Putnam County Groundwater Protection and Utilization Plan

Putnam County, New York

September 2004

THE Chazen COMPANIES

Prepared for:
Putnam County Legislature
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EXECUTIVE SUMMARY

The Putnam County Legislature, in response to concerns raised by the public regarding groundwater availability, felt there was a need to investigate the issue. Subsequently, the Putnam County Division of Planning and Development was asked to seek grant funds in order to defray the cost of a study to evaluate groundwater availability.

The resulting investigation has inventoried groundwater resources, determined approximate levels of present groundwater utilization in Putnam County, and developed management approaches for future protection and utilization of groundwater resources in Putnam County.

A groundwater protection and utilization committee met monthly during late 2003 and early 2004 to review groundwater maps and data, identify additional areas of inquiry, and to formulate groundwater resource planning recommendations. The committee consisted of representatives appointed from Putnam County municipalities as well as agency staff from Putnam County's Division of Planning and Development, Soil & Water Conservation District, and Department of Health. Grant monies were used to retain a hydrogeologist from The Chazen Companies to assist with this effort.

An estimated 80,000 Putnam County residents use groundwater in their homes. Of these, an estimated 50,000 rely on individual wells not monitored or otherwise evaluated in any systematic way. The rest draw water from central water supplies that rely on groundwater sources.

Critical hydrogeologic findings of this project are summarized here:

- Aquifers underlie all parts of Putnam County. These can be categorized as higher or lower capacity depending on geologic conditions, or higher or lower priority in their need for protection, but all warrant groundwater management.

- In general, adequate quantities of groundwater are available to support most present water requirements in Putnam County. However, groundwater resources in some locations have been overused in some instances, either because of over extraction resulting in inadequate well yields, or by locally overloading aquifers with septic system wastes or salt residues, causing poor groundwater quality. Future water demand can be accommodated in Putnam County, but should rely on site specific analyses and management practices outlined in this report.

- Management of groundwater quantity (e.g. available capacity), is integrally related to management of groundwater quality. Overuse or depletion of groundwater resources often causes quality reductions. Conversely, degradation of quality is a form of groundwater over-use since dilution is the most cost-effective management solution for many non-point pollution sources, including septic system wastewater.

- Putnam County has three sharply different land use formats, including <u>high density</u> areas such as lake communities and other community centers including most commercial and business centers, <u>moderate density</u> areas including most open residential areas and some commercial centers, and <u>low density</u> areas such as dedicated open space areas and New York City watershed areas. Different groundwater management strategies are warranted and recommended herein for each region.

- Federal and State environmental regulations passed since the 1970s, as well as growing availability of improved remediation techniques, have together been significantly successful in reducing groundwater threats from point sources such as gas stations, dry cleaners, and heavy industry activities. Although the enforcement of regulations have and will continue to be a concern, outright prohibition of such land uses is only warranted in highest-risk aquifer areas. Such highest-risk areas could be defined on the basis of aquifer capacity or within near-well recharge areas of a high-capacity central water supply well (e.g. a wellhead protection area).

- Septic systems represent a wide-spread and potentially-significant source of non-point aquifer contamination. Contaminants from septic systems include compounds with existing regulatory standards such as nitrate or *e*-coli, and more recently recognized constituents such as caffeine, pharmaceuticals, and hormone residues, for which no standards yet exist. The coincident use of septic systems and groundwater wells requires an evolving management strategy to ensure continued sustainable use of both.

- Existing Putnam County Health Department pumping test procedures for proposed Community Water System wellfields (e.g. water district) are adequately rigorous to ensure viability of such sources. At such sites, a 72-hour pumping test is conducted at twice average estimated project water demand levels and includes analysis of on-site and off-site aquifers and should consider the water demands of previously approved wells, whether in use or not. However, aquifer testing required at equivalent subdivisions using individual wells is not as thorough and warrants improved permitting protocols. Recommended test protocols are recommended herein.

- Minimum residential density recommendations are provided in this report. Where more concentrated density is proposed, additional testing protocols are recommended herein.

- Particular attention should be paid to proposed future groundwater uses in areas with extensive sewer districts. Larger sewer districts provide significant protection of groundwater quality as long as pipes are properly maintained, but reduce groundwater replenishment which might otherwise replenish aquifers through on-site septic systems.

- Road salt and water softener salts are non-point contaminant sources affecting groundwater and stream quality. Management programs are warranted for both.

- Former metal mines may represent continuing sources of localized groundwater contamination.

On the basis of these summary conditions, the groundwater protection and utilization committee has recommended various protection and management strategies. Some can be implemented immediately. Others will require research and preparation to be implemented. Brief summaries of these committee recommendations follow. Full recommendations are found in Section 4.0 of this report.

- Intensive management is warranted in densely settled areas that without central water or sewage districts, such as some commercial centers and most lake communities. Site-specific studies are recommended for individual high density areas; however, for lake communities shown to have water quality difficulties, installation of central sewerage is a preferred remedy for any discovered water quality defects since centralized wastewater collection and treatment both improves well water quality and lake quality. Installation of central water only improves potable water quality.

- Broadly applied aquifer management is recommended outside of highly concentrated centers, although not necessary in open space lands. A high level of protection is recommended for recharge areas around community water system wells. More general protection measures are recommended for all surrounding aquifer areas, including areas used for residential wells.

- Only limited management is warranted in open space lands.

- Proposed projects should evaluate whether they are self supporting. A method is presented which may be used to determine if proposed water consumption is balanced by natural recharge. Credits for enhanced recharge and/or low-impact development techniques can be part of this methodology. Self-supporting projects are preferred and less SEQRA review needs to be required for such sites.

- An improved pumping test protocol is recommended for proposed subdivisions using individual wells. Only subdivisions using central wells currently undergo 72-hour pumping tests. Subdivisions using individual wells warrant similar analysis, using pre-drilled test wells pumped simultaneously at the proposed subdivision demand rate for 72-hours.

- Additional recommendations found in the report include programs to manage de-icing chemicals, discourage future use of buried homeowner heating oil tanks, implement a program to identify sustainable septic system densities, and discussion of a County-wide groundwater monitoring network.

A GIS-based database of digitally-preserved driller's well logs used to support this report will be available at the Putnam County Health Department and select other locations.

1.0 INTRODUCTION

1.1 Project Objectives

In response to County concerns about groundwater availability, the Putnam County Division of Planning & Development sought grant funding and initiated formation of an intermunicipal groundwater protection and utilization committee to evaluate groundwater resources in Putnam County.

Project objectives have been to inventory groundwater resources, determine whether groundwater is being over-utilized in Putnam County, and to develop management approaches for any future uses of groundwater in the County. The investigation has focused primarily on available quantities of groundwater in the county. However, as explored in this report, ensuring groundwater potability is a necessary capacity consideration so some discussion of groundwater quality is included.

1.2 Committee Composition and Process

A groundwater protection and utilization committee consisting of representatives from most municipalities in Putnam County met monthly during late 2003 and early 2004 to review groundwater maps and data, identify additional areas of inquiry, and to formulate the groundwater resource planning recommendations found in this report.

The following individuals were members of the committee:

Town of Carmel: Town Engineer John Karell, Jr., P.E.
Town of Kent: CAC member George Baum
Town of Patterson: Town Planner Richard Williams
Town of Putnam Valley: Lake Oscawana Advisory Committee
Chair Kathleen McLaughlin
Town of Southeast: CAC member Don Cuomo
Village of Brewster: Mayor John Cesar
Village of Nelsonville: Trustee Steve Marino
Putnam County Health Department: Senior Public Health Sanitarian Anne Bittner,
Director of Engineering Mike Budzinski, P.E.
Putnam County Soil & Water Conservation District: District Manager Lauri Taylor
Putnam County Division of Planning and Development:
Senior Environmental Planner Lauri Taylor
Director of Planning and Development John Lynch
Consulting Hydrogeologist: Russell Urban-Mead, CPG, Chazen Companies

Ex-officio members to the Groundwater Utilization and Protection Committee included:

County Legislature: Arne Nordstrom
County Executive Office: Frank DelCampo

1.3 Scope of Report

This report was prepared for the Putnam County Division of Planning and Development, the Putnam County Department of Health, and the Putnam County Soil & Water Conservation District Board. It includes a technical summary of the County's aquifers prepared by The Chazen Companies (TCC) and a series of groundwater management recommendations developed by the project committee.

Sections 2.0 and 3.0 of this report describe geographic and hydrogeologic factors influencing Putnam County's groundwater. The work draws primarily upon existing data and reports but includes limited new data from stream flow measurements and well log analyses.

Section 4.0 describes groundwater resource management strategies developed and recommended by the committee.

Section 5.0 provides references and a list of organizations and offices contacted by TCC to assemble the data and reports contributing to this study.

2.0 PUTNAM COUNTY HYDRO-GEOGRAPHY

Climate, human water consumption, water quality threats, vegetation cover, and geology all influence groundwater resources and hence aquifer management strategies. The following topical summaries are provided based on available reports and studies.

2.1 Setting and Population

Putnam County lies in the southeastern portion of New York State, bounded to the west by the Hudson River and to the east by the state of Connecticut. Putnam County lies approximately 45 miles north of New York City. Putnam County has an area of approximately 235 square miles, divided into six Towns and three Villages (Figure 1). Based on census data, the 2000 population of Putnam County was 95,745, up from 83,941 during the 1990 census. Table 1 provides a summary of the approximate population of Putnam County's Towns, including Villages, in 2000, and their associated estimated uses of groundwater.

Historic settlement patterns in Putnam County have led to population clusters along transportation corridors or around Putnam County's lakes and reservoirs.

- In the Town of Putnam Valley, many residents live near Lake Peekskill, Lake Oscawana, or Roaring Brook Lake.
- In the Town of Kent, significant population centers around Lake Carmel.
- The Town of Patterson has large population clusters around Putnam Lake and some concentration is found along the Route 22 transportation corridor.
- In the Town of Southeast, population is somewhat more widely distributed but many residents live near Lake Tonetta and near the Village of Brewster.
- Population is more widely distributed in the Town of Carmel with considerable density in the southwest quarter of the Town south of and adjacent to Lake Mahopac.
- Population in Philipstown is also somewhat widely distributed, with some population concentrations along the NYS Route 9 corridor, near the Villages of Nelsonville and Cold Spring, and the Continental Village community near Cortlandt Lake.

Referenced locations are shown on Figure 1 and land use patterns are evident on Figure 2.

Portions of New York City's water supply lie in Putnam County. The watershed boundaries of these supplies are shown on Figure 1 and include the Amawalk, Muscoot, East Branch, Bog Brook, Croton Falls, Diverting, Middle Branch, West Branch, and Boyd's Corners reservoirs and Gleneida Lake, Giliad Lake, and Kirk Lake which are all controlled lakes.

A limited number of community water systems in Putnam County use surface water sources. These include

- Carmel's District 2 which draws water from Lake Gleneida,
- Carmel's Districts 8 and 10 which draw water from Lake Mahopac,
- a water system around Lake Peekskill which is being taken out of service,
- a water system at Cortlandt Lake which draws water from the Delaware Aqueduct,
- a water system in Brewster Heights which draws water from the Middle Branch Reservoir, and
- water systems in Cold Spring and portions of Nelsonville which use a local reservoir.

Some of these Districts also employ sewage districts for waste disposal, in which case they neither require groundwater as a source of supply nor are discharging wastewater to Putnam County's aquifers.

Most if not all other central water supplies in Putnam County come from groundwater resources.

2.2 Topography

Most of Putnam County is underlain by rocky landscapes characteristic of the Hudson Highlands physiographic province. High ridge elevations rise to over 1,400 feet above mean sea level (asl) in central and western parts of the County. Portions of Putnam County adjoining the Hudson River drop abruptly to sea level. Elevations in southeastern Putnam County drop gradually to a series of water reservoirs generally lying between 300 and 400 feet asl.

A graphic sense of the County's topography is provided by black-to-white hillside analysis (Figure 1) and by digital elevation modeling (Figure 8). Western parts of Putnam County exhibit deeply incised, steep-sided valleys and ridges oriented northeast to southwest. Ridges between the valleys separate aquifers and restrict groundwater movement. Eastern portions of Putnam County exhibit more moderate terrain. Large portions of the Town of Patterson and parts of the Town of Southeast lie in the broad valley of the East Branch Croton River (Figures 6 and 8).

2.3 Land Uses that Influence Groundwater Quality

Threats to groundwater quality from various existing land uses are reviewed below.

2.3.1 Land Use Map Interpretation of Threats

Forested lands (including lightly settled lands) and wetlands are the dominant land uses in Putnam County (Figure 2), followed by low-density residential land uses.

Concentrated residential areas lie around many of Putnam County's waterbodies, including Peach Lake and Lake Tonetta in Southeast, Putnam Lake in Patterson, Lake Louise and Lake Carmel in Kent, Lake Mahopac, Lake McGregor Lake Baldwin, Secor Lake and Kirk Lake in Carmel, Roaring Brook Lake and Lake Oscawanna and Lake Peekskill in Putnam Valley, and Cortlandt Lake in Philipstown (Figures 1 and 2).

Additional residential development is also evident throughout each Town, including areas far from waterbodies. NYCDEP's land use cover map defines Low Intensity Residential Land as areas with structures covering 30 to 80% of land, thereby failing to include homes on larger lots, so Figure 2 does not provide a full view of outlying residential settlement in Putnam County. When evaluating areas where low-density residential land uses may threaten groundwater quality, TCC used Putnam County's 2002 digital parcel map to include all lots of 2.5 acres or smaller (Figures 3 and 4), estimating that subdivided parcels of this size or smaller are all likely to be in residential use. Low Intensity residential areas shown on Figures 3 and 4 are therefore more inclusive than Low Intensity Residential areas shown on Figure 2.

Commercial, manufacturing, industrial, warehousing, and golf land uses are generally clustered along transportation corridors or near waterbodies. Clusters of such uses are found along northern parts of NYS Route 9 in Philipstown, along Route 6 near the south shore of Lake Mahopac and areas east of Lake Gleneida in Carmel, areas near the intersection of Routes 84, 684, 6, and 22 in Southeast, in areas near Routes 84 and 312 in Southeast, and along various sections of Route 22 in Southeast and Patterson.

The New York State Department of Health (NYSDOH) has developed a groundwater quality threat matrix to assign threat levels to land uses. The matrix comes from NYSDOH's Source Water Assessment Program (SWAP) for water supplies and was applied by TCC to Putnam County's land use maps (Figures 2 through 4).

Figure 3 identifies areas where the SWAP approach suggests there may presently be Low/Medium to Medium/High threats of chemical and salt contamination of groundwater quality. Where water districts are shown, chemical and salt groundwater quality exposure risks to residents are reduced since individual wells are not in use. Water districts are mapped approximately, from Putnam County Department of Health district map records.

Figure 4 identifies areas where the SWAP approach suggests there may presently be Low/Medium to Medium/High threats of nitrate and bacterial/viral contamination of groundwater quality. Sewer districts shown on Figure 4 are among the larger districts that discharge treated wastewater to surface waters and so protect groundwater from wastewater impacts. Where water districts are shown, residential exposure to wastewater degradation of groundwater quality is reduced since individual wells are not in use. Water districts are mapped approximately, from Putnam County Department of Health district map records. Wastewater exposure risks to Putnam County residents from impacted groundwater are reduced by the following measures:

1. <u>Sewer Districts</u>: Use of central sewage systems that treat wastewater and discharge it to surface water prevents wastewater from being released to groundwater as long is collection pipes area maintained to prevent leakage. (Regional sewage districts are shown on Figure 4. Sewage treatment systems for individual sites are not shown.)

2. <u>Central Water</u>: Use of community water systems that provide regularly sampled water to large service area ensures that the potable water supply meets drinking water standards. Groundwater under the served homes may be impacted by wastewater if septic systems are used but residential exposure is prevented by use of the central water supply source. (Regional water districts where water supply wells may be far from water users are shown on Figures 3 and 4. Single site community water system wells are not shown since in such areas wells and contaminant sources may influence one another.)

3. <u>Adequate Recharge to Dilute Wastewater</u>: Where sufficient aquifer recharge falls on individual parcels, the aquifer may be able to dilute wastewater releases from septic systems. Areas with sandy soil allow higher recharge rates. (Areas which may include potentially-extensive sand and gravel deposits are shown on Figure 4).

A summary of land uses which may be affecting groundwater quality in Putnam County follows:

- The dominant occupied land use in Putnam County is low-intensity residential (Figures 2 and 4). Where septic systems are employed, groundwater quality may be suffering from wastewater releases of nitrate, bacteria, and viruses (Figure 4). High intensity residential land uses pose the same wastewater contaminant threats to groundwater quality where septic systems are used. Groundwater quality in residential areas is also threatened by homeowner chemical uses and/or intensive lawn maintenance practices. Large parts of Putnam County are developed by residential lots of 2.5 or smaller acres. Where average lot sizes (or effective local density) in areas using individual wells and septic systems fall below approximately 3 acres, wellwater quality may suffer due to inadequate dilution of wastewater by aquifer recharge. (As is outlined later in this report, parcels as small as 0.5 to 1 acres may be sustainable in limited areas where sandy soils allow high recharge rates.)

- In areas with commercial/industrial land uses, groundwater quality may be suffering from releases of petroleum, solvents, pesticides/herbicides, and metals contamination (Figure 3). Risks associated with road deicing (salt) contamination can increase in commercial centers because de-icing efforts may be more intensive and because paved coverage increases.

- Agricultural threats to groundwater quality recognized by the SWAP analytical approach are generally low (Figure 2).

- Threats to groundwater quality from forested and other low-intensity land uses including wetlands are low (Figure 3).

Areas of groundwater contamination known to Putnam County Department of Health personnel are included in a summary of contaminant sites found in Section 2.3.4. The review was not conducted to attempt an inventory of contaminant sites in Putnam County since this was not within the scope or interest of this study. Rather, the review was conducted to confirm the general contaminant associations identified by use of the SWAP matrix.

2.3.2 Salt

Virtually all full-season roads in Putnam County pose road salt contamination threats to groundwater quality. A recent USGS study (Heisig, 2000) estimated that 2 lane roads in Putnam and Westchester counties are salted at average rates of 37 tons per mile of road per year, and that the Taconic Parkway and Interstate 84 receive 75 and 298 tons of salt annually per mile, respectively. Eight of the USGS' study sampling sites were situated in Putnam County.

The USGS study documented that streams in watersheds with more roads contain higher concentrations of chloride. The research links road salting practices to salt concentrations in aquifers. Chloride concentrations ranged from approximately 5 to nearly 200 mg/l (parts per million) depending on the miles of road in each sampled watershed (Heisig, 2000). The study indicates that elevated sodium concentrations would also be expected in groundwater in these aquifers. Sodium in drinking water over 20 mg/l are not recommended for those on severely restricted sodium diets and water containing 270 mg/l should not be used by people on moderately restricted sodium diets, according to NYS Department of Health regulations.

Road salt contamination tends to impact aquifers most intensively:

- In roadside areas where flat topography or inadequate curbing or other road runoff management allows excessive infiltration of salty snowmelt into the ground.

- At ends of cul-de-sacs where salty piles of snow may be piled on unpaved areas, allowing infiltration of melting saltwater to groundwater.

- Any remaining uncovered salt-storage piles.

Homeowner complaints of road salt contamination are reportedly received by the Putnam County Department of Health every winter. Where seasonal variation is noted in salt complaints, road salting rather than water softeners is the suspected source of salt since road salting is heaviest during winter and spring months. Many complaints were reportedly received during the heavy snow winter of 2002-03 (Bittner, PCDOH, personal communication). Salt has been found in groundwater near the town center on Route 311 in Patterson, in wells near the intersection of Canopus Hollow and Oscawana Lake roads in Putnam Valley, and in areas along Croton Falls Road and Route 6 in Carmel (Bittner, PCDOH, personal communication; Werper, PCDOH, personal communication). The source of salt contamination on Route 311 in Patterson is not fully understood and may include contamination by water softeners (Williams, Patterson Town Planner, personal communication). Salt found along Canopus Hollow and Lake Oscawana Roads in Putnam Valley may be associated with salt storage practices (McLaughlin, personal communication).

Rates of road salting have generally increased in all northeastern States over the past 3 decades as public expectations for winter road drivability have evolved. No regional well sampling program has documented whether road salt is a more pervasive problem than presently documented.

Water softeners release salt to aquifers when regeneration wastes are transmitted to septic systems. Heisig (2000) addresses water softener salts as a likely secondary source of sodium chloride in watersheds and indicates that residents can use up to 700 or even 1,000 pounds of salt per year (equal to as many as 25 forty pound bags per year). Heavy softener use is most likely in areas with carbonate bedrock formations that cause hard water conditions in Patterson, Southeast and along valleys with carbonate rock in Philipstown and Putnam Valley. Since softeners are also used to remove the iron which may be found in many of Putnam County's bedrock formations, softener use may be widespread throughout the County.

Three of the small watersheds sampled during the USGS salt study are fully sewered. In these watersheds, water softener discharges could not have been contributing to the salt observed in the streams since softener salts would most likely be discharging to the sewage collection system. Since salt levels in these streams were as high as salt levels in unsewered watershed (Heisig, 2003, personal communication), road salt appears to be the dominant source of regionally elevated chloride.

Conversations with Putnam County Department of Health personnel confirm that water softener salt complaints are usually received from individual sites, while road salt complaints normally come from clusters of well owners (Bittner, PCDOH, personal communication). Sampling guidance developed by the NYS Department of Transportation already exists to help distinguish between road salt and water softener salt contamination. The guidance document is available from the Putnam County Department of Health.

2.3.3 Septic Systems

Regional central sewage collection systems in Putnam County are found primarily in southern and northeastern parts of Carmel, in and near the Village of Brewster, and in the Village of Cold Spring (Figure 3). Up to 50 smaller sewage treatment systems are operated at specific facilities throughout Putnam County (Werper, PCDOH, personal communication). Otherwise, individual septic systems are used throughout the County, releasing wastewater to aquifers as a broadly distributed non-point source of wastewater release (Figure 4). Using generally accepted estimates that 80 percent of water used in homes and businesses becomes wastewater, wintertime discharges of wastewater to aquifers from septic systems was estimated by this study to be as high as 8.5 million gallons daily (Table 1). In summer when evaporation and plant roots capture some water released to leaching fields the quantities of daily wastewater returns to aquifers may fall to approximately 6 million gallons daily.

Various wastewater constituents may impact groundwater quality, as addressed below:

Contaminant	**Behavior**	**Management Approach**
Nitrogen compounds	Nitrogen compounds normally convert to <u>nitrate</u> in aquifers. Nitrate does not decay in groundwater or bond to soils, so it travels long distances from septic systems. The drinking water standard for nitrate in water is 10 mg/l.	Density of installed systems must be managed so nearby recharge can dilute nitrate in the aquifer to meet drinking water standards.
Phosphorous compounds	Phosphate bonds to soil. However, as soil bonding capacity is used up, phosphorous travels further and further from septic systems, eventually developing long plumes. No drinking water standard exists for phosphorous.	Where environmental impacts of phosphorous loading to wetlands and streams exceed surface water standards, wastewater treatment is necessary.
Bacteria & viruses	Bacteria and viruses generally die off within 100 feet from leachfields; however, they can sometimes travel much further.	Adequate separation is needed between septic systems and wells. Where feasible, wells should not be installed immediately down gradient from septic systems.
Household chemicals, pharmaceuticals, caffeine, personal care chemicals, detergent byproducts.	Caffeine, detergent byproducts, and other chemicals have been found in streams near septic system leachfields, confirming that these migrate through the aquifers to the streams. They do not appear to decompose easily. No drinking water standards yet exist.	Research universities, USGS, and Federal health studies are presently evaluating these contaminants, their potential impacts, and appropriate responses.

Because of current regulatory priorities and budgets, little systematic sampling of residential wells and no known monitoring of domestic septic systems occurs in New York State. Available data describing such sites are usually found only in research documents or as parts of contamination investigations.

Nitrates and Septic Systems

The average person releases approximately 10 pounds of nitrogen waste per year (NJDEP, 2002). Where septic systems are used, nitrogen is released to the subsurface and generally converts to nitrate in the aquifer.

Elevated groundwater nitrate concentrations were discovered by a recent Putnam County Department of Health investigation near Putnam Lake in Patterson. Nitrate was sampled in approximately 50 residential wells on the southwest shore of Putnam Lake. Samples contained nitrate substantially exceeding the drinking water standard of 10 parts per million. Septic system density in this area is the suspected cause of the elevated nitrates (Bittner, 2003, personal communication; Budzinski, 2003, personal communication). Elevated nitrate may be present in other densely settled areas throughout Putnam County depending on aquifer conditions and specific settings; however no other data could be located.

Various investigators have used nitrate as a tool for recommending sustainable densities for septic systems (NJDEP, 2002; Chazen, 1999). Nitrate releases from septic systems must be diluted with clean aquifer recharge to remain below drinking water standards. The recent USGS study (Heisig, 2000) in Putnam and Westchester Counties identified nitrate concentrations up to 3 mg/l in small watersheds where septic systems are in use, convincingly demonstrating that nitrate moves from septic systems through aquifers to streams. The study cannot, however, be used to predict nitrate concentrations in aquifers because nitrate levels are rapidly reduced in and under streams by biological process.

A limited water quality survey from community water systems (central water supplies) in Philipstown identified no nitrate concentrations exceeding 2.1 mg/l (Miller, 1991). And according to Putnam County Department of Health personnel, no community water systems in Putnam County experience chronically elevated nitrate potentially attributable to septic systems. Since community wells are seldom situated near densely spaced septic systems, these findings do not provide a uniform assurance that some individual wells in Putnam County do not exhibit elevated nitrate.

Coliform and Septic Systems

Over 10 percent of respondents to a recent water quality survey distributed in the Town of Carmel, near Agor Ridge, 0.75 mile south of Lake Mahopac indicated that their well water contained bacteria and that some had resorted to use of UV lamps. Fully 63 percent of those surveyed reported some type of capacity of quality defect, including high iron content, sediment, bacteria, or odors (LBG, 1998). A recent NYCDEP study of septic systems confirms that coliform routinely migrates more than 100 feet from septic system leaching fields (NYCDEP, 2000).

The Putnam County Department of Health does not routinely collect homeowner well samples for coliform analysis (Bittner, 2003, personal communication). Water quality samples collected in Dutchess County, however, showed that *e*-coli coliform contamination in water samples rose during 2002 to approximately 10% of submitted samples during dry summer months (TCC, 2003). *E*-coli coliform is a potential indicator of waste transmission between septic systems and wells. The increase in *e*-coli detections during dry periods indicates that wells may be drawing water from more distant locations during dry months including from under septic system leach fields.

The data suggest that wells and streams can be affected by coliform from septic systems, and that some wells are affected by *e*-coli contamination particularly during periods of low aquifer recharge.

Phosphorous and Septic Systems

Phosphorous is not regulated as a drinking water contaminant. However, phosphorous is a significant contaminant in surface water bodies. A recent NYCDEP study (NYCDEP, 2000) concluded that phosphorous readily travels more than 100 feet from septic systems toward streams or other open waters. The average person releases approximately 3 pounds of total phosphorous wastes each year (USEPA, 1980).

Because phosphorous bonds to soil particles, plumes advance as soil capacity to hold the phosphorous progressively reaches saturation. Studies elsewhere indicate that phosphorous plumes therefore advance approximately 3 feet per year (Dr. William Harman, University of Binghamton, personal communication). At such rates, new homes situated 300 feet from streams might expect phosphorous to reach the stream after approximately 10 years. The NYSDEP (2000) study conclusively documents a wide range of capabilities in different soil types to hold phosphorous, explaining why rates of plume migration will vary widely.

Personal Chemicals and Septic Systems

Recent research indicates that a wide range of lifestyle chemicals are being released to our wastewater systems (USGS, 2002), including from septic systems. Chemical examples include caffeine and medicines such as steroids, nonprescription drugs such as ibuprofen and acetaminophen, detergent byproducts and plasticizer chemicals from our many flexible plastic containers. Few of these chemicals decay when released to septic systems. Many have been found in watershed streams where septic systems are the only sources of wastewater release (P. Phillips, USGS, 2003, personal communication), demonstrating that these chemicals appear to migrate through aquifers from septic systems to the streams.

No studies of such chemicals in groundwater are known to be occurring in Putnam County aquifers. Sewage treatment plants are also not presently required to analyze wastewater for these chemicals so few wastewater treatment data are available.

No standards yet exist for these classes of chemicals but standards may be anticipated in coming years. For many, dilution with aquifer recharge, appears to be the most readily available management approach. Thus, like for nitrate discharges, management of septic system density appears to be a potential management strategy.

2.3.4 Specific Areas of Concern

This study was not designed to focus on particular contaminant sites. However, various specific groundwater contamination occurrences in Putnam County are enumerated here to confirm general occurrences of threats to drinking water quality and consider their land uses associations. This list is a brief summary of issues and sites mentioned to TCC during interviews with municipal officials, Putnam County Department of Health personnel, and as a result of a review of DEC spill sites. Sites not believed to threaten groundwater wells are not listed.

- Town of Patterson: Salt contamination near town center on Route 311. Some difficulties with natural concentrations of iron and manganese in community water system wells. Reported coliform failures in wells. A Getty station spill on Route 22. Nitrate contamination confirmed at Putnam Lake. Potential salt contamination also reported around Putnam Lake.

- Town of Southeast: Various petroleum spills of concern, including Citgo, Amoco, and ATI stations on Route 22. A former Texaco station (now a Mobil station) on Route 6 and Drewville Road. Groundwater concerns at a Metro North parcel on Prospect Hill Road. Ongoing remediation of public water supply wells in the Village of Brewster but the rest of the Village is on central water so individual spills do not immediately threaten human health.

- Town of Kent: Persistent organic contaminants in some domestic wells near Lake Carmel with reported ongoing treatment. Various sites on Route 52, including MTBE at Kent Elementary school, Texaco and Getty stations, Kent Elementary School and Kent Centre, near intersection of Farmers Mills Road, Kent Library. Kent Town Hall reportedly has water quality concerns. An MTBE spill near intersection of Amazon and Towner's roads. Wellwater quality is also a concern in residential areas around Lake Carmel.

- Town of Carmel: Various chemical spills and road salt in the Mahopac business district, including many sites along Route 6. Various gas station sites include the Mobil at Clark and Route 6, Citgo and Texaco stations at Baldwin Place and Route 6, the Loving Care Cleaners dry-cleaning site in the Mahopac Business district. Also Beckom and Jungwirth sites on Beach Road, a Shell station on Stoneleigh and Route 6, and a Citgo station at Fowler and Route 52. The Mahopac Fire Department on Route 6. The Secor Lake community water system is being treated with carbon. Some MTBE near intersection of Drewville Road and Route 6.

- Town of Putnam Valley: Road salt and MTBE in groundwater near Canopus Hollow and Oscawana Lake roads. Wellwater quality is a concern throughout the community surrounding Lake Peekskill since many residents use individual wells. Water quality concerns are also noted by the Putnam County Department of Health at the Gallante residence on Becker Street at Lake Peekskill, at Lakeside Market & Deli on Lake Drive at Lake Peekskill, and Auto World on Peekskill Hollow Road.

- Town of Philipstown: Pete's Hometown Grocery on Route 301. Hustis Dairy and Garrison Texaco on Routes 9 and 9D, respectively. Marathon Battery site on Kemble Avenue. Failing septic systems in the Village of Nelsonville. The Village of Cold Spring is on central water so individual spills do not threaten human health.

In general, these occurrences confirm the associations used by the NYSDOH Source Water protection program and the mapping prepared for this study (Figures 3 and 4) defining classes of groundwater threats associated with land use classes.

2.3.5 Sewage Districts:

Sewer systems play varying roles in groundwater quality protection.

- Where pipe leaks are minimized, districts beneficially collect and treat waste contaminants rather than allowing them to be released to aquifers via septic systems.
- Districts minimize water evaporative losses since evaporative losses from septic system leaching fields are avoided.
- Districts guarantee a daily flow into streams or open waterbodies.

Sewer districts, however, normally fail to replenish aquifers. This can reduce available groundwater in wells within or near sewer districts, and can result in stream depletion upstream of sewage treatment discharge points. Such impacts must be assessed during any sewer district design process.

Sewer districts are employed most widely in the Town of Carmel where substantial groundwater volumes are collected for treatment and released to surface water bodies. Flow in streams is assured, but impacts to aquifers are presently unknown. Although few of Carmel's areas of reported groundwater shortage appear situated near areas with central sewage collection, potential aquifer dewatering impacts should be evaluated wherever future sewage districts in Putnam County are proposed.

2.4 Water Requirements, Consumption, and Wastewater Generation

Residents on individual wells generally use between 80 to 100 gallons per day (gpd). Residents receiving water from central water supplies, who pay directly for their water, generally use between 60 and 80 gpd. Water uses in Putnam County are expected to peak in summer due to inflows of summer residents, activity at camps, and watering/irrigation requirements.

Using conservative water use estimates, approximately 80,000 residents in Putnam County use groundwater, withdrawing a maximum of approximately 8 million gallons per day (mgd) (Table 1, residential total). The balance of Putnam County residents receive water from surface water sources.

Of the total gallons delivered, each resident is estimated to "consume" approximately 20 gallons of water daily, therefore generating between 60 to 80 gallons of wastewater. The "consumed" fraction refers to water evaporated or transpired to the atmosphere rather than returned as wastewater. Water is consumed by perspiration, steam from cooking, and evaporation from watering of plants, washing of cars, and during drying by dishwashers and clothes driers.

During winter, virtually 100 percent wastewater released to septic systems returns to aquifers except in rare instances where septic wastes travel laterally along clay layers directly to nearby water bodies. Wintertime residential uses of groundwater therefore result in 5.6 mgd of wastewater discharged to septic systems and hence to aquifers. Some 0.7 mgd of withdrawn groundwater also passes to central sewage treatment plants where sewage districts collect wastewater from areas using groundwater sources.

During summer, 30 to 50 percent of wastewater passing to septic leaching fields may be drawn upward by evaporation or root transpiration (Chazen, 1999; LBG, 2001). Summertime septic system evaporation and transpiration losses are estimated at 1.7 mgd, so just 3.9 mgd of wastewater released to septic systems replenishes aquifers during warmer months of the year (Table 1).

Water used by commercial and industrial users is not as readily summarized and so are added to Table 1 as estimates. Prior investigations have simply estimated that non-residential water uses in Putnam County are 50% in addition to residential use estimates (Goodkind & Odea, 1970). Using this approximate value, total groundwater use and consumption estimates for residential and commercial/business/organizational sectors in Putnam County are estimated below and detailed by Town on Table 1:

Total Groundwater withdrawn from aquifers:	12 million gallons daily
Total groundwater returned to Sewer systems:	1 million gallons daily
Water returned to Aquifers via Septic Systems (winter):	8.5 million gallons daily
Water returned to Aquifers via Septic Systems (summer):	6 million gallons daily

Putnam County Department of Health personnel indicate that total daily wastewater discharges in Putnam County sum to approximately 2 mgd (Werper, PCDOH, personal communication). Since approximately 1 mgd of this comes from districts receiving water from surface water sources, which have been excluded from the Table 1 groundwater inventory, the sewage wastewater values appear to be approximately correct.

2.5 Climate

Precipitation data show that average annual precipitation in Putnam County typically varies between 43 to 49 inches, with a median value of approximately 48 inches annually (LBG, 2001), including rainfall equivalents for frozen precipitation. A large percentage of Putnam County's yearly precipitation falls in the form of snow and frozen rain, remaining locked in snowpack while air temperatures are below freezing. As springtime temperatures rise, water in the melting snowpack either seeps into the ground or flows overland to surface water bodies. Aquifer recharge, accordingly, occurs primarily in the autumn and spring when precipitation is not required for plant processes and when the ground is also not frozen.

The mean average annual temperature at a weather station in Carmel is 48.5 F. Temperatures of less than 0 F or greater than 90 F occur on average less than 10% of the time. Air temperatures extremes in Carmel have been as low as –24 F and as high as 103 F (Grossman, 1957). Typical pan evaporation rates, characterizing evaporation rates off of open water bodies, average between 30 and 35 inches annually (Viessman, et al., 1989). Losses of groundwater to evaporation or transpiration are less than pan losses except where watertables are close to ground level in wetland or in equivalent shallow watertable settings.

Future climate patterns in the region are not fully understood, however, many investigators believe that future weather may include more frequent severe storms with longer rainless periods between storms, and overall warmer temperatures. Such projections would affect aquifer recharge rates, increase evaporation losses, and place heavier reliance on long-term groundwater storage between recharge events.

2.6 Vegetation

Wetlands near streams, and upland forest vegetation or other deeply rooted flora use large quantities of groundwater. Up to 50% of precipitation in Putnam County returns to the atmosphere via evaporation and plant transpiration processes. Figure 2 confirms that large portions of Putnam County are covered by forest and wetlands where such processes occur.

Soil Conservation Service programs, such as TR-55 document how runoff-coefficients change as land uses change. Such changes also impact percentages of precipitation that successfully recharge aquifer rates. In general, increases in runoff result in decreases in aquifer recharge

2.7 Geology

Geologic formations are broadly described as bedrock formations, requiring blasting to be removed, or surficial formations, which can be readily removed with a backhoe. Putnam County's bedrock and surficial geologic formation characteristics are briefly reviewed below.

2.7.1 Physiographic Provinces and Bedrock Geology

Most lands in Putnam County fall within the Hudson Highlands physiographic province. A portion of Putnam County south of the East Branch Reservoir and East Branch Croton River Diverting Reservoir in Southeast lies within the Manhattan Prong physiographic province (Figure 5). The Manhattan Prong, which is more broadly expressed across Westchester County south of Putnam County exhibits generally more rolling landscapes than the Hudson Highland province underlying most of Putnam County.

Hudson Highland bedrock formations consist of igneous or high-grade metamorphic rocks including granites, gneisses and amphibolites formed under high temperature and pressure conditions. Manhattan Prong bedrock formations include carbonate formations and schists and gneisses. Carbonate formations underlie several of Putnam County's valleys due to their limited resistance to erosion and weathering. The Inwood Marble and Stockbridge Marble are found under much of the valley of the East Branch Croton River and the associated Great Swamp wetlands in the Town of Patterson. Carbonate formation slivers also lie under valleys in Putnam Valley and in southern Southeast (Groff, et al., 1986) (c.f. Figures 1, 5, 6).

Significant faults separate the Hudson Highlands and Manhattan Prong provinces in Southeast. The zone is believed to consist of sub-parallel faults (Ratcliffe, 1980) and includes zones of crushed rock up to 600 feet wide. The rest of the southern margin of the Hudson highlands is defined by additional faults, some of which extend along Canopus and Peekskill Hollow valleys. Ratcliffe (1980) reports abundant mylonite (crushed rock) along fault zones west of Lake Peekskill.

The structural geology of Putnam County includes intersecting folds, faults and fractures or joints in the bedrock formations (Isachsen, et al. 1991). For hydrogeologic purposes, joints and fractures are extremely beneficial structures since groundwater is stored and transmitted in such openings. Bedrock formations in Putnam County have no inherent porosity (e.g. between grains or within other pores paces) available for groundwater storage, so joints and fractures are critical groundwater transmission and storage features.

Most major faults in Putnam County trend approximately from the southwest to the northeast. Smaller faults with other orientations occur throughout the county (Groff, Anders, Jaehnig; 1985). Most faults mapped by Groff are shown on Figure 5 since they may enhance yields of wells drilled in bedrock aquifers. Groff, et al (1986) displayed extensive data on the locations and orientations of fractures and foliations in Putnam County.

Geologic well logs available in the Putnam County Department of Health offices indicate that some wells intersect more than one formation. This occurs primarily in areas near boundaries of Patterson and Kent. This is consistent with general geologic interpretations (Isacsen, et al, 1991) describing various thrust faults in that region. In most locations, however, there is little opportunity to drill through one formation into another within Putnam County. More importantly, from a hydrogeologic perspective, there is little yield advantage to drilling into deeper formations since yields are generally similar in all bedrock formations.

2.7.2 Surficial Geology

Surficial deposits overlie Putnam County's bedrock formations, remnants of former glaciation of Putnam County. Unsorted and usually silt or clay-rich glacial till is found on hillsides and hilltops, and water-sorted deposits including sand and gravel deposits or layered silt, sand and clay occupy valleys. Sediment deposits in upland areas are often no thicker than 3 to 10 feet although some thick deposits have been found (Caldwell, 1989). Valley deposits in Putnam County range in thickness from a few feet to many tens of feet thick some locations (Irwin, 1987; Grossman, 1957). Sediments over 100 feet thick have been noted in the lower Peekskill Hollow Creek valley (Miller, 1989)

Glacial till is usually highly unsorted and can contain boulders. These sediments were either transported under glacial ice and so are highly compressed, or were transported within ice and so drape land landscape as an unsorted mantle. Runoff rates are usually high from these soils because surface water only infiltrates slowly. Glacial till seldom contains open enough porosity to support modern wells.

Sand and gravel deposits in valleys are water-sorted sediments deposited by moving de-glacial streams. As glacial meltwater carried away smaller-sized particles, only the heavier sand and gravel sediments remained. These usually occupy valleys but can sometimes also be found in upland areas, marking former ice margins. Glacial outwash deposits free of clay and silt-size sediments and below the present watertable can support high-capacity wells. Deposits of sand and gravel in Putnam County are limited to the valleys of the Canopus Creek and Peekskill Hollow Brook (HES, 2001), Clove Creek valley in northern Philipstown, and scattered valley deposits in the Towns of Patterson and Southeast (Figure 5). In general, highly permeable sand and gravel deposits can be identified on soil conservation service maps as Hydrologic Group A soils. There are very few Hydrologic Group A soils in Putnam County.

Where melting glaciers created temporary lakes, wide ranges of sediments flowed inward, sometimes completely filling former lakes. Silt and clay usually dominate glacial lake deposits. Glacial lake deposits are seldom sufficiently permeable to support water wells. Calm water deposits containing significant silt and clay are found under Cold Spring and under much of the Great Swamp in Patterson (Figure 5).

2.7.3 Mineral Deposits and Quarries

Iron, manganese, and occasional hardness are common water quality defects in Putnam County bedrock aquifers. Treatment is usually accomplished with water softeners. Bedrock formations in Putnam County are otherwise generally free of natural contaminants except near former mines.

A wide range of former mine and existing mineral deposits in Putnam County, including former arsenic, sulfur and copper mines, numerous former iron mines and miscellaneous other small mines (Table 2, Figure 6). In 1988, the Putnam County Department of Health collected groundwater samples from domestic and other wells near many of these former mines and determined that few drinking water standards were exceeded in the sampled areas (Bittner, 1989).

A brief summary of mineral deposits which could potentially impact groundwater quality follows:

- Arsenic-containing minerals occur in several locations in Putnam County, particularly in the Town of Kent. An "Old Arsenic Mine" is reported to be 4 to 5 miles northwest of Carmel (Beck, 1842), where the primary ore mineral is arsenopyrite, an arsenic-iron sulphide mineral. Beck (1842) reports there are three other arsenopyrite sites near the Old Arsenic Mine: two are described as being 3 miles west of the Arsenic Mine; the third is "Brown's Serpentine Quarry," 3.5 miles northwest of Carmel (Beck, 1842).

- The N.Y. State Museum has one arsenopyrite sample from Philipstown, reportedly from the Anthony's Nose area, associated with copper and iron minerals.

- The only confirmed radioactive minerals in Putnam County come from the "Phillips Mine" region in the extreme southwest corner of the county. Phillips Mine lies near the intersection of Lehman Road and Iron Mountain Road. The mine site includes three shafts reportedly within 100 feet of the Westchester County line and two adit entrances near Lehman Road. According to U.S. Geological Survey Bulletin 1074-E (Klemic et al., 1959), the ore body is composed mainly of iron sulfide and copper-iron sulfide minerals such as pyrrhotite, pyrite and chalcopyrite. The source of uranium is the mineral uraninite. Detailed site investigations would be needed to further define geologic areas containing radioactive elements in this area.

Several other specimens in the collection of the NYS Museum come from Putnam County and contain radioactive minerals. Unfortunately the locations from which the specimens were collected are vague, labeled simply as coming from the "Town of Kent, Taconic State Parkway." These specimens include the minerals Thorite, Allanite, Zircon and Malachite, containing thorium, rare-earth elements, zirconium and copper, respectively. No further details on these sample locations were available.

- A former copper mine reported also lies near Anthony's Nose in Philipstown.

- Numerous former iron mines occur in Putnam County. Most of these mines exploited magnetite and a few extracted iron from the iron oxide mineral limonite. The largest and best-studied iron mine in Putnam County is the Tilly Foster Mine, approximately 2 miles northwest of the Village of Brewster. Januzzi (1994) lists the minerals found at Tilly Foster, including minerals containing lead, arsenic, barium, copper, boron, cobalt, titanium, zinc, thorium, zirconium and manganese. Other iron mines are found throughout the County, including the Deans Corners Mine, Daisy Lane Mine, Joe's Hill Mine, Bryant Pond Mine, Peekskill Hollow Mine, Canada Mines, Pelton Pond, China Pond Mine, Brewster Village Mine, South Lake Mine, and the Mahopac Mines.

- A variety of other more minor ores have been mined in Putnam County over the past centuries, producing lead, mercury, molybdenum, gold, silver and graphite. Some of the reported gold and silver mines may have been mythic; others appear to be real deposits, including Sprague's Gold Prospects, Braasch Gold Prospects (aka Smith's Gold Mine), Graymoor Gold Mine (aka Wayside Mine), Mowatts Gold and Silver Mine as well as Manitou Silver Mine and Joe's Hill Silver Mine. Lead mines include the Warren Ridge Lead Mine and the Indian Brook Lead Mine, which utilized lead carbonate as ore.

- Records of one mercury mine exist, known as the E. Mosher's Quicksilver Mine.

- Several mines extracted molybdenite to produce molybdenum, including Eugene Owens Molybdenite Pits, Constitution Island North and Constitution Island South.

- Graphite was produced at Tillers Blacklead Mine, the Taylor Mine and Burdick's Blacklead Mine.

Details summarized herein were identified from reports at the Putnam County Historian's office or the NYS Museum in Albany. Where coordinates were available, mine locations are shown on Figure 6.

2.7.4 Dominant Fracture Systems

Grossman (1957) reports that many fractures in Putnam County strike northeast, approximately parallel to the dominant geologic structures of the Peekskill and Canopus hollows in Putnam Valley (Miller, 1989) and to the more subtle structure of the Breakneck Brook in Philipstown. A second fracture set strikes northwest, intersecting the first set at an angle. The alignment of the West Branch River and the Boyd Corners Reservoir in Kent most clearly shows this linear pattern, as do the general traces of the Secor Brook in Carmel, and the Roaring Brook, Wiccopee Brook and similar east-flowing brooks in Putnam Valley. Most dominant fracture systems in western Putnam County have steep dips, meaning that the fracture penetrates downward. Some decompression sheet jointing, approximately parallel to the land surface, has been noted in Garrison (Grossman, 1957).

Multi-scale fracture trace mapping was previously conducted for the entire county (Maslansky & Rich, 1984). Aerial photos, of unknown scale, date, and finish, were reviewed in conjunction with USGS 7.5 Minute topographic quadrangles, Landsat imagery, and privately flown infra-red imagery. Major fracture traces, with orientations oblique to previously mapped structural features, were identified in northwestern Putnam County. Parallel fracture trace systems were also mapped on the Oscawana Lake USGS Quadrangle.

Detailed mapping of fractures and geologic features throughout Putnam County was completed by Groff, Anders & Jaehnig (1985). Faults identified during this mapping effort are shown on Figure 5. Prucha (1968) noted that bedrock is more extensively fractured in western portions of Putnam County, a factor which may correlate to the generally more rugged terrain in the western portion of the County.

A limited supplemental fracture trace and lineament mapping exercise was conducted by TCC in the western half of the Town of Carmel (Figure 7) to test correlations between high well yields and suspected fracture zones. The area was selected because of the density of available well data, a record of water well failures in this area, and the relatively limited evidence of bedrock fractures. The linear feature analysis method used by TCC is summarized in Appendix B. The assessment identified linear features primarily orientations oblique to the northeast-southwest trending fault systems of the Canopus or Peekskill hollows, and several parallel fracture traces lie in the southern third of the study area. Similar parallel trending fractures were noted by Maslansky & Rich (1984) in the Oscawana Lake USGS Quadrangle, and are also observed on the Preliminary Brittle Structures Map of New York (Figure 7).

2.8 Soils

Along with land uses and vegetative cover, soil type substantially control rates of surface water infiltration (e.g. recharge) into underlying aquifers. Although not intended quantitatively for analyses of aquifer recharge rates, hydrologic soil groups (HSGs) in Putnam provide an indication of rates of groundwater recharge through different soils.

Group A soils allow high infiltration rates and consist chiefly of deep, well to excessively drained sand or gravel. There are few Group A soils in Putnam County. Group B soils have moderate infiltration rates and consist chiefly of soils with moderately fine to moderately coarse textures. Group C soils have low infiltration rates and consist chiefly of soils with a layer that impedes recharge. These soils have moderately fine to fine textures. Group D soils have very low infiltration rates and consist primarily of clay. As discussed herein, Group D soils also include soils rated as A/D or C/D which are more granular but which limit aquifer recharge due to already saturated site conditions.

Philipstown includes approximately half Group B soils, with the rest of soils consisting of a mix of Group C and mostly Group D soils.

Putnam Valley has many Group B soils in the southern half of the Town. An area of Group C soils lies in the southeast portion of Town near Barger Pond, and soils in the northern half of the Town become increasingly weighted toward Group D soils.

Kent soils fall primarily in Group B. A zone of Group C soils lies east of Lake Carmel and some Group D soils lie in the south-central part of the Town.

Carmel has Group C soils in up to half of the Town. Nearly all areas in the southwest quadrant of Town are Group C soils, along with some areas east of Lake Mahopac and areas in the northeast quadrant of the Town. Remaining areas are primarily Group B soils with some Group D soils.

Patterson appears to have an approximate balance of Group B, C and D soils. Group C and D soils appear somewhat associated with lowland areas under and near the Great Swamp and other associated low areas.

Southeast has Group C soils in up to half of the Town. Nearly all areas in the southeast quadrant of the Town are Group C soils, along with most lands in the northwest quadrant of the Town. Remaining areas are a mix of Group B and D soils.

This general discussion above includes Villages within these geographic area summaries. In general, aggregate infiltration rates may be lower in Patterson, Southeast, and Carmel than in Kent, Philipstown and Putnam Valley. Readily available soils maps may be referenced for these general soil summaries.

3.0 PUTNAM COUNTY GROUNDWATER RESOURCES

Aquifers represent the primary source of water supply for most of Putnam County. Characteristic yields and other hydrogeologic characteristics of the County's aquifers are reviewed in this section. Due to the limited number of water-bearing sand and gravel aquifers throughout Putnam County, most groundwater in the County is withdrawn from bedrock aquifers. Groundwater in Putnam County generally resides in fractures and joints in bedrock formations or within pore spaces in the County's surficial formations.

Aquifers are geologic formations that provide useful amounts of groundwater. The Putnam County Department of Health requires yields of 5 gpm for wells without supplemental storage but will allow use of wells providing as little as 2 gpm as long as storage capacity is available in the wells or in a storage tank. Therefore, any formations with fractures providing yields as low as 2 gpm are considered suitable aquifers for residential purposes even though projects needing higher yields would dismiss a 2 gpm yield as a poor yield. This leads to widespread confusion over what is, or is not, an aquifer. TCC treats all geologic formations in Putnam County as aquifers, while acknowledging that some areas provide higher yields than others.

Precipitation recharges aquifers as it infiltrates through soils to the deeper geologic formations. Recharge occurs on all geologic formations in Putnam County. Once it reaches the watertable, which usually lies 20 to 30 feet below grade except near streams, this recharge migrates with other groundwater through pore spaces or fractures toward lower elevations where it eventually re-emerges at grade in hillside springs or as baseflow in streambeds. In general, groundwater follows the same topographic basins as surface water watersheds. Figures 1 and 8 show surface water and groundwater drainage systems in Putnam County. Groundwater contributions from aquifers as baseflow to streams are the sole sources of water flow in streams during extended rainless periods.

3.1 Bedrock Aquifers

3.1.1 Summary of Well Log Analysis and Previously-Published Data

Bedrock aquifers underlie all of Putnam County. These consist of solid rock formations that have no primary porosity but can contain, store and transmit groundwater in their fracture or joint openings. Bedrock formations have lower average well yields than sand and gravel aquifers because of lower overall porosity; however, the ubiquitous presence of bedrock aquifers throughout Putnam County, and the lack of alternate sources of readily available groundwater, requires their acknowledgement as significant aquifers. Where several bedrock formations occupy a common drainage area or watershed, groundwater migrates through interconnected fractures in the several formations before emerging in streams as baseflow.

Georeferenced digital well logs available at the Putnam County Department of Health were evaluated to assess well yields throughout Putnam County. Results are summarized below and compared to prior hydrogeologic studies. The well log database is the largest well data set available to hydrogeologists working in Putnam County and encompasses logs submitted between the 1960s and the present although logs reviewed as part of this study terminated in the late 1990s. The well log database will also help planners and project applicants during specific project reviews, allowing inspection of numbers of wells, depths of wells, geologic formations of wells, and yields of wells near proposed project sites. Figure 6 shows the locations of available digitized well logs.

Methods used by TCC to evaluate the well log data are described in Appendix A. Conclusions of the analysis as well as a review of findings by prior investigators are summarized here.

- <u>All bedrock formations support wells:</u> Although dry holes can be drilled in any bedrock formation in Putnam County where fractures are missed during drilling, typical well yields from all 18 bedrock formations (Figure 6) in Putnam County show <u>median</u> yields of between 7 and 12 gallons per minute and median depths of approximately 275 to 300 feet (Table 3). Median values are those where half of reported values are higher than the median and half are lower. Median data identify no significantly higher- or lower-yielding formations in Putnam County and confirm that useful wells can normally be installed in all formations in the County.

- <u>Higher yield bedrock formations exist:</u> The Manhattan, Walloomsac, and Stockbridge formations support highest <u>average</u> yields in Putnam County (Table 3). These values indicate that high-yield fractures are encountered most frequently in wells drilled in these formations. Accordingly, TCC has identified these three formations and the geologically similar calcitic/dolomitic marble and amphibolite pelitic schists as Higher Yielding bedrock formations (Figure 5). The Inwood Marble is not included as a Higher Yielding formation because a substantial number of well records indicate consistent low yields. Other formations with recognized moderate to high-yield include the garnet rich gneiss, the rusty/gray paragneiss, and the gabbro/norite/diorite (Table 3). These are shown on Figure 6 but are not included in the recommended Higher Yielding group due to limited numbers of well logs from these formations and their greater geologic similarities to the Lower Yielding formations.

- Higher Yielding formations provide better yields at all drilled depths: Database analysis demonstrates that the Higher Yielding formations support better yields at all well depth (Table 4). For example, typical 300 feet deep wells drilled in Higher Yielding formations provide average yields nearly 50% above yields in equivalently deep well Lower Yielding formations. Similar advantages are found between all equal depth groupings.

- Low elevation wells provide better yields at depth: TCC separated wells installed above 450 feet above mean sea level (amsl) from those below 450 feet amsl. The 450 foot elevation generally separates upland and valley areas in Putnam County. The sorting analysis indicates that wells less than 400 feet deep had similar yields in both high and low elevations. However, as wells were advanced to between 400 and 700 feet deep, yields in high elevation settings dwindled while lower elevation yields in deep wells continued to provide strong yields (Table 5). Prior investigators have recognized that lower elevation wells produced more water than upland wells but understanding that this advantage only becomes apparent in the deepest of wells was not previously recognized.

- Local glacial geologic cover types are not as important to yield as previously believed: TCC sorted wells in Higher Yielding and Lower Yielding bedrock formations by overlying surficial geologic formation. In areas with surficial geologic formations generally believed to limit infiltration, yields in Higher Yield and Lower Yielding formations were virtually identical (Table 6). These findings suggest that short term bedrock well yields are more a function of fracture frequency in the bedrock formation than of surficial geologic types. This conclusion may have been different if well drillers employed longer term tests to estimate sustainable yields.

- Newer wells are being drilled deeper than older wells: Table 7 indicates that wells are being drilled deeper today than in past decades. This may be a function of new construction occurring in less accessible locations, changed drilling methods, and of increased water flow demands in modern households. It is not interpreted to mean that regional aquifer levels are falling or being depleted.

The findings above were developed by TCC using statistical and GIS analysis on more than 5,000 well logs available in the Putnam County well database, dating from prior to 1970, to the present. Discussion of how these findings agree or disagree with prior studies follows:

<u>All investigations agree that highly-fractured bedrock offers better yields than bedrock with few fractures</u>. Minimally-fractured bedrock offers little groundwater storage capacity and few pathways for groundwater flow into wells. Wells installed along faults and joints, such as those within the Canopus Creek and Peekskill Hollow valleys, have higher yields (HES, 2001). Maslansky & Rich (1984) indicate that upland well yields range between just 0 to 3 gpm unless intersecting significant fractures.

<u>All investigators agree that all bedrock formations provide useful quantities of water.</u> A Putnam Valley study confirmed that there were few differences in yield between most bedrock formations (HES, 2001). The most common well yield in Putnam Valley is 5 to 10 gpm from wells between 100 and 300 feet deep (HES, 2001). A review of well yields in Philipstown indicates that most wells are drilled in the Granitic gneiss and only 10 percent of the bedrock wells had yields over 30 gpm (Jaehnig, 1988). An earlier Putnam Valley study of 438 unsorted bedrock wells identified an average yield of 11.6 gpm (Miller, 1988).

<u>One early investigator agrees that the Manhattan schist and the Diorite are high yield formations:</u> Grossman (1957) identified yields of 11 gpm in Putnam County granite and gneisses, and higher yields of 12 and 19 gallons per minute from schists of the "Hudson River Formation" (aka Manhattan) and from the Pochuck diorite, respectively. This is consistent with the present database finding that the Manhattan Schist and the Gabbro/Norite/Diorite formation have high yields (Table 3).

<u>Most investigators found that well yields increase at lower elevation</u>: Grossman (1957) determined that yields in schist, granite, and carbonate formations all increased, and in some cases nearly doubled, where wells were installed in the same geologic formations within valleys. TCC believes this is because lower elevation aquifers benefit from recharge occurring in upland areas which migrates toward lower elevation areas. A previous county-wide study completed by Maslansky and Rich (1984) agrees with this finding. Prior investigators did not recognize that it is the deepest wells in low elevations which have a clear advantage over deep upland wells.

<u>Some investigators found that well yields are higher when overlaid by sand and gravel deposits</u>. Using limited numbers of wells, Grossman (1957), suggested that yields can double where bedrock formations are covered by sand and gravel rather than clayey till soils. More recently, however, Jaehnig (1988) observed that high yield wells cannot be correlated to thick soil cover and that higher yields are instead found in basins (e.g. at lower elevations). TCC concurs with Jaehnig's findings. A review of soil types in Putnam County (Section 2.8) indicates there are few to no

Group A soils in the County that allow high-rates of groundwater infiltration. Instead, most soils allow only modest to low rates of groundwater infiltration, making fracture density and interconnections an equally if not more significant factor influencing the short term yield tests documented by well drillers.

<u>Investigators agree that not all carbonate formations provide high yields</u>. A questionnaire distributed to residents in Patterson indicated that most high-yielding wells (over 50 gpm) were completed in fractured limestone and marble of the Wappinger (aka Stockbridge) formation. A large number of such high-yield wells lie in and around the central Patterson hamlet and south of the hamlet in the vicinity of Routes 22 and 164 (TRC, 1990). The recent database study conducted by TCC identified carbonate wells as one of the higher yield bedrock grouping (Table 3). However, carbonate well yields in Putnam Valley reportedly average only 8 gpm while yield from non-carbonate formations is 10 gpm (HES, 2001). Earlier work by Miller (1989) in Putnam Valley also ranked wells installed in the Inwood carbonate formation behind yields from other formations (Miller, 1989). Data analyzed during this study also did not include the Inwood Marble, mapped within in Peekskill Hollow, as a High-yield formation. Carbonate in western Putnam County is relatively limited and does not show the yield advantages found in larger carbonate formations in eastern Putnam County. There is also evidence that although carbonate formations have multitudes of interconnected fractures, where they are covered by Group C or D soils recharge rates are sufficiently low that high-yield wells can dewater the bedrock aquifer over large areas due to only limited infiltration rates providing replacement groundwater (Rich Williams, Patterson Town Planner, personal communications).

In summary, the GIS-based analysis of Putnam County's well log data and prior studies have identified

- Higher and Lower Yielding bedrock formations in Putnam County.
- A clear advantage experienced by deep wells in Lower Elevation settings.
- No clear short-term flow advantage for bedrock wells installed under sand and gravel formations although longer term testing data bases would be expected to show such relationships.

This summary has noted that well drillers record their observed yields on the basis of short duration flow tests. Accordingly, the available well log data provide an acceptable record of short-term flow-rate capability in wells but cannot be used to predict long-term sustainable flow rates from wells. Lower elevation wells receiving the benefit of upgradient recharge in addition to adjacent area recharge, and wells situated near areas of high-permeability soils allowing ready recharge, are likely to have greater long-term yield reliability than higher-elevation wells in areas with clayey soils, but this cannot be verified by the present dataset.

3.1.2 Fracture Trace Analysis

Fracture trace analysis seeks to identify fractures that a well driller can intersect to increase well yields. The analysis includes evaluation of air photos at different scales to identify visible linear features. Linear features may either be caused by bedrock fractures of by common human features like fencelines or old roadways, so linear features must usually be field checked to determine if they are geologic rather than anthropogenic features.

Analysis of wells installed near Baldwin Place Road south of Lake Mahopac indicates that wells located within 300 feet of linear features interpreted to be fractures had average depths of 326 feet and yields over 12 gpm, while wells situated more than 300 feet from the linear features had average depths of 512 feet and yield of 4.5 gpm (LBG, 1988). The analysis showed that wells installed near these linear features had a higher likelihood of improved well yields. Other investigators have also shown that drilling wells near obvious linear features can benefit well yields (Moore et. al., 2002).

As a limited study of applied linear feature methodology, Chazen examined records from wells installed near linear features in western Carmel to analyze whether yields improved near potential fractures (Figure 7). The area was selected for preliminary analysis because periodic water supply difficulties have been reported in this area. No field checks of the linear features were conducted given project limitations. The analysis identified few pronounced linear features, which may contribute to the limited well yields in the area. Statistical analysis of well yields near these linear features identified no clear yield advantage for wells situated nearest to the linear features observed (Table 8). The limited study suggests that either these linear features are not water-bearing fractures, or that well yield and location data were not sufficiently detailed to confirm benefits of drilling near the limited numbers of fractures in this area. Careful field checks may be needed of the identified linear features and/or or the drilled well locations. The analysis does not invalidate the usefulness of linear feature and fracture trace analysis but points to the care, budget and time needed for such studies.

3.2 Surficial Aquifers

3.2.1 Summary of Known or Published Data

Where saturated glacial deposits are found, coarser sediments can store or transmit significant quantities of groundwater. Few domestic wells are installed in these surficial formations but significant groundwater quantity can be made available for public water system wells. As an example, the Village of Brewster draws its water from wells installed in such granular sand and gravel deposits.

General relationships reported in available regional studies and regional studies are summarized below:

- High yields can be expected from sand and gravel formations. In the Town of Putnam Valley, yields greater than 25 gpm are anticipated from valley glacial deposits (HES, 2001). Grossman (1957) indicates that the average well yield from surficial aquifers in Putnam County is 33 gpm, ranging from 1 to 450 gpm. Sand and gravel offer a matrix that transmits water readily, and high porosity within which to store considerable groundwater.

- Generally, only limited sand and gravel deposits are found in Putnam County. Mapping completed by Irwin (1988) and Cadwell (1989) indicate the limited number of areas with recognized high yield surficial deposits (Figure 5). The limited aquifer zones with generally more permeable glacial deposits lie in Peekskill Hollow, along the Canopus Creek, and along the Clove Creek (HES, 2001; Jaehnig, 1988). More limited sediments also lie along the valley of the East Branch Croton River near Patterson and along the Haviland Hollow Brook (Irwin, 1988).

- Stream gauging confirms the absence of sand and gravel deposits in Patterson near the Great Swamp wetland (Section 3..3.2). Hydrogeologic studies completed in the Towns of Putnam Valley (HES, 2001) and Philipstown (Miller, 1991) indicate that the sand and gravel deposits are of relatively limited aerial extent.

- Glacial valley-fill aquifers receive recharge from runoff and precipitation. Some recharge comes from direct infiltration of rainfall. Additional recharge comes as a result of runoff from adjoining hillslopes (USDA, 2002; Gerber, personal communication). A Dutchess County study estimated that recharge to valley sand and gravel deposits can be doubled over expected direct rainfall because of runoff from valley sidewalls (TCC, 1999).

- Valley-fill aquifers are conduits for groundwater flow from upland bedrock aquifers toward the valley streams. Groundwater recharged to upland bedrock aquifers migrates through bedrock fractures and usually must pass through the more permeable sand and gravel formations to reach valley streams. This enhances groundwater reserves in sand and gravel formations.

- Valley surficial deposits can also include silts and clays providing little to no useful groundwater yields. Valley sediment deposits are the result of glacial depositional patterns that were changeable, sometimes resulting in abrupt changes in sediment size distribution over short distances. Stream gauging conducted as part of this study identified valley segments with both modest and large groundwater discharges (Section 3.3.2), suggestive of variability in the valley sediments. Careful groundwater investigations are required to identify high-yield aquifer sediments in valley settings. Some areas where silt and clay valley deposits have been recognized by regional geologic studies are shown on Figure 5.

- Glacial till is present as a cover soil over most hillslope and upland lands throughout the County. These soils tend to have poor water-bearing properties even where saturated. Till depths up to 100 feet have been noted in Putnam Valley (HES, 2001). Till as deep as 180 feet is found on Agor Ridge in Carmel (LBG, 1998). Areas with till soils are found in all pale green areas without hatches or cross-hatching on Figure 5. Till may also underlie some valley sand and gravel, or lake deposits, reducing groundwater flow between the bedrock and surficial aquifers.

- Alluvial deposits along streams are seldom useful as aquifers. Such deposits tend not to be thick, and normally consist of fine-grained sediments. Many also lie above the watertable and therefore would be unsaturated.

Figure 5 identifies the few significant surficial aquifer areas in Putnam County. These have been mapped by two sets of investigators with generally good agreement. Bugliosi & Trudell (1988) assigned potential yields to select valley-fill deposits on the basis of available well data and site reconnaissance. Cadwell (1989) mapped glacial sediments containing primarily sand and gravel deposits. Areas of mapped offset between the two studies occurs primarily near Brewster and is likely a function of mapping scale.

3.3 Groundwater Recharge & Aquifer Capacity

3.3.1 Recharge Rates

A USGS study conducted in conjunction with NYCDEP on Westchester County lands similar to Putnam County lands estimates that 8.45 inches of annual recharge enter till and silty soils and that 19.17 inches of annual recharge enter sand and gravel soils (Wolcott & Snow, 1995).

A similar USGS study in Connecticut anticipates that average recharge occurs at rates of just 7 inches where soils are rich in clay, and calculates that evapotranspiration accounts for losses of approximately 47% of total precipitation (Cervione, etc. al 1972). Work by Jaehnig (1988) in Philipstown used USGS studies of areas in southern Dutchess County (Snavely, 1980) and other studies from Connecticut to identify recharge rates of 7 to 10 inches annually in areas with glacial till and up to 21 inches annually in areas with sand and gravel soils. A Putnam County study by Maslansky & Rich (1984) developed a bulk (e.g. county-wide) estimate for county-wide annual recharge of 13.27 inches.

These prior studies allow development of several estimates of County-wide and Town recharge rates in Putnam County (Table 9).

Method 1: Maslansky & Rich (1984):

County-wide average recharge can be estimated using Maslansky and Rich's average annual recharge estimate of 13.27 inches. As shown on Table 9, this predicts average daily County-wide recharge of 150 million gallons, allocating between 20 and 32 million gallons per Town, including Villages.

Method 2: Wolcott & Snow (1995):

By this method, County-wide recharge is calculated based on 19.17 inches of recharge per year on sand and gravel deposits and 8.45 inches per year on silty/clay lacustrine or till deposits. Figure 5 was used to identify sand and gravel acreage in Putnam County. The method was used to estimate an average daily County-wide recharge rate of 100 million gallons, with between 15 to 23 million gallons allocated per Town, again including Villages.

Method 3: Gerber (1982):

By this method, County-wide recharge is estimated from recharge on sand and gravel ranging between 14 to 18 inches per year and recharge on silty-clay lacustrine and till deposits of between 2.3 to 6.8 inches per year (Table 13). Using general values of 17 inches for sand and gravel deposits and 6 inches for silty/clay soils, the method predicts average daily County-wide recharge of 80 million gallons, with between 11 to 14 million daily gallons coming from each Town, including Villages.

The different recharge estimates reached by these methods points to difficulties experienced by hydrogeologists seeking to quantify regional recharge rates. TCC has discussed such discrepancies with Robert Gerber previously (personal communication) who believes many deposits near valley walls are recharged not only by direct precipitation but also by upland runoff which can substantially increase recharge. Supplementing Gerber's relatively low recharge estimates to correct for such surcharges would bring Gerber's estimates closer to those of Wolcott and Snow.

Accordingly, Methods 2 and 3 converge on common estimates of approximately 90 million gallons daily once accounting for valley-wall gravel surcharges suggested by Gerber. Method 1 is likely to overestimate typical annual aquifer recharge.

Summary: Method 4: Putnam County

For purposes of developing regional recharge estimates in Putnam County, TCC believes values of 18 inches/year for sand and gravel deposits, and 7 inches per year for till and silt/clay lacustrine deposits are most accurate (Table 9). The values predict an average daily County-wide recharge rate of 90,000 million gallons, allocated at between 13 to 20 million gallons per Town, including Villages (Table 9). No Towns have extensive areas with Group A soils, however, Towns with Group B soils at base of steep hillside areas, such as those found on the east margins of Patterson and Southeast, and in the Canopus and Peekskill hollows primarily in Putnam Valley, may expect additional aquifer recharge from upland runoff and so may achieve effective infiltration rates characteristic of Group A soils. Elsewhere, recharge rates throughout much of Putnam County would be approximately 7 inches annually.

Recharge estimates above assume average annual precipitation rates. When annual precipitation rates vary, recharge rates will increase or decrease respectively. A Town of Somers report (1988) in Westchester County suggests that during the 10-year recurrence drought, precipitation may fall to approximately 80 percent of average, and that precipitation during the one-year-in-thirty drought may drop to as low as 67 percent of average. During such drought years, recharge would be reduced. Drought recharge estimates for a study in Carmel present a conservative drought recharge rate of just 3.6 inches per year in areas with till soils during extreme droughts (LBG, 1998).

Using the approximate values identified above, estimated aquifer recharge during the 1 in 10 year and 1 in 30 year droughts in Putnam County are 70 million gallons daily and 60 million gallons daily, respectively (Table 9)

3.3.2 Aquifer Discharge from Characteristic Geologic Terrains

During the dry summer of 2002, TCC selected 17 stream gauging sites in six Putnam County watersheds for detailed aquifer discharge characterization (Figure 8). Locations were selected to evaluate aquifer discharges from four characteristic geologic terrains identified during the County-wide study. Comparison of Figures 5 and 8 demonstrates that the selected stream segments isolate geologic settings characterizing Higher vs. Lower-yield bedrock aquifers, and areas covered by sand and gravel versus areas covered by more clayey soils.

Since dry season stream levels are normally supported only by aquifer discharges, late-summer baseflow gauging is a useful tool for comparative analysis of aquifer discharges. To the degree possible, TCC selected gauging sites outside of managed Croton watershed areas to avoid encountering stream fluctuations associated with reservoir management. Appendix C provides detailed discussion of gauging sites relative to one another. Comparative discharges from the four geologic terrains under investigation are listed in Table 10 and summarized below:

Aquifer regions with **Lower-Yield Bedrock Formations** covered predominantly by **silt/clay soils** were assessed by gauging segments upstream of sites 1, 2, 10, 11, 13, and 14. Recorded baseflow discharges ranged from 1 to 96 gallons per day per acre (gpd/acre). The average discharge was **40 gpd/acre**.

Aquifer regions with **Higher-Yielding Bedrock Formations** covered predominantly by **silt/clay soils** were assessed by gauging segments upstream of sites 15 and 17. Recorded baseflow discharges were 69 and 78 gallons/day/acre. The average discharge was **74 gpd/acre.**

Aquifer regions with **Lower-Yielding Bedrock Formation** covered with soils containing some **sand and gravel** were assessed by gauging segments upstream of sites 6, 8, 12 and 16. Recorded baseflow discharges ranged from 101 to 729 gpd/acre. The average discharge was **243 gpd/acre**.

Aquifer regions with potentially **Higher-Yielding Bedrock Formation** covered by soils more likely to have some **sand and gravel** were assessed by gauging segments upstream of sites 3, 4 and 5. Recorded baseflow discharges were 37 and 421 gpd/acre. Carbonate formations lie upstream of site 5. The average was **306 gpd/acre**. HES (2001) and Miller (1989) both indicate that carbonate in Putnam

Valley is not as productive other formations, so in this area it may not be a higher-yield formation.

The stream gauging data reveal the following relative aquifer relationships:

1. Higher-Yield bedrock aquifers support higher baseflow discharges to streams than Lower-Yield bedrock aquifers where subwatershed soils are predominantly silt-clay rich. (e.g. Case 2 above is better than Case 1)

2. Stream segments containing sand and gravel have substantially higher discharges than segments without sand and gravel (Cases 3 and 4 above are both better than Cases 1 and 2). This is true regardless of whether the bedrock aquifer is Higher or Lower yield. The data show that sandy deposits, regardless of the characteristics of the underlying bedrock formation, support significant baseflow entering dry season streams. This occurs because of the substantial storage capacity of valley sediment formations which can release water over extended periods following recharge events. Yield variations among stream segments with sandy sediments are not likely to be primarily influenced by underlying Higher and Lower yield bedrock formations. Instead, the differences are more likely attributable to sand and gravel thickness, extent, and sediment mix.

The data collected by TCC demonstrate that although thick sediment formations may be of limited aerial extent in Putnam County, and although well database analysis indicates that the presence of thick valley sediments do not substantially influence short-term bedrock well yield tests, thick sediment deposits nonetheless substantially contribute to stream baseflow discharges and so are equally likely to favorably influence long-term well viability and uses.

3.4 Sustainable Groundwater Use

"Sustainable groundwater use" may be defined on the basis of well reliability, preserved well water quality, and/or preservation of aquifer baseflow to support streams and other surface water resources.

<u>Evidence for Failure of Well Reliability:</u> During the dry summer of 2002, the Putnam County Department of Health received many re-drill requests. The Glenmar Gardens and Williamsburg Ridge community water systems reportedly need new wells. Water well yields are also known to be low at Rolling Greens. The Town of Southeast water district operator identified some water shortages in Town water districts during the summer of 2002. Water shortages have been experienced near Agor Ridge south of Lake Mahopac, at the Williams Ridge Condominiums in Mahopac, and Tonetta Heights. Most of these sites lie over the lower-yielding

bedrock aquifer (Figure 5) which generally provides adequate water for domestic wells (Section 3.1.1); however, water shortages will occur if there is an unusually low density of waterbearing fractures or if overpumping is occurring.

Evidence for Reductions in Well Water Quality: Limited sampling near Putnam Lake has demonstrated that well water quality can decline seemingly as a result of septic system discharges to aquifers. Threats to groundwater quality from various land uses are also discussed in section 2.3 and mapped on Figures 2, 3 and 4.

Evidence of Reductions in Stream Baseflow: Human groundwater consumption can modify stream flow rates since water removed from an aquifer can no longer provide baseflow to streams or other surface waters. Increased frequencies of "dry stream" events have been noted in Dutchess County (Horsley & Witten, Inc. 1994). No data describing reduced baseflow discharges to Putnam County streams were available for this report.

Taken together, Section 2.4 estimates of water uses and Section 3.3 recharge evaluations suggest that groundwater uses in Putnam County is likely to be sustainable on a regional basis. Nonetheless, since groundwater cannot readily move toward areas where it is being overused, clear examples exist where local overuse may be occurring.

The general conclusion of sustainable groundwater use is consistent with analysis conducted by the Highlands Regional Study (USDA, 2002) which has estimated that present human uses of groundwater in Putnam County do not exceed 10 percent of available recharge, which is a standard that organization appears to accept as a threshold sustainable use value.

This study estimates that present summer groundwater reductions do not exceed approximately 6 million daily gallons (Table 1) from a County-wide estimated average recharge of approximately 90 million daily gallons, representing an estimated 7 percent reduction in available groundwater (Section 2.4). The Towns of Philipstown and Putnam Valley reduce summertime available groundwater by less than 4 percent, and the Towns of Southeast, Kent, and Patterson reduce volumes by between 6 and 9 percent (Table 15). Carmel is the only Town reducing groundwater flows by more than 10 percent due to its greater use of sewer districts which discharge groundwater to surface water bodies rather than returning the wastewater to septic systems. Region-wide wintertime groundwater reductions in areas served by septic systems are less above since evaporative losses from septic system leachfields are reduced and wastewater infiltration rates increase accordingly.

Various management approaches are recommended to manage ground water uses in Putnam County and to ensure sustainability of future groundwater demands. These are introduced here and addressed again in Section 4.0.

Sustainable Use on Individual Sites: Wherever future Putnam County residents are likely to continue relying on individual wells and septic systems, net density recommendations are provided which will allow sufficient aquifer recharge on individual parcels to both meet well requirements and to dilute septic system discharges. Analytical models for this approach are described:

- Table 13 provides density recommendations developed by Gerber (1982). Difference between thick and thin till or thick and thin sand and gravel must be determined in the field based on whether depth to bedrock is less than or greater than approximately 5 feet. Gerber's density recommendations for development on silty clay soils range from 2.7 to 5.7 net acres per dwelling and 1 to 1.3 acres per dwelling in areas with sandy soils.

- Table 14 presents a more general relationship between recharge and recommended density developed by the State of New Jersey. The table identifies sustainable septic system densities for any recharge rate. Since most Putnam County lands receive approximately 7 inches of annual recharge (Section 3.3.1), this method recommends average density of around 3 acres per system.

Either method ensures sustainable use of groundwater resources because future effective density would ensure that recharge meets residential well demand and dilution requirements for wastewater management. Since the reserved recharge fraction for wastewater dilution is several times the volume of recharge needed to simply meet the need of the domestic well, this strategy also ensures preservation of groundwater requirements flowing under residentially sites to support riparian wetlands and streams.

Where subdivisions are proposed using individual wells and septic systems more densely than recommended above (or Per Table 14), an aquifer pumping tests are recommended. The Department of Health currently requires only pre-installation and testing of 10% of proposed wells on such subdivisions. Testing of such wells may occur individually and tests usually lasts less than one day. This study recommends longer tests, conducted simultaneously, in the predrilled wells, with combined well discharge equaling twice the proposed subdivision's anticipated water requirement.

Sustainable Public Water System Wells: Where wells are installed for public water system purposes, wells should continue with presently required testing. Wells intended for such uses are required to undergo testing for at least 72 hours, at pumping rates equal to twice the average estimated daily demand rate. Frequently, off site monitoring of existing wells, streams and wetlands are also required. Consideration of any well sites already permitted for construction (e.g. for an approved but as yet unbuilt subdivision) should also be considered. This 72-hour test protocol is inherently conservative since the test is conducted at twice average daily demand, and so is likely to successfully identify groundwater defects associated with proposed projects.

Present testing protocols for non-community wells is believed to be reasonably conservative and no changes are recommended.

3.5 Groundwater Quality

3.5.1 Natural Groundwater Quality Issues

Grossman (1957) summarizes general groundwater quality trends associated with the County's various geologic formations. Differences in total dissolved solids reflect tendencies of various formations to influence groundwater quality. Groundwater in carbonate formations is, for example, generally higher in dissolved solids than other rocks. Deeper wells also tend to have higher degrees of mineralization largely because the greater residence time of groundwater cycling through deeper fractures.

General groundwater mineralization trends summarized by Grossman (1957) are shown on Table 11. Groundwater in carbonate formations such as the Stockbridge limestone tends to have higher sulfate, hardness, and total dissolved solids than other formations. Iron and sulfate are highest in groundwater from granitic, gneiss and schist formations. Unconsolidated deposits may exhibit elevated total dissolved solids and hardness but have few other native defects. Such formations may, however, be more susceptible to land use contaminants due to their proximity to grade. Studies have noted that manganese often accompanies elevated iron (Miller, 1991). In some cases, mineral deposition in wells can lead to decreased yields over time which do not signal aquifer depletion, but rather indicate that the well may need to be rehabilitated or redrilled.

Radon 222 is a natural daughter product of Radium-226, which is a native constituent in some of the Hudson Highlands gneisses. Deep fractures provide pathways for radon contact with groundwater resources (Miller, 1991). Putnam County wells sampled during 1989 and 1990 recorded the highest average radon concentrations in New York State (NYSDOH, 1990), with an average concentration of nearly 4,000 picoCuries per liter of water. This substantially exceeds presently contemplated standards of approximately 300 pCi/l of radon and could in some cases contribute also to airborne radon in homes. The distribution of elevated radon-containing groundwater in Putnam County is not well understood. Treatment methods are difficult but available.

Section 2.7.3 of this report detailed readily available information describing former mine and existing ore deposits in Putnam County. The Putnam County Department of Health (Bittner, 1989) studied groundwater quality near many former mines. Mines included in the investigation included the "Old Arsenic Mine", an old copper mine is reported near Anthony's Nose in Philipstown, the Tilly Foster mine, the Deans Corners Mine, Daisy Lane Mine, Joe's Hill Mine, Bryant Pond Mine, Peekskill Hollow Mine, Canada Mines, Pelton Pond, China Pond Mine, Brewster Village Mine, South Lake Mine and the Mahopac Mines. Groundwater samples show considerable variability, with some samples exceeding standards for iron, manganese or copper, other samples exhibiting no apparent problems, and still others showing elevated of aluminum, iron or lead although below standards. The variability in these analyses may in part be explained by sampling limitations where wells accessible to the Department of Health were not always situated downgradient of the mines.

3.5.2 Introduced Contaminants

Section 2.3 of this report provides detailed analysis of areas where land uses threaten groundwater quality. The following summary of threats is provided:

Region and Source	**Type of Threat**
Commercial Industrial – Facility	Petroleum, solvents, metals, other chemicals
Commercial Industrial – Septics	Nitrate, bacteria, virus, any facility chemicals
Commercial Industrial – Roads	Salt
Residential – Septics	Nitrate, bacteria, virus, personal chemicals
Residential – Roads	Salt

Figures 3, 4 and 5 show regions where such threats to groundwater quality are likely to exist.

3.5.3 Vulnerability

TCC's review of NYSDEC files, SWAP records in the Putnam County Department of Health offices, and other known instances of groundwater contamination confirm links between the identified land uses shown on Figure 2, the risk categories established by the NYSDOH also shown on Figure 2, and actual groundwater defects being experienced in Putnam County. Specifically:

- Most chemical spills have occurred within or near areas that land-use maps categorize as commercial/industrial areas,

- Most known instances of bacteria or nitrate contamination in Putnam County occur in areas with many septic systems (e.g. around Putnam Lake and potentially around other lakes also relying on wells and septic systems).

- Putnam County Department of Health personnel confirm that many cases of salt contamination are likely to be caused by road de-icing activities and occur near roads.

Together, these findings demonstrate that aquifers in Putnam County are vulnerable to contamination.

Aquifer vulnerability can also vary depending on permeability of soils, distance of the spill to a discharging location, and resistance of the formation to spill remediation. These are addressed below:

Soil Permeability

Where dense glacial till exists, groundwater recharge rates are low and rates of contaminant penetration into aquifers can be reduced. The recently completed NYCDEP (2000) Septic Siting Project found that septic wastes sometimes flowed laterally over low-permeability clay-rich layers rather than sinking directly downward. Where clay-rich soils exist under some of Putnam County's settled lake communities, concentrated septic wastes may be traveling laterally to lakes without substantially impacting groundwater quality in deeper wells. Sampling would be needed to determine site specific details; however, where this may occur, select wells in otherwise densely settled areas may not be affected by septic system wastewater returns.

Areas with soils falling in Hydrologic Group B are more likely to see transmission of short-term contaminant releases into aquifers than areas with Hydrologic Groups C and D. In any area with chronic contaminant releases, soil permeability only delays but seldom fully prevents eventual transmission of contaminants into underlying aquifers.

Proximity to Aquifer Discharge Points

Aquifer recharge occurs on all soils in Putnam County. Accordingly, all areas in the County should be considered to be "recharge areas" except for the streams, waterbodies, and associated riparian wetlands which serve as aquifer discharge points. There are no known parts of Putnam County where soil or buried rock layers are known to completely prevent direct-downward aquifer recharge. Putnam County is unlike places in Western New York, Texas, or elsewhere where aquifer recharge sometimes takes place miles from well locations.

Difficulty of Remediation

Threats to groundwater quality are highest in permeable aquifers since contaminant spills can readily enter an aquifer. However, aquifer remediation is also easier in sand and gravel formations than in bedrock formations because granular soils are amenable to simple excavation or to a host of remedial technologies, making prospects of such aquifer remediation reasonable.

Groundwater quality threats are somewhat lower in aquifers covered by clayey soils because recharge and spill penetration occur more slowly. However, groundwater remediation of low-permeability surficial aquifer and/or bedrock aquifers is difficult and time-consuming, often with uncertain results because contaminated groundwater follows pathways through formations which are difficult to locate or remediate during site remediation investigations.

3.6 Future Water Supplies

For existing community water systems, necessary future water supply sources must necessarily come from areas close enough to users to justify pipe installation and other transmission costs. This limitation necessarily focuses efforts on saturated sediment deposits or bedrock formations near proposed project areas or near present areas requiring water.

This evaluation has noted Higher-Yielding and Lower-Yield bedrock formations, and acknowledged previously-identified sand and gravel formations in several valleys. Opportunities to intercept high-capacity fractures are best in Higher-Yielding bedrock formations. However, individual high-flow fractures have also been tapped in all bedrock geologic formations in Putnam County so prospects always exist to install high-capacity wells throughout Putnam County.

In general, future groundwater resource development in Putnam County will require site-specific reviews of surficial geology, perhaps supplemented by more tightly-segmented stream gauging and drilling of test-wells in bedrock formations. Exploration of bedrock well yields can be enhanced by use of linear feature analysis.

A prior countywide evaluation of potential future groundwater centralized sources of supply identified 11 locations having promising groundwater potential for public water supplies (Goodkind & Odea, 1970). These are listed on Table 12. Some of these locations may by now have been investigated, developed, or discounted. The present study was not intended to identify specific sites for future water supply wells, but rather to identify general areas where future site-scale exploratory drilling of wells may be warranted. The general areas identified by Goodkind and Odea (1970), affirmed by this study, are summarized below:

Town of Patterson:

Sediments underlying the Great Swamp wetland are generally fine-grained and are not likely to offer opportunities as an overburden aquifer formations unless select higher-permeability zones can be identified. Some permeable sediments able to support surficial yields may lie along Haviland Hollow.

As indicated elsewhere in this report, a residential survey identified various high-yielding wells in the carbonate formation (TRC, 1990). Bedrock formations in the northern half of Patterson are among those recognized as higher-yielding bedrock formations, based on well log database analysis. Further use of groundwater from these formations may be feasible depending on the results of pumping tests in candidate production wells.

The Town Planner in Patterson has reported cases of disappearing streams in northeast sections of Patterson, suggestive of open fracture systems in the carbonate formation exposed at grade into which surface water can flow (Williams, 2003, personal communication). Such recharge would flow sub-grade until emerging at aquifer discharge points. Where such open conduits to the surface are present, groundwater quality may require filtration if it transports micro-organisms characteristic of surface waterbodies or streams.

Care must be taken not to overuse this carbonate bedrock aquifer system since heavy drawdown in one area may result in drawdown over a large area due to highly interconnected fracture relationships and to low recharge rates associated with the relatively high prevalence of Group C and D soils.

Town of Kent:

Few sand and gravel surficial geologic deposits have been identified in Kent. Bedrock aquifers or negotiated access to water from reservoirs are likely to provide the dominant source of future water supply in Kent. All bedrock geologic formations have been shown to produce reliable groundwater resources (Table 3)

With exception of bedrock formations near the extreme east margin of Kent, the various bedrock formations are all among the Lower-Yielding bedrock formations in Putnam County (Figure 5). The Higher Yield carbonate formation is mapped near Wonder Lake, at the boundary between the towns of Patterson and Kent.

A high ratio of more permeable Group B soils are found in Kent, providing some assurance of reliable aquifer recharge to the bedrock formations.

Town of Southeast / Village of Brewster

The Village of Brewster obtains water from a series of shallow sand and gravel wells. Other locations with surficial deposits may offer additional groundwater resource potential. Aquifers with State-recognized yield potential lie along Route 84, along Route 22. Town personnel report some areas in Southeast where domestic well yields are low and central water supplies would be beneficial (Levine, 2003, personal communication).

Bedrock in the southern third of the Town includes geologic formations recognized as among the higher-yielding formations in Putnam County (Table 3). Among other higher-yield formations, the Inwood Marble is mapped within this southern region (Figure 6), and faults separating the Hudson Highland and Manhattan Prong physiographic province lie in the south section of the Town of Southeast.

Notwithstanding the above, many soils in Southeast fall in Hydrologic Group C which substantially limits infiltration rates which can replenish underlying aquifers. Care will be needed in evaluating aquifer pumping tests.

Town of Carmel

Most soils in Carmel are derived from glacial till, limiting recharge rates to the underlying bedrock aquifers. Evidence of such recharge limits are provided by the prevalence of Hydrologic Group C soils particularly in the southwest and northeast quadrants. Bedrock aquifers or negotiated access to reservoir resources are expected to represent the primary source of future groundwater supplies in Carmel. Instances of water shortages have been documented near Agor Ridge south of Lake Mahopac.

Bedrock formations found in the Town of Carmel are among the Lower-Yielding formations in Putnam County. However, all formations exhibit sufficient fractures to support residential wells and occasional high-yield fractures able to support higher-yield wells. Care will be needed in evaluating aquifer pumping tests for higher priority wells.

Town of Putnam Valley

The valleys of the Canopus and Peekskill Hollow creeks contain considerable glacial lake and outwash formations potentially suited to development of high-capacity surficial wells. Stream gauging data suggests greater opportunity to develop surficial water supply wells in Peekskill Hollow than in the Canopus valley.

Water-bearing bedrock fractures are also suspected under both valleys, potentially providing optimal locations for deep, high-yield wells (HES, 2001).

Bedrock formations elsewhere in Putnam Valley are primarily among those recognized as Lower-Yielding formations in Putnam County (Figure 5), however, a zone of Higher-Yielding bedrock lies under Canopus Hollow. All bedrock geologic formations have been shown to produce reliable groundwater resources (Table 3). Soils in the southern part of the Town are primarily in Hydrologic Group B and are hence likely to allow reasonable rates of aquifer recharge.

Town of Philipstown/Villages of Cold Spring and Nelsonville

Unconsolidated deposits with potential to support shallow surficial wells are found only in the Canopus Creek valley near Continental Village, near Cold Spring, and approximately along NYS Route 9 near Clove Creek.

Additional sources of groundwater supply are expected to come from bedrock formations. All bedrock formations in Philipstown, Cold Spring, and Nelsonville consist of formations of Lower-Yielding potential (Table 3), although all formations have been shown to provide sufficient water for residential purposes and occasional high yield wells.

Many soils in Philipstown fall in Hydrologic Group B which allows reasonable volumes of infiltration to underlying aquifers. Where Group D soils are situated greater care is needed when interpreting aquifer test data for high priority projects.

4.0 GROUNDWATER PROTECTION AND UTILIZATION

4.1 Summary of Groundwater Conclusions

4.1.1 Expanded Conclusions

Committee review of the prior text sections identified the following conclusions describing groundwater capacity and related quality relationships in Putnam County.

This study concludes that Putnam County's groundwater resources are copious but can be locally overtaxed.

Precipitation provides an average of 90 million gallons of aquifer recharge each day in Putnam County. This falls to approximately 70 million daily gallons during a 1-in-10 year drought and to approximately 60 million daily gallons during a 1-in-30 year drought. Aquifer recharge occurs primarily in the autumn and spring months when vegetation requirements are minimal. Generally, little meaningful aquifer recharge occurs during summer months.

Total groundwater withdrawals in Putnam County to meet residential, commercial, industrial, institutional and residential requirements are estimated at 12 million gallons per day. Up to 8.5 million gallons of wastewater are returned daily to aquifers through septic systems. During the growing season only approximately 6 million gallons per day actively return to aquifers due to transpiration losses over septic fields. During non-growing seasons, the full 8.5 million gallons of daily wastewater returns replenish groundwater withdrawals.

On a county-wide basis, therefore, this study estimates that no more than approximately 7 percent of total annual groundwater resources are presently withdrawn from County aquifers each year. Towns of Philipstown (including Cold Spring and Nelsonville) and Putnam Valley use just approximately 4 percent of available groundwater, while the Towns of Southeast (including Brewster), Kent, and Patterson use between 6 and 9 percent of available recharge. Carmel, due to its greater use of sewer districts discharging treated wastewater to streams rather than aquifers withdraws up to 20 percent of its annual aquifer recharge.

Accordingly, this study concludes that many Putnam County residences and businesses are not using excessive amounts of groundwater, and that further groundwater uses are acceptable within framework recommendations provided by this study. Without overlooking the very real instances of water shortages in some locations, the general overall and regional availability of groundwater is a critical and hopeful finding of this study. Where specific water capacity shortages are known to The Chazen Companies (TCC), they have arisen because aquifer resources cannot move readily from place to place or localized areas with unusually limited fracture densities, making it possible to locally overuse accessible resources even though sufficient regional resources exist for sustained and even additional uses in other areas. Where water is locally overused, it is evidenced by well failures, septic system wastewater concentrations in groundwater, or surface water flow decreases as extracted groundwater depletes streams.

This study suggests improvements for testing and approval protocols which should limit negative consequences of specific new projects.

<u>This study concludes that individual well owners are vulnerable to water quality defects since little is known about the performance of quality of these wells.</u>

A Putnam County 1984 groundwater study estimated that 15 to 20 thousand wells were withdrawing groundwater in Putnam County (Maslansky and Rich, 1984). Since 1984, well logs records submitted to the Department of Health indicate that at least 3,000 more wells have been drilled throughout the County. Approximately 80,000 Putnam County residents use wells for their source of domestic water supply. Some of these get their well water through centralized sources (e.g. water districts) which must conduct routine quality testing and satisfy NYS capacity regulations to assure some reliability of the public wells.

But an estimated 50,000 Putnam County residents rely on individual wells which are not monitored or otherwise continuously evaluated in any systematic way after the day they are drilled. Very little administrative attention has been paid to the status, reliability, or potability of individual wells in Putnam County.

<u>This study concludes that all geologic formations in Putnam County deserve aquifer protection and that nearly all serve as aquifer recharge areas for the County's aquifers.</u>

Since wells have been successfully installed in all geologic formations in Putnam County, this report concludes that all lands in Putnam County should be considered to overlie useful aquifers.

That said, there are also regional variations in yield potential of different aquifers, so different levels of protection may be warranted in different areas.

The highest-yielding wells in Putnam County are installed in regionally mapped sand and gravel deposits. These aquifers cover less than 10 percent of Putnam County and are found primarily in valleys in Southeast (including near Brewster), Putnam Valley, and Philipstown (Figure 5).

In areas without sand and gravel deposits, more clayey soils are seldom useful as aquifers. In such areas, wells installed in the underlying bedrock formations provide the sole sources of groundwater supply. Well log analysis shows that wells in higher-yield bedrock formations identified by this study can provide up to 50 percent greater yields than wells installed in the lower-yield bedrock formations. The analysis also shows that bedrock wells in valleys generally out-perform wells in high elevation settings. Wells with little to no yield can nonetheless be found in both high-yield and low-yield aquifer areas if a well boring misses any water-bearing fractures.

Average annual aquifer recharge in Putnam County varies based on soil cover and underlying geology. In general, USGS regional studies estimate that average aquifer recharge where there is deep sandy soil is approximately 18 inches per year. In Putnam County, these granular sand and gravel deposits are rare and may be found only where Hydrologic Group A soils lie in linear valleys in Philipstown and Putnam Valley, and in some basin areas in Patterson and Southeast (Figure 5). Regional studies estimate that average aquifer recharge on all other areas in Putnam County are approximately 7 inches per year.

All land over a particular aquifer and all land upgradient (e.g. uphill) of said aquifer comprises the Aquifer Recharge Area for that aquifer. Since the committee has determined that all geologic formations in Putnam County should be considered as aquifers, this effectively means that all Putnam County land should be recognized and protected as aquifer recharge areas. Only perennial (flowing year around) streams, streamside wetlands, and natural open water bodies such as natural ponds or lakes are not recharge areas since these are locations where groundwater instead discharges naturally at grade. Controlled lakes and reservoirs may locally provide aquifer recharge if held at elevations substantially above natural aquifer water table elevations. Such situations occur most frequently around the dams or spillways of reservoirs and artificial lakes.

This study recognizes that traditional well-head protection measures can be used to protect discrete wells.

Where particular wells warrant special protection, those aquifer areas from which recharge flows to the wells may be assigned particular levels of land-use protection through local zoning or wellhead protection programs adopted through NYSDOH regulations. Putnam County Department of Health files indicate that many listed contamination sites which could pose threats to particular wells lie in commercial and industrial areas.

This study recognizes that individual septic systems represent a widely distributed source of potential groundwater contamination.

In areas where wells and septic systems are both in use, wastes from septic systems must either be adequately biologically degraded, or they must be adequately diluted with clean groundwater if groundwater is to remain potable.

A common wastewater contaminant which does not decay but must instead be diluted is Nitrate. The New York State drinking water standard for nitrate is 10 milligrams per liter. Domestic wastewater typically contains nitrate levels in concentrations of approximately 40 milligrams per liter. Where insufficient recharge occurs in closely settled residential neighborhoods using septic systems, nitrate may not be adequately diluted to ensure potability of groundwater. Other wastewater constituents may also not be adequately diluted. Where wells are also used, well water quality can suffer.

Samples from around at least one Putnam County lake identified nitrate concentrations in many wells exceeding drinking water standards.

Therefore, in areas where build-out development is allowed under present zoning, minimum density regulations may help ensure that adequate recharge occurs to dilute wastewater constituents including nitrate.

Other typical septic system wastes include bacteria and viruses, occasional chemical releases, and various personal chemicals including caffeine, over-the-counter and prescription pharmaceuticals including ibuprofen and hormones, and detergent byproducts. Density guidelines for distances between wells and septic systems necessary to dilute caffeine and other personal care chemicals have not yet been developed and no drinking water standards exist for most such compounds. These chemicals have, however, been found in streams near septic systems (USGS, 2002), providing evidence that these compounds travel through aquifers, from septic systems to streams, and so are likely to be found in some domestic wells.

<u>This study recognizes road salt as a contaminant class warranting a management strategy.</u>

Salt is a regionally-recognized contaminant found in groundwater now routinely found in streams. Cases of chloride concentrations in wells have also been documented in Putnam County. Road salt is a primary source of salt in groundwater. Water softener salt discharges can also contaminate wells.

<u>This study recognizes former bedrock mineral mines as potential sources of groundwater contamination.</u>

Many historic mines and residual mineral deposits lie in Putnam County (Figure 6). Some may locally impact groundwater quality due to groundwater migration through mineralized zones. Sand and gravel mines are not in and of themselves sources of groundwater contamination although the historic trend to reclaim such sites with industrial land uses does raise questions about post mining groundwater threats from sand and gravel mines and quarries.

4.1.2 Simplified Hydrogeologic Conclusions

A condensed version of the summary above includes:

1. Aquifers underlie all parts of Putnam County. These can be categorized as higher or lower capacity depending on geologic conditions, or higher or lower priority in their need for protection, but all warrant groundwater management.

2. In general, adequate quantities of groundwater are available to support most present water requirements in Putnam County. However, groundwater resources in some locations have been overused in some instances, either because of over extraction resulting in inadequate well yields, or by locally overloading aquifers with septic system wastes or salt residues, causing poor groundwater quality. Future water demand can be accommodated in Putnam County, but should rely on site specific analyses and management practices outlined in this report.

3. Management of groundwater quantity (e.g. available capacity), is integrally related to management of groundwater quality. Overuse or depletion of groundwater resources often causes quality reductions. Conversely, degradation of quality is a form of groundwater over-use since dilution is the most cost-effective management solution for many non-point pollution sources, including septic system wastewater.

4. Putnam County has three sharply different land use formats, including high density areas such as lake communities and other community centers including most commercial and business centers, moderate density areas including most open residential areas and some commercial centers, and low density areas such as dedicated open space areas and New York City watershed areas. Different groundwater management strategies are warranted and recommended herein for each region.

5. Federal and State environmental regulations passed since the 1970s, as well as growing availability of improved remediation techniques, have together been significantly successful in reducing groundwater threats from point sources such as gas stations, dry cleaners, and heavy industry activities. Although the enforcement of regulations have and will continue to be a concern, outright prohibition of such land uses is only warranted in highest-risk aquifer areas. Such highest-risk areas could be defined on the basis of aquifer capacity or within near-well recharge areas of a high-capacity central water supply well (e.g. a wellhead protection area).

6. Septic systems represent a wide-spread and potentially-significant source of non-point source of aquifer contamination. Contaminants from septic systems include compounds with existing regulatory standards such as nitrate or *e*-coli, and more recently recognized constituents such as caffeine, pharmaceuticals, and hormone residues, for which no standards yet exist. The coincident use of septic systems and groundwater wells requires an evolving management strategy to ensure continued sustainable use of both.

7. Existing Putnam County Health Department pumping test procedures for proposed Community Water System wellfields (e.g. water district) are adequately rigorous to ensure viability of such sources. At such sites, a 72-hour pumping test is conducted at twice average estimated project water demand levels and includes analysis of on-site and off-site aquifers and should consider the water demands of previously approved wells, whether in use or not. However, aquifer testing required at equivalent subdivisions using individual wells is not as thorough and warrants improved permitting protocols. Recommended test protocols are recommended herein.

8. Minimum residential density recommendations are provided in this report. Where more concentrated density is proposed, additional testing protocols are recommended herein.

9. Particular attention should be paid to proposed future groundwater uses in areas with extensive sewer districts. Well maintained larger sewer districts provide significant protection of groundwater quality but reduce groundwater replenishment which might otherwise replenish aquifers through on-site septic systems.

10. Road salt and water softener salts are non-point contaminant sources affecting groundwater and stream quality. Management programs are warranted for both.

11. Former metal mines may represent continuing sources of localized groundwater contamination.

4.2 Regional Recommendations

4.2.1 Groundwater Management for Low Density Areas

The following recommendations apply to dedicated open-space lands in Putnam County. These are held in the form of parks administered at various levels, permanent land development easements, and as lands managed by New York City's water supply program:

With the exception of heavily-used portions of some of these parks, little to no active groundwater management is generally required on parklands held by Municipal, County, State, or Federal entities. General management recommendations would include minimization of impermeable surfaces and implementation of stormwater management processes to limit peak runoff flows and to limit turbidity discharges from activity areas.

The management of lands owned or managed under New York City's water supply programs has not been considered by this study. Preferred groundwater management strategies would likely include measures similar to those in the prior paragraph.

Notwithstanding the minimal management strategies prioritized for these open lands, dedicated open space can serve as crucial groundwater recharge areas for high and medium intensity land uses if they lie, for example, upgradient of lake communities or other residential neighborhoods within the same watersheds. As such, low density areas can provide compensatory recharge for any groundwater overuse occurring in adjacent more intensively utilized areas.

4.2.2 Groundwater Management for High Density Areas

Lake communities and other high-density residential areas are often constructed on extremely small lots and typically have a majority of septic systems constructed prior to current standards. High density uses of individual wells and septic systems occur also in some commercial and business centers. Some high density areas in Putnam County are served by public water but most are not and have both densely placed septic systems and individual wells.

For all lake communities or similar densely settled areas, the current condition of both groundwater and surface water resources should be evaluated to determine if the use of septic systems is affecting either resource. If impacts are occurring, measures to improve or replace on-site wastewater treatment should be evaluated, potentially through use of on-site treatment enhancements to reduce nutrient loading, if these are available, and a treatment management district. Otherwise, a centralized wastewater treatment program should be considered.

In those few lake communities and in any other high density areas that have central water supplies, the Putnam County Groundwater Protection committee recommends the wastewater study recommended above and recommends adoption of aggressive wellhead protection for the recharge area to any well(s) used by the community water system. Suggested conditions to be applied to Community Wellhead Protection management areas are offered in Section 4.2.3.1.

In high density areas relying on individual wells and on-site wastewater treatment systems, the following groundwater management recommendations apply:

- Water conservation practices should be implemented. Such practices will preserve groundwater resources and result in beneficial reductions in wastewater discharges to septic systems.

- Lawn irrigation from groundwater sources should not be allowed.

- Groundwater quality protection policies such as those recommended for Community Wellhead Protection areas (as detailed in Section 4.2.3.1) should be implemented throughout the community to protect the quality of individual wells.

- If soil and site conditions allow, measures to enhance local recharge should be encouraged. Such practices can be implemented on individual parcels or in common space areas. Examples of such measures include installation of roof-drain dry wells and in-garden recharge areas, disconnection of drainage conveyances that pass over porous soils, and replacement of paved areas with porous surface grading.

- Well water quality sampling may be warranted on a local or region-wide basis to confirm groundwater potability.

- Where community support exists for development of central services, wastewater treatment should be considered ahead of provision of central water. Centralized treatment of wastewater both benefits environmental health and the environment since groundwater quality and nearby stream or lake quality are both improved. If central water is installed, without installation of a sewage district, there is no secondary benefit to protect groundwater quality or surface water quality.

- Educational materials should be periodically distributed to landowners. These can encourage water conservation techniques and address proper disposal for many household chemicals, discourage chemical lawn uses, discourage use of septic systems for any compounds other than human wastes.

- Septic system management techniques should be investigated and implemented where appropriate. Such techniques could include use of simple septic system maintenance programs such as pump-out or repair programs, or potential use of advanced on-site treatment systems if these are confirmed to provide a higher quality effluent flow into aquifers (as considered under Section 4.3.8).

- Pools should not be filled using any on-site domestic well.

4.2.3 Groundwater Management for All Other Lands

In medium density areas, two classes of groundwater quality and capacity protection are recommended. The highest level of protection is recommended for community water system wellhead recharge areas and future high-capacity wellfield sites. More general, regional groundwater management is recommended for all other areas.

In all areas, educational mailings addressing ways to protect and conserve water resources should be distributed at least annually to all property owners. Mailings can be similar to those recommended in the prior section for high-density communities.

4.2.3.1 Community Water System Priority Recharge Areas

Wellhead protection is recommended for recharge areas at existing Community Water System wells and around designated future high-capacity wellfields. Wellhead protection strategies usually provide highest levels of protection for recharge areas nearest to wells and less stringent protection for more distant areas.

Primary recharge areas differ between bedrock wells and sand and gravel wells:

<u>Priority Recharge Area for sand and gravel wells</u>:

> The primary recharge area for wells completed in unconsolidated materials (e.g. sand and gravel materials) typically includes all lands within 200 feet of each supply wellfield and all land upgradient of the wellfield extending to the limits of the saturated, unconsolidated formation.

Priority Recharge Area for bedrock wells:

The primary recharge area of wells completed in bedrock formations (e.g. drilled into solid rock) will include all land within 200 feet of each supply wellfield and all areas upgradient of the well through which water flows in one year toward the well, and not less than 500 feet upgradient from the well.

Prohibited Uses:

Within the priority recharge area the following uses should be prohibited.

- Installation of any underground fuel tank or tanks, whose combined capacity is less than 1,100 gallons. Any such tanks should be removed at points of sale.
- Municipal, private and C&D landfills as defined in 6 NYCRR Part 360-2 and 6 NYCRR Part 360-7.
- Land application of septage, sludge, or human excreta, including land application facilities as defined in 6 NYCRR Part 360-4.
- Disposal, by burial, of any hazardous waste
- Large Quantity Generators of Hazardous Waste.
- Gas stations and Major Oil Storage Facilities.
- On-site dry cleaning.
- Junkyards and Junked car lots.

Special Permit:

Within the priority recharge area the following uses should be permitted by a special use permit which requires the elements described in Section 4.2.4.1, below:

- Photo labs.
- Auto repair facilities and truck terminals, including engine repair and machine shops.
- Furniture stripper/painter, metal works, wood preservers.
- Printers and the use of printing presses.
- Small Quantity Generators and Conditionally Exempt Generators of Hazardous Waste.
- Solid waste management facilities not involving burial, including incinerators, composting facilities, liquid storage, regulated medical waste, transfer stations, recyclables handling & recovery facilities, waste tire storage facilities, used oil, C&D processing facilities, and junk or salvage yards in general.
- Salt storage facilities.
- Projects where Water Consumption exceeds triggers identified in Section 4.2.4.2.
- Cemeteries, including pet cemeteries, veterinary hospitals and offices.

- Storage or disposal of manure, fertilizers, pesticides/herbicides
- Open storage or stockpiling of agricultural chemicals within 100 feet of any waterbody or well

4.2.3.2 Management for Other Medium Density Aquifer Areas

These groundwater resource management recommendations apply to all lands not included in priority recharge areas defined above (Section 4.2.3.1), Low Density Areas (Section 4.2.1) or High Density Areas (Section 4.2.2):

Prohibited Uses:

- Installation of any underground fuel tank or tanks, whose combined capacity does not exceed 1,100 gallons. Any such existing tanks should be removed at points of sale.
- Land application of septage, sludge, or human excreta, including land application facilities defined in 6 NYCRR Part 360-4.3.

Special Permit:

- Disposal by burial of any hazardous waste, as defined in 6 NYCRR Part 371.
- Gasoline service stations and Major Oil Storage Facilities.
- On-site Dry cleaning.
- Junkyards and Junked car lots.
- Land Quantity, Small Quantity, and Conditionally Exempt Generators of Hazardous Waste.
- Auto repair facilities and truck terminals, including engine repair and machine shops.
- Furniture stripper/painter, metal works, wood preservers.
- Salt storage facilities.
- Open storage or stockpiling of agricultural chemicals, including fertilizers and pesticides/herbicides within 100 feet of any waterbody or well.
- Sites where Water Consumption exceeds triggers identified in Section 4.2.4.2.

4.2.4 Recommended Changes to the Land Use Review Process

4.2.4.1 Special Use Permits

Submissions for a special use permit should require that the following information be included as part of the application.

- A complete list of any Hazardous Substances to be used on site along with quantity to be used and stored on site.
- A description of hazardous substance storage or handling facilities and procedures.
- an assessment evaluating why less hazardous materials cannot be used;
- A discussion of applicability special use conditions listed below.
- Description of any hazardous substance or other chemical discharges to the environment and their concentrations relative to groundwater standards.
- The source and quantity of water to be used on the site.
- Proposed water use minimization or recycling measures.
- Wastewater discharge measures.
- Point Source or Non-Point Discharges.
- Grading and/or storm water control measures to enhance on-site recharge of surface water.

Conceptual Special Conditions

One or more of the following types of specific permit conditions are suggested for groundwater management at sites requiring special use permits:

- Hazardous Substances: To minimize chemical release risks, typical special permit conditions for any activity using hazardous substances should include the following:
    - activities must take place within an enclosed building in an area with an impermeable floor;
    - such activities must take up no more than 10% of the floor area of the building in which the activity occurs;
    - hazardous substances used in connection with the activity must be stored indoors at all times within an impermeable containment area capable of containing at least the volume of the largest container of any hazardous substance or hazardous waste in the area;
    - incompatible hazardous substances or wastes which could combine to create a hazard of fire, explosion or generation of toxic substances must not be stored together;

- o all wastewaters from processes using hazardous substances or wastes must be lawfully disposed of through connection to a publicly owned treatment work or through another permitted discharge or process;
- o no person shall use, maintain or install floor drains, dry wells or other infiltration devices which allow release of any wastewaters to the ground without a Federal or State permit. Floor drains should drain to a holding tank;
- o activities involving the use of lubricating oil shall not involve cleaning of metals with chlorinated solvents;
- o a materials management plan shall be developed and implemented for each site, including:
  - a process flow diagram identifying where hazardous materials are stored, disposed of and used, and where hazardous wastes are generated, stored, and disposed of.
  - An inventory of all hazardous materials likely to be manufactured, produces, stored, used, or otherwise handled on the site
  - The name and contact details for an emergency contact
  - A record-keeping system accounting for types, quantities, and disposition of hazardous materials which is submitted annually to the municipality and which may be made available at the site during normal business hours for inspection by the municipality or its agents.
  - An emergency response plan setting forth methods used to prevent and abate any release to the underlying aquifer.

- Chloride Salts: Storage of chloride salts is prohibited except in structures designed to minimize contact with precipitation and constructed on low permeability pads designed to control seepage and runoff.
- Generators of Hazardous Waste shall provide municipalities with copies of all applicable permits provided by State and/or Federal regulators and copies of all annual, incident, and remediation-related reports.
- Any projects where Water Consumption exceeds triggers identified in Section 4.2.4.2 shall demonstrate through SEQRA how such impact will be mitigated through, for example, use of Low Impact Development (LID) techniques resulting in compensatory recharge equal to identified recharge deficits or through other artificial on-site or off-site recharge techniques, or provision or identification of compensatory natural recharge areas elsewhere in project recharge area.
- Storage or stockpiling of agricultural chemicals including fertilizers, manure, pesticide/herbicides: Special use permit to be consistent with recommendations to be developed by the Putnam County Soil & Water Conservation District in conjunction with municipal planning personnel.
- Any activity involving the dispensing of oil or petroleum from an above-ground storage tank or tanks with an aggregate volume of 2,000 gallons or more are

subject to the following: dispensing activities must take place on a paved surface covered by a roof; secondary containment is provided for the above-ground storage tanks(s) and all associated piping is either above-ground or has secondary containment (e.g. double walled).

Where special permits are required, an annual report describing compliance with the permit conditions should be submitted to the Municipal Code Enforcement Officer.

4.2.4.2 SEQRA and Environmental Evaluation

Projects with the following characteristics must be designated a Type I Action under SEQRA unless the action is specifically listed as a Type II action under SEQRA.

a. any action resulting in discharges to the environment exceeding groundwater standards for any compounds other than domestic wastewater constituents;

b. any projects involving more than 20 acres where Water Consumption is more than 20% greater than the Natural Recharge rate.

In general, aquifer recharge in much of Putnam County is approximately 7 inches per year. Some areas, primarily found in valleys where granular sand and gravel deposits are found, recharge up to 18 inches per year may occur. Site specific recharge rates may apply if available and verifiable.

In evaluating whether a sustainable level of water withdrawal exists on a site using individual wells and septic systems, the existing or potential land use upgradient of the site and its effect on groundwater resources must be considered.

The following methodology should be considered in determining whether a proposed project's potential affect on groundwater resources will rise to a level which should be considered "significant".

Calculation of Consumption:

Typically, a share of water extracted by on-site wells is returned to groundwater via septic systems. As a first order calculation, therefore:

First Order Consumption = Extracted groundwater less wastewater returned on-site and below-grade

Example (for a domestic wastewater site): A typical single home site may require extraction of 300 gallons daily and may return 240 gallons daily to an on-site septic system, yielding a first-order consumption value of 60 gallons daily.

If water is instead released to a central wastewater treatment plant, the first-order groundwater consumption value is 300 gallons per day.

A correction to the first order consumption estimate is warranted in some cases where wastewater returned to groundwater must be adequately diluted to ensure near-site groundwater potability. A correction is required where other dilution sources are not readily available. No other dilution sources are considered available if:

- more than 50% of upgradient lands within 3,000 feet of the site are or may be developed under present zoning or is otherwise developable land, AND;
- more than 50% of said upgradient developed or developable lands are or will be developed using septic systems, AND;
- Where on-site individual or central wells may or could be developed on lands downgradient and within 3,000 feet of the site, AND;
- Where on-site wastewater includes domestic waste.

Where these conditions are met, the first-order consumption calculation must be increased by a correction factor of 6 times the wastewater discharge volume to achieve a better than 4-times dilution of the wastewater. Such dilution will reliably reduce typical nitrate discharges of approximately 40 ppm to below the drinking water standard of 10 ppm.

Effective Consumption = First Order Consumption + (Wastewater Returns multiplied by 6)

Example (using the domestic site above). If the single home lies in a neighborhood where all surrounding sites use individual wells and septic systems, and where upgradient areas within 3,000 feet do not include lands owned by NYCDEP or parklands or lands under perpetual easements, and if downgradient areas include other existing or potential sites with wells and septic systems, the first order consumption must be corrected by the addition of 6 times the wastewater volume of 240 gallons daily, to account for recharge needed to dilute the wastewater concentrations to potable limits. Effective Consumption of the sample home therefore increases to 60 gallons plus (240 gallons of wastewater x 6), equaling a total of 1,500 gallons daily.

Estimating Natural Recharge

Applicants should use recharge rates outlined in this report or recharge rates from equivalent technical studies to characterize average effective recharge rates entering the site. Applicants should apply the recharge rate to project areas where permeable surfaces will remain following development. Except for areas in Putnam County with washed sand and gravel deposits (e.g. Hydrologic Class A soils), the average Natural Recharge rate throughout Putnam County is approximately 7 inches annually.

Upon demonstration of effectiveness of measures, Applicants may also take credit for constructed Low Impact Development (LID) measures to enhance natural groundwater recharge. Such measures could include installing roof-drain dry wells, installing recharge areas in landscaped gardens, allowing free drainage rather than closed conveyances wherever stormwater passes over porous soils, and replacement of paved areas with porous surface grading.

Example: (for a domestic home site): A 3 acre site proposed for development may result in 0.3 acre conversion to impermeable surfaces. In the absence of any LID compensatory recharge, a general recharge estimate of 7 inches annually provides 1,406 gallons of average daily recharge.

Calculations:
2.7 acres x 43,560 ft/acre x 7 inches/yr x 1/12 ft/inch = 68,607 cubic ft recharge per yr.
68,607 cubic feet recharge per yr x 7.48 gals/cubic foot x 1/365 yr/day = 1406 gals/day

Considering the sample Effective Consumption estimate of 1,500 gpd calculated previously, and the sample site Natural Recharge estimate of 1406 gpd above, the example site can proceed with permitting without a special use permit since Effective Consumption does not exceed Natural Recharge by more than 20%.

4.3 County-wide and other General Recommendations

Various general recommendations have been developed which are applicable throughout Putnam County. These include the following:

4.3.1 Management Strategies for Road De-Icing.

Management methods should be developed to minimize threats of salt contamination of groundwater resources. For salt threats associated with road de-icing, curbing and impermeable snow-pile aprons are needed in vulnerable areas to avoid introduction of salt from melting snow-piles into groundwater near wells. Protocols developed by the NYS Department of Transportation can be used to help distinguish between road salt and water softener contamination in wells. Areas particularly vulnerable to road salt contamination can be identified for special road construction and de-icing protocol evaluations.

4.3.2 Groundwater Sampling.

A systematic program for sampling wells for existing threats (nitrate, salt, bacteria) and emerging threats (caffeine, home pharmaceuticals, plasticizers) should be considered in Putnam County. Wells should be situated in both settled and pristine areas for comparison purposes. Until more data exist, it is difficult to assign management priorities for road salt, nitrate, or personal chemicals contaminants.

4.3.3 Improved Testing Protocols for Subdivisions Using Individual Wells.

The Putnam County Department of Health or individual Municipalities are encouraged to develop a pumping test protocol for any subdivision proposing more than 10 individual wells. The present practice of pre-drilling 10% of wells may be continued, but at any subdivisions where effective densities are less than those recommended by use of Table 14 based on 7 inches of annual recharge, the pre-drilled wells should be collectively flow tested for 72 hours at a combined rate equal to twice the flow rate of the proposed future subdivision water requirements, with drawdown data collected from adjacent streams, lakes, wetlands, and any surrounding existing wells. A formal aquifer report comparable to reports required for Community Water System wells should be required by the Putnam County Department of Health and/or individual municipalities for review.

4.3.4 Homeowner Fuel Tank Upgrades.

Putnam County or individual municipalities should consider local laws to require proper abandonment or exhumation of homeowner heating oil fuel tanks. This could occur at the time of property transfer. No new tanks should be buried.

4.3.5 Identification of Future High-Capacity Groundwater Well Sites.

This report has identified general areas for future high-capacity wells. The next step would be for the County or individual municipalities to conduct site specific studies to identify and protect future sources of water supply. Regions with the highest potential for future high-yield wells have been identified in this report and include sand and gravel deposits, such as those along Peekskill Hollow, Canopus Hollow, near Brewster, and potentially in parts of Patterson.

4.3.6 Monitoring of Aquifers.

Putnam County municipalities should monitor groundwater levels across the county to identify impacts of droughts or aquifer over use. Without data describing aquifer conditions during droughts and over time, it is difficult to identify water capacity trends over time. Up to 10 monitoring stations across the County in both settled and pristine locations are recommended. Such data would provide a much needed historical data base to gauge future development and could serve as a useful educational tool for the community and a useful planning and management baseline for municipal leaders.

Groundwater sampling must also be considered, either in suspected areas of concern, or regionally. Among other specific project objectives, sampling is warranted to identify the need for sewer/water investments in densely settled areas, or in areas near roads to assess the need for de-icing chemical management programs.

4.3.7 Evaluation of Effects of Extensive Sewer Systems.

Regional wastewater collection systems transfer groundwater directly to streams rather than recharging aquifers through septic systems. These transfers can result in groundwater deficits in sewered areas or in areas near sewer districts. It is unlikely that any more central wastewater plants will be proposed within NYCDEP watersheds without in-ground disposal, so this matter may not be critical in eastern Putnam County. In western parts of Putnam County, however, the removal of water to wastewater plants should be examined on a case-by-case basis.

4.3.8 Evaluation of On-Site Wastewater Treatment Systems.

The effectiveness of onsite wastewater treatment units (e.g. septic systems) to reduce contaminant transfer to aquifers should be assessed. If such systems can reliably reduce contaminant release into aquifers, such systems may be well suited for use in lake communities provided that a management district with a maintenance employee is established to ensure long-term maintenance and operational integrity of such systems. On-site treatment systems that do not reduce actual nutrient levels in wastewater preserve operational status of leaching fields but do not reduce contaminant loading in the receiving aquifer. Such systems provide little benefit to aquifers.

4.3.9 Protection of Recharging Wetlands.

Wetlands that facilitate aquifer recharge are particularly important to groundwater resource reliability. Wetlands that promote aquifer recharge should be identified so they may receive protection under municipal law if not otherwise protected under State or Federal regulations. Permits that allow wetland and wetland buffer incursions should be discouraged.

4.3.10 Evaluation of Groundwater Threats near Former Ore Mines.

A prior study of domestic wells near former metals mines identified few to no wells with groundwater exceeding standards for arsenic or other compounds often associated with ore mines. Subsequent construction of new homes near such mines and modified drinking water standards may warrant re-evaluation of potential human health risk exposures near such mines.

4.3.11 Preparation of Bedrock Geology Fracture Maps.

Future bedrock wells installed along the traces of fracture systems are most likely to provide high groundwater yields. Preparation of fracture maps for developable portions of Putnam County will help drillers and others identify sites for high-capacity bedrock wells.

4.3.12 Radon Evaluation.

Bedrock wells in Putnam County may contain radon. An assessment of the distribution, prevalence, and concentration of radon in groundwater is needed to help determine the need for and types of BMPs which can moderate these occurrences.

4.3.13 Household Hazardous Waste Management.

Continued efforts are needed to limit releases of household hazardous wastes to groundwaters in residential and other presently unregulated areas. Continued funding for household hazardous waste pickup days and BMPs identifying property use and disposal of household hazardous waste products are encouraged.

4.3.14 Use of Recharge Rate Analysis during Municipal Rezoning Efforts.

Investigators have developed a simplified relationship between average rainfall and recommended minimum effective densities of septic systems. This relationship should be considered when establishing sustainable development densities in zoning districts or on any large-scale project (e.g. over approximately 20 acres) if individual wells and septic systems will generally be used. Since annual aquifer recharge in much of Putnam County is approximately 7 inches, the relationship recommends septic system densities of approximately 1 system per every 3 acres (Table 14). Where other regional recharge rates are identified and can be verified, other effective densities may be sustainable.

4.4 Recommended Follow-up Steps

The Putnam County Groundwater Committee has recommended various groundwater management strategies in the prior section. The committee suggests developing an Implementation Committee which would work with Municipalities and with Putnam County to implement groundwater management programs. Some specific short term and long-term implementation tasks are listed below:

4.4.1 Short Term Implementation Goals

The following short-term goals are recommended.

1. Develop a county-wide map showing actual or approximate boundaries of the three aquifer regions discussed in Sections 4.2 and showing community water system well recharge areas.

2. Develop a model zoning ordinance that can be considered for adoption by individual municipalities based on the recommended groundwater management strategies generally outlined in Section 4.2.3.

3. Identify wetlands that promote aquifer recharge and work with municipalities to protect those recharging wetlands not otherwise protected by existing State or Federal regulations.

4. Encourage the Putnam County Department of Health to develop a pumping test protocol for any new subdivision proposing more than 10 individual wells. This can be used by the Department of Health or required for use by municipal planning boards. Test protocols for new community wells should also include consideration of any permitted wells which have not yet been placed in service.

5. Develop water management educational materials to distribute in high density and medium density areas. Establish programs so that these educational materials can be distributed regularly, through signage, local mailings, tax mailings, or other opportunities.

6. Update the County's digital well log data base each year.

4.4.2 Long-Term Implementation Goals

The following long-term goals are recommended:

1. Establish groundwater level monitoring in multiple locations across Putnam County, focusing on lake community locations, traditional neighborhood areas, and open land areas. These data will assist in evaluations of aquifer responsiveness to precipitation events and to local uses of groundwater. To establish these stations, unused wells can be equipped with data loggers and recording devices for water level and rainfall.

2. Develop de-icing protocols for County and Municipal DPW or Highway departments to reduce concentrated salt releases to areas which may impact groundwater quality. Identify groundwater areas most sensitive to salt contamination and consider low or no-salt programs for such areas.

3. Develop construction guidance for curbing and snow accumulation aprons to limit contact between salty snow and permeable soils near domestic or public wells.

4. Work with Municipal and County personnel to assess options for potential groundwater sampling and stream sampling programs to identify areas with groundwater quality or capacity limits.

5. Evaluate whether commercially available, advanced on-site wastewater treatment units are available which can release a cleaner effluent, freer of nutrients or other contaminants, to aquifers. If such capabilities are verified, then use of such treatment units can be encouraged in lake community areas as part of wastewater management districts.

6. Re-evaluate groundwater quality in existing wells near former ore mines.

7. Develop bedrock fracture maps in GIS format available for use by well drillers and others to locate potentially higher-yield well drilling areas.

8. Finance studies, or monitor availability of studies by others, of recharge rates through soils and in into aquifer formations in Putnam County. Improved understandings of precise recharge rates will increase precision in estimates of sustainable water use across Putnam County and increase precision of calculations in Section 4.2.4.2.

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5.2 Individuals Contacted During Study

Baisley, Annemarie. Kent Town Supervisor. Referred TCC to Town Planner Gene Ryan, Town Clerk, and CAC member George Baum.

Baker, James. Kent Recycling program. TCC phone message was not returned.

Bartos, Ed, 2003. Putnam County Department of Health. Review SWAP files. Review copies of water supply master listings.

Baum, George. Town of Kent CAC. Telecon referred TCC to James Baker, Recycling coordinator.

Bittner, Anne, 2003. Putnam County Department of Health. Discuss water quality problems and water supply systems.

Budzinksi, Mike, 2003. Putnam County Department of Health. Discuss sewage treatment programs and areas of water quality concern in Putnam County.

Cesar, John, Village of Brewster Mayor. Telecon. TCC was referred to Dan Crawford at Highway Department.

Collisanti, Vittoria, Putnam Valley Planning Department staff. Site visit to review and borrow reports, discuss water resource issues in the Town.

Crawford, Dan. Village of Brewster Highway Department. Telecon to discuss water sources for Village.

DelCampo, Frank. Carmel Town Supervisor. Referred TCC to Town engineer Jack Karell.

Griffin, M. Patterson Town Supervisor. Telecon. Referred TCC to Rich Williams.

Harman, Willard, 2003. State University of NY at Oneonta Biological Field Station. Presentation given April 11, 2003, at AWRA regional conference, Utica NY. (topic: Otsego Lake Watershed Management).

Karell, John. Town of Carmel Town Engineer. Site visit to review files and discuss Town water issues.

Levine, Mike. Special Water Districts operator, Town of Southeast. Telecon to discuss water status of Town districts and review concerns and areas of suspected water shortages in Southeast.

Mazzuca, Bill, Town of Philipstown Supervisor. Supervisor referred TCC to Town Clerk.

Merando, Bill. Village of Nelsonville Mayor. TCC phone message was not returned.

Miller, Tim. Town of Philipstown Town Planner. Telecon confirming aquifer reports available from Philipstown and Villages of Nelsonville and Cold Spring.

Phillips, Anthony. Village of Cold Spring Mayor. TCC call not returned.

Philipstown Clerk's office. Referred TCC to Tim Miller. Provided copies of Route 9 aquifer study.

Phillips, Pat., 2003. USGS. Presentation given April 11, 2003, at AWRA regional conference, Utica NY. (topic: Pharmaceuticals and Other Organic Wastewater Compounds in the Croton Watershed, NY August 2000).

Ryan, Gene, Kent Town Planner. Telecon confirming absence of aquifer studies in Kent. Mr. Ryan also indicated there is no local expert in groundwater issues we could meet with. He noted quantity and quality difficulties in lake community around Lake Carmel due to conversion of summer cottages to full-year homes.

Santos, Carmelo., Putnam Valley Town Supervisor. Telecon. Referred TCC to Town Planning office.

Werper, Larry. 2003. Putnam County Department of Health. Discuss areas with specific groundwater quality defects. Review extent and capacity of sewage treatment districts in County.

Williams, Rich. Town of Patterson Town Planner. Site visit to review files and discuss Town water concerns and trends.

Zutell, Lois, Town of Southeast Supervisor. Telecon confirming that Southeast has no aquifer reports. Supervisor reported there are few to no water quality or capacity difficulties in Southeast. Some capacity difficulties in the Lakeview Manor area.

Tables

Table 1 - Population and Groundwater Consumption Estimates

A	B	C	D = % of C	E	F	G	H	I = C*E	J = C*((100-D)/100)*G	K = C*D/100*G	L=K*(H/100)	M=K-L	N= (I*0) - M	0 = N*1.5
Towns (including enclosed Villages)	Total Population (Year 2000)	Estimated Residents Using Groundwater Sources+	% of Residents using Groundwater that have Septics (% approx*)	Per Capita Summer Daily Water Use (daily gals)	Per Capita Domestic Evaporation Losses (daily gals)	Per Capita Wastewater Generation (daily gals)	Summer Evaporation Losses at Septics** (%)	Total Groundwater Extracted at Residential Sites (daily gallons)	Extracted Groundwater Returned to Surface water via Central Sewers*** (daily gallons)	Extracted Groundwater Returned to Septic Systems (Wintertime Aquifer Recharge) (daily gals)	Summer Evaporative Losses by Groundwater Users From Septics (daily gals)	Summertime Wastewater Returns to Aquifers (daily gals)	Summertime Aquifer Reduction (consumption plus evaporative losses) (daily gals)	Total Summertime Aquifer Reduction (Residential plus other uses) (daily gals)
Carmel	33,006	26,000	80	100	20	80	30	2,600,000	350,000	1,730,000	519,000	1,211,000	1,389,000	2,083,500
Kent	14,009	14,000	95	100	20	80	30	1,400,000	56,000	1,064,000	319,200	744,800	655,200	982,800
Patterson	11,306	11,300	95	100	20	80	30	1,130,000	45,200	858,800	257,640	601,160	528,840	793,260
Putnam Valley	10,686	6,700	95	100	20	80	30	670,000	26,800	509,200	152,760	356,440	313,560	470,340
Philipstown^	9,422	5,200	95	100	20	80	30	520,000	20,800	395,200	118,560	276,640	243,360	365,040
Southeast^	17,316	15,500	90	100	20	80	30	1,550,000	124,000	1,116,000	334,800	781,200	768,800	1,153,200
TOTALS	95,745	78,700					TOTALS							
							Residential	7,870,000	622,800	5,673,200	1,701,960	3,971,240	3,898,760	
							+50% for non-residential uses (commercial, industrial, institutional)	11,805,000	934,200	8,509,800	2,552,940	5,956,860	5,848,140	5,848,140

* Rounded to nearest 5 percent. Carmel has sewer districts 5, 7, and part of 1. Southeast has Blackberry and Village sewer discharges 0.13mgd. Patterson has Patterson Village, Cornwall Meadows, Rox Run Condos 0.1 mgd. Assumptions elsewhere.
** Average summertime net estimate. Actual ET losses will vary based on soils and installation detailing
*** Assumption that all significant central sewage facilities discharge to streams. Treated groundwater is released from Carmel sewer districts 4, 5, 6, 7 (0.3 mgd total). Mahopac Business District sewer adds another 0.15 mgd (50% additional).
+Calculated by subtracting estimated surfacewater customers in Village of Cold Spring + Continental Village (4,200) from Philipstown, Lake Peekskill (4,000) from Putnam Valley, Carmel Water Districts #2 and 8 (7,000) from Carmel, and Brewster Heights/Eagle Ridge (2,000) from Patterson/Brewster
^The Philipstown population includes populations of Cold Spring and Nelsonville. The Southeast population includes Brewster Village population. Population data from Federal Census website 2000 data

OTHER NOTES

County-wide typical wastewater discharges of approximately 2 mgd confirmed by Larry Werper, Putnam County Department of Health. Approximately 1 mgd of this flux comes from surface water sources of supply. including Carmel Sewer Districts 2 & 8 (0.7 mgd), Brewster Heights/Eagles Ridge in Southeast (0.12 mgd), and Cold Spring (.25 mgd).

Based on a review of 2003 DOH records approximately 27,000 residents receive groundwater from community water systems.
Based on an estimated 80,000 residents using groundwater, approximately 53,000 residents use domestic wells

Water Districts shown on Figures 3 and 4 from PCDOH mapping.
Columns J and K for Carmel manually inserted based on review of sewer district data.

Table 2 - Partial List of Mines in Putnam County

Mines with Known Locations

PRIMARY NAME	Town	COMMODITIES	COMMENTS
Blackberry Magnetite Mine	Carmel	Iron	aka Canopus Island Mine, Grand Island Mine
Brady Farm Shaft	Southeast	Iron	
Brewster Mines	Southeast	Iron	aka Brewster Village Mine: Brew, Iron Mine
Brown's Quarry	Kent	Arsenic Iron Sulfur Copper	
Canada Mine	Putnam Valley	Iron Titanium	aka Philipse Mine
Canopus Mine	Philipstown	Iron Titanium	aka Nelson Mine
Chalmers Fahnestock Uranium	Kent	Uranium	
Coal Grove Magnetite Mine	Putnam Valley	Iron	aka Coalgrove Mine
Constitution Island Occurr	Philipstown	Molybdenum	
Croft Mine	Putnam Valley	Iron Sulfur	aka Indian Lake Mine
Croton Magnetite Iron Mine	Southeast	Iron Copper	
Croton-Theall Magnetite Mine	Southeast	Iron Sulfur Copper	
Denny Mine	Putnam Valley	Iron Titanium	aka Denny's Mine, Parrett Mineaka Philipse Mine
Harvey Pit	Southeast	Iron	
Hatfield Adit	Southeast	Iron	
Hobby Pyritiferous Ore	Patterson	Iron Sulfur	
Hurtis Quarry	Philipstown	Titanium	
Kemble Magnetite Mine	Putnam Valley	Iron	in Fahnestock State Park; Bunnel Mine
Kinnaird Graphite Property	Philipstown	Graphite	
Magnetite Mine No. GK-012	Carmel	Iron	
Mahopac Mine	Carmel/Southea	Iron	aka Travis' Mine, Hill Mine, Clover Hill Mine?
Nathaniel Bradley's Limoni	Putnam Valley	Iron Manganese	
Phillips Sulfide, Magnetite		Iron Sulfur Copper Nickel Uranium	
Pratt Mine	Putnam Valley	Iron Titanium	aka Forman Mine
Putnam County Arsenic Mine	Kent	Arsenic Iron Sulfur Copper	aka Carmel Arsenic Mine, Carmel Silver Mine
Sackett Mine	Putnam Valley	Iron Titanium	
Stewart Mine	Putnam Valley	Iron Titanium	
Tilly Foster Mine		Iron	aka Townsend Mine
Towners Pyrite Deposit	Patterson	Sulfur	
Travis' Magnetite Mine	Carmel	Iron	
Unnamed Magnetite Mine	Kent	Iron	aka Constitution Island North
Vivian Pit	Southeast	Iron	

Source: NYS Museum records, Putnam County Historian office

Mines with Locations Known only Approximately

PRIMARY NAME	Town	COMMODITIES	COMMENTS
Anthony's Nose Copper Mine		Copper	may be "Phillips Sulfide" Mine
Brush Iron Mine	Southeast	Iron	
Bryant Pond Mine	Putnam Valley		
Burch Mine		Iron?	200' East of Hobby Iron Mine
Burdick's Blacklead Mine	Southeast	Graphite	
Carl Mine	Philipstown	Gold	aka James Smith's Gold Mine, aka Smith Mine
Chapman's Iron Mine	Philipstown	Iron	
China Pond Iron Mine	Kent	Iron	
Conklings Mine	Putnam Valley	Iron	
Constitution Island, South	Philipstown	Molybdenum	
Crosby Iron Mine	Southeast	Iron	aka Harvey Iron and Steel Company
E. Mosher's Quicksilver Mine	Philipstown	Mercury	
Eugene Owens Mo. Pits	Philipstown	Molybdenum	
Everett Prospect		Iron	
Garrison Mine at Continent. Vill.	Philipstown	Iron	
Graymoor Gold Mine		Gold	aka Wayside Mine
Hobby Iron Mine	Patterson	Iron	may be "Hobby Pyritiferous Ore"
Hopper Mine	Philipstown	Iron	aka Mine Lot
Indian Brook Lead Mine	Philipstown	Lead	lead carbonate ore
Joe's Hill Silver Mine	Southeast	Silver	
Luddingtonville Iron Mine	Kent	Iron	
Manitou Iron Mine		Iron	
Manitou Silver Mine	Philipstown	Silver	
McCollum Mine	Carmel	Iron	aka Croton Magnetic; aka Croton Mines; may be "Croton Magnetite Iron"
Moshier's Iron Mine	Putnam Valley	Iron	
Mowatt's Gold and Silver Mine		Gold, Silver	
O'Dells Iron Mine	Putnam Valley	Iron	
Peekskill Hollow Mine	Putnam Valley	Iron	limonite; aka Bradely Mine, aka Kemey's Mine
Smalley Mountain Mine	Kent	Iron, Arsenic, Silver	
South Lake Mine	Kent	Iron	
Sprague's Gold Prospects		Gold?	
Sprague's Iron Mine	Kent	Iron	
Sunk Mines		Iron	aka shaft 1, 2, 3, 4 and 5; aka Phillipse, Hamilton and Stewart Mines
Taylor Mine	Putnam Valley	Graphite	
Tillerson's Blacklead Mine	Carmel	Graphite	
Todd Mine		Iron	
Townsend's Mine		Iron	aka Simewog Mine
Warren Ridge Lead Mine	Philipstown	Lead	
Yoeman's Iron Mine	Philipstown	Iron	aka Merritt's Iron Mine

Source: NYS Museum records, Putnam County Historian office

Figure 2 (Continued)

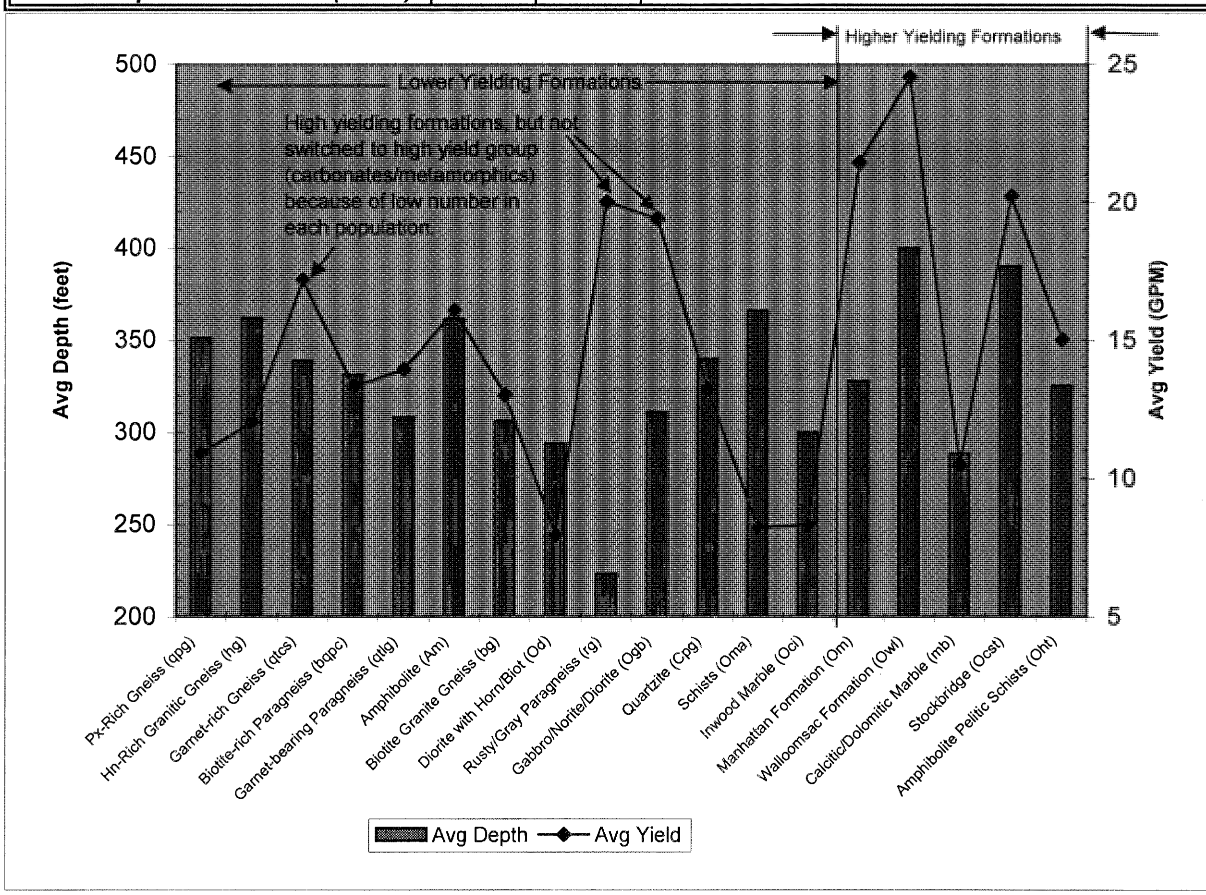
Mines with No Confirmed Location

PRIMARY NAME	TOWN	COMMODITIES	COMMENTS
Clover Hill Mine			
Daisey Lane Mine			
Deans Corners Mine			
Hamilton Mines			in Fahnestock S.P.
Pelton Pond			aka Canada Mines?
West Point Mine			in Fahnestock S.P.
Williams Mine		Iron?	

Source: NYS Museum records, Putnam County Historian office

Table 3 - Well Statistics
Depth and Yield by Bedrock Formation
Putnam County Well Log Database

Bedrock Formation Statistics			Yield			Depth		
	Number	Percent	Average	Median	Mode	Average	Median	Mode
Px-Rich Gneiss (qpg)	95	1.70	10.87	7	5	350.94	325	130
Hn-Rich Granitic Gneiss (hg)	3	0.05	12	10	NA	361.67	400	NA
Garnet-rich Gneiss (qtcs)	63	1.13	17.17	8	5	338.57	320	426
Biotite-rich Paragneiss (bqpc)	1817	32.53	13.3	8	5	330.95	300	300
Garnet-bearing Paragneiss (qtlg)	236	4.22	13.92	10	10	307.78	281	200
Amphibolite (Am)	1118	20.01	16.07	10	5	361.11	300	205
Biotite Granite Gneiss (bg)	1624	29.07	13	8	5	305.86	275	200
Diorite with Horn/Biot (Od)	13	0.23	7.92	9	5	293.5	260	200
Rusty/Gray Paragneiss (rg)	6	0.11	20	11.5	NA	223	270	NA
Gabbro/Norite/Diorite (Ogb)	8	0.14	19.38	8.5	5	310.63	270	500
Quartzite (Cpg)	21	0.38	13.19	8	5	339.4	300	300
Schists (Oma)	19	0.34	8.21	8	10	365.63	305	300
Inwood Marble (Oci)	24	0.43	8.29	9	10	299.64	300	300
Manhattan Formation (Om)	292	5.23	21.42	12	10	327.36	297.5	285
Walloomsac Formation (Owl)	58	1.04	24.53	8	5	399.69	305	285
Calcitic/Dolomitic Marble (mb)	21	0.38	10.43	10	10	288.07	300	200
Stockbridge (Ocst)	167	2.99	20.2	10	5	389.78	323.5	300
Amphibolite Pelitic Schists (Oht)	1	0.02	15	NA	NA	325	NA	NA
Entire Population Values (EPVs):	***5586***	***100***						



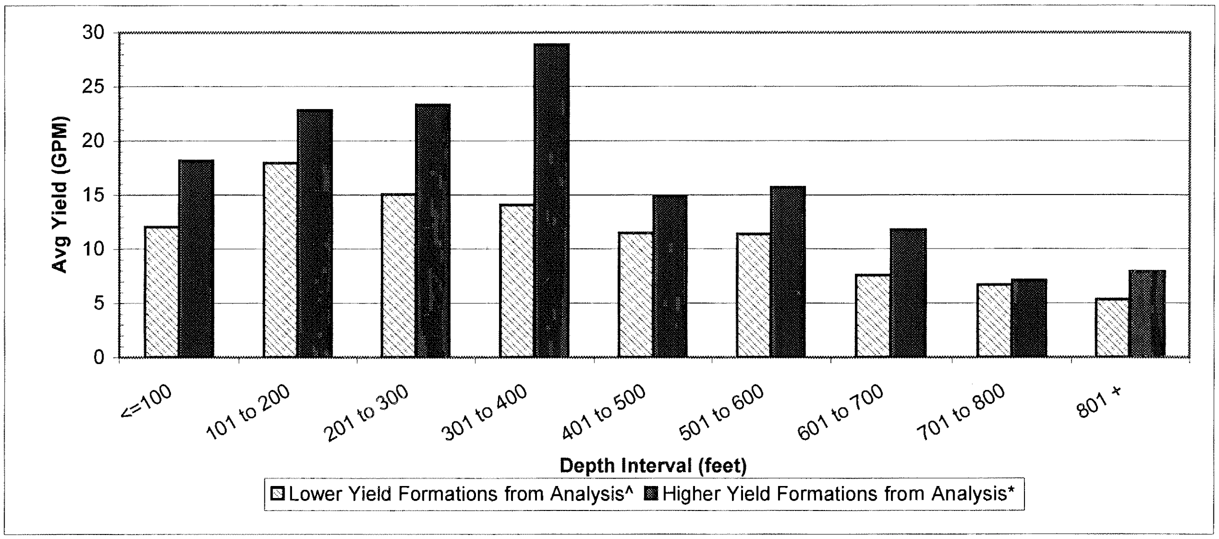
These data describe typical yields & depths for wells installed in geologic formations in Putnam County. Ranges of yields & depths vary from dry wells to yields over 100 gpm, and depths may range from less than 100 feet to over 800 feet. The analysis helps identify higher and lower yielding geologic formations.

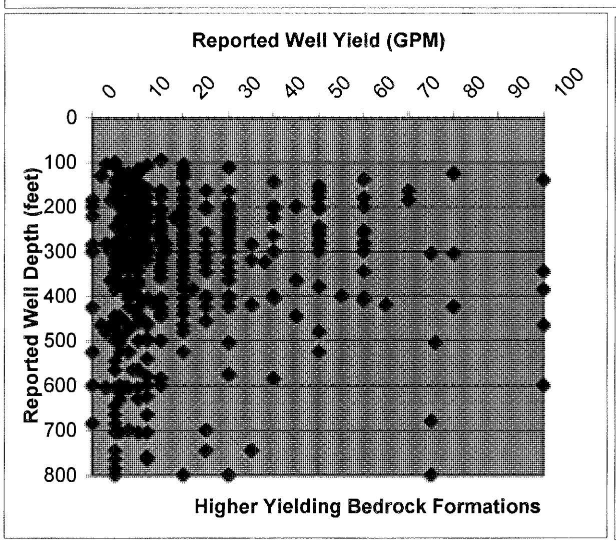
The Chazen Companies
September 2004

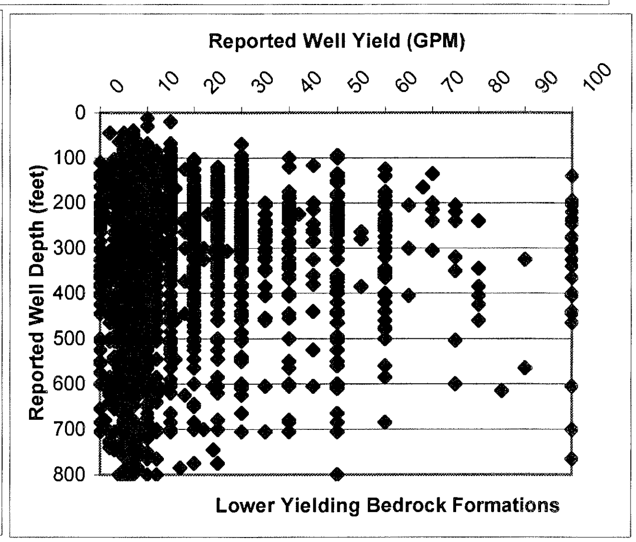
Table 4 - Depth and Yield Statistics for Higher and Lower Yield Bedrock Formations
Putnam County Well Log Database

	Lower Yield Formations from Analysis^						Higher Yield Formations from Analysis*					
Well Depth	Number	%	Average	Median	Mode	Std Dev	Number	%	Average	Median	Mode	Std Dev
<=100	813	16.1	12.06	8	5	14.77	56	10.4	18.16	10	10	19.95
101 to 200	877	17.4	17.96	12	10	18.59	89	16.5	22.82	15	20	29.02
201 to 300	1391	27.6	15.06	10	10	16.05	154	28.5	23.34	12	10	50.64
301 to 400	867	17.2	14.07	8	5	22.55	97	18.0	28.89	15	10	72.07
401 to 500	502	9.9	11.49	6	5	16.24	66	12.2	14.89	8	5	22.00
501 to 600	239	4.7	11.41	5	5	20.54	25	4.6	15.72	5	5	18.82
601 to 700	201	4.0	7.59	5	5	11.30	22	4.1	11.77	5	5	14.35
701 to 800	83	1.6	6.69	5	5	10.75	19	3.5	7.11	6	5	3.77
801 +	74	1.5	5.35	5	5	3.65	12	2.2	7.92	6	6	7.13
EPVs:	***5047***	***100***	***13.81***	***8***	***5***	***17.74***	***540***	***100***	***20.94***	***10***	***5***	***44.17***

Table 3 lists bedrock descriptions and letter codes.
^qpg, hg, qtcs, bqpc, qtlg, Am, bg, Od, rg, Ogb, Cpg, Oci, Oma
*Oht, Owl, mb, Ocst, Om





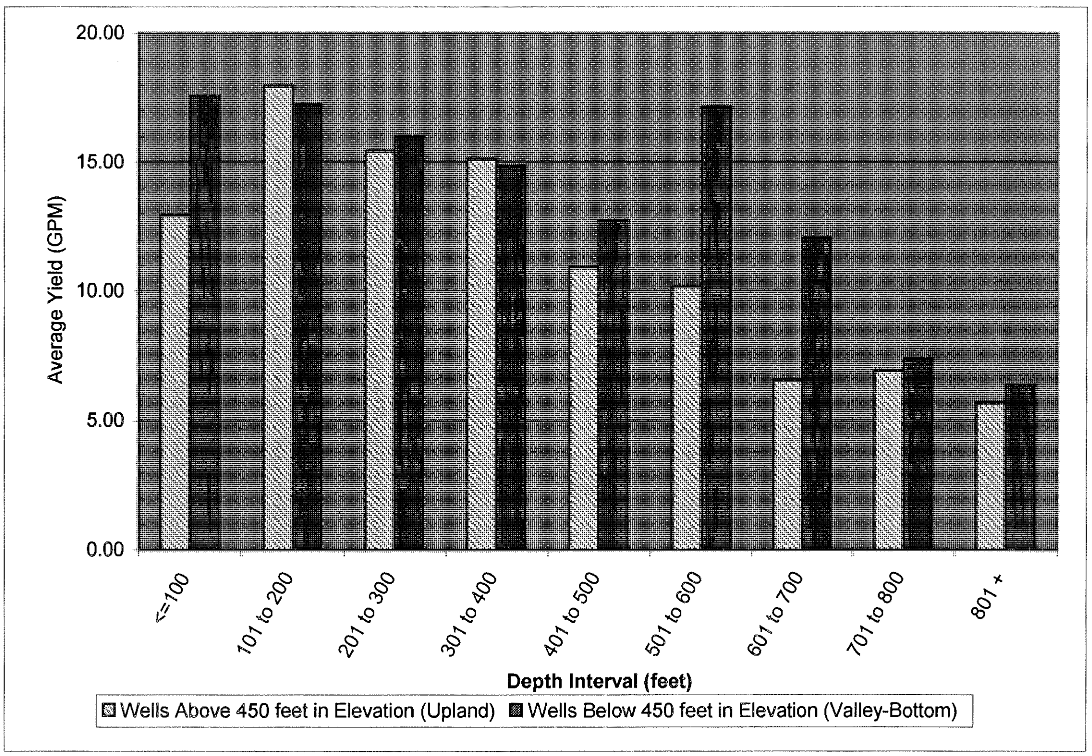


These data, as presented most clearly in the center graph, show that wells drilled in the higher yield bedrock formations outperform wells installed in lower yield bedrock in all depth classes.
The highest well yields in the higher-yield bedrock formation occur in wells between 300 and 400 feet deep.

Table 5 - Impact of Elevation on Well Depth and Yield
Putnam County Well Log Database

	Wells Above 450 feet in Elevation (Upland)					
Well Depth	Number	%	Average	Median	Mode	Standard Deviation
<=100	60	1.4	12.92	10	6	12.16
101 to 200	934	22.1	17.94	12	10	20.04
201 to 300	1392	32.9	15.41	10	10	21.99
301 to 400	844	20.0	15.10	8	5	31.31
401 to 500	462	10.9	10.91	6	5	16.93
501 to 600	209	4.9	10.16	5	5	17.13
601 to 700	177	4.2	6.55	5	5	7.13
701 to 800	83	2.0	6.90	5	5	10.83
801 +	68	1.6	5.68	5	5	4.19
EPVs:	***4229***	***100***	***14.43***	***8***	***5***	***22.5***

	Wells Below 450 feet in Elevation (Valley-Bottom)					
Well Depth	Number	%	Average	Median	Mode	Standard Deviation
<=100	31	2.4	17.55	12	7	16.24
101 to 200	279	21.5	17.22	12	10	20.18
201 to 300	419	32.3	15.98	10	10	17.58
301 to 400	257	19.8	14.83	8	5	25.53
401 to 500	147	11.3	12.71	7	5	14.53
501 to 600	77	5.9	17.12	5	5	27.45
601 to 700	55	4.2	12.05	5	5	19.32
701 to 800	17	1.3	7.35	6	5	6.30
801 +	17	1.3	6.35	5	5	5.04
EPVs:	***1299***	***100***	***15.35***	***10***	***5***	***20.32***



The bar graph above indicates that wells deeper than 500 feet in low elevation settings outperform equally deep wells in upland settings. Wells between 100 and 400 feet deep in high elevation and low elevation have roughly comparable yields.

Table 6 - Impact of Soil Cover on Well Depth and Yield
Putnam County Well Log Database

				Yield			
Bedrock Classification	**Overburden Cover+**	**Number**	**Percent**	**Average**	**Median**	**Mode**	**Std Dev**
Lower Yield^	Sand & Gravel	645	11.55	14.12	8	5	17.2
	Silt & Clay	4402	78.80	13.76	8	5	17.82
Higher Yield*	Sand & Gravel	94	1.68	20.29	10	10	33.11
	Silt & Clay	445	7.97	21.08	12	5	46.2
	EPVs:	***5586***	***100***				

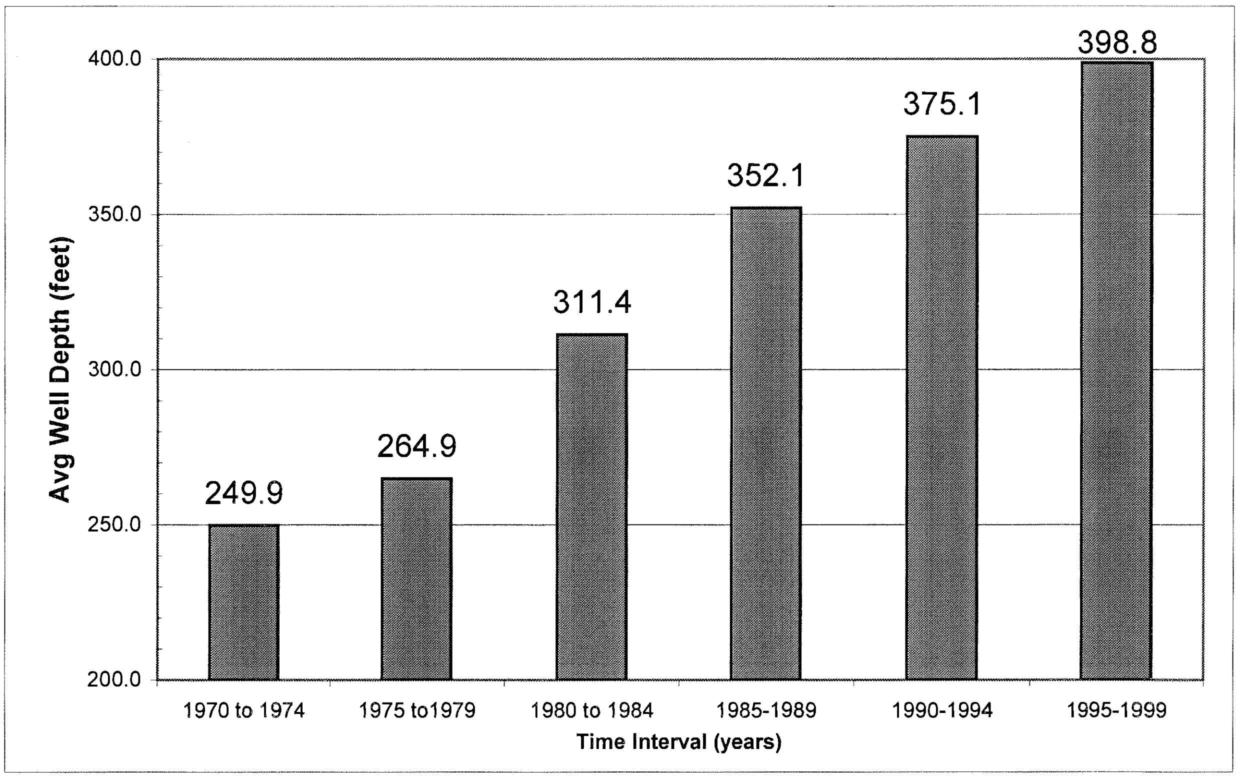
				Depth			
Bedrock Classification	**Overburden Cover+**	**Number**	**Percent**	**Average**	**Median**	**Mode**	**Std Dev**
Lower Yield^	Sand & Gravel	645	11.55	333.3	300	200	187.1
	Silt & Clay	4402	78.80	329.08	300	300	163.98
Higher Yield*	Sand & Gravel	94	1.68	371.4	300	300	240.5
	Silt & Clay	445	7.97	349.6	305	285	181.4
	EPVs:	***5586***	***100***				

Table 3 lists bedrock descriptions and letter codes.
^qpg, hg, qtcs, bqpc, qtlg, Am, bg, Od, rg, Ogb, Cpg, Oci, Oma
*Oht, Owl, mb, Ocst, Om
+ Figure 5 shows surficial sand and gravel formations. All other areas in Putnam County are assumed to have lacustrine silts and clays (in valleys) or clayey glacial till (on hillsides and uplands)

The data above suggest that soil cover near wells in Putnam County appears to have little obvious impact on well yields. This is likely explained by the short-duration of testing conducted by well drillers or by by imprecise understanding of mapped sand and gravel formations which may also contain silt or clay. Analysis of wells tested for longer periods and improved delineations of granular versus silty soils could suggest a different conclusion.

Table 7 - Well Depth and Yield Trends over Three Decades
Putnam County Well Log Database

Well Statistics for Time Periods			***Yield***		***Depth***
Time Period	***Number***	***Percent***	***Average***	***Median***	***Average***
1965 to 1970	1	0.0	NA	NA	NA
1970 to 1974	824	15.3	13.66	8	249.9
1975 to1979	680	12.6	12.60	8	264.9
1980 to 1984	538	10.0	15.40	10	311.4
1985-1989	1484	27.5	16.45	10	352.1
1990-1994	833	15.5	10.85	7	375.1
1995-1999	920	17.1	16.60	10	398.8
2000 to present	109	2.0	14.01	10	383.1
Total:	*5389*	*100*			



<u>This analysis indicates that newer wells are being drilled deeper than older wells.</u> This is interpreted to be the result of new construction occurring in less accessible locations, changed drilling methods which can block smaller water-bearing fractures and so result in deeper well drilling, and of increased water demands in modern households. This analysis is not interpreted to mean that regional aquifer levels are falling or being depleted.

Table 8 - Well Depth and Yield Relative to Limited Linear Feature Analysis
Putnam County Well Log Database

	Wells Within 150 feet of Mapped Geo-structure					
Well Depth	Number	%	Average	Median	Mode	Standard Deviation
<=100	10	28.6	13.70	8	8	11.61
101 to 200	5	14.3	13.40	10	NA	8.67
201 to 300	10	28.6	14.70	10	10	16.67
301 to 400	3	8.6	9.00	6	6	5.20
401 to 500	3	8.6	11.00	8	NA	7.94
501 to 600	2	5.7	7.50	8	NA	3.54
601 to 700	1	2.9	5.00	5	NA	NA
701 to 800	1	2.9	5.00	5	NA	NA
801 +	0	0.0	NA	NA	NA	NA
EPVs:	***35***	***100.0***	***12.46***	***8***	***5***	***11.48***

	Wells Within 250 feet of Mapped Geo-structure					
Well Depth	Number	%	Average	Median	Mode	Standard Deviation
<=100	17	20.7	13.59	10	10	12.36
101 to 200	15	18.3	12.40	10	10	7.87
201 to 300	21	25.6	14.29	10	20	12.49
301 to 400	10	12.2	9.80	6	6	8.48
401 to 500	8	9.8	8.63	6	5	5.73
501 to 600	4	4.9	7.75	8	10	2.63
601 to 700	3	3.7	11.00	8	NA	7.94
701 to 800	3	3.7	6.00	5	NA	3.61
801 +	1	1.2	4.00	4	NA	NA
EPVs:	***82***	***100***	***11.83***	***10***	***10***	***9.95***

	Wells Not Within 250 feet of Mapped Geo-structure					
Well Depth	Number	%	Average	Median	Mode	Standard Deviation
<=100	170	13.5	10.54	7	5	9.14
101 to 200	203	16.1	16.06	10	10	16.27
201 to 300	384	30.5	13.00	10	10	13.90
301 to 400	200	15.9	14.36	6	5	30.90
401 to 500	153	12.2	10.76	5	5	17.21
501 to 600	63	5.0	9.11	5	5	10.92
601 to 700	45	3.6	6.40	5	5	4.77
701 to 800	26	2.1	5.00	5	5	1.83
801 +	13	1.0	4.92	5	5	0.28
EPVs:	***1257***	***100***	***11.99***	***7***	***5***	***16.89***

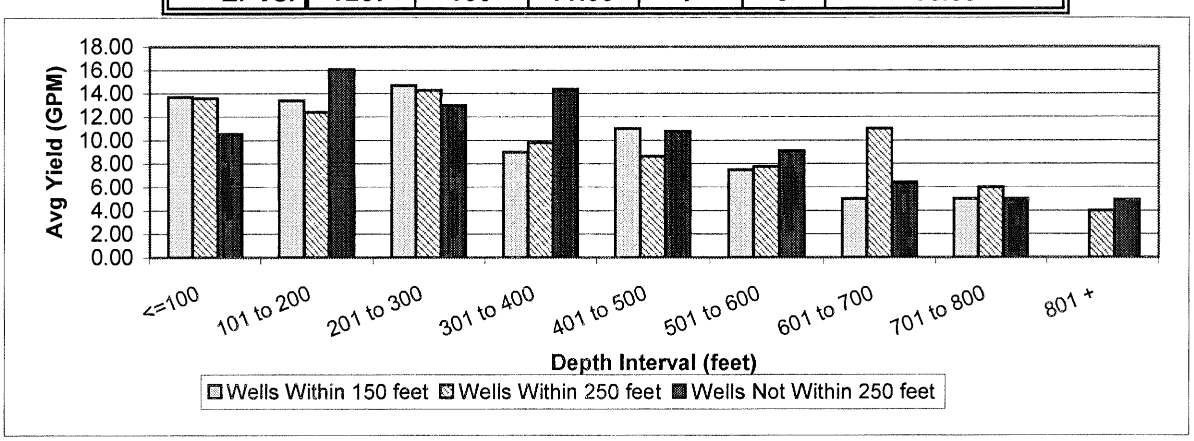


Table 9 - Putnam County Aquifer Recharge Rate Estimates

	Method 1 (Maslansky & Rich, 1984)		Method 2 (Wolcott & Snow, 1995)					Method 3 (Gerber, 1982)				
Town (w/ Villages)	Approximate Area of Town (with Villages) (mi2)	Average Recharge @13.27"/yr (gals/day)	Valley bottom area (mi2)	Upland area (mi2)	Valley Recharge @19.17"/yr	Upland Recharge @ 8.45"/yr	Total Recharge (gals/day)	Valley bottom Area (mi2)	Upland Area (mi2)	Valley Recharge @17"/yr	Upland Recharge @6"/yr	Total Recharge (gals/day)
Carmel	37	23,410,380	0.8	36.3	715,842	14,591,599	15,307,441	0.8	36.3	634,811	10,360,899	10,995,709
Kent	40	25,295,692	2.3	37.7	2,091,225	15,185,859	17,277,084	2.3	37.7	1,854,503	10,782,859	12,637,362
Patterson	32	20,381,164	3.4	28.9	3,072,492	11,623,877	14,696,369	3.4	28.9	2,724,693	8,253,640	10,978,333
Philipstown	51	32,377,561	5.3	45.9	4,850,034	18,479,351	23,329,384	5.3	45.9	4,301,021	13,121,432	17,422,453
Putnam Valley	42	26,668,220	4.0	38.2	3,643,558	15,375,593	19,019,150	4.0	38.2	3,231,115	10,917,581	14,148,696
Southeast	34	21,663,174	3.3	31.0	3,040,320	12,454,409	15,494,729	3.3	31.0	2,696,162	8,843,368	11,539,530
TOTALS	237	149,796,191	19.1	218.0	17,413,470	87,710,687	105,124,158	19.1	218.0	15,442,306	62,279,778	77,722,084

Summary Method 4: Putnam County							
	Valley bottom Area (mi2)	Upland Area (mi2)	Valley Recharge @18"/yr	Upland Recharge @ 7"/yr	Total Average Recharge (gals/day)	20% reduction (1 in 10 drought) (gals/day)	30% reduction (1 in 30 drought) (gals/day)
Carmel	0.8	36.3	672,153	12,087,715	12,759,867	10,207,894	8,931,907
Kent	2.3	37.7	1,963,592	12,580,002	14,543,593	11,634,875	10,180,515
Patterson	3.4	28.9	2,884,969	9,629,247	12,514,216	10,011,373	8,759,951
Philipstown	5.3	45.9	4,554,022	15,308,338	19,862,360	15,889,888	13,903,652
Putnam Valley	4.0	38.2	3,421,181	12,737,178	16,158,358	12,926,687	11,310,851
Southeast	3.3	31.0	2,854,760	10,317,262	13,172,022	10,537,618	9,220,416
TOTALS	19.1	218.0	16,350,676	72,659,741	89,010,418	71,208,334	62,307,292

Valley Bottom Area estimated by by TCC using sand and gravel areas on Figure 5 as a general indication of areal extent of higher permeability soils with supplemental recharge from valley-wall runoff. All other area assigned as Upland Area with lacustrine or till based soils

TABLE 10 - Select Site Stream Gauging Data, September 9 - 11 2002
Putnam County

Watersheds	Site #	Waterway Name and Gaging Location	Contributing Area Upstream of Gaging Site	September 9-11, 2002 Streamflow			Groundwater Yield per Acre (for the immediate watershed)	Groundwater Yield per Acre (for all upstream areas)
			acres	cfs	gpm	gal / day	gal / day / acre	gal / day / acre
Canopus Creek	1	Canopus Creek @ Sunken Mine Road	**2,858**	0.03	15	21,677	**8**	**8**
	2	Canopus Creek @ Cimarron Road	**6,087**	0.14	62	88,965	**15**	**21**
	3	Canopus Creek @ Highland Drive (or Canopus Hollow Road)	**9,303**	0.54	240	346,199	**37**	**80**
Peekskill Hollow Creek	8	Peekskill Hollow Creek @ Taconic Parkway crossing	**5,917**	0.93	415	597,971	**101**	**101**
	7	Wiccopee Brook from Wiccopee Reservoir*	**2,662**	10.41	4671	6,725,814	**2527**	**2527**
	6	Peekskill Hollow Creek @ Peekskill Hol. Road near Tinker Hill Rd.	**10,732**	12.10	5430	7,819,832	**729**	**230**
	4	Peekskill Hollow Crk @ Peekskill Hol. Rd. near Oscawana Lk Rd.	**20,200**	14.44	6480	9,330,594	**462**	**159**
	5	Peekskill Hollow Creek below Oscawana Brook	**26,364**	17.17	7707	11,098,525	**421**	**286**
Cold Spring	9	Foundry Brook in Cold Spring @ Route 9D crossing	**3,133**	0.15	67	95,894	**31**	**31**
Clove Creek	10	Clove Creek @ Campbell Road	**3,606**	0.003	2	2,210	**1**	**1**
	11	Clove Creek @ Campbell Road, unnamed tributary	**2,294**	0.14	64	91,906	**40**	**40**
	12	Clove Creek @ Post Road	**8,021**	1.05	473	681,636	**85**	**277**
Muscoot River	14	Muscoot River @ Potter Road; Contribution from Lake Mahopac	**4,593**	0.53	238	342,547	**75**	**75**
	13	Muscoot River @ Route 6	**8,771**	1.30	583	840,210	**96**	**119**
Croton River	17	Stephen's Brook near Route 22	**896**	0.10	43	61,833	**69**	**69**
	16	Haviland Hollow Brook @ Haviland Hollow Rd/Doansburg Rd	**7,807**	0.68	305	439,494	**56**	**56**
	15	Croton River @ Route 65	**37,511**	4.50	2020	2,908,418	**78**	**84**

Stream gauging conducted by TCC in select locations to evaluate aquifer capacity variations in select hydrogeologic settings

* High flow attributed to Wiccopee Reservoir management

Table 11 - Natural Groundwater Quality in Various Aquifer Formations* (in ppm except pH)

	Granite and gneiss, undifferentiated		Pochuck diorite		Walloomsac Hudson River formation		Inwood/Wappinger Stockbridge limestone		Unconsolidated deposits overlying limestone		Unconsolidated deposits overlying granite, gneiss, diorite, and schist	
	Median and range	Number of analyses	Median and range	Number of analyses	Median and range	Number of analyses	Median and range	Number of analyses	Median and range	Number of analyses	Median and range	Number of analyses
Iron (Fe)	0.20 0.02-2.5	56	0.13 0.01-2.5	9	0.29 0.10-3.0	10	0.10 0.03-.17	7	0.10 0.03-.60	11	0.11 0.0-1.4	36
Sulfate (SO_4)	15 5.0-44	36	20 7.8-26	5	16 5.8-209	12	25 4-182	8	14 8.0-46	10	17 6-29	23
Chloride (Cl)	4.0 .8-29	69	8.7 4.8-37	8	2.4 .8-19	12	3.6 2.0-17	8	7.0 1.0-29	11	3.2 1.2-55	37
Nitrate (NO_3)	.5 .0-12	31	7.6 1.3-13	4	12 --	1	.6 --	1	3.5 --	1	.9 .0-12	13
Dissolved solids	120 43-255	17	132 69-256	7	143 52-370	11	293 198-513	3	503 74-600	5	130 36-258	19
Total hardness (as $CaCO_3$)	72 16-390	73	63 12-156	10	99 38-280	12	176 140-236	7	220 46-290	11	75 18-160	38
Carbonate hardness	52 6-307	68	44 12-123	8	78 12-144	12	160 140-218	7	188 18-399	11	65 4-213	37
Noncarbonate hardness	14 0-99	72	28 0-55	8	13 0-262	12	12 0-20	7	11 0-81	11	10 0-126	37
pH	7.0 5.6-9.8	70	6.8 6.2-7.6	10	7.3 6.2-8.0	12	7.6 7.2-8.1	8	7.2 6.9-7.5	11	6.9 6.0-8.1	37

*from Grossman, I.G., 1957, The Ground Water Resources of Putnam County, New York, USGS, Bulletin GW-37

Table 12 - Previously Identified Areas with Promising Groundwater SupplyPotential

Municipality	Locality	Aquifer Area	Possible Dependable Yield (million gallons per day)
Patterson	Patterson hamlet	East Branch Croton River	0.5
Patterson	Putnam Lake	East Branch Croton River	0.5
Southeast/Brewster	Brewster	East Branch Croton River	0.5 - 1.0
Kent	Lake Carmel	Middle Branch Croton River	0.2 - 0.5
Carmel	Mahopac	Peekskill Hollow Creek	0.5 - 1.0
Putnam Valley	Adams Corners	Peekskill Hollow Creek	0.5 - 1.0
Putnam Valley	Lake Peekskill	Peekskill Hollow Creek	0.5
Putnam Valley	Oscawana Corners	Canopus Creek	0.5
Philipstown	Continental Village	Canopus Creek	0.5 - 1.0
Cold Spring	Cold Spring	Hudson River	2.0 +
Philipstown	North Highland	Clove Creek	0.2 - 0.5
Total			6.4 - 9.0 +

*from Goodkind and O'Dea, 1970, Putnam County, NY Report on Comprehensive Public Water Supply Study

Table 13 - Gerber (1982) Recommended Lot Sizes for Septic System Nitrate Dilution

Soil Type	Natural Recharge Rate (gpm/acre)	Natural Recharge Rate (inches/year)	Acres Per Dwelling (approx)	Dwellings Per Acre (approx)
thin sand and gravel	0.74 gpm/acre*	14.3	1.3	0.8
thick sand and gravel	0.93 gpm/acre*	18.0	1	1
thin soil over rock	0.35 gpm/acre	6.8	2.7	0.4
thick silty till	0.17 gpm/acre	3.3	5.7	0.2
lacustrine silt and clay	0.12 gpm/acre	2.3	7.9	0.1

General Formula for calculating recommended housing densities:

$C_{nitrate} = C_b + (C_s X q_s X d) / q$

$C_{nitrate}$ is the resultant concentration of nitrate-nitrogen in ground water as a result of subsurface sewage disposal systems; maximum acceptable concentration = 5 mg/L (ppm)

C_b is the background concentration of nitrate-nitrogen in ground water, which is equal to about 0.25 mg/L (ppm) in a forested area

C_s is the concentration of nitrate-nitrogen in septic tank discharges that reach the ground water = 30 mg/L (ppm)

q_s is the average leachfield discharge rate per dwelling, which is equal to 70% of 300 gallons per day or 0.15 gallons per minute

q is the rate of Natural Recharge Rate in gpm/acre, averaged over the year

d is the allowable housing density in Dwellings per Acre, which is derived algebraically

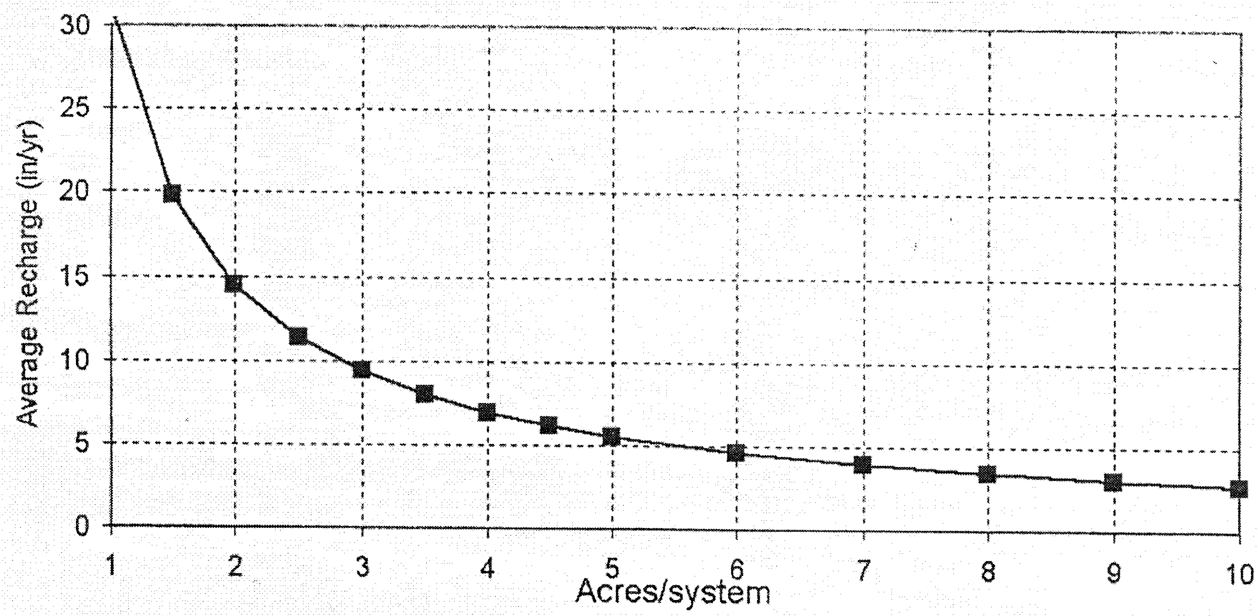
Method from Gerber,1982. Modified by The Chazen Companies, 1999

* In some locations, overland flow from adjacent upland areas flows onto sand and gravel areas and provides higher recharge rates. In such locations, smaller lot sizes may be supportable.

Gerber's thick and thin soil types may correlate approximately to SCS Hydrologic Group A soils.
Gerber's thin soil over rock type may correlate approximatley to SCS Hydrologic Group B soils
Gerber's thick silty till may correlate approximately to SCS Hydrologic Group C soils.
Gerber's lacustrine silt and clay may correlate approximately to SCS Hydrologic Groud D soils.

The Chazen Companies
September 2004

Table 14 – Recommended Lot Sizes for Septic System Nitrate Dilution



Source: A Recharge-Based Nitrate-Dilution Model for New Jersey, New Jersey Department of Environmental Protection Land Use Management, 2002

Typical annual aquifer recharge in Putnam County is approximately 7 inches. The method above recommends net density of septic systems equaling approximately 3 acres per system.

Table 15 – Town Water Consumption in Putnam County

Town (includes Villages)	Available Recharge (Table 9) (mgd)	Present Summertime Removal Rates+ (Table 1, column O)	% Removed from Aquifers (summer maximum)
Carmel	12.8 10.9*	2.0	16 18 *
Kent	14.5	1.0	7
Patterson	12.5	0.8	6
Philipstown (plus Cold Spring and Nelsonville)	19.9	0.4	2
Putnam Valley	16.2	0.5	3
Southeast (plus Brewster)	13.2	1.2	9

+Calculated as groundwater extraction rates compensated for by summertime septic system wastewater returns.
*approximately 15% of Carmel lies with Water District 1, which uses a surfacewater source of supply. Groundwater recharge in this area is largely inaccessible to wells in the balance of the Town, so effective available recharge is reduced to 85% of the Town.

Figures

Putnam County: Reference Map

Legend

Croton System Watershed Divide

Rivers & Streams

Lakes & Ponds

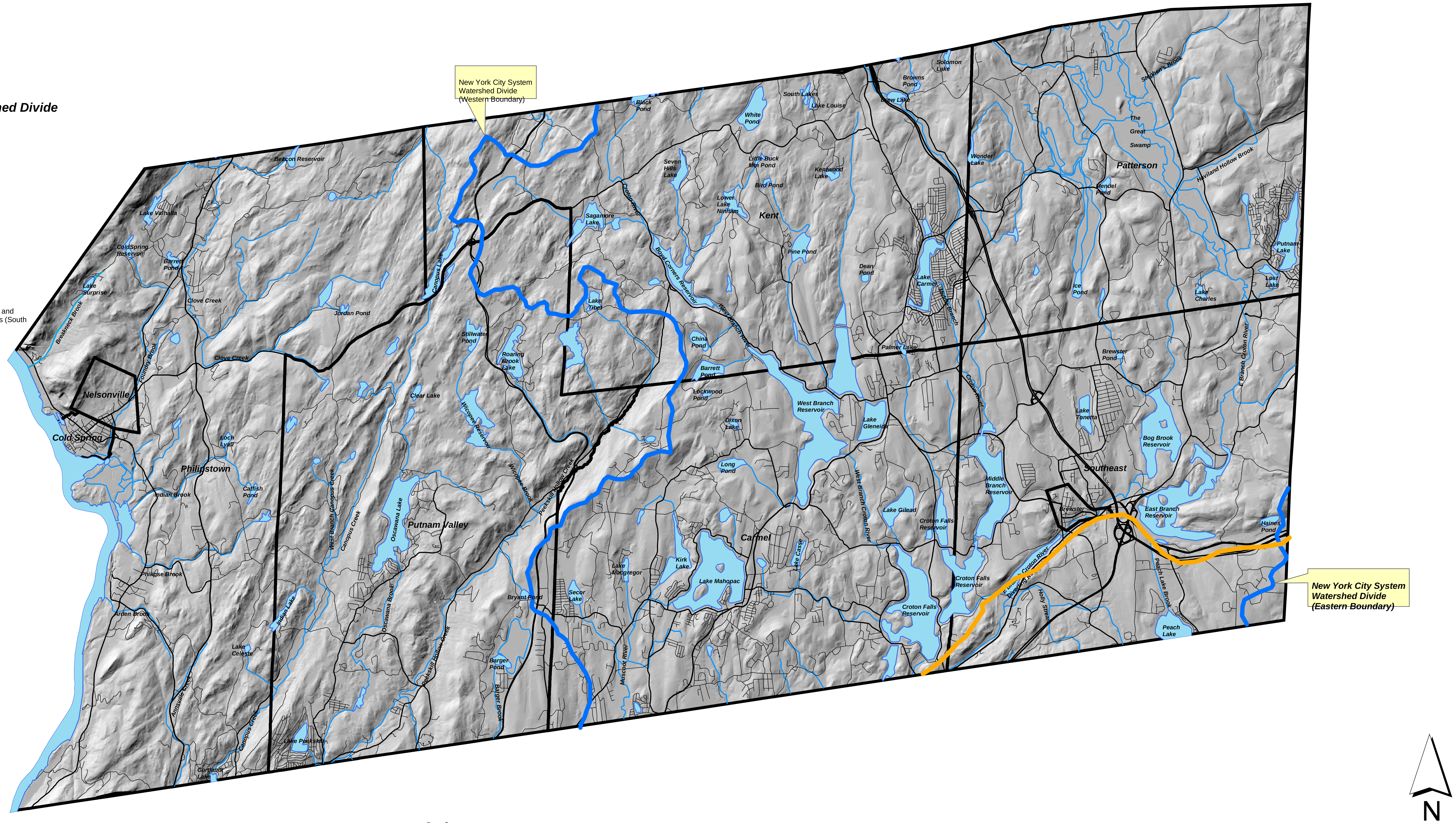
Road Types

Local Road

County & State Roads

Federal Road or Interstate

Approximate boundary between Hudson Highlands (North of Orange Line) and Manhattan Prong Physiographic Provinces (South of Orange Line).



Data Source:
Hillshade Plot calculated using ArcMap GIS software (ESRI), based on USGS Digital Elevation Model (DEM): (Azimuth 315 degrees/Altitude 45 degrees).
Roads, Municipal Boundaries, Hydrologic Features: Putnam County Divsion of Planning.
Geologic Boundary from NYS Geological Survey Bedrock Geology Map.
Croton System watershed divide was delineated and digitized on-screen by The Chazen Companies.

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Planners
Environmental Scientists
GIS Consultants

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North Country Office:
110 Glen Street
Glens Falls, New York 12801
Phone: (518) 812-0513

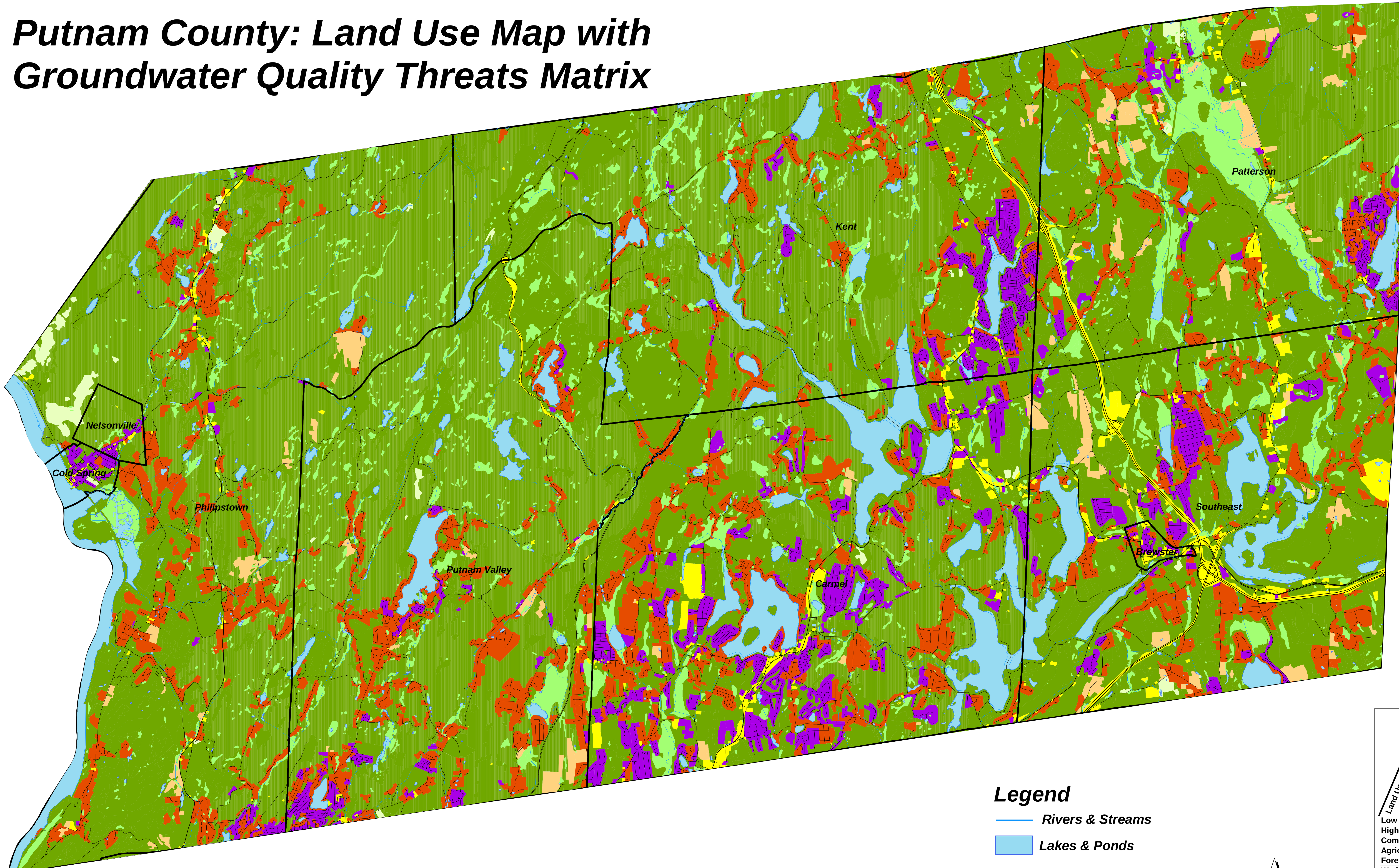
Figure 1: Putnam County Reference Map

Putnam County
Division of Planning & Department of Health
Groundwater Utilization & Protection Plan

Created by:	D. Michaud R. Urban-Mead
Date:	Sept. 2004
Scale:	1 inch = ~2 miles
Project #:	40214.00

Figure 1-Reference Map

Putnam County: Land Use Map with Groundwater Quality Threats Matrix



Legend

Low Intensity Residential*
includes areas mapped as low-density housing, residential, and single family units.

High Intensity Residential**
includes areas mapped as apartment complexes, medium density housing, mobile home parks, multi-family units, urban or built-up land, or residential hotels.

Commercial/Industrial
includes areas mapped as central business district, commercial and services, impervious services, industrial, suburban shopping centers, or office park/institutional, and golf courses.

Agricultural Land
includes areas mapped as agricultural land, rotated crop lands and pasture, permanent hay and pasture, orchards, groves, vineyards, & nurseries.

Forest & Managed Land
includes areas mapped as forest and mixed forest land, deciduous or coniferous forest land, managed land, or parks, brushland or successional land & shrub cover.

Wetland
includes areas mapped as forested and non-forested wetland.

Barren Land
includes areas mapped as barren land, strip mines, quarries, and gravel pits.

Water
includes areas mapped as water, streams, or canals.

Sources:
NYCDEP Land Use Cover (1992): Watershed Lands and Community Planning Department.
Roads, Lakes, Municipal Boundaries: Putnam County Division of Planning
Wetlands Areas follow NWI (National Wetlands Inventory) Datasets

*Low-Intensity Residential: Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80% of the cover. Vegetation may account for 20-70% of the cover. These areas most commonly include single family housing units. Population densities will be lower than in high-intensity residential areas. Residential areas with less intensive constructed coverage or vegetative clearing areas not mapped as a low-intensity residential land use.

**High Intensity Residential: Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20% of the cover. Constructed materialsaccount for 80-100% of the cover.

Legend

- Rivers & Streams
- Lakes & Ponds

Road Types

- Local Road
- County & State Roads
- Federal Road or Interstate

N

Groundwater Quality Threats Matrix

Land Use Type	Halogenated Solvents	Petroleum Products	Pesticides/Herbacides	Other Industrial Organics	Metals	Nitrates	Phosphorus	Sediments/Turbidity	Protozoa	Intestinal Bacteria	Intestinal Viruses	Salts	Industrial Radionuclides	Disinfection Byproducts
Low Intensity Residential	L(M)	L	L(M)	L	L	M(H)*	N	N	M	M	M*	L(M)	N	N
High Intensity Residential	L(M)	L(M)	M	M	L	M(H)	N	N	M(H)	M(H)	M(H)	M(H)	N(L)	N
Commercial/Industrial	M(H)	M(H)	M	L(M)	M	M	N	N	L(M)	L(M)	L(M)	M(H)	N(L)	N
Agricultural Land	N(L)	N(L)	L(M)	N(L)	N(L)	L(M)*	N	N	L(M)	L(M)	L(M)	L	N	N
Forest and Managed Land	N	N	N	N	N	N	N	N	L	L	L	N	N	N
Wetland	N	N	N	N	N	N	N	N	L	L	L	N	N	N
Barren Land	N	N(L)	N	N	N	L	N	N	L	L	L	L	N	N
Water	N	N	N	N	N	N	N	N	N	L	L	N(L)	N	N

*Modified by TCC from SWAP recommendation of "M" for Residential Nitrate and "H" for Intestinal Viruses and "M(H)" for Agricultural Land Nitrates.

N = Negligable Threat
L = Low Threat
M= Medium Threat
H = High Threat

Risk Rankings adapted by TCC to this study area from NYSDOH Source Water Assessment Program (SWAP) analyses.

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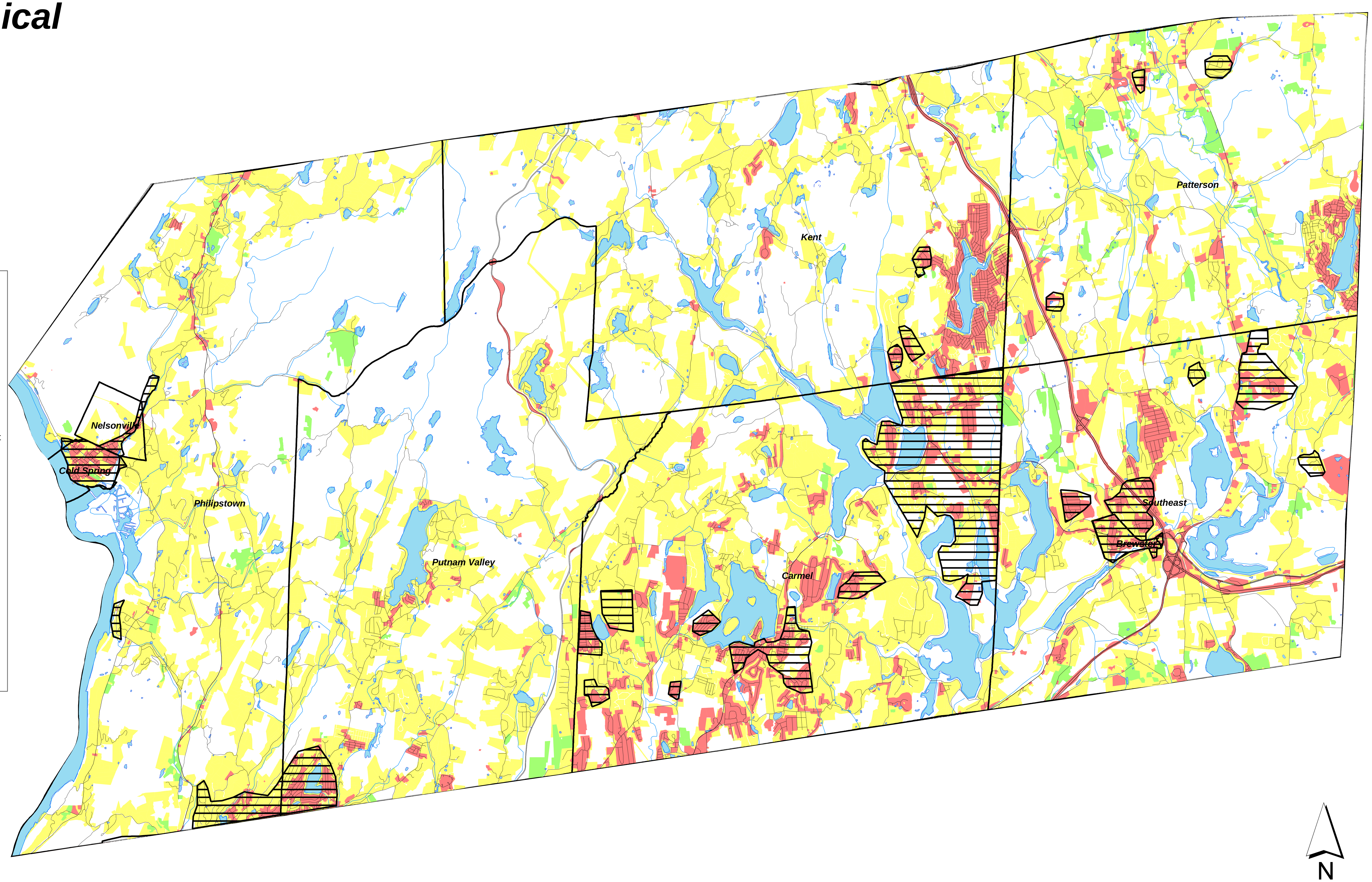
Figure 2: Land Use Map with Groundwater Quality Threats Matrix

Putnam County Division of Planning & Department of Health Groundwater Utilization & Protection Plan

Created by: D. Michaud, R. Urban-Mead
Date: Sept. 2004
Scale: 1 inch = ~2 Miles
Project #: 40214.00

Figure 2: Land Use Map

Putnam County: Chemical and Salt Threats Map



Groundwater Quality Threats Matrix- Chemical & Salt

Land Use Type	Halogenated Solvents	Petroleum Products	Other Industrial Organics	Metals	Salts	Industrial Radionuclides	Highest Resultant Risk
Low Intensity Residential^	L(M)	L	L	L	L(M)	N	L(M)
High Intensity Residential	L(M)	L(M)	M	L	M(H)	N(L)	M(H)
Commercial/Industrial	M(H)	M(H)	L(M)	M	M(H)	N(L)	M(H)
Agricultural Land	N(L)	N(L)	N(L)	N(L)	L	N	L
Forest and Managed Land	N	N	N	N	N	N	N
Wetland	N	N	N	N	N	N	N
Barren Land	N	N(L)	N	N	L	N	L
Water	N	N	N	N	N(L)	N	N(L)

N = Negligable Threat
L = Low Threat
M= Medium Threat
H = High Threat

^Includes all subdivided parcels under 2.5 acres (2002 tax parcel data set).
Risk Rankings adapted by TCC to this study area from NYSDOH
Source Water Assessment Program (SWAP) analyses.

Risk Color Scale

- Negligable Threat
- Low Threat
- Low to Medium Threat
- Medium Threat
- Medium to High Threat
- High Threat

Legend

- includes areas mapped as water, streams, or canals.
- *Water Districts* Impacts from chemical & salt threats are significantly mitigated in areas with central water.

Road Types

- Local Road
- County & State Roads
- Federal Road or Interstate

Sources:
NYCDEP Land Use Cover (1992): Watershed Lands and Community Planning Department, NYCDEP
Roads, Municipal Boundaries, Hydrologic Features: Cornell GIS Data Cooperative (CUGIR).
Water districts shown include only those of substantial areal coverage, within
which groundwater quality concerns are lessened.

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Environmental Scientists
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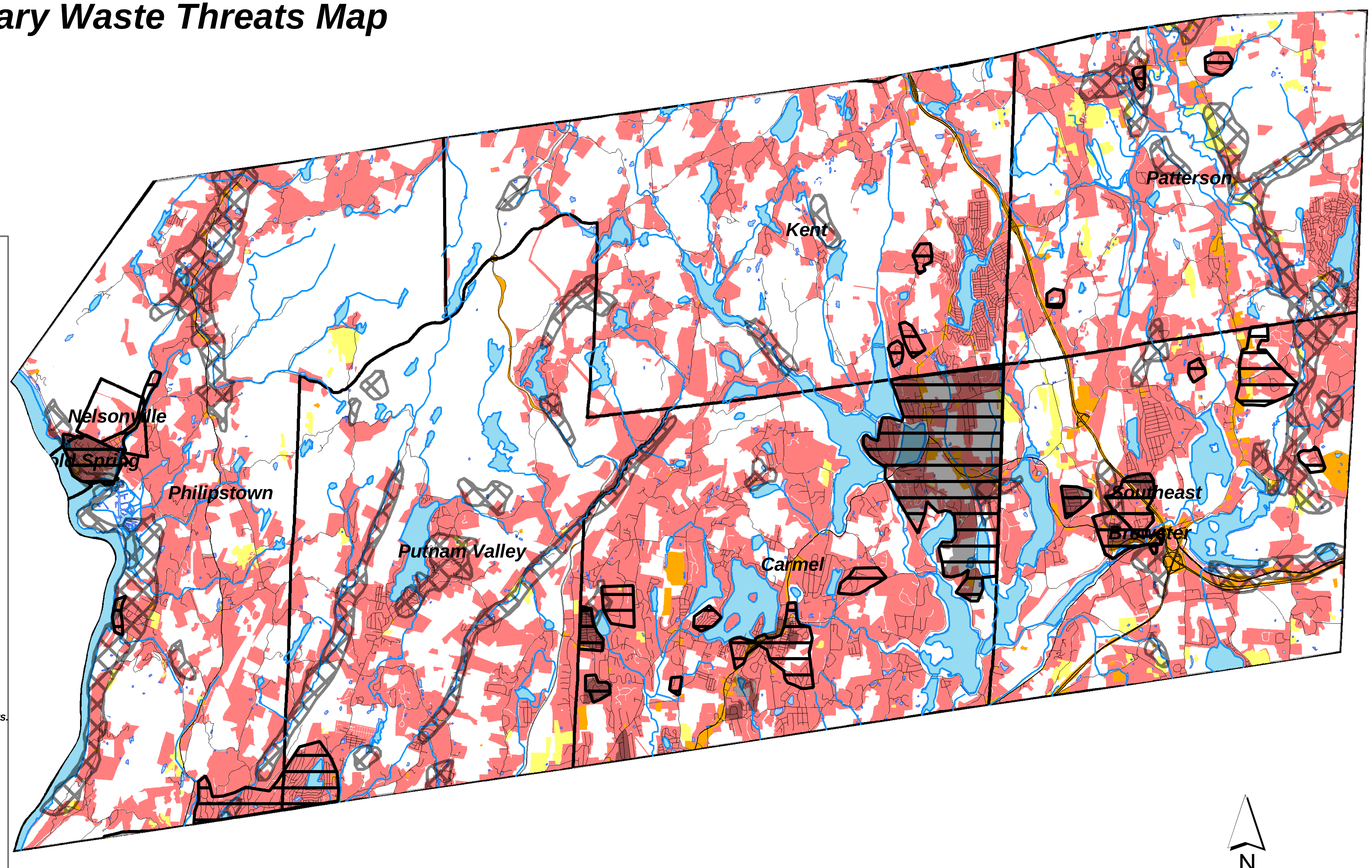
Figure 3: Chemical and Salt Threats Map

Putnam County
Division of Planning & Department of Health
Groundwater Utilization & Protection Plan

Created By: *D. Michaud*, *R. Urban-Mead*
Date: *Sept. 2004*
Scale: *1 inch = ~2 Miles*
Project #: *40214.00*

Figure 3: Chemical & Salt Threats

Putnam County: Sanitary Waste Threats Map



Legend

Groundwater Quality Threats Matrix- Wastewater Discharges

Land Use Type	Nitrates	Protozoa	Intestinal Bacteria	Intestinal Viruses	Highest Resultant Risk
Low Intensity Residential^	M(H)*	M	M	M*	**M(H)**
High Intensity Residential	M(H)	M(H)	M(H)	M(H)	**M(H)**
Commercial/Industrial	M	L(M)	L(M)	L(M)	**M**
Agricultural Land	L(M)*	L(M)	L(M)	L(M)	**L(M)**

N = Negligable Threat
L = Low Threat
M= Medium Threat
H = High Threat

^ Includes all subdivided parcels under 2.5 acres from (2002 parcel data).
*Modified by TCC from SWAP recommendation of "M" for Residential Nitrate, "H" for Intestinal Viruses, and "M(H)" for Agricultural Nitrate.

Risk rankings adapted by TCC to this study area from NYSDOH Source Water Assessment Program (SWAP) analyses.

Risk Color Scale

- Negligable Threat
- Low Threat
- Low to Medium Threat
- Medium Threat
- Medium to High Threat
- High Threat

Water Districts

Road Types

- Local Road
- County & State Roads
- Federal Road or Interstate

Aquifers with sandy soils where higher recharge helps dilute septic waste discharges.

Sewer Districts where domestic wastewater is not discharged to aquifers.

includes areas mapped as water, streams, or canals.

Impacts from septic threats are greatest in areas shown in pink (medium to high threat level), and is eliminated in areas supplied by sewer services, and significantly mitigated in areas with sandy soils or central water.

Sources:
NYCDEP Land Use Cover: Watershed Lands and Community Planning Department.
Roads, Municipal Boundaries, Hydrologic Features: Putnam County Divsion of Planning & Cornell GIS Data Repository (CUGIR).
Surficial Geologic Cover: Cornell University GIS Data Repository
Sewer Districts: Digitized onscreen based on information from Putnam County Department of Health & Town of Carmel.
Tax Parcels: Putnam County Division of Planning (2002).
Water districts were digitized onscreen by TCC using NYSDOH maps.
Sewer and water districts shown include only those of substantial areal coverage, within which groundwater quality concerns are lessened.

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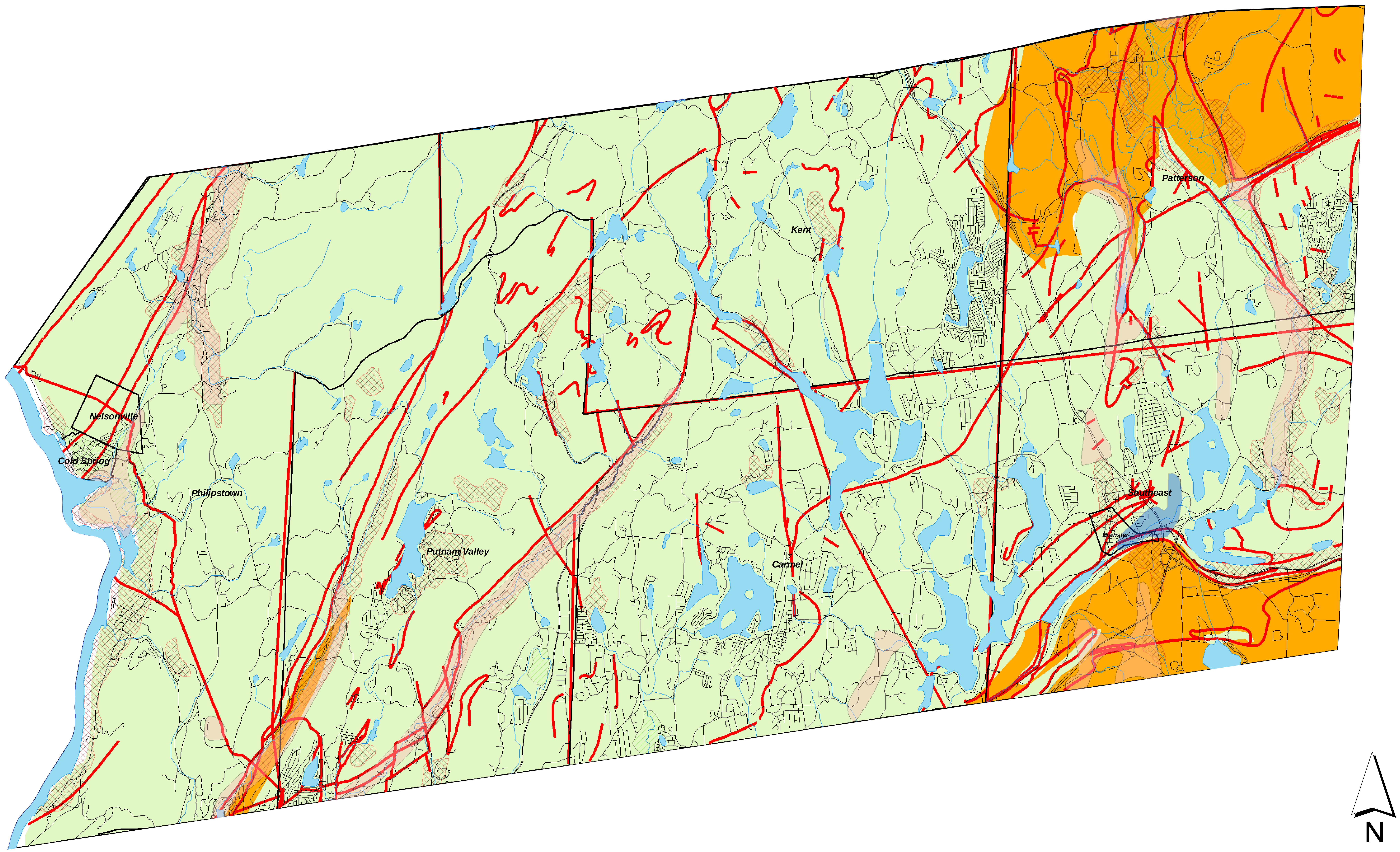
Figure 4: Sanitary Waste Threats Map

Putnam County
Division of Planning & Department of Health
Groundwater Utilization & Protection Plan

Created by: *D. Michaud*, *R. Urban-Mead*
Date: *April 2003*
Scale: *1 inch = 5000 feet*
Project #: *40214.00*

Putnam County: Bedrock & Surficial Aquifers



Legend

- Rivers & Streams
- Lakes & Ponds

Road Types

- Local Road
- County & State Roads
- Federal Road or Interstate

- Municipal Boundaries
- Lacustrine Delta, Lacustrine Silt & Clay, or Swamp Deposits

Glacial till or areas of exposed bedrock left blank.

Surficial Aquifer

- Outwash Gravels, Kame Deposits & Aquifer Materials (Approx. Locations)

Potential Yields

- 10-100 gallons per minute (gpm)
- Greater than 100 gpm

Bedrock Aquifers & Faults

- Lower Yield Bedrock Aquifer
- Higher Yield Bedrock Aquifer
- Major Faults

Sources:
Roads, Municipal Boundaries, Hydrologic Features: Putnam County Divsion of Planning & Cornell GIS Data Repository (CUGIR).
Surficial Geologic Cover and Surficial Aquifers: Cornell University GIS Data Repository from NYS Geologic Survey and USGS.
Generalized Bedrock Geology: Modified by The Chazen Companies from Statewide Bedrock Geologic Map of New York, NYS Geologic Survey.

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Figure 5: Bedrock & Surficial Aquifers

Putnam County
Division of Planning
Water Resource Investigation

Created by: D. Michaud, R. Urban-Mead
Date: Sept. 2004
Scale: 1 inch = ~2 Miles
Project #: 40214.00

Putnam County: Bedrock Geology with Mine Sites

Sources:
Roads, Municipal Boundaries: Putnam County Division of Planning & Cornell GIS Data Repository (CUGIR).
Bedrock Geology from Bedrock Geologic Map of New York, NYS Geologic Survey via Cornell GIS Data Repository (CUGIR).
Mine locations plotted as a result of research by The Chazen Companies.
Well-log data provided by Putnam County Dept. of Health.

Figure 6: Bedrock Geology and Mines

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Figure 6: Bedrock Geology of Putnam County with Mine Sites

Putnam County
Division of Planning& Department of Health
Groundwater Utilization & Protection Plan

Created by: D. Michaud, R. Urban-Mead
Date: April 2003
Scale: 1 inch = ~2 Miles
Project #: 40214.00

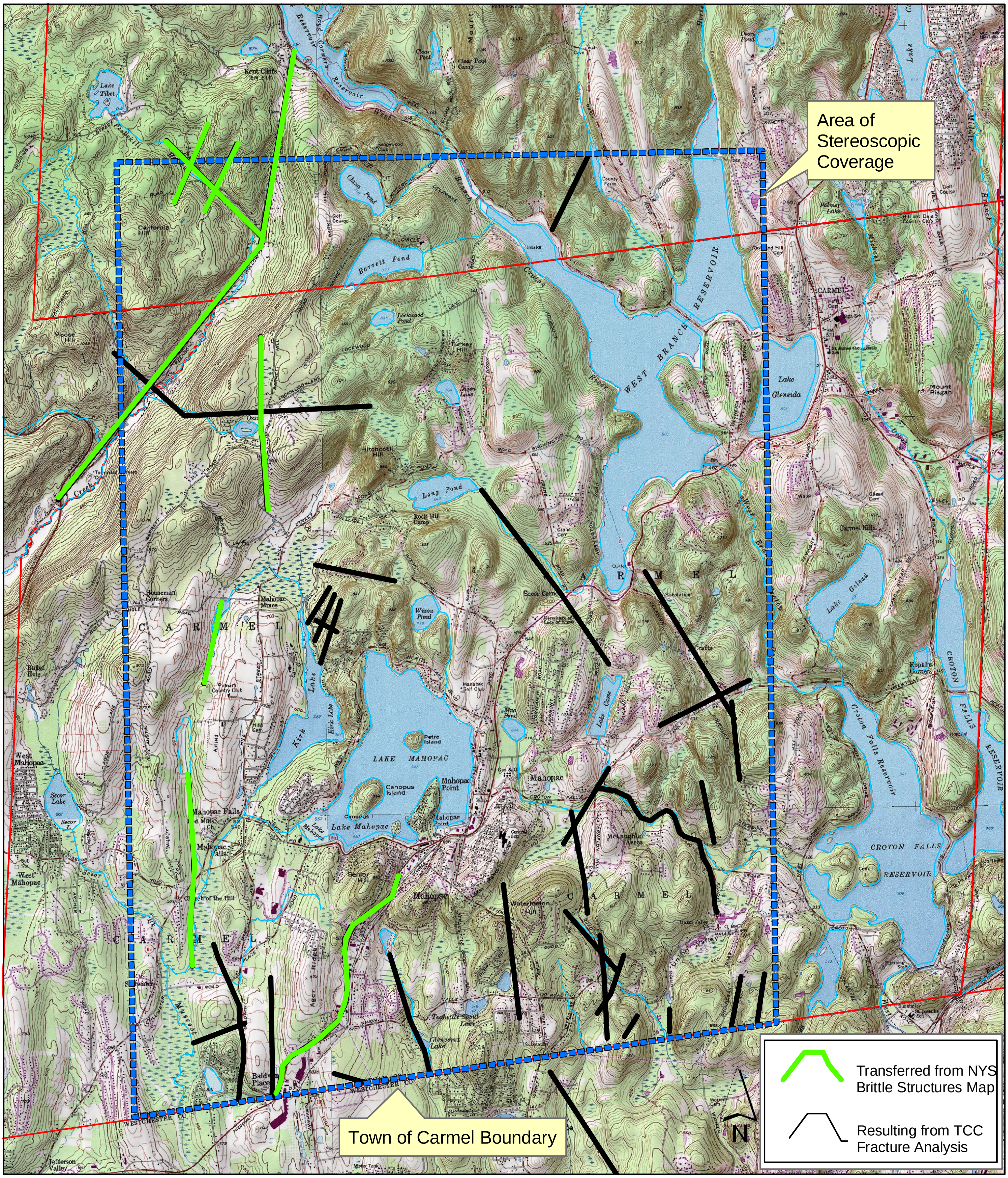

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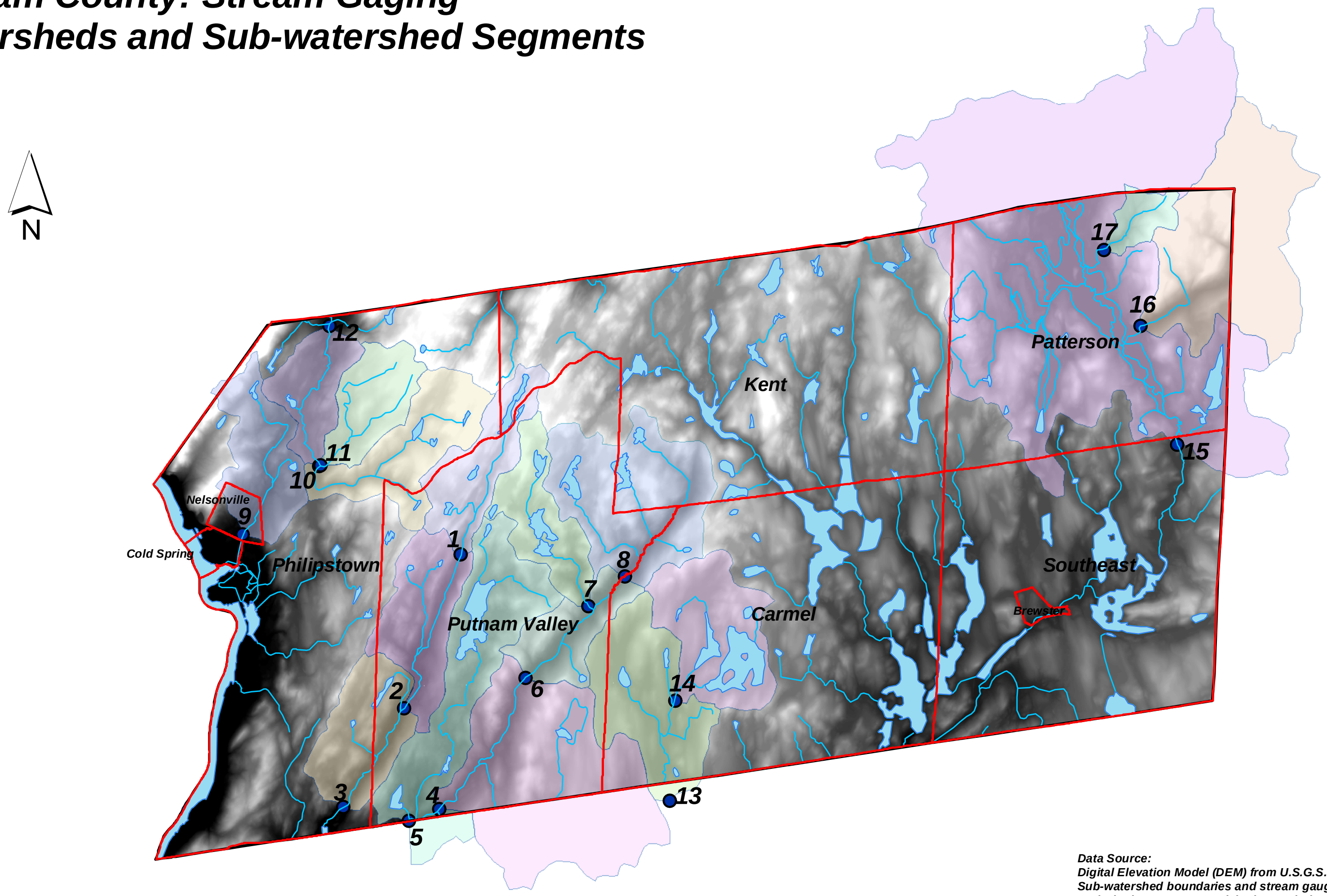
Figure 7- Part-Town Linear Feature Analysis for Carmel

Putnam County
Division of Planning & Dept of Health
Groundwater Utilization & Protection Plan

Created by: DM RUM
Date: Sept 2004
Scale: 1 inch = 5,000 feet
Project #: 40214.00

Putnam County: Stream Gaging Watersheds and Sub-watershed Segments



Legend

- Rivers & Streams
- Stream Gaging Locations
- #1 - Canopus @ Sunken Mine Rd
- #2 - Canopus @ Cimarron Rd
- #3 - Canopus @ Canopus Hollow Rd
- #8 - Peekskill Hollow @Taconic Parkway
- #7 - Wicopee Brook
- #6 - Peekskill Hollow @ Rtes 20 & 21
- #4 - Peekskill Hollow @ P.H. Rd
- #5 - Peekskill Hollow below Oscawana Brook
- #9 - Foundry Brook @ Rte 9D
- #10 - Clove @ Campbell Rd
- #11 - Clove @ Campbell Rd; Unnamed Tributary
- #12 - Clove @ Post Rd
- #13 - Muscoot @ Rte 6
- #14 - Muscoot @ Potter Rd
- #15 - Croton @ Rte 65
- #16 - Haviland Hollow Brook
- #17 - Stephen's Brook near Rte 22
- Lakes & Ponds
- Towns/Villages

DEM Values

High : 1545 fasL (feet above sea level)

Low : 0 fasl

Data Source:
Digital Elevation Model (DEM) from U.S.G.S.
Sub-watershed boundaries and stream gauging locations were digitized on-screen by TCC, (2003).
Hydrologic Features, Municipal Boundaries provided by Cornell GIS Data Repository (CUGIR) and Putnam County Division of Planning, respectively.

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Figure 8: Stream Gauging Watersheds and Sub-watersheds Segments

Putnam County
Division of Planning & Department of Health
Groundwater Utilization and Protection Plan

Created by: D. Michaud, R. Urban-Mead

Date: Sept. 2004

Scale: 1 inch = 19,600 feet

Project #: 40214.00

Appendices

Appendix A: Well Log Analysis

Well Log Analysis
The Chazen Companies

County-wide descriptive hydro-statistical analyses were performed using a database of more than 5,400 private water supply wells available from the Putnam County Department of Health offices. Installation dates of the wells range from the 1960s to the mid-1990s. These had been transferred previously from paper records to digital format. The well-log database included well tax parcel I.D., construction details, installation date, geology, yield, and additional information not relevant to this statistical study. Most if not all well logs were for bedrock wells, so this analysis focuses solely on bedrock aquifer characteristics.

Precise geographic coordinates for each well were not available because wells in the dataset were installed before integration of hand-held Global Position System (GPS) units into field operations. Each well was therefore initially plotted at the centroid of tax parcel polygons in a Geographic Information System (GIS). To correct for large location errors, TCC repositioned the well locations over county orthophotos, and well locations were moved manually from parcel centroids to each site's main structure (i.e. private residence, manufacturing building, etc.). In general, this correction is believed to reposition each well within approximately 100 feet of its actual location because most wells are drilled near their functional structure. On some large parcels, wells were manually moved up to thousands of feet to the main parcel structures.

Some remaining georeferencing difficulties included the following:

1. There are some parcels where well logs were provided but no structures were observable on orthophotos, suggesting a parcel ID error or lands where wells were installed but no structures have been built;

2. Some larger parcels contained many wells, making it difficult to know where to estimate the proper locations for wells.

Well logs associated with sites as described above were not relocated from centroids postings.

This study included yield and well depth comparisons with several variables, including bedrock geologic formation, surficial formation, elevation, and other characteristics.

Publicly available county-wide geographic coverages were used to help with spatial analyses of the well log database. In addition, TCC generated two temporary GIS coverages:

1. An elevation of approximately 450 feet asl was defined to distinguish between lower-elevation (valley setting) and higher elevation (hillsides and upland) areas. The elevation dataset was generated from the USGS Digital Elevation Model defining areas above and below 450 feet asl. This allowed the testing of the effect of well yield and depth within each of these elevation classes.

2. Fracture and lineament locations were determined from stereoscopic work for a portion of the Town of Carmel, as described elsewhere. The resultant lineaments were digitized into the GIS to assess whether wells near fractures produce higher yield than wells farther from fractures.

Driller-reported well yield and depth values are defined as "endogenous variables," meaning that the well's installed specifications are driven by the well owner's water needs (Moore et al., 2002). Such wells are only drilled to depths that meet homeowner's needs, rather than being installed to uniform depths that would simplify statistical analysis. Using domestic well yields as statistical indicators of regional aquifer can mischaracterize true aquifer characteristics unless both depth and yield are considered simultaneously.

Various spatial queries were completed by TCC to sort wells according to spatial characteristics such as bedrock lithology and elevation using a Geographic Information System (GIS). The Putnam County GIS was constructed using ESRI software (ARCMap, Version 8.2). Spatial queries were designed to test the following variables:

- Bedrock geology versus well depth and yield;
- Unconsolidated geologic cover effects on bedrock well yields and depths;
- Average well depth and yield over time;
- Well elevation versus well depth and yield.

Spatial arguments were designed in the GIS to sort wells according to geographic location and then consider additional variables. The resultant well data subsets were exported to spreadsheet software for statistical parameter calculation. Typically, average, median and mode values were calculated for yield and depth, (unless yield was expressed as a function of depth), with some standard deviations also calculated. To address differences between wells drilled to various depths, these analyses were conducted by sorting wells into depth families of one hundred foot classes. Reported yields are for all wells finished to a certain depth range. It is important not to interpret that given yields come from the stated interval (e.g. yields for wells drilled between 200 and 300 feet deep addresses yields from wells between 200 and 300 feet deep, not from the geologic horizon between 200 and 300 feet).

Yield and depth statistics of wells in each bedrock formation identified two general bedrock groupings, separable on the basis of average yield potential and total average depth (Table 4 – main report). Lower yield formations included granite and gneissic complexes of the Hudson Highlands. Higher yield formations consisted of carbonate and schistose metamorphic rocks. Three granitic sub-classes suggested high yield characteristics but were left grouped with lower yield formations based on the low number of well installed in the formation and their overall geologic similarity to the lower yield formations. Similarly, some carbonates lay on the boundary between low and high yield sub-groups, but were left with the higher-yield formations based on geologic similarities. The locations of these higher yield and lower yield bedrock formations are spatially displayed on figures in body of the parent report.

Summaries of further statistical analysis follow:

- Statistical analysis of low and high yield bedrock groupings show on Table 4 (main report) indicate that average yields in the higher yield sub-group remain high in all well depth groupings. Average yields for wells in higher yield formations, with depths down to 400 feet average more than 20 gpm, compared to low yielding formations, in which average yields are between 10 and 15 gpm. Approximately 91% of all bedrock wells in Putnam County's georeferenced well log database lie in lower-yield formations and 9% lie in higher yielding formations.

- Elevation statistics were evaluated without bedrock type sorting (Table 5 – main report). For all wells down to 400 feet deep, lower and higher elevation wells yields are generally similar. However, valley bottom wells installed deeper than 400 feet show clear statistical yield improvements over wells installed in upland areas.

- Bedrock sub-grouping and overburden cover characteristics were combined to evaluate whether bedrock wells installed through high porosity unconsolidated cover (sand and gravel on the NYS surficial geologic map) showed enhanced yields from bedrock formations (Table 6 – main report). The analysis shows only small yield advantages for wells completed under permeable soils (Table 7), if any. This data seems to indicate that overall, wells drilled in higher-yield formations are slightly deeper than those installed in lower-yield formations.

- Table 7 indicates that average well depths have generally increased between 1970 and 1999. We believe this is related to several factors, including sequential development of increasingly remote or complicated sites, increased homeowner demands for water, and perhaps changes in drilling techniques. Based on the County groundwater budget estimated for this project and on the continuing baseflow discharges to the County's streams, we would estimate that this trend is not related to regional decreases in the watertable.

Appendix B: Linear Feature Method

Linear Feature Analysis
The Chazen Companies

Photogeologic fracture traces (or simply fracture traces) are natural linear features consisting of topographic (including straight stream segments), vegetation, or soil tonal alignments, visible primarily on aerial photographs, and expressed continuously for less than one mile. Similar features greater than one mile in length are referred to as lineaments. This type of mapping is particularly useful for prospecting potential high yielding wells in fracture-flow dominated bedrock aquifers, such as those found in Putnam County.

Black and white aerial photographs for the subject area (10 X 10", matte finished, 1:35,000 scale), dated 10-24-74, were obtained by TCC from the USDA-FSA Aerial Photography Field Office, Salt Lake City, Utah. Six photos were used for the analysis, each affording a two-thirds overlap of common area in adjacent photos for stereoscopic (3-D) viewing (see Figure 7 – main report). The photos were studied using a portable stereoscope (10X magnification), and area features were noted using mylar overlays and colored pencils.

All water bodies, stream systems, vegetation tonal anomalies, major anthropogenic features, and information from New York State Bedrock Geology, Surficial Geology, and maps were first delineated. These delineations were used to consider, reject, or verify the possibility of fracture traces. Fracture trace and lineament interpretations were then made based on photo identification of non-anthropogenic linear features including the following criteria:

1. Surface Sags and Depressions

2. Breaks in topographic slope oblique to stratigraphic and structure strike

3. Straight segments and abrupt changes in valley alignment and angular relationships with tributary valleys.

4. Gullies and tributary valleys that are oblique to the local or regional topographic slope.

5. Soil tonal zones, often darker gray in tone, reflecting increased moisture content, accumulation of organic matter, and/or eroded soil profiles on adjacent uplands.

6. Soil tonal zones, often lighter in gray tone, reflecting better subsurface drainage of soil water.

Delineated linear features interpreted as fracture traces noted by TCC generally trend north-south, following criteria features listed above, with few trending differently than the prevailing orientation.

Appendix C: Stream Gauging Assessment

The following general comments summarize gauging data presented on Table 10. Comments are organized from upstream to downstream segments, by basin. Yield values are relative only to one another but provide insight on aquifer variability in these study areas. The geologic settings are characteristic of geologic areas throughout Putnam County:

Canopus Creek:

Station 1. Groundwater support to this stream segment is among the lowest in the County, likely limited by headwater silty till over low-yield bedrock formation, limiting aquifer recharge and storage capacity.

Station 2. Groundwater discharge remained low between stations 1 and 2 in spite of surficial deposits located between the two stations. These surficial deposits are therefore suspected to be low-yield in nature.

Station 3. Modest groundwater flow gain was observed between stations 2 and 3, suggesting that these surficial deposits contribute more to aquifer recharge and storage capacity than the sediments between stations 2 and 1. The greatest potential yield capacity for future community or private wells in this valley would appear to lie between stations 2 and 3.

Peekskill Hollow Creek

Station 8. Modest flows were observed at this headwater station. The stream segment contains surficial deposits that may be supporting higher aquifer discharges.

Station 7. Controlled discharges are assumed to have been occurring from the Wiccopee Reservoir during this sampling event, leading to unreasonably high flows relative to the contributing watershed acreage. The calculate gpd/acre value is not supportable by normal aquifers during dry conditions.

Station 6. Calculated stream growth between station 6, and stations 7 and 8 indicates that stream gain over this watershed segment is 230 gpd/acre. This is a strong aquifer discharge value relative to other segments. This yield may be related to permeable surficial aquifer materials and potential groundwater migration from fractures in the underlying bedrock aquifer.

Station 4. Calculated stream growth between station 4 and 6 indicates that stream gain over this watershed segment is 159 gpd/acre. This is also a strong aquifer discharge although not as strong as the aquifer discharges supported upstream or downstream within this same valley (cf. Stations 6 and 5).

Station 5. Calculated stream contribution from the Oscawana Brook and discharges along the Peekskill Creek up to station 4 continues to identify strong aquifer contributions of 286 gpd/acre. Underlying aquifers supporting this discharge include the surficial aquifer, carbonate bedrock, and potential faults underlying Peekskill Hollow. The surficial aquifer is estimated to contain sediments capable storing and transmitting groundwater.

Cold Spring

Station 9. Flow in Foundry Creek was low compared to other values. No mapped high-capacity bedrock or surficial aquifers have been noted in this drainage.

Clove Creek

Station 10. Extremely low flow was observed emerging from this headwater segment. The segment includes no surficial aquifers and drains bedrock formations only typically associated with lower yield wells.

Station 11. Low groundwater yield was also observed from this stream segment. Again, the segment includes no surficial aquifers or bedrock formations typically associated with lower yield wells.

Station 12. Calculated stream contribution from the Clove Creek downstream of Stations 10 and 11 indicate strong aquifer contribution of 277 gpd/acre. Underlying aquifers include a surficial aquifer known to contain sand and gravel sections; potential bedrock faults may also follow the alignment of the valley.

Muscoot River

Station 14. Groundwater and potential reservoir overflow from Lake Mahopac support modest stream flows. Aquifers in this subwatershed typically support only low yield wells. There are no known overlying productive surficial aquifers in this location.

Station 13. Continuing modest aquifer baseflow discharges were observed between stations 13 and 14. Aquifers in this subwatershed are consistent with those noted above Station 14.

East Branch Croton River

Stations 16 and 17. Low aquifer baseflow discharges were observed coming from these headwater streams. Each subwatershed drains upland bedrock formations covered by no known sand and gravel sediments.

Station 15. Calculated stream contribution from the East Branch Croton River downstream of stations 16 and 17 indicate continuing modest aquifer contributions of just 84 gpd/acre. Underlying aquifers include an extensive surficial aquifer and a carbonate formation supporting some of the highest-yielding wells in the County; however, the stream gauging data suggest that the sediments in the valley likely consist primarily of fine-grained lacustrine deposits which may limit overall recharge into the carbonate formation. Alternatively, wetland evapotranspiration losses from the Great Swamp may be so high that the recorded stream gauging flow underestimates the volume of water actually discharged by the local aquifer systems.