specific ecoregion, then the 1:250,000-scale ecoregion and land-surface form map equivalent to the map sheet was checked to ensure that the candidate site was indeed in that ecoregion.

In some cases, the NADP Coordinator knew of interest in establishing a monitoring site in an area of need, or knew of other special study sites. Lists of watershed studies were furnished by the U.S. Geological Survey and the TVA.

More than 300 candidate sites were identified in this manner before the final 42 new sites were selected. (See Appendix C for a list of new sites). All 300 sites were closely analyzed for proximity to local influences and practically of operation. Emission plots were used to provide detailed data on stationary and area sources near each candidate site. The best site in an area that provided adequate spatial resolution with adjacent stations was chosen. An example of how this sorting was done for one ecoregion follows in the next section.

EXAMPLE OF SITE SELECTION ON EQUAL–AREA BASIS BY ECOREGION

The Prairie Parkland Province, 2510, is a large irregular area extending from the Gulf of Mexico to the Great Lakes (Figure 13). Seven sites are planned for the province according to the distribution model of 100 sites adopted for ecoregion representation (Table 3). These are distributed with four in section 2511 and three in section 2512.

In section 2511, two if the existing sites are in the Chicago urban area, Argonne, IL19, and Indiana Dunes, IN34, and were dropped from further consideration as equal–area sites. Bondville/Champaign, IL11/M5, was chosen to represent the northeastern part of the ecoregion and Salem, IL47, was chosen to represent the southeastern part of the ecoregion. Lancaster, U12, was selected in the West. A new site, McNay Research Center, N30, is proposed for the northwestern corner. The existing site at Shabbona, IL18, and the new site at Roseville, N42, were added later based on the high gradient definition.

In section 2512, (Figure 13), the existing site at Victoria, TX53, and the planned site at McKinney Falls, TX52, had less than desirable site characteristics. Three new sites, N15, Attwater Prairie Chicken National Wildlife Refuge; N17, USDA Black Creek Headquarters (now part of the LBJ National Grassland); and N19, the National Severe Storms Laboratory were selected for the ecoregion.

Figure 14 shows the 96 sites recommended on the basis of representing each of the ecoregions in proportion to its area, i.e., 97 sites (Table 4), 2 desert sites not retained, plus 1 site added in A3140. (A distribution of 96 sites fitted the spatial distribution better in parts of the East and West than the model of 100 sites depicted in Table 2.) The 96 sites are the core of the NTN, the minimum monitoring effort over the long–term.

SITE SELECTION BASED ON GRADIENT DEFINITION

Semonin's (1981) isopleths for hydrogen ion, sulfate, nitrate, and ammonium (see Figure 5) were used to identify areas east of the Rocky Mountains where more sites were needed to better define the nature and extent of the gradients. Figure 14 (96–site map) was overlain by Semonin's gradient maps. The steep gradient areas were highlighted. Existing sites with acceptable siting criteria were also highlighted, again with an eye toward spatial distribution. If no existing sites were in an area of steep gradient or if the existing sites were not acceptable, new sites were nominated using the method outlined earlier. Figure 15 shows the gradient sites chosen.

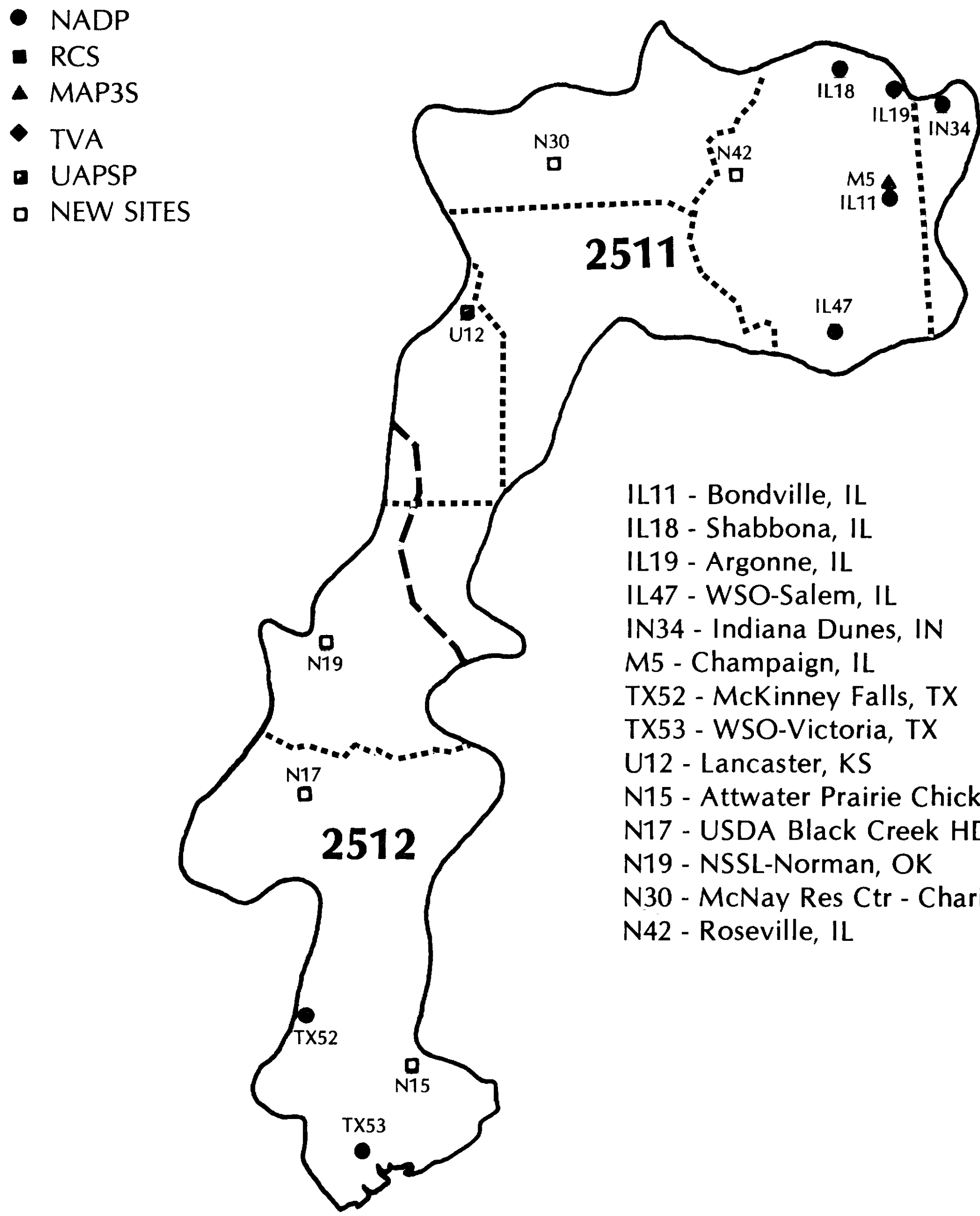
SITE SELECTION TO ENSURE COVERAGE OF SENSITIVE AREAS

The task group required that sensitive areas be monitored by an NTN site whenever possible. A preliminary copy of the map of alkalinity of surface waters by Omernik and Powers (1982) was used as a surrogate for sensitivity. This map was checked against the list of new and candidate sites. Sensitive area sites had to meet all the siting criteria outlined above. In some cases a region of high sensitivity was not picked because of the lack of stable land ownership, proximity to large emission sources, or because a suitable existing monitoring site was close by in a slightly less sensitive area. The sites selected are shown in Figure 16.

ALLOWANCES FOR OTHER CONSIDERATIONS

As the network developed and the preliminary working maps were shown to associates, the authors came under criticism for developing a positive network; a network whose sites were located in such a manner that the deposition recorded nationwide would understate the actual deposition. The problem

2510
PRAIRIE PARKLAND PROVINCE



IL11 - Bondville, IL
IL18 - Shabbona, IL
IL19 - Argonne, IL
IL47 - WSO-Salem, IL
IN34 - Indiana Dunes, IN
M5 - Champaign, IL
TX52 - McKinney Falls, TX
TX53 - WSO-Victoria, TX
U12 - Lancaster, KS
N15 - Attwater Prairie Chicken NWR, TX
N17 - USDA Black Creek HDQS, TX
N19 - NSSL-Norman, OK
N30 - McNay Res Ctr - Chariton, IA
N42 - Roseville, IL

Figure 13 - Possible Monitoring Sites in Province 2510 Considered for Inclusion in the NTN.

TABLE 4

Final Ecoregion Distribution of Sites Based on Equal Area (97 Sites)

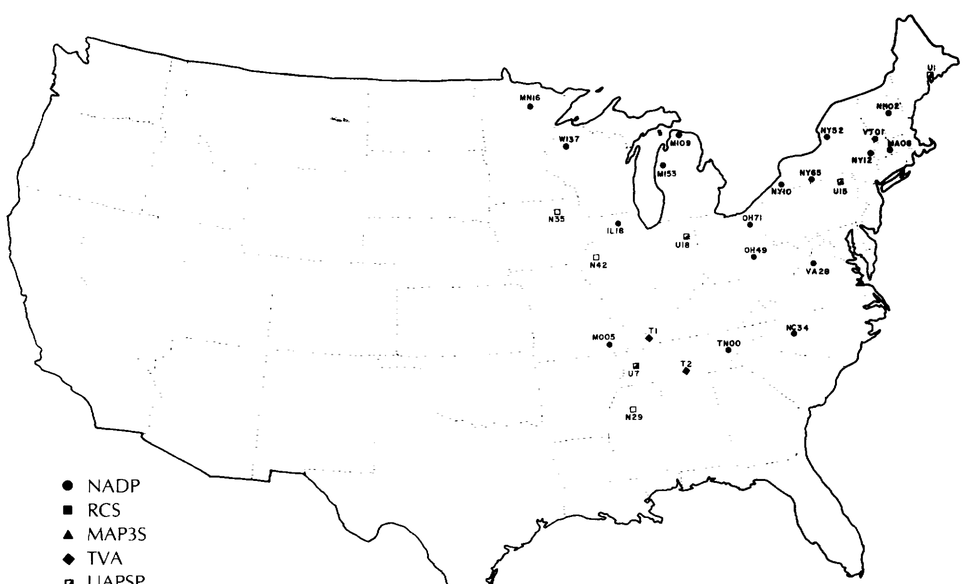
Humid Domain (2000)		Dry Domain (3000)		Tropical Domain (4000)	
Ecoregion	Required	Ecoregion	Required	Ecoregion	Required
2111	1	3111	3	4110	1
2112	1	3112	4		
2113	3	3113	4		
2114	2	M3111	1		
M2111	1	M31112	3		
M2112	1	M3113	2		
2211	1	3120	1		
2212	2	M3120	1		
2213	2	3131	3		
2214	4	3132	1		
2215	4	3133	2		
2311	4	3134	1		
2312	1	3135	0		
2320	9	P3131	1		
2410	1	P3132	2		
M2411	0	3140	1		
M2412	0	A3140	1		
M2413	1	3211	1		
M2414	0	3212	1		
M2415	1	3221	1		
2511	4	3222	2		
2512	3				
2521	1				
2522	1				
2523	1				
2531	4				
2532	2				
2533	2				
3610	1				
M2610	1				
M2620	1				
Total 2000	60	Total 3000	36	Total 4000	1

ECOSYSTEM EQUAL-AREA SITES

Note: See appendix C for site abbreviations code.

Figure 14 - Ninety-six Sites Proposed for Incorporation into NTN Based on the Equal Area Distribution.

DEPOSITION GRADIENT SITES



Note: See appendix C for site abbreviations code.

Figure 15 - Twenty-seven Sites Proposed for Incorporation into NTN Based on Semonin's Gradient Maps.

SENSITIVITY SITES

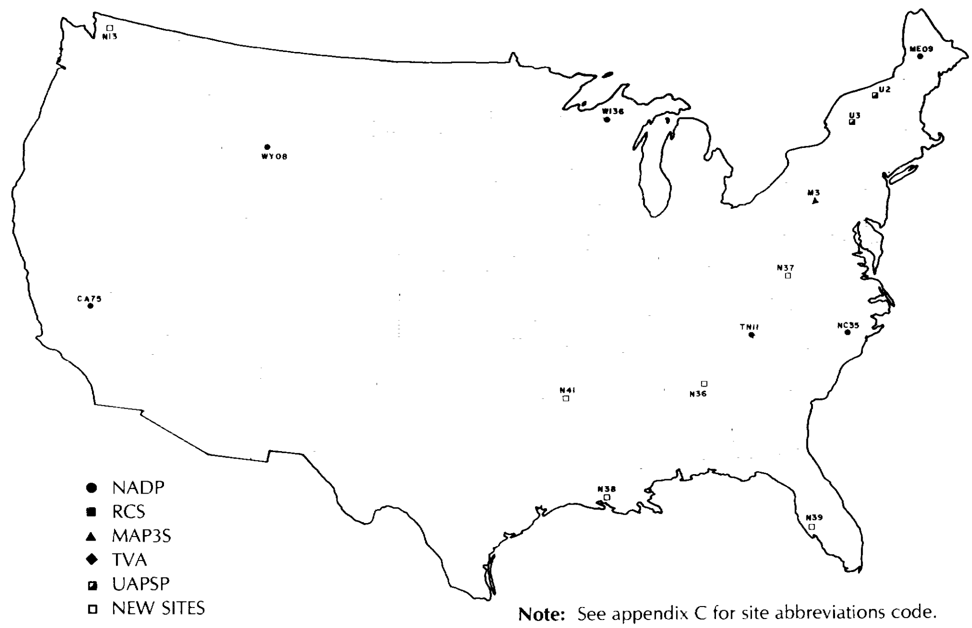


Figure 16 - Fifteen Sites Proposed for Incorporation into NTN Based on Sensitive Area Coverage.

SUPPLEMENTARY SITES

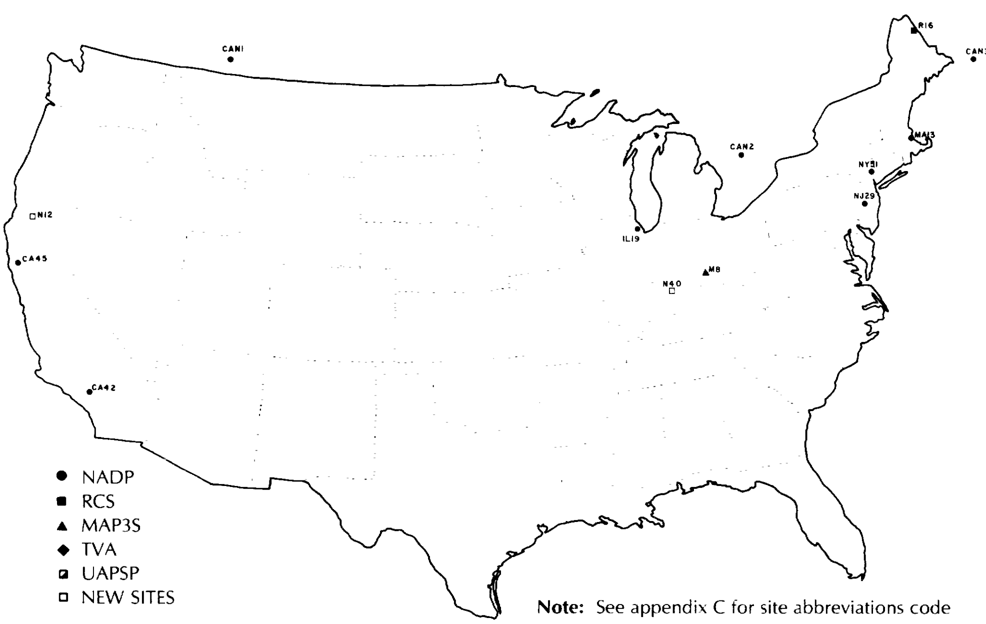


Figure 17 - Thirteen Sites Proposed for Incorporation into NTN Based on Other Considerations.

at hand was how to walk the fine line between a regionally representative site and one not overly affected by local influences. In response to the objections, five sites were added to the network even though they did not generally meet the NTN siting criteria because of their location near large urban complexes (Figure 17). These sites are located near Los Angeles, Philadelphia, and New York, and in the urban complexes of Chicago and Boston. These sites should show up as hot spots in the data.

Other sites were selected to continue the intercomparison of U.S. and Canadian data. NADP and CANSAP have had 6 colocated collectors operating (3 in the U.S. and 3 in Canada) for the past several years. To ensure continuation of this effort the three U.S. sites in Canada were selected for the NTN. The remaining five sites chosen were selected to fill gaps (areas with low site density) in the network.

THE PROPOSED NATIONAL TRENDS NETWORK

Figure 18 represents the complete design of 151 NTN sites recommended to the Task Group on Deposition Monitoring. It embodies the best of the model development and the advice and guidance of the Bear Mountain reviewers as it evolved over the course of the study (attachment A). There are four elements built into the design: (1) assurance that all areas of the country are represented in the network on the basis of regional ecological properties; (2) placement of additional sites east of the Rocky Mountains to better define high deposition gradients; (3) assurance that potentially sensitive regions are representated; and (4) allowance for other considerations, such as urban area effects, intercomparison with Canada, and apparent disparities in regional coverage.

On July 8, 1982, the task group met in Washington, D.C., to review the design and program plan. The plan was adopted, and follow-up site visitations were funded to confirm the suitability of the sites.

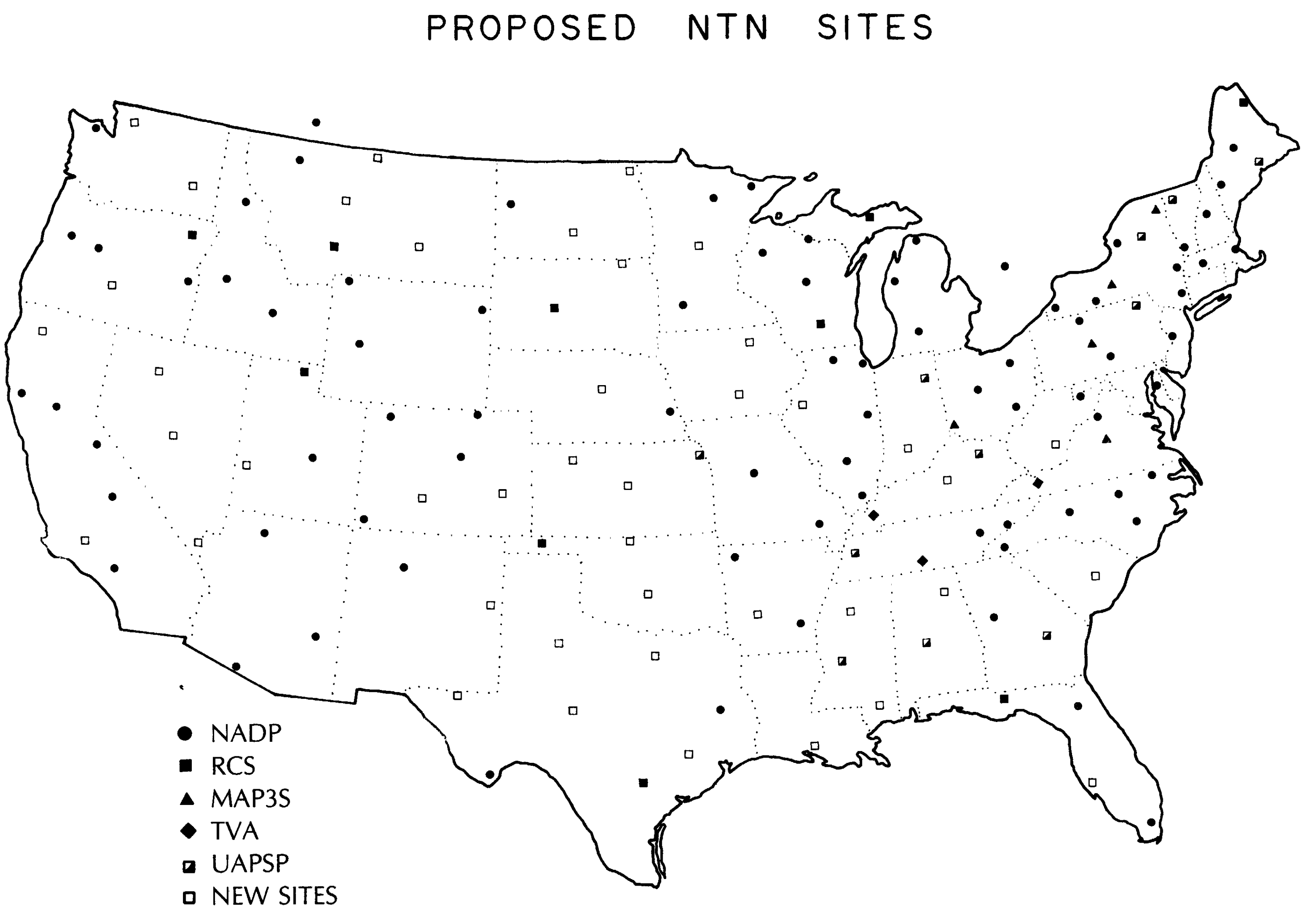


Figure 18 - Proposed National Trends Network Sites.

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APPENDIX A

GUIDELINES FOR DESIGN OF A NATIONAL TRENDS NETWORK (NTN)

Purpose

To determine the spatial and temporal variations in the quality of atmospheric deposition within the United States for a period measured in decades.

Objective

To establish a record that will allow the detection of temporal and spatial trends in the chemical composition of atmospheric deposition in an effort to provide information needed to gain a better understanding of the sources, movement, and transformation of materials contributing to or associated with acidic atmospheric deposition in the United States.

To determine the chemical composition of atmospheric deposition on a broad regional and national scale, validate transport models, estimate the exposure of large areas to acidic deposition, develop a sound technical basis for decisions on land and water management practices, and monitor the effectiveness of emission control strategies.

Approach

Long-term monitoring of the chemistry of atmospheric deposition will be conducted in a National Trends Network (NTN) consisting of 100-150 sites nationwide. Sites will be placed so as to collect precipitation samples whose chemical composition is representative of precipitation falling over a broad region. This requires that the sites be located outside the influence of local atmospheric emission sources.

The foundation for development of the NTN will be existing public agency networks such as the NADP, WMO/NOAA/EPA, TVA, DOE and MAP3S networks, and appropriate private-sector networks such as UAPSP and NCA.

Justification

Recent evidence indicates that acid-forming materials in atmospheric deposition have caused acidification of a number of lakes and streams in the United States and Canada. Other chemical constituents may also be causing problems of which we as yet are unaware. In order to maintain a continuing assessment of the chemical composition of atmospheric deposition, a national network of deposition monitoring sites operated on a consistent basis is needed.

In order to observe and understand geographic differences in the chemical composition of atmospheric deposition, it will be necessary to monitor such deposition in areas known, or anticipated, to be receiving acidic deposition as well as those areas expected to have alkaline deposition but which serve as sources for downwind deposition in acidic-deposition areas. Emphasis, however, will be on areas receiving acidic deposition.

It is envisioned that within any particular region there will exist a range in chemical compostion of atmospheric deposition depending upon the proximity and direction of local atmospheric emission sources. However, there will be areas within a region that are outside the noticeable influence of any one emission source and represent an average of atmospheric deposition derived from sources outside the region plus contributions, after dispersion and mixing, from sources within the region. Sites will be located in such areas and the data obtained should be suitable for the objectives of the network as stated above.

A site is considered representative of the region in which it is located when measurements taken at that site are within a prescribed variation, range, or limit of other measurements taken elsewhere in the region. The allowable variation or range may differ from region to region depending upon various factors such as soil sensitivity, proxmity to emission sources, and other factors.

Chemical and physical measurements will be made in the field and laboratory of those properties and chemical constituents of atmospheric deposition which pose the greatest real or potential threat to terrestrial and aquatic ecosystems. Each site should also operate equipment needed to obtain data to support efforts to understand the influence or meteorological conditions on the chemical composition of the atmospheric deposition samples.

Site Location Criteria

In the placement of sites, it is not possible to be quantitative with regard to distance downwind of major point or line emission sources, local topographic influences, proximity to structure and the like since local conditions may influence beneficially or adversely the regional representativeness of the atmospheric deposition samples collected. Good judgment in the design of the network must prevail. Future assessments of site suitability will be based on an analysis of data obtained. The following guidelines are offered.

(1) Sites are to be located in areas where the prevailing land use is unlikely to change for a period of decades. It is desirable that the surrounding land be Federally owned but State or other public ownership is acceptable.

(2) Grass cover or equivalent should surround the site for a distance equal to or greater than twice the height of the nearest object taller than the deposition sample collector.

(3) Sites should be located in rural areas sufficiently far away from urban centers, major industrial areas, and large fossil-fueled powerplants to prevent the chemical composition of the samples collected from being dominated by emissions from one source. In selecting the site, prevailing wind direction, storm tracks, and nearby emission sources should be considered. In the case of very large industrial areas, cities or powerplants, sites may have to be 50 kilometers or more downwind to avoid domination by emissions frone one source area.

(4) Sites should be located so as to minimize influence from local controlled burning. In most rural areas, a few kilometers distance should suffice. Forest and brush fires cannot be avoided but the site operator should be aware of their occurrence and note the fact on the sample documentation.

(5) Sites should be located to minimize influence from major line sources of emission such as heavily-traveled interstate highways, major airports, and railroad complexes. Sites may have to be as much as 15 km from such emission sources. Sites should be located near enough to secondary roads to provide convenient access but far enough to avoid influence from exhaust and dust from vehicles using those roads. In most cases in rural areas, 1 km distance should be adequate. Where possible, the access road to the site should be paved. If not, the site should be upwind of the access road and several hundred meters away from it to avoid dust.

(6) Influences from local topographic features such as rain shadows, valleys where fog and dew may accumulate, and oceans or salt-water bodies which may contribute significant salt spray should be avoided.

(7) Because they have research potential, areas with soils sensitive to acid deposition and areas where related studies are ongoing or planned should be given priority consideration as site locations. Preferred locations of opportunity are:

- Calibrated watersheds where material budgets are being studied.
- Basins where the streams and lakes are being monitored for effects of acid deposition.

- Areas with sensitive soils regardless of whether or not effects of acid deposition have been observed.
- Areas where related research on effects of acid deposition on soils, forests, aquatic systems, or materials is ongoing and expected to continue for decades.
- Areas where extensive meteorological, air-quality, or precipitation chemistry data are available.

(8) Logistics have moderate priority when cost of sampling gear, analyses, interpretation, and impact of possible regulatory action are considered; costs of getting power and personnel to sampling sites should not be of prime importance except where costs are unusually high.

Operational Criteria

The objective of the program can be accomplished only by long-term station operation. Each station should be operated for decades in a manner consistent with the operations at all stations in the program. Changes in operational criteria during the life of the program will be made as the technology advances but each change will be fully investigated and documented as to the bias it introduces in or removes from the data.
Deposition monitoring stations will be operated along the following guidelines:

(1) An appropriate wet/dry deposition collector will be used at each station. Modifications to the collector will be made as the technology advances to provide for improved sample integrity between collections.

(2) To provide supporting data, each station will have a suitably placed precipitation gage to provide a continuous record of rainfall. Whenever feasible, stations should include instruments to measure and record wind speed and direction, relative humidity, and temperature.

(3) The wet deposition sample will be collected or analyzed until a better understanding is gained through research of the processes involved in the deposition of the other-than-wet material and a logical basis for the interpretation of data on the chemical composition of dry deposition is established.

(4) The following measurements and analyses will be performed on the wet deposition sample:

Field Measurements: pH, specific conductance, and quantity of sample collected using appropriate portable instruments. When convenient and accurate instrumentation becomes available at reasonable cost, acidity by Gran's titration method and alkalinity by an incremental titration method will be added to the field protocol.

Laboratory Analyses: Samples will be sent to an approved laboratory for analysis. Samples will be filtered in the laboratory as necessary for proper performance of analytical instrumentation. The samples will be analyzed for the following:

pH	Chloride
Specific conductance	Sulfate
Calcium	Nitrite plus nitrate
Magnesium	Ammonium
Sodium	Orthophosphate
Potassium	

Analyses for selected trace metals and manmade organic compounds will be investigated and incorporated into the laboratory analysis protocol as appropriate.

(5) Because the field operations require great skill and attention to detail in order to obtain suitable field measurements and avoid sample contamination, scientifically trained personnel should be used whenever possible. Where an untrained observer must be employed, every effort should be made to provide adequate training and careful supervision.

Quality Assurance

A quality assurance program including training for site operators will be established for the NTN consistent with the procedure and limits recommended in the "Quality Assurance Handbook for Precipitation Chemistry Measurements Systems" USEPA, EMSL/RTP, 1981, and "Quality Assurance Practices for the Chemical and Biological Analyses of Water and Fluvial Sediments," USGS Open-File Report 81-650, 1981. The plan will encompass site and laboratory operations and anlayses, and data transfer, storage, and retrieval practices.

Data Base Management

1. Data should go by the most expeditious route to the Acid Deposition System (ADS) established by the Environmental Protection Agency at the Pacific Northwest National Laboratory.

2. The ADS data base should be upgraded to meet the needs of all agencies that supply data to it.

APPENDIX B

ECOREGION HIERARCHY

				Section Area Sq. Miles	Province Area Sq. Miles
2000	Humid Temperate Domain				
	2100	Warm Continental Division			
		2110	Laurentian Mixed Forest Province		
		2111	Spruce-Fir Forest Section	35,900	
		2112	Northern Hardwoods-Fir Forest Section	18,000	
		2113	Northern Hardwoods Forest Section	91,600	
		2114	Northern Hardwoods-Spruce Forest Section	59,200	
			Total 2110		204,700
		M2110	Columbia Forest Province		
		M2111	Douglas-Fir Forest Section	11,400	
		M2112	Cedar-Hemlock-Douglas-fir Forest Section	33,900	
			Total M2110		45,300
	2200	Hot Continental Division			
		2210	Eastern Deciduous Forest Province		
		2211	Mixed Mesophytic Forest Section	38,400	
		2212	Beech-Maple Forest Section	58,300	
		2213	Maple-Basswood Forest + Oak Savanna Section	44,300	
		2214	Appalachian Oak Forest Section	103,400	
		2215	Oak-Hickory Forest Section	123,400	
			Total 2210		367,800
	2300	Subtropical Division			
		2310	Outer Coastal Plain Forest Province		
		2311	Beech-Sweetgum-Magnolia-Pine-Oak Forest Section	107,500	
		2312	Southern Floodplain Forest Section	42,600	
			Total 2310		150,100
		2320	Southeastern Mixed Forest Province		257,900
	2400	Marine Division			
		2410	Willamette-Puget Forest Province		13,000
		M2410	Pacific Forest Province		
		M2411	Sitka Spruce-Cedar-Hemlock Forest Section	6,300	
		M2412	Redwood Forest Section	5,100	
		M2413	Cedar-Hemlock-Douglas-fir Forest Section	22,000	
		M2414	California Mixed Evergreen Forest Section	4,300	
		M2415	Silver-Fir-Douglas-fir Forest Section	25,300	
			Total M2410		63,000

		Section Area Sq. Miles	Province Area Sq. Miles
2000	Humid Temperate Domain Continued		
2500	Prairie Division		
2510	Prairie Parkland Province		
2511	Oak-Hickory-Bluestem Parkland Section	124,200	
2512	Oak + Bluestem Parkland Section	80,400	
	Total 2510		204,600
2520	Prairie Brushland Province		
2521	Mesquite-Buffalo Grass Section	32,200	
2522	Juniper-Oak-Mesquite Section	24,100	
2523	Mesquite-Acacia Section	27,300	
	Total 2520		83,600
2530	Tall-Grass Prairie Province		
2531	Bluestem Prairie Section	111,600	
2532	Wheatgrass-Bluestem-Needlegrass Section	49,400	
2533	Bluestem-Grama Prairie Section	62,000	
	Total 2530		223,000
2600	Mediterranean Division		
2610	California Grassland Province		20,200
M2610	Sierran Forest Province		32,600
M2620	California Chaparral Province		35,500
3000	Dry Domain		
3100	Steppe Division		
3110	Great Plains-Shortgrass Prairie Province		
3111	Grama-Needlegrass-Wheatgrass Section	83,800	
3112	Wheatgrass-Needlegrass Section	102,800	
3113	Grama-Buffalo Grass Section	131,000	
	Total 3110		317,600
M3110	Rocky Mountain Forest Province		
M3111	Grand Fir-Douglas-fir Forest Section	32,600	
M3112	Douglas-fir Forest Section	94,500	
M3113	Pondersoa Pine-Douglas-fir Section	60,200	
	Total M3110		187,300

				Section Area Sq. Miles	Province Area Sq. Miles
3000	Dry Domain Continued				
	3120	Palouse Grassland Province			12,400
	M3120	Upper Gila Mountains Forest Province			36,100
	3130	Intermountain Sagebrush Province			
		3131	Sagebrush-Wheatgrass Section	89,800	
		3132	Lahontan Saltbush-Greasewood Section	33,300	
		3133	Great Basin Sagebrush Section	46,900	
		3134	Bonneville Saltbush-Greasewood Section	22,200	
		3135	Ponderosa Shrub Forest Section	11,200	
			Total 3130		203,400
	P3130	Colorado Plateau Province			
		P3131	Juniper-Pinyon Woodland + Sagebrush Saltbush Mosaic Section	39,600	
		P3132	Grama-Galleta Steppe + Juniper-Pinyon Woodland Mosaic Section	55,100	
			Total P3130		94,700
	3140	Mexican Highland Shrub Steppe Province			17,500
	A3140	Wyoming Basin Province			
		A3141	Wheatgrass-Needlegrass-Sagebrush Section	13,100	
		A3142	Sagebrush-Wheatgrass Section	29,200	
			Total A3140		42,300
3200	Desert Division				
	3210	Chihuahuan Desert Province			
		3211	Grama-Tobosa Section	18,200	
		3212	Tarbush-Creosote Bush Section	45,900	
			Total 3210		77,500
	3220	American Desert Province			
		3221	Creosote Bush Section	36,700	
		3222	Creosote Bush-Bur Sage Section	40,800	
			Total 3220		64,100
4000	Humid Tropical Domain				
4100	Savanna Division				7,800
	4110	Everglades Province			

APPENDIX C

SITE CODES AND ABBREVIATIONS USED IN THE REPORT

Multistate Power Production Pollution Study (MAP3S) +

Code	Site	State	Latitude	Longitude	Ecoregion
M1	Whiteface	NY	44°24'	73°52'	2114
M2	Ithaca	NY	42°23'	76°43'	2113
M3	Penn State	PA	40°47'	77°57'	2214
M4	Virginia	VA	38°03'	78°33'	2320
M5	Illinois	IL	40°03'12"	88°22'19"	2511
M6	Brookhaven	NY	40°52'	72°53'	2214
M7	Lewes	DE	38°46'	75°00'	2320
M8	Oxford	OH	39°32'	84°44'	2212
M9	Oak Ridge	TN	35°57'41"	84°17'14"	2214

Reference Climatological Stations (RCS) + +

R1	Arlington	WI	43°18'	89°21'	2213
R2	Beeville	TX	28°27'	97°42'	2523
R3	Bozeman	MT	45°40'	111°09'	M3112
R4	Blue Hill	MA	42°13'	71°07'	2214
R5	Calhoun	LA	32°31'	92°20'	2320
R6	Chatham	MI	46°21'	86°56'	2112
R7	Cottonwood	SD	43°58'	101°52'	3112
R8	Crete	NE	40°37'	96°57'	2531
R9	Davis	CA	38°32'	121°46'	2610
R10	Geneva	NY	42°53'	77°02'	2113
R11	Goodwell	OK	36°36'	101°37'	3113
R12	Grand Canyon	AZ	36°03'	112°09'	M3120
R13	Jackson	TN	35°37'	88°50'	2215
R14	Logan	UT	41°40'	111°54'	M3112
R15	Norfolk	CT	41°58'	73°13'	2214
R16	Presque Isle	ME	46°39'	68°00'	2114
R17	Quincy	FL	30°36'	84°33'	2311
R18	NM State Univ	NM	32°17'	106°45'	3211
R19	Sterling	VA	38°59'	77°28'	2320
R20	Union	OR	45°13'	117°53'	M3111
R21	Wooster	OH	40°47'	81°55'	2212

Tennessee Valley Authority Trends Stations (TVA) + + +

T1	Land Between the Lakes	KY	36°47'27"	88°04'01"	2215
T2	Giles County	TN	35°17'05"	86°54'11"	2215
T3	Loves Mill	VA	36°44'12"	81°41'13"	2214

Utility Acid Precipitation Study Program (UAPSP)*

Code	Site	State	Latitude	Longitude	Ecoregion
U1	Winterport	ME	44°37'05"	68°58'30"	2114
U2	Underhill	VT	44°31'42"	72°52'08"	2114
U3	Big Moose	NY	43°49'03"	74°54'08"	2114
U4	McArthur	OH	39°14'06"	82°28'41"	2211
U5	Gaylord	MI	44°56'58"	84°38'30"	2113
U6	Clearfield	KY	38°08'10"	83°27'17"	2211
U7	Alamo	TN	35°47'06"	89°07'06"	2215
U8	Uvalda	GA	32°03'18"	82°28'25"	2311
U9	Selma	AL	32°28'25"	87°05'03"	2320
U10	Clinton	MS	32°21'06"	90°17'15"	2320
U11	Marshall	TX	32°39'58"	94°25'06"	2320
U12	Lancaster	KS	39°34'10"	95°18'17"	2511
U13	Brookings	SD	44°19'54"	96°49'45"	2531
U14	Turners Falls	MA	42°35'50"	72°32'55"	2114
U15	Tunkhannock	PA	41°34'30"	75°59'40"	2113
U16	Zanesville	OH	39°59'02"	82°01'05"	2214
U17	Rockport	IN	37°53'40"	87°07'15"	2215
U18	Fort Wanye	IN	41°02'08"	85°19'30"	2212
U19	Raleigh	NC	35°43'43"	78°40'48"	2320

National Atmospheric Deposition Program (NADP) * - (as of 30 May 1982)

Code	Site	State	Latitude	Longitude	Ecoregion
AK03	Mt McKinley	AK	63°43'27"	148°57'55"	-----
AR02	Warren	AR	33°36'15"	92°06'02"	2320
AR27	Fayetteville	AR	36°06'02"	94°10'24"	2215
AS01	Samoa-GMCC	AS	-14°15'08"	170°33'48"	-----
AZ03	Grand Canyon Natl Park	AZ	36°04'18"	112°09'11"	M3120
AZ06	Organ Pipe	AZ	31°57'02"	112°48'00"	3222
AZ99	Oliver Knoll	AZ	33°04'17"	109°51'53"	3140
CA34	WSO-Bishop	CA	37°22'15"	118°21'59"	3132
CA42	Tanbark Flat	CA	34°12'17"	117°45'39"	M2620
CA45	Hopland	CA	39°00'17"	123°05'05"	M2414
CA75	Sequoia Nat Pk	CA	36°34'09"	118°46'40"	M2610
CA88	Davis	CA	38°32'07"	121°46'30"	2610
CA99	Yosemite Na'l. Park	CA	37°47'49"	119°51'30"	M2610
CAN1	Lethbridge	CAN	49°38'13"	112°47'16"	3110
CAN2	Mt Forest	CAN	43°59'29"	80°44'46"	2110
CAN3	Kejimkujik	CAN	44°25'58"	65°12'20"	2110
CO00	WSO-Almosa	CO	37°26'36"	105°51'55"	M3113
CO15	Sand Spring	CO	40°30'27"	107°42'07"	A3142
CO19	Rocky Mountain Nat. Pk	CO	40°21'52"	105°33'37"	M3113
CO21	Manitou	CO	39°06'04"	105°05'31"	M3113
CO22	Pawnee	CO	40°48'23"	104°45'15"	3113
CO99	Mesa Verde Nat'l. Pk	CO	37°11'56"	108°29'26"	P3132

Code	Site	State	Latitude	Longitude	Ecoregion
FL03	Bradford	FL	29°58’29”	82°11’53”	2311
FL11	Everglades	FL	25°23’40”	80°41’45”	4110
GA41	Georgia Stn	GA	33°10’40”	84°24’22”	2320
HI00	Mauna Loa	HI	19°32’22”	155°34’45”	M4210
ID03	Craters of the Moon	ID	43°27’48”	113°33’31”	3131
IL11	Bondville	IL	40°03’12”	88°22’19”	2511
IL18	Shabbona	IL	41°50’29”	88°51’04”	2511
IL19	Argonne	IL	41°42’04”	87°59’43”	2511
IL35	SIU	IL	37°42’36”	89°16’08”	2215
IL47	WMO Salem	IL	38°38’36”	88°58’01”	2511
IL63	Dixon Springs	IL	37°26’08”	88°40’19”	2215
IN34	Indiana Dunes	IN	41°37’57”	87°05’16”	2511
MA01	Atlantic Coastal Laboratory	MA	41°58’23”	70°01’12”	2214
MA08	Cadwell Creek	MA	42°21’40”	72°23’27”	2114
MA13	East	MA	42°23’02”	71°12’53”	2214
ME00	WSO Caribou	ME	46°52’08”	68°00’55”	2214
ME02	Bridgton	ME	44°06’27”	70°43’44”	2114
ME09	Greenville Stn	ME	45°29’23”	69°39’52”	2114
ME99	Acadia Nat Park	ME	44°22’27”	68°15’39”	2214
MI09	UM Biological Stn	MI	45°33’40”	84°40’42”	2113
MI22	Houghton	MI	47°13’33”	88°37’50”	2112
MI25	Isle Royale Natl Park	MI	47°54’43”	89°09’10”	2111
MI26	Kellogg Bio Stn	MI	42°24’37”	85°23’34”	2212
MI53	Wellston	MI	44°13’28”	85°49’07”	2113
MN16	Marcell Exp Forest	MN	47°31’52”	93°28’07”	2111
MN18	Fernberg Stn	MN	47°56’45”	91°29’43”	2111
MN27	Lamberton	MN	44°14’14”	95°18’02”	2531
MO03	Ashland Wildlife Area	MO	38°45’13”	92°11’55”	2215
MO05	University Forest	MO	36°54’39”	90°19’06”	2215
MS14	WSO-Meridian	MS	32°20’04”	88°44’42”	2320
MT05	Glacier Fire Weather	MT	48°30’37”	113°59’44”	M2112
NC03	Lewiston	NC	36°07’40”	77°10’30”	2320
NC11	RTI	NC	35°54’09”	78°52’12”	2320
NC25	Coweeta	NC	35°03’38”	83°25’50”	2214
NC33	EPA-RTP	NC	35°53’47”	78°51’38”	2320
NC34	Piedmont Research Stn	NC	35°41’48”	80°37’22”	2320
NC35	Clinton Crops Rsch Stn	NC	35°01’26”	78°16’45”	2320
NC41	Finley Farm	NC	35°43’43”	78°40’52’	2320
ND07	Teddy Roosevelt	ND	47°36’09”	103°15’54”	3112
NE15	Mead	NE	41°09’11”	96°29’34”	2531

Code	Site	State	Latitude	Longitude	Ecoregion
NH02	Hubbard Brook	NH	43°56’35”	71°42’12”	2114
NJ99	Washington Crossing	NJ	40°18’54”	74°51’17”	2214
NM09	Cuba	NM	36°02’27”	106°58’17”	P3132
NY08	Aurora	NY	42°44’02”	76°39’35”	2113
NY10	Chautaugua	NY	42°17’58”	79°23’47”	2113
NY12	Knobit	NY	42°22’41”	73°30’10”	2113
NY20	Huntington	NY	43°58’19”	74°13’25”	2114
NY51	West Point	NY	41°21’00”	74°02’22”	2214
NY52	Bennett Bridge	NY	43°31’34”	75°56’50”	2113
NY65	Jasper	NY	42°06’22”	77°32’08”	2113
OH17	Delaware	OH	40°21’19”	83°03’58”	2212
OH49	Caldwell	OH	39°47’34”	81°31’52”	2211
OH71	Wooster	OH	40°46’48”	81°55’31”	2212
OR02	Alsea Guard Stn	OR	44°23’13”	123°37’22”	M2413
OR08	Lost Creek Dam	OR	42°40’04”	122°40’59”	M2415
OR10	Andrews Exp Forest	OR	44°13’23”	122°14’32”	M2415
OR11	Vines Hill	OR	43°53’57”	117°25’37”	3131
OR17	WSO-Pendleton	OR	45°41’23”	118°50’16”	3120
OR99	Schmidt Farm	OR	44°37’35”	123°12’50”	2410
PA29	Kane Exp Forest	PA	41°35’52”	78°46’04”	2113
PA42	Leading Ridge	PA	40°39’32”	77°56’10”	2214
SC18	Clemson	SC	34°40’28”	82°50’09”	2320
SD00	WSO-Huron	SD	44°23’02”	98°13’14”	2532
TN00	Walker Branch	TN	35°57’41”	84°17’14”	2214
TN11	Elkmont	TN	35°39’52”	83°35’25”	2214
TX04	K-Bar	TX	29°18’07”	103°10’38”	3212
TX38	Forest Seed Ctr	TX	31°33’38”	94°51’39”	2320
TX53	WSO-Victoria	TX	28°50’43”	96°55’12”	2512
UT02	Cedar Mountain	UT	39°10’15”	110°37’05”	P3131
VA13	Horton’s Stn	VA	37°20’06”	80°33’28”	2214
VA28	Shenandoah Ntl Park	VA	38°30’51”	78°25’45”	2214
VT01	Bennington	VT	42°52’34”	73°09’48”	2114
WA14	Olympic Natl Pk	WA	47°51’36”	123°55’57”	M2411
WI36	Trout Lake	WI	46°03’09”	89°39’11”	2112
WI37	Spooner	WI	45°49’21”	91°52’30”	2111
WV18	Parsons	WV	39°05’23”	79°39’44”	2214
WY06	Pinedale	WY	42°55’44”	109°47’12”	A3142
WY08	Tower-Yellowstone	WY	44°55’02”	110°25’13”	M3112
WY99	Newcastle	WY	43°52’24”	104°11’32”	3112

NADP Inactive Sites (as of 30 May 1982)

AZ01	Tombstone	AZ	31°42’30”	110°03’24”	3140
CA85	Channel Islands	CA	34°00’57”	119°21’43”	M2620
FL00	Austin Cary	FL	29°45’37”	82°11’56”	2311
NJ29	GFLD Princeton	NJ			2214

NADP Sites Planned But Not in operation (as of 30 May 1982)

Code	Site	State	Latitude	Longitude	Ecoregion
ID04	Headquarters	ID	46°37'40"	115°49'10"	M2112
ID15	Smith's Ferry	ID	44°17'56"	116°04'36"	M3111
MD13	Wye	MD	38°54'47"	76°09'09"	2320
NM07	Bandelier Natl Monument	NM	35°46'54"	106°16'03"	M3113
TX21	Longview	TX	32°22'53"	94°42'49"	2320
TX52	McKinney Falls	TX	30°10'44"	97°43'14"	2512
WI28	Lake Dubay	WI	44°39'53"	89°39'08"	2113

New Stations

Code	Site	State	Latitude	Longitude	Ecoregion
N01	Chuchupate Ranger Station	CA	34°48' 22"	119°00' 38"	M2620
N02	Havre Experiment Station	MT	48°29' 52"	109°47' 44"	3111
N03	Custer National Battlefield	MT	45°34' 02"	107°26' 21"	3111
N04	Alder Ranger Station	CO	37°43'	106°43'	M3113
N05	Dryland Experimental Station	WA	47°00'	118°35'	3120
N06	Silver Lake Ranger Station	OR	43°07' 22"	121°03' 28"	3131
N07	Winnemucca	NV	40°58'	117°44	3132
N08	Meadows Canyon Ranger Station	NV	38°43'	116°55'	3133
N09	Desert Range Experimental Farm	UT	38°35' 44"	113°45' 12"	3134
N10	Guadalupe Mountains Nat. Pk.	TX	31°54' 30"	104°48' 10"	3212
N11	Davis Dam	NV	35°13'	114°35'	3221
N12	Shasta National Forest-Castle Lake	CA	41°13' 51"	122°22' 32"	M2610
N13	Sauk Guard Station	WA	48°29'	121°38'	M2415
N14	Texas A&M Spur	TX	33°30'	100°50'	2521
N15	Attwater Prairie Chicken NWR	TX	29°41' 20"	96°16' 29"	2512
N16	San Angelo	TX	31°20'	100°30'	2521
N17	LBJ National Grassland	TX	33°23' 30"	97°38' 23"	2512
N18	NM State AG Farm Clovis	NM	34°36' 00"	103°12' 55"	3113
N19	Severe Storms Laboratory	OK	34°58' 48"	97°31' 16"	2512
N20	Oklahoma State Fish Hatchery	OK	36°45'	98°10'	2533
N21	Los Animas State Fish Hatchery	CO	38°07' 04"	103°18' 57"	3113
N22	Kanapolis State Park	KS	34°40'	98°00'	2531
N23	Fort Hartsuff State Hist. Park	NE	41°45'	99°00'	2532
N24	Icelandic State Park	ND	48°46' 57"	97°45' 15"	2531
N25	Camp Ripley	MN	46°14' 58"	94°29' 50"	2213
N26	Perryville Battlefield State Park	KY	37°40' 39"	84°57' 25"	2215
N27	Janice	MS	31°01' 51"	88°59' 09"	2311
N28	Santee State Park	SC	33°30'	80°30'	2320
N29	Coffeyville Pines	MS	34°00' 06"	89°47' 40"	2215
N30	McNay Memorial Research Ctr.	IA	40°57' 51"	93°23' 29"	2511
N31	Sand Lake NWR	SD	45°45'	98°15'	2532
N32	Colby Agricultural Station	KS	39°20'	101°03'	2533
N33	Mead Ranger Station	MT	47°10'	111°00'	3111
N34	Canfield Lake	ND	47°12' 24"	100°24' 06"	3112
N35	Nashua Agricultural Station	IA	42°54'	92°32'	2531
N36	Sand Mtn. Agricultural Center	AL	34°17' 30"	85°57' 32"	2211
N37	Babcock State Park	WV	37°58' 47"	80°56' 59"	2214
N38	Iberia Livestock Experimental Station	LA	29°55' 47"	91°42' 54"	2312
N39	Myakka River State Park	FL	27°15'	82°15'	2311
N40	Bedford Agricultural Station	IN	38°46'	86°30'	2212
N41	Caddo River	AR	34°10' 46"	93°05' 55"	2320
N42	Roseville	IL	40°50'	90°30'	2511

Legend

Locations were obtained from sources below.

+Source: MacCracken, 1979.
++Source: Richard S. Cram, National Climatic Center, Asheville, N.C.
+++Source: William Parkhurst, Tennessee Valley Authority.
*Source: Measured from maps marked by each site operator.