3.12 - Earthquake Hazard Profile

The earthquake hazard in New York State is often underestimated because other natural hazards occur more frequently (e.g., hurricanes, tornadoes, flooding) and are much more visible. However, few can be as devastating as an earthquake. The Mitigation Plan Development Team researched the earthquake hazard as it affects NYS. Contents of this section result from research and outreach including the following sources;

- FEMA Report - HAZUS 99 Estimated Annualized Earthquake Losses for the United States. Produced in cooperation with National Institute of Building Sciences (NIBS). This report indicates NY earthquake events as high loss potential, although low frequency, and provides calculated annualized earthquake losses and comparisons by state.

- New York City Consortium for Earthquake Loss Mitigation (NYCEM) http://www.nycem.org/default.asp

- United States Geological Survey (USGS), www.usgs.gov

- New York State Geological Survey (NYSGS)

- New York State Geologist Robert H. Fakundiny Ph.D. – Outreach to the NYS Geological Survey.

- New York State Statistical Yearbook, 2003 and 2006, The Nelson A. Rockefeller Institute of Government, State University of New York.

- Multidisciplinary Center for Earthquake Engineering Research (MCEER) at the State University of New York _ Buffalo, NY.

The following chart provides a few terms to know regarding an earthquake event.

Term	Definition
Earthquake	Both sudden slip on a fault, and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the earth.
Earthquake hazard	Anything associated with an earthquake that may affect the normal activities of people. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunamis, and seiches.
Earthquake risk	The probable building damage, and number of people that are expected to be hurt or killed if a likely earthquake on a particular fault occurs
Magnitude	A number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph.
Velocity	How fast a point on the ground is shaking as a result of an earthquake.
Intensity	A number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures.
Acceleration	Change from one speed, or velocity, to another is called acceleration
Peak acceleration	The largest acceleration recorded by a particular station during an earthquake
Seismic Waves	Vibrations that travel outward from the earthquake fault at speeds of several miles per second. Although fault slippage directly under a structure can cause considerable damage, the vibrations of seismic waves cause most of the destruction during earthquakes
Aftershocks	Earthquakes that follow the largest shock of an earthquake sequence. They are smaller than the mainshock and within 1-2 fault lengths distance from the mainshock fault. Aftershocks can continue over a period of weeks, months, or years. In general, the larger the mainshock, the larger and more numerous the aftershocks, and the longer they will continue.
Epicenter	The point on the earth's surface vertically above the hypocenter (or focus), point in the crust where a seismic rupture begins
Hypocenter	The location beneath the earth's surface where the rupture of the fault begins
Fault	A fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture.
For more in-depth definitions regarding Earthquake terminology please reference the U.S. Geological Survey website at www.usgs.gov, **Source: USGS/FEMA**	

Earthquake intensity and classification are commonly measured on two different scales, the Maximum Modified Mercalli Intensity scale and by the Richter Magnitude scale. The following table provides ranking and classification definitions for the two scales.

Table 3-53

Magnitude and Intensity Comparison	
Richter Magnitude Scale	**Typical Maximum Modified Mercalli Intensity**
1.0 to 3.0	I
3.0 to 3.9	II to III
4.0 to 4.9	IV to V
5.0 to 5.9	VI to VII
6.0 to 6.9	VII to IX
7.0 and Higher	VIII or Higher
Defined Modified Mercalli Intensity Scale Rating	
I	Not Felt except by a very few under especially favorable conditions
II	Felt only by a few persons at rest, especially on upper floors of buildings
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration Estimated
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors, disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: USGS

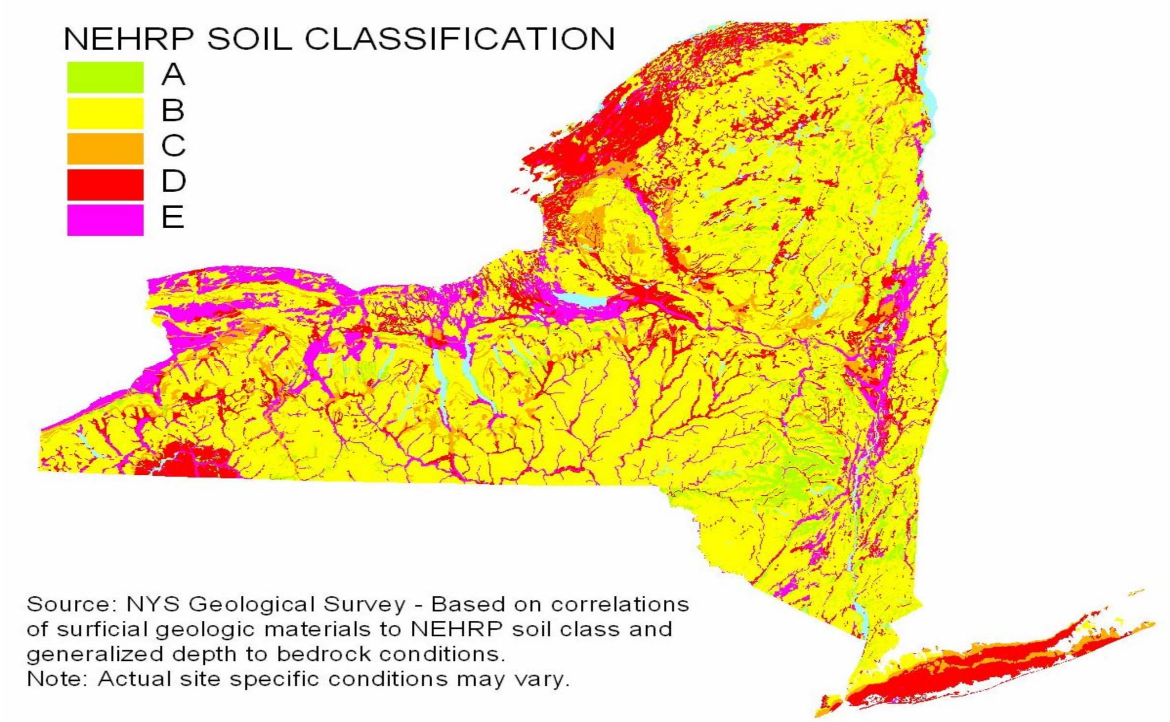
Affecting Conditions – Earthquake Hazard:

Soil type can substantially increase earthquake risk. For instance, "liquification" of soils during an earthquake is a commonly used term to describe how certain saturated "soft soil" ground can sometimes take on the characteristics of fluid when shaken by an earthquake. Amplification (strengthen) of shaking also results in areas of "soft soils" which includes fill, loose sand, waterfront, and lake bed clays. Accordingly, the National Earthquake Hazard Reduction Program (NEHRP) developed a soil classifications graphic **(figure 3-127)** for New York State which indicates 5 NEHRP soil classes, A through E (low (green) to high (purple)). The NEHRP soil classes graphic indicates types of soils that either tend to further amplify and magnify (high (red/purple) or reduce (low (green)) ground motions from an earthquake classified into the following 5 categories.

- **"A" - Very hard rock (e.g., granite, gneisses; and most of the Adirondack Mountains)**
- **"B" - Rock (sedimentary) or firm ground**
- **"C" - Stiff Clay**
- **"D" - Soft to medium clays or sands**
- **"E" - Soft soil (including fill, loose sand, waterfront, lake bed clays)**

Overlaying the NEHRP soil classes map with the %PGA map indicates those areas that may experience an amplification of ground motion and higher risk to a given magnitude. For instance areas of NYS that would experience an amplification of ground motion during seismic activity according to the NEHRP soil classification map would include but not be limited to the following; in northwest NY - northern Erie county, north central and northeast NY - Jefferson, St. Lawrence and northern Franklin counties, upper Hudson river area of eastern NY - northern Saratoga, Washington and southern Warren counties, and southeastern NY, western Nassau county, and New York City.

Figure 3-127



Geographic Location/Extent/Severity - Earthquake Hazard:

The potential for Earthquakes exists across the entire state and the entire Northeastern U.S. Scientific and historical data exists which indicate those areas of the state having a higher risk for reasons including both the likelihood of occurrence and the resulting ground motion.

An Earthquake Hazard Map, commonly referred to as a Percent Peak Ground Acceleration (%PGA) map, for the State of New York is included as **Figure 3-128.** The map shows the Percent Peak Ground Acceleration (%PGA) values for New York State with a 10% chance of being exceeded over 50 years. %PGA is a common earthquake measurement that shows three things: the geographic area affected (all colored areas on the map), the probability of an earthquake of each given level of severity (10% chance in 50 years), and the strength of ground movement (severity) expressed in terms of percent of the acceleration force of gravity (%g) (the PGA is indicated by color). **Table 3-54** entitled "Modified Mercalli Intensity (MMI) and PGA Equivalents" provides the corresponding intensity equivalents in terms of (MMI) as well as perceived shaking and potential damage expected for given values.

Table 3-54
Modified Mercalli Intensity (MMI) and PGA Equivalents

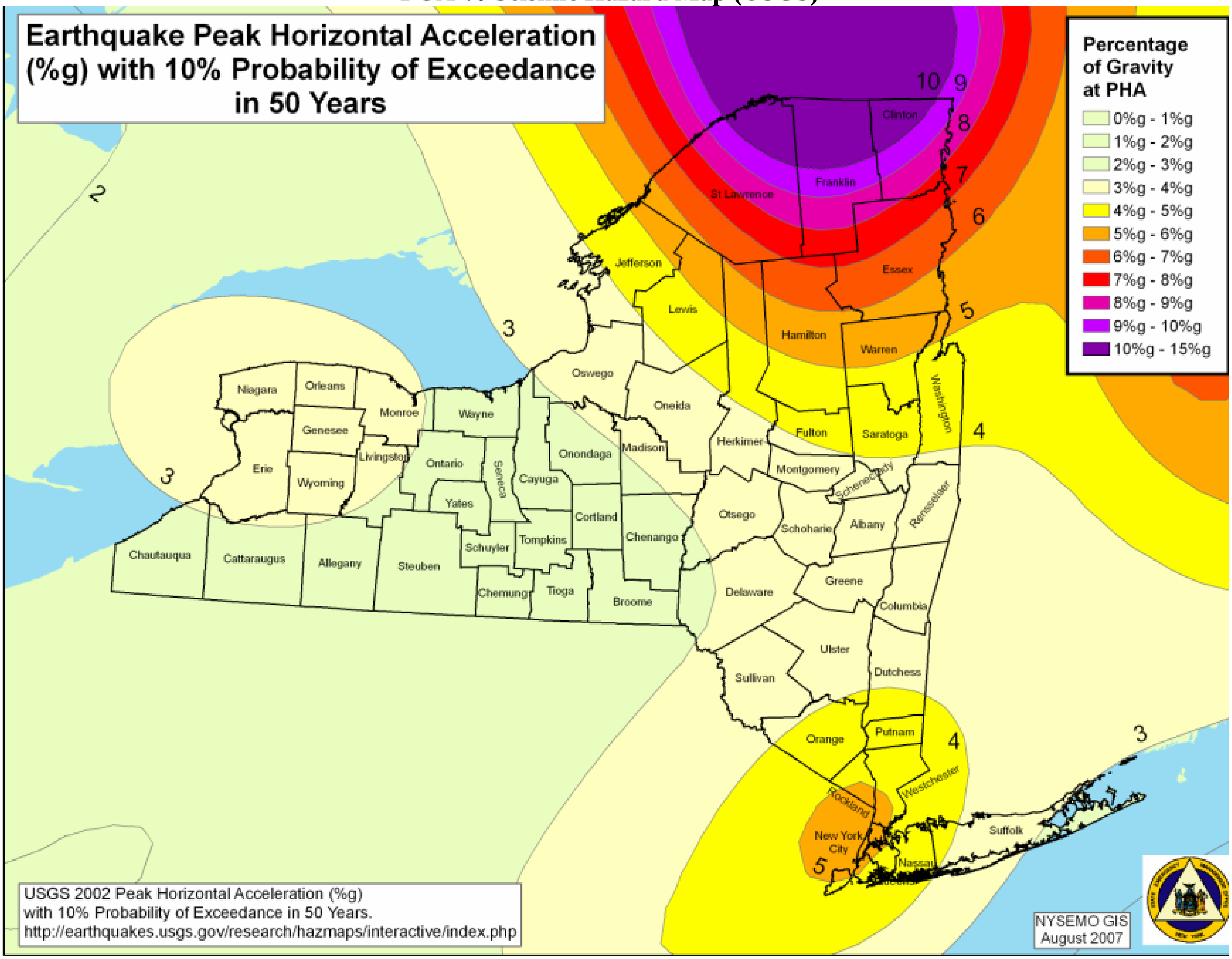
MMI	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	< .17	Not Felt	None
II	.17 – 1.4	Weak	None
III	.17 – 1.4	Weak	None
IV	1.4 – 3.9	Light	None
V	3.9 – 9.2	Moderate	Very Light
VI	9.2 - 18	Strong	Light
VII	18 – 34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy
IX	65 – 124	Violent	Heavy
X	> 124	Extreme	Very Heavy
XI	> 124	Extreme	Very Heavy
XII	> 124	Extreme	Very Heavy

Source: FEMA mitigation planning "how to" guide 386-2.

Note: Any jurisdiction that has a PGA of 3% or higher, is required by FEMA to fully profile the Earthquake Hazard, in order to receive approval of your Local Hazard Mitigation.

Figure 3-128 indicates general regions that have a seismic risk that tends to be higher. Those regions include; The North and Northeast third (1/3) of NYS (The North Country/Adirondack Region including a portion of the Greater Albany-Saratoga region), the Southeast corner (including the greater NYC area and western Long Island), and the Northwest corner (including the City of Buffalo and vicinity) of NY State, in that order from higher to lower. A NYS Geological Survey (GS) report entitled "Earthquake Hazard in New York State" supports the indications of the PGA map by identifying and characterizing these regions in NYS as "more active" (seismically). The New York State Geological Survey (NYS GS) studies the epicenters and size of all known historical and recent earthquakes. **Figure 3-133** portrays that Spectral Acceleration across NYS combined with the NEHRP soil classes. As opposed to Peak Acceleration which is what is experienced by a particle on the ground, SA (spectral acceleration) is approximately what is experienced by a building. This advancement in mapping allows for greater insight into location specific vulnerabilities. It is recommended that any jurisdiction that is portrayed with some vulnerability fully examine their earthquake risk. One key note is that this map creates a better understanding of risk to jurisdictions than that of the 10% Peak Acceleration map. For instance jurisdictions that may fall under 3% PGA on the previous map may actually have some areas of high vulnerability within their borders.

Figure 3-128
PGA % Seismic Hazard Map (USGS)



New York State Earthquake Probability That Factors the Affect of Local Soil Conditions: Adjusted USGS 0.2 Second Spectral Acceleration (SA) with 2% Probability of Exceedance in 50 Years

The USGS Seismic Hazard Maps (http://earthquake.usgs.gov/research/hazmaps/) provide the USGS's best estimate of the probability of earthquakes expressed in terms of "Peak Ground Acceleration" and "Spectral Acceleration" (spectral acceleration is used as a better indicator of damage to specific buildings types and heights). As these maps cover the entire United States, it has not been possible for the USGS to tailor these maps to reflect the affect of local soil conditions in amplifying seismic waves on a national scale. Consequently, the USGS uses an average (NEHRP B-C) soil condition that is applied throughout.

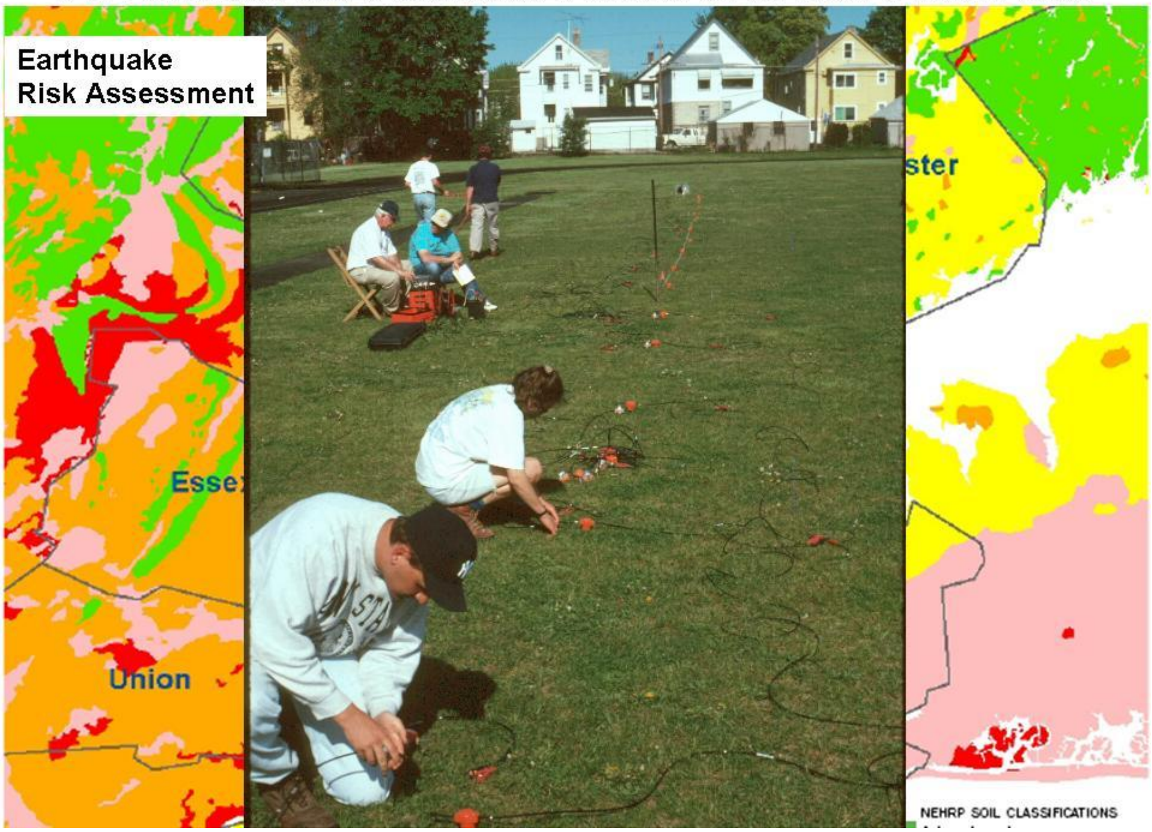
The affect of local soil conditions on seismic waves and the resulting level of damage can be significant. In certain cases, it can more than double accelerations due to wave amplifications than shown on the baseline USGS maps. As a result, a first inspection of the USGS maps used to determine the earthquake hazard in one's locale can be misleading if this is not understood.

Seismic waves propagate out from the earthquake epicenter and travel outward through the bedrock up into the soil layers. As the waves move into the soils, the speed or velocity of the waves is affected by how stiff or soft the soil is. Generally, in a stiff or "hard" soil, the wave will travel at a higher velocity. In the case of "soft" soils, the wave will slow, traveling at lower velocities. When the wave is slowed, the seismic energy is modified, resulting into a wave with greater amplitude. This amplification results in greater earthquake damage.

While the USGS has not conducted seismic micro hazard zonation studies throughout the U.S. enabling it to provide locally specific hazard maps, the New York State Geological Survey has conducted seismic shear-wave tests of the State's surficial geology (glacial deposits). These studies measure the velocity of a wave through representative surficial geologic materials. Tests were run in various parts of the State to provide an understanding of how the various glacial materials varied from one region to another. In each region, a variety of glacial materials were measured, such as till, glacial lake sands and clays, outwash, etc. The velocity measurements are obtained by a recorder connected to sensors placed at set intervals along the ground. A small blast is generated and the arrival times of the wave are recorded at each sensor. From this information, the velocity of the wave through a particular soil type is determined. See **Figure 3-129**

Figure 3-129

NEW YORK STATE GEOLOGICAL SURVEY SEISMIC SHEAR WAVE VELOCITY TESTS



Based on the results of these tests it has been possible to classify the surficial geologic materials according to the National Earthquake Hazard Reduction Program's Soil Site Classifications. See **Figure 3-130**

Figure 3-130

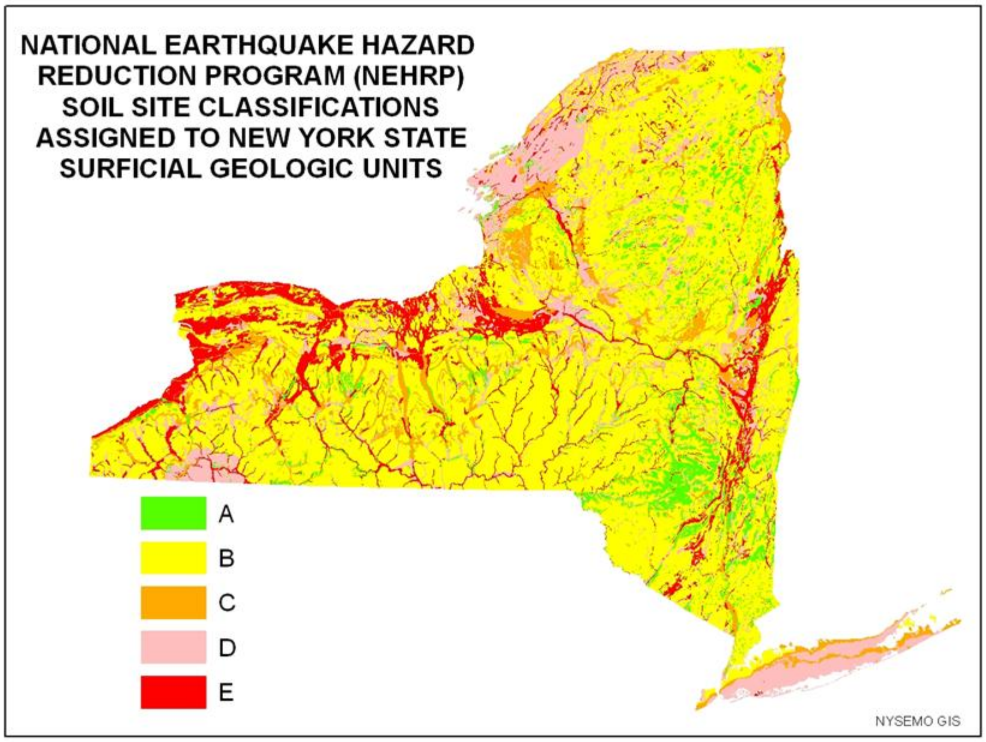


Figure 3-131

NEHRP Site Class

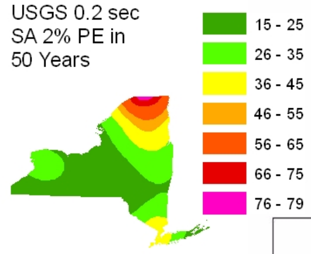
Site Classifications taken from Table 1615 1.1 Site Class Definitions published in 2000 International Building code, International Code Council, Inc. on page 350.

Table 1615 1.1 Site Class Definitions partially reproduced below

Site Class	Soil Profile Name	Average Properties in Top 100 feet (as per 2000 IBC section 1615.1.5) Soil Shear Wave Velocity, V_s	
		Feet/second	Meters/second
A	Hard Rock	$V_s > 5000$	$V_s > 1524$
B	Rock	$2500 < V_s \leq 5000$	$762 < V_s \leq 1524$
C	Very dense soil and soft rock	$1200 < V_s \leq 2500$	$366 < V_s \leq 762$
D	Stiff soil profile	$600 < V_s \leq 1200$	$183 < V_s \leq 366$
E	Soft soil profile	$V_s < 600$	$V_s < 183$

This classification of the State's surfical geologic materials by NEHRP soil site class has enabled the affect of soils to be factored with the USGS seismic hazard maps to give an adjusted, more regionally refined picture, of the State's earthquake hazard based. The level of adjustment to USGS map is based on use of the NEHRP's soil site coefficients for each soil class, which varies according to the USGS mapped accelerations. The reference for the appropriate coefficient is found in "The 2003 NEHRP Recommended Provisions for New Building and Other Structures – Part: Provisions (FEMA 450). These coefficients provide the level of increase or decrease to the USGS's seismic hazard map spectral accelerations. See **Figure 3-132**

Figure 3-132



The 2003 NEHRP Recommended Provisions For New Building And Other Structures Part 1: Provisions (FEMA 450)

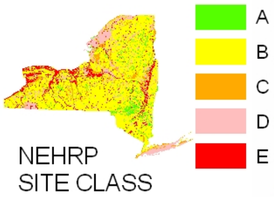
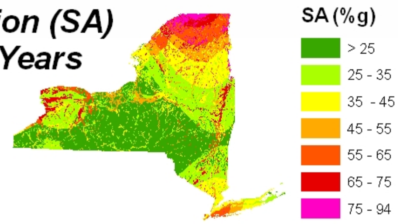


Table 3.3-1 Values of Site Coefficient F_a

Site Class	Mapped MCE Spectral Response Acceleration Parameter at 0.2 Second Period [a]				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	—[b]	—[b]	—[b]	—[b]	—[b]

[a] Use straight line interpolation for intermediate values of S_S.
[b] Site-specific geotechnical investigation and dynamic site response analyses shall be performed.

Adjusted USGS 0.2 sec Spectral Acceleration (SA) with a 2% Probability of Exceedance in 50 Years Based on Soil Site Class and Acceleration Parameter Coefficients



A review of the adjusted maps that factor soil conditions will show some areas of the state with a significantly higher hazard than is shown on the USGS map.