APPENDIX K

DESCRIPTION OF THE NATIONAL STREAM SURVEY (NSS)

To understand how the NSS data will serve as a regional framework for population estimation requires some background on the design and objectives of the NSS. In the spring of 1986, the U.S. Environmental Protection Agency (EPA) conducted the NSS on a probability sample of 446 streams in the mid-Atlantic and southeastern United States (Kaufmann et al. 1988, 1991; Sale et al. 1988). This full-scale field effort was preceded a year earlier by a pilot survey of 54 streams in the Southern Blue Ridge. The pilot survey demonstrated the feasibility of the design, logistics, and analytical protocols used in the full-scale survey (Messer et al. 1986, 1988). The objectives of the NSS were to:

- determine the percentage, extent (number and length), location, and chemical characteristics of streams in the Survey regions that are presently acidic, or that have low ANC and thus might become acidic in the future (Figure K-1 summarizes NSS results),

- identify streams representative of important classes in each region that might be selected for more intensive study or long-term monitoring.

The NSS is unique in that it employed a randomized systematic sampling design to make unbiased population estimates of the chemical status of an explicitly defined population of streams. These design properties are important if one wishes to make definitive statements about regional surface water quality.

Site Selection and Sample Weighting

Sampling units for the NSS were stream reaches defined as blue-line headwater segments or segments between confluences on 1:250,000-scale U.S. Geological Survey (USGS) topographic maps. The hierarchical nature of stream networks makes sampling and population extrapolation somewhat more difficult than for resources such as lakes, which comprise discrete, countable units. It is very important to note that the number and total length of mapped stream reaches is strongly dependent on map scale. The maps chosen establish the explicit identity of the population of stream reaches being described.

Within the NSS study area, the targeted resource was identified as those streams draining land areas less than 155 km^2, but large enough to be represented as blue lines on 1:250,000-scale USGS topographic maps. This size range includes streams large enough to be important for fish habitat, yet still small enough to represent the principal resource at risk from acidic deposition.

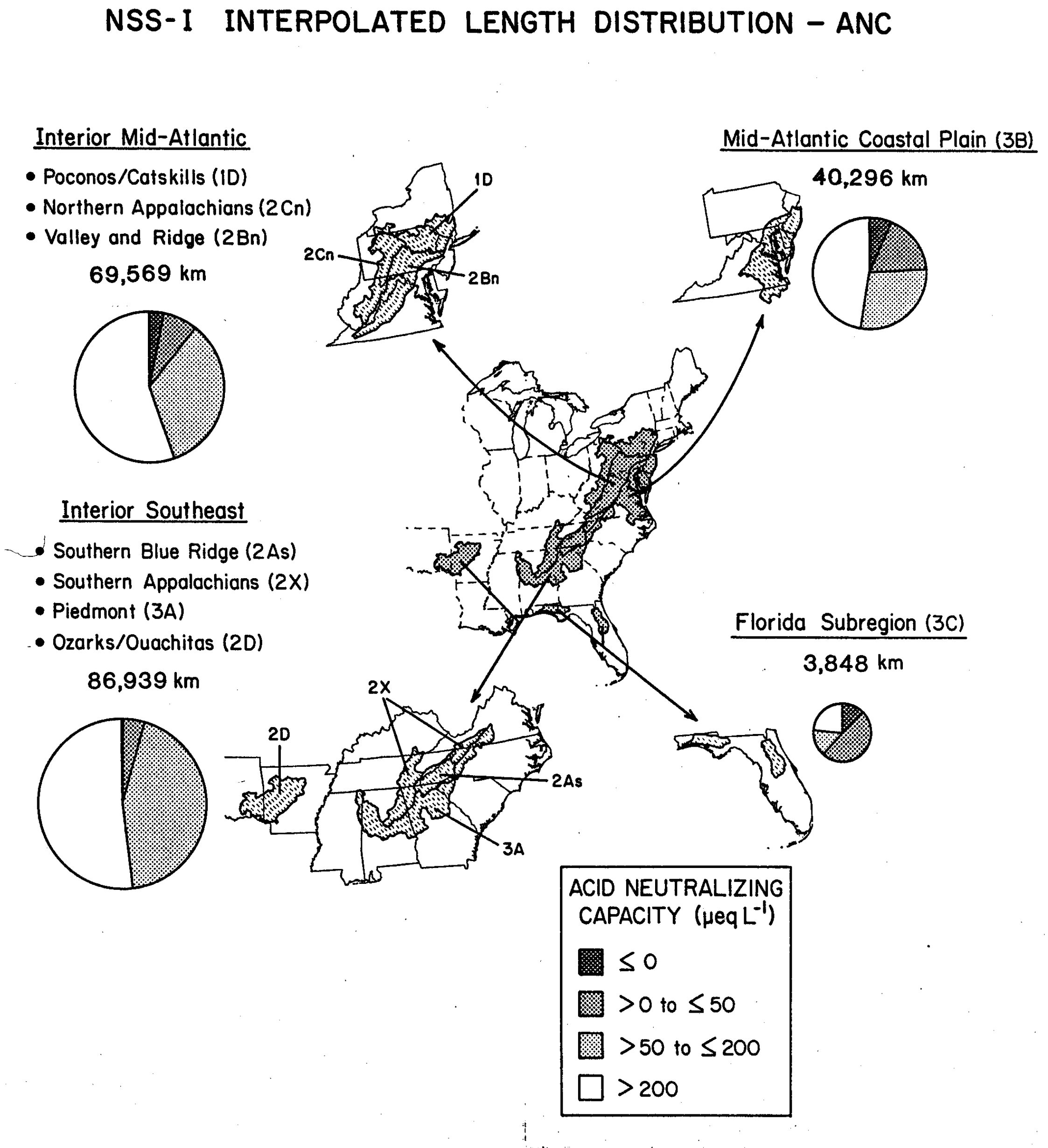

Figure K-1. Map showing the location of the 9 NSS subregions and pie diagrams showing the estimated stream length in 4 ANC classes.

Tidal reaches or reaches within mapped (1:250,000) urban areas were excluded from sampling because they were expected to be subject to influences that would largely mask the effects of acidic deposition.

A two-stage sampling procedure was used to obtain a randomized, systematic sample of 500 reaches with good spatial distribution (Figure K-2) over each of the nine NSS subregions (Overton 1987, Kaufmann et al. 1988). In the first stage of sampling, reaches were systematically selected by randomly placing an acetate grid (with dots in a square pattern at 8 mile intervals) on 1:250,000-scale USGS maps. Grid dots falling within the direct drainage area of a given reach identified that reach for sampling. Due to the impracticality of sampling all 2,301 stream reaches chosen in this manner in Stage I, a second stage subsample of 500 reaches was chosen for field sampling and chemical measurements. In Stage I, reach inclusion probabilities were directly proportional to the product of the sampling grid point density (number of dots per area) and the land area draining directly into each particular reach. The Stage II subsample (reaches to be visited) was chosen with site inclusion probabilities inversely related to their first stage inclusion probabilities. The final sample inclusion probabilities for reaches visited in the field (Stage II sample) were calculated as the product of inclusion probabilities in Stage I and Stage II. The two-stage procedure resulted in roughly equal final sample inclusion probabilities within geographic subregions, which were used as sampling strata (Overton 1987; Kaufmann et al. 1988).

To increase the precision of population estimation of high-interest streams at the low end of the ANC distribution, all Stage I sites located in mapped areas expected to have surface waters with ANC predominantly less than 50 µeq/L (Omernik and Powers 1983) were placed within a separate sampling stratum within each subregion stratum. All such sites were included for field sampling and thus they had Stage II inclusion probabilities of 1.0, yielding final inclusion probabilities equal to their Stage I inclusion probabilities. Thus, a map of sampled NSS streams shows a higher density of sample sites in areas of low stream ANC. These sites had higher probability of selection and thus lower sample weights used in the regional extrapolation.

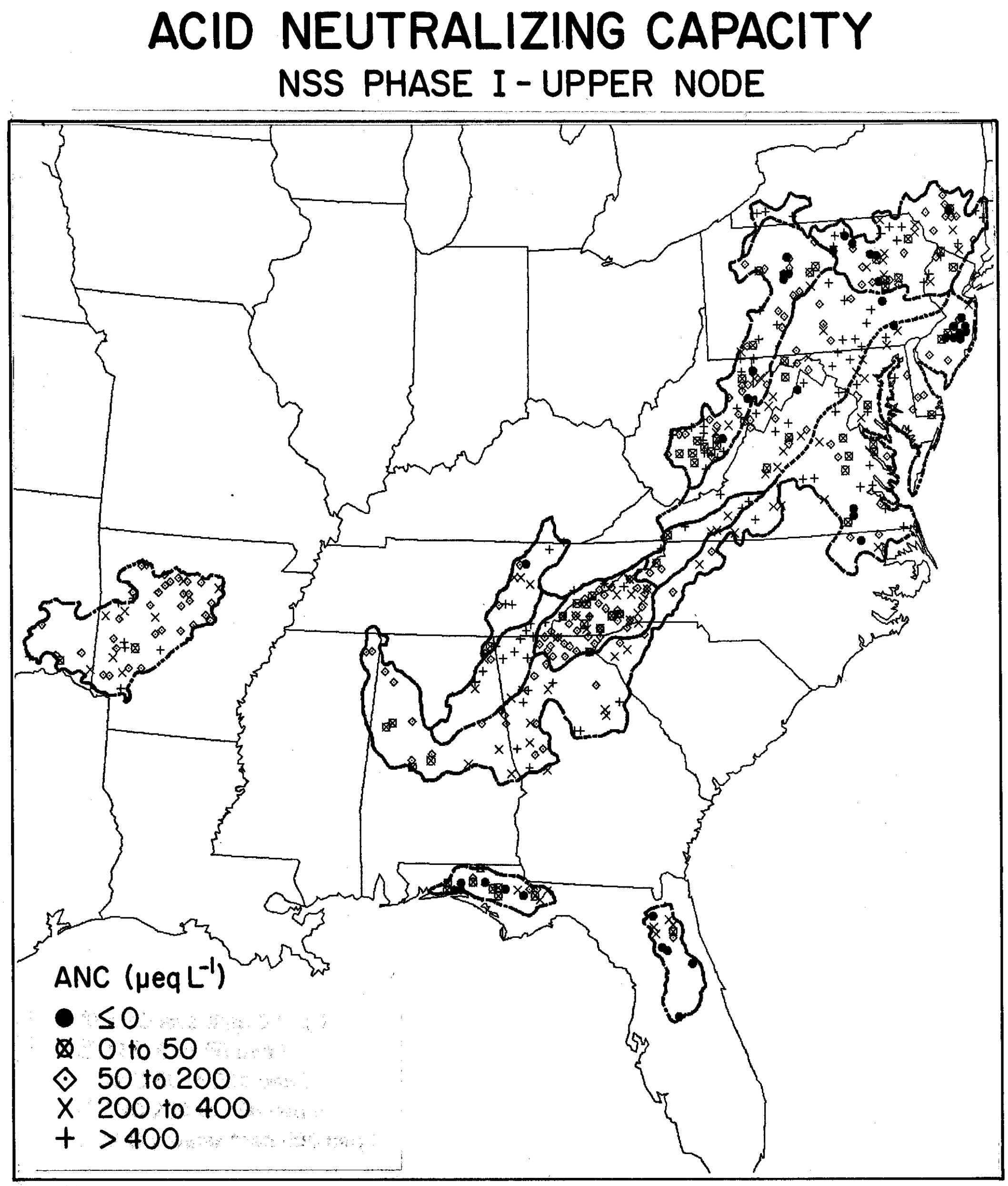

Figure K-2. Location and upstream reach end ANC class of NSS sample sites.

Field Sampling and Chemical Analyses

Stream reaches were visited and chemical measurements were made at each sample reach during spring baseflow between snowmelt and leafout (between March 15 and May 15). Reaches were sampled three times during 1985 spring baseflow in the Southern Blue Ridge subregion (Figure K-1). During spring baseflow of the following year (1986), measurements were made twice in the Mid-Atlantic (includes Virginia and West Virginia in SAMI), and once in the remaining Southeast subregions. Because the inclusion of storm-induced pH depressions would not accurately depict chronic conditions, hydrologic episodes were explicitly avoided during field sampling.

Chemical measurements were made at both ends of each stream reach in the Stage II sample. This meant that measurements were made at the downstream end of the reach just above the point of confluence with another stream identified as a blue line on 1:250,000-scale maps. Similarly, measurements at the upstream end of the sample reach were made far enough downstream of a blue-line confluence to allow adequate mixing. If the sample reach was identified as a headwater reach on the 1:250,000-scale maps, the upstream sampling location was the headward extent of blue-line representation for that particular reach.

All water samples were collected at mid-stream, stored at 4°C, and preserved at the central processing laboratory within 36 hours of collection (Cougan et al. 1988; Kaufmann et al. 1988). ANC was measured by Gran analysis of acid titration data, pH by potentiometric analysis of a closed headspace sample, SO_4^{2-}, NO_3^-, and Cl^- by ion chromatography, base cations by atomic absorption spectroscopy, and dissolved organic carbon (DOC) by infrared spectroscopy after acidification. Inorganic monomeric aluminum was calculated as the difference between total monomeric and organic (nonexchangeable) monomeric aluminum measured by pyrocatechol violet colorimetry on a closed headspace sample before and after passing it through a strong cation exchange column (Hillman et al. 1987). Standardized quality control and quality assurance protocols were followed during sample handling, chemical analysis, and data base manipulation (Cougan et al. 1988).

Chemical Index Values

Population estimates were based on separate chemical index values for the upstream and downstream ends of each sample stream reach. These index values were calculated as the arithmetic mean of the one to three spring chemical measurements made at each field sampling location. These index water chemistry values are sufficiently robust to represent each stream for the purposes of classification and regional extrapolations. Results of the NSS Pilot Survey in the Southern Blue Ridge showed very little difference in separate population distributions of pH, ANC, and major cations and anions based on three successive spring baseflow samples during the spring sampling window (Messer et al. 1986, 1988). Chemical variability was greater in streams of the Mid-Atlantic region, but differences between population distributions based on first and second sample visits were well within the 95% confidence bounds of estimates based on the spring baseflow average (Kaufmann et al. 1988).

The choice of spring as the sampling period for indexing stream chemistry involved a trade-off between minimizing within-season and episodic chemical variability and maximizing the probability of sampling chemical conditions potentially limiting for aquatic organisms. Studies of seasonal chemical variation in Mid-Atlantic and Southeastern streams indicate that spring is generally the season with the lowest streamwater ANC and pH (Kaufmann et al. 1988). In addition, spring is the time when acid-sensitive swim-up fry of important sport fish are present in the NSS-I study area, although fry of some trout (Salmo sp.) populations may also be present at other times of the year.

Population Extrapolation Procedures

All NSS population estimates (numbers, length, median chemistry) are based on weighted extrapolation from characteristics measured on individual sample reaches. Sample weights were calculated for each reach as the inverse of the reach's probability of being selected and are equivalent to the number of reaches each represents in the target population. Any regional statistics (mean, SD, percentiles) were all weighted. A population extrapolation procedure was used to estimate both the population totals and the fraction of those populations with chemical index values within criteria ranges. Details of estimation, and the statistical foundation of the methods, are provided elsewhere (Overton 1987; Kaufmann et al. 1988). The general form of the estimator is provided by:

$$\hat{T}_y = \sum_{S} w\, y \qquad (1)$$

where $\hat{T}_y$ is the estimate of the total of any attribute, y, over the population and w is the sample reach weight. The variable y is any stream reach attribute of interest (e.g., number, length, or direct drainage area) known over the set of sample stream reaches, S.

By assigning different definitions to y, and by summing over different sets of sample reaches, S, all of the various population attributes can be estimated from this one equation. For example, the number ($\hat{N}$) of upstream reach ends in Virginia with pH $\leq$ 5 is estimated by summing the sample weights (w) of all NSS upstream reach ends in Virginia with index pH $\leq$ 5 (for number estimates y equals one, for direct drainage area estimates, y=direct drainage area). Note that the upstream reach ends and the downstream reach ends are two separate populations and must be estimated separately as they are different attributes of the same reach.

The estimates of stream length with concentrations of a chemical constituent below reference values presented in this report are interpolated length estimates ($\hat{L}(x)$) calculated as follows:

$$\hat{L}(x) = \sum_{S} w\, L\, P_{ref} \qquad (2)$$

where L is the length of the stream segment on the map and w again is the sample weight. P_{ref} is the proportion of the length of each stream reach having concentrations below the reference value as estimated by linear interpolation between index chemistries measured at the upstream and downstream reach end sampling locations. If both reach ends have chemistry below the reference value, then P_{ref}=1. If both reach ends exceed the reference value then P_{ref}=0.

Variances in the population estimates, leading to estimated standard errors (SE) of the attributes (stream numbers or length), were obtained using an original application of the Horvitz-Thompson variance estimator (Overton 1987) shown in equation (3).

$$\mathrm{Var}(\hat{T}_y) = \sum_{S} y^2 w\,(w-1) + \sum_{i\in S}\ \sum_{\substack{j\in S\\ j\neq i}} y_i\, y_j\, v_{ij} \qquad (3)$$

where $v_{ij} = ((w_i + w_j)/2 - w_i w_j)/(n - 1)$, if i and j are from the same stratum; if i and j are from different strata, then $v_{ij} = 0$. The variable n is the effective sample size for that strata (see Mitch et al. 1990). For interpolated length estimates, the attribute "y" is equal to P_{ref}*L.

Refining the NSS Target Population

After field sampling, the set of sample reaches representing the NSS target population was further refined by excluding stream reach ends that were dry, had intermittent flow, or had no stream channel (e.g., swamp). In addition, streams that were grossly impacted by anthropogenic activities (in situ conductivity greater than 500 µS/cm), or affected by tidal influences (conductivity greater than 250 µS/cm in coastal areas) were also excluded. Finally, streams that were acidic due to acid mine drainage (Herlihy et al. 1990) were also excluded from the NSS target population. These deletions removed less than 10% of the sites in most subregions.

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