The reductions in emissions of sulfur dioxide in New York State, neighboring states, and Canada, should be followed closely by reductions in acidic deposition and by gradual improvements in the water quality of impacted areas. It is therefore important for DEC to continue monitoring deposition levels and also most importantly to monitor lakes and streams which have been adversely impacted by acidic deposition. LaZerte and Dillon (1984) documented improvements in the water quality of lakes in the Sudbury region when sulfur dioxide emissions were reduced. It is important to continue efforts to reduce emissions and resulting deposition in New York State until the waters damaged by acidic deposition are able to recover.

IV. ENVIRONMENTAL SETTING

A. Areas with Acidified Lakes Where Liming May be Appropriately Considered

1. *Locations, Geological and Land Use Characteristics of Areas Sensitive to Acid Deposition*

Three major geographic areas of New York State, the Adirondack region, the central Catskill region and the Hudson Highlands have been identified as sensitive to acidic deposition. In addition, two smaller areas, the Rensselaer Plateau and eastern Long Island, also appear potentially sensitive to acidification processes (NYSDEC 1985).

The Adirondack Mountain region of northeastern New York was described as having the highest number and percentage of "acidic lakes", (having an acid neutralizing value (ANC) of less than or equal to zero based on the results of the 1984 EPA Eastern Lake Survey Phase I of the National Surface Water Survey). Survey data collected by the Adirondack Lakes Survey Corporation (ALSC), on 1469 waters investigated during 1984-1987, confirmed these results and also documented at least 346 waters without fish populations and 352 acidic waters having a pH of 5.0 or less (Kretser et al. 1989).

Several unique physical attributes appear to contribute to the vulnerability of this area to atmospheric acidification. The bedrock geology of the Adirondack Mountain region is dominated by the southernmost extension of the Grenville Province of the Precambrian Canadian Shield. The soils are predominantly shallow, stony and infertile overlying glacial till. Most of the surface waters exhibit low acid neutralizing capacity and pH values less than 7.0. These conditions reflect the dominance of well weathered metamorphic and igneous rocks, represented by gabbro, syenite, anorthosite, gneiss and schist. Limited outcrops of calcite marble provide localized oases of fertility in this generally unproductive environment. The Adirondack Region is also unique in that the land mass exhibits specific historical, physical, chemical and biological characteristics which diverge widely from other physiographic regions of New York State. Along with obvious differences in bedrock geology accompanying infertile soils, low solar radiation and a relatively short frost-free period, the nutrient poor Adirondack waters exhibit low natural ion content. Values for calcium, magnesium and bicarbonate are particularly depressed and account for the soft waters which characterize the aquatic environments. Consequently, the poor buffering capacity of these waters makes them particularly sensitive to acidification. This vulnerability is compounded by heavy annual precipitation and downwind location from sources of air pollution.

By far the most dominant land use of the Adirondack Mountain region is logging, which reflects the abundance of forested lands, divided between state and private ownership. While logging is prohibited on state lands, in the Forest Preserve, much of the private land is in the ownership of paper and forestry companies, which actively engage in timber harvest. The Adirondack Park State Land Master Plan has categorized Forest Preserve lands into seven distinct classifications, in terms of regulating human use of the resource. Designated wilderness areas represent the most restrictive land use category and several of these areas including Five Ponds, Pepperbox and Pigeon Lake wilderness areas contain the largest concentrations of critically acidified lakes and ponds. The majority of these critically acidified waters are located in the Oswegatchie-Black watershed which appears as the most seriously impacted among the major watersheds included in the 1984-1987 ALSC study.

The 1984 Eastern Lake Survey Phase I of the National Surface Water Survey did not specifically address the Hudson Highlands as a single geographic area but included it in the EPA-described Pocono and Catskill sub-region. The results of this study indicated that this area contained relatively few low pH or acidic lakes. While the 1987 ALSC Hudson Highland survey data is still being summarized, preliminary indications confirm the EPA results. It should be noted the ALSC definition of the Hudson Highlands included some waters located in the Wallkill Valley, Hudson Valley, Southern Taconic Mountains and Southeastern Appalachian Highlands. This land area exhibits considerable diversity of bedrock, including granite, shale, sandstones and limestone along with an accompanying diversity of soil types. While there are large forested land areas there is more development and active agriculture when compared to the Adirondack and Catskill Mountain regions.

The 1984 EPA Eastern Lake Survey Phase 1 of the National Surface Water Survey did not address the Rensselaer Plateau as an independent geographic area but included it in the Northern New England sub-region. This area was described as having some medium to small size lakes of low alkalinity, particularly in the more rugged forested regions. The 1987 ALSC survey, involving 25 waters, identified a single critically acidified pond. Geologically speaking, the lithology of this area is unique in that the bedrock is dominated by Rensselaer Graywacke, noted for its resistance and durability, associated with interbedded lower Mettawee slates. The rolling landscape is forested at higher elevations while varied agricultural activity dominates the valleys.

2. General Characteristics of Waters in Acid Sensitive Areas of New York State

The pH of waters sampled by the ALSC in these sensitive geographic areas of New York represent summer surface laboratory air equilibrated meter determinations. The classification system splits waters into three broad categories on the basis of a mid-summer pH reading taken at the 1.5m depth. Waters having a pH value ≤5.0 are considered "critical"; waters exhibiting a value >5.0-<6.0 are considered "endangered"; while waters having a value ≥6.0 are considered "satisfactory".

Waters with ANC values below 40 ueq/l and greater than zero are considered sensitive to acidification while waters exhibiting a negative ANC are categorized as being acidified.

ALSC surveys were conducted on ponded waters located in the Adirondack Ecological Zone, Catskill Mountain area, Hudson Highlands and Rensselaer Plateau region. Three major Adirondack watersheds, the Lake Champlain, St. Lawrence-Raquette and Oswegatchie-Black, were sampled in the 1984 to 1986 time frame while the Upper Hudson and Mohawk Hudson watersheds and areas in lower New York were sampled in 1987. With one exclusion, all surveys were limited to waters under 202 hectares in surface area. As summarized in Table 6, it is evident that the Adirondack region represents the most sensitive geographic area of New York where fisheries resources appear to have been significantly impacted by acidification.

Approximately 16% of the Adirondack region ALSC survey waters (1984-87) were classified as bog or marginal bog waters based primarily on the abundance of Sphagnum along the shoreline. Many of these waters are naturally acidic and relatively unproductive. A certain number of waters are also unsuitable for fish life because of low oxygen levels, particularly during late winter. The ALSC data for the lower New York regions indicated only seven critically acidified waters.

3. Loss of Fisheries Resource Due to Acidic Conditions

Although historical fisheries or chemistry data are lacking for many Adirondack waters, it is clear that many important fisheries have been lost as a result of acidification. Schofield (1977) surveyed the fish populations in 40 Adirondack high elevation lakes and compared the results with data from surveys conducted in the 1930's. Whereas only four lakes were fishless in the 1930's, a total of 21 were fishless in 1975. Similarly only three waters had a pH level less than 5.0 in the 1930's, but in 1975 19 of the 40 waters studied had a pH <5.0.

Pfeiffer and Festa (1980) presented case histories of a number of selected Adirondack waters which have experienced acidification and a loss of important fisheries. These waters which historically supported excellent fishing include: Flowed Lands, Lake Colden, South Lake, Metcalf Lake, Silver Lake, Spruce Lake, Big Moose Lake, Canada Lake, Twitchell Lake, Honnedaga Lake, Brook Trout Lake, Horn Lake, and

TABLE 6. Summary of Waters Surveyed by Adirondack Lakes Survey Corporation 1984-1987

PARAMETER	ADIRONDACK ECOLOGICAL ZONE (1984-1987) # PONDS	HECTARES	LOWER CATSKILL AREA 1987 # PONDS	HECTARES	HUDSON HIGHLANDS 1987 # PONDS	HECTARES	RENSSELAER PLATEAU 1987 # PONDS	HECTARES
SAMPLE SIZE	1469	23869.6	28	219.1	201	3674.5	25	309.5
AIR EQ pH								
≤5.0	352	1995.7	2	41.4	4	29.7	1	29.7
>5.0 AND < 6.0	273	5908.4	0	0.0	9	112.7	5	84.6
≥6.0	847	18163.2	26	177.7	188	3532.1	19	222.5
≤5.5	504	3706.4	2	41.4	8	103.3	1	2.4
ANC (ueq/l)								
<40	697	7064.6	2	41.4	19	227.7	8	110.2
<200	1202	18478.4	8	112.4	53	1200.5	23	244.5
PONDS WITH FISH	1123	22226.8	26	177.7	200	3673.5	25	309.5
%	76.4%	93.1%	92.9%	81.1%	99.5%	100.0%	100.0%	100.0%
PONDS WITHOUT FISH	346	1641.8	2	41.4	1	1.0	0	0.0
%	23.6%	6.9%	7.1%	18.9%	0.5%	0.03%	0.0%	0.0%

Cranberry Lake. Many other waters could be added to this list, but historical records of the water chemistry and fishery are lacking.

Based on the survey data collected by the ALSC during the 1984-1987 study period, fish were not captured in 346 waters representing 1641 hectares of surface area. If these survey data are extrapolated to the entire Adirondack region we would estimate approximately 650 waters without fish. Recent survey results indicate that a number of the waters without fish are natural bog waters or physically can not harbor fish as a result of oxygen and/or temperature problems during critical periods of the year. Results of the ALSC surveys are currently being analyzed and should provide a more accurate estimate of waters that have acidified and can no longer support fish populations.

Numerous sensitive waters, such as Big Moose Lake and South Lake, undoubtedly have lost important fisheries due to acidification, but still do possess some fish life. These waters, although not fishless, have been severely affected and these effects should be considered with those of the fishless waters when discussing fisheries resources lost due to acidification. Stream fish populations have probably been severely affected. Toxic conditions and streams devoid of fish life have been documented (Schofield and Driscoll 1987; Johnson et al. 1987).

4. Fish Resource Management in the Adirondack Zone

Fisheries management goals, objectives and major activities are discussed in detail in a report by Pfeiffer (1979), "A Comprehensive Plan for Fish Resource Management Within the Adirondack Zone." Overall objectives for the fisheries program in the Adirondacks include the following:

1. Perpetuate all existing species of fish and attempt to restore extirpated native species of fish.

2. Produce diverse and satisfactory fishing opportunities.

The various sub-program areas discussed by Pfeiffer (1979) are lake trout, landlocked salmon, brook trout ponds, coldwater ponds and lakes, two-story ponds and lakes, coldwater streams, warmwater streams, unknown ponds, and endangered species.

The DEC liming program primarily contributes to the management objectives of the brook trout ponds sub-program. The potential exists however for restoration or protection of other waters which are part of the lake trout or endangered species sub-programs. In Adirondack wilderness, primitive and canoe areas specific guidelines for fisheries management will be followed.

B. Significance of Water Resources

1. Waters Classified as Acidic or Sensitive to Acidification

The water resources of concern in regards to acidic deposition in New York State represent a sizeable number of important waters. As was discussed above and presented in Table 6, 352(23.9%) of the 1469 Adirondack waters surveyed from 1984 to 1987 were classified acidic (pH≤ 5.0). An additional 269 (18.3%) had pH levels between 5 and 6 and according to Colquhoun et al. (1984) would be classified as endangered. If these percentages are applied to the entire Adirondack ecological zone a total of 659 ponded waters out of 2759 would be classified acidic and an additional 505 would be expected to have a pH between 5 and 6 and would be termed endangered. Acidic waters were found by the Adirondack Lakes Survey Corporation to be most common at higher elevations and were smaller in size than the other lakes surveyed.

If acid neutralizing capacity (ANC) is used to classify waters instead of pH the result is also a significant number of ponds and lakes. Waters with ANC values less than 0 μeq/l are termed acidified, from 0 to 40 μeq/l are extremely sensitive, and from 41 to 200 μeq/l are termed moderately sensitive (Colquhoun et al. 1984). If the Adirondack Lake Survey Corporation data in Table 6 are again applied to the entire Adirondack ecological zone, a total of 1322 out of 2759 would be classified as either acidified or extremely sensitive and an additional 957 would be termed moderately sensitive.

It should be noted that a certain percentage of the waters surveyed are naturally acidic bog waters. Of the 1469 Adirondack waters surveyed from 1984 to 1987 a total of 140 (9.5%) were identified by the Adirondack Lakes Survey Corporation as bog or marginal bog waters. The pH of these waters ranged from 3.9 to 8.0 with a median value of 5.17. If we assume approximately 65% of these bogs had a pH less than 6.0 and apply these percentages to the Adirondack ecological zone, we would estimate that there are about 170 acidic bog ponds out of 2759 lakes and ponds in the Adirondacks. The effects of acidic deposition on naturally acidic bog communities is unknown in many cases and needs additional research (Gorham et al. 1984), but further loss of ANC and resultant increase in acidification is possible.

It is also important to note that the presence of _Sphagnum_ and other acidophilic vegetation does not always identify a water as a naturally acidic bog. _Sphagnum_ and other bog vegetation may become established in an area as acidification occurs as a result of acidic deposition. Identifying a naturally acidic bog community is therefore difficult and may require an intensive study of the hydrology, chemistry, and biology of the area.

Lakes and ponds which support viable wilderness brook trout populations are of great value in the Adirondacks, Catskills, and other areas. Very few wilderness areas remain in the eastern United States, and New York State has had the foresight to establish forest preserve lands designated as wilderness. However, it is these important wilderness brook trout waters which are among the most impacted by acidic deposition. Roadside lakes and ponds and waters ringed with cottages are less affected because of other activities in their watersheds and because they are generally at lower elevations with low gradient and thicker soils. Many wilderness ponds which once had significant brook trout fisheries can no longer support viable fish populations.

Streams and rivers also represent an important resource in New York State and have also been adversely impacted by acidic deposition. Acidic streams have been found in the Adirondacks, Catskills, Hudson Highlands, Rensselaer Plateau, and eastern Long Island (Colquhoun et al. 1981, 1982, 1984; Armstrong et al. 1983; unpublished NYSDEC data). Spring snowmelt and large precipitation events frequently result in episodes of acidic stream water which are toxic to aquatic life.

The ALSC lake survey data for the Catskill Mountains, Hudson Highlands, and Rensselaer Plateau are presented in Table 6. *Twenty-one waters of 254 surveyed in 1987 had pH* value *less than* 6.0 and 21 waters had ANC values less than 40 ueq/l. Becker and Boyle (1986) found that 13 Hudson Highlands lakes out of the 43 they surveyed had a pH level less than 6.0 and that 12 had ANC values less than 40 μeq/l, classifying them as either acidic or extremely sensitive.

2. Waters with Potential for Restoration by Liming

Not all waters that are acidic or have been impacted by acidic deposition are suitable for restoration by liming. Naturally acidic waters, for example, are part of unique ecosystems which include rare and uncommon plants and animals which have adapted to the acidic environment and provide functions and benefits unique to these types of systems. In order to preserve and protect these valuable bog communities, they should not be neutralized by liming.

Of the waters which have become acidic most likely because of acidic deposition, not all are suitable for restoration by liming. These waters include both seepage and drainage type systems and have a full range of hydraulic flushing rates. Schofield et al. (1986) found that flushing rate was one of the best criteria to evaluate how long a pond would maintain satisfactory water quality following liming. In ponds with high flushing rates the neutralized water passes out the outlet, is replaced by acidic precipitation or acidic tributaries, and the pond reacidifies, often within a year. Although it is technologically possible to lime systems with high flushing rates it is not practical or cost effective. Based on past experience (Kretser and Colquhoun 1984) and current research (Schofield et al. 1986) a flushing rate of 2.0 times per year or less has been used to select ponds with a potential for restoration by liming. Ponds with flushing rates greater than 2.0 although impacted by acidic deposition and important in terms of damaged aquatic ecosystems, are not necessarily good candidates for a liming program. The flushing rate criterion is the most limiting of criteria in terms of selecting waters with potential for restoration. Only 24% of the acidic waters in the Adirondacks have flushing rates of 2.0 or less. This also emphasizes the fact that liming can not adequately and practically mitigate all effects of acidic deposition.

Figure 9 is based on data from the Adirondack Lakes Survey (Kretser et al. 1989) and illustrates the relatively small percentage of Adirondack waters which are suitable for liming. Sixty two percent of the waters have a pH ≥ 5.7, leaving 38% which are acidic (based on the pH 5.7 threshold). Of these acidic waters most have a flushing rate greater than 2.0 times per year and are therefore unsuitable for liming. Of the acidic waters which also have low flushing rates over half are either private, bogs, or have unsuitable temperatures or oxygen levels, or have no record of the presence of previous fisheries. Based on the ALSC data (Kretser et al. 1989) approximately 4% of the waters they surveyed would meet the new policy criteria as possible candidates for liming. In addition approximately 100 waters which are privately owned would meet the liming criteria, and a certain number may enter the state liming program if the water is open to public fishing. These crude estimates may change as acidification continues and as additional research and survey data become available. A few waters in other sensitive areas of the state are also expected to meet the criteria in the new policy. Available resources and logistical limitations will limit the program. Any additions to the program over current levels will be consistent with the State Land Master Plans as implemented by the unit management planning process and will comply with the eligibility criteria for liming.

The neutralization of streams, although desirable in many cases, is technologically difficult and has not been successfully demonstrated in New York State. Ice jams and high water during spring snowmelt create stream conditions difficult to monitor and treat during this time period when water quality may be very acidic. In addition to technological problems many acidic streams are remote, with no road access to allow delivery of large quantities of lime. The liming of streams is regarded as an area where additional research is needed. Certain selected sites may be suitable for research in this field and may at some point in the future demonstrate a real potential for restoration of these waters. However, a program to completely mitigate all affected streams would be enormous and prohibitively costly in terms of money and impact.

C. Environmental Setting with Proposed Liming

The objective of the proposed liming program is to restore and/or protect certain selected waters so that they can support viable fish populations and preserve heritage strains or species of fish native to the state. Certain waters impacted by acidic deposition have been or will be restored to provide recreational fisheries. Other waters which contain unique heritage strains of fish or threatened or endangered species may require protective liming in order to prevent these waters from acidifying. The intention of both restorative and protective liming is to improve the water quality of degraded ecosystems in an effort to restore viable aquatic communities.

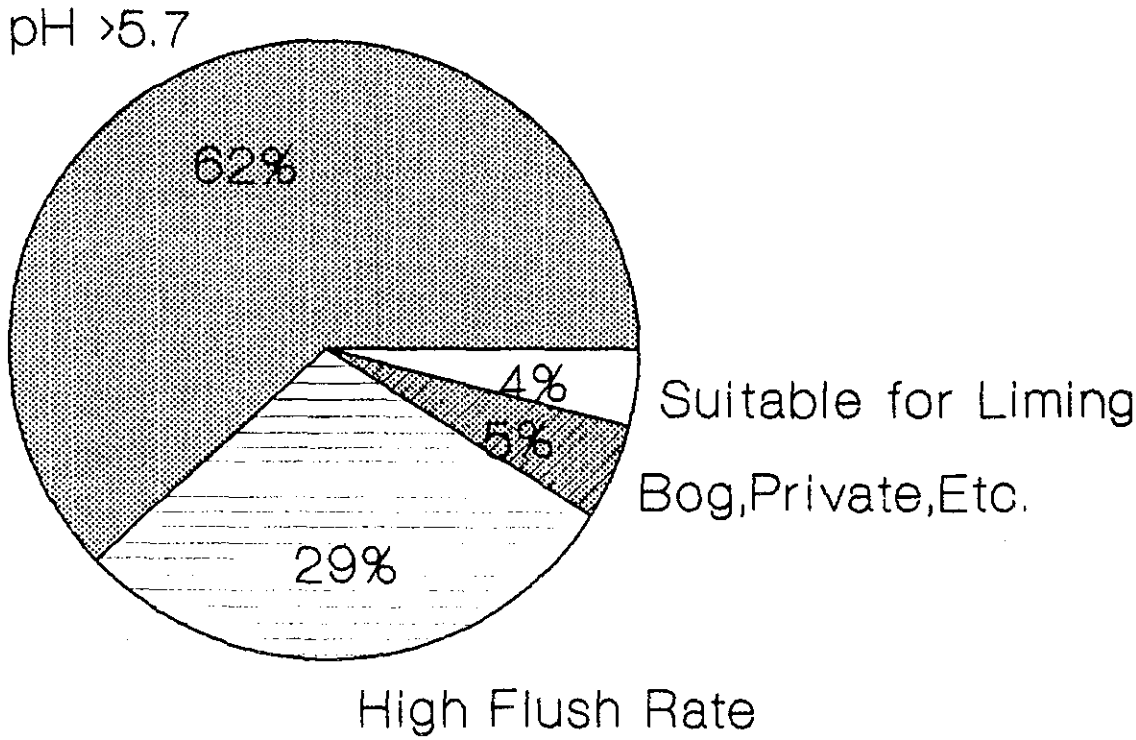

Figure 9. Percentage of Adirondack waters suitable for liming by the DEC according to the proposed liming criteria (data from Adirondack Lakes Survey Corp. 1989; total of 1483 waters surveyed). Data were sorted first by pH, second by flushing rate, and third by bog, private, etc.