The Revised Division of Fish and Wildlife Liming Policy (Section I.) severely limits the number of acidic waters which will be treated. It is not therefore expected that the environmental setting will change substantially from the current situation. The great majority of the lakes and streams acidified by acidic deposition will remain so in spite of the proposed liming program. The limited number which are part of the liming program will be improved from culturally acidified waters unable to support fish or other aquatic life to restored waters capable of supporting a healthy aquatic community and/or quality recreational fishing experiences.

The impact of the proposed liming on the environmental setting surrounding the lake or pond is expected to be minimal. Lime is applied in an unobtrusive manner directly to the water or on the ice in winter, and the impacts or alterations to the shoreline communities will be minimal. The terrestrial vegetation and appearance of the area will be unchanged with the exception of a potential change in lake clarity.

V. SIGNIFICANT ENVIRONMENTAL IMPACTS

A. Adverse Impacts

1. Ecosystem Impacts Resulting from Liming

a. Adjacent Wetlands

The possible impacts of liming on wetlands are directly related to the location of the wetlands in regards to water flow paths. Wetlands located on tributaries and upstream from a limed pond would not be expected to be impacted, whereas wetlands on the outlet and downstream from the pond may be impacted. Depending on the amount of water in the wetland certain plant species would be affected differently. Few studies could be found which documented adverse impacts on the wetlands adjacent to a limed pond. Submerged aquatic macrophyte species would be expected to be more greatly impacted than emergent and terrestrial species. The Adirondack Park Agency uses the term "deepwater wetland" to refer to an area where submerged aquatic macrophytes occur.

Fraser et al. (1985) reviewed some of the Scandinavian literature including the effects of liming on macrophytes. They reported that *Sphagnum* mosses frequently become a dominant plant species in acidic environments. Section III.C.3 of this FEIS also discusses how macrophyte communities may be replaced by *Sphagnum* as a pond or lake acidifies. When base materials are applied the *Sphagnum* mats may be severely damaged or eradicated. This decrease in *Sphagnum* abundance probably benefits other plant species such as *Lobelia*, *Littorella*, and *Isoetes.* This decrease in *Sphagnum* also may not constitute a loss of wetlands, but more accurately a restoration of wetlands plant species which prefer the more basic environment. The diversity of the wetland vegetation may also increase as a result of the reduction in *Sphagnum* abundance.

The extension of the Lake Acidification Mitigation Project (discussed in Sec. II. C.6.b.) will involve experimental watershed liming of several drainages in the Woods Lake watershed. The data from this project will provide a better understanding of how liming affects adjacent wetlands and terrestrial plant species. In an acidic environment liming would create a habitat less toxic to acid sensitive plants; these plants could then become established; and the acid tolerant species may decrease in abundance.

b. Endangered or Threatened Species

It is not expected that liming will have any adverse impacts on the threatened or endangered animals found in New York State. The areas where most are found are either not acidic, or else any liming impact would most likely be beneficial. The endangered round whitefish may be declining in abundance because of acidification, and liming may represent a viable strategy to protect certain populations (Pfeiffer 1979). The bog turtle has not been reported in the Adirondacks for many years, and is found in areas where soil calcium levels are high and where the environment is well buffered. An acidic, poorly buffered water suitable for liming would not be good bog turtle habitat.

There are however, certain plants which are found only in acidic environments and which may be adversely affected by liming. These plants may also be found in acidic waters with high flushing rates, which will not be limed. It should be remembered that liming projects will occur only on waters culturally acidified with an objective to restore the aquatic ecosystem to its pre-acidified state. A Listing of Endangered, Threatened and Rare Plants in New York State was adopted by the DEC in June 1989 and is periodically updated by the NY Natural Heritage Program. Consultation with this group is one of the guidelines in the revised liming policy.

c. Fish

The impacts of liming on fish populations depend to a large extent on the liming material used. The proposed action is to use agricultural limestone which does not result in rapid pH changes and would not be expected to cause fish mortalities. In addition, many of the liming projects would be done on the ice during the winter months: and the lime would therefore gradually enter the lake as the ice melts. Waters which have become acidic and are being limed for the first time would not be stocked until after the water chemistry had stabilized. The objective of most liming projects is to restore or protect healthy and viable fish populations and the vast majority of projects do create water quality conditions where healthy fish populations can survive. The following discussion reviews several reported cases where fish mortalities were observed. In all cases these situations resulted from the use of liming materials or methods which are not part of the proposed DEC liming program.

Zurbach (1984) reported that in Summit Lake, West Virginia, fish mortality was observed following annual treatments with agricultural limestone and hydrated lime. On several occasions fish kills occurred involving rainbow trout, smallmouth bass and green sunfish. Although investigations were conducted no definitive cause of mortality could be identified. It appears possible that the hydrated lime may have been the problem, since this material dissolves quickly and can cause rapid and potentially toxic changes in pH. When Bone Pond in the Adirondacks was treated with soda ash the pH rose over 9.0, and fish mortalities were observed (Colquhoun, personal communication).

Swedish reports cited by Fraser and Britt (1982) documented that fish mortalities were also observed in limed waters when these waters were stocked immediately after liming. Immediately following the liming of acidic waters there is a transition period when water chemistry fluctuations may be toxic to fish. Driscoll et al. (1987) observed a transition period of several weeks during which the water chemistry gradually stabilized and trace metal concentrations declined.

Also in Sweden, Dixon (1983) reported that rainbow trout died after being stocked in recently limed Lake Ravekarrs Langevatten and that the mortality was due to toxic aluminum concentrations. Slow aluminum hydrolysis and precipitation processes in the cold water were blamed for the toxicity. Again these mortalities appear to have occurred during the transition period of unstable fluctuating water chemistry immediately following liming.

In flowing water situations the potential for changing water chemistry is even greater due to changes in flow. Hasselrot and Hultberg (1984) cited several Swedish reports where periods of high flow resulted in temporary drops in pH and increased aluminum concentrations. Although the river was limed, the high flow conditions resulted in toxic water quality and mortality in presmolts of Atlantic salmon. Similarly, several fish kills were reported in Swedish fish hatcheries despite liming of the inflow water. In these cases unprecipitated aluminum was also believed to be the reason for the toxicity.

The response of a pre-existing fish community to liming may be complex and has resulted in several cases of negative impacts (Hasselrot and Hultberg 1984). In a limed Swedish lake the roach population rapidly increased at the expense of the more desirable cisco. Similarly in a limed stream the sculpin population greatly increased and had adverse impacts on the populations of seatrout and Atlantic salmon (Hasselrot and Hultberg 1984).

d. *Amphibians*

Amphibians which are present in a limed water during the transition period immediately following liming may experience adverse impacts, since it is during this period that toxic water conditions may exist. However, no references could be found documenting any negative impacts on amphibians as a result of liming. The objective of the liming, to improve the water quality for fish life, would be expected to also improve the water quality for amphibians.

e. Wildlife

Adverse impacts of lake and pond liming on wildlife would not be expected, and no information on the subject could be found.

f. Other Biological Effects

Although conclusive evidence is lacking, the short-term biological effects resulting from liming have not generally proven to be detrimental. Planktonic algae have exhibited increased species diversity following neutralization, with a simultaneous decrease in acidophilic algae and mosses (Grann et al. 1974; Hultberg and Andersson 1982). Immediately following the liming of Woods Lake (see Section II.C.6.b.) the phytoplankton density was observed to decline, most likely due to the low CO_2 levels which resulted from the powdered calcite treatment. Pennate diatoms appeared to increase in abundance and diversity several weeks following the treatment (Bukaveckas 1989). The decrease in mats of acidophilic algae and benthic mosses such as *Sphagnum*, are believed to increase the availability of nutrients (Hultberg and Andersson, 1981).

Yan and Dillon (1982) reported that following the addition of alkaline material, the biomass of zooplankton declined immediately, probably due to the rapid rise in pH, followed by an eventual recovery up to less than pre-neutralization levels. However, recovery of zooplankton biomass, when compared to phytoplankton, often takes several years instead of several months (Bengtsson et al. 1980; Yan and Dillon 1982), probably due to the slower rates of reproduction in zooplankton (Schneider and Dillon 1976). Changes in taxonomic composition of zooplankton are also reported. In several lakes an initial predominance of cladocerans was followed by a shift to copepods after neutralization (Hultberg and Andersson 1981; Yan and Dillon 1982).

Schaffner (1989) also reported a dramatic decline in zooplankton abundance in Woods Lake due to the rapid rise in pH from 5.0 to 9.0, the decline in phytoplankton biomass, and modifications in the predator-prey interactions (see Section II.C.6.b.). He reported that rotifer species were greatly reduced following liming, and crustacean species became prominent in the lake. Over the long term Schaffner (1989) reported that liming and the introduction of brook trout tended to have an overall positive effect on the zooplankton community. Siegfried et al. (1987) found that in three neutralized Adirondack waters the species richness and standing crops of phytoplankton and rotifers approached or exceeded pretreatment values within a year of neutralization.

An immediate and substantial reduction in biomass of benthic macroinvertebrates has been observed after experimental liming of a limited number of acidified lakes (Scheider and Dillon 1976; Hultberg and Andersson 1981). Henrikson and Oscarson (1984) however found that limnetic insect populations increased after liming without fish introduction. In Woods Lake and Cranberry Pond (Section II.C.6.b.) and in most waters, liming is followed by introducing fish predators.

Evans (1989) reported that limnetic insect populations declined dramatically following liming and fish stocking and that the calculated trout predation levels on the limnetic insects suggested that predation was the major cause for the decline.

In general, species diversity and richness may increase as a result of lake neutralization. The biological community present however may not be the same as the community which was present prior to acidification by acidic deposition.

g. Water Quality

Immediately following liming, lake transparency tends to increase, especially in colored waters (Yan and Dillon 1981; Hultberg and Andersson 1982). This appears to be due to the coagulation and precipitation of dissolved organic carbon (DOC) by trace metals (Yan and Dillon 1981), although a decrease in Chlorophyll may also contribute. However, the intermediate effect of liming is reduced transparency (Yan and Dillon 1981; Hultberg and Andersson 1982). Observations suggest that precipitation of humic substances to bottom sediments eventually decreases relative to pre-treatment levels. Together with an increased abundance of planktonic organisms, the decreased humic precipitation generally leads to decreased secchi depth in limed lakes (Hultberg and Andersson 1982). Although change in transparency resulting from base addition probably influences the thermal regime of lakes, very little has been published on this subject. Yan (1983) indicates that for Lohi Lake, Ontario, secchi depth transparency is positively correlated with thermocline depth, epilimnetic thickness, and hypolimnetic heating rate. Thus, variations in water column light penetration caused by base addition could directly affect the overall lake heat budget, timing of mixing, and oxygen profiles; all of which could affect the composition of biological communities (Hultberg and Andersson 1982; Yan 1983).

Phosphorus is of special interest in oligotrophic lakes, as it usually is the limiting nutrient for primary production by phytoplankton, macrophytes, and benthic algae. Previous studies of total phosphorus concentrations following neutralization activities have produced conflicting results. Hasler et al. (1951), Waters (1956), and Wilander and Ahl (1972) indicated that phosphorus concentrations in limed surface waters increased. Yan and Dillon (1982) reported no significant changes in total phosphorus occurred after liming four lakes near Sudbury, Ontario. Hultberg and Andersson (1982) measured total phosphorus concentrations in epilimnetic waters of three limed and one reference lake from 1973 to 1980 and in all lakes, both acid and limed, the long-term trend in phosphorus was downward. This decline has been attributed to an increased precipitation of phosphate in watershed soils, where elevated concentrations of aluminum form stable aluminum-phosphate (Broberg and Persson 1984).

Reacidification is an important consideration of neutralization. Driscoll et al. (1982) reported that base addition resulted in the removal of DOC from the water column. DOC is an important pH buffer in low ionic strength waters and removal of organic ions may enhance the susceptibility of lake water to reacidification (Driscoll et al. 1982). Organic ligands complex trace metals, particularly Al, reducing metal toxicity to aquatic organisms (Driscoll et al. 1980; Baker and Schofield 1982). Long-term trends in water chemistry following base additions show declines in pH, Ca^{+2}, and ANC due to stream and groundwater inputs of acidic water (Dillon and Scheider 1984). DOC may also enter the lake via these inputs. Accompanying reacidification would be the reintroduction of elevated concentrations of trace metals, either from input water and/or remobilization from sediments (Driscoll et al. 1982). Upon reacidification, lake transparency would increase and thermal stability would decrease (Yan and Dillon 1981).

A major component of the proposed revision of the Division of Fish and Wildlife's Liming Policy (Section I) is to not allow any waters in the liming program to reacidify. Water quality monitoring on an annual or more frequent basis will insure that waters can be scheduled for reliming in a timely manner maintaining satisfactory water quality for aquatic life. The adverse effects associated with reacidification are therefore not expected to result from the proposed liming program.

In an acidic lake the water chemistry remains relatively acidic during the entire year. In a limed lake however fluctuations occur as a result of acidic episodes (discussed in section VII.A.), and also as a result of periodic retreatments with lime. The acidic episodes occur regardless of the liming program, but may impact the aquatic organisms which become established following the lake neutralization. Limed drainage waters can develop problems for aquatic life at the interface with tributary streams during the spring snowmelt episode. Shallow ponds of this type are especially vulnerable since they may lack deep water refuge areas that are not critically acidified by the inflow.

Inorganic forms of aluminum can create toxic conditions for aquatic life as a lake acidifies or is subjected to acidic episodes. This toxicity is discussed in more detail in Section III.C.6. Effects of Acidification on Fish. Organic methyl mercury represents another toxic metal which can be mobilized under certain acidic conditions and enter the food chain. Some concern has been expressed that liming may exacerbate this phenomenon, but a DEC study (Sloan et al. 1983) involving both limed and unlimed waters, did not support this theory as the brook trout tissue samples from Horn Lake contained lower levels of mercury following liming than before treatment.

Periodic reliming of a water results in water chemistry fluctuations as the pH increases and conditions stabilize. Using agricultural limestone will help insure that rapid pH changes do not occur and cause fish mortalities. Similarly, yearly water quality monitoring and timely retreatment will help insure that limed waters are not allowed to reacidify to toxic levels. With uncertainties associated with adequate funding for reliming and the unpredictability