DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM FOR THE QUINNIPIAC RIVER WATERSHED: REMOTE SENSING DATABASE & INFORMATION MANAGEMENT

Final Project Report

1995 -1996

to the

Quinnipiac River Fund

The Community Foundation for Greater New Haven

70 Audubon Street

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by

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January 12, 1997

Introduction

The Quinnipiac River Watershed (QRW) is a significant ecologic region of Connecticut. It is comprised of urban, suburban and agricultural landscapes, which in combination put extensive pressures on the environmental quality of the region. Much work is being done to study, preserve, restore and manage the environmental quality of the Quinnipiac River, its watershed and the New Haven Harbor area. These efforts have provided improvements to environmental quality and have also generated much information that is valuable to ongoing and future work centering on the region. Concurrently, there is much available information on the QRW that has been collected in the past by, for example, the CT DEP, the USGS, individual researchers, that is used in managing this important region of our state. Two of the biggest hurdles in using this information are access and format. Individual organizations or researchers often collect the needed information on their own from diverse sources and subsequently organize it, usually reanalyze it and finally display it in some form in order to make use of it relative to their project focus. This becomes especially critical in the overall management of large regions such as the QRW, where many types and a large amount of information must be organized, manipulated and analyzed in order to develop and carry out specific management, restoration and conservation plans.

To this end, we are developing a geographic information system (GIS) for the Quinnipiac River Watershed via funding from the Quinnipiac River Fund (QRF). A GIS is a computerized set of tools for collecting, storing, retrieving, transforming, displaying and analyzing spatially related data for a particular set of purposes (Burrough 1986). Our main objective is that the Quinnipiac River Watershed and Region GIS will provide a framework which can pull together information gathered from various studies of the Quinnipiac River, its watershed and New Haven Harbor. Once the information is entered into the system, one can map, for example, the distribution of critical habitats and natural communities, chemical pollutants, and potential conservation lands relative to the distribution of municipalities, industrial areas, watercourses, roadways, etc. In turn, this information and subsequent analyses utilizing GIS can help manage and protect the QRW region. The use of GIS for these activities is well established and has made significant contributions to environmental management (e.g. Johnston et al. 1988, Ahern et al. 1992, Kempka et al. 1992, Urenda 1992).

Within the scope of this project, we have assembled a diverse, and increasingly extensive, database for the QRW that is in digital format, and have developed the basic framework for a QRW GIS. This information includes, for example, municipal boundaries within the watershed, main transportation routes (interstate and state roadways, railroads), hydrographic features of the watershed (river features and sub-watersheds), demographic data from the U.S. Census Bureau, surface geologic materials, land use - land cover, and leachate and wastewater sources.

Under this proposal, we extended this work, focusing on enhancing features of the GIS that have been assembled and adding new types of information. In particular this phase of the project centered on developing a database of aerial photographic images of the QRW and region. As a type of remotely sensed data, aerial photographs contain a wealth of information on the spatial content (e.g. the kinds of land uses) and characteristics (e.g. the relative proportion of different types of land areas) of a given area (e.g. Avery and Berlin 1992). They are a key component of environmental assessment and general municipal and state planning. The State of Connecticut obtains sets of state-wide aerial photographs for these purposes every five years (but see below). In developing our view of the of the GIS, we felt that a fully digitized aerial photographic data base would greatly enhance its usefulness.

Methods

This work is being conducted at the GIS Laboratory at the University of New Haven. The laboratory uses PC Arc/Info and ArcView, a world leading GIS software package, and is equipped with personal computers, large format digitizers, a color and laser printers and a large format plotter. The development of this GIS falls within the general activities of the Graduate Program in Environmental Sciences at the University of New Haven, specifically our concentration in GIS.

The overall objective of this specific portion of the project was to develop aerial photographic coverage for the entire QRW and key sections of other watersheds which drain into New Haven Harbor. As the work was initiated, several situations presented themselves which slowed the development of the database. First, we were planning to purchase the most up-to-date, 1995 aerial photographs for state, but these are not yet available due to disputes between the State of Connecticut and the contractor which performed the overflights. [They were supposed to be available for purchase by the public in April 1995.] During most of the project period we were unable to do the bulk of this portion our 95-96 grant efforts. We were hoping that the dispute would be resolved and the most recent photographs could be used. Unfortunately, there is no resolution to date, with no clear indication when there might be. As such, we decided to go ahead and purchase 1990 aerial photographs to continue developing these coverages. We are obtaining just one section of the watershed at a time in the event that 1995 or more recent photos do become available. At the present time we are working on developing these coverages for the main stem of the Quinnipiac River in the Wallingford / Meriden / Hamden area. The second task that proved to be time consuming was correctly registering the images in geographic space, as explained below.

The procedure to enter the photographs into the GIS included scanning the images, enhancing the images, registering them into space and entering the area covered into a GIS index that will be used to identify and access the aerial photograph coverage. Scanning and image enhancement were done using a Umax high resolution scanner and Adobe Photoshop software. The black and white aerial photographs were purchased from Aerographics (Bohemia, NY). The photographs were scanned using a 256 grey scale at a resolution of 300 dpi. Contrast and sharpness filters were then applied at set values to enhance the images. The resulting digital images were saved in a TIF format.

A combination of software programs were used to register the digital aerial images into geographic space. The digital images do not have any associated geographic coordinates and also the images tend to be warped spatially at their edges due to the curvature of the earth, the angle of flight and the imaging systems themselves. Thus, it is necessary to attach specific geographic coordinates to the image and then use these coordinates to fit the image into geographic space. This process is commonly referred to as "rubber sheeting". The software used to rubber sheet the images was The Geographic Transformer (Blue Marble Geographics, Gardiner, Maine) running in conjunction with ArcView (the GIS viewing software used at the University of New Haven).

Rubber sheeting makes up for the distortion in the photographs and positions each photo into space. The process of geographic registering and transformation requires that reference points be identified that are found both in the existing GIS and the image. These reference points should be fixed locations such as street intersections, piers, cul-de-sacs and tiny islands that are evident in existing GIS coverages. We used these types of points during our processing, especially road intersections at the edges of the image, where most of the warping is found.

Hydrologic features were not used due to their tendency to shift location. After coordinates were chosen and applied, the image was inspected with a road coverage overlay to assess the fit of the image to the existing coverage. The fit was also assessed using least squares estimates. If the spatial error was above a specific threshold, new and/or additional control points were added to the image, and it was transformed again. This procedure was repeated until spatial errors were below an acceptable level. This has turned out to be a slow step as it takes a number of iterations, depending on the distortion in each photo, in order to get the best fit to features in existing coverages (e.g. road networks).

Following successful transformation the images were given an identifying code and the outline of the imaged area was clipped and used to develop a coverage showing the area covered by each image. This coverage will be used to help end-users identify specific images that they want to bring into the GIS. A catalogue of the digital images is being produced, plus users notes how to access them via the GIS.

Results & Discussion

The aerial photographic coverage can be used for a variety of applications. With aerial photographs, users of the GIS can "fill in the gaps" by visual inspection with respect to particular problems. For example, understanding and controlling non-point source pollution is an important component of enhancing water quality. To help assess impacts in a particular area, the GIS would provide information on hydrology (Figure 1), general types of land uses (Figure 2) and other important factors such as slope and aspect of the terrain (Figure 3). This may be sufficient to make an initial assessment. However, more detailed analysis may need information on housing density and/or the detailed spatial layout and characteristics of landscape patches such as woodlots, agricultural fields and residential and commercial areas in relation to the local hydrology (Figures 1 & 4). This may be critical if, for example, a system of buffers was going to be developed.

By having the aerial photography available as a data coverage in the GIS, a planner or researcher could display the photo and compare it to more general information and assess such relationships. The aerial photo coverages also provide more up-to-date information (e.g. Figures 1 and 4) and can help assess the accuracy of other mapped features. Additional examples of the photographic coverage are shown in Figures 5 and 6. Figure 5 shows an area of New Haven, where Interstate 91 crosses the Quinnipiac River. Although the extent of development can be extrapolated from the road coverage, the aerial photograph makes this very clear and also shows heavily commercialized zones and residential zones exactly. Figure 6 depicts an area of the main stem of the Quinnipiac River in the Wallingford area, and shows how individual images can be put together to form a mosaic of a more extensive area. In this case the photographs show variation in river corridor structure.

At the present time we have obtained aerial photographs for approximately 70% of the Quinnipiac River watershed and for portions of the Mill and West River watersheds (Figure 7). We plan to obtain aerial photographs for the remaining portions of the New Britain, Bristol, Southington and Bradford quadrangles which are in the Quinnipiac River watershed. Of the photographs obtained, approximately 60% of them have been registered into geographic space. These primarily fall along the main stem of the Quinnipiac River and portions of Wallingford, New Haven and the West River. The other 40% of the aerial photographs, primarily covering the Meriden and Wallingford areas, have been scanned are are still being rubber-sheeted. The developing reference coverage is shown in Figure 8.

The data interpretation, analysis and display functions of a GIS become much more powerful by having the ability to overlay information from existing data coverages, and those being developed, with digitized aerial photography. There are several other potential applications of aerial photographs within the GIS. Related to the examples and discussion given above, new developments in GIS technology are allowing users to digitize and collect data directly off the computer screen. The aerial photographic data base will enable end-users to modify and develop coverages that they need directly, based on the information in the aerial photographs. This should go a long way towards making the QRW GIS meet the needs of a diverse set of end-users. The educational aspects of the GIS could also be enhanced. For example, students could more easily understand and work with mapped information if they can relate it to photographs of the area. Furthermore, features on the aerial photographs can be linked via the GIS and query programs such as ArcView to ground-level photographs or even larger scale images such as satellite images.

The aerial photographs can also be used to assess the accuracy of other mapped features. For example, Huo (1996) compared land use classification between the land use / land cover coverage developed for Connecticut based on satellite imagery and one she developed based on aerial photographs for a portion of the Quinnipiac River on the border of Meriden and Cheshire. The analysis indicated, for example, that the satellite-based coverage overestimated the amount of forest cover and underestimated the amount of residential area (64.8% vs. 47.7% and 11.9% vs. 30.8% of the area, respectively).

The aerial photographic coverage being added to the Quinnipiac River Watershed and Region GIS is available to all working on the QRW and, as such, specific applications could be developed for these projects. The completed aerial photographic coverage for the QRW should be generally available February 1, 1997. Those wishing to obtain this coverage will need approximately 65 MB of hard disk space to store the images. Transfer of the material onto a laptop computer or via a tape cartridge is available. We are exploring ways to make these photographic coverages as well as the overall QRW GIS available via the Internet. Those interested in obtaining the aerial photographic coverages and/or other QRW GIS coverages, should contact R.N. Zajac (203-932-7114) at the University of New Haven.

Acknowledgments
The development of the QRW GIS has been funded by the Quinnipiac River Fund as administered by the Community Foundation for Greater New Haven. Several graduate students at the University of New Haven have made key contributions to this portion of the overall Quinnipiac River Watershed and Region GIS project, including Sue Wilson, Anne Gallup, Jennifer Howald, Colleen Sawicki and James Athey. Yuhong Huo, a graduate student at Central Connecticut State University, compared land-use classification as part of her GIS internship at the University of New Haven. To all our deepest thanks.

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FIGURE LEGENDS

Figure 1. Portion of QRW GIS coverages showing the road networks and hydrologic features in the area of Sleeping Giant State Park, Hamden / Cheshire. These coverages overlay a portion of the aerial photo coverage developed for this area.

Figure 2. Land use/cover map for a section of the area depicted in Figure 1. This coverage, included in the QRW GIS, was developed from satellite imagery by researchers at the University of Connecticut.

Figure 3. Elevation coverage of the study area shown in Figure 1, developed at UNH based digital elevation data. This type of coverage would be used to study hydrologic patterns and processes in the area as well as identifying potential sources of non-point source pollution.

Figure 4. Detail of aerial photo coverage for a portion of the study area (see Figure 1). The yellow circle encloses and area showing more up-to-date information (new road and buildings) which is not found in the other coverages.

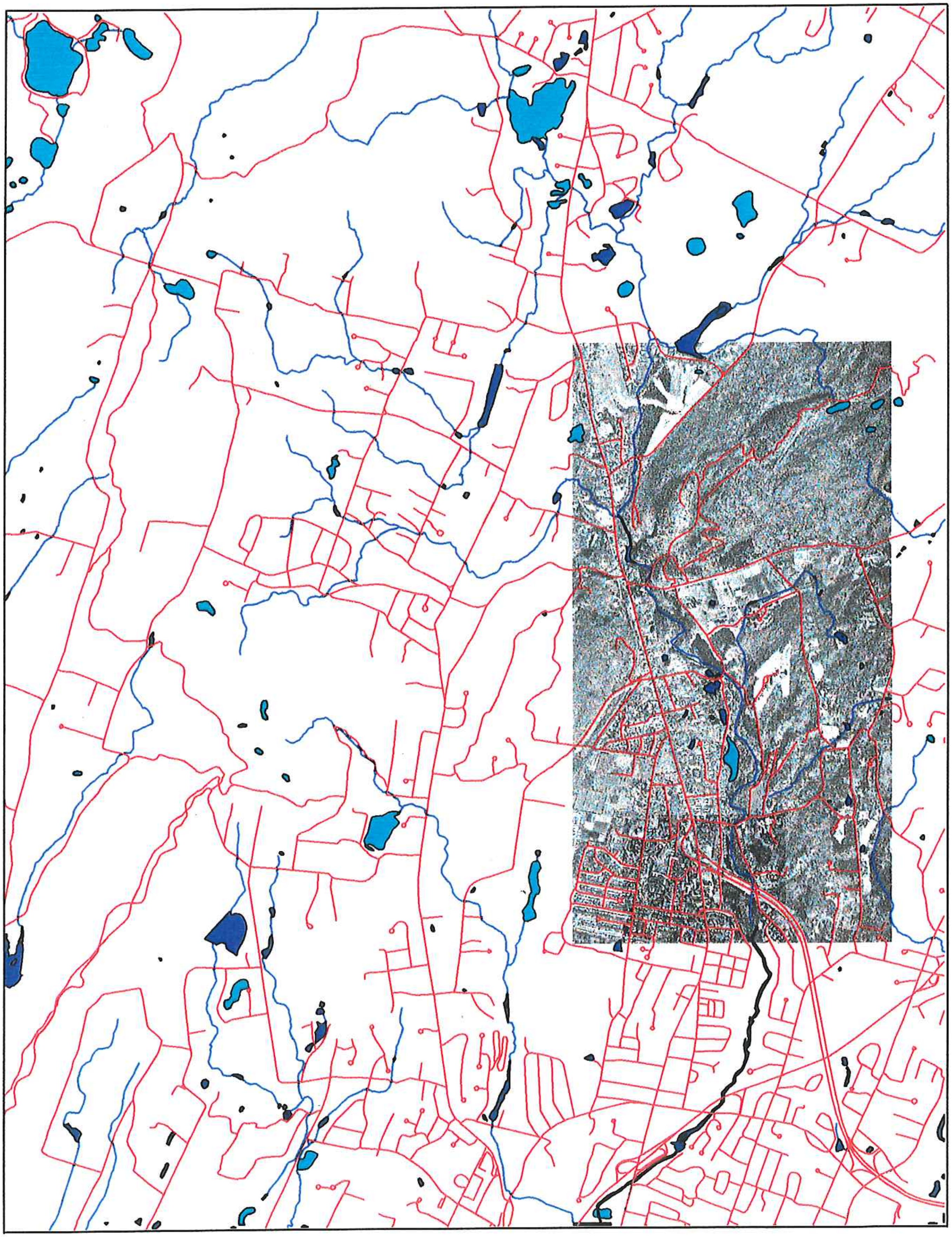
Figure 5. Example of aerial photographic image in ArcView with roadway and hydrologic cover overlays. The area depicted is where Interstate 91 crosses the Quinnipiac River in New Haven.

Figure 6. Example of several aerial photographic image fitted together in a mosaic in ArcView with roadway and hydrologic cover overlays. The area depicted is along the Quinnipiac River in Wallingford.

Figure 7. Location map of the area covered by the Quinnipiac River watershed region GIS (noted simply as Quinnipiac River Watershed in the map legend) and the areas which have aerial photo coverages completed, in progress of being completed or for which photos still have to be obtained.

Figure 8. Aerial photograph reference coverage that is being developed. This coverage will allow end-users to identify the area for which photographs are desired and provide instructions to access the photos in the GIS.

Figure 1



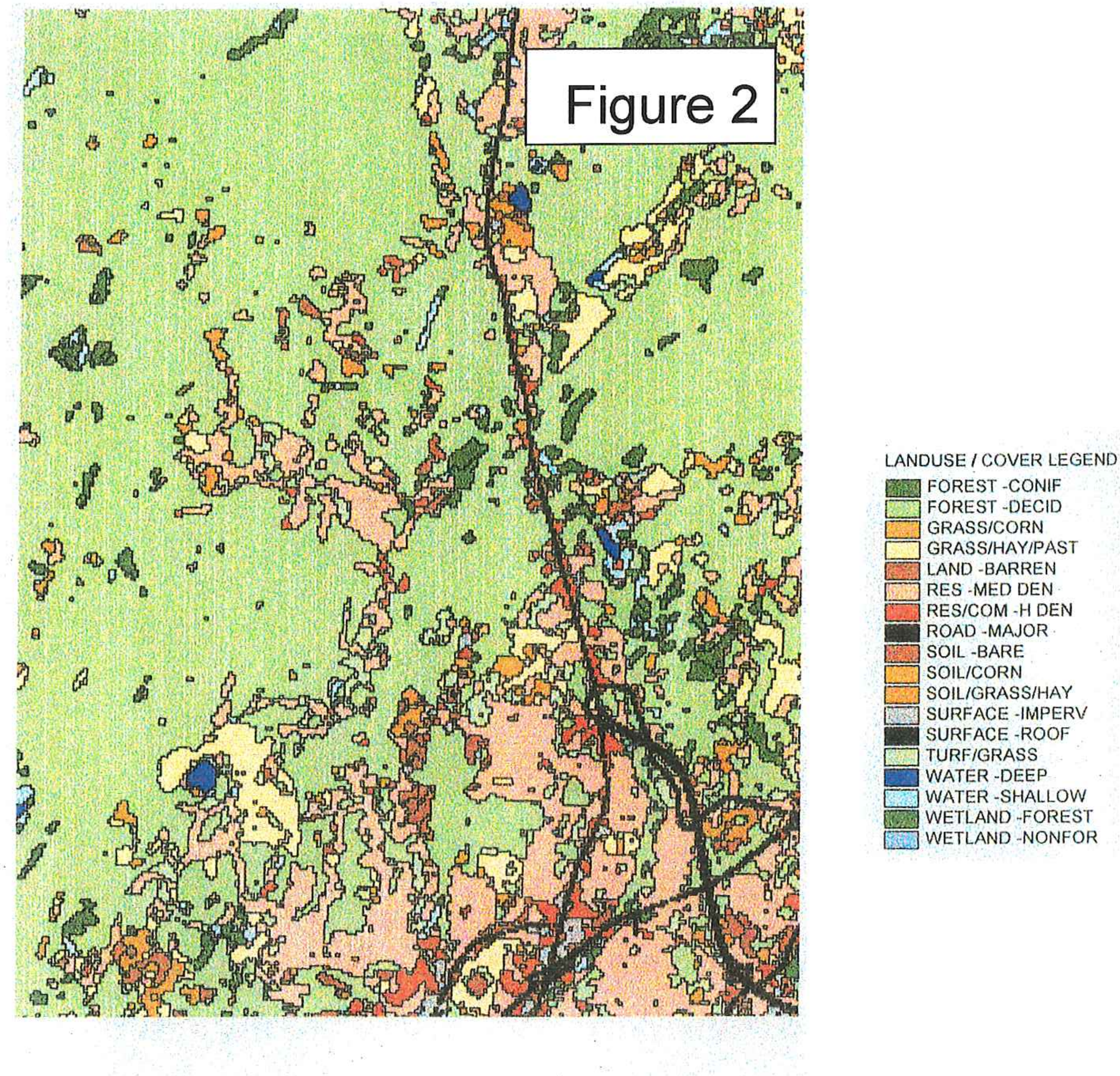


Figure 2
LANDUSE / COVER LEGEND
FOREST -CONIF
FOREST -DECID
GRASS/CORN
GRASS/HAY/PAST
LAND -BARREN
RES -MED DEN
RES/COM -H DEN
ROAD -MAJOR
SOIL -BARE
SOIL/CORN
SOIL/GRASS/HAY
SURFACE -IMPERV
SURFACE -ROOF
TURF/GRASS
WATER -DEEP
WATER -SHALLOW
WETLAND -FOREST
WETLAND -NONFOR
6000
0
6000
12000 Feet

Figure 3

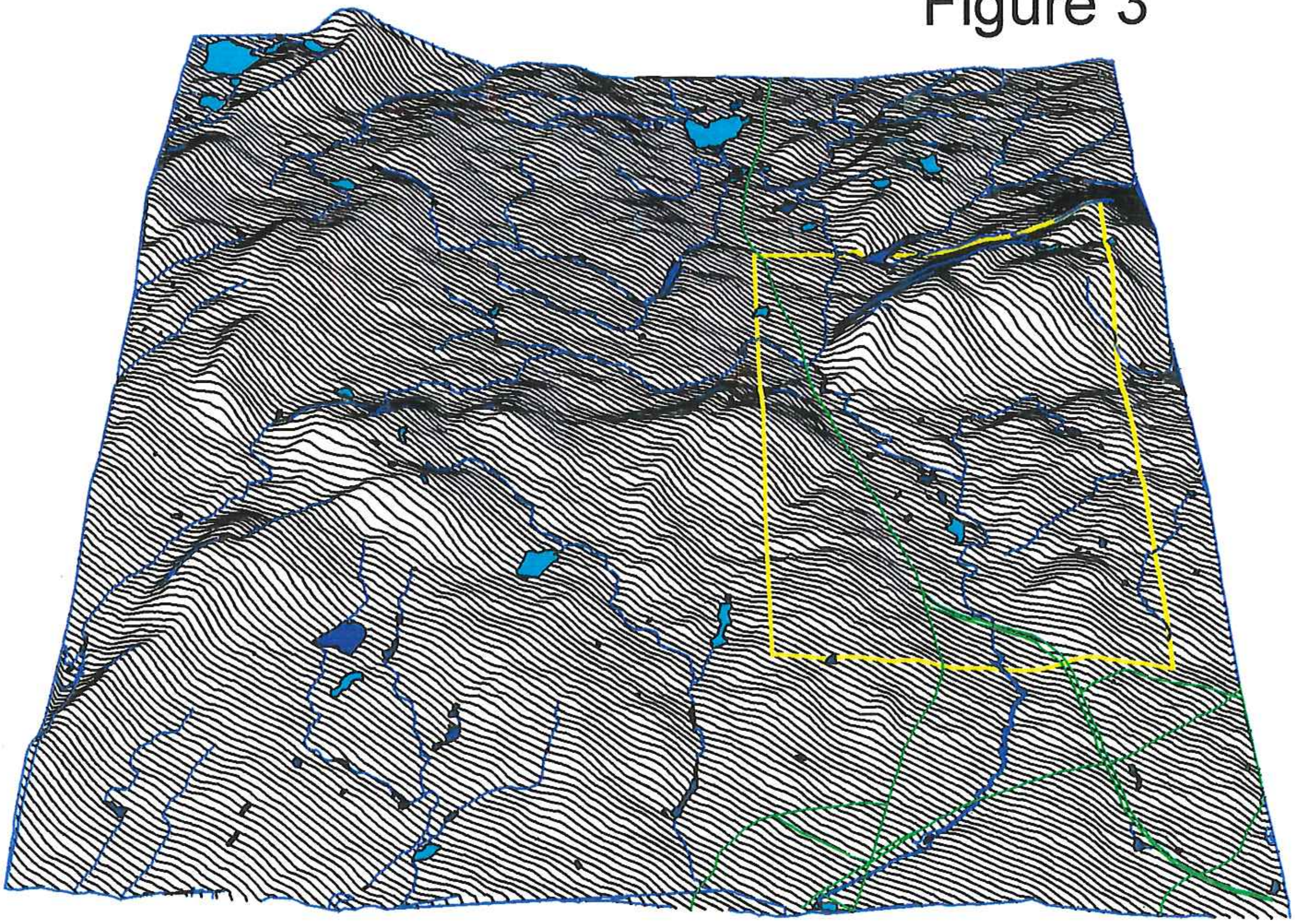


Figure 4

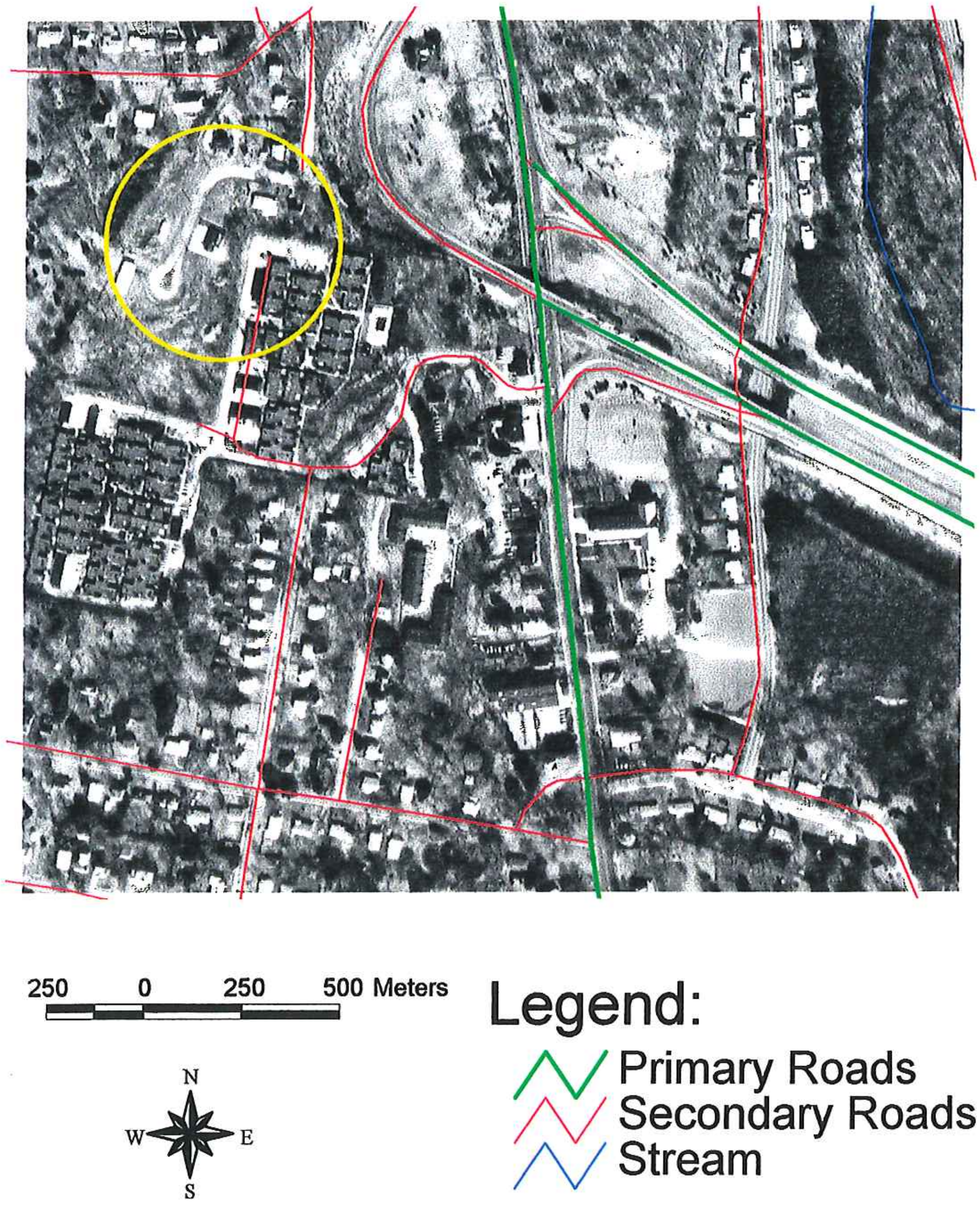

250 0 250 500 Meters
N
W
E
S
Legend:
Primary Roads
Secondary Roads
Stream

FIGURE 5.

New Haven, Connecticut Aerial Photo

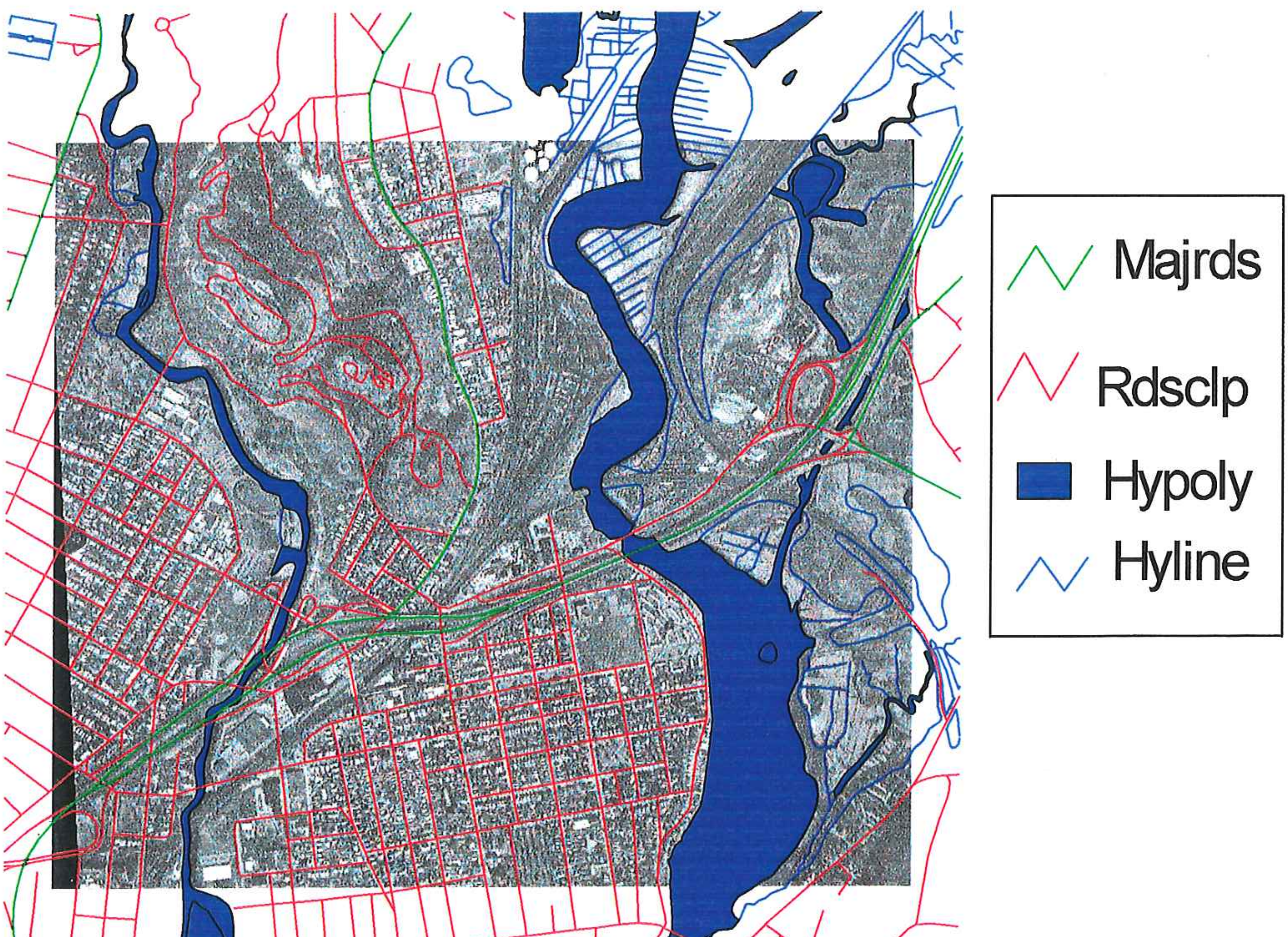
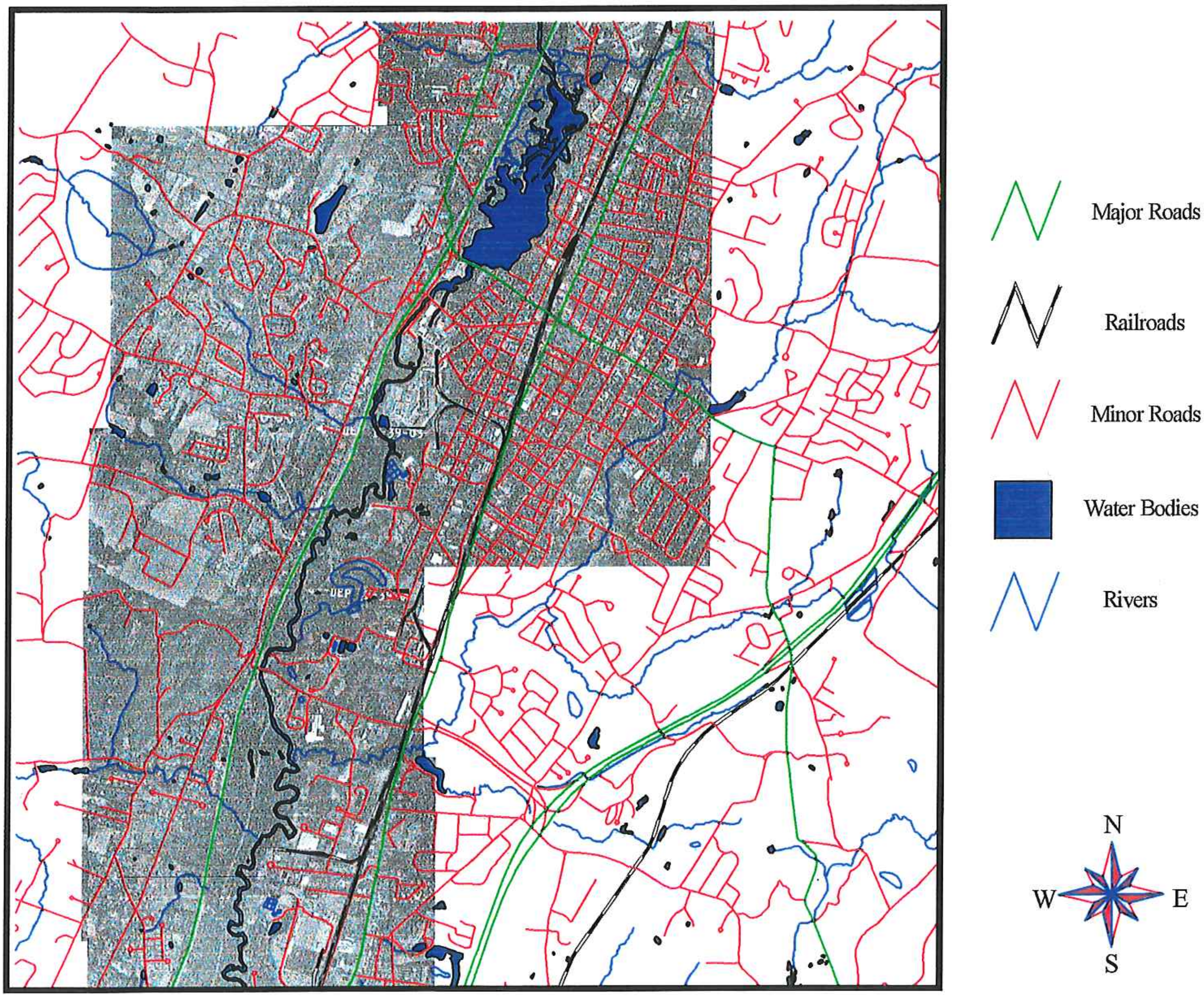
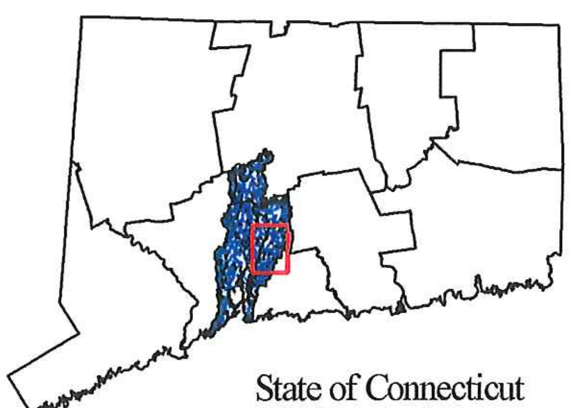


FIGURE 6.

Quinnipiac River Watershed Region
Wallingford Aerial Photos

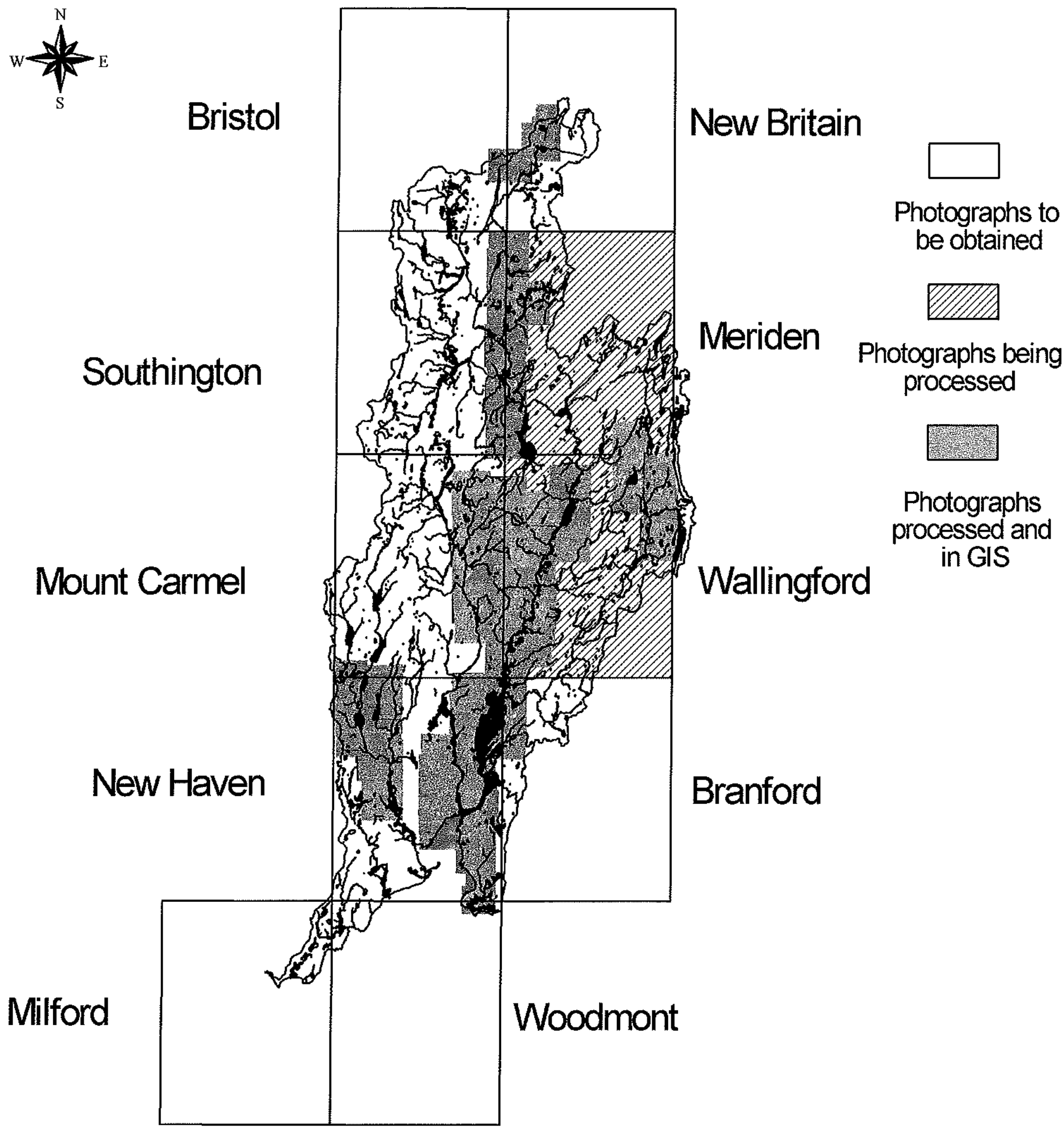




State of Connecticut
Wallingford Quad

University of New Haven
Environmental Science Program
Geographic Information Systems

Figure 7



Status of aerial photograph GIS coverage for the Quinnipiac River Watershed and Region

Figure 8