5.4.6 EARTHQUAKE

This section provides a profile and vulnerability assessment for the earthquake hazard.

HAZARD PROFILE

This section provides profile information including description, extent, location, previous occurrences and losses and the probability of future occurrences.

Description

An earthquake is the sudden movement of the Earth's surface caused by the release of stress accumulated within or along the edge of the Earth's tectonic plates, a volcanic eruption, or by a manmade explosion (Federal Emergency Management Agency [FEMA], 2010; Shedlock and Pakiser, 1997). Most earthquakes occur at the boundaries where the Earth's tectonic plates meet (faults); however, less than 10 percent of earthquakes occur within plate interiors. New York State is in an area where plate interior-related earthquakes occur. As plates continue to move and plate boundaries change over geologic time, weakened boundary regions become part of the interiors of the plates. These zones of weakness within the continents can cause earthquakes in response to stresses that originate at the edges of the plate or in the deeper crust (Shedlock and Pakiser, 1997).

The location of an earthquake is commonly described by its focal depth and the geographic position of its epicenter. The focal depth of an earthquake is the depth from the Earth's surface to the region where an earthquake's energy originates (the focus or hypocenter). The epicenter of an earthquake is the point on the Earth's surface directly above the hypocenter (Shedlock and Pakiser, 1997). Earthquakes usually occur without warning and their effects can impact areas of great distance from the epicenter (FEMA, 2001).

According to the U.S. Geological Society (USGS) Earthquake Hazards Program, an earthquake hazard is anything associated with an earthquake that may affect resident's normal activities. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunamis, and seiches. A description of each of these is provided below.

- Surface faulting: Displacement that reaches the earth's surface during slip along a fault. Commonly occurs with shallow earthquakes, those with an epicenter less than 20 kilometers.
- Ground motion (shaking): The movement of the earth's surface from earthquakes or explosions. Ground motion or shaking is produced by waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the earth and along its surface.
- Landslide: A movement of surface material down a slope.
- Liquefaction: A process by which water-saturated sediment temporarily loses strength and acts as a fluid, like when you wiggle your toes in the wet sand near the water at the beach. This effect can be caused by earthquake shaking.
- Tectonic Deformation: A change in the original shape of a material due to stress and strain.
- Tsunami: A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major submarine slides, or exploding volcanic islands.

- Seiche: The sloshing of a closed body of water from earthquake shaking (USGS, 2009).

Extent

Seismic waves are the vibrations from earthquakes that travel through the Earth and are recorded on instruments called seismographs. The magnitude or extent of an earthquake is a measured value of the earthquake size, or amplitude of the seismic waves, using a seismograph. The Richter magnitude scale (Richter Scale) was developed in 1932 as a mathematical device to compare the sizes of earthquakes (USGS, 1989). The Richter Scale is the most widely-known scale that measures the magnitude of earthquakes (Shedlock and Pakiser, 1997; USGS, 2004). It has no upper limit and is not used to express damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, may have the same magnitude and shock in a remote area that did not cause any damage (USGS, 1989). Table 5.4.6-1 presents the Richter Scale magnitudes and corresponding earthquake effects.

Table 5.4.6-1. Richter Scale

Richter Magnitude	Earthquake Effects
2.5 or less	Usually not felt, but can be recorded by seismograph
2.5 to 5.4	Often felt, but only causes minor damage
5.5 to 6.0	Slight damage to buildings and other structures
6.1 to 6.9	May cause a lot of damage in very populated areas
7.0 to 7.9	Major earthquake; serious damage
8.0 or greater	Great earthquake; can totally destroy communities near the epicenter

Source: USGS, 2006

The intensity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features, and varies with location. Intensity is expressed by the Modified Mercalli Scale; a subjective measure that describes how strong a shock was felt at a particular location (Shedlock and Pakiser, 1997; USGS, 2004). The Modified Mercalli Scale expresses the intensity of an earthquake's effects in a given locality in values ranging from I to XII. Table 5.4.6-2 summarizes earthquake intensity as expressed by the Modified Mercalli Scale. Table 5.4.6-3 displays the Modified Mercalli Scale and peak ground acceleration equivalent.

Table 5.4.6-2. Modified Mercalli Intensity Scale

Mercalli Intensity	Description
I	Felt by very few people; barely noticeable.
II	Felt by few people, especially on upper floors.
III	Noticeable indoors, especially on upper floors, but may not be recognized as an earthquake.
IV	Felt by many indoors, few outdoors. May feel like passing truck.
V	Felt by almost everyone, some people awakened. Small objects moves, trees and poles may shake.
VI	Felt by everyone; people have trouble standing. Heavy furniture can move, plaster can fall off walls. Chimneys may be slightly damaged.
VII	People have difficulty standing. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.
VIII	Well-built buildings suffer slight damage. Poorly built structures suffer severe damage. Some walls collapse.

Mercalli Intensity	Description
IX	Considerable damage to specially built structures; buildings shift off their foundations. The ground cracks. Landslides may occur.
X	Most buildings and their foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, lakes. The ground cracks in large areas.
XI	Most buildings collapse. Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed.
XII	Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.

Source(s): Michigan Tech University, 2007; Nevada Seismological Laboratory, 1996

Table 5.4.6-3. Modified Mercalli Intensity (MMI) and PGA Equivalents

MMI	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	< .17	Not Felt	None
II	.17 – 1.4	Weak	None
III	.17 – 1.4	Weak	None
IV	1.4 – 3.9	Light	None
V	3.9 – 9.2	Moderate	Very Light
VI	9.2 – 18	Strong	Light
VII	18 – 34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy

Source: NYSDPC, 2008

Seismic hazards are often expressed in terms of Peak Ground Acceleration (PGA) and Spectral Acceleration (SA). USGS defines PGA and SA as the following: 'PGA is what is experienced by a particle on the ground. Spectral Acceleration (SA) is approximately what is experienced by a building, as modeled by a particle mass on a massless vertical rod having the same natural period of vibration as the building' (USGS, Date Unknown). Both PGA and SA can be measured in *g* (the acceleration due to gravity) or expressed as a percent acceleration force of gravity (%g). PGA and SA hazard maps provide insight into location specific vulnerabilities (NYSDPC, 2008).

PGA is a common earthquake measurement that shows three things: the geographic area affected, the probability of an earthquake of each given level of severity, and the strength of ground movement (severity) expressed in terms of percent of acceleration force of gravity (%g). In other words, PGA expresses the severity of an earthquake and is a measure of how hard the earth shakes (or accelerates) in a given geographic area (NYSDPC, 2008).

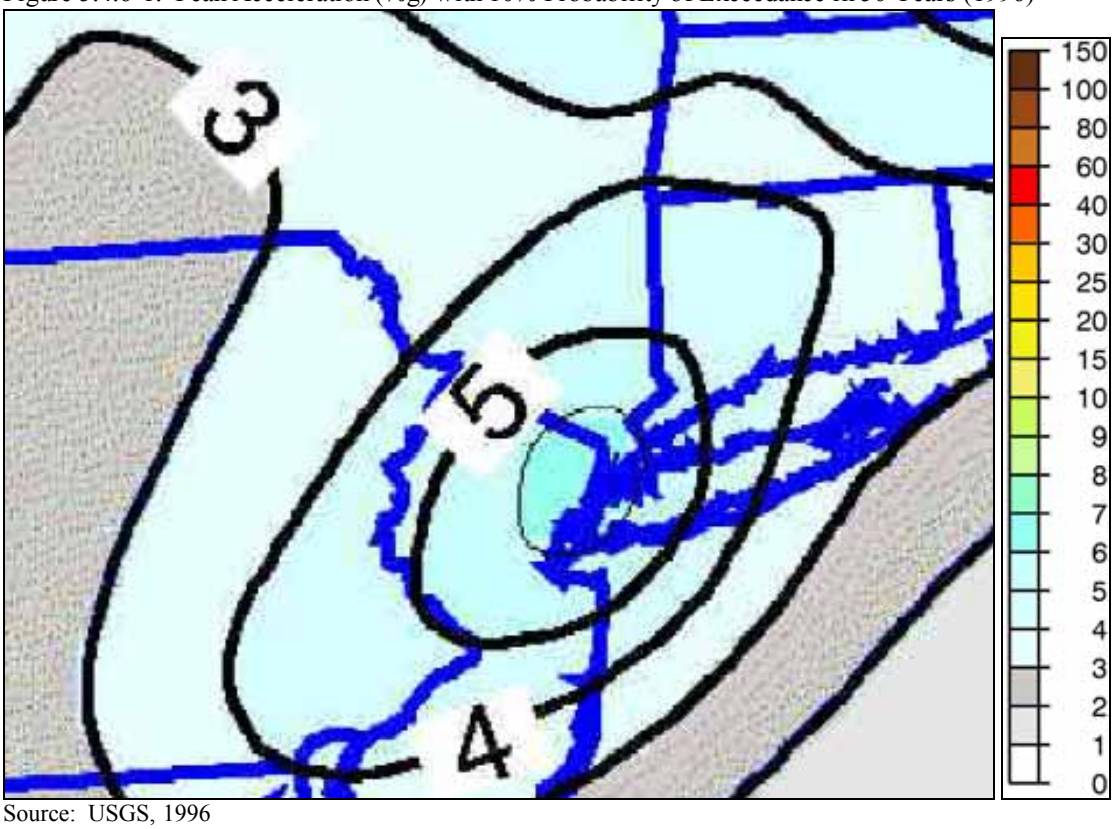
National maps of earthquake shaking hazards have been produced since 1948. They provide information essential to creating and updating the seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities and land use planning used in the U.S. Scientists frequently revise these maps to reflect new information and knowledge. Buildings, bridges, highways and utilities built to meet modern seismic design requirements are typically able to withstand earthquakes better, with less damages and disruption. After thorough review of the studies, professional organizations of engineers update the seismic-risk maps and seismic design requirements contained in building codes (Brown et al., 2001).

The USGS recently updated the National Seismic Hazard Maps in 2008. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these

revised maps, which supersede the 1996 and 2002 versions. The 2008 map represents the best available data as determined by the USGS (USGS, 2008).

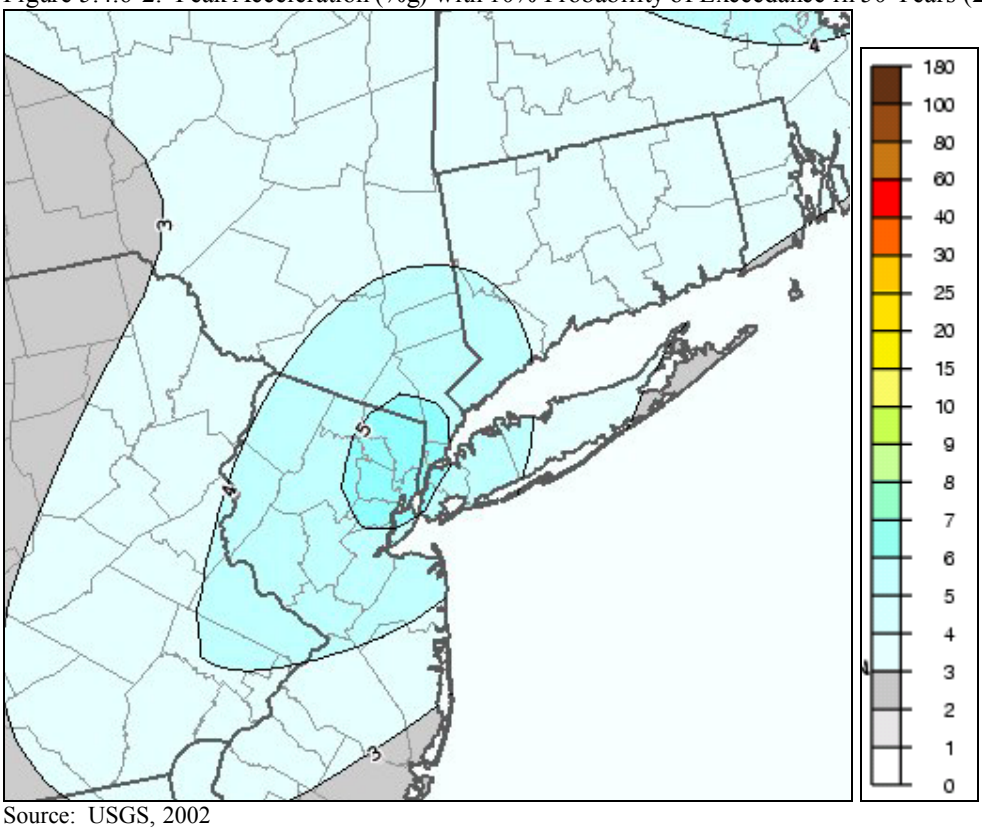
The 1996 Seismic Hazard Map shows that Westchester County has a PGA between 5 and 6% (Figure 5.4.6-1). The 2002 Seismic Hazard Map shows that Westchester County has a PGA between 4 and 5% (Figure 5.4.6-2). The 2008 Seismic Hazard Map shows that Westchester County has a PGA of 3% (Figure 5.4.6-3). These maps are based on peak ground acceleration (%g) with 10% probability of exceedance in 50 years. The difference in PGA from the 1996 to the 2002 Seismic Hazard Map is most likely due to the incorporation of new data collected and reviewed by the USGS.

Figure 5.4.6-1. Peak Acceleration (%g) with 10% Probability of Exceedance in 50 Years (1996)



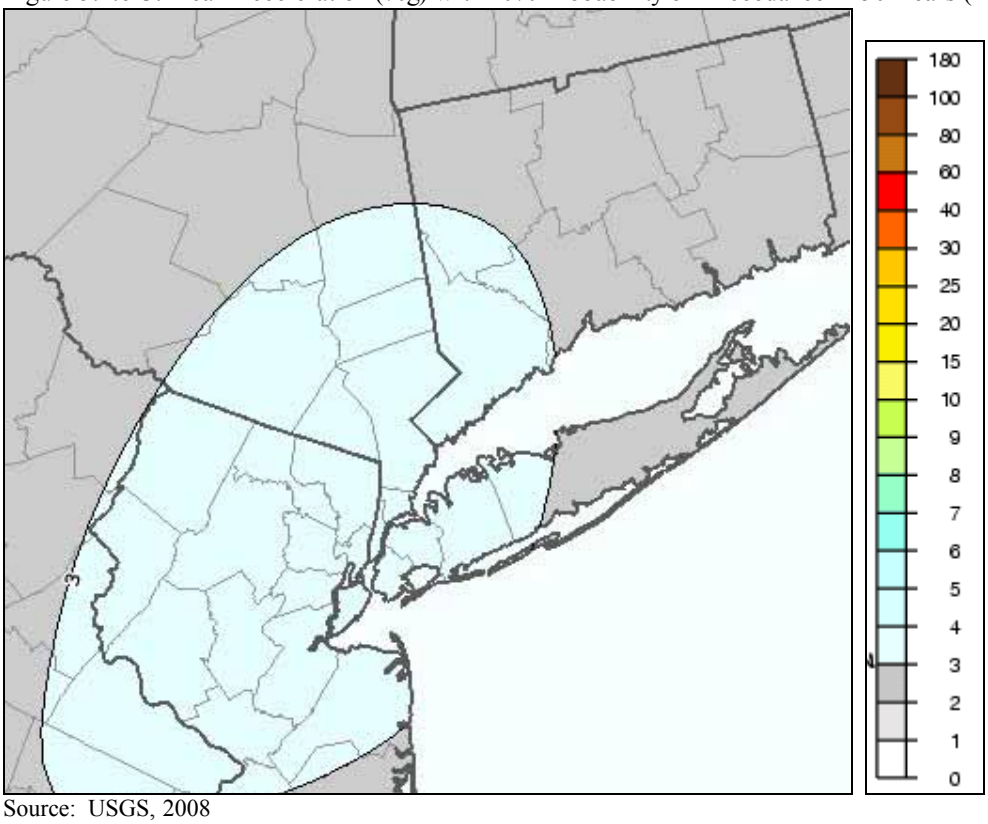
Source: USGS, 1996

Figure 5.4.6-2. Peak Acceleration (%g) with 10% Probability of Exceedance in 50 Years (2002)



Source: USGS, 2002

Figure 5.4.6-3. Peak Acceleration (%g) with 10% Probability of Exceedance in 50 Years (2008)

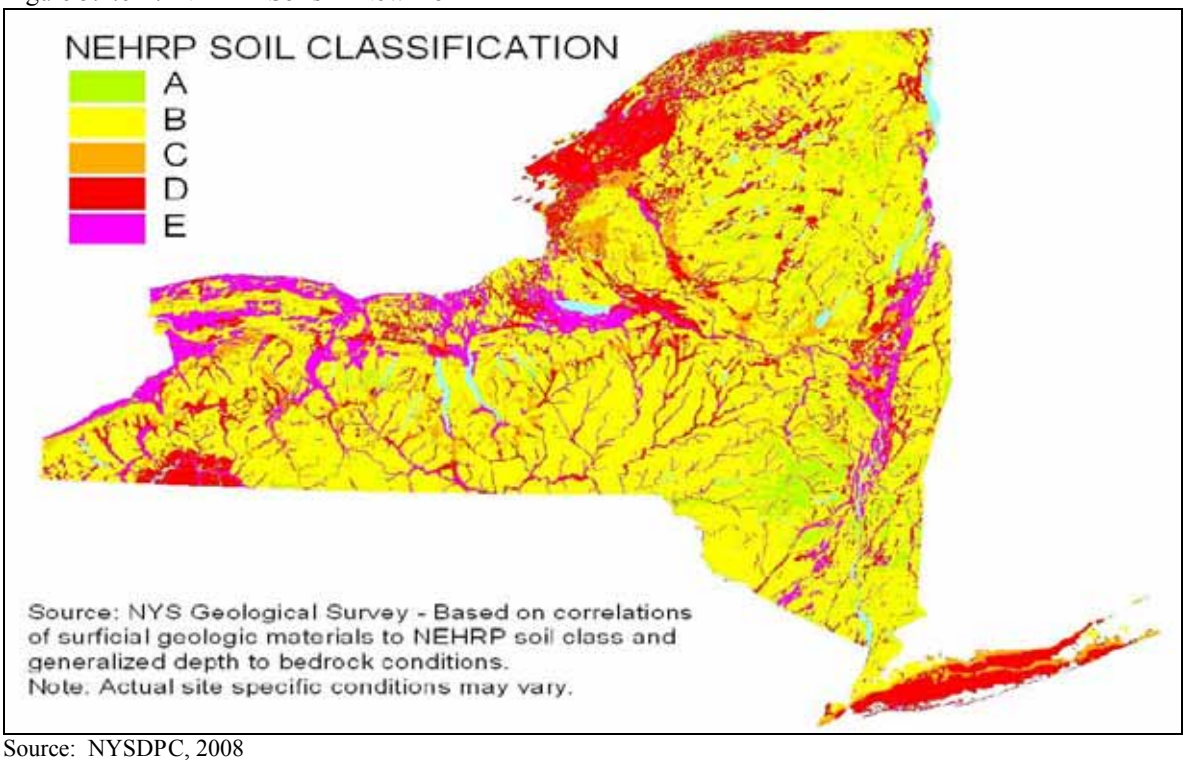


Source: USGS, 2008

The New York State Geological Survey conducted seismic shear-wave tests of the State's surficial geology (glacial deposits). Based on these test results, the surficial geologic materials of New York State were categorized according to the National Earthquake Hazard Reduction Program's (NEHRP) Soil Site Classifications (Figure 5.4.6-X). The NEHRP developed five soil classifications that impact the severity of an earthquake. The soil classification system ranges from A to E, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building damage and losses. Figure 5.4.6-4 illustrates the NEHRP soil classifications in Westchester County, as provided by NYSEMO (O'Brien, 2008). Table 5.4.6-4 summarizes the NEHRP soil classifications shown on Figure 5.4.6-4.

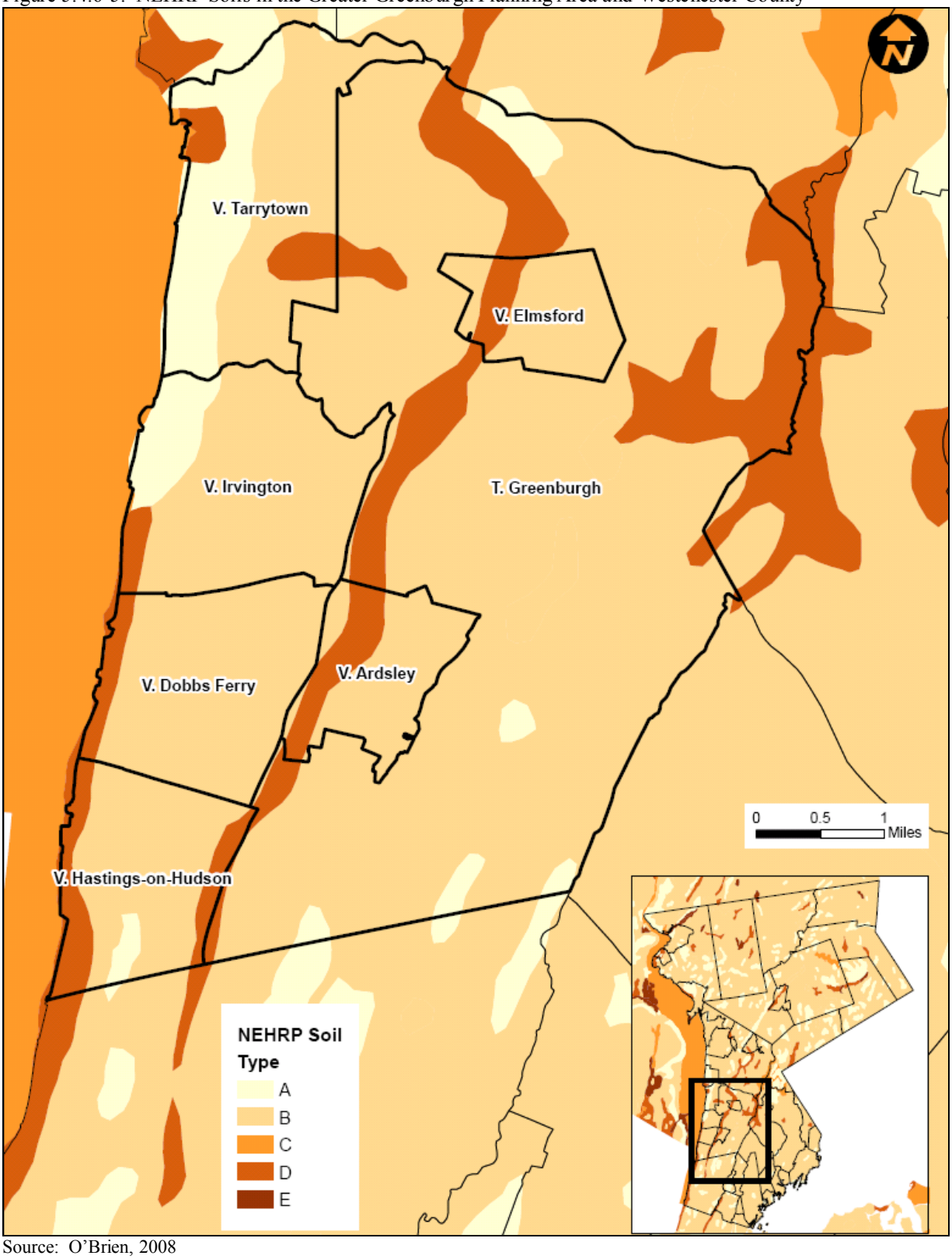
As illustrated in Figure 5.4.6-5, Unincorporated Greenburgh is mainly comprised of soil class B, sedimentary rock/firm ground, respectively in terms of NEHRP soil classes. There is a band of soil class D that runs from north to southwest, starting in Unincorporated Greenburgh and continues through the Villages of Elmsford and Ardsley. Another thin band of soil class D runs in a north/south direction starting in the Village of Irvingtn and continues through the Village of Hastings-on-Hudson. A band of soil class A is found in the northwest corner of the Greater Greenburgh Planning Area, in the Village of Tarrytown and continues south into the Village of Irvington.

Figure 5.4.6-4. NEHRP Soils in New York



Source: NYSDPC, 2008

Figure 5.4.6-5. NEHRP Soils in the Greater Greenburgh Planning Area and Westchester County



Source: O'Brien, 2008

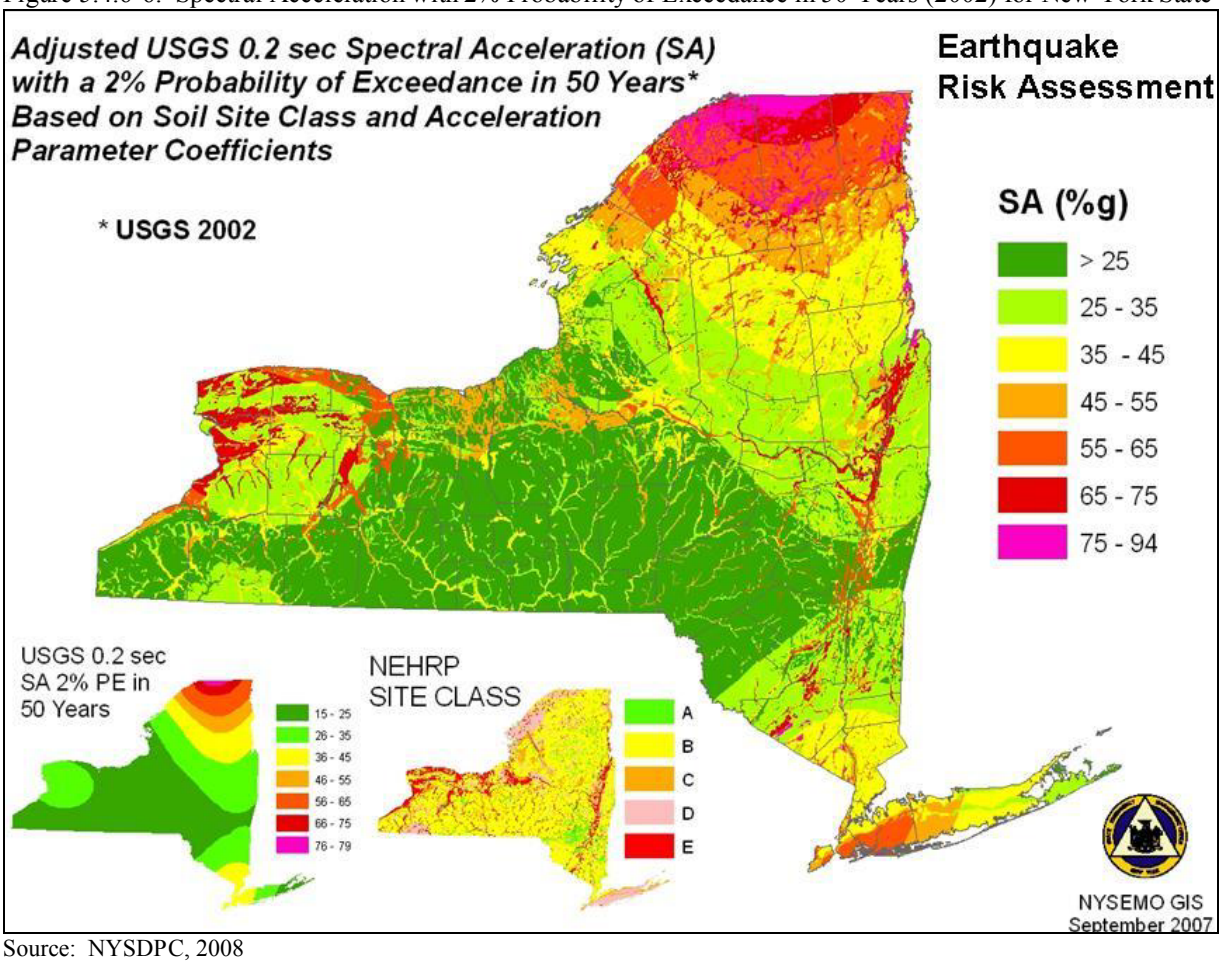
Table 5.4.6-4. NEHRP Soil Classifications

Soil Classification	Description	Map Color
A	Very hard rock (e.g., granite, gneisses)	Green
B	Sedimentary rock or firm ground	Yellow
C	Stiff clay	Orange
D	Soft to medium clays or sands	Red
E	Soft soil including fill, loose sand, waterfront, lake bed clays	Pink

Source: FEMA, 2007

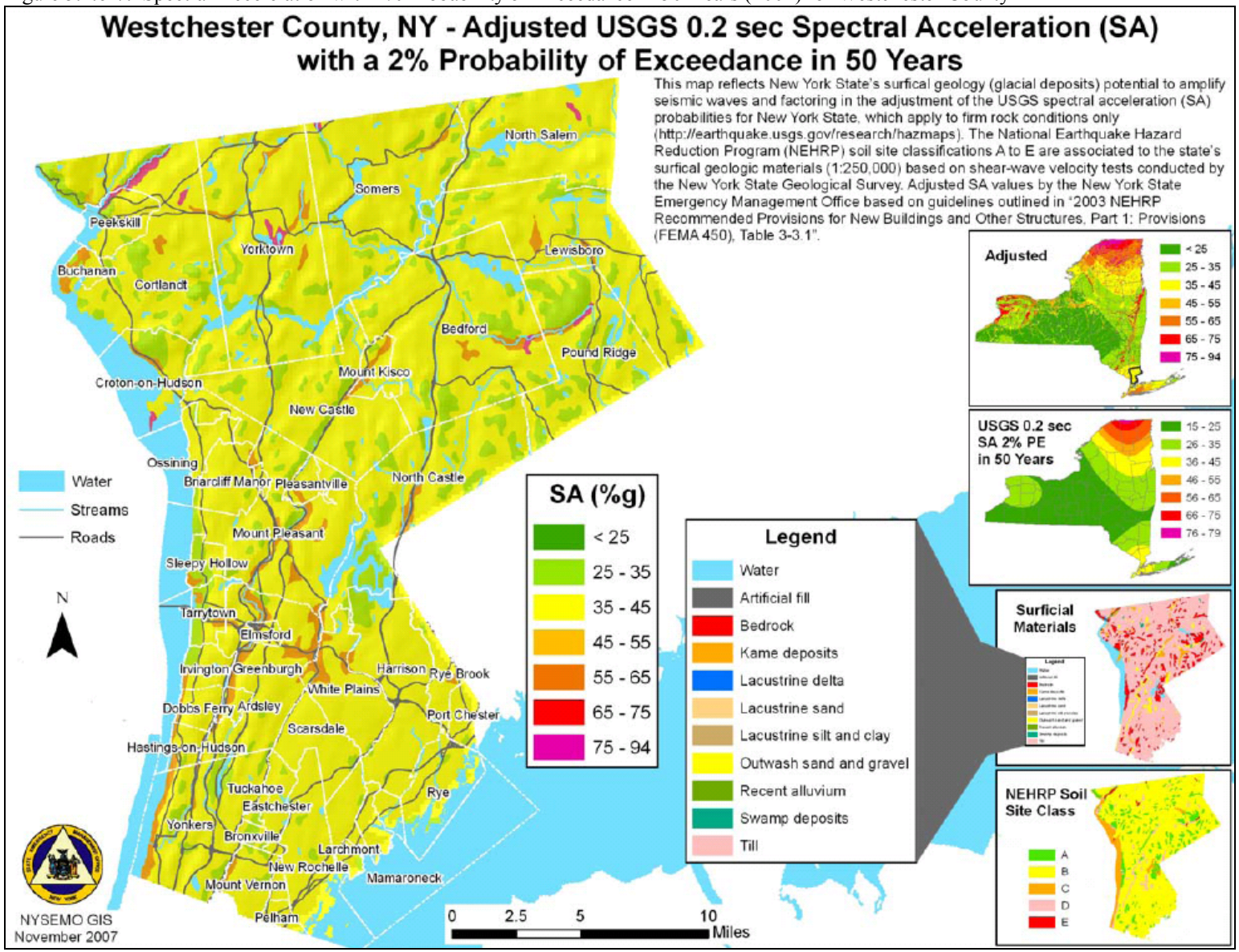
The NEHRP soil classification for the State has enabled the affect of soils to be factored with the 2002 USGS seismic hazard maps. Figures 5.4.6-6 and 5.4.6-7 now illustrate the State and County's earthquake SA hazard with local soil types factored in, respectively. This updated hazard map illustrates a significantly higher hazard for Westchester County than what is shown on the USGS national map (NYSDPC, 2008).

Figure 5.4.6-6. Spectral Acceleration with 2% Probability of Exceedance in 50 Years (2002) for New York State



Source: NYSDPC, 2008

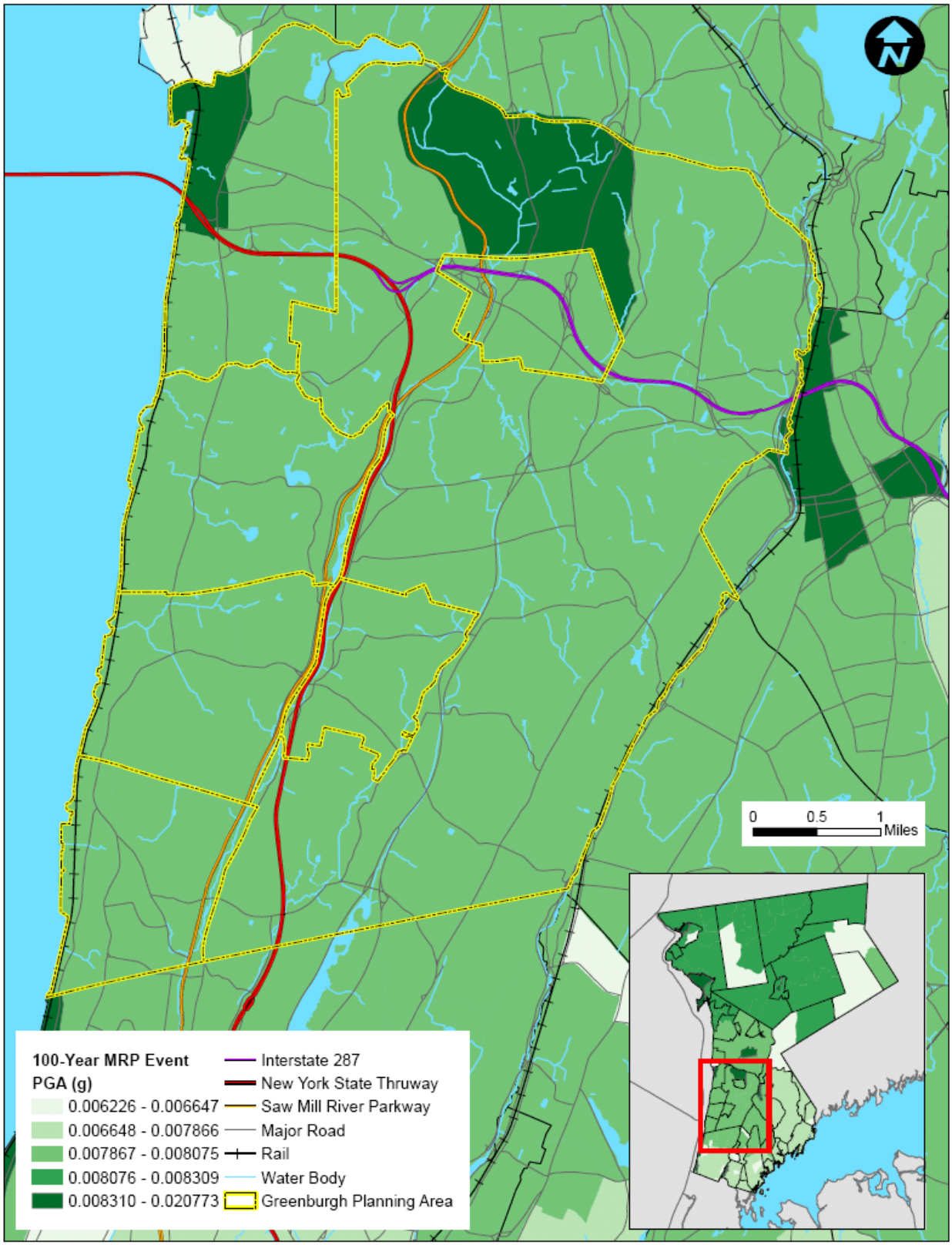
Figure 5.4.6-7. Spectral Acceleration with 2% Probability of Exceedance in 50 Years (2002) for Westchester County



Source: NYSDPC, 2008

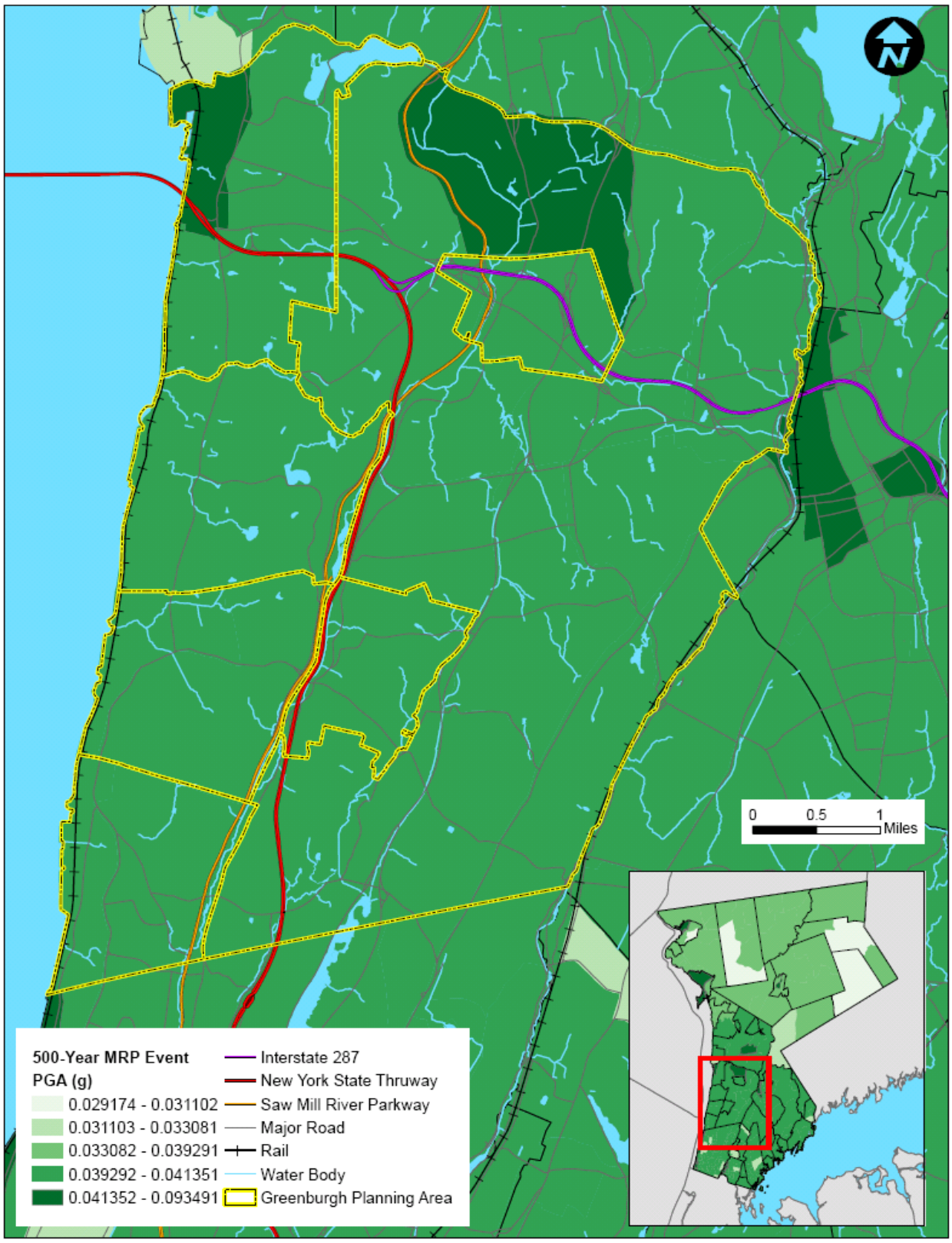
A probabilistic assessment was conducted for the 100-, 500- and 2,500-year mean return periods (MRP) through a Level 1 analysis in HAZUS-MH MR3 to analyze the earthquake hazard for the Greater Greenburgh Planning Area. The HAZUS-MH MR3 analysis evaluates the statistical likelihood that a specific event will occur and what consequences will occur. A 100-year MRP event is an earthquake with a 1% chance that the mapped ground motion levels (PGA) will be exceeded in any given year. For a 500-year MRP, there is a 0.2% chance the mapped PGA will be exceeded in any given year. For a 2,500-year MRP, there is a 0.04% chance the mapped PGA will be exceeded in any given year. Figures 5.4.6-8 through 5.4.6-10 illustrates the geographic distribution of PGA (*g*) across the Greater Greenburgh Planning Area for 100-, 500- and 2,500-year MRP events at the Census-Tract level.

Figure 5.4.6-8. Peak Ground Acceleration in the Greater Greenburgh Planning Area for a 100-Year MRP Earthquake Event



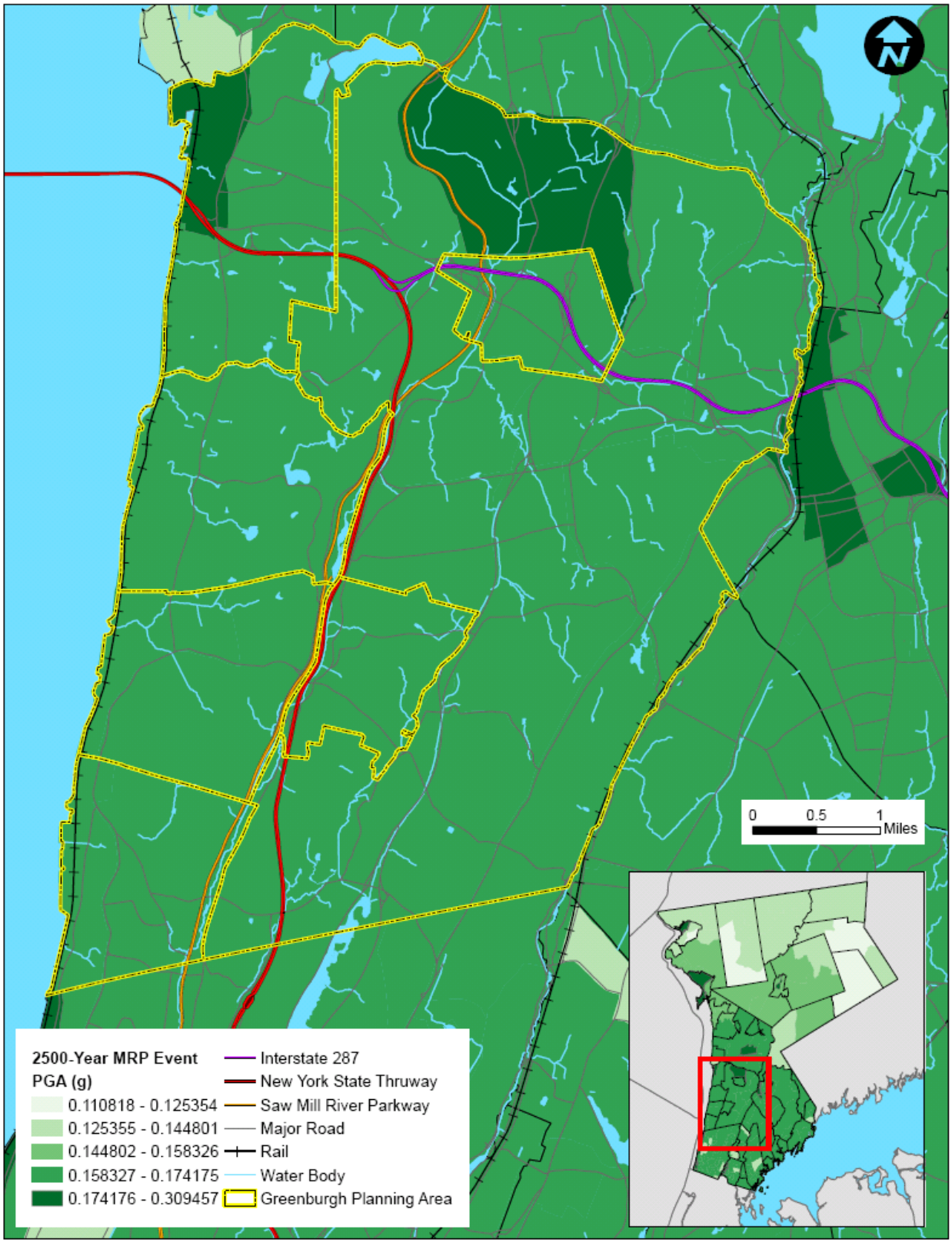
Source: HAZUS-MH MR4

Figure 5.4.6-9. Peak Ground Acceleration in the Greater Greenburgh Planning Area for a 500-Year MRP Earthquake Event by Census Tract



Source: HAZUS-MH MR4

Figure 5.4.6-10. Peak Ground Acceleration in the Greater Greenburgh Planning Area for a 2,500-Year MRP Earthquake Event by Census Tract



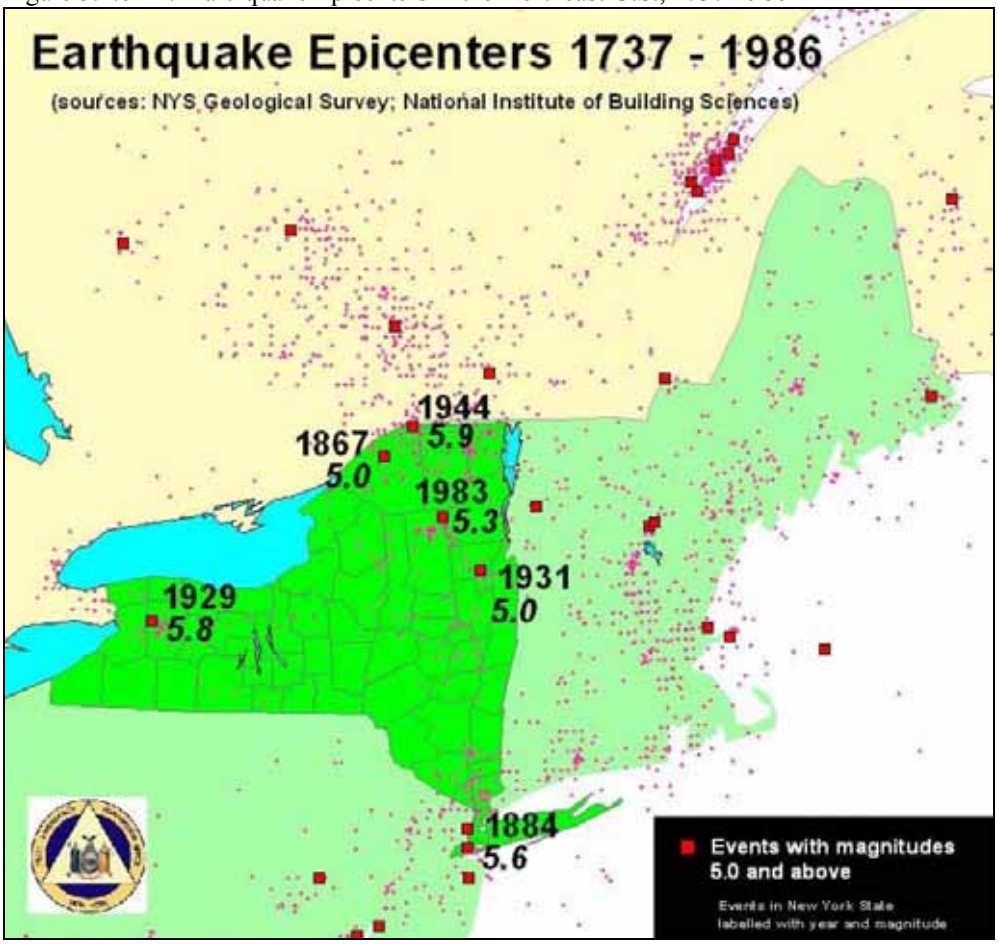
Source: HAZUS-MH MR4

Location

As noted in the NYS HMP, the importance of the earthquake hazard in New York State is often underestimated because other natural hazards (for example, hurricanes and floods) occur more frequently and because major floods and hurricanes have occurred more recently than a major earthquake event (NYSDPC, 2008). Typically areas east of the Rocky Mountains experience fewer and generally smaller earthquakes than the western U.S. However, the potential for earthquakes exists across all of New York State and the entire northeastern U.S.

The New York City Area Consortium for Earthquake Loss Mitigation (NYCEM) ranks New York State as having the third highest earthquake activity level east of the Mississippi River (Tantala et al., 2003). Figure 5.4.6-11 illustrates historic earthquake epicenters across the northeast U.S. and New York State between 1737 and 1986. Looking at Figure 5.4.6-11, the concentration of earthquakes in New York State is located in three general regions. These regions are: the north and northeast third of the State, which includes the North Country/Adirondack region and a portion of the greater Albany-Saratoga region; the southeast corner, which includes the greater New York City area and western Long Island; and the northwest corner, which includes Buffalo and its surrounding area. These regions have a seismic risk that tends to be higher than other parts of the State. Overall, these three regions are the most seismically active areas of the State, with the north-northeast portion having the higher seismic risk and the northwest corner of the State has the lower seismic risk (NYSDPC, 2008).

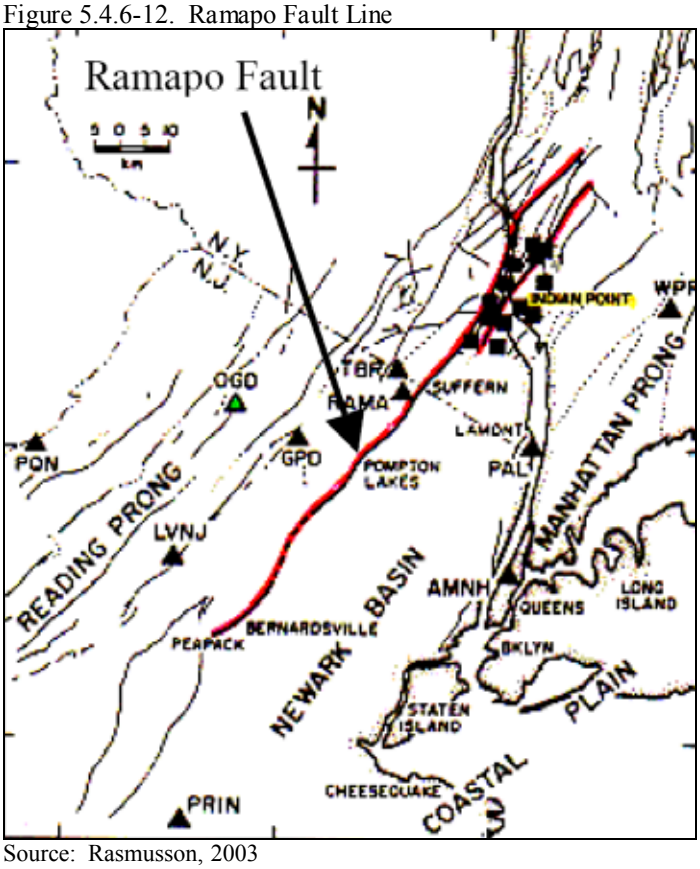
Figure 5.4.6-11. Earthquake Epicenters in the Northeast U.S., 1737-1986



Source: NYSDPC, 2008

The Ramapo Fault (Figure 5.4.6-12) is part of a system of northeast striking, southeast-dipping faults, which runs from southeastern New York to the Hudson River at Stony Point, through eastern Pennsylvania and beyond. The fault is a hairline fracture, 50 miles long, and is located 35 miles from New York City. Seismographic stations, part of the Advanced National Seismic System, are used to monitor earthquakes and ground motion near important buildings and critical infrastructure along this fault (Lamont-Doherty, 2004; Pasfield, Unknown). Numerous minor earthquakes have been recorded in the Ramapo Fault zone, a 10 to 20 mile wide area lying adjacent to and west of the actual fault (Dombroski, 2005).

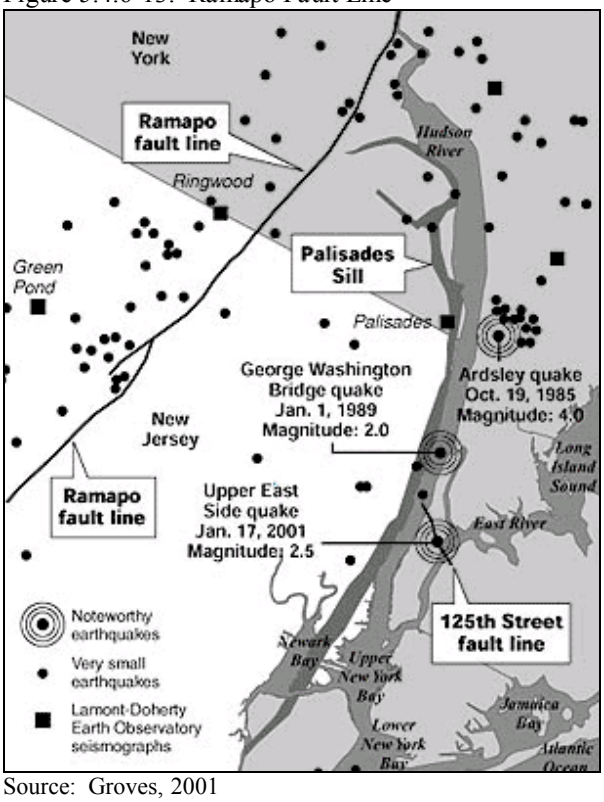
Figure 5.4.6-12. Ramapo Fault Line



Source: Rasmusson, 2003

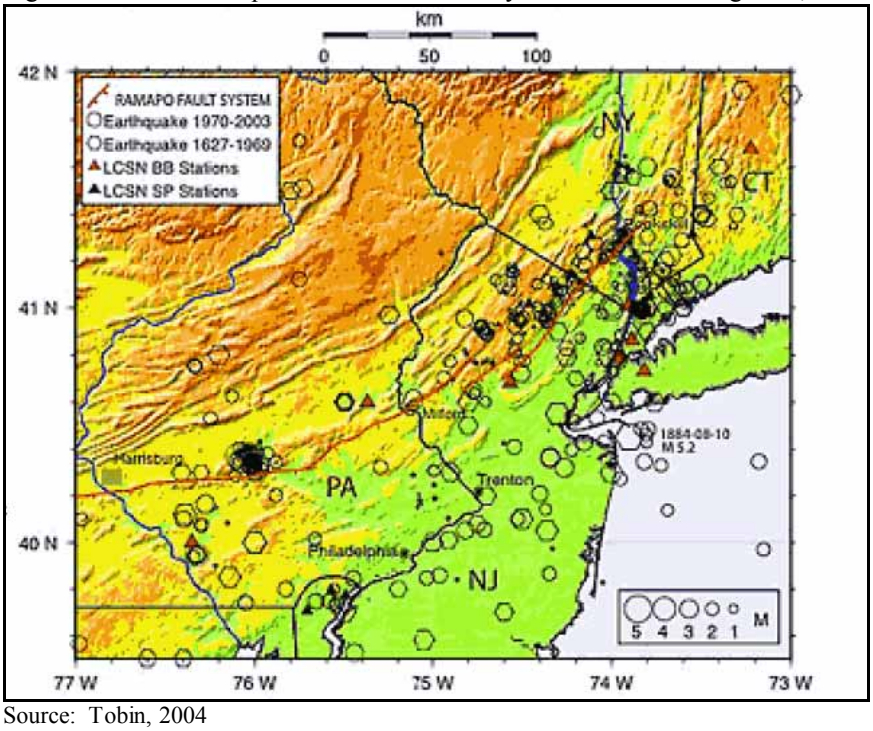
Figures 5.4.6-13 and 5.4.6-14 show the Ramapo Fault Line and the earthquakes that have occurred in the surrounding area of the fault.

Figure 5.4.6-13. Ramapo Fault Line



Source: Groves, 2001

Figure 5.4.6-14. Earthquakes in New York City and the Surrounding Area, 1627-2003



Source: Tobin, 2004

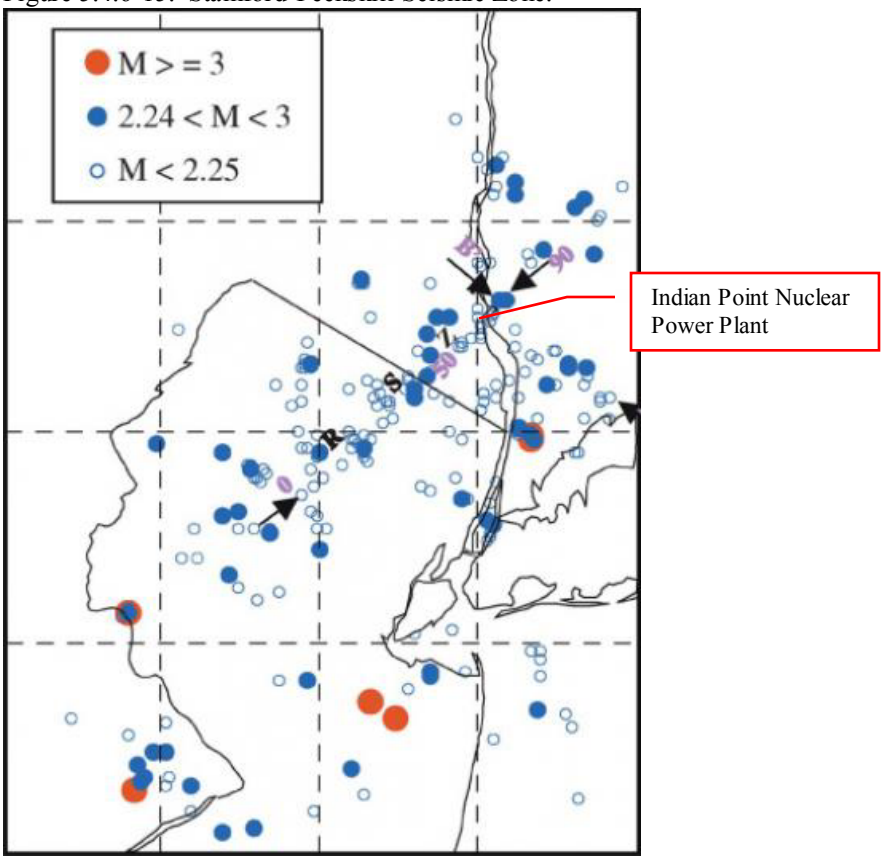
Note: The Ramapo Fault System is shown as a red line. Hexagons indicate earthquake events prior to 1970 and circles indicate earthquakes post 1970 (when systematic earthquake monitoring began in the region). The symbol size is proportional to magnitude.

The Dobbs Ferry Fault also extends through Westchester County to the southeast of the Ramapo Fault. The fault zone extends southeastward from the east bank of the Hudson River and crosses the Bronx River to Reservoir No. 1. The fault zone strikes northwest, and is between 8 and 10 kilometers long and 400 meters wide at its widest point.

According to a study conducted by the Lamont-Doherty Earth Observatory, research has found evidence of an active seismic zone running at least 25 miles from Stamford, Connecticut to the Hudson Valley Town of Peekskill, New York, known as the Stamford-Peekskill line. Small clusters of earthquake events are found along the length of the line and to its immediate southwest. Just north of the line, there are no recorded earthquakes. The Stamford-Peekskill line runs parallel to the other faults beginning at 125th Street and researchers believe this fault is in the same family capable of producing at least a magnitude 6 earthquake. This fault also intersects the Ramapo seismic zone (Sykes et al., 2008).

The study complied information from 383 earthquakes within a 15,000 square mile area around New York City since 1677 and analyzed 34 years of new data on tremors recorded by modern technology. Based on this research, magnitude 5 earthquakes should be expected in the region about every 100 years, with the most recent one in 1884 (Gardner, 2008; Neroulias, 2008; Environmental News Service, 2008. Figure 5.4.6-15 depicts the Stamford-Peekskill seismic zone, along with earthquakes between 1974 and 2007.

Figure 5.4.6-15. Stamford-Peekskill Seismic Zone.



Source: Sykes et al., 2008
Note: Quakes located by instruments 1974-2007. Arrows indicate the Peekskill-Stamford fault line and Ramapo seismic zone (RSZ), which intersect near Indian Point. Purple numerals indicate distance in kilometers.

In the 1970s and 1980s, earthquake risk along the Ramapo Fault became more known due to its proximity to the Indian Point Nuclear Power Generating Station, operated by Entergy Nuclear and located in the Village of Buchanan, New York. The Stamford-Peekskill seismic zone passes less than one mile north of the Indian Point nuclear power plant. Seismic evidence confirms that Indian Point is situated at the intersection of both the Ramapo and Stamford-Peekskill seismic zones (Sykes et al., 2008). Approximately 20 million people live within 50 miles of Indian Point, which includes all of New York City.

The combination of New York State's geology and human footprint may increase the problem with earthquakes and Indian Point. Many New York earthquakes occur near the surface, withinin the upper mile of the extremely hard, rigid rocks underlying Manhattan and much of the lower Hudson Valley. These rocks can build large stresses, and then suddenly transmit engery over long distances. The region's major highways, commuter and long-distance rail lines, and the main gas, oil and power transmission lines all run parallel with active faults (Sykes et al., 2008).

East of the Rocky Mountains, including New York State, earthquake faults do not break the ground surface. As previously stated, many New York earthquakes occur near the surface, within the upper mile. Their locations are determined by interpreting seismographic records. Geological fault lines seen on the surface today are evidence of ancient events. The presence or absence of mapped faults does not denote either a seismic hazard or the lack of one, and earthquake can occur anywhere in New York State (Westchestergov.com, 2010; Dombroski, 2005).

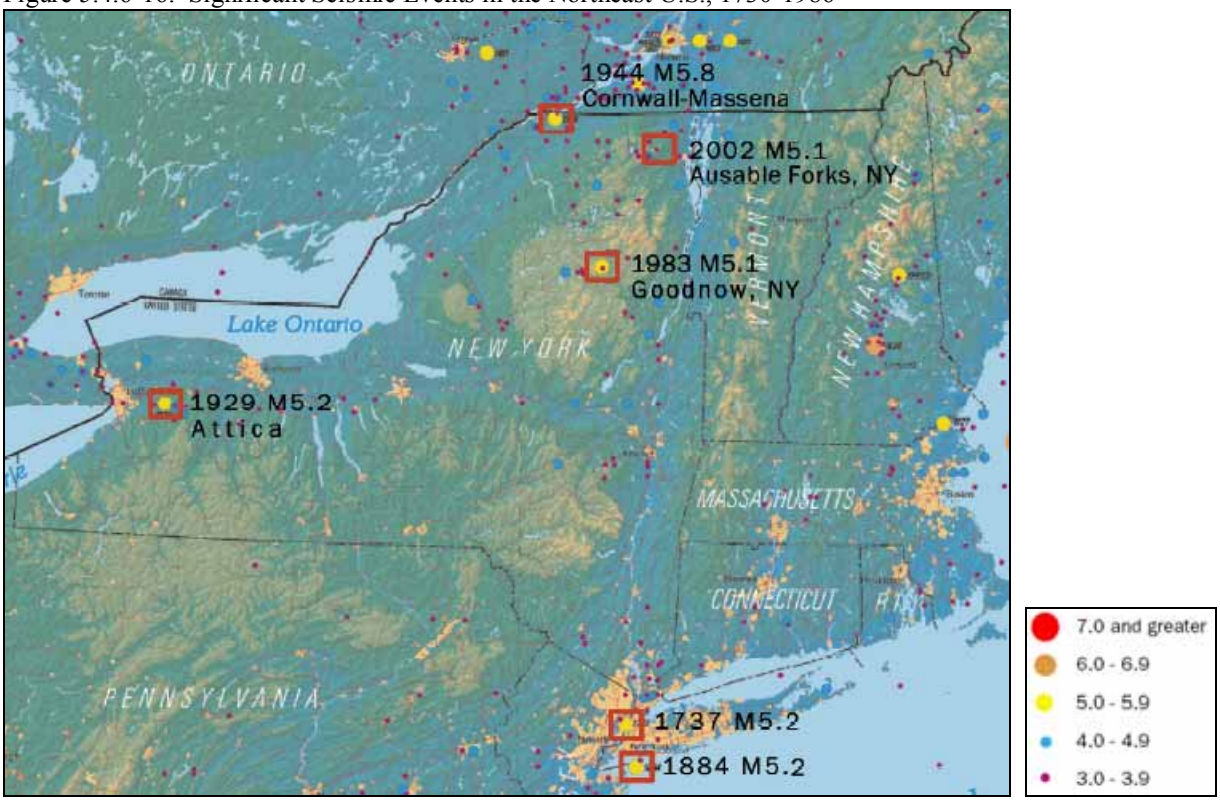
The closest plate boundary to the East Coast is the Mid-Atlantic Ridge, which is approximately 2,000 miles east of Pennsylvania. Over 200 million years ago, when the continent Pangaea rifted apart forming the Atlantic Ocean, the Northeast coast of America was a plate boundary. Being at the plate boundary, many faults were formed in the region. Although these faults are geologically old and are contained in a passive margin, they act as pre-existing planes of weakness and concentrated strain. When a strain exceeds the strength of the ancient fault, it ruptures causing an earthquake (Lehigh Earth Observatory, 2006).

Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with earthquakes throughout New York State and the Greater Greenburgh Planning Area. Therefore, with so many sources reviewed for the purpose of this HMP, loss and impact information for many events could vary depending on the sources.

Based on seismic records, thousands of earthquakes with magnitudes larger than 2.0, have occurred in New York State over the past few centuries. Between 1730 and 1986, more than 400 earthquakes with a magnitude of greater than 2.0 are on record in New York State, but many more have occurred unrecorded (Figure 5.4.6-16) (Tantala et al., 2003).

Figure 5.4.6-16. Significant Seismic Events in the Northeast U.S., 1730-1986



Source: Tantala et al., 2003

According to the NYSDPC, New York Times and Lamont-Doherty, approximately 55 earthquake events have affected New York State between 1971 and 2010. Additional sources have noted other earthquake events within New York State as well. Table 5.4.6-5 depicts these earthquakes events. Several of these events were located within the immediate vicinity of the Greater Greenburgh Planning Area.

Table 5.4.6-5. Earthquake History in New York State, 1971-2010

Event Date / Name	Location	Size / General Magnitude	Losses / Impacts	Source(s)
Earthquake May 23, 1971	Blue Mountain Lake, New York	3.5 - 4.1	No reference and/or no damage reported	NYSDPC
Earthquake June 7, 1974	Wappingers Falls, New York	3.0	Windows broken	NYSDPC
Earthquake June 9, 1975	Plattsburgh, New York	3.5	Chimneys and fireplaces cracked	NYSDPC
Earthquake November 3, 1975	Raquette Lake, New York	4.0	No reference and/or no damage reported	NYSDPC
Earthquake February 2, 1983	Scarsdale-Livingston, New York	3.0	Chimneys cracked	NYSDPC
Earthquake October 7, 1983	Newcomb, New York	5.1	Tombstones rotated, some cracked chimneys, windows broken, walls damaged	NYSDPC
Earthquake April 22, 1984	Lancaster, Pennsylvania	4.1	Residents in northern New Jersey, Westchester County, Staten Island and Queens felt mild tremors from an earthquake that struck 15 miles south of Lancaster, PA. No damage was reported. It was felt as far south as Baltimore, Maryland.	New York Times
Earthquake October 18, 1985	White Plains, New York	4.0	Windows broken, walls damaged; many people in New York City reported feeling the earthquake. Felt from Philadelphia, Pennslyvania to Canada.	NYSDPC, Kim, Hozik
Earthquake October 19, 1985	Ardsley, New York	4.0	Many people in the New York City area felt the earthquake.	LDEO
Earthquake January 4, 1986	Ardsley and Scarsdale, New York	2.0 and 3.0	A minor earthquake struck Westchester County. It was centered between Ardsley and Scarsdale. Police departments in the area of the epicenter received reports of people having felt the earthquake.	New York Times
Earthquake December 20, 1986	Ardsley, New York	Not Stated	Parts of Westchester County experienced a minor earthquake. Seismologists stated that this event was so small that initial instrument checks failed to establish its time, location or force. The earthquake was very minor and could hardly be felt.	New York Times
Earthquake	Summit, New York	4.1	No reference and/or no damage reported	NYSDPC

Event Date / Name	Location	Size / General Magnitude	Losses / Impacts	Source(s)
June 17, 1991				
Earthquake March 10, 1992	East Hampton, New York	4.1	No reference and/or no damage reported	NYSDPC
Earthquake March 22, 1994	Cuylerville, New York	3.6	No reference and/or no damage reported	NYSDPC
Earthquake February 15, 1995	North Tarrytown, New York	1.5	No reference and/or no damage reported	Lamont-Doherty
Earthquake January 1, 1997	Dobbs Ferry, New York	1.0	No reference and/or no damage reported	Lamont-Doherty
Earthquake April 20, 2000	Newcomb, New York	3.8	Aftershock of the 1983 event; no damage reported	NYSDPC
Earthquake January 17, 2001	Upper East Side of Manhattan, New York	2.5	No reference and/or no damage reported	Lamont-Doherty, USGS
Earthquake January 19, 2001	Upper East Side of Manhattan, New York	1.2	No reference and/or no damage reported	Lamont-Doherty
Earthquake October 27, 2001	New York City, New York	2.6	No reference and/or no damage reported	USGS
Earthquake April 20, 2002 (FEMA DR-1415)	Au Sable Forks, New York	5.1	Largest earthquake to hit New York State in 20 years. People felt the earthquake from Washington, D.C. to Bangor, Maine. A state of emergency was declared in Essex and Clinton Counties.	NYSDPC, USGS
Earthquake May 24, 2002	Au Sable Forks, New York	3.1	Aftershock of the 4/20/2002 event; no damage reported	NYSDPC, USGS
Earthquake January 11, 2003	Hastings-on-Hudson, New York	1.2 – 1.4	First of two minor earthquakes to hit Westchester County in five days. It struck around 9:30pm near Hastings-on-Hudson. Residents in the surrounding area of the epicenter reported hearing an explosion or feeling the earth shake.	Lamont-Doherty, New York Times
Earthquake January 15, 2003	Greenburgh, New York	1.2 – 1.4	Second minor earthquake to hit Westchester County in five days. Many residents in the area of the earthquake experienced a deep, resonating explosion.	Lamont-Doherty, New York Times
Earthquake February 27, 2008	Amsterdam, New York	2.7	No reference and/or no damage reported	USGS
Earthquake May 28, 2008	Saratoga Springs, New York	1.8	No reference and/or no damage reported	USGS
Earthquake June 23, 2010	Ontario-Quebec Border, Canada	5.0	An earthquake struck north of Ottawa. It was felt as far south as Brooklyn and Staten Island, New York. Parts of New Jersey, upstate New York, and Vermont were also affected. In the	New York Times, USGS

Event Date / Name	Location	Size / General Magnitude	Losses / Impacts	Source(s)
			Greater Greenburgh Planning Area, the Villages of Dobbs Ferry, Irvington and Tarrytown reported having felt the earthquake.	
Earthquake November 30, 2010	80 miles off the coast of Southampton, New York	3.9	The epicenter was approximately 122 miles from New York City and was at a depth of 4.1 miles in the Atlantic Ocean. This earthquake was the largest to hit the New York area in 18 years. It was felt across the New York metropolitan area, with reports indicating people felt the earthquake by seeing chandeliers swing and hearing windows rattle. Some people reported that it sounded like a truck passing by. In the Greater Greenburgh Planning Area, residents from the Villages of Dobbs Ferry and Irvington reported having felt the earthquake	Fertoli and Kramer, Carvajal, USGS

Source(s): NYSDPC, 2008; USGS, 2008; New York Times, Multiple Dates; Lamont-Doherty, 2002; Kim, 1999

Earthquakes in the Greater Greenburgh Planning Area are not common, with documented information on earthquake events and their location is being relatively scarce. According to Planning Area officials, there is no record of earthquake occurrences within the Planning Area. However, depending on the magnitude, the impacts of earthquake events can be far-reaching; therefore, reported incidences within the surrounding counties or states could have created indirect impacts upon the Planning Area. The following events described below may or may not have created indirect impacts upon the Greater Greenburgh Planning Area.

January 11-15, 2003: Two small earthquakes struck Westchester County, New York within five days. The Dobbs Ferry fault line that runs through the County was responsible for the earthquakes. The first earthquake struck near the Village of Hastings-on-Hudson during the evening on January 11th and measured 1.2 on the Richter scale. Residents that felt the earthquake said that it felt like an explosion (Foderaro, 2003).

The second earthquake struck near Unincorporated Greenburgh during the evening on January 15th and measured 1.4 on the Richter scale. Residents that felt the earthquake said ti felt like a rumble (Foderaro, 2003).

April 20, 2002 (FEMA DR-1415): A moderate earthquake occurred about 15 miles southwest of Plattsburgh, New York. The earthquake was felt widely across the northeastern U.S., Mid - Atlantic States and southern Canada, including Montreal, Quebec (USGS, 2002). Boston, Massachusetts; Bangor, Maine; Washington, D.C.; Cleveland, Ohio; and Baltimore, Maryland were among the cities that experienced indirect impacts from this event (Cappiello and Tilghman, 2002).

In New York State, this was the largest earthquake in nearly 20 years with an intensity of 5.1 on the Richter scale and resulted in widespread impacts. Governor George Pataki declared a state of emergency in Clinton and Essex Counties, after feeling the earthquake in Albany (Cappiello and Tilghman, 2002). Overall damage within the State included tipped chimneys and cracked roads; however, no injuries were reported. Road damage and closures were reported at Keeseville and Au Sable Forks (Essex County). Chimney damage was reported in Lake Placid (Essex County). The Township of Jay (Essex County), there was bridge damage and a reported landslide. Slight damage was reported at Blue Mountain Lake, Indian Lake, Minerva, and North River. The earthquake was also felt in Adirondack, Childwold, Moriah Center, Newcomb, North Creek, Old Forge, Olmstedville, Piercefield, Severance, Wanakena, and many other locailities of upstate New York, most reporting at an intensity of V (USGS, 2002).

Reports of having felt the earthquake were noted in the Greater Greenburgh Planning Area (USGS, 2002). Details regarding the impact of the earthquake in the Planning Area were unavailable in the materials reviewed to develop this plan. Additionally, two aftershocks were felt the morning of the earthquake, which registered 2.2 on the Richter scale. Seven seismographs were set up around the epicenter of the earthquake to gauge activity and pick up data that could help seismologists gain a better understanding of earthquakes (Hughes, 2002).

This earthquake resulted in a FEMA Disaster Declaration (FEMA DR-1415) on May 16, 2002. Through this declaration, the following Counties were declared eligible for federal and State disaster public assistance funds: Clinton, Essex, Franklin, Hamilton, Warren and Washington. Westchester County and the Greater Greenburgh Planning Area were not declared eligible for assistance from this FEMA disaster.

Probability of Future Events

Earthquake hazard maps illustrate the distribution of earthquake shaking levels that have a certain probability of occurring over a given time period. According to the USGS, in 2008, Westchester County

and the Greater Greenburgh Planning Area had a PGA of 3%g for earthquakes with a 10-percent probability of occurring within 50 years. Moderate shaking and very light damage is generally associated with a 3 to 4%g earthquake.

The NYSDPC indicates that the earthquake hazard in New York State is often understated because other natural hazards occur more frequently (for example: hurricanes, tornadoes and flooding) and are much more visible. However, the potential for earthquakes does exist across the entire northeastern U.S., and New York State is no exception (NYSDPC, 2008).

Earlier in this section, the identified hazards of concern for the Greater Greenburgh Planning Area were ranked. NYSEMO conducts a similar ranking process for hazards that affect the State. The probability of occurrence, or likelihood of the event, is one parameter used for ranking hazards. Based on historical records and input from the Planning Committee, the probability of occurrence for earthquakes in the Planning Area is considered "rare" (not likely to occur within 100 years as presented in Table 5.3-3). Although no reported incidences have occurred within the Planning Area, it is anticipated that the Greater Greenburgh Planning Area will continue to experience indirect impacts from earthquakes that may affect the general building stock, local economy and may induce secondary hazards such ignite fires and cause utility failure.

VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the earthquake hazard, Unincorporated Greenburgh and the Villages of Ardsley, Dobbs Ferry, Elmsford, Hastings-On-Hudson, Irvington and Tarrytown (Greater Greenburgh Planning Area) have been identified as the exposed hazard area. Therefore, all assets in the Planning Area (population, structures, critical facilities and lifelines), as described in the Regional Profile (Section 4), are vulnerable. The following section includes an evaluation and estimation of the potential impact of the earthquake hazard on the Greater Greenburgh Planning Area including the following:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, safety and health of residents, (2) general building stock, (3) critical facilities, (4) economy and (5) future growth and development
- Further data collections that will assist understanding of this hazard over time
- Overall vulnerability conclusion

Overview of Vulnerability

Earthquakes usually occur without warning and can impact areas a great distance from their point of origin. The extent of damage depends on the density of population and building and infrastructure construction in the area shaken by the quake. Some areas may be more vulnerable than others based on soil type, the age of the buildings and building codes in place. Compounding the potential for damage – historically, Building Officials Code Administration (BOCA) used in the Northeast were developed to address local concerns including heavy snow loads and wind; seismic requirements for design criteria are not as stringent compared to the west coast's reliance on the more seismically-focused Uniform Building Code). As such, a smaller earthquake in the Northeast can cause more structural damage than if it occurred out west.

The Greenburgh Planning Area is not located within the Indian Point Power Plant Emergency Planning Zone, or 10-mile radius. However, Indian Point is vulnerable to the earthquake hazard as evidenced by the active Stamford-Peekskill and Ramapo seismic zones in the region. According to the Indian Point Hazard Mitigation Plan, *Indian Point is vulnerable to earthquake, flooding, drought and effects of extreme temperatures. There are vulnerabilities to the reactor itself with its aging concrete dome and obsolete wiring, to the supporting infrastructure of buildings, water pipes, electrical wires and transmission lines which are necessary to the safe functioning of the reactors and to the spent nuclear fuel accumulating on site.* Therefore, the entire population of the Greater Greenburgh Planning Area is vulnerable to the earthquake hazard as well as the secondary hazards related to an earthquake that impacts Indian Point.

In summary, the entire population and general building stock inventory of the Greater Greenburgh Planning Area is at risk of being damaged or experiencing losses due to impacts of an earthquake. Potential losses associated with the earth shaking were calculated for Westchester County for three probabilistic earthquake events, the 100-year, 500- and 2,500-year mean return periods (MRP). The impacts on population, existing structures, critical facilities and the economy within Unincorporated and the Villages of Ardsley, Dobbs Ferry, Elmsford, Hastings-On-Hudson, Irvington and Tarrytown are presented below, following a summary of the data and methodology used.

As discussed earlier, Figure 5.4.6-5 in this profile illustrates the NEHRP soil classifications in Westchester County and the Greater Greenburgh Planning Area, as provided by NYSOEM (O'Brien,

2008). The Greater Greenburgh Planning Area is comprised of soil classes A and B (very hard rock or sedimentary rock/firm ground, respectively in terms of NEHRP soil classes) as well as soil class D (soft to medium clays or sands). NEHRP soil class D is located in the northeastern portion of Unincorporated Greenburgh, along the Saw Mill River, an area within the Village of Tarrytown and into Unincorporated Greenburgh and along the Hudson River shoreline. According to NYCEM, softer soils (NEHRP soils D and E) can amplify ground shaking to damaging levels even in a moderate earthquake (NYCEM, 2003). Therefore, these areas in the Planning Area are most vulnerable to the earthquake hazard.

Data and Methodology

A probabilistic assessment was conducted for the Greater Greenburgh Planning Area for the 100-, 500- and 2,500-year MRPs through a Level 2 analysis in HAZUS-MH MR4 to analyze the earthquake hazard and provide a range of loss estimates for the Town and its inclusive villageas. The probabilistic method uses information from historic earthquakes and inferred faults, locations and magnitudes, and computes the probable ground shaking levels that may be experienced during a recurrence period by Census tract. According to NYCEM, probabilistic estimates are best for urban planning, land use, zoning and seismic building code regulations (NYCEM, 2003). The default assumption is a magnitude 7 earthquake for all return periods. In addition, an annualized loss run was also conducted in HAZUS-MH MR4 to estimate the annualized general building stock dollar losses for the Greater Greenburgh Planning Area.

As discussed in Section 5.2, a Level 1 analysis is a basic estimate of earthquake losses based on national databases and using the default data in the model. Default demographic and general building stock data in HAZUS-MH MR4 were used for the earthquake analysis. However, critical facilities (essential facilities, transportation features, utilities and user-defined facilities) were updated and used in place of the HAZUS-MH MR4 defaults. Additionally, a local soil map provided by NYSEMO with Westchester County's NEHRP soil classes was entered into HAZUS-MH MR4 to replace default soil conditions (Figure 5.4.6-7). These data updates allowed for a Level 2 earthquake analysis. Please note, according to the HAZUS-MH technical manual, there is considerable uncertainty related to the characteristics of ground motion in the eastern U.S. Therefore, loss estimates may be overestimated.

The occupancy classes available in HAZUS-MH MR4 were condensed into the following categories (residential, commercial, industrial, agricultural, religious, government, and educational) to facilitate the analysis and the presentation of results. Residential loss estimates address both multi-family and single family dwellings. Impacts to critical facilities were also evaluated.

Data used to assess this hazard include data available in the HAZUS-MH MR4 earthquake model, USGS data, data provided by NYSEMO, professional knowledge, and information provided by the Planning Area's Planning Committee. All exposure and loss estimates discussed in the assessment below are for the.

Impact on Life, Health and Safety

Overall, the entire population of the Greater Greenburgh Planning Area is exposed to the earthquake hazard event. According to the 2000 U.S. Census, the Planning Area had a population of 86,764 people. The impact of earthquakes on life, health and safety is dependent upon the severity of the event. Risk to public safety and loss of life from an earthquake in the Planning Area is minimal with higher risk occurring in buildings as a result of damage to the structure, or people walking below building ornamentation and chimneys that may be shaken loose and fall as a result of the quake.

Populations considered most vulnerable include the elderly (persons over the age of 65) and individuals living below the Census poverty threshold. These socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Table 5.4.6-6 summarizes the population over the age of 65 and individuals living below the Census poverty threshold in the Planning Area.

Table 5.4.6-6. Greater Greenburgh Planning Area Population Statistics (2000 U.S. Census)

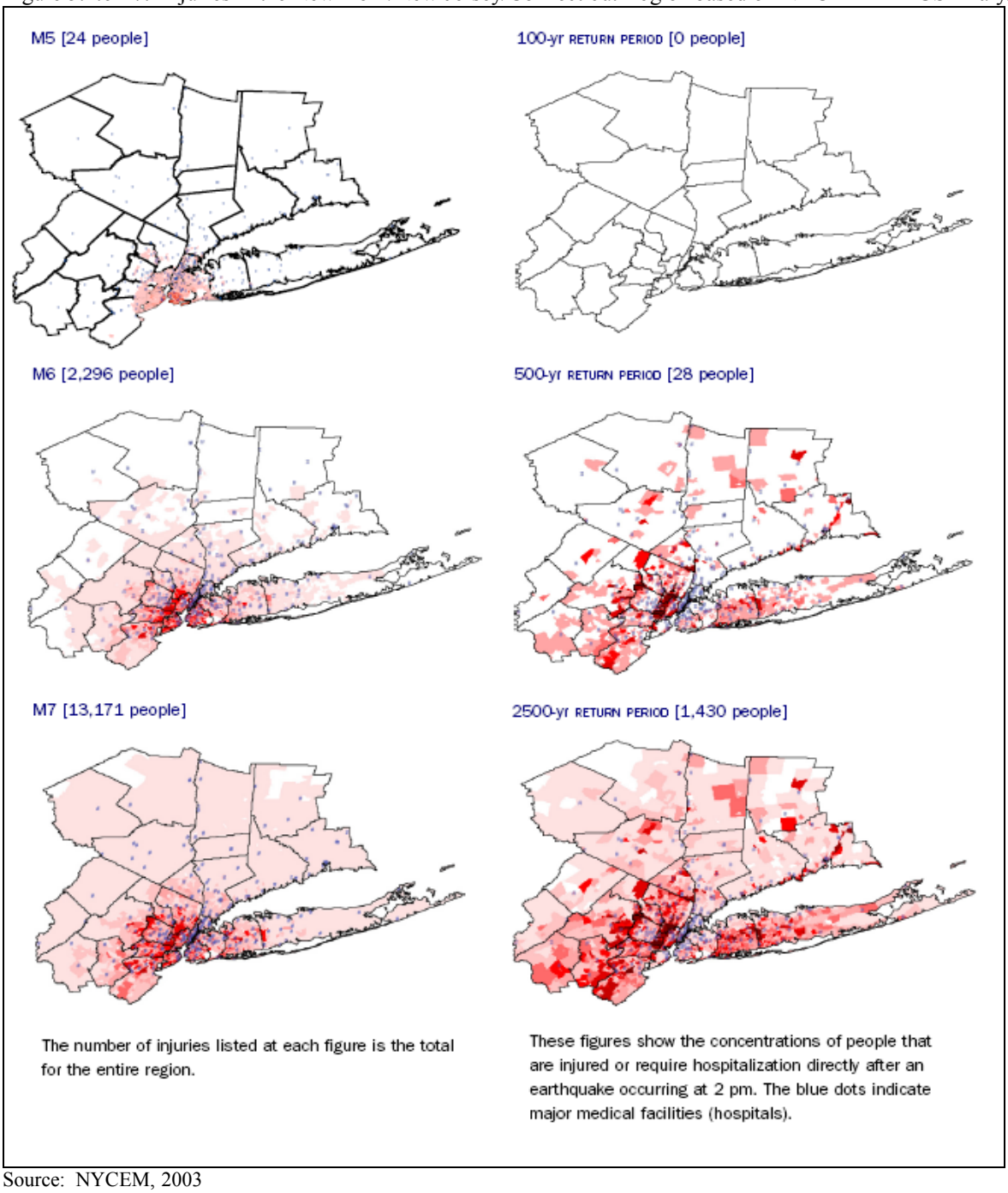
Census/HAZUS-MH 2000 Population	HAZUS-MH Population Over 65	HAZUS-MH Low-Income Population
Unincorporated Greenburgh	41,828	1,319
Village of Ardsley	4,269	40
Village of Dobbs Ferry	10,622	416
Village of Elmsford	4,676	162
Village of Hastings-on-Hudson	7,648	284
Village of Irvington	6,631	187
Village of Tarrytown	11,090	459
Planning Area Total	**86,764**	**2,867**

Source: U.S. Census 2000; HAZUS-MH MR4
Note: For the purposes of this Plan, the poverty level used is income less than $20,000. U.S. Census Families Below Poverty is based on households, not individuals. HAZUS-MH Population Below Poverty is based on individuals, not families.

According to the 1999-2003 NYCEM Summary Report (*Earthquake Risks and Mitigation in the New York / New Jersey / Connecticut Region*), there is a strong correlation between structural building damage and the number of injuries and casualties from an earthquake event. NYCEM conducted a HAZUS analysis for the New York, New Jersey, Connecticut region for M5, M6 and M7 deterministic scenarios (1884 M5.2 historic earthquake) and three probabilistic scenarios (100-, 500- and 2500-year events). Figure 5.4.6-17 is a graphic summary of the injury estimates for the different earthquake scenarios in the entire New York, New Jersey, Connecticut region, occurring at 2 pm. The color code indicates that the highest number of injuries would be concentrated in the New York City metropolitan area due to high population concentration.

Residents may be displaced or require temporary to long-term sheltering due to the event. For the 100-year MRP, HAZUS-MH MR4 estimates that zero households will be displaced and zero people will seek temporary shelter. For the 500-year MRP, HAZUS-MH MR4 estimates twelve (12) households will be displaced and of these, six (6) will seek temporary shelter. For the 2,500-year MRP, HAZUS-MH MR4 estimates 163 households will be displaced due to the earthquake event and 91 people will seek temporary shelter in public shelters. The number of people requiring shelter is generally less than the number displaced as some displaced persons use hotels or stay with family or friends following a disaster event. Table 5.4.6-7 summarizes the population HAZUS-MH MR4 estimates will be displaced or will require short-term sheltering as a result of 500- and 2,500-year MRP earthquake events by municipality.

Figure 5.4.6-17. Injuries in the New York/New Jersey/Connecticut Region based on NYCEM HAZUS Analysis



Source: NYCEM, 2003

Table 5.4.6-7. Estimated Sheltering Needs for the 500- and 2,500-year MRP Earthquake Events for the Greater Greenburgh Planning Area

Municipality	500-Year MRP		2,500-Year MRP	
	Displaced House-holds	People Requiring Short-Term Shelter	Displaced House-holds	People Requiring Short-Term Shelter
Unincorporated Greenburgh	5	3	56	31
Village of Ardsley	0	0	1	1
Village of Dobbs Ferry	1	1	14	8
Village of Elmsford	0	0	3	3
Village of Hastings-on-Hudson	1	0	9	4
Village of Irvington	1	0	7	4
Village of Tarrytown	4	2	72	41
Planning Area Total	**12**	**7**	**163**	**91**

Source: HAZUS-MH MR4

HAZUS-MH MR4 estimates the number of people that may potentially be injured and/or killed by an earthquake depending upon the time of day the event occurs. These estimates are provided for three times of day (2:00am, 2:00pm and 5:00pm), representing the periods of the day that different sectors of the community are at their peak. The 2:00am estimate considers the residential occupancy at its maximum, the 2:00pm estimate considers the educational, commercial and industrial sector at their maximum and the 5:00pm estimate represents peak commuter time.

No injuries or casualties are estimated for the 100-year event. Tables 5.4.6-8 and 5.4.6-9 summarize the injuries and casualties estimated for the 500-year and 2,500-year MRP earthquake events.

Table 5.4.6-8. Estimated Number of Injuries and Casualties from the 500-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
Injuries	3	5	4
Hospitalization	0	1	0
Casualties	0	0	0

Source: HAZUS-MH MR4

Table 5.4.6-9. Estimated Number of Injuries and Casualties from the 2,500-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
Injuries	34	50	40
Hospitalization	7	10	8
Casualties	1	2	2

Source: HAZUS-MH MR4

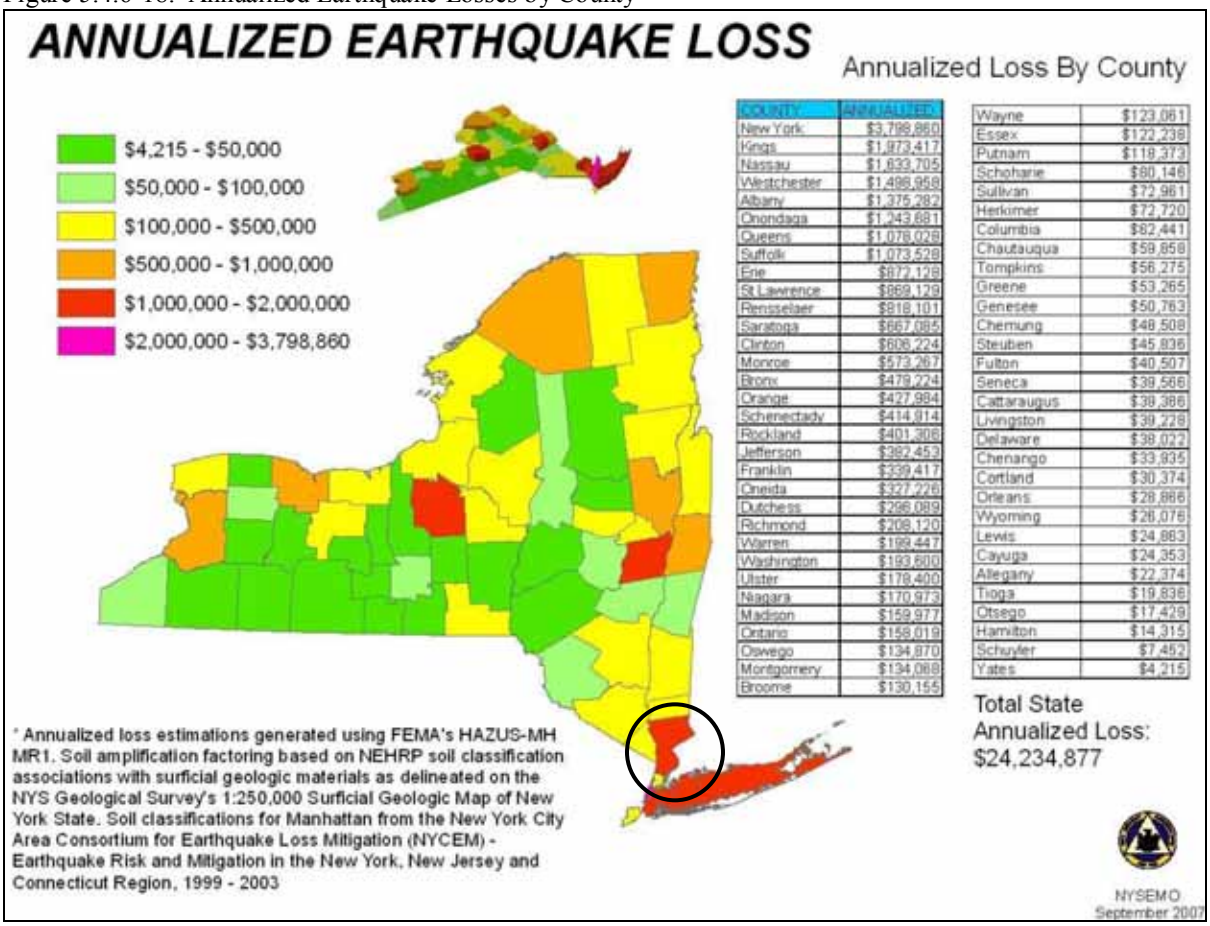
Earthquakes can cause secondary hazard events such as fires. No fires are anticipated as a result of a 100- or 500-year MRP event. For the 2,500-year MRP event, the HAZUS-MH model estimates that there will be four (4) ignitions that will displace approximately 644 people and damage approximately $65 Million in general building stock value.

Impact on General Building Stock

After considering the population exposed to the earthquake hazard, the value of general building stock exposed to and damaged by 100-, 500- and 2,500-year MRP earthquake events was evaluated. In addition, annualized losses were calculated using HAZUS-MH MR4. The entire study area's general building stock is considered at risk and exposed to this hazard. The HAZUS-MH MR4 model estimates the value of the exposed building stock and the loss (in terms of damage to the exposed stock). Refer to Table 4-X in the Regional Profile (Section 4) for general building stock data replacement value statistics (structure and contents).

The NYS HMP conducted a HAZUS vulnerability assessment and reports estimates of earthquake losses factoring in NEHRP soil classes by County. For Westchester County, the estimated annualized earthquake loss is nearly $1.5 million per year (Figure 5.4.6-18). Using HAZUS-MH MR4, a probabilistic model was run for the purposes of this Plan to estimate annualized dollar losses for the Greater Greenburgh Planning Area, also factoring in NEHRP soil classes. Annualized losses are useful for mitigation planning because they provide a baseline upon which to 1) compare the risk of one hazard across multiple jurisdictions and 2) compare the degree of risk of all hazards for each participating jurisdiction. Please note that annualized loss does not predict what losses will occur in any particular year. The estimated annualized losses are approximately $174,000 per year for the Planning Area (Table 5.4.6-10).

Figure 5.4.6-18. Annualized Earthquake Losses by County



COUNTY	ANNUALIZED
New York	$3,798,860
Kings	$1,973,417
Nassau	$1,833,705
Westchester	$1,488,958
Albany	$1,375,282
Onondaga	$1,243,681
Queens	$1,078,028
Suffolk	$1,073,528
Erie	$872,128
St Lawrence	$869,129
Rensselaer	$818,101
Saratoga	$667,085
Clinton	$606,224
Monroe	$573,267
Bronx	$479,224
Orange	$427,984
Schenectady	$414,914
Rockland	$401,306
Jefferson	$382,453
Franklin	$339,417
Oneida	$327,226
Dutchess	$296,089
Richmond	$208,120
Warren	$199,447
Washington	$193,600
Ulster	$179,400
Niagara	$170,973
Madison	$159,977
Ontario	$158,019
Oswego	$134,870
Montgomery	$134,068
Broome	$130,155
Wayne	$123,061
Essex	$122,238
Putnam	$119,373
Schoharie	$80,146
Sullivan	$72,961
Herkimer	$72,720
Columbia	$62,441
Chautauqua	$59,858
Tompkins	$56,275
Greene	$53,265
Genesee	$50,763
Chemung	$48,508
Steuben	$45,836
Fulton	$40,507
Seneca	$39,566
Cattaraugus	$39,386
Livingston	$39,228
Delaware	$38,022
Chenango	$33,935
Cortland	$30,374
Orleans	$28,866
Wyoming	$26,076
Lewis	$24,883
Cayuga	$24,353
Allegany	$22,374
Tioga	$19,836
Otsego	$17,429
Hamilton	$14,315
Schuyler	$7,452
Yates	$4,215

Source: NYSDPC, 2008
Note: The black circle indicates the approximate location of the Westchester County

Table 5.4.6-10. Summary of Estimated Annualized Earthquake General Building Stock Losses for the Greater Greenburgh Planning Area

Municipality	Total (Buildings + Contents)	Buildings	Contents
Unincorporated Greenburgh	$84,451	$63,311	$21,140
Village of Ardsley	$6,766	$5,043	$1,722
Village of Dobbs Ferry	$15,381	$11,449	$3,932
Village of Elmsford	$6,700	$4,893	$1,807
Village of Hastings-on-Hudson	$11,677	$8,716	$2,961
Village of Irvington	$9,495	$7,119	$2,377
Village of Tarrytown	$39,698	$30,290	$9,408
Planning Area Total	**$174,167**	**$130,821**	**$43,347**

Source: HAZUS-MH MR4

According to the New York City Area Consortium for Earthquake Loss Mitigation (NYCEM), where earthquake risks and mitigation were evaluated in the New York, New Jersey and Connecticut region, most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking (NYCEM, 2003). NYCEM indicates there is a strong correlation between PGA and the damage a building might experience. The HAZUS-MH M4 model is based on the best available earthquake science and aligns with these statements. HAZUS-MH MR4 methodology and model were used to analyze the earthquake hazard for the general building stock for the Greater Greenburgh Planning Area. See Figures 5.4.6-8 through 5.4.6-10 earlier in this profile that illustrate the geographic distribution of PGA (g) across Westchester County and the Planning Area for 100-, 500- and 2,500-year MRP events at the Census-Tract level.

According to NYCEM, a building's construction determines how well it can withstand the force of an earthquake. The NYCEM report indicates that un-reinforced masonry buildings are most at risk during an earthquake because the walls are prone to collapse outward, whereas steel and wood buildings absorb more of the earthquake's energy. Additional attributes that contribute to a building's capability to withstand an earthquake's force include its age, number of stories and quality of construction. HAZUS-MH considers building construction and the age of buildings as part of the analysis. Because the default general building stock was used for this HAZUS-MH analysis, the default building ages and building types already incorporated into the inventory were used.

Potential building damage was evaluated by HAZUS-MH MR4 across the following damage categories (none, slight, moderate, extensive and complete). Table 5.4.6-11 provides definitions of these five categories of damage for a light wood-framed building; definitions for other building types are included in HAZUS-MH technical manual documentation. General building stock damage for these damage categories by occupancy class and building type on a Planning Area-wide basis is summarized for the 100-, 500- and 2,500-year events in Tables 5.4.6-12 through 5.4.6-14.

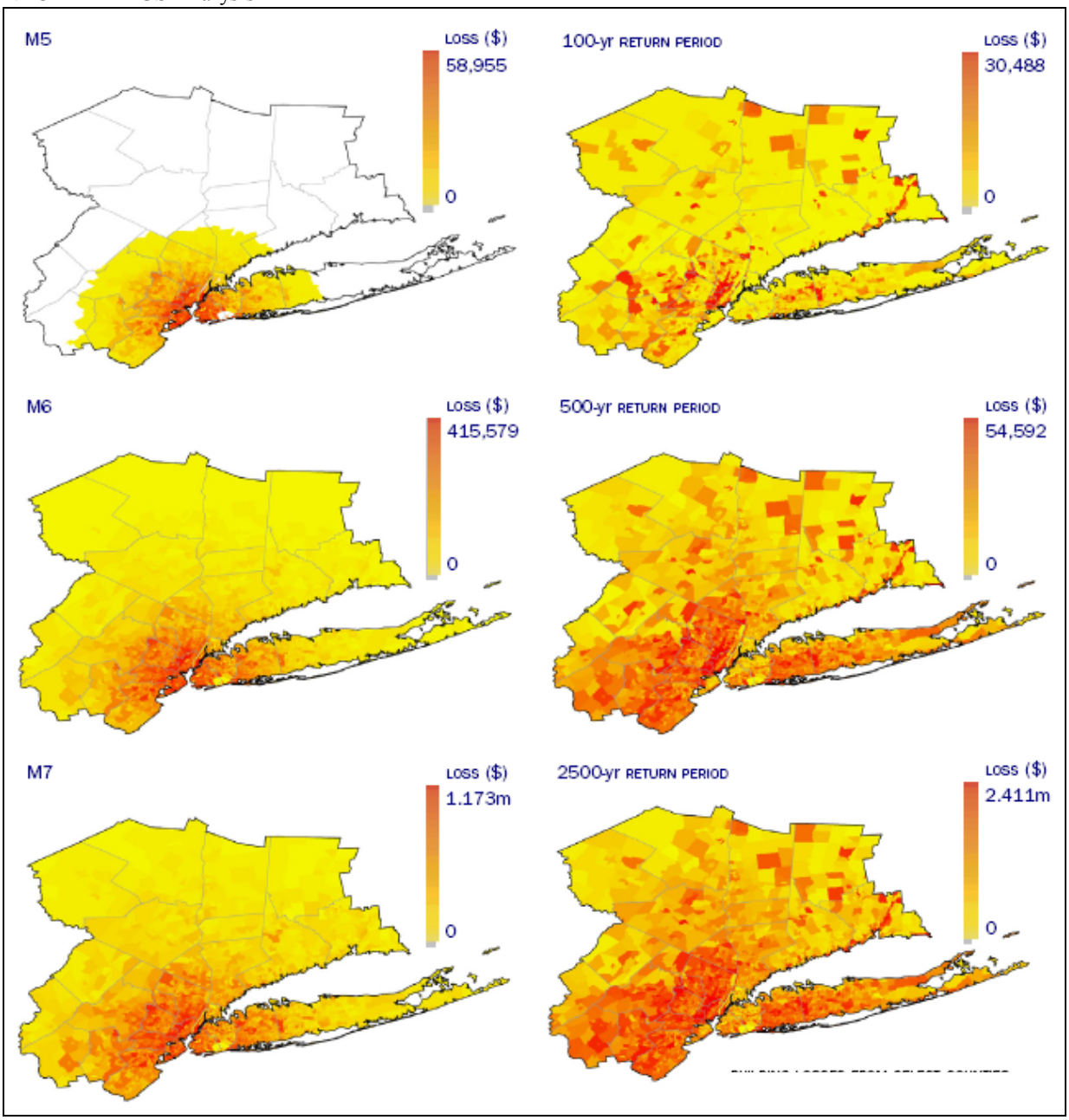
Table 5.4.6-11. Example of Structural Damage State Definitions for a Light Wood-Framed Building

Damage Category	Description
Slight	Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations.
Complete	Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Source: HAZUS-MH Technical Manual

Figure 5.4.6-19 is a graphic summarizing the total building-related losses per Census tract for the New York, New Jersey and Connecticut region, based on the magnitude of the deterministic scenario earthquakes (M5, M6, M7) or the average return period (100, 500, 2,500 years) for the probabilistic case. The total value listed next to each figure includes both direct building losses and building-related business interruption losses (NYCEM, 2003).

Figure 5.4.6-19. Total Building-Related Losses for the New York/New Jersey/Connecticut Region based on NYCEM HAZUS Analysis



Source: NYCEM, 2003

HAZUS-MH MR4 estimates zero damage to the Greater Greenburgh Planning Area's general building stock as a result of a 100-year MRP event. Table 5.4.6-14 summarizes the damage estimated for the 500- and 2,500-year MRP earthquake events for each participating municipality. Damage loss estimates include structural and non-structural damage to the building and loss of contents.

Table 5.4.6-12. Estimated Number of Buildings Damaged by General Occupancy for 100-year, 500-year and 2,500-year MRP Earthquake Events

Category	Average Damage State														
	100-Year MRP					500-Year MRP					2,500-Year MRP				
	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Residential	24,257 (87.6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	23,771 (85.9%)	380 (1.4%)	<1%	<1%	<1%	20,921 (75.6%)	2,443 (8.8%)	745 (2.7%)	<1%	<1%
Commercial	8.6%	0%	0%	0%	0%	8.3%	<1%	<1%	<1%	0%	6.9%	1%	<1%	<1%	<1%
Industrial	2.2%	0%	0%	0%	0%	2.1%	<1%	<1%	<1%	0%	1.8%	<1%	<1%	<1%	<1%
Education, Government, Religious and Agricultural	1.6%	0%	0%	0%	0%	1.5%	<1%	<1%	0%	0%	1.2%	<1%	<1%	<1%	<1%

Source: HAZUS-MH MR4

Note (1): Only the residential category contains building counts because the residential sub-categories RES1 (single-family dwellings) and RES2 (manufactured houses) building counts are based on census housing unit counts. All other occupancy class building counts are calculated in HAZUS-MH MR4 based on regional average square footage values for specific occupancy class/building types, and may significantly over- or under-estimate actual structure counts. Therefore, percent buildings damaged of the total region inventory are provided for all other occupancy classes in the table above.

Note (2): The percentages in the table above are based on the Planning Area's building count in the HAZUS-MH MR4 earthquake model of 27,678 buildings.

Table 5.4.6-13. Estimated Number of Buildings Damaged by Building Type for 100-year, 500-year and 2,500-year MRP Earthquake Events

Category	Average Damage State														
	100-Year MRP					500-Year MRP					2,500-Year MRP				
	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Wood	72.9%	0%	0%	0%	0%	72.2%	<1%	<1%	0%	0%	64.8%	6.7%	1.3%	<1%	<1%
Steel	5.9%	0%	0%	0%	0%	5.8%	<1%	<1%	<1%	0%	4.9%	<1%	<1%	<1%	<1%
Concrete	2.5%	0%	0%	0%	0%	2.5%	<1%	<1%	0%	0%	2.0%	<1%	<1%	<1%	0%
Reinforced Masonry	2.5%	0%	0%	0%	0%	2.4%	<1%	<1%	<1%	0%	2.0%	<1%	<1%	<1%	0%
Un-reinforced Masonry	16.1%	0%	0%	0%	0%	15%	<1%	<1%	<1%	<1%	11.7%	2.4%	1.5%	<1%	<1%
Manufactured housing	< 1%	0%	0%	0%	0%	<1%	0%	0%	0%	0%	<1%	0%	0%	0%	0%

Source: HAZUS-MH MR4

Note: The percentages in the table above are based on the Planning Area's building count in the HAZUS-MH MR4 earthquake model of 27,678 buildings.

Table 5.4.6-14. Estimated Building Value (Building and Contents) Damaged by the 500- and 2,500-Year MRP Earthquake Events

Municipality	Estimated Total Damages*		Percent of Total Building and Contents RV**		Estimated Residential Damage		Estimated Commercial Damage	
	500-Year	2,500-Year	500-Year	2,500-Year	500-Year	2,500-Year	500-Year	2,500-Year
Unincorporated Greenburgh	$4,918,381	$76,227,113	0.06	0.94	$2,838,990	$40,740,656	$1,495,022	$24,888,648
Village of Ardsley	$391,934	$6,752,628	0.05	0.78	$286,181	$6,879,299	$73,167	$1,452,267
Village of Dobbs Ferry	$885,979	$14,809,817	0.05	0.78	$619,406	$9,445,526	$135,808	$2,696,909
Village of Elmsford	$386,676	$5,861,560	0.05	0.69	$171,718	$15,983,570	$173,277	$3,243,918
Village of Hastings-on-Hudson	$667,597	$11,529,075	0.05	0.78	$467,385	$8,982,814	$146,937	$2,848,941
Village of Irvington	$544,934	$9,475,596	0.05	0.79	$395,326	$7,559,068	$117,102	$2,282,840
Village of Tarrytown	$2,355,622	$33,485,648	0.10	1.37	$1,227,696	$21,091,820	$805,172	$12,770,690
Planning Area Total	**$10,151,122**	**$158,142,435**	**0.06**	**0.94**	**$6,007,701**	**$110,682,753**	**$2,946,484**	**$50,184,213**

Source: HAZUS-MH MR4
RV Replacement Value
*Total is sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious and government)].
**Total replacement value for the Planning Area is nearly $17 billion.

It is estimated that there would be $10 million in building damages during a 500-year earthquake event. This includes structural damage, non-structural damage and loss of contents, representing less than one-percent of the total replacement value for general building stock in the Greater Greenburgh Planning Area. For a 2,500-year MRP earthquake event, the estimated total building damage is greater than $158 million or approximately one-percent of the total general building stock replacement value (total replacement value is greater than $17 billion for the Town and inclusive Villages). Residential and commercial buildings account for most of the damage for earthquake events. This is likely because they comprise the majority of the building inventory.

Impact on Critical Facilities

After considering the general building stock exposed to, and damaged by, 100-, 500- and 2,500-year MRP earthquake events, critical facilities were evaluated. All critical facilities (essential facilities, transportation systems, lifeline utility systems, high-potential loss facilities and user-defined facilities) in the Greater Greenburgh Planning Area are considered exposed and vulnerable to the earthquake hazard. Refer to subsection "Critical Facilities" in Section 4 (Regional Profile) of this Plan for a complete inventory of critical facilities.

HAZUS-MH MR4 estimates the probability that critical facilities may sustain damage as a result of 100-, 500- and 2,500-year MRP earthquake events. Additionally, HAZUS-MH estimates percent functionality for each facility days after the event. For the 100-Year MRP event, HAZUS-MH MR4 estimates it is nearly 100% probable that emergency facilities (police, fire, EMS and medical facilities), schools and specific facilities identified by the Greater Greenburgh Planning Area as critical (i.e., user-defined facilities such shelters, municipal buildings and Departments of Public Works) will not experience any structural damage. These facilities are estimated to be 100% functional on day one of the 100-year MRP earthquake event. Therefore, the impact to critical facilities is not significant for the 100-year event.

Tables 5.4.6-15 and 5.4.6-16 list the probability of critical facilities sustaining the damage category as defined by the column heading and percent functionality after the event for the 500-year and 2,500-year MRP earthquake events.

Table 5.4.6-15. Estimated Damage and Loss of Functionality for Critical Facilities in the Greater Greenburgh Planning Area for the 500-Year MRP Earthquake Event

500-Year MRP Event									
Name	Municipality	Type	Percent Probability of Sustaining Damage					Percent Functionality	
			None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
Ardsley P.D.	Ardsley (V)	Police	92.2	5.5	2	0.3	0	92.1	97.5
Ardsley F.D.	Ardsley (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Ardsley EMS	Ardsley (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Ardsley High School	Ardsley (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Concord Road Elementary School	Ardsley (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Lyceum Kennedy School - French	Ardsley (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Ardsley Village Highway Garage	Ardsley (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Ardsley Community Center	Ardsley (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Ardsley Village Salt Shed	Ardsley (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Woodlands Senior Living Community	Ardsley (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Lincoln Rest Home	Ardsley (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Ardsley Senior Citizens Center	Ardsley (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Ardsley Village Hall	Ardsley (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Dobbs Ferry Hospital	Dobbs Ferry (V)	Medical	98.1	1.5	0.4	0	0	98	99.5
Dobbs Ferry P.D.	Dobbs Ferry (V)	Police	92.2	5.5	2	0.3	0	92.1	97.5
Dobbs Ferry F.D.	Dobbs Ferry (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Dobbs Ferry F.D.	Dobbs Ferry (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Dobbs Ferry VAC	Dobbs Ferry (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Dobbs Ferry Middle School	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Springhurst Elementary School	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
St. Christopher's School (Special Ed.)	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Children's Village (Special Ed.)	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Mercy College	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Long Island University-Westchester Campus	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Masters School (The)	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Our Lady of Victory Academy	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Dobbs Ferry High School	Dobbs Ferry (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Sacred Heart Seniors/Church	Dobbs Ferry (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6

500-Year MRP Event									
			Percent Probability of Sustaining Damage					Percent Functionality	
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
St. Cabrini Nursing Home	Dobbs Ferry (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Dobbs Ferry Village Hall	Dobbs Ferry (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Respite of Dobbs Ferry	Dobbs Ferry (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Dobbs Ferry Senior Citizens Center	Dobbs Ferry (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Elmsford P.D.	Elmsford (V)	Police	92.2	5.5	2	0.3	0	92.2	97.5
Elmsford F.D.	Elmsford (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Elmsford F.D.	Elmsford (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Elmsford VFD Rescue	Elmsford (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Elmsford Village Civil Defense	Elmsford (V)	EOC	92.2	5.5	2	0.3	0	92.2	97.5
Our Lady of Mt. Carmel School	Elmsford (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
Carl Dixson Elementary School	Elmsford (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
Alice E. Grady Elementary School	Elmsford (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
Alexander Hamilton High School	Elmsford (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Montefiore Westchester DIV	Elmsford (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Elmsford Senior Citizens	Elmsford (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Elmsford Village Hall	Elmsford (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Westchester Medical Center	Greenburgh (U)	Medical	98	1.6	0.4	0	0	98	99.5
Greenburgh P.D.	Greenburgh (U)	Police	92.2	5.5	2	0.3	0	92.1	97.5
Fairview F.D.	Greenburgh (U)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Fairview F.D.	Greenburgh (U)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Hartsdale F.D.	Greenburgh (U)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Hartsdale F.D.	Greenburgh (U)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Greenville F.D.	Greenburgh (U)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Greenburgh Police Dept.	Greenburgh (U)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Greenburgh Town Civil Defense	Greenburgh (U)	EOC	92.2	5.5	2	0.3	0	92.2	97.5
Greenburgh P.D.	Greenburgh (U)	EOC	92.2	5.5	2	0.3	0	92.1	97.5
Daytop Village Secondary School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Maria Regina High School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Sacred Heart School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Mohawk Country Home School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5

500-Year MRP Event									
			Percent Probability of Sustaining Damage					Percent Functionality	
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
NY School - Deaf	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.2	97.5
Ardsley Middle School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Woodlands Middle School/High School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Greenburgh Early Childhood	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Highview Elementary School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Virginia Road Elementary School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.2	97.5
Edgemont Middle School/High School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Greenville Elementary School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Seely Place Elementary School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Bailey Elementary School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Lee F. Jackson Elementary School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Empire State College (S.U.N.Y.) at Harts	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Westchester Community College	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.2	97.5
Solomon Schechter School	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.1	97.5
Greenburgh BOCES	Greenburgh (U)	School	92.2	5.5	2	0.3	0	92.2	97.5
Vaughn Glanton Employment Residence	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Town Park Multi Purpose Center	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Theodore D Young Comm Center	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Greenburgh Town Garage	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Greenburgh Gas Storage	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Rangers Knicks Training Center	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Radiation	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Planned Parenthood	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Shooting Range	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Fairview-Greenburgh Community Center	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Sacred Heart Leisure Club	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Sprain Brook Manor Nursing Home	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Open Door Community Center	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Sprain Brook Manor	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Hebrew Hospital Home	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7

500-Year MRP Event									
			Percent Probability of Sustaining Damage					Percent Functionality	
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
Westchester Meadows	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Manhattan Ave Senior Housing	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Greenburgh Town Hall	Greenburgh (U)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Hastings-on-Hudson F.D.	Hastings-On Hudson (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Hastings-on-Hudson F.D.	Hastings-On Hudson (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Hastings-on-Hudson F.D.	Hastings-On Hudson (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Hastings-on-Hudson F.D.	Hastings-On Hudson (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Hastings-on-Hudson VFDAC	Hastings-On Hudson (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Hastings-On-Hudson P.D.	Hastings-On-Hudson (V)	Police	92.2	5.5	2	0.3	0	92.1	97.5
St Matthew's School	Hastings-On-Hudson (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Hillside Elementary School	Hastings-On-Hudson (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Farragut Middle School	Hastings-On-Hudson (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Hastings High School	Hastings-On-Hudson (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Graham - Martin Luther King JHS	Hastings-On-Hudson (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Orchard School	Hastings-On-Hudson (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Harmon Community Center	Hastings-on-Hudson (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Andrus on Hudson	Hastings-on-Hudson (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Hastings-on-Hudson Village Hall	Hastings-on-Hudson (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Irvington P.D.	Irvington (V)	Police	92.2	5.5	2	0.3	0	92.1	97.5
Irvington F.D.	Irvington (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Irvington VAC	Irvington (V)	Fire	92.2	5.5	2	0.3	0	92.1	97.5
Immaculate Conception School	Irvington (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Abbot School (Special Ed.)	Irvington (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Irvington High School	Irvington (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Irvington Middle School	Irvington (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Main Street School	Irvington (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Dows Lane Elementary School	Irvington (V)	School	92.2	5.5	2	0.3	0	92.1	97.5
Leisure Time Club	Irvington (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
Irvington Village Hall	Irvington (V)	User Defined	92.2	5.5	2	0.3	0	92.1	97.6
N.Y.S.P.D. Troop T - Thruway	Tarrytown (V)	Police	92.2	5.5	2	0.3	0	92.2	97.5

500-Year MRP Event									
Name	Municipality	Type	Percent Probability of Sustaining Damage					Percent Functionality	
			None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
Tarrytown P.D.	Tarrytown (V)	Police	92.2	5.5	2	0.3	0	92.2	97.5
Tarrytown F.D.	Tarrytown (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Tarrytown F.D.	Tarrytown (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Tarrytown F.D.	Tarrytown (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Tarrytown F.D.	Tarrytown (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Tarrytown F.D.	Tarrytown (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Tarrytown F.D.	Tarrytown (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Tarrytown VAC	Tarrytown (V)	Fire	92.2	5.5	2	0.3	0	92.2	97.5
Hackley School	Tarrytown (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
John Paulding Elementary School	Tarrytown (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
Tappan Hill Elementary School	Tarrytown (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
Washington Irving Interm Middle School	Tarrytown (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
E.F. Schools	Tarrytown (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
St Jude Habilitation Institute	Tarrytown (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
Transfiguration School	Tarrytown (V)	School	92.2	5.5	2	0.3	0	92.2	97.5
Tarrytown Library	Tarrytown (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Neighborhood House	Tarrytown (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Tarrytown Seniors	Tarrytown (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Church of the Transfiguration - Seniors	Tarrytown (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Tarrytown Hall Care Center	Tarrytown (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Tarrytown Village Hall	Tarrytown (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7
Tarrytown Public Works	Tarrytown (V)	User Defined	92.2	5.5	2	0.3	0	92.2	97.7

Source: HAZUS-MH MR4; Greater Greenburgh Planning Area Committee, 2010

Table 5.4.6-16. Estimated Damage and Loss of Functionality for Critical Facilities in the Greater Greenburgh Planning Area for the 2,500-Year MRP Earthquake Event

2,500-Year MRP Event										
			Percent Probability of Sustaining Damage					Percent Functionality		
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 14	Day 30
Ardsley P.D.	Ardsley (V)	Police	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Ardsley F.D.	Ardsley (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Ardsley EMS	Ardsley (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Ardsley High School	Ardsley (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Concord Road Elementary School	Ardsley (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Lyceum Kennedy School - French	Ardsley (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Ardsley Village Highway Garage	Ardsley (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Ardsley Community Center	Ardsley (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Ardsley Village Salt Shed	Ardsley (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Woodlands Senior Living Community	Ardsley (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Lincoln Rest Home	Ardsley (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Ardsley Senior Citizens Center	Ardsley (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Ardsley Village Hall	Ardsley (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Dobbs Ferry Hospital	Dobbs Ferry (V)	Medical	71.7	16.2	10.4	1.3	0.4	71.6	87.8	98.3
Dobbs Ferry P.D.	Dobbs Ferry (V)	Police	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Dobbs Ferry F.D.	Dobbs Ferry (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Dobbs Ferry F.D.	Dobbs Ferry (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Dobbs Ferry VAC	Dobbs Ferry (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Dobbs Ferry Middle School	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Springhurst Elementary School	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
St. Christopher's School (Special Ed.)	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Children's Village (Special Ed.)	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Mercy College	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Long Island University-Westchester Campu	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Masters School (The)	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Our Lady of Victory Academy	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Dobbs Ferry High School	Dobbs Ferry (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Sacred Heart Seniors/Church	Dobbs Ferry (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
St. Cabrini Nursing Home	Dobbs Ferry (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4

2,500-Year MRP Event										
			Percent Probability of Sustaining Damage					Percent Functionality		
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 14	Day 30
Dobbs Ferry Village Hall	Dobbs Ferry (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Respite of Dobbs Ferry	Dobbs Ferry (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Dobbs Ferry Senior Citizens Center	Dobbs Ferry (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Elmsford P.D.	Elmsford (V)	Police	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Elmsford F.D.	Elmsford (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Elmsford F.D.	Elmsford (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Elmsford VFD Rescue	Elmsford (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Elmsford Village Civil Defense	Elmsford (V)	EOC	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Our Lady of Mt. Carmel School	Elmsford (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Carl Dixson Elementary School	Elmsford (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Alice E. Grady Elementary School	Elmsford (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Alexander Hamilton High School	Elmsford (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Montefiore Westchester DIV	Elmsford (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Elmsford Senior Citizens	Elmsford (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Elmsford Village Hall	Elmsford (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Westchester Medical Center	Greenburgh (U)	Medical	71.8	16.2	10.4	1.3	0.4	71.7	87.9	98.3
Greenburgh P.D.	Greenburgh (U)	Police	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Fairview F.D.	Greenburgh (U)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Fairview F.D.	Greenburgh (U)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hartsdale F.D.	Greenburgh (U)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hartsdale F.D.	Greenburgh (U)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenville F.D.	Greenburgh (U)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenburgh Police Dept.	Greenburgh (U)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenburgh Town Civil Defense	Greenburgh (U)	EOC	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Greenburgh P.D.	Greenburgh (U)	EOC	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Daytop Village Secondary School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Maria Regina High School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Sacred Heart School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Mohawk Country Home School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
NY School - Deaf	Greenburgh (U)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7

2,500-Year MRP Event										
			Percent Probability of Sustaining Damage					Percent Functionality		
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 14	Day 30
Ardsley Middle School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Woodlands Middle School/High School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenburgh Early Childhood	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Highview Elementary School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Virginia Road Elementary School	Greenburgh (U)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Edgemont Middle School/High School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenville Elementary School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Seely Place Elementary School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Bailey Elementary School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Lee F. Jackson Elementary School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Empire State College (S.U.N.Y.) at Harts	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Westchester Community College	Greenburgh (U)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Solomon Schechter School	Greenburgh (U)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenburgh BOCES	Greenburgh (U)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Vaughn Glanton Employment Residence	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Town Park Multi Purpose Center	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Theodore D Young Comm Center	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenburgh Town Garage	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenburgh Gas Storage	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Rangers Knicks Training Center	Greenburgh (U)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Radiation	Greenburgh (U)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Planned Parenthood	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Shooting Range	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Fairview-Greenburgh Community Center	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Sacred Heart Leisure Club	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Sprain Brook Manor Nursing Home	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Open Door Community Center	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Sprain Brook Manor	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hebrew Hospital Home	Greenburgh (U)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Westchester Meadows	Greenburgh (U)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7

2,500-Year MRP Event										
			Percent Probability of Sustaining Damage					Percent Functionality		
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 14	Day 30
Manhattan Ave Senior Housing	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Greenburgh Town Hall	Greenburgh (U)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hastings-on-Hudson F.D.	Hastings-On Hudson (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hastings-on-Hudson F.D.	Hastings-On Hudson (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hastings-on-Hudson F.D.	Hastings-On Hudson (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hastings-on-Hudson F.D.	Hastings-On Hudson (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hastings-on-Hudson VFDAC	Hastings-On Hudson (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hastings-On-Hudson P.D.	Hastings-On-Hudson (V)	Police	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
St Matthew's School	Hastings-On-Hudson (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hillside Elementary School	Hastings-On-Hudson (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Farragut Middle School	Hastings-On-Hudson (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hastings High School	Hastings-On-Hudson (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Graham - Martin Luther King JHS	Hastings-On-Hudson (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Orchard School	Hastings-On-Hudson (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Harmon Community Center	Hastings-on-Hudson (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Andrus on Hudson	Hastings-on-Hudson (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Hastings-on-Hudson Village Hall	Hastings-on-Hudson (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Irvington P.D.	Irvington (V)	Police	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Irvington F.D.	Irvington (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Irvington VAC	Irvington (V)	Fire	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Immaculate Conception School	Irvington (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Abbot School (Special Ed.)	Irvington (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Irvington High School	Irvington (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Irvington Middle School	Irvington (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Main Street School	Irvington (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Dows Lane Elementary School	Irvington (V)	School	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Leisure Time Club	Irvington (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
Irvington Village Hall	Irvington (V)	User Defined	55.6	22.7	16.2	4.7	0.8	55.6	78.3	94.4
N.Y.S.P.D. Troop T - Thruway	Tarrytown (V)	Police	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown P.D.	Tarrytown (V)	Police	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7

2,500-Year MRP Event										
Name	Municipality	Type	Percent Probability of Sustaining Damage					Percent Functionality		
			None	Slight	Moderate	Extensive	Complete	Day 1	Day 14	Day 30
Tarrytown F.D.	Tarrytown (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown F.D.	Tarrytown (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown F.D.	Tarrytown (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown F.D.	Tarrytown (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown F.D.	Tarrytown (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown F.D.	Tarrytown (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown VAC	Tarrytown (V)	Fire	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Hackley School	Tarrytown (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
John Paulding Elementary School	Tarrytown (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tappan Hill Elementary School	Tarrytown (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Washington Irving Interm Middle School	Tarrytown (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
E.F. Schools	Tarrytown (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
St Jude Habilitation Institute	Tarrytown (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Transfiguration School	Tarrytown (V)	School	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown Library	Tarrytown (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Neighborhood House	Tarrytown (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown Seniors	Tarrytown (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Church of the Transfiguration - Seniors	Tarrytown (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown Hall Care Center	Tarrytown (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown Village Hall	Tarrytown (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7
Tarrytown Public Works	Tarrytown (V)	User Defined	56.7	22.4	15.7	4.5	0.8	56.7	79.1	94.7

Source: HAZUS-MH MR4; Greater Greenburgh Planning Area Committee, 2010

Impact on Economy

Earthquakes also have impacts on the economy, including: loss of business function, damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. A Level 2 HAZUS-MH analysis estimates the total economic loss associated with each earthquake scenario, which includes building- and lifeline-related losses (transportation and utility losses) based on the available inventory (facility [or GIS point] data only). Direct building losses are the estimated costs to repair or replace the damage caused to the building. This is reported in the "Impact on General Building Stock" section discussed earlier. Lifeline-related losses include the direct repair cost to transportation and utility systems and are reported in terms of the probability of reaching or exceeding a specified level of damage when subjected to a given level of ground motion. Additionally, economic loss includes business interruption losses associated with the inability to operate a business due to the damage sustained during the earthquake as well as temporary living expenses for those displaced. These losses are discussed below.

For the 500-year event, HAZUS-MH MR4 estimates the Greater Greenburgh Planning Area will incur approximately $3.8 million in business interruption losses. For the 2,500-year event, HAZUS-MH MR4 estimates the Planning Area will incur nearly $35 million in income losses, mainly to the commercial occupancy classes associated with wages, loss of income, rental and relocation.

For the 100-year MRP event, in terms of utilities, HAZUS-MH MR4 estimates zero damages. Damage results are not considered to be significant as a result of a 100-year event; therefore, utility loss estimates are not discussed further in this assessment for this HMP.

Tables 5.4.6-17 and 5.4.6-18 summarize the HAZUS-MH MR4 estimated probability of damage that each utility may sustain (as defined by the column heading) and estimated loss of use in days a result of a 500-year and 2,500-year MRP earthquake event, respectively. Damage categories are related to the damage ratio (defined as ratio of repair to replacement cost) for evaluation of direct economic loss. Refer to the HAZUS-MH Earthquake Technical Manual for a description of the damage categories for each utility feature.

The HAZUS-MH analysis conducted did not compute damage estimates for roadway segments and railroad tracks. However, it is assumed these features will experience damage due to ground failure and regional transportation and distribution of these materials will be interrupted as a result of an earthquake event. Losses to the community that result from damages to lifelines can be much greater than the cost of repair (HAZUS-MH MR3 Earthquake User Manual, 2007).

For the 100-year MRP event, HAZUS-MH MR4 estimates all highway bridges in the Planning Area will be fully functional day one of the event. For the 500-year MRP event, HAZUS-MH MR4 estimates highway bridges will be 99% functional day one of the event. For the 2,500- year MRP event, HAZUS-MH MR4 estimates highway bridges will be 85 to 100% functional day one of the event.

Tables 5.4.6-19 and 5.4.6-20 summarize the estimated damages and functionality of transportation features in the Greater Greenburgh Planning Area for 500- and 2,500-year MRP events.

Table 5.4.6-17. Estimated Utility Impacts in the Greater Greenburgh Planning Area from the 500-year MRP Earthquake Event

500-Year MRP Event									
			Percent Probability of Sustaining Damage					Percent Functionality	
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
United Water Treatment Facility	Ardsley (V)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
United Water PWPS	Ardsley (V)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Chauncy WWPS	Dobbs Ferry (V)	WW	97.4	2.1	0.5	0	0	98.1	99.9
Judson Ave WWPS	Dobbs Ferry (V)	WW	97.4	2.1	0.5	0	0	98.1	99.9
Landing Dr WWPS	Dobbs Ferry (V)	WW	97.4	2.1	0.5	0	0	98.1	99.9
Springhurst Park WWPS	Dobbs Ferry (V)	WW	97.4	2.1	0.5	0	0	98.1	99.9
Elmsford Pump Station	Elmsford (V)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Elmsford ConEd Substation	Elmsford (V)	Electric	97.4	2.1	0.5	0	0	98.5	99.9
Juniper Lane WST	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Tennis Court WST	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Birchwood WST	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Chelsea WST	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Knollwood Road WST	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Skeggs Road WST	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
State Police Comm WST	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Crest Drive WST	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
NYC DEC Potable Water Facility	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
United Water Res/Treatment Facility	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Potable Water Treatment Facility	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Greenburgh PWPS 1	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Greenburgh PWPS 2	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Ardsley Road Pump Stations	Greenburgh (U)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Greenburgh Sewage PS	Greenburgh (U)	WW	97.4	2.1	0.5	0	0	98.1	99.9
Greenburgh ConEd Substation 1	Greenburgh (U)	Electric	97.4	2.1	0.5	0	0	98.4	99.9
Greenburgh ConEd Substation 2	Greenburgh (U)	Electric	97.4	2.1	0.5	0	0	98.5	99.9
WFAS 1230	Greenburgh (U)	Communication	97.4	2.1	0.5	0	0	99.7	99.9
WFAS-FM CH 280	Greenburgh (U)	Communication	97.4	2.1	0.5	0	0	99.7	99.9
WARY CH 201	Greenburgh (U)	Communication	97.4	2.1	0.5	0	0	99.7	99.9
Light Path Communications Center	Greenburgh (U)	Communication	97.4	2.1	0.5	0	0	99.7	99.9

500-Year MRP Event									
			Percent Probability of Sustaining Damage					Percent Functionality	
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
Birchwood WST Comm	Greenburgh (U)	Communication	97.4	2.1	0.5	0	0	99.7	99.9
Chelsea WST Comm	Greenburgh (U)	Communication	97.4	2.1	0.5	0	0	99.7	99.9
State Police WST Comm	Greenburgh (U)	Communication	97.4	2.1	0.5	0	0	99.7	99.9
WHOH TV Radio	Hastings-on-Hudson (V)	Communication	97.4	2.1	0.5	0	0	99.7	99.9
Legend Hollow PWPS	Irvington (V)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Riverview Road PWPS	Irvington (V)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
Ardsley-on-Hudson Sewer PS	Irvington (V)	WW	97.4	2.1	0.5	0	0	98.1	99.9
Irvington Sewer PS	Irvington (V)	WW	97.4	2.1	0.5	0	0	98.1	99.9
Shaft 10 PWPS	Tarrytown (V)	Potable Water	97.4	2.1	0.5	0	0	99.7	99.9
Low Service WST	Tarrytown (V)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9
High Service WST	Tarrytown (V)	Potable Water	97.4	2.1	0.5	0	0	98.8	99.9

Source: HAZUS-MH MR4; Greater Greenburgh Planning Area Committee, 2010

Table 5.4.6-18. Estimated Utility Impacts in the Greater Greenburgh Planning Area from the 2,500-year MRP Earthquake Event

2,500-Year MRP Event											
			Percent Probability of Sustaining Damage					Percent Functionality		
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 14	Day 30
United Water Treatment Facility	Ardsley (V)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
United Water PWPS	Ardsley (V)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Chauncy WWPS	Dobbs Ferry (V)	WW	69	16.2	13.2	1.3	0.3	75.9	98.4	98.6
Judson Ave WWPS	Dobbs Ferry (V)	WW	69	16.2	13.2	1.3	0.3	75.9	98.4	98.6
Landing Dr WWPS	Dobbs Ferry (V)	WW	69	16.2	13.2	1.3	0.3	75.9	98.4	98.6
Springhurst Park WWPS	Dobbs Ferry (V)	WW	69	16.2	13.2	1.3	0.3	75.9	98.4	98.6
Elmsford Pump Station	Elmsford (V)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Elmsford ConEd Substation	Elmsford (V)	Electric	69	16.2	13.2	1.3	0.3	78.4	99.7	99.8
Juniper Lane WST	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Tennis Court WST	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Birchwood WST	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Chelsea WST	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Knollwood Road WST	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Skeggs Road WST	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
State Police Comm WST	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Crest Drive WST	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
NYC DEC Potable Water Facility	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
United Water Res/Treatment Facility	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Potable Water Treatment Facility	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Greenburgh PWPS 1	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Greenburgh PWPS 2	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Ardsley Road Pump Stations	Greenburgh (U)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Greenburgh Sewage PS	Greenburgh (U)	WW	69	16.2	13.2	1.3	0.3	75.9	98.4	98.6
Greenburgh ConEd Substation 1	Greenburgh (U)	Electric	69	16.2	13.2	1.3	0.3	78.3	99.7	99.8
Greenburgh ConEd Substation 2	Greenburgh (U)	Electric	69	16.2	13.2	1.3	0.3	78.4	99.7	99.8
WFAS 1230	Greenburgh (U)	Communication	69	16.2	13.2	1.3	0.3	92	99.5	99.8
WFAS-FM CH 280	Greenburgh (U)	Communication	69	16.2	13.2	1.3	0.3	92	99.5	99.8
WARY CH 201	Greenburgh (U)	Communication	69	16.2	13.2	1.3	0.3	92	99.5	99.8
Light Path Communications Center	Greenburgh (U)	Communication	69	16.2	13.2	1.3	0.3	92	99.5	99.8

2,500-Year MRP Event											
			Percent Probability of Sustaining Damage					Percent Functionality		
Name	Municipality	Type	None	Slight	Moderate	Extensive	Complete	Day 1	Day 14	Day 30
Birchwood WST Comm	Greenburgh (U)	Communication	69	16.2	13.2	1.3	0.3	92	99.5	99.8
Chelsea WST Comm	Greenburgh (U)	Communication	69	16.2	13.2	1.3	0.3	92	99.5	99.8
State Police WST Comm	Greenburgh (U)	Communication	69	16.2	13.2	1.3	0.3	92	99.5	99.8
WHOH TV Radio	Hastings-on-Hudson (V)	Communication	69	16.2	13.2	1.3	0.3	92	99.5	99.8
Legend Hollow PWPS	Irvington (V)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Riverview Road PWPS	Irvington (V)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Ardsley-on-Hudson Sewer PS	Irvington (V)	WW	69	16.2	13.2	1.3	0.3	75.9	98.4	98.6
Irvington Sewer PS	Irvington (V)	WW	69	16.2	13.2	1.3	0.3	75.9	98.4	98.6
Shaft 10 PWPS	Tarrytown (V)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
Low Service WST	Tarrytown (V)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99
High Service WST	Tarrytown (V)	Potable Water	69	16.2	13.2	1.3	0.3	82.4	98.8	99

Source: HAZUS-MH MR4; Greater Greenburgh Planning Area Committee, 2010

Table 5.4.6-19. Estimated Impacts to Transportation Features in the Greater Greenburgh Planning Area from the 500-year MRP Earthquake Event

Name	Municipality	Type	Percent Probability of Sustaining Damage					Percent Functionality	
			None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
Tower Ridge Yacht Club	Hastings-on-Hudson (V)	Port	97.4	2.1	0.5	0	0	99.6	99.9
Hastings Pioneer Boat Club	Hastings-on-Hudson (V)	Port	97.4	2.1	0.5	0	0	99.6	99.9
Palisade Boat Club	Hastings-on-Hudson (V)	Port	97.4	2.1	0.5	0	0	99.6	99.9
Irvington Boat Club	Irvington (V)	Port	97.4	2.1	0.5	0	0	99.6	99.9
Westchester Express	Tarrytown (V)	Bus	90.3	9.7	0.1	0	0	99.9	99.9
New York Waterways Dock.	Tarrytown (V)	Port	73.5	26.1	0.4	0	0	99.6	99.9
Hudson Harbor	Tarrytown (V)	Port	73.5	26.1	0.4	0	0	99.6	99.9
Frank's Fuel Service Wharf.	Tarrytown (V)	Port	73.5	26.1	0.4	0	0	99.6	99.9
Tarrytown Boat Club	Tarrytown (V)	Port	97.4	2.1	0.5	0	0	99.6	99.9
Washington Irvington Boat Club	Tarrytown (V)	Port	97.4	2.1	0.5	0	0	99.6	99.9

Source: HAZUS-MH MR4

Table 5.4.6-20. Estimated Impacts to Transportation Features in the Greater Greenburgh Planning Area from the 2,500-year MRP Earthquake Event

Name	Municipality	Type	Percent Probability of Sustaining Damage					Percent Functionality	
			None	Slight	Moderate	Extensive	Complete	Day 1	Day 7
Tower Ridge Yacht Club	Hastings-on-Hudson (V)	Port	69	16.2	13.2	1.3	0.3	90.3	98.7
Hastings Pioneer Boat Club	Hastings-on-Hudson (V)	Port	69	16.2	13.2	1.3	0.3	90.3	98.7
Palisade Boat Club	Hastings-on-Hudson (V)	Port	69	16.2	13.2	1.3	0.3	90.3	98.7
Irvington Boat Club	Irvington (V)	Port	69	16.2	13.2	1.3	0.3	90.3	98.7
Westchester Express	Tarrytown (V)	Bus	23.3	66.2	8.5	1.8	0.3	92.8	98.3
New York Waterways Dock.	Tarrytown (V)	Port	10.1	65.8	17.4	5.5	1.2	83.3	94.5
Hudson Harbor	Tarrytown (V)	Port	10.1	65.8	17.4	5.5	1.2	83.3	94.5
Frank's Fuel Service Wharf.	Tarrytown (V)	Port	10.1	65.8	17.4	5.5	1.2	83.3	94.5
Tarrytown Boat Club	Tarrytown (V)	Port	69	16.2	13.2	1.3	0.3	90.3	98.7
Washington Irvington Boat Club	Tarrytown (V)	Port	69	16.2	13.2	1.3	0.3	90.3	98.7

Source: HAZUS-MH MR4

HAZUS-MH MR4 also estimates the volume of debris that may be generated as a result of an earthquake event to enable the study region to prepare and rapidly and efficiently manage debris removal and disposal. Debris estimates are divided into two categories: (1) reinforced concrete and steel that require special equipment to break it up before it can be transported, and (2) brick, wood and other debris that can be loaded directly onto trucks with bulldozers (HAZUS-MH Earthquake User's Manual).

For the 100-year MRP event, HAZUS-MH MR4 estimates approximately no debris will be generated. For the 500-year MRP event, HAZUS-MH MR4 estimates approximately 6,612 tons of debris will be generated (approximately 4,978 tons of brick/wood debris and 1,634 tons of reinforced concrete/steel debris). For the 2,500-year MRP event, HAZUS-MH MR4 estimates 53,180 tons of debris will be generated (approximately 32,282 tons of brick/wood debris and 20,898 tons reinforced concrete/steel debris).

Table 5.4.6-21. Estimated Debris Generated by the 500- and 2,500-year MRP Earthquake Events

Municipality	500-Year		2,500-Year	
	Brick/Wood (tons)	Concrete/Steel (tons)	Brick/Wood (tons)	Concrete/Steel (tons)
Unincorporated Greenburgh	2,319	786	15,148	10,197
Village of Ardsley	186	46	1,104	475
Village of Dobbs Ferry	494	144	2,906	1,510
Village of Elmsford	243	75	1,410	791
Village of Hastings-on-Hudson	359	94	2,119	985
Village of Irvington	286	74	1,688	774
Village of Tarrytown	1,090	415	7,907	6,166
Planning Area Total	**4,978**	**1,634**	**32,282**	**20,898**

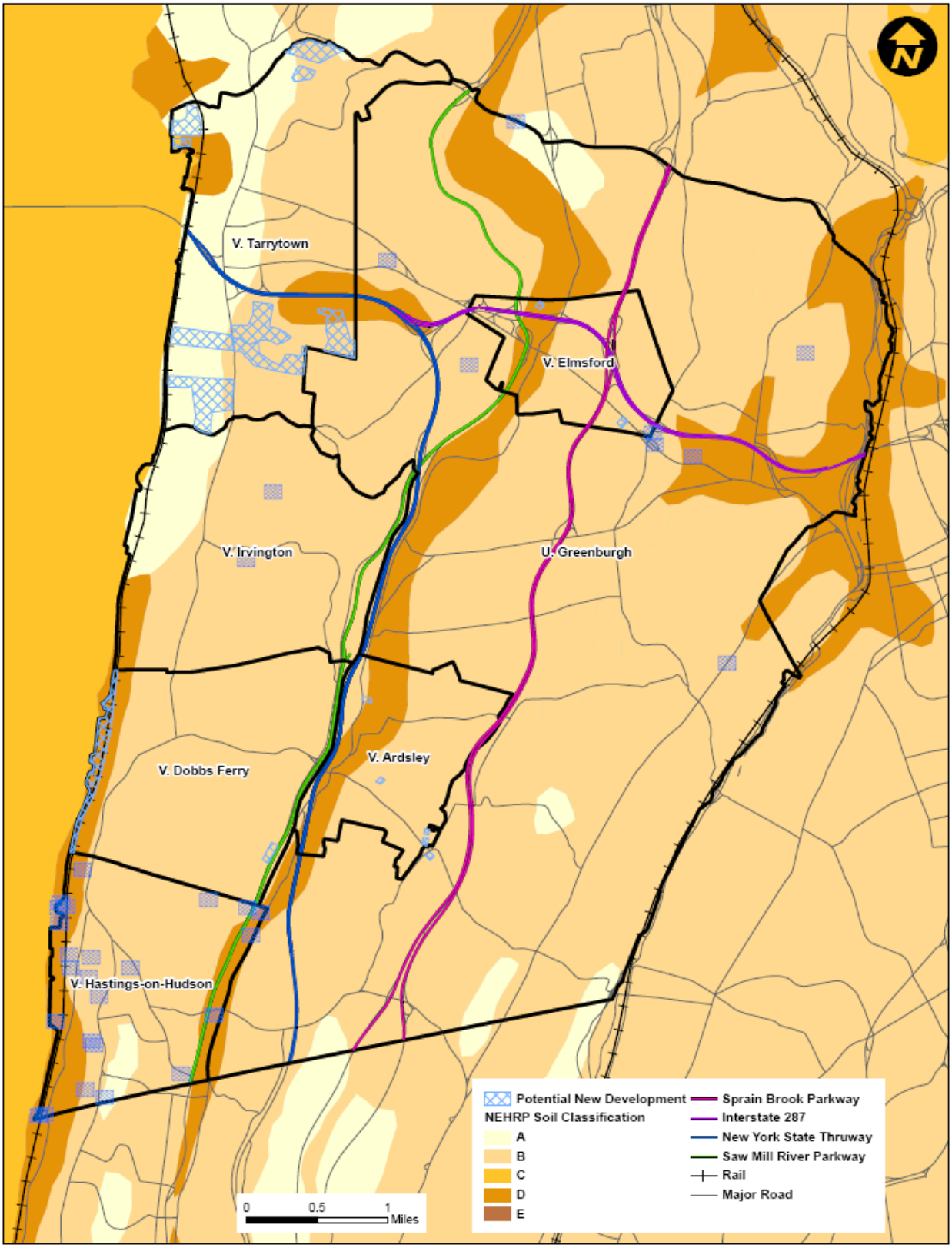
Source: HAZUS-MH MR4

Future Growth and Development

As discussed in Section 4, areas targeted for future growth and development have been identified across the Greater Greenburgh Planning Area. It is anticipated that the human exposure and vulnerability to earthquake impacts in newly developed areas will be similar to those that currently exist within the Planning Area. Current building codes require seismic provisions that should render new construction less vulnerable to seismic impacts than older, existing construction that may have been built to lower construction standards.

New development located in areas with softer NEHRP soil classes (D) may be more vulnerable to the earthquake hazard. As noted earlier, NEHRP soil class D is located in the northeastern portion of the Unincorporated Greenburgh, along the Saw Mill River, an area within the Village of Tarrytown and into the Unincorporated Greenburgh and along the Hudson River shoreline. According to NYCEM, softer soils (NEHRP soil D and E) can amplify ground shaking to damaging levels even in a moderate earthquake (NYCEM, 2003). Therefore, these areas in the Planning Area are most vulnerable to the earthquake hazard. Refer to Figure 5.4.6-20 with NEHRP soil and new development in the Greater Greenburgh Planning Area.

Figure. 5.4.6-20. Potential Development and NEHRP Soil Classification for the Greater Greenburgh Planning Area



Source: Planning Committee, 2011

Additional Data and Next Steps

A Level 2 HAZUS-MH earthquake analysis was conducted for the Greater Greenburgh Planning Area using the default model data, with the exception of the updated critical facility inventory which included user-defined data. Additional data needed to further refine the Planning Area's vulnerability assessment include: (1) updated demographic and building stock data to update the default data in HAZUS-MH; and (2) soil liquefaction data. In terms of general building stock data, updated building age, construction type and current replacement value would further support the refined analysis. Additionally, the Planning Area can identify un-reinforced masonry critical facilities and privately-owned buildings (i.e., residences) using local knowledge and/or pictometry/orthophotos. These buildings may not withstand earthquakes of certain magnitudes and plans to provide emergency response/recovery efforts for these properties can be set in place.

Overall Vulnerability Assessment

Earthquakes have a "rare" probability of occurrence in the study area (hazard event is not likely to occur within 100 years) causing impacts and losses mainly to the Planning Area's structures and facilities. Existing and future mitigation efforts should continue to be developed and employed that will enable the study area to be prepared for these events when they occur. The overall hazard ranking for this HMP for earthquake hazard is low (see Tables 5.3-3 through 5.3-6 in Section 5.3).