Analyzing Connecticut's Conservation Policies: A Case Study of Newtown, CT

Over 300 years of New Englander's living in Connecticut the landscape has changed a lot, from old growth forest, to clear cut agriculture, and finally back to what we see today as fragmented second growth forest. Through the years the state's residents have etched out their lifestyles development into nature.

In recent years, the town commissions have increased their interest in land conservation, restoration, and open space within Connecticut. With this interest there has been increased education of the commissions responsible for enforcing regulations based on this conservation initiative. They are responsible for protecting each town's natural resources for future generations. The commissions range from conservation, inland-wetlands, planning and zoning, and others. Unfortunately, some Connecticut towns have not established all commissions allowed by state statute. Also, not all towns have separated inland/wetlands and conservation commissions into two entities. Also many times in a combined inland/wetlands conservation commission the inland wetlands responsibilities take precedent of the conservation duties, which primarily include open space acquisition and preservation. This is an important detail because it can change a town's policy since each commission can have its own conflicting perspectives on what should be conserved for future generations.

There can also be watershed associations and land trusts set up in the towns, usually not for profit, that assist in the ideals of open space resource conservation and restoring nature to the way it was before urbanization. Unfortunately, this is a daunting task because Connecticut's landscape has changed so dramatically that it is hard to say what is natural. Management of the resources could be one of the only options left to help bring the state and towns into a smart growth pattern.

This conservation initiative couldn't come at a better time with Connecticut's growth exponentially rising causing an increase in fragmentation of what could be open space. Even though Connecticut's landscape is 59.3% forested land 41.2% is fragmented forest, only 18.1% is interior forest (Center for Land Use Education and Research, UCONN). In addition to the fragmentation, the increase in development has brought more impervious surfaces, like roads, which usually drain into the watercourses. With this drainage there is an increase in nutrient and thermal pollution increasing stresses on the flora and fauna species that help to keep those systems categorized as healthy. There is no question that each town has different scenarios with their growth patterns, but many are trying to balance economic development and the protection of natural resources for future generations.

In the case of Newtown Connecticut, one of the fastest growing towns in the state, development has increased exponentially. The town is managing this growth in a resourceful fashion by updating all of its planning and zoning regulations and creating new open space requirements. For instance, the town deducts slopes that are more than 25%, and deducts wetlands for its total calculation of usable lot area. Also, large developments must establish 15% of the total acreage to open space, or pay a fee in lieu to purchase or maintain that open space area.

ADD Paragraph concerning the GIS program and its use in planning etc.

In my thesis I will be using Newtown Connecticut as a case study of the 21^{st} century growth patterns and conservation initiative. Using data from the town and from UCONN's CLEAR information I will be analyzing the town's development from 1985 to 2007. Also I will be calculating the percent increase of impervious surfaces using ISAT (Impervious Surface Analysis Tool) a ArcGis 9.2 extension created by NEMO. Also land that is greater than 25% sloped and known wetlands will be calculated and calculated decrease, if applicable, will be analyzed. I will also be using a computer program compatible with ArcGis 9.2 called Community Viz which will help to map out impacts of development on forest resources and show fragmentation through town. This is an important aspect of getting to know Newtown's urban growth because it actually quantifies what has been nearly impossible to visualize.

In another section of my thesis I will use 2006-2007 thermal pollution data from Deep Brook River to determine if impervious surface increases have a negative effect on waterway ecosystems. This data will be correlated through the percent increase mapped out using ISAT.

I will also be going through town clerk subdivision maps from 1957, the time planning and zoning was initiated, to today. With these maps I will be creating GIS data layers to demonstrate the change the town has seen since the commission started to regulate development. It will also be interesting to analyze the historical significance of Connecticut's planning regulations since they were purchased from a Florida based company, and it is ironic that Florida is known for strip malls which many Connecticut town's now have dotted along their landscape. By examining this relationship it is easy to understand that the New England character of close community development was bought out in 1957. Also with these data layers I will be able to calculate the percentages of approved subdivisions throughout those years compared to census data, and compare the planning regulations to each year's conservation initiative.

Also after carefully analyzing the town's conservation strategies and land use strategies I will come up with suggestions for the town's future development and planning to reduce the amount of ecosystem fragmentation, as well as help the town in creating conservation plans for unique ecosystems like vernal pools.

METHODOLOGY

The analysis outlined below was used to create data for five categories of interest. They include the town of Newtown's percent impervious cover for watersheds, percent impervious cover within 100 feet of wetlands and watercourses, percent impervious cover within 300 feet of wetlands and watercourses, percent impervious cover within the aquifer protection area, and percent impervious cover within the aquifer recharge areas all within the year of 2002[1]. Also described below is the methodology used to create the average percent impervious coverage within the town's residential zones—R-1, R-2, and R-3. Within the analysis ESRI's ArcGIS 9.2 will be utilized to create individual layers that will calculate for the above mentioned five categories. The results from the watershed based analysis will provide the data necessary to back up the data created from the second residential analysis to create policy for the town's residential areas.

Data Utilized

Utilizing ArcGIS the procedure for creating the overall impervious cover for Newtown required several processing steps. First, data was obtained from the town's Geographic Information Systems and Technology Department; which included 2002 aerial black and white digital orthophotography,[2] and the town's 2002 planimetric data[3].

[1] The year 2002 was used because this is the data that was provided by the town of Newtown, CT, and data for 2007 was not compiled by the town as of yet.

[2] Taken at national map accuracy standards—1"=100ft—which is federally mandated for maps used in any government (Golden Aerial 2002). They were "standards established in 1941 by the U.S. Bureau of the Budget to set accuracy standards for all federally produced maps. The current standards were revised in 1947 as United States National Map Accuracy Standards (http://gislounge.com/national-map-accuracy-standards-nmas/)."

[3] Planimetric data is a two dimensional representation of any geographical space (http://www.extension.umn.edu/distribution/naturalresources/components/DD6097hr.html). This planimetric data was created using the 2002 black and white photography and had two quality control checks including GPS control point (Golden Aerial 2002).

Listed in the table is the all of the town's planimetric, or feature data, as well as other GIS features utilized for the analysis (Table 1). The data obtained by the town was buildings, streams, open water, aerial wetlands, forested areas, and road edges. Even though the aquifer protection district and aquifer recharge areas were obtained from the town they were created by the town's GIS and Technology Department using a 1974 study of aquifers done by the United States Geological Survey (USGS). Also, the sub regional watershed data that was retrieved from the Connecticut Department of Environmental Protection (CTDEP) was modified using the town's boundary to only include the watersheds within the town. Within all of the GIS features—except for the aquifer recharge areas and aquifer protection area—used there are more defined categories. For example, the buildings feature includes buildings, decks, patios, pools, concrete slabs, foundations, greenhouses, ruins, steps, and courtyards. The open water feature includes dams, docks, retaining walls, lakes, reservoirs, and rivers. The forested area feature includes orchards and vegetation. The road edges feature includes bridges, driveways paved and unpaved, parking paved and unpaved, roads paved and unpaved, and sidewalks. Also the sub watershed regions feature includes nine regions. These regions are Aspetuck River, Deep Brook, Halfway River, Limekiln Brook, Pequonnock River, Pond Brook, Pootatuck River, and Shepaug River.

Table 1. List of GIS Layers Used in Analyzing Impervious Surface in Newtown, CT.

Feature	**Type**	**Source of Data**
Buildings	Polygons	Town of Newtown, CT
Streams	Line	Town of Newtown, CT
Open Water	Polygon	Town of Newtown, CT
Aerial Wetlands	Polygon	Town of Newtown, CT
Forested Areas	Polygon	Town of Newtown, CT
Road Edges	Polygon	Town of Newtown, CT
Sub-Watershed Regions	Polygon	Connecticut Department of Protection

Newtown Aquifer Protection District	Polygon	Town of Newtown, CT
Newtown Stratified Aquifer Recharge Areas	Polygon	Town of Newtown, CT
Town Line	Polygon	Town of Newtown, CT
2002 Parcels	Polygon	Town of Newtown, CT
Newtown Zoning	Polygon	Town of Newtown, CT
Borough Zoning	Polygon	Town of Newtown, CT

Merged Features

Once the feature data was uploaded into ArcGIS certain data needed to be in polygon form. The data features utilized in this step were buildings, streams, open water, aerial wetlands, forested areas, and road edges. All features are polygons except for the stream data feature. Converting all the data to the same feature type takes a few steps, and these conversions are mainly applied in the ArcInfo licensed product from ESRI's ArcGIS. All of the following steps were necessary for the data to be utilized in creating a land use layer.

The first step was to create definitions[4] based on certain characteristics for the features and feature's attributes to be merged to create new feature layers (Table 2). This process is necessary to break out a developed layer that will be utilized as the impervious surface layer. The other layers created from this merging process were agriculture, turf-grass, wetland, mine-exposed earth, and water. So, in utilizing each feature their attributes needed to be examined to see if they met the characteristics of the new definitions. Naturally, developed included all attributes in the buildings and road edges features, but it also included attributes from open water— dams, docks, retaining walls.

[4] The definitions were based off of the University of Connecticut's Center for Land use Education and Research's land cover category descriptions (http://clear.uconn.edu/projects/landscape/category_description.htm.)

For now the agriculture feature included orchards from the forested feature's attributes. Wetlands stayed the same because there were no other attributes to merge. With the water feature only what was left in open water— lakes, reservoirs, and rivers—were merged with streams—before this merge was completed the streams layer was converted to a polygon. [5] Lastly, mine-exposed earth was yet to be created using the 2002 aerial photography. All of these layers collectively make up what will be the 'landuse' layer.

Once these new data features were created a new geodatabase was created called landuse was created. First all of the features were converted to polylines. Once the features were converted to polylines label points were then created. Now that the points were created from each polyline they are merged together to create one feature. This creation of the point allowed each polygon to have a center point, or centroid. Then, the polyline data was merged together to create one feature, and the feature points were merged together to create one feature. With all of these above processes finished the polygon feature was created at a tolerance of 0.01 feet, and the polygon was named LANDUSE. Creating this feature allowed the true areas of the features to be measured because the categories were broken up, and this entire process creates the first step in what will be the complete '*land-use*' feature data, but for analysis purposes the only features that will be utilized for the impervious cover percentages will be developed, water, and wetlands.

Table 2. Land Use definitions.

Feature Class	**Definition**
Developed	Any built-up area that is associated with being impervious or impedes waters ability to permeate through the soil.
Agriculture	Any land that has any farm animals residing, or the land's resources are harvested and sold like hay, straw, orchards, or P.A. 490 forest.

[5] For the stream data feature an assumption was made of all streams having a three foot streambed, so a buffer of one and a half feet was created along the polyline feature.

Turf-Grass	Any land that has lawn, grassland, or a golf course.
Forested	Any area covered by deciduous or coniferous trees.
Wetlands	Any land that can be categorized as having wetland soils.
Mine-Exposed Earth	Any industrial right of ways, railroad tracks, landfills, brown fields, or mined earth.
Water	Any stream, river, brook, reservoir, lake, pond, or vernal pool.

Setting up 'Land-Use' Attributes

So, within the merged land-use feature two new fields were created in the attribute table. One field named TYPE and the other field will be called ISAT. The TYPE field corresponds with a particular text description which is particular to the feature (for example, under developed it could be a pool, or patio, or under water it could be a vernal pool), and the ISAT field corresponds with a numerical description for the TYPE (Table 3). Each number then corresponds with a particular color; which helps to organize the entire layer with what's colored and what's not.

Table 3. TYPE and ISAT description

TYPE	**ISAT**
Developed	2
Agriculture	4
Turf-Grass	5
Forested	6
Wetlands	10
Mine-Exposed Earth	17
Water	18

Editing 'Land-Use' Feature

Within the process of creating the land-use feature edits may need to be made to the dataset to make sure that all features have a corresponding TYPE and ISAT number. This would be the case if there were errors when the data was merged, or if some of the data did not have a description like a pool or wetland. To note, there were no new features added only the polygons were cut.

With this process completed and all the polygons having an associated number and description the developed layer was clipped out to create its own layer to be used with calculating percent impervious coverage for the subregional watersheds, 100 foot buffer, 300 foot buffer, within the aquifer protection area, and the aquifer recharge area. This clip was based on a selection of all ISAT= '2'.

Calculating Impervious Surface Coverage within Subregional Watershed

Using the subregional watershed layer and the developed layer the percent impervious coverage for each watershed was calculated. With this calculated for each watershed there was a visualization of the areas in need of regulatory attention. In order to find these numbers the developed layer was clipped based on each separate watershed and the field geometry was always in acres not square feet. Three new fields were then added to the attribute table called watershed acre, developed acre, and percent impervious. The acre fields were copied from the shape area field and the numbers were field calculated divided by 43,560 to convert from square feet to acres. Then the calculation for the percent impervious field was entered as: developed acre / watershed acre * 100. With this the percent impervious calculated was a visual guide for the town, and color coated based on percentages.

Calculating Impervious Surface Coverage within 100 and 300 Feet of Wetlands and Watercourses

Next the impervious surface is calculated within 100 and 300 feet of wetlands and watercourses. The overall need for stream and wetland corridors to protect the quality of the town's water resources are stated in Newtown's 2004 Plan of Conservation and Development Report. The justification for calculating within 100 feet of wetlands and watercourses was based on laws passed in states like Massachusetts and New Jersey to protect surface water being polluted or degraded, and that Connecticut presently has no regulations set up to date to completely prohibit development within this area. With regards to the justification of impervious cover calculation within 300 feet is based on studies that show this is the minimum footage needed to protect the surrounding wetland and watercourse ecosystem, and also based on studies that found septic tanks leached bacteria up to 300 feet away.

To accomplish this wetlands and watercourses from the land use layer were selected out based on the ISAT number and merged together. After this buffers were created around wetlands and watercourses of 100 and 300 feet. Then the developed layer was clipped for both classifications of 100 and 300 feet. Next the clipped developed buffered layers were clipped based on the subregional watersheds. The acreage was again converted to acres from square feet and a field called percent impervious was added to both 100 and 300 feet developed buffer clipped layers. The calculation within the percent impervious field was as basic as before: developed buffer / area acre * 100. Once completed this aided in visualizing the areas of the highest impervious cover based a color classification of the percent impervious coverage.

Calculating Impervious Surface Coverage within the Aquifer Protection Area

Then an impervious surface coverage was calculated for Newtown's regulated aquifer protection district[6]. This was a done by clipping out the developed layer based on the boundary of the aquifer protection area. Then a new field was added to the attribute table called percent impervious and the calculation for this field was: developed acreage / total protected area * 100. Even though this was only one percentage number it was important to draw conclusions from on the basis that the area has regulations set up for its protection. There was another area that could have been calculated based on CTDEP's aquifer protection areas; which are different from the town's because they protect the well heads that are within the recharge area. These areas are limited protected areas, so they have been left out of the analysis. Moreover, the EPA has designated the Pootatuck aquifer as a sole source aquifer, and had the same outline of the area as the town had for the protection boundaries, so this helped to make the decision of where to calculate the impervious coverage.

Calculating Impervious Surface Coverage of Aquifer Re-Charge Areas

Even though the Pootatuck aquifer recharge area is protected the other aquifer recharge areas are not because they don't meet the requirements for protection most

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[6] This Aquifer Protection District Data is derived from a 1974 USGS study of aquifer re-charge areas. There will be scale difference between the land-use data and the aquifer district. The scale for the protection district is 1"=48,000 feet, and the land-use scale is 1"=100 feet.

notably they are not considered Class A[7] drinking water areas and are Class B, so they will never be considered for protection under current CT state legislation. Even with this as the situation many private wells draw from these Class B recharge zones, and were seen to need impervious coverage calculations just as much as Class A drinking areas.

Calculating the impervious coverage of these areas involved clipping out the developed layer based on the boundaries of the aquifer recharge areas. With this the developed aquifer recharge areas were then clipped based on the subregional watershed boundaries. New attribute table fields were added as aquifer acres and percent impervious. The calculation used within the percent impervious surface was: developed aquifer / aquifer acres * 100. With the calculation completed visualization is created with the areas of the highest percent impervious coverage.

Calculating Residential Impervious Cover

These last calculations are necessary with creating policy recommendations within the residentially zoned areas of Newtown and the Borough of Newtown, specifically R-1 (one acre), R-2 (two acre), and R-3 (three acre). The zoned area that is will be analyzed but left out of the policy recommendation is R-1/2 (half acre). This zone is left out based on the strict guidelines of the parcels within the Department of Health in town because of its restricted acreage.

The data features used for this analysis were historical 2002 parcel layer, zoning layers for the town of Newtown and the Borough, and the land use developed layer used in the above calculations. The numbers created by the analysis were the average percent

[7] There are 5 inland surface water classifications, and only Class AA and Class A are considered drinking water, and once the water is at Class B it's no longer seen as drinking water potential but more for habitat, recreation, and agriculture uses (http://www.ct.gov/dep/cwp/view.asp?a=2719&q=325620).

impervious surface coverage within each parcel within each zone. First the parcels and zone layers were merged. This was done to help with the end result of organizing the percent impervious averages per parcel. Then, the land use developed layer was clipped based on the merged parcel and zone layer. Using this developed layer merge/clip all of the roads—public and private—was deleted, and the right of ways were deleted. This omitted the residentially zoned areas that did not have residences on the parcel. Then, the parcels with no development were deleted so the averages were not skewed lower. Once all of these steps were completed the ArcGIS statistics tool was utilized, and it was based on the zone merge layer, and the minimum, maximum, and total averages were calculated. The importances of both the minimum and maximum averages of impervious surfaces were important factors in analyzing the overall differences between parcel to parcel developments. The average coverage percentages are needed for the policy recommendations.

In addition to the information stated above on all five categories and the residential analysis there are current policy implications that can be drawn. There are current gaps in the protection of Newtown's water resources as well as conclusions and policy to be made in the residential area. Between the impacts that impervious surfaces cause, as stated in previous sections, to the local resources, the lack of an overall awareness with how much development is truly being built in town, and current policy flaws this analysis can help to answer and maybe resolve some of these issues.

POLICY RECCOMENDATIONS

Looking at the above results with regards to the impervious cover within watershed areas, and taking into consideration all of the mentioned impacts impervious surfaces can have within a watershed there is an obvious need to assess the town of Newtown's management of impervious cover, specifically within Article II- Aquifer Protection District, and within Article VII- Area, Height and Yard Requirements of the zoning regulations.

Article II, or the Aquifer Protection district, was also looked at within the context of limiting impervious coverage. Within this regulation are clear intents and purposes:

> "It is the intent of this section to promote the health and general welfare of the community by preventing the contamination of ground resources and to protect *ground water* quality within the Town of Newtown and in particular the Pootatuck Aquifer to ensure a present and future supply of safe and healthy drinking water. The Aquifer Protection District is designated as an overlay *zone*.
>
> The purpose of this section is to facilitate the adequate provision of clean water by prohibiting, within the Aquifer Protection District, land *uses* which can contaminate *ground water* resources and by regulating other land *uses* which may have the potential to contaminate or downgrade existing and potential *ground water* supplies (Article II)."

This district is within the Pootatuck River watershed, and it regulates the federally protected sole source Pootatuck Aquifer. This regulation is very strict with what it allows and does not allow, and only permits four particular uses; which are "single family dwellings of two or more acres, open space and passive recreation, managed forest land, and wells and accessory equipment for the purpose of providing water supply (2.01.310-2.01.340)." Any other use is strictly prohibited, and variances shall not be granted. With all of this in mind the Aquifer Protection District had over 10% impervious cover. This is worrisome because as mentioned this federally protected sole source aquifer has a high susceptibility to pollution because of its geologic composition, and its high water table.

So, is this regulated district truly protecting the integrity of the Pootatuck Aquifer, and are there weaknesses to the regulation? It seems that even with such a rigorous regulation with very specific use definitions has been lacking in enforcement. For example, each property that is larger than two acres is supposed to have a fertilizer management plan submitted to the town, but this has not occurred. Also there is supposed to be no direct drainage into the river system, but this has happened in recent years. Within this regulation there is no lack of clear intent and purpose, but there is the lack of enforcement that has lead to a high impervious cover percentage. Although this area has such high impervious cover there could be a solution within Article VII to create limits on impervious coverage.

Article VII is an important regulatory section because of its purpose which states: "the intensity of the *development* will not damage the ecology of the *lot* and the properties and watersheds it impacts (Article VII)," and within this regulation section there is impervious coverage limits for all commercial or business zoned parcels; which help to protect the impacts on surrounding watersheds, but there are no current limitations of impervious coverage for residentially zoned parcels. As mentioned above the business and commercially zoned areas only make up about 5% of the entire town while the residentially zoned areas make up about 95%. This means that out of the entire town only about 5% has limitations on how much impervious cover can be put on each parcel; which means about 95% of the town has parcels that can just about pave their entire property with the exception of the septic and well systems. This is case in point of answering the question of whether the watersheds are currently truly protected from all impacts that would limit safe drinking water, and if there are no impacts on the present ecology, and the answer is no.

After taking this issue at hand and trying to come up with significant numbers to decrease the impacts on the watersheds and the surrounding ecology an analysis was done for each residential zone—R-1/2, R-1, R-2, and R-3—and a median for each was taken as a threshold percentage of impervious coverage. These median impervious cover percentages were considered to be justifiable because all parcels with development within each zone were analyzed. These analyses followed a trend in percentages that was expected from the lowest acreage with the highest median to the highest acreage with the lowest median (Figure 1, Figure 2, Figure 3, Figure 4).

After applying these medians to real world application each zone was given a different percent coverage limitation, except the R-1/2 zoned parcels because there were too few developed parcels—13—with percentages that varied too much which made the median insignificant. So, the R-1 zone should have a percent impervious coverage limitation of 10 % based on the median. The R-2 zone should have a percent impervious coverage limitation of 8 % based on the median. Finally, the R-3 zone should have a percent impervious coverage limitation of 6% based on the median.

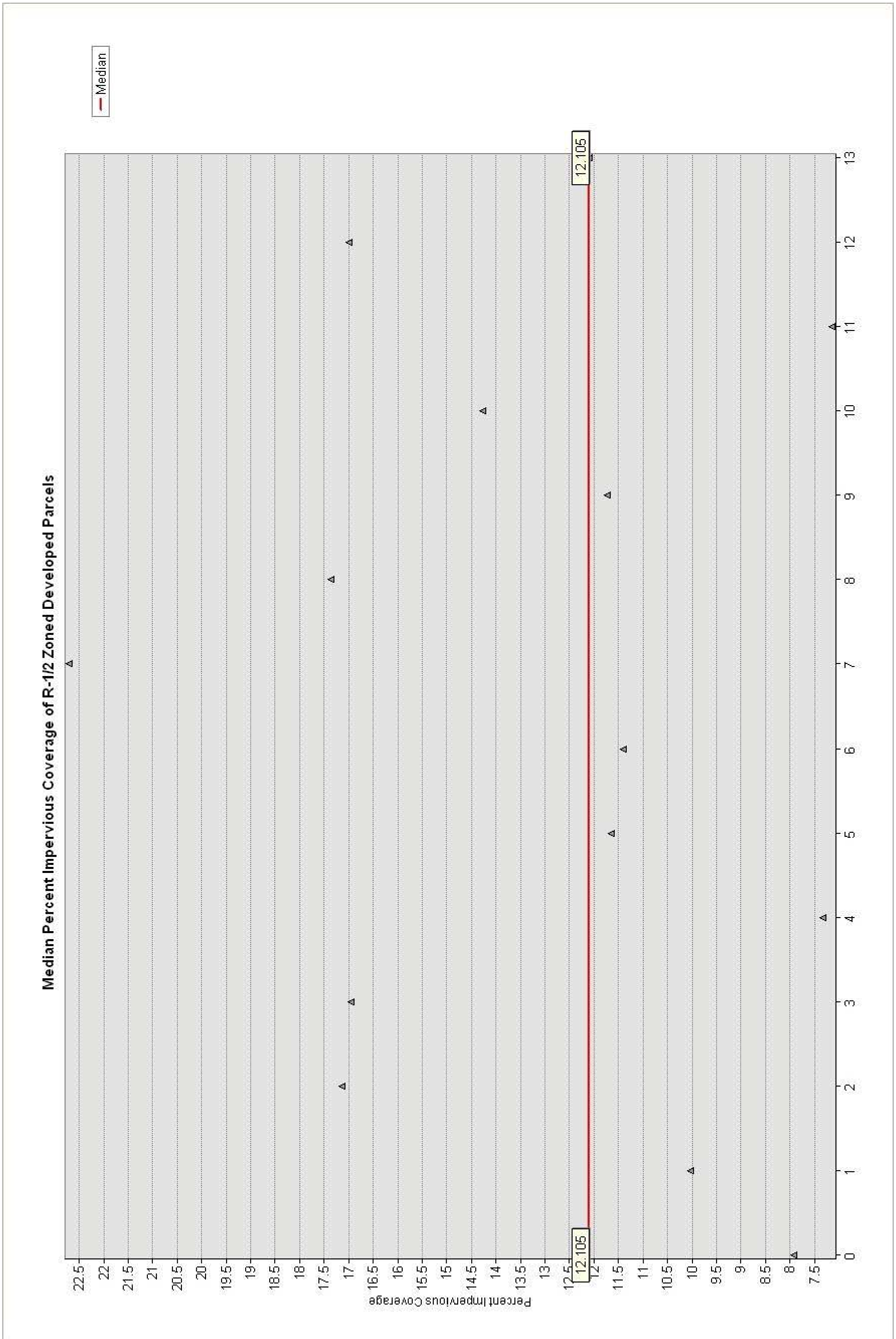

Figure 1. The median of all developed parcels in R-1/2 zone.

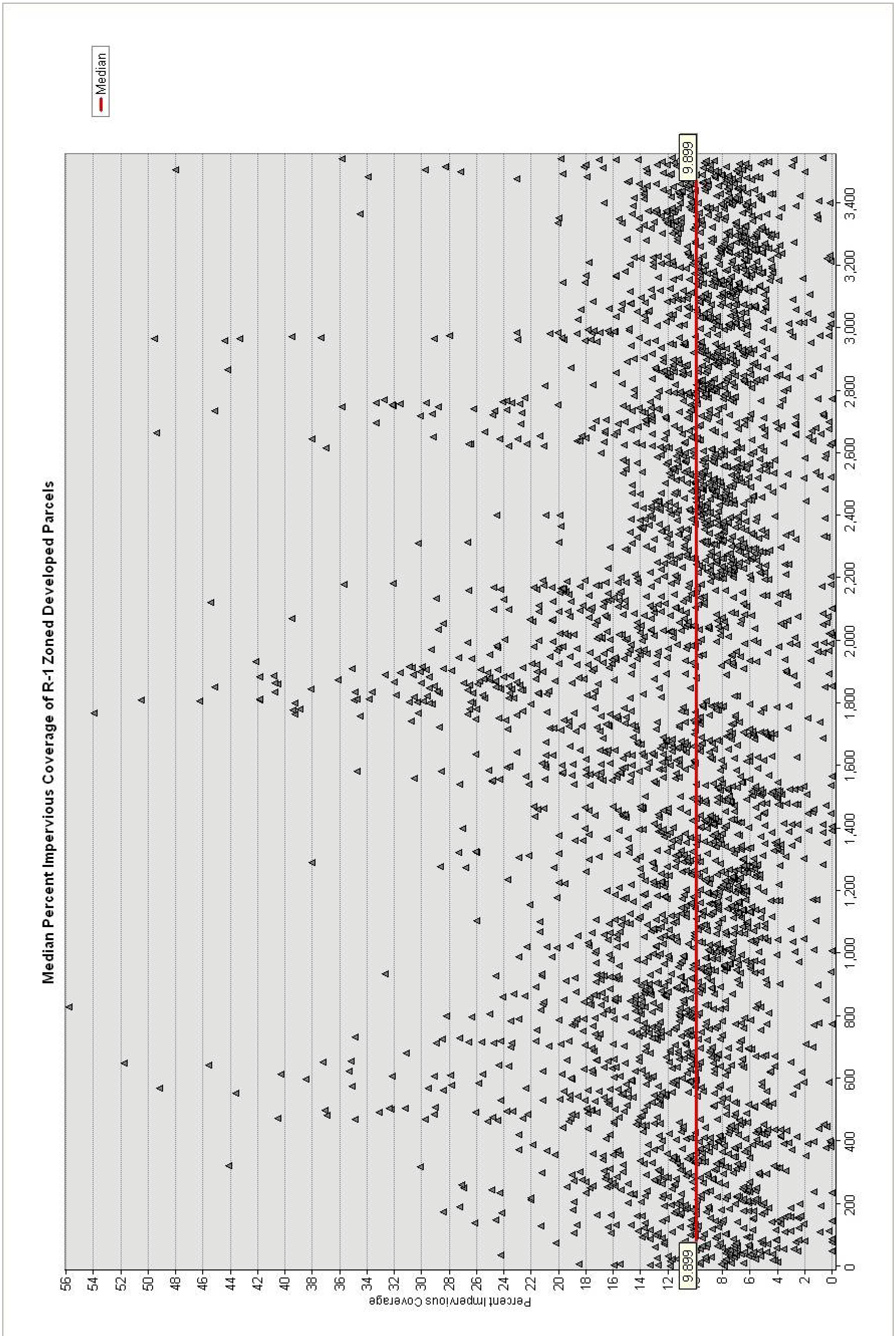

Figure 2. The median of all developed parcels in R-1 zone.

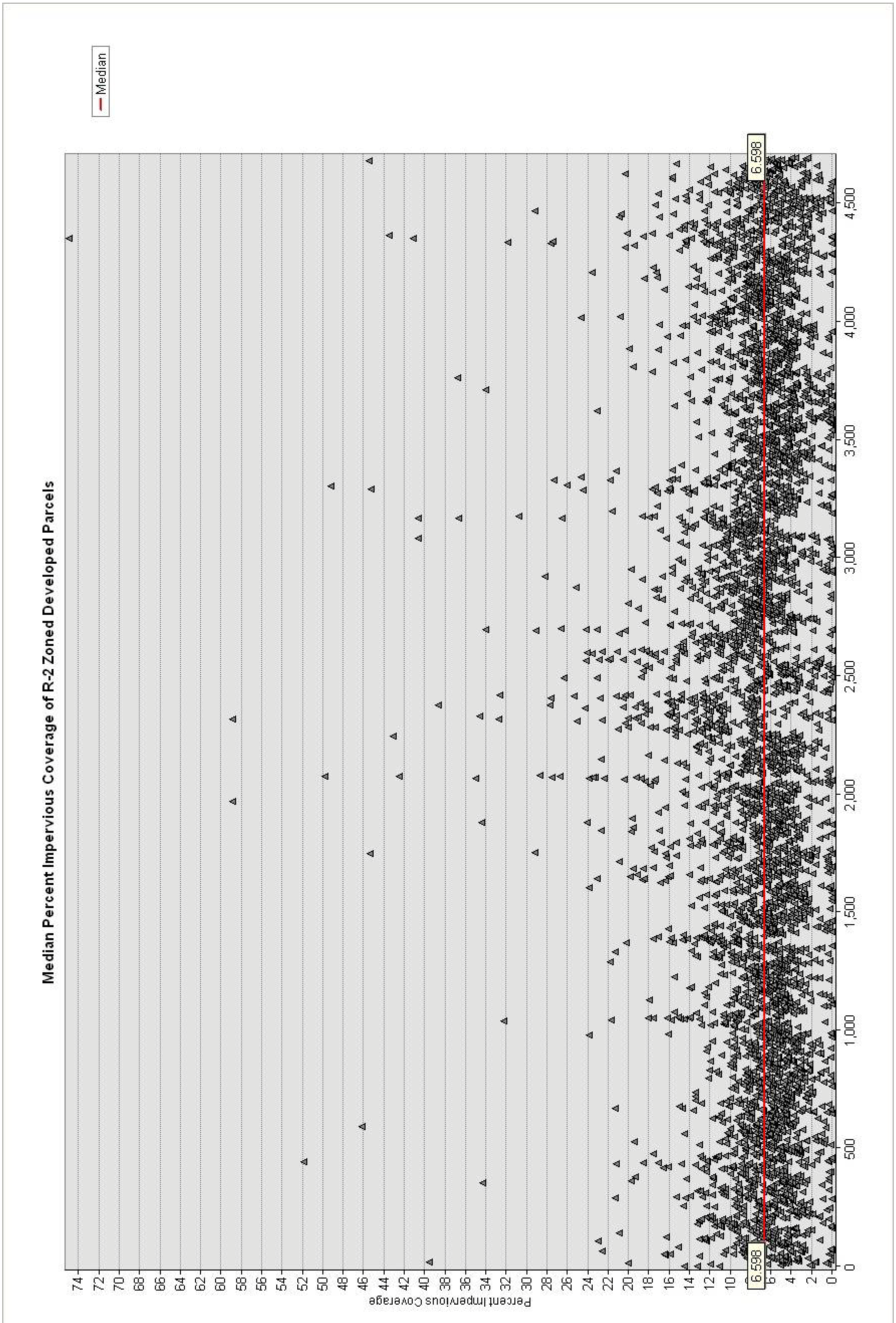

Figure 3. The median of all developed parcels in R-2 zone.

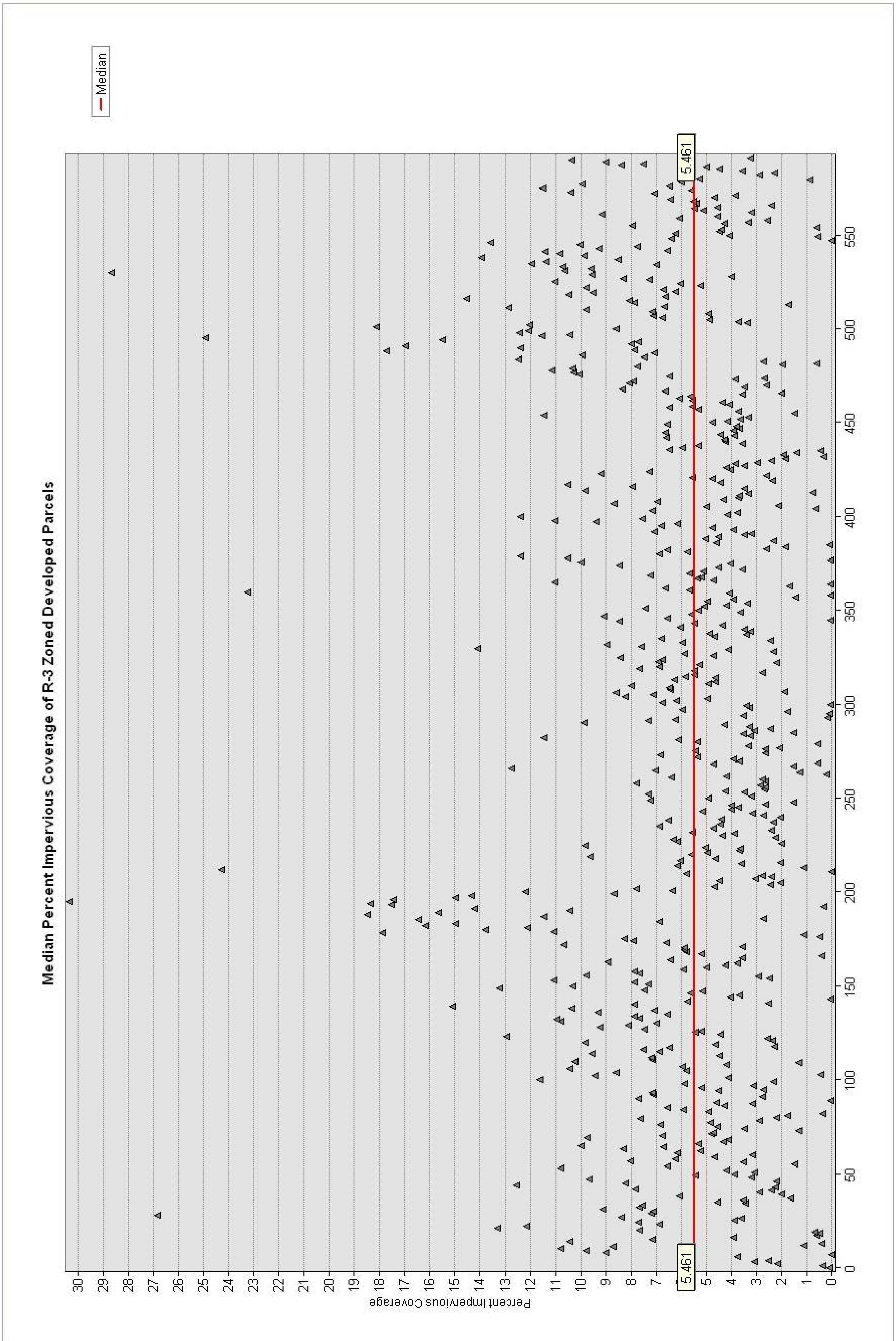

Figure 4. The median of all developed parcels in R-3 zone.

Chapter 1. Introduction

1.1 Impervious surfaces and the connection with sprawling development

According to the Census Bureau, in 1900, the total United States population was about 75 million people. In 1904 93% of America's roads were unpaved. With the increased production of automobiles and increased construction of the interstate highway system an increased population growth in was experienced "suburbia," or suburbs (Arnold and Gibbons 1996). One of the many facets of sprawl is the increase in impervious surface cover, or ISC. Impervious surfaces are any surfaces that denote impermeable qualities. Examples of impervious surfaces include and are not limited to rooftops, buildings, parking lots, roads, and even some lawns based on soil compaction. According to Forman, (2000) by the year 2000, an increase in impervious surfaces had resulted in an estimated one-fifth of the total U.S. land area. This increased coverage of new public road systems and buildings was correlated to direct affects toward ecological services. These impacts were predicted to increase as the percent of impervious surfaces increase (Forman 2000).

These ecological services are all a part of the greater scheme of a watershed. A watershed, according to the Environmental Protection Agency, is "the area of land where all of the water that is under it drains off of it and goes into the same place, and that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course" (EPA 2008). Impervious surfaces break this link with the replacement of naturally pervious and porous surfaces like wetlands, wooded areas, and flood plains with surfaces like pavement and channeled drainage systems. These surfaces inhibit rainwater infiltration with compacted soils, decrease groundwater recharge, and increase stormwater runoff through curbs, pipes and catch basins; which all flow to outlets—point source pollution (Center for Watershed Protection 2003). Pervious surfaces however play a key role in the hydrologic process with the dispersion of water through aquifers and other porous material (Figure 1). With the interruption of the infiltration of water to groundwater there is an increase of decreased available water along with other environmental impacts. Before the presence of human development there is equilibrium of water amount set within the groundwater between recharge to discharge, and after human development there is an imbalance of this equilibrium with more water being discharged than recharged (Alley et al 1999).

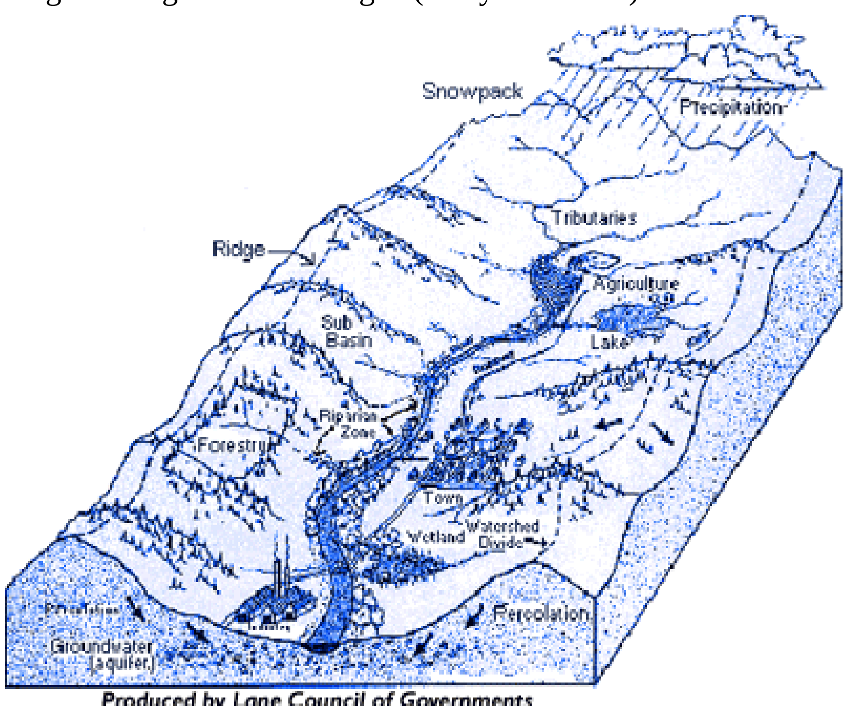

Figure 1. Watershed hydrologic cycle. Source: www.epa.gov.

1.2 Impervious surfaces have negative environmental impacts

Impervious surfaces have become an accurate predictor of urbanization and urban impacts determined by calculating its percentage over a total acreage. There have been many models created, but the Impervious Surface Model (ISM), a compilation of many studies, created by the Center for Watershed Protection, has been used throughout present literature to assess impervious cover in watersheds, and thresholds of impacts on stream systems. The percentage of impervious cover is measured by taking the total impervious surface cover (ISC) divided by the total area (CWP 1998). It has been estimated that with this percentage measurement in mind, "an ISC increases from 10-20%, runoff increases twofold, an ISC increase of 35-50% increases runoff threefold, and an ISC increase of 75-100% results in surface runoff more than fivefold over forested catchments" (Paul and Meyer 2001) (Figure 2). Studies have shown that, within an urban town, if the coverage reaches 10% there can be a perceptible or significant disturbance to the local ecosystem (Booth et al 1996; Booth 1991; Hicks and Larson 1997; Horner et al 1996; Klein 1979; May et al 1997). According to the University of Connecticut's Center for Land Use Education And Research (CLEAR) program, the increase in development and associated impervious surfaces alongside watershed lands show a definite impact on water resources (Chabaeva et al. 2007). As an example of this development small tributaries are usually covered by the increasing infrastructure and are being replaced with first and second order networks of roads and ditches. With the new road networks built the tributaries receive increased stormwater loading, pollution, stream scouring, and erosion, and as an added factor communities down stream from the suburban community can experience more frequent flooding (Zipperer et al. 2000).

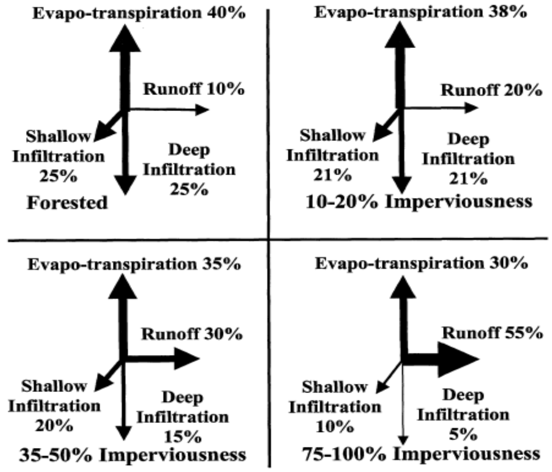

Figure 2. Changes in hydrologic flows with increasing impervious surface cover in urbanizing catchments (Paul and Meyer, 2001).

Impervious surfaces can be categorized with point and non point source pollution. With this in mind impervious surfaces have impacts on the entire surrounding environment. When impervious surfaces encroach on areas like natural flood zones, negative environmental impacts often result. For example, an imperviously affected watershed will have a decreased ability to naturally filter the water through the ground to recharge the aquifer as stated above. This reduction in the unit water yield, or recharge, is the direct result of a greater proportion of precipitation becoming runoff, and ends in a reduction of base flow discharge (Figure 3) (Paul and Meyer 2001). Overall, there is a negative change in hydrologic flow associated with increased impervious surface cover resulting in a lower yield of clean water returned to aquifers from runoff (Figure 4) (Arnold and Gibbons 1996). A study done by Erlich, Erlich and Holdren (1977) found that it takes 100s to 10,000 years for groundwater to exchange clean new water with the old water reservoir in the ground.

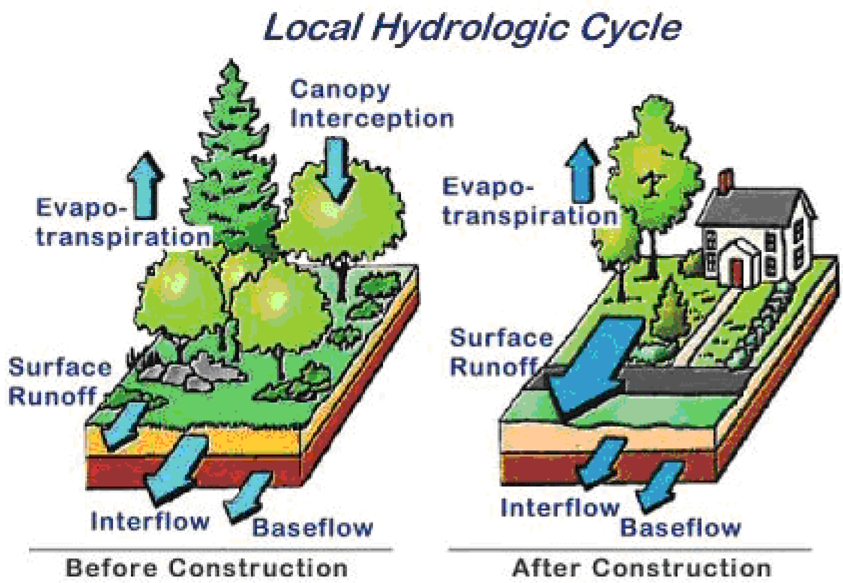

Figure 3. Change in Hydrologic Flow within Urban vs. Non-Urban area.
www.mde.state.md.us/assets/image/Hyd_cycle(1).jpg

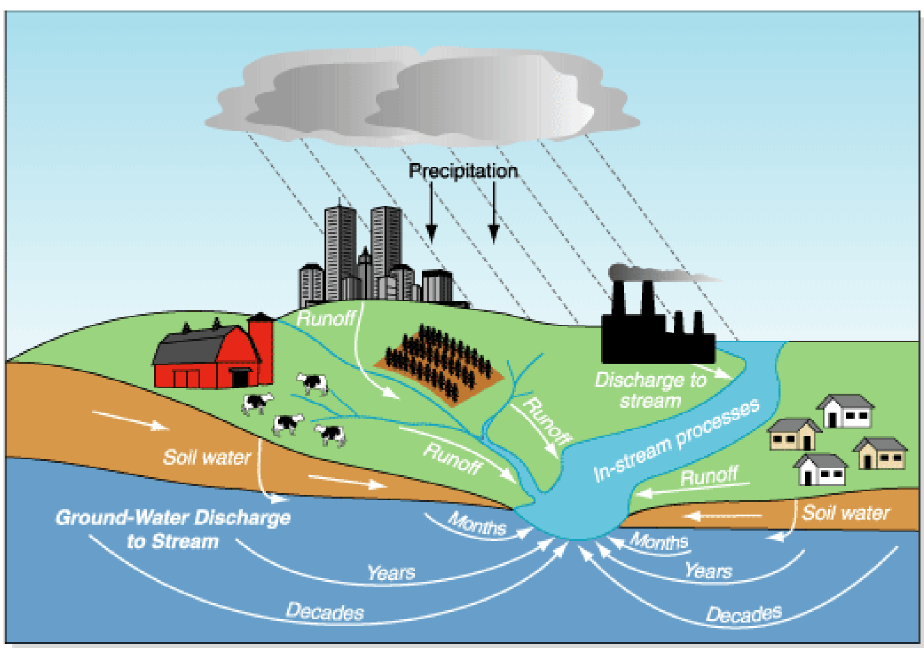

Figure 4. Conceptual watershed showing the relation between nutrient sources, streams, and ground water *(Nitrogen moves from point and nonpoint sources and is transported to a stream through runoff, soil water, and ground water. Once in the ground-water system, nitrogen may take less than a year to decades to be transported to a stream. The distribution of flow paths in the ground-water system will affect the nitrogen concentration and the "lag time" between implementation of management practices in a watershed and the decrease of nitrogen concentrations in a stream.)* (modified from Phillips and others, 1999).

http://md.water.usgs.gov/publications/fs-150-99/html/figure2.gif

The impervious surfaces also have a tendency to funnel runoff into one area, thus increasing water velocity into and around one location. The increased velocity of the runoff from unnatural drainage can cause significant denuding and erosion to the area. Blocked culverts, drains, and swales can decrease the amount of water coming through at one point, and only when the drainage system is designed properly and maintained can there be some alleviation of the peak flood discharges (Paul and Meyer, 2001). Ultimately, changes in the stream banks alter the stream's bed and often increase stresses on aquatic life with large amounts of sedimentation that have altered a once rocky/riffled oxygenated habitat to one of sand and silt. This erosion silt is known to alter aquatic environments by screening out light, changing heat radiation, and retaining organic material and other substances which create unfavorable conditions at the bottom for aquatic species like fish and macroinvertebrates (Ellis 1936; Trimble 1997).

Also, research has found that the increase in impervious surfaces has resulted in the decrease of resident and anadromous fish with as little as a 10% ISC; however, streams that have high riparian forest cover appear less affected by this percentage (Steedman, 1988). This erosion causes the loss of large trees and vegetation that are needed by the aquatic species for cover and temperature control. In a study done by Paul and Meyer (2001) aquatic macro invertebrates were affected by the ISC at any percentage although some variations occurred region to region.

Impervious cover can lead to higher water temperatures. Dark asphalt paved areas like streets and parking lots absorb much heat from the sun during the day, and as a result these areas create warm runoff to flow into stream water from storm events. This increase in temperature decreases the oxygen content of the water furthering stresses on aquatic life, specifically sensitive species such as native fish. Also, as these surfaces absorb more and more heat from the sun it has been seen in studies that the more urban and developed an area becomes the weather in this area can change with this increase of solar energy stored in impervious surfaces. This process creates an "urban heat island," effect and can cause both summer and winter to be warmer (CWP 2003).

In essence, impervious cover on a landscape can effect how an ecosystem would work normally. In some cases areas with greater than 75% impervious surface cover—like cities—may not have the ability to reduce this coverage to make a significant impact or change, but towns that are assessed early enough could manage the impervious coverage before it truly effects their ecosystem. In the case of Newtown, Connecticut an assessment of the town's impervious cover will be preformed using Geographic Information System with the town's planimetric data and aerial photography. From this analysis policy recommendations will be made to the town as to how they should manage their present situation.

1.3 Newtown a typical New England Town

Newtown, Connecticut is facing an increased population due to its rural character and residential appeal. This has caused an increase in development which has led to an increase in impervious surfaces. It is the fifth largest town in Connecticut and one of the fastest growing, primarily due to its location, close to larger urban communities like New Haven, Danbury, and its close proximity to New York City. It has become a Bedroom Community for the working individuals trying to raise families affordably. The dilemma for Newtown is how to manage the increased development to sustain a healthy community while keeping its rural character.

Newtown lies within an area of glacial deposits consisting of a variety of soils, specifically sandy loam mix; which according to the Natural Resource Conservation Service (NRCS) (2007) would be categorized as very low runoff potential and very high infiltration rates even if very saturated (Figure 4 Find Figure). Based on this map created by NRCS this soil makeup sets the town up for the perfect soil for aquifer recharges within its watersheds.

According to the USGS, out of Newtown's 38,000 total acres, approximately 9,000 acres are considered primary aquifer recharge areas. According to the Census Bureau, approximately 60 square acres 2% of the town. The town also lies within a part of the Housatonic watershed (Figure 5), and has eight subregional watersheds within its boundaries (Figure 6).

Climate is an important factor to the watersheds and aquifer recharge in terms of the hydrologic cycle. Being located in New England, Newtown experiences a humid summer, a cold winter, and a wet spring and fall. Newtown averages between 4-5 inches of precipitation per month, and the total average yearly is just over 51 inches (www.IDcide.com 2008). The temperature ranges with the coldest a little under 20 degrees Fahrenheit while the warmest is usually in July in the high 80s. This weather plays a role with the introduction of impervious surface coverage. For example, with impervious surface coverage along with the precipitation and warm weather there is the introduction of warm water into stream systems that shock the species in that ecosystem

(CWP 2003). With increasing pressures of development from the increasing population there has been more impervious surface cover.

As stated previously Newtown has had a constant increasing population. Since the 1930s the population of Newtown has grown from 2,635 to over 25,000 in the year 2000, causing a greater demand for residential housing (Figure 7). With this population boom the number of households also increased past 8,000 by the year 2000. According to the Census Bureau, the numbers of households in the town dramatically changed from years 1970 to 2000 (Table 1). Over these forty years, the town went from 4,029 households to 8,325—at a constant increase (Figure 7).

Table 1. United States Census Bureau Households in Newtown, CT.

Number of Households 1970 to 2000 Newtown, Connecticut

Census	**Households**	**% Change**
1970	4,209	-
1980	5,750	36.6%
1990	6,798	18.2%
2000	8,325	22.5%

Source: US Census Bureau

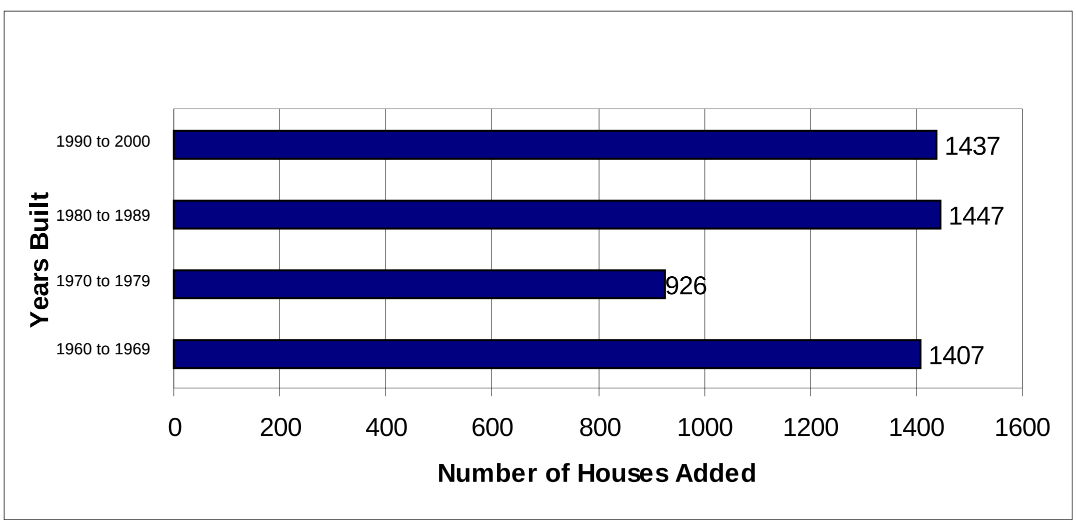

Figure 6. Houses added per decade 1960-2000, Newtown, Connecticut
Source: United States Census Bureau

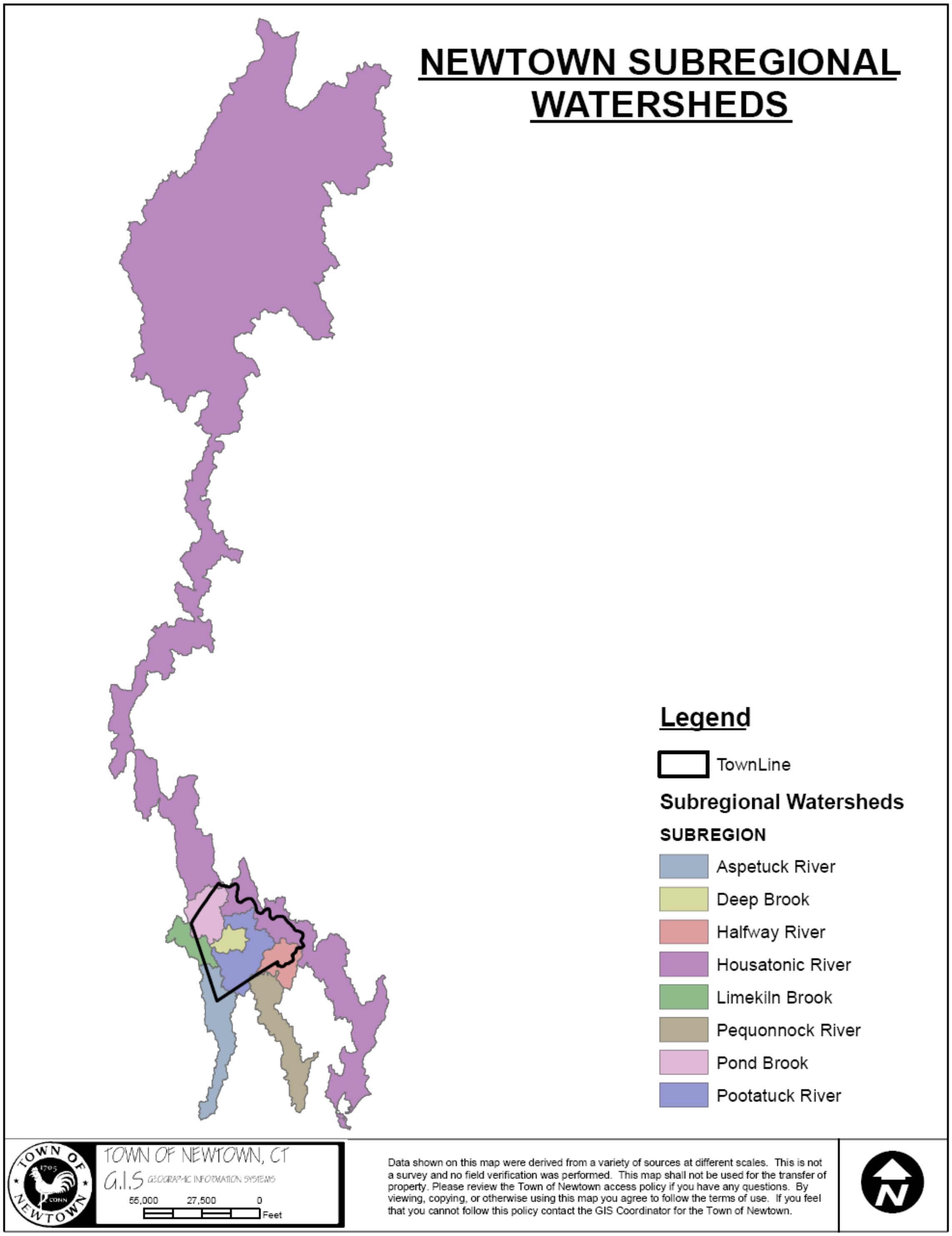

Figure 6. Partial Subregional Watersheds within the Housatonic Watershed in Relation to Newtown, CT. Source: CTDEP and Newtown GIS Department.

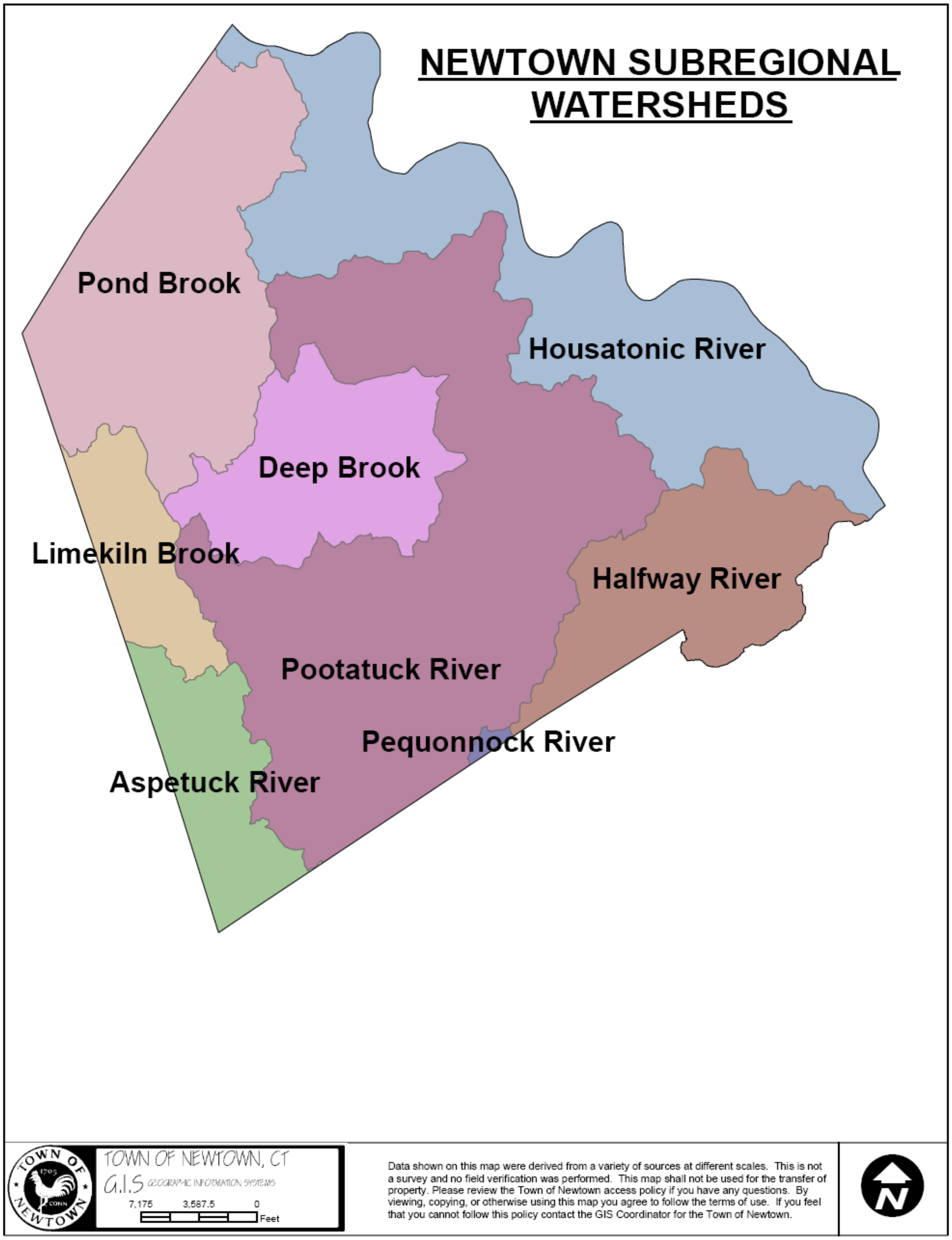

Figure 7. Subregional watersheds within Newtown, CT.
Source: CTDEP and Newtown GIS Department.

From 1998 to 2006 Newtown had a growth spurt, having been documented again as one of the faster growing town's in the state of Connecticut with continual development of its available land. As of 2002, the town's largest land use was residential (17,100 acres), and there was still much land available to develop (11,500 acres) (Figure 7).

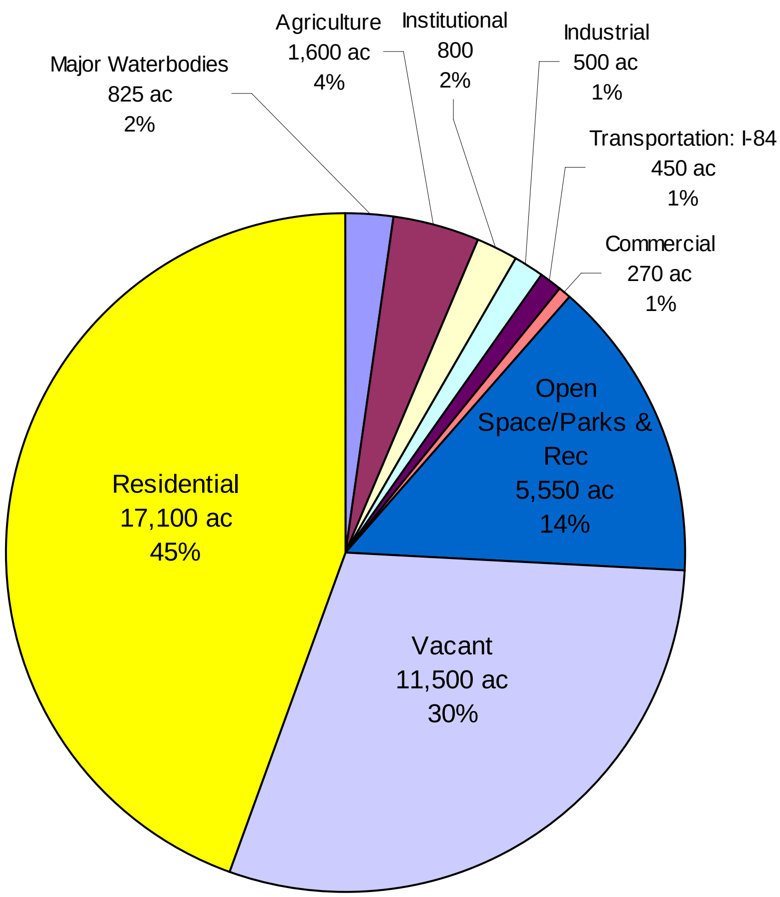

Figure 7. Town of Newtown Land Use Data, 2002.
Source: US Census Bureau

The town has been very involved in its land use with planning and zoning throughout the years. Newtown is made up of two government bodies, the Borough and Newtown. The Borough is the historical center of town, and roughly outlines the Deep Brook Watershed, and Newtown is the remainder of the land mass (FigureCreate Map). The Borough has had local zoning set up since 1927 and still has its own zoning today but uses the same regulations for wetlands and watercourses as Newtown. The town of Newtown has been actively amending local planning and zoning regulation as well as inland wetlands and watercourses regulations. Because Connecticut is a home rule state the municipalities hold the police powers and can adopt and enforce their own regulations.[8] With the town being zoned primarily for residential there was the increase interest of developers building subdivisions.[9] With subdivision after subdivision there was little effort looked at in the way of environmental harm to the ecosystem environmental effects until the 1970s. Then finally in 1974 Newtown and the Borough adopted regulations for inland wetlands and watercourses based on the state's regulations. Over the past thirty years there have been more amendments and inclusive regulations and programs set up to protect natural resources and sensitive habitats, but they are very secluded to specifics which have seemed to weaken their full potential. For instance, the CTDEP has aquifer protection areas except they only protect public drinking wells that service 1,000 residents or more this reduces the area in which weakens this protective policy. The town of Newtown also has an aquifer protection district, but through years of

[8] In 1956, Newtown adopted their first planning regulations, and soon after in 1957 zoning regulations were adopted by the town ordinances. These regulations were a bit before their time by outlawing factories such as cement, tanning, refineries, and even slaughter houses from being built. With outlawing such factories the town's zoning resulted in more residential then commercial zones, and this eventually resulted in higher property taxes today.

[9] The town's definition for a subdivision is a parcel being split into three or more parcels. If a parcel is only split into two parcels it is considered a split.

mismanagement in the land use and inland wetlands departments this area has had a lot of development within its boundaries.

More recently, Newtown has taken an initiative with looking at subdivisions and individual housing units with respect to its natural resources. Also, Newtown has recently passed amendments and new regulations as of the fall of 2007 that incorporate new building regulations with some natural resource awareness. But have these new amendments looked at what is at the heart of development—impervious surfaces? With researching the new regulations the town's policies have not approached the idea of managing impervious cover of residential zoned properties. The only property they regulate in this manner are parcels zoned commercial; which make up less than 5% of the town.

With all of this policy in place there is evidence that it's not acting to control the increase of impervious surfaces. Analysis of impervious surfaces within the more urban areas needs to be assessed as to the effects they are having on the natural ecosystem services of the town. To note, it is not just the impervious surfaces themselves that have the effect on the natural resources, but it is the percent as a whole as to the true impacts they can create. And it is an idea of success when there is more energy put into monitoring than on preventing these surfaces from being built, and hopefully being built in sustainable ways. In this study I'm looking at and analyzing the town's current regulatory policies that pertain to impervious surfaces within residentially zoned areas—since the town is over 90% residentially zoned—and their potential effects on the town's natural resources such as the aquifer recharge areas, wetlands and watercourses, and the watersheds as a whole.

RESULTS AND ANALYSIS

Impervious Surface Coverage within Each Watershed in Newtown, CT
Results:

Watershed	% Impervious Surface
Housatonic	5 %
Pond Brook	6 %
Pootatuck River	8 %
Limekiln River	7 %
Deep Brook	10 %
Halfway River	5 %
Aspetuck River	3 %
Pequonnock River	11 %

Analysis:

As seen in the above table only one of the watersheds is below 3.5% impervious coverage (Figure 1), and this was the threshold percentage that emphasizes any number above this causes "significant increase in water level fluctuation, conductivity, fecal coli form bacteria, and total phosphorus (Taylor et al 1995)." This low percentage in the Aspetuck River Watershed was expected because most of the southern corner of the watershed in Newtown is owned by the local water company. The Housatonic River Watershed was also expected to have a lower impervious cover percentage because it has two large state parks within its boundary in Newtown—Northern Paugussett State Park, and Southern Paugussett State Park. With these state parks having much of the Housatonic River Watershed's land the area has fewer acres available for development purposes, so the impervious cover would not be expected to increase much higher.

The remaining watersheds were within the sensitive to impacted with impervious surface cover percentages ranging from 7 % to 11 %. These are the watersheds that raise the most concern for having impervious impacts because since 2002 (the analysis year) there has been an exponential increase in development within Newtown.

Out of all the watershed regions the two that post the most concern are Deep Brook and Pootatuck River Watersheds. These two watersheds at 10 % and 8 % have had the greatest impacts, and high percentages were expected because town centers are located in these regions along with many residences.

Overall, these percentages are worrisome based on the aforementioned research because there are physical and biological declines of the most sensitive species at just 5% impervious cover (May et al 1997), and in 2002 all subregional watersheds were at this number or higher—and it is now 2008. Also, as mentioned before, as the impervious cover percentage increases the watershed becomes increasingly sensitive and exposed to erosion and species loss as well as increased chemical and thermal exposures. These effects were apparent after a stream assessment was completed in the summer of 2007 with the most impacted areas of the stream correlated with the higher impervious cover.

For purposes of this study the model used to assess the acute impacts was the Center for Watershed Protection's Impervious Cover Model. If we take this into consideration with all percentages found for the watersheds they are all over 0 % so most are within range of being sensitive, and two are at or above 10% ISC so they would be in impacted range.

The only outlier is the Pequannock River Watershed's percentage. This is due to the small proportion of total land area that the developed area within the watershed is divided by, and with any analysis through the study this area will continue to have higher overall percentages.

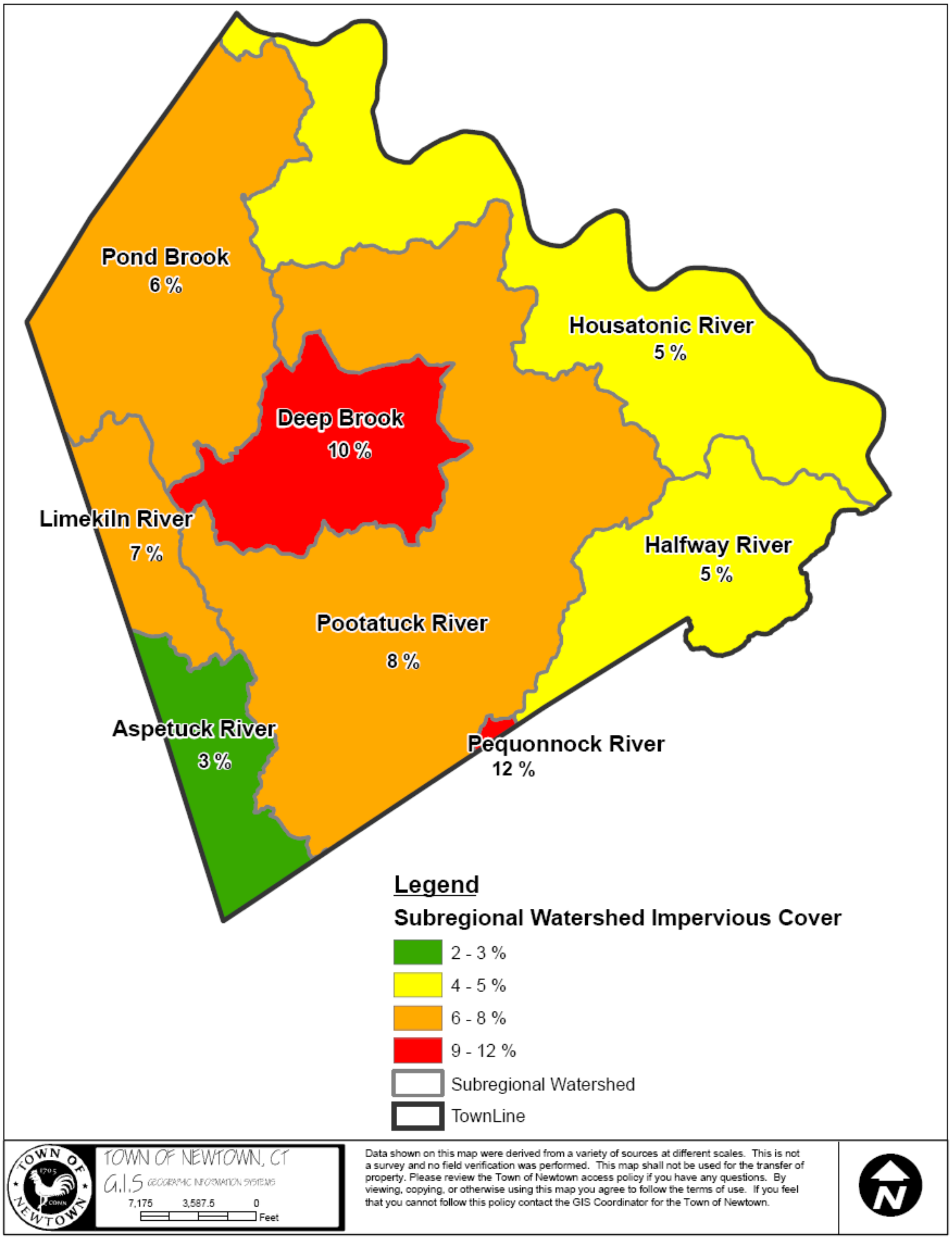

Figure 1. Map of percent impervious coverage of the subregional watersheds in Newtown, CT.

Wetland and Watercourse Percent Impervious Coverage within 100 feet
<u>*Results:*</u>

Watershed	% Impervious Surface
Housatonic	2 %
Pond Brook	4 %
Pootatuck River	4 %
Limekiln River	4 %
Deep Brook	4 %
Halfway River	4 %
Aspetuck River	2 %
Pequonnock River	11 %

<u>*Analysis:*</u>

The result from analyzing impervious cover within 100 feet of all wetlands and watercourses was very interesting (Figure 2). As with the above watershed analysis the lowest percentages were in the Housatonic River and Aspetuck River Watersheds at 2 %. Again the lower percentages were expected in these watersheds because of the land use being protected state parks—Housatonic—and water company owned land—Aspetuck. According to the literature mentioned, at 2% impervious cover there shouldn't be any impact on the health of the hydrologic system.

But, the middle section of the town was within the 4 % range of impervious cover; which is over 3.5 %, or as mentioned the threshold of where nutrient loading within the water system occurs. This means that more than ¾ of the town has nutrient loading occurring within 100 feet of wetlands and watercourses. We can also make the assumption that the average percent cover for the town was at 4 % within 100 feet within wetlands and watercourses, and within the ICM this results in the areas lying within the sensitive impact with the Pequannock being the outlier at 11 %, or impacted range.

If there is this much development within 100 feet of all wetlands and watercourses it can also be assumed that some older unmanaged private septic systems within this frontage, and it is plausible that seepage from these areas is happening.

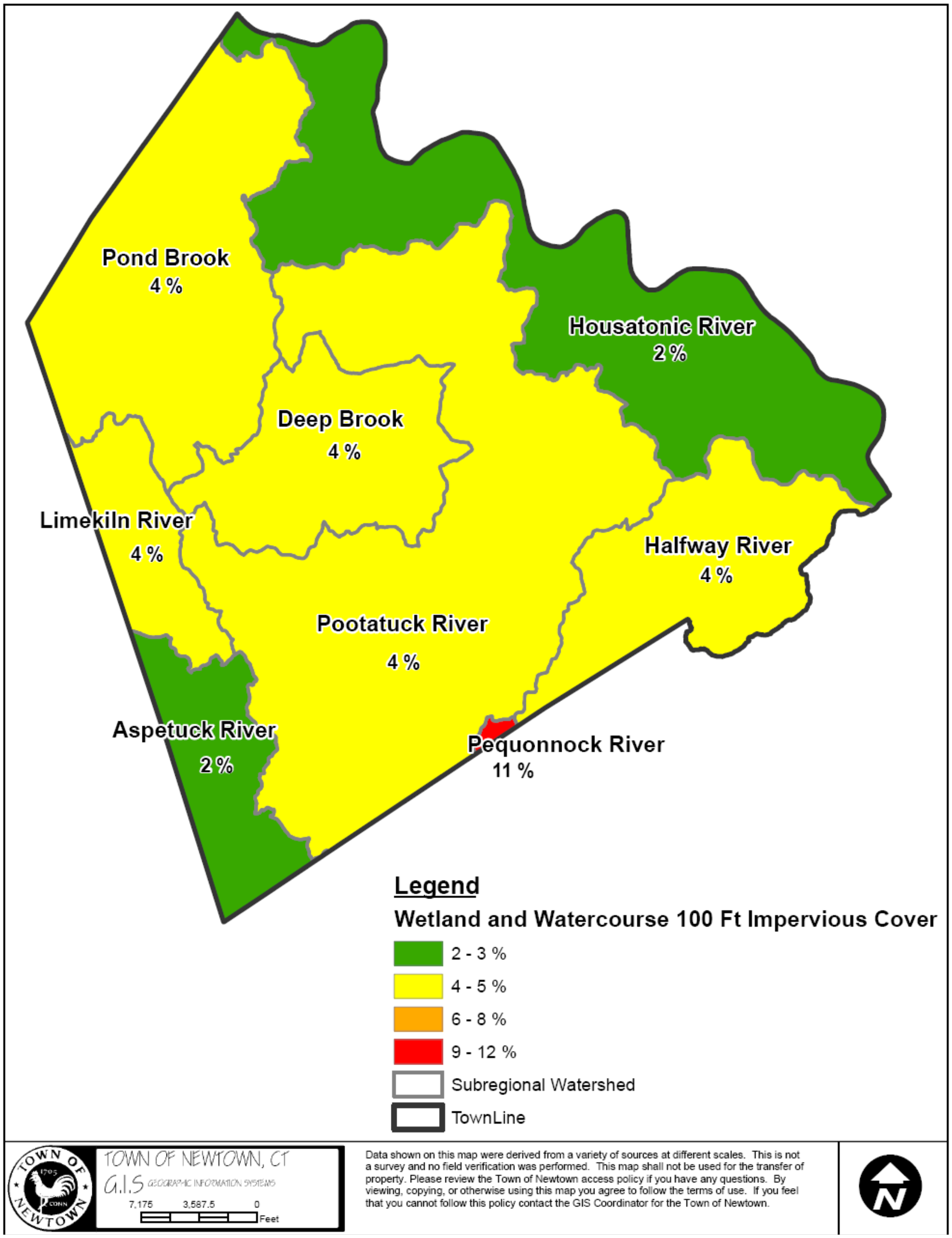

Figure 2. Map of percent impervious coverage of Wetlands and Watercourses within 100 feet in Newtown, CT.

Wetland and Watercourse Percent Impervious Coverage within 300 feet

Results:

Watershed	% Impervious Surface
Housatonic	4 %
Pond Brook	6 %
Pootatuck River	7 %
Limekiln River	7 %
Deep Brook	9 %
Halfway River	5 %
Aspetuck River	3 %
Pequonnock River	11 %

Analysis:

The percentages were very different than the impervious cover percentage within 100 feet of wetlands and watercourses (Figure 3). Interestingly the percentages were very close to those percentages found for the overall subregional watershed impervious cover analysis. With such high numbers there is an obvious correlation with an increased impact on the water systems, and yet again the Housatonic and Aspetuck River Watersheds were the outliers with the lower percentages. According to the literature, all of the other watersheds'—excluding the two low percentages—wetlands and watercourses are seeing impacts to the most sensitive flora and fauna, and nutrient loading has started within these systems. In particular, Deep Brook is seeing this impact to its water systems, and is very close if not within the impacted zone of the Impervious Cover Model, and both the Pootatuck River and Limekiln watersheds aren't very far behind with coming into the impacted zone.

The Pequannock River watershed again has the highest percentage, but should not be cause for complete alarm because of the small land area that Newtown manages in relation to the watersheds entirety.

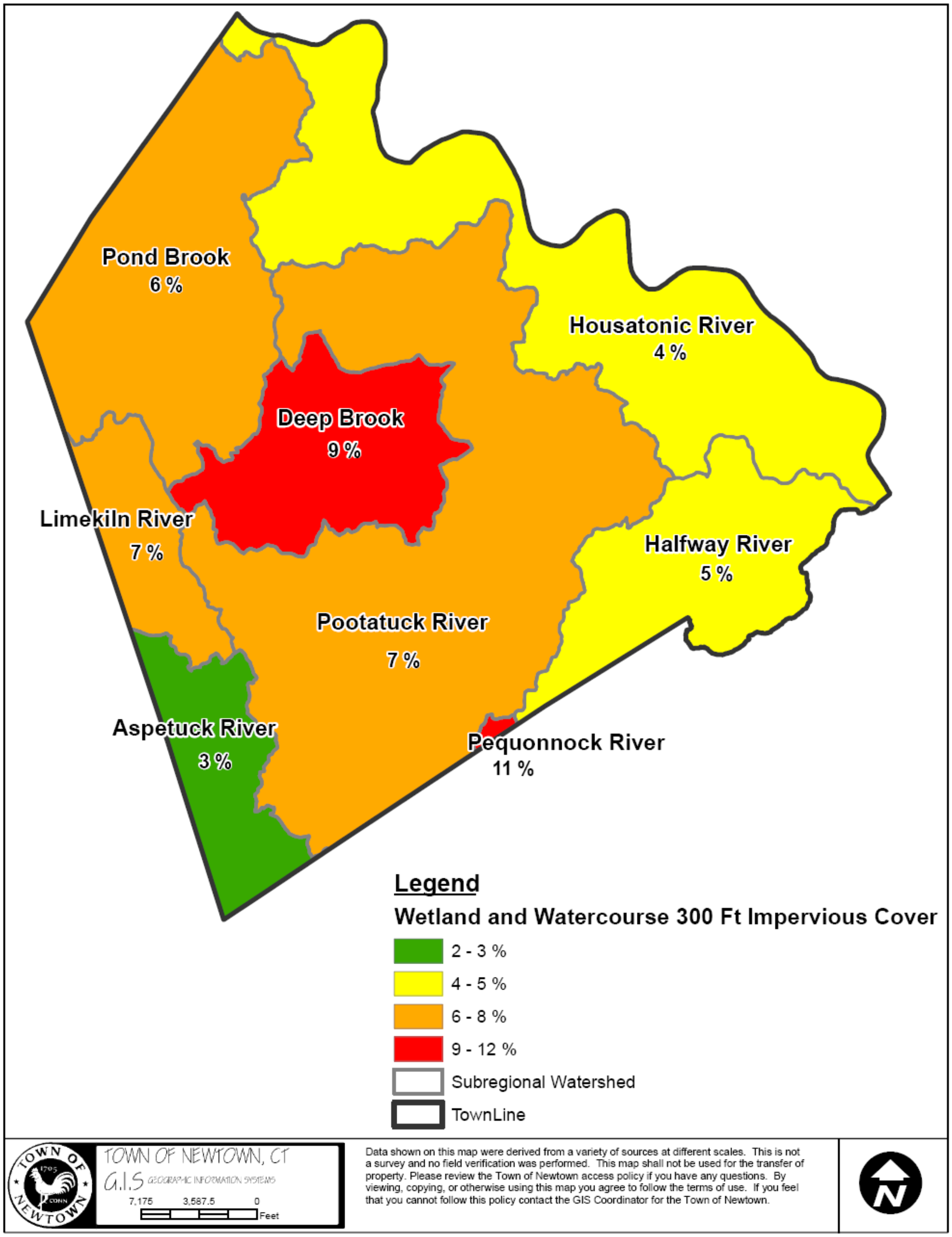

Figure 3. Map of percent impervious coverage of Wetlands and Watercourses within 300 feet in Newtown, CT.

Aquifer Protection District with Impervious Surface Coverage

Results:

Percent Impervious Surface = 10 %

Analysis:

Out of the about 3,500 acres that were considered to be a federally protected Aquifer Recharge Area approximately 340 acres were developed. With taking these numbers into consideration the area is approximately covered by 10% impervious cover. Because of the Pootatuck Aquifer's composition of predominately inter-bedded layers of sand and gravel with lesser amounts of silt and clay this area is highly susceptible to contamination. With its relatively high permeability and its shallow water table that is recharged mainly by precipitation percolating through the soil we can assume that this area can be treated as if it was surface water, and this aquifer is within the impacted zone in the Impervious Cover Model. To illuminate this idea of impact, and if we consider the previously mentioned literature, the area will be assumed to have nutrient loading seeping into groundwater that is consumed by the town's citizens in this area. These nutrients that can contaminate the drinking water include nitrogen (nitrate and nitrite), phosphorous, and other inorganic contaminates, such as MTBE, to name a few (EPA 2008). All of these nutrients mentioned can have health effects when consumed particular to infants six months and younger.

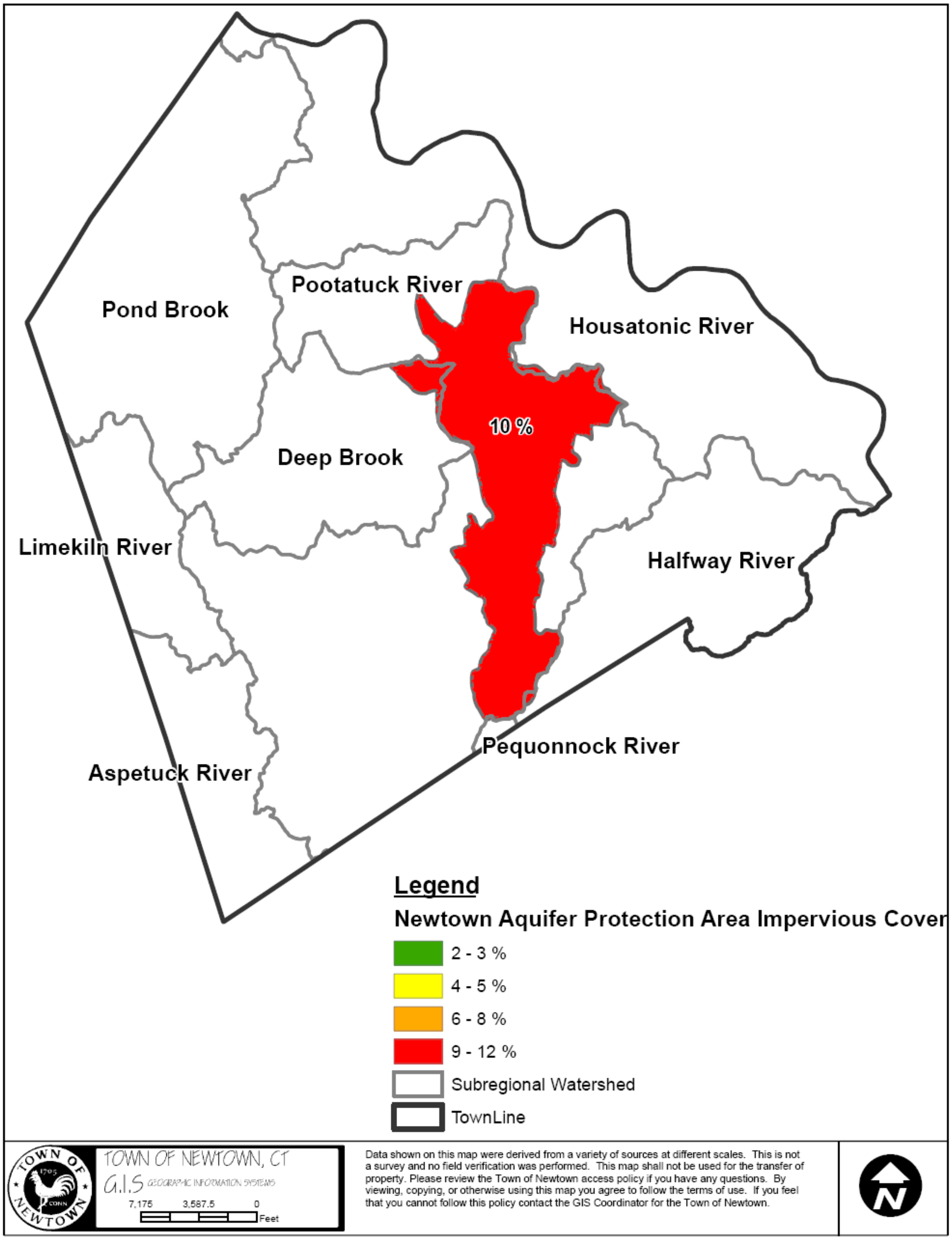

Figure 4. Map of percent impervious coverage within the Aquifer Protection Area in Newtown, CT.

Results:

Percent Impervious Surface = 8.18%

Results:

Watershed	% Impervious Surface
Housatonic	8 %
Pond Brook	8 %
Pootatuck River	9 %
Limekiln River	8 %
Deep Brook	6 %
Halfway River	7 %
Aspetuck River	5 %
Pequonnock River	10 %

Analysis:

The percent of impervious cover within the aquifer recharge areas was particularly high. Out of a little over 8,800 acres of recharge over 700 acres are developed. When broken up by the subregional watersheds the percentages that have impervious cover are very high, and average about 8 % impervious coverage (Figure 5). What was surprising about these numbers was that the usually low impact level Housatonic River and Aspetuck River Watershed regions had high impervious cover within their aquifer recharge zones. With regards to each aquifer recharge area only the Pootatuck Aquifer in the Pootatuck River Watershed has been extensively studied in terms of its geologic make-up. This means that the other aquifer recharge areas could have limiting factors with the infiltration of contaminants. This is an important factor to understand when looking at the relatively high impervious coverage percentages because more needs to be known about each one's geology before real assumptions can be made.

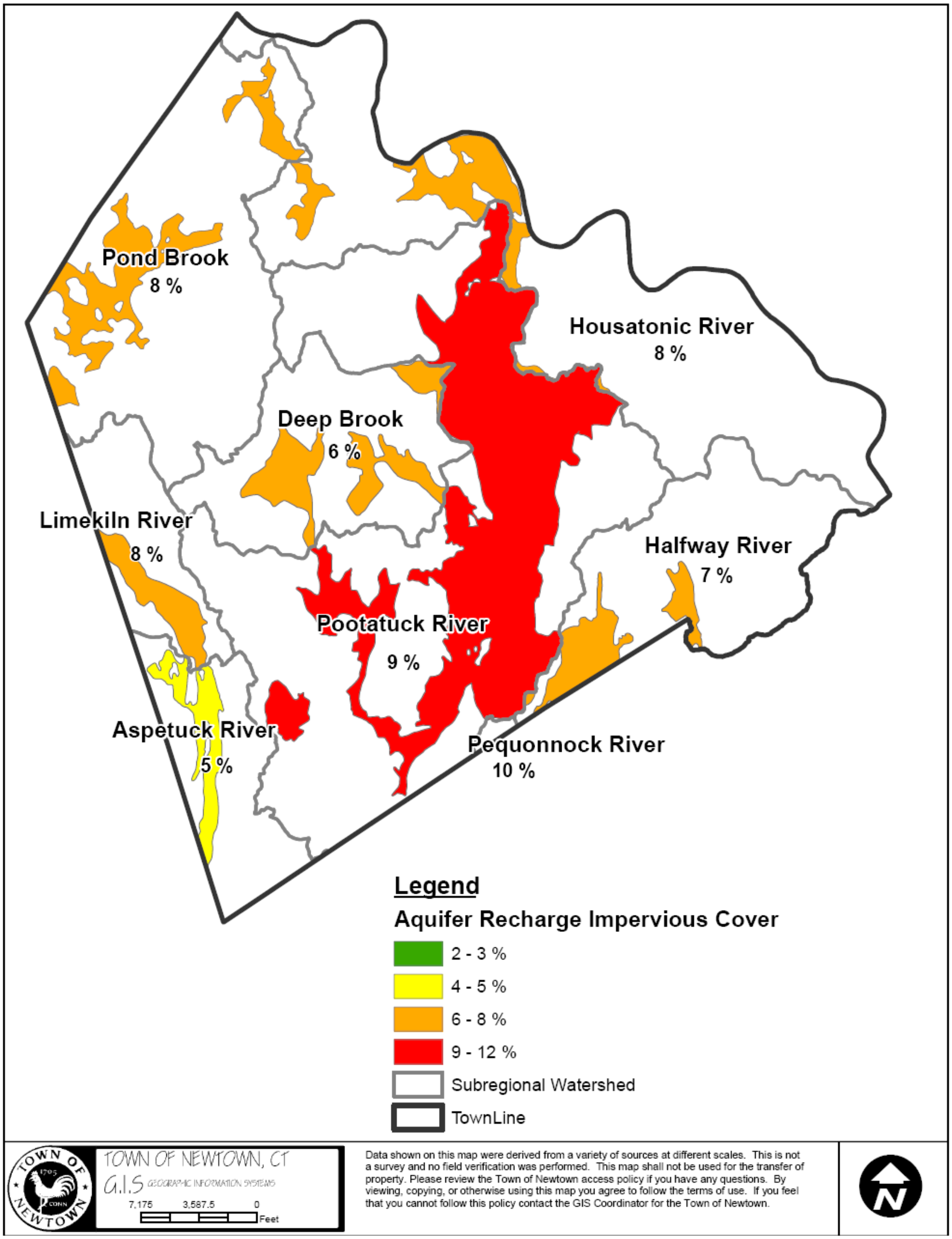

Figure 5. Map of percent impervious coverage within aquifer recharge areas in Newtown, CT.