Watershed Scale Protection for Adirondack Wetlands: Implementing a Procedure to Assess and Predict Cumulative Impacts from Development Activities to Wetlands and Watersheds in the Oswegatchie, Black and Greater Upper Hudson River Watersheds of the Adirondack Park, New York State, USA

Final Report

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The study team wishes to acknowledge the important contributions made to this project by the Peer Review Group. Their insight and contribution to the project contributed greatly. The Peer Review Group consisted of:

Chairperson	Dr. Barbara Bedford, and
Members	Dr. Charles Canham Dr. Charles Driscoll Dr. Carol Johnston Dr. Jeff McDonnell

Description of the Peer Review Group

At the outset of this project, APA staff recognized that the project needed the knowledge and experience of a group of independent experts to direct staff to appropriate data and information and to advise on the most appropriate methods of achieving project goals. In addition, the review offered by such a group would help to offset and avoid controversy or criticism should the report of the Agency staff be considered non-technical or political in some of its recommendations. It was determined that a Peer Review Group (PRG) acting as a technical advisory body should be assembled to help guide staff. The members of the PRG were selected based on their expertise and experience in appropriate scientific fields. The members of the PRG are:

Dr. Barbara L. Bedford, PRG Chair
Expertise: Wetland Ecology and Cumulative Impact Assessment
Department of Natural Resources
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Dr. Charles D. Canham
Expertise: Forest Ecology
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Dr. Carol Johnston
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Landscape Analysis with GIS and Wetland Ecology
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University of Minnesota – Duluth

Initially, Dr. Jeff McDonnell (Hydrology, SUNY College of Environmental Science and Forestry) also was a member but left the group upon taking an academic position in Washington State.

The overall charge to the PRG was to serve as an external source of scientific advice to APA staff on the data, concepts, and methods used in this project. Specifically, the PRG was asked to provide advice on: (a) suitability and adequacy of data layers; (b) additional data needs; (c) appropriate use of existing data layers; (d) choice of methods for assessing cumulative impacts and their implementation; and (e) appropriate scientific literature relevant to the project. The PRG also was asked to review and comment on the final report for the project, and to make

recommendations on the need for any post-project research.

The group met for the first time in January 1998 and subsequently met twice each year to address questions posed by staff and to review progress to date. Between meetings, project staff corresponded with the PRG to keep them abreast of the project's progress and to seek guidance on specific issues.

Report of the Peer Review Group

The Adirondack Park Agency (APA) undertook the work reviewed here with the goal of eventually developing the capacity to conduct cumulative effects assessments for the Park. As population and its attendant pressures for further development within the Park continue to increase, this capacity will become an essential tool for planning and for sound decision-making by the Agency. It will allow the Agency to view individual proposed actions within the broader context of past, present, and future actions that affect the Park. Only by explicitly recognizing that significant environmental impacts can and do occur when many apparently insignificant actions accumulate, and developing the tools to evaluate them, will the Agency be able to meet its mandate to protect natural resources within the Park. Making decisions about proposed actions and permit applications on a case-by-case basis will fail to address the most significant, long-term impacts of those actions because they are only manifested over time as the cumulative impact of many different actions on a wetland, stream, lake, or forest.

This chapter of the report presents a review by the Peer Review Group (PRG) of the APA's progress toward developing the tools needed for cumulative impact analysis. Specifically, the PRG reviewed the APA's development of data bases, geographic information systems (GIS), models, and procedures for assessing cumulative impacts to wetlands and watersheds that may result from development activities in watersheds of three major rivers within the Park – the Oswegatchie, Black, and Upper Hudson. The chapter is divided into three sections: general comments on the APA's final report on the project, specific comments on that report, and recommendations for future work.

GENERAL COMMENTS

The capacity to evaluate cumulative effects consists of several components, none of which is obtained easily. By definition, cumulative impact assessment requires tools that allow managers to think about a myriad of development activities and the various environments which they might affect in comprehensive and integrated ways. Because past, present, and potential future activities must be considered, those tools also must provide a type of institutional memory easily accessible to staff when specific decisions need to be made. Because aquatic resources, including wetlands, lakes, and streams are at stake, the tools also must provide a visual image of how activities in a given watershed array themselves in space, e.g., clumped or widely dispersed throughout a watershed, clustered along lake shores or specific roads, close to streams and wetlands or far removed from streams and wetlands. Thus the location of the resources and the location of development must be known and related to one another. The most effective way to achieve this is through development of a geographic information system (GIS) and models or other formal procedures to relate the data in the GIS to the potential for cumulative impacts to aquatic resources.

The PRG believes that the staff involved with this project have done an admirable job in:

(a) identifying and acquiring the data appropriate to assessing cumulative effects on a watershed basis; (b) conducting the requisite quality checks on data accuracy; (c) assembling these data into an up-to-date and widely familiar geographic information system (GIS); (d) documenting the procedures used to generate the major data layers in the GIS; (e) developing a number of approaches to the problem of assessing cumulative impact; and (f) providing explicit examples of the use of the landscape-scale data assembled by the project to examine cumulative impacts. Given the small number of staff dedicated to this project, a great deal has been accomplished, and a strong foundation has been laid for future development and use by the Agency of the data bases and tools for cumulative impact assessment generated under this project. Additional commitment of staff time to analysis of the data base that has been developed, and further development of tools for cumulative effects assessment, will be needed before the full potential of the data base can be realized.

SPECIFIC COMMENTS

The PRG provided the Agency with numerous detailed comments on the final report while it was in the preparation phase. All of these comments have been incorporated into the present draft. Some additional comments specific to certain sections of the report follow.

Data Layer Descriptions and Discussion; Additional Data Layers and Data Sources; Data Verification. The Agency has identified and assembled many layers of data appropriate to assessing cumulative impacts to wetlands and watersheds in the watersheds of the Oswegatchie, Black, and Upper Hudson rivers. These include data layers on the resources of concern (e.g., locations and boundaries of wetlands and watersheds), land condition (soils maps, surface and bedrock geology maps), past activities potentially contributing to cumulative effects (e.g., agency permit locations, fire maps, sewer district maps), and land use (tax parcel data). The material is presented in a way that is easily understood. Given the hierarchical complexity of the U.S. standard for wetland classification (Cowardin et al. 1979), the clarity in the description of the wetland data is especially noteworthy.

Furthermore, the Agency has done a very complete job of documenting the procedures used to generate the major data layers. In general, these methods of database generation were quite sound. Although the thorough documentation of the methods used probably will have limited readership because of its technical nature, it will contribute to the long-term utility of the data and serve well the future users of the data.

Of the data sets created under this project, the upland land cover may have the least utility because of it coarse resolution (i.e., few classes). The need to limit the number of classes to ones that can be detected accurately from remote imagery is a legitimate concern, but the PRG agrees with the report authors in questioning the value of generating a new data layer for uplands when two alternatives exist: the GAP analysis maps and the EPA’s new "Multi-Resolution Land Characteristics" (MRLC) land cover data set. As suggested in the report, these sources should be evaluated before producing upland classification maps for additional watersheds. Furthermore, if

the Agency continues to commission remote sensing image analysis for land cover mapping in the future, it should investigate the use of multi-temporal image analysis techniques that can generate more detailed forest classification than the four classes used in the present analysis (deciduous, coniferous, and mixtures thereof).

Data Analysis – Flushing Rates. One of the key analyses carried out with the new data layers was to recalculate flushing rates for ponds in the Oswegatchie, Black, and Upper Hudson watersheds that had been sampled by the Adirondack Lake Survey Corporation during the 1980's in order to document effects of acid deposition. Flushing rate, i.e., the amount of time that it takes for the entire volume of water in a lake or pond to be replaced, is also critical to cumulative impact assessment. It is one of the major variables required in estimating the sensitivity of lakes to nutrient enrichment from development activities or other land use changes on lakes, and in estimating the longevity of the effects of liming on lake pH. The newly calculated flushing rates used watershed areas and estimates of runoff determined with the new data from this project, as well as new methods for making the calculations, all of which are of better quality than those available in the 1980's.

As the authors note, the newly calculated flushing rates still have limitations based on the coarseness of available weather data. Given the importance of flushing rates to estimating the cumulative consequences of development activities on aquatic resources, efforts should be made to identify areas where development is likely to increase and add weather stations to these areas if they do not already exist.

Cumulative Impacts. Mitigating cumulative impacts presents significant challenges to the Adirondack Park Agency. One set of challenges occurs in the realm of policy and implementation: what processes can be used to guide decisions about proposed actions and permit applications on a case-by-case basis when the most significant, long-term impacts of those actions are only manifested as the cumulative impact of many different actions on a lake, stream, or forest? The more fundamental challenge occurs in developing the scientific basis for monitoring and assessing cumulative impacts on biological resources within the park. This chapter focuses largely on this second goal.

The chapter opens by recognizing four different approaches to the assessment of cumulative impacts, based on the quantity and quality of available data, and whether the impacts have occurred already or are predicted to occur in the future. These are useful and important distinctions. The last three categories ("inferred", "potential", or "anticipated" impacts) are distinguished, in part, by the degree of certainty in the predictions of future impacts. It would be useful for the Agency to explicitly consider the degree to which variation in the certainty of the predictions of future impacts should influence management decisions or guide programs within the Agency to improve the ability to predict cumulative impacts.

In general, it would be worthwhile for the Agency to invest even more effort into enunciating a clear strategy for dealing with cumulative impacts. The most immediate benefit

would be in communicating the strategy within the APA. In a broader sense, the Agency is going to need to be able to enunciate a clear strategy for dealing with cumulative impacts to elected officials and the public. Ultimately, we would hope that the GIS-based approach presented in the report as a whole becomes a formal tool for cumulative impact assessment throughout the Park.

The bulk of the chapter presents the results of three examples of use of the landscape-scale data generated under EPA funding to examine cumulative impacts. The first example concerns the analysis of residential development within the park. The analysis takes two forms: (1) a comparison of the change in distribution of residential tax parcel centroids between 1989 and 1998, and (2) calculations of "parcel saturation", i.e. the degree to which development has saturated land currently zoned for that form of development. Both forms of analysis are valuable tools for analyzing past and future development trends. In both cases, the density and distribution of residential parcels are assumed to provide surrogates for the complex cumulative impacts of residential development (e.g. habitat fragmentation, construction of septic systems, nutrient run-off into lakes, etc.). The results of the analyses can provide insight into both general policies and specific areas of concern. An example of the former is the report's discussion of the general pattern of creation of many new, isolated, small parcels, rather than outward expansion of existing, larger clusters of parcels. This is a classic symptom of "sprawl". The report does a good job of demonstrating the power of the data sets compiled by the project to bring the problem into focus. An example of a more specific use of this type of analysis would be to cross-reference specific areas of rapid or potential development (based on either past trends or percent saturation) against areas with resources that are particularly sensitive to this form of development (i.e., along lakes or wetlands that are particularly sensitive to nutrient loading).

The second example concerns a comparison of methods to assess the sensitivity of lakes to phosphorus loading. Specifically, the example compares different methods of computing Carlson's Trophic State Index (TSI), a key parameter in a model (LAKEMOD) used by Agency staff to assess potential impacts of residential development on lakes. The principal goal of this section was to test whether Secchi disk measurements could be used to calculate TSI, rather than the more expensive and time consuming methods based on chlorophyll *a* or total phosphorus measurements. One of the major challenges in using Secchi disk measurements to assess trophic state and productivity in Adirondack lakes is the significant variation in lake color and transparency due to often striking variation among lakes in concentrations of dissolved organic compounds. The chapter provides clear evidence that Secchi disk measurements will not provide an adequate basis for calculation of TSI.

The third example focuses on calculation of a lake sensitivity index based on flushing rates and an index of nutrient retention. The sensitivity index was originally developed in the 1970's for lakes of the upper Midwest, and was designed to provide qualitative rankings of sensitivity of lakes to changes in nutrient loading. The index is not applicable to a significant fraction of Adirondack lakes, particularly shallow lakes and seepage lakes. For the roughly 2/3 of the lakes in the Oswegatchie/Black and Upper Hudson drainages that could be used in the analysis, slightly over half of the lakes would be considered insensitive or very insensitive to

nutrient input, with the remainder ranging from moderately sensitive to very sensitive. One of the most important limitations of the analysis is that the overall accuracy and validity of the lake sensitivity index has never been explicitly tested in the Adirondacks. The most important message from the analysis is to reaffirm the general sense that Adirondack lakes are likely to vary dramatically in their sensitivity to the effects of nutrient loading. This is a critical issue for cumulative impact assessment. Management that fails to account for inherent variation in lake sensitivity is quite likely to either fail to protect vulnerable lakes, or require unnecessarily strict levels of "across the board" restriction on development, threatening public support for management.

Overall, the chapter does a good job of highlighting the usefulness of the data sets compiled by the Agency. The analyses presented in the chapter provide just a few, brief examples of the potential uses of the data sets. Frankly, given the size and the workload of the current Agency staff, it is unlikely that the staff will be able to make full use of the data sets. By making the data sets widely available to the research community, the Agency has increased the chances that additional analyses will be done. However, this approach gives the Agency very little leverage in ensuring that the most valuable analyses are done.

There is no question that EPA funding has resulted in a significant improvement in the ability of the Agency to begin to address watershed-scale impacts of development within the Park. However, it is equally clear that the Agency has a long way to go in the development of procedures to assess and predict cumulative impacts of development on wetlands and lakes within the Park.

RECOMMENDATIONS FOR FUTURE WORK

The value and potential usefulness of the data layers and GIS developed under this project cannot be overstated. With a clear mandate to protect the natural resources of the Park, the Agency must operate with the clearest possible vision of the resources and the development activities that potentially affect them. In an area as large as the Park, this can be achieved only with a formal structure for integrating, manipulating, and displaying data on the distribution of resources and development activities. This structure is the GIS developed under this project, and similar projects for the Oswegatchie and Black River watersheds. It can provide a clear and objective context within which sound decisions can be made.

However, only some of the potential usefulness of the products of this project could be realized with the limited commitment of staff and time to the project. With the large amount of tedious work required to ensure the quality of the data layers and to thoroughly document how they were generated, along with the time needed to run many of the analyses with such large data sets, it is not surprising that staff did not have time to move beyond what is presented in the report. The Agency would be remiss if it failed to take the next logical steps in the development and use of these tools for assessing cumulative effects.

In order that this valuable investment not be lost, the PRG makes the following recommendations:

a) The Agency should continue to pursue collaborations with the academic community. Such collaborations would allow them to make greater use of the existing data base to answer resource-relevant questions. Such collaborations also would allow the agency to draw on more extensive knowledge of up-to-date models for estimating watershed-lake and watershed-wetland interactions than is likely to occur otherwise.

b) The Agency should invest in an additional staff person with extensive experience in the use of GIS and models to assess impacts to natural resources. A person with a Ph.D. degree in a relevant field is likely to be needed. The use of GIS in resource management is likely to become a tool of ever-increasing importance in natural resource management. Without staff expertise to utilize fully the resources provided by this and the Oswegatchie/Black River watershed projects, the Agency will be wasting an already significant investment and losing one of the best modern tools for sound decision-making.

c) In the near future, Agency staff should begin using global positioning systems (GPS) to locate projects and their boundaries. These data will provide the coordinates needed to relate projects to the digital map data in the system. They will improve the capacity to estimate if and where impacts might occur, and allow cumulative effects on aquatic resources to be related to activities on the land.

d) For similar reasons, the Agency should purchase digital tax maps as they become available for counties not already entered into the system.

e) The Agency should attempt to identify especially vulnerable wetlands, i.e., fens, and examine these in relation to the location of potential impacts.

f) Given the highly significant effects that beaver have on wetlands, and the number of beaver-impacted wetlands noted in the study, the Agency should make some effort to assess the cumulative consequences of beaver activity on the wetlands of the Park. Beavers can alter the diversity of wetland types in the landscape, the flows of water on the landscape, and biogeochemical cycles within wetlands and other beaver-flooded areas.

g) The Agency should evaluate the implications of the fact that the wetland coverage does not seem to be a fully integrated hydrologic system, i.e., some stream segments are missing, or not assigned through large wetlands. Consequently, the wetland coverages do not match with other hydrologic coverages and do not function as one themselves. Tracking the movement of nutrients, sediments, or other pollutants to wetlands and other water bodies requires that the wetlands be hydrologically linked with other systems. The Agency should assign resources to develop a flow routing GIS coverage that shows the connectivity, Horton stream order, and directionality of water flow in the landscape,

regardless of whether the water is in a stream, river, wetland or lake.

CONCLUSIONS

The work completed under this project, and the associated projects for watersheds of the Oswegatchie and Black rivers, represent significant advances in the Agency's capacity to evaluate the cumulative effects of proposed actions and permitted activities within the Park into the next decade. Every effort should be made to extend this capability to the remaining watersheds of the Park, to maintain and update the GIS system as new data and models become available, and to undertake further development of tools and procedures for cumulative impact assessment. The capacity of staff to utilize the invaluable resource embodied in the data and GIS depends on the Agency supporting staff with extensive experience in the use of GIS and modeling to assess potential impacts.

submitted by:

Barbara L. Bedford, PhD.

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Introduction

The Adirondack Park is a mixture of public and private lands intermingled over an area larger than the State of Vermont. The Adirondack Park Agency is responsible for regulating development on private lands within the Park so that natural resources are protected. Because of the large area involved, the Park Agency has, over the last 10 years, constructed a library of digital map data for the Park to aid Agency staff. The Park Agency recently accelerated this effort through grants from the State Wetland Protection Program at the U. S. Environmental Protection Agency to map land cover, wetlands, and watersheds in the Oswegatchie and Black River watersheds, and gather other available historical and environmental data (Roy et al. 1996, Roy et al. 1997). This project continued and extended the collection of digital map data, created a framework to use these data to approach assessment of cumulative impacts in the Park, used the available map and other data to improve environmental data available for examining cumulative impacts, and created a system for integrating this information into decision making by Agency staff using the Agency Data Lookup System. This report describes the methods used to collect data, the sources of data collected from third parties, the methods used to create derivative products from existing source data, and methods and approaches for looking at cumulative impacts.

The Adirondack Park covers a 2.4 million hectare predominantly forested region in northern New York State which roughly corresponds to the Adirondack Ecological Zone (Will et al. 1982). It is the largest wilderness area east of the Mississippi River with high quality unfragmented public and private wilderness habitat, high species and structural diversity, a wide variety of wetland types, and regionally recognized exemplary wetland communities. During the most recent glaciation, approximately 25-30000 years B.P. the entire region was covered by an ice sheet. The receding glacier left behind a very complex terrain with large areas of flat outwash sand plains in the west, high exposed bedrock mountains in the central region, and rolling farm land perched on marine and lacustrine clays above Lake Champlain in the east. Within the Park, bedrock varies from slow-to-weather granitic anorthosite, to bands of highly erodible calcareous rock. Because of its position on the boundary between mesic hardwood forests and boreal forests, elevation range (28.4 meters mean sea level at Lake Champlain to 1628.9 meters mean

sea level at the top of Mt. Marcy), and large area (the Park stretches across 2 degrees of longitude and nearly 2 degrees of latitude), the Park contains regionally important examples of boreal spruce/fir and northern hardwood forests, pristine examples of large wetland and aquatic ecosystems such as muskeg/bog, and relict alpine/arctic tundra-like communities on the higher mountain peaks. The Park contains approximately 340000 hectares of lakes, ponds, and wetlands. Wetlands range in size from small isolated kettlehole bogs to large complexes of bog, fen, shrub swamp, forested swamp, and emergent marshes. In addition, the Park contains more than 3,000 lakes and ponds ranging in size from less than a hectare to more than 10000 hectares (Lake George and Great Sacandaga Lake).

The Adirondack Park was created by act of the New York State Legislature in 1892 to "be forever reserved, maintained and cared for as ground open for free use of all people" (State of New York 1892). In 1894, the legislature increased protection of the Park by including Article XIV in the State constitution that declared that State lands acquired and held within the boundary of the Park (also known as the Blue Line) would be held in the public trust to remain "forever wild." Since its creation in 1892, the Park has been a mixture of public and private ownership. Originally remote, the building of roads and highways has made the Adirondacks more accessible to large population centers. Construction of the Northway (Route 87) between Albany and Montreal in the 1960's brought access to millions of people. Increasing access led to concern for the consequences of private land development on preservation of the character and resources of the public lands within the Park. This concern eventually led to the formation of the Adirondack Park Agency Act (The Act) by the State Legislature in 1971.

The Act created the Adirondack Park Agency (APA), which was charged with administering the Act (Executive Law, Article 27), the State Freshwater Wetlands Act (Environmental Conservation Law, Article 24), and the Wild, Scenic and the Recreational River System Act (Environmental Conservation Law, Article 15, Title 27) within the Park. These acts give the APA responsibility for protection of the Park's natural resources, including regulating activities on public and private lands that may reasonably be expected to result in degradation of wetlands and waterbodies. The Act also mandated that the Adirondack Park Land Use and Development Plan (APLUDP) be created. This land use management plan divided the lands of the Park into 14

land use categories and described the limitations of development to be allowed in each land use type.

The State of New York owns approximately 43 percent, or 1 million of the 2.4 million hectares of land within the Blue Line. The remaining private lands are devoted principally to forestry, agriculture, and open space recreation. In recent years, residential development, particularly the subdivision of remote lands within the Park, has increased. Approximately 26,000 additional seasonal and permanent residences were built in the Park between 1967 and 1992 (Banta 1993). Much of this development has been concentrated in the region surrounding the Northway (Route 87) corridor, which is aligned north/south, and bisects the of the Upper Hudson River watershed. Since the construction of the Northway in the 1960's, negative impacts such as disruption of wildlife travel patterns, destruction of wetlands, creeping urbanization, and increased runoff and sedimentation have been noted, but not measured or described.

Since 1973, the Agency has conducted reviews of proposed development projects according to conventional impact assessment methods: as individual isolated cases. Each application for a permit is evaluated on the basis of the expected impacts of the activities described in the permit on the area near the permit location. The Agency and its staff have come to realize that looking at individual projects without taking into account the other projects that have already occurred nearby, or can reasonably be anticipated to occur in the near future, can result in overlooking serious environmental impacts through the cumulative effects of many projects acting together. Recent discussions of cumulative impact (Preston and Bedford 1988, Risser 1988) suggest that to evaluate the full environmental impact of a project, a view of the environment that is broader than the immediate project must be used to determine the significance of the project’s impacts. The geographic scale of the contributing area in which effects are looked for, the number of perturbing events, and the timespan within which they occur, are all factors in a cumulative effects assessment (Preston and Bedford 1988).

With the goal of eventually developing the capability to conduct cumulative effects assessment for the Park, the Park Agency undertook the present project. This project extends the digital mapping work started in the Oswegatchie and Black River watersheds to the Upper Hudson River watershed, a significant addition to the Park digital resource map database. Because the

Park covers over 2.4 million hectares (6 million acres), digital data is essential to any regional resource assessment program. The Park Agency has little digital map data regarding the physical setting or composition of either the large watersheds or small subcatchments of the Adirondack Park on which to base a cumulative effects assessment method. Several research projects over the last decade have examined small study sites, but these investigations comprise a very small portion of the Adirondack Park. Few of these data are available in digital form, making them difficult to use, particularly for regional analyses. To date, no systematic quality-controlled digital watershed scale resource maps have been compiled for the Adirondack region, with the exception of those produced for the Oswegatchie and Black River watersheds (EPA Grants # X 002777-01-0, and CD992087-01: Figure 1). The project in the Oswegatchie and Black watersheds produced digital files and maps of watersheds for ponds with New York State Department of Conservation pond numbers, and wetlands based on National Wetland Inventory methods, and obtained or created digital files of surface and bedrock geology and other data.

For the purposes of this study, the Greater Upper Hudson River watershed includes those portions of the Sacandaga and Mid-Hudson River watersheds within the Park, as well as the Upper Hudson River watershed. The Greater Upper Hudson (UH) watershed, which contains 694794 hectares and, comprising 33% of the surface area of the Park, is the largest of the five major drainage basins originating within the Adirondack Park (Figure 1). The watershed of the Upper Hudson contains the full diversity of landforms and cultural development in the Park. It contains the most highly urbanized area of the Park, and the most mountainous regions. Because of thin poor glacial soils over most of the region, there is very little agricultural land except on lacustrine benches in the lowlands in the southeast. Three major rivers arise within its boundaries: the Schroon, the Sacandaga, and the Hudson. The Upper Hudson River watershed contains the fourth largest lake wholly within New York State and the second largest wholly within the Adirondack Park, the Great Sacandaga Lake, as well as many other smaller but highly developed lakes among the over 1,000 ponds and lakes in the watershed.

Approximately 7% of the land surface area of the UH watershed is wetland of various types. Many small wetlands are interspersed with larger, regionally recognized significant aquatic

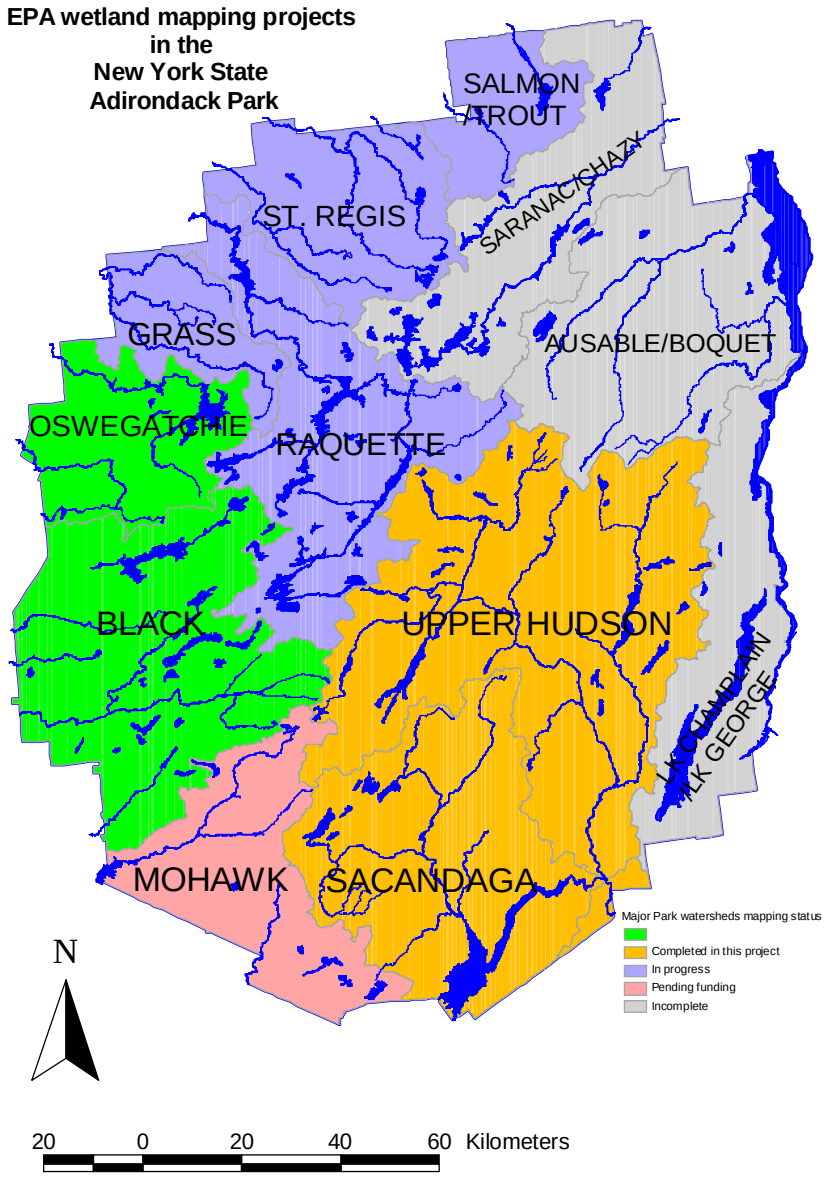

Figure 1. Major Watersheds in the Adirondack Park. The Oswegatchie and Black watersheds were part of an earlier EPA project. This report addresses the Upper Hudson watershed. Watersheds draining towards the St. Lawrence river are being mapped as part of a third EPA project. Funding is being sought to complete the remaining portions of the Park.

complexes such as Kunjamuk Creek Marsh, Augur Flats Floodplain Swamp, and Jenks Swamp. These wetlands and waterbodies are sensitive receptors of inputs from increasingly urbanized shorelines and floodplains. The UH watershed is also bisected by a major interstate highway system, I-87, the "Northway." Because of its location and physical features, the UH watershed has the greatest degree of actual and threatening human disturbance of any watershed in the Park.

The relationship between wetland resources and watershed characteristics is complex, and only qualitatively understood (Bedford 1999). The physical and chemical setting of watersheds affect wetland size, distribution, and cover types. In turn, wetlands affect the physical, chemical and biological characteristics of their watersheds (Brinson 1993). In addition, atmospheric deposition, residential development, and historical forestry and agricultural activities contribute to the complexity of Adirondack watershed and wetland interactions. There is no nationally accepted methodology or approach for watershed or wetland characterization that could be utilized at a practical scale (Risser 1988).

The digital map data developed by this project will provide a basis upon which to begin to examine cumulative impacts in the Adirondack Park. The project has five primary goals:

1. To develop GIS coverages for the Upper Hudson watershed: wetlands, watersheds, upland cover types, APA land use map, existing land use, forest cover from TM data;
2. To develop a GIS-based institutional framework in which to detect and track cumulative effects to wetlands and characterize resource conversion trends in the Park;
3. To develop a methodology to assess the significance of cumulative effects on wetlands in the Park using data developed for the Oswegatchie and Black River watersheds and from this project;
4. To provide a landscape context for wetlands resource analysis; and,
5. To identify long-term data and monitoring needs.

Project Organization

The project was organized and conducted in two concurrent parts:

Part I extended the wetland/watershed digital map database developed for the Oswegatchie and Black River watersheds (OB) to the Greater Upper Hudson River (UH) watershed. The GIS wetland, watershed, and upland land cover database was created using similar methods and source data for both the OB and UH projects, and data from both can be accessed, modified and used in the same ways. The Adirondack Lakes Survey Corporation (ALSC) database of lake chemistry (Baker et al. 1990) was integrated into the watershed maps to evaluate correlations between lake water chemistry of hydrologically similar lakes and landscape features, such as wetlands. This database development is an important step towards developing a cumulative effects assessment and cumulative impact tracking system for the Adirondack Park. A GIS-based assessment and tracking system is an efficient way for the Adirondack Park Agency to analyze the effects of proposed development activities on the area and function of existing aquatic resources (lakes and wetlands) and assess if, how, and to what extent those resources would be affected.

Part II utilizes the digital map database to develop a cumulative effect assessment and cumulative impact tracking system. Part II adds additional data layers to those obtained in the OB project and in part I of this project, such as Department of Equalization and Assessment parcel centroids, the locations of permits approved by the Adirondack Park Agency, and land use and forest cover from classified LANDSAT Thematic Mapper (TM) imagery. Several exploratory studies were conducted to validate the map data in the field, compare it to other data sources, and test it against other, more detailed studies.

These resource databases will aid the Agency in considerations of the appropriateness of proposed public and private development, and in determining the type and location of mitigation activities. These new resources will enhance the ability of the Agency to carry out its legislated mission.

The end products of this project are intended to be used by Agency staff during permit application review after approval by the Agency Members. Consequently, it was felt that a technical advisory committee of eminent scientists should be assembled to advise and guide

project staff as the project developed. The Peer Review Group (PRG) members and their affiliations are:

Dr. Barbara Bedford - Cornell University, Ithaca, New York, (Chair),
Dr. Charles Canham - Institute of Ecosystem Studies, Millbrook, New York,
Dr. Charles Driscoll - Syracuse University, Syracuse, New York,
Dr. Carol Johnston - Natural Resources Research Institute, Duluth, Minnesota

The committee members fields of study are in Wetlands Ecology, Hydrology, Limnology, Forest Ecology, and Cumulative Impact Analysis. They are nationally and internationally known and respected scientists in their fields. All have had research experience in the Adirondacks and are qualified to comment on needed data layers, their quality and completeness. Project staff have kept the PRG informed of the steps taken to complete the project and solicited their input through a series of mailings and periodic working meetings. The PRG report that accompanies this project report is intended as an impartial critique of methods and results presented in this report, and will aid the Agency Members in determining the utility of the data layers and the cumulative impact assessment procedure described in this report.

Report Organization

Data Layers

Digital resource maps were collected in two phases. In phase 1, digital wetland and watershed maps were created for the Upper Hudson watershed using protocols similar to the previous EPA funded study in the Oswegatchie and Black River (Roy et al. 1997) at the Remote Sensing Laboratory at the State University of New York at Plattsburgh. In phase 2, additional map data layers were created at the Adirondack Park Agency (Adirondack Park Agency Historic Project Site Location, 1916 Fire Map, Water and Sewer Districts inside the Adirondack Park) or obtained from other sources (current Department of Equalization and Assessment tax map parcel centroids for Warren County, New York State Digital Elevation Models, Lake Champlain Basin Program digital map output, New York State Gap Analysis Program map output). Additional digital map data previously created for, or obtained by the Agency (Soils, Hydrography, County Roads), or created as part of the Oswegatchie and Black River project, (Surface and Bedrock Geology, Landscape disturbance (1950 and 1995 blowdown, Ollinger precipitation and deposition models: Ollinger et al. 1995) were also obtained. Additional non-map data on lake chemistry gathered in the mid 1980's was obtained from the Adirondack Lake Survey Corporation. The methods used to create individual map data layers are described where appropriate. Many of the sections include comments on the utility and limitations of particular data sets.

Data Analysis

In any study where many data types are used from different sources, it is necessary to evaluate how well the different data sources work together. This is especially true in this study, inwhich many data layers were created at different scales, and at different levels of field verification by different organizations, using information collected at different times.

Several projects were undertaken to test the wetland and watershed data layers using field and other digital information. These included comparisons of wetland maps to field conditions for selected locations, a time series comparison of wetlands using wetlands delineated from 1990 aerial photography with wetlands delineated from earlier photography, and comparison of

watersheds delineated manually from 1:24000 and 1:25000 US Geological Survey (USGS) topographic quadrangle maps to watersheds generated from new 1:24000 digital elevation models created from the contour lines on the same maps.

New estimates of precipitation, evapotranspiration, and runoff were calculated for all sub-watersheds in the Oswegatchie, Black, and Upper Hudson watersheds using methods similar to Ollinger et al. (1995). These estimates were compared to actual measurements of runoff from US Geological Survey gaging stations and used to calculate new flushing rates for lakes sampled by the Adirondack Lakes Survey Corporation. The flushing rates were used to estimate the sensitivity of the AlSC lakes to new nutrient inputs.

Cumulative Impact Analysis

Cumulative impacts occur when there are several impacts to the same resource (wetland or lake for instance) that occur in close proximity in space or time so that the affected system does not have time to recover or is irreversibly changed. Resources can be defined on the local scale (a wetland), the regional scale (a group of wetlands of the same type or different types in a large area), or a global scale (all wetlands). It is clear from this perspective that there are many potential sources and types of cumulative impact, and potentially impacted systems in the Adirondack Park. Most permits issued by the Agency are concerned with local and regional scale effects from development projects. This report centers on the effect of local scale actions on local and regional scale wetlands and waterbodies. First, four general approaches to cumulative impacts are described, along with examples of each. Then examples are developed for lake sensitivity to new inputs of nutrients and the build-out saturation of land use areas defined by the Adirondack Park Land Use and Development map with tax parcels.

Implementation

The map products collected during the data development phase and produced by the cumulative impact investigation phase of the project were incorporated into the Adirondack Park Agency Data Look-Up System below. The digital resource maps created for this project provide new and improved information to project review officers and other technical staff. The impact maps will be used to identify areas in which special consideration should be given.

Data Layer Descriptions And Discussions

This section includes detailed descriptions of the source data and methods used to generate new data layers for this project. These layers include watersheds mapped from topographic maps, wetlands mapped from aerial photography, upland land cover interpreted from LANDSAT 5 Thematic Mapper satellite imagery, the location of Agency permits granted over the last 10 years, and the Upper Hudson section of the 1916 Fire map.

Upper Hudson River Drainage Basin Watershed Maps

A total of 954 watersheds were mapped in the Upper Hudson drainage as part of this project (Figure 2). These included major river watersheds, and ponds identified by the ALSC and the New York State DEC Bureau of Fisheries (BOF). See Appendix 1 for a list of USGS topographic maps used in this project. Ponds that appear on USGS topographic maps that did not have an ALSC or BOF identification number were not included unless they had been surveyed in the field. Pond identification numbers were transferred onto separate sets of the most recently available USGS topographic quadrangles. When they were available, 1:25000 scale maps were used for the watershed delineation (see Appendix 1 for a list of quadrangles used). Watersheds were delineated starting and ending at the pond or lake outlet as indicated on the topographic map using conventional delineation methods (USDA 1977). When the exact location of the pond outlet was in question, field-checked ALSC bathymetric maps were used.

Watershed boundaries were independently determined at the Remote Sensing Laboratory at the State University of New York at Plattsburgh and at the Adirondack Lakes Survey Corporation. Boundary differences on the two sets of watershed maps were reconciled by a third person at the Adirondack Park Agency, overlaying the maps on a light . Most differences occurred in areas of low relief or when the location of the pond outlet was uncertain. Differences in lines were checked with 1968 (1:20000) panchromatic aerial photos and ALSC bathymetric maps. In some cases, watershed boundaries were also field checked. Final watershed boundaries were transferred onto a clean set of topographic maps in preparation for digitizing at the Remote Sensing Laboratory at SUNY Plattsburgh. Only non-folded maps were used in the final copy. Watersheds were converted to digital form using a digitizing t. Finally, each quadrangle was printed at the scale of the paper source quadrangle map, the two were compared, and any

differences between the digital and paper watershed lines corrected. After all the quadrangles were digitized, they were edge matched, and joined into one coverage. At this point, quadrangle boundary lines were removed, and each watershed was labeled with the ALSC pond number, or a descriptive name code for non-ponded (river) watersheds.

Each digital watershed polygon was given a unique identifying number in the polygon data (THIS# in the polygon attribute). Watershed flow direction was determined on the paper topographic maps and added to the digital map by adding the identifying number of the receiving polygon to each sending polygon (FLOWTO# in the polygon attribute). Field visits were made to watersheds where the drainage direction of the polygon was not clear from the topographic map or aerial photographs. In a few cases watersheds drained in more than one direction. In these cases both flow to watersheds were retained in the database. Polygons only represented the area flowing out through the local watershed pourpoint (the local watershed). Areas flowing through pourpoints located upstream representing the larger regional contribution to flow through each local watershed were represented through the creation of regional watersheds. Regional watersheds were generated from local watersheds using Arc-Info to select all watersheds flowing into each watershed and convert these into a single regional watershed polygon. Thus, the area information contained in the polygon attribute reflects only the immediate watershed source area for stream discharge out of that polygon, and the regional area information reflects the contribution of upstream subwatersheds to stream discharge. Metadata for this dataset can be found in Appendix 2.

Upper Hudson River Wetlands Maps

Methodology

Wetlands were delineated from U.S. Geological Survey National Aerial Photography Program (NAPP) and National High Altitude Program (NHAP) aerial imagery. NAPP positive color infrared transparencies at 1:40000 scale were obtained from the US Geological Survey - EROS Data Center and used to delineate most of the Upper Hudson River drainage basin. NAPP photography was flown under leaf-off conditions in 1994 or 1995 when deciduous vegetation was dormant, and according to U.S. Geological Survey criteria: aircraft altitude 20000 feet above

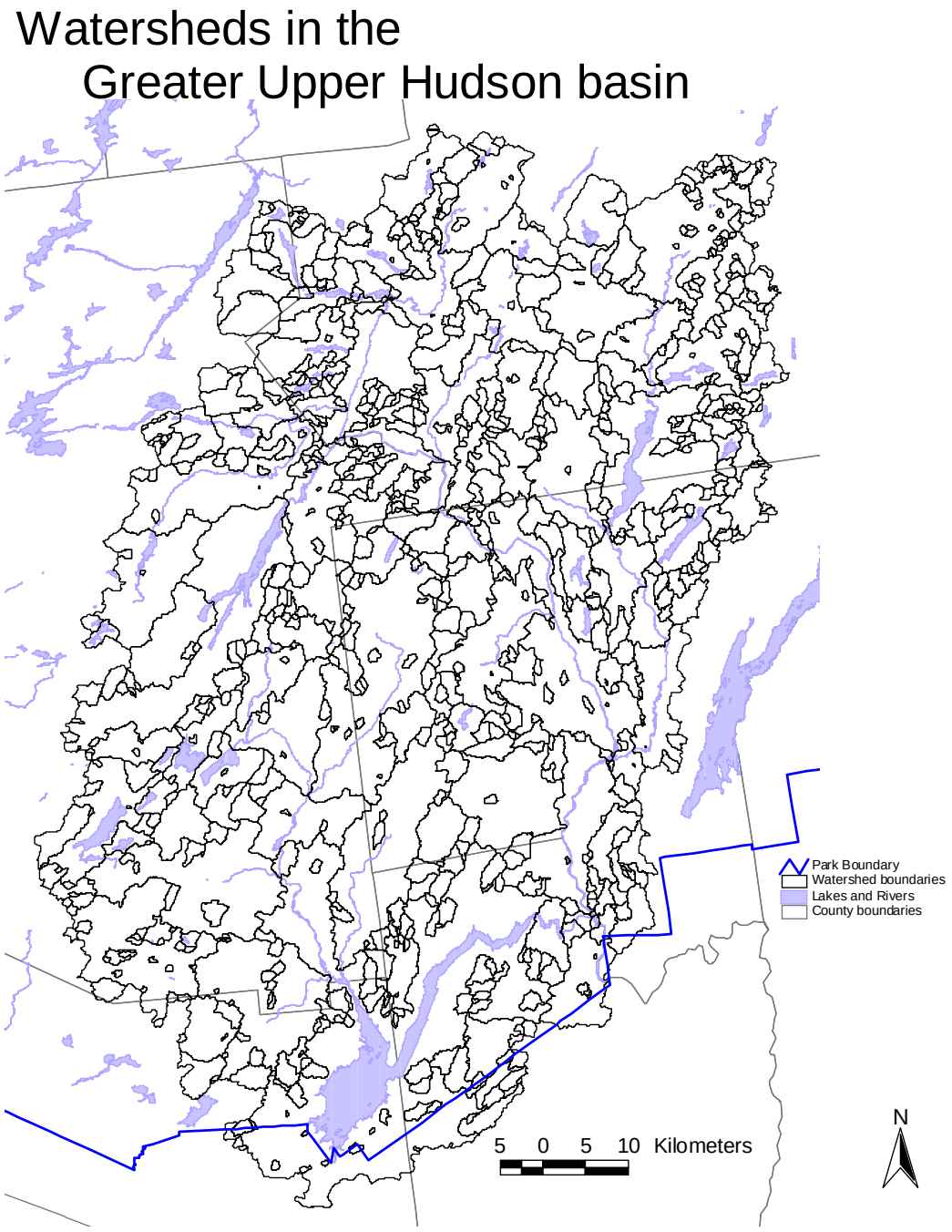

Figure 2. Watersheds Delineated for the Greater Upper Hudson Basin. Nine hundred and fifty four watersheds were delineated as part of the Greater Upper Hudson project.

mean terrain, sun-angle greater than 30 degrees to minimize shadows, stereoscopic coverage (approximately 60% forward overlap), no cloud cover, minimal haze, and taken with a 6 in. (152 mm) focal-length lens mapping camera. This imagery was unavailable for nine quadrangles, and infrared positive transparencies gathered as part of the NHAP in 1985 and 1986 were used. Flight specifications for this imagery were similar to specifications for the NAPP imagery except that it was flown at an altitude of 40,000 feet and taken at a scale of 1:58000.

The quality of the color infrared photographs was somewhat variable. All photographs had excellent resolution, but color brightness on some flight lines was poor (strong exposure falloff), and leaf-out had occurred on flight lines in the southern part of the watershed. Interpretation of the NHAP and NAAP imagery was supplemented with paper prints of 1:24000 panchromatic imagery flown in 1968 by Lockwood, Kessler and Bartlett as part of the LUNR (Land Use and Natural Resource) Inventory for New York State, with quadrangle-centered 1:80000 panchromatic transparencies flown by USGS in 1976 - 78, and with ground truth field notes on 1:24000 USGS quadrangles where wetland boundaries or cover types were difficult to interpret. Both sets of backup imagery were flown under leaf-off conditions, primarily in spring, but occasionally in fall.

The following steps were employed in creating the wetlands data layer (Figure 3):

(1) A clear mylar overlay was prepared for each 1/4 quad-centered aerial photograph (4 photographs per 7.5' quadrangle). The quadrangle border was inked on the appropriate overlays.

(2) Wetland areas were delineated onto the mylar overlay using a 5x0 tungsten carbide pen with acetate ink and an Image Interpretation Systems SIS-95 zoom stereoscope. Because of the complexity of the delineations and lack of space, shorthand notation was employed to label wetlands on the acetate sheet. Where necessary, wetlands were verified on both the 1:80000 and 1:20000 panchromatic emulsion imagery, and topographic maps with field check notes. Each acetate was examined by a second photo interpreter as a Quality Assurance/Quality Control (QA/QC) step, and differences between interpreters were rectified before further steps were taken.

Figure 3. Procedure Used in Delineating Wetlands.

Collateral Imagery and Field Data		Primary Source Data and Work Activities		Quality Assurance and Quality Control activity
		1995-95 1:40000 CIR and 1985-86 1:58000 CIR transparencies		
1968 1:20000 B&W 1980-81 1:80000 B&W Field Notes	→	WETLAND DELINEATION	←	Check of photo overlay by independent interpreter
1995-95 1:40000 CIR and 1985-86 1:58000 CIR transparencies	→	WETLAND TRANSFER	←	Superimpose photo/wetland overlay on 1:24000 scale rectified wetland map using Kail Reflecting Projector
1995-95 1:40000 CIR and 1985-86 1:58000 CIR transparencies	→	WETLAND DIGITAL DATABASE CREATION	←	Compare hard copy of scanned linework with 1:24000 rectified wetland map. Check polygon integrity and wetland labels by two people. Compare label list, and other computer quality control protocol

(3) Wetland labels were added to the acetate according to National Wetlands Inventory (NWI) label conventions (Appendix 3) as described in Cowardin et al. (1979). In some areas, wetlands and uplands were too intermixed to separate easily. In these cases, an additional modifier was used (/U) to indicate that wetlands and uplands were too mixed for homogeneous separation. Although this designation is not an official Cowardin et al. (1979) label, it is in use by various NWI offices and was suggested for use in this project by Ralph W. Tiner, Jr., of the U.S. Fish

and Wildlife Service (Tiner, Personal Communication). The most commonly identified wetland cover types encountered during this study are described in Table 1.

(4) An Image Interpretation Systems Stereo Zoom Transfer Scope was used to remove scale changes and image displacement while transferring wetland polygons and linear features from the acetate photographic overlays to mylar overlays of s base 1:24000 B&W orthophoto quadrangles.

(5) A separate overlay of labels was made from the acetate overlays using a Kail optical reducer/enlarger and a second piece of mylar with the wetland polygon overlay produced in step 4 as a base. At this time, the polygons on the mylar quadrangle overlay were compared with the photo overlay to insure that all polygons and polygon labels were correctly transferred.

(6) The mylar wetland polygon data overlays were either hand digitized using a digitizing and PC Arc-Info software, or digitally scanned and vectorized at Applied Ordinance Technology in Waldorf, Maryland and delivered as a Arc-Info interchange file. The vector lines for each file were printed and compared with the mylar polygon overlay and checked for precision of line work, missing or extraneous lines, polygon closure, and inappropriate line ends.

(7) Wetland labels were entered into each digital wetland quadrangle using a digitizer menu designed for the project. The menu allowed labels to be entered from the digitizing t by overlaying the label mylar with a digital polygon and label printout. The digital polygons and labels were displayed on the computer screen and the digitizing puck was used as a mouse to choose polygons and add label information through the menu. Using the menu reduced spelling errors and increased the efficiency of interns involved in labeling. At this step all polygons were labeled, including upland areas, and all unlabeled areas were clearly highlighted on the computer screen. Sections of the full NWI label were entered into separate fields (System, Subsystem Class1, Class2, Water Regime, Special1, Special2, and Special3 in the polygon attribute) in the digital data , and unified NWI labels were created by concatenating the columns using dBase IV and inserting the full label in the polygon attribute .

Table 1. Major Wetland Cover Types of the Upper Hudson Watershed

Wetland Classification	**NWI Cover Type Label**	**Representative Plant Species**
Aquatic bed	AB3	Pondweed, milfoil, eelgrass
Open Water	OW	Pondweed, milfoil, eelgrass, or none (open water)
Persistent leaved emergent	EM1	Cattail, grasses, sedges
Broad-leaved deciduous scrub shrub	SS1	Speckled alder, willow
Needle-leaved deciduous scrub shrub	SS2	Eastern larch
Broad-leaved evergreen scrub shrub	SS3	Leatherleaf
Needle-leaved evergreen scrub shrub	SS4	Stunted or young black spruce or balsam fir
Dead scrub shrub	SS5	dead shrubs
Broad-leaved deciduous forested	FO1	Red maple, silver maple, black/green ash
Needle-leaved deciduous forested	FO2	Eastern larch
Needle-leaved evergreen forested	FO4	Balsam fir, red and black spruce
Dead forested	FO5	Dead trees

(8) The labeling procedure was designed as a final QA/QC on wetland polygons and linear features. As missing lines and polygons were discovered during labeling they were corrected. A table of wetland labels was made, and odd or incorrect labels and label combinations were identified following completion of labeling for all quadrangles in the watershed. These were checked against the original labels on the acetate photo overlays and corrected as necessary. The

maps were assumed to be completed following these checks. Metadata for these data can be found in Appendix 4.

Results and Discussion

The wetland maps can be used to gain an understanding of the regional patterns of wetland types and the size of the polygons associated with each of these types. For instance, wetlands occupy 7 percent of the total area of the Greater Upper Hudson watershed. There were 49649 hectares of wetlands out of 711303 hectares in the Greater Upper Hudson watershed. In contrast, wetlands covered 15.2 percent (Roy et al. 1996) of the area in the Oswegatchie and Black watersheds, a much larger percentage.

Wetland labels were assigned using the Cowardin system used by the National Wetland Inventory (Cowardin et al. 1979). Rules for assigning names in this system are described in Cowardin et al. (1979). Many wetland types are not found in pure stands in the field, but instead consist of two or three interspersed vegetation types. In the Cowardin system, names are assigned to the two most common vegetation cover types present (each with a minimum of 30% areal coverage) and drainage or special conditions in the wetland are indicated by additional codes. The tallest vegetation type receives the Class1 label, the shorter vegetation the Class2 label.

There were 280 different wetland label combinations included in the digital wetland files prepared for the Upper Hudson watershed (Appendix 5 and 6). Of these, the most common vegetation types represented in the wetland labels were forested needle-leaved evergreen (FO4) alone or with needle-leaved evergreen scrub shrub (SS4), and broad-leaved deciduous scrub shrub alone or with persistent-leaved emergent (EM1). These four combinations (PFO4, PFO4/SS1, PSS1, PSS1/EM1) accounted for the eleven most common label types (Appendix 5), 60 percent of the total wetland area (Table 2), and 50 percent of the wetland polygons (Table 3). Two hundred fifty-six of the wetland label types represented only 20 percent of the wetland area. This indicates the degree of complexity that can be expressed using the Cowardin label system and the diversity of landscape positions and wetlands types present in the Greater Upper Hudson watershed.

Wetland hydrologic regime modifiers indicate how wet a wetland is, and when it is likely to be wet. Over 85 percent of the wetland area was in saturated water regimes (water regime labels B and E, Table 4), suggesting high year round water s for most Upper Hudson wetlands.

In some cases, the information can be used to gain an understanding of the types of impacts that are occurring to wetlands. Anecdotal evidence suggests that beaver are increasing in numbers in the Park, and the special beaver modifier in the wetland map may be used as an indication of the extent of beaver present and the types of wetlands and landscape positions they prefer within the limits of the interpretation from aerial photography (Table 5). Signs of beaver were indicated by a b special modifier in the wetland digital map database. Beaver influence was suggested for 17.11 percent of wetland area, and 9.05 percent of pond and lake area (OW polygons) (Table 5), and 13.13 percent of the number of wetland polygons and 42.7 percent of the number of pond and lake polygons (OW polygons) (Table 5).

Unfortunately, the Cowardin labels are really physognomic types, not true vegetation types. The probable vegetation types present in most wetland polygons for most labels can be inferred from the experience of the aerial photograph interpreter. For the Upper Hudson wetland maps, these types are listed in 1. Thus, the Cowardin labels cannot be used directly to find wetlands that contain rare and endangered plants. Indications of where there might be rare and endangered plants may be found using the wetland maps in conjunction with soil and geology maps that may indicate special groundwater or surface water chemistry, or with digital elevation models that may identify wetlands in special topographic positions.

Table 2. Area of Class1 and Class2 Wetland Labels for Wetland Maps in the Greater Upper Hudson Basin. Area in hectares. Abbreviations are as in Table 1.

Class1	Class2 None	/AB3	/EM1	/FO1	/FO2	/FO4	/FO5	/OW	/SS1	/SS2	/SS3	/SS4	/SS5	Total
AB3								54.45						54.45
EM1	3383.70	5.42						671.11						4060.23
FO1	816.17		109.98			569.84	1.09	9.50	1185.13		1.58	78.77		2772.05
FO2	9.37		42.44			27.06	4.07		31.46	8.30	53.28	9.64		185.61
FO4	7165.06		567.21	1025.71	67.56		39.04	54.40	1832.24	6.91	39.62	9691.28	1.17	20490.20
FO5	49.25		124.14		2.84	11.70		1175.43	44.87		1.53	3.19	10.60	1423.54
SS1	1989.43	1.87	10007.03					129.83		4.25	186.62	1039.75	0.80	13359.59
SS2	2.75		21.28						9.85		1.88	2.43		38.19
SS3	310.37		1868.90					64.59	165.92	8.70		89.92	3.18	2511.59
SS4	1651.10		1398.14					13.43	1434.87	58.86	137.14		3.94	4697.48
SS5	1.07		20.31					30.48	1.07		3.12			56.04
Total	15378.26	7.29	14159.42	1025.71	70.40	608.60	44.20	2203.22	4705.39	87.02	424.77	10914.98	19.69	49648.96

Table 3. Number of Polygons for Class1 and Class2 Wetland Labels for Wetland Maps for the Greater Upper Hudson Basin. Abbreviations are as in Table 1.

Class1	Class2 None	/AB3	/EM1	/FO1	/FO2	/FO4	/FO5	/OW	/SS1	/SS2	/SS3	/SS4	/SS5	Total
AB3								25						25
EM1	2231	2						491						2724
FO1	2265		99			730	4	25	812		2	114		4051
FO2	14		22			21	4		14	5	27	8		115
FO4	7010		457	1203	36		44	116	1103	5	18	4313	2	14307
FO5	49		56		2	16		1033	34		2	6	4	1202
SS1	2196	1	3750					136		1	102	705	1	6892
SS2	5		11						9		2	5		32
SS3	396		734					57	93	4		66	1	1351
SS4	1768		1005					27	1052	5	83		4	3944
SS5	3		7					27	1		2			40
Total	15937	3	6141	1203	38	767	52	1937	3118	20	238	5217	12	34683

Table 4. Distribution of Wetland Cover Type Water Regime Labels by Wetland Class1 Label for the Greater Upper Hudson Basin. Area in hectares. Codes for water regime as follows: B saturated, D seasonally flooded-well drained, E seasonally flooded-saturated, F semi-permanently flooded, H permanenetly flooded. Other abbreviations are as in Table 1.

	Water regime				
NWI label	B	D	E	F	H
AB3					56.79
EM1	573.04	5.79	2317.39	497.38	676.53
FO1	1518.19	178.56	1104.04	8.64	10.70
FO2	150.81		34.80		
FO4	14790.48	39.88	5581.88	20.81	63.96
FO5	38.22		127.26	26.90	1231.16
SS1	3546.30	49.10	8179.72	1485.72	159.67
SS2	26.51		11.68		
SS3	1956.26		405.14	40.11	110.08
SS4	3052.73	6.25	1515.44	110.75	14.82
SS5	15.26		4.09	0.30	36.39
Total	25667.81	279.58	19281.45	2190.60	2360.10
Percent of total	51.56	0.56	38.73	4.40	4.74

Table 5. Wetlands with the Beaver Special Modifier (b) by Area and Number of Open Water Polygons and Wetlands Organized by Class 1 Label. The total column contains the sum of the area for all wetlands in the class, or the number of polygons for that class

	area			number		
NWI Label	b	Total	% of total	b	Total	%of Total
AB3	14.22	56.79	25.04	6	27	22.22
EM1	1901.50	4070.12	46.72	1109	2732	40.59
FO1	29.59	2820.13	1.05	43	4066	1.06
FO2	3.65	185.61	1.96	4	115	3.48
FO4	321.23	20497.02	1.57	329	14318	2.30
FO5	1420.14	1423.54	99.76	1195	1202	99.42
SS1	3998.72	13420.52	29.80	1383	6925	19.97
SS2		38.19	0.00		32	0.00
SS3	414.23	2511.59	16.49	217	1351	16.06
SS4	357.02	4700.00	7.60	239	3950	6.05
SS5	56.04	56.04	100.00	40	40	100.00
Total	8516.34	49779.54	17.11	4565	34758	13.13
OW	2954.354	32632.78	9.05	1965	4602	42.70

Upper Hudson Upland Land Cover Classification

This section describes the procedures and data used to create an upland land cover classification map for the Greater Upper Hudson (UH) watershed area using LANDSAT 5 Thematic Mapper (TM) satellite imagery. The upland land-cover map is intended as the upland complement for the wetland maps created as part of this project, and for the corresponding upland classification created for the Oswegatchie/Black (OB) project (Roy et al. 1997).

The Thematic Mapper (TM) senses visible, near-and mid-infrared energy reflected from the Earth's surface in six regions of the spectrum and one region of emitted thermal infrared energy. The reflected radiation is received and stored as a grid of pixels, or cells, that are 30 meters on a side. For each pixel in a TM scene, the spectral pattern of reflectance for the six reflected bands is determined by the ground cover of the pixel. Thus, a scene consists of pixels that contain six-dimensional data that can be grouped into land-cover classes using multivariate statistical methods. An additional TM sensor receives emitted infrared (commonly called thermal) radiation, and stores the information as pixels 120 meters on a side. Because of the coarse resolution, the thermal band degraded the classification when combined with the reflective bands, and it was not used in any of the final classification efforts.

General Classification Method

This section describes the data, methods and processes used to create the upland land-cover map for the Greater Upper Hudson watershed. Because the study area extends into two TM scene frames, scenes from row 14, path 29 and 30 were used. Scenes were available from several dates for use in this effort (see Table 6 for a list of scenes available and the names used in the discussion below). Each available scene was examined for use in the classification. Scenes with defects, such as striping and clouds, were discarded. Three scenes were used in the final land-cover classification.

A scene is composed of grid data that represents geographical locations on the Earth's surface. Geo-referencing allows an image to be used as an overlay with other geo-referenced data. The Northern and Southern images were purchased as raw data from EOSAT and geo-referenced by the Adirondack Lakes Survey Corporation (ALSC), New York State Department of Environmental Conservation, Ray Brook, NY. After they were purchased, it was discovered that

a portion of both images was covered by clouds, and the previously purchased Middle image was used to fill in the space. The Middle image was purchased from EOSAT as a precision corrected product.

The three geo-referenced scenes were classified separately into upland land cover types using unsupervised and supervised classification techniques. In an unsupervised classification,

Table 6. Imagery Assessed for Use in the Upland Land Classification of the Upper Hudson Drainage Basin. Images in bold italics were used in the final classification. North, South, and Middle indicate the source image for these sections in the final product, and referred to by these names in the text. Other images were tested for suitability.

Scene	Date	Georeferenced:	Image Quality	Notes
14/30	May 31, 1995	ALSC	Clouds in NE corner and in center, haze in south	Pre-leaf in high altitude
	July 23, 1997 SOUTH	***ALSC***	***Clouds/haze in NW, Scattered cumulus in west***	***2 clouds (near Lewey Mtn) in section used***
	May 20, 1991	EROS	No clouds Striping in band 3	Leaf-out in lower elevations; pre-leaf in highest elevations
	June 23, 1992 MIDDLE	***EROS***	***Scattered cumulus clouds Striping in bands 1, 2, and 7, very strong in band 3***	***Full leaf-out***
14/29	***June 16, 1995 NORTH***	***ALSC***	***Cloud free***	***Leaf-out***
	August 19, 1995	ALSC	Scattered clouds	Full leaf-out
	May 20, 1991	EROS	No clouds, haze	Leaf-out lower elevations, pre-leaf high elevations; no snow
	August 21, 1990	EROS	Thick clouds in SE corner; scattered clouds S edge and E side: unusable	Full leaf-out

the computer software divides the image into a predetermined number of clusters containing pixels with similar spectral signatures. Image pixels in the same cluster should represent the same land cover type. These clusters are compared with field notes, and other available ground truth data to determine which land cover types they represent. Unsupervised classification can be used to obtain estimates of the spectral signature of different land cover types for comparison with known locations used in supervised classification, and to identify unusual signatures.

The supervised classification was performed using ground-truth knowledge of the area to be analyzed gathered from aerial photographs, field visits and other map-based information. Ground-truth information was used to choose areas in the TM scene to use as training samples. Several training samples representing each land cover class desired in the classified output were chosen. Principal components and other band transformations were utilized to find combinations that enhanced the contrast between land cover types. The classification results were evaluated by comparison to additional ground truth information. The area represented by the South scene was classified first, using both supervised and unsupervised classification. The Middle and North scenes were classified using only supervised classification. The steps and considerations used in the final classification are listed in Table 7.

Data Acquisition

Several TM scenes were available from different projects. All scenes listed in 6 were considered for use in the classification, while only the three scenes in bold type were actually used. The South (June 23, 1997) and North (June 16, 1995) imagery was purchased from EOSAT by the Adirondack Park Agency as part of a separate EPA-funded project. Images were obtained as unrectified full scenes in BSQ format and transformed into UTM Zone 18 projection. The Middle (June 23, 1992) imagery was purchased from EOSAT as part of a New York state-wide purchase agreement for the Northern Forest Lands Inventory and the Lake Champlain Management Conference Program. This scene was purchased as a precision-corrected map oriented product with Transverse Mercator (TM) USGS map zone 61 projection, resampled from the original 30 meter to a 25 meter pixel size (0.15 acres, 0.062 hectares). The scaling parameters match the Universal Transverse Mercator (UTM) Zone 18 parameters of the PC Arc-Info

watersheds and wetlands databases developed for this project. Header files that describe then scene parameters for the images used in this project are located in Appendix 7.

Table 7. Upper Hudson River Drainage Basin Image Processing Variables.

IMAGE REGISTRATION
- check imagery with vector wetlands
- check rasterized wetlands and imagery alignment

IMAGE ENHANCEMENT
- scaling of display based on image histogram
- wetlands rasterization and masking

IMAGE PROCESSING

Unsupervised

Processing Variables
- number of statistical clusters
- initialize from statistics
  - principal axis
  - diagonal axis
- scaling range
- standard deviation
- automatic
- maximum iterations
- convergence threshold
- classification of 0's

Imagery Assessment
- band clarity assessments
  * clouds, haze
  * striping
- band recombination
  * band redundancy
  * principal components

Supervised

Signature Selection
- select quadrangles for training areas
- select training sites
- air photo interpretation; ancillary data
- evaluation of within-class signatures
- evaluation of between-class signatures

Imagery Assessment and Processing Variables
- band recombination
  * band redundancy
  * best separability
  *principal components
- Maximum Likelihood classifier options
  *signature a priori values
  *signature processing order
  *classification of zeros
- Band Clarity Assessments
  * clouds, haze
  * striping

CLASSIFICATION EVALUATION:

Visual assessment
- screen display of classification
- assessment against aerial photographs
- comparison with notes on topographic and planimetric maps
- ellipse plots over feature space diagrams
- threshold (display of signature histograms)

Accuracy assessment
- stratified random pixel selection generated by software
  - for each scene subset classification
  - for entire classified file
- consultation with aerial photographs; ancillary data

GIS FILE MANIPULATION
- replace cloud and cloud shadow raster cells with data derived from air photo interpretation
- merge north, south, and middle images

Rectification and Image Registration

The North and South images were purchased as unrectified images, and were projected using the ERDAS Imagine 8.3.1 rectification procedure by AlSC. Subsets were created that included the Upper Hudson watershed and the surrounding area. Ground control points (GCPs) were entered using road intersections from NYS DOT digital county road maps. Roads were used because they were easily visible on the TM scenes, were well distributed over the study area, and were more reliably located than natural features. Coordinates for the GCPs were obtained by creating an ArcView project that displayed road coverages for the desired region and zooming in to the desired intersection. The coordinate was identified and recorded into a . The same intersection was located on the TM image, and a GCP was entered along with the coordinate derived from ArcView. A fourth-order polynomial transformation was used which required a minimum of 15 GCPs. Seventy four GCPs were used to rectify the North image. The residual mean square (RMS) of the GCPs used in the rectification was 0.4774. The South image had a defect in the northeast corner that could not be removed by rectification. This area was discarded from the scene. The final rectification used 108 points, and had an RMS value of 0.545.

Wetland arcs were displayed over the ERDAS LANDSAT image to verify that the projection and geo-referencing of the Landsat images matched between the data sets. Agreement between the Arc-Info wetland files and the EOSAT precision-corrected imagery was good and between the Arc-Info files and the ALSC geo-referenced imagery was outstanding.

Wetlands Mask

Wetlands were delineated using air photo interpretation on 1:40000 and 1:58000 color infrared transparencies as part of this project (see above). Consequently, their identification was more precise and consistent than could be achieved through TM digital image classification techniques. Therefore, digital wetland files created for the Upper Hudson project were used to mask out wetland pixels on the LANDSAT TM imaging before classification. Individual USGS quadrangle-based digital wetland coverages were joined into a single study-area-wide coverage. Wetland polygon values were re-coded into numeric values based on the file item SYSTEM. Areas outside the study area (SYSTEM = blank) were assigned a value of 0, wetland areas (SYSTEM = P, L1, R2, R3, or R4) were coded 1, and upland areas (SYSTEM = U) were coded

2. The unified wetland coverage was converted to a raster file using Arc-Info POLYGRID with a 25 meter grid size. Linear wetlands were not included in the final raster file. The result was examined using the vector wetlands as an overlay on the rasterized wetlands to verify that wetland polygons, upland polygons, and cells outside the study were correctly coded and transformed. Registration between the TM images and the raster wetland coverages were accep, and wetlands were masked from each image leaving only upland for further classification. In all classification efforts, wetlands were masked from the image before classification.

Preliminary Land Cover Classes

The Upper Hudson drainage basin is predominantly mixed northern hardwood and boreal coniferous forest. While some large areas of pure deciduous forest do occur, coniferous forests are more limited in extent and often are not found in pure stands. There is some agriculture in the watershed to the south and east. Villages tend to be small, and individual dwellings are often widely spaced with interspersed trees and lawns. Non-forested areas include bare rock; gravel pits, rock quarries, roads, golf courses,
ski areas, lawns, tiled agriculture, hay/pasture, mixed shrub and grass pasture, and abandoned pasture with deciduous shrubs, coniferous shrubs, or both.

To ensure similar nomenclature between the two projects, preliminary land cover classes were chosen to match land cover classes used in the EPA Oswegatchie/Black (OB) watershed project (Roy et al. 1997). These classes were: Deciduous forest, Mixed forest, Conifer forest, Deciduous/Open, Open with Vegetation, Open without Vegetation, Cloud, Cloud Shadow, Open Water, and Wetlands. In the OB project, Deciduous forest and Conifer forest classes represented regions where 75% or more of the land cover could be identified as Broadleaf Deciduous trees or Needle-leaved Evergreen trees, respectively. All other forested pixels were placed in the Mixed forest class. Open with Vegetation and Open without Vegetation were non-forested classes. Open with Vegetation includes golf courses, lawns and athletic fields; while Open without Vegetation included rock quarries, gravel pits, parking lots, and commercial buildings. The OB class Deciduous/Open was derived purely from image processing techniques and represents an odd signature that appeared to be open canopied deciduous forest stands. Open

Water and Wetlands were extracted from the wetlands data layer, which was derived from air photo interpretation techniques.

All OB upland land cover classes were selected as preliminary land cover classes for the Upper Hudson image processing. As with the OB classification, Open Water and Wetlands were extracted from the Arc-Info wetlands database. Image analyses for the UH project demonstrated that the Mixed forest class could be subdivided into Deciduous/Conifer forest and Conifer/Deciduous forest, and that the Deciduous/Open class that had been observed in the Oswegatchie and Black watersheds was not observed in the Upper Hudson watershed. In the Upper Hudson land cover analysis, Cloud and Cloud Shadow regions were limited in extent and either interpreted from other satellite data sources or replaced through air photo interpretations.

Training Sample Selection

Potential training sample and classification accuracy sites were identified on aerial photography and sketched onto USGS 7.5' topographic maps or 7.5' planimetric plots prior to image classification. Representative training samples were chosen for each preliminary land class type. The Glen, Jackson Summit, and Lake Luzerne, Mount Adams, Paradox Lake, Tahawus, Blue Ridge, and Eagle Lake quadrangles all contain a mix of landcover types and were used for training signature selection. In addition, the Broadalbin quadrangle was used for locating signatures for roads, agriculture and shrubs, and the Bullhead Mountain quadrangle was chosen for higher elevation forests in the southern and middle scenes.

Training samples were chosen in areas that typified each upland land cover class. Training samples were selected based on air photo interpretation and field reconnaissance. Aerial photographs used in the wetlands delineations (1985-1986 1:58000 and 1994-1995 1:40000 color infrared transparencies) were examined for appropriate training samples. Bullhead Mountain and The Glen were chosen as the primary quadrangles for training samples because of their position in the study area, the diversity of landcover types present, and range of elevation. Field work to view specific signatures noted on aerial photographs was undertaken in the eastern part of the study area and the Sacandaga Reservoir area.

Training sample selections for both Conifer forest and Deciduous forest were confined to areas that were either pure stands or had rare inclusions of other classes. Mixed

Conifer/Deciduous forest training samples were collected in areas with an estimated 75% conifer and vice versa for mixed Deciduous/Conifer training samples. Open with Vegetation training samples were collected in areas with ground cover but no trees, such as golf course fairways/greens, ski areas, and hay fields. It was very difficult to find training samples for Open without Vegetation because areas of bare rock, gravel pits, and stone quarries were quite small.

Unsupervised Classifications

Unsupervised classifications were conducted on the best quality imagery covering most of the study area (Scene 14/30 dates May 31, 1995, July 23, 1997, and May 20, 1991). Unsupervised classifications were performed using 25 output classes. Clusters were assigned land cover values based on photo interpretation using Bullhead Mountain and The Glen quadrangles, and checked against other quadrangles for consistency. A summer leaf-on (July 1997) unsupervised classification indicated that the final classification should be able to distinguish between Deciduous with Conifer forest and Conifer with Deciduous forest, so these were added to the land cover class list. Review of the unsupervised classes showed no unusual or unidentifiable signatures, and demonstrated that the OB land cover classes were sui for the Upper Hudson Project. The unsupervised classifications showed that additional spring leaf-off imagery training samples, samples for high and low elevation deciduous forest, and mixed conifer/deciduous forest would be needed.

Supervised Classification

Using the initial training samples, Jefferies-Matusita and Transformed Divergence separability analyses were conducted (ERDAS 1991). These tests indicated that Bands 2 versus 5, Bands 5 versus 7, and Bands 3 versus 4 were most valuable for evaluating separability of training samples. Feature space diagrams were created using these bands and training samples were shown as ellipses on the feature space plots.

The ERDAS procedure THRESH (ERDAS 1991) also was used to evaluate training samples and improve classifications. The digital numbers of the pixels that make up each signature can be described in relation to the mean and standard deviation of the digital numbers of the pixels in the training sample. Poor training samples result in signatures that have more than one peak, show a curve that is not smooth, or are not centered at the origin. A distance file

that indicates how far each classified pixel is from the mean of the training sample was displayed as a histogram. Pixels that occupy the tails of the histogram are most likely to be mis-classified, and can be eliminated from the class using THRESH. THRESH was used mainly to refine Conifer forest classes, although, very few pixels were changed.

South Image

Several different classifications were attempted using images from row path 14/30, including principal components transformations, and combinations of leaf-on (July 23, 1997) and leaf-off (May 20, 1991) images. The ERDAS Maximum Likelihood classifier (ERDAS 1991) was used for all classification attempts. This method allows the analyst to assign *a priori* probabilities to each landcover type before classification. Training samples were assigned equal weights, normalized weights (the sum of probabilities for all signatures equals 1), and user-assigned probabilities. The best classification resulted from an analysis of the leaf-on July 1997 image. Cloudy areas in the northeast section were removed from the final classified image and were replaced with the cloud-free imagery from the Middle image.

Middle Image

Classification of the Middle image employed the techniques developed for the South image. The best classification for the Middle region was obtained with Scene 14/30 imagery date June 23, 1992. Clouds in this image necessitated adding classes for Cloud and Cloud Shadow. The scene was classified with the cloud classes and without Band 3, which exhibited severe striping. Cloud and Cloud Shadow pixels in the subset used in the final classification were examined and land cover values re-assigned based on air photo interpretations. This subset comprised approximately 16% of the final image.

North Image

The northern area of the watershed was obtained from the June 16, 1995 image from 14/29 row path. The June 1995 image was the most sui image in terms of image quality, leaf-out condition, and clouds. Training samples were collected primarily from the Mount Adams and Tahawus quadrangles. Additional training samples were collected from the Paradox Lake quadrangle for Deciduous forest and Conifer forest . The image was processed using the same procedures described above. All classifications were run with the Maximum Likelihood

classifier. Classifications were evaluated in the area that overlapped with the southern image in the Blue Ridge quadrangle, and with the northeast corner of the southern classified file particularly in the Eagle Lake and Paradox Lake quadrangles. Approximately 8% of the study area is found in the northern subset.

Merging Files

Aerial photographs were used to assess which classification best represented upland land cover in overlap areas, and how to subset the files. Polygons were created to subset the classified images. Subset boundaries followed roads or rivers as much as possible to produce a seamless product (Figure 4). Files subsets were merged with the classified South image overwriting the classifications of both the Middle and North images, except in the Blue Ridge quadrangle where the Middle image classification was retained. The Middle image was chosen in preference to the North image where they overlapped.

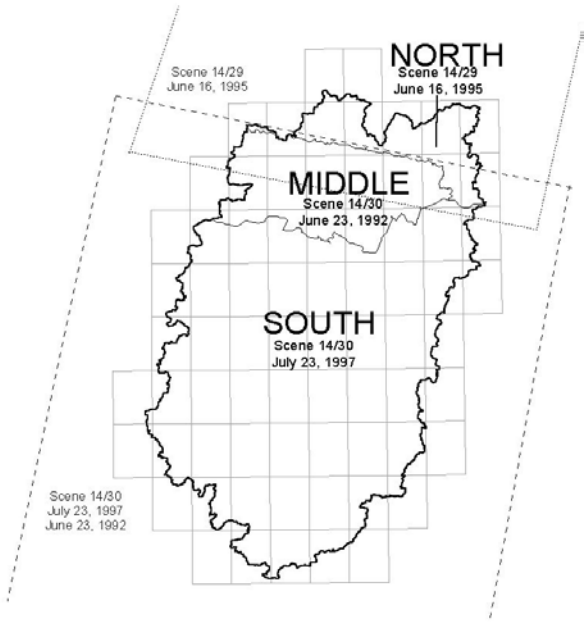

Figure 4. Map of the Upper Hudson Watershed Showing Which TM Scenes Were Used for Which Areas in the Final Classified File.

Accuracy Assessment

The classification accuracy assessment report for the final upland landcover image was created from 316 pixels gathered from the South, Middle, and North classified scenes (221, 52, and 43 pixels respectively). Points were chosen for assessment of classification accuracy by stratified random sampling of the classified image files. Unclassified pixels (wetlands and background) were excluded from consideration. Classification accuracy points were checked against aerial photography (1994-95 1:40000 color infrared aerial transparencies and, in a few cases, 1985-86 1:58000 color infrared aerial transparencies). Where

the air photo interpretation differed from the classified file value, the photos were rechecked. Misclassified pixels often occurred in areas where mixed land cover classes existed, and the predominant land cover class was difficult to ascertain. Much of the study area is covered with mixed forests, with varying proportions of coniferous and deciduous trees. The percentage of each scene included in the final classified scene were sed to make a weighted accuracy assessment and to verify that the classification accuracy points used for each scene were representative of the overall file.

Overall classification accuracy was computed by dividing the total number of correct pixels by the total number of classified pixels. Accuracy assessments also may be expressed as producer's accuracy or user's accuracy. The producer's accuracy is determined by the number of pixels classified correctly divided by the number of pixels in a given class according to ground truth information for that land class. User's accuracy is an dividing the number of pixels classified correctly in the final image by the number of pixels evaluation of how well the classified file represents ground conditions and is calculated by classified into that land cover class. The value assesses how well that land cover class in the final digital file represents ground conditions. The overall accuracy is an expression of the user's accuracy across all classes. The classification accuracy assessment report for the Upper Hudson Watershed upland landcover file is shown in Table 8. The overall classification accuracy for the final merged scene was 85.76%. Producer's and user's accuracy for the final landcover classes are shown in Table 9.

Discussion

The study area is a mix of deciduous and coniferous forest cover types with small patches of open non-forested land and dwellings interspersed in all cover types. Densely settled urban and residential areas are not common. Individual houses and small clusters of homes were generally classified as Open withVegetation, and Open without Vegetation, although many homes obscured by trees were probably included in the forested land cover classes.

Based on intensive evaluation of aerial photographs, the primary division between forested and non-forested (open land) land cover classes is reliable, and reflects actual ground conditions. Examination of aerial photographs suggests that areas dominated by small shrubs and early tree regeneration were placed in the Open with Vegetation class, while larger saplings were

		Reference Data						
Classified Data	Scene	Deciduous	Deciduous/ Conifer	Conifer/ Deciduous	Conifer	Open with Vegetation	Open without Vegetation	Totals
Deciduous	South	**78**	12	1	0	0	0	**91**
	Middle	**24**	0	0	0	0	0	**24**
	North	**15**	3	0	0	0	0	**18**
	Final	**117**	15	1	0	0	0	**133**
Deciduous/ Conifer	South	6	**39**	3	1	1	0	**50**
	Middle	1	**10**	0	0	0	0	**11**
	North	0	**5**	1	0	0	0	**6**
	Final	7	**54**	4	1	1	0	**67**
Conifer/ Deciduous	South	0	2	**25**	3	0	0	**30**
	Middle	0	0	**7**	1	0	0	**8**
	North	1	0	**6**	0	0	0	**7**
	Final	1	2	**38**	4	0	0	**45**
Conifer	South	1	1	5	**28**	0	0	**35**
	Middle	0	0	0	**5**	0	0	**5**
	North	0	0	0	**10**	0	0	**10**
	Final	1	1	5	**43**	0	0	**50**
Open with Vegetation	South	0	0	0	0	**12**	1	**13**
	Middle	1	0	0	0	**3**	0	**4**
	North	0	0	0	0	**1**	0	**1**
	Final	1	0	0	0	**16**	1	**18**
Open without Vegetation	South	0	0	0	0	0	**2**	**2**
	Middle	0	0	0	0	0	**0**	**0**
	North	0	0	0	0	0	**1**	**1**
	Final	0	0	0	0	0	**3**	**3**
Totals	South	**85**	**54**	**34**	**32**	**13**	**3**	***217***
	Middle	**26**	**10**	**7**	**6**	**3**	**0**	***52***
	North	**16**	**8**	**7**	**10**	**1**	**1**	***43***
	Final	**127**	**72**	**48**	**48**	**17**	**4**	***316***

Table 8. Classification Accuracy Assessment Report for the Upper Hudson River Watershed Upland Land Cover Image. Error Matrix Derived from Areas Used in the Final Classified Image. Reference data were obtained from field visits and aerial photography. Numbers in the indicate the number of TM image cells.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Deciduous	127	133	117	92.13%	87.97%
Deciduous/Conifer	72	67	54	75.00%	80.60%
Conifer/Deciduous	48	45	38	79.17%	84.44%
Conifer	48	50	43	89.58%	86.00%
Open with Vegetation	17	18	16	94.12%	88.89%
Open without Vegetation	4	3	3	75.00%	75.00%
Totals	316	316	271		

Table 9. Accuracy of Land Cover Classes Derived from the Full Classified File. Producers Accuracy = Number Correct / Reference Totals. Users Accuracy = Number Correct / Classified Totals. See text for explanation.

classified as one of the forest land cover classes.

The intention of the division between Deciduous with Conifer, and Conifer with Deciduous land cover classes was to identify mixed forest stands that contained a preponderance of either deciduous or coniferous trees. The percentage mix of coniferous and deciduous trees in many forest stands varies greatly. Training samples for the mixed forest land cover classes were obtained in areas where one forest type was clearly dominant over the other. The ideal mixed forest training sample contained approximately 75% of either deciduous or coniferous trees. Pure Deciduous or Conifer forests were preferentially classified by processing these classes first and assigning them a probability of one. Mixed forest classes (Deciduous/Conifer, and Conifer/Deciduous) were always given lower probability than pure forest classes in both order of processing, and *a priori* probabilities. Class probabilities for the mixed forest classes were manipulated until classifications represented forest cover types as determined by air photo interpretations. Some deciduous forest stands contained many pixels of Open with Vegetation. Air photo checks suggest that these areas have an open canopy. Many of these regions appear to have been lumbered.

Although good sites from which to select training samples for Open with Vegetation and Open without Vegetation were limited, these distinctive signatures were verified at various locations across the study area. Roadways are represented by both land cover classes. Many roads were obscured by tree crowns, and therefore these classes do not fully represent transportation corridors. Gravel pits were classified as Open without Vegetation.

Summary

A major goal of this project was to create a classification that was comparable to the classified land cover file created for the OB project. The process of including wetlands and open waterbodies in the final classified file was the same for both watersheds. Unsupervised classification of the Landsat TM data for the UH watershed demonstrated that the Mixed forest class used in the OB project could be refined into two classes in the UH. The Deciduous forest, Coniferous forest, Open with Vegetation, and Open without Vegetation land cover classes have identical definitions to the final classified file produced by the OB project. Metadata for this image can be found in Appendix 8. A more detailed report of the procedures and images used in this classification can be obtained from the Remote Sensing Laboratory at the State University of New York at Plattsburgh.

Adirondack Park Agency Permit Records

One of the responsibilities of the Adirondack Park Agency is to evaluate activities undertaken within the Park boundary by private individuals on private land and public agencies on public land for compliance and compatibility with the three legislative acts the Agency administers. When these activities are approved by the Agency members, or the Director of Regulatory Programs at their behest, a permit is issued. These permits usually apply to a designated location that corresponds to a tax map parcel. The location is recorded on a paper map, and becomes an official part of the permit that is issued. In most cases the permit location is drawn onto a section of a USGS 1:24000 quadrangle map and copied onto the back of the approved permit notice. In special cases where the project permit affects an area of large size, or the nature of the project warrants, the project map included with the file is of a different size or scale.

The location of projects and the permit conditions are important considerations in future applications to the Agency for activities on the same parcel of land, and may be considered in future applications in the nearby area as potential sources of cumulative impact. For these reasons, starting in 1992, the Agency undertook a project to digitize the location of permits that have been issued since the inception of the Agency in 1973. Applications remaining from that earlier project and new applications up to 1998 were digitized as part of this project. The procedure used in this continuation differed from the earlier effort, and the differences are described here. In addition, a procedure was set up so that new Project Application maps could be entered into the database as the permit applications were completed.

As part of the permit application procedure, the environmental program specialist in charge of the permit application prepares a map of the tax parcel affected by the application. Permit application location maps are usually drawn by transferring the tax map parcel from a tax map in the Agency files to the permit map.

While most of the over 1400 permit maps examined for this project were adequate for digitizing, many did not contain enough information to locate the boundaries of the project. This happened for two reasons. First, many of the rejected maps were made from the Agency lookup system which generates a nice looking map, but indicates a project location with a symbol, and

does not draw the project boundary. Second, in some cases, the environmental program specialist drew only the approximate boundaries of the project, or indicated the project location with an arrow or an **X**. These maps were redrawn.

In a few cases, the area affected by a project is much smaller than the parcel on which it is undertaken, for instance, a small gravel pit on a tract of several thousand acres. In these cases, the permit map may show only the location affected by the actual permitted activity. Where the activity is linked to a structure or a location (such as a culvert replacement or a microwave repeater tower) rather than a tax parcel, the permit map may show a well defined geographic area that includes the permitted activity.

The project map is not intended to show the actual location of project activity, or the area that is directly impacted by the project. The project location map is used by environmental program specialists to discover if new permit applications involve a property that is already encumbered by a permit. To assign a set of map coordinates to the project activity would require a mapping effort in the field that is not currently practical in the time available. As the accuracy of GPS receivers improves and their cost goes down, mapping the actual impact site will become a reasonable consideration.

The 1992 Project Digitizing Procedure

In the 1992 conversion project, historical project locations were transferred from permit maps to clean 1:24000 USGS maps. Once all the projects were transferred, the polygons on each USGS map were digitized using a Calcomp 9000 digitizing t and Arc-Info. Following this, errors in the digitized polygons were corrected by removing dangling arcs and closing open polygons. Each polygon was assigned its permit number and finally, all the digitized map sheets were merged into one geographic coverage.

The procedure was accurate in locating the projects as they were drawn, but was time consuming, and required technical training in the operation of the digitizing and the process for projecting polygons and correcting errors. Since the initial project was undertaken, the technology for adding new project data to the project database has improved. The New York State Department of Transportation (DOT) has supplied scanned copies of the 1:24,000 scale USGS planimetric maps for the Park that contain the same background information that was used

to create the project file maps. Also, the software for adding new data has improved so that it can be digitized on screen over a background of the planimetric maps with a little technical training in the use of the software. Because of these improvements, and because the expected use of the project location data set does not include using the size or location of the digitized project polygon for other than representation of the permit location, a faster, simpler, but less accurate procedure was designed. This procedure is summarized briefly below, and described in detail in Appendix 9.

New Project Digitizing Procedure

Project maps were sorted by USGS 7.5' topographic quadrangle and digitized using the GIS software Arc-View. A separate view was created for each quadrangle map, and of the appropriate digital DOT planimetric map was added to the view. A new map theme was created within the view to hold the permit location polygons. Polygons were added to the new theme by matching the spatial information on the project map with spatial information on the computer screen. The project application number and year were added to the data for the new polygon theme. After digitizing, project maps were converted to Arc-Info coverages and appended together using a batch program (see Appendix 10). The permit information for each polygon was quality checked using an Arc-Info program with menu choices that allowed the operator to select polygons from the screen, or by project year and number, and change the project information when necessary. The finished map is shown in Figure 5. Metadata for this dataset can be found in Appendix 11.

Future Improvement

Most permit maps are based on a tax map parcel. As counties develop their own geographic information systems, one of the first datasets that will be converted will be tax maps. The Agency should begin purchasing digital tax maps for each county as they become available. These maps will allow project officers to locate their parcel more +quickly. These maps will contain more accurate boundary lines than can be created by the method used in 1992 or in this project. These will also allow more complete permit histories to be constructed for the parcels, and may allow the location of the actual permit activity to be mapped within the parcel polygon.

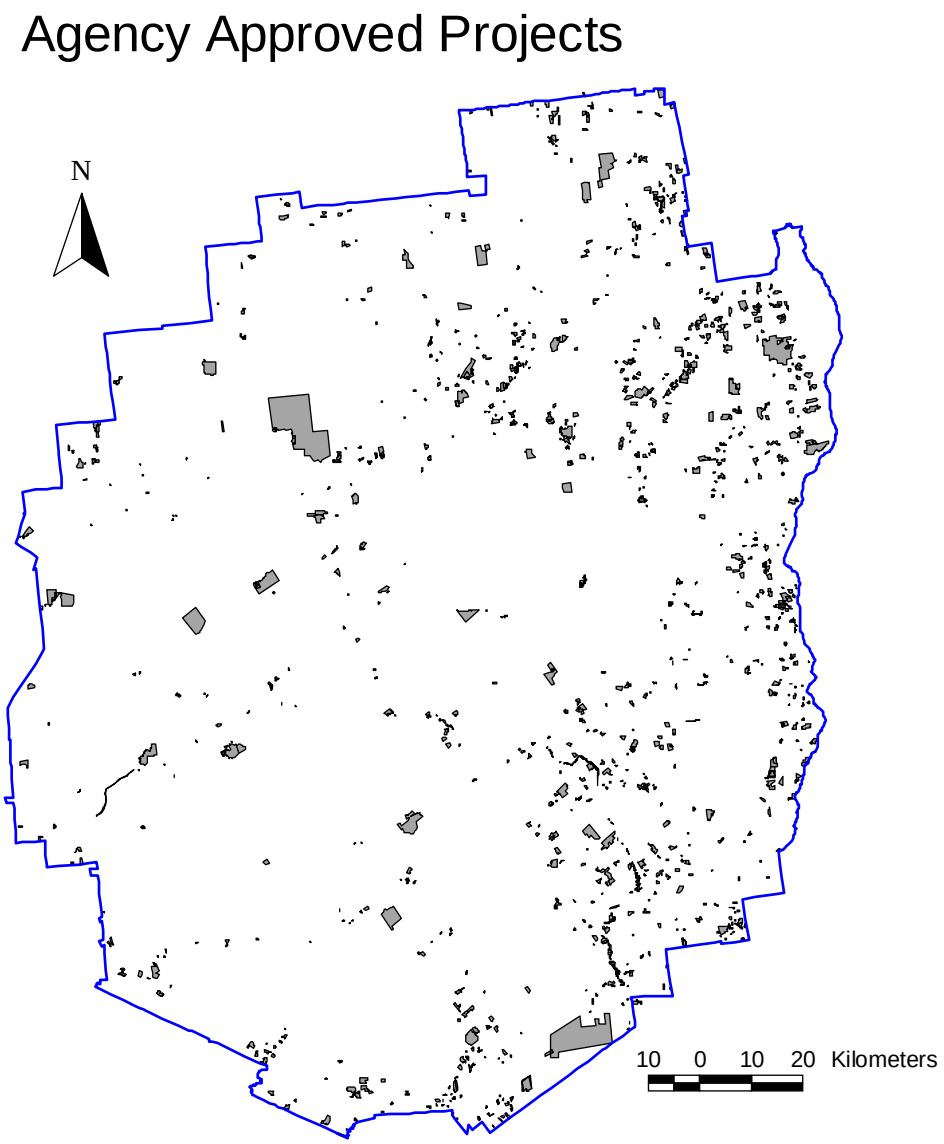

Figure 5. Map Showing the Location of Projects Approved by the Adirondack Park Agency Between 1990 and 1997. Polygons on the map represent the tax parcel boundaries for parcels where applications were made and approved by the Agency.

Once digital tax maps are available, several steps can increase the speed and accuracy of the Agency Approved Permit map updates. The first step would be to make the digital tax maps a prin part of the Agency lookup system. This would provide accurate boundaries on a paper map that could be included in the project file. The officer in charge of the permit application could select the tax map polygon on screen and save it to a temporary file from which it can be added to the project database. The temporary file should be examined before it is included in the permanent permit map database to insure each entry's accuracy and completeness. For projects that are not described by a tax map parcel boundary, a system similar to the on-screen digitizing procedure used in this project should be used.

1916 Fire Map

This project extends work started in the Oswegatchie and Black watershed mapping project (Roy et al. 1997) to identify the location of major disturbances to the landscape. Such known and documented disturbances include a series of major forest fires that occurred at the turn of the last century.

According to McMartin (1994), in the Adirondacks "before 1890, fires had been small and scattered. In the period between 1890 and 1910, however, fires, mostly caused by railroad locomotives, plagued landowners, seriously affecting timber tracts for the first time." Much of the Adirondacks was burned by devastating fires between 1903 and 1908 (Barret et al.. 1961). McMartin (1994) estimates that over one million acres burned Park wide during this period.

Forest fires significantly affect landscape processes in several ways. Organic matter on the forest floor is oxidized, eliminating ion exchange sites for nutrients. The exposed soil surface is reduced to ash, which increases the potential for erosion from uplands to lowlands. The effects of the fires described above are still apparent on the landscape today (Kudish 1992).

Prior to the Oswegatchie Black Watershed Project, no digital map data showing historical fires existed for the Adirondack Park. A paper map of fire disturbance for the period between 1890 and 1910 was prepared by K. Schmitt and others, for the State of New York Conservation Commission (Schmitt et al. 1916). This map, which was originally prepared to show the location of fire fighting resources and identify regions potentially vulnerable to fire, is the best available description of forest fire history for northern New York.

Conversion of the Paper Map to Digital form

The Upper Hudson portion of the 1916 fire map was transferred to a mylar overlay to protect the original map from excess handling. Polygons on the original map were drawn onto the mylar along with codes identifying the landscape fire class of the polygon. The projection of the paper map is unknown, but the map includes lines of latitude and longitude, and the intersections of these lines were transferred to the mylar for use in projecting the map. The mylar was scanned to a TIFF format file using an ANATech E sized scanner at 300 DPI. The polygon outlines in the resulting TIFF file were converted from raster to vector form using Arc-Info (GRIDLINE). Errors and extraneous lines present in the vector line coverage were cleaned using the ARCEDIT

module of Arc-Info, and converted to a polygon coverage. The appropriate value was assigned to an item in the polygon attribute (PAT) for each polygon. These values were checked by comparing each polygon with the original. Missing polygons were added and mistakes in the polygon attribute values were corrected. Finally, the map (Figure 6) was projected to UTM coordinates using the latitude and longitude locations on the scanned map.

Discussion

The 1916 fire history map has several limitations that should be understood by the user. It was originally drawn at a scale of one inch equals two miles, or roughly 1:125000 scale. The map is drawn on a non-s medium that changes size and shape with humidity. The methods by which features depicted on the map were located on the base map is unknown, and the actual location of the features on the ground may vary considerably. Because of these factors, the location of the smaller polygons may not be as correct as desired, and there will certainly be errors in classification at all polygon edges.

For the Upper Hudson, the map shows the pattern of 19th century settlement (Figure 6: OPEN LAND-farmland and grazing), along valley bottoms and near streams and bodies of water. The map gives the impression that cutting occurred primarily in large blocks near settled areas in Warren and Essex counties. The more remote areas in the western part of the watershed were left relatively undisturbed, although some large areas in the northwest were selectively cut for softwood. The map does not include logging or fires that took place after 1916. Metadata for this map can be found in Appendix 12.

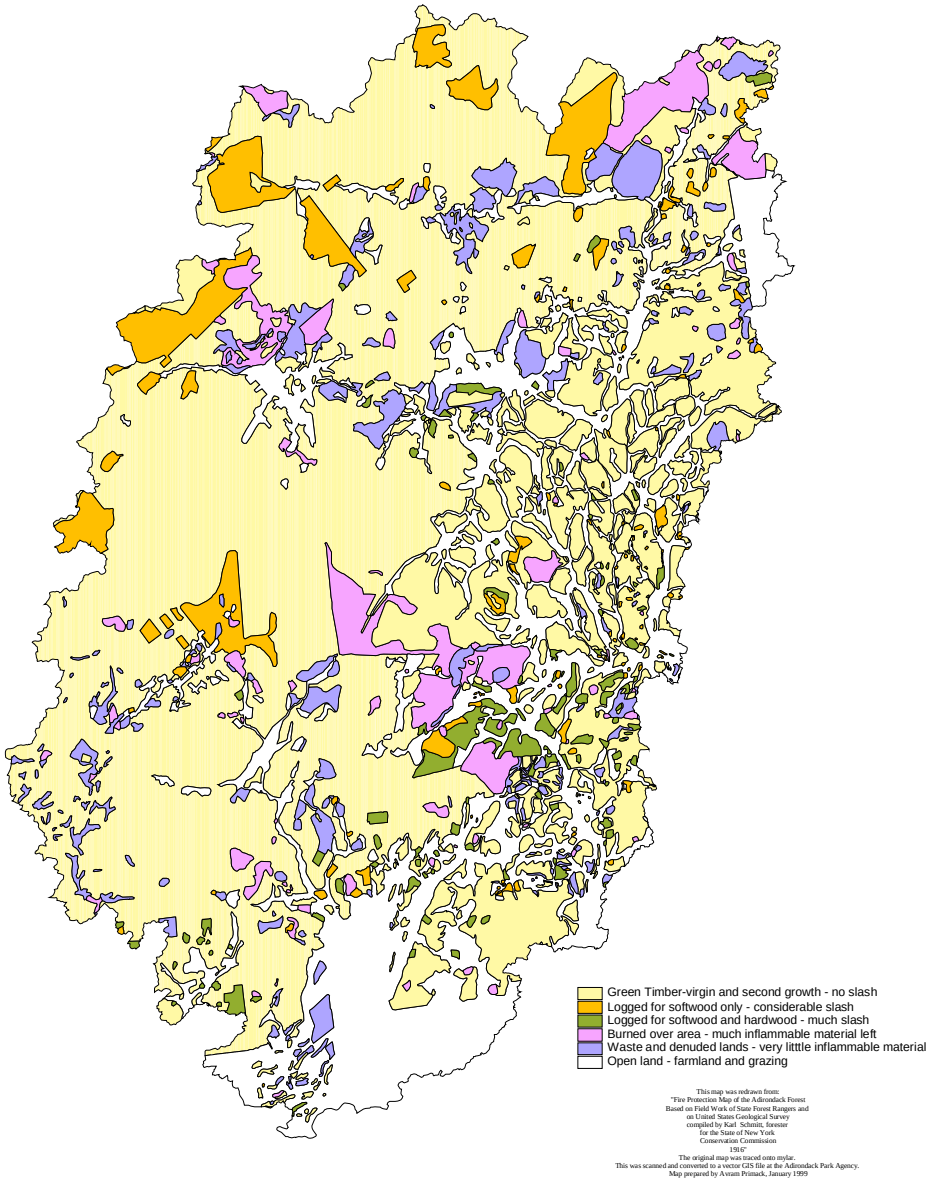

Figure 6. Upper Hudson Section of the 1916 Fire Map Derived from Schmitt et al. 1916.

Sewer District Maps

During the early part of the project, it became clear that onsite septic systems were an important potential source of nutrient enrichment to aquatic systems. Rural dwellings are most likely to be using septic fields for sewage disposal, however, many hamlets have sewage disposal plants. In order to properly treat development in these areas from a nutrient point of view it was necessary to create a map of the locations of sewer districts. A letter was sent to each of the town and municipal jurisdictions with area inside the Park, requesting a map of sewage districts, if any, located in the town. The number of sewage districts that replied was checked against the number of permits issued by New York State Department of Environmental Conservation, and towns with missing districts were recontacted until the location of each sewer district was determined. The final map includes a district for each permit location. Maps were digitized using the same procedure as used above for the Agency Approved Project Permits map (see Appendix 9). The final map is shown in Figure 7. Metadata for this layer can be found in Appendix 13.

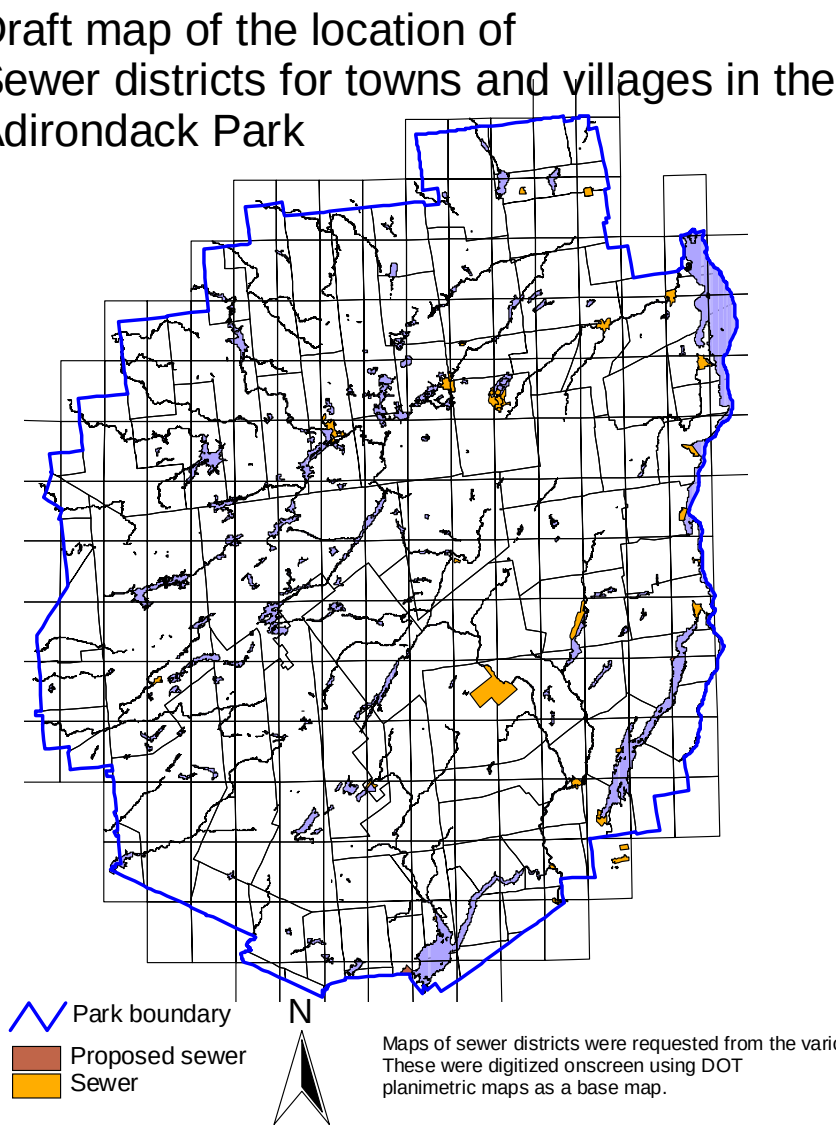

Figure 7. The Location of Existing and Proposed Sewer Districts in the Adirondack Park. Lines not in the key include county boundaries and quad map boundaries to show location.