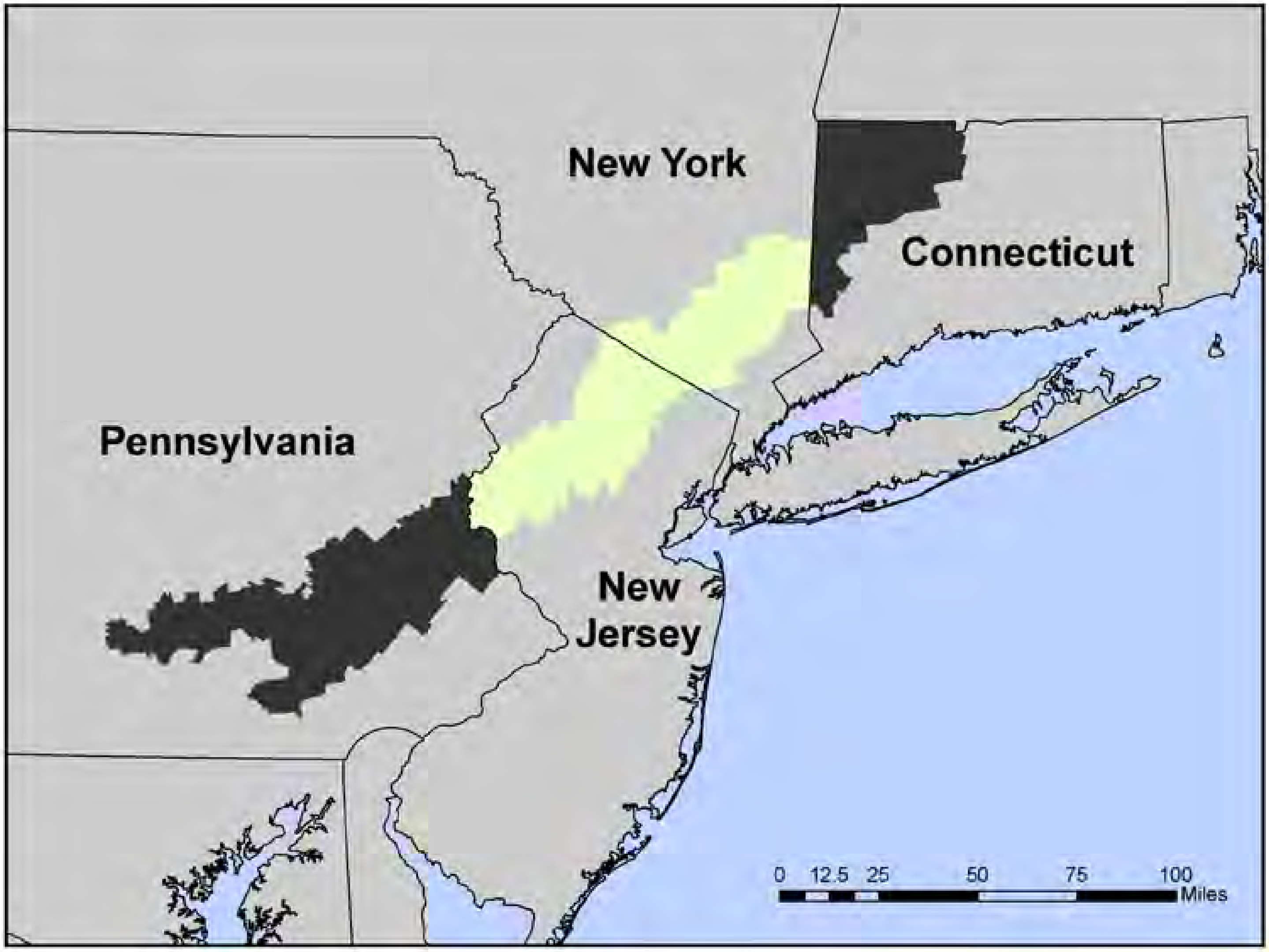
Highlands Regional Study: Connecticut and Pennsylvania 2010 Update

United States Department of Agriculture
Forest Service
Northeastern Area State and Private Forestry
Newtown Square, PA

NA-TP-01-11

November 2010



The addition of the Connecticut and Pennsylvania Highlands extends the New York – New Jersey Highlands boundary by approximately 2 million acres, for a total of 3.5 million acres in the four-state Highlands region.

Cover: Neversink Mountain Reserve overlooking Reading and Mt. Penn, PA (Photo by Jenn Heisey)

Highlands Regional Study: Connecticut and Pennsylvania 2010 Update

Martina C. Barnes, Compiler

United States Department of Agriculture
Forest Service
Northeastern Area State and Private Forestry
11 Campus Boulevard, Suite 200
Newtown Square, PA 19073
www.na.fs.fed.us

NA-TP-01-11
November 2010

Acknowledgments

A large team of colleagues and partners was responsible for making this study possible,and the compiler thanks each of them for their contributions to this project. Special thanks go to Edward Boyer, Highlands Coordinator, U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry, who played an integral part in organizing and managing the study process from the beginning, and for writing the first report draft.

Thanks go to members of the study teams for the Conservation Values Assessment, and the Resource Characteristics and Growth and Impact Analysis, who guided the study process, conducted the analyses and prepared the report, and patiently wrote and rewrote several drafts:

- Mary Tyrrell, Ann Camp, Ellen Hawes, Samuel Price, and Larissa Yocum of Yale University's Global Institute of Sustainable Forestry for overall coordination of the forest and agricultural resource analysis, and growth and impact analysis.
- Myrna Hall and Seth Myers of the State University of New York, College of Environmental Science and Forestry for the growth model and impact analysis.
- Nels Barrett of the USDA Natural Resources Conservation Service for ecological mapping and classification.
- Rob Pirani, Jennifer Cox, John Atkin, Emily J. Moos, and Heidi Wailand of the Regional Plan Association for coordinating public input (Connecticut only) and the build-out analysis.
- Rick Lathrop of Rutgers University Center for Remote Sensing and Spatial Analysis for the Highlands Regional Information System.
- Helen Butalla, Brett Butler, Constance Carpenter, Robert Fitzhenry, Mary Paterson, Chuck Reger, Jim Steinman, and Ann Steketee of the Northeastern Area State and Private Forestry, for study coordination and technical support.

Thanks go to the following study team members for the Connecticut portion of the study:

- Tom Worthley and Joel Stocker of the University of Connecticut Cooperative Extension System, for the agricultural and forest resources analysis and GIS mapping.
- Fred Borman, Helene Hochholzer, Chris Martin, and Susan Peterson of Connecticut's Department of Environmental Protection, for the forest resources analysis.
- Virginia de Lima, Elizabeth Ahearn, and David M. Bjerklie of the U.S. Geological Survey, Connecticut Water Science Center, for the water resources analysis.

Thanks go to the following study team members for the Pennsylvania portion of the study:

- Jim Finley, Al Luloff, Mark McDill, and Wayne Myers of Pennsylvania State University, for overall coordination of the public input, forest resource analysis, and GIS mapping.
- Curtis Schreffler, Edward Koerkel, Patricia Lietman, and Tammy Zimmerman of the U.S. Geological Survey, Pennsylvania Water Science Center, for the water resources analysis.
- Clare Billett of the Natural Lands Trust, for the biological resources analysis.
- Kristen Sykes of the Appalachian Mountain Club, for contributions to the public input section.
- John Storelli, Ken Kimball, and David Publicover of the Appalachian Mountain Club, for GIS mapping and resource analysis.

- Dan Devlin, Diane Kripas, and Stuart Reese of the Pennsylvania Department of Conservation and Natural Resources, for the forest resource and geology analysis and general resource assistance.
- John Booser and Diane Wilson of the Pennsylvania Department of Environmental Protection, for general resource assistance.

The following organizations and individuals provided valuable data and advice, without which this analysis would not have been possible.

Bret Magdasy, Appalachian Mountain Club
Jessica Rittler Sanchez, Delaware River Basin Commission
Debra Lermitte, Wildlands Conservancy
Laurie Schoonhoven, Sustainable Forestry Partnership
Todd Stell, Stell Environmental Enterprises
David Jastenski, Pennsylvania Department of Environmental Protection
Arianna Proctor, Pennsylvania Department of Environmental Protection
Diane Matthews-Gehringer, Wildlands Conservancy
Mary Walsh, the Nature Conservancy, Pennsylvania Natural Heritage Program
Kirk D. Sinclair, Housatonic Valley Association
Elaine LaBella, Housatonic Valley Association

The Creative Services Staff of the Northeastern Area State and Private Forestry provided invaluable contributions—Roberta Burzynski for her patience and thoroughness in editing this report, and Juliette Watts for her creativity in designing and producing the layout.

This Highlands Regional Study: Connecticut-Pennsylvania 2010 Update was accomplished through the cooperation of Federal and State agencies, universities, and non-profit organizations:

U.S. Forest Service
U.S. Geological Survey
Yale University
Pennsylvania State University
University of Connecticut Extension
Rutgers University Center for Remote Sensing and Spatial Analysis
Pennsylvania Department of Conservation and Natural Resources
Connecticut Department of Environmental Protection
Regional Plan Association

Table of Contents

List of Figures

List of Tables

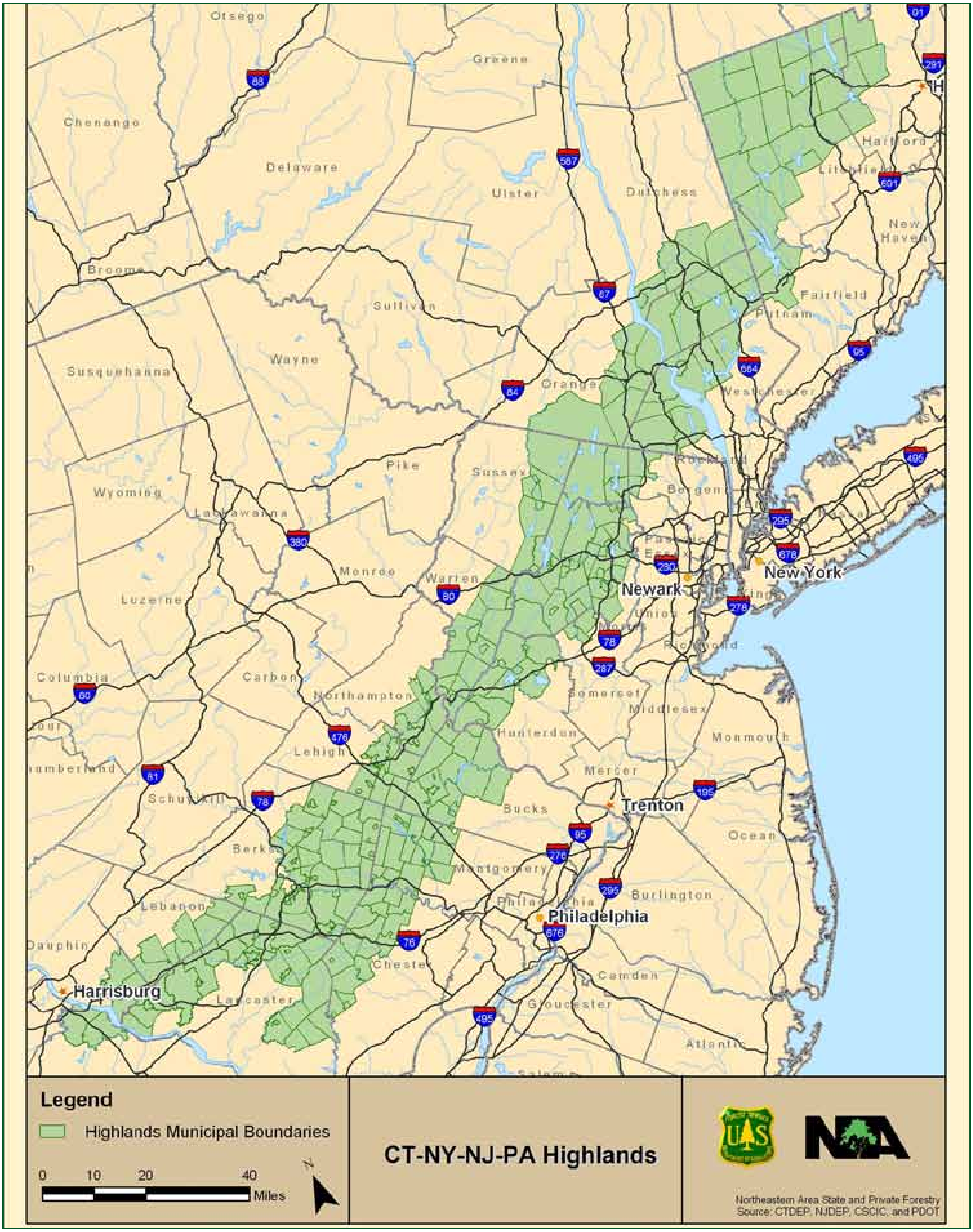


Figure 1. Four-state Highlands region. *The Highlands region was identified as nationally significant by Congress in 2004 with the passage of the Federal Highlands Conservation Act. The region contains 3.4 million acres, 25 counties, and 319 municipalities.*

Section 1. Introduction

Background

The boundary of the Highlands region has been expanding over the years in response to state involvement and Congressional directives. Most recently, the Connecticut and Pennsylvania Highlands were added to the New York and New Jersey Highlands, with the passage of the Federal Highlands Conservation Act of 2004 (P.L. 108-42, United States Statutes at Large). The resulting Highlands boundary now encompasses 3.4 million acres, 25 counties, and 319 municipalities (Figure 1).

The four-state Highlands region contains a wealth of natural resources and associated benefits: forests of oak, hickory, ash, pine, and hemlock; a rugged landscape of discontinuous, steep-sided ridges and plateaus; streams and lakes that provide drinking water for millions; forests that provide timber and game, and shelter hundreds of rare and beautiful plants and animals; and open spaces that offer diverse recreational opportunities. Development threatens to erase, fragment, and degrade forests, streams, and plant and animal communities in the Highlands. Also threatened are the benefits that these natural resources provide for residents of the Highlands and the vast metropolitan area to the east, such as clean drinking water and unfragmented forests.

The 2004 Highlands Conservation Act (Section 2, Purposes and Section 3, Definitions) recognized this region as having national significance to the United States and stated that the Forest Service, U.S. Department of Agriculture, will complete a report that "identifies areas having high conservation values in the States of Connecticut and Pennsylvania in a manner similar to that utilized in the Study and Update" (Appendix A). The Study refers to the original New York – New Jersey Highlands Regional Study (Michaels and others 1992), and the Update refers to the New York – New Jersey 2002 Update (Phelps and Hoppe 2002). This Connecticut and Pennsylvania Update is the third report on the Highlands region published by the U.S. Forest Service. Each of these studies recognizes the natural resources and their geographic scope, in order to help provide a proper balance between environmental stewardship, and economic and housing demands.

Original New York – New Jersey Study

The original Highlands study was authorized by the 1990 Farm Bill (Food Agricultural Conservation and Trade Act of 1990, P. L. 101-624, 104 Stat. 3359, Nov. 28). The study identified important areas, issues, and actions related to resource conservation in a region that included the Hudson Highlands on the west side of the Hudson River in New York State, and continued across similar terrain in New Jersey to the Delaware River at its western limit.

This region, long known to geologists as an extension of ancient crystalline rocks characteristic of the New England Physiographic Province, corresponds with ecological subsections 221Ae and 221Am, as identified by the U.S. Forest Service (Cleland and others 1997, Keys and others 1995, McNab and others 2005). The landscape is a combination of ridges and broad, hilly plateaus. Bedrock geology is varied and complex, consisting of sedimentary, igneous, and metamorphic rocks. Forest vegetation includes oak-hickory, white-red-jack pine, maple-beech-birch, and aspen-birch cover types (Figure 2).

In the original Highlands study, the boundary of the biophysical region was modified by the decision to follow municipal boundaries in its delineation. The

Figure 2. Monksville Reservoir, from Horse Pond Mountain, New Jersey. *Monksville Reservoir is located in the heart of the New Jersey Highlands. (Photo by Wilma Frey, New Jersey Conservation Foundation.)*

result was an area delimited by political boundaries containing most of the geological and ecological resources that defined it.

New York – New Jersey Update

The same line of reasoning was followed in delimiting the boundary 10 years later in 2000, when Congress added the Hudson Highlands east of the river, as far as the Connecticut border (P. L. 106-291). The updated study included a scientific analysis of resource values, namely those covered by the goals to conserve water resources, forests, important biological resources, farmland, and recreational and cultural resources.

Connecticut and Pennsylvania

The 2004 Highlands Conservation Act extended the Highlands boundary into Connecticut and Pennsylvania (map on inside front cover). In Connecticut, the Highlands include those municipalities (towns) that cover the New England Physiographic Province and the corresponding ecological subsection, 221Ae. In Pennsylvania, the Reading Prong and its related ecological subsection, 221Am, constitutes the core of the Highlands region. To this range of hills and ridges were added large areas of rugged, hilly terrain covered by forests and interspersed with belts of farmland at lower elevations (Figure 3).

These landscapes are found to the southeast and to the southwest of the Reading Prong; they are part of the Gettysburg Piedmont Lowland, corresponding to the Forest Service subsection 221Da.

The area is a nonglaciated plain sloping to the coast, with hilly to rolling terrain with occasional high ridges. Bedrock is mostly a mixture of conglomerates and sandstone-shale with igneous intrusions. Vegetation is a mixture mainly of oak-hickory cover types.
The most prominent hills and ridges are characteristically made of diabase or trap rock, a durable rock that resists erosion better than the sandstone and shale found throughout the basin. The addition of parts of these sedimentary basins to the Highlands of Pennsylvania complicates the ecological definition of the Highlands developed for the previous two studies.

Four-State Highlands Region

The entire Highlands region is defined by a set of biophysical attributes, and is delimited by the municipal boundaries that include it. The result is a naturally defined region whose limits correspond to political units that include the fringes of adjacent biophysical and ecological regions (Figure 4). Thus, there was a strong biophysical basis for defining the Highlands region.

Figure 3. Oley Hills, Pennsylvania. *Contour planted farmland in the Oley Hills is typical of the Pennsylvania Highlands. (Photo by Tom Gettings, Wildlands Conservancy).*

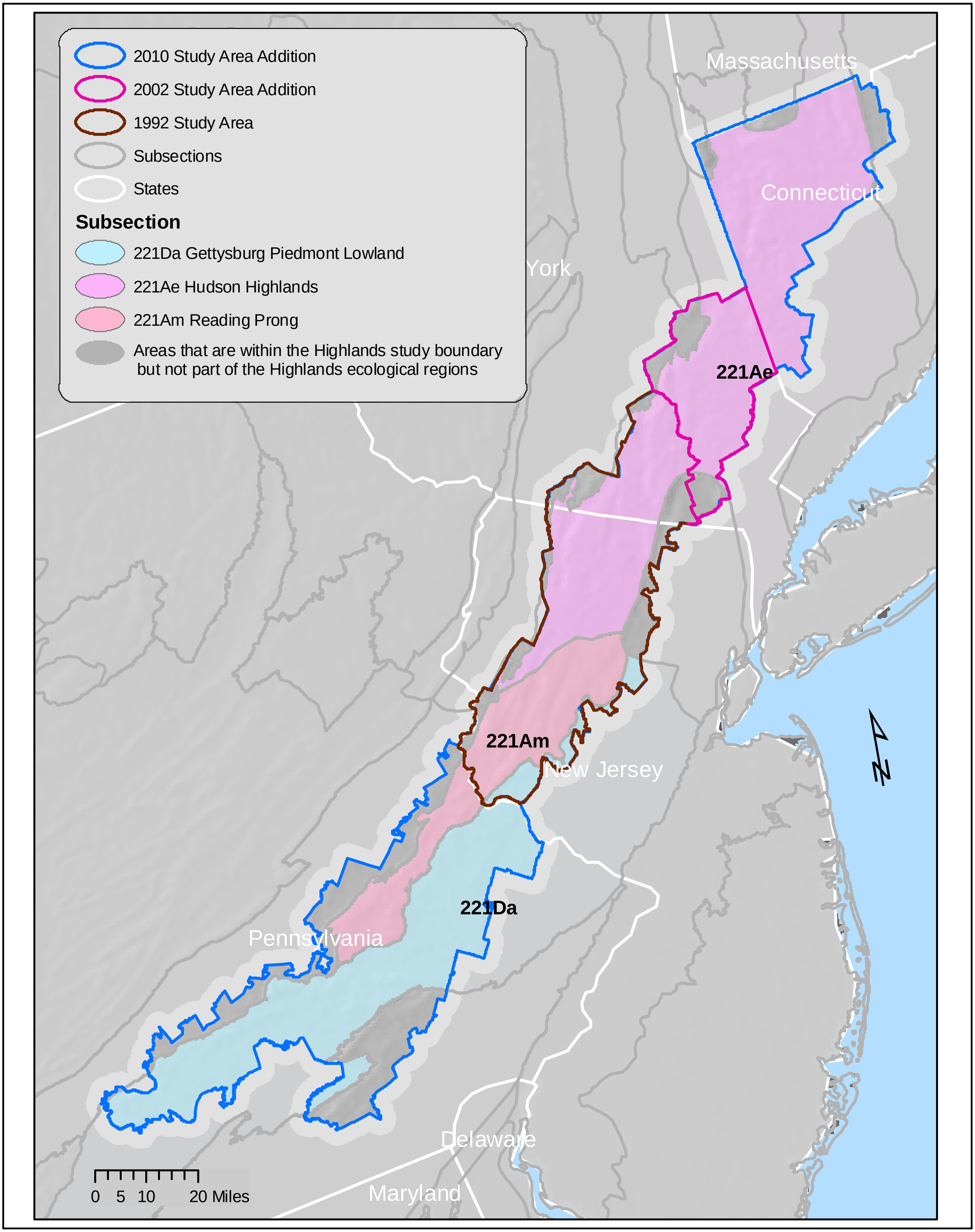


Figure 4. Highlands ecological regions. The Highlands region in outline, superimposed on an outline map of Forest Service, U.S. Department of Agriculture, ecological regions, subregions, sections, and subsections, with State boundaries, and a background shaded-relief map.

Highlands Conservation Act of 2004

The Highlands Conservation Act is designed to assist all four Highlands States—Connecticut, New York, New Jersey, and Pennsylvania—in conserving land and natural resources in the Highlands region. The act authorizes Federal assistance for land conservation projects in which a State entity acquires land or an interest in land from a willing seller, to permanently protect resources of high conservation value.

Each year, governors of the four Highlands States may jointly submit land conservation projects in the Highlands for funding not to exceed 50 percent of the total cost. Projects must be consistent with areas identified in the Highlands Regional Study and its updates as having high resource value. The U.S. Forest Service is responsible for doing the resource assessments and preparing updates for the States involved. The U.S. Department of the Interior, Fish and Wildlife Service, has responsibility for project grants.

The purposes of the Highlands Conservation Act (Section 2, Purposes, p. 1) are …

- to recognize the importance of the water, forest, wildlife, agricultural, recreational, and cultural resources of the Highlands region, and the national significance of the Highlands region to the United States;
- to authorize the Secretary of the Interior to work with the Secretary of Agriculture to provide financial assistance to the Highlands States to preserve and protect high priority conservation land in the Highlands region;
- and to continue the ongoing U.S. Forest Service programs to assist the States, local units of government, and private forest and farm landowners in the conservation of land and natural resources in the Highlands region.

Study of Connecticut and Pennsylvania Highlands

The study for Connecticut and Pennsylvania was divided into two parts (Appendix B). Part 1 assessed resources, and its principal product is a composite Conservation Values Assessment in map form. The assessment was completed by two study teams, one led by the University of Connecticut, and one led by the Pennsylvania State University.

Part 2 modeled growth and analyzed the likely effects of growth on resources, with particular attention to water, forest, and agricultural resources. The principal activities for Part 2 were modeling growth, developing a build-out model, modeling water resources, and analyzing the models' results. The identification of resources at risk, conservation focal areas, and the development of conservation strategies are among the most important products from Part 2. The U.S. Forest Service solicited proposals for the various tasks involved. A study team led by Yale University undertook growth modeling, impact analysis, and detailed analyses of trends in forest and agricultural resources for both Connecticut and Pennsylvania. The U.S. Geological Survey Water Science Centers in Connecticut and Pennsylvania analyzed water resources (Appendix C).

The Conservation Values Assessments have been completed, and the likely effects of future urban growth on the Highlands of Connecticut and Pennsylvania have been analyzed. The following important issues have been identified:

- Conserving landscape character and existing land-use activities
- Protecting quality and quantity of surface and ground water.
- Conserving the landscape for wildlife, rare plants, and environmental quality
- Sustaining important components of the forest ecosystem for long-term forest health
- Retaining working forests and farms to ensure economic viability and livability
- Providing appropriate recreational opportunities near the urban corridor

Public Input

Several approaches were used to obtain public input on the issues identified, including meetings and Web-based input on draft report findings. The entire study, including the public input process was guided by a four-State Steering Committee consisting of Federal, State, and local government officials who work for natural resources and conservation agencies and meet approximately once a year. More frequently, State and local conservation officials and other members of the interested public and conservation organizations provided feedback to the study teams who completed the assessment and wrote the report. In each state, a group of approximately 30-40 persons was formed to represent a range of resource interests. Group members guided the study process and commented on draft results as potential users of the findings.

Meetings were held in each state from 2005 to 2007 for Parts 1 and 2 of the study (Appendix D). The meetings and discussions were conducted to develop and refine the scope of the conservation values assessment and growth and impact analysis, to review the initial results, and to develop conservation strategies.

Part 1—Conservation Values Assessment

The study teams for both states solicited community values and perceptions regarding the Highlands through a variety of methods. One method was a series of group discussions organized by subregion in each state. The study teams identified common priorities among attendees, then developed computer models and maps to enable participants to add their views and comments.

The Connecticut conservation values assessment benefited from extensive public involvement, including two public meetings and three listening sessions, held from September 2005 to March 2006. A total of 150 people participated. At the public meetings, the group completed a natural resource assessment survey and a conservation focal area exercise. These exercises permitted participants to identify broad areas as well as special places that they judged to be important. The listening sessions informed residents about the Highlands study, discussed its implications for the region, and allowed residents to convey their ideas regarding resources, values, and places of special importance.

The Pennsylvania study team used two processes to gather community input: key informant interviews and facilitated group discussions. Seventy-seven key informant interviews provided a broad context for understanding which places are important and why, and the concerns citizens have about these places. Information from the interviews helped to frame four group discussions, during which participants engaged in three mapping exercises and discussed their level of agreement with the data from the key informant interviews. The three mapping exercises were compiled to provide the summary map shown in Figure 5. This map depicts the geographic areas identified for conservation and includes the names people identified with some of these important places.

Part 2—Resource Characteristics and Growth and Impact Analysis

For Part 2 of the study, the growth and impact analysis, the study team held a tour and hosted three workshops in both States. Members of the study team also gave two presentations for conservation agency staff at Connecticut's Department of Environmental Protection and Pennsylvania's Department of Conservation and Natural Resources.

The study team hosted two workshops, in winter and fall 2007, to get input and share results from the growth and land-use change models, and the low and high constraint build-out models, and water resources analysis. Participants also identified conservation focal areas and conservation strategies.

In fall 2008, the Forest Service presented the study results to the Forestry Task Force of the Pennsylvania Legislature's Joint Legislative Air and Water Pollution Control and Conservation Committee. The Forest Service will provide the task force with additional information about the public comment period and will notify them when the final report is released.

Detailed information on the public input on the pre-draft and draft report is provided in Section 2 of this report for Connecticut and in Section 3 for Pennsylvania. Meeting locations, dates, and the number of attendees are given in Appendix D.

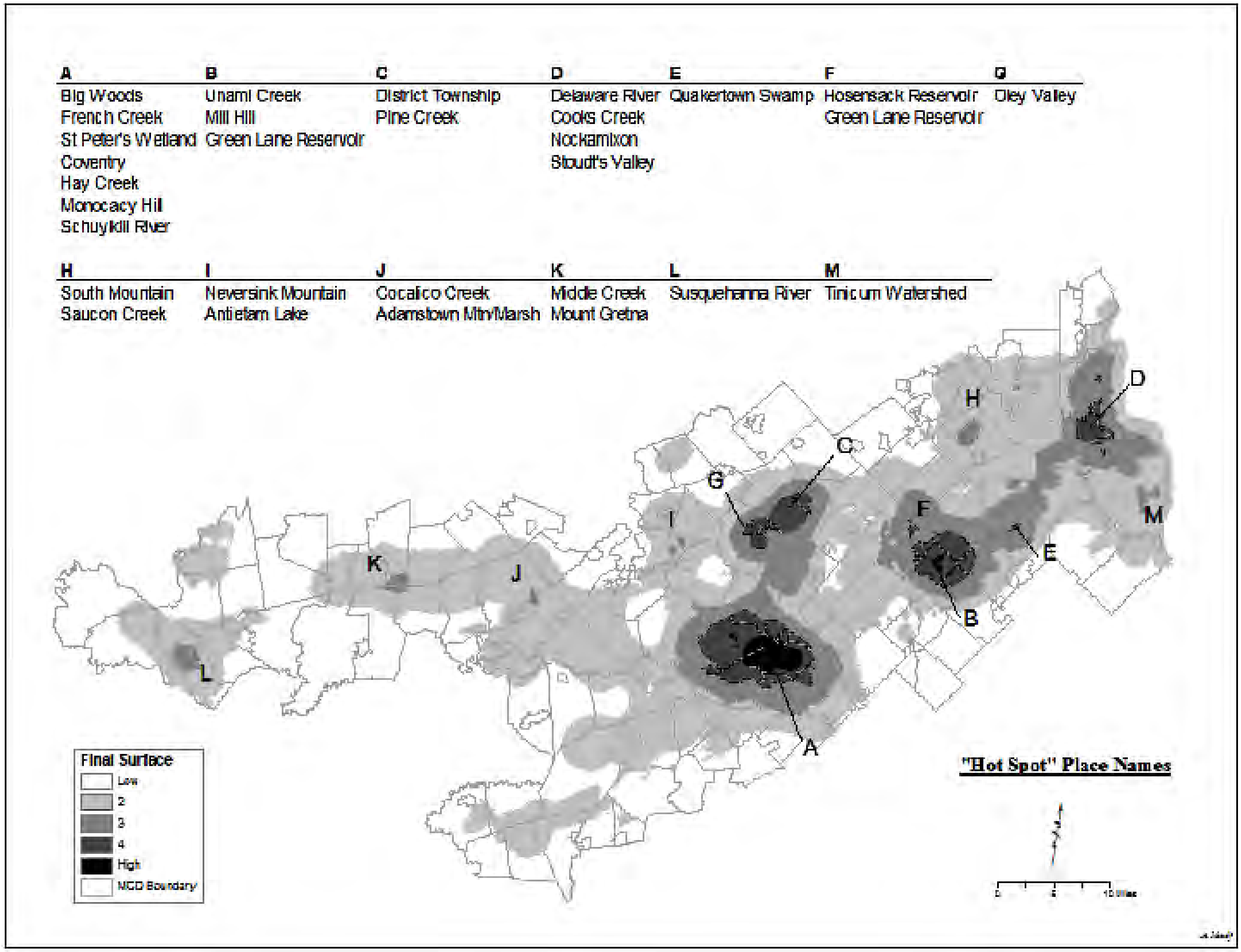


Figure 5. Hot spot place names. Hot spots are geographic areas in the Pennsylvania Highlands that were identified for conservation by the public through three mapping exercises. This map includes the names people identified with some of these important places.

Input on Draft Report

The request for public comments on the Highlands study and public meetings were announced in the Federal Register on May 3, 2010. The draft study was available for public comment at the Forest Service Highlands Web site through June 18, 2010. The public could view the report online and submit comments electronically. An announcement about the availability of the public review draft and planned public meetings was emailed to key stakeholders in the region, as well as to numerous local and regional newspapers in Connecticut and Pennsylvania affiliated with the Associated Press.

In addition to seeking public comments on the Highlands study document, two public meetings were held to present the key study results and seek additional public input. Approximately 10 people attended the public meeting to discuss the Pennsylvania portion of the study on May 24, 2010, at the Nolde Forest Environmental Education Center in Reading, PA. Members of local land trusts and the Pennsylvania Bureau of Forestry attended the Pennsylvania meeting, and approximately 30 verbal comments were recorded. Approximately 10 people attended the public meeting to discuss the Connecticut portion of the study on May 26, 2010, at the University of Connecticut Cooperative Extension office in Torrington, CT. Members of local land trusts, local residents, and the Connecticut Department of Environmental Protection attended the Connecticut meeting, and approximately 25 verbal comments were recorded. In addition to the feedback received at the public meetings, written comments on the draft were submitted by Housatonic

Valley Association, Connecticut Department of Environmental Protection's Bureau of Water Protection and Land Reuse, Audubon Connecticut, and the Appalachian Mountain Club. Their comments are summarized in Appendix E.

The comments received on the draft report were used to revise certain sections of the report, including the conservation strategies, forest resources analysis, and water resources analysis sections. For example, a separate forest fragmentation analysis was completed to better understand the potential impacts of forest fragmentation on biodiversity at a regional scale, to help identify key forested landscapes for protection. Details are described in Appendix E.

About This Update

Following this introductory section, this report covers the study of the Connecticut Highlands in section 2 and of the Pennsylvania Highlands in section 3. Each State section contains the results for the Conservation Values Assessment, the land and water resources analysis, the growth and impact analysis, and a summary of conservation actions, regional resources at risk, resource condition and conservation focal areas. The parts on the land and water resources and human population characteristics provide the foundation for the growth and impact analysis. Section 4 of this report reviews the Highlands stewardship goals and lists potential conservation strategies for the Connecticut and Pennsylvania region as a whole.

A separate technical report containing detailed information about all of the analyses in this Connecticut and Pennsylvania update to the Highlands Regional Study has been completed by the study teams for Parts 1 and 2. A listing of the topics in the technical report can be found in Appendix F.

A Glossary was added.

References for Section 1

Cleland, David T.; Avers, Peter E.; McNab, W. Henry; Jensen, Mark E.; Bailey, Robert G.; King, Thomas; Russell, Walter E. 1997. National hierarchical framework of ecological units. Ecosystem management: applications for sustainable forest and wildlife resources. New Haven, CT: Yale University Press. p. 181-200.

Keys, J. E., Jr.; Carpenter, Constance A.; Hooks, S. L.; Koenig, F. G.; McNab, W. Henry; Russell, Walter E.; Smith, M-L. 1995. Ecological units of the eastern United States—first approximation (map and booklet of map unit tables). Presentation scale 1:3,500,000, color. Atlanta, GA: U.S. Department of Agriculture, Forest Service.

McNab, W. Henry; Cleland, David T.; Freeouf, J. A.; Keys, J. E., Jr.; Nowacki, G. J.; Carpenter, Constance A., compilers. 2005. Description of ecological subregions: sections of the conterminous United States [CD-ROM]. Washington, DC: U.S. Department of Agriculture, Forest Service. 80 p.

Michaels, Joseph A.; Neville, L. Robert; Edelman, David; Sullivan, Tim; DiCola, Leslie A. 1992. New York – New Jersey Highlands Regional Study. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 130 p.

Phelps, Marcus G.; Hoppe, Martina C., compilers. 2002. New York – New Jersey Highlands regional study: 2002 update. NA-TP-02-03. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 209 p.

Section 2. Connecticut Highlands

This section contains the results of the study in Connecticut. The section is divided into six parts. Parts 1 and 2 describe the Conservation Values Assessment and related public input. Parts 3, 4, and 5 describe the land, water, and human population characteristics that feed into the growth and impact analysis, and related public input. Part 6 describes the conservation actions, regional resources at risk, resource condition and lists the conservation focal areas.

The Highlands of Connecticut cover 677,680 acres in the northwestern corner of the State, in the basins of the Housatonic and the Farmington Rivers. Twenty-eight towns in Fairfield, Hartford, and Litchfield counties comprise the Highlands (Figure CT-1, Appendix G).

Part 1. Conservation Values Assessment

The purpose of Part 1 was to assess the Highlands' natural resources and to identify the areas of highest conservation value on a map, known as the Conservation Values Assessment map.

Resource Assessment

The resource assessment identified areas of high conservation value in the Highlands of Connecticut in five resource categories. A digital Geographic Information System (GIS) based assessment of available spatial data used scientific analysis and expert opinions to identify and weight conservation values. A community input process involved interested citizens and the public in a separate identification of important conservation areas.

The Conservation Values Assessment for Connecticut was done under the direction of Thomas Worthley and Joel Stocker of the University of Connecticut, Middlesex County Extension Center. Meetings to evaluate the data were organized by the University of Connecticut and attended by representatives from the Connecticut Department of Environmental Protection (DEP), Regional Plan Association, and the Housatonic Valley Association. Study team members are listed in Appendix B.

The assessment studied the same five categories of resources as were studied in the New York—New Jersey Highlands Regional Study: 2002 Update (Phelps and Hoppe 2002): water, forests, biological resources, agriculture, and recreational and cultural resources.

- **Water**—Water resources are streams, lakes, and other water bodies, as well as underground sources of water. One of the Highlands stewardship goals is to maintain an adequate supply of high quality water.
- **Forests—**Forests are a renewable source of fiber and other woodland products. Forests are habitat for most of the plant and animal communities of greatest concern. Forests protect the quality and dependability of water resources, and they contribute immensely to air quality. One of the Highlands stewardship goals is to conserve productive forest lands.
- **Biological resources—**Biological resources not including forests, in the context of this study, are native flora and fauna possessing importance because of their rarity or the richness and diversity of their communities. Conservation values are related to habitat suitability, among other factors. One of the Highlands stewardship goals is to conserve areas of high biodiversity and habitat value.
- **Agriculture**—Agriculture is both a resource and a land use. Agriculture provides food, open space, and economic benefits to the Highlands and to the larger society. One of the Highlands stewardship goals is to conserve productive agricultural land.
- **Recreational and cultural resources**—Recreational and cultural resources are sites, lands, or waters available for public use. Scenic and open space resources that may be in private ownership are included. One of the Highlands stewardship goals is to provide adequate recreational opportunities, including natural, historic, and cultural resource-based uses.

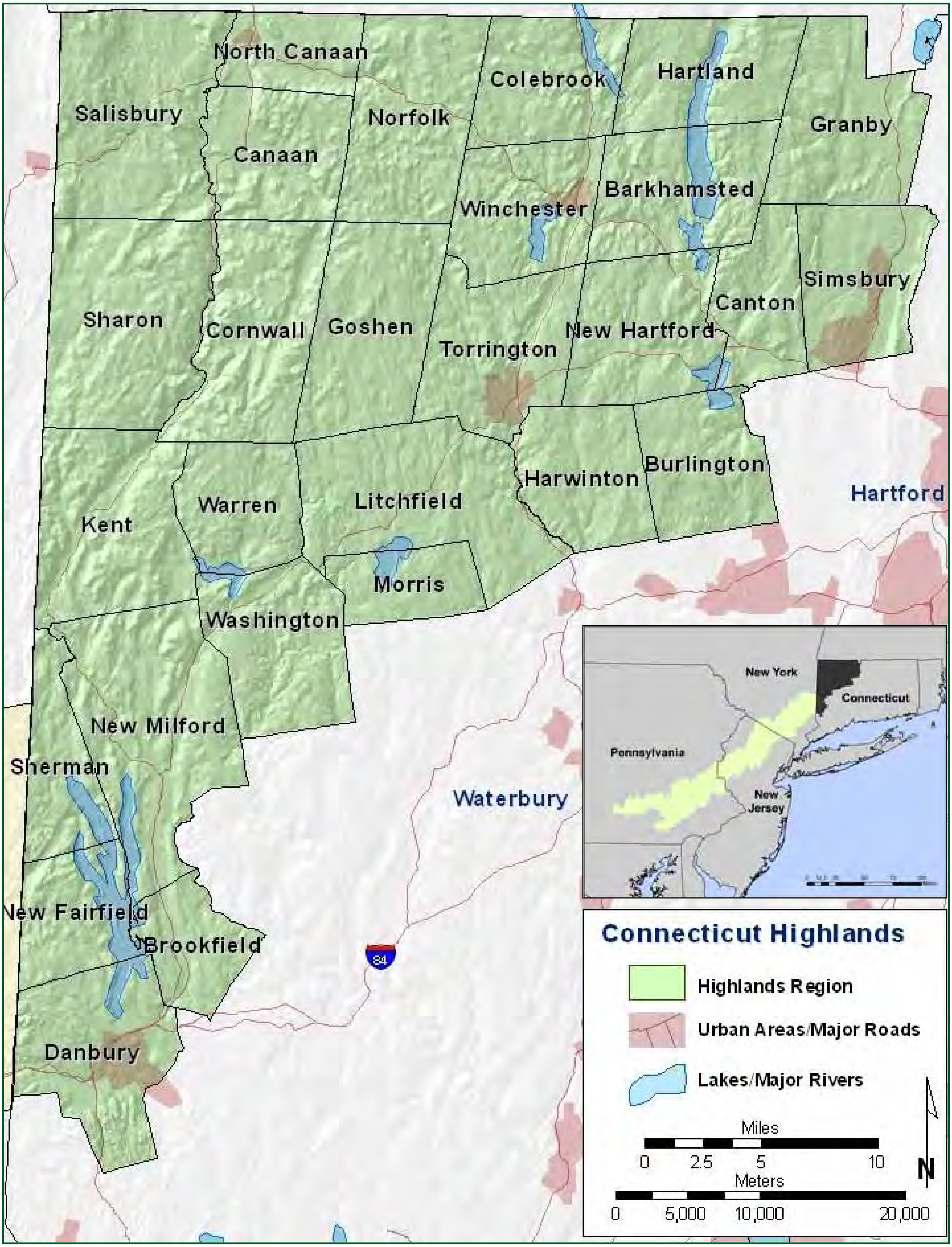


Figure CT-1. Connecticut Highlands towns. *The Connecticut Highlands encompass 28 towns.*

For each of these resources the study team collected existing spatial data created by Federal, State, county, regional, and nongovernmental organizations. The DEP provided spatial information regarding streams, geological units with groundwater potential, threatened and endangered species, and other factors. The University of Connecticut's Center for Land Use Education and Research (CLEAR) provided satellite derived land cover and land use data.

The Conservation Values Assessment followed the study format and content previously used for New York and New Jersey, except when better data, interpretations, or public input justified a departure from the precedent (Phelps and Hoppe 2002, p. 70).

Data regarding resources or resource components were collected from many sources, mostly State and Federal governments (Table CT-1). Data layers for the GIS were evaluated for accuracy and utility by the study team, and then given weights by an open panel of experts and interested participants. Each layer's model compared weights and assigned the highest weight as the cell's value. For example, if a cell in the water resources model had weights of 4 for unconsolidated valley fill plus 1 for forest cover, 4 for wellhead protection area plus 1 for forest cover, 4 for riparian zone, 2 for steep slope, and 3 for wetlands, its value would be 5, not the sum of all weights. This "maximum value" system was also used in the New York–New Jersey Highlands Study (Phelps and Hoppe 2002, p. 70). Note that an added value, such as for forest cover, applies to the layer's score. Scores for resource layer models were divided into five ranks using natural breaks. This method is used to identify breakpoints between classes by identifying groupings and patterns within the data. The quantile method counts up the number of features and divides the breakpoints evenly, so there is about the same number in each group.

Water resources

The water model had eight layers with the maximum possible score of 5. Maintaining adequate supplies of high quality water is a high priority throughout the Highlands. The objective for the water resource component was to identify those locations on the landscape that play a critical role in protecting water quality. The Connecticut DEP, Bureau of Water Protection and Land Reuse, provided valuable help mapping, interpreting, and evaluating water resource data.

Carbonate aquifers were mapped as bedrock units. Valley fill aquifers, sands, and gravels deposited by glacial action were mapped; their position is typically above most of the carbonate aquifers. Any overlap of valley fill aquifers with carbonate aquifers was compensated by their higher weight. Other bedrock units were mapped and ranked. Wellhead protection zones for community water supply and surface water supply protection zones were mapped by the DEP. Headwater streams and riparian areas were mapped and ranked, as were floodplains, wetlands, and slopes greater than 15 percent.

Forest resources

The forest model had two layers with the maximum possible score of 5. The resource values of forest land are greater than the value of its timber alone. The parameters for the forest resource model apply whether the forest is managed for timber, habitat, or other purposes; large contiguous forest blocks and better soil types increase the timberland harvest value. Forest management for economic return, biodiversity, or wildlife is easier and more robust over large areas or blocks of forest.

Soil classes were ranked according to their silvicultural potential using the data in county soil surveys. Forest cover was interpreted by the University of Connecticut using Multi-Resolution Land Cover (MRLC) data from the U.S. Geological Survey. Blocks of interior forest were identified and ranked according to size. Lands in the U.S. Forest Service's Forest Stewardship Program were identified by the DEP, Bureau of Forestry.

Biological resources

The biological model had three layers with the maximum possible score of 5. The protocols to identify and rank habitat for endangered and threatened animals, plants, and natural communities were similar to those developed for the New York–New Jersey Highlands Study (Phelps and Hoppe 2002). The source of data regarding species habitats was the DEP. The spatial locations of many features are confidential; for this reason the DEP could not release unmodified data. Accordingly, the GIS analysis was completed by the DEP, Wildlife Division, and provided to the Highlands study as parameter layers. The records were limited to the fields required for weighting in the composite model, but the layers retained their spatial accuracy for the model. Final printed and digital forms of the model's output were spatially generalized for public review and reports.

The current available data relies on threatened and endangered species information but does not take into account species that may be common in Connecticut, such as the bluewinged warbler, which is quite common in Connecticut. A decline in blue-winged warblers in Connecticut would impact the global population of the species. Future analyses of the biological resources in Connecticut might include information on the distribution and abundance of these species, as well as on threatened and endangered species, to help prioritize future conservation efforts (Comins 2010).

Agricultural resources

The agricultural model had two layers with the maximum possible score of 5. The objective for the Connecticut Highlands agricultural resource assessment was to identify those areas that have the highest value for maintaining agriculture as a viable activity. The model assigns higher weights to areas with prime farm soils, contiguous tracts of farm land, or farms already under some form of protection from land use change. There was significant input from the public sessions to protect farm land because of its scarcity, scenic value, or simply to forestall development. Prime agricultural soils were ranked, even if the land was not in agriculture, as long as it was not developed for other uses.

Recreational and cultural resources

The recreational model had four layers with the maximum possible score of 5. The objective for the recreation and cultural resources assessment was to identify those areas that have the highest value for outdoor recreation or as cultural or open space resources.

Conservation Values Assessment maps

Five separate maps were created for each of five resource categories in the Conservation Values Assessment: water (Figure CT-2), forests (Figure CT-3), biological (Figure CT-4), agriculture (Figure CT-5), and recreational and cultural resources (Figure CT-6). These resource maps were then combined in a composite map to show the distribution of relative conservation values across the region (Figure CT-7). Each of the five resource categories counted for 20 percent of the composite Conservation Values Assessment score. Scores for the composite map of conservation values were grouped into five ranks by quantiles so that each rank had, as near as possible, the same number of cells. For some layers, such as agriculture and forest, many cells were blank; they have no value if the resource is absent.

The current available data relies on threatened and endangered species information but does not take into account species that may be common in Connecticut, such as the blue-winged warbler, which is quite common in Connecticut. A decline in blue-winged warblers in Connecticut would impact the global population of the species. Future analyses of the biological resources in Connecticut might include information on the distribution and abundance of these species, as well as on threatened and endangered species, to help prioritize future conservation efforts (Comins 2010).

Table CT-1. ***Data sources and weights.*** *Data sources and weights applied to individual layers of the Connecticut Highlands Conservation Values Assessment.*

Data Layer	Weight (point score)	Data source
WATER RESOURCES		
Carbonate aquifer recharge area other bedrock aquifer recharge area unconsolidated valley fill aquifer with forest cover, add 1	3 1 4	Connecticut DEP, Geographic Information Center 2003
Aquifer (wellhead) protection area with forest cover, add 1	4	Connecticut DEP, Geographic Information Center 2003
Surface water supply protection zone with forest cover, add 1	4	Connecticut DEP, Geographic Information Center 2003
Riparian zone (150-foot stream buffer), ranked	5 4 3 2 1	Connecticut DEP, Geographic Information Center 2003, rank based on quality of stream.
Steep slopes > 15 percent In surface water supply zone, add 1	2	University of Connecticut, Map and Geographic Information Center 1982, Digital Elevation Model
Floodplain (100 year)	—	Floodplain data were not used because of problems with map resolution and conformity.
Wetlands > 50 acres Wetlands 5 to 50 acres With forest cover, add 1	3 2	U.S. Fish and Wildlife Service 1998, National Wetlands Inventory
Headwater streams 300-foot buffer In surface water supply zone, add 1	3 2	University of Connecticut 2005b, data modified for this study
FOREST RESOURCES		
Contiguous Forest Tracts, rank by size > 5,000 acres > 1,000 to 5,000 acres > 300 to 1,000 acres > 100 to 300 acres 25 to 100 acres	 5 4 3 2 1	University of Connecticut a2005b, analysis of Multi-Resolution Land Classification (MRLC) data
Lands in Forest Stewardship Program Buffer to 500 feet Buffer from 500 to 1,000 feet Buffer from 1,000 to 1,500 feet On prime forest soils, add 1	4 3 2 1 1	University of Connecticut Cooperative Extension 2005a
BIOLOGICAL RESOURCES		
Faunal Habitat containing listed species Federally listed Endangered or Threatened State listed Endangered State listed Threatened State listed Species of Concern	 5 4 3 2	Zyko, Karen. 2005. Connecticut Natural History Survey. Hartford: Connecticut Department of Environmental Protection. Unpublished data.

Continued

Data Layer	Weight (point score)	Data source
Floral Habitat containing listed species Federally listed Endangered or Threatened State listed Endangered State listed Threatened State listed Species of Concern	 5 4 3 2	Zyko, Karen. 2005. Connecticut Natural History Survey. Hartford: Connecticut Department of Environmental Protection. Unpublished data.
Significant Natural Vegetation Communities State B1 listing (none) State B2 listing State B3 listing (none) State B4 listing (none)	 4	Zyko, Karen. 2005. Connecticut Natural History Survey. Hartford: Connecticut Department of Environmental Protection. Unpublished data.
AGRICULTURAL RESOURCES		
Agricultural land (pasture or row crops) On prime agricultural soils, add 4 In large contiguous areas, add 1	3	U.S. Department of Agriculture, Natural Resources Conservation Service 2005, University of Connecticut 2005b, Connecticut DEP 2003
Agricultural land under farm land easement Buffer to 1,000 feet In large contiguous areas, add 1	4 3	Sinclair, Kirk. 2005. Unpublished natural resources data. Cornwall Bridge, CT: Housatonic Valley Association. For more information, go to: www.hvatoday.org (28 September 2009) University of Connecticut 2005b
RECREATIONAL AND CULTURAL RESOURCES		
Recreational Trails Buffer to 150 feet Buffer from 150 to 300 feet	5 4 3	University of Connecticut 2005b
Parkland dedicated to public access and use Land protected by conservation easement Buffer to 1,000 feet Buffer from 1,000 to 2,000 feet Buffer from 2,000 to 3,000 feet	5 4 3 2 1	Connecticut DEP 2003 Sinclair, Kirk. 2005. Unpublished natural resources data. Cornwall Bridge, CT: Housatonic Valley Association. For more information, go to: www.hvatoday.org (28 September 2009) University of Connecticut 2005b
Historical or Cultural site with 150 foot buffer	3	University of Connecticut 2005b
Lake reservoir with public access Buffer to 300 feet Canoe-able stream Buffer to 150 feet Buffer from 150 to 300 feet Trout production stream Buffer to 150 feet Other lakes Buffer to 300 feet	5 4 5 4 3 4 3 3 2	University of Connecticut 2005b

Connecticut DEP – Connecticut Department of Environmental Protection

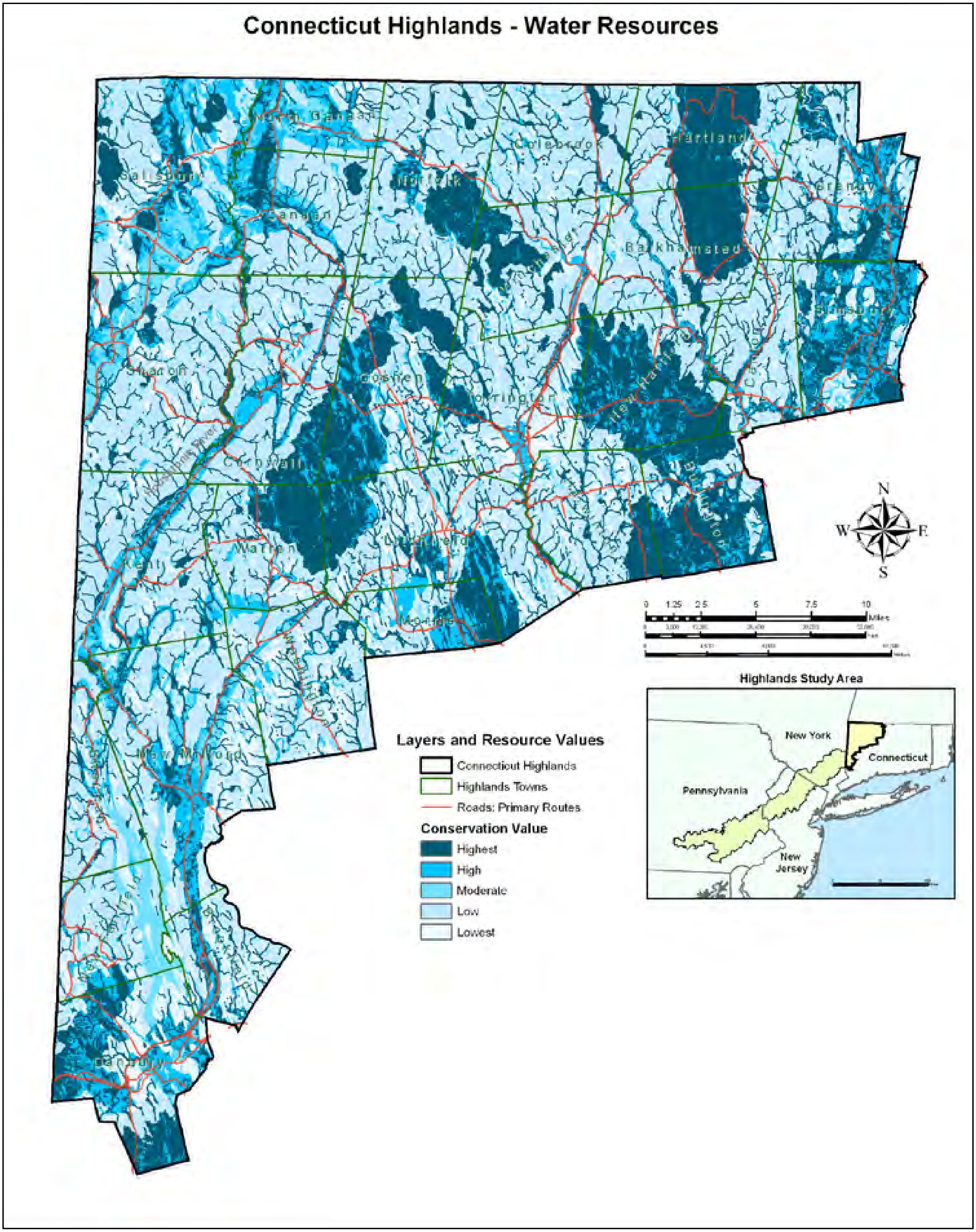


Figure CT-2. Water resource values. *The conservation values assessment identified areas in the Connecticut Highlands that have high conservation value for high quality water.*

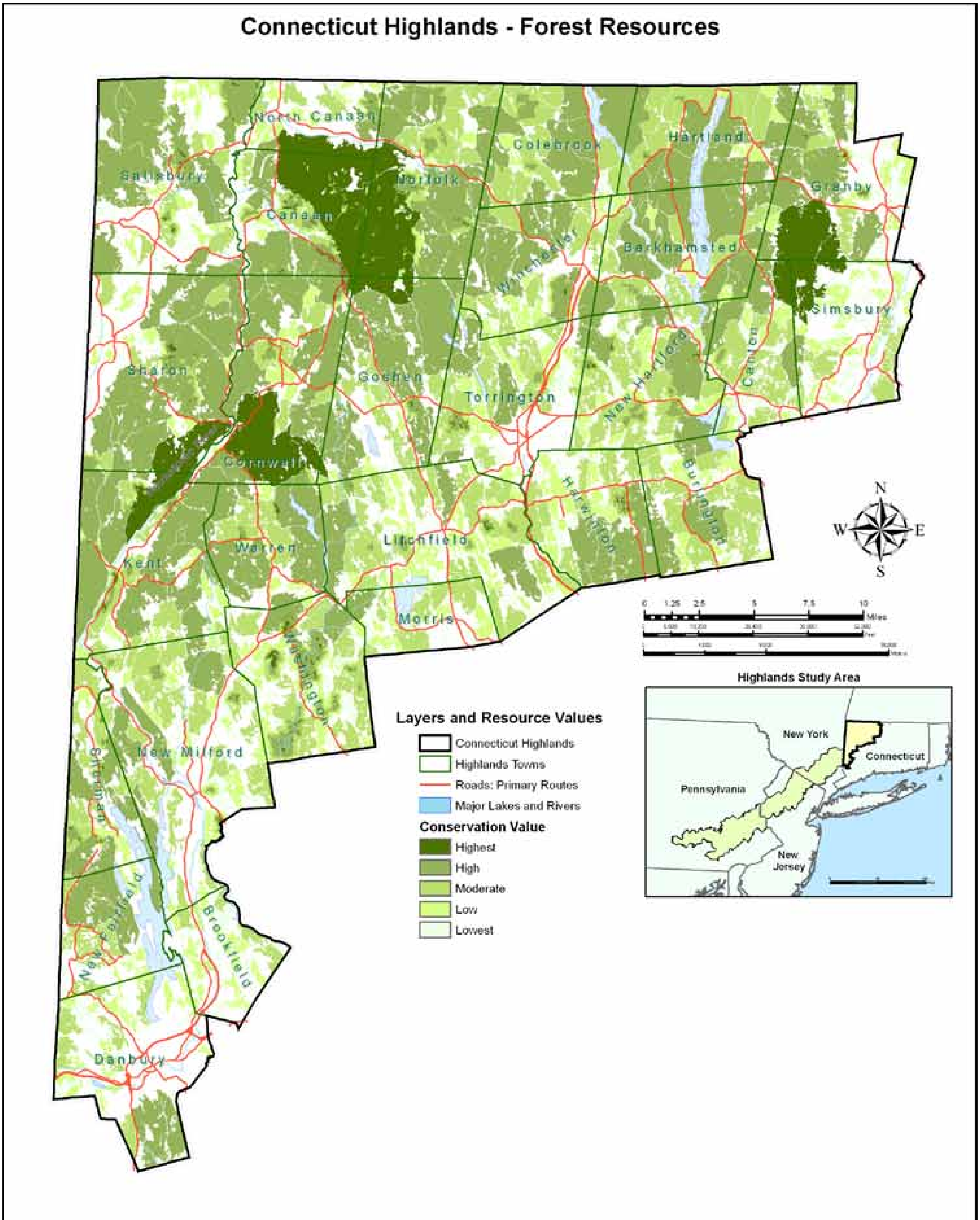


Figure CT-3. Forest resource values. *The conservation values assessment identified areas in the Connecticut Highlands that have high conservation value for productive forest resources.*

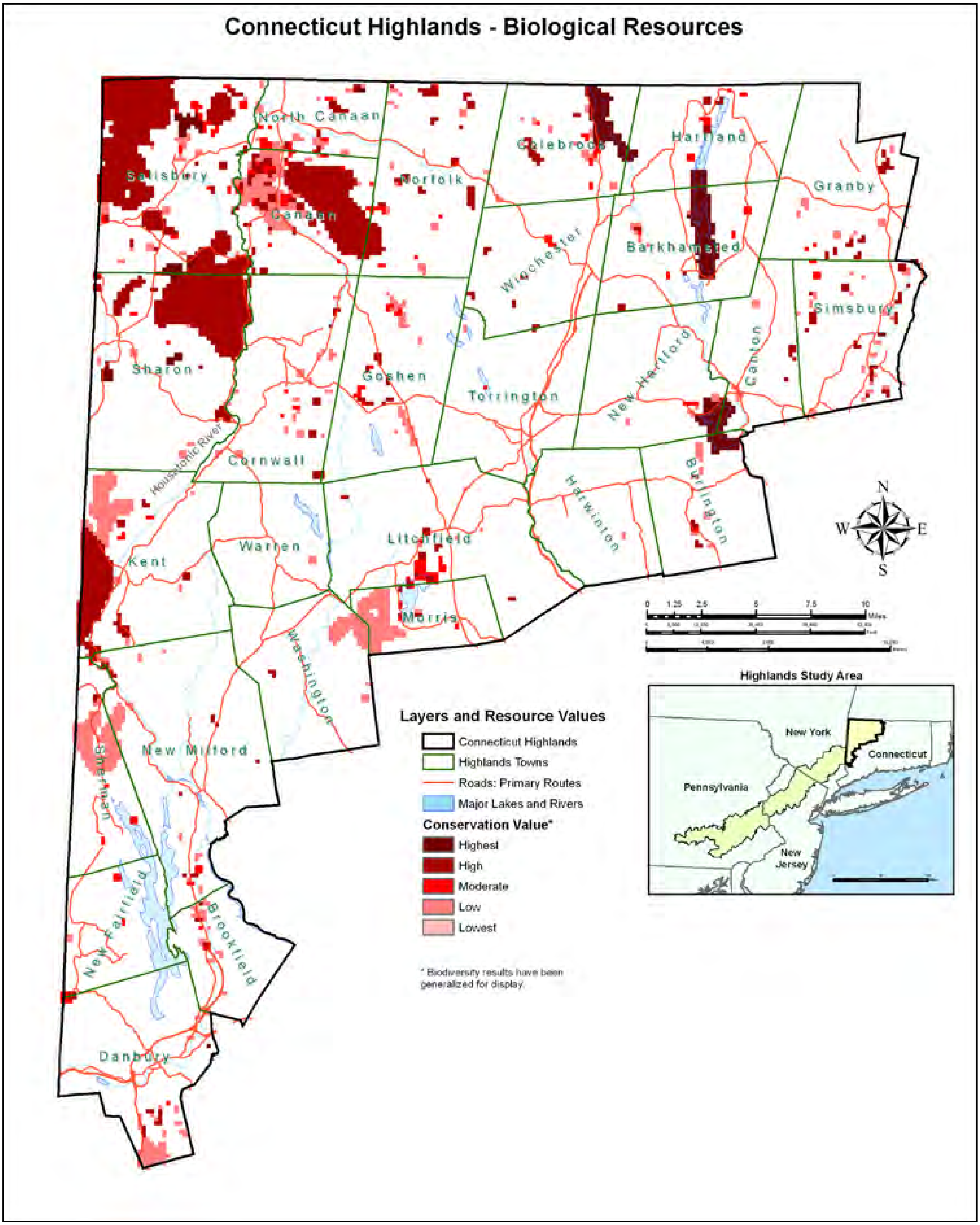


Figure CT-4. ***Biological resource values.*** *The conservation values assessment identified areas in the Connecticut Highlands that have high conservation value for habitat that supports state or federally listed threatened and endangered species.*

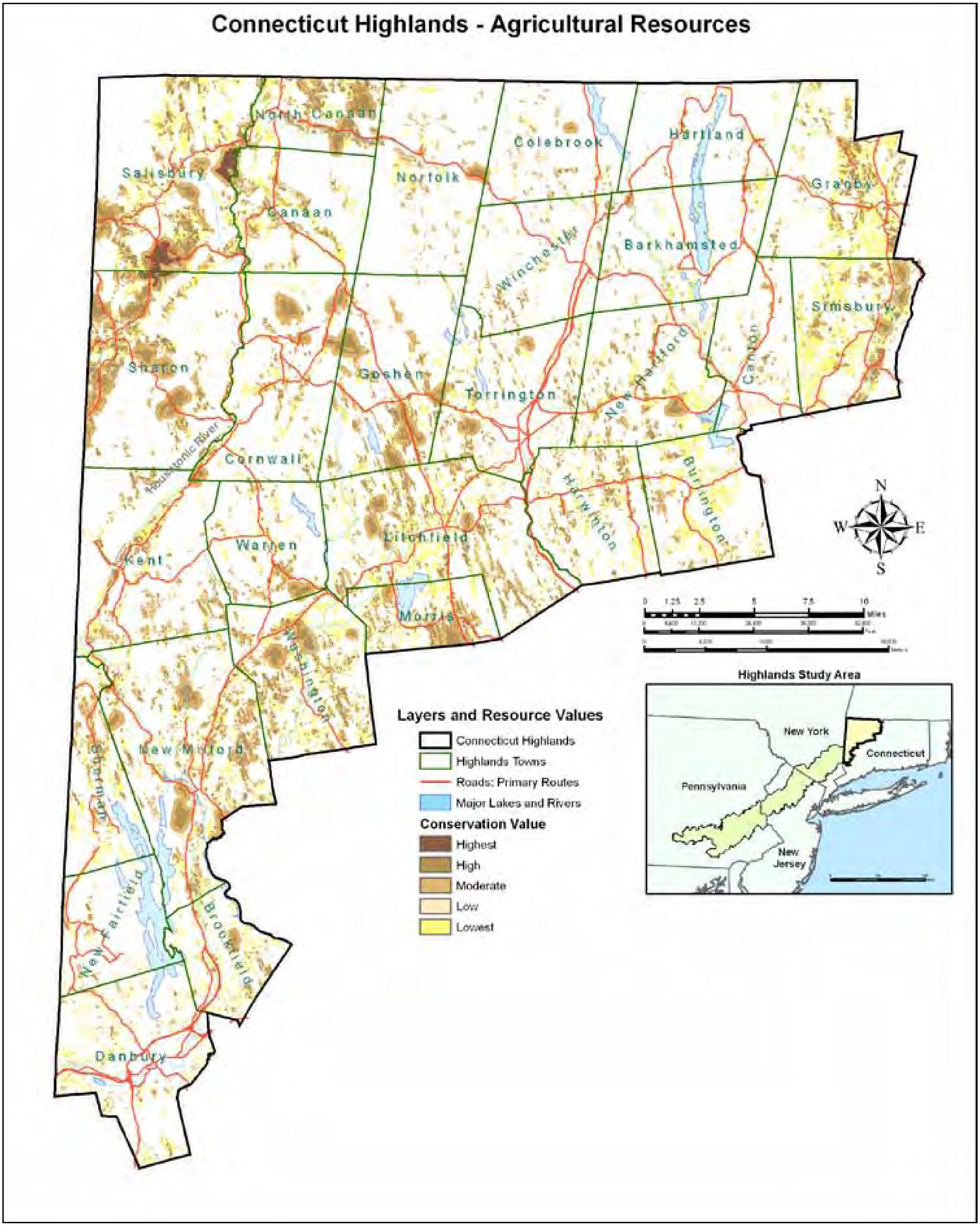


Figure CT-5. Agricultural resource values. *The conservation values assessment identified areas in the Connecticut Highlands that have high conservation value for productive farm land.*

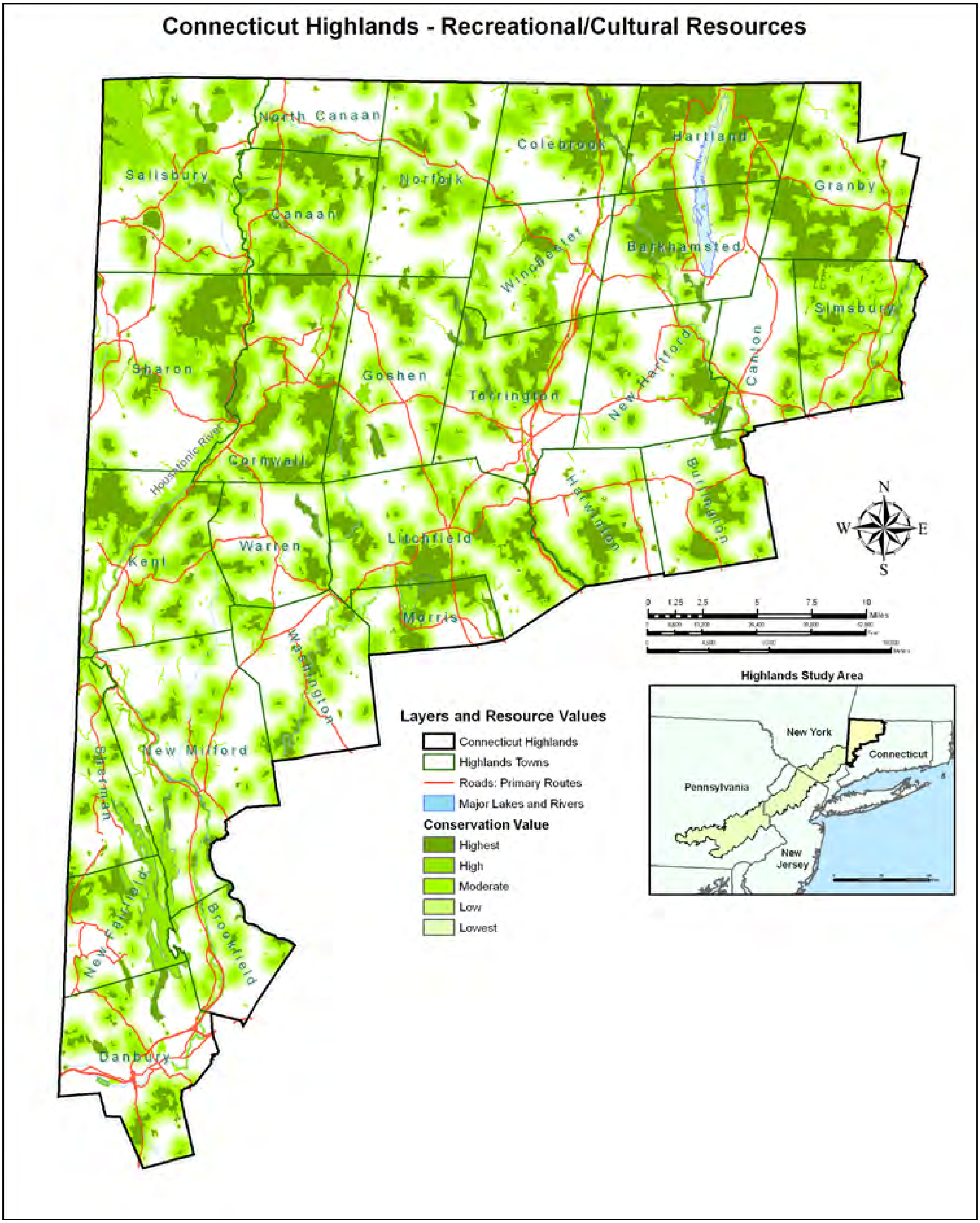


Figure CT-6. Recreational and cultural resource values. *The conservation values assessment identified areas in the Connecticut Highlands that have high conservation value for recreation opportunities, and historical and cultural sites.*

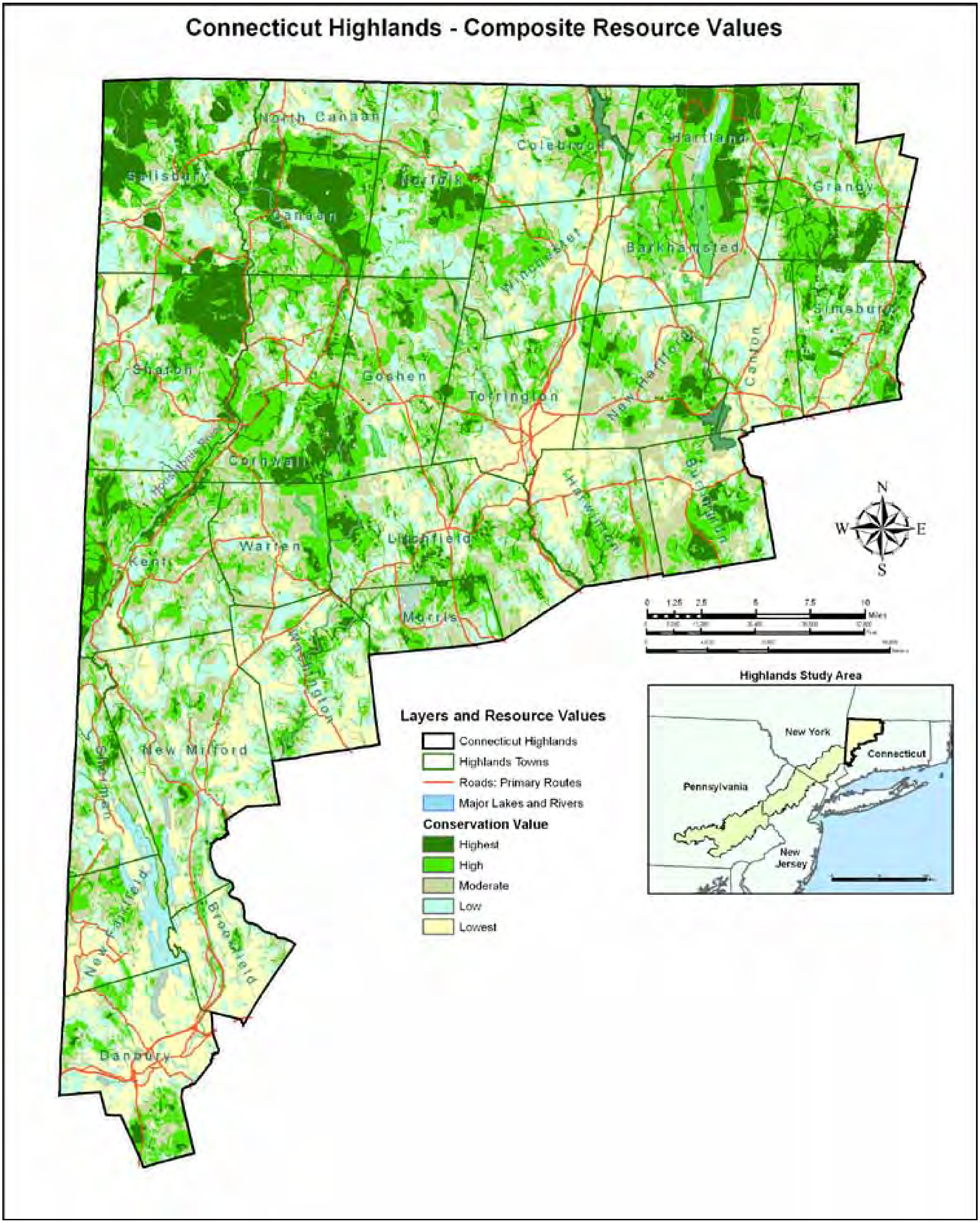


*Figure CT-7. **Composite resource values.** The conservation values assessment identified areas in the Connecticut Highlands that have higher or highest conservation value for all resource categories (water, forest, biological, agricultural, and recreational and cultural).*

Conservation Values Assessment—Key findings

- Water resources—Public water supply watersheds and the streams and buffers found within them were given additional points within the model. These areas are important as water supplies for major cities, with some of those cities outside the Highlands region. Also highlighted are several valleys that include gravels and other materials significant for ground water recharge, and provide direct benefits to people relying on local and municipal wells.
- Forest resources—Large unbroken forest blocks are better suited as working forests than are smaller fragmented areas. Larger blocks also provide better wildlife habitat and upland water quality. Soils with good tree-growing potential provided additional weight. Canaan Mountain, the Cornwall area, and sections along the Farmington River stand out because of these overlapping qualities.
- Biological resources—Large unbroken forests are important for larger wildlife species and overall diversity. Sections in the northwest Highlands stand out as primary areas of significant habitat. Smaller, less visible yet significant habitat is scattered throughout the Highlands, including areas influenced by wetlands and special soil types for rare plants.
- Agricultural resources—The rare valleys and open plateaus provide the flat lands required for agriculture in the Highlands. Larger clustered farms were rated higher based on the efficiency for modern agriculture and the threat of their conversion to another use. The northwest and central Highlands have several large active farming communities. Smaller scattered farms, while less visible on map, are valuable for their nearby local communities and are under increasing pressure for conversion.
- Recreational and cultural resources—Protected State and municipal lands were included within this analysis. These areas stand out on the maps as the primary areas of interest and are included with surrounding buffers. The combination helps to identify significant corridors where gaps need to be filled. Protecting the gaps would also enhance biological and recreation resource values.
- Composite resource values—The combination of priorities in the forest, biological, and recreation resource layers draws out the importance of the larger unbroken tracts in the northwest Highlands and areas around the Barkhamsted Reservoir, Litchfield County. Inputs from user groups helped identify the importance of smaller areas closer to the urban centers. Because there is very little overlap between the agriculture features and the other protection layers, agriculture does not stand out as much in the composite value map. No less significant, the farm land layer is better represented on its own.

Part 2. Public input—Conservation Values Assessment

The community input process involved an interested citizen workshop and public meetings; it was conducted under the direction of Robert Pirani and Emily Moos of the Regional Plan Association. The workshop was convened with assistance from the Housatonic Valley Association.

Workshop

The workshop gathered local interested citizens in order to seek the advice of knowledgeable people in preparation for the listening sessions. Issues were explored, mailing lists were developed, and locations were determined to ensure adequate coverage of the region and attendance by the public. Approximately 1,100 postcards were mailed. The study team also coordinated newspaper and radio announcements in the local media.

Listening sessions

Meetings were held at three locations in the Connecticut Highlands: New Milford, Torrington, and Falls Village. Participants included farmers, foresters, and conservationists, representatives from community organizations, local business owners, planners, developers, local planning and zoning commissioners, and state and local representatives. The agenda for each meeting was the same. The evening began with a quick overview of the Highlands. Participants were given questionnaires regarding the five resource topics (water, forests, biological resources, agriculture, and recreational and cultural resources) to help initiate a general discussion of the Highlands' resources. Participants were asked whether they felt the conservation of these resources was important. Participants went on to provide input on resources, issues, or places that were important to them.

Wall map exercise

Finally, participants had a chance to locate places they believed to be important on large maps of the Highlands (Figure CT-8). Participants used numbered dots that were keyed to their questionnaires so they could, if they chose, add descriptive and other information regarding the locations.

Summary

Priorities within all resource categories reflect greater interest in open space and ecosystem protection than in active recreation or resource production (Table CT-2). These sentiments were true for the listening sessions and the workshop.

Ground water and wetlands were the top concerns related to water resources. Habitats for non-game species were considered more important than those for game species. Large contiguous forests were valued for their ecological and scenic importance, more than for their forest products. Preserving stands of mature trees was of greater concern than managing for forest health. Protecting, buffering, and connecting existing parks and conservation easements was valued above recreational uses. Indeed, there was a strong feeling that conserved land should be accessible for passive recreation alone.

Special habitats or locations elicited more concern than the protection of overall resource values. People were interested in the preservation of specific places and were engaged in the special places mapping exercise. People wanted to know how the study would help them protect their resource priorities and how the resource assessment would relate to special places, even to specific parcels of real estate.

People were concerned about social and economic change in the Highlands and saw sprawl and the threat of development as a critical problem. The loss of farm land and the farming economy, and the lack of affordable housing bothered them. As land values rise, it becomes increasingly difficult for young residents to afford a house in the region. All activities that win a living from the land are affected by high real estate valuations, which accelerates changes that are not readily apparent in the landscape. While relatively few new houses are built, they are expensive and they are owned by those whose income is earned elsewhere and is on a scale local people cannot touch. At the same time, local land trusts and conservancies try to save the landscape by out-bidding newcomers, thereby pushing land values higher.

Table CT-2. Resource ranking. *Ranking of resources, using maps and surveys, at three public meetings.*

Special places identified on maps 222 dots placed and resources identified; dots can relate to more than one resource	**Resource categories ranked on surveys** Average scores: 0 to 5 (89 surveys)
Water resources — **116** places	**Water** resources — **3.66**
Biological resources — **110** places	**Agricultural** resources — **3.38**
Recreational resources — **103** places	**Biological** resources — **3.28**
Forest resources — **60** places	**Recreational** resources — **2.51**
Agricultural resources — **48** places	**Forest** resources — **2.39**

Source: Pirani and Moos (2007)

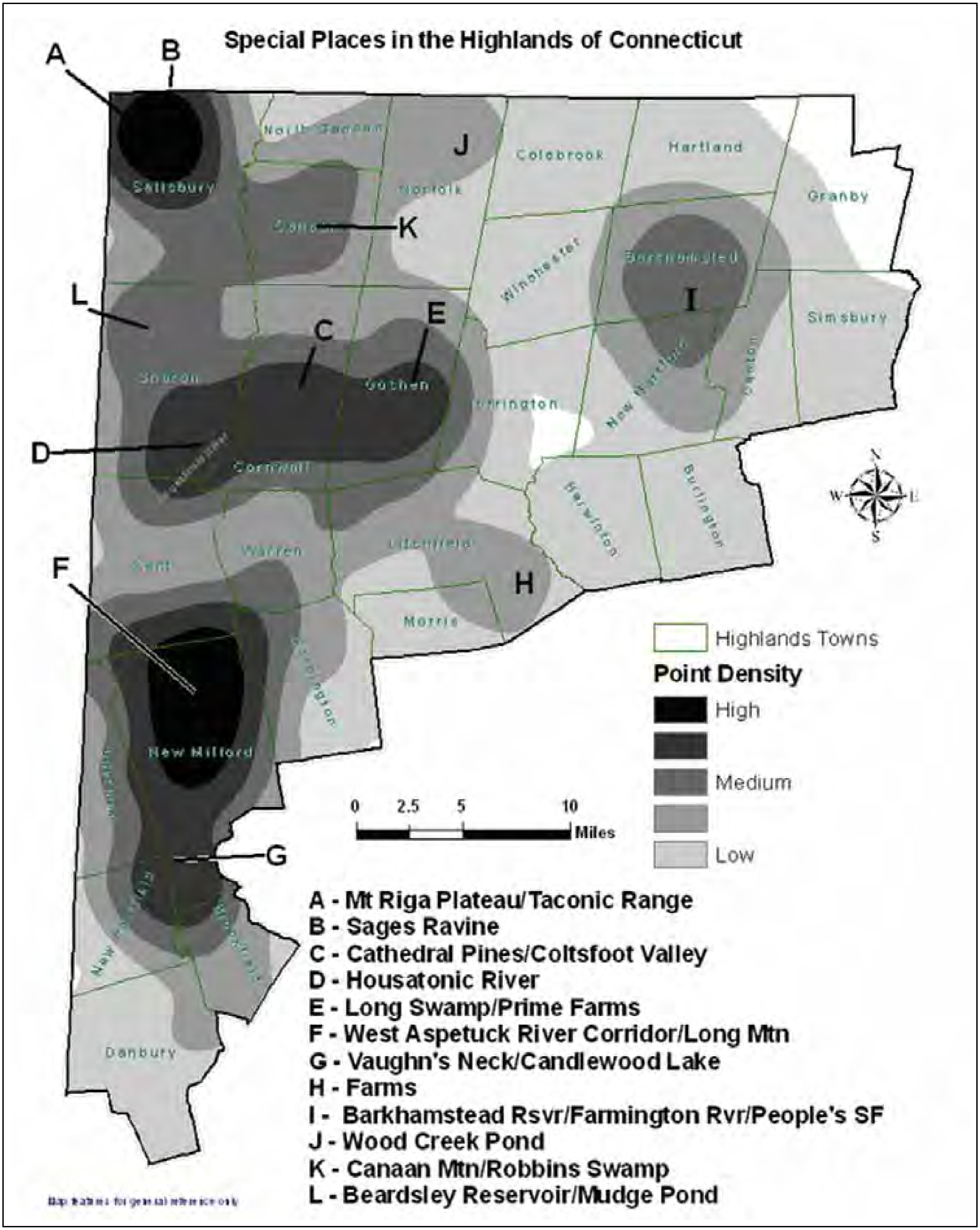


*Figure CT-8. **Special places.** Special places in the Connecticut Highlands were identified on a map by people who attended the listening sessions.*

Public input—Conservation Values Assessment—Key findings

- Across all resource categories, there is greater interest in open space and ecosystem protection than in active recreation or resource production.
- Special habitats or locations elicited more concern than the protection of overall resource values.
- People saw sprawl and the threat of development as a critical problem.

Part 3. Land and water resource characteristics

This part describes the protected land, forest land, agricultural land, water resources and human population characteristics of the Connecticut Highlands region. These characteristics are an important component of the overall study because they form the basis for the growth and impact analysis that describes the effects of future land use change on the natural resources in the region.

Protected land

Description

In the Connecticut Highlands, at least 160,660 acres (24 percent) are in conservation ownership (Figure CT-9). These acres include public lands, private lands permanently protected from development by conservation easements, and lands owned by municipal water companies. Water company lands (17,640 acres) are not permanently protected from development, but they were considered to be in "conservation ownership" for the purposes of this study. Approximately 393,050 Highlands acres are in private ownership, the largest being Great Mountain Forest.

Producing an accurate "protected lands layer" was an important early step in the study, since those lands already protected are masked out in the process of spatially identifying conservation priorities. Land was considered protected when a conservation easement restricting development on the land is held in trust by a conservation organization or public agency, or when the land is owned outright by a public agency or private conservation organization.

There is no statewide, comprehensive, up-to-date source for spatial information on lands that are protected from development. Therefore, the protected lands GIS data layer used in this study was compiled from numerous sources, and is the most complete information currently available from existing spatial data.

Most of the protected lands in the Connecticut Highlands are considered *high* or *highest* conservation value according to the Part 1 Conservation Value Assessment. Nearly two-thirds of the *highest* value land is currently conserved (Figure CT-10).

Protected land—Key findings

- 24 percent of the Highlands is in conservation ownership; 58 percent of the conserved land is privately owned.
- Most of the protected lands in Connecticut are considered high or highest conservation value according to the Part 1 Conservation Value Assessment. Almost two-thirds of the highest value land is currently conserved.

Forest land

Description

There are approximately 457,200 forested acres in the Connecticut Highlands, or 67 percent of the region, with an additional 20,200 acres of forested wetlands, according to the 2002 land cover map developed by the University of Connecticut's Center for Land Use Education and Research (CLEAR). In accordance with Forest Inventory and Analysis data (Alerich and others 2007), forests are a mixture of deciduous and coniferous species, dominated by oak-hickory (64 percent), with smaller components of northern hardwood and softwood forest types (Table CT-3). Seventy-seven percent of forest stands are more than 60 years old (Figure CT-11). These stands are a result of a major reforestation wave that occurred following agricultural abandonment and the end of the charcoal industry in the early twentieth century. Red maple

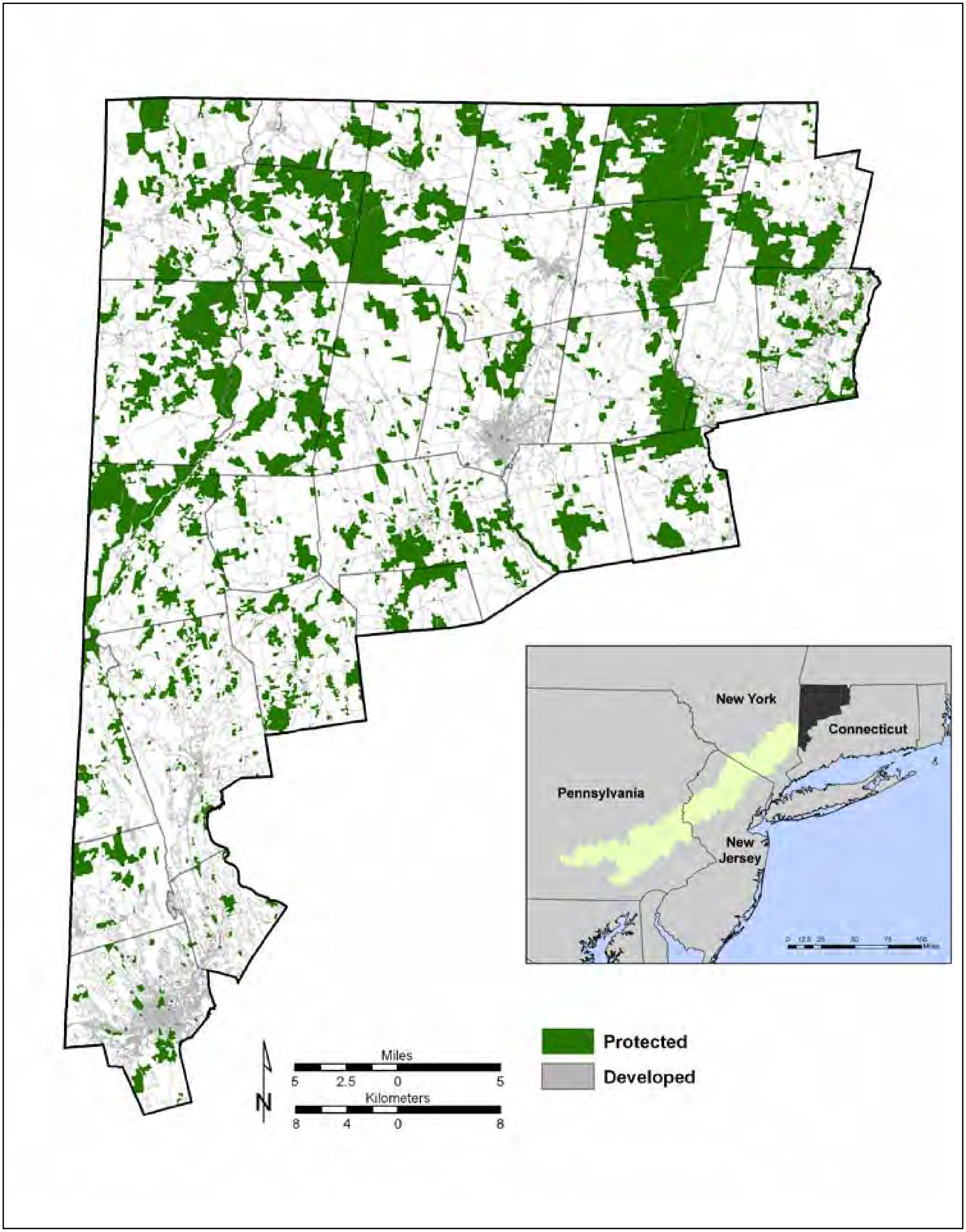
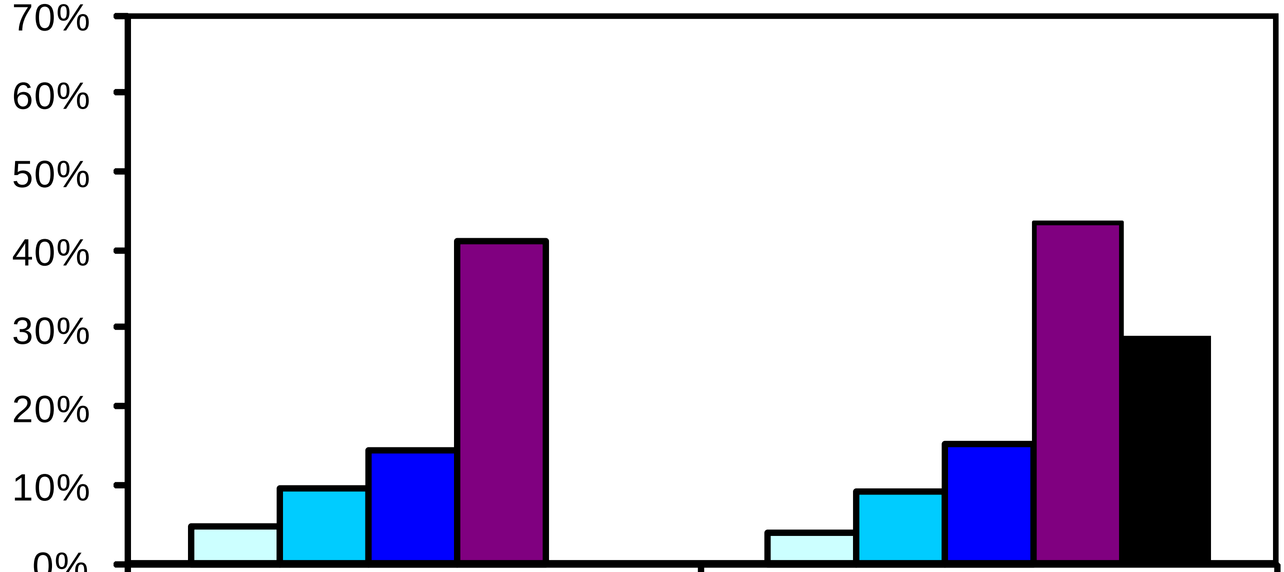


Figure CT-9. Protected land.



	Land in Each CVA Value Protected from Development	Total Protected Land in Each CVA Category
Lowest	5%	4%
Low	10%	9%
Medium	14%	15%
High	41%	43%
Highest	65%	29%

Figure CT-10. Protected land as percent of Conservation Values Assessment. *Percentage of land in the Connecticut Highlands that is protected from development, as determined by the Conservation Value Assessment (CVA). CVA data is from Part 1 of this section.*

(*Acer rubrum*) is a dominant species in both the overstory and understory (Figure CT-12). Black (sweet) birch (*Betula lenta*), which does well on a wide range of sites, is increasing in both density and basal area.

Stand structure is fairly homogeneous, with 76 percent comprised mostly of sawtimber size trees, generally larger than 11 inches in diameter. Landowners who actively manage for timber, for example state agencies and water companies, are beginning to regenerate a large portion of their forest stands and will continue to conduct regeneration harvests over the next 10 to 20 years, resulting in a greater diversity of age and size classes.

There is no "virgin forest" in the region. A virgin forest is a forest or woodland having a mature or overly mature ecosystem more or less uninfluenced by human activity. The last virgin forest in the State, located in Colebrook, was cleared in 1912 (Nichols 1913). Current timber management has favored red oak (*Quercus rubra*), while Ward (2005) found that long-term unmanaged plots are increasingly dominated by species like Eastern hemlock (*Tsuga canadensis*) and American beech (*Fagus grandifolia*).

Table CT-3. Forest types in Connecticut. Forest types (percent), from U.S. Forest Service Forest Inventory and Analysis (FIA) plots, selected State forests, and Metropolitan District Commission (MDC) forest land.

Forest Type	FIA	State	MDC
Mixed/Other Hardwoods	2%	34%	26%
Oak-Hickory	64%	20%	28%
Northern Hardwoods	23%	6%	1%
Softwood-Hardwoods	4%	19%	31%
Mixed Softwoods	—	6%	2%
Pine	1%	4%	8%
Hemlock	5%	10%	3%
Plantation	—	1%	1%

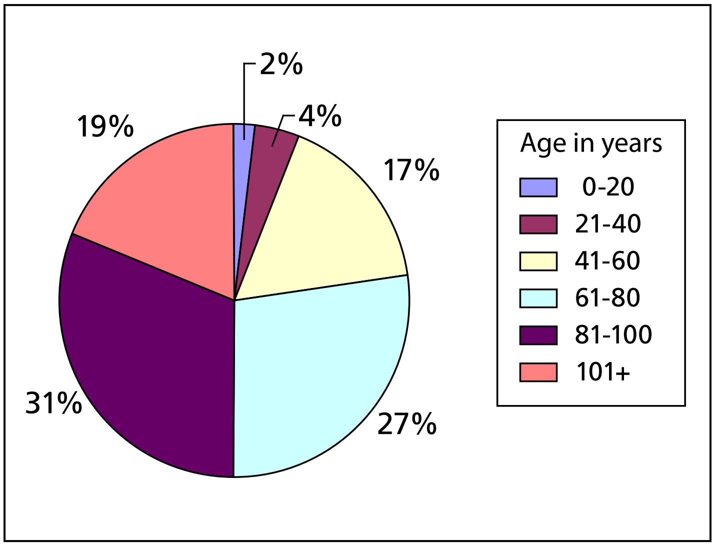


Figure CT-11. Stand age. Average stand age in U.S. Forest Service Forest Inventory and Analysis plots in the Connecticut Highlands.

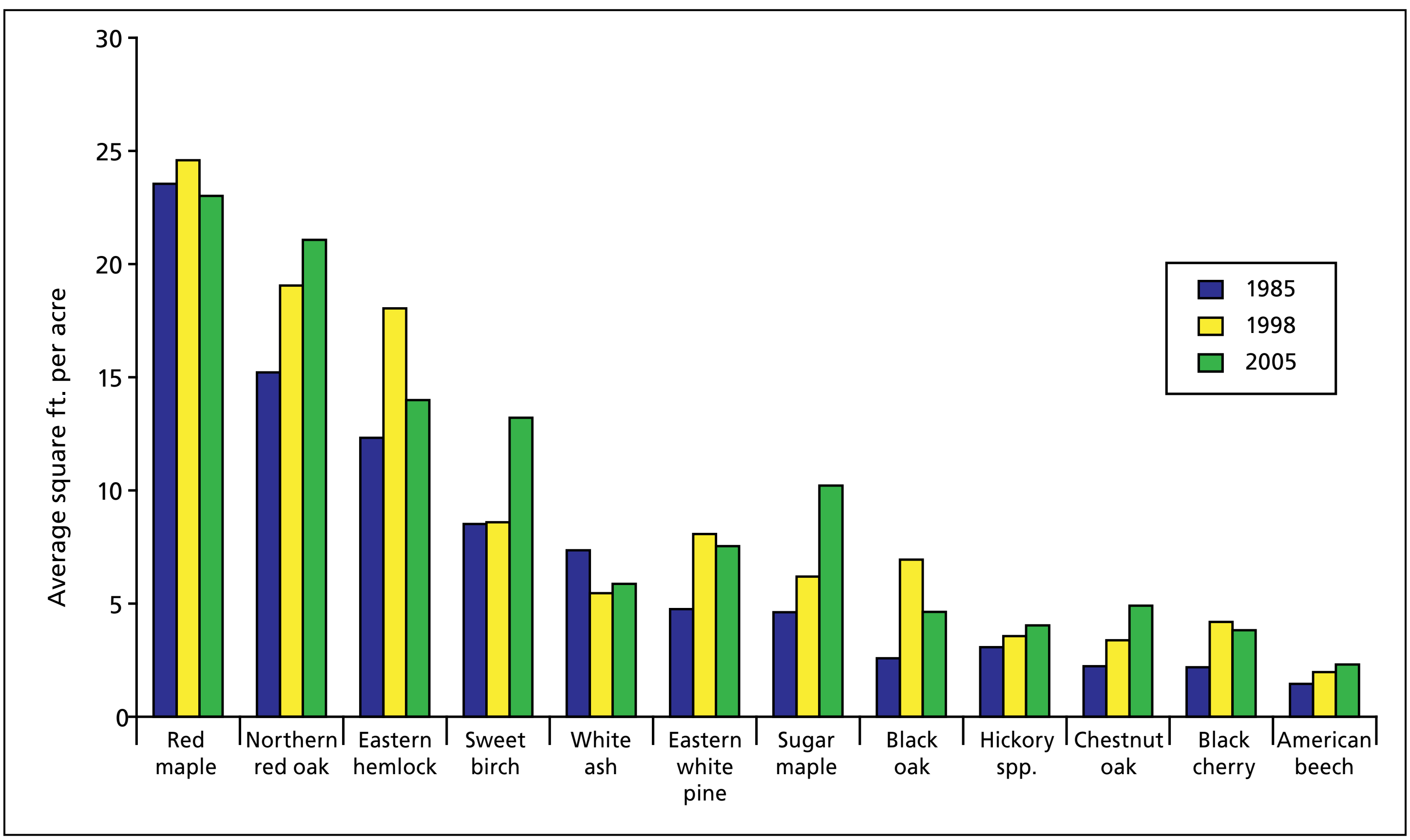


Figure CT-12. Basal area. Average basal area by species in U.S. Forest Service Forest Inventory and Analysis plots in Connecticut, 1985, 1998, and 2005.

Forest ownership

There is no federally managed forest land in the Connecticut Highlands. The Connecticut Department of Environmental Protection manages 41,640 acres of State forests as well as several state parks and wildlife management areas in the Highlands. Great Mountain Forest, at 6,400 acres, is the largest private, family-owned forest in the State. Other large tracts are the 3,800 acres of forest belonging to the White Memorial Foundation, the 4,300-acre Mount Riga property, and the Metropolitan District Commission's (MDC) 18,785 acres of mostly forest land. MDC is a nonprofit municipal corporation chartered by the state to provide regional water services. The vast majority of the forested land in the region, however, is comprised of small, privately owned parcels.

In Connecticut, 77 percent of the forest land is owned privately, 50 percent by families. Of the State's family forest owners, 19 percent are over age 65 (Butler 2008). With an aging landowner population, there is a higher risk that forested parcels will be subdivided and developed. Future management of small, privately owned lands is uncertain, but the actions of these small private owners will have important consequences for the forest resource. According to the small sample of landowners in the Connecticut Highlands region who responded to the National Woodland Owners Survey, the majority of land holdings are less than 50 acres.[1] Smaller land holdings may suggest sporadic timber harvesting that is driven more by economic need than biological considerations. Only one quarter of respondents had received professional advice in conducting harvests. None of the respondents had a written management plan. Recreational activities are the most common use of privately owned forests in the Connecticut Highlands.

Forest conversion

The analysis of land use change showed that, overall in the Connecticut Highlands, there has been a net loss of 10,808 acres of forest between 1985 and 2002; this overall rate is small—2.4 percent over 17 years. Most of the loss was due to development and associated land cover classes. Forest loss has slowed since 1990, with more than half of the loss between 1985 and 2002 occurring before 1990. The University of Connecticut's CLEAR conducted a forest fragmentation analysis for Connecticut, using the 2002 land cover map, and a 9 by 9 cell (18.6 acre) window of analysis. Their results show that the forests of the Connecticut Highlands were more fragmented in 2002 than they were in 1985 (Clear 2002). Although core forest still dominates, at 42 percent of the area, there are approximately 24,300 fewer acres of core forest and 12,400 more acres of perforated forests (Butler 2008, Table CT-4).

A comparison of forest fragmentation and the Forest Inventory and Analysis (FIA) plot data for the Highlands region showed that fragmentation has a significant impact on stand composition and structure. Fragmentation leads to a larger proportion of edge forest and less core forest, which increases temperature, light, and wind levels. Edge habitats are more prone to temperature extremes and wind disturbance, and are ideal for invasive species, which tend to thrive in disturbed habitats; roads can create pathways for invasion of nonnative species. Fragmented habitat can be fatal to species that rely on interior forest, have large ranges, or require specialized habitats such as vernal pools. Fragmentation also results in smaller parcels of forest, which can be more difficult to manage and create challenges for sustainable management on the landscape.

There is a distinct difference in species composition between core and edge forests. In Connecticut, edge forests had less oak, beech, hemlock, and yellow birch than core forests did. The edge forests had lower basal areas and were younger than core forests. Red maple was a dominant species in both edge and core forests.

Although one of the concerns about fragmentation is the propensity of invasive species to invade forest edges, there were no invasive tree species found in the FIA plots. However, this observation does not indicate whether there is a problem with invasive species in edge forests. Shrubs and vines, which are typically the biggest invasive species problems in forests, are not included in the FIA inventory.

[1]Butler, Brett J. 2007. Unpublished results from the U.S. Forest Service National Woodland Owner Survey. U.S. Department of Agriculture, Forest Service, Northern Research Station.

Table CT-4. Composition by fragmentation category. *Forest acres and percent composition in the Connecticut Highlands, by forest fragmentation category for 1985 and 2002, using an 18.6-acre window of analysis (9 by 9 cell).*

Fragmentation category*	1985		2002		Change 1985-2000	
	Acres	Percent	Acres	Percent	Acres	Percent
Core	221,319	47	197,015	43	–24,304	–10.9
Patch	11,557	2	12,561	3	1,003	8.7
Transition	28,627	6	30,643	7	2,016	7.0
Edge	118,300	25	115,132	25	–3,168	–2.7
Perforated	94,522	20	106,891	23	12,369	13.1

*For definitions of forest fragmentation categories, see the Glossary.

Forest health

There are currently no major forest insect or disease outbreaks in the Connecticut Highlands. In fact, of the 14 forest health plots which are part of the FIA Forest Health monitoring system, most are described as being in good health. Nevertheless, there are ongoing forest health concerns, including gypsy moth (*Lymantria dispar*), hemlock woolly adelgid (*Adelges tsugae*), hemlock scale (*Fiorinia externa*), and beech bark disease complex (*Neonectria coccinea*). Chestnut blight (*Cryphonectria parasitica*) remains prevalent among American chestnut (*Castanea dentate*) saplings.

A significant threat is the potential for major mortality from the emerald ash borer (*Agrilus planipennis*), which is now spreading in the Midwest United States and southwestern Ontario. Ash species represent 5 percent of the basal area in the Connecticut Highlands.

The U.S. Forest Service recently updated the 2002 National Risk Map for Insects and Diseases (Krist and others 2007). The revision depicts areas throughout the United States where tree mortality is likely to cumulatively exceed 25 percent over the next 15 years (1.7 percent annual loss) as a result of biotic agents and forest decline complexes. The data suggest that 59,305 acres (about 12 percent of the total forested acres) in the Connecticut Highlands are at risk of exceeding 25 percent mortality by 2022. The biggest threats are from Asian longhorned beetle (*Anoplophora glabripennis*), ash decline, gypsy moth, hemlock woolly adelgid, and oak decline. According to the National Risk Map, gypsy moth defoliation and oak decline are the greatest threats. Oak decline, the name given to the decline and death of oaks over widespread areas, is caused by a complex interaction of environmental stresses and pests. Oak decline is not currently a problem in Connecticut; however, the risk increases with a warmer climate and more droughts.

Forest land—Key findings

- Forests cover 67 percent of the Highlands region in Connecticut and are mostly oak-hickory and mixed hardwoods; red maple is the dominant species overall.
- There is a fairly even mix of forest age classes, except for a low percentage of young stands (less than 40 years).
- Stand structure is fairly homogeneous, with 76 percent comprised mostly of sawtimber size trees, generally larger than 11 inches in diameter.
- There was a net loss of 10,808 acres of forest between 1985 and 2002.
- In the State of Connecticut, 77 percent of the forest land is owned privately, and 50 percent by families. Of family forest owners, 25 percent are over age 65. These landowner demographics are likely the same for the Highlands region.
- Forests of the Connecticut Highlands are more fragmented than they were in 1985; although core forest still dominates, at 42 percent of the area, there were 24,300 fewer acres of core forest in 2002.
- A comparison of forest fragmentation and the Forest Inventory Analysis (FIA) plot data for the Highlands region showed that fragmentation has a significant impact on stand composition and structure.
- There are currently no major forest insect or disease outbreaks in the Connecticut Highlands.

Agricultural land

Description

Based on the agricultural resources analysis in which all active farm fields were digitized from aerial photos, only 6 percent (43,500 acres) of the land in the Connecticut Highlands is active agricultural land (Figure CT-13). Although it is a relatively minor component of the landscape, agricultural land is an important part of the heritage and culture of the region. Since 1997, acreage has been steadily lost from active agricultural use. The USDA Census of Agriculture indicated that from 1997 to 2002, cropland, pasture, and range in the Connecticut Highlands decreased by 16.7 percent (U.S. Department of Agriculture 1999, 2004).

Another trend is towards smaller farms and an increase in grazing (livestock) activities. For example, breeding, raising, and boarding of horses are mentioned as being on the increase. For the region as a whole, the average farm size decreased approximately 6 percent between 1997 and 2002, although in some sections of the region, particularly Litchfield County, there was a gain in average farm size. Overall, loss of farm acreage for the same period was only 9 percent. This could indicate a loss of smaller farms.

Comparisons of the Agricultural Census data for the Highlands Region, adjusted for county proportions, are shown in Table CT-5 for 1997 and 2002. All categories of agricultural land, including woodlands that are part of farm properties) decreased from 1997 to 2002 by approximately 9 percent. In 2002, there were 133 (13.4%) fewer farms and a 9,592-acre loss in active farm land (Table CT-5). Some cropland has reverted back to forest, more than in the reverse direction, and some has been converted to other agriculture-related purposes, such as ponds, roads, and structures.

Spatial data for the analysis of agricultural resources was derived or developed from two sources: satellite data from the University of Connecticut's Land Use and Land Cover (LULC) series developed by CLEAR, and a digitized map of active agricultural lands. The digitized map shows that only about half (43,440 acres) of the land classified as "other grasses & agriculture" in the CLEAR LULC data were in active agricultural use in 2004. Using both of these data sets, along with the agricultural census data, we estimated that almost 13,500 acres of farm land have been lost since 1995.

Currently only about 18 percent (7,800 acres) of active agricultural land is protected from development with a conservation easement.

To provide a social and cultural context to this analysis, a series of interviews were conducted with 43 individuals who are associated with agriculture in the region. Among agricultural producers fewer than half consider farming to be their primary occupation (42 percent in 1997 and 47 percent in 2002), and while the percentage of full-time farmers is increasing, the actual number of full-time farmers decreased by 4 percent. Nearly 25 percent of the agricultural producers in the region are over 65 years of age, a proportion that remained constant from 1997 through 2002. The greatest loss in the number of agricultural producers was among those younger than age 44. The farmer population is aging, and few young people are going into farming. The high value of land coupled with the retirement of farmers is the principal reason why land is being converted to other uses, mainly residential development. In many cases the only hope for agriculture to continue at a particular location is for the person who inherits the farm to continue the farming operation.

Most agricultural producers will continue in farming activities as long as they can, and as long as the land they work under lease arrangements continues to be available. There is no guarantee that a farm will remain a farm after the current owner retires unless steps are taken to permanently protect the productive land and to link the farm to someone who wishes to farm it. The fact that much of the active agricultural land is not located in areas considered high priority for agriculture according to the Conservation Values Assessment (Figure CT-5) could be a concern. This result was partly due to the fact that prime agricultural soils were used to identify high conservation value areas for agriculture, some of which are in forest or open areas not actively farmed.

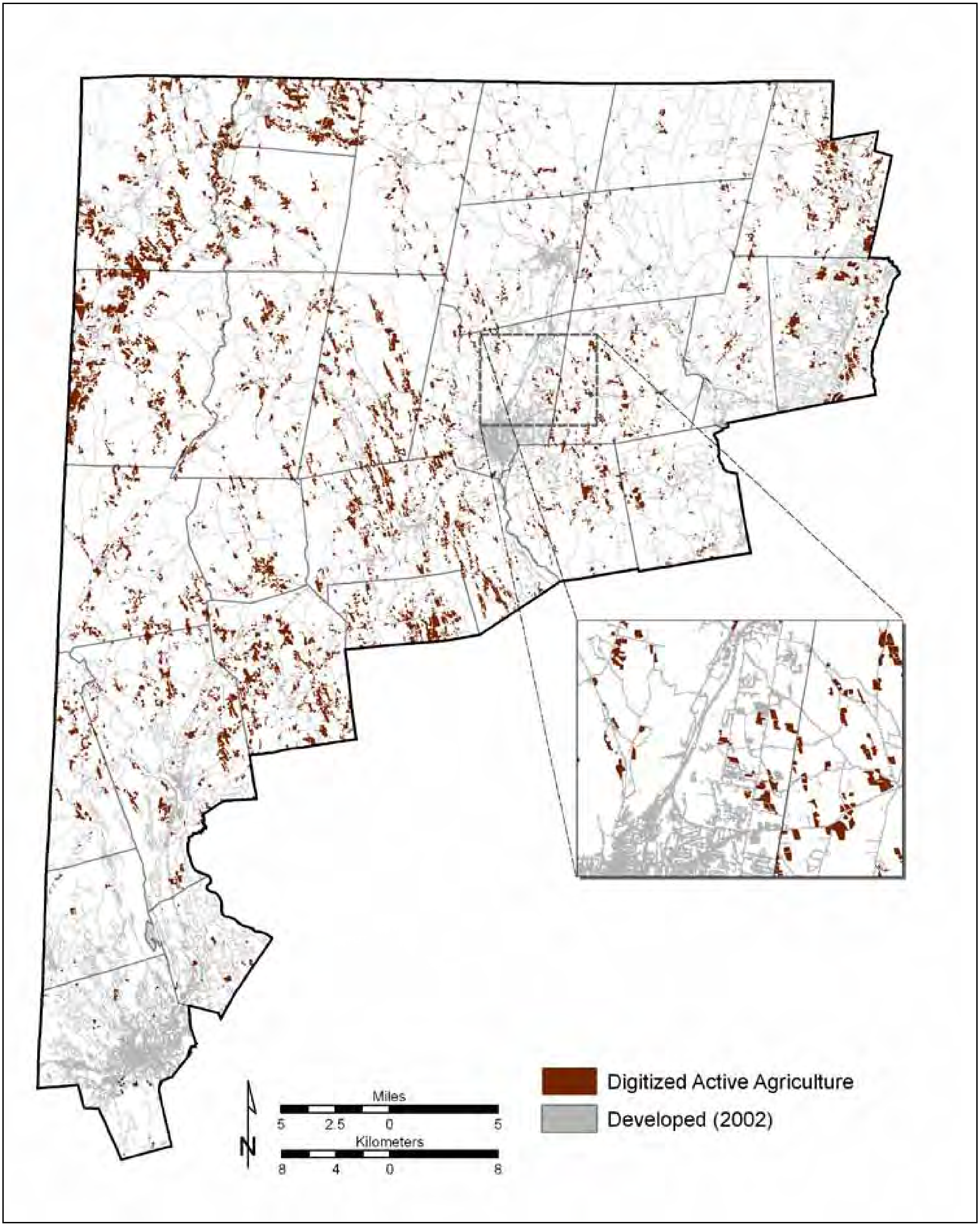


Figure CT-13. Agricultural lands. Digitized map of active agricultural lands in the Connecticut Highlands, in 2004.

Table CT-5. Agriculture statistics. *Summary of Census of Agriculture statistics for the Connecticut Highlands, for 1997 and 2002.*

Statistic	1997		2002		Change 1997 to 2001	
	Acres or number	% of Total	Acres or number	% of Total	Acres or number	% from 1997
Farm Acreage Cropland Acreage	50,340	50.8%	42,091	46.5%	–8,249	–16.4%
Pasture/Range Acreage	7,268	7.3%	5,925	6.5%	–1,343	–18.5%
Cropland/Pasture/Range Acreage	57,608	58.1%	48,016	53.0%	–9,592	–16.7%
Woodland Acreage	32,432	32.7%	33,007	36.4%	575	1.8%
Other Acreage	9,128	9.2%	9,571	10.6%	443	4.9%
Total Farm Acreage	99,168	100.0%	90,575	100.0%	–8,593	–8.7%
Number of Farms	994	—	861	—	–133	–13.4%

Agricultural land—Key findings

- Only 6 percent of the land in the Connecticut Highlands is in active agriculture.
- The USDA Census of Agriculture indicated that from 1997 to 2002, cropland, pasture, and range in the Connecticut Highlands decreased by 16.7 percent.
- The trend is towards smaller farms.
- Since 1995, 13,500 acres of farm land have been lost.
- Of active agricultural land, 8 percent is protected from development with a conservation easement.
- The farmer population is aging. Few young people are going into farming; and fewer than half consider farming to be their primary occupation.

Water resources

Description

Connecticut Highlands' water resources have long been recognized as the region's most valuable resource. The Highlands are noted for good water quality because they are sparsely settled, largely forested, and poorly adapted for agricultural use. The Connecticut Highlands are the source of ground water and surface water for approximately 800,000 people in Connecticut, of which about 300,000 reside in the Highlands. More than 500,000 people living outside the Highlands near Hartford, Connecticut's capital, and adjacent to the Highlands, and in municipalities such as Waterbury and Bristol, depend on water from the Highlands' reservoirs.

Highlands' ground and surface water quality is generally excellent, with a few exceptions. For example, the Housatonic River is on the State's "Impaired waters list," but a remediation process led by the U.S. Environmental Protection Agency is currently underway (Connecticut Department of Environmental Protection 2008). In some areas, stream quality and aquatic communities have improved since the late 1990s because of increased environmental regulation and improved wastewater-treatment facilities. Currently, only minor water quality problems prevail in the Highlands' watersheds, although the U.S. Environmental Protection Agency's (1999) National Watershed Characterization considers the watersheds to be highly vulnerable based on indicators such as urban-runoff potential, population change, and hydrologic modification.

Continued land use change and expected population growth and development in the Highlands could have a significant effect on stream- and ground-water quality and aquatic communities. Declining ground-water levels, changes in the natural flow of streams, habitat degradation, reduction in biological diversity, and a shift towards species more tolerant of disturbance are associated with increasing urban and suburban development. A description of the quality and quantity of ground and surface water resources in the Highlands follows.

Ground water—aquifers and wells

Ground water is the primary source of water for residents and businesses in the Highlands. Aquifer characteristics and the function of the ground-water-flow system are directly related to the underlying geology, which controls an aquifer's ability to store and transmit water for various uses. Descriptions of aquifer types are provided to aid in understanding the information on ground-water use that follows.

An aquifer is a permeable layer of underground rock or sand that holds or transmits groundwater below the water table that will yield water to a well in sufficient quantities.

Aquifer types

Two major aquifer types are present in the Highlands: bedrock and stratified glacial deposits. Each of the two aquifers has characteristics and water-bearing properties that determine the amount of potentially available water. Thousands of years ago, glaciers covered the Connecticut Highlands and shaped the land by scouring the underlying rock and depositing glacial till and stratified glacial deposits. Glacial till—an unsorted mix of glacial deposits—is the most extensive material in the Connecticut Highlands; however, it is an inadequate water source for most modern requirements. Bedrock underlies the entire area and is discontinuously mantled by till and stratified glacial deposits. The stratified glacial deposits were laid down by flowing water melting from the glacier and consist of interbedded layers of sand, gravel, silt, and clay that accumulated in the valley bottoms. Typically, stratified glacial deposits are the only units capable of supplying large quantities of water on a sustained basis. The bedrock in the area is part of the New England Upland and Taconic sections physiographic provinces (Fenneman 1938). Wells tapping bedrock generally yield quantities of water sufficient for domestic and commercial use.

Bedrock Aquifers

The bedrock aquifers in the Highlands are composed predominately of crystalline metamorphic and igneous rocks of Ordovician age or older (Figure CT-14). Most prevalent rock types are schist and gneiss. Areas of clastic sedimentary rock of Mesozoic age are found along the eastern edge of the area. These rocks are less resistant and form part of the Connecticut Valley Lowland physiographic province (Fenneman 1938). The rocks or the province are not considered part of the Highlands topographically, but are included in this discussion because they are in towns that are considered to be in the Highlands region as defined for this study.

Bedrock aquifers are the primary source of water for self-supplied homes and small public or commercial water systems. Well yield depends on the number, size, and interconnection of the fractures. Wells tapping carbonate aquifers supply harder water—with higher levels of calcium and magnesium—and typically have larger well yields because fractures in the rock allow water to flow more readily. Marble is less resistant than other types of bedrock and tends to underlie many of the valleys in the Highlands. Because these carbonate rocks tend to be relatively lower topographically, glacial stratified material accumulated in these areas.

Glacial aquifers

Glacial aquifers are composed mainly of unconsolidated gravel, sand, and silt of Pleistocene age; they form narrow belt-like deposits, typically in stream valleys, and make up about 12 percent of the Highlands. These aquifers can provide significant storage and yields of water. Areas with greater potential for ground water supply, which are based upon the texture and thickness of surficial aquifer deposits, have been identified by the State for resource protection, water management, nonpoint source pollution prevention, and land-use planning (Figure CT-15). The resulting hydrostratigraphic units define areas of coarse-grained deposits, coarse overlying fine-grained deposits, fine-grained deposits, and areas where fine-grained deposits overlie coarse-grained deposits. Aquifer deposit thickness intervals are 1–50 feet, 50–100 feet, 100–200 feet, 200–300 feet, and 300–400 feet.

Aquifer recharge

Ground-water recharge or replenishment to the bedrock aquifers in the Highlands is predominantly through precipitation that percolates through the overlying soil to fractures, joints, or solution openings in the underlying bedrock (Figure CT-16). More recharge occurs in areas with a thick layer of overlying unconsolidated material. Ground water moves from upland recharge areas to discharge areas, such as springs and streams at lower elevations.

Glacial aquifers receive recharge from runoff caused by precipitation that falls on the surrounding bedrock uplands, by infiltration from precipitation that falls directly on the valley-fill aquifers, and by inflow from adjacent bedrock aquifers. These sources are usually sufficient to maintain aquifer water levels above those of streams, so that water moves from the aquifer to streams. During droughts, however, discharge by seepage to adjacent bedrock, evapotranspiration, and withdrawals from wells can lower aquifer water levels until flow is reversed and water moves from the stream to the aquifer (Figure CT-17).

Aquifer recharge can be highly variable because it is (1) determined by local precipitation, (2) influenced by topographic relief, and (3) based on the capacity of the land surface to accept infiltrating water. The degree to which the aquifers in the Highlands have the ability to store and transmit recharge water is based on the amount and connectivity of openings in the underlying bedrock or sediment. This is known as the aquifer's permeability and has a direct bearing on the aquifer's ability to yield sufficient quantities of water to wells.

Ground water yields

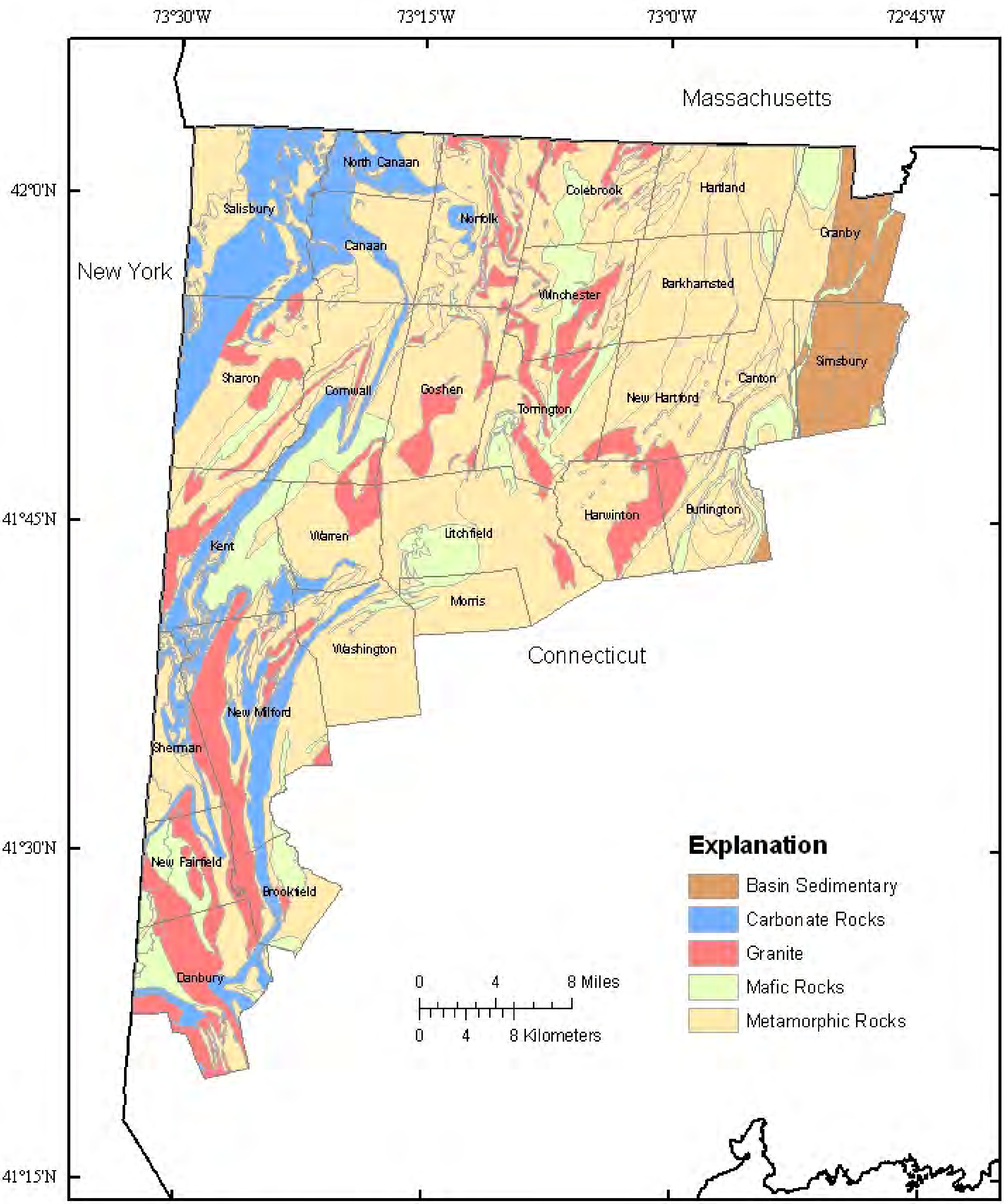
Ground-water safe yields were compiled for community wells used for municipal supply, and industrial, commercial, irrigation, and mining uses. In Connecticut, safe yield is defined as the maximum dependable quantity of water per unit of time which may flow or be pumped continuously from a source of supply during a critical dry period without consideration of available water limitations. (Connecticut General Statute 25-32d-4).[2] In general, annual ground-water withdrawals from community wells are about 75 percent of the total safe yield, and during summer, when demand increases, some of the smaller community systems have ground-water withdrawals that reach 90 and 100 percent of their safe yields.[3]

Figure CT-18 shows the location of 196 wells that yield more than 0.001 million gallons per day (Mgal/d) and were operating in 2000, and provides information on the volume of withdrawals per well by aquifer type. Of these wells, 46 are in stratified glacial material and had a combined safe yield of 15.3 Mgal/d in 2000.[3] One hundred and fifty of the wells are in bedrock (both crystalline and carbonate) and had a combined safe yield of 3.92 Mgal/d in 2000. No apparent relationship was observed between the yield of bedrock wells and the type of bedrock in which the wells are located. As mentioned above, glacial aquifers cover many areas of carbonate rock, so wells in these locations generally tap the glacial aquifer and not the underlying bedrock.

---

[2] Connecticut General Statute 25-32d-4. 2008. Connecticut Department of Public Health. Public Health Code. Water Supply Plans. 20 p. www.dir.ct.gov/dph/PHC/docs/156_water_supply_plans.doc (28 August 2009).

[3] Messer, Steve, Supervising Sanitary Engineer, Connecticut Department of Public Health. [Telephone conversation with Elizabeth Ahearn, Hydrologist, U.S. Geological Survey]. 9 May 2008.



Base from U.S. Geological Survey, 1:24,000, 1969 to 1984, Connecticut State Plane projection.

Base from U. S. Geological Survey 1:24,000, 1969 to 1984, Connecticut State Plane projection

Figure CT-14. Major bedrock aquifers of the Connecticut Highlands. *Bedrock aquifers are classified by their rock type, which affects water infiltration, storage, availability, and chemistry. The hydrologic properties of the various rock types are similar in that ground water moves primarily through fractures; however, the degree of fracturing and the geometry of fracture systems differs among rock types (geology modified from Rodgers 1985).*

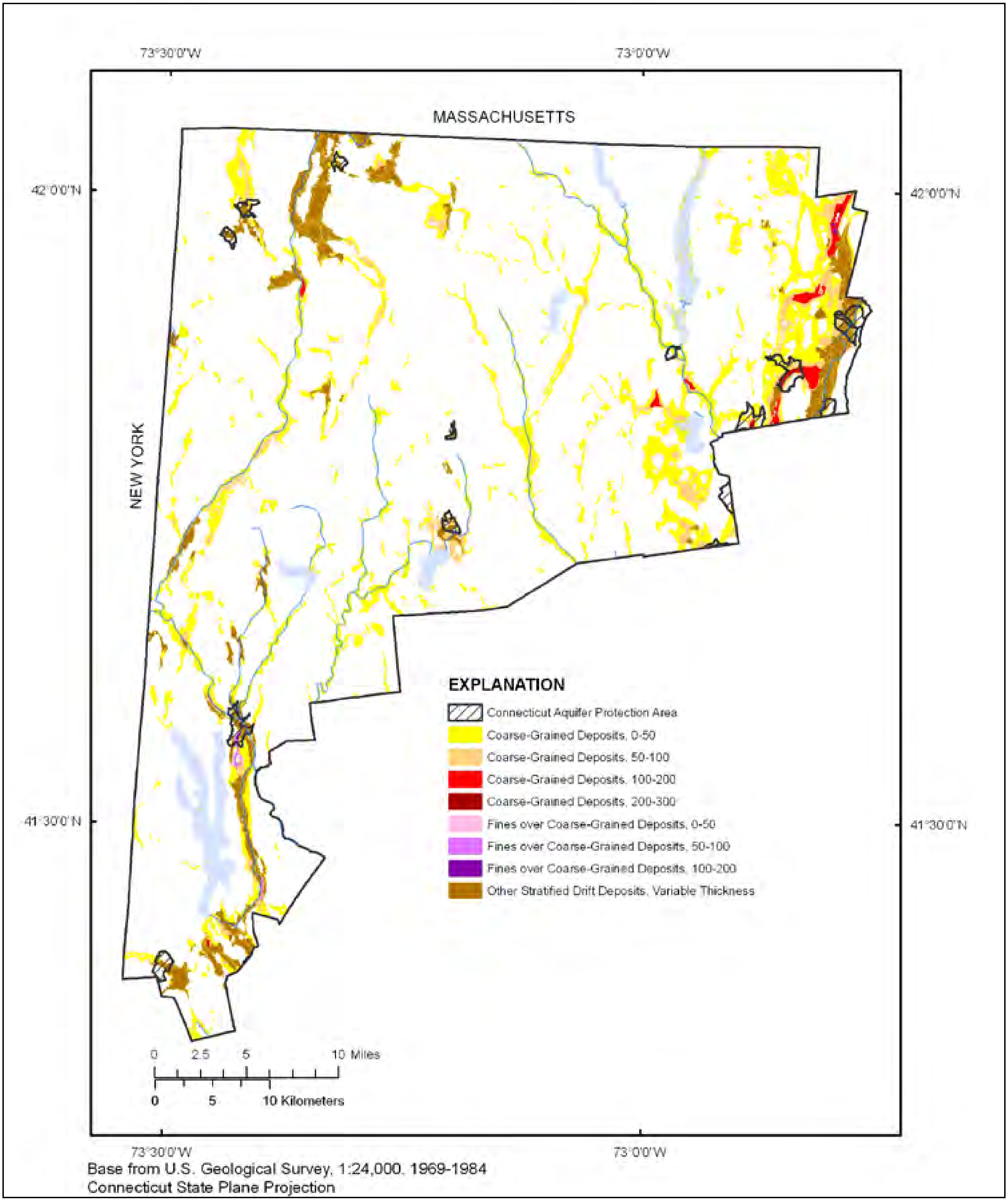


Figure CT-15. Surficial aquifer potential. *Surficial aquifers generally have a greater potential for ground water supply than bedrock aquifers, and make up about 12 percent of the Connecticut Highlands. Aquifers with coarse-grained stratified drift are the most productive surficial aquifers in Connecticut and provide large water yields for public and industrial uses. Aquifers with fine-grained stratified drift are generally considered poor surficial aquifers, particularly where not interbedded with coarse sediment layers. Areas on the map with the designation "Aquifer Protection Area" have been identified by the State as having greater potential for ground water supply and are important for resource protection.*

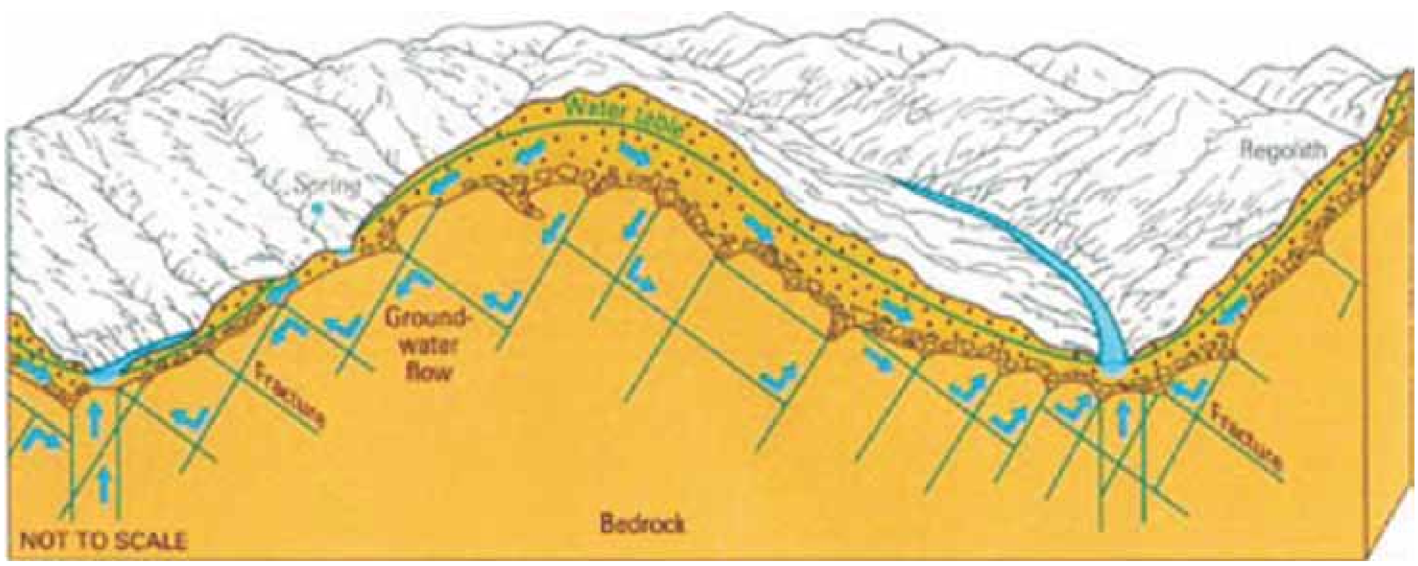


Figure CT-16. Recharge and flow in bedrock aquifers. *Ground water in bedrock aquifers is predominantly precipitation that has infiltrated the overlying soil and the bedrock. At lower elevations the ground water feeds springs and streams (modified from Heath 1980, p. 10).*

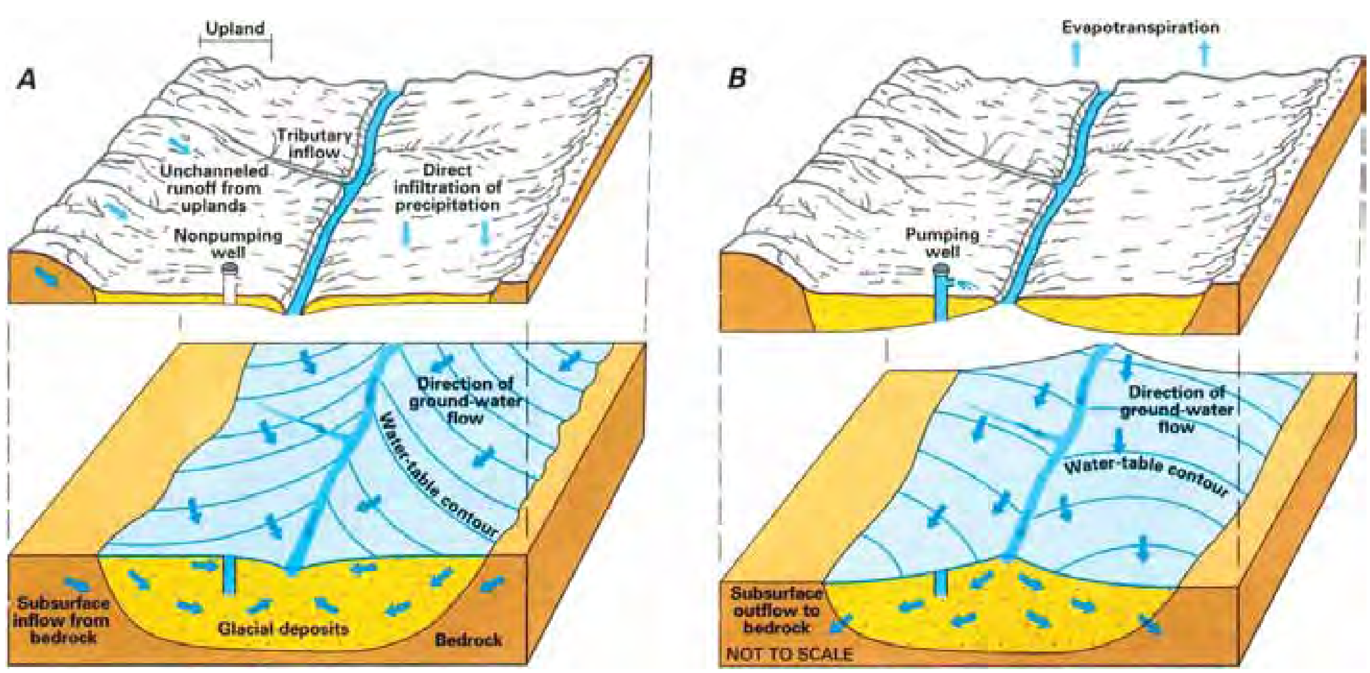


Figure CT-17. Recharge and flow in glacial aquifers. *Ground water enters glacial aquifers in three ways: as runoff from the surface of surrounding bedrock, as underground flow from adjacent bedrock, and by infiltration of precipitation that falls directly over the aquifer. (A) When the water level in a glacial aquifer is above that in streams, ground water flows from aquifer to stream. (B) When the water level in a glacial aquifer drops below that in streams due to withdrawal from wells, drought, evapotranspiration, and seepage into adjacent bedrock, water flows from stream to aquifer (modified from Rosenshein 1988, p. 186).*

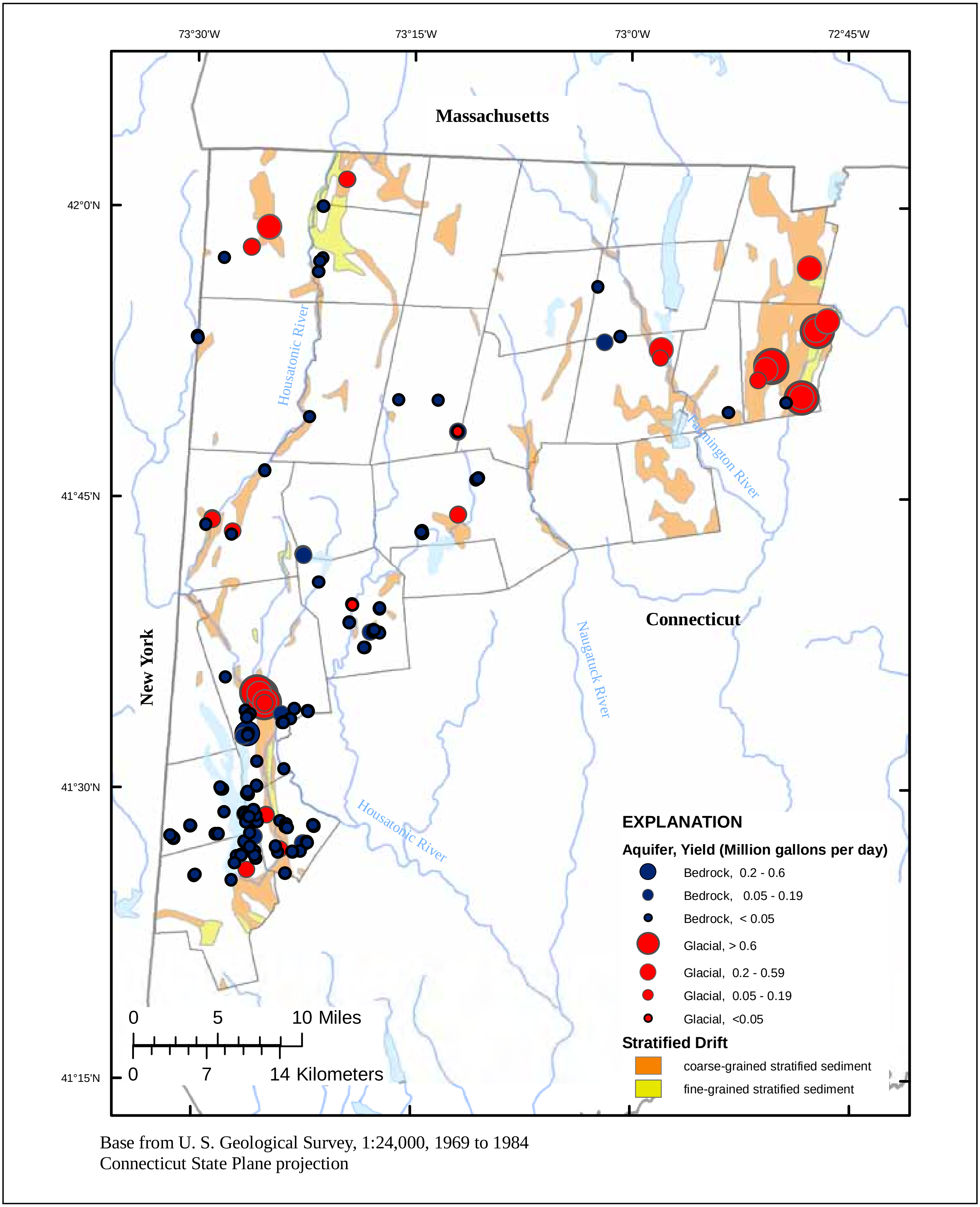


Figure CT-18. Safe yields. *Distribution and water yields of the community water-supply wells in the Connecticut Highlands in 2000. The amount of water withdrawn differs regionally and by aquifer type. Community wells located in coarse-grained stratified drift provided the large yields for public supply and industrial uses. Note: yield represents the amount of water that was withdrawn from the well and not the maximum amount of water the well can provide.*

Major public water supply wells in sand and gravel aquifers are protected under Connecticut's Aquifer Protection Area Program to ensure a plentiful supply of public drinking water for present and future generations. Aquifer protection areas (sometimes referred to as "wellhead protection areas") are shown in active well fields in sand and gravel aquifers that serve more than 1,000 people (Figure CT-15). The Aquifer Protection Area Program responsibilities are shared by the state Department of Environmental Protection, the municipalities, and the water companies. Land use regulations are established in the aquifer protection areas to minimize the potential for contamination of the well field and to restrict development of certain new land-use activities that use, store, handle, or dispose of hazardous materials. In addition, existing regulated land uses in the aquifer protection area must be registered and should incorporate best management practices.

Monitoring ground water levels

Changes in ground water levels reflect the general response of the ground water system in the Highlands to climate changes, changes in seasonal recharge patterns, and ground water withdrawals.

Figure CT-19 shows variations in ground water levels from five monitoring wells in the Highlands region with more than 20 years of monthly records. These hydrographs show typical fluctuations of ground water levels in the glacial till and stratified glacial aquifers of the study area. Water moves more readily through stratified glacial deposits than through glacial till. No significant trends in ground-water levels from water withdrawals were observed in any of the long-term wells in the Connecticut Highlands. The effects of periodic drought on monitoring well BU 2 (in Burlington), typical of other wells in the Connecticut Highlands, are shown in Figure CT-20. Shallow wells constructed just below the water table could have problems with water yield or go dry during prolonged dry periods.

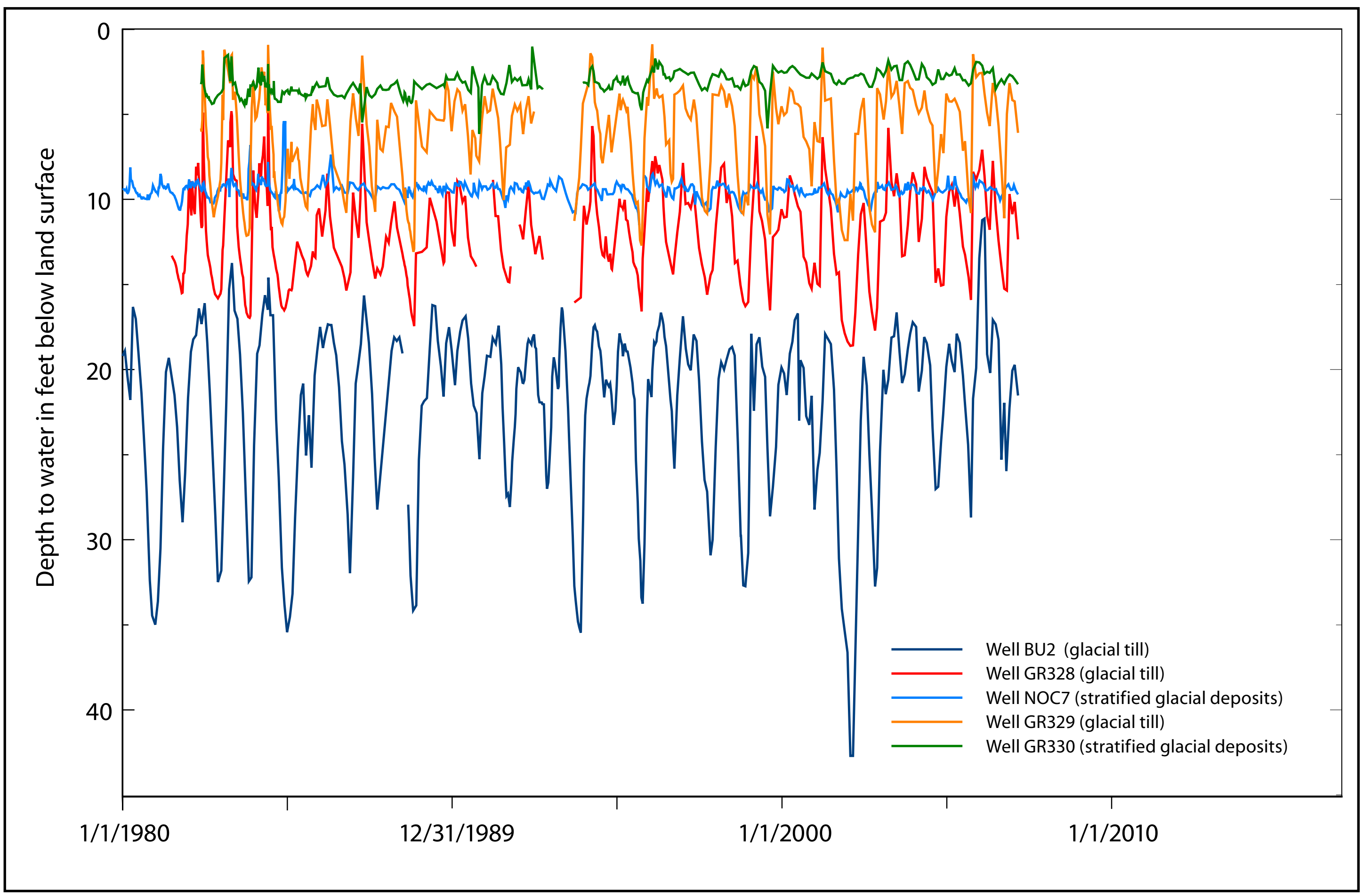


Figure CT-19. Variation in ground-water levels. *Hydrographs for five ground-water monitoring wells in the Connecticut Highlands show typical seasonal fluctuations in ground-water levels from 1980 to 2005.*

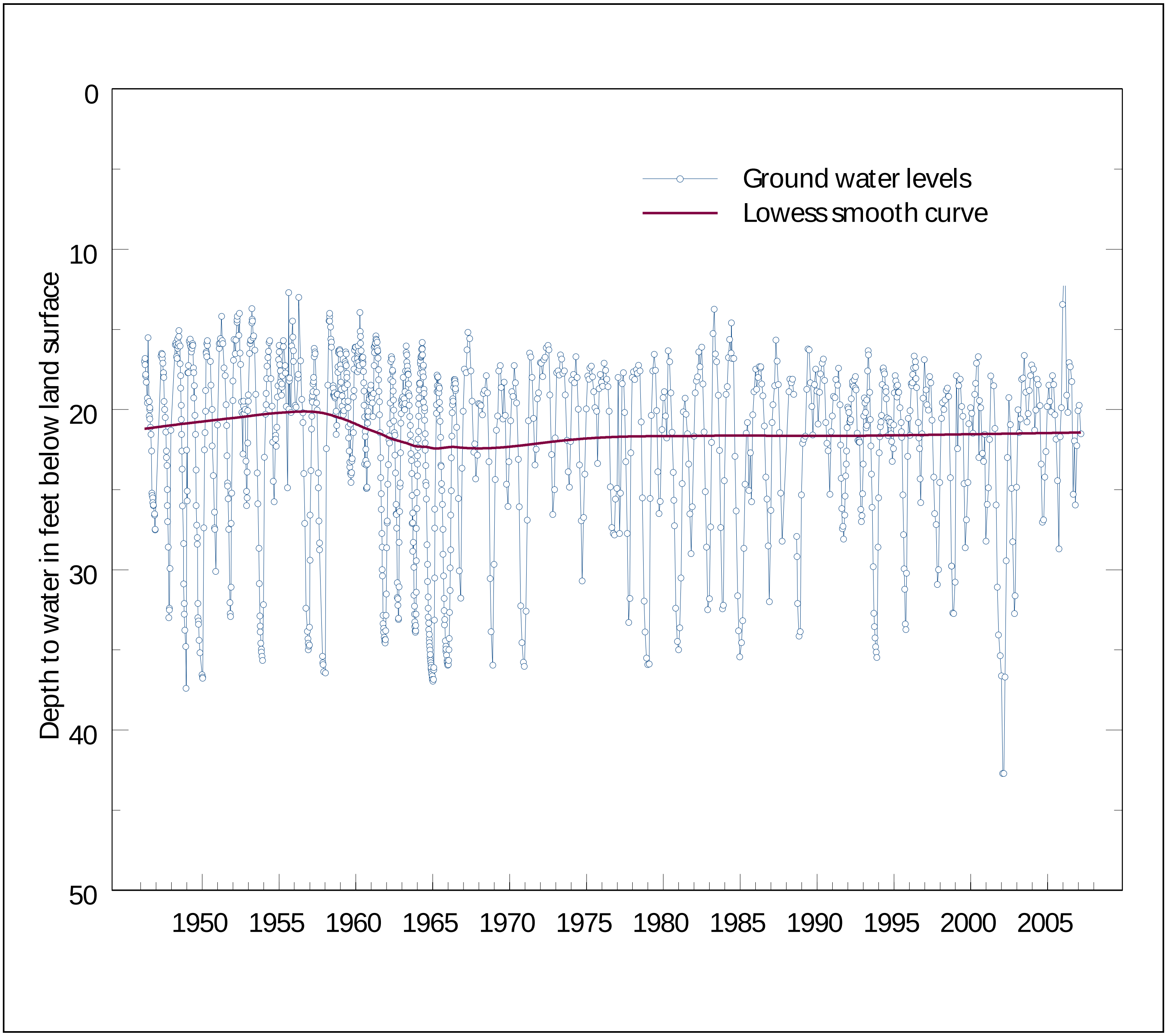


Figure CT-20. Seasonal and climatic trends in ground water levels. *A smooth curve plotted through the hydrograph for ground-water monitoring well BU 2 (Burlington) in the Connecticut Highlands represents the long-term trend of ground water levels for this well. A short-term decline in ground water levels occurred during the 1960s drought.*

Ground water—Key findings

- Safe yields of community water system wells in glacial aquifers ranged from 0.06 to 1.14 million gallons per day, with a combined safe yield of 15.3 million gallons per day in 2000. Safe yields of community water system wells in bedrock aquifers ranged from 0.0001 to 0.0162 million gallons per day, with a combined safe yield of 3.92 million gallons per day in 2000.
- Long-term ground water levels in the monitoring wells in the Connecticut Highlands show that there are no significant, long-term upward or downward trends in ground water levels.
- Long-term ground water level monitoring has recorded several dry periods during the last 60 years, the worst of which was 6 consecutive years of low water levels from 1961 to 1966.

Surface water—streams, rivers, and reservoirs

Approximately 1,230 miles of streams and rivers, and 540 named lakes and ponds are in the Connecticut Highlands. Of the 540 named lakes and ponds, 37 have surface areas larger than 100 square miles, and are an important source for drinking water, flood storage, and outdoor recreation to communities both in and adjacent to the Highlands. The streams and rivers serve as habitats for fish, plants, and wildlife, and contribute to the scenic qualities of the Connecticut Highlands.

Drainage basins

Farmington River Basin

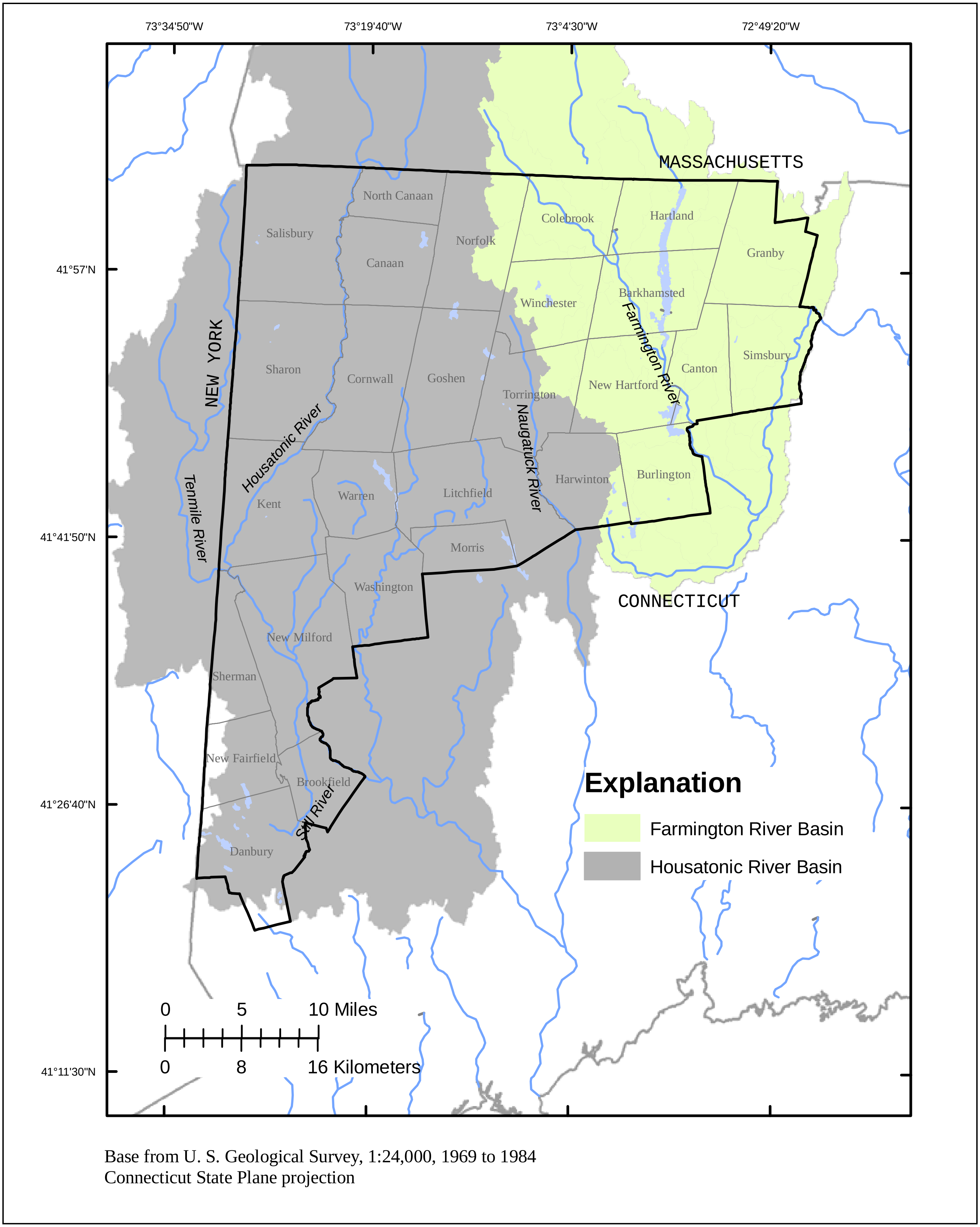
The rivers and streams in the Connecticut Highlands are in two major drainage basins—the Farmington River Basin (32 percent of the area) and the Housatonic River Basin (68 percent of the area) (Figure CT-21). The Farmington River Basin has a 609 square mile drainage area, and the river is a tributary of the Connecticut River. Headwaters of the Farmington River Basin are in the Berkshire Hills of western Massachusetts from where the river flows south from the Litchfield Hills of northwestern Connecticut to the town of Farmington, outside the Highlands. In Farmington, the river changes direction and flows north to Tariffville (Simsbury), defining the lower limit of the Connecticut Highlands study area. Major tributaries of the Farmington River include the Clam River and the Buck River in Massachusetts, and the Still River, Mad River, Nepaug River, Roaring Brook, Pequabuck River, and Salmon Brook in Connecticut.

The area of the Farmington River Basin that is considered part of the Connecticut Highlands encompasses 329 square miles of the total drainage area (609 square miles). A 14-mile stretch of the Farmington River between Colebrook and Canton was designated as a Federal Wild and Scenic River in 1994, the first in Connecticut to receive this designation. The towns of Barkhamsted, Burlington, Canton, Colebrook, Granby, Hartland, and Simsbury are completely within the Farmington River Basin, as are major portions of New Hartford and Winchester. The basin also includes parts of the towns of Harwinton, Norfolk, and Torrington. All of these municipalities obtain their water supply from within the Farmington River Basin.

Housatonic River Basin

The Housatonic River Basin and its tributaries drain an area of 1,948 square miles (Cervione and others 1972). The basin has rugged terrain in the uplands, and rolling hills and flat stretches of marshland in the lowlands. The Housatonic River divides the Taconic Mountains and New England Upland sections of the New England Physiographic Province (Fenneman 1938). The main stem of the Housatonic River flows south-southeasterly for about 130 miles from its headwaters in the Berkshire Hills in western Massachusetts to its outlet at Milford Point in Long Island Sound, where the river drops about 1,430 feet in elevation from its headwaters. Flow from the lower Housatonic River is diverted to Candlewood Lake, the largest lake in Connecticut. Candlewood Lake is a pump-storage reservoir; its lake water is occasionally needed for power generation at the Rocky River Pumped-Storage Hydroelectric Station in New Milford.

Major tributaries of the Housatonic River are the Williams, Green, and Konkapot Rivers in Massachusetts, the Tenmile River in New York, and the Naugatuck, Shepaug, Still, and Pomperaug Rivers in Connecticut. The lower limit of the main stem of the Housatonic River, as defined for this study, is Lake Lillononah at the most southern point of the town of Brookfield. The area of the Housatonic River Basin that is considered part of the Connecticut Highlands encompasses 712 square miles of the total drainage area (1,948 square miles). The Housatonic River Basin of the Connecticut Highlands includes all or parts of 20 municipalities. Brookfield, Canaan, Cornwall, Danbury, Goshen, Kent, Litchfield, Morris, New Fairfield, New Milford, North Canaan, Salisbury, Sharon, Sherman, Warren, and Washington are completely within the basin, as are major portions of Harwinton, Norfolk, and Torrington. The basin also includes parts of the town of New Hartford and Winchester. All of these municipalities obtain their water supply from within the Housatonic River Basin.



Base from U. S. Geological Survey, 1:24,000, 1969 to 1984
Connecticut State Plane projection

Figure CT-21. Housatonic and Farmington River basins. *The area of the Farmington River Basin that is considered part of the Connecticut Highlands encompasses 329 square miles, and the area of the Housatonic River Basin that is considered part of the Connecticut Highlands encompasses 712 square miles.*

Reservoir storage and transfers

Thirty-three major reservoirs in the Connecticut Highlands provide water for customers both in and out of the Highlands (Figure CT-22). Safe yields (defined under Ground water—ground water yield section) are 40.6 Mgal/d for the Housatonic and 77.1 Mgal/d for the Farmington River Basins, for a total of 117.7 Mgal/day. Estimating safe yield is a major concern of State and municipal authorities charged with managing water supply systems. One variable affecting a system's safe yield is population growth, which increases demand on the water supply system.

During 2007, water suppliers reported an annual production (water delivered to customers) of 32.3 billion gallons (average 88.6 Mgal/d) from 28 of 33 supply reservoirs; annual production from five smaller water-supply reservoirs was not available. About 87 percent, or 28.2 billion gallons of the annual production, was transferred out of the Highlands. The largest public supplier of drinking water from the Connecticut Highlands, the Metropolitan District Commission (MDC), exported 55.4 Mgal/d from the Farmington River Basin to about 400,000 people in the Hartford area. Their source of water is the Barkhamsted Reservoir (Figure CT-22; map label 2) and Nepaug Reservoir (Figure CT-22; map label 22). These two largest reservoirs in the Highlands have a combined water supply storage capacity of 39.8 billion gallons (Table CT-6). Other water suppliers transferred a total of 21.9 Mgal/d from surface water reservoirs to about 175,000 customers outside the Highlands, primarily in the municipalities of Waterbury and Bristol. Lake McDonough can be used as a public-water supply reservoir during emergencies, such as prolonged droughts.

Reservoirs in the Highlands are especially important because of their ability to store water for use during critical times, such as prolonged drought. Historically, Connecticut has been affected by many episodes of drought, of varying severity and duration. A recent prolonged dry period occurred in 2002. The Barkhamsted and Nepaug Reservoir system held a total of 29.8 billion gallons of water near the end of the 2002 drought, representing 75 percent of the system's capacity. The 1961-1966 drought was the longest and most severe in the recorded history of the region. This drought had a frequency of occurrence, on average, of once in about 160 years and had major effects on agriculture and water supplies (Barksdale and others 1966). In December 1965, Barkhamsted Reservoir held a total of 11.5 billion gallons, representing about 38 percent of capacity. In December 1964, Nepaug Reservoir held a total of 4.7 billion gallons of water, representing 49 percent of capacity. As a combined system, the volume of storage dropped to about 40 percent of capacity during this drought.

Surface water—Key findings

- Reservoirs in the Connecticut Highlands are the major water-supply source for numerous communities in and adjacent to the Highlands. Surface-water withdrawals from 33 public water-supply reservoirs in the Connecticut Highlands averaged 88.6 million gallons per day in 2007.
- Approximately 77.3 of 88.6 million gallons per day of surface water withdrawn for public supply is transferred out of the Connecticut Highlands to supply water for approximately 575,000 people living in the regions centered around the State's capital of Hartford and the municipalities of Waterbury and Bristol.
- Major reservoir systems in the Highlands (in the Farmington and Housatonic River Basins) have a combined safe yield of about 118 million gallons per day.
- Reservoirs in the Highlands are especially important because of their ability to store water for use during critical times. During the 1960s drought (Connecticut's most severe in recorded history), the Barkhamsted and Nepaug Reservoir system (the largest in the Connecticut Highlands) held a total of 16.2 billion gallons of water near the end of the drought, representing about 40 percent of the system's capacity.

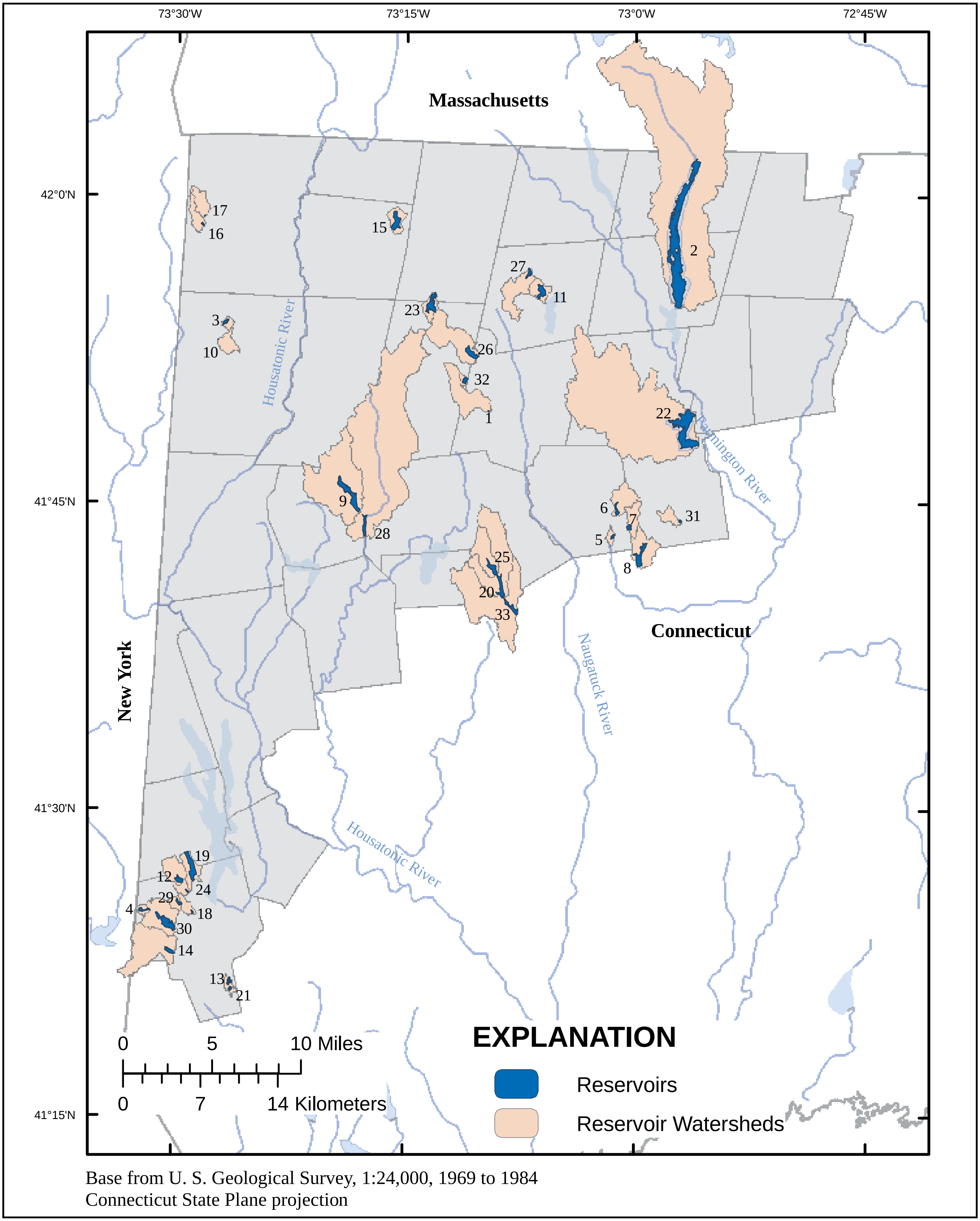


Figure CT-22. Water supply reservoirs. *Surface-water withdrawals from the water-supply reservoirs in the Connecticut Highlands were 88.6 Mgal/d in 2007. About 87 percent of the water was transferred to approximately 575,000 people living outside the Connecticut Highlands. The numbers on the map refer to the reservoir names listed in Table CT-6.*

Table CT-6. Reservoir production. *Total production of major water-supply reservoirs in the Connecticut Highlands, by major basins. Source of the annual water production for the various reservoir systems is the Connecticut Department of Public Utilities (2009).*

Map label*	Reservoir name	Total production** (Mgal/d)
Farmington River Basin		
	MDC System	55.4
2	Barkhamsted Reservoir	
22	Nepaug Reservoir	
	Winchester System	0.98
27	Rugg Brook Reservoir	
11	Crystal Lake Reservoir	
	Other Systems	6.33
5	Bristol Reservoir #2	
6	Bristol Reservoir #4	
7	Bristol Reservoir #5	
8	Bristol Reservoir #7	
31	Whigville Reservoir	
Housatonic River Basin		
	Danbury System*	7.16
30	West Lake Reservoir	
4	Boggs Pond	
18	Lower Kohanza Reservoir	
29	Upper Kohanza Reservoir	
14	Lake Kenosia Diversion	
19	Margerie Reservoir	
12	East Lake Reservoir	
24	Padanaram Reservoir	
13	Eureka Lake	
21	Mountain Pond	
	Waterbury System	15.4
9	Cairns Reservoir	
28	Shepaug Reservoir	
25	Pitch Reservoir	
20	Morris Reservoir	
33	Wigwam Reservoir	
	Torrington System	3.10
23	North Pond	
26	Reuben Hart Reservoir	
32	Whist Pond	
1	Allen Dam Reservoir	
	Other Systems	0.264
15	Lake Wangum	
16	Lakeville No.2	
17	Lakeville No.3	
3	Beardsley Pond Reservoir	
10	Calkinstown Reservoir	
	Total	88.6

*Map labels are shown in Figure CT-22.
**Total production is based on 2007 data.

Water use

Many existing sources of water are stressed by withdrawals from aquifers and diversions from rivers and reservoirs to meet the needs of communities. Although Connecticut has abundant water resources, they are not uniformly distributed, and supplies are not always near the centers of demand (Healy 1990). Periodic droughts have drawn attention to limits in the reliability of local and regional water supplies and have affected short-term water use for all users. Quantitative assessments derived from a water-use compilation can be used in a number of ways: to evaluate the impacts of population growth, trends in water use, conservation activities, and water-management policies, as well as to plan for more effective use of the water resources, and to make projections of future demand. In the following section, estimates are presented for four categories of water withdrawals in the Connecticut Highlands: (1) registered and permitted water withdrawals, (2) self-supplied domestic water withdrawals and domestic deliveries, (3) public-supply water withdrawals, and (4) irrigation water withdrawals (for golf courses). Total water use in the Connecticut Highlands for 2005 are listed in Table CT-7.

Consumptive use is the part of water withdrawals that is evaporated, transpired, consumed, or otherwise removed from the immediate water environment. Consumptive use was computed as 20 percent of water withdrawals for domestic and commercial purposes, and 100 percent of water withdrawals for irrigation. Consumptive use in the Connecticut Highlands in 2005 was estimated at about 8 Mgal/d.

Return flow is the quantity of water that is discharged to a surface or ground water source after use and becomes available for reuse. Return flows were not estimated for this study.

Registered and permitted water withdrawals

The State of Connecticut requires registration or permits for all ground water or surface water withdrawals exceeding 50,000 gal/day. In the Connecticut Highlands, there are 162 registered diversions and 67 permitted diversions. (Permitted diversions represent 127 diversion locations.) The State has no regulatory control over registered diversions; it does have control over permitted diversions. Registered diversions began when the General Assembly enacted the Diversion Act in 1982. Registered diversions existing at the time the law was passed allow registrants to continue diverting water indefinitely.

Public water supply is the largest water use category with an estimated total of 2,254 Mgal/d—56 Mgal/d from ground water and 2,198 Mgal/d from surface water sources, primarily surface water reservoirs. In Connecticut, however, many reservoirs are part of interconnected systems, each with its own registered or permitted water withdrawal; thus, water passing through the multiple reservoirs is counted more than once. Only the withdrawal from the last or "service" reservoir in the system that goes to a filtration plant and to a district or town should be considered water removed from the water environment. The registered and permitted water withdrawals by public suppliers that exclude the withdrawals from nonservice reservoirs total an estimated 374 Mgal/d, which is higher than the actual usage.

Self-supplied domestic water withdrawals and domestic water use

Total water withdrawals in the Connecticut Highlands during 2005 for domestic purposes were estimated as 25.45 Mgal/d (9,290 Mgal) with 16.56 Mgal/d (6,045 Mgal) from ground water and 8.89 Mgal/d (3,245 Mgal) from surface water. Domestic use is for household purposes by residential populations and can be served by either public suppliers or private wells (self-supplied).

For this study, the number of self-supplied consumers was determined by subtracting the estimated population served by public suppliers from the town population as reported by the U.S. Census Bureau (2005). The self-supplied populations were cross-checked using information from the 1990 Census data, which reported about 60,000 private wells in the Connecticut Highlands. The difference between the population served and total population indicated that 47 percent of the population (145,000) was self-supplied and 53 percent of the population (154,000) was served by public suppliers in 2005. A per capita

Table CT-7. ***Total water use.*** *Estimated total water use (surface and groundwater) in the Connecticut Highlands in 2005, in million gallons per day.*

Use	Withdrawals
Domestic self supplied	12.33
Public supply withdrawals*	109.22
Domestic deliveries (13.12)	
Commercial deliveries (3.35)	
Industrial deliveries (0.71)	
Other uses and losses (92.04)	
Mining	0.26
Irrigation	1.72
Agriculture	0.28
Industrial (self supplied)	0.85
Total	**124.7**

*Public supply withdrawal numbers are based on community well and reservoir withdrawals, and not on private wells. The State of Connecticut requires only community well reporting. Public supply exported out of the Highlands region is 77.3 Mgal/d.

water-use coefficient, 85 gal/d/person, representing the average amount of water typically used for domestic purposes was multiplied by the self-supplied population in each town to estimate the domestic water withdrawals in each town.

Self-supplied domestic withdrawals were estimated as 4,500 Mgal/yr (12.33 Mgal/d). The largest self-supplied domestic withdrawals by town were in Danbury (875 Mgal/yr or 2.399 Mgal/d) and the smallest self-supplied domestic withdrawals were in Canaan (11.5 Mgal/yr or 31,400 gal/d) (Figure CT-23).

Public suppliers delivered about 4,800 Mgal/yr (13.12 Mgal/d) of water to domestic users (51 percent of total domestic water use): 68 percent of the public supply (3,300 Mgal/yr or 8.89 Mgal/d) was from surface water and 32 percent of the public supply (1,500 Mgal/yr or 4.23 Mgal/d) was from ground water. Public supplied domestic water use ranged from none in Colebrook and Hartland to 1,600 Mgal/yr (4.29 Mgal/d) in Danbury.

Public supply water withdrawals

Public supply water refers to water served to at least 25 people or through a minimum of 15 connections. Public supply water may be delivered to users for domestic, commercial, and industrial purposes, and for public services, such as in public buildings or to flush water mains. Public supply withdrawals are listed by category in Table CT-7. For this study, public supply withdrawals for 2005 were estimated as 109.22 Mgal/d by combining total withdrawals from community wells and total withdrawals from surface water reservoirs for all 28 towns in the Highlands. Public supply withdrawals were about 88 percent of total withdrawals.

Irrigation water withdrawals

The quantity of water withdrawn for irrigation for Litchfield County, one of the Highlands' counties, during 2005 was estimated as 1.72 Mgal/d. Irrigation includes all water artificially applied to assist in the growing of crops and pastures or to maintain vegetative growth on recreational lands such as golf courses. Irrigation is generally consumptive because water evaporates directly from surfaces or is transpired by plants to the atmosphere. The amount of water used for irrigation can be highly variable among golf courses, depending on annual or seasonal precipitation, soil type, or other local conditions. The amount of

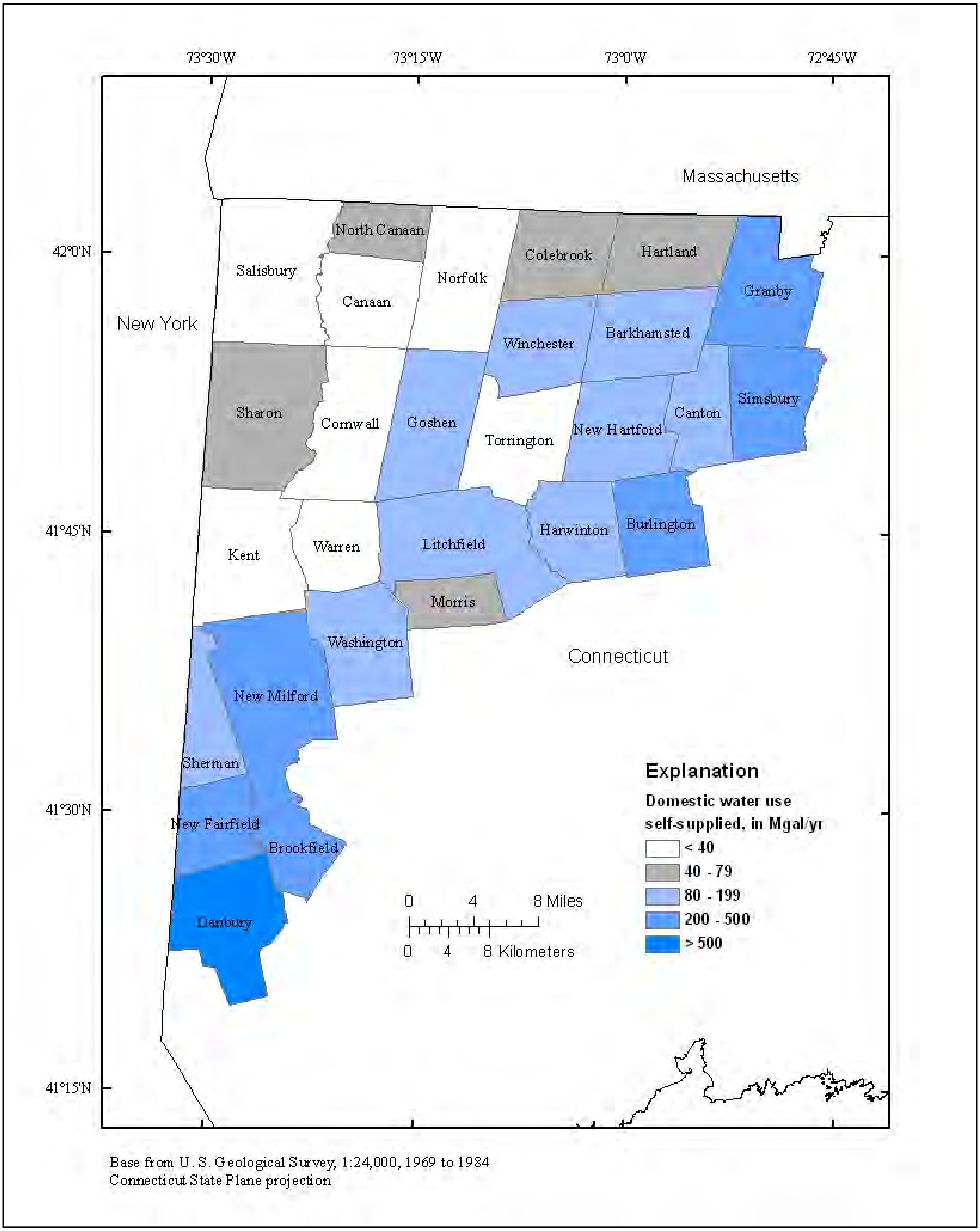


Figure CT-23. Withdrawals from domestic wells, by town. *Estimated water withdrawals from domestic wells in the Connecticut Highlands in 2005 were the largest in the towns of Danbury, Brookfield, New Fairfield, New Milford, Burlington, Simsbury, and Granby.*

water used for irrigation at some golf courses in Connecticut ranged from 60,000 to 150,000 gallons per day (Mullaney 2004). Using the lower number and information on the number of golf courses in the Connecticut Highlands in 2005, it is estimated that 1.26 Mgal/d of water was withdrawn for irrigating golf courses, or about 70 percent of the total irrigation for Litchfield County.

Hydroelectric power water use

Hydroelectric power plants use water directly to generate power. This means that water is diverted outside the stream, sometimes for some distance, and is returned back to the river. Although hydroelectric power plants typically are the largest users of water compared with any industrial, commercial, or domestic users, about 98 percent of the water diverted is returned to its source. Therefore, it is primarily defined as nonconsumptive use.

Water use—Key findings

- Estimates of water use in the Connecticut Highlands indicate that about 124.7 million gallons per day were withdrawn for all uses during 2005. Consumptive use was estimated to have been about 8 million gallons per day or about 4 percent of the total water withdrawn.
- Total registered and permitted diversions in the Connecticut Highlands are estimated to be 374 million gallons per day. The registered and permitted diversions are the maximum daily withdrawals authorized by the State.
- In 2005, an estimated 25.45 million gallons per day (9,290 million gallons) of water from area aquifers and reservoirs were withdrawn for domestic use in the Connecticut Highlands. Withdrawals for domestic uses were an estimated 16.56 million gallons per day (6,045 million gallons) from ground water and 8.89 million gallons per day (3,245 million gallons) from surface water.
- Approximately 47 percent of the population (145,000) in the Connecticut Highlands have private wells and depend upon local ground water for drinking water. The other 53 percent of the population (154,000) obtained water from public suppliers, who used an estimated 4.23 million gallons per day of ground water to meet domestic needs in 2005.
- Estimated water withdrawals by public suppliers for domestic, commercial, industrial, and other uses in the Connecticut Highlands were 109.2 million gallons per day during 2005.
- An estimated 1.26 million gallons of water per day was withdrawn for golf course irrigation in the Connecticut Highlands in 2005.
- Rivers in the Highlands are important for generating hydroelectric power to communities in and adjacent to the Connecticut Highlands. The seven hydroelectric power plants may be the largest users of water compared with industrial, commercial, or domestic uses in the Connecticut Highlands; however, 98 percent of this water is returned to the river.

Water Quality

In order to assess changes in water quality within the Connecticut Highlands region, a review was conducted of previous ground and surface water quality studies that had monitoring sites in the region.

Ground water

Ground water in the study area generally is of good quality and can be used for domestic and commercial purposes without treatment. The natural water quality is affected by the aquifer properties and associated geology. See Ground water—Aquifer types for more information.

Ground water quality classification

The State of Connecticut classifies ground water quality (Connecticut Department of Environmental Protection 2002). Class GAA consists of areas that contribute water to a public-supply well or future supply well. Class GAAs contains areas that contribute ground water discharge to a public supply reservoir. Areas with GA designation are areas with private domestic water supplies that the Connecticut DEP presumes to be potable without treatment. The other designated use for GA areas is for contributing baseflow to hydraulically connected streams. Areas designated as GB typically have urban centers with historical contamination. These areas are considered to have ground water unsuitable for human consumption, but may be used for cooling or other industrial processes (Connecticut Department of Environmental Protection 2002).

Large parts of the study area are classified as GA, GAA, and GAAs. About 3.2 percent of the Connecticut Highlands is classified as GB, or impaired with a goal of GA, or GAA. Most of the GB areas are in urbanized areas, and include parts of Danbury, Brookfield, New Milford, Torrington, and Winchester (Figure CT-24).

Substances in ground water

Ground water quality is affected by the overlying land cover and use. Water samples from wells in stratified glacial aquifers in urban and agricultural areas tend to have higher concentrations of dissolved solids, nitrate, and chloride, and a greater detection frequency of pesticides and volatile organic compounds (VOCs) than samples from wells in forested areas (Grady and Mullaney 1998, Grady 1994).

Ground water samples were collected from 65 wells in or near the Connecticut Highlands region from 1986 to 2006, primarily in stratified glacial deposits. The most commonly detected VOCs in these wells were trichloromethane, trans-1,2-dichloroethene, 1,1,1-trichloroethane, toluene, tetrachloroethene, trichlorofluoromethane, trichloroethene, 1,2-dichloropropane, and methyl tert-butyl ether (MTBE). The sources of these solvents include wastewater and septic-system discharge, industrial applications, and fuel spills. The compounds 1,1-dichloroethene, tetrachloroethene, trichloroethene, and 1,2 dichloropropane were detected above the current U.S. Environmental Protection Agency (EPA) maximum contaminant level in one or more of the wells sampled.

Samples from 28 wells in and near the Connecticut Highlands were analyzed for dissolved pesticides as part of the USGS National Water Quality Assessment Program from 1993 to 2005. The most frequently detected pesticides were deethylatrazine in 11 wells, and atrazine in 8 wells. Atrazine is used primarily on agricultural fields as a preemergent herbicide, but also has been used in urbanized areas. Deethylatrazine is a breakdown product of atrazine. All detections were at low concentrations, with the exception of one sample that exceeded the EPA maximum contaminant level for atrazine of 3 micrograms per liter.

Nitrate concentrations are elevated in shallow ground water in the stratified glacial deposits underlying urban and agricultural areas. Samples from 74 monitoring wells in or near the Highlands were analyzed for nitrate and nitrite from 1986 to 2006. Concentrations of nitrate plus nitrite nitrogen were very low in forested areas (0.11 mg/L, median of 20 samples), and much greater beneath urban (2.3 mg/L, median of 37 samples), and agricultural areas (2.5 mg/L, median of 17 samples).

Private domestic wells tapping fractured (crystalline) bedrock in the Connecticut Highlands commonly have elevated radon concentrations. Radon levels in domestic well water ranges from 300 to 5,000 picocuries per liter (pCi/L). Localized areas with concentrations greater than 5,000 pCi/L are possible (Thomas and McHone 1997). The Connecticut Department of Public Health recommends homeowners served by a private well consider treatment if their average annual radon in water concentration is 5,000 pCi/L or greater (Kasprak 2006). The EPA currently has a proposed MCL of 300 pCi/L in water.

Surface water

Surface water quality of streams unaffected by human activities reflects the underlying geology. In the Connecticut Highlands, the major difference is whether the water body and its watershed are underlain by crystalline or carbonate (marble) bedrock and whether the surficial geologic materials contain sediments derived from these bedrock types. See Ground water—bedrock aquifers section for more information.

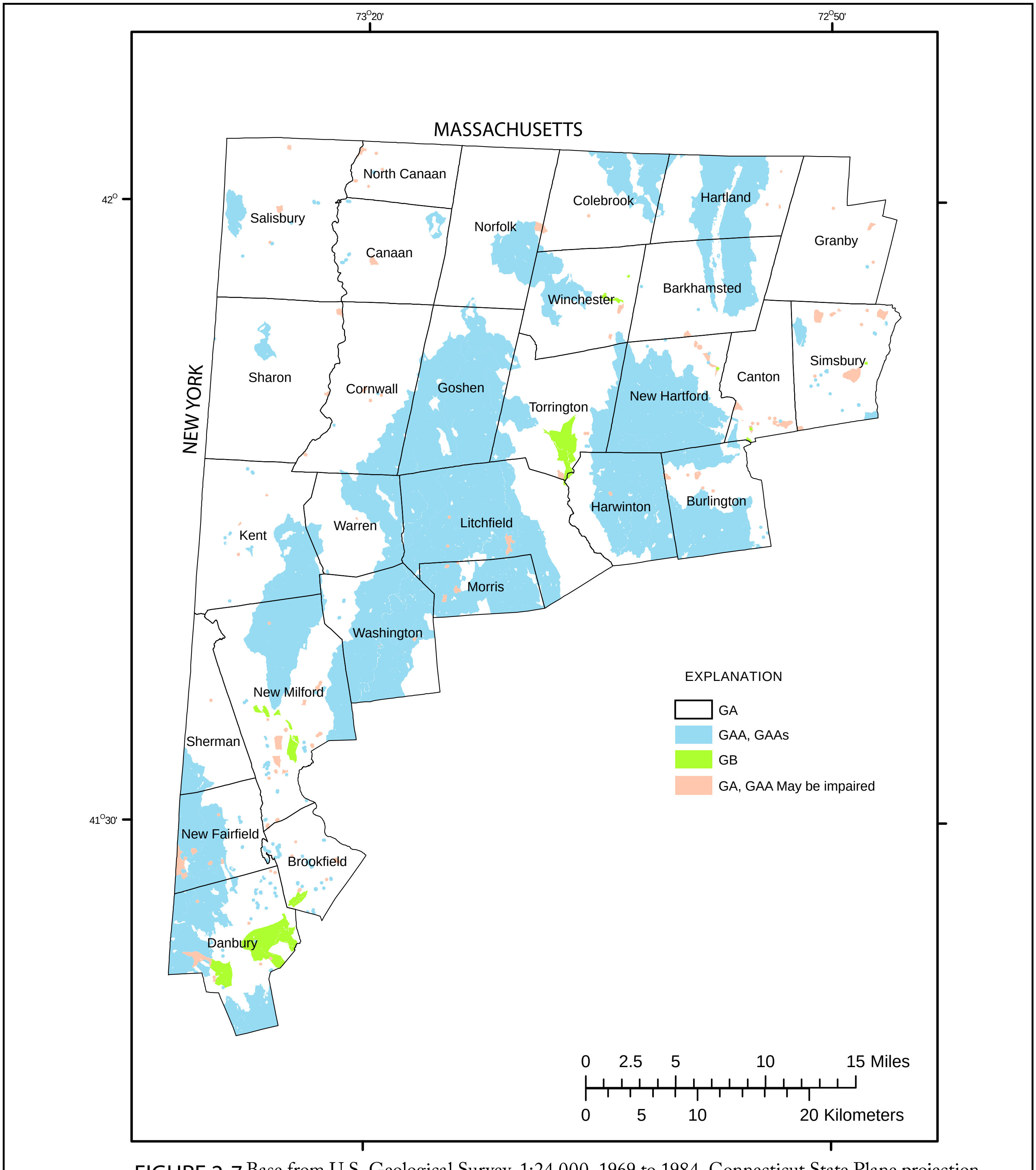


FIGURE 2-7.

Figure CT-24. Classification of ground water quality in the Connecticut Highlands.
GAA—areas contribute water to a public supply well or future supply well.
GAAs—areas contribute ground water discharge to a public supply reservoir.
GA—areas with private domestic water supplies that the Connecticut Department of Environmental Protection presumes to be suitable for drinking or other domestic uses without treatment.
GB—areas are assumed to be degraded due to a variety of pollution sources and unsuitable for human consumption (Connecticut Department of Environmental Protection 2002).

Surface water quality classification

The State of Connecticut classifies inland surface water quality relative to the designated use as AA, A, B, C, and D (Figure CT-25) (Connecticut Department of Environmental Protection 2002). Class AA includes existing and proposed drinking water supplies, and stream reaches protected for habitat and wildlife, recreation, and water supply for industry and agriculture. Class A is similar to class AA, but also includes potential drinking water supplies and stream reaches maintained for navigation. Class B water is not intended for drinking water supplies but still provides important water resource values and is considered fishable and swimmable. Class C waters generally are those waters not meeting Class B criteria due to point and nonpoint source discharges of wastewater and stormwater. Class C waters are determined to have problems that are potentially correctable under established management programs. Class D waters are determined to have water quality problems that are not readily correctable such as contamination of bottom sediments or fish.

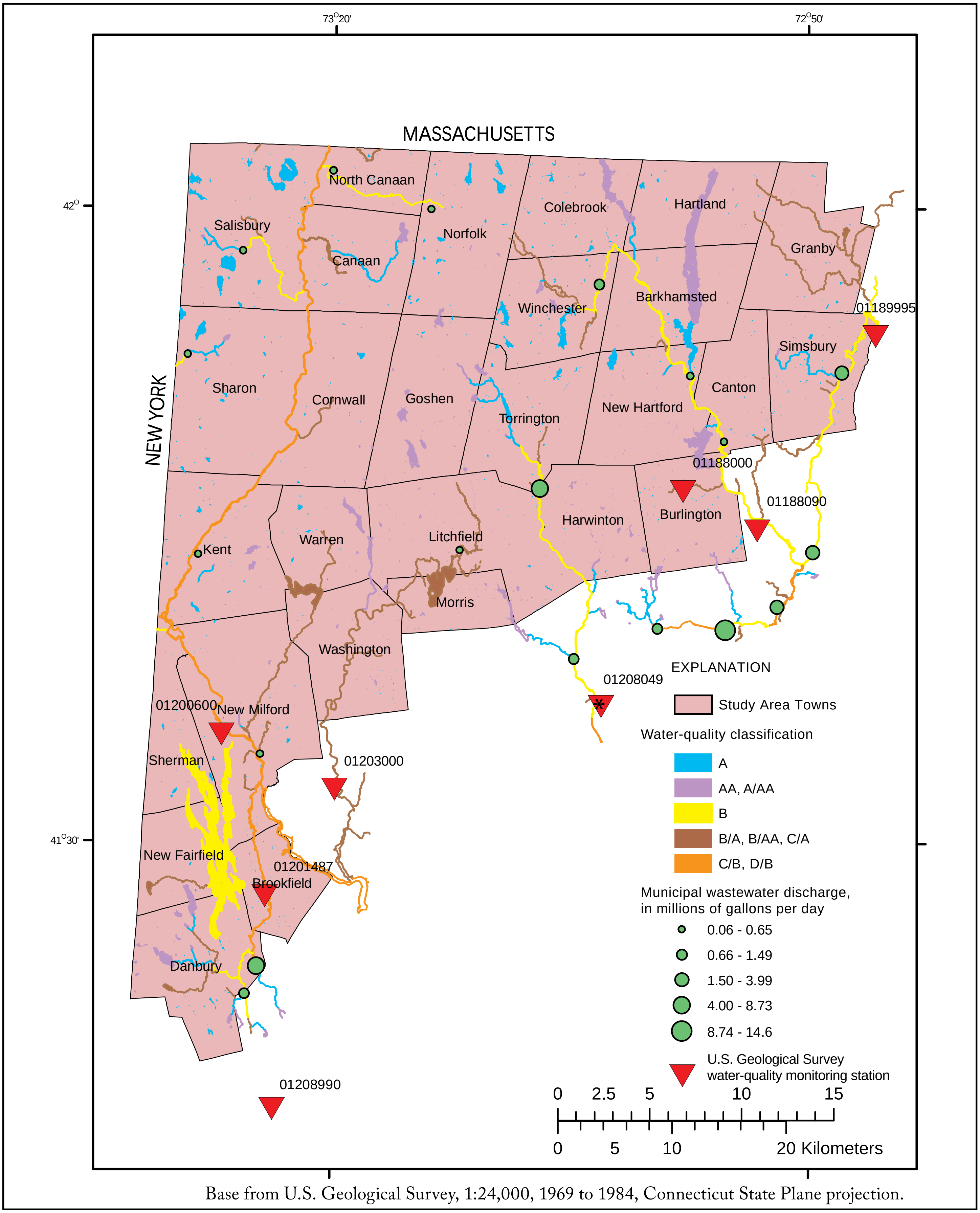
The State's water-quality classifications are based on uses and discharge restrictions. Class A indicates potential drinking water supply, and Class AA indicates existing or proposed drinking water supply, Class B (nondrinking water supply) indicates other uses such as agricultural and industrial supply; and Classes C and D (none in the Connecticut Highlands) indicate unacceptable quality. Discharge restrictions exist for what can be discharged for different stream classes: class A and AA can receive discharges from drinking water systems, and emergency and clean water discharges; and Class B and Class C can receive discharges from industrial and municipal wastewater treatment facilities (Connecticut Department of Environmental Protection 2002).

Substances in surface water

The State of Connecticut maintains a list of impaired water bodies that currently do not meet their designated use under the State's water quality standards (Connecticut Department of Environmental Protection 2008). Major rivers in the Highlands on this list include the Housatonic River, the Still River, and the Naugatuck River. The impairment for the Housatonic River is for fish consumption, caused by polychlorinated biphenyls (PCBs) in the sediments, originating from a site in Pittsfield, MA. The Housatonic River is classified as D/B, indicating that it is currently Class D, with a goal of Class B. The Still River is classified as C/B, and is impaired for recreation and for support of aquatic life. The Naugatuck River within the towns of Litchfield and Harwinton is classified as B, and is impaired for recreation because of *E. coli* bacteria. Table CT-8 contains a generalized list of water quality impairments in the Highlands.

Many rivers in the Connecticut Highlands are classified as A or B, and generally have good water quality; many smaller rivers and ponds have not been assessed. Some rivers adjacent to the Connecticut Highlands have a significant impact on water quality in the Highlands because they drain to rivers in the Highlands. For instance, the Pequabuck River, which drains into the lower Farmington River in the Highlands, contains a large amount of wastewater discharge. Municipal wastewater discharges in the Connecticut Highlands total about 51 Mgal/d based on information from Mullaney and others (2002).

Water quality in the Connecticut Highlands generally has been improving due to water quality improvements at wastewater treatment facilities since the inception of the Clean Water Act in 1972 (P.L. 92-500, Federal Water Pollution Control Amendment of 1972). However, increasing development has contributed to increased nonpoint-source runoff with constituents such as chloride, due to increased use of deicing salt and increases in the number of septic systems for an increasing population.



Base from U.S. Geological Survey, 1:24,000, 1969 to 1984, Connecticut State Plane projection.

Figure CT-25. Water quality classification, municipal wastewater discharges, and U.S. Geological Survey long-term monitoring stations in the Connecticut Highlands study area. *Class A indicates potential drinking water supply, Class AA indicates existing or proposed drinking water supply, Class B (non-drinking water supply) indicates other uses such as agricultural and industrial supply; and Class C indicates unacceptable quality.*

A study of trends in surface water quality from 1989 to 1998 by the USGS (Colombo and Trench 2002) included data from seven long-term monitoring stations in the Connecticut Highlands.

- Increases in dissolved oxygen as a percent saturation were noted in the Still and Shepaug Rivers, indicating improvement in the ability of these rivers to support aquatic life.
- Upward trends in chloride concentrations were detected in the Farmington River at Unionville and Tariffville. Increases in chloride concentration have typically been attributed to increasing use of deicing salts, and wastewater discharge.
- A statewide downward trend was reported in sulfate concentrations in streams. Declines in sulfate concentrations have been attributed to declines in sulfate in precipitation, due to reductions in sulfur dioxide emissions from power plants (Driscoll and others 2001).
- There was a downward trend in concentrations of ammonia plus organic nitrogen in the Still River, and a downward trend in total phosphorus concentrations in the Farmington River at Tariffville, indicating improvements in the treatment of municipal wastewater.

Table CT-8. Impaired water bodies. *Many rivers in the Connecticut Highlands are classified as A or B, and generally have good water quality. Impaired water bodies that do not meet their designated use under the State's water quality standards include the Housatonic River, the Still River, and the Naugatuck River (Connecticut Department of Environmental Protection 2008).*

Water Body	Segment ID	Impairment(s)	Cause(s)
Farmington River Basin			
Munnisunk Brook (Simsbury)	CT4300-44_01	Recreation	*E. coli*
Mad River (Winchester)	CT4302-00_01	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*
Mad River (Winchester)	CT4302-00_02a	Recreation	*E. coli*
Mad River (Winchester)	CT4302-00_02b	Habitat for fish, other aquatic life and wildlife	Other flow regime alterations
Still River (Colebrook)	CT4303-00_02	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*
Still River (Winsted)	CT4303-00_03	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*
Morgan Brook	CT4305-00_01	Recreation	*E. coli*
	CT4305-00_02	Recreation	*E. coli*
	CT4305-00_04	Recreation	*E. coli*
Farmington River, East Branch	CT4308-00_01	Habitat for fish, other aquatic life and wildlife	Other flow regime alterations
		Recreation	*E. coli*
Compensating Res. (L. McDonough) (Barkhamsted/New Hartford)	CT4308-00-1-L2_01	Fish consumption	Mercury
Cherry Brook (Canton)	CT4309-00_02	Recreation	*E. coli*
Nepaug River	CT4310-00_01	Habitat for fish, other aquatic life and wildlife	Other flow regime alterations
		Recreation	Other flow regime alterations
Pequabuck River	CT4315-00_06	Recreation	*E. coli*
Salmon Brook, West Branch (Granby)	CT4319-00_01a	Recreation	*E. coli*
Salmon Brook (East Granby)	CT4320-00_01	Recreation	*E. coli*

Continued

Table CT-8. Impaired water bodies. (continued)

Water Body	Segment ID	Impairment(s)	Cause(s)
Housatonic River Basin			
Housatonic River	CT6000-00_02	Recreation	*E. coli*
	CT6000-00_03	Fish consumption	Polychlorinated biphenyls
	CT6000-00_04	Fish consumption	Polychlorinated biphenyls
		Recreation	*E. coli*
	CT6000-00_05	Fish consumption	Polychlorinated biphenyls
	CT6000-00_06	Fish consumption	Polychlorinated biphenyls
		Recreation	*E. coli*
	CT6000-00_07	Fish consumption	Polychlorinated biphenyls
Lillinonah, Lake	CT6000-00-5+L1_01	Fish consumption	Polychlorinated biphenyls
		Recreation	Chlorophyll-a, excess algal growth, nutrient/eutrophication, biological indicators, debris/trash, taste and odor
Zoar, Lake	CT6000-00-5+L2_01	Fish consumption	Polychlorinated biphenyls
		Recreation	*E. coli*
Konkapot River	CT6004-00_01	Fish consumption	Mercury
Mill Brook (Cornwall)		Habitat for fish, other aquatic life and wildlife	Unknown
Hatch Pond (Kent)	CT6016-00-1-L3_01	Habitat for fish, other aquatic life and wildlife	Non-native aquatic plants, chlorophyll-a, dissolved oxygen saturation, excess algal growth, nutrient/eutrophication, biological indicators, sedimentaition siltation
Blackberry River	CT6100-00_01	Fish consumption	Polychlorinated biphenyls
	CT6100-00_02a	Fish consumption	Polychlorinated biphenyls
		Recreation	*E. coli*
	CT6100-00_02b	Fish consumption	Polychlorinated biphenyls
Hollenbeck River	CT6200-00_01	Recreation	*E. coli*
Ball Pond (New Fairfield)	CT6402-00-1-L1_01	Recreation	Chlorophyll-a, excess algal growth, nutrient/eutrophication, biological indicators
Still River (New Milford/Brookfield)	CT6600-00_01	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*

Continued

Water Body	Segment ID	Impairment(s)	Cause(s)
Still River (Danbury/Brookfield)	CT6600-00_02	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*
Still River (Danbury)	CT6600-00_03	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*
	CT6600-00_04	Habitat for fish, other aquatic life and wildlife	Unknown
	CT6600-00_05	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*
Kenosia, Lake (Danbury)	CT6600-01-1-L3_01	Recreation	Chlorophyll-a, excess algal growth, nutrient/eutrophication, biological indicators, non-Native aquatic plants
Miry Brook (Danbury)	CT6601-00_01	Recreation	*E. coli*
Kohanza Brook (Danbury)	CT6602-00_01	Recreation	*E. coli*
Padanaram Brook	CT6603-00_01	Habitat for fish, other aquatic life and wildlife	Physical substrate habitat alterations, unknown
		Recreation	*E. coli*
Sympaug Brook	CT6604-00_01	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*
Limekiln Brook	CT6606-00_01	Habitat for fish, other aquatic life and wildlife	Copper, zinc
		Recreation	*E. coli*
Shepaug River	CT6700-00_02	Habitat for fish, other aquatic life and wildlife	Other flow regime alterations
Naugatuck River	CT6900-00_06	Habitat for fish, other aquatic life and wildlife	Unknown
		Recreation	*E. coli*
	CT6900-00_07	Habitat for fish, other aquatic life and wildlife	Unknown
	CT6900-00_08	Habitat for fish, other aquatic life and wildlife	Unknown
Hart Brook	CT6902-00_01	Habitat for fish, other aquatic life and wildlife	Other flow regime alterations
West Branch Naugatuck River	CT6904-00_01	Habitat for fish, other aquatic life and wildlife	Physical substrate habitat alterations, unknown
East Branch Naugatuck River	CT6905-00_01	Habitat for fish, other aquatic life and wildlife	Unknown

An analysis of selected water quality constituents at USGS monitoring stations in or immediately downstream of the Connecticut Highlands demonstrates differences in water quality from natural and human causes. Water hardness is noticeably higher in the main stem of the Housatonic River and in the Still River, and is likely due to the carbonate bedrock and carbonate-bedrock-derived sediments underlying these watersheds. It also may be due to discharge of municipal wastewater. Chloride concentrations are higher in the areas with greater urban land use and greater population density. In addition to traditional chloride sources, other potential local sources include landfills and septic systems.

Median nitrogen and phosphorus concentrations are noticeably higher in the Farmington River at Tariffville, the Still River, and the upper reach of the Naugatuck River. Although water quality for these constituents has been improving, concentrations still commonly exceed EPA recommended nutrient criteria (U.S. Environmental Protection Agency 2000, 2001a).

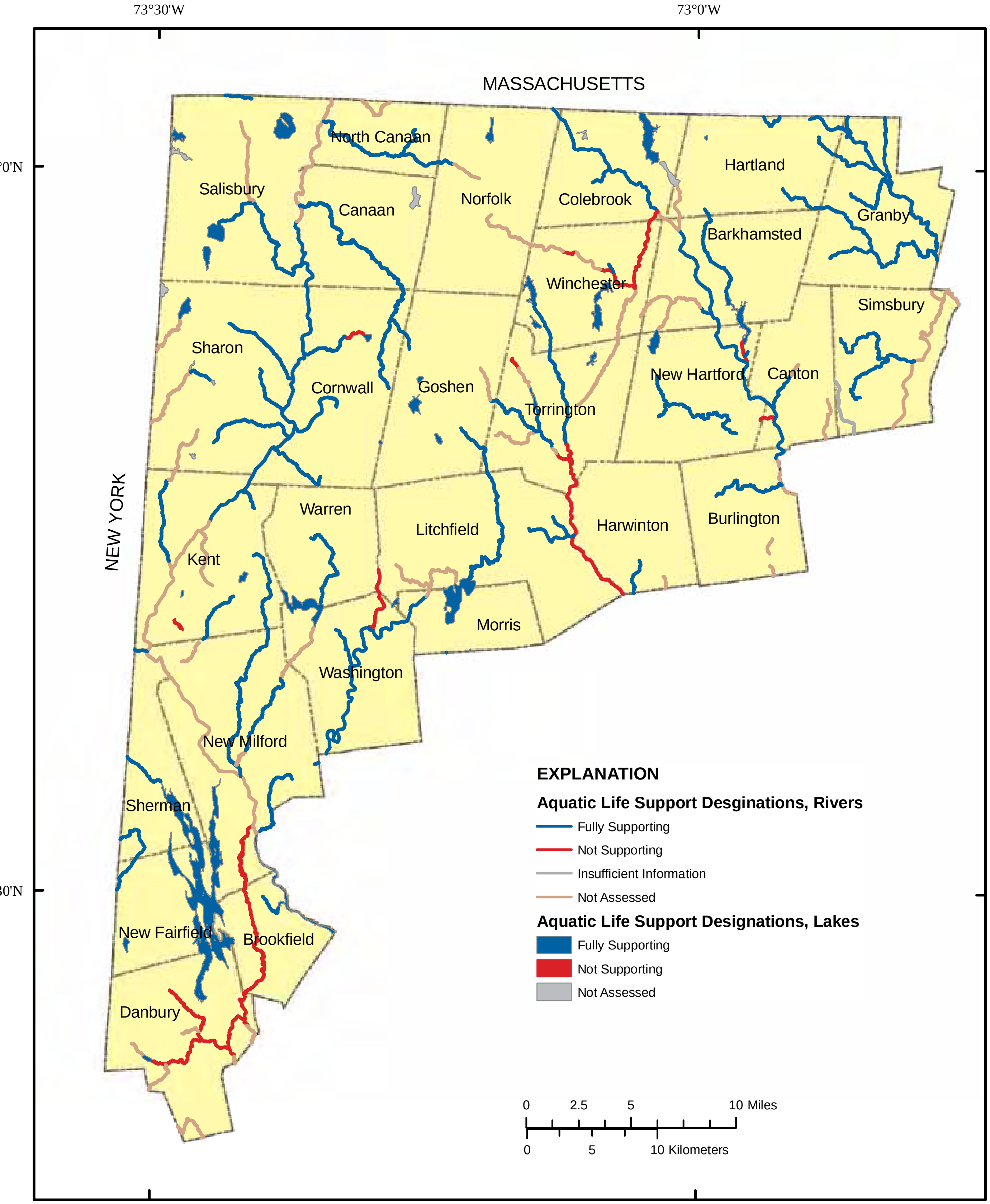
Fecal coliform counts are indicative of the sanitary quality of the water. Watersheds with municipal wastewater discharge and significant stormwater discharge tend to have higher concentrations of indicator bacteria such as *E. coli*. All but one of the sites had at least one sample with a concentration greater than the 400 colonies per 100 mL standard in effect during the time period described in this paper (Connecticut Department of Environmental Protection 1996). The highest count of fecal coliform was 60,000 colonies per 100 mL, measured in the Still River.

Concentrations of selected dissolved metals were higher in the Still, Naugatuck, and Farmington Rivers. Elevated concentrations of copper, nickel, and zinc are likely related to discharges of municipal wastewater and stormwater, as well as historical contamination of river bed sediments from metal-working facilities in these watersheds. Iron and manganese concentration do not appear to be related to the basin urbanization and may reflect differences in the bedrock underlying sampled watersheds.

The type of macroinvertebrate species found is directly related to the water quality and biological community health of the water body. The DEP has been collecting macroinvertebrate data for a number of years through their bioassessment program. This program uses biological criteria to assess water quality and aquatic habitat in streams and lakes of the state. Figure CT-26 shows which streams and lakes in the Connecticut Highlands have been classified as fully supporting or not supporting aquatic life. Streams that do not fully support aquatic life include the Still River in Danbury, Brookfield, and New Milford; the lower reach of the Blackberry River in North Canaan; the upper Shepaug River in Washington; the upper reach of Factory Brook in Salisbury; the Mad River in Winchester; the Mill Brook in Cornwall; two short reaches of the Farmington River in New Hartford and Canton; and portions of the Naugatuck River in Harwinton and Torrington.

Water quality—Key findings

- Ground water has suitable quality for most uses in the Connecticut Highlands and provides high quality water to streams. Natural water contaminants include locally elevated concentrations of radon, iron, and manganese, and high levels of calcium and magnesium (hardness) due to carbonate bedrock.
- The State of Connecticut has classified only about 3 percent of the Connecticut Highlands as impaired or unsuitable for its ground water.
- Urbanization and agriculture have contributed to excess concentrations of nitrate nitrogen and the presence of volatile organic compounds and pesticides. Concentrations of nitrate nitrogen beneath urban and agricultural areas are frequently as much as 20 times higher than concentrations in forested areas. Pesticides rarely exceed any established maximum contaminant levels, but concentrations of solvents may exceed drinking water standards especially in some areas with historical and high-intensity urban development.
- Surface water quality in many smaller upland streams and tributaries may be suitable for most uses. Water quality is impaired in some of the larger streams and rivers in the Connecticut Highlands, including the Housatonic and Still Rivers.



Base from U.S. Geological Survey, 1:24,000, 1969 to 1984, Connecticut State Plane projection.

Figure CT-26. Aquatic life support designations for waterbodies. *Connecticut's designation "fully supporting" indicates that the waterbody meets all criteria for a designated use, "not supporting" indicates that the water quality conditions do not permit a designated use, and "not assessed" indicates that the waterbody has not been assessed (Connecticut Department of Environmental Protection 2008).*

Table CT-9. Population and growth. Population and growth in Connecticut from 1970 to 2000.

Year	Highlands		State	
	Population	Growth for previous decade (percent)	Population	Growth for previous decade (percent)
1970	203,472	—	3,032,217	—
1980	238,560	17.2	3,107,576	2.5
1990	264,131	10.7	3,287,116	5.8
2000	285,730	—	3,405,565	—
1970 - 2000	—	40.4*	—	12.3*

*Total growth, 1970 – 2000

- Water quality has been improving downstream from municipal wastewater-treatment facilities since the 1970s, due to improvements in sewage-treatment practices. Recommended nutrient criteria are still commonly exceeded and concentrations of dissolved trace metals are elevated in several of the larger rivers. Current challenges include reducing the effects of nonpoint-source pollutants such as nutrients, bacteria, and chloride.
- Many high quality streams and lakes fully support aquatic life in the Highlands.

Human population and housing

Description

In the 2000 census, the Connecticut Highlands had a population of 285,730, representing just 8.4 percent of the state (GeoLytics 2004[4]). However, population and housing in the Highlands region is growing much faster than the state as a whole. Table CT-9 shows population and growth for the Highlands and State as a whole from 1970 to 2000. Population estimates for 2005 are that the Connecticut Highlands will reach 299,400, a 4.8 percent increase from 2000.
The Connecticut Highlands' 28 municipalities in Fairfield, Hartford, and Litchfield counties range in size from 18 to 64 square miles. The population in each of these municipalities ranged from 1,081 to 74,848 in 2000, and together had increased by about 82,000 people over a 30-year period. Although population has increased in every census period since 1970, this growth is slowing down. In the 1990s, the rate of population increase was only about half of what it had been in the 1970s.

Growth is not even across the Highlands—the southern and northeastern areas are growing much faster than the northwest corner. In Danbury, the only city with more than 70,000 people, population increased nearly 50 percent from 1970 to 2000.

Most municipalities experienced population growth between 1970 and 2000. Sherman stood out, growing 184 percent. Burlington, New Fairfield, and Goshen all experienced more than 90 percent growth. Winchester and Norfolk were the only municipalities that decreased in population between 1970 and 2000 (Figure CT-27). Municipalities with between 10,000 and 17,000 people experienced the most growth.

Overall, the population of the Connecticut Highlands is getting older: the population over 65 years old is growing much faster than the population under 30 years old. There was a decrease in the number of children and a very small increase in young adults. In 1970 the percentage of people under 30 years old was over 50 percent; in 2000 it was 36 percent.

[4] All US Census data were derived from a CD produced by GeoLytics, a company that packages U.S. Census data for ease of analysis.

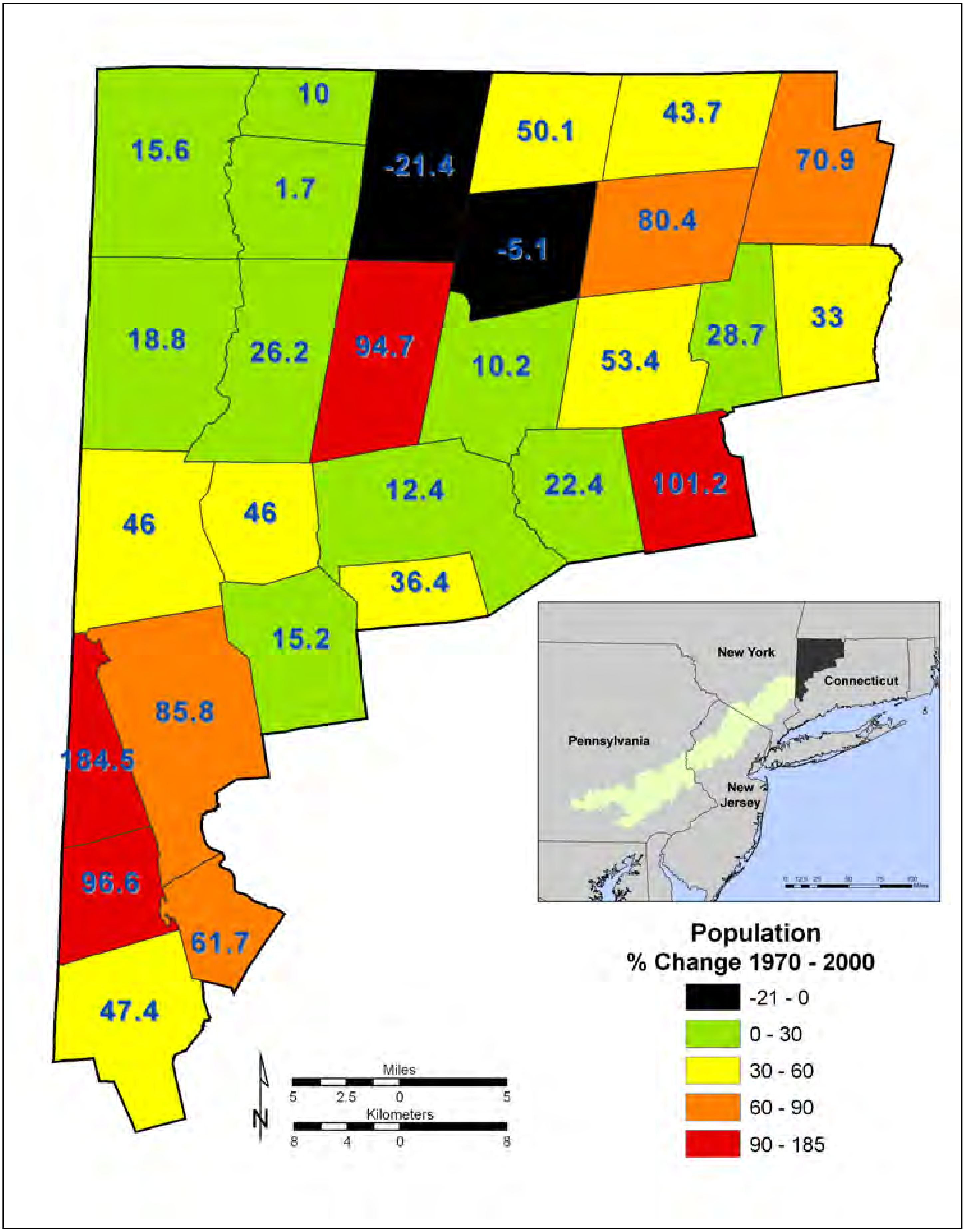


Figure CT-27. Population growth. *Population growth and percent change by municipality in the Connecticut Highlands, 1970–2000.*

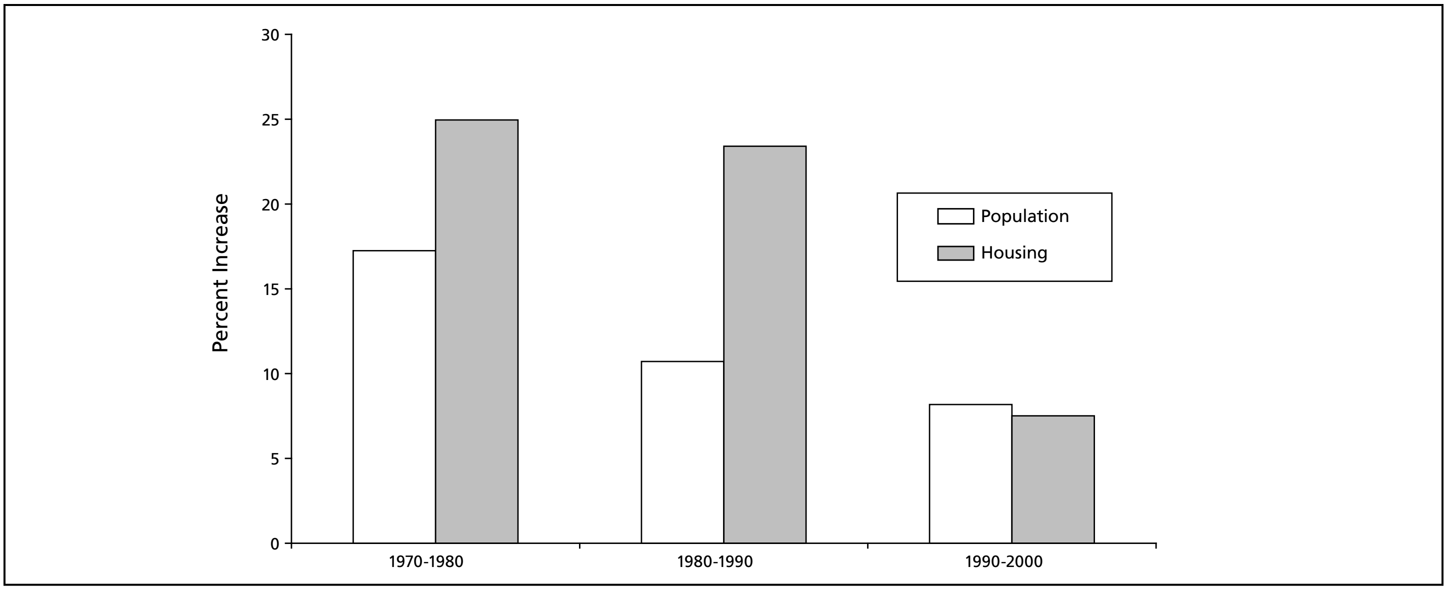


Figure CT-28. ***Housing and population growth.*** *Comparison of housing and population growth in the Connecticut Highlands, 1970–2000.*

Table CT-10. Housing unit growth. *Housing units and growth in the Connecticut Highlands compared with State-wide trends for 1970–2000.*

Year	Highlands		State	
	Housing units	Growth for previous decade (percent)	Housing units	Growth for previous decade (percent)
1970	70,701	—	981,158	—
1980	88,345	25.0	1,158,884	18.1
1990	109,026	23.4	1,320,850	14.0
2000	117,211	7.5	1,385,975	4.9
1970-2000	—	65.8*	—	41.3*

*Total growth, 1970 – 2000

From 1970 to 1990, housing grew much faster than population, so that fewer people lived in each household by 1990. However, this proportion has been stable since 1990 at approximately 2.4 people per household (Figure CT-28). By 2000, there were 46,500 more housing units in the Connecticut Highlands than there were in 1970. Housing growth in the Highlands increased faster than housing growth in the State as a whole from 1970 to 2000: housing units increased 65.8 percent in the Connecticut Highlands compared with 41.3 percent in the State (Table CT-10).

Human population and housing—Key findings

- In the 2000 census, the Connecticut Highlands had a population of 285,730, representing just 8.4 percent of the State.
- Population and housing in the Highlands region are growing faster than in the State as a whole.
- Population density increased from 192 to 270 people per square mile between 1970 and 2000.
- The population over 65 years old is growing faster than the population under 30 years old.
- From 1970 to 1990, the number of housing units grew much faster than the population, with fewer people living in each household by 1990; this proportion has been stable since 1990 at approximately 2.4 people per household.

Part 4. Growth and impact analysis

Land use trends

Zoning build-out analysis

Methods

A build-out analysis was conducted to estimate for the year 2030 the extent and configuration of future residential land use if all developable lands were built upon, based on current zoning regulations. The build-out analysis determines the quantity and density of new structures, and helps assess possible future consequences in terms of population growth and increased impervious surface, which could negatively affect water quality. It shows the worst case scenario whereby all available land is built-up with residences according to current zoning ordinances.

The analysis was restricted to detached single-family residential growth; all nonresidential uses were excluded from the analysis. The study included 25 of the 28 municipalities in the Connecticut Highlands. Either the other municipalities do not have specified zoning regulations, or the information was not available. The residential build-out analysis was conducted using a geographic information system (GIS). The build-out analysis results were compared with the existing Connecticut State Conservation and Economic Development Plan. This analysis will provide information about how well current municipal zoning regulations fit into larger regional or State plans for the Highlands region.

The build-out analysis was done under two conditions, referred to as the low-constraint and the high-constraint scenarios, in which different levels of environmental protection of sensitive areas limit the amount of land available for development (Table CT-11). The only legal constraints to development are permanently protected open space and Federal wetlands regulations, some of which have a direct effect on the amount of land available for development. Most municipalities within the region, however, have zoning guidelines for protection of sensitive environmental areas, particularly riparian areas, wetlands, and steep slopes. These constraints are not necessarily written into zoning regulations, or if they are, they are considered guidelines, not hard and fast restrictions.

The *low-constraint* scenario is "business as usual," with minimal restrictions on development. The low-constraint scenario assumes that already-developed land, protected land, land where zoning does not permit residential uses, water bodies, floodways, wetlands, and slopes greater than 25 percent cannot be developed.

The *high-constraint* scenario uses a high standard for protecting environmentally sensitive areas. The high-constraint scenario assumes already developed land, protected land, land where zoning does not permit residential uses, water bodies, floodways, floodplains, wetlands, lands within 100 feet of streams and water bodies, lands within 50 feet of wetlands, and slopes greater than 15 percent cannot be developed.

Table CT-11. Build-out constraints. *Constraints used to limit the build-out model for the Connecticut Highlands under the low- and high-constraint scenarios.*

Low-Constraint Scenario	High-Constraint Scenario
Protected open space public or private conservation ownership or easement	Protected open space public or private conservation ownership or easement
Water bodies	Water bodies
Floodway FEMA delineation	Floodway + 100 year floodplain FEMA delineation
No riparian buffer	100-ft wide riparian buffer
Wetlands National Wetland Inventory + hydric soils	Wetlands National Wetland Inventory + hydric soils
No wetland buffer	50-ft wide wetland buffer
Slopes greater than 25 percent	Slopes greater than 15 percent

Results

As of 2000, roughly 87 percent of the Connecticut Highlands is zoned for residential use, mostly in 1- to 2-acre lots. Although only 5 percent of the Connecticut Highlands is zoned as protected open space or outdoor recreation, 24 percent of the region is currently conserved as protected open space. Agricultural districts comprise only 4 percent of the region.

Total potentially developable land under the low-constraint scenario is approximately 230,147 acres (Table CT-12). The build-out analysis yielded 148,602 new single family residential units and 376,560 new residents based on current average persons per housing unit across the Connecticut Highlands. This is 42,917 more single-family residences than under the high constraint scenario. This would create 48,016 additional acres of impervious surface, and would increase housing in the region by 135 percent and population by 132 percent.

Build-out analysis is a tool to predict growth and plan for potential impacts under different development scenarios. Single-family detached is one option for residential development (Figure CT-29). Higher density development is another option that consumes less land per capita and protects open space.

Connecticut has adopted a comprehensive conservation and development plan (State of Connecticut, n.d.). This plan lays out explicit goals and objectives for future land use in the State. There is an emphasis on the conservation of open space and the clustering of new development near existing transportation nodes. According to the plan, the highest priority for land conservation shares many of the same characteristics as the land excluded by the constraints in the high constraint build out scenario in this analysis. The State plan for Connecticut calls for new development along existing transportation corridors and redevelopment and revitalization of existing urbanized areas. By concentrating new development in higher densities and in proximity to public transportation, there is reduced dependence on the automobile and easier access to employment, shopping and recreation by a larger cross-section of the public.

Table CT-12. Build-out results. *Zoning build-out analysis results for the Connecticut Highlands.*

Statistic	**Low Constraint**	**High Constraint**
Buildable acres - build-out scenario	230,147	164,453
Single family dwelling units		
Actual 2000	109,766	109,766
Additional under zoning build-out	148,602	105,685
Percent new units	135	96
Residents		
Actual 2000	285,730	285,730
Additional under zoning build-out	376,560	268,158
Percent new residents	132	94
Impervious surface (acres)		
Actual 2001	16,333	16,333
Additional under zoning build-out	41,754	27,860
Percent new impervious surface	256	171

Figure CT-29. Residential development. Aerial view of residential development in the Connecticut Highlands. (Photo by Joel Stocker, University of Connecticut)

Zoning build-out analysis—Key findings

- 87 percent of the Connecticut Highlands is zoned for residential use, mostly in 1-2 acre lots.
- Total potentially developable land is 230,148 acres under a low-constraint scenario, representing a low standard for protecting environmentally sensitive areas, and 164,453 acres under a high-constraint scenario, representing a high standard for protecting environmentally sensitive areas.
- The low-constraint scenario would increase housing in the region by 135 percent and population by 132 percent.
- The high-constraint scenario would increase housing in the region by 96 percent and population by 94 percent.

Analysis of land use and land cover change

Methods

The goal of the land use and land cover analysis was to quantify development growth trends in the Connecticut Highlands over time. Trends were analyzed using available land use and land cover data derived from satellite imagery. For Connecticut, the 1985, 1990, 1995, 2002 time series produced by the University of Connecticut's Center for Land Use Education and Research (CLEAR) was used.

To capture all of the major trends, five different transitions in land cover were quantified. These trajectories of change included…

- *agriculture* to *developed;*
- *agriculture* transitioning back to *forest*;
- *forest* to *agriculture*;
- *forest* to *developed*; and
- *wetlands* to *developed* land.

Sometimes the terms land use and land cover are confused, and they are often mistakenly used interchangeably. In this study, changes in land cover were analyzed, which is land cover derived from satellite imagery according to scientific techniques for classifying spectral imagery. Although they are sometimes the same (e.g., agriculture), land cover differs from land use particularly in the categories of grasses, and rural and low-density residential development. Since it is difficult to distinguish structures beneath trees in low-density residential areas from satellite imagery, tree-covered areas are often classified as forest. The land cover in these instances is trees (forest), but the land use is low-density residential and developed, or both. Nevertheless, the common term used throughout the literature and in this report is land use and land cover.

Results

According to the CLEAR land use and land cover data, in 2002 the Connecticut Highlands were predominantly forest: 67 percent was forest, 14 percent was agricultural fields or grasses, and 10 percent was developed. However, from analysis of aerial photographs, about 8 percent of the 14 percent classified as agricultural fields or grasses is actually grasses associated with development, not active farm land. Therefore, development is estimated to be closer to 18 percent than to 10 percent of the landscape. Urban areas and agricultural land are predominantly at lower elevations in the river valleys and other areas of low relief (Figure CT-30). According to the land cover derived from satellite imagery, there were 9,800 acres of new development and associated land uses (open grassy and barren areas), which represent a 12 percent increase in developed land use over the 17 years. If we add development-associated grassy areas such as lawns, which are estimated to have increased by approximately 15,400 acres, the total increase in developed land use is approximately 25,000 acres, or 26 percent (Table CT-13). This estimate of developed land is most certainly understated because there are no useful data on farm land loss and consequent increase in development-associated grassy areas before 1995.

Table CT-13. ***Developed land use, 1985 – 2002.*** *Farm land acres in the Connecticut Highlands derived from USDA Census of Agriculture (1997 and 2002) and digitized active agriculture layer (2004). Farmland acres in 1995 were estimated from the rate of change between 1997 and 2004; before 1995 farm land was assumed to be relatively constant.*

Land Use	1985	1990	1995	1997	2002	2004	1995-2002	1985-2002
Farmland vs. Other Development-Associated Grasses (acres)								
Other grass and agriculture (LULC class)	79,313	80,107	81,345	—	81,202	—	–143	—
Farmland	61,500	61,500	61,500	57,608	48,016	43,516	–13,484	—
Other grass	17,813	18,607	19,845	—	33,186	—	13,341	—
Summary of All Development Classes (acres)								
Developed	62,199	67,013	68,053	—	70,211	—	2,158	8,012
Turf and grass	13,323	13,499	13,581	—	13,583	—	2	260
Other grass	17,813	18,607	19,845	—	33,186	—	13,341	15,373
Barren land	3,148	3,334	3,774	—	4,707	—	933	1,559
Utility right-of-way	1,306	1,297	1,294	—	1,287	—	–6	–19
Total	97,789	103,750	106,547	—	122,974	—	16,427	25,185
Percent of the total Highlands area	14	15	16	—	18	—	—	—

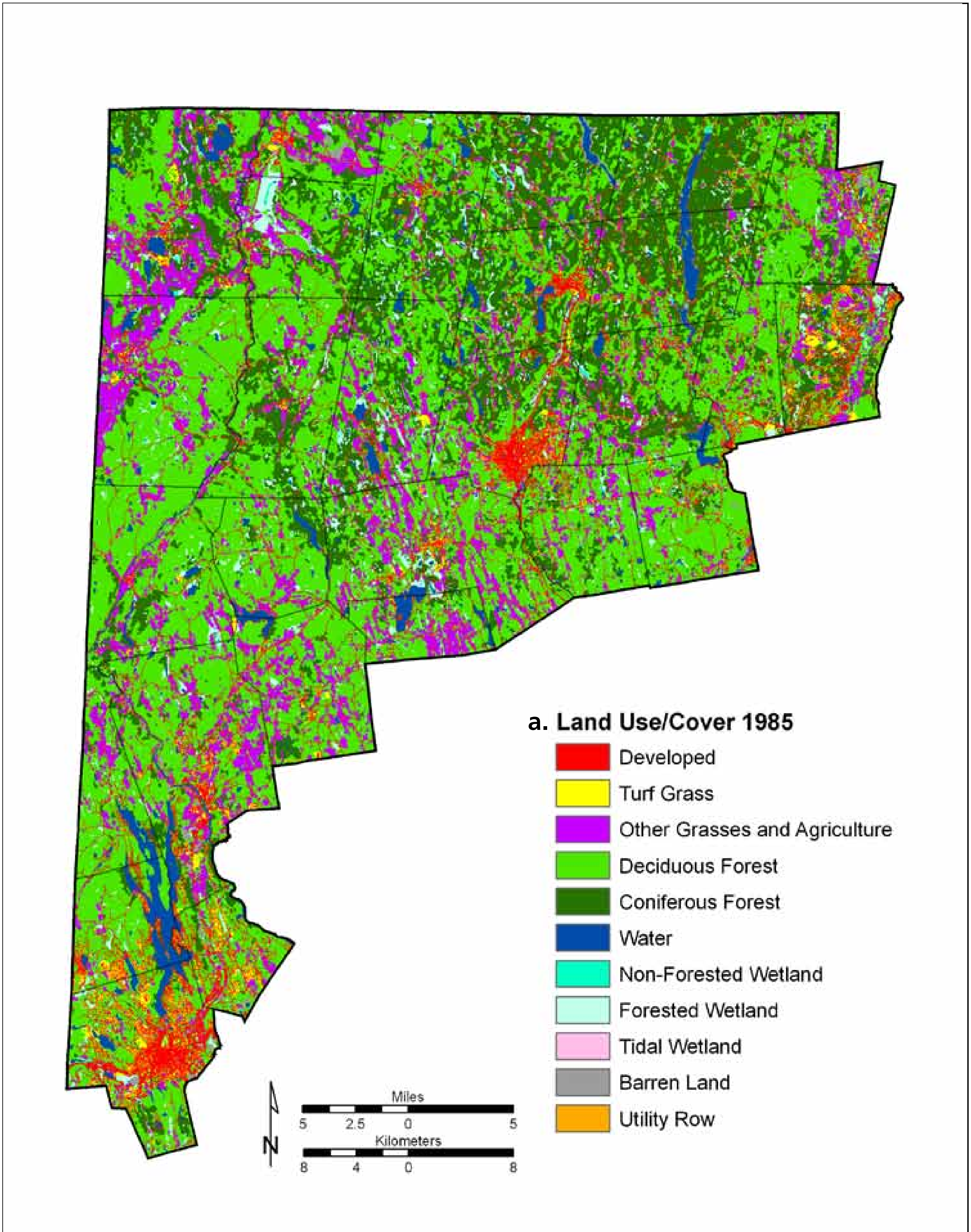


Figure CT-30a. ***Land use and land cover, 1985.*** *Land use and land cover in the Connecticut Highlands in 1985.*

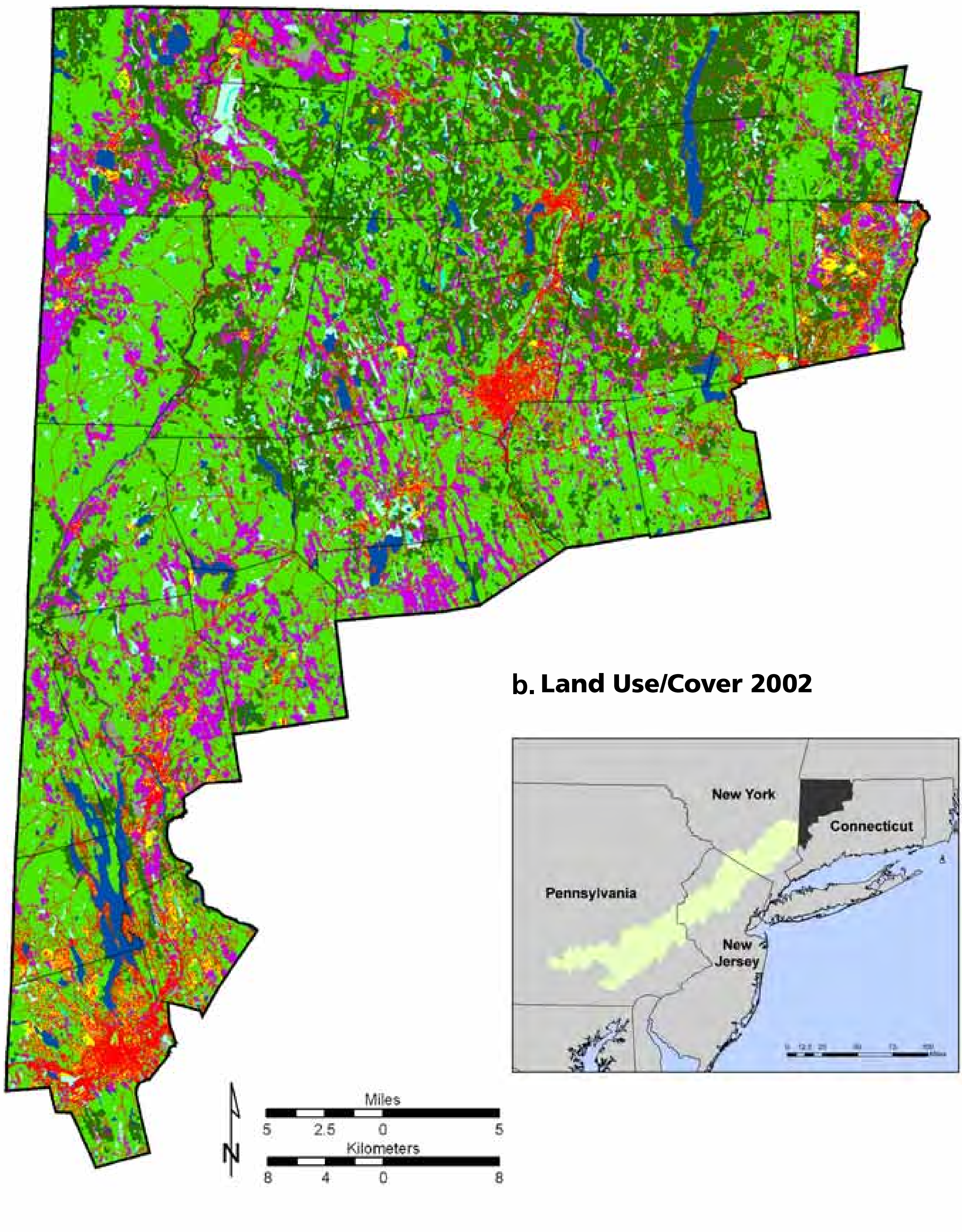


Figure CT-30b. Land use and land cover, 2002. *Land use and land cover in the Connecticut Highlands in 2002.*

During the study period the amount of development was about equal on forests and farm lands. Approximately 13,500 acres of agricultural lands were converted to development-associated land uses and 13,270 acres of forest were converted to other uses. Recently, however, the impact has been much greater on farm land than on forests. Twenty-two percent of farm land was lost in the 7 years from 1995 to 2002, for an average annual loss of 3.1 percent, compared with an average annual loss of 0.16 percent over 17 years for forest land.

Most of the new development occurred in the southern and eastern portions of the Highlands, close to Fairfield County and the Connecticut River valley.

The northwest corner, which is predominantly forested, had very little new development. Overall, development slowed considerably after 1990 then picked up again between 1995 and 2002. More than half of the development in the 17-year period of analysis took place in the 5 years between 1985 and 1990 (Figure CT-31). Although this is still a mostly forested region, 18 percent of the land is developed, and development will continue to affect the rural character in the Connecticut Highlands.

As Table CT-14 of urban land cover shows, the proportion of development by town in the Highlands varied greatly over the period 1985-2002.

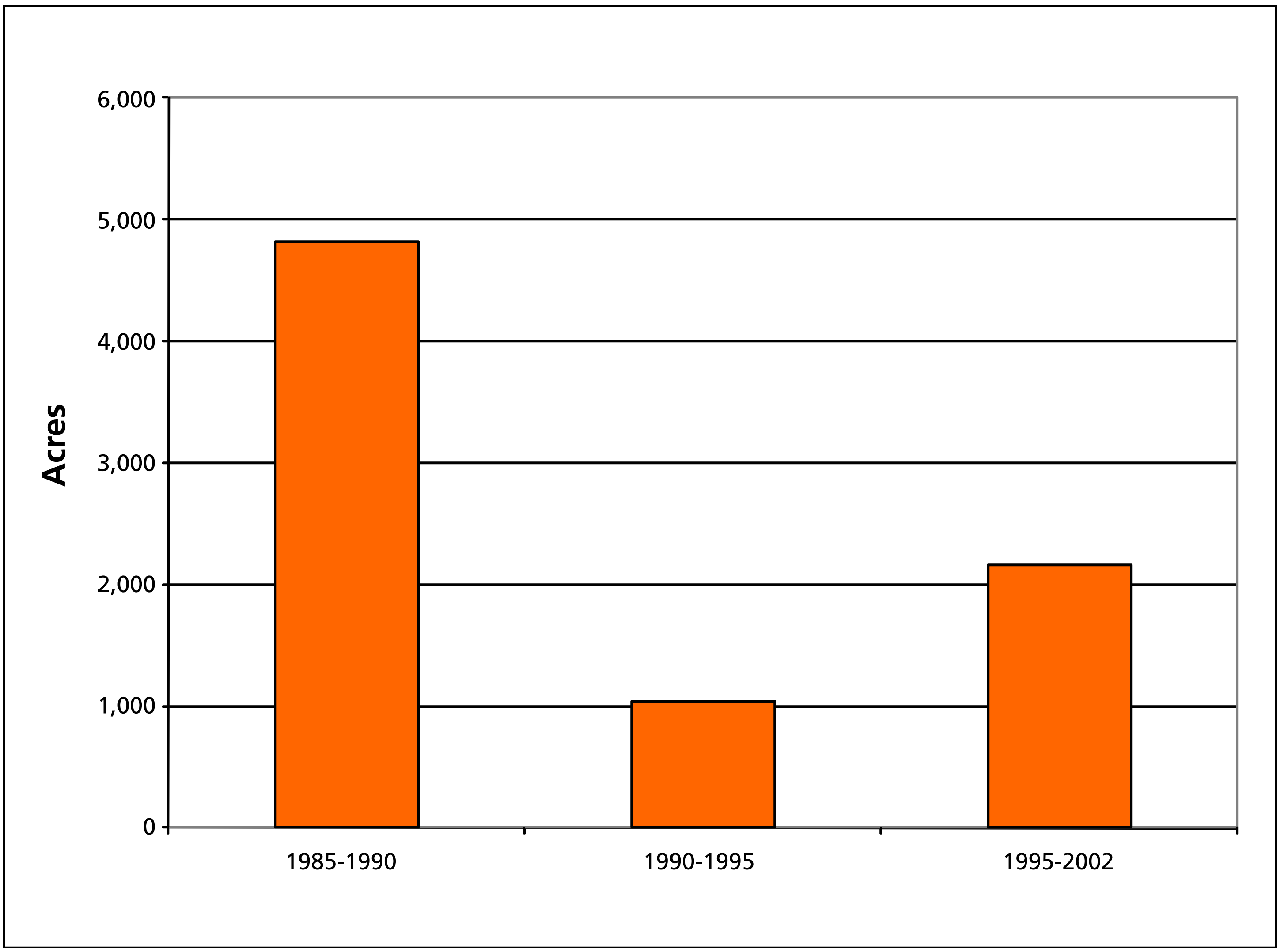


Figure CT-31. New development. *Acres of new development in the Connecticut Highlands by time period, from 1985 through 2002.*

Table CT-14. ***Urban land cover.*** *Urban land cover change in the Connecticut Highlands, by town, 1985 – 2002.*

Town	Area with urban land cover in the Connecticut Highlands						Share of Highlands development 1985-2002 (percent)
	1985		2002		Change		
	Acres	Percent	Acres	Percent	Acres	Percent	
Barkhamsted	1,595	6.4	1,769	7.1	174	10.9	2.2
Brookfield	2,736	21.0	3,262	25.1	526	19.2	6.6
Burlington	1,601	8.2	2,076	10.7	475	29.7	5.9
Canaan	941	4.4	993	4.7	52	5.5	0.6
Canton	1,642	10.3	2,005	12.5	362	22.1	4.5
Colebrook	997	4.7	1,069	5.1	72	7.3	0.9
Cornwall	1,566	5.3	1,641	5.5	75	4.8	0.9
Danbury	7,977	28.4	9,191	32.7	1,213	15.2	15.1
Goshen	1,570	5.4	1,672	5.8	103	6.5	1.3
Granby	1,938	7.4	2,446	9.3	508	26.2	6.3
Hartland	1,167	5.3	1,241	5.7	73	6.3	0.9
Harwinton	1,502	7.6	1,744	8.8	242	16.1	3.0
Kent	1,604	5.0	1,759	5.5	154	9.6	1.9
Litchfield	3,177	8.7	3,422	9.4	244	7.7	3.1
Morris	948	7.9	992	8.3	44	4.7	0.5
New Fairfield	1,986	12.3	2,279	14.2	294	14.8	3.7
New Hartford	1,906	7.8	2,211	9.1	304	16.0	3.8
New Milford	4,730	11.6	5,500	13.5	770	16.3	9.6
Norfolk	1,471	5.0	1,540	5.2	69	4.7	0.9
North Canaan	1,093	8.8	1,215	9.7	122	11.1	1.5
Salisbury	2,689	7.0	2,794	7.3	105	3.9	1.3
Sharon	2,185	5.7	2,275	6.0	91	4.2	1.1
Sherman	1,151	7.7	1,336	8.9	185	16.0	2.3
Simsbury	3,761	17.1	4,252	19.4	490	13.0	6.1
Torrington	5,002	19.4	5,832	22.6	830	16.6	10.4
Warren	956	5.4	1,099	5.7	52	5.5	0.6
Washington	1,990	8.1	2,105	8.5	115	5.8	1.4
Winchester	2,315	10.7	2,581	11.9	265	11.5	3.3
Highlands	62,142	9.2	70,153	10.4	8,012	12.9	100

Table CT-15 shows the increase in population, housing, and urban land cover from 1990 to 2002. Developed land use has increased at more than double the rate of population and housing growth.

Table CT-15. Population and land use change. *Increase in population (1990 – 2000) and land use (1990 – 2002) in the Connecticut Highlands.*

Population and land use	Increase (percent)	Source
Population	8	Derived from GeoLytics 2004
Housing	8	Derived from GeoLytics 2004
Urban area	5	Derived from CLEAR* 2002
All developed land	18	This study

*Center for Land Use Education and Research

The LULC analysis was also completed at the town and watershed level for Connecticut. Some towns in the region changed very little over the 17 years, and others had more than 1,000 acres of new development. Most of the new development occurred in towns closer to Hartford to the east and Danbury and Fairfield County to the south. Development tended to occur near larger towns, such as Torrington, and main roads, such as Route 8.

Brookfield, Danbury, and Torrington—the towns with the most development in 1985—also had the fastest rates of forest loss from 1985 to 2002. All three were among the 10 least forested towns in the region as of 2002, with forest cover of 43 percent (Brookfield), 50 percent (Danbury), and 58 percent (Torrington). Danbury, Torrington, and New Milford had the greatest increases in developed acreage across all time periods, while Burlington, Granby, and Canton had the greatest increases above their 1985 levels—30 percent (Burlington), 29 percent (Granby), and 23 percent (Canton). At the watershed level of analysis, the Mine Brook and Pequabuck River and parts of the Farmington River and Still River watersheds each had greater than a 25 percent increase in developed land from 1985 to 2002. The results indicate where development is concentrated, as some of these small watersheds had much larger increases in developed area than any town in the region.

The amount of grasses and agriculture increased in 26 of the 28 towns. This is certainly due to the increase in development-associated grasses, as agriculture declined throughout the entire region. The town of Sharon has the most land in active agriculture at 4,713 acres; New Fairfield the least at 109 acres. Forest land decreased in acreage across all time periods in all towns. The largest losses occurred in New Milford, Danbury, and Torrington.

Analysis of land use and land cover change—Key findings

Developed land use increased by 25,000 acres (26 percent) between 1985 and 2002; 60 percent of the development occurred between 1985 and 1990.

- Developed land use has increased at more than double the rate of population and housing growth.
- Development occurred about equally on forests and farm lands; however, the impact on farm lands has been much greater as there is much less farm land than forest in the region.
- Development tended to occur near larger towns and main roads.

Water budget

A water budget is a valuable tool in understanding how human activities can alter the natural cycle and availability of water in the Highlands. The water budget considers all surface and ground water entering, leaving, or being stored in a watershed. Each component of the hydrologic cycle—precipitation, infiltration, overland runoff, evapotranspiration, and ground and surface water withdrawals—can be assigned a value in order to create a water budget (Figure CT-32).

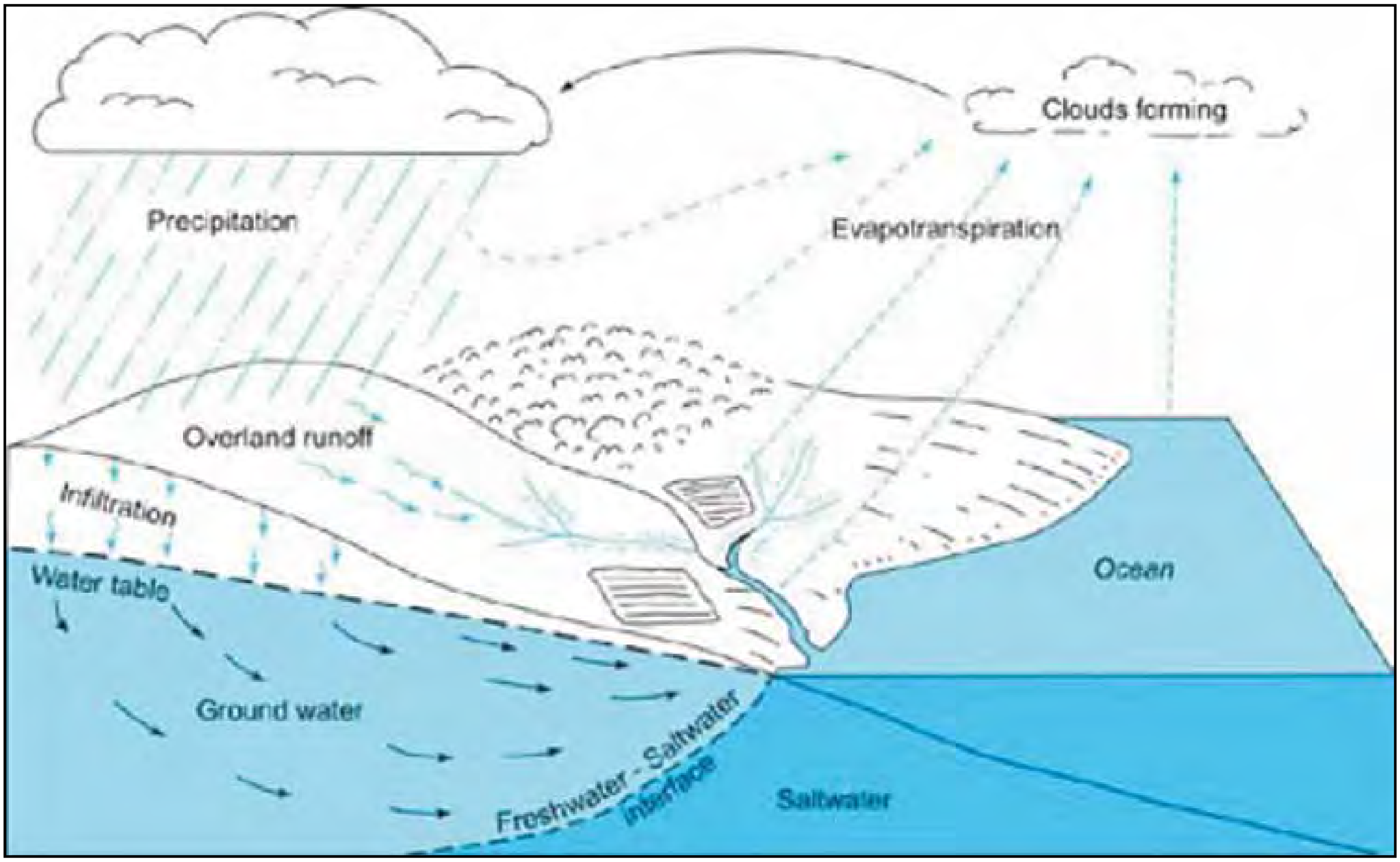


Figure CT-32. Hydrologic cycle. *The constant movement of water above, on, and below the Earth's surface constitutes the hydrologic cycle. Precipitation runs over the land surface and into streams, which discharge into the ocean. Some precipitation infiltrates into the ground water system and discharges to streams or the ocean. Transpiration and evaporation return water to the atmosphere, completing the cycle (modified from Heath 1983, p. 5).*

Analysis at a regional scale

A water budget for the Connecticut Highlands provides a basis for understanding the magnitude and function of the various budget components (Figure CT-33). The primary source of water to the Highlands is precipitation, which averages about 49 inches annually over the area. This amount is equivalent to receiving 5,296 Mgal/d of water over the 2,262 square miles. Of the total precipitation, an estimated 2,642 Mgal/d evaporates from land or water surfaces or transpires from vegetation; these components are typically combined and referred to as evapotranspiration. The remainder of the precipitation runs off the land to surface water sources during storms or snowmelt (919 Mgal/d) or infiltrates the ground and recharges ground water (1,735 Mgal/d). The ground water in turn discharges to streams. Baseflow is responsible for maintaining flow in streams even during prolonged dry periods and generally equals the amount of water that infiltrates or recharges the ground. In the Highlands, 7.5 Mgal/d is the consumptive use of ground water (estimated as 20 percent of domestic and commercial withdrawals). In addition, a total of 77.3 Mgal/d of water from surface water reservoirs is transferred out of the Highlands. Streamflow leaving the Highlands is a combination of the reduced ground water discharge to streams (1,727 Mgal/d as baseflow) and the reduced surface runoff (842 Mgal/d), and totals 2,569 Mgal/d.

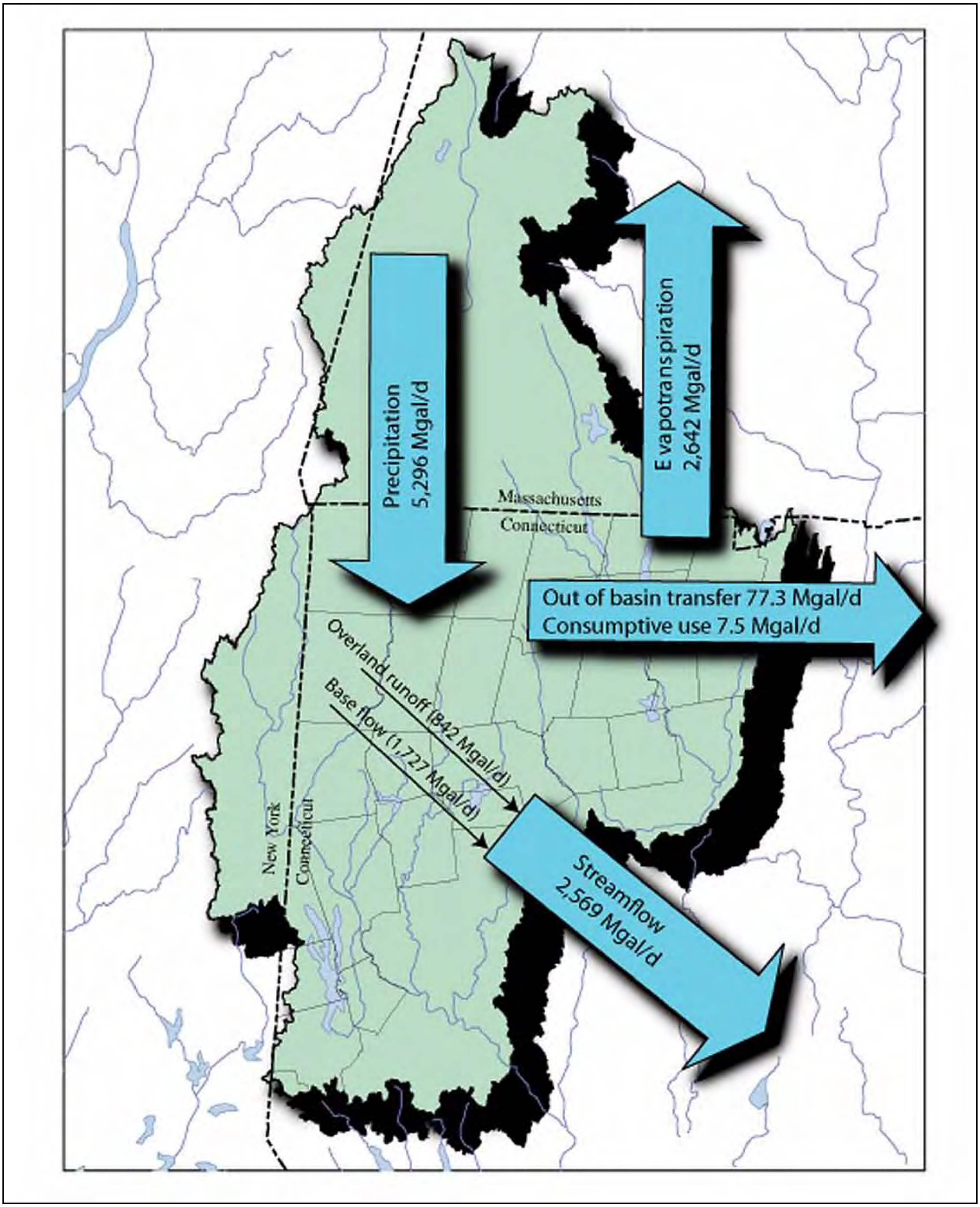


Figure CT-33. Regional water budget. *The water budget considers all water, both surface and ground, that enters and leaves the region. On an average annual basis, the Connecticut Highlands receive about 49 inches of precipitation, which is the equivalent of 5,296 Mgal/d. Water that leaves the Connecticut Highlands includes evapotranspiration (2,642 Mgal/d), streamflow (2,569 Mgal/d), transfers (77.3 Mgal/d), and consumptive use (7.5 Mgal/d).*

Analysis at a watershed scale

The amount of precipitation that falls on the Connecticut Highlands ranges from about 46 to 54 inches per year. Since the early 1900s, annual average precipitation has differed by 10 to 20 inches. The annual variability in precipitation can have a significant effect on annual totals of stream discharge, particularly during very dry and very wet periods. These variations in turn affect the quantity and quality of water available to downstream users. An example of how the major water budget components are influenced by annual fluctuations in precipitation in the Connecticut Highlands is shown graphically in Figure CT-34. Annual mean streamflow for a period of 93 years, recorded at the gauging station on the Housatonic River at Falls Village, Connecticut, is compared with local annual precipitation (National Weather Station (NWS) - Falls Village) for the period. Assuming the Falls Village NWS station is representative of the entire gauged watershed, approximately 54 percent of the precipitation that falls on the watershed leaves the watershed as streamflow. Most of the remainder leaves the basin as evapotranspiration. A similar relationship exists over most of the region.

Long-term droughts or prolonged dry periods occurred during the periods 1910-1911, 1930-1931, and 1964-1966 (Northern Regional Climate Center 2006). Each of these periods had a number of individual years well below the average precipitation. During the 1960s drought, annual streamflow at the Housatonic River at Falls Village was 30 to 60 percent less than the long-term average. The average annual precipitation from June 1964 through November 1965 was 29.9 inches compared to the long-term average from 1913 through 2005 of 41.3 inches. During unusually wet years, such as 1972 and 1996, total annual streamflow at the gauge was 50 to 65 percent greater than long-term streamflow average. Other stream-gauging stations in the Highlands indicate similar ranges of departure from average streamflow conditions during extremely dry and wet periods.

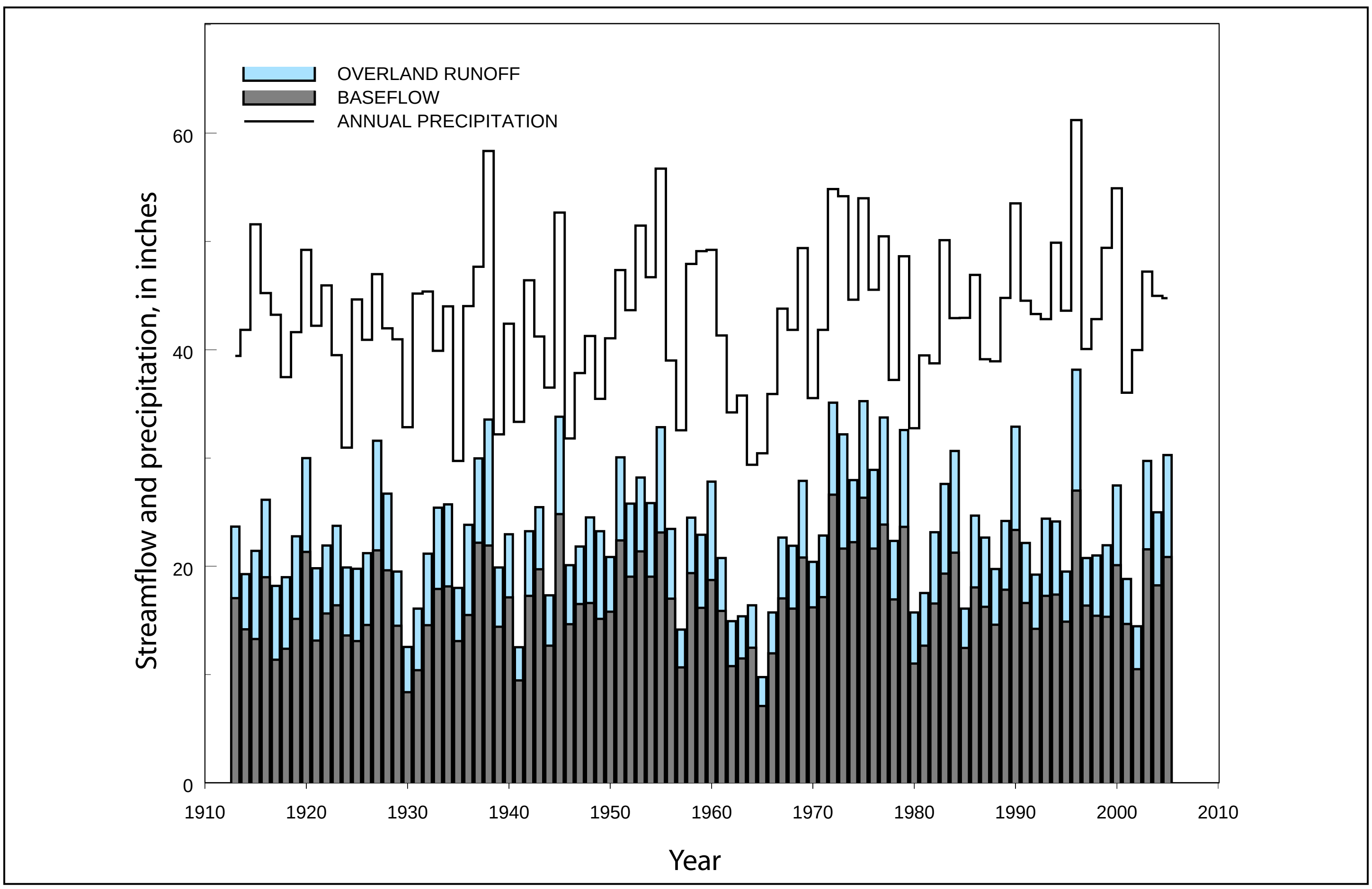


Figure CT-34. Relationship between precipitation and streamflow. *The direct relationship of annual precipitation to stream discharge for the Housatonic River at Falls Village, CT, is representative of most of the Connecticut Highlands. Approximately one-half (54 percent) of the precipitation that falls on the watershed leaves as streamflow. As precipitation increases total streamflow increases, but the percentages of the components of total streamflow (base flow and runoff) vary only slightly.*

Annual baseflow and overland runoff make up 72 and 28 percent of the annual streamflow with minor variation in this percentage from year to year at the Housatonic at Falls Village stream-gauging station (Figure CT-34). Annual baseflows ranged from 62 to 80 percent of the annual streamflow from 1913 through 2005. Overland runoff ranged from 20 to 38 percent of the annual streamflow during the period of stream-gauging record. Baseflow and runoff characteristics of streams vary between watersheds and are important indicators of dependable ground and surface water yields and changing hydrologic conditions. The percentage of streamflow that is composed of baseflow and runoff can be modified by land-use changes. New buildings, paving, soil compaction, and other human activities can increase surface runoff and reduce recharge to ground water.

Model simulation

In order to evaluate existing conditions on a watershed scale and potential changes to watershed hydrology based on future development scenarios, a generalized water-balance model, referred to as the Precipitation-Runoff Modeling System (PRMS), was developed. Application of PRMS provides a method for estimating water budgets at a subwatershed scale in the Highlands. The model incorporates detailed climatic, topographic, geologic, land-cover, and soils data and is calibrated to existing long-term streamflow data. Using these data, processes of the hydrologic cycle can be simulated and individual components of the water budget can be derived.

Water budgets were analyzed at subwatershed scales related to previously defined 12-digit Hydrologic Unit Codes (HUC). These codes use a standardized system to identify watershed boundaries and the geographic area of watersheds. In the Highlands PRMS model, 12-digit-HUC subwatersheds have an average area of about 30.6 square miles and a maximum area of 62.0 square miles. The modeled area (2,262 mi^2) is substantially larger than the Connecticut Highlands (1,059 mi^2) because the model boundaries must follow natural watershed boundaries (Figure CT-35). There are 74 12-digit-HUC subwatersheds in the model, 56 of which are located either wholly or partially within the study area. A daily water balance and energy balance were computed for each 12-digit-HUC subwatershed.

The PRMS model divides the flow regime into three components: surface runoff, subsurface flow, and ground water. In this report, baseflow is considered to be ground water flow plus a portion of the subsurface flow. The percentage of total streamflow that is baseflow, calculated from model-generated water budgets for each 12-digit-HUC subwatershed for the period 1960-2006, is shown in Figure CT-35.

Baseflow is a good indicator of the water-yielding capacity of the underlying aquifer and the stream's ability to sustain flow during periods of little or no rainfall and snowmelt. Model results indicate that, on average, baseflow (1,735 Mgal/d) made up approximately 65 percent of total streamflow in the Connecticut Highlands during the period of model simulation (1960-2006). The percentage of baseflow ranged from 23 to 86 for individual subwatersheds, and the range of baseflow contribution for the individual subwatersheds was from 1.2 to 62 Mgal/d, depending in large part on the watershed area.

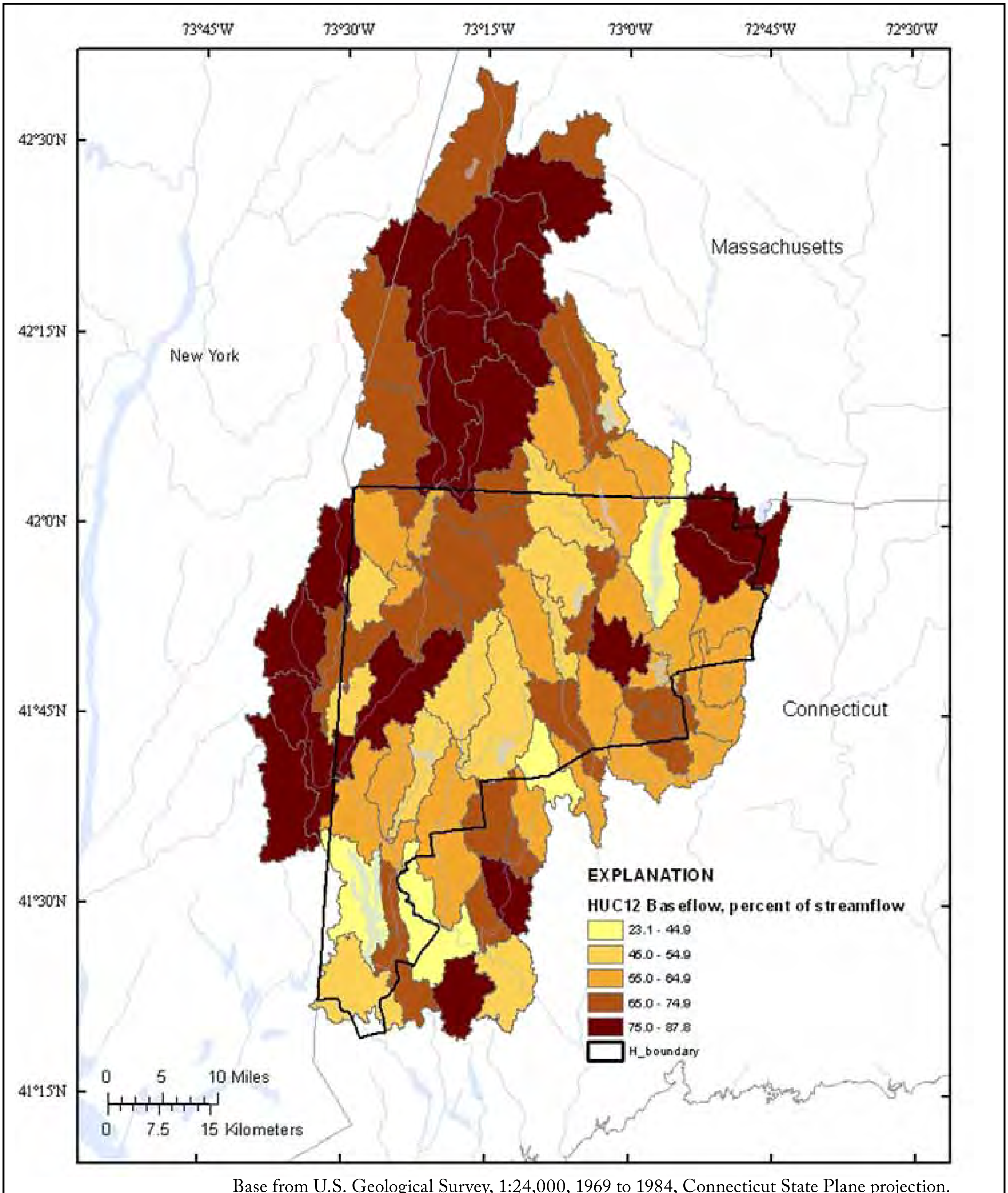
The percentage of baseflow contribution to a stream is dependent on the geology, soils, land cover, open-water surface area, and the amount of impervious surface in the watershed. Based on model results, baseflow accounts for more than 80 percent of streamflow in many watersheds underlain by a high percentage of stratified glacial deposits that have relatively high recharge rates and water-storage capacity. Baseflow accounts for less than 60 percent of streamflow in watersheds underlain by glacial till or watersheds with a high percentage of impervious surface area (such as urban areas).

In the study area, the amount of ground water storage and discharge to streams is the result of two geologic formations capable of yielding water. These consist of watersheds dominated by relatively low yielding bedrock and glacial till, and watersheds that are dominated by relatively high yielding stratified glacial deposits. The stratified glacial deposits occur primarily in the valleys of the larger rivers and streams, and the exposed bedrock and glacial till generally occur on the steeper uplands. In rocky areas with little or no sediment cover or with soils of low permeability, the ground-water recharge and contribution to streamflow is small. In areas dominated by glacial till or fine stratified drift (predominantly clay, silt, and very fine sand), recharge is significantly reduced, and flow is relatively low. In areas dominated by stratified glacial deposits (Figure CT-15), ground water recharge, storage, and flow is relatively high. Thus, watersheds with the highest percentage of coarse-grained sediments (stratified glacial deposits) will contribute the largest baseflow percentage to streams.

In addition to providing an evaluation of existing conditions, model-generated water budgets are useful for evaluating the potential effects of future change on land cover and water withdrawals on water resources, therefore aiding scientists to better estimate whether there is enough water available to support future population growth.

Water budget—Key findings

- Regionally, the Connecticut Highlands receive about 5,296 million gallons per day of water from precipitation. Forty-eight percent or 2,569 million gallons per day leave the Highlands as streamflow, and about 2 percent or 85 million gallons per day is lost as consumptive water use and transfers. An estimated 50 percent or 2,642 million gallons per day is lost to evapotranspiration.
- On a watershed scale, the amount of precipitation varies geographically across the region from about 46 to 54 inches per year. Annual precipitation has varied from these averages by as much as 10 to 20 inches during unusually wet and dry periods.
- Streamflow records fromthe USGS long-term gauging station on the Housatonic River at Falls Village show that during periods of prolonged drought, total annual streamflow can be 30 to 60 percent less than long-term average annual totals. During unusually wet years, streamflow can be 50 to 65 percent greater than long-term averages. These climatic variations affect the quantity and quality of water to downstream users.
- A watershed model used to simulate streamflow characteristics and provide water budgets for 74 12-digit-HUC subwatersheds indicates that on average, baseflow makes up about 67 percent of streamflow in the Connecticut Highlands. Baseflow in a watershed is affected by the underlying geology. Baseflow accounts for more than 80 percent of streamflow in many watersheds underlain by a high percentage of stratified glacial deposits with relatively high recharge rates and water-storage capacity. Baseflow accounts for less than 60 percent of streamflow in watersheds underlain by glacial till or having a high percentage of impervious surface area.



Base from U.S. Geological Survey, 1:24,000, 1969 to 1984, Connecticut State Plane projection.

Figure CT-35. Variations in base flow by subwatersheds. *The percentage of total streamflow that is base flow was calculated from model-generated water budgets for each 12-digit Hydrologic Unit Code subwatershed in the Connecticut Highlands, using the 1960 – 2006 average climate and impervious surface data. The highest base flow percentages are generally associated with those watersheds that are underlain with the highest percentage of stratified glacial deposits.*

Land use modeling

Modeling future land use change

Methods

The goals in modeling land use change were to:

- Understand the factors that have contributed to both the rate and the spatial distribution of land use change in the region;
- Create a map of development suitability (risk) showing the places most vulnerable to change after 2002 in Connecticut, based on those factors that have made land historically attractive for development;
- Use that map of development suitability to project where development is most likely to occur before 2022.

The model used to predict where future development is likely to occur is described in more detail below. The GIS-based growth model, GEOMOD, that was used for this study tests the assumption that spatially explicit factors that correlated with development in the past are good predictors of where future development is likely to occur. In this report, the term "suitable" means areas that are historically preferred for development, and "suitability" maps show where these areas exist across the landscape.

The model determines the rate of historical land use conversion, extrapolates that rate into the future, and—most importantly—simulates the location of future land use change based on statistical analysis of the historical pattern. The model tested more than 120 spatially distributed data sets to find those that described best where development had occurred historically.

To project development forward in time GEOMOD requires a map representing spatial variability in development suitability, and the model needs to know how much land to develop in a given time. All projections for the future are based on the actual data for 2002 for Connecticut. The projection horizon was set to the year 2022. A separate development rate was calculated for each stratum (e.g., town, county or region) by dividing the map into smaller units. Future land use was projected out to 2022 on a map using three different rates and three development constraints (none, low, and high). Cells were selected based on their rank within their town for future land use projection because it consistently yielded the best match to the 1995-2002 development pattern during model validation.

Results

The factors that were best able to predict where development occurred in the past (1985-2001) within each town were proximity to roads, existing development, lakes, and agricultural lands; topography; and soils (Figure CT-36). The factors that were best able to predict where development occurred within the region were poverty rate, population over age 65, income, unemployment, proximity to development, and elevation. In the other approach, data were stratified by town (Figure CT-37). The predictive ability was slightly higher for the town approach than for the regional approach.

Demographic factors tend to explain more of the variation in development patterns across the region than do physio-economic variables. Demographic variables vary across the region and attract or constrain new development accordingly. These demographic factors have less explanatory power at the town level because most of the demographic factors are aggregated at the census block level, and do not vary much within an individual town. Within a town, there is significantly higher correlation between hot spots for new development and areas of existing development or infrastructure such as roads.

Three rates of possible future growth were derived from the historic rate of development: high; medium; and low. The historic rate of development varied: more development occurred during 1985 to 1990 than from 1990 to 1995, or from 1995 to 2002 (Figure CT-38).

At the medium development rate (linear extrapolation of 1985 to 2002 trend), there would be 8,930 acres of new development by 2022 (Table CT-16). Three towns accounted for 35 percent of the growth in the region between 1985 and 2002: Danbury (15 percent), Torrington (10 percent), and New Milford (10 percent). Brookfield, Granby, Simsbury, and Burlington each account for about 6 percent of the regional change. The remaining towns individually account for between only 0.5 and 4.5 percent of the development observed.

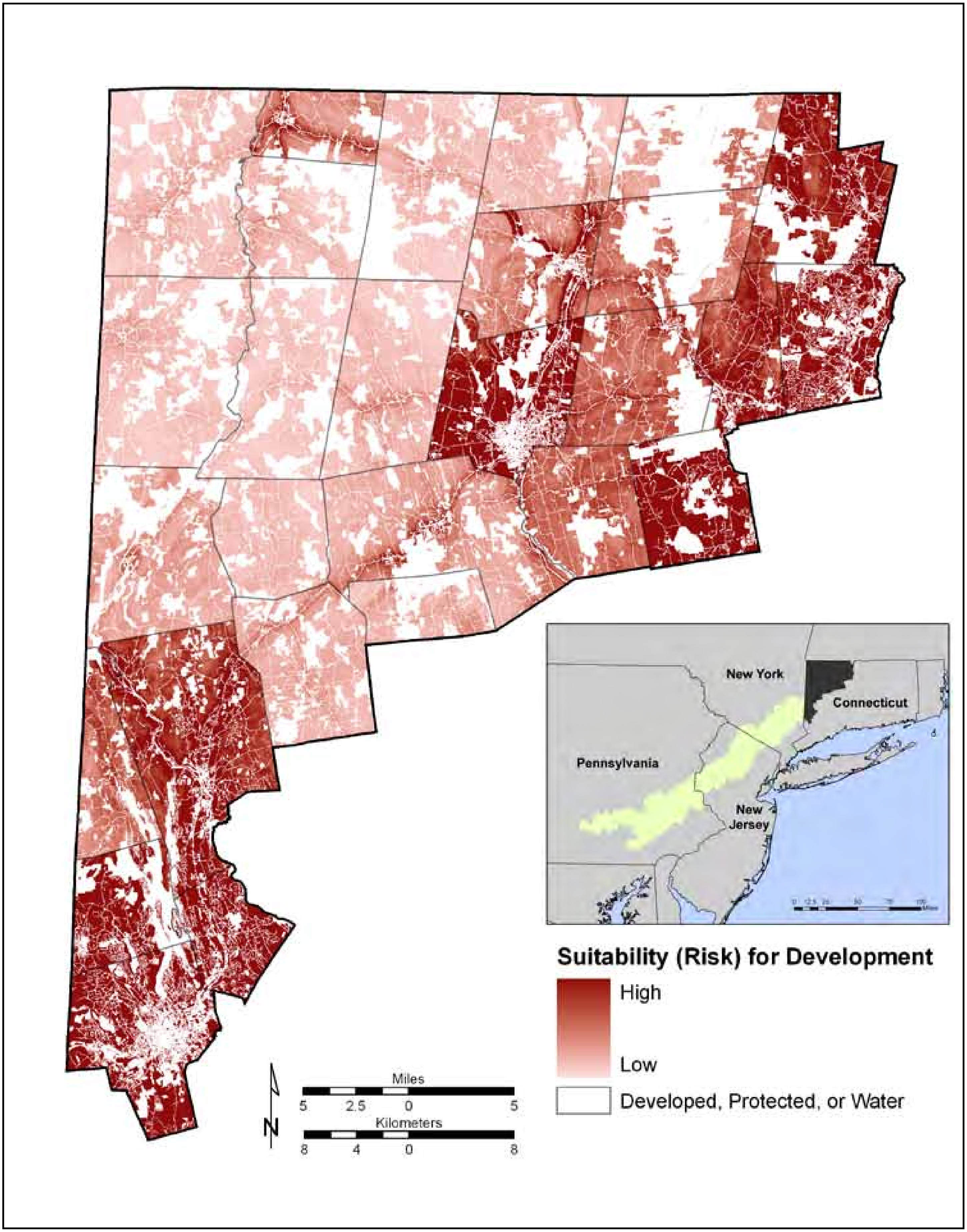


Figure CT-36. Suitability map by town. *Areas of low to high suitability for new development in the Connecticut Highlands as of 2002, using the town approach.*

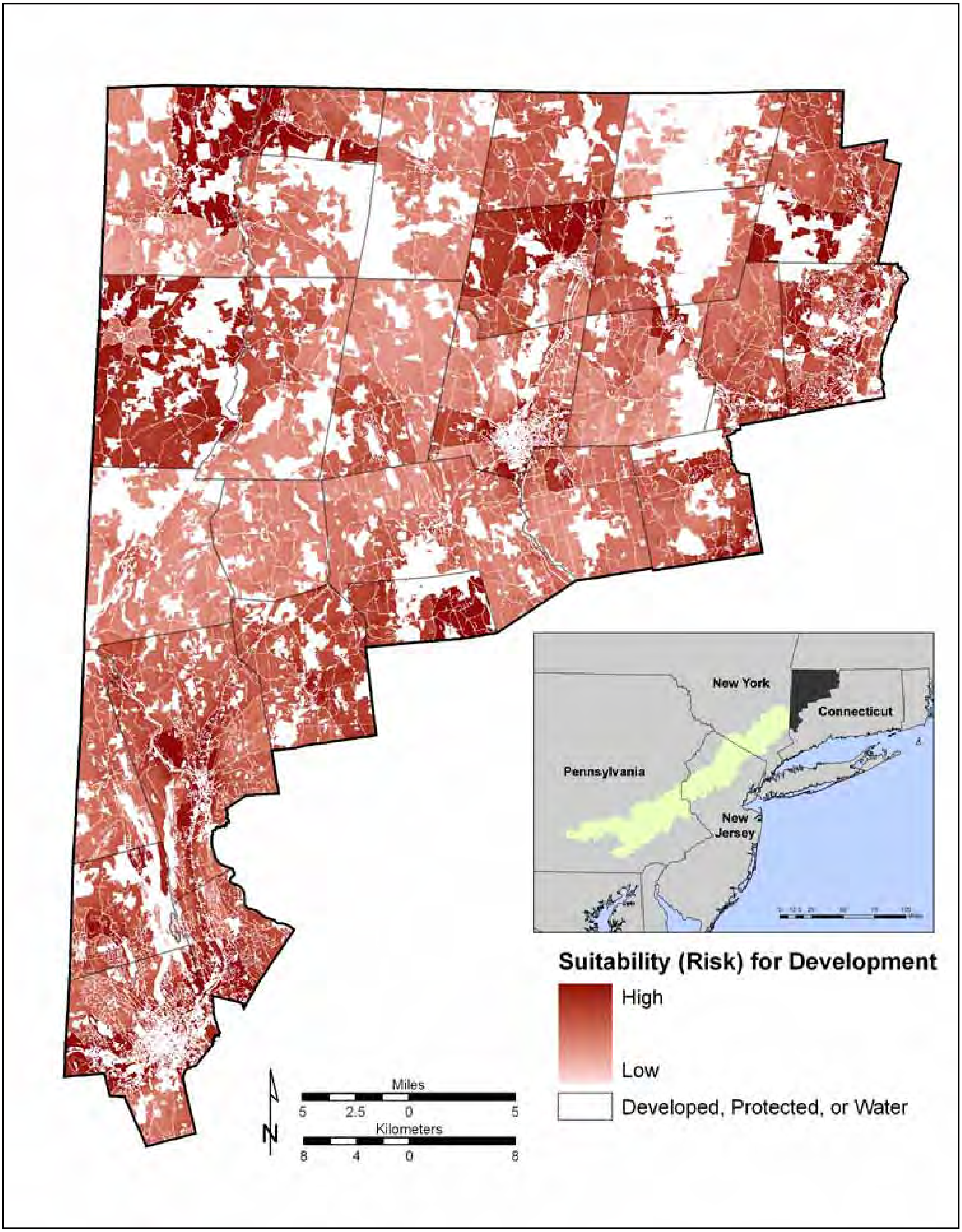


Figure CT-37. Suitability map by region. *Areas of low to high suitability for new development in the Connecticut Highlands as of 2002, using the regional approach.*

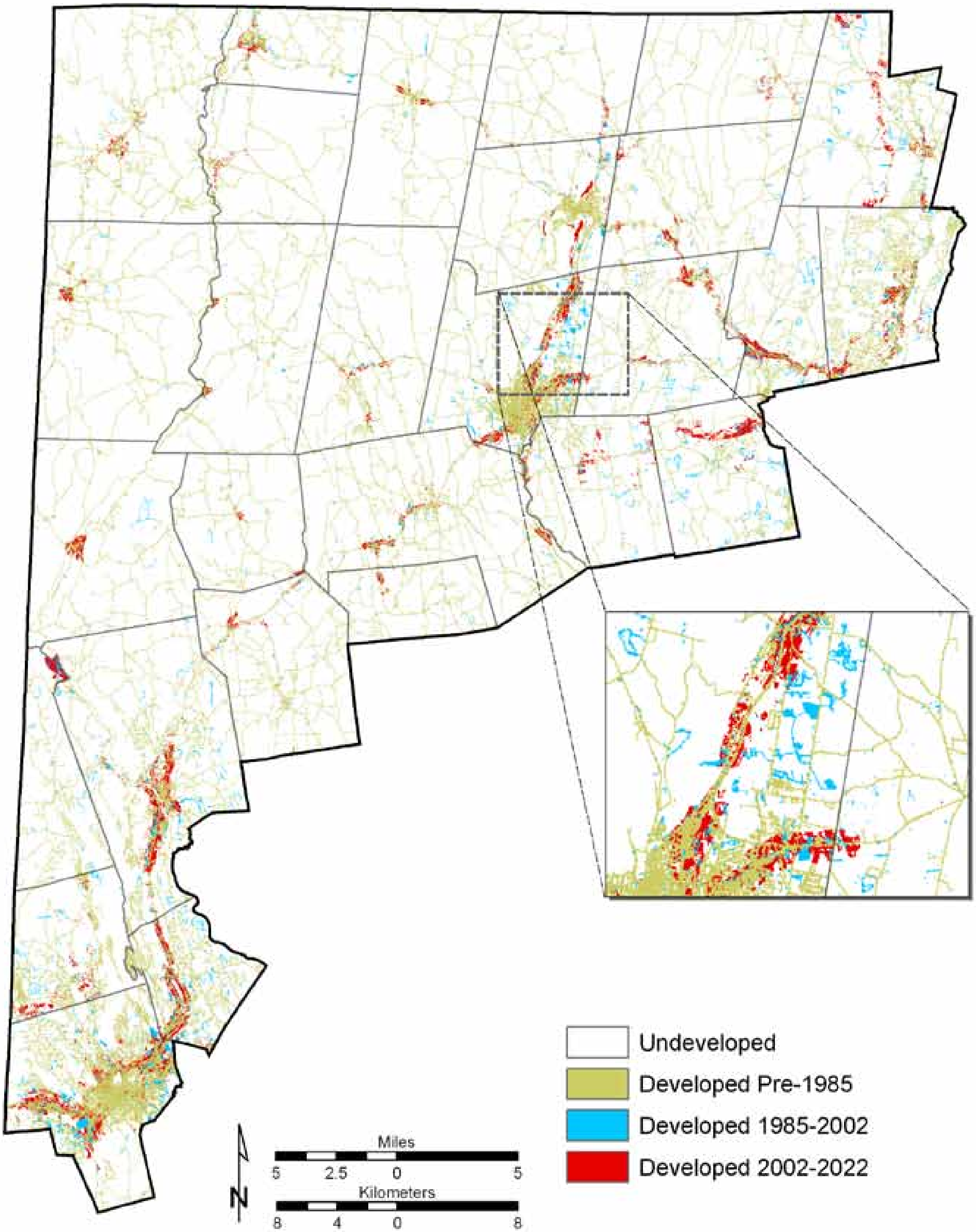


Figure CT-38. Projected development to 2022. *Development in the Connecticut Highlands was projected to the year 2022 using the medium development rate scenario and no constraints. The inset shows the pattern of development in the area around Torrington.*

Table CT-16. Projected development, by town. *Acres of new development projected for each town in the Connecticut Highlands from 2002 to 2022, based on the medium development rate and no constraints.*

Town	Acres of New Development	Change from 2002 (Percent)	Total Developed Acres by 2022	Area Developed by 2022 (Percent)
Danbury	1,374	15	10,565	38
Torrington	958	16	6,790	26
New Milford	899	16	6,399	16
Brookfield	613	19	3,875	30
Granby	553	23	2,999	11
Burlington	521	25	2,597	13
Simsbury	512	12	4,764	22
Canton	397	20	2,402	15
New Fairfield	352	15	2,631	16
New Hartford	324	15	2,535	10
Winchester	300	12	2,881	13
Harwinton	268	15	2,012	10
Litchfield	267	8	3,689	10
Sherman	206	15	1,542	10
Barkhamsted	185	10	1,954	8
Kent	163	9	1,922	6
North Canaan	140	12	1,355	11
Washington	125	6	2,230	9
Goshen	108	6	1,780	6
Salisbury	106	4	2,900	8
Sharon	102	4	2,377	6
Colebrook	80	7	1,149	5
Norfolk	80	5	1,620	5
Hartland	74	6	1,315	6
Cornwall	61	4	1,702	6
Warren	59	6	1,068	6
Canaan	56	6	1,049	5
Morris	48	5	1,040	9
Total	8,930	13	79,141	12

Table CT-17. Projected land use change, 2002 – 2022. Acres and percent change for different types of land use in the Connecticut Highlands, based on the medium development rate, and low- and high-constraint scenarios.

Land use	2002 Base (acres)	2022 projected								
		No constraints			Low constraint			High constraint		
		acres	Change		acres	Change		acres	Change	
			acres	percent		acres	percent		acres	percent
Urban	70,211	79,156	8,945	12.7	79,156	8,945	12.7	79,156	8,945	12.7
Agriculture and Grasses	94,785	92,651	–2,134	–2.3	92,401	–2,384	–2.5	92,040	–2,745	–2.9
Forest	457,167	451,082	–6,085	–1.3	450,884	–6,283	–1.4	451,236	–5,931	–1.3
Wetland	23,889	23,584	–305	–1.3	23,818	–71	–0.3	23,825	–64	–0.3

In the medium development rate, open spaces protected by public or private conservation ownership or easement, and water bodies are not subject to change. For low- and high-constraint scenarios, limitations are the same as those that apply to the build-out model.

Development is projected to occur mostly on forested lands. Urban land use and land cover is expected to increase by 8,945 acres (12.7 percent) over 21 years at the medium historical rate of growth (Table CT-17). This does not include grasses associated with development, as there was not sufficient information to model changes in this land use over time. This expected increase is a conservative estimate. As more environmental constraints are imposed on development in sensitive areas such as riparian buffers and steep slopes, some development is pushed away from forests and wetlands on to agricultural lands and open grassy areas.

Modeling future land-use change—Key findings

- The following factors were best able to predict where development occurred within each town:
    - proximity to roads, existing development, lakes, and agricultural lands;
    - topography; and
    - soils.
- Factors that were best able to predict where development occurred within the region were:
    - poverty rate;
    - population over age 65;
    - income;
    - unemployment;
    - proximity to development; and
    - elevation.
- With a medium development rate, there would be 8,930 acres of new development plus an estimated 14,000 acres of grasses associated with development by 2022.

Impacts of land-use change on the land

In addition to using a GIS-based growth model to test the assumption that spatially explicit factors correlated with past development are good predictors of where future development is likely to occur, another way to estimate the effect of development on resources is to find measurable indicators of resource integrity. Any index of resource integrity for this study has to be measured spatially, since the model is a spatial model. A simple statistical measure (percentage) of the acreage of altered vegetation over time is one way to estimate changes in resource integrity. How much of the altered landscape is likely to be covered by impervious surfaces in the future is another measure with implications for stormwater impacts and stream health. The ecological effects of vegetation change are many and can be measured several ways. Diminished or fragmented forest blocks impact forest and animal ecology. Alteration of forested riparian corridors affects stream ecology and has deleterious impacts on water quality. The loss of prime agricultural soils is a resource impact with potential long-term costs.

To characterize the impacts of human activity on the landscape of the Highlands, eight indicators were used to measure how development and land use change have altered the natural landscape:

1. Altered land—percentage of land in altered state (all land uses except forest, wetland, and water)
2. Impervious surface cover—percentage of land covered by impervious surface
3. Riparian corridors (wide)—percentage of riparian area in altered land use within 295 feet (90 meters) of stream corridors
4. Riparian corridors (narrow)—percentage of riparian area in altered land use within 100 feet (30 meters) of stream corridors
5. Forest fragmentation (location)—the percentage of land covered by interior forest (patches larger than 25 acres, and more than 295 feet from an edge)
6. Forest fragmentation (size)—the percentage of land covered by largest forest patch
7. Forest fragmentation (ratio)—the perimeter-to-area ratio (sum of the perimeters of all forest patches divided by the area of all forest patches), which is an indicator of edge amount relative to interior forest.
8. Farmland soils—percentage of important farm land soils (prime farm land or farm land of statewide importance) in developed land use

Regional level

Within the Connecticut Highlands as a whole, from 1985 to 2002, all measures indicated a slight increase in anthropogenic impacts. This is because the area is mostly forested, with relatively little developed land. There is a small increase in impervious surface, which is directly proportional to the amount of new development that has occurred. Development has occurred mostly on prime farm land.

Overall, estimates of these measures in the year 2022 under the development projection scenarios indicate that anthropogenic impacts, as quantified by these measures, will increase only slightly. One reason is the propensity of new development to occur near previously developed areas. Another reason is that the amount of projected development is low—8,930 acres, or 1.5 percent of the available land, at the medium historical development rate.

Town level

Overall impact levels as measured by the indicators are positively related to development in 2002. This is especially true for percent impervious surface as expected given that development is the primary source of impervious surfaces. Two adjacent towns, Danbury and Brookfield, each had the greatest impacts in 2002 in three of the eight measures. This pair of towns also accounted for four of the eight greatest changes over time.

Using "business as usual" constraints and medium development rate as the most likely of the nine scenarios to reflect future development dynamics, estimates of almost all measures in 2022 indicate that anthropogenic impacts will increase in all towns over 2002 levels.

Watershed level

In all watersheds, the perimeter-to-area ratio, percent interior forest, percent impervious surface, and percent developed prime farmland showed an increase in impacts from 1985 to 2002. Percent altered land increased in 44 of the 45 watersheds. Altered riparian area increased in 41 watersheds when using a 295-foot riparian buffer, and in 38 watersheds when using a 100-foot buffer.

Using "business as usual" constraints and the medium development rate as the most likely of the scenarios to reflect future development dynamics, the estimates of most measures in the year 2022 under the three development projection scenarios indicate that anthropogenic impacts will increase from 2002 levels in all watersheds.

Impacts of land use change on the land—Key findings

- Close to a third of riparian buffers have been cleared of natural vegetation.
- Forests are more fragmented in 2002 than they were in 1985; unfragmented forest declined from 47 percent of the forest area to 43 percent.

Impacts of land use change on water resources

The hydrologic cycle is intimately linked with changes in precipitation and atmospheric temperature. Human activities, such as altering the land cover and extracting ground water, affect the hydrologic systems and the available water resources. Changes in the hydrologic cycle due to changing climate trends or human activities are accompanied by ecological and hydrological impacts—increased frequency of flooding, decreased water-supply storage, degraded water quality, and stressed ecosystems.

Changes in land use can have wide-ranging environmental impacts. Several studies indicate that water quality and aquatic ecosystems are degraded as impervious cover increases; when impervious cover exceeds 10 percent of the basin is when sensitive stream elements are lost from the system (Center for Watershed Protection 2003, Schueler 1994). Studies of the impacts of impervious cover for the Mid-Atlantic region of the United States indicate that the biotic community is affected when impervious surface is greater than about 3 percent of the watershed area, and that significant degradation of the biotic community is observed beginning when impervious surface reaches 10-15 percent (Horner and others 1997, May and others 1997, U.S. Environmental Protection Agency 2001b, VanderWilt and others 2003, Wang and Kanehl 2003). Recently, the Connecticut Department of Environmental Protection (Bellucci and others 2008) evaluated stream conditions for aquatic biota at 30 locations having impervious cover between 6 and 14 percent of the basin. In a second study (Bellucci and others 2009), the Connecticut Department of Environmental Protection evaluated stream conditions in "natural" (unaltered flow) basins with impervious cover less than 4 percent. Key findings of the two studies show that (1) basins with 12 percent or more of impervious cover generally did not meet the State's aquatic life goals, (2) the ecological integrity of the streams and rivers was comprised (degraded water quality, and lack of species diversity and abundance) for basins with impervious cover between 6 and 12 percent, and (3) the biological conditions as they pertain to ecological integrity for stream segments with less than 4 percent impervious cover generally are healthy (diverse communities dominated by sensitive organisms).

Changes in land cover affect the hydrologic cycle by altering the magnitude, frequency, duration, and timing of flows. An increase in impervious surface decreases the amount of land through which precipitation can infiltrate and recharge an aquifer. This decrease may then result in a reduction in aquifer storage and a reduction in natural base flow to streams. A change in storage (indicated by changing ground water levels) is usually more easily determined than are changes in ground water discharge to streams. The effects of reduced ground water discharge on streams and their ecosystems are more difficult to quantify and may become apparent only over extended periods. Urban features, such as buildings, roads, and parking lots, are impervious and reduce infiltration as well as increase surface runoff of precipitation. Runoff may be channeled through storm sewers to streams, leading to increased streamflow and more frequent flooding. Development of native forests, grasslands, and wetlands, as well as deforestation, leads to changes in patterns of infiltration, ground water discharge, and evapotranspiration.

Impact of land use change on the water budget

The effects of high- and low-constraint development scenarios on the Connecticut Highlands' water budget were evaluated using the watershed model described earlier in this section under Water Budget—Analysis at a watershed scale. The projected increases in impervious surface area and ground-water withdrawals are the factors driving the change in water-budget components between current conditions (2006) and the projected development scenarios. The simulated water budgets show substantial change between existing conditions and the projected development scenarios but little change between the high- and low-constraint

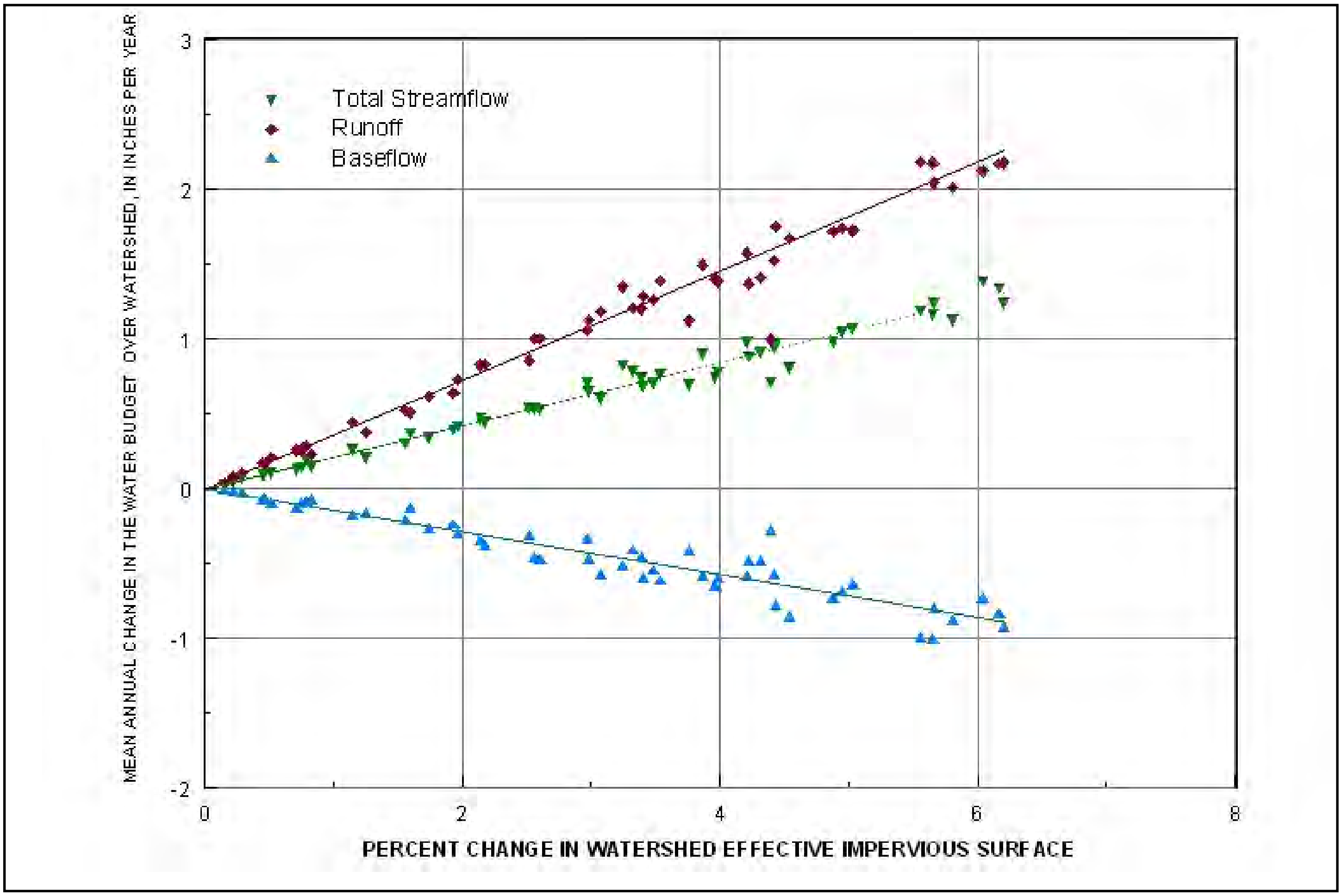


Figure CT-39. Effect of impervious surfaces on the water budget. Observed changes in the water budget are directly related to increases in the amount of effective impervious surface area, as shown here for 74 12-digit Hydrologic Unit Code watersheds in the Connecticut Highlands.

development scenarios. Discussion focuses on the low-constraint development scenario because it represents a larger impact on the water budget and hydrologic processes than does the high-constraint scenario.

Impact of increase in impervious surface

Model-simulated differences in runoff, base flow, and total streamflow between existing conditions and low-constraint development are shown in Figure CT-39. The data points in the figure represent the water-budget components of 12-digit-HUC watersheds plotted in order of increasing change in effective impervious surface cover over existing conditions. Trend lines show the relationship between increasing effective impervious surface area and the water-budget components. Land modifications to accommodate new buildings, roads, and parking lots tend to increase runoff and decrease infiltration (base flow). As the percentage of impervious surface area in a watershed increases, runoff increases, base flow decreases, and total streamflow increases. Runoff increases substantially more than base flow decreases.

Changes in the water budget are directly proportional to the changes in the effective impervious surface area. Under the low-constraint scenario, the total impervious surface area increases from 37,100 to 78,100 acres. This increase results in increases in annual mean streamflow (45 Mgal/d), annual mean runoff (76 Mgal/d), and in a decrease in annual mean base flow (31 Mgal/d). The maximum change in effective impervious surface area in all the 12-digit-HUC watersheds analyzed is about 6.5 percent for the low-constraint scenario, and 5 percent for the high-constraint scenario. Mean annual streamflow for the period 1960-2006 averaged about 26 inches per year in the Connecticut Highlands' watersheds. For the period 1960-2006 mean annual base flow averages about 18 inches per year, and mean annual runoff averages about 8 inches.

From Figure CT-39, a 5-percent increase in the effective impervious surface from the current conditions (2006) indicates about a 1.7 inch per year increase in mean annual runoff, 0.6 inch per year decrease in mean annual base flow, and 1.1 inch per year increase in mean annual streamflow.

An example is Mudge Pond Brook, which has a 5 percent increase in effective impervious surface under the low-constraint scenario. The water budget model indicates a potential 1.7 inch per year (1.6 Mgal/d) increase in runoff, a 1.1 inch per year (1.0 Mgal/d) increase in streamflow, and a 0.6 inch per year (0.6 Mgal/d) decrease in mean annual base flow for Mudge Pond Brook. A streamflow change of 1.0 Mgal/d represents a large portion of the available water in the river during seasonal dry periods and can compromise water availability and quality, and ecosystem health. Under the low-constraint scenario, 8 of 74 12-digit-HUC subwatersheds have increases in effective impervious surface greater than 5 percent.

Impact of increase in population

Also under the low-constraint scenario, the population in the Connecticut Highlands increases from about 300,000 to 670,000 people. Based on the proposed population increase for the low-constraint scenario and an 85-gallon per day per person water use, an estimated additional 31.5 Mgal/d of ground water will be withdrawn from aquifers in the modeled area. At the regional water budget scale, an additional 31.5 Mgal/d of ground water withdrawals for domestic use represents a minor change in total mean annual base flow (about 2 percent).

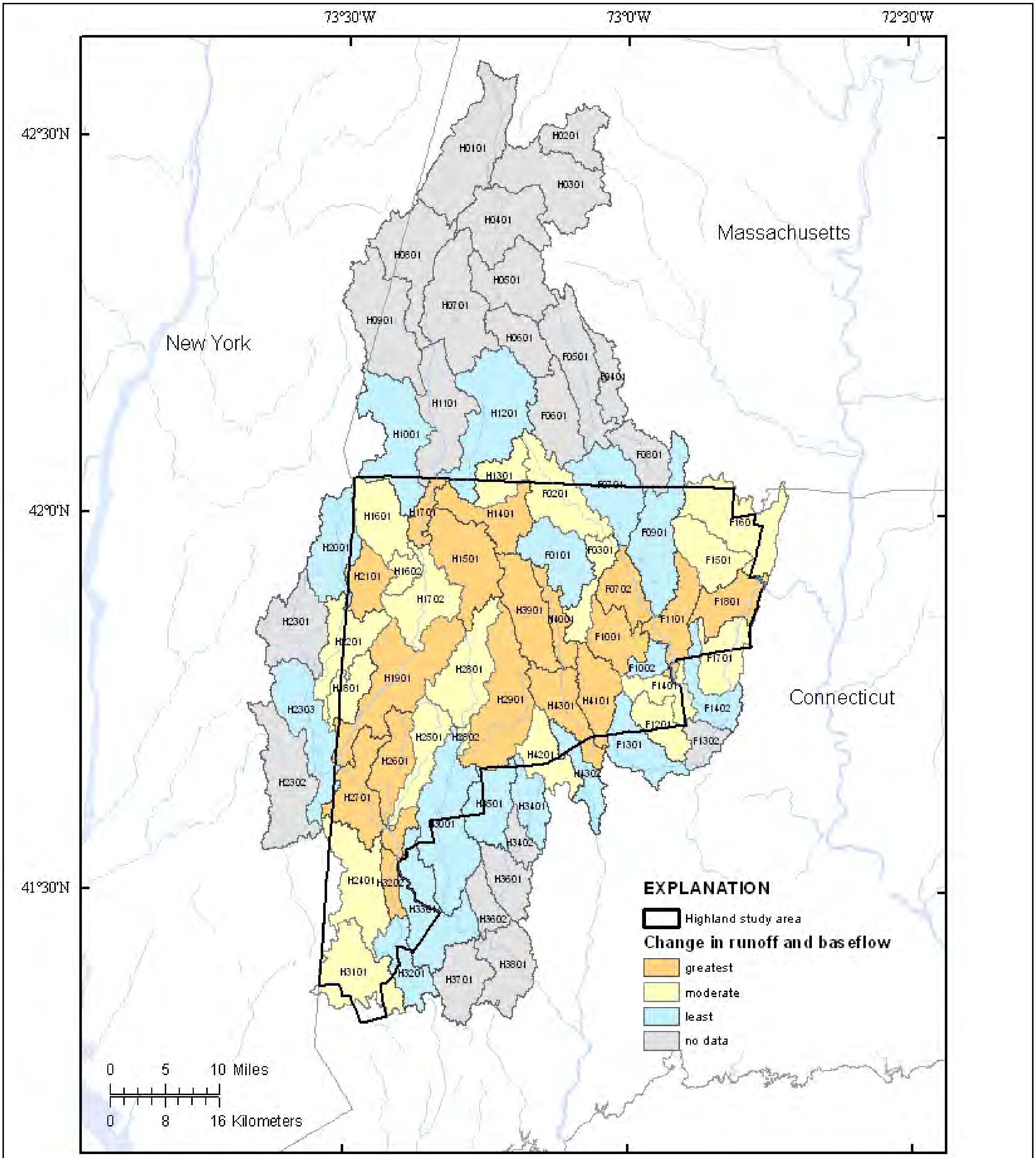
At the subwatershed (12-digit-HUC) scale, the additional ground water withdrawals range from 0.1 to 7 percent of the mean annual base flow, which represents less than 1 inch more water withdrawn per year in each watershed. The average decrease in base flow is 3 percent. The 12-digit-HUC subwatersheds where ground water withdrawals exceed 5 percent of the mean annual base flow include West Aspectuck River, Leadmine Brook, and the lower reach of the Still River (tributary of the Housatonic River). The 12-digit-HUC watersheds with about 50 percent or more area outside the Highlands boundary or lacking supporting development data, or both were excluded from this analysis.

Figure CT-40 shows the predicted change in runoff and base flow at the 12-digit-HUC subwatershed scale under the low-constraint development scenario. The areas of moderate and greatest change are directly related to the projected increase in impervious surface area and ground water withdrawals. Nine of 17 12-digit-HUC watersheds with the greatest predicted change had a total change in runoff and base flow greater than 2.5 inches: Farmington River, headwaters to Burlington Brook (basin identifier-F1101 on Figure CT-40), Nepaug River (F1001), Housatonic River mainstem, Furnace Brook to Tenmile Brook (H1901), Blackberry River (H1401), West Aspectuck River (H2601), Naugatuck mainstem, East Branch to Hancock Brook (H4301), Housatonic mainstem, Tenmile River to Still River (H2701), Leadmine Brook (H4101), and the West Branch Naugatuck River (H3901).

In this study, model-simulated changes in water budgets are used to evaluate how the increases in impervious surface and ground water withdrawals due to population increase affect the annual mean streamflow, runoff, and base flow. Changes in these water budget components under the low-constraint scenario in the Highlands appear minor to moderate; however, the water budget analysis did not include estimating monthly changes. Therefore, the potential impacts on water availability, water quality, and ecosystem health on a seasonal basis are unknown. An assessment of water supplies on the 74 subwatersheds or aquifers in the Highlands on a monthly or daily time scale would permit optimal water management.

Impacts of land use change on water resources—Key findings

- Water budget analysis of 12-digit-HUC watersheds in the Highlands shows that as the percent of impervious surface area increases, overland runoff increases at a greater rate than base flow decreases.
- Water budget calculations indicate that a 5-percent increase in effective impervious surface area could result in a 15-percent increase in mean annual runoff, a 5-percent decrease in mean annual base flow, and a 4-percent increase in mean annual streamflow (Figure 3-15).



Base from U.S. Geological Survey, 1:24,000, 1969 to 1984, Connecticut State Plane projection.

Base from U. S. Geological Survey, 1:24,000, 1969 to 1984
Connecticut State Plane projection

Figure CT-40. Predicted change in runoff and base flow. *The change predicted to occur at the 12-digit Hydrologic Unit Code watershed scale in the Connecticut Highlands is based on the change between the simulated water budgets for the period 1960 – 2006 and the low-constraint development scenario. The areas of moderate and greatest change are directly related to the projected increase in impervious surface area and water withdrawals. The predicted change is expressed as the sum of the absolute values of the runoff and base flow. "Greatest" represents a change greater than 2 inches in the runoff and base flow, "moderate" represents a change between 1 and 2 inches in the runoff and base flow, and "least" represents a change less than 1 inch in the runoff and base flow.*

- Based on the increase of impervious surface area and the increase in ground-water withdrawals to meet projected population increases for the low-constraint development scenario, the 12-digit-HUC watersheds with a combined change in runoff and base flow greater than 2.5 inches include the Farmington River, headwaters to Burlington Brook, Nepaug River, Housatonic River mainstem, Furnace Brook to Tenmile Brook, Blackberry Brook, West Aspectuck River, Naugatuck mainstem, East Branch to Hancock Brook, Housatonic mainstem, Tenmile River to Still River, Leadmine Brook, and the West Branch Naugatuck River.
- Increasing the impervious surface area and increasing ground water withdrawals to meet population demands are important factors affecting the natural hydrologic cycle. The increase in impervious surface area, as projected by the high- and low-constraint build-out scenarios, had a greater impact on changing the Highlands' water budget than did the additional ground-water withdrawals estimated from projected population growth. Model-simulated water budgets showed little change between the high- and low-constraint scenarios.
- Based on the proposed population increase (about 370,000 new residents) for the low-constraint development scenario, and an 85 gallon per day per person water use, estimated additional withdrawals of 31.5 Mgal/d of ground-water was assumed. The additional ground water withdrawals range from 0.1 to 7 percent of the base flow for the 12-digit-HUC watersheds. The 12-digit-HUC watersheds most affected (where ground water withdrawals exceed 5 percent of the mean annual base flow) include: West Aspetuck River, Leadmine Brook, and the lower reach of the Still River, tributary of the Housatonic River.

Increases in impervious surface area have been attributed to increased frequency of flooding for storms of similar intensity and duration, loss of recharge water to aquifers, decreased water supply storage during periods of droughts, degraded water quality, and stressed ecosystems.

Part 5. Public input—Land and water characteristics, and growth and impact analysis

Workshops

Eighteen foresters, conservationists, planners, developers, and representatives of land preservation trusts met at a Connecticut Highlands Workshop on October 18 and 19, 2007, at the Litchfield County Extension Center in Torrington to learn about the Highlands Regional Study and talk about land use change. The workshop provided an opportunity for interested citizens to review the results of the Highlands Resource Assessment and offer their estimates of what factors are driving change in the region.

The Forest Service and the study team sought to engage interested citizens in a review of the study results, a determination of what the results mean for the Highlands' future, and a formulation of conservation strategies to insure the protection of those resources that the community values.

This two-day workshop began with the study team's presentation of the results from their analyses, and a general discussion of implications for the future. Participants proposed, discussed, and agreed upon workable strategies for conservation, and identified conservation focal areas on a map.

Public input—Land and water characteristics and growth and impact analysis—Key findings

- Attendees identified conservation focal areas as part of a facilitated discussion.
- Participants proposed collaborative scenarios, identifying the resources, places, or issues with the greatest promise for accomplishing results through cooperative conservation.
- Participants developed a synthesis of what all of the information means for the Highlands and their resources.
- Attendees learned the results of the growth and impact analysis, including the growth model and build-out analysis.

Figure CT-41. Bantam Lake. *Canoeist on Bantam Lake in the Connecticut Highlands. (Photo by Wendy Carlson, Litchfield Hills Greenprint project)*

Part 6. Conservation actions, regional resources at risk, resource condition summary and conservation focal areas

Conservation actions

Description

The New York-New Jersey Highlands Regional Study: 2002 Update (Phelps and Hoppe 2002) highlighted the history of conservation actions in the New York and New Jersey region since the establishment of the Palisades Interstate Park Commission (PIPC) in 1937. Since 2002, several key conservation actions have occurred in the four-state region (for more information, see Appendix H), including for example, one land acquisition project and one partnership in Connecticut.

Deluca property—In early 2008, the 308-acre Deluca Property was acquired by the Connecticut Department of Environmental Protection. This property provides an additional 2,700 feet of frontage along the Upper Housatonic River Trout Management area, increases recreational opportunities, and improves water quality (Figure CT-41). It will also expand the Housatonic State Forest and create a contiguous tract of 1,000 acres that is well suited for migratory songbirds. The property included a public-private partnership; funds to protect it came from the Highlands Conservation Act ($500,000 from FY07 HCA, $2.5 million from the State of Connecticut, and $100,000 from the Cornwall Conservation Trust). For more information on this project, see the Web site of the Connecticut Department of Environmental Protection (2009).

Litchfield Hills Greenprint—A project of the Housatonic Valley Association, began in 2005 to promote coordinated, long-term, and locally driven conservation action in northwest Connecticut to protect the ecological qualities of the landscape and the character of its communities for generations to come (Figure CT-42). Together with local and regional partners across 20 of Connecticut's 28 Highlands communities and an additional 7 adjacent towns, the Greenprint shares a vision that will increase the pace and quality of conservation activity across the Litchfield Hills by 50,000 acres by 2020. For more information on this project, see the Web site of the Housatonic Valley Association (2009).

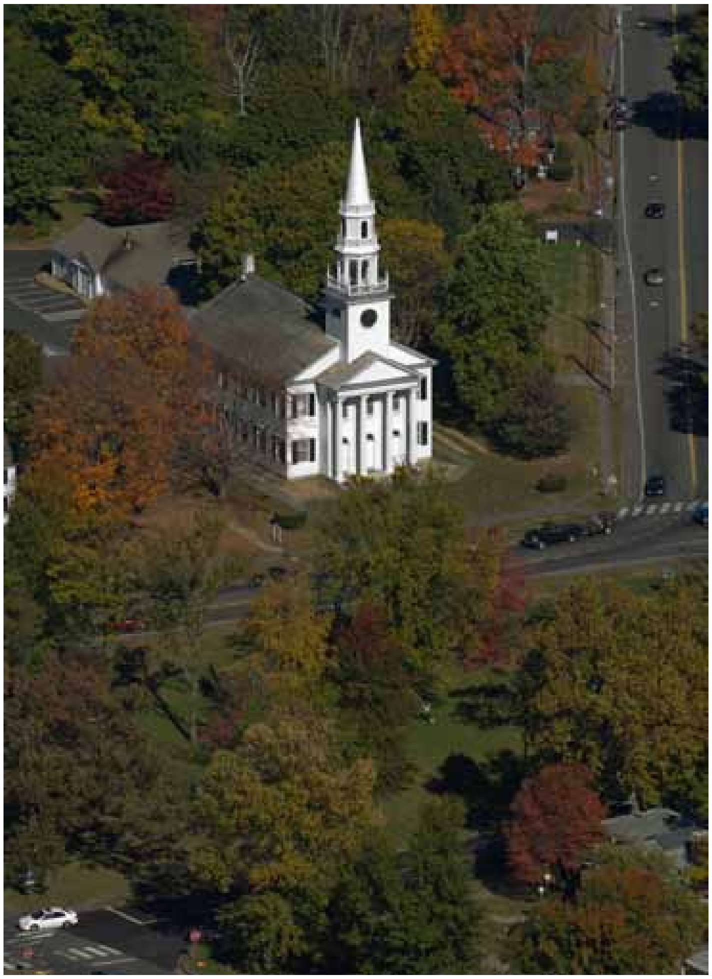


Figure CT-42. Aerial view of Litchfield Green. *Litchfield Green in Litchfield County, Connecticut, is a typical town in the Connecticut Highlands. (Photo by Wendy Carlson, Litchfield Hills Greenprint Project)*

Conservation actions—Key findings

- The 308-acre Deluca Property provides an additional 2,700 feet of frontage along the Upper Housatonic River Trout Management area, increases recreational opportunities, and improves water quality.
- The Litchfield Hills Greenprint actively promotes coordinated, long-term, and locally driven conservation action in northwest Connecticut.

Regional resources at risk

One of the main goals of this study was to understand which valuable natural resources are at risk of being lost to growth and sprawling development by 2028. Looking at where high conservation value lands overlap with lands at high risk of converting from forest or agriculture to development provides a way to think about conservation priorities in the Highlands, taking into account both value and risk.

Table CT-18. Resources at risk. Acres of high and highest conservation value in each development risk category, for each resource and for combined resources in the Connecticut Highlands.

Suitability for or risk of development	Water	Forests	Biological resources	Agriculture	Recreation and culture	Composite
High Risk	66,000 (39%)	30,100 (18%)	250 (2%)	9,900 (33%)	6,200 (25%)	31,000 (27%)
Medium Risk	59,000 (35%)	55,000 (33%)	2,500 (18%)	12,000 (40%)	6,700 (27%)	35,900 (32%)
Low Risk	45,400 (27%)	80,300 (49%)	11,500 (81%)	7,900 (26%)	12,000 (48%)	46,600 (41%)

Methods

Value-risk overlay maps were constructed from the stratified suitability (risk) maps produced for growth modeling (see Part 4. Growth and impact analysis—Land use modeling), and the conservation value maps (see Part 1. Conservation values assessment). The stratified approach accounts for the town-by-town or county-by-county variation in rate of growth, and is the most realistic in terms of understanding where development pressure exists across the region.

Value-risk overlay maps show the relationship between likelihood of development or suitability and conservation importance across the landscape. Maps were produced for each of the five resources: water, forest, biological, agriculture, and recreation and culture, as well as for the combination of resources (composite) in the Conservation Values Assessment (Figures CT-43 to CT-48). Relative suitability for development is displayed in three quantiles; conservation value is displayed in five quantiles. Because the suitability analysis was stratified by town and county, its output accentuates political boundaries.

Results

Twenty-seven percent (31,000 acres) of the land on the composite CVA map has both "high or highest conservation value" and is projected to be in the high suitability or risk for development category (Figure CT-48). High value water protection lands and agricultural lands are most at risk, with 39 percent and 33 percent of the high and highest value lands also in the high risk category (Table CT-18). Altogether, 27 percent of the land that is considered to be of high and highest conservation value is also at high risk of being developed.

Regional resources at risk—Key findings

- Twenty-seven percent of the land that is considered to be of high and highest conservation value is at high risk of being developed.
- High value water protection lands and agricultural lands are most at risk of being developed.

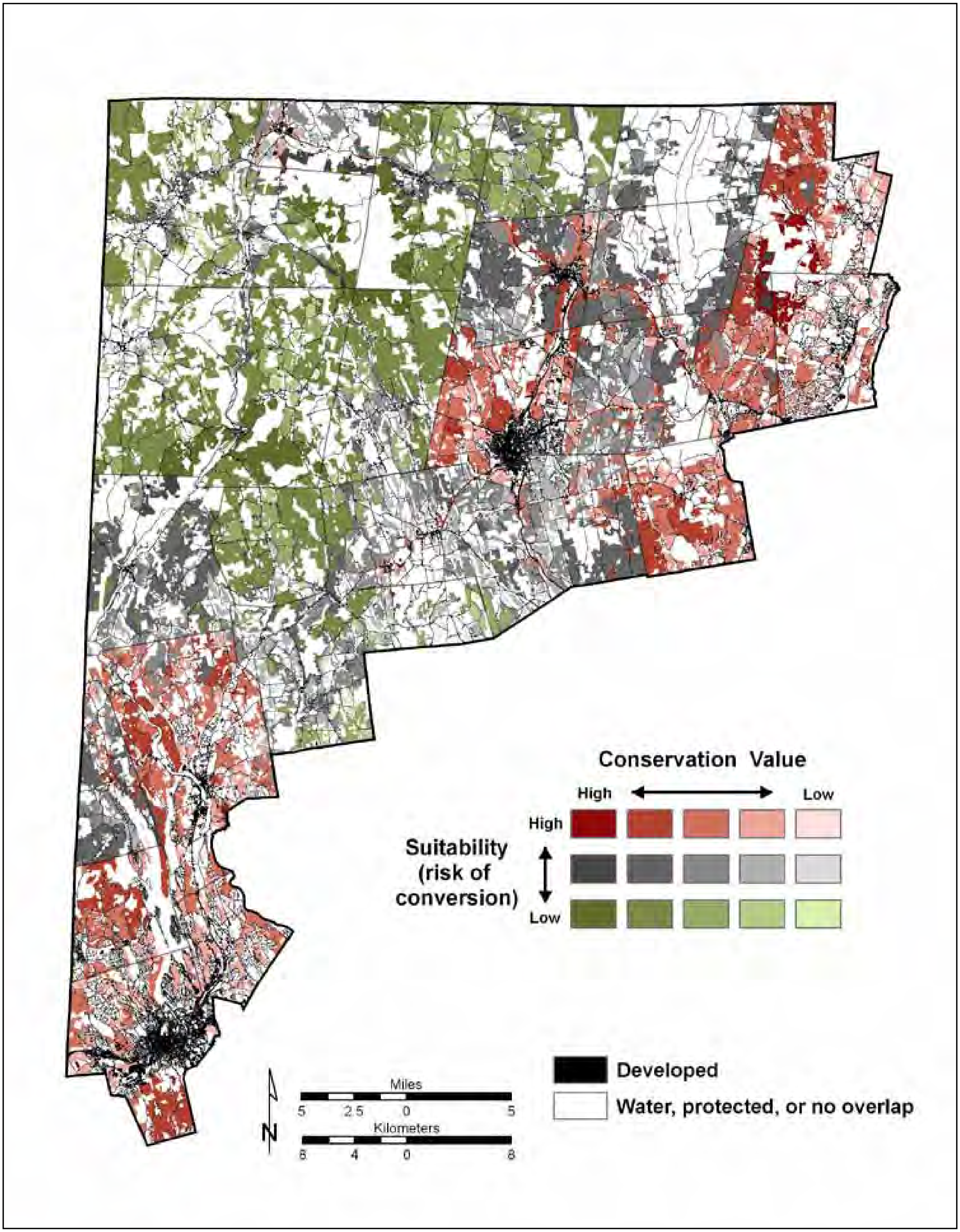


Figure CT-43. Suitability map for water resources. Overlay of high to low conservation values for water with high to low suitability (risk of being developed) in the Connecticut Highlands.

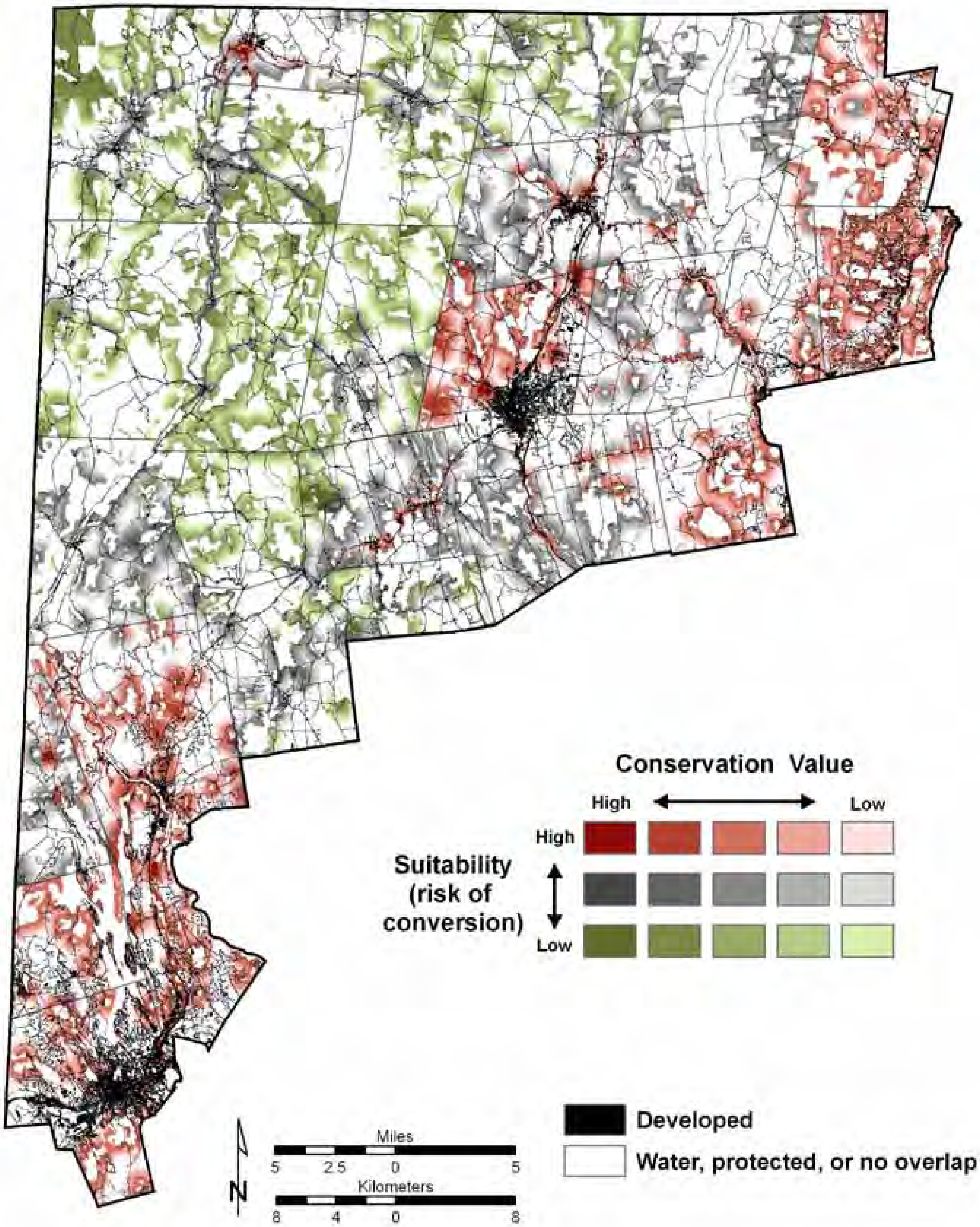


Figure CT-44. Suitability map for forest resources. *Overlay of high to low conservation values for forest with high to low suitability (risk of being developed) in the Connecticut Highlands.*

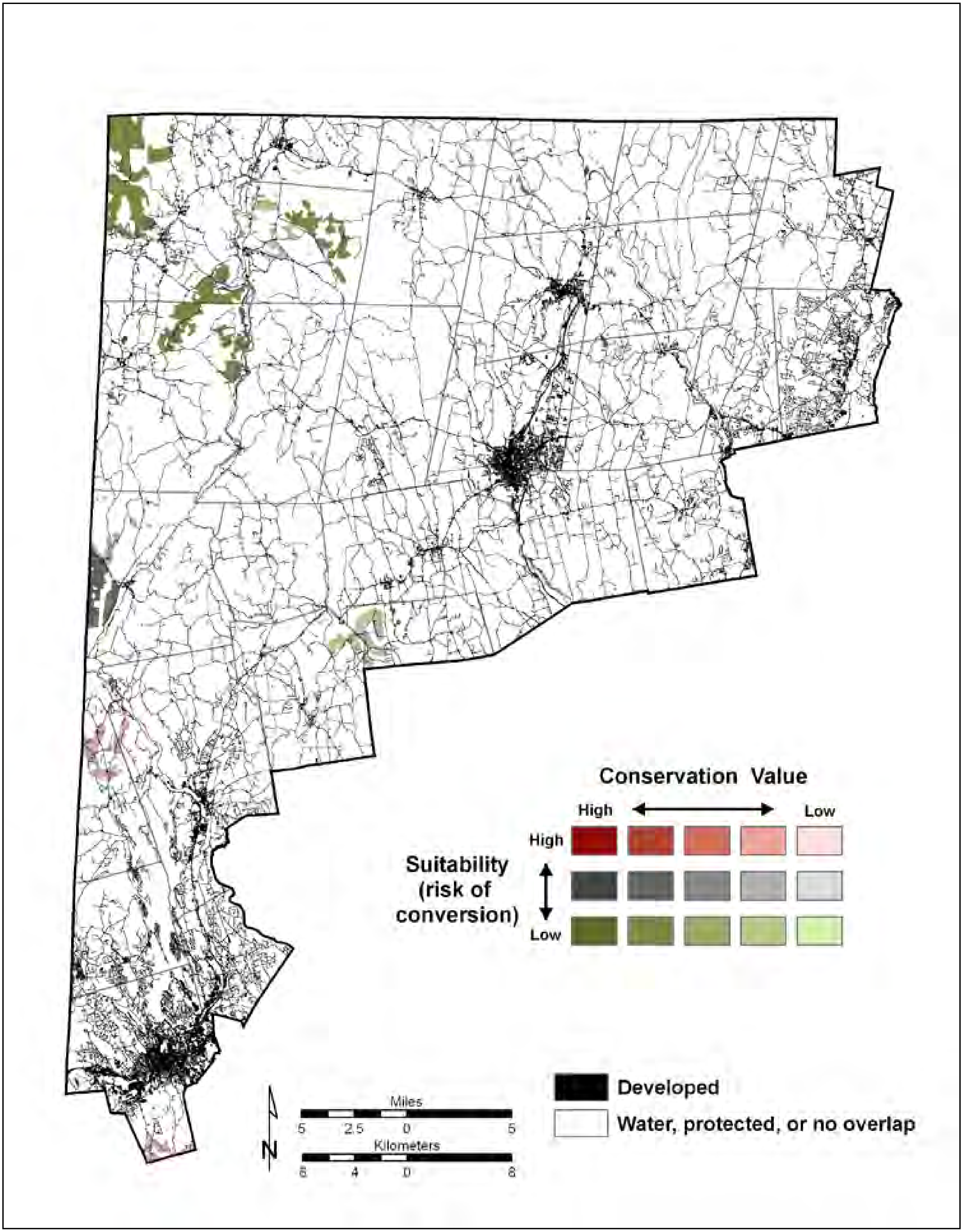


Figure CT-45. Suitability map for biological resources. *Overlay of high to low conservation values for biological resources with high to low suitability (risk of being developed) in the Connecticut Highlands.*

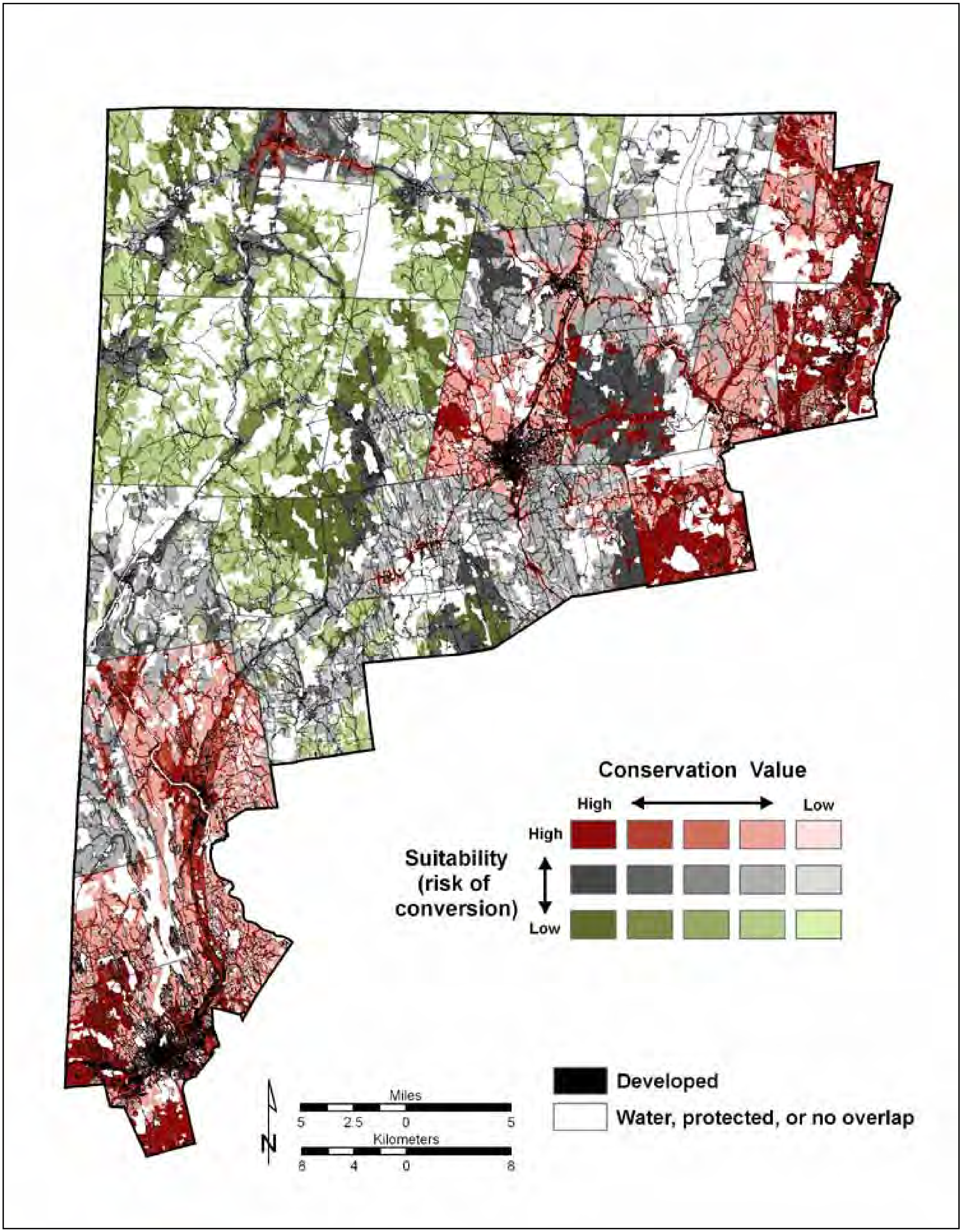


Figure CT-46. Suitability map for agricultural resources. Overlay of high to low conservation values for agriculture with high to low suitability (risk of being developed) in the Connecticut Highlands.

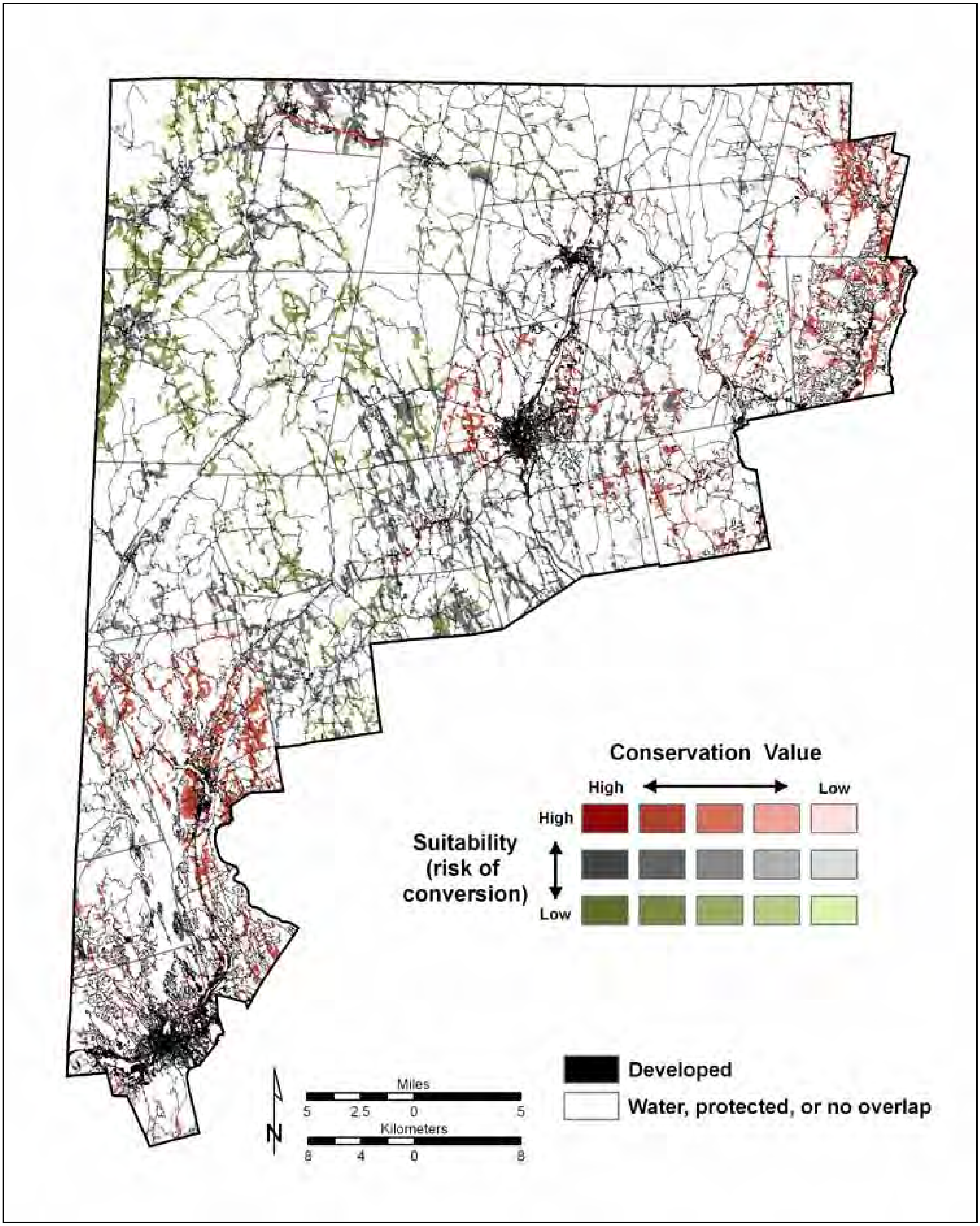


Figure CT-47. Suitability map for recreational and cultural resources. *Overlay of high to low conservation values for recreational and cultural resources with high to low suitability (risk of being developed) in the Connecticut Highlands.*

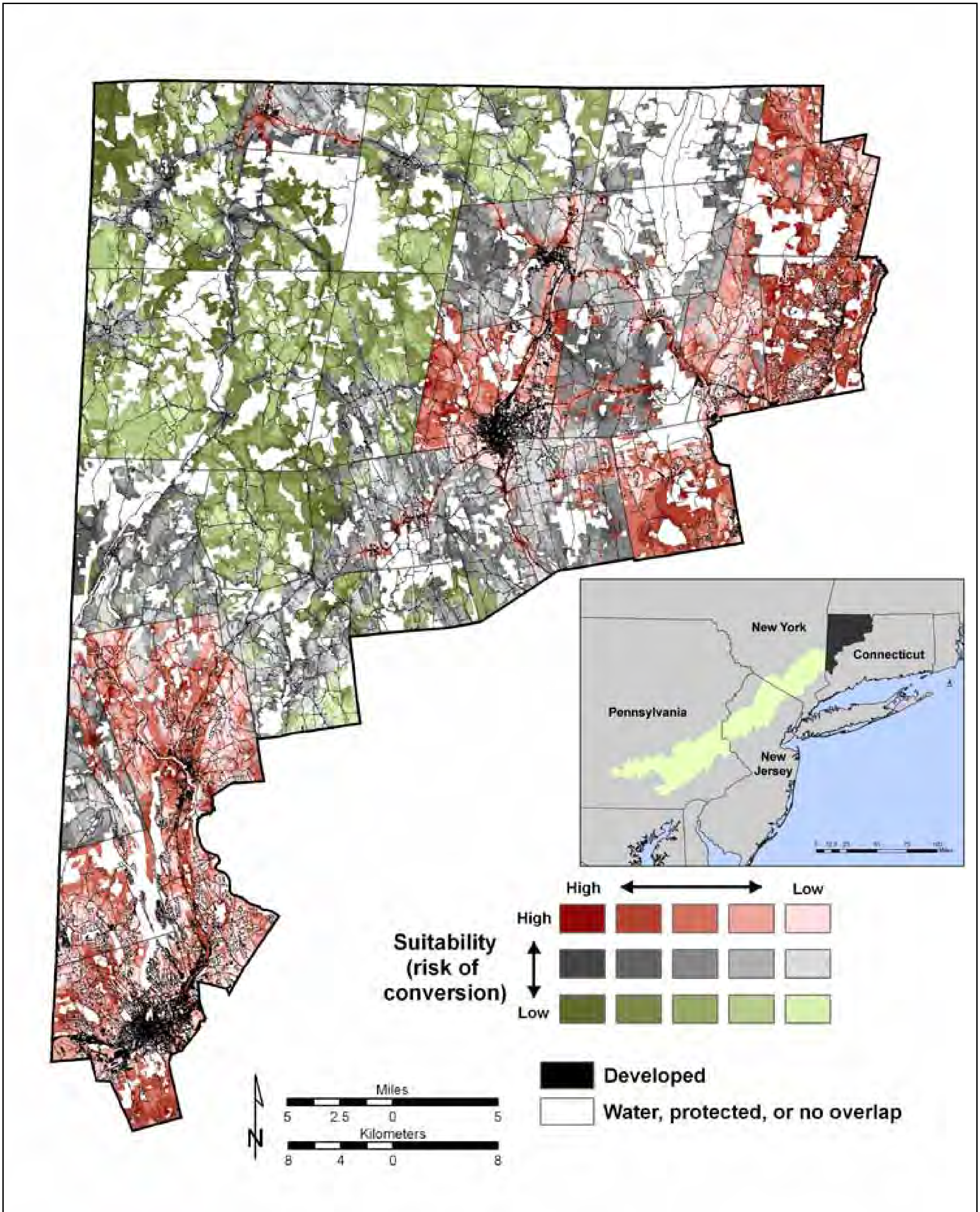


Figure CT-48. ***Suitability map for composite resources.*** *Overlay of high to low conservation values (composite) with high to low suitability (risk of being developed) in the Connecticut Highlands. Land that is already developed is shown in black and protected open space and water are shown in white. Areas of high value and high suitability are shown in deep red.*

Resource condition summary

Nearly three-quarters of the Connecticut-Pennsylvania Highlands region is privately owned. Approximately 25 percent of the bi-State region's high conservation value lands, or 515,000 acres, are at risk of development. Many of these unprotected lands are critical to the sustainability of the specific resource values that people currently enjoy.

In the Connecticut Highlands, forests are the predominant regional characteristic: 67 percent is forested; however, 77 percent of the forestland is privately owned and subject to development. Moreover, these forests protect the watersheds around the Barkhamsted and Nepaug Reservoir systems that supply water to more than 500,000 people in Hartford, Waterbury, and Bristol. If the lands that define the Highlands' landscape quality and contain its resource values are not protected, those lands will become vulnerable to further fragmentation and urbanization.

Through the use of a Conservation Values Assessment and future growth modeling, significant habitats and ecosystems were identified for conservation and protection. This assessment also identified the following existing natural resource conditions in 2008 and projected changes that would occur without additional conservation measures by 2028:

Water

Existing conditions:

- Eighty-six percent of the Connecticut Highlands surface water is transferred out of the Highlands to supply water to more than 500,000 people living in Hartford, Bristol, and Waterbury.
- Forty-seven percent of the Highlands population have private wells and depend on the local ground water for drinking water.
- Surface water quality in upland streams and tributaries is suitable for most uses.
- Ground water provides high quality water to streams and is suitable for most uses.
- Almost one-third of the riparian areas have been cleared of natural vegetation since 1985.

Projected changes:

- High value water protection lands are most at risk for future development. These lands affect surface water, ground water and wetlands.
- As the percent of impervious surface area increases with development, overland runoff increases and base flow decreases, affecting water quantity and quality.

Forests

Existing conditions:

- The Highlands are predominantly forested (67 percent), with mostly oak-hickory and mixed hardwood species.
- There is a fairly even mix of age classes except for a low percentage of young stands less than 40 years old.
- Forests were more fragmented in 2002 than they were in 1985, with 24,300 fewer acres of core forest.

Projected changes:

- As forest fragmentation increases, stand composition and stand structure will become more homogeneous. Also, forest management for economic return, biodiversity, or wildlife habitat is less effective on smaller forest blocks.
- Forestland owners are aging; the trend is towards fewer young forestland owners in the future.

Biological resources

Existing conditions:

- Plant and animal biodiversity (where state and federally listed species were identified) is greatest in the northwestern portion of the Highlands in Salisbury, Canaan, and Sharon, and further east in Colebrook, Barkhamsted, and the intersection of the towns of New Hartford, Canton, and Burlington.

Projected changes:

- Lands that ranked high in biological resources are located mainly in areas that have a low risk of future development.

Farms

Existing conditions:

- Six percent of the land is in actively farmed or grazed.
- The trend is towards smaller farms.
- Since 1995, 13,500 acres have been lost to development.

Projected changes:

- Eight percent of active agricultural land is protected; the rest is subject to future development.
- Like forestland owners, the farmer population is aging, and the trend is towards fewer young people going into farming.

Recreation and culture

Existing conditions:

- Across the Highlands, there is a good distribution of lands that ranked high for their recreational and cultural value, meaning that these areas are accessible to the public and are important for outdoor recreation and cultural pursuits.

Projected changes:

- Like lands that ranked high in biological resources, lands that ranked high for recreation and culture are located mainly in areas that have a low risk of future development.

Human population and housing

(Note: this is not a resource category but an important element of the study.)

Existing conditions:

- Population and housing in the Highlands are growing at much faster rates than in the State as a whole.
- The population is aging. The population over 65 years old is growing much faster than the population under 30 years old.
- The Highlands population represents just 8.4 percent of the entire state.

Projected changes:

- Under the low-constraint or "as is" build-out scenario, regional housing would increase by 135 percent and population by 132 percent by 2028.
- Under the high constraint or "environmentally sensitive" build-out analysis, regional housing would increase by 96 percent and population by 94 percent in the future.

Resource condition summary— Key findings

- Sixty-seven percent of the region is forested; however, 77 percent of the forestland is privately owned and subject to development.
- High value water protection lands are most at risk for future development.
- Under the "as is" build-out scenario, regional housing would increase by 135 percent and population by 132 percent by 2028.

Conservation focal areas and map

Description

Regional conservation focal areas are places in the Connecticut Highlands where three conditions coincided: a large contiguous tract or major land cluster, a high (in the top 40 percent) composite resource value in the Conservation Values Assessment, and absence of permanent protection (Figure CT-49). Feedback from key interested citizens, including governmental and nonprofit organizations was also considered in identifying the conservation focal areas. Input from persons familiar with the project at a local level allowed identification of areas across the region that have a high resource value and are important to the community. Areas identified as conservation focal areas do not automatically qualify for funding under the Highlands Conservation Act (HCA). A separate evaluation and ranking process applies to HCA project proposals (see Section 1. Introduction, Highlands Conservation Act of 2004).

A. Taconic Ridge and Riga Plateau—Encompassing more than 36,000 forested acres at the junction of three states, these uplands are not only critical habitat for wide ranging species, such as neotropical migrants and black bear, but also provide an essential source of nutrient poor, calcium rich water to highly significant lowland fens and calcareous wetlands. The Connecticut portion includes the State's High Point and a prominent section of the Appalachian Trail, with wide views of the surrounding landscape in New York, Massachusetts, and Connecticut. This area ranked highest for its forest and biological resources in the Conservation Values Assessment.

B. Greater Robbins Swamp—Robbins Swamp is Connecticut's largest inland wetland complex with an abundance of State-listed rare and endangered species. This area ranked high in several categories of the Conservation Values Assessment—water, biological, forest, and recreational and cultural resources.

C. Canaan Mountain—Canaan Mountain contains the largest area of interior forest remaining in Northwestern Connecticut. With more than 15,000 acres in permanent conservation, including large areas of state forest and 6,000 private acres protected under a Federal Forest Legacy easement, Canaan Mountain lies at the very heart of the Connecticut Highlands. Like the Taconic Ridge and Riga Plateau, it is hydrologically linked to a series of rare wetland types, including Robbins Swamp (Conservation Focal Area B). This area ranked highest for its forest and biological resources in the Conservation Values Assessment.

D. Mad River Uplands—The Mad River Uplands in Norfolk, Colebrook, and Winchester were swept by floods during the hurricanes of 1955 and today remain among the most unique parts of the region. Predominantly forested, today this area links to other large forest systems and buffers the public water supply for the Town of Winchester. This area ranked highest for its water, forest, and recreational and cultural resources in the Conservation Values Assessment.

E. Sharon-Macedonia Forest Block—The Nature Conservancy and Audubon Society both recognize the Sharon-Macedonia Forest Block as one of the three best remaining areas of intact interior forest in Northwest Connecticut. Along with a significant section of the Appalachian Trail, the area has many publicly conserved lands, including Macedonia Brook State Park and Skiff Mountain, recipient of two Forest Legacy appropriations to conserve over 770 acres on private lands. This area ranked highest for its forest, biological, and recreational and cultural resources in the Conservation Values Assessment.

F. Mohawk-Shepaug River Corridor—The Shepaug River, which rises in two branches on either side of prominent Mohawk Mountain, is a source of high quality drinking water for more than 100,000 people and a highly significant wildlife corridor. This area ranked highest for its water, forest, and recreational and cultural resources in the Conservation Values Assessment.

G. Naromi Brook Watershed—The southwest corner of Sherman, CT, is linked to New York City's Croton Reservoir. It includes some of the best native brook trout habitat remaining in Connecticut's Highlands. This area ranked highest for its water, forest, and biological resources in the Conservation Values Assessment.

H. Vaughn's Neck–Candlewood Lake—Vaughn's Neck is one of the few remaining large, undeveloped tracts on the shores of Candlewood Lake, a vast impoundment owned by Northeast Utilities that extends into portions of five Highlands communities. It is a prominent, forested natural area and regarded by the communities that surround Candlewood Lake as a top conservation priority. This area ranked highest for its forest and recreational and cultural resources in the Conservation Values Assessment.

I. Farmington River Corridor and Tributaries—The portion of the Farmington River Watershed within the Connecticut Highlands is an exceptional regional resource. A 14-mile stretch of the West Branch of the river in Hartland, Barkhamsted, New Hartford, and Canton is a federally designated Wild and Scenic River. The Farmington River Valley is currently the only place in Connecticut with nesting bald eagles. This area ranked highest for its water, forest, biological, and recreational and cultural resources in the Conservation Values Assessment.

Conservation focal areas and map—Key findings

- Conservation focal areas A, B, C, and E each contain large forest areas that are part of or adjacent to federally protected areas such as the Appalachian Trail or Forest Legacy tracts.
- Each conservation focal area ranked high for its forest resource values, and most areas also ranked high for their water, biological, and recreational and cultural resources.

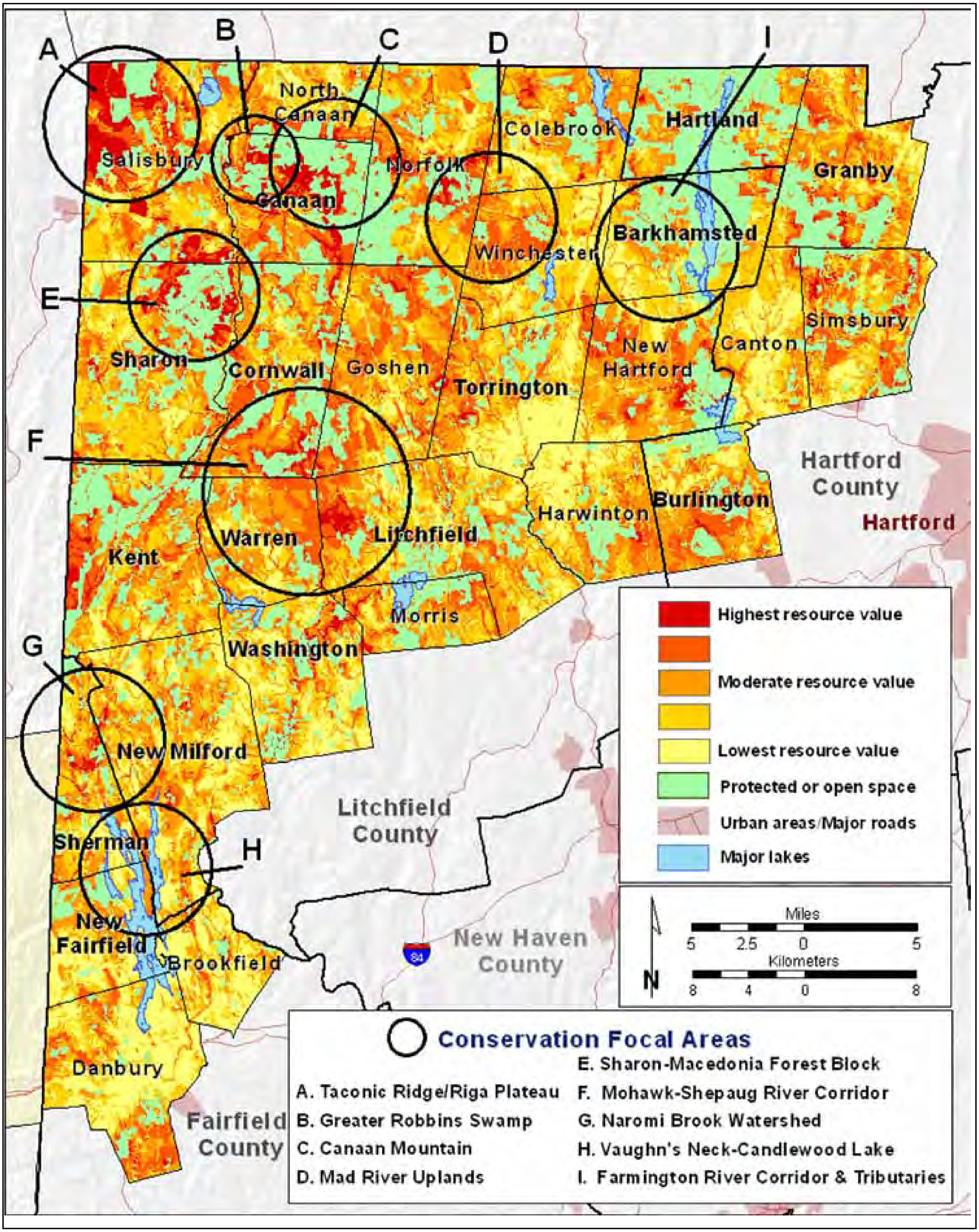


Figure CT-49. Conservation focal areas. *In each of the nine conservation focal areas identified in the Connecticut Highlands region three conditions coincide: large contiguous tract or major land cluster, a high composite resource value in the Conservation Values Assessment, and absence of permanent protection.*

References for Section 2

Alerich, Carol L.; Klevgard, Laurie; Liff, Charles; Miles, Patrick D.; Knight, Barbara; Conkling, Barbara L. 2007. The Forest Inventory and Analysis Database Description and Users Guide, Version 3.0. U.S. Department of Agriculture, Forest Service. Forest Inventory and Analysis National Program. 230 p. www.fia.fs.fed.us/tools-data/docs/pdfs/FIADB_user%20guide_v3-0_P2_06_01_07.pdf (3 February 2010)

Barksdale, H. C.; O'Bryan, Deric; Schneider, W. J. 1966. Effects of drought on water resources in the Northeast: Hydrologic Investigation Atlas 243. U.S. Geological Survey. 1 sheet.

Bellucci, Chris; Beauchene, Mike; Becker, Mary. 2008. Physical, chemical, and biological attributes of moderately developed watersheds within Connecticut. Connecticut Department of Environmental Protection, Bureau of Water Protection and Land Reuse, Planning and Standards Division. 33 p.

Bellucci, Chris; Beauchene, Mike; Becker, Mary. 2009. Physical, chemical, and biological attributes of least disturbed watersheds in Connecticut. Connecticut Department of Environmental Protection, Bureau of Water Protection and Land Reuse, Planning and Standards Division. 33 p.

Butler, Brett J. 2008. Family forest owners of the United States, 2006. Gen. Tech. Rep. NRS-27. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 73 p.

Center for Land Use Education and Research (CLEAR). 2002. Forest fragmentation: Connecticut's changing landscape project. Haddam, CT: University of Connecticut.

Center for Watershed Protection. 2003. Impacts of impervious cover on aquatic systems. Watershed Protection Research Monograph No. 1. Ellicott City, MD. [To create an account from which you can download the monograph free of charge, go to the Center for Watershed Protection Web site] www.cwp.org/categoryblog/100-watershed-research.html (9 August 2010).

CLEAR—See Center for Land Use Education and Research.

Cervione, M. A., Jr.; Mazzafero, D. L.; Melvin, R. L. 1972. Water resources inventory of Connecticut; Part 6, Upper Housatonic River basin, Connecticut. Water Resources Bulletin 21. 84 p.

Colombo, M. J.; Trench, E.C.T. 2002. Trends in surface-water quality in Connecticut. Water-Resources Investigations Report 02-4012. U.S. Department of the Interior, U.S. Geological Survey. 39 p.

Comins, Patrick M. [Letter to Martina Barnes]. 2010 June 18. 2 pages. Located at: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry, Newtown Square, PA.

Connecticut Department of Environmental Protection. 1996. Connecticut water quality standards. Hartford, CT: Bureau of Water Management. 55 p.

Connecticut Department of Environmental Protection. 2002. Connecticut water quality standards. Hartford, CT; Connecticut Department of Environmental Protection. 28 p. + app. www.ct.gov/dep/lib/dep/water/water_quality_standardsl/wqs.pdf. (18 January 2008).

Connecticut Department of Environmental Protection. 2003. Environmental GIS Data for Connecticut 2003 Edition. DEP Bulletin 37. Hartford, CT: Geographic Information Center.

Connecticut Department of Environmental Protection. 2004. Connecticut water quality standards. Hartford, CT: Connecticut Department of Environmental Protection. 8 p. www.ct.gov/dep/lib/dep/water/water_quality_management/305b/2004_factsheet.pdf (1 April 2008).

Connecticut Department of Environmental Protection. 2008. Table 3-3. Connecticut 2008 impaired waters list. In: 2008 State of Connecticut integrated water quality report. Hartford, CT. p. 134–284. http://www.ct.gov/dep/lib/dep/water/water_quality_management/305b/2008_final_ct_integratedwqr.pdf (19 September 2010).

Connecticut Department of Environmental Protection. 2009. Governor Rell: Cornwall and Canaan, Open Space Parcel to be Protected. www.kids.ct.gov/dEP/cwp/view.asp?A=2711&Q=405146 (11 August 2009)

Connecticut Department of Environmental Protection, Bureau of Water Protection and Land Reuse. 2008. Connecticut surficial aquifer potential map. www.ct.gov/dep/cwp/view.asp?a=2701&Q=431436&depNav_GID=1641 (9 August 2010).

Connecticut Department of Environmental Protection, Bureau of Water Protection and Land Reuse. 2010. Connecticut aquifer protection map. http://cteco.uconn.edu/map_catalog/maps/state/stateAPA.pdf (9 August 2010).

Connecticut Department of Public Utilities – Department of Public Utility Control. 2009. Water, Annual reports, Annual production information available by year and by water utility company. www.dpuc.state.ct.us/dpucinfo.nsf/$FormWaterView?OpenForm (17 September 2009)

Driscoll, C. T.; Lawrence, B. B.; Bulger, A. J.; Butler, T. J.; Cronan, C. S.; Eagar, C.; Lamber, K. F.; Likens, G. E.; Stoddard, J. L.; Weathers, K. C. 2001. Acid rain revisited: advances in scientific understanding since the passage of the 1970 and 1990 Clean Air Act amendments. Science Links Publication, vol. 1, no. 1. Hanover, NH: Hubbard Brook Research Foundation. 22 p. www.hubbardbrookfoundation.org/filemanager/filedownload/phpoYit2t/Acid_Rain_Revisited.pdf. (26 August 2009)

Fenneman, N. M. 1938. Physiography of Eastern United States. New York, NY: McGraw-Hill Book Co. 714 p.

GeoLytics. 2004. Census CD for 1970, 1980, 1990, 2000. East Brunswick, NJ: GeoLytics, Inc. Product available through Sterling Memorial Library, Yale University, New Haven, CT. www.geolytics.com/USCensus,Census-1970-1980-1990,Categories.asp (23 September 2009)

Grady, S. J. 1994. Effects of land use on quality of water in stratified-drift aquifers in Connecticut—Chapter B, Analysis of nonpoint-source ground-water contamination in relation to land use: Water-Supply Paper 2381. U.S. Geological Survey. 56 p.

Grady, S. J.; Mullaney, J. R. 1998. Natural and human factors affecting shallow water quality in surficial aquifers in the Connecticut, Housatonic, and Thames River Basins. Water-Resources Investigations Report 98-4042. U.S. Department of the Interior, U.S. Geological Survey. 81 p.

Healy, D. F. 1990.Connecticut water supply and use, with sections on "public-supply water use" by H. D. Sternberg and "water management" by C. J. Hughes. In: Carr, J. E.; Chase, E. B.; Paulson, R. W.; Moody, D. W., compilers. National Water Summary 1987—Hydrologic events and water supply and use. Water-Supply Paper 2350. U.S. Department of the Interior, U.S. Geological Survey; p. 193-200.

Heath, R. C. 1980. Basic elements of ground-water hydrology with reference to North Carolina. Water-Resources Investigations Open-File Report 80-44. Raleigh, NC: U.S. Department of the Interior, U.S. Geological Survey, North Carolina District. 93 p.

Heath, R. C. 1983. Basic ground-water hydrology. Water-Supply Paper 2220. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 84 p.

Horner, R. R.; Booth, D. B.; Azous, A.; May, C. W. 1997. Watershed determinants of ecosystem functioning. In: Roessner, C., ed. Effects of watershed development and management on aquatic ecosystems. New York, NY: American Society of Civil Engineers: 251-274.

Housatonic Valley Association. The Litchfield Hills Greenprint Project. 2009. www.hvatoday.org/show.cfm?page=land/greenprint.htm&folder=land (11 August 2009).

Kasprak, John. 2006. Radon in drinking water. OLR Research Report 2006-R-0655. State of Connecticut, General Assembly, Office of Legislative Research. www.cga.ct.gov/2006/rpt/2006-R-0655.htm. (4 February 2010).

Krist, F.; Sapio, F.; Tkacz, B. 2007. Mapping risk from forest insects and diseases. FHTET 2007-06. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Health Protection, Forest Health Technology Enterprise Team, 115 p.

May, C.W.; Horner, R.R.; Karr, J.R.; Mar, B.W.; Welch, E.B. 1997. Effects of urbanization on small streams in the Puget Sound Lowland Ecoregion. Watershed Protection Techniques 2: 483–493.

Michaels, Joseph A.; Neville, L. Robert; Edelman, David; Sullivan, Tim; DiCola, Leslie A. 1992. New York – New Jersey Highlands Regional Study. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 130 p.

Mullaney, John R. 2004. Water use, ground-water recharge and availability, and quality of water in the Greenwich area, Fairfield County, Connecticut and Westchester County, New York, 2000-2002. Water-Resources Investigations Report 03-4300. East Hartford, CT: U.S. Department of the Interior, U.S. Geological Survey. 64 p. http://water.usgs.gov/pubs/wri/wri034300/ (27 August 2009).

Mullaney, J. R.; Schwarz, G. E.; Trench, E.C.T. 2002. Estimation of nitrogen yields and loads from basins draining to Long Island Sound. 1988-98. Water-Resources Investigations Report 02-4044. U.S. Department of the Interior, U.S. Geological Survey. 84 p.

Nichols, G. E. 1913. The vegetation of Connecticut. II. Virgin forests. An old-growth hemlock stand. Connecticut Arboretum Bulletin No. 9: 29-32.

Northeast Regional Climate Center. 2006. Historical listing of periods of severe or extreme drought, through March 2006. www.nrcc.cornell.edu/drought/CT_drought_periods.html (11 August 2008)

Phelps, Marcus G.; Hoppe, Martina C., compilers. 2002. New York – New Jersey Highlands Regional Study: 2002 Update. NA-TP-02-03. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 209 p.

Pirani, Robert; Moos, Emily. 2007. The Connecticut Highlands Part I: Public Input Technical Report. New York, NY: Regional Plan Association. Unpublished draft supplied by author. 7 p.

Rodgers, John. 1985. Bedrock geological map of Connecticut. Connecticut Natural Resources Atlas Series. Hartford: Connecticut Geological and Natural History Survey. http://ngmdb.usgs.gov/Prodesc/proddesc_54245.htm (24 November 2009).

Rosenshein, J. S. 1988. Region 18, Alluvial valleys. In: Back, William; Rosenshein, J. S.; Seaber, P. R., eds. Hydrogeology. Boulder, CO: Geological Society of America, Decade of North America Geology, v. O-2, p. 165-175.

Schueler, T. 1994. The importance of imperviousness. Watershed Protection Techniques 1: 100–111.

Solley, W. B. 1998. Estimates of water use in the western United States in 1990, and water-use trends, 1960–90. Open-File Report 97–176. U.S. Department of the Interior, U.S. Geological Survey. 15 p.

Starn, J. J.; Stone, J. R. 2004. Simulation of ground-water flow to assess geohydrologic factors and their effect on source-water areas for bedrock wells in Connecticut. Scientific Investigations Report 2004-5132. Reston,VA: U.S. Department of the Interior, U.S. Geological Survey. 86 p. http:// pubs.usgs.gov/sir/2004/5132/sir2004-5132.pdf (28 September 2009).

State of Connecticut. [N.d.]. Conservation and Development Policies Plan for Connecticut 2005-2010. Hartford, CT: Office of Planning and Management, Intergovernmental Policy Division.

Thomas, M. A.; McHone, N. W. 1997. Indoor radon potential map of Connecticut. Hartford, CT: Connecticut Department of Environmental Protection, Natural Resources Center. 2 sheets. www.ct.gov/dep/lib/dep/geology/radon/RadonPotential.pdf (18 January 2008).

U.S. Census Bureau. 2005. American FactFinder. U.S. Department of Commerce. http://factfinder.census.gov/home/saff/ (8 February 2008).

U.S. Department of Agriculture. 1999. 1997 Census of Agriculture, Connecticut State and County Data. Volume 1, Geographic Area Series, Part 7. March 1999.

U.S. Department of Agriculture. 2004. 2002 Census of Agriculture, Connecticut State and County Data. Volume 1, Geographic Area Series, Part 7. AC-02-A-7. June 2004.

U.S. Department of Agriculture. 2005. Soil Data Mart. Tolland, CT: Natural Resources Conservation Service. http://soildatamart.nrcs.usda.gov/ (28 September 2009)

U.S. Environmental Protection Agency. 1999. Index of Watershed Indicators. National Watershed Characterization. Washington DC: U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds. www.unl.edu/nac/atlas/Map_Html/Clean_Water/National/EPA_IWI-1999/National_water_quality.htm (28 August 2009).

U.S. Environmental Protection Agency. 2000. Ambient water quality criteria recommendations—Information supporting the development of State and Tribal nutrient criteria; rivers and streams in nutrient ecoregion XIV. EPA-822-B00-022. Washington, DC: U.S. Environmental Protection Agency, Office of Water 4304. 25 p. + app. www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_14.pdf (19 September 2010).

U.S. Environmental Protection Agency. 2001a. Ambient water quality criteria recommendations—Information supporting the development of State and Tribal nutrient criteria; rivers and streams in nutrient ecoregion VIII. EPA-822-B-01-015. Washington, DC: U.S. Environmental Protection Agency, Office of Water. 142 p.

U.S. Environmental Protection Agency. 2001b. Our built and natural environments: a technical review of the interactions between land use, transportation, and environmental quality. EPA-231-R-01-002. Washington, DC: U.S. Environmental Protection Agency; Development, Community, and Environment Division (1808). 93 p.

U.S. Fish and Wildlife Service. 1998. National Wetlands Inventory. Arlington, VA: U.S. Department of the Interior, U.S. Fish and Wildlife Service. http://wetlandsfws.er.usgs.gov/imf/sites/NWI_CONUS/CONUS_metadata/status_map.htm (25 September 2009).

University of Connecticut. 1982. 1982 Digital Elevation Model. Storrs, CT: Map and Geographic Information Center. http://magic.lib.uconn.edu/cgi-bin/MAGIC_DBsearch2.pl?Geography=37811&Loc=0001 (24 September 2009)

University of Connecticut. 2005a. Cooperative Extension Center. Haddam, CT. www.canr.uconn.edu/ces/forest/steward.htm (28 September 2009).

University of Connecticut. 2005b. Laboratory for Earth Resources Information Systems. Storrs, CT. http://clear.uconn.edu/LERIS/index.html (28 September 2009).

Van der Wilt, Margaret; Meredith, Andrew; Menard, Stephen. 2003. The relationship between impervious surface coverage and water quality. In : Proceedings of the 3rd Biennial Coastal GeoTools Conference. 2003 January 6–9. Charleston, SC. [CD-ROM] NOAA/CSC/20312-CD.

Wang, L.; Kanehl, P. 2003. Influences of watershed urbanization and instream habitat on macroinvertebrates in cold water streams. Journal of the American Water Resources Association 39(5): 1181–1196.

Ward, Jeffrey S. 2005. Stand dynamics in Connecticut forests: the new series plots (1959-2000). Bulletin 995. New Haven, CT: The Connecticut Agricultural Experiment Station. 35 p.

Section 3. Pennsylvania Highlands

The Highlands of Pennsylvania cover 1,382,693 acres, comprising 174 municipalities in 10 counties—Berks, Bucks, Chester, Dauphin, Lancaster, Lebanon, Lehigh, Montgomery, Northampton, and York counties cover the Highlands (Appendix G). The Highlands are in the basins of the Susquehanna, Schuylkill, and Delaware Rivers (Figure PA-1).

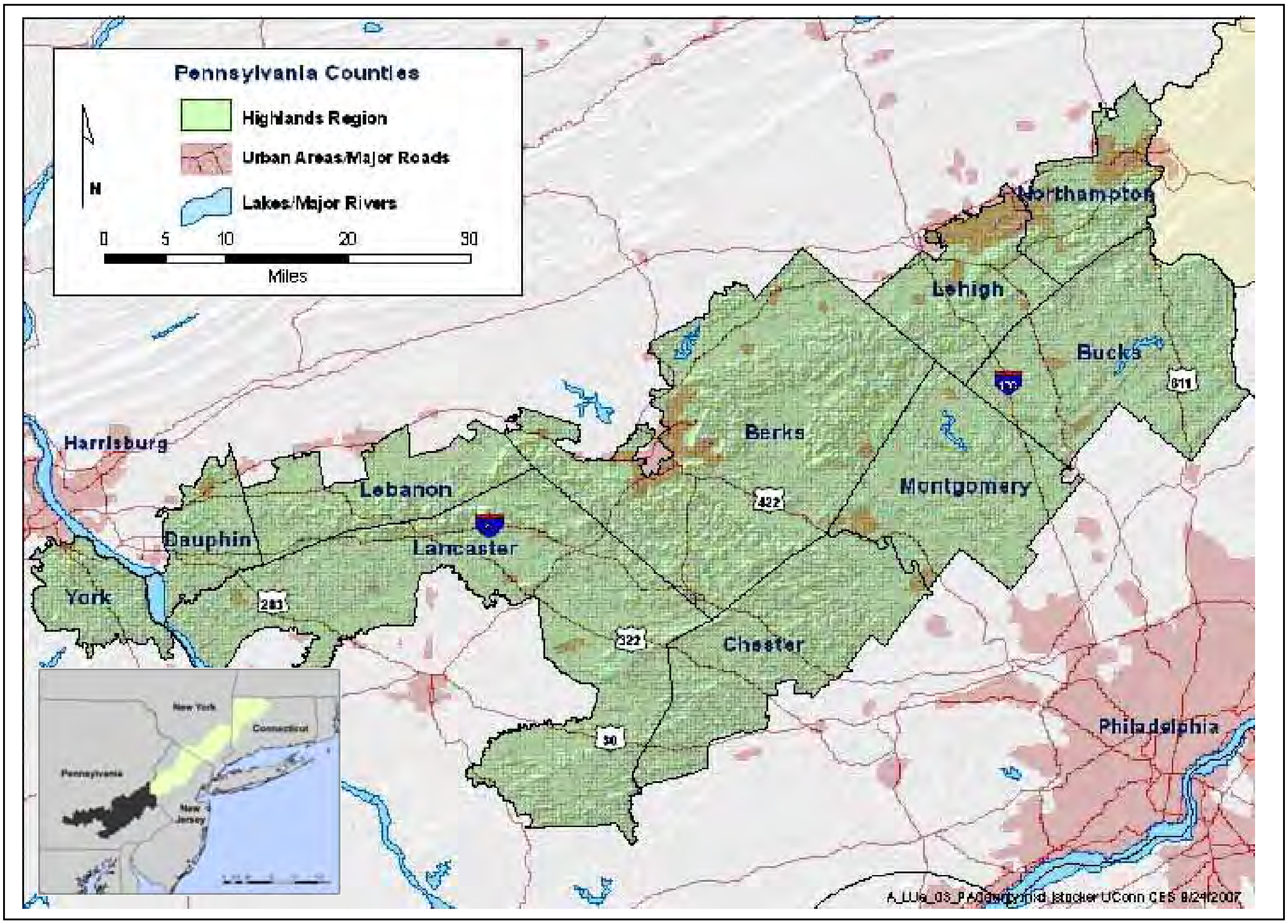


Figure PA-1. Pennsylvania Highlands. *Ten counties are included in the Pennsylvania Highlands.*

Part 1. Conservation Values Assessment

The purpose of the resource assessment was to identify areas of high conservation value in the Pennsylvania Highlands using a digital Geographic Information System (GIS). The GIS-based assessment of available spatial data used scientific analysis and expert opinion to identify and weight conservation values. A community input process involved the interested public in a separate identification of important conservation areas.

The Conservation Values Assessment for Pennsylvania was completed under the direction of J. C. Finley and Wayne L. Myers of the School of Forest Resources, Pennsylvania State University. Professor Myers and Clare Billett and Diane Rosencrance of the Natural Lands Trust (NLT) organized a series of meetings at which experts evaluated the data. Natural Lands Trust performed all GIS analyses with the financial assistance of the Pennsylvania Department of Conservation and Natural Resources (DCNR). Several data sets, particularly those related to biological resources, were provided from a peer-reviewed assessment done previously by NLT for the DCNR. Bret Magdasy, GIS Staff Scientist with the Appalachian Mountain Club (AMC), compiled data for the assessment of recreational and cultural resources. These data were part of a detailed, complementary analysis that identified hubs and corridors including a greenway map of the Pennsylvania Highlands.

Resource assessment

The Resource Assessment for Pennsylvania studied the same five categories of resources as were studied in the Highlands Regional Study: New York-New Jersey Update (Phelps and Hoppe 2002), and for Connecticut (Section 2).

- Water resources are streams, lakes, and other water bodies, as well as underground sources of water.
- Forests are a renewable source of fiber and other woodland products. Forests are habitat for most of the plant and animal communities of greatest concern. Forests protect the quality and dependability of water resources, and they contribute immensely to air quality.
- Biological resources, in the context of this study, are native flora and fauna possessing importance because of their rarity or the richness and diversity of their communities. Conservation values are related to habitat suitability, among other factors.
- Agriculture is both a resource and a land use. Agriculture provides food, open space, and economic benefits to the Highlands and to the larger society.
- Recreational and cultural resources are sites, lands, or waters available for public use. Scenic and open space resources that may be in private ownership are included.

For each of these resources the study team collected existing spatial data created by Federal, State, county, regional, and nongovernmental organizations. Pennsylvania's DCNR and Department of Environmental Protection (DEP) provided spatial information regarding streams, geological units with groundwater potential, land cover, threatened and endangered species, and other factors.

The evaluation of resources in the Pennsylvania Highlands varied from the study format and content previously used for New York and New Jersey, when better data, interpretations, or public input were available. Resource data was available mostly from State and Federal governments in a GIS format. The Pennsylvania DCNR had been working with the NLT on an open-space planning study that involved collecting and scientifically evaluating natural resource information to identify the most suitable areas for plant and animal habitat. These data layers, as well as layers regarding other resource categories, were evaluated once more by a team of experts for inclusion in the Highlands study.

The Pennsylvania resource study team included resource specialists from State and nongovernmental institutions. Professor Wayne Myers of the Penn State University School of Forest Resources coordinated the GIS-based conservation values assessment for Pennsylvania. The NLT conducted the GIS operations. Data layers were evaluated for accuracy and utility, and then given weights by a panel of experts and interested participants during a series of meetings held at the offices of the Pennsylvania Bureau of Topographic and Geologic Survey. The team elected to rank the results of their evaluation on a scale of 10 to 0, high to low, for the purpose of achieving greater discrimination compared to the range of weights used for the New York–New Jersey Highlands study, which was 5 to 0. Therefore, to compare the assessments, divide the Pennsylvania scores by 2.

Water resources

The water model had 11 layers with a maximum possible score of 89. Aquifer recharge areas were mapped as bedrock units and ranked according to average yield. The susceptibility of aquifers to pollution was evaluated based on the U.S. EPA's DRASTIC model (Aller and others 1987). Groundwater protection zones and surface water protection zones were derived from Pennsylvania DEP determinations (Reese and Lee 1999).

Riparian buffers were defined as 150 feet along both sides of a stream; ranking was based on an evaluation of buffer vegetation quality done previously by Natural Lands Trust. Slopes were derived from the digital elevation model and classified as greater than 25 percent and 15 to 25 percent. The 100-year floodplain was based on Federal Emergency Management Agency (FEMA) data. Wetlands were identified and ranked according to a previous analysis by Natural Lands Trust. Hydric soils were added to cover wetlands not found by the wetland inventory. Exceptional value streams and their 150 foot buffers were identified by the DEP.

Watersheds ranked by Natural Lands Trust according to the percent of their area in forest were included. Impervious areas, cells with more than 25 percent impervious cover, were used as a mask on the assumption that imperviousness eliminated any potential value for water resources. Stream segments rated non-attaining by the Pennsylvania DEP in its 2005 reports pursuant to the Clean Water Act (Sections 303(d) and 305(b), P.L. 92-500) were likewise treated as having no conservation value.

Forest resources

The forest model had three layers with a maximum possible score of 30. Soil classes were ranked according to their silvicultural potential using the data in county soil surveys. Forest cover was identified from the 2000 National Land Cover Data (NLCD) set. Blocks of interior forest were identified and ranked according to size.

Biological resources

The biological resources model was the most complex, with 14 layers and a maximum possible score of 100. Habitat potential was available from a peer-reviewed evaluation completed by NLT in 2004. Habitat potential in the Highlands was mapped for mammals, fish, birds, and terrestrial or aquatic "herps" (reptiles and amphibians). Important bird areas and important mammal areas were identified by the Audubon Society. Generalized locations of rare species came from the Pennsylvania Natural Heritage Project. The NLT's habitat analysis informed the DCNR's Green Infrastructure project by identifying "hub areas"—places with superior habitat value. These were included in the model. Interior forest blocks and unfragmented blocks of natural vegetation were identified and ranked. Existing parks and preserves with buffers were mapped. The Nature Conservancy's identification of "matrix" habitats was included. Finally, the model included areas enrolled in the Conservation Reserve Enhancement Program (CREP), a Federal program administered by the USDA Farm Services Agency to set aside and improve the conservation value of eligible farmland.

Agricultural resources

The agriculture model had four layers with a maximum possible score of 30. Prime agricultural soils were included, derived from county soil surveys. Cultivated fields and hay or pasture lands were mapped in 1994 and 2000. Values were assigned to these data according to which cover type appeared and when. Agricultural Security Areas, which are established through the mutual actions of farmers, municipalities, and the Pennsylvania Department of Agriculture, were identified for the model. Farmland protected from change through easements or other arrangements were identified, and buffers were mapped around them (Pennsylvania Department of Agriculture 2005a).

Recreational and cultural resources

The recreational and cultural model had five layers with a maximum possible score of 46. Recreational trails and buffers were mapped. Visible ridge tops were mapped and ranked according to land-cover type. Historic, cultural, or recreational sites were identified as points and assigned buffer zones. Recreational waters and shorelines with their buffer zones were identified. This resource category included public parks, forests, and hunting lands. Privately owned land subject to conservation restrictions was included where spatial data could be obtained. Not all land under easements or other development restrictions was identified. These data are dispersed, not always in digital form, and their use is frequently restricted.

Conservation Values Assessment maps

The Conservation Values Assessment involved creating separate maps for each of five resource categories: water, forest, biological resources, agriculture, and recreational and cultural resources (Figures PA-2 through PA-6). These categories were then combined in a composite map to show the distribution of relative conservation values across the region (Figure PA-7). Each of the five resource categories counted for 20 percent of the composite Conservation Values Assessment. Table PA-1 summarizes the data sources and weights applied to individual layers of the Pennsylvania Highlands conservation values assessment.

Table PA-1. Data sources and weights. *Data sources and weights applied to individual layers of the Pennsylvania Highlands conservation values assessment.*

Data Layer	Weight	Remarks
Aquifer Recharge Areas (bedrock), ranked units ranked by yield	10 to 2	Reese 2005, Schreffler 2005
Aquifer Recharge Areas ranked according to pollution susceptibility	10 to 0	DRASTIC analysis (Aller and others 1987)
Aquifer (wellhead) Protection Zone	10	Kelly 2005, Zone II only
Surface Water Supply Protection Zone	10	Kelly 2005, Zone A only
Riparian Zone (with 150-foot buffer), ranked	10 to 0	Rosencrance 2005, riparian analysis, rank by buffer vegetation quality
Steep Slopes > 25 percent 15 – 25 percent	 10 4	Rosencrance 2005
Floodplain (100 year, not urbanized)	5	Rosencrance 2005
Wetlands, ranked	10 to 0	Rosencrance 2005
Hydric soils	2	Rosencrance 2005
Watersheds ranked by percent of area forested	10 to 0	Rosencrance 2005
Exceptional Value Streams (with 150-foot buffer)	2	Kelly 2005
Impervious surface (> 25 percent impervious surfaces)	Mask: sets cell to 0	Rosencrance 2005
Stream quality below state threshold for listed uses ("non-attaining reaches" of streams)	Mask: sets cell to 0	Kelly 2005, based on Clean Water Act: Sec. 305(b) Sec. 303(d).
Stream quality impaired by acid mine drainage (affected reaches of streams)	Mask: sets cell to 0	Kelly 2005
Maximum theoretical score	**89**	
Soils ranked by silvicultural potential	10 to 0	Rosencrance 2005, analysis by species and soil type
Forested Landcover	10	Rosencrance 2005, analysis of 2000 MRLC data (Multi-Resolution Land Characteristics) Consortium. MRLC developed the National Land Cover Dataset (NLCD) for 1992 and 2001, which is used throughout this report).
Interior Forest Blocks >5,000 acres >1,000 to 5,000 acres >500 to 1,000 acres >100 to 500 acres 25 to 100 acres	 10 8 6 4 2	Rosencrance 2005, analysis of 2000 MRLC data
Maximum theoretical score	**30**	
Mammals Habitat Conservation Value, ranked	10 to 0	Rosencrance 2005, analysis by species with cumulative taxa results
Fish Habitat Conservation Value, ranked	10 to 0	Rosencrance 2005, analysis by species with cumulative taxa results

Continued

Table PA-1. Data sources and weights. (Continued)

Data Layer	Weight	Remarks
Birds Habitat Conservation Value, ranked	10 to 0	Rosencrance 2005, analysis by species with cumulative taxa results
Aquatic Herps Habitat Conservation Value, ranked	7 to 0	Rosencrance 2005, analysis by species with cumulative taxa results
Terrestrial Herps Habitat Conservation Value, ranked	7 to 0	Rosencrance 2005, analysis by species with cumulative taxa results
Important Bird Areas, Core Buffer	5 3	Audubon Pennsylvania 2005
Important Mammal Areas	4	Audubon Pennsylvania 2005.
Plant and Animal Rarity, ranked	10 to 2	Rosencrance 2005, PA Natural Heritage Program 2005, eco-regionally ranked by Natural Lands Trust.
Green Infrastructure Hubs, ranked	2 to 0	Rosencrance 2005.
Interior Forest Landscape Blocks, ranked	10 to 0	Rosencrance 2005, analysis and ranking of 1992-1994 MRLC data.
Unfragmented Natural Landscape Blocks, ranked	10 to 0	Rosencrance 2005, analysis and ranking of 1992-1994 MRLC data.
Parks and Preserves with Buffers, ranked by land cover type	10 to 0	Magdasy 2005, includes lands with conservation easements.
The Nature Conservancy's Matrix Habitat sites	2	Walsh, Mary. 2005. The Nature Conservancy and Pennsylvania Natural Heritage Program. Unpublished data provided specifically for Conservation Values Assessment. Harrisburg, PA: The Nature Conservancy.
Conservation Reserve Enhancement Protection Areas (CREP, leased conservation areas)	3	USDA Natural Resources Conservation Service 2005.
Maximum theoretical score	**100**	
Prime Agricultural Soils	10	USDA Natural Resources Conservation Service 2005.
Agricultural crops in both 1994 and 2000 Agricultural crops in either 1994 or 2000 Hay or pasture in both 1994 and 2000 Hay or pasture in either 1994 or 2000	10 5 3 0	Rosencrance 2005, analysis of 1994-2000 MRLC data.
Preserved farms (agricultural easement) Buffer to 500 feet Buffer 500 to 1,000 feet	5 4 3	PA Department of Agriculture 2005.
Agricultural Security Area	5	PA Department of Agriculture 2005.
Maximum theoretical score	**30**	
Recreational Trails Buffer to 150 feet Buffer from 150 to 300 feet	10 8 6	Magdasy 2005.
Visible undeveloped Ridgetops and Hilltops With natural vegetation With other vegetation	 10 5	Magdasy 2005.

Continued

Data Layer	Weight	Remarks

Parkland dedicated to public access and use
Land protected by conservation easement
  Buffer to 1,000 feet
  Buffer from 1,000 to 2,000 feet
  Buffer from 2,000 to 3,000
	10
	8
	6
	4
	2
		Kripas 2005, plus information from Highlands counties.

Historical or Cultural site with 150-foot buffer	6	Kripas 2005, most features are points

Lake, reservoir with public access
  Buffer to 300 feet
Canoe-able river or stream
  Buffer to 150 feet
  Buffer from 150 to 300 feet
Trout production stream
  Buffer to 150 feet
Trout maintenance stream
  Buffer to 150 feet
Other lakes
  Buffer to 300 feet
Cold water fishery
Warm water fishery
	10
	8
	10
	8
	6
	8
	6
	6
	4
	6
	4
	5
	5
		Magdasy 2005.

Maximum theoretical score	**46**	

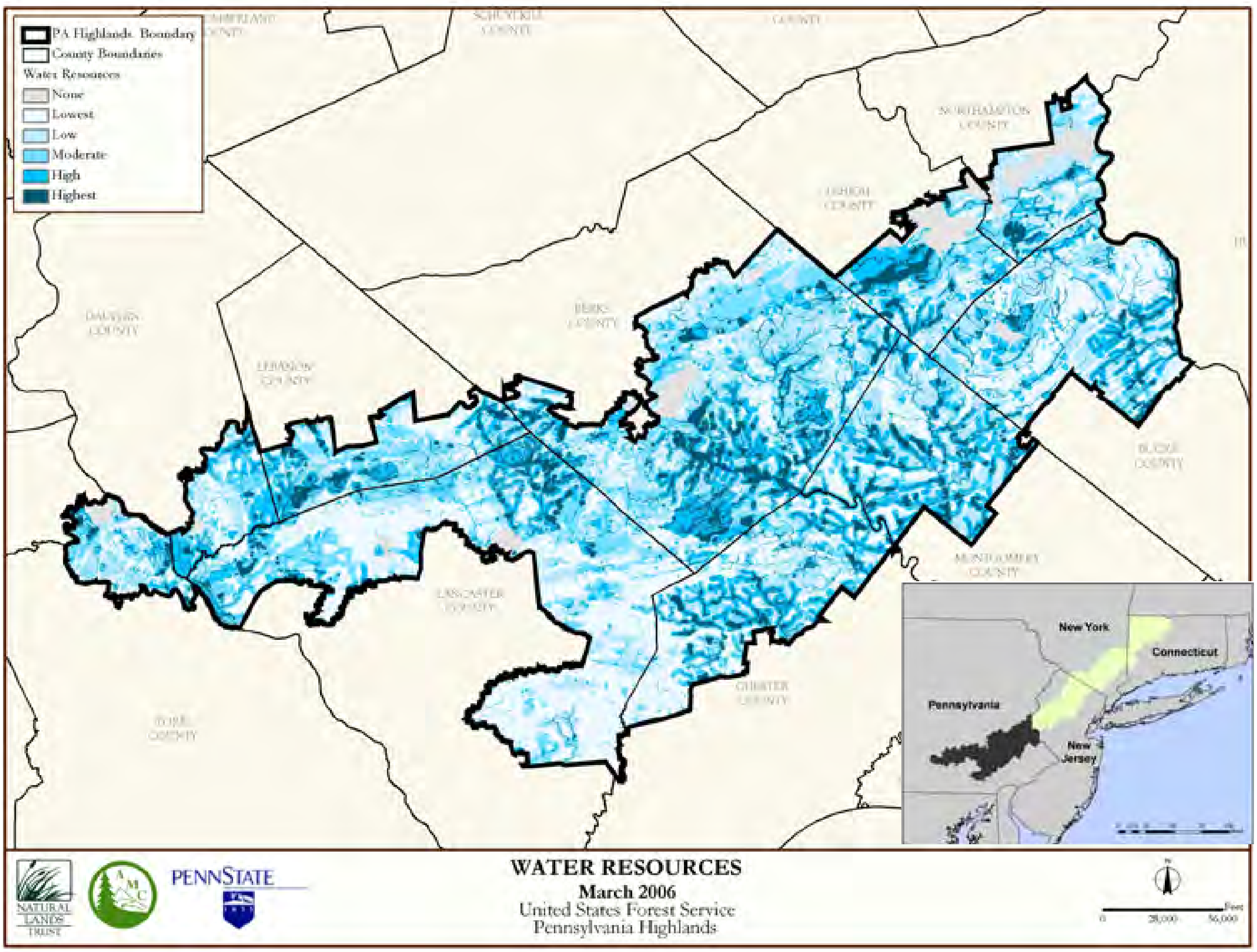


Figure PA-2. Water resource values. The Conservation Values Assessment identified areas in the Pennsylvania Highlands that have high conservation value for high quality water.

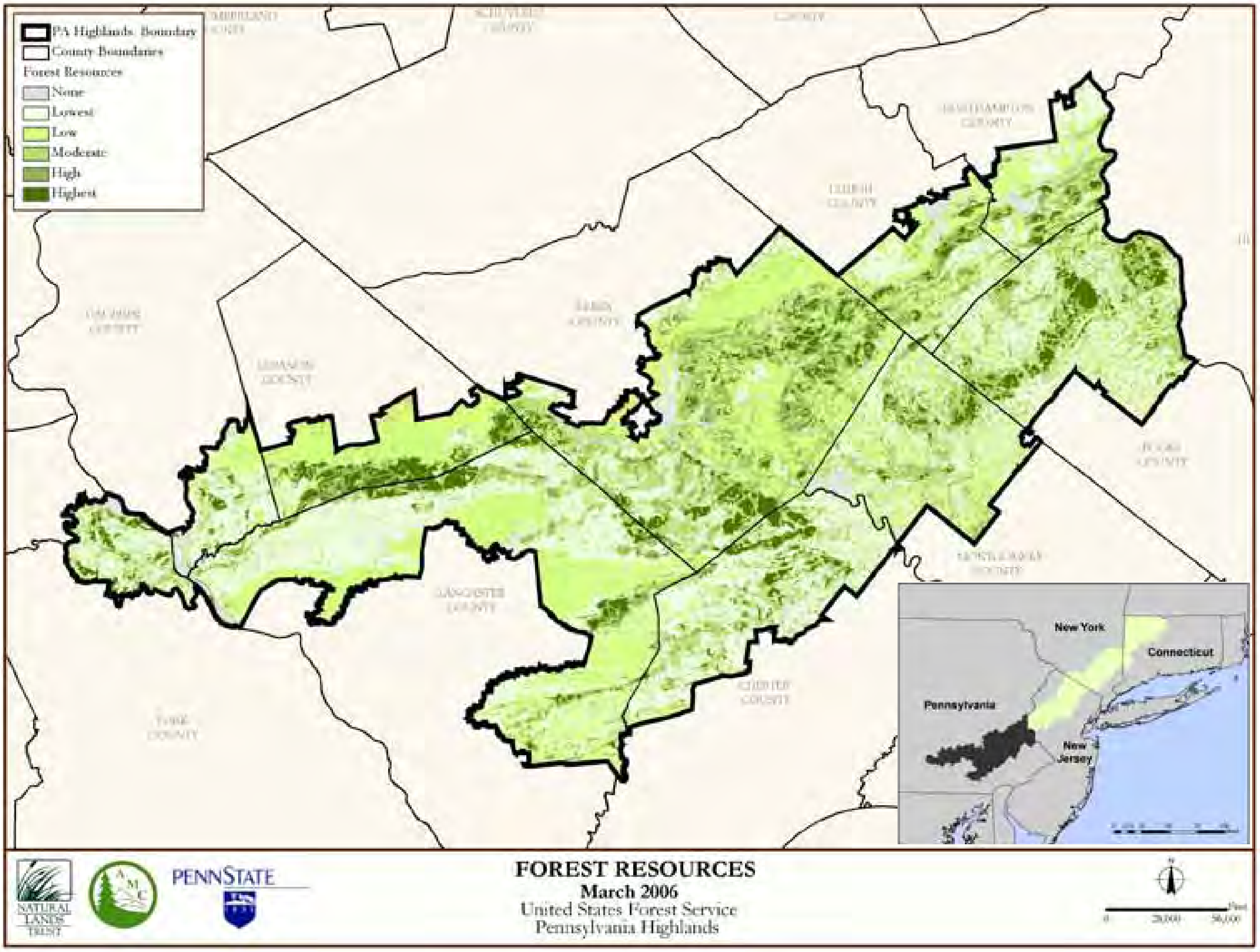


Figure PA-3. Forest resource values. *The Conservation Values Assessment identified areas in the Pennsylvania Highlands that have high conservation value for productive forest resources.*

Conservation Values Assessment—Key findings

- Water resources—Water resources in the Pennsylvania Highlands are spread throughout the region, with the highest values typically near the perennial streams. Some of the most concentrated and highest value areas are located near the larger metropolitan areas. The most concentrated include the Swabia and Little Lehigh watersheds south of Allentown, the Schuylkill River corridor south of Reading, and the Conewago Creek watershed south of Hershey.
- Forest resources—Three areas are notable for high forest resource values in the Pennsylvania Highlands. In the eastern portion of the region the largest sector is concentrated near Nockamixon State Forest. In the center of the region the largest section is located in French Creek State Park. In the western portion of the region the forest resources are concentrated near the border of Lebanon and Lancaster counties surrounding the State Game Lands.

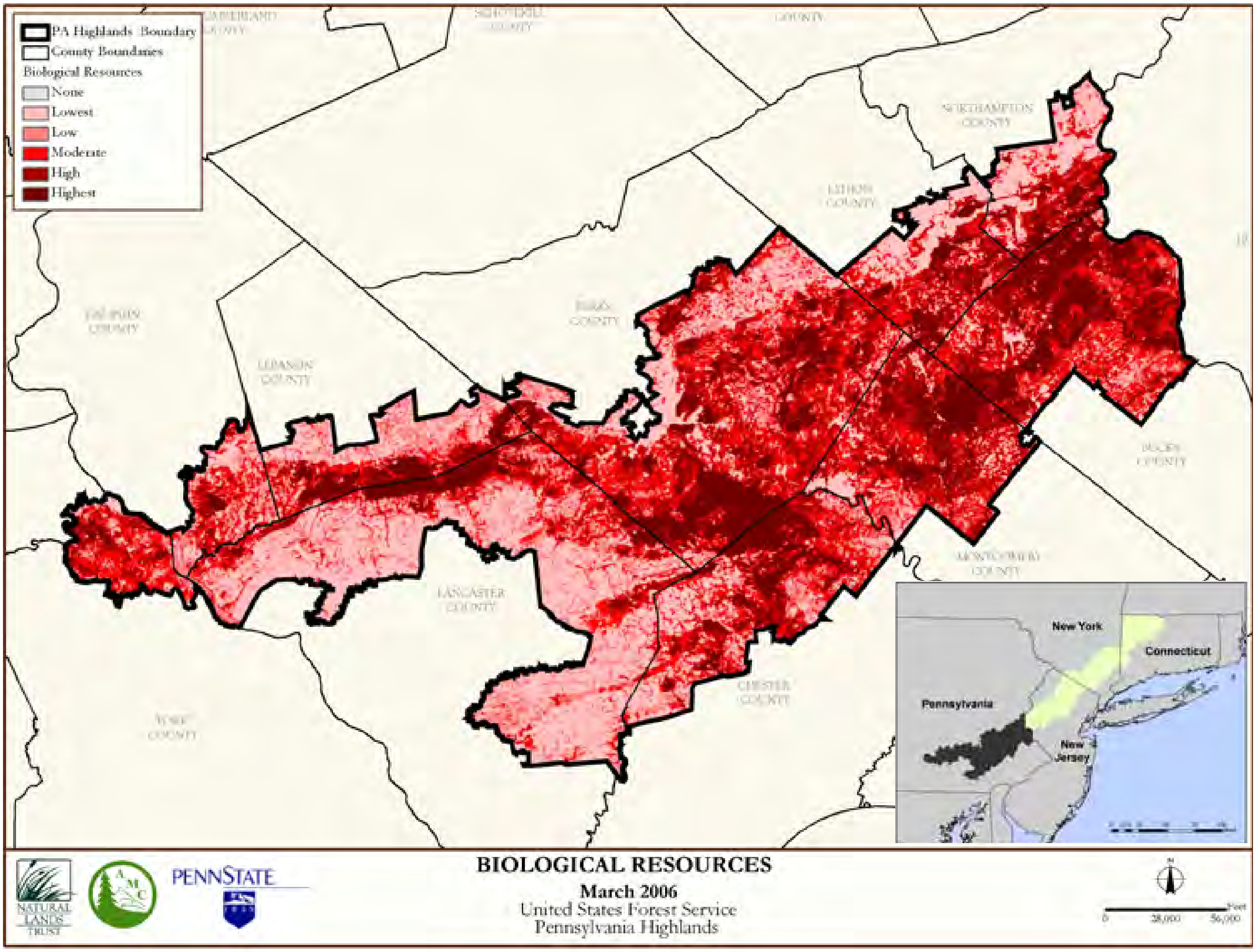


Figure PA-4. Biological resource values. *The Conservation Values Assessment identified areas in the Pennsylvania Highlands that have high conservation value for habitat that supports state or federally listed threatened and endangered species.*

- Biological resources—The biological resources are spread throughout the region with the largest concentration farthest from population centers and traditional agricultural strongholds. As for the forest and recreation resources; two major regions with large areas of high value biological resources are near the State game lands on the Lebanon and Lancaster County boundary and French Creek State Park area in Berks County. The Northeastern corners of Montgomery and Bucks counties also have large areas with high value biological resources.

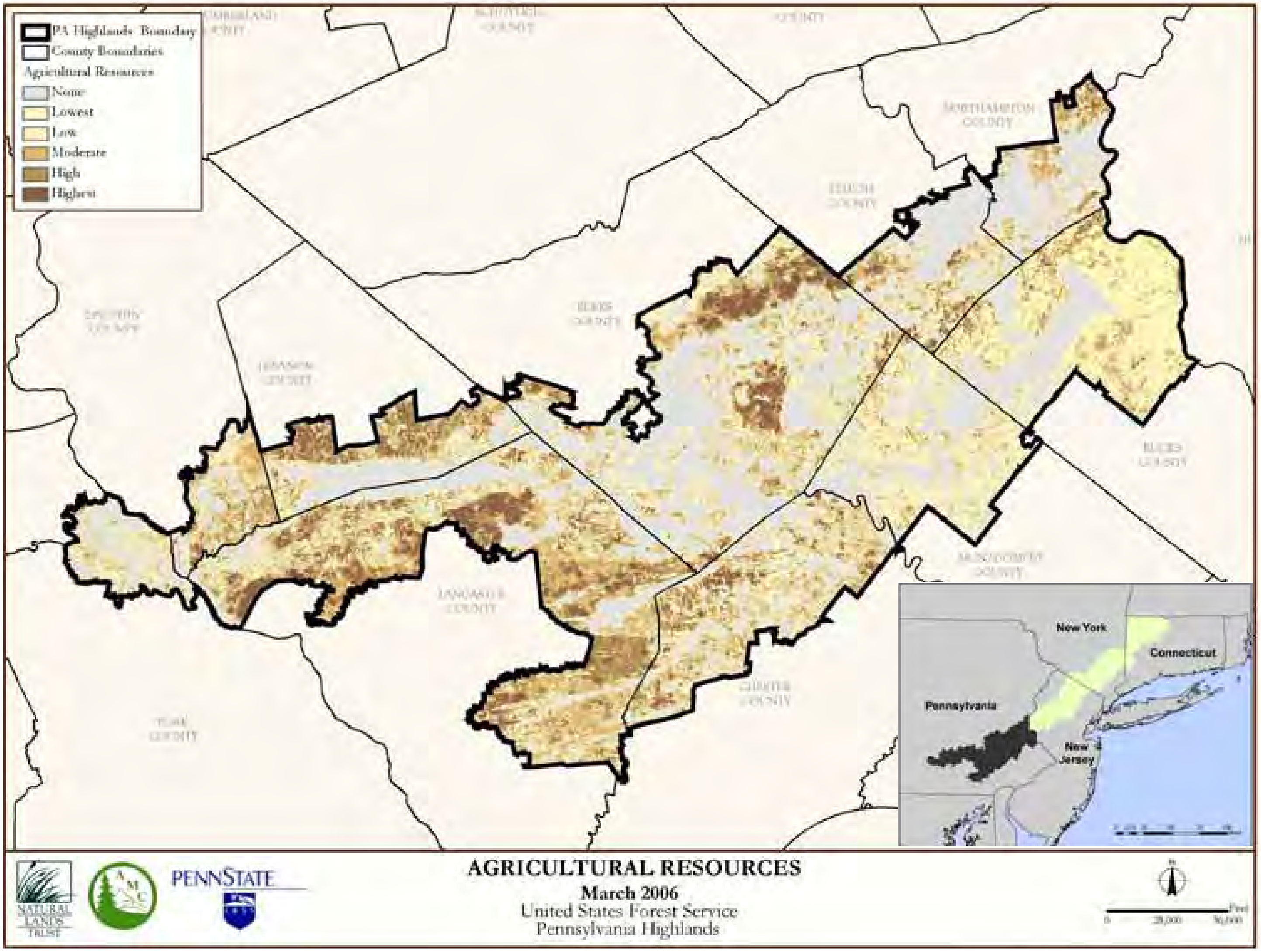


Figure PA-5. Agricultural resource values. *The Conservation Values Assessment identified areas in the Pennsylvania Highlands that have high conservation value for productive farmland.*

- Agricultural resources—The two areas with the highest agricultural resource values are located in the heart of the traditional agricultural areas of Lancaster, Berks, and Lebanon counties.

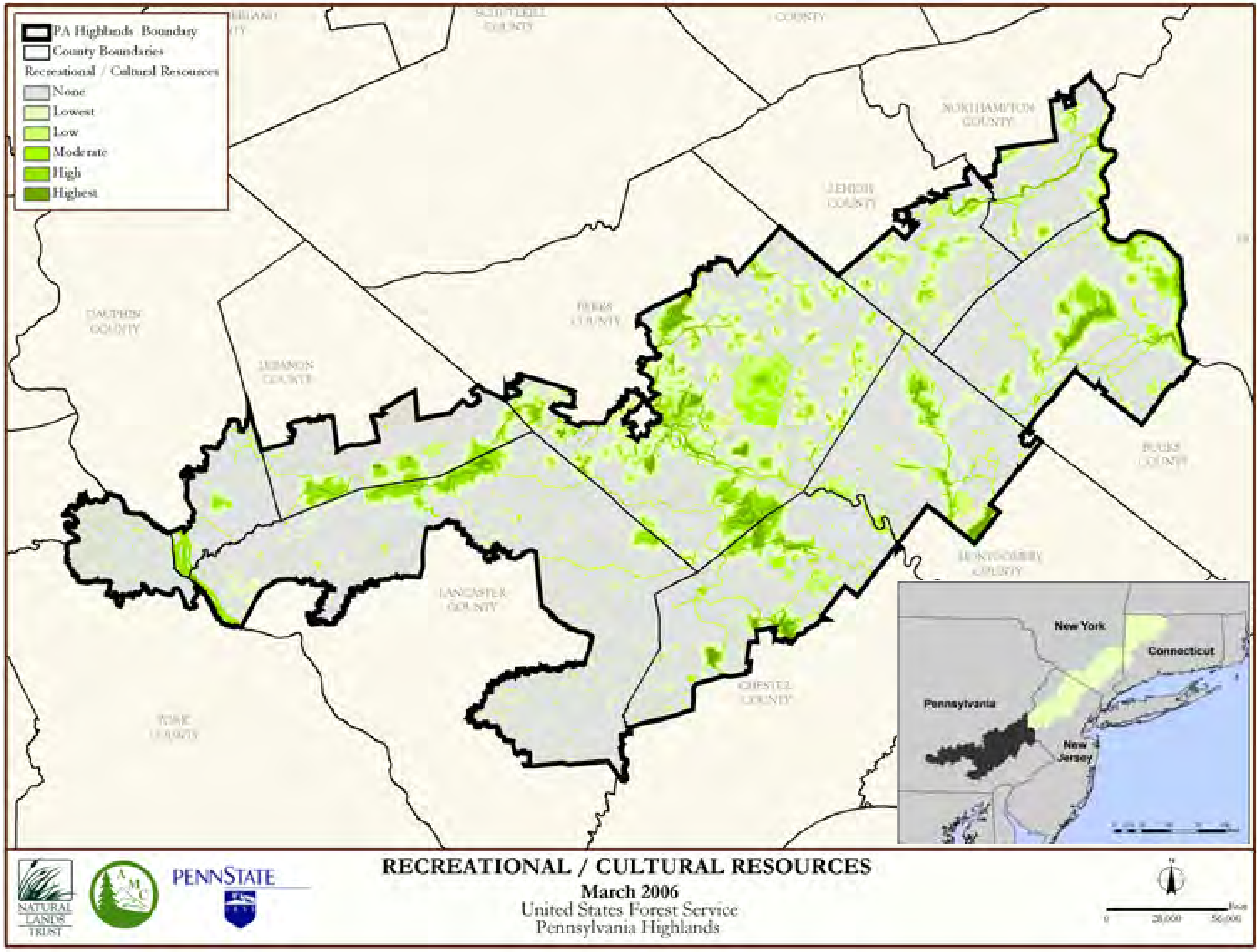


Figure PA-6. Recreational and cultural resource values. *The Conservation Values Assessment identified areas in the Pennsylvania Highlands that have high conservation value for recreation opportunities, and historical and cultural sites.*

- Recreational and cultural resources—The recreational resources in the Pennsylvania Highlands are generally spread throughout the northern portion of the region; however, the largest concentrations are located on State park and State game lands and in local or county parks. Berks County had the majority of identified areas. One of the larger areas is within Bucks County surrounding Nockamixon State Park. The border of Lebanon and Lancaster counties also has a large concentration of high recreation value located on the state game lands.

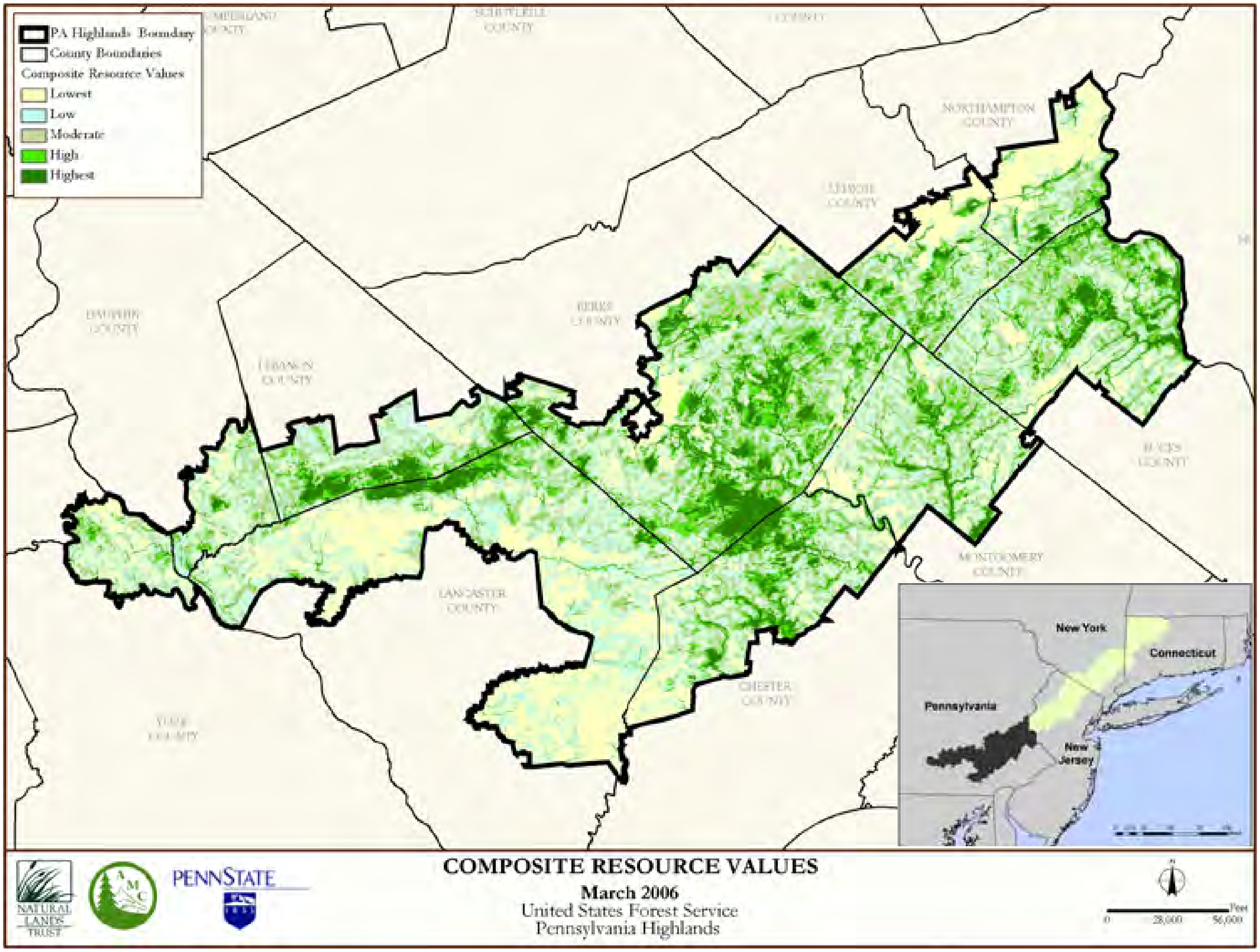


Figure PA-7. Composite resource values. *The Conservation Values Assessment identified areas in the Pennsylvania Highlands that have high and highest conservation value for all resource types (water, forest, biological, agricultural, and recreation and cultural).*

- Composite resource values—The major centers of the CVA are located in same regions as those found for forest, biological, and recreational resources. They are located near the State Game lands of Lebanon and Lancaster Counties border, French Creek State Park in Berks County, and Nockamixon State Park in Bucks County.

Part 2. Public input—Conservation Values Assessment

The public input for the Conservation Values Assessment involved key informant interviews and public meetings. It was conducted under the direction of J. C. Finley of the School of Forest Resources and A. E. Luloff of the Department of Agricultural Economics and Rural Sociology at the Pennsylvania State University.

Key informant interviews

The key informant approach is less costly and time-consuming than surveys covering the entire Pennsylvania Highlands. Key informants are individuals who are knowledgeable about the region and who were selected as being broadly representative of local interest groups. To ensure a level of uniformity, the key informant interviews followed a predetermined script and were conducted between early August and late September 2005.

Interviews were conducted until redundant information was collected, leading to a reasonable certainty that the sample of informants' opinions was fairly comprehensive on these topics: (1) the impacts of land use change on their communities; (2) their values and perspectives concerning the Pennsylvania Highlands; (3) their ideas about areas worthy of conservation in the Highlands; and (4) their ideas on what would protect the long-term integrity of the region.

The study team conducted 77 interviews with a total of 82 people. When asked who is protecting the places they identified as special earlier in the interview, informants named land trusts and conservancies twice as often as any other, followed by municipalities, farmland preservation groups, and watershed groups. When asked who should protect them, informants named State government overwhelmingly, followed by municipalities, Federal government, and county government. Informants' concerns about their special places and communities related to growth and its impacts; the loss of open space, increased traffic, and impaired quality of life.

Facilitated group discussions

Four facilitated group discussions were held in Ephrata, Middletown, Pottstown, and Quakertown. About 180 individuals participated in the sessions, which each lasted 2 hours. Data drawn from analysis of key informant interviews informed the facilitated discussions in which Interested citizens expressed their concerns about the Highlands. The topics of the group discussions were (1) the identification of important places, (2) important conservation values, (3) perceived threats and concerns, and (4) reactions to the key informant findings. Three separate mapping exercises afforded participants more than one way to express their opinions and values. The facilitated group discussions were completed from late October to early November 2005.

In general, participants could name specific places they believed were important to conserve. Most often places were associated with streams and rivers. The conservation values of interest were consistent: three of the four groups emphasized water resources. All groups championed biological resources, and three of the four groups said that concerns about biological resources should have received more emphasis from the key informants. Three of the four groups recognized development as the largest threat to conservation.

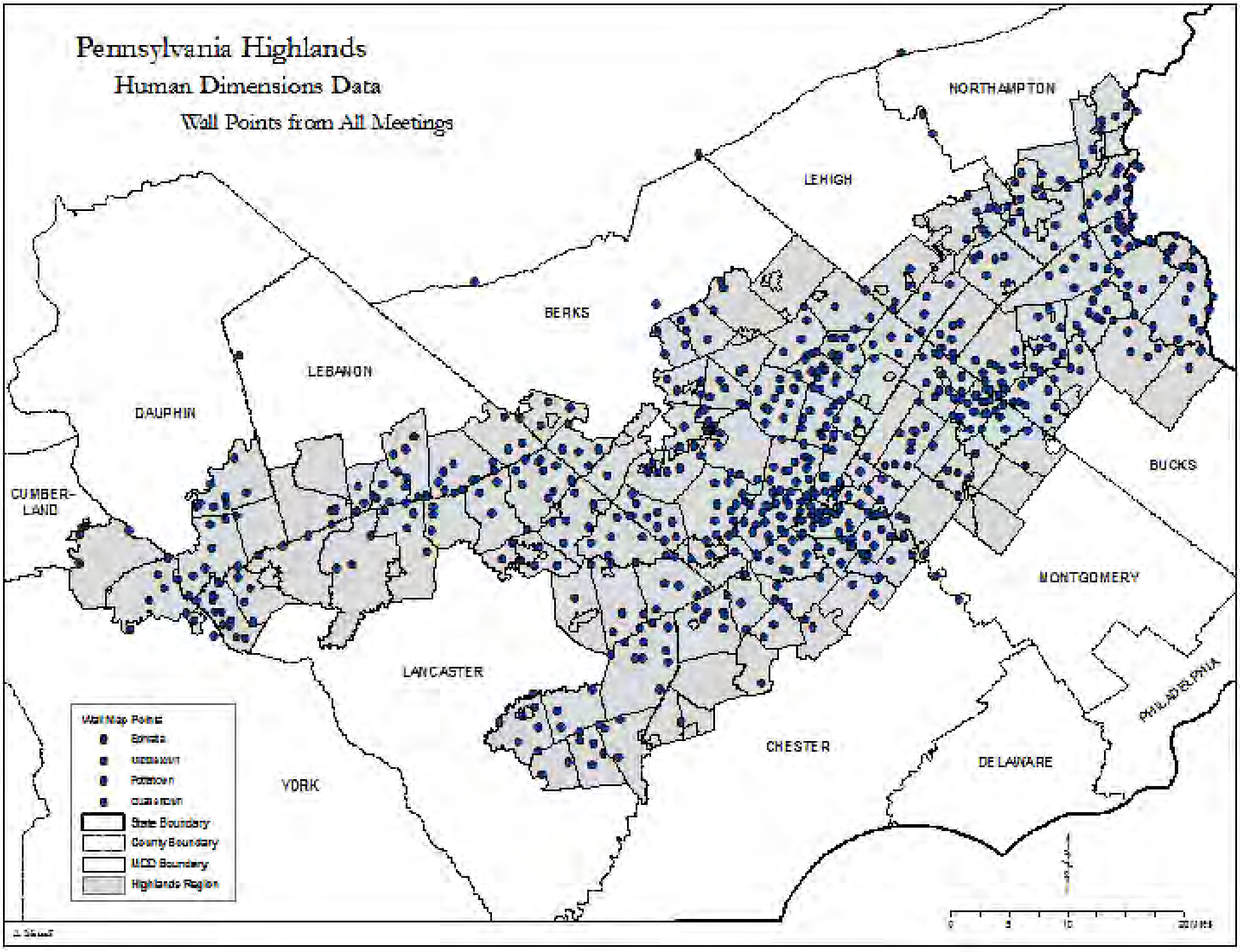


Figure PA-8. ***Wall map summary.*** *Composite of wall maps depicting participants' choices for areas of importance in the Pennsylvania Highlands.*

Map exercises

Wall map exercise

During the wall map exercise, each participant had the opportunity to place up to five dots on important places in the Highlands. While the decision where to place dots was an individual choice, the exercise encouraged discussion as participants milled around the map discussing the location of potential areas they wished to acknowledge. There was no attempt to identify or name the places located in this exercise.

The composite of wall maps brings the products from all four meetings together (Figure PA-8). Generally, the map indicates widespread concern across the Highlands. A heavy clustering in the central region reflects concern for an area known locally as the "Big Woods." In addition, several other clusters are apparent, including the Oley Valley just to the north of the Big Woods.

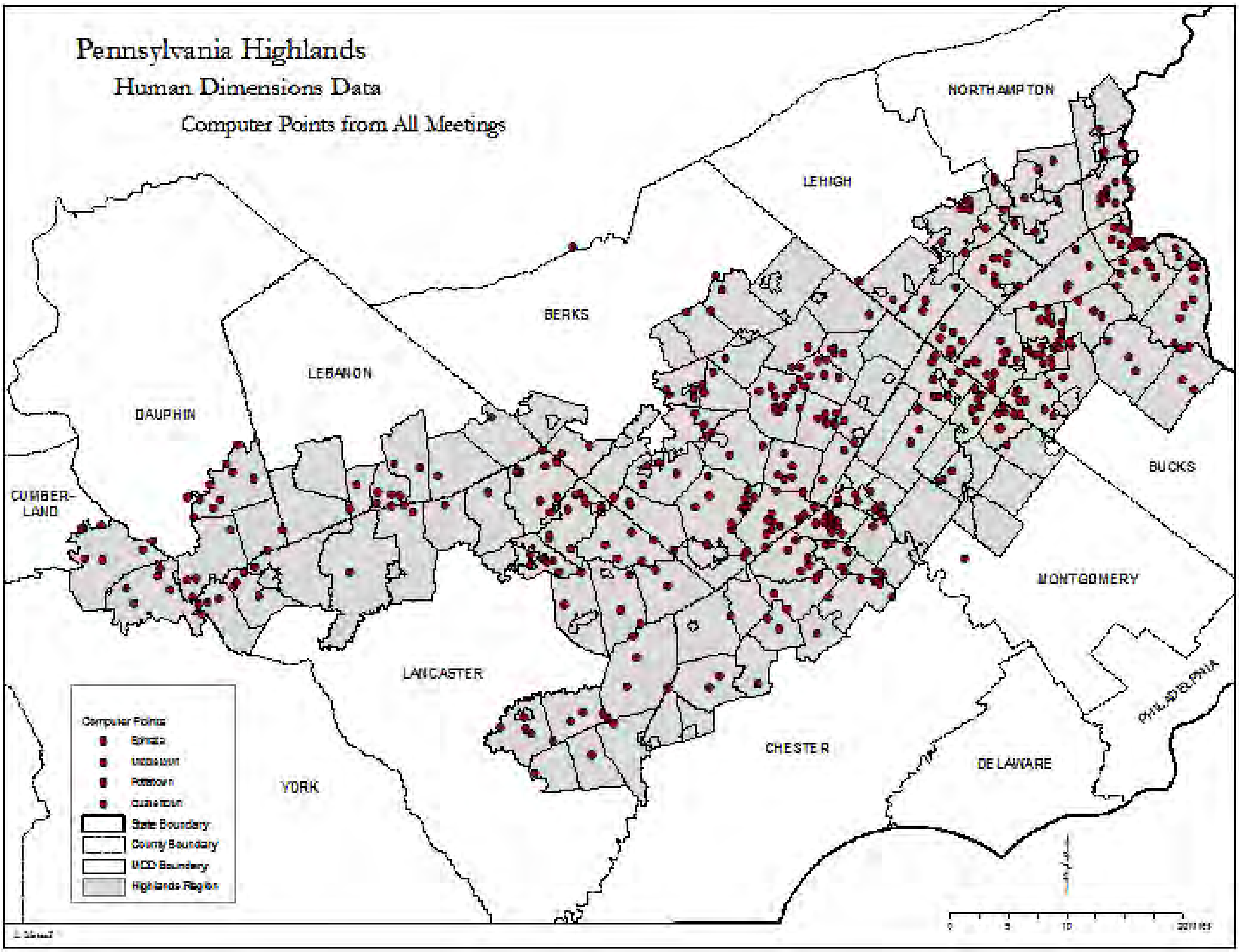


Figure PA-9. Computer map summary. *Composite of all computer maps depicting participants' choices for areas of importance in the Pennsylvania Highlands.*

Computer map exercise

In the second mapping exercise, individuals were instructed to work independently on laptop computers. As they selected the location, the computer prompted them to identify the conservation value they associated with the location, to provide a name, and to identify the perceived threat for the site. The composite of computer points indicates general interest across the entire region with several areas of heightened concern (Figure PA-9). Again, the Big Woods and Oley Valley emerge, but there is also a concentration of points around the Unami Creek, Mill Hill, Green Lane Reservoir area.

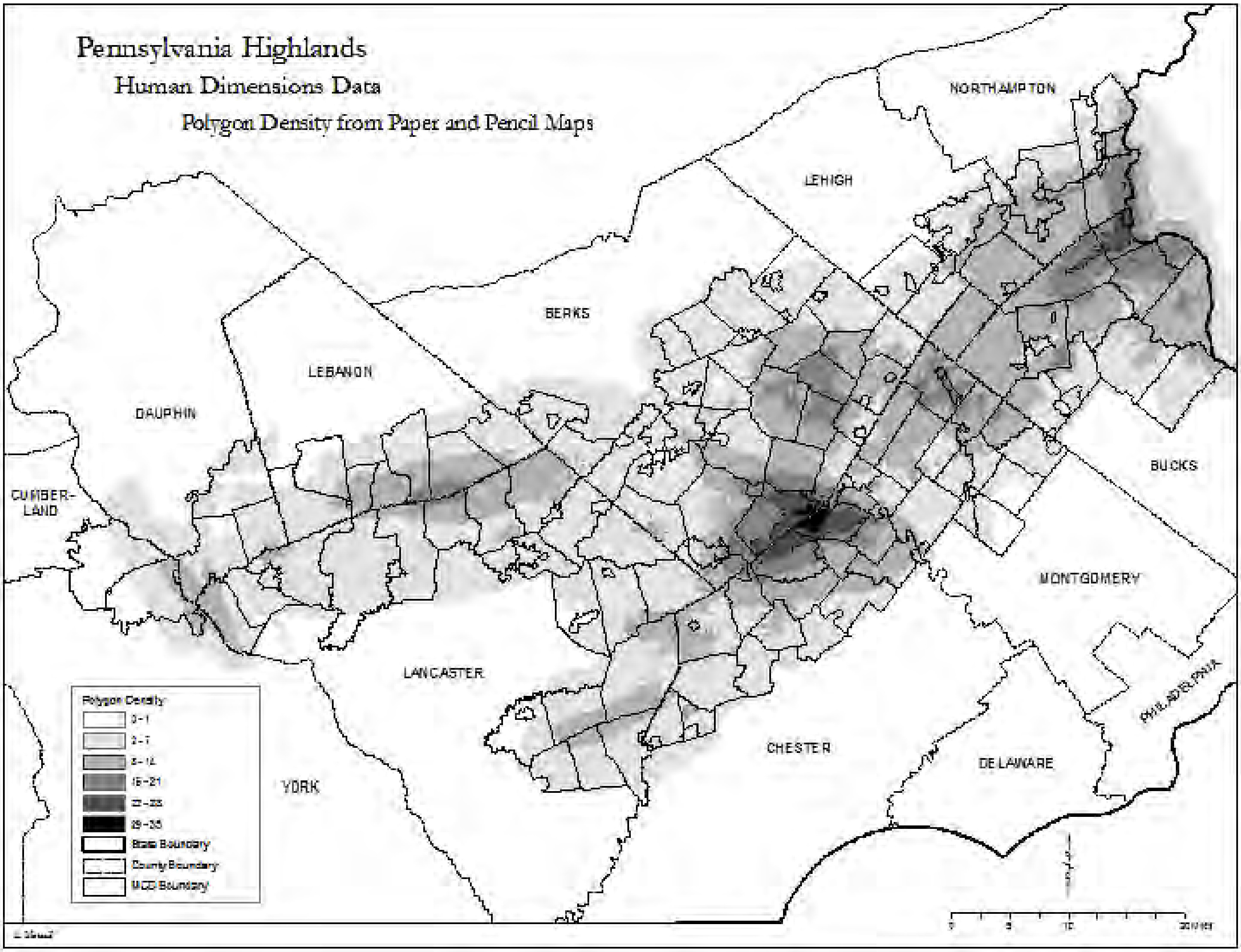


Figure PA-10. ***Pencil and paper map summary.*** *Composite pencil and paper map depicting choices for areas of importance in the Pennsylvania Highlands, by participants from all four public meetings.*

Pencil and paper exercise

The final mapping exercise was a paper and pencil effort where each participant was asked to draw a line around each important place. The object was to make some shape on the paper providing a spatial frame for understanding places that were important to the participants. Combining all polygons in the computer permits generation of a polygon density map, where the darkest areas represent the greatest number of overlapping polygons (Figure PA-10). The Big Woods emerges as the major area of concern; other areas identified through the wall map and computer map exercises are visible as well.

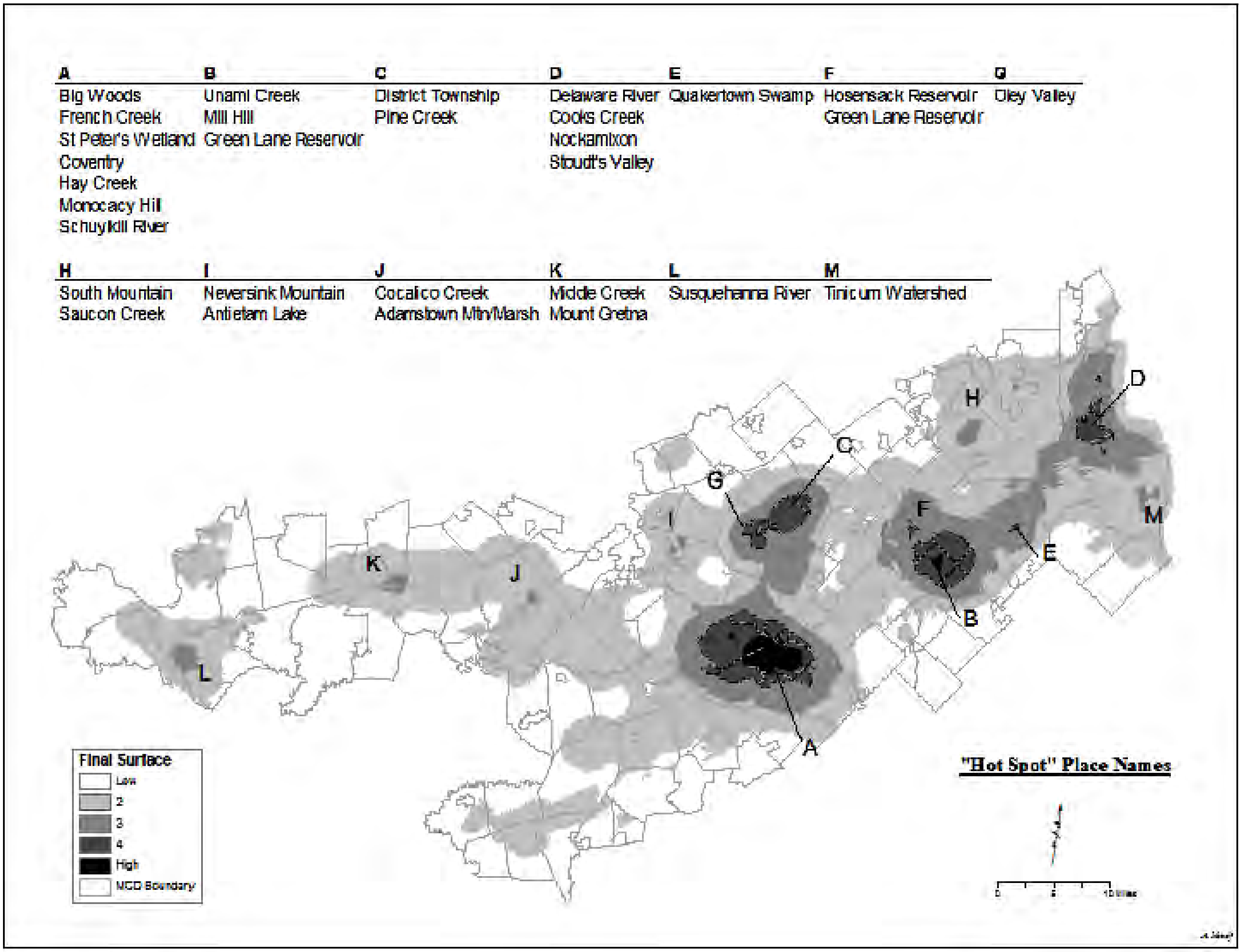


Figure PA-11. Hot spot map. A composite density map of all three map exercises shows the "hot spots" in the Pennsylvania Highlands and their names.

Composite of map exercises

The final map aggregates information collected through each of the three mapping exercises from all locations onto one density surface (Figure PA-11). Names on the map associated with the density points were indicated by participants and obtained from maps available at the meetings.

In general, results from the three mapping exercises correlated well. Special places, whether entered as dots on a wall map, computer points, or polygons on a paper and pencil map clustered in the same parts of the Highlands. The density of dots tended to increase with proximity to the site of each public meeting.

Areas of importance covered the entire Highlands region. The distribution of points was not uniform; when a density surface map was generated, the patterns became quite apparent. Ten "hot spots" of dot density were identified on a composite map that used all three mapping exercises. These hot spots were named according to the participants' identification or, if not identified, according to the dominant natural features within them.

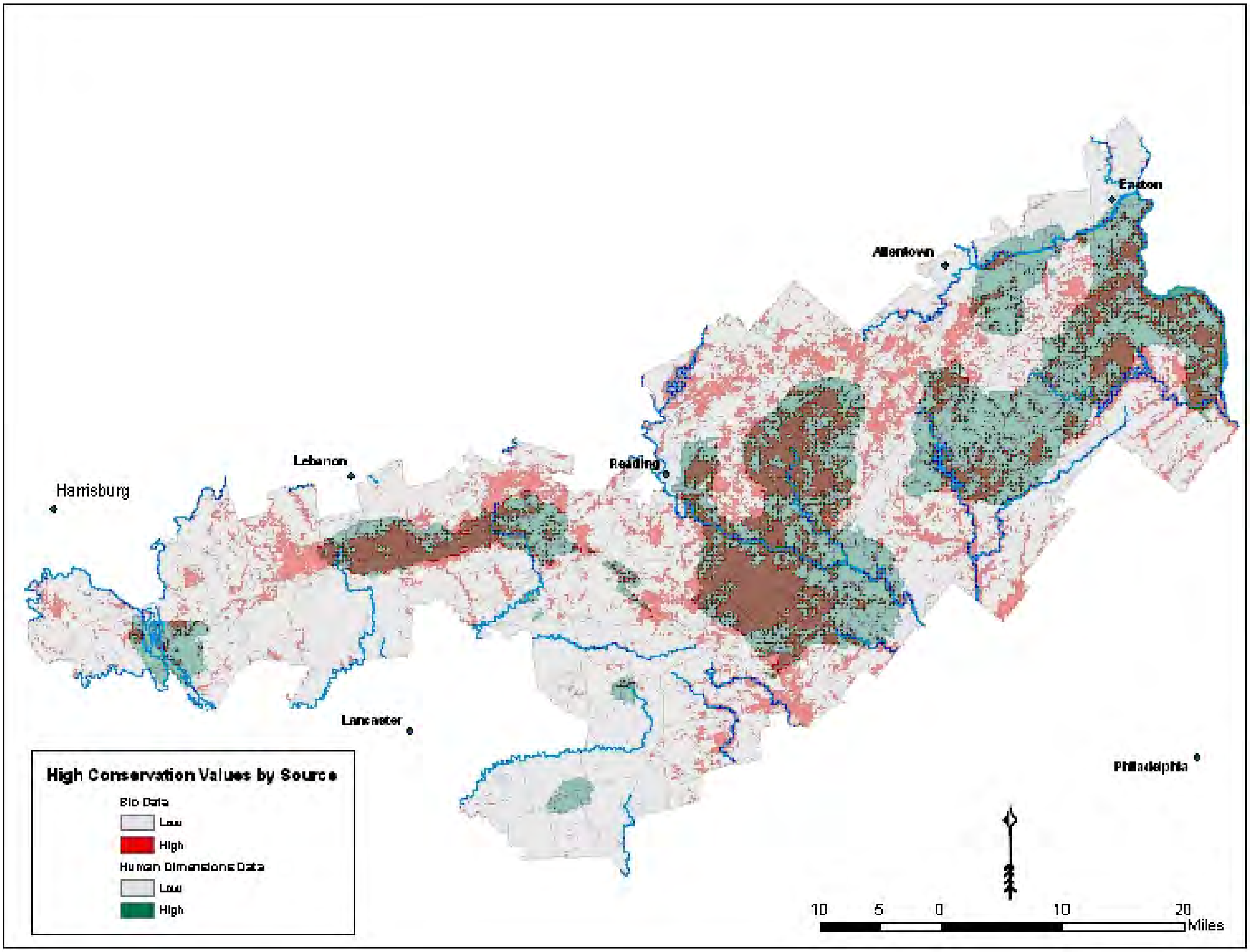


Figure PA-12. Overlay map of Conservation Values Assessment and community input. *Composite of biophysical data for the Pennsylvania Highlands from the Conservation Values Assessment (red) with human dimensions data from community input (green). (Map and analysis are by David Matarrita, Penn State University)*

Merging community input with biophysical data

A composite map was made to test the congruence of data gathered through the public input map exercises with the results of the conservation values assessment (Figure PA-12). The composite Conservation Values Assessment map (Figure PA-7) and the composite of the public input map exercises (Figure PA-11) were simplified by keeping only the top 40 percent of each set of data, then combining them into one map (Figure PA-12).

This study demonstrated that it was possible to gather information from the public that accurately and consistently reflected their conservation values. Moreover, this information was found to correspond to a high degree with the areas of high conservation value identified through the Conservation Values Assessment.

Public input— Conservation Values Assessment— Key findings

- Participants in the key informant interviews were most concerned about growth and its impacts; the loss of open space, increased traffic, and impaired quality of life in the areas of high conservation value.
- Participants in the facilitated group discussions could name specific places they believed important to conserve.
- The Oley Valley and Big Woods areas emerged as high conservation value areas through the three map exercises.
- Information gathered through public input on conservation corresponded to a high degree with the areas of high conservation value identified through the Conservation Values Assessment.
- In addition, the Forest Service heard from other groups through letters, visits, and other venues expressing the need for the Highlands area to retain a viable and sustainable natural resource-based economic component related to agriculture and forest products.

Part 3. Land and water characteristics

Protected land

Description

In Pennsylvania, there is no State-wide, comprehensive, up-to-date source for spatial information on lands that are protected from development. Counties maintain information on farmland preservation easements, and most are in spatial format.

There are at least 223,200 acres (16 percent) protected from development (Figure PA-13). This includes public lands as well as private lands, mostly farmland, permanently protected from development by conservation easements. Sixty-eight percent of protected lands are in public ownership, the rest consists of more than 3,000 parcels of mostly small farmlands, which are on average each a little more than 20 acres. More than half of the protected lands in the Pennsylvania Highlands are considered highest conservation value according to the Conservation Value Assessment.

Throughout the Pennsylvania Highlands, only 31 percent of the highest value land, however, is currently conserved (Figure PA-14). See Part 1 for description of the Conservation Values Assessment.

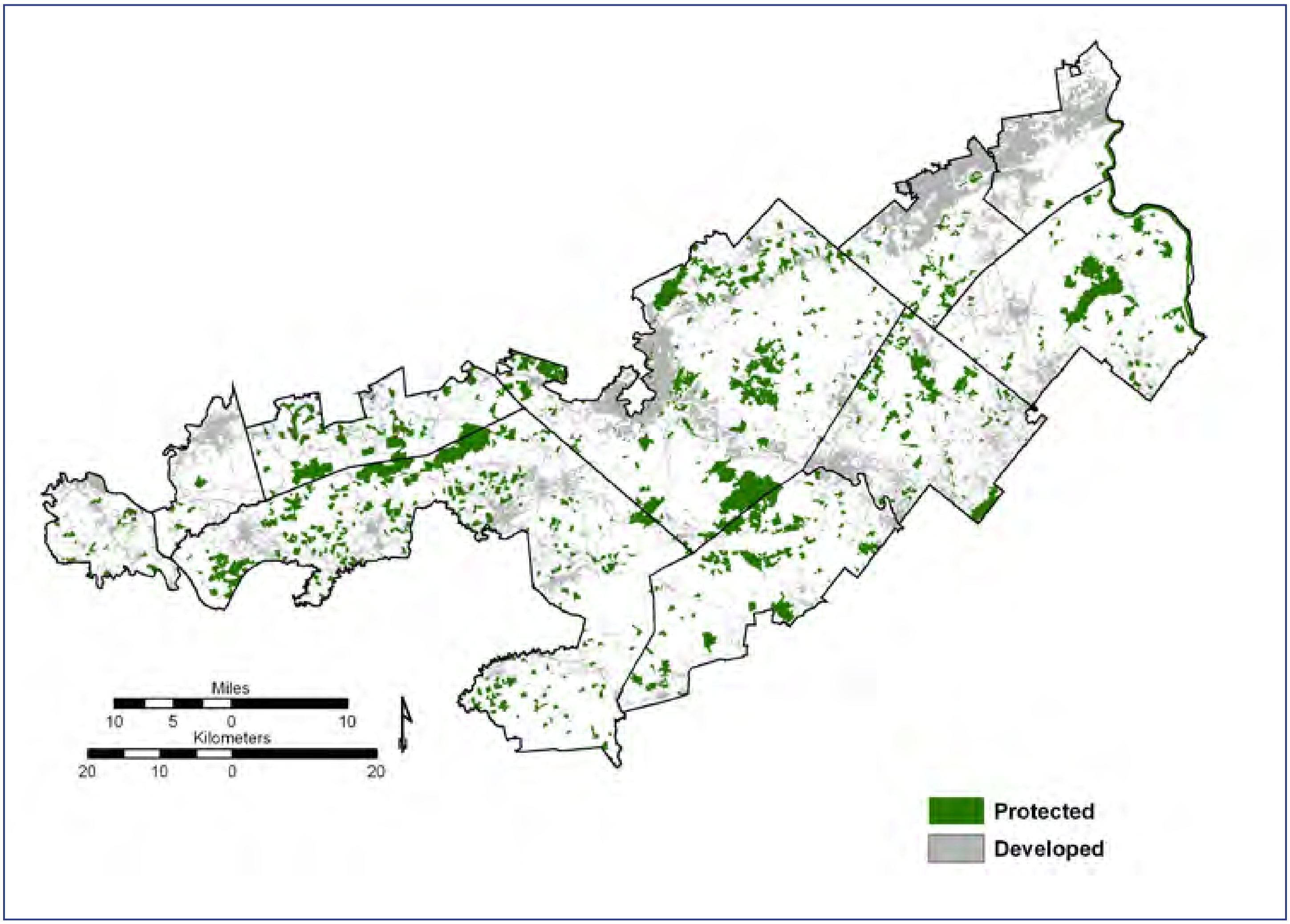
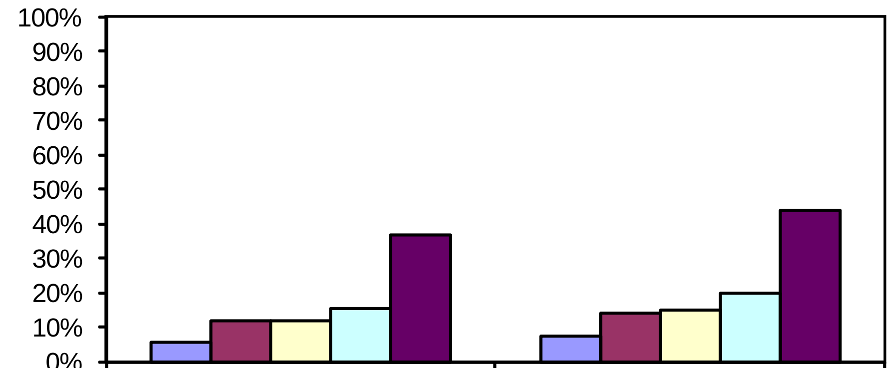


Figure PA-13. ***Protected lands.*** *Protected and developed lands in the Pennsylvania Highlands (Rosencrance 2005).*



	Land in Each CVA Value Protected from Development	Total Protected Land in Each CVA Category
Lowest	6%	7%
Low	12%	14%
Medium	12%	15%
High	15%	20%
Highest	37%	44%

Figure PA-14. Protected land as percent of Conservation Values Assessment. *As determined by the Conservation Value Assessment (CVA) category. CVA data is from Part 1 of this section.*

Protected land—Key findings

- Sixteen percent of the Pennsylvania Highlands is protected from development.
- Sixty-eight percent of all protected lands are in public ownership.
- More than half of protected lands in the Pennsylvania Highlands are in the highest conservation value category.

Forest land

Description

There are approximately 444,700 forested acres in the Pennsylvania Highlands, according to the 2001 National Land Cover Dataset (NLCD Change Product); this represents 32 percent of the region. This percent is low relative to the more extensive prime agricultural land in Pennsylvania. The stand structure is fairly homogeneous, comprised mostly of sawtimber size trees (64 percent), generally larger than 11 inches in diameter. There is a fairly even distribution of age classes as can be seen in Figure PA-15.

Forest cover was relatively stable from 1992 to 2001, the only years for which land cover data is available.

According to FIA data, the forests are dominated by oak-hickory (60 percent), with smaller components of northern hardwood and softwood forest types. Tulip poplar (*Liriodendron tulipifera*) has the largest basal area for an individual species over the study area, but when taken together, oaks (*Quercus* spp.) are the largest component of the forest. Red maple (*Acer rubrum*) is a dominant species in both the overstory and understory.

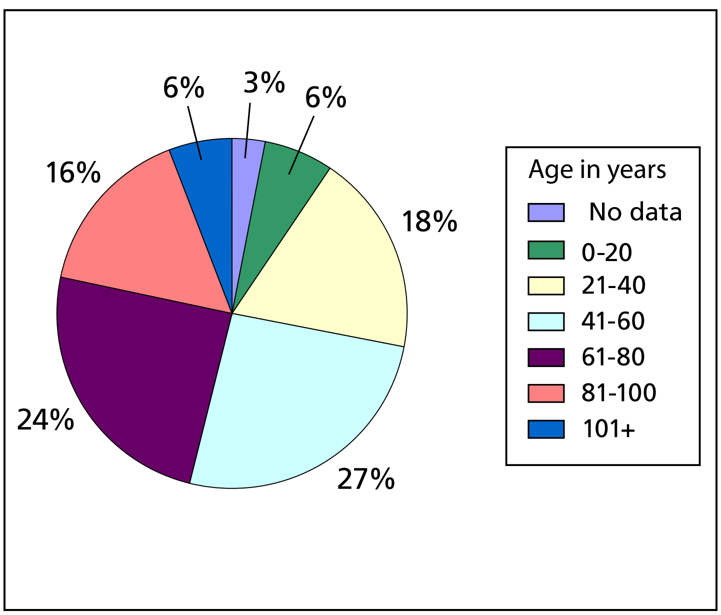


Figure PA-15. Stand age. *Stand age in U.S. Forest Service Forest Inventory and Analysis plots, from 1992 to 2001.*

The region has several important forest blocks. The Hopewell Big Woods is a 73,000-acre forest in Chester and Berks counties, of which 14,800 acres are protected in easements, State parks and game lands. The Oley Hills region in Berks County is 75 percent forested and covers 27,500 acres. The Furnace Hills, containing approximately 64,000 acres of contiguous forest, are in Berks and Lebanon Counties. Another important forest area is the Unami Hills in northeastern Montgomery and northwestern Bucks counties.

There is no federally managed forestland in the Pennsylvania Highlands. While Pennsylvania has no State forests in the region, the Pennsylvania Game Commission actively manages 24,530 acres, of which 20,867 are forested. The majority (56 percent) is made up of mixed oak stands. Most were cut over repeatedly in the early 20th century and subsequently acquired by the State from the 1920s through 1950s. Currently, State-managed lands have a good distribution of age classes, and are under even-aged management. Nonetheless, 63.5 percent of the stands are made up of large diameter timber (greater than 11 inches in diameter).

The Pennsylvania Highlands forests are highly fragmented, however forest cover has remained stable, and was not significantly more fragmented in 2001 than in 1985. According to the 2001 land cover analysis, only 23 percent was core forest, at a 18.6-acre scale of analysis (Table PA-2). Interestingly, the amount of interior forest, defined as forest patches 25 acres or larger, was only 12 percent of the total forest area in 2001—about half of the "core" forest. This shows dramatically the importance of scale—just a small difference in the scale of analysis produces very different results.

Table PA-2. Composition by fragmentation category. *Forest acres and percent composition in the Pennsylvania Highlands, by forest fragmentation category in 2001, using an 18.6-acre window of analysis (9 by 9 cell).*

Forest fragmentation category*	Acres	Percent
Core	104,122	23
Patch	39,948	9
Transition	61,614	14
Edge	157,750	35
Perforated	80,778	18

*For definitions of fragmentation category, see the Glossary.

A comparison of forest fragmentation and the Forest Inventory Analysis (FIA) plot data for the Highlands Region showed that fragmentation has a significant impact on stand composition and structure. Fragmentation leads to a larger proportion of edge forest, which increases temperature, light, and wind levels. There is a distinct difference in species composition. Edge forests have less oak and tulip poplar, lower basal areas and were younger than core forests. Red maple was a dominant species in both edge and core forests.

Forest ownership

The majority of forest land in the Highlands is owned by non-industrial private landowners. The actions of these small private owners will have important consequences for the forest resource. In Pennsylvania, 71 percent of the forestland is owned privately, 54 percent by families. Of these family forest owners, 30 percent are over age 65 (Butler 2008). With an aging landowner population, there is a higher risk that forested parcels will be subdivided and potentially developed.

According to the small sample of landowners in the Pennsylvania Highlands region who responded to the National Woodland Owners Survey, the majority of land holdings are less than 20 acres. None of the survey respondents owns forests larger than 500 acres. Slightly less than 50 percent of the forest area is part of a farm, and about 80 percent—in terms of both area and ownership—are part of a primary residence. About half of these owners reported having harvested timber at some point; however, only two respondents reported having a management plan for the property. Esthetics, nontimber forest products, and family legacy dominate the reasons given for owning forests. Ninety-seven percent of the owners have no written management plan and have sought no advice on management.[5]

Deer and invasive species

Heavy deer populations have had a negative impact on the forests of Pennsylvania. Deer browse has in some instances severely limited regeneration of important

[5] Butler, Brett J. 2007. Unpublished results from the U.S. Forest Service National Woodland Owner Survey. U.S. Department of Agriculture, Forest Service, Northern Research Station.

species, such as oak. The densities of all oak species and red maple are decreasing, while the densities of black birch (*Betula lenta*), cherry (*Prunus serotina*), sassafras (*Sassafras albidum*), black walnut (*Juglans nigra*), and sugar maple (*Acer saccharum*) are increasing. The State Game Commission instituted an aggressive deer management program starting in 2000, which has been able to successfully regenerate oak by fencing in seedlings.

Invasive species are becoming an important concern, since one outcome of fragmentation is the propensity of invasive species to invade forests along edges. The species of concern identified by the State Game Commission are royal pawlonia (*Paulownia tomentosa*), tree of heaven (*Ailanthus altissima*), and multiflora rose (*Rosa multiflora*). While still making up only a small proportion of basal area and density, the invasive trees Norway maple (*Acer platanoides*) and tree of heaven were found in FIA plots in the Highlands. Shrubs and vines, which are typically the biggest invasive species problems in forests, are not included in the FIA inventory.

Pennsylvania has in the past suffered from serious pest outbreaks, particularly from the nonnative gypsy moth (*Lymantria dispar*). Gypsy moth outbreaks are cyclical, and since 1990 gypsy moth has remained the most important source of forest damage. Other current threats include the hemlock woolly adelgid (*Adelges tsugae*), hemlock scale *(Fiorinia externa*), and fall cankerworm (*Alsophila pometaria*). Chestnut blight (*Cryphonectria parasitica*) remains prevalent among American chestnut (*Castanea dentate*) saplings.

Forests in Pennsylvania are vulnerable to mortality caused by the emerald ash borer (*Agrilus planipennis*), which is now spreading from its point of introduction in the Midwest. Ash species (*Fraxinus* spp.) represent 11 percent of the basal area in the Pennsylvania Highlands.

The USDA Forest Service recently updated the 2002 National Risk Map for Insects and Diseases (Krist and others 2007). It suggests that 33,853 acres (9 percent of the total) in the Pennsylvania Highlands are at risk of exceeding 25 percent mortality over the next 15 years. The biggest threats are from Asian longhorned beetle (*Anoplophora glabripennis*), ash decline, gypsy moth, hemlock woolly adelgid, and oak decline. Oak decline, the name given to the decline and death of oaks over widespread areas, is caused by a complex interaction of environmental stresses and pests. Currently, oak decline is not a problem in Pennsylvania. Nevertheless, there is the risk that it may become a problem with a warmer climate and more droughts. There is currently little risk of defoliation from Asian longhorned beetle in Pennsylvania. While the majority of the region is only at risk of 0-5 percent mortality from the hemlock woolly adelgid, this could represent a large loss of the hemlock component, an important source of thermal cover for wildlife.

Forest land—Key findings

- 32 percent of the Pennsylvania Highlands region is forested and consists mostly of oak species. Red maple forest cover remained stable between 1992 and 2001.
- Stand structure is fairly homogeneous, comprised mostly of sawtimber-sized trees, generally larger than 11 inches in diameter. There is a fairly even distribution of age classes.
- Seventy-one percent of the forestland is owned privately, and 54 percent by families. Thirty percent of family forest owners are over age 65. These landowner demographics are likely the same for the Highlands region.
- The Pennsylvania Highlands forests are highly fragmented; only 23 percent is core forest.
- A comparison of forest fragmentation and the Forest Inventory Analysis (FIA) plot data for the Highlands region showed that fragmentation has a significant impact on stand composition and structure.
- The ash component of forests in the Pennsylvania Highlands are vulnerable to mortality caused by the emerald ash borer which has been found in western Pennsylvania.
- Forest products continue to contribute to the economy and culture of the Highlands region.

*Table PA-3. **Farmland acres by county.** Data were apportioned to the Highlands based on the percentage of each county that lies within the Pennsylvania Highlands (U.S. Department of Agriculture statistics 1997 and 2002).*

County	Farmland acres within Highlands 2002	Farmland acres within Highlands 1997	Change in farmland 1997 to 2002	
			Acres	Percent
Berks	106,894	120,496	–13,602	–11.3%
Bucks	27,370	35,008	–7,638	–21.8%
Chester	40,356	47,324	–6,967	–14.7%
Dauphin	10,727	10,928	–201	–1.8%
Lancaster	185,304	195,413	–10,109	–5.2%
Lebanon	39,518	37,881	1,638	4.3%
Lehigh	27,042	30,966	–3,924	–12.7%
Montgomery	15,807	17,204	–1,396	–8.1%
Northampton	19,087	21,483	–2,396	–11.2%
York	17,925	18,259	–334	–1.8%
Total	490,032	534,962	–44,930	–8%

Agricultural land

Description

Most of the recent development in the Pennsylvania Highlands has occurred on agricultural land. For this study, data was gathered from the U.S. Censuses of 1970, 1980, 1990, and 2000, the U.S. Censuses of Agriculture of 1997 and 2002, and a key informant survey. The censuses indicate that agricultural land use is on the decline in all Highlands counties except Lebanon County, where it increased moderately (Table PA-3). Bucks County lost agricultural land at the fastest rate among Highlands counties between 1997 and 2002. In total, the Highlands region lost between 46,000 and 54,000 acres of agricultural land from 1992 to 2001—an 8–11 percent loss—and 44,930 acres of farmland between 1997 and 2001. About 15,700 acres were converted to "urban" use, the rest to development-associated grasses or open meadows. Nonetheless, at 35 percent of the landscape, agriculture is still an important activity and central to the culture and identity of eastern Pennsylvania. The vast majority of agricultural land is in cropland, with pasture and rangeland making up the balance.

Significant changes are taking place in the nature of farms and farming in the region. The number of farms, on-farm populations, farm jobs, and medium-sized farms (50–999 acres) all declined around the major cities of the Highlands region, as well as along the state highways connecting them. Larger, higher-income farms and some medium-sized farms remain clustered in and around the good soils of Lancaster County, the leading agricultural producer among the Highlands counties. This area, along with southern Lebanon County and the northwestern edge of Berks County, was identified as the area with the highest agricultural resource value in the Conservation Values Assessment.

Farms larger than 1,000 acres have disappeared. The loss of a larger farm represents a loss to the agricultural community, since larger farms produce more, contribute more to the local economy, and keep more open space out of development. The number of smaller farms is on the rise; from 1997 to 2002, there was a 48 percent increase in farms of 50 acres or less. Fragmentation of farmland is driving the increase in the number of small farms.

Loss of farms and gain in housing work synergistically to the disadvantage of medium farms, by increasing the chance of conflicts with neighbors and by reducing competition among suppliers of agricultural goods and services. Small farms are less capital-intensive and easier to maintain under mounting development pressure. Furthermore, the movement of urban professionals to rural areas is driving the boom in small farms, many of which are operated for lifestyle purposes and sell very few agricultural products.

To gauge perceptions of agricultural land use in the Pennsylvania Highlands, the study team interviewed 27 people working in farmland conservation and agriculture in or near the Pennsylvania Highlands by telephone. Survey respondents overwhelmingly felt that the loss of agricultural land to residential development was occurring when entire farms in areas not zoned for agriculture were sold to land developers.

Survey respondents from the agricultural land conservation community indicated that cooperation and synergy between municipal governments, farmers, and the county was critical for effective conservation. To encourage municipalities to enact agricultural zoning, the county agricultural preservation programs value farmland within agricultural zones more highly than farmland outside of agricultural zoning. This factor, as well as the variability in soil quality within the Highlands, has led to the current clumped distribution of preserved farmland (Figure PA-16).

Several survey respondents expressed concern over the impact of the agricultural land conservation program. Widespread conservation and strong agricultural zoning laws in some counties are causing homebuilders and buyers to look further into rural areas for developable land, increasing the pressure on farmland there.

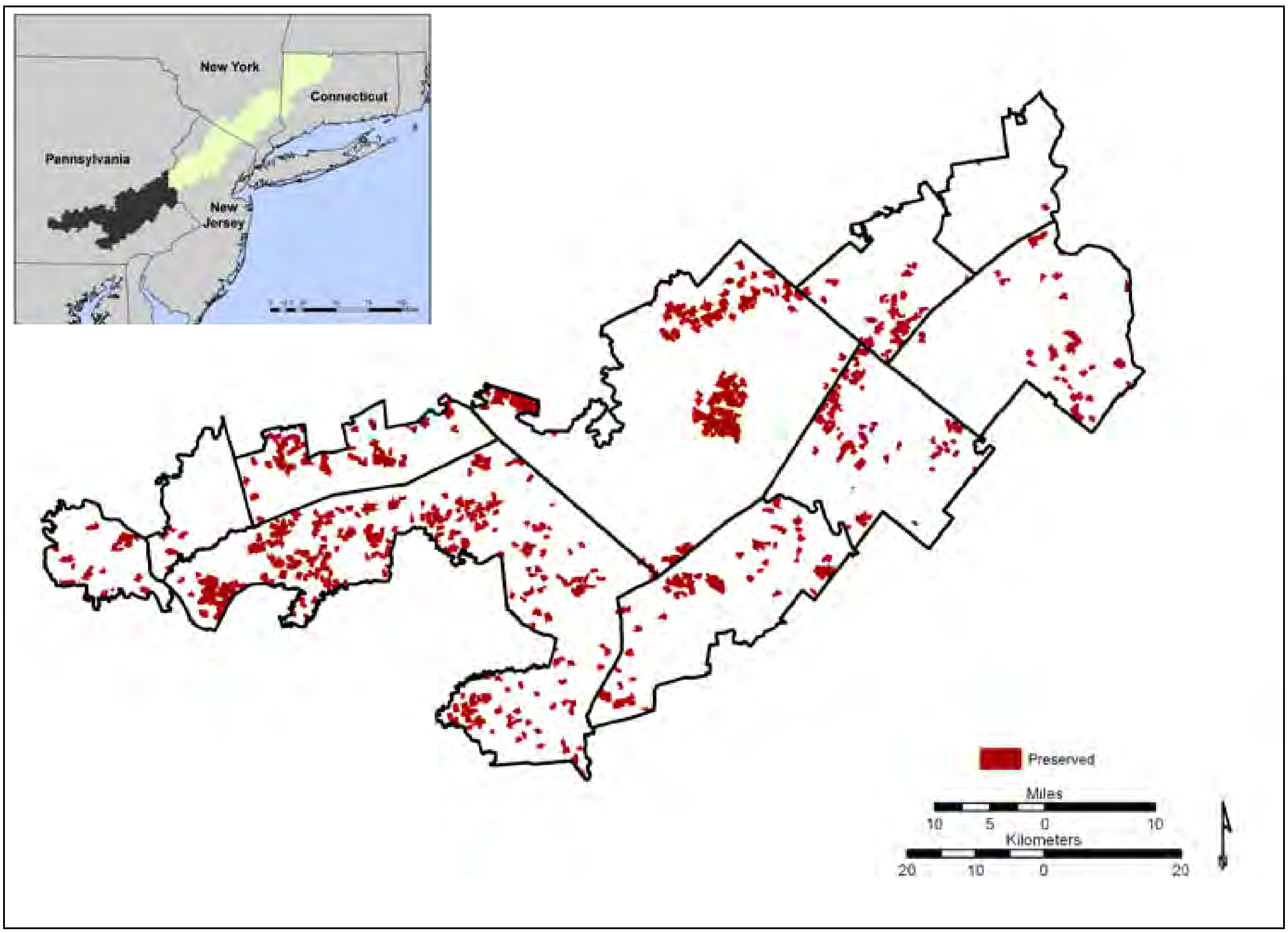


Figure PA-16. Agricultural land. *Preserved agricultural land in the Pennsylvania Highlands.*

Conservation of farmland is a high priority in the region. The majority of the conservation work is being done in the counties with the most farmland acres in active agricultural use, led by Lancaster and Berks counties (Figure PA-16). About 16 percent of farmland is preserved from development with an agricultural conservation easement. Notably, 64 percent of State funding for agricultural land preservation went to the 10 Highlands counties (including parts of the counties that are outside the Highlands boundary) (Commonwealth of Pennsylvania 2007a, b).

Lancaster County has many square miles of good farmland in the Highlands, as well as a strong agricultural land preservation program, and therefore has the most total number of acres preserved and the most properties preserved compared with other county programs. As the largest farms are preserved, county agricultural preservation boards must increasingly preserve small and medium-sized farms to secure the agricultural land base (Pennsylvania Department of Agriculture 2005b).

Agricultural land—Key findings

- At 35 percent of the landscape, agriculture is still an important activity and central to the culture and identity of eastern Pennsylvania.
- Most of the recent development in the Pennsylvania Highlands has occurred on agricultural land; 44,930 acres of farmland were lost between 1997 and 2001.
- Agricultural land use is on the decline in all Highlands counties except Lebanon.
- The numbers of farms, on-farm populations, farm jobs and medium sized farms (50-999 acres) all declined around the major cities of the Highlands region as well as along the state highways connecting them.
- Farms larger than 1,000 acres have disappeared. The number of smaller farms is on the rise. From 1997 to 2002, there was a 48 percent increase in farms of 50 acres or less.
- About 16 percent of farmland is preserved from development with an agricultural conservation easement.

Water resources

The Highlands ground water and surface water are sources of public water supply for approximately 1.3 million people in Pennsylvania. Additionally in Pennsylvania, over 400,000 people rely on individual wells to supply their own water for domestic uses. Also, in the Pennsylvania Highlands, a large number of people depend on water that is conveyed through the Highlands by streams and rivers.

The quality of ground and surface water within the region is generally of good quality except for some localized areas of contamination. Land-use activities are major factors in changing hydrologic and environmental conditions within any watershed. The expected continued growth and development in the Highlands with their respective land-use change could have a significant effect on stream and ground-water quality and aquatic communities. Given the prospect for continued development of the Highlands, which would increase demands on Highlands water resources both within the Highlands and in adjacent areas, adequate monitoring and assessment of water quantity and quality and of biological resources is essential for sustainable land-use planning and conservation.

Ground water—aquifers and wells

Ground water is a major source of water for residents and businesses in the Highlands region. Public water suppliers and local residents rely on ground water withdrawals for their daily use. The underlying geology is the controlling factor in how much water can be stored and how much water can be withdrawn from aquifers. The type of rock, for example limestone or shale, has different aquifer characteristics with respect to water storage and movement. Descriptions of the type of aquifer are provided to aid in understanding the information on ground water use that follows.

Aquifer types

Major aquifer types in the Highlands region of Pennsylvania are classified by the bedrock exposed at or near the land's surface. These include crystalline, carbonate, and clastic rocks typical of Highlands geologic formations (Figure PA-17). The formations consist of sedimentary, igneous, and metamorphic rocks of the Newark and Gettysburg Basins, the Piedmont Uplands, and the Great Valley.

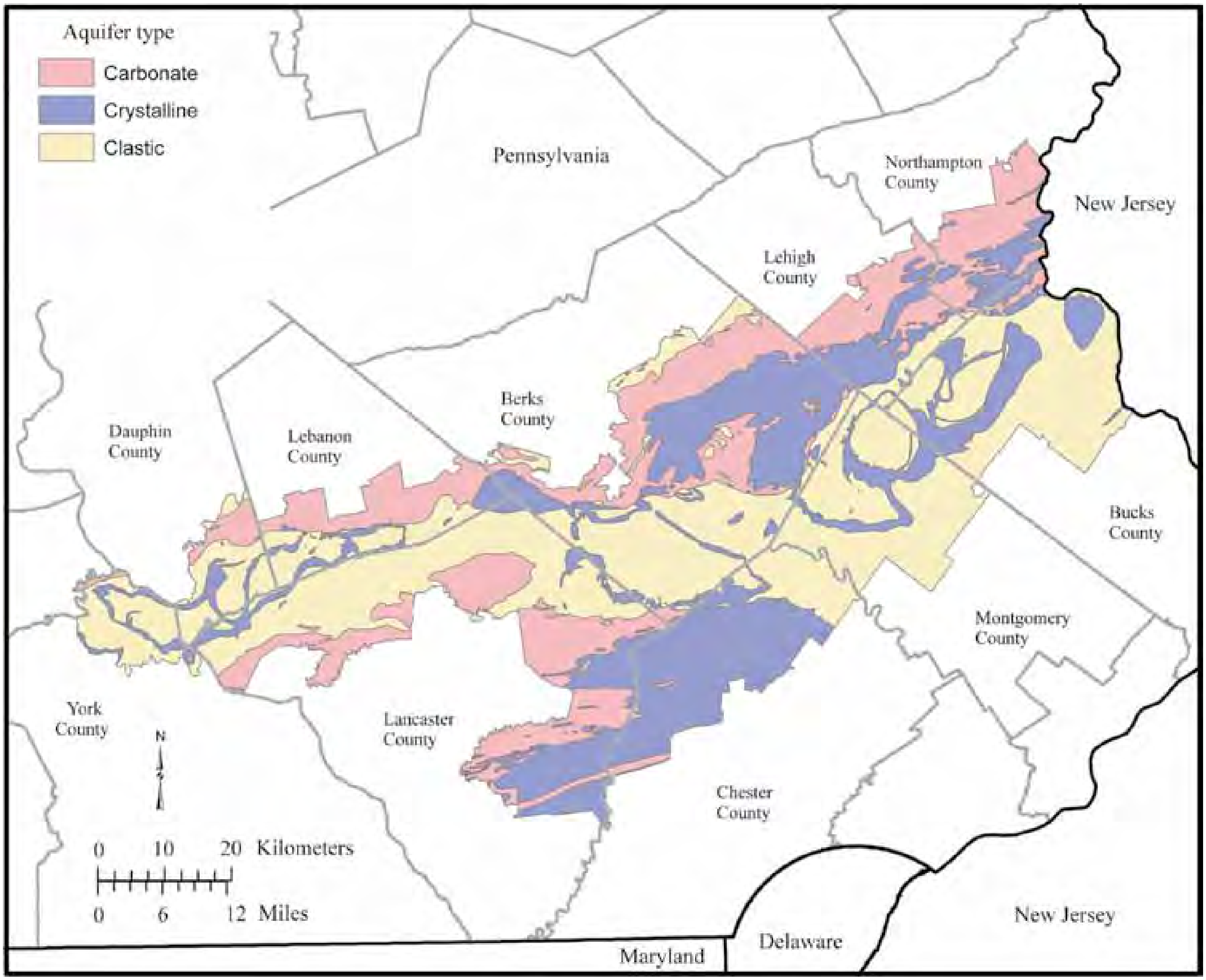


Figure PA-17. Aquifer types of the Pennsylvania Highlands. Major aquifer types are classified by their surface bedrock (carbonate, crystalline, and clastic), which affects water storage, availability, and chemistry. Carbonate aquifers usually yield the most water. Crystalline and clastic aquifers usually yield less water, and crystalline aquifers produce the least.

Aquifer recharge

Recharge to bedrock aquifers is predominantly through precipitation that percolates downward through the overlying soil to fractures, joints, bedding planes, faults, or solution openings in the underlying bedrock (Figure PA-18). The ground water moves from upland recharge areas to discharge areas, such as springs and streams at lower altitudes.

Aquifer recharge can be highly variable because it is determined by many factors, including the duration and intensity of local precipitation and antecedent soil-moisture conditions. Recharge also is influenced by topographic relief and the capacity of the land surface to accept infiltrating water. The degree to which Highlands aquifers store and transmit recharge water is based on the amount and connectivity of openings in the underlying rock. This is also known as aquifer permeability and has a direct bearing on aquifer yield to wells. Water is stored and transmitted through fractures and joints in the crystalline rock aquifers and through fractures, joints, and bedding planes in clastic rock aquifers. Water is stored and transmitted through fractures and joints as well as solution openings in the carbonate aquifer systems.

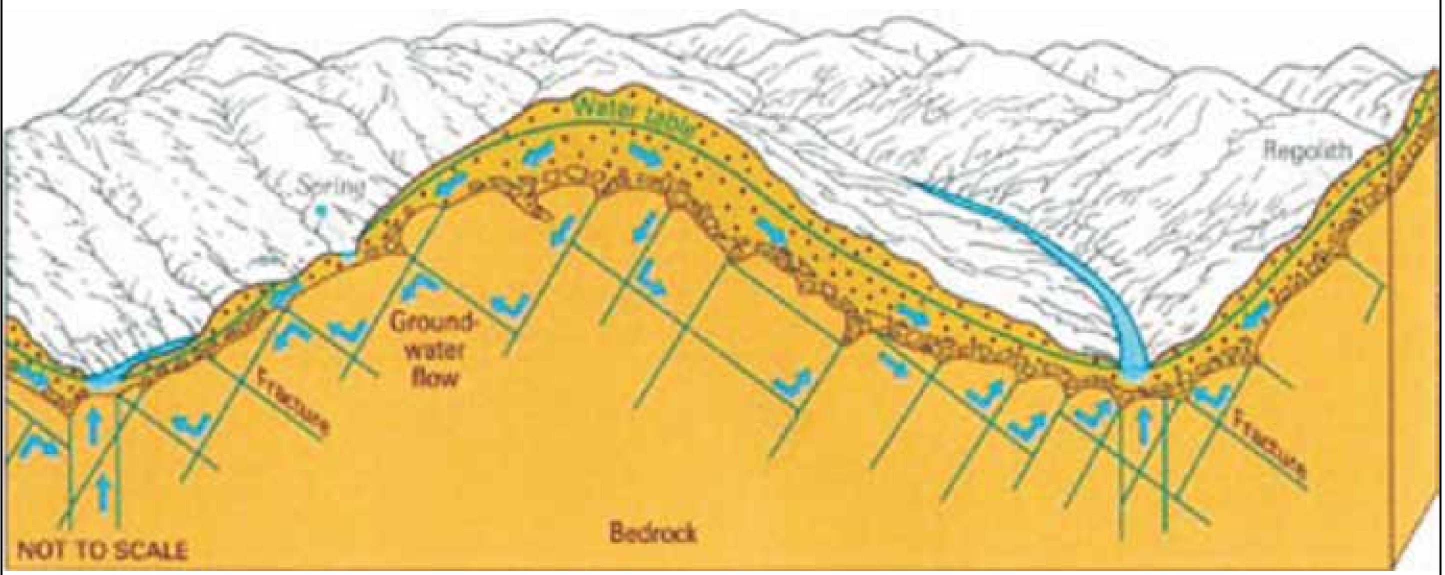


Figure PA-18. ***Recharge and flow in bedrock aquifers.*** *Ground water in bedrock aquifers is predominantly precipitation that has infiltrated the overlying soil and the bedrock. At lower elevations the ground water feeds springs and streams (modified from Heath 1980, p. 10).*

Ground water use

Public, industrial, commercial, irrigation, and mining wells

Water-use data for 2000 was compiled for more than 1,000 wells for which owners are required to report water withdrawal data to Federal, State, Interstate River Basin Commissions, or local agencies. These wells include those used for municipal supply, and industrial, commercial, irrigation, and mining uses, particularly quarry dewatering. Figure PA-19 shows the location of wells operating in 2000 and provides information on the volume of withdrawals per well by aquifer type. Areas of note include the northern extent of the Highlands boundary where large withdrawals from carbonate aquifers occur. Also, carbonate aquifers provide large amounts of ground water in the northeastern part of Lancaster County. These are areas underlain by carbonate rocks which have the capacity to yield large volumes of water because of solution openings of fractures and bedding planes. Figure PA-19 also shows the widespread consistency of low yields of clastic and crystalline rock aquifers.

The graph in Figure PA-19 shows total ground-water withdrawals by aquifer type within the Highlands study area. Carbonate aquifers are the most productive with almost 51 million gallons per day (Mgal/d) withdrawn. The combined total withdrawal from the three bedrock aquifers is about 81 Mgal/d.

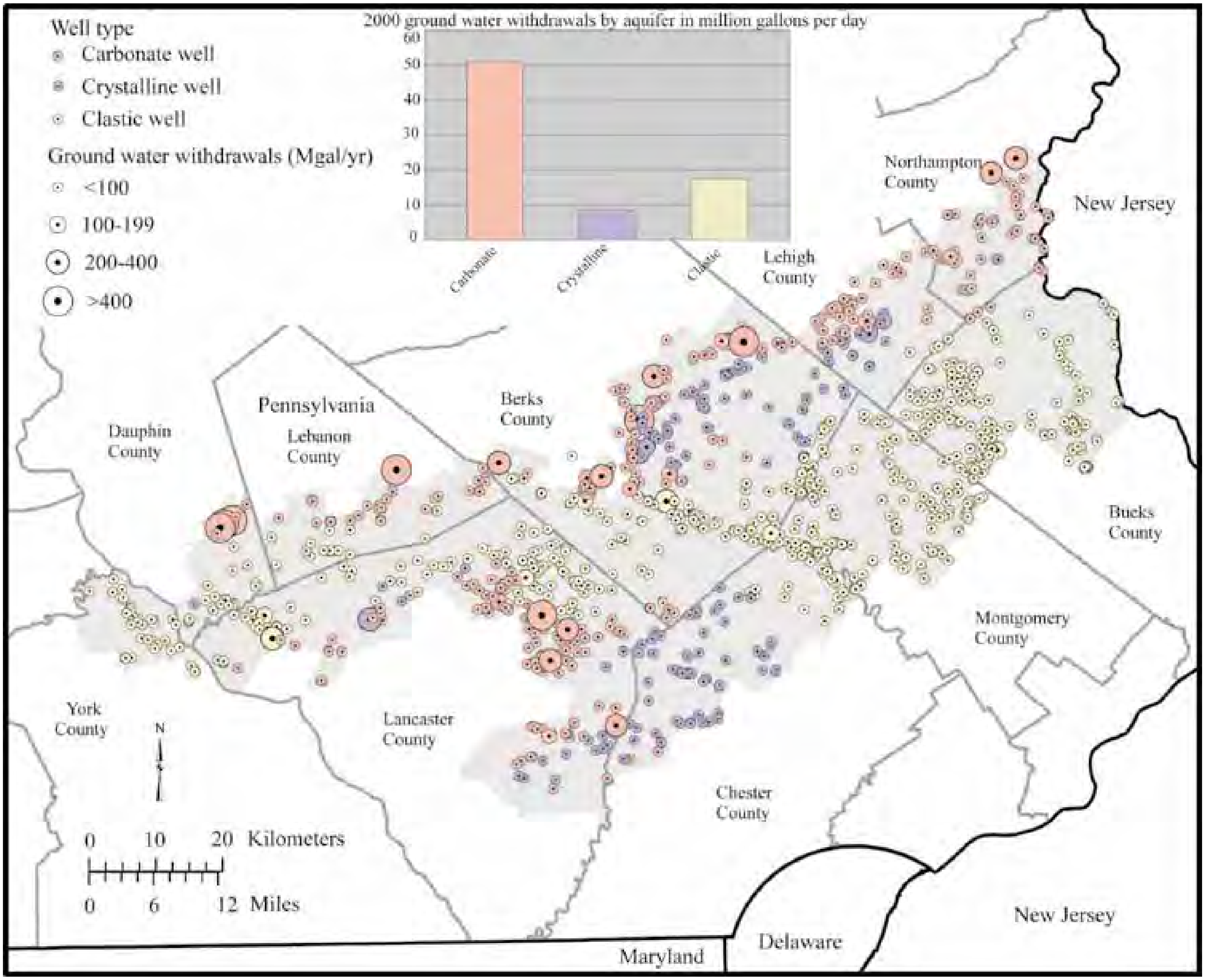


*Figure PA-19. **Withdrawals from ground water wells in the Pennsylvania Highlands in 2000, by aquifer type.** Wells in carbonate aquifers usually yield the highest amount of water. Wells in crystalline and clastic aquifers usually yield less water with wells completed in crystalline aquifers producing the least.*

Domestic wells

The amount of water supplied by domestic wells across the region was estimated in order to account for this significant source of potable water in rural areas. The number of people that depended on water from domestic wells was estimated from the 2000 census data (U.S. Department of Commerce, U.S. Census Bureau 2007; Figure PA-20). Each person supplied by a domestic well was assumed to use 60 gallons per day. Total domestic withdrawals for the Highlands region was estimated to be approximately 26 Mgal/d. Areas with the largest domestic withdrawals (greater than 0.5 Mgal/d) are Salisbury Township in Lancaster County, Plumstead Township in Bucks County, Upper Saucon Township in Lehigh County, and Newberry Township in York County. On a county basis, wells in Berks and Lancaster Counties had the most withdrawals for domestic use, with each providing approximately 6 Mgal/d.

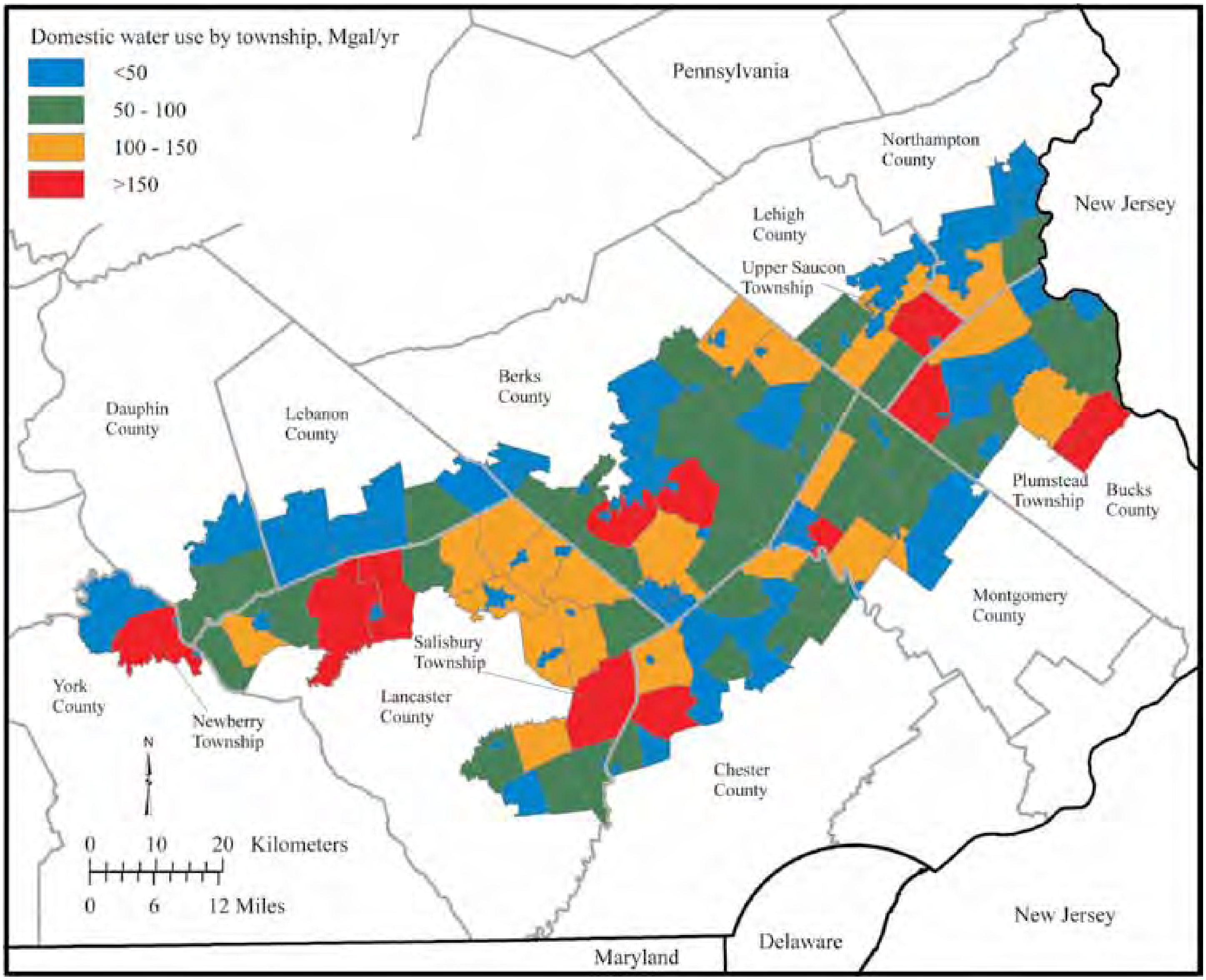


Figure PA-20. Withdrawals from domestic wells by township. *Estimated water withdrawals from the Pennsylvania Highlands in 2000 were greatest in Salisbury Township in Lancaster County, Plumstead Township in Bucks County, Upper Saucon Township in Lehigh County, and Newberry Township in York County (U.S. Department of Commerce 2007).*

Monitoring ground water levels

Water-level data provided important information on how the Highlands ground-water system fluctuated in response to seasonal changes in precipitation, changes in recharge patterns, evapotranspiration, and the effect of ground-water withdrawals. Water levels generally rise in late fall, winter, and early spring when temperatures are lower, evapotranspiration is at a minimum, and recharge is at a maximum from snowmelt and spring rains. Ground-water levels generally decline in late spring, summer, and early fall when evapotranspiration is at a maximum, recharge is at a minimum, and water use is highest.

Figure PA-21 shows hydrographs from four selected U.S. Geological Survey network observation wells in the Pennsylvania Highlands. The hydrographs show typical fluctuations of ground-water levels within the various aquifers of the study area. Ground-water level monitoring data have been measured in two wells since 2001 (one in Lancaster County and one in York County). More long-term ground-water level monitoring data is available from two additional wells in the Highlands region—one operating in Berks County since 1975 and one operating in Bucks County since 1967. The water levels can fall by 5 to 15 feet in the Berks County well. Shallow wells constructed just below the water table could have problems with water yield or go dry during prolonged dry periods.

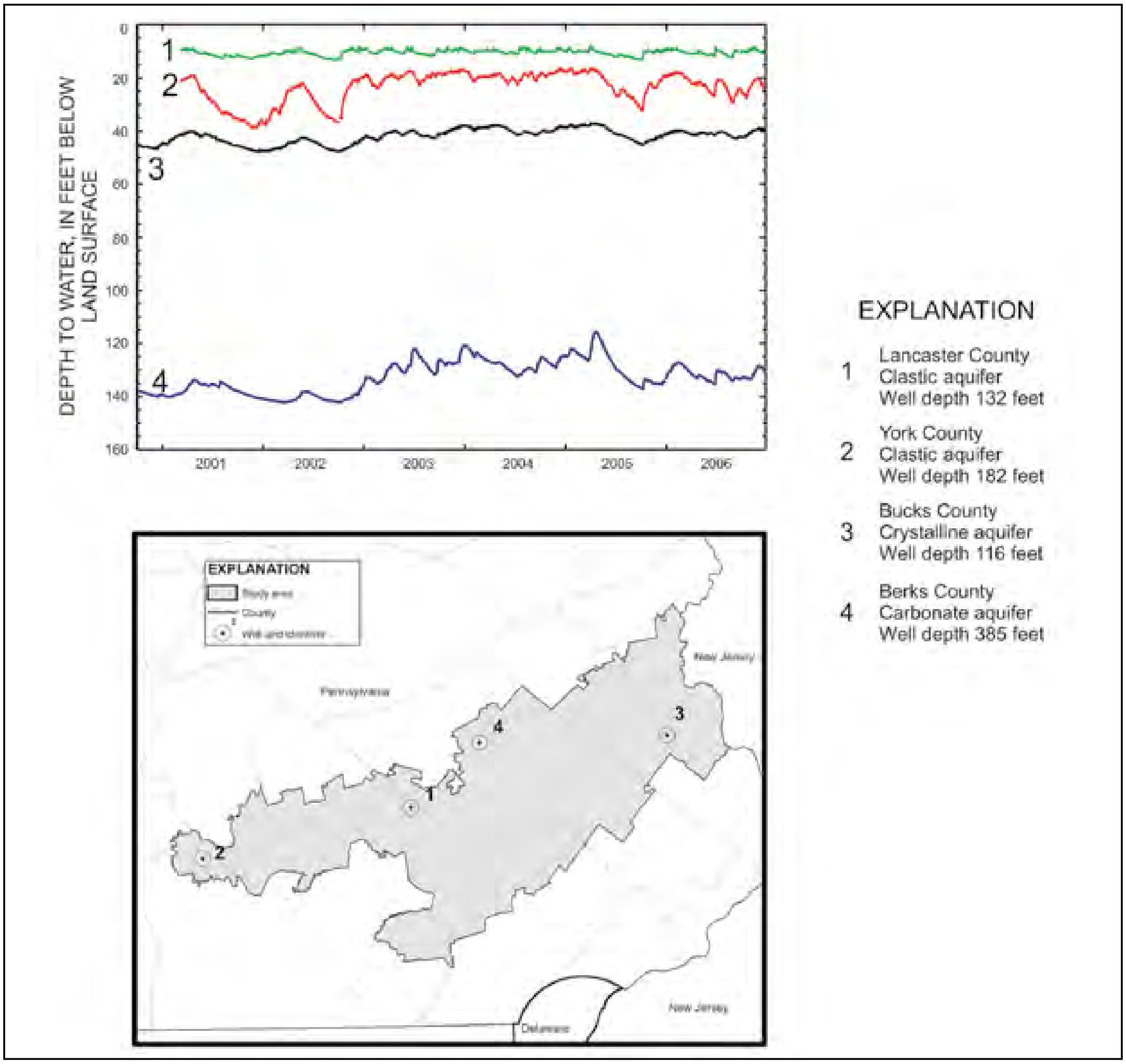


Figure PA-21. Trends in ground-water levels. *Hydrographs for four wells in the Pennsylvania Highlands show typical seasonal fluctuations in ground-wtaer levels. Inset map shows the location of each well.*

Ground water—aquifers and wells—Key findings

- In 2000, more than 107 million gallons of water per day were withdrawn from Highlands aquifers.
- Total nondomestic water use data show that carbonate aquifers are the most productive, with 51 million gallons per day withdrawn. Crystalline and clastic aquifers combined produced approximately 30 million gallons per day.
- Total domestic withdrawals for 2000 are estimated to be approximately 26 million gallons per day.
- Monitoring of ground-water levels at multiple wells shows no long-term declines. Short-term declines of 5 to 15 feet have occurred during drought conditions and could result in reduced yield or dry wells.

Surface water—streams, rivers, and reservoirs

Delaware and Susquehanna drainage basins

The rivers and streams within the Pennsylvania Highlands are contained within two major drainage basins: the Delaware and Susquehanna (Figure PA-22). The Delaware River drainage comprises 65 percent of the region and the Susquehanna River drainage comprises 35 percent. The Schuylkill River drainage comprises 61 percent of the Highlands area in the Delaware Basin. The remainder of the area is comprised of Brandywine Creek in the southern extent, Little Lehigh and Saucon Creeks in the northeastern extent, and direct drainage to the Delaware River in the eastern part of the Highlands region. The major tributaries of the Susquehanna Basin are the Conestoga River, Conewago, Pequea, Octoraro, and Chickies creeks. The Conestoga River drainage encompasses the most area (around 61 percent) in the Susquehanna Highlands drainage.

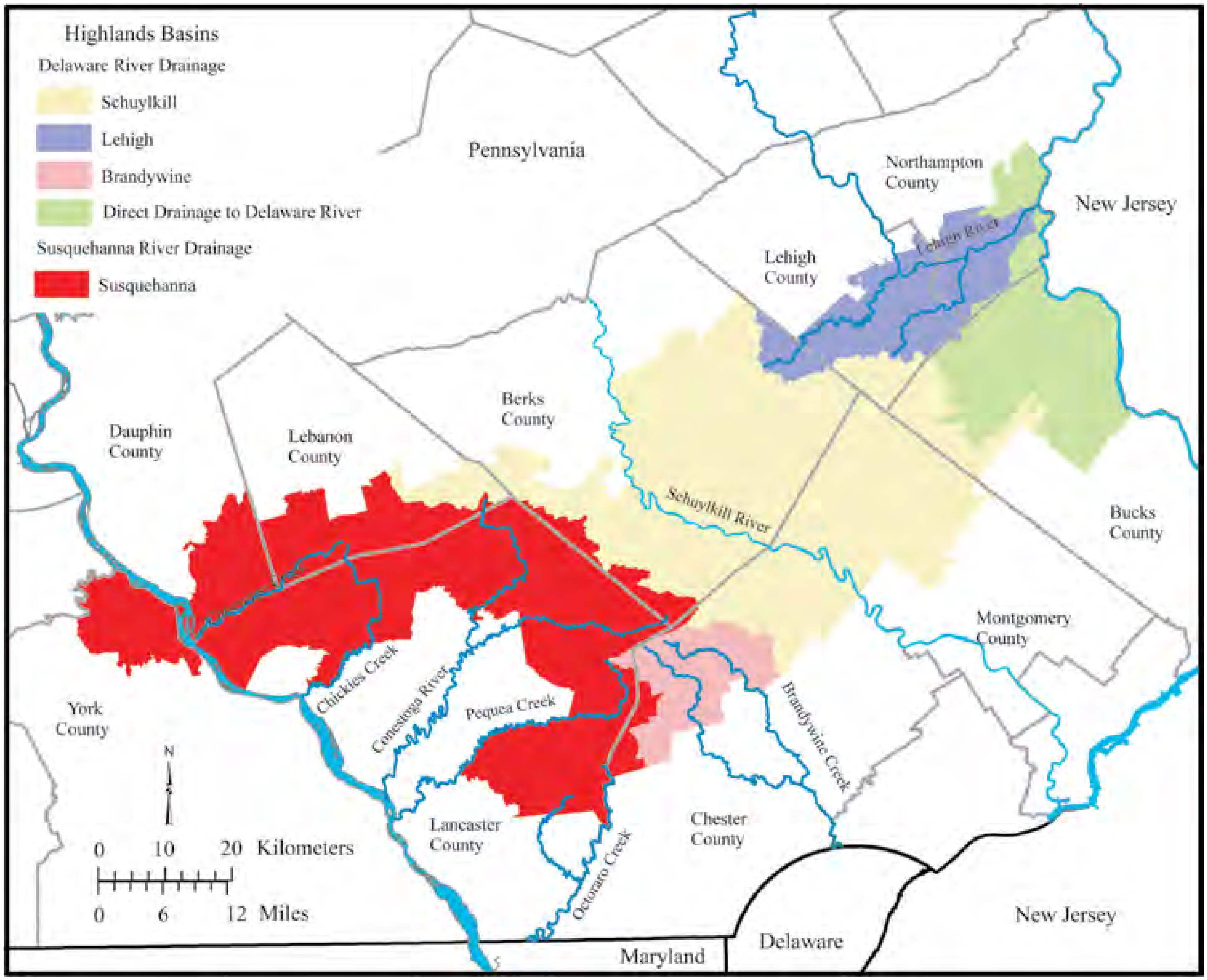


Figure PA-22. Major surface-water drainage systems. Surface water from the Pennsylvania Highlands region drains to the Delaware and Susquehanna River systems. The Delaware River drainage comprises 65 percent of the total Highlands region, and the Susquehanna River drainage comprises 35 percent.

Reservoir storage and conservation release

Seven reservoirs in the Highlands region have substantial storage capacity. The combined capacity is approximately 24.5 billion gallons (Figure PA-23, Table PA-4). These reservoirs have multiple purposes—mainly water supply, recreational use, and maintaining minimum streamflow through conservation releases.

A conservation release is the minimum flow of water from a dam or reservoir that must be maintained at all times in the stream channel immediately downstream of a dam or reservoir (Pennsylvania Department of Environmental Protection 2007). Some releases must be constant throughout the year while others may vary depending on the time of year and reservoir levels. In Pennsylvania, the Department of Environmental Protection's Bureau of Waterways Engineering Division of Dam Safety has the primary authority to set conservation releases. However, other divisions within the Pennsylvania Department of Environmental Protection (DEP), such as Water Use Planning, may request a change in a conservation release as part of the water allocation permit process[6].

[6] Denslinger, Thomas. 2007. Re: Conservation releases in Pennsylvania reservoirs. tdenslinge@state.pa.us. (1 May 2007).

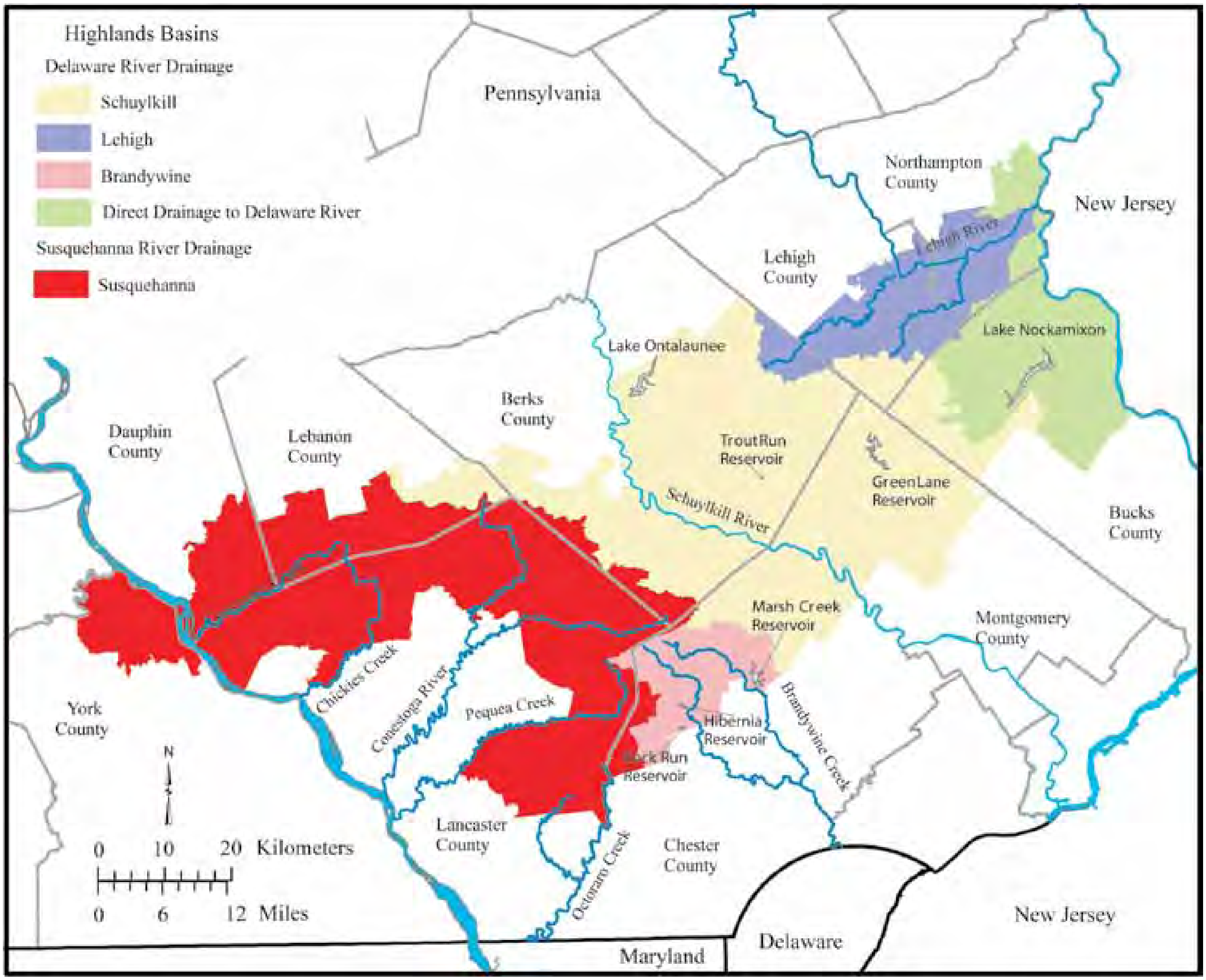


*Figure PA-23. **Major reservoirs.** Seven major reservoirs are located within the Pennsylvania Highlands study area.*

For water supply, water is either withdrawn directly from the reservoir, or the water is released from the reservoir and withdrawn at some point downstream. Water released from the Green Lane Reservoir, withdrawn from Lake Ontelaunee, and pumped to a storage reservoir from Trout Run, supply water to the Highlands region. Hibernia, Marsh Creek, and Rock Run reservoirs are all located on the southern boundary of the Highlands Region. These three reservoirs have conservation releases; water is released and withdrawn downstream, supplying areas that are outside the Pennsylvania Highlands, such as the city of Coatesville. Lake Nockamixon is a recreational-use-only reservoir but has a conservation release to maintain streamflow in Tohickon Creek.

Surface water use

Surface water withdrawals were compiled from USGS estimated use of water in the United States in 2000 (Hutson and others 2004). There were a few notable exceptions: data for the Three Mile Island (TMI) nuclear electric generating station and the Brunner Island coal-fired electric generating facility were not included in the surface-water withdrawal analysis. Although these facilities are within the boundary of the Highlands, the water used by those facilities does not originate in the Highlands. That water is taken directly from the Susquehanna River and is derived from upper basin rivers and streams that are outside the Highlands.

Table PA-4. Type of reservoir, storage capacity, and conservation release. Reservoirs in the Pennsylvania Highlands have substantial storage capacity.

Reservoir	Type	Storage Capacity (billion gallons)	Conservation Release (Mgal/d)	Percent of Upstream Drainage in Study Area
Green Lane	Public Supply, Conservation Release	4.4	11.5	100
Hibernia	Public Supply, Conservation Release	0.4	0.65	100
Lake Ontelaunee	Public Supply, Direct Withdrawal	3.9	0	31
Lake Nockamixon	Conservation Release	13.0	7.1	100
Marsh Creek	Public Supply, Conservation Release	2.1	0.65[1] 1.94[2] —[3]	100
Rock Run	Public Supply, Direct Withdrawal	0.3	0.60	100
Trout Run	Public Supply, Pumped to a reservoir	0.4	0.11	100
Total	—	**24.5**	—	—

[1] Conservation release is 0.65 Mgal/d when flow at the USGS streamflow gauging station, Brandywine Creek at Chadds Ford, PA, (01481000) is 140 cubic feet per second (ft^3/s) or greater.

[2] Conservation release is 1.94 Mgal/d when flow at a surface-water supply intake on the East Branch of Brandywine Creek near Downingtown is less than 23.5 ft^3/s.

[3] Conservation release is based on numerous other regulations when flow at the USGS streamflow gauging station, Brandywine Creek at Chadds Ford, PA, (01481000) is less than 140 ft^3/s.

Table PA-5. Use of surface water. Use of surface water from the Pennsylvania Highlands, by category of use in 2000.

Type of use	Withdrawals (Mgal/year)	Withdrawals (Mgal/day)
Commercial	295	0.8
Electric generation	19,500	53.4
Industrial	1,330	3.6
Mining	35	0.1
Public supply	19,800	54.2
Totals	**40,960**	**112.2**

Mgal = million gallons

Withdrawals were categorized as commercial, electric generation, industrial, mining, or public supply. Highlands surface-water withdrawals for 2000 were estimated at more than 40 billion gallons or 112 Mgal/d (Table PA-5). Public-supply withdrawals accounted for 48 percent of total withdrawals, and electric generation accounted for approximately the remaining surface water use at 48 percent of total withdrawals. The other three categories of use represented 4 percent of the total.

Surface water—Streams, rivers, and reservoirs—Key findings

- Surface-water withdrawals from Highlands reservoirs and streams were approximately 112 Mgal/d in 2000. Public-supply withdrawals accounted for about 48 percent of the total withdrawals, and electric generation accounted for another 48 percent of total surface water

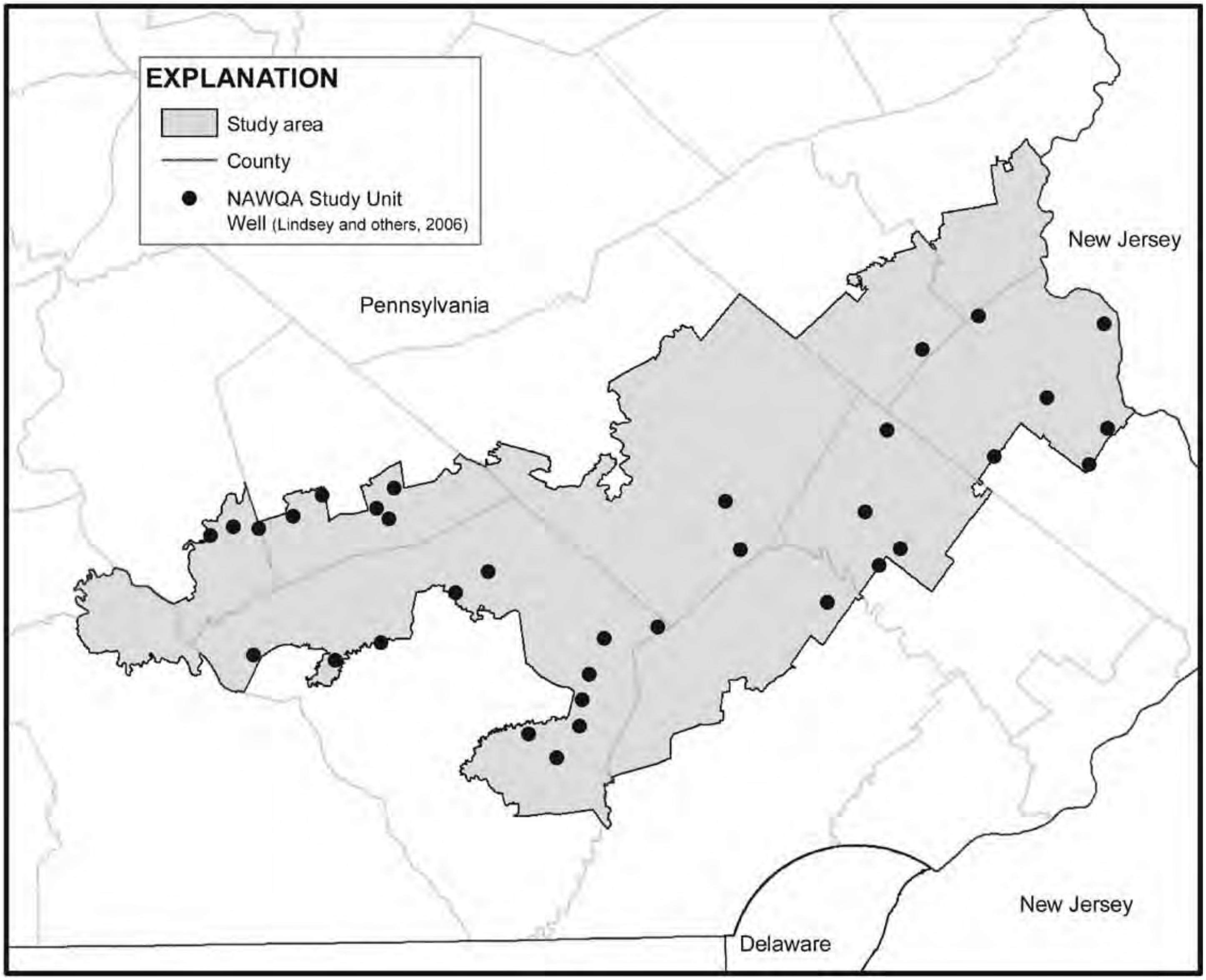


Figure PA-24. Ground water quality sampling sites. Thirty-four National Water-Quality Assessment (NAWQA) Program sites were located within the Pennsylvania Highlands study area.

withdrawals. Commercial, industrial, and mining uses comprised the remaining 4 percent.

- Highlands reservoirs supply water mainly for areas within the Highlands area. The seven reservoirs in the area have a combined storage capacity of approximately 24 billion gallons of water.

Water quality

To assess changes in water quality within the Pennsylvania Highland's region, a review was conducted of previous ground- and surface water-quality studies that had monitoring sites in the study area.

Ground water

Ground-water sampling by the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program from 1993 to 2003 included 34 wells in the Pennsylvania Highlands (Figure PA-24). Lindsey and others (2006) reported the results.

Nitrate

Nitrate was present in nearly all ground-water samples analyzed; concentrations were below 3 mg/L at most of the sites within the Pennsylvania Highlands. Eight of the 34 NAWQA wells in the Pennsylvania Highlands region that were in agricultural land-use areas underlain by carbonate bedrock had concentrations above the U.S. Environmental Protection Agency maximum contaminant limit of 10 mg/L. Nitrate concentrations were positively correlated with the percentage of agricultural land use around the well, the total input of nitrogen from all sources, dissolved oxygen concentration, depth to water, rock type, and soil-matrix characteristics.

Pesticides
Water samples were analyzed for 47 pesticides. No ground-water sample had a pesticide concentration that exceeded any drinking water standard or advisory. Desethyl atrazine (a degradation product of atrazine) was detected most frequently—in more than 45 percent of 251 samples. Atrazine, simazine, metoloachlor, and dieldrin were also frequently detected. Factors such as land use and application rate, depth to water, and percentage of well-drained soils, sand, or silt were positively and significantly correlated with higher pesticide concentrations.

Volatile Organic Compounds
Water samples were analyzed for 59 volatile Organic Compounds (VOCs) were analyzed. No ground-water sample had a VOC concentration that exceeded any drinking-water standard or advisory. Trichloromethane (chloroform) and methyl-tert butyl ether (MTBE) were the most frequently detected VOCs—in more than 10 percent of 206 samples. Chloroform was detected in six of the NAWQA sites in the Pennsylvania Highlands region and MTBE was detected in three. In general, VOC detections were related to well depth and land use. Chloroform and MTBE were positively and significantly correlated with urban land use, leaking underground storage tanks, population density, and well depth.

Radon
Concentrations of naturally occurring radon (radon-222) in groundwater are related to specific bedrock types, or lithologies, due to the source of radon—uranium. Concentrations of radon were highest in crystalline-rock aquifers with felsic mineralogy and lowest in crystalline-rock aquifers with mafic mineralogy. More than 90 percent of 187 samples had concentrations that exceeded the proposed U.S. Environmental Protection Agency maximum contaminant limit of 300 pCi/L (picoCuries per liter) and 13 percent had concentrations that exceeded 4,000 pCi/L, an alternative maximum contaminant level. A radon study in Chester County, PA, reported similar results (Senior 1998).

Trends in ground water quality
A study by Reese and Lee (1999) used ground water quality data to analyze for trends in 35 ground water basins in southeastern Pennsylvania from 1985 to 1996 as part of the DEP ambient ground water monitoring program. Most of the basins monitored were within or adjacent to the Pennsylvania Highlands region. Monitoring near known point sources of contamination was avoided (Pennsylvania Department of Environmental Protection 1998).

Land use and rock type (lithology) affect the direction of water quality trends (Reese and Lee 1999). Upward trends in dissolved mineral concentrations such as chloride, sodium, potassium, magnesium, and calcium may have been due to an increase in urban and residential land uses (developed areas). For example, the application of road salts for winter maintenance in areas with a high density of roads could contribute to higher amounts of salts. Areas underlain by carbonate bedrock were particularly vulnerable to increased concentrations of chloride and sodium.

Downward trends observed in nitrate and sulfate may have been the result of land-use changes from farmland to residential land use. Downward trends in nitrate and sulfate concentrations also could be from improved agricultural practices and sewage disposal systems.

Surface water
To assess changing conditions in surface water quality over time, the Pennsylvania Department of Environmental Protection (2006) analyzed fixed water-quality network (WQN) stations located throughout Pennsylvania during 1995. About 31 of those stations were located in southeastern Pennsylvania either within or adjacent to the Pennsylvania Highlands region. The period of record varied by station, and only stations with at least 5 years of data were used. An upward trend indicated values are generally increasing over time and a downward trend indicated values are generally decreasing over time.

Throughout Pennsylvania, predominantly upward trends were observed for pH, total alkalinity, total hardness, and total dissolved solids in streams. Predominantly downward trends were observed for total sulfate, total nitrite plus nitrate, and total phosphorus. A nearly equal mix of upward and downward trends was observed for total iron, total aluminum, and total manganese.

Sulfate and phosphorus
Downward trends in sulfate and phosphorus were attributed to changes in land use from farmland to residential development in the southeastern part of the state and to improved agricultural practices and sewage-treatment systems. A downward trend in phosphorus also was observed in streams in the Lower Susquehanna River Basin where in addition the trend was attributed to the ban on phosphate detergents (Lindsey and others 1998).

Nitrite plus nitrate
The predominant upward trend in total nitrite plus nitrate observed at the WQN stations in southeastern Pennsylvania differed from downward trends observed statewide at those stations. However, only 7 of 31 the WQN stations had significant trends for total nitrite plus nitrate (6 upward, 1 downward). The majority of WQN stations showed no trend for nitrite plus nitrate. According to Helsel and Hirsch (1992), the fact that no trend was detected does not prove that a trend does not exist; rather, the evidence is insufficient to conclude there is a trend. The Lower Susquehanna River Basin NAWQA study found downward trends in total nitrogen in streams and attributed the decrease to improvements in sewage-treatment systems and agricultural practices (Lindsey and others 1998).

Pesticides
Pesticides were detected more frequently and in higher concentrations in surface water than in ground water in NAWQA studies that included sites in the Pennsylvania Highlands region (Lindsey and others 1998; Fischer and others 2004). Concentrations of pesticides in water from wells and streams rarely exceeded drinking water standards or advisories and were generally less than 1 part per billion. The most commonly detected pesticides were atrazine, metolachlor, simazine, prometon, and alachlor, and cyanzine—agricultural herbicides used primarily on corn (Hainly and others 2001). Pesticides were more likely to be detected in samples from agricultural and urban areas.

Volatile Organic Compounds
The most frequently detected VOCs were trichloromethane (chloroform), a disinfection byproduct of chlorine, and methyl-tert butyl ether (MTBE), a gasoline additive (Daly and Lindsey 1996, Fischer and others 2004). In general, VOCs were more likely to be found in urban watersheds.

Biological indicators
The health of a stream is measured by examining how aquatic communities such as benthic macroinvertebrates and algae respond to changes in water quality. These aquatic communities serve as biological indicators of stream health and are affected by natural and anthropogenic influences that modify habitat or other environmental features such as land use, water chemistry, and streamflow.

A long-term stream water quality monitoring program was established in 1970 by the Chester County Water Resources Authority and the U.S. Geological Survey. A network of sites was established in Chester County, PA from which physical, chemical, and biological data were collected from 1981 to 1997 to assess stream conditions and determine trends (Reif 2002). Chester County is only partially in the Pennsylvania Highlands region and only 10 of the 43 sites were in the Highlands. Sites in the Pennsylvania Highlands were among those assessed as nonimpacted with stable physical and chemical data during the 17-year study period. The areas with the poorest water quality were outside the Pennsylvania Highlands region.

Reif (2002) also tested for trends in the biological metrics from 1981 through 1997 at the 43 sites. Trends in Chester County indicated unchanged or improving stream conditions at most of the sites. The improvements in stream health could be due to such factors as upgraded wastewater-treatment plants, improved farm-management procedures, and land use change from agricultural to suburban.

A study done as part of the National Water-Quality Assessment (NAWQA) Program in the Delaware River Basin surveyed water chemistry, physical conditions, and ecological communities at 28 sites in the Philadelphia metropolitan area and 21 sites in the Pocono plateau region during 2000 (Fischer and others 2004). The effects of urbanization were compared by dividing watersheds into categories ranging from minimally to highly urbanized. The study showed decreases in biological indicators of healthy streams, such as mayflies, caddisflies, and stoneflies, and increases in chemical indicators of human activity with increases in percentage of urban land use (Fischer and others 2004). The decline in biological indicators may be the result of multiple disturbances that include chemical inputs from point and nonpoint sources, loss of habitat, and alterations of natural flow regimes.

Water quality—Key findings

- The natural ground water within the Highlands is of good quality for most uses. Samples did not exceed drinking water standards or advisories for nitrate, pesticides, or volatile organic compounds.
- Elevated ground-water nitrate concentrations have been attributed to agricultural land use around the well, the total input of nitrogen from all sources, dissolved oxygen concentration, depth to water, rock type, and soil-matrix characteristics.
- Pesticide occurrence in ground water is related to source factors such as land use and application rate, and transport factors such as depth to water and percentage of well-drained soils, sand, or silt.
- VOCs in ground water are related to well depth and land use.
- Chloroform and methyl tert butyl ether (MTBE) were detected most frequently and were positively and significantly correlated with urban land use, leaking underground storage tanks, population density, and well depth.
- Elevated concentrations of naturally occurring radon-222 are common in Highlands' ground water, particularly from crystalline aquifers.
- Many Highlands' streams show improving conditions since 2000. Decreases in sulfate, phosphorus, and nitrate may be may be the result of land-use changes from farmland to residential and improved agricultural practices and sewage treatment plant upgrades. The decrease in phosphorus also is attributable to a ban on phosphate detergents.
- Pesticides (herbicides and insecticides) were detected more frequently and in higher concentrations in Highlands' surface water than in ground water, but rarely did levels approach drinking water standards or health advisories.
- Sampling of Highlands' streams indicate comparatively healthy aquatic macroinvertebrate populations due to stable physical and chemical data during a 17-year study period.

Human population and housing

Description

In the 2002 census, the population in the Pennsylvania Highlands was 1,216,700 (GeoLytics 2004).[7] Population and housing in the Highlands region are growing dramatically faster than in the State as a whole. From 1970 to 2000, the rate of Highlands' growth increased from 8.4 percent to 11.1 percent.

While growth in the Highlands out-paced that in the State, the region does not include the fastest growing counties in Pennsylvania. From 1970 to 1990, the population in the Highlands increased 33.1 percent, by an additional 302,500 persons, compared with only a 4.1 percent increase in the entire State. Population growth increased from 0.8 percent per year in the 1970s to 1.1 percent per year in the 1990s, and population density increased from 423 to 563 people per square mile. Estimates for 2005 were that the Pennsylvania Highlands had a population of 1,437,800—an 18 percent increase from 2000 (Figure PA-25).

Pennsylvania's Highlands region includes 173 municipalities, ranging in size from one-tenth of a square mile to almost 50 square miles, and from a population of under 250 to over 100,000 and parts of ten counties. The northwestern portion of the Highlands, near the older cities of Bethlehem and

[7] All US Census data were derived from a CD produced by GeoLytics, a company that packages U.S. Census data for ease of analysis.

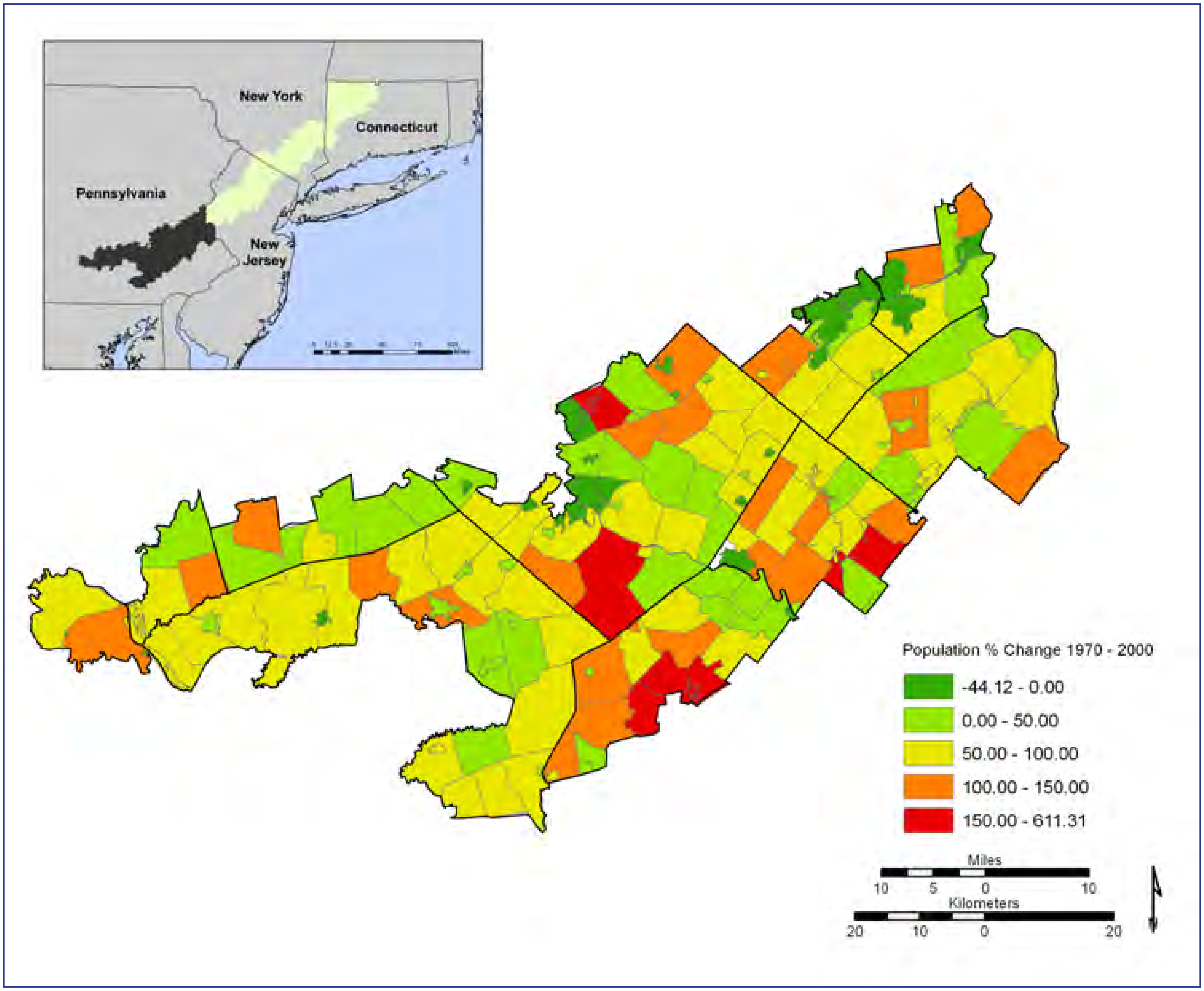


*Figure PA-25. **Population growth**. Population growth and percent change by township, in the Pennsylvania Highlands, 1970 – 2000.*

Allentown, had significantly lower population and housing growth than did the rest of the Highlands. The least-populous and most-populous municipalities have decreased in population size over the last 30 years, while the mid-sized municipalities all grew significantly between 1970 and 2000. Upper Uwchlan was the leader, with a 611-percent increase, or 5,887 more people in a municipality that had a population just under 1,000 in 1970. Allentown, Bethlehem, Easton, Reading, and Ontelaunee were among those municipalities that decreased in population during the same time period (Figure PA-25).

Bethlehem, Allentown, and Reading lost population during the 1970s, but Bethlehem and Allentown gained slightly during the 1980s, and Allentown and Reading gained slightly during the 1990s. Boroughs with fewer than 600 people lost 20 percent of their population, on average. Cities with over 70,000 people lost about 5 percent, on average. The majority of municipalities in the middle range are townships. Average population growth of such places ranged from 35 to 60 percent over the three decades. While all of the counties in the Pennsylvania Highlands gained in population between 1970 and 2000, Lehigh and Northampton gained the least, and the portion of York County that falls within the Highlands border gained the most (Figure PA-26). Most new growth was in the townships, which have the space for housing tracts and other extensive urban development.

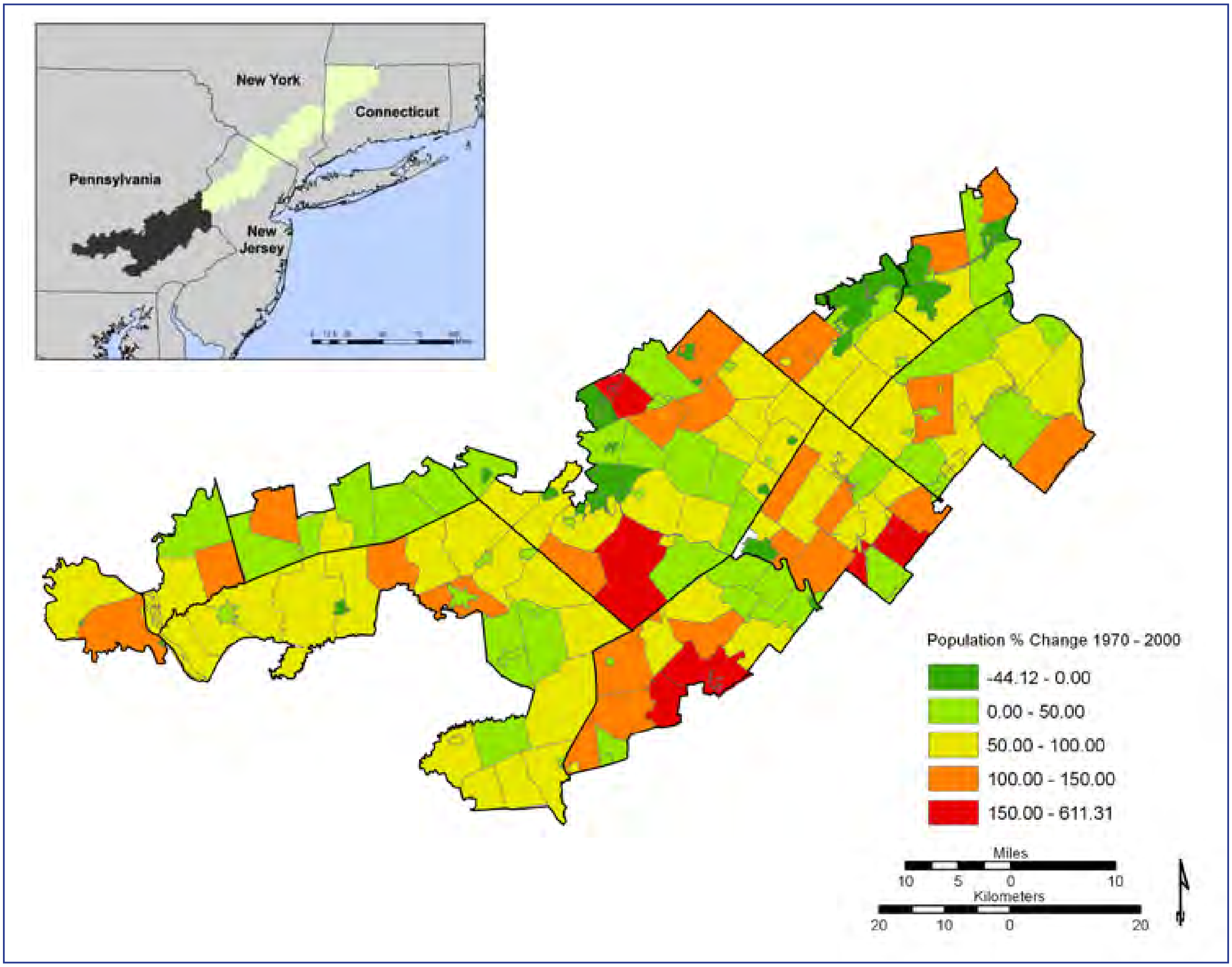


Figure PA-26. Population change. *Percent change in population between 1970 and 2000, by county. Only the portions of counties within the Pennsylvania Highlands are shown. Compare Figure SOC-13, which includes entire counties.*

A map of eastern seaboard counties from Virginia to Massachusetts and New York shows that the counties of the Pennsylvania Highlands are exhibiting low-to-average growth compared with surrounding areas. The Pennsylvania Highlands are surrounded on three sides by very high population growth, sprawling out from New York City, Philadelphia, and the Washington, DC, metropolis (Figure PA-27).

With an additional 180,600 new housing units, housing in the Pennsylvania Highlands has increased at a much higher rate than housing in the state of Pennsylvania as a whole. From 1970 to 2000, housing increased 60 percent in the Highlands and only 34 percent in Pennsylvania (Table PA-6). The increase in housing was greater than the increase in population; fewer people are living in each house, on average. In 1970, the average number of people per house was more than 3, while in 2000 the average number was closer to 2.5. The population is aging; the population of 30- to 40-year olds and those over 65 is growing much faster than the population under 30. From 1970 to 1990, housing grew much faster than the population did, with fewer people living in each household by 1990. This ratio has remained stable at about 2.6 people per household.

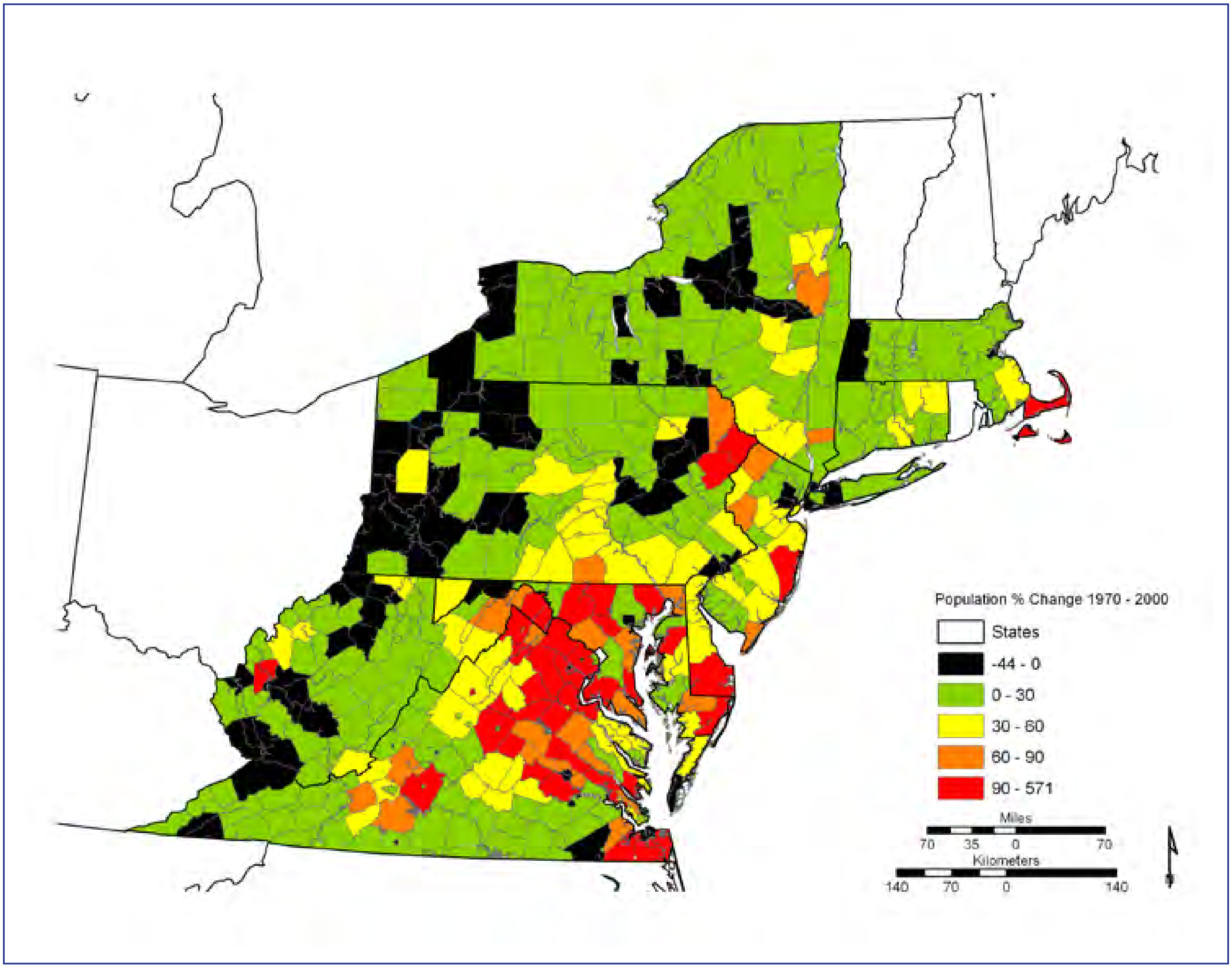


Figure PA-27. Population growth, by county. *Population growth for counties on the U.S. eastern seaboard from Chesapeake Bay to Cape Cod. Note: Data are for entire counties; compare Figure SOC-12, which includes only the portions in the Highlands. In most counties the Highlands portion is growing faster than the county as a whole.*

Table PA-6. Housing unit growth. *Housing unit growth in the Pennsylvania Highlands was almost twice that for the State of Pennsylvania between 1970 and 2000.*

Pennsylvania	1970	1980	Percent change 1970 - 1980	1990	Percent change 1980 - 1990	2000	Percent change 1990 - 2000	Percent change 1970 - 2000
Highlands	300,613	367,978	22.4	424,103	15.3	481,225	13.5	60.1
State	3,924,757	4,596,431	17.1	4,938,140	7.4	5,249,750	6.3	33.8

Human population and housing—Key findings

- In the 2000 census, the Pennsylvania Highlands had a population of 1,216,725, representing just 10 percent of the State.
- Population and housing in the Highlands region is growing much faster than in the state as a whole.
- Population density increased from 423 to 563 people per square mile between 1970 and 2000.
- The population of 30- to 40-year olds and those over 65 years old are growing much faster than the population under 30 years old.
- From 1970 to 1990, housing grew much faster than population did, with fewer people living in each household by 1990; this ratio has remained stable since 1990, at approximately 2.6 people per household.

Part 4. Growth and impact analysis

Land use trends

Zoning build-out analysis

Methods

A build-out analysis was conducted to estimate for the year 2030 the extent and configuration of future residential land use if all developable lands were built upon, based on current zoning regulations. The build-out analysis determines the quantity and density of new structures, and helps assess possible future consequences in terms of population growth and increased impervious surface, which could negatively affect water quality. It shows the worst case scenario whereby all available land is built-up with residences according to current zoning ordinances. The analysis was restricted to detached single-family residential growth; all nonresidential uses were excluded from the analysis. The residential build-out analysis was conducted using a geographic information system (GIS). This analysis will provide information about how well current municipal zoning regulations fit into larger regional or State plans for the Highlands region.

The build-out analysis was done under two conditions, referred to as the low-constraint and the high-constraint scenarios, in which different levels of environmental protection of sensitive areas limit the amount of land available for development (Table PA-7). The only legal constraints to development are permanently protected open space and Federal wetlands regulations, some of which have a direct effect on the amount of land available for development. Most municipalities within the region, however, have zoning guidelines for protection of sensitive environmental areas, particularly riparian areas, wetlands, and steep slopes. These constraints are not necessarily written into zoning regulations, or if they are, they are considered guidelines, not hard and fast restrictions.

The *low-constraint* scenario is "business as usual," with minimal restrictions on development. The low-constraint scenario assumes that already-developed land, protected land, land where zoning does not permit residential uses, water bodies, floodways, wetlands, and slopes greater than 25 percent cannot be developed.

Table PA-7. ***Build-out constraints.*** *Constraints used to limit the build-out model for the Pennsylvania Highlands under the low- and high-constraint scenarios.*

Low-Constraint Scenario	High-Constraint Scenario
Protected open space public or private conservation ownership or easement	Protected open space public or private conservation ownership or easement
Water bodies	Water bodies
Floodway FEMA delineation	Floodway + 100 year floodplain FEMA delineation
No riparian buffer	100-ft wide riparian buffer
Wetlands National Wetland Inventory + hydric soils	Wetlands National Wetland Inventory + hydric soils
No wetland buffer	50 ft wide wetland buffer
Slopes greater than 25 percent	Slopes greater than 15 percent

The *high-constraint* scenario uses a high standard for protecting environmentally sensitive areas. The high-constraint scenario assumes already developed land, protected land, land where zoning does not permit residential uses, water bodies, floodways, floodplains, wetlands, lands within 100 feet of streams and water bodies, lands within 50 feet of wetlands, and slopes greater than 15 percent cannot be developed.

Results

In 2000, 52 percent of the Pennsylvania Highlands was zoned for residential use (Figure PA-28). An additional 25 percent is zoned for agriculture, which allows for single family housing. Thirteen percent of the land is zoned as protected open space. At least 16 percent is currently in protected open space either through conservation easements or by virtue of being in public ownership.

Under the low-constraint scenario, about 65 percent of the land in the Pennsylvania Highlands potentially was available for new development. The low-constraint build-out analysis estimated 499,677 new single family residential units and 1.39 million new residents based on the current average number of persons per housing unit across the Pennsylvania Highlands. This development would create 170,889 additional acres of impervious surface, and increase housing in the region by 108 percent and population by 115 percent (Figure PA-29, Table PA-8).

Under a high-constraint scenario, about 54 percent of the land in the Pennsylvania Highlands potentially was available for new development. The high-constraint build-out analysis estimated 431,621 new single family residential units and 1.2 million new residents, based on the current average number of persons per housing unit across the Pennsylvania Highlands. This total was accompanied by 142,259 additional acres of impervious surface, and would increase housing in the region by 93 percent and population by 102 percent (Figure PA-30).

Chester, Lancaster and Lebanon counties are expected to have more new residential development in the Highlands than the other counties (Figure PA-31). This result is based on an index that compares the new development in each county (as a percent of total Highlands new development) to the county's portion of the Highlands area. In other words, the part of Chester County that is in the Highlands is expected to have more residential development than would be expected given how much of the Highlands is in Chester County.

Figure PA-28. Residential development. Aerial view showing examples of single-family detached residential development. (Photo by Joel Stocker, University of Connecticut)

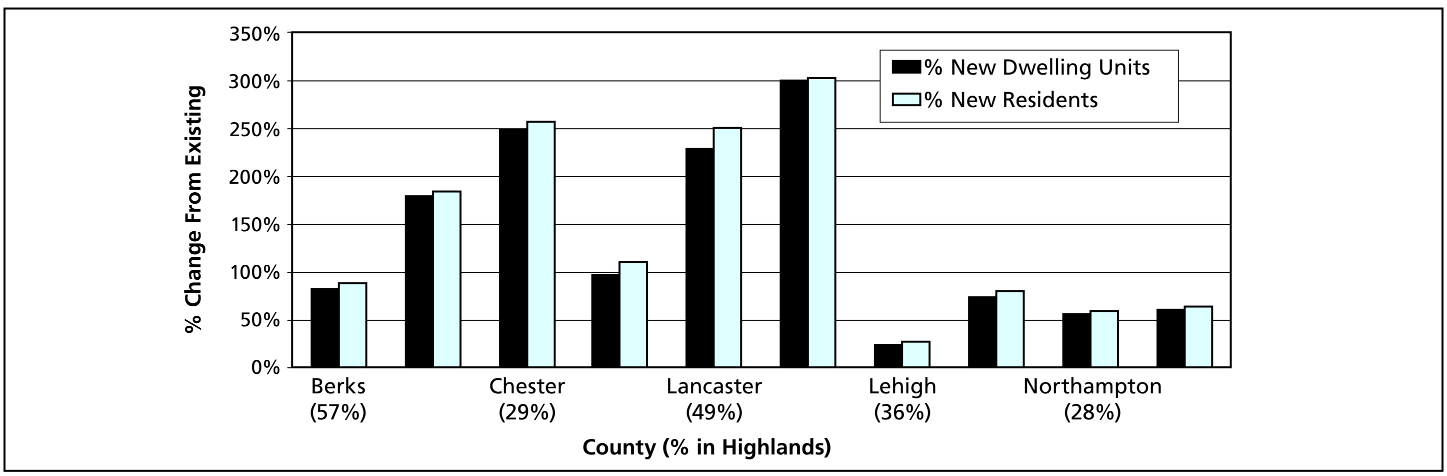


Figure PA-29. Low-constraint results. New units and population projection under the low-constraint scenario of the build-out analysis for the Pennsylvania Highlands.

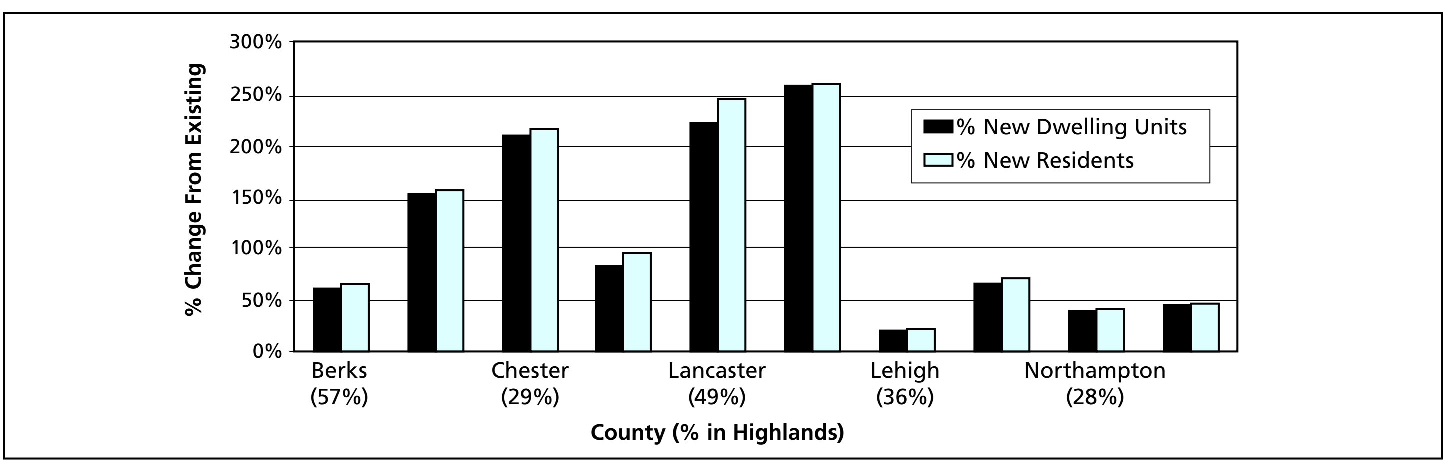


Figure PA-30. High-constraint results. New units and population projection under the high-constraint scenario of the build-out analysis for the Pennsylvania Highlands.

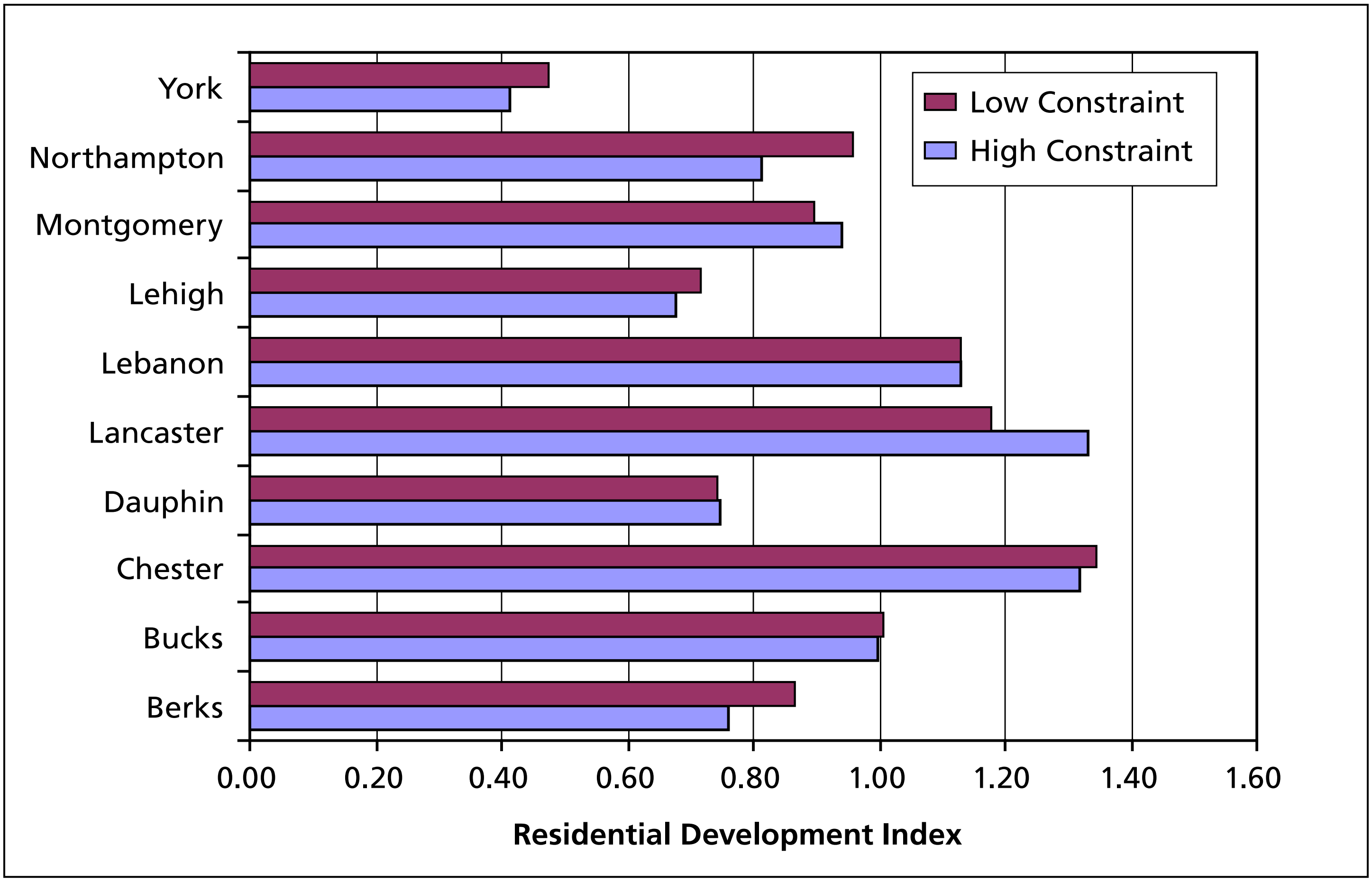


Figure PA-31. Residential development index under low- and high-constraint scenarios. *The development index is the ratio of each county's share of new development to the county's share of the Pennsylvania Highlands. An index of less than 1 indicates the county is expected to have less than its share of the Highlands development; an index of more than 1 means the county is expected to have more than its share of Highlands residential development.*

Table PA-8. Build-out analysis results. *Zoning build-out analysis results for the Pennsylvania Highlands under low- and high-constraint scenarios, by dwelling units, residents, and acres of impervious surfaces*

Build-out scenario	Buildable acres	Single-family dwelling units			Residents			Acres of new impervious surface
		Actual 2000	Additional under zoning build-out	Percent new units	Actual 2000	Additional under zoning build-out	Percent new residents	
Low constraint	596,207	461,833	499,677	108	1,216,725	1,393,741	115	170,889
High constraint	498,401	461,833	431,621	93	1,216,725	1,241,952	102	142,259

Several of the counties within the Pennsylvania Highlands have area-wide plans that set out a vision for future land use. In aggregate, these plans place an emphasis on conservation of open space and farmland. The plans of Lehigh and Northampton counties go further and emphasize preserving floodplains and wetlands, and minimizing environmental impacts of development on steep slopes (Lehigh Valley Planning Commission 2005). The goals set forth by these plans are consistent with the high-constraint build-out scenario, which allows for compact conservation-oriented development patterns.

Zoning build-out analysis—Key findings

- Fifty-two percent of the Pennsylvania Highlands is zoned for residential use, mostly in 1 to 2-acre lots. An additional 25 percent is zoned for agriculture, which allows for single family housing.
- Total potentially developable land is about 596,200 acres under a low-constraint scenario and 498,400 acres under a high-constraint scenario.
- The low-constraint scenario, representing a low standard for protecting environmentally sensitive areas, would increase housing in the region by 108 percent and population by 115 percent.
- The high-constraint scenario, representing a high standard for protecting environmentally sensitive areas, would increase housing in the region by 93 percent and population by 102 percent.

Analysis of land use and land cover change

The Pennsylvania Highlands is predominantly an agricultural and pastoral landscape. About half the land is in open agricultural fields, grass, or turf; about a third is in forest or wetlands; and the remaining 15 percent is urban. Visual comparison of land use, land cover, and elevation maps reveal that most forested land is found at higher elevations, along the ridges, areas that were historically hard to farm. Urban and agriculture land uses are found predominantly at lower elevations.

Methods

Three methods were used to assess land use and land cover change between 1992 and 2001, to provide different perspectives on landscape dynamics. (1) Using the National Land Cover Dataset (NLCD) change product, we quantified the area of seven land cover categories at three levels of stratification; (2) Using data aggregation, we condensed the seven classes into three categories to evaluate large-scale shifts in land cover; and (3) using Digital Aerial Photographs, we produced estimates of active agricultural land vs. development-associated grasses, such as large lawns, athletic fields and golf courses.

Results

The aggregate results indicate that the acreage of land altered by humans has increased while unaltered land has decreased (Figure PA-32). According to the NLCD Land Cover Change Product, the largest shifts between classes in the 9 years between 1992 and 2001 involved agriculture, forest, and urban land. According to the analysis, agriculture is the most prevalent land use and land cover type in the Pennsylvania Highlands, followed by forest and then urban. Forest cover is relatively stable over the 9-year period while agriculture is decreasing in acreage and urban land is increasing. An in-depth analysis of agricultural cells in the NLCD Land Cover Change Product, using aerial photography, indicates that the agriculture class contains on average 21 to 25 percent urban grasses (such as lawns or turf). The amount of area in these "development-associated grasses" grew by an estimated 12 to 15 percent between 1992 and 2001, with an increase somewhere in the range of 16,500 to 21,500 acres. Farmland decreased by 8 to 12 percent, with a loss in the range of 46,000 to 54,000 acres.

This detailed analysis of agricultural lands, which included comparison of randomly selected samples from the NLCD data with comparable time period aerial photography, supports the assumption that urban area is increasing faster than indicated by the NLCD Land Cover Change Product classification. Therefore, the total developed area likely increased within a range of 32,000 to 37,000 acres from 1992 to 2001, which is between a 9 and 10 percent increase over the 9-year period.

These dynamics vary across the landscape. Development is occurring more rapidly and to a greater extent in Berks, Lancaster, and Montgomery counties. In general, this development occurs near roads and previously developed areas. Bucks County, on the other hand, which is closest to the New York–New Jersey metropolitan area, had the least amount of new development (Figure PA-33).

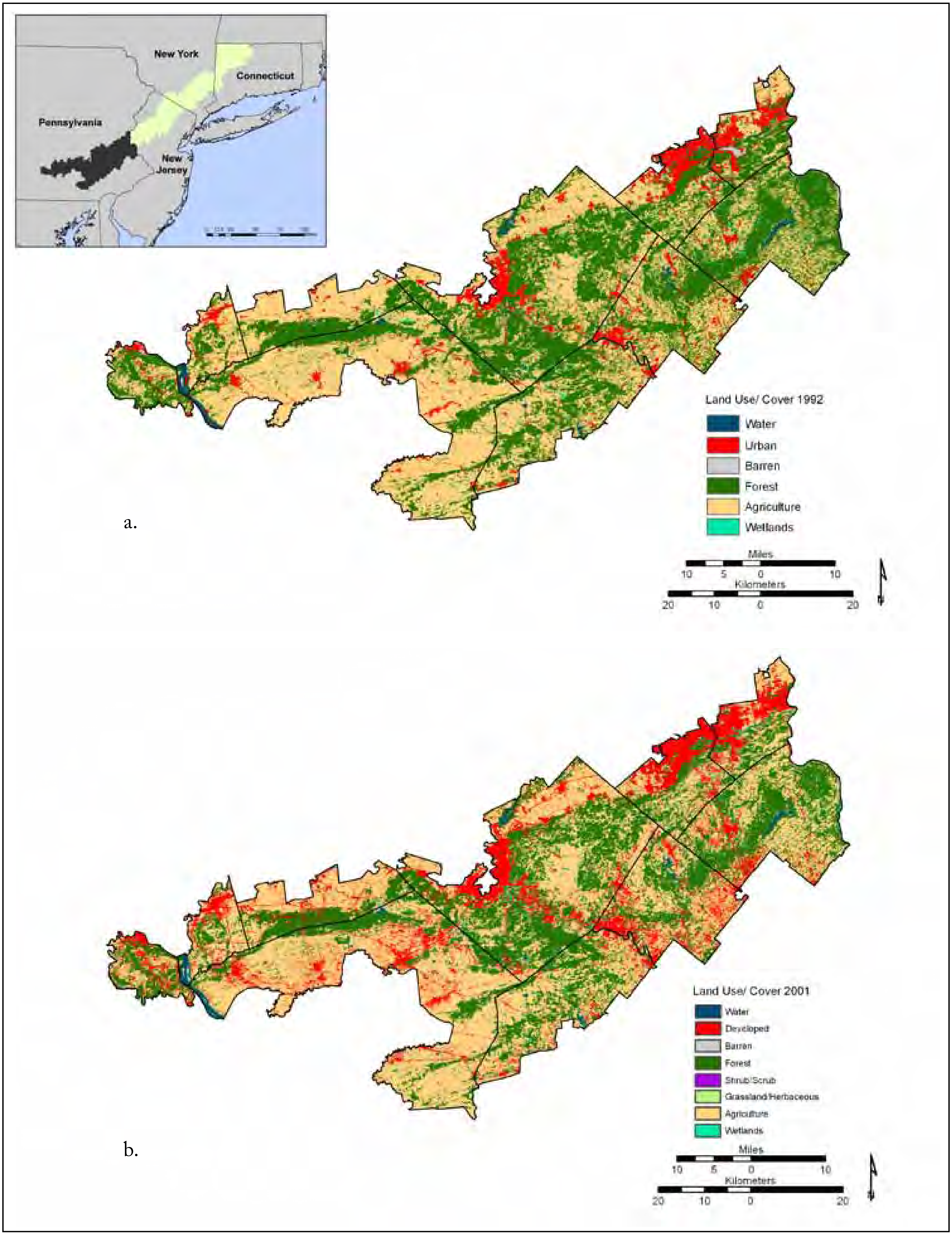


Figure PA-32. Land use change. *Land use and land cover in the Pennsylvania Highlands in 1992 (a) and 2001 (b).*

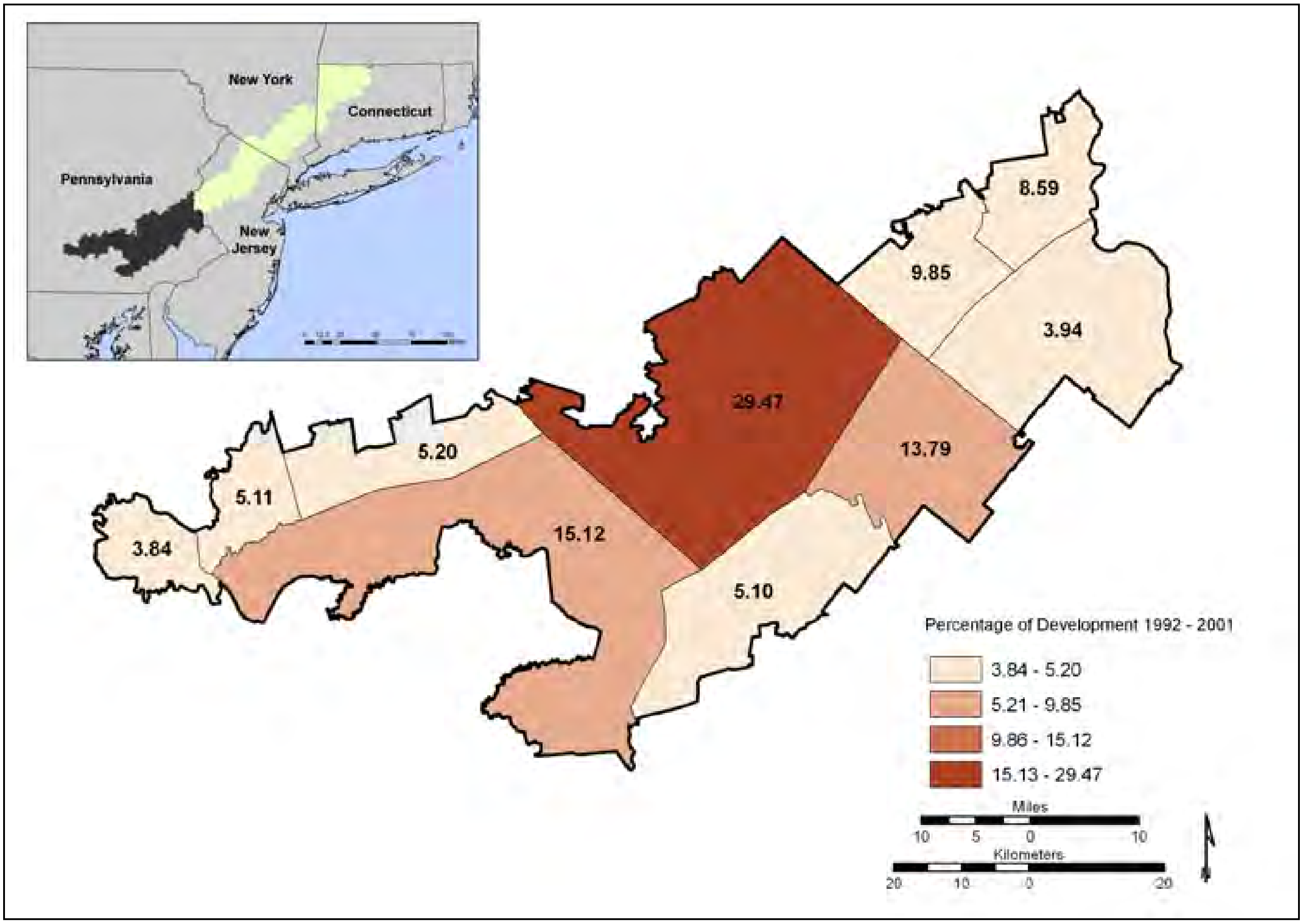


*Figure PA-33. **Change in regional development, by county.** Percentage of total development in the Pennsylvania Highlands region that occurred between 1985 and 2002.*

Table PA-9 shows urban land cover over the 9-year period; the proportion of development by county in the Highlands varied greatly from 1992 to 2001. This does not include development-associated grassy areas.

As Table PA-10 shows, housing and population grew faster than developed land use.

Analysis of land use and land cover change—Key findings

- Sixteen percent of the Highlands is in conservation ownership; most (68 percent) of the conserved land is in public ownership.
- More than half of the protected lands in Pennsylvania are considered highest conservation value according to the Conservation Value Assessment.
- Only 31 percent of the highest value land in Pennsylvania is currently conserved.
- The Pennsylvania Highlands is changing from an agricultural and pastoral landscape to one where development, agriculture, and forestland are interspersed. About one-third of the land is in agricultural fields; a third is in forest or wetlands; a third is developed, grass, or turf.
- Developed land use increased by 32,000–37,000 acres (9–10 percent) between 1992 and 2001.
- Development is occurring more rapidly and to a greater extent in Berks, Lancaster, and Montgomery counties. In general, this development occurs near roads and previously developed areas.
- Housing and population grew faster than did developed land use from 1992 to 2001.
- Development has occurred mostly on farmland.

Table PA-9. ***Urban land cover change.*** *Proportion of development by county in the Pennsylvania Highlands, from 1992 to 2001.*

County	Area with urban land cover in the Pennsylvania Highlands						Share of Highlands development 1992-2001 (percent)
	1992		2001		Change		
	Acres	Percent	Acres	Percent	Acres	Percent	
Berks	43,524	13.7	47,929	15.1	4,405	10.0	29.5
Bucks	13,678	8.0	14,267	8.4	589	4.3	3.9
Chester	9,482	6.8	10,244	7.3	762	8.0	5.1
Dauphin	8,597	18.9	9,361	20.6	764	8.9	5.1
Lancaster	36,105	11.7	38,365	12.4	2,260	6.3	15.1
Lebanon	9,633	11.7	10,411	12.7	778	8.1	5.2
Lehigh	25,969	32.5	27,442	34.3	1,473	5.7	9.9
Montgomery	24,086	18.6	26,147	20.2	2,061	8.6	13.8
Northampton	23,059	34.4	24,343	36.3	1,284	5.6	8.6
York	8,254	19.1	8,828	20.4	574	6.9	3.8
Highlands	202,387	14.6	217,336	15.7	14,949	7.4	100

Table PA-10. ***Housing, population, and land-use change.*** *Increase in housing, population, and urban land cover in the Pennsylvania Highlands in the 1990s.*

Characteristic	Time period	Increase (percent)	Source
Population	1990 – 2000	11	GeoLytics 2004
Housing	1990 – 2000	14	GeoLytics 2004
Urban land cover	1992 – 2001	7	U.S. Geological Survey n.d.
Total developed land	1992 – 2001	9 – 10	This study

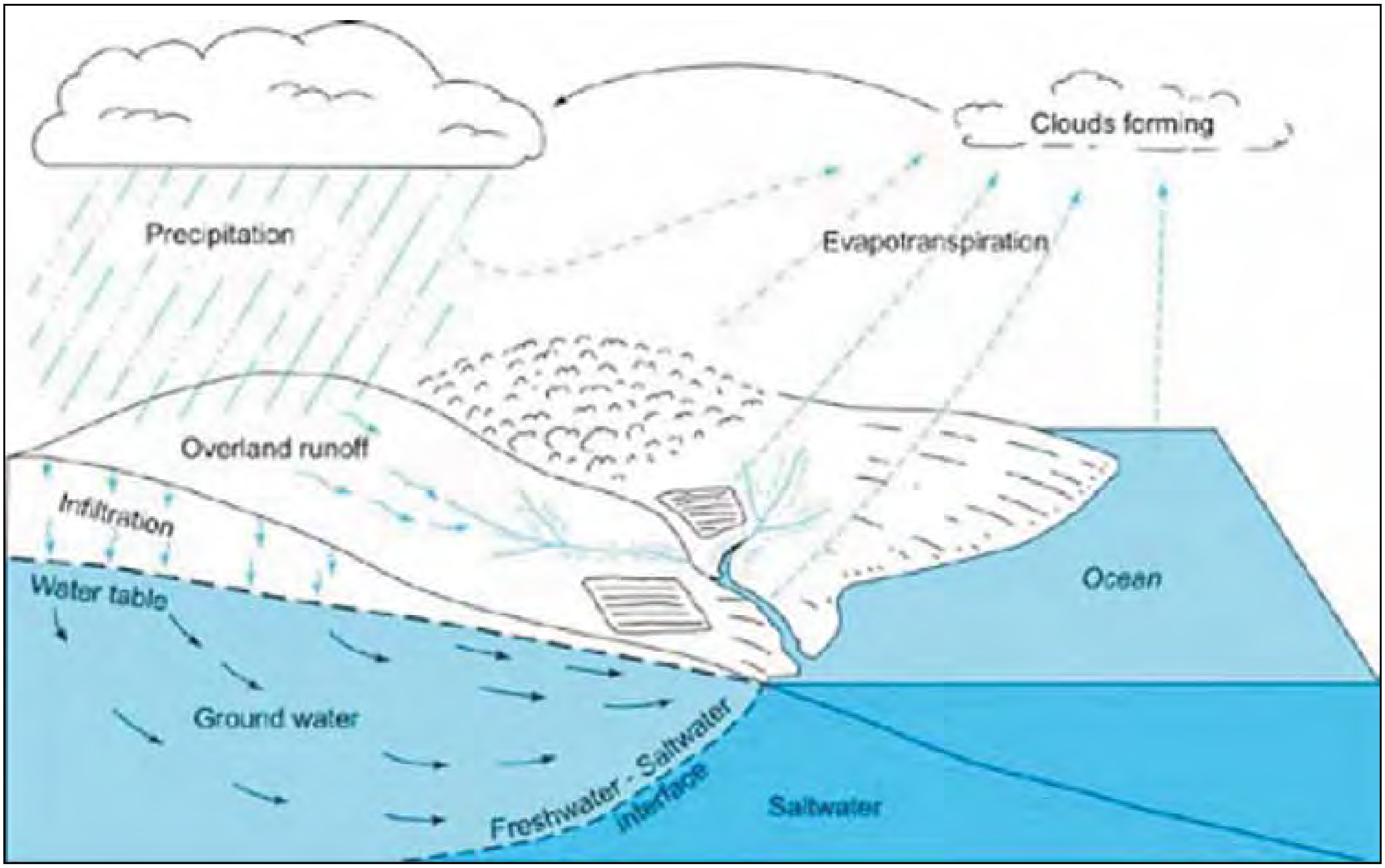


Figure PA-34. ***Hydrologic cycle.*** *The constant movement of water above, on, and below the Earth's surface constitutes the hydrologic cycle. Precipitation runs over the land surface and into streams, which discharge into the ocean. Some precipitation infiltrates into the ground-water system and discharges to streams or the ocean. Transpiration and evaporation return water to the atmosphere, completing the cycle (modified from Heath 1983, p. 5).*

Water budget

A water budget is a valuable tool in understanding how human activities can alter the natural cycle and availability of water in the Highlands. The water budget considers all water, both surface and ground, entering, leaving, or stored within a watershed. Each component of the hydrologic cycle (Figure PA-34)—precipitation, infiltration, overland runoff, evapotranspiration, and ground and surface water withdrawals—can be assigned a value in order to create a water budget.

Analysis at a regional scale

A water budget for the Pennsylvania Highlands region provides a basis for understanding the magnitude and function of the various budget components (Figure PA-35). The primary source of water to the Pennsylvania Highlands region is precipitation, which averages about 44 inches annually when averaged over the entire study area. This amount is equivalent to receiving 4,559 Mgal/d of water over the 2,159 square miles of the Pennsylvania Highlands region. Of the total precipitation, an estimated 2,469 Mgal/d evaporates from land or water surfaces or transpires from vegetation; these components are typically combined and referred to as evapotranspiration. The remainder of the precipitation infiltrates into the ground (1,337 Mgal/d) and recharges ground water, or runs off the land surface (710 Mgal/d) to surface-water sources during storms or snowmelt. The ground water in turn discharges to streams, which is known as stream baseflow, and generally equals the amount of water infiltration or recharge into the ground. Stream baseflow is responsible for maintaining flow in streams even during prolonged dry periods. Therefore, natural streamflow out of the Highlands region is a combination of ground-water discharge to streams (baseflow) and direct overland runoff and totals 2,047 Mgal/d.

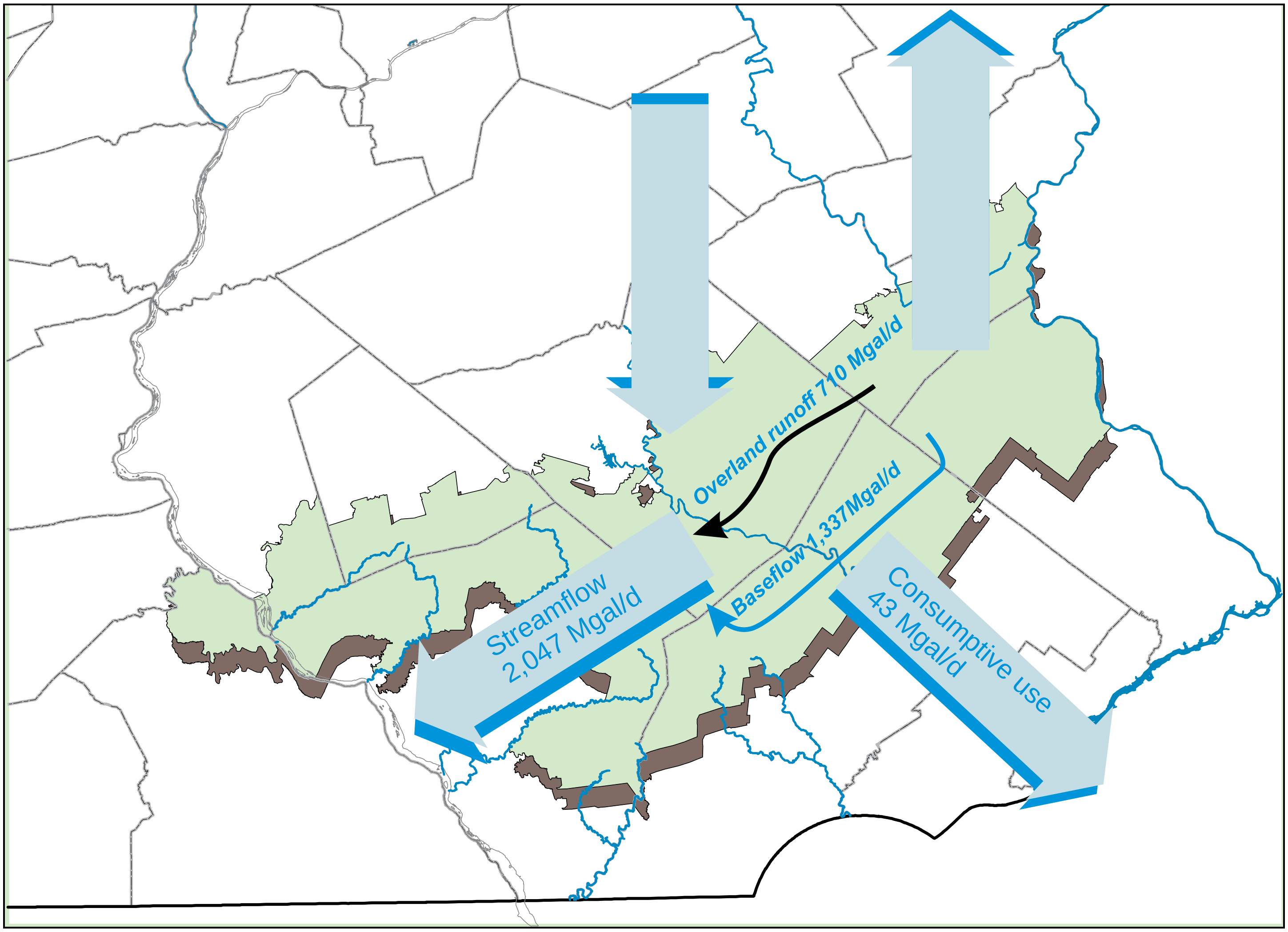


__Figure PA-35. Regional water budget.__ The water budget considers all water, both surface and ground, that enters and leaves the region. On an average annual basis, the Pennsylvania Highlands receive about 44 inches of precipitation, which is the equivalent of 4,559 million gallons per day (Mgal/d) over the study area. About 45 percent (2,047 Mgal/d) of this water leaves the region via streamflow. An estimated 54 percent (2,469 Mgal/d) is lost to evapotranspiration, and about 1 percent (43 Mgal/d) is consumptive water use that is not returned to Pennsylvania Highlands watersheds.

Human activities can add to or take away from evapotranspiration, infiltration, baseflow, and runoff. Consumptive use of surface and ground water amounts to an estimated 43 Mgal/d removed from the overall Pennsylvania Highlands water budget. This amount is based on 20 percent of the region's ground-water use (21 Mgal/d), and 20 percent of surface-water withdrawals (22 Mgal/d) for use within the Highlands.

Analysis at a watershed scale

The amount of precipitation that falls on Pennsylvania Highlands does not vary much across the region. An example of how the major water budget components are influenced by annual fluctuations of precipitation in the Pennsylvania Highlands region is shown graphically in Figure PA-36. Annual mean streamflow for a period of 32 years, recorded at a gauging station on Manatawny Creek near Pottstown, PA, is shown with local annual precipitation for the period. Approximately one-half of the precipitation that falls on the watershed leaves it as stream discharge. Most of the remainder leaves the basin as evapotranspiration. A similar relationship exists over most of the Pennsylvania Highlands region.

Changing streamflow characteristics are strong indicators of changing watershed conditions. Of particular importance in water budget analyses are the two components of streamflow—baseflow and runoff. At the Manatawny stream gauge (Figure PA-36), baseflow makes up about 68 percent of total stream discharge and runoff makes up the remaining 32 percent. The percentage of these two components

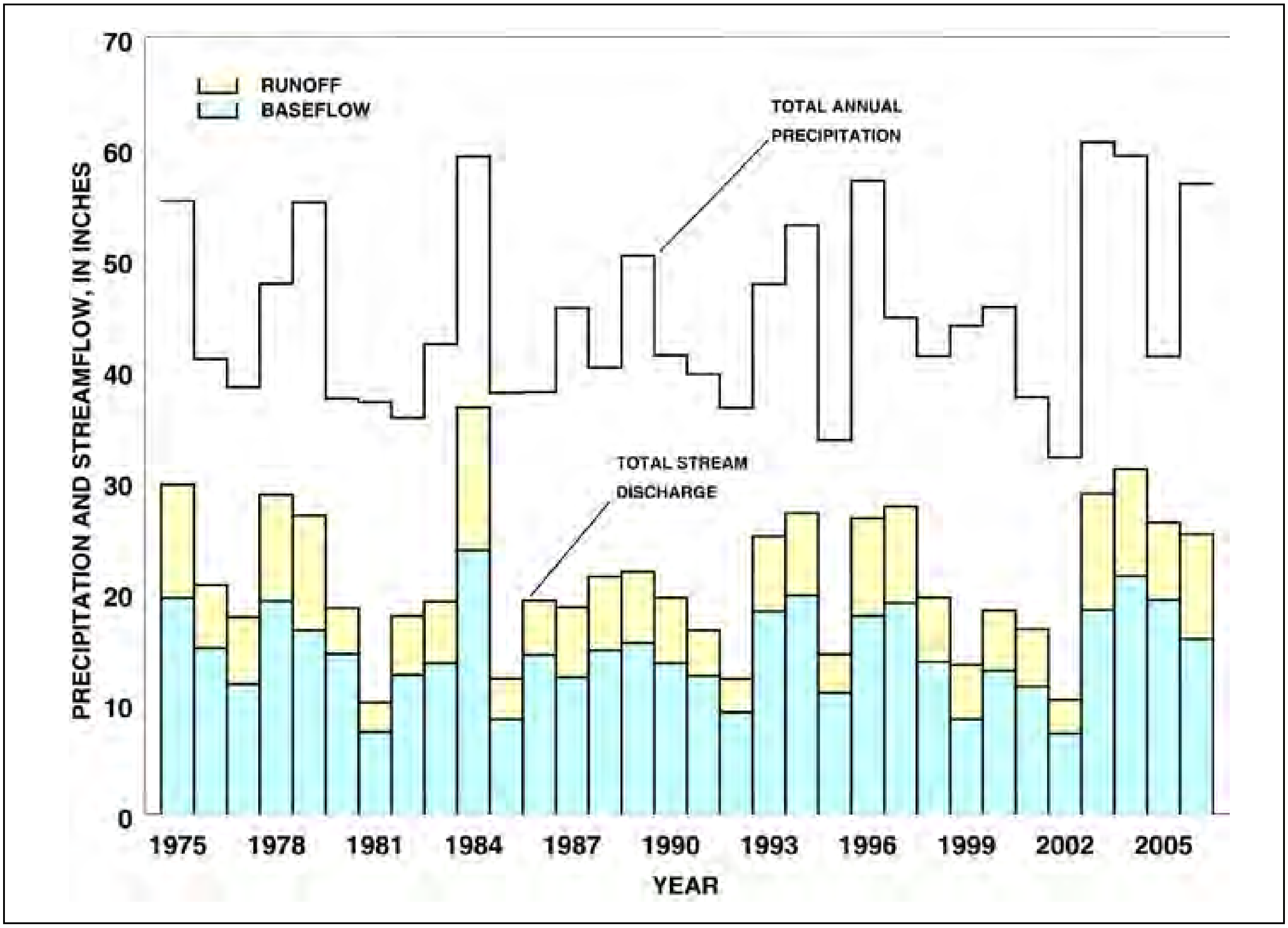


*Figure PA-36. **Relationship between precipitation and streamflow.** The direct relationship of annual precipitation to stream discharge for the Manatawny Creek near Pottstown, PA, is representative of most of the Pennsylvania Highlands. Approximately one-half of the precipitation that falls on the watershed leaves as stream discharge. As precipitation increases total discharge increases, but the percentages of the components of total streamflow (baseflow and runoff) vary only slightly.*

varies only slightly over the period of record. However, baseflow and runoff characteristics of streams vary from watershed to watershed and are important indicators of dependable ground and surface-water yields and changing hydrologic conditions. Baseflow and runoff can be modified by land-use changes that reduce recharge to ground water by increasing surface runoff. These changes can include increases in impervious cover such as new buildings, paving, soil compaction, and results of other human activities.

Model simulation

To evaluate existing conditions and potential changes to watershed hydrology based on future development scenarios (see Part 4. Growth and impact analysis, Land use modeling, for methods), a computer simulation model was used. The model was developed by the U.S. Geological Survey expressly for estimating water budgets at a subwatershed scale in the Pennsylvania Highlands. The model incorporates detailed climatic, topographic, geologic, landcover, and soils data, and it is calibrated to existing long-term stream gauge data. Using this data, processes of the hydrologic cycle are simulated, and individual components of the water budget are derived. In this way water budget information can be estimated where measured data do not exist.

The modeled area totals 3,050 square miles which is 42 percent larger than the 2,150 square miles within the Pennsylvania Highlands boundary. The modeled area is larger due to the necessity that the model boundaries fall on natural watershed boundaries and the choice of scale to define individual watersheds—14-digit

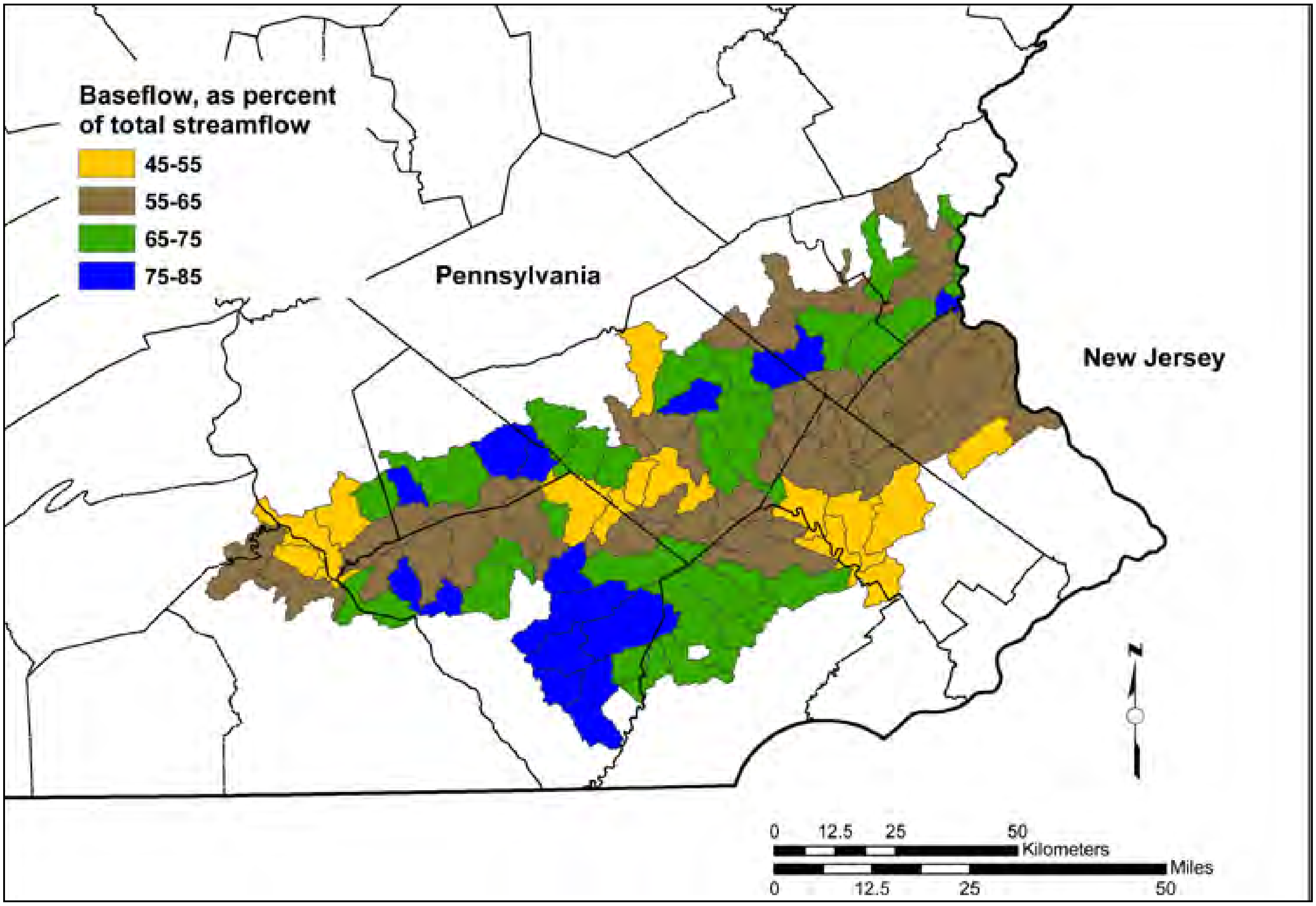


Figure PA-37. Variations in baseflow by subwatersheds. The percentage of total streamflow that is baseflow was calculated from model-generated water budgets for each 14-digit Hydrological Unit Code subwatershed in the Pennsylvania Highlands, using 1986 – 2001 average climate and impervious surface data. The highest baseflow percentages are generally associated with those basins that are underlain with the highest percentage of carbonate rock.

hydrologic unit codes (HUC) are formally called subwatershed units. An HUC series (from 2-digit through 14-digit) establishes the nominal size of the area bounded by the HUC. The nominal size for a 14-digit-HUC watershed is typically between 15 and 60 square miles but not less than 5 square miles. In the Pennsylvania Highlands, 14-digit-HUC subwatersheds have an average area of about 32 square miles and a maximum area of 66 square miles. There are 95 14-digit-HUC subwatersheds either wholly or partially within the Pennsylvania Highlands area.

The percentage of total streamflow that is baseflow was calculated from model-generated water budgets for each 14-digit-HUC subwatershed using the 1986-2001 average climate and impervious surface data (Figure PA-37). Model results indicate that, on average, baseflow comprised 65 percent of total streamflow over the Pennsylvania Highlands region during that period. The proportion of baseflow in a stream is strongly dependent on the geology, soils, and impervious cover (or land use) in that watershed.

The geology of the southeastern Highlands area consists of shales and sandstones of low permeability. In conjunction with moderate to high degrees of development, this area yields baseflow percentages of less than 55 percent. Other areas where baseflow accounts for less than 55 percent of streamflow are the more urbanized areas such as the Harrisburg metropolitan area near the extreme western end of the Highlands.

High baseflow percentages are found in areas with carbonate rocks especially those having sinkholes and well-developed solution channels. There greater percentages of available precipitation, aided by the presence of sinkholes, infiltrate rather than run off.

Solution channels provide high ground-water storage capacity and high yields to baseflow. Baseflow accounts for more than 80 percent of total streamflow in many of the watersheds along the northern and southwestern boundaries of the Pennsylvania Highlands.

In addition to providing an evaluation of existing conditions, model-generated water budgets are useful for evaluating the potential effects of future land use change, development and water withdrawals on water resources, as described in Part 4 of this report, titled Growth and impact analysis, Land use modeling.

Water budget—Key findings

- Regionally, the Highlands study area receives about 4,559 Mgal/d of water from precipitation. The Highlands loses about 45 percent or 2,047 Mgal/d from river and stream outflows and about 1 percent or 43 Mgal/d from consumptive water use. An estimated 54 percent or 2,469 Mgal/d is lost by evapotranspiration.
- On a watershed scale, the amount of precipitation does not vary much geographically across the region. Precipitation ranges from about 42 to 45 inches per year.
- A watershed model used to simulate streamflow characteristics and provide water budgets for 95 14-digit-HUC subwatersheds indicates that, on average, baseflow comprises 65 percent of streamflow over the Highlands study area.

Land use modeling

Modeling future land use change

Methods

The goals in modeling land use change were to:

- Understand the factors that have contributed to both the rate and the spatial distribution of land use change in the region;
- Create a map of development suitability (risk) showing the places most vulnerable to change after 2001 in Pennsylvania, based on those factors that have made land historically attractive for development;
- Use that map of development suitability to project where development is most likely to occur before 2022.

The model used to predict where future development is likely to occur is described in more detail below. The GIS-based growth model, called GEOMOD, that was used for this study tests the assumption that spatially explicit factors that correlated with development in the past are good predictors of where future development is likely to occur. In this report, the term "suitable" means areas that are historically preferred for development, and "suitability" maps show where these areas exist across the landscape.

The model determines the rate of historical land use conversion, extrapolates that rate into the future, and—most importantly—simulates the location of future land use change based on statistical analysis of the historical pattern. The model tested more than 120 spatially distributed data sets to find those that described best where development had occurred historically.

To project development forward in time GEOMOD requires a map representing spatial variability in development suitability, and the model needs to know how much land to develop in a given time. All projections for the future are based on the actual data for 2001 for Pennsylvania. The projection horizon was set to the year 2022. A separate development rate was calculated for each stratum (e.g., town, county or region) by dividing the map into smaller units.

Future land use was projected out to 2022 on a map using three different rates and three development constraints (none, low, and high). Cells were selected based on their rank within their town for future land use projection because it consistently yielded the best match to the 1995-2002 development pattern during model validation.

Results

In Pennsylvania, the study team compared each of four suitability images with the observed pattern of development in the time period that followed, i.e., the validation time period. To do this the study team divided the suitability values of each map into 100 intervals and looked for the proportion of cells within each interval that became developed in the validation time period. As the suitability value increases one would expect to see an increase in the proportion of cells that became developed.

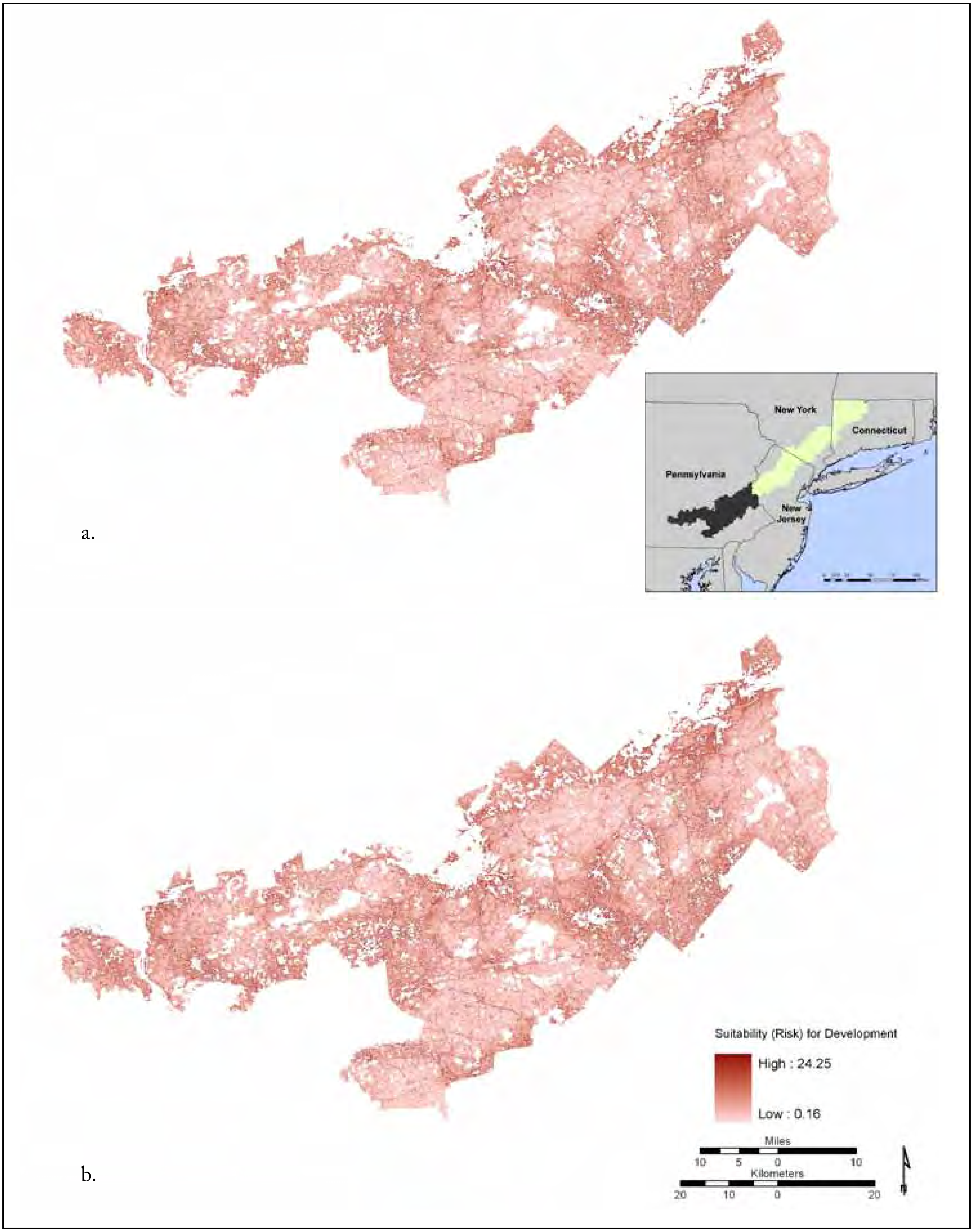


Figure PA-38. Suitability map, 2001. *Suitability (development risk) using the stratified (by county) approach (a), and non-stratified (regional) approach (b), Pennsylvania Highlands.*

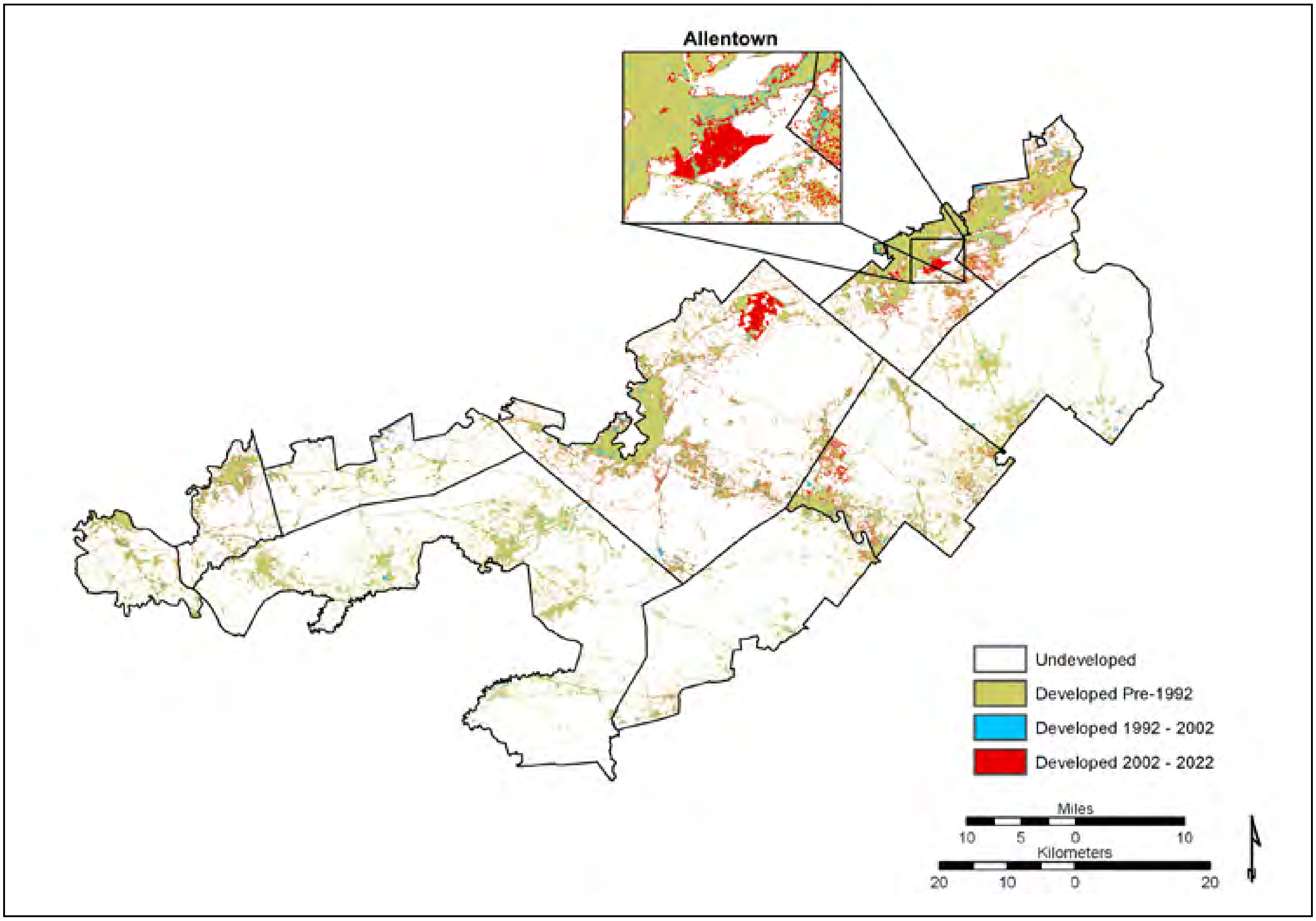


Figure PA-39. Development risk. *Projected development in the Pennsylvania Highlands in 2022 under no constraints and using the county-stratified suitability map. The inset provides a close look at the pattern of development in the area around Allentown.*

The factors that best predicted where development occurred in the past within each county, using the stratified (county) approach, were proximity to (1) roads, (2) existing development, (3) contiguous land use, and (4) employment in the construction sector (Figure PA-38a).

For the non-stratified (regional) approach, the factors that were best able to predict where development occurred were proximity to (1) existing development, (2) roads, (3) railroad lines, (4) urban centers, and (5) bedrock geology (Figure PA-38b).

Future land use was projected out to 2022 using three development constraint levels (none, low, and high), with development allocated by county. The suitability map stratified by county was selected because it had the best "fit" to the validation data compared to the non-stratified regional approach (Figure PA-39).

Berks (30 percent), Lancaster (15 percent) and Montgomery (14 percent) counties, in that order, comprised 59 percent of the growth in the region between 1992 and 2001, and projections extrapolate these empirical rates forward (Table PA-11). The remaining counties account for less than 10 percent of the growth each, with York County accounting for the least (4 percent).

Using the historical rate, 39,260 acres of new development would be added between 2001 and 2022. Projected development followed a similar pattern under all three constraint scenarios. The relatively high weights given to factors related to existing development caused new development projected to 2022 to cluster around road features and previously developed areas in all scenarios.

Table PA-11. Projected new development. *Rate of development and estimate of developed area in the Pennsylvania Highlands in 2022, using linear extrapolation of trends from 1992 to 2001.*

County	Acres of New Development in 2022	Increase from 2001 (percent)	Area Developed by 2022	
			Acres	Percent
Berks	10,613	22	58,542	18
Bucks	2,285	16	16,552	10
Chester	2,145	21	12,389	9
Dauphin	2,052	22	11,413	25
Lancaster	6,379	17	44,744	14
Lebanon	1,919	18	12,330	15
Lehigh	3,518	13	30,960	39
Montgomery	5,191	20	31,338	24
Northampton	3,632	15	27,975	42
York	1,525	17	10,353	24
Total	39,259	18	256,595	19

Table PA-12. Projected land use. *Acres and percent change for different types of land use in the Pennsylvania Highlands, 2001 – 2022, based on business as usual, and low- and high-constraint scenarios.*

Land Use	2001 base	2022 projected business as usual			2022 projected low constraint			2022 projected high constraint		
	Acres	Acres	Change		Acres	Change		Acres	Change	
			Acres	Percent		Acres	Percent		Acres	Percent
Urban	217,336	259,144	41,808	19.2	259,144	41,808	19.2	259,144	41,808	19.2
Agriculture and Grasses	666,423	636,510	–29,913	–4.4	635,404	–31,019	–4.7	633,967	–32,456	–4.9
Forest	444,726	435,968	–8,758	–2.0	435,793	–7,933	–1.8	437,971	–6,755	–1.5
Wetlands	27,202	25,449	–1,703	–6.3	25,758	–1,444	–5.3	26,024	–1,178	–4.3

In the business as usual scenario: open spaces protected by public or private conservation ownership or easement, and water bodies are not subject to change. For low- and high-constraint scenarios, limitations are the same as those that apply to the build-out model. The acres changed do not add up to zero due to new development projected to occur on previously barren lands.

In Pennsylvania, development is projected to occur almost entirely on agricultural land (Table PA-12). Urban land use and land cover is expected to increase by 41,800 acres (19.2 percent) over 22 years at the 1992–2001 historical rate of growth. This does not include development-associated grasses, as information was insufficient to model changes in this land use over time. So it is a conservative estimate. As more environmental constraints are imposed on development in sensitive areas, particularly riparian buffers, then development is pushed farther away from forests and wetlands on to agricultural lands.

Modeling future land use change—Key findings

- The factors that were best able to predict where development occurred within each county were…
    - Proximity to roads, existing development, and contiguous land use; and
    - Employment in the construction sector.
- The factors that were best able to predict where development occurred within the region were...
    - Proximity to existing development, roads, railroad lines, and urban centers; and
    - Bedrock geology.
- Using the historical development rate, there would be 39,260 acres of new development plus an estimated 43,200 acres of development-associated grasses by 2022.

Impacts of land use change on the land

In addition to using a GIS-based growth model, another way to estimate the effect of development on resources is to find measurable indicators of resource integrity. Any index of resource integrity for this study has to be measured spatially, since the model is a spatial model. A simple statistical measure (percentage) of the acreage of altered vegetation over time is one way to estimate changes in resource integrity. How much of the altered landscape is likely to be covered by impervious surfaces in the future is another measure with implications for stormwater impacts and stream health. The ecological effects of vegetation change are many and can be measured several ways. Diminished or fragmented forest blocks impact forest and animal ecology, and affect biodiversity. Alteration of forested riparian corridors affects stream ecology and has deleterious impacts on water quality. The loss of prime agricultural soils is a resource impact with potential long-term costs.

To characterize the impacts of human activity on the landscape of the Highlands, eight indicators were used to measure how development and land use change have altered the natural landscape:

1. Altered land—percentage of land in altered state (all land uses except forest, wetland, and water)
2. Impervious surface cover—percentage of land covered by impervious surface
3. Riparian corridors (wide)—percentage of riparian area in altered land use within 295 feet (90 meters) of stream corridors
4. Riparian corridors (narrow)—percentage of riparian area in altered land use within 100 feet (30 meters) of stream corridors
5. Forest fragmentation (location)—the percentage of land covered by interior forest (patches larger than 25 acres, and more than 295 feet from an edge)
6. Forest fragmentation (size)—the percentage of land covered by largest forest patch
7. Forest fragmentation (ratio)—the perimeter-to-area ratio (sum of the perimeters of all forest patches divided by the area of all forest patches), which is an indicator of edge amount relative to interior forest.
8. Farmland soils—percentage of important farm land soils (prime farm land or farm land of statewide importance) in developed land use

Regional level

According to the National Land Cover Dataset (NLCD) Change Product, percent interior forest increased slightly between 1992 and 2001. This result could be an artifact of the problems with classifying land use from satellite imagery along forest and agricultural edges, as it is unlikely that there were more large forest patches in 2001 than in 1992. Perimeter-area ratio decreased, which can happen when small parcels get developed, or when development happens along the edges of forests, essentially smoothing out the edges.

The percent developed prime farmland and impervious surface increased slightly over the same time period. Over half of the riparian buffers have been cleared of natural vegetation (forest or wetland); however, the percent of buffers in altered land use declined from 1992 to 2001. This positive trend reflects some amount of revegetation of riparian buffers.

Overall, estimates of all measures (except forest perimeter:area ratio) in year 2022 under the three development projection scenarios indicate that anthropogenic impacts will increase somewhat from 2001 levels. Development of 25,800 acres is projected to occur on farmland, with a resulting increase in impervious surface of almost 10,000 acres.

County level

In 1992, the greatest impacts of land use and land cover change were confined to three counties: Lancaster, Dauphin, and Northampton. In 2001, Lancaster and Northampton counties had the highest impacts. As would be expected, overall the indicators are positively related to development with higher impact measures generally more likely in more densely developed areas.

In all counties, anthropogenic impacts were projected to increase in all measures, except forest perimeter:area ratio by 2022. In all three development scenarios (no constraints, and low and high constraints), the greatest and least impacts according to the eight indicators are projected to be distributed across the counties in the exact same pattern as they were in 2001. This is because the model followed the historical pattern of projecting development in proximity to areas that were already developed.

Watershed level

In both 1992 and 2001, the greatest impacts were measured in the same two watersheds—Little Conestoga Creek and Jordan Creek. The least impacts in 1992 and 2001 were measured in four watersheds: Delaware River Tributaries had the lowest percent altered land; Paunnacussing Creek had the lowest percent impervious surface coverage, developed prime farmland, and altered riparian areas (295 ft); French Creek was the least impacted as measured by percent interior forest and percent coverage of largest forest patch; and Cocalico Creek had the lowest forest perimeter-to-area ratio.

In all watersheds, estimates of all measures (except forest perimeter-to area-ratio) in year 2022 under the three development projection scenarios indicate that anthropogenic impacts will increase from 2001 levels. In all three development scenarios, the greatest and least impacts are projected to be distributed across the watersheds in the exact same pattern as they were in 2001. This is because the model followed the historical pattern of projecting development to areas that were already developed.

Impacts of land use change on the land—Key findings

- The trend from 1992 to 2001 indicates some amount of revegetation of riparian buffers, however over half of the riparian buffers remain cleared of natural vegetation (forest or wetland).
- Only 12 percent of forests are unfragmented (larger than 25-acre patches). Unfragmented forests are critical for wildlife, biodiversity, and other ecological values.
- 23 percent of the land that is considered to be of high or highest conservation value is at high risk of being developed.
- High value recreation and water protection lands are most at risk.

Impacts of land use change on water resources

The quantity, quality, and distribution of water that recharges an aquifer or runs overland to streams can be affected by the land uses with which it is interconnected. An increase in impervious surfaces, such as parking lots, buildings, and roads, reduces the amount of permeable land surface through which precipitation can infiltrate, in turn reducing water available to soils and plants and transpiration, and reduces recharge of ground water supplies. At the same time an increase in the amount of precipitation that does not infiltrate increases the amount of runoff and with it the potential for increased soil erosion, flooding, and surface-water contamination. In addition, the loss of ground-water recharge changes the distribution of streamflow. During dry periods less water flows to streams during dry periods as baseflow, and more water flows to streams during wet periods as immediate runoff. These changes in the hydrology of a watershed are often accompanied by hydrological and ecological impacts: increased flooding frequency , decreased water supply storage during droughts, degraded water quality, and stressed ecosystems.

Impacts of land use change on the water budget

The effects of high- and low-constraint scenarios on the Pennsylvania Highlands' water budgets were evaluated using the watershed model described in Part 4 of this report, titled, Growth and impact analysis, Water budget. Projected increases in impervious surface cover and ground-water withdrawals are the factors driving the change in water budget components between existing conditions (1986–2001) and the projected development scenarios. The simulated water budgets show substantial change between existing conditions and the projected development scenarios but little change between the high- and low-constraint scenarios. Discussion focuses on the low-constraint development scenario because it represents the worst-case conditions.

Model-simulated differences in runoff, baseflow, total streamflow, and evapotranspiration between existing conditions and low-constraint development are shown in Figure PA-40. The data points in the figure represent the water-budget components of 95 14-digit-HUC subwatersheds plotted in order of increasing effective impervious surface over existing conditions and are expressed as inches per year over the subwatershed. Trend lines show the relationship between increasing impervious surface and each water budget component. The linear nature of the relationship implies changes in the water budget components are directly proportional to the changes in the effective impervious surface up to the maximum change simulated, which was approximately 15 percent. To bring this into perspective, under a build-out scenario where the increase in effective impervious area approaches 15 percent, runoff increases of 40 percent and baseflow decreases of 10 percent are likely.

Figure PA-41 shows the degree to which stream runoff and baseflow are predicted to change at the 14-digit-HUC subwatershed scale, based on the change between the simulated water budgets for 1986-2001 conditions and the low-constraint development scenario. The 14-digit-HUC subwatersheds with about 50 percent or more area outside of the Highlands boundary or lacking supporting development data were excluded from the analysis. The areas of moderate and greatest change are directly related to the projected increase in impervious surface cover and self-supplied ground-water withdrawals. Based on the predicted population increase for the low-constraint development scenario and a 60-gallon per day per person water use, consumptive use of ground water is estimated to remove an additional 11.9 million gallons per day from aquifers underlying the watersheds in the modeled area. About 80 percent of the areas of greatest change are almost exclusively self-supplied by ground water and had relatively low population density at the time of this study. These areas, if developed to the maximum allowable densities based on the low-constraint scenario, would have the greatest increases in runoff, decreases in ground-water recharge, and decreases in stream baseflow.

Impacts of land use change on water resources—Key findings

- Water budget analysis of 95 Pennsylvania Highlands subwatersheds shows that as the percent of impervious surface increases, direct runoff also increases, but baseflow and evapotranspiration decrease.
- Water budget calculations completed for build-out scenarios suggest that as increases in effective impervious surface area approach 15 percent, runoff increases of 40 percent and baseflow decreases of 10 percent are likely. This implies less water in streams during dry periods and higher peak flows during wet periods, given similar climatic conditions.
- The increase in impervious surface, as projected by the high- and low-constraint build-out scenarios, had a greater impact on the 14-digit-HUC subwatersheds' water budgets than did the additional ground-water withdrawals estimated

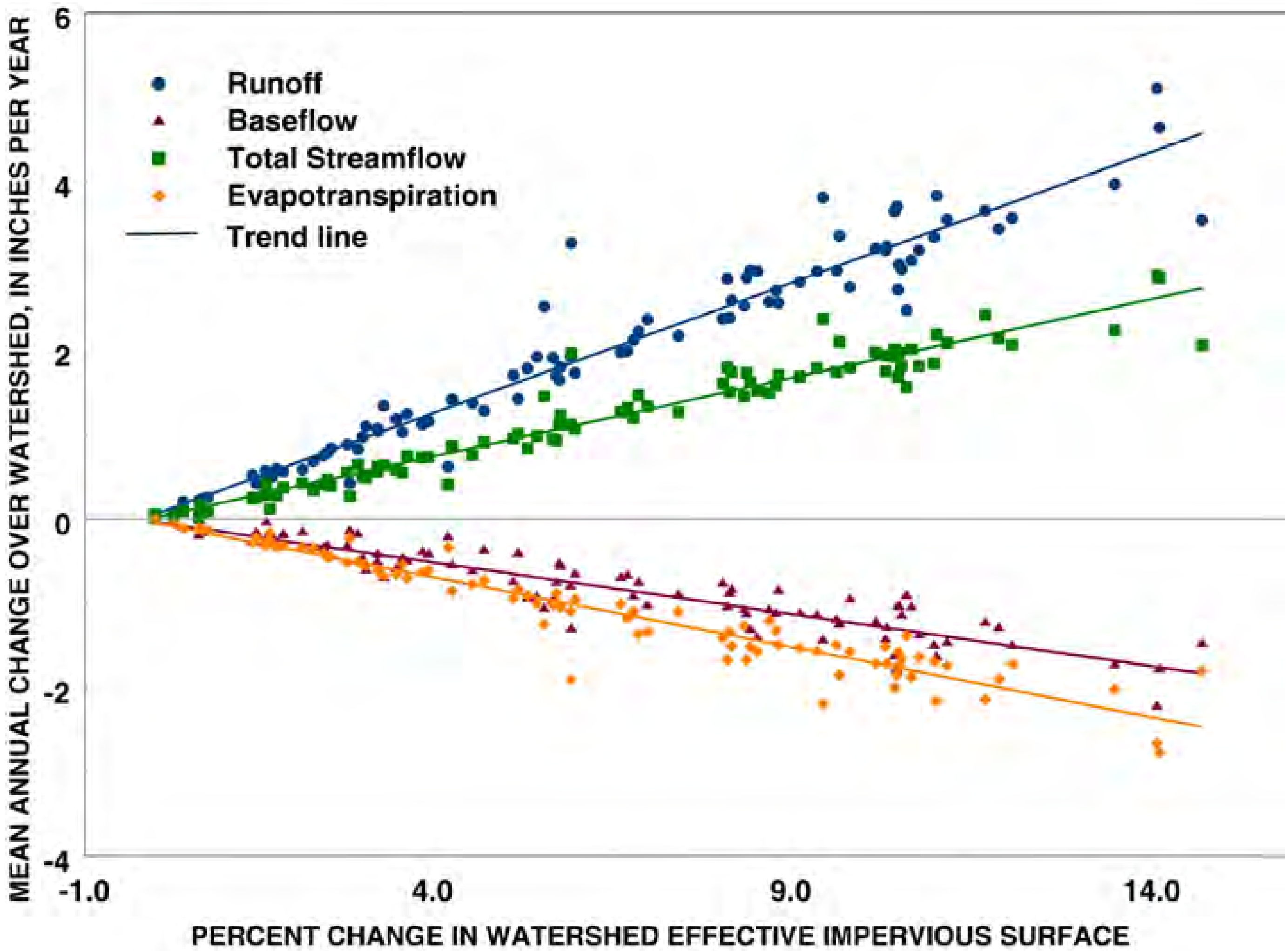


Figure PA-40. Effect of impervious surfaces on streamflow. Changes in streamflow characteristics and evapotranspiration are directly related to increasing impervious surface area, as shown here for 95 14-digit Hydrologic Unit Code subwatersheds in the Pennsylvania Highlands.

from projected population growth. Impervious surface and ground water withdrawals, however, were both substantial factors in decreasing baseflow.

- Based on the predicted population increase for the low-constraint scenario and water use of 60 gallons per day per person, consumptive use of ground water is 11.9 million gallons per day from aquifers underlying the Highlands' watersheds.

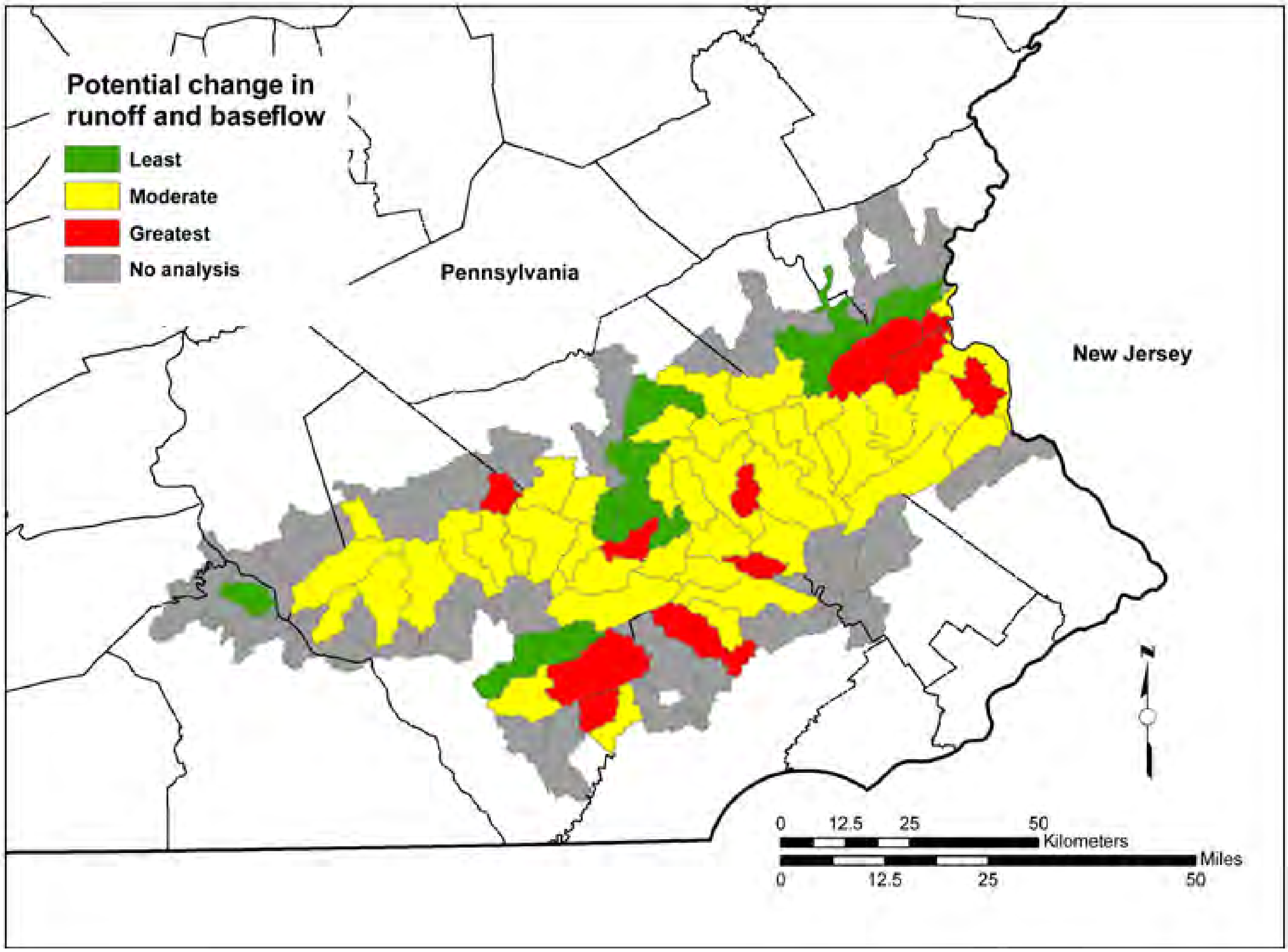


Figure PA-41. Predicted changes in streamflow. *Predicted change in runoff and baseflow at the 14-digit Hydrologic Unit Code subwatershed scale in the Pennsylvania Highlands, based on the change between the simulated water budgets for 1986 – 2001 conditions and the low-constraint development scenario. The areas of moderate and greatest change in runoff and baseflow are directly related to the projected increase in impervious surface cover and water withdrawals.*

Part 5. Public input—Land and water characteristics and growth and impact analysis

Workshops

Twenty-two foresters, conservationists, and planners met at a 2-day Pennsylvania Highlands workshop on October 25 and 26, 2007, at Nolde Forest Environmental Education Center in Reading, to learn about the Highlands Regional Study and talk about land use change. The workshop provided an opportunity for interested citizens to review the results of the Highlands resource assessment and offer their estimates of what factors are driving change in the region.

The Forest Service and the study team sought to engage interested citizens in a review of the impact study, a determination of what the results mean for the Highlands' future, and a formulation of conservation strategies to insure the protection of those resources that the community values.

The workshop began with the study team's presentation of the results from their analyses, and a general discussion of implications for the future. Participants proposed, discussed, and agreed upon workable strategies for conservation, and identified conservation focal areas.

Public input—Land and water characteristics and growth and impact analysis—Key findings

- Attendees were part of a facilitated discussion to identify conservation focal areas.
- Participants proposed collaborative scenarios, identifying the resources, places, or issues with the greatest promise for accomplishing results through cooperative conservation.
- Participants developed a synthesis of what all of the results mean for the Highlands and their resources.
- Attendees learned the results of the growth and impact analysis, including the growth model and build-out analysis.

Figure PA-42. Hopewell Big Woods. *Development is encroaching on the Hopewell Big Woods. (Photo by Tom Gettings, Wildlands Conservancy)*

Part 6. Conservation actions, regional resources at risk, resource condition summary, and conservation focal areas

Conservation actions

Description

The New York-New Jersey Highlands Regional Study: 2002 Update (Phelps and Hoppe 2002) highlighted the history of conservation actions in the New York and New Jersey region since the establishment of the Palisades Interstate Park Commission (PIPC) in 1937. Since 2002, several key conservation actions have been completed in the four-state region (see Appendix H for more information) and specifically in Pennsylvania:

York County Open Space and Greenways—County planning agencies in PA are considering the Highlands in their local land use planning practices and before adopting open space or special use ordinances. The Pennsylvania Highlands is one of five state-designated mega greenways. For example, the Highlands mega greenway is shown on some of the maps in the York County Open Space and Greenways Plan (York County Planning Commission 2006).

Hopewell-Big Woods—This 73,000-acre forest on the border of Chester and Berks counties is the largest remaining unfragmented woodland in southeastern Pennsylvania (Figure PA-42). A public-private partnership established in 2006 to conserve the area currently includes a total of 37 State and Federal agencies (including the National Park Service's Rivers,

Figure PA-43. Oley Hills. The Oley Hills form the headwaters of five State-designated Exceptional Value streams. (Photo by Tom Gettings, Wildlands Conservancy)

Trails, and Conservation Assistance Program), nonprofits, counties, municipalities, and individuals. For more information on this project, go to the Natural Lands Trust Web site (Natural Lands Trust 2004).

Oley Hills—In this region of the Highlands, 2007 was the most successful year to date. The Berks County Conservancy reported that five properties totaling 661 acres were protected in the Oley Hills, and one in the Schuylkill Highlands (outskirts of Oley Hills). The Oley Hills boast more than 60 miles of pristine rivers that represent the region's most valuable watersheds, and contain 27,500 acres of mixed deciduous woodlands that cover 75 percent of the region (Figure PA-43). For more information on this project, go to the Oley Hills region description on the Berks County Parks and Recreation Plan Web site (Berks County Parks and Recreation Plan 2007).

Cooks Creek—This scenic waterway, which curls through rural Upper Bucks County in a 30-square mile watershed, is a critical natural resource. Since 2004, 1,000 acres in the watershed have been secured by the locally based Heritage Conservancy. Cooks Creek has the highest value waters as designated by Pennsylvania's Department of Environmental Protection and has been recognized by the Pennsylvania Fish and Boat Commission as the only viable coldwater fishery in Bucks County. The Highlands Conservation Act was federally funded for \$1.5.million in Fiscal Year 2009; a portion of those funds were used to protect additional lands in this watershed. For more information on this project, go to the Cooks Creek Watershed Association Web site (Cooks Creek Watershed Association 2004).

Conservation actions—Key findings

- The York County Open Space and Greenways plans highlights the Highlands as one of its regional greenways.
- A 37-member public-private partnership was established in 2006 to conserve the Hopewell-Big Woods area.
- Nearly 700 acres were protected in the Oley Hills in 2007; it is one of the region's most valuable watersheds.
- One thousand acres have been protected in the Cooks Creek watershed to date, and more lands are planned for protection using Federal Highlands Conservation Act funds received in Fiscal Year 2009.

Regional resources at risk

One of the main goals of this study was to understand which valuable natural resources are at risk of being lost to growth and sprawling development by 2028. Looking at where high conservation value lands overlap with lands at high risk of converting from forest or agriculture to development provides a way to think about conservation priorities in the Highlands, taking into account both value and risk.

Methods

Value-risk overlay maps were constructed from the stratified suitability (risk) maps produced for growth modeling (see Part 4. Growth and impact analysis—Land use modeling), and the conservation value maps (see Part 1. Conservation values assessment). The stratified approach accounts for the town-by-town or county-by-county variation in rate of growth, and is the most realistic in terms of understanding *where* development pressure exists across the region. Value-risk overlay maps show the relationship between likelihood of development or suitability and conservation importance across the landscape. Maps were produced for each of the five resources: water, forest, biological, agricultural, and recreational and cultural, as well as for the combination of resources (composite) in the Conservation Values Assessment (Figures PA-44 through PA-49). Relative suitability for development is displayed in three quantiles; conservation value is displayed in five quantiles. Because the suitability analysis was stratified by town and county, its output accentuates political boundaries.

Results

Only 5 percent (49,100 acres) of the land on the composite CVA map is both of high or highest conservation value and projected to be in the high *suitability* or risk for development category (Figure PA-49). Most of the high suitability areas are of moderate to low resource value. However, in southern Berks County, a large area of dark red indicates high suitability and high resource value.

High value recreation and water protection lands are most at risk, with 37 percent of the high value recreation lands and 30 percent of the highest value water lands also in the high risk category (Table PA-13). Altogether, 23 percent of the land that is considered to be of high and highest conservation value is at high risk of being converted to development.

Regional resources at risk—Key findings

- Only 5 percent of the land on the composite CVA map is both of high or highest conservation value and projected to be in the high suitability or risk for development category.
- Thirty percent of the highest value water lands are also in the high suitability or risk for development category.

Resource condition summary

Nearly three-quarters of the Connecticut-Pennsylvania Highlands region is privately owned. Approximately 25 percent of the region's high conservation value lands, or 515,000 acres, are at risk of development. Many of these unprotected lands are critical to the sustainability of the specific resource values that people currently enjoy.

In Pennsylvania, forestry and agriculture is an important activity central to the region's culture and identity. For example, agriculture comprises 35 percent of the landscape; however, only 16 percent of the farmland is

In Pennsylvania, forestry and agriculture is an important activity central to the region's culture and identity. For example, agriculture comprises 35 percent of the landscape; however, only 16 percent of the farmland ispreserved from development. If the lands that define the Highlands' landscape quality and contain its resource values are not protected, those lands will become vulnerable to further fragmentation and urbanization.

Through the use of a Conservation Values Assessment and future growth modeling, significant habitats and ecosystems were identified for conservation and protection. This assessment also identified the following

Table PA-13. Resources at risk. *Acres with high and highest conservation values in the Pennsylvania Highlands, by development risk category and resource.*

Suitability for or risk of development	Water	Forest	Biological resource	Agriculture	Recreation and culture	Composite
High Risk	87,000 (30%)	37,500 (18%)	79,400 (21%)	37,000 (25%)	11,100 (37%)	49,100 (23%)
Medium Risk	115,300 (39%)	76,000 (36%)	140,300 (37%)	57,100 (39%)	9,400 (32%)	76,100 (36%)
Low Risk	92,600 (31%)	96,900 (46%)	162,700 (43%)	53,200 (36%)	9,200 (31%)	87,100 (41%)

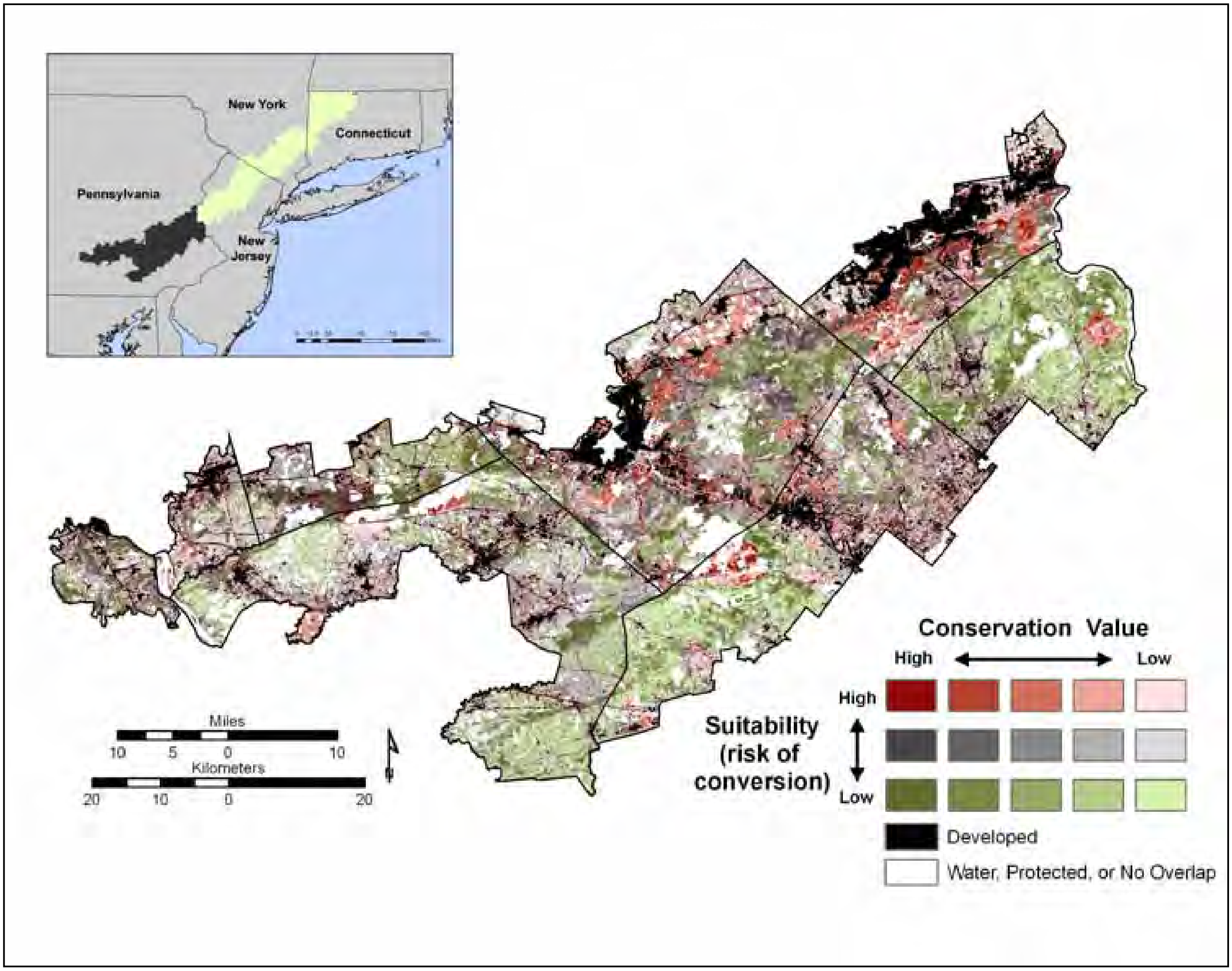


Figure PA-44. Suitability map for water resources. Overlay of high to low conservation values for water in the Pennsylvania Highlands with high to low suitability (risk of being developed).

existing natural resource conditions in 2008 and projected changes that would occur without additional conservation measures, in Pennsylvania, by 2028:

Water

Existing conditions:

- Pennsylvania Highlands surface water reservoirs mainly supply areas within the region.
- Ground water quality is good for most uses.
- Since 1998, many Highlands' streams have shown improving conditions. A stream sampling of macroinvertebrate communities indicates healthy aquatic invertebrate populations.
- Almost one-third of riparian areas have been cleared of natural vegetation since 1985.
- Baseflow comprises 65 percent of streamflow over the Highlands study area.

Projected changes:

- High value water protection lands are most at risk for future development.
- Although there has been some revegetation of riparian buffers, more than half remain clear of natural vegetation (forest or wetland), which will impact water quality.

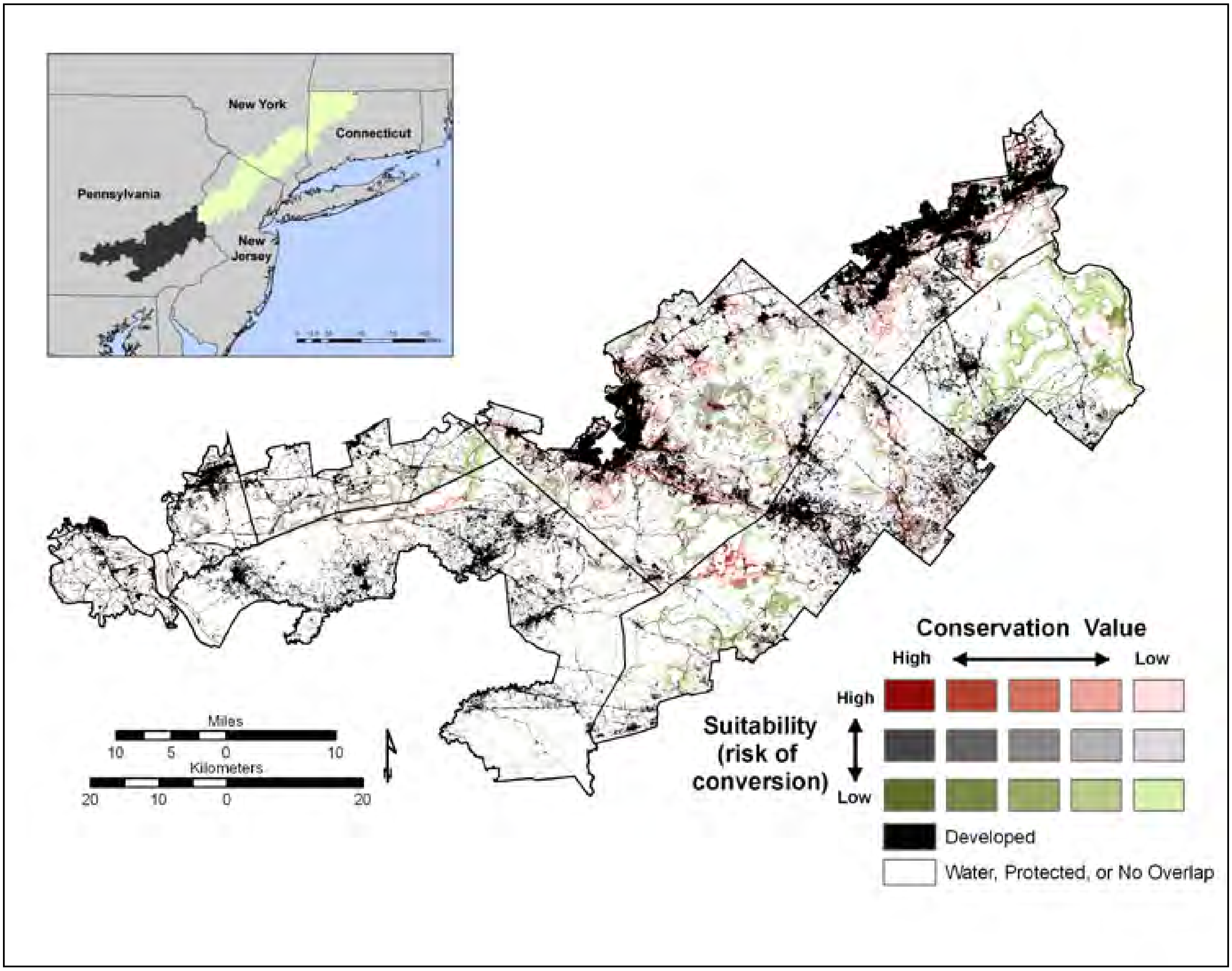


Figure PA-45. ***Suitability map for forest resources.*** *Overlay of high to low conservation values for forest in the Pennsylvania Highlands with high to low suitability (risk of being developed).*

Forests

Existing conditions:

- Thirty-two percent of the region is forested mainly with oak species and red maple.
- Stand structure is fairly homogeneous, but there is a fairly even distribution of age classes.
- Forests are highly fragmented; only 23 percent is core forest.
- Most forestland (71 percent) is privately owned.

Projected changes:

- As forest fragmentation increases, stand composition and stand structure will become more homogeneous.
- Forestland owners are aging; the trend is towards fewer young forestland owners in the future.

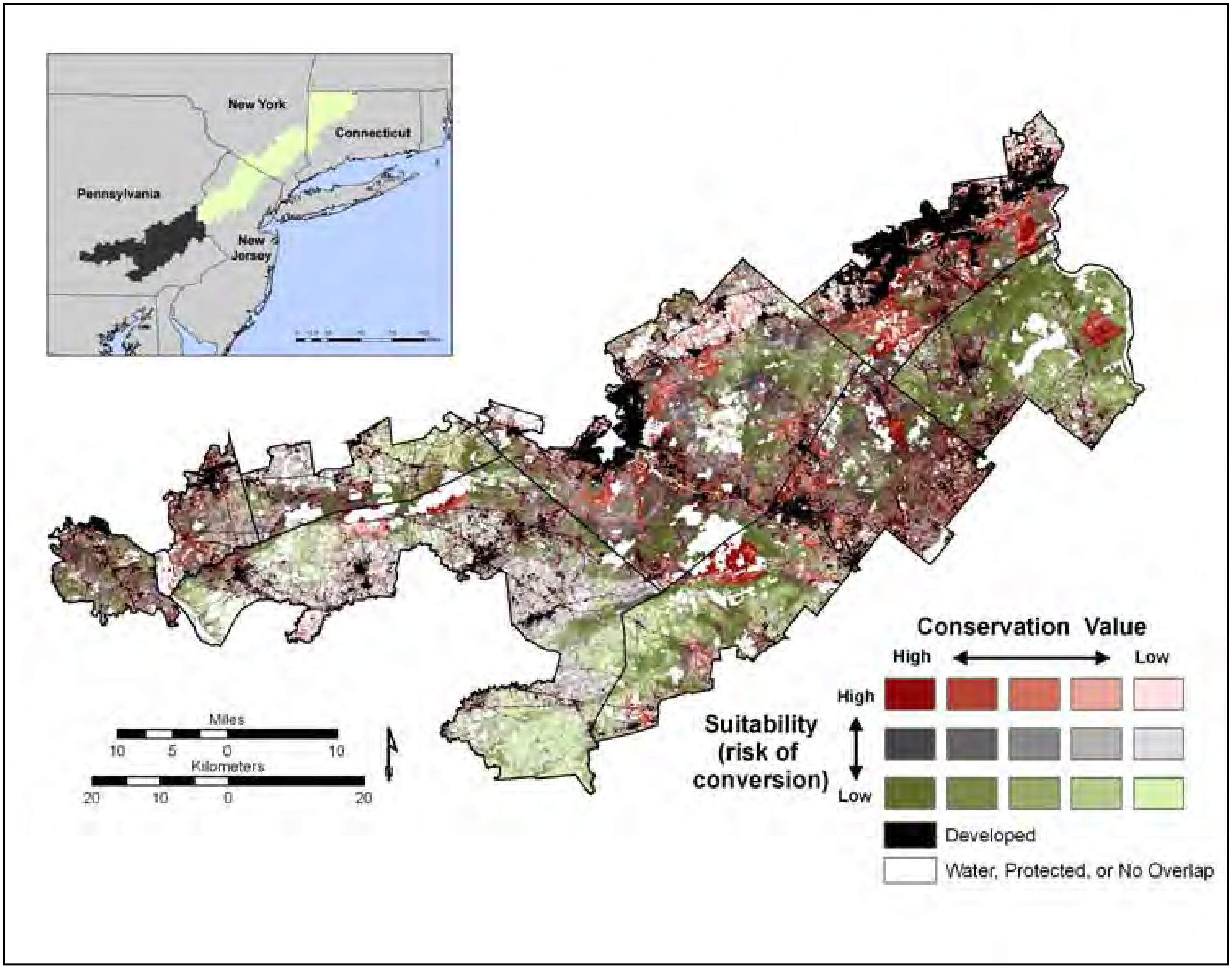


*Figure PA-46. **Suitability map for biological resources.** Overlay of high to low conservation values for biological resources in the Pennsylvania Highlands with high to low suitability (risk of being developed).*

Biological resources

Existing conditions:

- Many areas ranked high for biological resources, in part due to the extensive data layers available.
- Areas that ranked highest for biological resources closely matched areas that ranked high for forest resources.

Projected changes:

- Most lands that ranked high for biological resources are at low risk for future development.

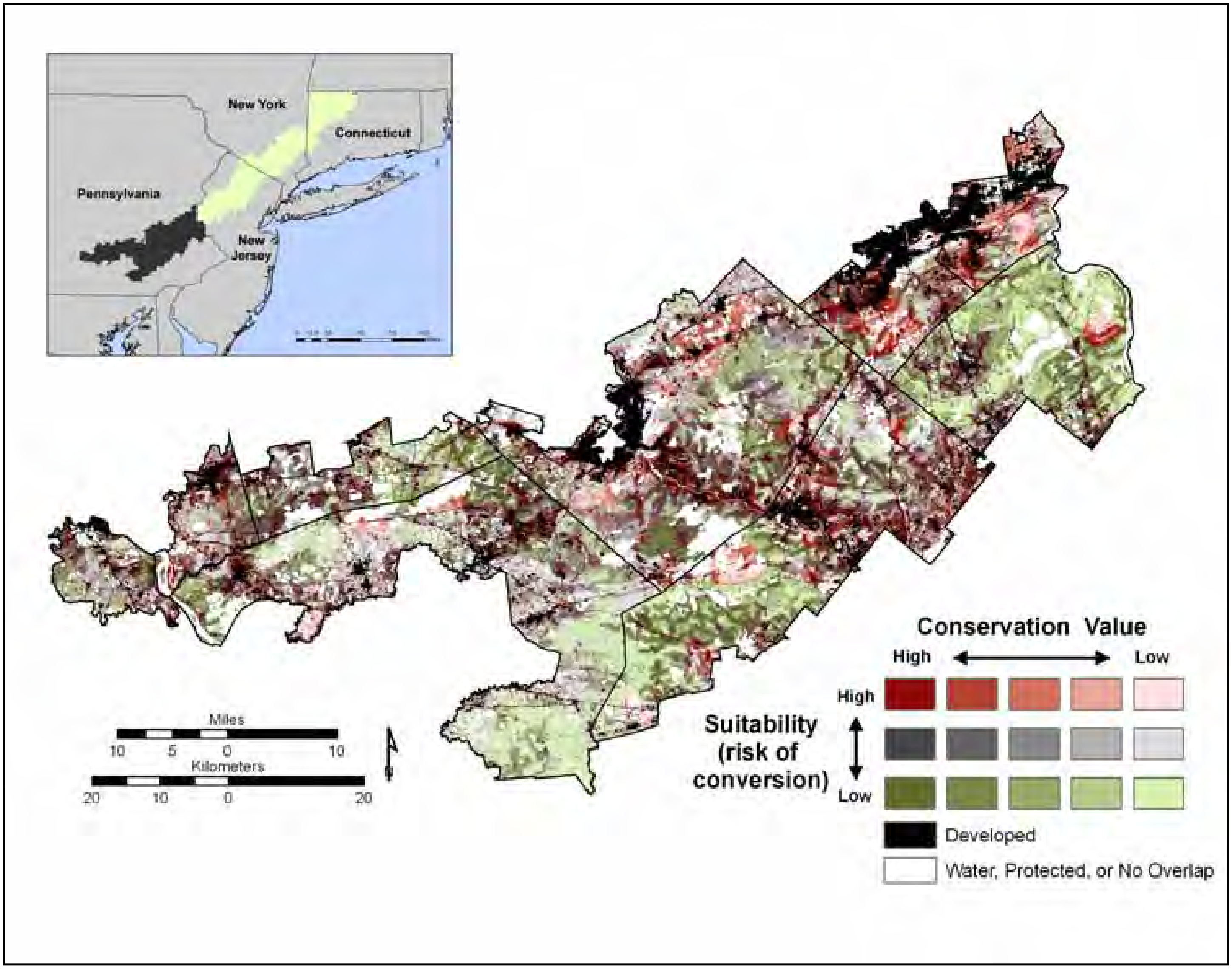


*Figure PA-47. **Suitability map for agricultural resources.** Overlay of high to low conservation values for agriculture in the Pennsylvania Highlands with high to low suitability (risk of being developed).*

Farms

Existing conditions:

- Agriculture makes up 35 percent of the Highlands landscape.
- Between 1997 and 2001, 44,930 acres of farmland were lost.
- The number of smaller farms (50 acres or less) is on the rise.

Projected changes:

- Only 16 percent of farmland is preserved with an agricultural conservation easement; the rest is subject to future development.
- Farming is on the decline in all of the Highlands except Lebanon County.

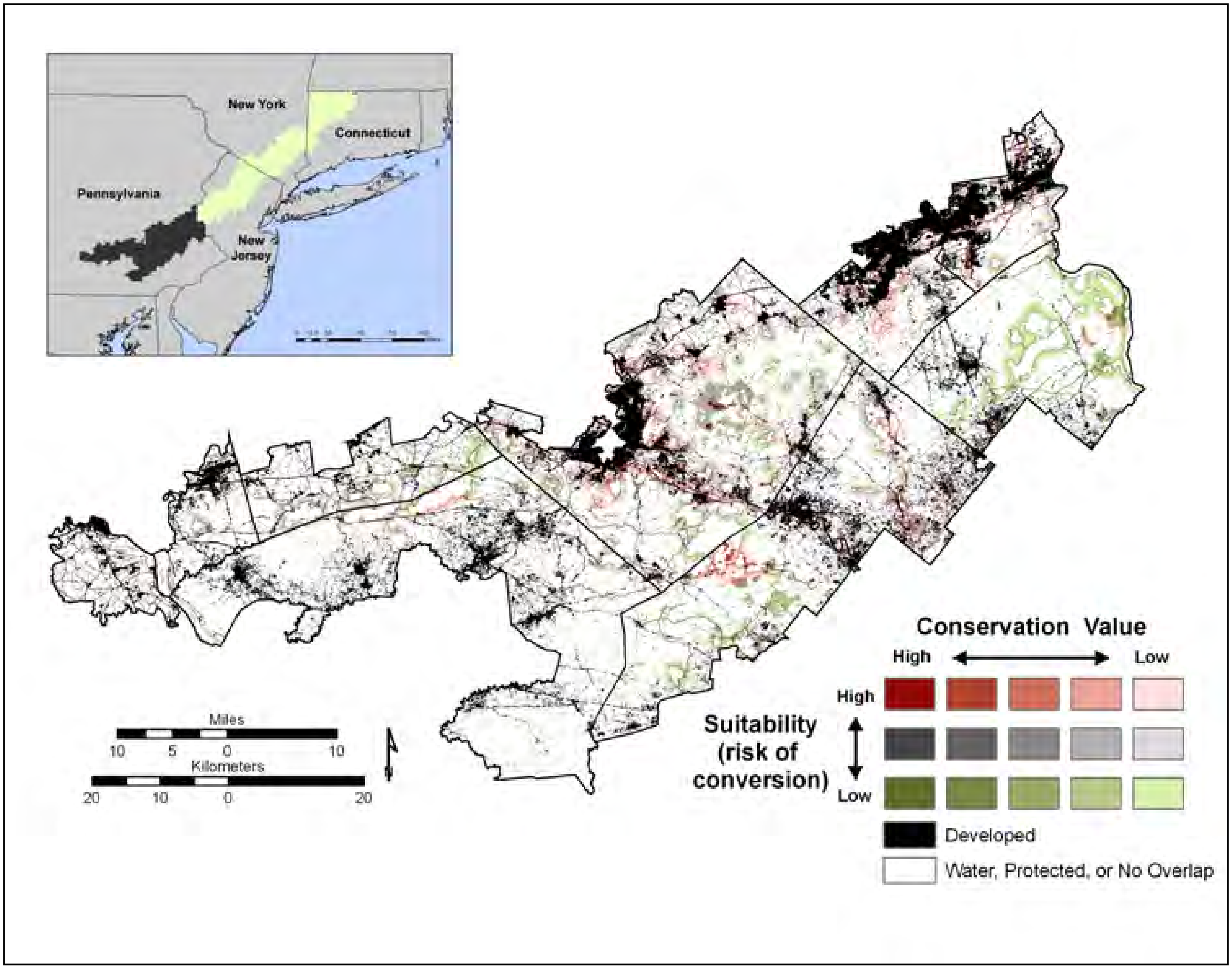


Figure PA-48. Suitability map for recreational and cultural resources. Overlay of high to low conservation values for recreation and cultural resources in the Pennsylvania Highlands with high to low suitability (risk of being developed).

Recreation and culture

Existing conditions:

- Areas that ranked high for their recreational and cultural values contained recreational trails, ridge tops, existing parks and protected lands, and other historic, cultural, recreational resources or recreational waters.
- The highest ranked areas were the Hopewell Big Woods, Furnace Hills, and Penn's Ridge.

Projected changes:

- Unlike lands that ranked high for biological resources, most areas that ranked high for recreation and culture are at high risk for future development.

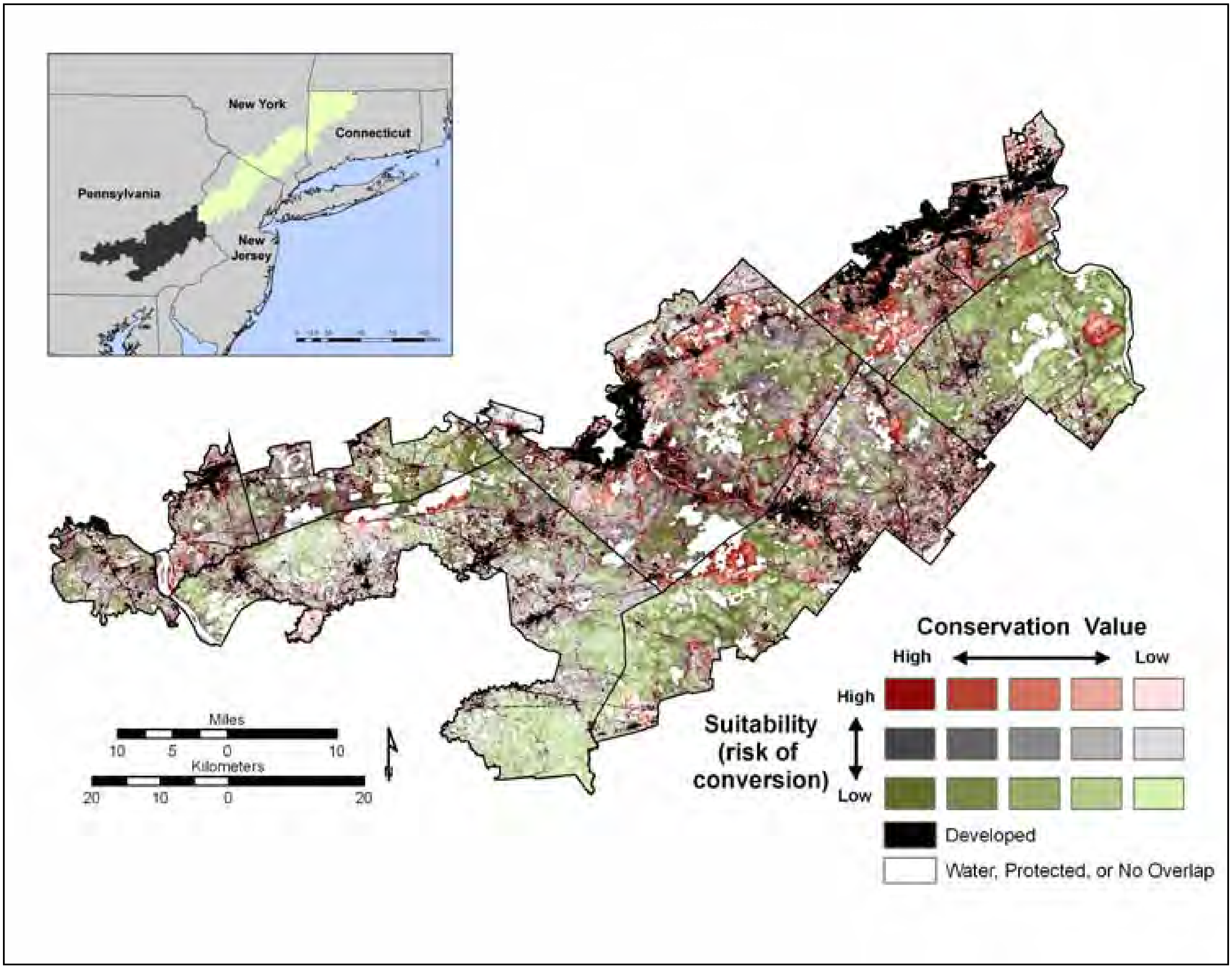


Figure PA-49. Suitability map for composite resources. *Overlay of high to low conservation values (composite) in the Pennsylvania Highlands with high to low suitability (risk of being developed). Land that is already developed is shown in black, and protected open space and water are shown in white. Areas of high value and high suitability are shown in red.*

Human population and housing

(Note: this is not a resource category but an important element of the study)

Existing conditions:

- The Highlands population represents 10 percent of the state.
- Population and housing in the Highlands are growing much faster than the state as a whole.
- The population is aging. Growth is higher among the 30-40 and over-65 age categories than among those under 30 years old.

Projected changes:

- Under the low-constraint or "as is" build-out scenario, regional housing would increase by 108 percent and population by 115 percent.
- Under the high-constraint or "environmentally sensitive" build-out scenario, regional housing would increase by 93 percent and population by 102 percent.

Resource condition summary—Key findings

- Ground and surface water quality is good for most uses. A stream sampling of macroinvertebrate communities indicates healthy aquatic invertebrate populations.
- Forests are highly fragmented; only 23 percent is core forest.
- Farming is on the decline in most of the Highlands region.
- Population and housing in the Highlands are growing much faster than the state as a whole.

Conservation focal areas and map

Description

Regional conservation focal areas are places in the Highlands where three conditions coincided: large contiguous tract or major land cluster, a high composite resource value in the Conservation Values Assessment (in the top 40 percent), and absence of permanent protection (Figure PA-50). Feedback from interested citzens, including governmental and non-profit organizations was also considered in identifying the conservation focal areas. Input from persons familiar with the project at a local level allowed identification of areas across the region that have a high resource value and are important to the community. Areas identified as conservation focal areas do not automatically qualify for funding under the Highlands Conservation Act (HCA). A separate evaluation and ranking process applies to HCA project proposals (see Section 1. Introduction—Highlands Conservation Act of 2004 for more information).

A. Delaware Palisades—The Delaware Palisades area is comprised of smaller tributaries of the Delaware River, with many waterfalls. The area is located in Bucks and Lehigh counties and includes Nockamixon Heights, Cooks Creek watershed, South Mountain, and Tohickon Creek. This area ranked highest for its water, forest, and biological resources in the Conservation Values Assessment.

B. Penn's Ridge—The Penn's Ridge area is on a rocky ridge. This feature has no well-known common name. Route 563, which runs the entire length, is called Ridge Road. Pennridge School District is in the area. Penn's Ridge is located in Bucks and Montgomery counties and includes Quakertown Swamp, Swamp Creek, and the upper reaches of Perkiomen Creek. This area ranked highest for its forest and biological resources in the Conservation Values Assessment.

C. Oley Hills—The Oley Hills area includes more than 60 miles of rivers representing the region's most valuable watersheds and approximately 27,500 acres of mixed deciduous woodlands (Stell and others 2006). Berks County Conservancy includes only District Pike and Rockland Townships in the Oley Hills, but this landscape can be expanded. The area ranked high in several areas of the Conservation Values Assessment: water, biological, agricultural, and recreational and cultural resources.

D. Hopewell Big Woods—This area forms the center of the Pennsylvania Highlands, and encompasses about 100 square miles of contiguous forest. It also contains two State-designated Exceptional Value streams, critical wildlife habitat, and important historic sites (Stell and others 2006). The formal name, Hopewell Big Woods, is in recognition of the national historic site within its boundary. The area is located in Berks County and includes Birdsboro Waters, Hay Creek Watershed, Glen Morgan Lake, North Branch French Creek Watershed, and Angelica Creek. The area ranked high in several areas of the Conservation Values Assessment: water, forest, biological, and recreational and cultural resources.

E. Furnace Hills—The Furnace Hills area forms a forested spine in the central Pennsylvania Highlands and encompasses about 31,000 acres. It contains important wildlife habitat and many historic sites from the nation's iron era (Stell and others 2006). This area is located in Lebanon and Lancaster counties and includes Middle Creek Wildlife Management Area. The area ranked high in several areas of the Conservation Values Assessment: water, forest, biological, and recreational and cultural resources.

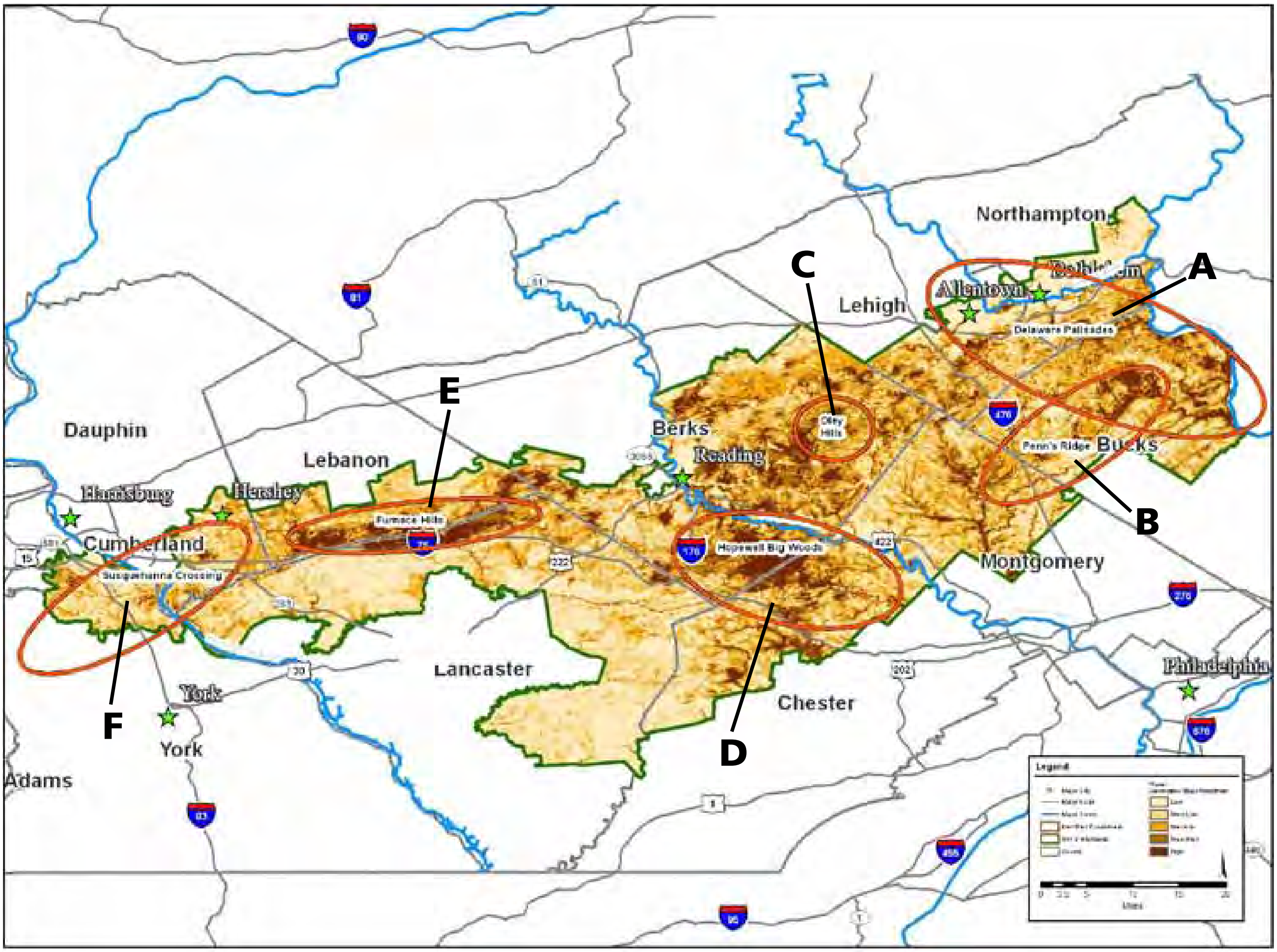


Figure PA-50. ***Conservation focal areas in the Pennsylvania Highlands.*** *Each conservation focal area is a place where three conditions coincide: large contiguous tract or major land cluster, a high composite resource value in the Conservation Values Assessment, and absence of permanent protection.*

F. Susquehanna Crossing—Sand Hills is one portion of the important Susquehanna Crossing focal area. It helps connect the eastern and western areas of the Highlands across the Susquehanna River. The area constitutes an almost 20-mile wide band through the Highlands region. This focal area encompasses the Conewago Mountains, Susquehanna River, and the Sand Hills (Stell and others 2006). The area ranked highest for its water and biological resources in the Conservation Values Assessment.

Conservation focal areas and map—Key findings

- Six conservation focal areas were identified in the Pennsylvania Highlands region.
- Almost all of the conservation focal areas ranked high for water and forest resource values in the Conservation Values Assessment.
- Several of the conservation focal areas are landscapes that contain important natural and historic resources.

References for Section 3

Aller, L., T. Bennett, J. H. Lehr, R. J. Petty, and G Hackett. 1987. DRASTIC: A standardized system for evaluating ground water pollution potential using hydrogeologic settings. US EPA 600/2-87/035. Ada, OK: U.S. Environmental Protection Agency.

Audubon Pennsylvania. 2005. Important Bird Area maps. Harrisburg, PA: Audubon Pennsylvania. http://pa.audubon.org/iba/maps.html (28 September 2009)

Berks County Parks and Recreation Plan. 2007. Oley Hills Region. www.co.berks.pa.us/planning/lib/planning/greenway_plan/final_doc/berksgreenway_3.4_oleyhillsregion.pdf (12 August 2009).

Butler, Brett J. 2008. Family forest owners of the United States, 2006. Gen. Tech. Rep. NRS-27. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 73 p.

Commonwealth of Pennsylvania, Pennsylvania Department of Agriculture. 2007a. Data & statistics: Farmland acres preserved in Pennsylvania. Farmland Preservation—2006 Allocation of funds by county. www.agriculture.state.pa.us/agriculture/cwp/view.asp?a=3&q=128824. (May 2007).

Commonwealth of Pennsylvania, Pennsylvania Department of Agriculture. 2007b. Data & statistics: Farmland acres preserved in Pennsylvania. Acreage by county. www.agriculture.state.pa.us/agriculture/cwp/view.asp?a=3&q=128824. (May 2007).

Cooks Creek Watershed Association. 2004. About the Cooks Creek Watershed. www.cookscreekpa.org/aboutcookscreek.htm (13 August 2009).

Daly, M. H.; Lindsey, B. D. 1996. Occurrence and concentrations of volatile organic compounds in shallow ground water in the Lower Susquehanna River Basin, Pennsylvania and Maryland: Water-Resources Investigations Report 96-4141. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 8 p.

Fischer, J. M.; Riva-Murray, K.; Hickman, R.E.; Chichester, D.C.; Brightbill, R.A.; Romanok, K.M.; Bilger, M. D. 2004. Water quality in the Delaware River Basin, Pennsylvania, New Jersey, New York, and Delaware, 1998-2001. Circular 1227. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 38 p.

GeoLytics. 2004. Census CD for 1970, 1980, 1990, 2000. East Brunswick, NJ: GeoLytics, Inc. Product available through Sterling Memorial Library, Yale University, New Haven, CT. www.geolytics.com/USCensus,Census-1970-1980-1990,Categories.asp (23 September 2009).

Hainly, R. A.; Zimmerman, T. M.; Loper, C. A.; Lindsey, B. D. 2001. Summary of and factors affecting pesticide concentrations in streams and shallow wells of the Lower Susquehanna River Basin, Pennsylvania and Maryland, 1993-95. Water-Resources Investigations Report 01-4012. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 75 p.

Heath, R. C. 1980. Basic elements of ground-water hydrology with reference to conditions in North Carolina. Open-File Report 80-44. City, ST: Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 93 p.

Heath, R. C. 1983. Basic ground-water hydrology. Water-Supply Paper 2220. City, ST: Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 84 p.

Helsel, D. R.; Hirsch, R. M. 1992. Statistical methods in water resources. New York, NY: Elsevier Science Publishers; 522 p.

Hutson, S. S.; Barber, N. L.; Kenny, J. F.; Linsey, K. S.; Lumia, D. S.; Maupin, M. A. 2004. Estimated use of water in the United States in 2000. Circular 1268. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 46 p.

Kelly, Kevin. 2005. Pennsylvania Department of Environmental Protection. Harrisburg, PA: Pennsylvania Department of Environmental Protection. Unpublished data provided specifically for Conservation Values Assessment.

Kripas, Diane. 2005. Pennsylvania Department of Conservation and Natural Resources. Harrisburg, PA: Pennsylvania Department of Conservation and Natural Resources, Greenways and Partnerships Division. Unpublished data provided specifically for Conservation Values Assessment.

Krist, F.; Sapio, F.; Tkacz, B. 2007. Mapping risk from forest insects and diseases. FHTET 2007-06. U.S, Dept. of Agriculture Forest Service, Forest Health Protection, Forest Health Technology Enterprise Team, Fort Collins, CO. 115 p.

Lehigh Valley Planning Commission. 2005. Comprehensive Plan: The Lehigh Valley: 2030. Lehigh and Northhampton Counties, PA. 129 p.

Lindsey, B. D.; Breen, K. J.; Bilger, M. D.; Brightbill, R. A. 1998. Water quality in the Lower Susquehanna River Basin, Pennsylvania and Maryland, 1992-95. Circular 1168. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 38 p.

Lindsey, B. D.; Falls, W. F.; Ferrari, M. J.; Zimmerman, T. M.; Harned, D. A.; Sadorf, E. M.; Chapman, M. J. 2006. Factors affecting occurrence and distribution of selected contaminants in ground water from selected areas in the Piedmont Aquifer System, Eastern United States, 1993-2003. Scientific Investigations Report 2006-5104. Reston,VA: U.S. Department of the Interior, U.S. Geological Survey. 72 p.

Magdasy, Bret. 2005. Appalachian Mountain Club. Bethlehem, PA: Mid-Atlantic Appalachian Mountain Club. Unpublished data provided specifically for Conservation Values Assessment.

Natural Lands Trust. 2004. Recent projects: Hopewell Big Woods. www.natlands.org/projects/ (12 August 2009).

Pennsylvania Department of Agriculture. 2005a. Agricultural Security Areas. Harrisburg, PA: Pennsylvania Department of Agriculture. www.agriculture.state.pa.us/agriculture/cwp/view.asp?q=129076 (29 September 2009)

Pennsylvania Department of Agriculture. 2005b. Farmland Acres Preserved in Pennsylvania. Harrisburg, PA: Pennsylvania Department of Agriculture. www.agriculture.state.pa.us/agriculture/cwp/view.asp?a=3&q=128824 (29 September 2009)

Pennsylvania Department of Environmental Protection. 2006. Addendum 1—Water quality trends at water quality network (WQN) fixed stations. In: 2006 Pennsylvania integrated water quality monitoring and assessment report. www.depweb.state.pa.us/watersupply/cwp/view.asp?a=1261&q=480056 (27 December 2007).

Pennsylvania Department of Environmental Protection. 2007. Conservation releases from dams in Pennsylvania. Fact Sheet 3140-FS-DEP 1896. Harrisburg, PA.

Pennsylvania Natural Heritage Program. 2005. County Natural Heritage Inventories. Harrisburg, PA: Pennsylvania Department of Conservation and Natural Resources. www.naturalheritage.state.pa.us/CNAI_Download.aspx (28 September 2009)

Phelps, Marcus G.; Hoppe, Martina C., compilers. 2002. New York – New Jersey Highlands Regional Study: 2002 Update. NA-TP-02-03. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 209 p.

Reese, Stuart. 2005. Pennsylvania Department of Conservation and Natural Resources, Topo-Geo Survey. Middletown, PA: Pennsylvania Department of Conservation and Natural Resources. Unpublished data provided specifically for Conservation Values Assessment.

Reese, Stuart O.; Lee, Joseph J., compilers. 1998. Summary of groundwater quality monitoring data (1985 – 1997) from Pennsylvania's ambient and fixed station network (FSN) monitoring program: Selected groundwater basins in southwestern, southcentral and southeastern Pennsylvania. Harrisburg, PA. Pennsylvania Department of Environmental Protection. 32 p. + app. www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/SrceProt/Ground/Sympos/Ground_Mont_Rpt.doc. (20 December 2007).

Reese, Stuart; Lee, Joseph J., Jr. 1999. Trend analysis of regional groundwater data, southeastern Pennsylvania. Pennsylvania Department of Environmental Protection, Bureau of Water Supply Management. www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/srceprot/ground/sympos/ground_paper.doc (20 December 2007).

Reif, A.G. 2002. Assessment of stream conditions and trends in biological and water-chemistry data from selected streams in Chester County, Pennsylvania, 1981-97. Water-Resources Investigations Report 02-4242. U.S. Department of the Interior, U.S. Geological Survey. 77 p.

Rosencrance, Diane. 2005. Natural Lands Trust. Media, PA: Natural Lands Trust. Unpublished data provided specifically for Conservation Values Assessment.

Schreffler, Curtis. 2005. U.S. Geological Survey. New Cumberland, PA: U.S. Geological Survey. Unpublished data provided specifically for Conservation Values Assessment.

Senior, L. A. 1998. Radon-222 in the ground water of Chester County, Pennsylvania. Water-Resources Investigations Report 98-4169. U.S. Department of the Interior, U.S. Geological Survey. 79 p.

Stell, Todd R.; Thomas, Patricia M.; Stell, Mary Jane. 2006. The Pennsylvania Highlands Conservation Atlas. Bethlehem, PA: Highlands Coalition. 30 p.

U.S. Department of Agriculture. 1999. 1997 Census of Agriculture, Pennsylvania State and County Data. Volume 1, Geographic Area Series, Part 38. Issued March, 1999.

U.S. Department of Agriculture. 2004. 2002 Census of Agriculture, Pennsylvania State and County Data. Volume 1, Geographic Area Series, Part 38. AC-02-A-38, Issued June, 2004.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. Soil Data Mart. Harrisburg, PA: USDA Natural Resources Conservation Service. http://soildatamart.nrcs.usda.gov/ (28 September 2009)

U.S. Department of Commerce, U.S. Census Bureau. 2007. 2000 Decennial Census. Summary File 1: 2000 Census of Housing and Population. www.census.gov/prod/cen2000/doc/sf1.pdf (22 September 2009)

U.S. Department of the Interior, U.S. Geological Survey. [N.d.]. National Land Cover Data Change Product, zones 60, 61, and 64.

York County Planning Commission. 2006. York County open space & greenways: a component of the York County comprehensive plan. York, PA. 208 p. www.ycpc.org/index_docs/Open%20Space%20Plan-complete%20with%20all%20maps.pdf (12 August 2009).

Section 4. Stewardship Goals, Conservation Strategies, and Closing Comments

Stewardship goals

The 2002 Highlands study report set out five goals that are still considered vital for the long-term stewardship of the Highlands:

1. Manage future growth that is compatible with the region's ecological constraints;
2. Maintain an adequate surface and ground water supply that meets the needs of local and downstream users;
3. Conserve contiguous forests using management practices that are consistent with private property rights and regional resources;
4. Provide appropriate recreational opportunities; and
5. Promote economic prosperity that is compatible with goals 1-4.

Conservation strategies

The responsibility for stewardship of the Highlands resources is shared among many agencies and stakeholders. While there have been some significant accomplishments in resource conservation since 2002 (Appendix H), this Connecticut-Pennsylvania Highlands study identifies conservation focal areas that are at risk for future development, in addition to conservation strategies specific to this region. The Forest Service will be one of the agencies that provides resources for States and cooperators to manage and protect the Highlands' most valuable natural resources. Conservation strategies were designed to help guide State, local, and nonprofit decisionmakers in the protection of the region's natural resources.

Seven strategies were identified to improve the stewardship of the Highlands' resources. These strategies were developed in stakeholder meetings and workshops held throughout the study process, and included input from Federal, State, local, and nonprofit organizations active in the region and familiar with the landscape. While the strategies may not be all-inclusive, they provide an array of choices reflecting what was heard at the meetings.

The seven strategies follow. (Numbers in parentheses tie each strategy to the stewardship goals for the Highlands):

1. Reach out and inform. (Goals 1-5)
2. Monitor landscapes and resources. (Goals 2-5)
3. Demonstrate conservation. (Goals 1-5)
4. Conserve land through acquisition. (Goals 2-4)
5. Make resource conservation a planning and design issue. (Goals 1 and 5)
6. Increase coordination with other Federal and State agencies, and with private groups. (Goals 2-4)
7. Consider the four-State Highlands region. (Goals 1-5)

Descriptions of the strategies included examples and potential measures of accomplishment or environmental change. The conservation strategies were developed using input from a series of key stakeholder workshops held in fall 2007. Potential strategies were shared and discussed with workshop participants. The following summary reflects the feedback received, with additional input from study team members to refine the key strategies.

Summary of conservation strategies for the Highlands

Actions may include:	Examples may include:	Potential measures of accomplishment or environmental change:
1. Reach out and inform		
Reach out Identify important audiences and target specific interest groups. Facilitate public meetings to bring parties with differing viewpoints together to find common ground. Identify gaps in existing outreach, and build on existing networks. Create a Highlands directory of services. Develop learning networks and other online resources to facilitate idea sharing (Harper and others 2006).	Reach out specifically to urban populations and other consumers who rely on ecosystem services from the Highlands. Reach out to the land development community and bring together diverse stakeholder groups. Reach out specifically to youth through school science and environmental education classes, and outdoor summer camps.	A more diverse group consistently participates in Highlands activities, such as meetings and conferences. The term "Highlands" is used by people of all age groups in discussions and publications.
Create a regional identity Create and market a regional identity. Use signage and other interpretive and marketing tools to raise awareness of the geography and natural resources of the Highlands, and to broaden connections with nature. Tailor the Highlands' conservation message to suit audiences within and outside the region.	Develop a Highlands image. Work with youth, urban citizens, the elderly, and other diverse stakeholder groups to tailor the message. Work with environmental agencies in each Highlands state to develop a consistent message.	A Highlands image is used consistently by government and nongovernmental organizations in their marketing materials and publications. The Highlands region is recognized by the public as a place of national significance: a greenbelt for the coastal metropolis.

Continued

Actions may include:	Examples may include:	Measures of accomplishment or environmental change:
Share resource information Maintain a regional information system. Provide consistent and updated information on the Highlands' resources. Make the Highlands study available to a diverse audience. Provide local land use planners with descriptions of ecological unit capabilities.	Map ecological units for Connecticut and Pennsylvania. Work with State land grant universities to maintain and update information systems for their states. Provide public forums and offer educational materials about the Highlands. Hold workshops to demonstrate tools available to protect and manage resources.	Highlands information is used by a wide audience, including local planners, developers, and citizens. Local land use planners consider the impacts of development on Highlands resources.
Share management information Provide up-to-date information on management practices: Prepare and distribute technical guides and best management practice manuals. Inventory resources and prepare a directory or "tool box" of available expertise.	Disseminate the latest information on management issues including invasive species, forest fragmentation, deer management, headwater areas, riparian corridors, water supplies, and soil erosion. Work with Federal, State and local government entities in the Highlands to develop a clearinghouse for Highlands resource information.	Information is readily available and used by State and local land use planners with specific management issues. A Highlands information clearinghouse is available online; links to it are available from all Highlands State, county, and municipal Web sites.
2. Monitor landscapes and resources		
Use indicators Establish and measure indicators using existing collection methods and indicators such as the Forest Service's sustainability criteria and indicators. Provide access to monitoring data and reports. Use watershed and ecological units to assess risks and cumulative effects.	Prepare a periodic report on the status of the Highlands' resources. Report on monitoring results and long-term trends, particularly on high priority lands. Develop long-term plans for monitoring implementation, analysis, and research.	Standardized set of environmental indicators is adopted by Highlands states to monitor resource change and effects. Monitoring information is distributed electronically to local land use planners and environmental managers.

Continued

Summary of conservation strategies for the Highlands (continued)

Actions may include:	Examples may include:	Measures of accomplishment or environmental change:
Use current data Gather and organize existing data. Organize activities such as research, studies, and resource monitoring, so resources are used effectively.	Share data with traditional and nontraditional partners, including Extension Services, developers, nongovernment organizations, and private industry. Coordinate with resource organizations that have demonstrated interest and expertise in Highlands conservation issues. Package knowledge appropriately for different users.	Data is used by decisionmakers, citizens, and companies in their natural resource planning and protection efforts. Study results are incorporated into and considered in ongoing research. For example, the Yale School of Forestry and Environmental Studies is creating town-level summaries for the Connecticut Highlands towns and county-level summaries for the Pennsylvania Highlands counties, based on the results of the growth and impact analyses in this study.
3. Demonstrate conservation		
Use creative techniques Invest in activities other than land acquisition. Take a collaborative approach to planning, financing, and implementing conservation projects on public and private lands.	Educate the public on the importance of working forests and agricultural lands, and the threats to their sustainable use, such as invasive species. Consider nontraditional funding sources in project development.	The general Highlands population has a better understanding of the major threats to the region, besides land lost to development. Traditional land conservation organizations such as land trusts focus on thinking beyond land protection.
Design customized, replicable projects Use the tools and talents of various groups and agencies to conserve resources. Focus on high priority landscapes or watersheds. Showcase the results of cooperative conservation (Harper and others 2006) on public and private lands.	Look at conservation focal areas identified in this report and other studies, such as Forests, Water and People (Barnes and others 2009), to identify project areas. Consider the role of agricultural and forest products interests in land conservation. Create a Highlands conservation bank to trade development rights, to encourage conservation in some areas and development in others.	A model forest is established in each Highlands state. At least two Highlands states partner to protect a common high priority landscape.

Continued

Actions may include:	Examples may include:	Measures of accomplishment or environmental change:
Promote private land stewardship Create a Highlands-specific approach for natural resource management on private forests and farmlands that focuses on the highest conservation value areas. Develop funding streams for technical assistance and stewardship. Assist municipalities and counties with options and choices for land use planning that keeps forests and farms intact.	Promote national policies and markets to help private landowners conserve open space (Harper and others 2006). Promote existing programs for private forests and farmland on qualifying properties managed for water, wildlife, or recreation, in addition to commodity production.	Highlands private forest landowners are informed about current tax laws and benefits for owning and managing their lands. Highlands landowners voluntarily receive regular electronic updates about land management tools and funding available for land management and conservation.
4. Conserve land through acquisition		
Prioritize lands for acquisition. Allow public and private partners to review priorities. Evaluate the fiscal impacts of land acquisition; provide consistent mechanisms to compensate documented losses of revenue. Use existing programs more effectively. Leverage resources to generate additional funding.	Priority lands identified by several sources, in Forest Service and other Federal, State, local and non-profit plans, are protected. More private landowners understand the benefits of placing a conservation easement on their land.	Federal, State, and local resources are used for acquisition. Lands dedicated for conservation are required in all new development proposals. New lands are acquired with private investments. Resources are leveraged to generate additional funding.
5. Make resource conservation a planning and design issue		
Integrate protection and planning Work with State and local governments to incorporate Highlands' data in their capital improvement, environmental constraints, open space, and master planning.	Advise local land use planners about planning tools they can consider to protect natural resources, such as low-impact and cluster development, transfer of development rights, zoning overlay districts, and aquifer protection overlay districts. Relate the Highlands study to current watershed studies and regulations in each Highlands state.	State and local governments identify the Highlands resources in their master plans. State and local governments use the Highlands study and consider its findings in developing new regulations. State and local governments develop planning standards providing for larger buffers around the highest quality streams and vernal pools.

Continued

Actions may include:	Examples may include:	Measures of accomplishment or environmental change:
Improve cross-jurisdictional planning Coordinate decisionmaking between States, landscapes, and watersheds. Keep Federal authorities and State legislatures informed on Highlands' issues.	Establish a public and private roundtable on conservation of Highlands' resources. Continue the Forest Service's leadership role in the Highlands. Convene an interagency and multi-stakeholder group annually.	There is coordinated protection of contiguous large forest blocks across political boundaries. A multi-state water protection compact is established.
Build local government capacity Strengthen communication among Federal, State, and local agencies. Train local officials on the basics of land use planning.	Improve government coordination, training, resources (Harper and others 2006). Use existing natural resource plans including State Forest Resource Assessments, to protect important natural resources, including valuable forest lands near headwaters and those with high timber or wildlife values (Stein and others 2005).	More new development in the Highlands does not contribute to increased forest fragmentation. Most Highlands municipalities adopt a greenway or open space plan as part of their master plan.
Align conservation and development Educate people on how to develop and meet conservation goals. Identify areas for different levels of conservation. Identify areas for different levels of development. Create win-win solutions to land use issues. Inform developers about conservation measures and facilitate resolution of conflicts over land use.	Host workshops to demonstrate to skeptics that conservation is a good investment. Use "environmental assessment forms" or "pre-planning charettes" to develop, test, and refine the planning, design, and development process. Provide incentives for compact, multi-use development, in-fill and brownfield development, and Best Management Practices (BMPs). Engage nontraditional conservation interests and use volunteers and youth.	With the support of the development community, local and county governments secure funds for purchasing land, easements, and development rights. Each Highlands state identifies and adopts a set of tools that municipalities can use to balance conservation and development. Development proposals with a good balance of conservation and development are expedited.

Continued

Actions may include:	Examples may include:	Measures of accomplishment or environmental change:
Develop comprehensive strategies Build on the Highlands Regional Study. Create a menu of strategies to preserve the integrity of the region. Define where each strategy would work best, recognizing that different strategies may be more or less appropriate in different places.	Use the conservation strategies identified in the Highlands studies to tailor specific strategies for a Highlands municipality or group of adjacent municipalities. Use existing plans and resources, such as those developed by State natural resource agencies, to guide local strategies.	Specific sets of conservation strategies are developed for Highlands towns, in coordination with the town's master plan, and open space and transportation plans. Local investments are aligned with conservation goals and reflect priorities identified in conservation plans.
6. Increase coordination with other Federal and State agencies, and with private groups		
Develop conservation projects at the landscape or watershed scales. Initiate projects with leadership from local stakeholders and landowners. Leverage financial and technical resources from diverse organizations using creative means.	Improve existing conservation programs by making programs more targeted and increasing the use of market mechanisms, consolidating programs that share common purposes and incentives. Provide "green payments" to enhance environmental benefits and provide income support. Develop programs that would reward producers for environmental performance. Encourage private sector markets for environmental services. Environmental markets with relevance to agriculture and forestry include water quality, air quality, wetlands, endangered species, greenhouse gases, and development rights.	A conservation project at the level of the landscape, watershed, or ecological unit is initiated. More multi-jurisdictional, landscape scale conservation projects are completed. It becomes common for private markets to supplement Federal efforts for conservation. Expertise of State and other conservation partners is sought and used to the extent possible. (Harper and others 2006). More State and local laws are passed that provide incentives for conservation.

Continued

Summary of conservation strategies for the Highlands (continued)

Actions may include:	Examples may include:	Measures of accomplishment or environmental change:
7. Consider the four-State Highlands region		
Inform key stakeholders in the New Jersey and New York Highlands about the Connecticut and Pennsylvania Update and its key findings. Produce a revised and expanded set of conservation focal areas and conservation strategies for the entire Highlands region.	Offer a public workshop in New York and New Jersey where stakeholders could learn about the entire region and the Forest Service role in the region. Send brochures about the four-state Highlands study to key stakeholders in New York and New Jersey. Following the release of the Connecticut-Pennsylvania study, produce a brochure and Web site highlighting the important places and significant features across the region.	Key stakeholders and members of the public across the region learn about its important places and significant features. Natural resource agencies across the four-State region are informed electronically and in public presentations of the key findings of both updates to the Highlands Regional Study.

Closing comments

The Highlands of Pennsylvania, New Jersey, New York, and Connecticut comprise a region of national significance bordering an expanding and vast metropolitan area. The region encompasses 3.4 million acres including 319 municipalities. It has abundant forests, fields, and natural resources that provide quality drinking water, recreation, and economic opportunities to its residents. Without a viable strategy to address new development and protect priority resources, these important natural resources may be lost or degraded. The economic cost of supplying the ecosystem services and benefits now provided by the region could be substantial for increased water treatment, public services, and infrastructure costs. Land management and conservation activities at the Federal, State, local, and nonprofit levels can provide complementary, shared approaches to conserve the Highlands resources.

In collaboration with State and local partners, the Forest Service played an important role in the Highlands conservation successes. The New York – New Jersey Update (Phelps and Hoppe 2002) and this Connecticut – Pennsylvania Update have identified conservation focal areas with critical resources in need of protection and potential conservation strategies. The conservation strategies identified by the public can be used by State, local and nongovernmental decisionmakers to protect the region's natural resources while supporting economic growth. A partnership approach to land conservation in the Highlands will protect water quality, wildlife, and plants, sustain forests and retain working forests and farms, and provide recreational opportunities.

References for Section 4

Barnes, Martina C.; Todd, Albert H.; Whitney Lilja, Rebecca; Barten, Paul K. Forests, Water and People: Drinking water supply and forest lands in the Northeast and Midwest United States. NA-FR-01-08. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 71 p.

Harper, Claire; Crow, Tom; Cooksey, Rick; Hoover, Ann. FS National Open Space Strategy, 2006. Cooperating Across Boundaries, Partnerships to Conserve Open Space in Rural America. Forest Service Report FS-861. Washington DC: U.S. Department of Agriculture, Forest Service. 49 p.

Stein, Susan M.; McRoberts, Ronald E.; Alig, Ralph J.; Nelson, Mark D.; Theobald, David M.; Eley, Mike; Dechter, Mike; Carr, Mary. 2005. Forests on the edge: housing development on America's private forests. General Technical Report PNW-GTR-636. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p. www.fs.fed.us/openspace/fote/national_forests_on_the_edge.html (May 2, 2008).

Appendix A
Legislative language for the Highlands Regional Study: Pennsylvania and Connecticut 2010 Update

The following language appears in the Highlands Conservation Act (PL 108-42), (Engrossed Amendment as agreed to by Senate), HR 1964 EAS, October 10, 2004:

SEC. 5. FOREST SERVICE AND USDA PROGRAMS IN THE HIGHLANDS REGION.

(a) IN GENERAL—To meet the land resource goals of, and the scientific and conservation challenges identified in, the Study, Update, and any future study that the Forest Service may undertake in the Highlands region, the Secretary of Agriculture, acting through the Chief of the Forest Service and in consultation with the Chief of the Natural Resources Conservation Service, shall continue to assist the Highlands States, local units of government, and private forest and farm landowners in the conservation of land and natural resources in the Highlands region.

(b) DUTIES—The Forest Service shall—

(1) in consultation with the Highlands States, undertake other studies and research in the Highlands region consistent with the purposes of this Act, including a Pennsylvania and Connecticut Update;

(2) communicate the findings of the Study and Update and maintain a public dialogue regarding implementation of the Study and Update; and

(3) assist the Highland States, local units of government, individual landowners, and private organizations in identifying and using Forest Service and other technical and financial assistance programs of the Department of Agriculture.

(c) AUTHORIZATION OF APPROPRIATIONS—There is authorized to be appropriated to the Secretary of Agriculture to carry out this section $1,000,000 for each of fiscal years 2005 through 2014.

Appendix B
Work plan and budget for the Highlands Regional Study: Connecticut and Pennsylvania 2010 Update

Summary of Work Plan

Major Steps	**Completion Date**
Part 1 – Conservation Values Assessment	
Complete study logistics and study kick-off	June 2005
Public listening sessions	October 2005
Assess natural resources and identify areas of high resource value	November 2005
Draft report	July 2006
Public comment period	July-August 2006
Final report	April 2007
Part 2 – Growth and Impact Analysis	
Complete study logistics and study kick-off	July 2006
Data collection and assessment	December 2006
First Pennsylvania and Connecticut stakeholder workshops	March 2007
Data analysis	September 2007
Second Pennsylvania and Connecticut stakeholder workshops	October 2007
Draft report	May 2008
Team review	June 2008
Final report	March 2010 (Part of compilation report)

Major Steps	**Completion Date**
Compilation of Part 1 and Part 2	
Draft report	Winter 2010
Public comment period	Spring 2010
Final study report	Fall 2010

Budget (Forest Service only)

Expense	**Amount**
Phase 1 – Conservation Values Assessment	
Salary	$290,000
Assessment and analysis	$210,000
Phase 2 – Growth and Impact Analysis	
Salary	$185,000
Assessment and analysis	$950,000
Compilation of Part 1 and Part 2	
Study report printing	$50,000
Total	**$1,685,000**

Appendix C
Study team members

The study teams guided the process and provided the technical services and skills needed to conduct the study and prepare the update. Team members are listed in alphabetical order under their organization, by state, phase of the study, and subject area.

Connecticut Part 1 – Conservation Values Assessment

University of Connecticut Cooperative Extension System (team leaders)

Sandy Prisloe, geospatial extension specialist
Thomas E. Worthley, associate extension educator

University of Connecticut Cooperative Extension System (Geographic Information System Mapping (GIS))

Joel Stocker, assistant extension educator
Assisted by Kirk D. Sinclair, GIS manager, Housatonic Valley Association

USDA Natural Resources Conservation Service, U.S. Department of Agriculture (ecological mapping and classification)

Nels Barrett, ecologist

Connecticut Department of Environmental Protection (forestry)

Fred Borman III, program specialist I—forestry
Larry Rousseau, forester

U.S. Geological Survey, Connecticut Water Science Center (hydrology)

Elizabeth Ahearn, supervisory hydrologist
Virginia de Lima, director

Regional Plan Association (public input)

John Atkin, planner
Emily J. Moos, associate planner
Robert Pirani, director of environmental programs
Heidi Wailand, associate planner
Assisted by Elaine LaBella, planner, Housatonic Valley Association

Forest Service, U.S. Department of Agriculture (study coordination)

Martina Barnes, regional planner
Edward Boyer, Highlands coordinator
Helen Butalla, information technology specialist
Brett Butler, research forester
Constance Carpenter, sustainability coordinator
Robert Fitzhenry, public and legislative affairs
Mary Paterson, communications officer
Ann Steketee, GIS specialist

Rutgers University Center for Remote Sensing and Spatial Analysis (Highlands Regional Information System (HiRIS))

Rick Lathrop, director

Connecticut Part 2 – Growth and Impact Analysis and Forest and Agricultural Resource Analysis

Forest Service, U.S. Department of Agriculture (study coordination)

Martina Barnes, regional planner
Edward Boyer, Highlands coordinator
Jim Steinman, forest health management coordinator

Yale University, Yale School of Forestry and Environmental Studies

Ann Camp, Ph.D., director of programs on forest health
Ellen Hawes, research assistant
Samuel Price, student
Mary Tyrrell, executive director
Larissa Yocum, research assistant

State University of New York, College of Environmental Science and Forestry (growth model and impact analysis)

Myrna Hall, Ph.D., assistant professor
Seth Myers, Ph.D. candidate

University of Connecticut Extension (agricultural analysis)

Joel Stocker, assistant extension educator
Thomas Worthley, associate extension educator

Regional Plan Association (build-out analysis)

Jennifer Cox, geographer
Robert Pirani, director of environmental programs

U.S. Geological Survey, Connecticut Water Science Center (hydrology)

Elizabeth Ahearn, supervisory hydrologist
David M. Bjerklie, hydrologist
Virginia de Lima, director

Connecticut Department of Environmental Protection (State contacts, forest and water resources assistance)

Susan Peterson, watershed manager and Housatonic Watershed coordinator

Pennsylvania Part 1 – Conservation Values Assessment

Forest Service, U.S. Department of Agriculture (study coordination)

Martina Barnes, regional planner
Edward Boyer, Highlands coordinator
Helen Butalla, information technology specialist
Brett Butler, research forester
Constance Carpenter, sustainability coordinator
Mary Paterson, communications coordinator

Charles M. Reger, public affairs team leader
Ann Steketee, GIS specialist

Pennsylvania State University (team leaders)
James C. Finley, professor of forest resources
Albert E. Luloff, professor of rural sociology

Pennsylvania State University (GIS mapping)
Wayne Myers, professor of forest biometrics
Assisted by Clare Billett, landscape conservation program manager, Natural Lands Trust
Assisted by Bret Magdasy, GIS staff scientist, Appalachian Mountain Club

Pennsylvania State University (forestry)
Mark E. McDill, school of forest resources
Assisted by Daniel A. Devlin, state forester, Pennsylvania Department of Conservation and Natural Resources

Pennsylvania Department of Conservation and Natural Resources (geology)
Stuart Reese, senior geological scientist

U.S. Geological Survey, Pennsylvania Water Science Center (hydrology)
Patricia L. Lietman, Pennsylvania district chief, U.S. Geological Survey
Curtis Shreffler, supervisory hydrologist, U.S. Geological Survey
Tammy Zimmerman, hydrologist, U.S. Geological Survey
Assisted by Jessica Rittler Sanchez, river basin planner, Delaware River Basin Commission

Natural Lands Trust (biodiversity)
Clare Billett, program manager for landscape conservation
Assisted by David Jastenski, Pennsylvania Department of Environmental Protection
Assisted by Arianna Proctor, Pennsylvania Department of Environmental Protection
Assisted by Diane Matthews-Gehringer, Wildlands Conservancy
Assisted by Mary Walsh, the Nature Conservancy, Pennsylvania Natural Heritage Program

Appalachian Mountain Club (public input)
Kristen Sykes, Highlands advocate
Assisted by Debra Lermitte, director, land conservation and planning, Wildlands Conservancy
Assisted by Mary Paterson, communications coordinator, Forest Service, U.S. Department of Agriculture
Assisted by Laurie Schoonhoven, program specialist, Sustainable Forestry Partnership
Assisted by Todd Stell, vice president, Stell Environmental Enterprises

Rutgers University Center for Remote Sensing and Spatial Analysis (Highlands Regional Information System (HiRIS)
Rick Lathrop, director

Pennsylvania Phase 2 – Growth and Impact Analysis and Resource Analysis

Forest Service, U.S. Department of Agriculture (study coordination)
Martina Barnes, regional planner
Edward Boyer, Highlands coordinator
Jim Steinman, forest health management coordinator

Yale University, Global Institute of Sustainable Forestry (team leader)
Ann Camp, Ph.D., director of programs on forest health
Ellen Hawes, research assistant
Samuel Price, student
Mary Tyrrell, executive director
Larissa Yocum, research assistant

State University of New York, College of Environmental Science and Forestry (growth model and impact analysis)
Myrna Hall, Ph.D., assistant professor
Seth Myers, Ph.D. candidate

Regional Plan Association (build-out analysis)
Jennifer Cox, geographer
Robert Pirani, director of environmental programs

Appalachian Mountain Club, through a subcontract to the Pennsylvania Department of Conservation and Natural Resources (agricultural analysis)
Kenneth Kimball, Ph.D., director of research
David Publicover, Ph.D., assistant research director
John Storelli, GIS staff scientist

U.S. Geological Survey, Pennsylvania Water Science Center (hydrology)
Edward Koerkel, hydrologist
Patricia Lietman, director
Curtis Schreffler, supervisory hydrologist
Tammy Zimmerman, hydrologist

Pennsylvania Department of Conservation and Natural Resources (State contacts, general resource assistance)
Daniel A. Devlin, State forester
Diane W. Kripas, chief, Greenways and Conservation Partnerships Division

Pennsylvania Department of Environmental Protection (State contacts, general resource assistance)
John Booser, associate director for River Basin Cooperation
Diane Wilson, chief, Watershed Support Section

Appendix D
List of Public Meetings

Study team members are not included in the number of attendees.

Connecticut Part 1 – Conservation Values Assessment

Work group meeting, Torrington, September 23, 2005
19 attendees

Listening session, Falls Village, October 18, 2005
33 attendees

Listening session, Torrington, October 20, 2005
17 attendees

Listening session, New Milford, October 25, 2005
47 attendees

Connecticut Part 2 – Growth and Impact Analysis

Meeting and tour, Haddam, November 3, 2006

5 attendees

Workshop 1, Torrington, January 19, 2007
10 attendees

Workshop 2, Torrington, October 18-19, 2007
17 attendees

Pennsylvania Part 1 – Conservation Values Assessment

County forum, Elverson, October 4, 2005
15 attendees

Public facilitated group discussion, Middletown, October 27, 2005
Number of attendees not known.

Public facilitated group discussion, Ephrata, November 1, 2005
Number of attendees not known.

Public facilitated group discussion, Pottstown, November 3, 2005
Number of attendees not known.

Public facilitated group discussion, Quakertown, November 9, 2005
Number of attendees not known.

Pennsylvania Part 2 – Growth and Impact Analysis

Meeting and tour, Bethlehem, November 17, 2006
8 attendees

Workshop 1, Elverson, March 8, 2007
14 attendees

Workshop 2, Reading, October 25-26, 2007
22 attendees

Appendix E—Public comments on the draft report

The public comment period to seek input on the draft report was open from May 3 through June 18, 2010.

Four persons and organizations submitted detailed comments:

1. Elaine LaBella, Housatonic Valley Association (May 26, 2010)
2. Susan Peterson, Connecticut Department of Environmental Protection, Bureau of Water Protection and Land Reuse (June 27, 2010)
3. Patrick M. Comins, Audubon Connecticut (June 18, 2010)
4. Mark Zakutansky, Appalachian Mountain Club, (June 18, 2010)

Summary of public comments

Comments received at the public meetings and in the detailed written comments focused primarily on the water, forest, and biological resource analyses; the build-out analysis; the conservation strategies section; and other general comments. The comments are described below.

Water resources

- Include additional information in the report about how land-use changes potentially will affect water quality.
- Include a new section about trends in water quality.
- Include a discussion about the impacts of inter-basin transfers and downstream water releases.
- Add a discussion about the impacts of build-out on ground water quality.
- Consider the impact of water withdrawals on all Highlands resources.
- Identify a critical "breaking point" when additional withdrawals would have serious environmental impacts.
- Explain the additional consumptive water use by 14-digit HUC subwatersheds.

Biological resources

- In Connecticut, available biological resources information is limited to threatened and endangered species, and may not consider species that are locally common but may be globally significant.

Forest resources

- Prioritization of forest resources should include an analysis at the 1-kilometer (regional) scale. In response to this comment, the study team performed an additional analysis at the 1-square-kilometer scale to better understand the potential impacts of forest fragmentation to biodiversity at a regional scale, and to help identify key forested landscapes that may not have been identified in the smaller forest block approach to prioritization, as was performed in the original analysis. This additional analysis looked at the impacts of forest fragmentation in three classes of forest cover: less than 70 percent; between 70 and 80 percent; and more than 80 percent. The results show that 43 percent of the fragmentation occurs in areas with less than 70 percent forest cover; 39 percent of the fragmentation occurs in areas of more than 80 percent forest cover; and the remaining 18 percent occurs in areas with between 70 and 80 percent forest cover.
  This analysis shows that there are larger impacts with regard to forest fragmentation (more edge forest created) in areas with more than 80 percent forest cover than the Highlands study analysis shows. In other words, the impacts caused by forest fragmentation at the 1-square-kilometer (247 acres) scale are greater than at the 18.6-acre scale that was used for the original Highlands study analysis. Therefore, based on this additional analysis, forest fragmentation affects a greater area than was shown in the original analysis.
- Describe what forest types and age classes will better support regional biodiversity.
- Place stronger emphasis on the importance of forests, and that many of them are unprotected.

Build-out analysis

- Include a discussion of limiting factors on housing and commercial development besides zoning regulations, such as drinking water availability.
- Include a discussion about the impacts of different build-out conditions on water quality.
- Consider additional constraints for the build-out approach.
- Consider scientifically defensible standards developed by other regional planning entities.
- Explain why large-lot zoning causes fragmentation.

Conservation strategies

- Outline the specific tasks the Forest Service will undertake to protect the Highlands natural resources.
- Outline the specific role that the States, nonprofit organizations, and other partners will play in protecting the Highlands natural resources.

Other general comments

- Place increased emphasis on the work that other partners have done in the Highlands.
- Make all of the Highlands data sets, maps, and GIS layers available to partner organizations.
- Distill some of the information presented in the study down to the local level.

Some of the information requested through the public comments is available in the technical reports that each of the study teams prepared; they are posted on the Forest Service's Highlands Web site at http://na.fs.fed.us/highlands/techreports/index.shtm.

Appendix F—Topics in the Pennsylvania and Connecticut Highlands Technical Report

The full technical report can be found on the U.S. Forest Service's Highlands Web site (www.na.fs.fed.us/highlands/regional/index.shtm).

Connecticut—Conservation Values Assessment

Written by Joel Stocker and Thomas Worthley of the University of Connecticut, Cooperative Extension System

- Introduction
- Descriptive items
- Water resources conservation values assessment
- Biodiversity resource conservation values assessment
- Recreation and cultural conservation values assessment
- Agricultural resources conservation values assessment
- Forest resources conservation values assessment
- Composite conservation values assessment

Connecticut—Public Input

Written by Emily Moos and Rob Pirani of the Regional Plan Association

- Summary of key findings
- Appendix A, Summary of Listening Sessions
- Appendix B, Sample Questionnaire

Connecticut—Water Resources

Written by Elizabeth Ahearn, US Geological Survey, Connecticut Water Science Center

Ground water—aquifers and wells
Surface water—streams, rivers, and reservoirs
Water use
Water quality
Water budget
Impacts of land use change on water resources and on the water budget

Pennsylvania—Conservation Values Assessment and Public Input

Written by Jim C. Finley, Al E. Luloff, and Wayne L. Myers, Pennsylvania State University

- Executive summary
- Introduction to GIS-based Conservation Values Assessment
- GIS-based conservation assessment
- Community input for conservation values in the Highlands
- Summary of community input for conservation values in the Highlands
- Findings and conclusions of community input for conservation values in the Highlands

Pennsylvania—Water Resources

Written by Curtis Schreffler, US Geological Survey, Pennsylvania Water Science Center

Water Resources

Withdrawals of ground and surface water

Ground water level data

Streamflow data and baseflow determination

Watershed assessment

Ground and surface water quality

Connecticut and Pennsylvania—Growth and Impact Analysis

Written by Mary Tyrrell and her study team, Yale University Global Institute of Sustainable Forestry, School of Forestry and Environmental Studies

Acknowledgments

- Chapter 1: Introduction
- Chapter 2: Conserved Land
- Chapter 3: Socio-Demographic Characteristics and Trends
- Chapter 4: Forest Resources Characteristics and Trends
- Chapter 5: Agricultural Resources Characteristics and Trends
- Chapter 6: Zoning Build-out Analysis
- Chapter 7: Analysis of Land Use and Land Cover
- Chapter 8: Models of Land Use and Land Cover Change
- Chapter 9: Impacts of Land Use and Land Cover Change on the Resources of the Highlands
- Chapter 10: Development Risk on High Conservation Value Lands
- References
- Appendixes

Definitions of Fragmentation Categories

Types of Zoning Build-Out Analyses

Municipality Zoning Build-Out Data

Description of GEOMOD

Agricultural Key Informant Survey

Connecticut Data

Pennsylvania Data

Appendix G
Municipalities and counties in the Connecticut and Pennsylvania Highlands

Connecticut

	Name	Type	County
1	Barkhamsted	Town	Litchfield
2	Brookfield	Town	Fairfield
3	Burlington	Town	Hartford
4	Canaan	Town	Litchfield
5	Canton	Town	Hartford
6	Colebrook	Town	Litchfield
7	Cornwall	Town	Litchfield
8	Danbury	City	Fairfield
9	Goshen	Town	Litchfield
10	Granby	Town	Hartford
11	Hartland	Town	Hartford
12	Harwinton	Town	Litchfield
13	Kent	Town	Litchfield
14	Litchfield	Town	Litchfield
15	Morris	Town	Litchfield
16	New Fairfield	Town	Fairfield
17	New Hartford	Town	Litchfield
18	New Milford	Town	Litchfield
19	Norfolk	Town	Litchfield
20	North Canaan	Town	Litchfield
21	Salisbury	Town	Litchfield
22	Sharon	Town	Litchfield
23	Sherman	Town	Fairfield
24	Simsbury	Town	Hartford
25	Torrington	City	Litchfield
26	Warren	Town	Litchfield
27	Washington	Town	Litchfield
28	Winchester	Town	Litchfield

Pennsylvania

	Name	Type	County
1	Adamstown	Borough	Lancaster County
2	Adamstown	Borough	Berks County
3	Akron	Borough	Lancaster County
4	Alburtis	Borough	Lehigh County
5	Allentown	City	Lehigh County
6	Alsace	Township	Berks County
7	Amity	Township	Berks County
8	Annville	Township	Lebanon County
9	Atglen	Borough	Chester County
10	Bally	Borough	Berks County
11	Bart	Township	Lancaster County
12	Bechtelsville	Borough	Berks County
13	Bedminster	Township	Bucks County
14	Bern	Township	Berks County
15	Bethlehem	Township	Northampton County
16	Bethlehem	City	Northampton County
17	Bethlehem	City	Lehigh County
18	Birdsboro	Borough	Berks County
19	Boyertown	Borough	Berks County
20	Brecknock	Township	Lancaster County
21	Brecknock	Township	Berks County
22	Bridgeton	Township	Bucks County
23	Buckingham	Township	Bucks County
24	Caernarvon	Township	Lancaster County
25	Caernarvon	Township	Berks County
26	Caln	Township	Chester County
27	Centre	Township	Berks County
28	Christiana	Borough	Lancaster County
29	Clay	Township	Lancaster County
30	Coatesville	City	Chester County
31	Colebrookdale	Township	Berks County
32	Colerain	Township	Lancaster County
33	Collegeville	Borough	Montgomery County
34	Conewago	Township	Dauphin County
35	Conewago	Township	York County
36	Conoy	Township	Lancaster County
37	Coopersburg	Borough	Lehigh County
38	Cornwall	Borough	Lebanon County

Continued

Pennsylvania (continued)

39	Cumru	Township	Berks County
40	Denver	Borough	Lancaster County
41	Derry	Township	Dauphin County
42	District	Township	Berks County
43	Douglass	Township	Montgomery County
44	Douglass	Township	Berks County
45	Doylestown	Township	Bucks County
46	Dublin	Borough	Bucks County
47	Durham	Township	Bucks County
48	Earl	Township	Lancaster County
49	Earl	Township	Berks County
50	East Brandywine	Township	Chester County
51	East Cocalico	Township	Lancaster County
52	East Coventry	Township	Chester County
53	East Donegal	Township	Lancaster County
54	East Drumore	Township	Lancaster County
55	East Earl	Township	Lancaster County
56	East Fallowfield	Township	Chester County
57	East Greenville	Borough	Montgomery County
58	East Hanover	Township	Dauphin County
59	East Hempfield	Township	Lancaster County
60	East Lampeter	Township	Lancaster County
61	East Manchester	Township	York County
62	East Nantmeal	Township	Chester County
63	East Pikeland	Township	Chester County
64	East Rockhill	Township	Bucks County
65	East Vincent	Township	Chester County
66	Easton	City	Northampton County
67	Eden	Township	Lancaster County
68	Elizabeth	Township	Lancaster County
69	Elizabethtown	Borough	Lancaster County
70	Elverson	Borough	Chester County
71	Emmaus	Borough	Lehigh County
72	Ephrata	Township	Lancaster County
73	Ephrata	Borough	Lancaster County
74	Exeter	Township	Berks County
75	Fairview	Township	York County
76	Fleetwood	Borough	Berks County

Continued

77	Forks	Township	Northampton County
78	Fountain Hill	Borough	Lehigh County
79	Franconia	Township	Montgomery County
80	Freemansburg	Borough	Northampton County
81	Glendon	Borough	Northampton County
82	Goldsboro	Borough	York County
83	Green Lane	Borough	Montgomery County
84	Greenwich	Township	Berks County
85	Hanover	Township	Lehigh County
86	Hanover	Township	Northampton County
87	Haycock	Township	Bucks County
88	Heidelberg	Township	Lebanon County
89	Heidelberg	Township	Berks County
90	Hellam	Township	York County
91	Hellertown	Borough	Northampton County
92	Hereford	Township	Berks County
93	Highland	Township	Chester County
94	Hilltown	Township	Bucks County
95	Honey Brook	Township	Chester County
96	Honey Brook	Borough	Chester County
97	Hummelstown	Borough	Dauphin County
98	Jackson	Township	Lebanon County
99	Kenhorst	Borough	Berks County
100	Kutztown	Borough	Berks County
101	Laureldale	Borough	Berks County
102	Leacock	Township	Lancaster County
103	Lebanon	City	Lebanon County
104	Leesport	Borough	Berks County
105	Lewisberry	Borough	York County
106	Limerick	Township	Montgomery County
107	Londonderry	Township	Dauphin County
108	Longswamp	Township	Berks County
109	Lower Allen	Township	Cumberland County
110	Lower Alsace	Township	Berks County
111	Lower Frederick	Township	Montgomery County
112	Lower Heidelberg	Township	Berks County
113	Lower Macungie	Township	Lehigh County
114	Lower Milford	Township	Lehigh County
115	Lower Nazareth	Township	Northampton County

Continued

Pennsylvania (continued)

116	Lower Pottsgrove	Township	Montgomery County
117	Lower Providence	Township	Montgomery County
118	Lower Salford	Township	Montgomery County
119	Lower Saucon	Township	Northampton County
120	Lower Swatara	Township	Dauphin County
121	Lyons	Borough	Berks County
122	Macungie	Borough	Lehigh County
123	Maidencreek	Township	Berks County
124	Manheim	Township	Lancaster County
125	Manheim	Borough	Lancaster County
126	Marion	Township	Berks County
127	Marlboro	Township	Montgomery County
128	Maxatawny	Township	Berks County
129	Middletown	Borough	Dauphin County
130	Milford	Township	Bucks County
131	Millcreek	Township	Lebanon County
132	Mohnton	Borough	Berks County
133	Monaghan	Township	York County
134	Mount Gretna	Borough	Lebanon County
135	Mount Joy	Township	Lancaster County
136	Mt. Joy	Borough	Lancaster County
137	Mt. Penn	Borough	Berks County
138	Muhlenberg	Township	Berks County
139	New Britain	Township	Bucks County
140	New Cumberland	Borough	Cumberland County
141	New Hanover	Township	Montgomery County
142	New Holland	Borough	Lancaster County
143	New Morgan	Borough	Berks County
144	Newberry	Township	York County
145	Nockamixon	Township	Bucks County
146	North Cornwall	Township	Lebanon County
147	North Coventry	Township	Chester County
148	North Lebanon	Township	Lebanon County
149	North Londonderry	Township	Lebanon County
150	Oley	Township	Berks County
151	Ontelaunee	Township	Berks County
152	Palmer	Township	Northampton County
153	Paradise	Township	Lancaster County

Continued

154	Parkesburg	Borough	Chester County
155	Penn	Township	Lancaster County
156	Pennsburg	Borough	Montgomery County
157	Pequea	Township	Lancaster County
158	Perkasie	Borough	Bucks County
159	Perkiomen	Township	Montgomery County
160	Perry	Township	Berks County
161	Pike	Township	Berks County
162	Plainfield	Township	Northampton County
163	Plumstead	Township	Bucks County
164	Pottstown	Borough	Montgomery County
165	Providence	Township	Lancaster County
166	Quakertown	Borough	Bucks County
167	Quarryville	Borough	Lancaster County
168	Rapho	Township	Lancaster County
169	Reading	City	Berks County
170	Red Hill	Borough	Montgomery County
171	Richland	Township	Bucks County
172	Richland	Borough	Lebanon County
173	Richlandtown	Borough	Bucks County
174	Richmond	Township	Berks County
175	Riegelsville	Borough	Bucks County
176	Robeson	Township	Berks County
177	Robesonia	Borough	Berks County
178	Rockland	Township	Berks County
179	Royalton	Borough	Dauphin County
180	Royersford	Borough	Montgomery County
181	Ruscombmanor	Township	Berks County
182	Sadsbury	Township	Chester County
183	Sadsbury	Township	Lancaster County
184	Salford	Township	Montgomery County
185	Salisbury	Township	Lehigh County
186	Salisbury	Township	Lancaster County
187	Schwenksville	Borough	Montgomery County
188	Sellersville	Borough	Bucks County
189	Shillington	Borough	Berks County
190	Sinking Spring	Borough	Berks County
191	Skippack	Township	Montgomery County
192	Solebury	Township	Bucks County

Continued

Pennsylvania (continued)

193	Souderton	Borough	Montgomery County
194	South Annville	Township	Lebanon County
195	South Coventry	Township	Chester County
196	South Hanover	Township	Dauphin County
197	South Heidelberg	Township	Berks County
198	South Lebanon	Township	Lebanon County
199	South Londonderry	Township	Lebanon County
200	South Whitehall	Township	Lehigh County
201	Spring	Township	Berks County
202	Spring City	Borough	Chester County
203	Springfield	Township	Bucks County
204	St. Lawrence	Borough	Berks County
205	Stockertown	Borough	Northampton County
206	Strasburg	Township	Lancaster County
207	Strasburg	Borough	Lancaster County
208	Swatara	Township	Dauphin County
209	Tatamy	Borough	Northampton County
210	Telford	Borough	Montgomery County
211	Telford	Borough	Bucks County
212	Terre Hill	Borough	Lancaster County
213	Tinicum	Township	Bucks County
214	Topton	Borough	Berks County
215	Towamencin	Township	Montgomery County
216	Trappe	Borough	Montgomery County
217	Trumbauersville	Borough	Bucks County
218	Union	Township	Berks County
219	Upper Frederick	Township	Montgomery County
220	Upper Hanover	Township	Montgomery County
221	Upper Leacock	Township	Lancaster County
222	Upper Macungie	Township	Lehigh County
223	Upper Milford	Township	Lehigh County
224	Upper Nazareth	Township	Northampton County
225	Upper Oxford	Township	Chester County
226	Upper Pottsgrove	Township	Montgomery County
227	Upper Providence	Township	Montgomery County
228	Upper Salford	Township	Montgomery County
229	Upper Saucon	Township	Lehigh County
230	Upper Uwchlan	Township	Chester County

Continued

231	Uwchlan	Township	Chester County
232	Valley	Township	Chester County
233	Wallace	Township	Chester County
234	Warrington	Township	York County
235	Warwick	Township	Chester County
236	Warwick	Township	Lancaster County
237	Washington	Township	Berks County
238	Wernersville	Borough	Berks County
239	West Brandywine	Township	Chester County
240	West Caln	Township	Chester County
241	West Cocalico	Township	Lancaster County
242	West Cornwall	Township	Lebanon County
243	West Donegal	Township	Lancaster County
244	West Earl	Township	Lancaster County
245	West Easton	Borough	Northampton County
246	West Fallowfield	Township	Chester County
247	West Hempfield	Township	Lancaster County
248	West Lampeter	Township	Lancaster County
249	West Lawn	Borough	Berks County
250	West Nantmeal	Township	Chester County
251	West Pikeland	Township	Chester County
252	West Pottsgrove	Township	Montgomery County
253	West Reading	Borough	Berks County
254	West Rockhill	Township	Bucks County
255	West Sadsbury	Township	Chester County
256	West Vincent	Township	Chester County
257	Whitehall	Township	Lehigh County
258	Williams	Township	Northampton County
259	Wilson	Borough	Northampton County
260	Womelsdorf	Borough	Berks County
261	Wyomissing	Borough	Berks County
262	Wyomissing Hills	Borough	Berks County
263	York Haven	Borough	York County

Appendix H
Conservation actions in the Highlands region since 2002

Regional (four-state) actions

U.S. Forest Service completed the New York-New Jersey Highlands Regional Study: 2002 Update. The Highlands Study update provided a comprehensive assessment of the land, water, and people in the 1.4-million-acre region, including a detailed analysis of watershed condition, forest fragmentation, and biological diversity, and identification of conservation focal areas and conservation strategies. This study provided the basis for the passage of the 2004 Highlands Conservation Act and the expansion of the Highlands region to include Connecticut and Pennsylvania.

Congress passed Highlands Conservation Act (HCA) (PL 108-421) in November 2004. The HCA is designed to assist the States of Connecticut, New Jersey, New York, and Pennsylvania to conserve priority land and natural resources in the Highlands region. The law authorizes the Forest Service to assist the Highlands States, local units of government, and private forest and farm landowners in natural resource conservation. The law also authorizes Federal assistance for land conservation partnership projects in the region. To date, $9.2 million have been allocated for land conservation partnership projects from Federal fiscal year (FY) 2007 through FY 2010. Projects funded in FY 2007 were the Deluca property (Connecticut), the Wyanokie Highlands – Camp Vacamas (New Jersey), Arrow Park (New York), and the Berks County Highlands (Pennsylvania). Projects funded in FY 2008 were the Embree property (Connecticut), the Wyanokie Highlands (New Jersey), Great Swamp (New York), and the Oley Hills (Pennsylvania). Projects funded in FY 2009 were Cook's Creek (Pennsylvania), Ramapo Highlands (New Jersey), Sterling Forest (New York), and Ethel Walker (Connecticut). Projects funded in FY 2010 were Northern Highlands (New Jersey), Greater Sterling Forest (New York), Naugatuck/Mad River Headwaters (Connecticut), and Texter Mountain/Furnace Hills/Middle Creek Protection Area (Pennsylvania).

Connecticut

Protected 450 acres on Skiff Mountain in 2004. The protected area is located in the middle of a 5,300-acre greenway and open space corridor that includes Macedonia Brook State Park, the Appalachian Trail, and other land trust properties. Skiff Mountain is habitat for bear, bobcat, and golden-winged and blue-winged warblers. This area would not have been protected without a strong public-private partnership: $1.25 million from the Connecticut Open Space and Watershed Land Acquisition Grant Program and nearly $1.5 million from private donations helped fund the acquisition. Currently, the Trust for Public Land is working with residents to preserve an additional 1,000 acres on Skiff Mountain.

Governor Rell signed Public Act 08-174 of 2008 into law for preservation of farmland. The act preserves farmland, and creates a municipal grant program for development projects, loans for brownfield purchasers, and tax exemptions for open-space land held by or for corporations. This was a significant victory for open space, historic, and farmland preservation advocates across the State, and opened the way for even more significant gains in the coming years.

New Jersey

Protected nearly 31,000 additional acres in the Newark and Pequannock watersheds through easements in 2002 and 2004. Easements included 9,000 acres of the Pequannock Watershed preserved in 2002 using New Jersey Department of Environmental Protection's Green Acres and U.S. Forest Service's Forest Legacy funds; and 5,677 additional acres protected in 2004. The 35,000-acre watershed contains five major reservoirs and is the largest contiguous forested area in the New Jersey Highlands, protecting the drinking water supply for more than 2 million people. The land is owned by the City of Newark for drinking water and sits within the Pequannock Watershed, about 35 miles northwest of Newark in portions of Morris, Passaic, and Sussex counties. In addition, the land contains significant forests and rich species diversity, including several Federal and State threatened and endangered species. The acquisition of these conservation easements ensures drinking water, aquifer recharge area, habitat protection, and protection from development; and allows for public recreational uses, including hunting and fishing.

Passed the New Jersey Highlands Water Protection and Planning Act in 2004. This act safeguards the water supply for more than half of New Jersey's residents. The law placed the development of the Highlands region under the supervision of the New Jersey Department of Environmental Protection. The act also preserves the rich biodiversity in the area and large volumes of New Jersey's fresh water sources for 5.4 million residents.

Protected Gerard Woods in Sparta in 2004. The 1,200-acre Gerard Woods property surrounds Lake Gerard and Beaver Lake, and includes hiking access to Gerard Lake. The land includes forested mountain terrain and several streams. It serves as habitat for wildlife including the barred owl, cold water trout, great blue heron, and neotropical migratory birds. Its protection secured a critical link in the Sparta Mountain Greenway by creating a 10,000-acre greenway that links Hamburg Mountain Wildlife Management Area, Sparta Mountain Wildlife Management Area, and the Newark-Pequannock Watershed lands. The $4 million property was purchased using nearly $3 million from the U.S. Forest Service's Forest Legacy Program, $569,000 from the New Jersey Department of Environmental Protection's Green Acres Program, and $450,000 from the Doris Duke Charitable Foundation through the Trust for Public Land.

Protected 707 acres on Crown Towers property in 2004 and 2007. The acquisition of this property, located in Mount Olive Township, Morris County, will protect wildlife habitat, provide public recreation opportunities, and preserve drinking water resources for New Jersey residents. The New Jersey Department of Environmental Protection Division of Parks and Forestry will manage Crown Towers as an addition to the 7,770-acre Allamuchy Mountain State Park. The property was threatened by development and is an example of a public-private partnership for land protection. The $7.7 million purchase included $3.2 million in funding from the U.S. Forest Service's Forest Legacy Program; $2 million from the Morris County Open Space Trust Fund; $1.3 million from the New Jersey Department of Environmental Protection's Green Acres Program; $1 million from Mount Olive Township; and $200,000 from the Doris Duke Charitable Foundation through a grant to the Trust for Public Land.

New York

Preserved 874 acres of Sterling Forest in 2002. Combined with 2,000 acres protected by the State of New Jersey, more than 19,500 acres of Sterling Forest have been preserved to date. The forest has tremendous value as the single largest block of intact forest in the New York Highlands and serves as a source of drinking water for more than 2 million New Jersey residents. Sterling Forest also links existing parks in New York and New Jersey, creating a 150,000-acre greenbelt of parkland that contains vital habitat for the survival of thousands of wildlife species.

Preserved 600 acres in Quaker Brook-Haviland Hollow Watershed in Patterson in 2008. The preserved area is adjacent to Cranberry Mountain Wildlife Management Area and the Michael Ciaiola Conservation Area. The Quaker Brook flows into the Great Swamp, is an ecologically unique and important waterway, and has one of the highest trout stream ratings given by the State of New York. This watershed is designated as a Critical Treasure for the Connecticut and New York committees of the Highlands Coalition because the brook begins in the Connecticut town of Sherman and flows through Fairfield before entering New York. This acquisition was a partnership between New York State's Office of Parks, Recreation, and Historic Preservation and the Trust for Public Land. This acquisition helps protect New York's Great Swamp and the East Branch Croton River Watershed, which is part of New York City's drinking water supply.

Pennsylvania

Passed the Growing Greener II bond initiative (Pennsylvania State Act 45) in 2005. Through 2010, this act will designate $625 million for protection of natural and agricultural lands, environmental cleanup, community revitalization, and improved recreational opportunities. Over $217 million is designated to the Pennsylvania Department of Conservation and Natural Resources to preserve natural areas and open spaces, improve state parks, and enhance local recreational needs.

Protected Birdsboro Water Authority property in 2007. The Birdsboro property, located in the Hopewell Big Woods area, houses several reservoirs and provides clean, abundant water and outdoor recreation opportunities to Birdsboro residents and surrounding municipalities. This area faces huge development pressure due primarily to its close proximity to the City of Philadelphia. The Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry, completed a conservation easement on the 1,727-acre Birdsboro Waters project on November 20, 2007. The $2,200,000 value of the easement was acquired from the Birdsboro Water Authority using $800,000 from the U.S. Forest Service's Forest Legacy Program, $320,000 from the William Penn Foundation, and $1,080,000 from the Pennsylvania Department of Conservation and Natural Resources via the State's Growing Greener II initiative.

Formed the Hopewell Big Woods Partnership in 2008. The Hopewell Big Woods Partnership was formed by the Natural Lands Trust, a regional conservation organization, to give public and private stakeholders a forum for discussing the future vision of this significant landscape. The area, which is recognized by the Pennsylvania Department of Conservation and Natural Resources as one of the State's top five natural resource priorities, contains the largest unfragmented forest in southeastern Pennsylvania—approximately 100 square miles. Located in northwestern Chester County and southeastern Berks County, the area has 10,000 acres of protected land, due to targeted conservation efforts by the Highlands Coalition partners and various public agencies. The area's unusual size and relative natural condition make it one of the most significant natural communities in the Philadelphia region, and an important conservation asset and outdoor recreational destination.

Launched Schuylkill Highlands and Lehigh Valley conservation landscape initiatives in 2008. The Pennsylvania Department of Conservation and Natural Resources has recognized the Schuylkill Highlands and the Lehigh Valley as two of seven important landscapes that will be given special attention within the state. The Schuylkill Highlands encompasses portions of Berks, Montgomery, Chester, and Bucks counties, and includes the Hopewell Big Woods and the Schuylkill River Trail corridor. The Lehigh Valley contains all of Lehigh and Northampton counties.

Completed the Highlands Conservation Atlas in 2006. This atlas was created through a partnership with the Trust for Public Land, the Appalachian Mountain Club, and the Highlands Coalition, with input from local land trusts and county agencies. The document provides an analysis of the region, highlights 11 areas in which to concentrate conservation measures, and identifies the most important natural, historical, and cultural resources in each one.

Passed local earned income tax (EIT) credit in various years. Using income tax to pay for open space preservation ensures protection of open space for future generations. Townships that passed 0.25 percent EITs include these:

Williams Township in 2004,

Moore Township in 2005,

Bushkill Township in 2005,

Lower Mount Bethel Township in 2006,

Lower Saucon Township in 2006,

Upper Mount Bethel Township in 2007, and

Plainfield Township in 2007.

Bucks County passed an open space preservation bond in 2007. An $87 million bond with 74% approval, included these allocations:

$25 million for farmland preservation,

$11 million for natural area preservation,

$26 million for municipal open space protection,

$18 million for county parks, and

$7 million for the Delaware riverfront.

Glossary

Terms are defined as they pertain to this Connecticut and Pennsylvania Update of the Highlands Regional Study.

Altered land, altered riparian land—Land that has been changed from its natural state.

Aquatic invertebrates—Any animal living in water that lacks a vertebral column, or backbone.

Aquifer—A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Baseflow or **stream baseflow**—Ground water that discharges into the stream and is responsible for sustainaing flow during prolonged dry periods.

Build-out analysis—An estimate of residential land use if all developable lands were built upon, based on current zoning regulations.

Composite resources and composite map—The combination of the five resource categories: water, forest, biological, agricultural, and recreation and cultural, that were part of the Conservation Values Assessment. The overlay of the five resources displayed on a map is the composite map.

Conservation easement—A legally enforceable land preservation agreement between a landowner and a government agency or a qualified land protection organization, such as a land trust for the purposes of conservation. It restricts real estate development, commercial and industrial uses, and certain other activities on a property. The property remains the private property of the landowner. If farmland is being protected, it is known as a farmland conservation easement.

Conservation focal areas—Geographic areas where three conditions coincided: a large contiguous tract or major land cluster, a high (top 40 percent) composite resource value in the Conservation Values Assessment, and the absence of permanent protection.

Conservation release— A conservation release is the minimum flow of water from a dam or reservoir that must be maintained at all times in the stream channel immediately downstream of the dam or reservoir. Some releases must be constant throughout the year while others may vary depending on the time of year and reservoir levels.

Conservation strategies—Strategies designed to guide State, local, and nonprofit decisionmakers in the protection of the region's natural resources and to improve the stewardship of the Highlands' resources.

Conservation Values Assessment—Part 1 of the Highlands study wherein areas with high conservation value areas were identified for five resource categories: water, forest, biological resources, agriculture, and recreation and cultural, and mapped based on their relative resource value across the region.

Deer browse— Evidence of vegetation eaten by deer, typically tree seedlings and low shrubs broken off at deer height.

Ecological subsections—Subsections are a refinement of an ecological unit hierarchy formulated in 1993 by the Forest Service, the USDA Soil Conservation Service (now the Natural Resources Conservation Service), and the Nature Conservancy, based on physical and biological criteria. The hierarchy allows integration of Forest Service activities (e.g., timber harvest, monitoring, watershed analysis) into broader scale analyses, assessments, and management decision-making.

Evapotranspiration—A collective term that includes water lost through evaporation from soil and surface-water bodies and by plant transpiration.

Forest fragmentation categories:
1. Core—Areas of intact forest cover (not fragmented by development, agriculture, or roads).
2. Patch—Small fragments of a forest that are entirely surrounded by development, e.g., small wooded lot within an urbanized or suburban region.
3. Transition—Small areas of forest in a matrix of forest and development.
4. Edge—Forest along the outside edge of a forest patch, such as would occur along the boundary of a suburban home, road, or agricultural field.
5. Perforated—Forest cover mostly intact, but with a small forest opening, such as would occur if a small clearing or house was built within a continuous tract of forest.

Forest perimeter:area ratio (also known as **ratio of forest perimeter to forest area**) —An indicator of the extent of forest fragmentation; a higher ratio means there is more edge per unit of area and the forest is more fragmented; a lower ratio means there is less edge per unit of area and the forest is less fragmented.

Forest stand structure— The physical arrangement and characteristics of the forest, particularly the levels of canopy, sub-canopy, and understory trees.

Fragmentation—The process of dividing large tracts of forest into smaller isolated tracts surrounded by human-modified environments.

Geographic Information System (GIS)—Integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.

GIS—Geographic Information System

Ground water—Groundwater is the water beneath the surface that can be collected with wells or tunnels, or that flows naturally to the earth's surface via seeps or springs.

Ground water recharge—Hydrologic process where water infiltrates the groound and reaches the saturated zone. Ground water is recharged naturally by rain and snowmelt and in some instances by surface water (rivers and lakes).

Impervious surface—Constructed surfaces such as rooftops, sidewalks, roads, and parking lots that are covered by impenetrable materials such as asphalt, concrete, brick, and stone. These materials seal surfaces, repel water, and prevent precipitation and snowmelt from infiltrating soils. Soils compacted by urban development are also highly impervious.

Indicators of resource integrity—Measure used to establish the effects of development on the natural resource.

Interior forest—Areas of intact forest cover (not fragmented by development, agriculture, or roads), away from forest edges.

Invasive species—Species of plants or animals that expand beyond their native environments or niches, because of human actions that aid in their introduction and spread, and that out-compete native species, resulting in a significantly changed ecosystem.

Macroinvertebrate—An invertebrate is an animal without a vertebral column; a macroinvertebrate is large enough to be seen without the use of a microscope; benthic macroinvertebrates are aquatic organisms that live in, on, or near the bottom of lakes, streams, or oceans.

Prime agricultural soils—Soils that are suitable for most kinds of field crops.

Runoff or overland runoff—Excess rainwater or snowmelt that is transported over land surfaces to streams channels and is . not absorbed by the soil.

Sinkholes— A circular depression in a karst area. Its drainage is subterranean, its size is measured in meters or tens of meters, and it is commonly funnel-shaped.

Solution channels—Tubular or planar channel formed by solution in carbonate-rock terranes, usually along joints and bedding planes. It is the main water carrier in carbonate rocks.

Streamflow—The flow of water in streams, rivers, and other channels, and is a major element of the water cycle.

Surface water—Surface water is an open body of water collecting on the surface of the earth, on the ground or in a stream, river, lake, wetland, or ocean.

Volatile organic compounds—Organic chemicals that have a high vapor pressure relative to their water solubility and are capable of entering the gas phase from either a liquid or solid form.

Water budget—An accounting of the inflow, outflow, and storage changes of water in a hydrologic unit.