Hazard Profile - Earthquake

An earthquake is caused by a sudden slip on a fault. Stresses in the earth's outer layer push the sides of the fault together. Stress builds up and the rocks slip suddenly, releasing energy in waves that travel through the earth's crust and cause the shaking that is felt during an earthquake. The amount of energy released during an earthquake is usually expressed as a Richter magnitude and is measured directly from the earthquake as recorded on seismographs. Another measure of earthquake severity is intensity. Intensity is an expression of the amount of shaking at any given location on the ground surface as felt by humans and defined in the Modified Mercalli scale (see Table 5-40). Seismic shaking is typically the greatest cause of losses to structures during earthquakes. The following databases were searched for information on the potential for earthquakes to impact the study area:

- HAZUS-MH and Associated Guidance
- New York City Consortium for Earthquake Loss Mitigation (NYCEM) http://www.nycem.org/default.asp
- United States Geological Survey (USGS), http://www.usgs.gov
- New York State 2008 Hazard Mitigation Plan, http://www.semo.state.ny.us
- Albany Times Union Newspaper http://www.timesunion.com
- Laredo, Texas Morning Times http://www.lmtonline.com
- Lamont-Doherty Observatory, Columbia University, New York http://www.Ideo.columbia.edu

Table 5-43 Earthquake Definitions

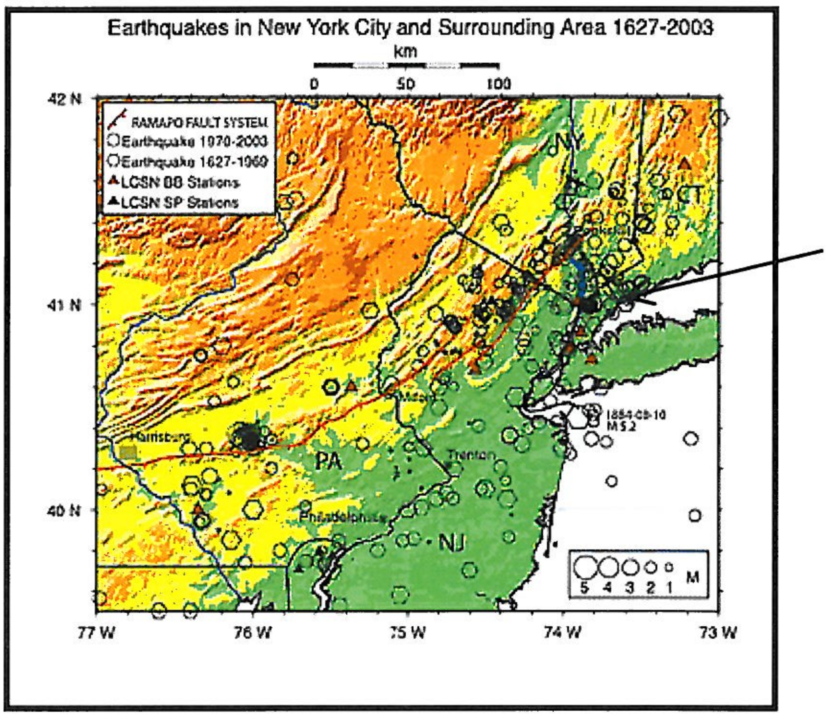
Term	Definition
Earthquake	Both sudden slip on a fault, and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the earth.
Earthquake hazard	Anything associated with an earthquake that may affect the normal 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 cture.
For more in-depth definitions regarding Earthquake terminology please reference the U.S. Geological Survey website at www.usgs.gov,	

Source: NYSHMP/USGS

Geographic Location and Extent

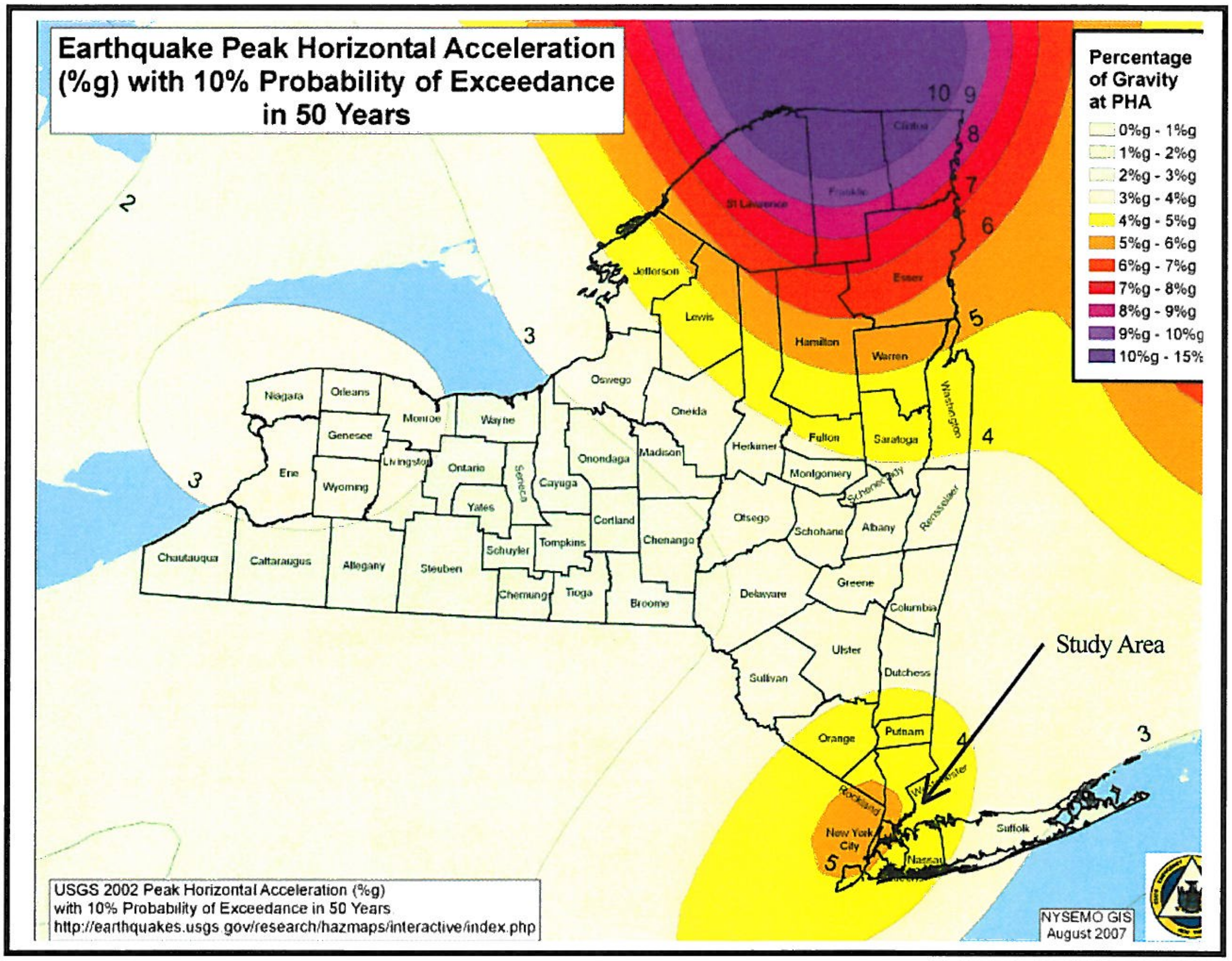
There are no documented faults within the study area. The study area is however, in close proximity to several fault lines including those located in New York City. The Ramapo Fault (see Figure 5-26) runs from Southeastern New York into eastern Pennsylvania. This fault line is of considerable interest due to its close proximity to the Indian Point Nuclear Power Plant in Buchanan, New York. Indian Point is approximately 20 miles from the study area at its closest point. The study area has experienced shaking as a result of earthquake activity, the most recent occurring in April 2002 from an earthquake measuring 5.1 on the Richter Scale and located near Au Sable Forks, New York.

Figure: 5-29 Ramapo Fault (red line) and associated earthquakes / seismic monitoring stations



Source: http://www.ldeo.columbia.edu

Figure: 5-30 Earthquake Hazard Map of New York State



Source: NYS Multi-Hazard Mitigation Plan 2008

Severity of an earthquake is a function of the amount of energy released and is expressed by its magnitude and intensity. Table 5-44 below combines the Richter and Mercalli Scales in order to present a clear picture as to the relationship of these scales.

Table 5-54 Richter Scale and Modified Mercalli Scale

Modified Mercalli Intensity	Description	Richter Magnitude
I	Instrumental: detected only by seismographs	3.5
II	Feeble: noticed only by sensitive people	4.2
III	Slight: like the vibrations due to a passing train; felt by people at rest, especially on upper floors	4.3
IV	Moderate: felt by people while walking; rocking of loose objects, including standing houses	4.8
V	Rather Strong: felt generally, most sleepers are awakened and bells ring	4.8-5.4
VI	Strong: trees sway and all suspended objects swing; damage by overturning and falling loose objects	5.5-6.0
VII	Very strong: general alarm; walls crack, plaster falls	6.1
VIII	Destructive: car drivers seriously disturbed; masonry fissures; chimneys fall; Poorly constructed buildings damaged	6.2
IX	Ruinous: some houses collapse where ground begins to crack, and pipes Break open	6.9
X	Disastrous: ground cracks badly; many buildings destroyed and railway lines bend; landslides on steep slopes	7.0-7.3
XI	Very disastrous: few buildings remain standing; bridges destroyed; all services (transportation and Utility) affected; landslides and floods	7.4-8.1
XII	Catastrophic: total destruction; objects thrown into the air, ground rises and falls in waves	>8.1

Earthquakes can cause structural damage, injury, and loss of life, as well as damage to infrastructure networks, such as water, power, communication, and transportation lines. Other damage-causing effects of earthquakes include surface rupture, fissuring, settlement, and permanent horizontal and vertical shifting of the ground. Secondary impacts can include landslides, soils liquefaction, fires, and dam failure.

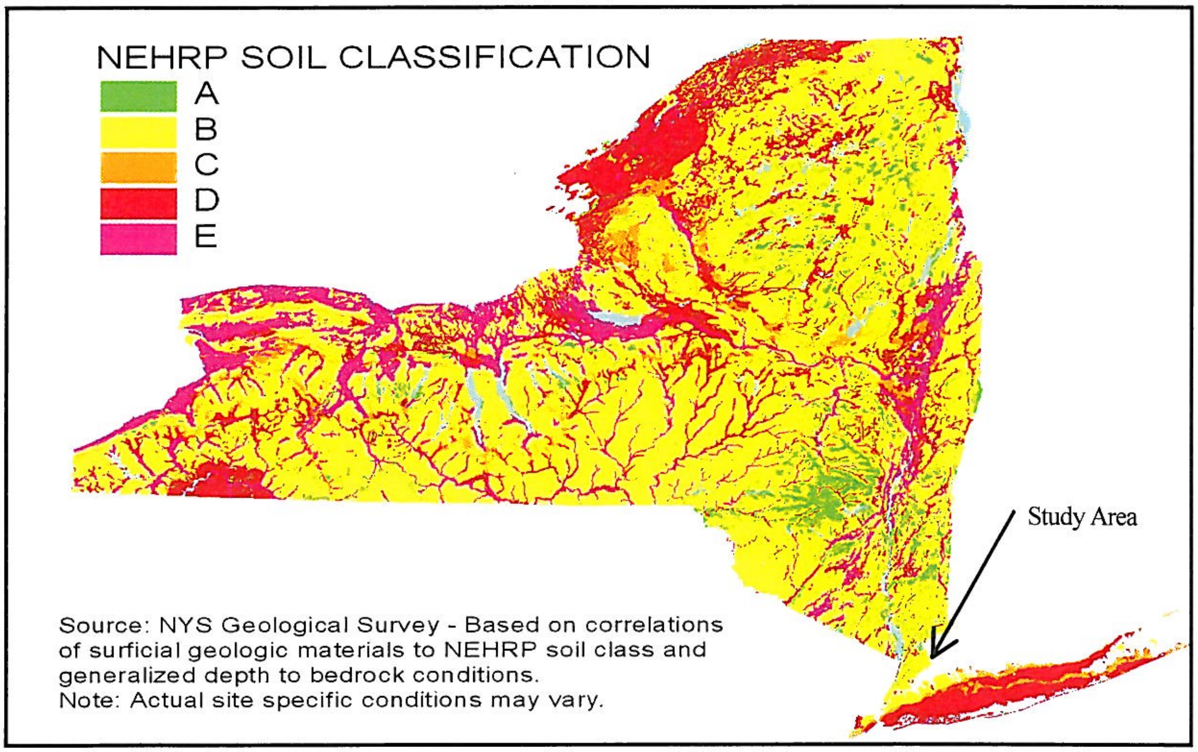
Besides magnitude and intensity of an earthquake, the other factor which can have and impact on damage is the local soil type. The National Earthquake Hazard Reduction Program (NEHRP) lists five soil classifications which can have an impact on the severity of an earthquake. Table 5-55 outlines these soil classifications and Figure 5-31 illustrates them. Westchester County which includes the Town / Village of Harrison, includes in the majority class B, C, and D soils

Table 5-55 Soil Classification Descriptions

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

Source: NYS Hazard Mitigation Plan

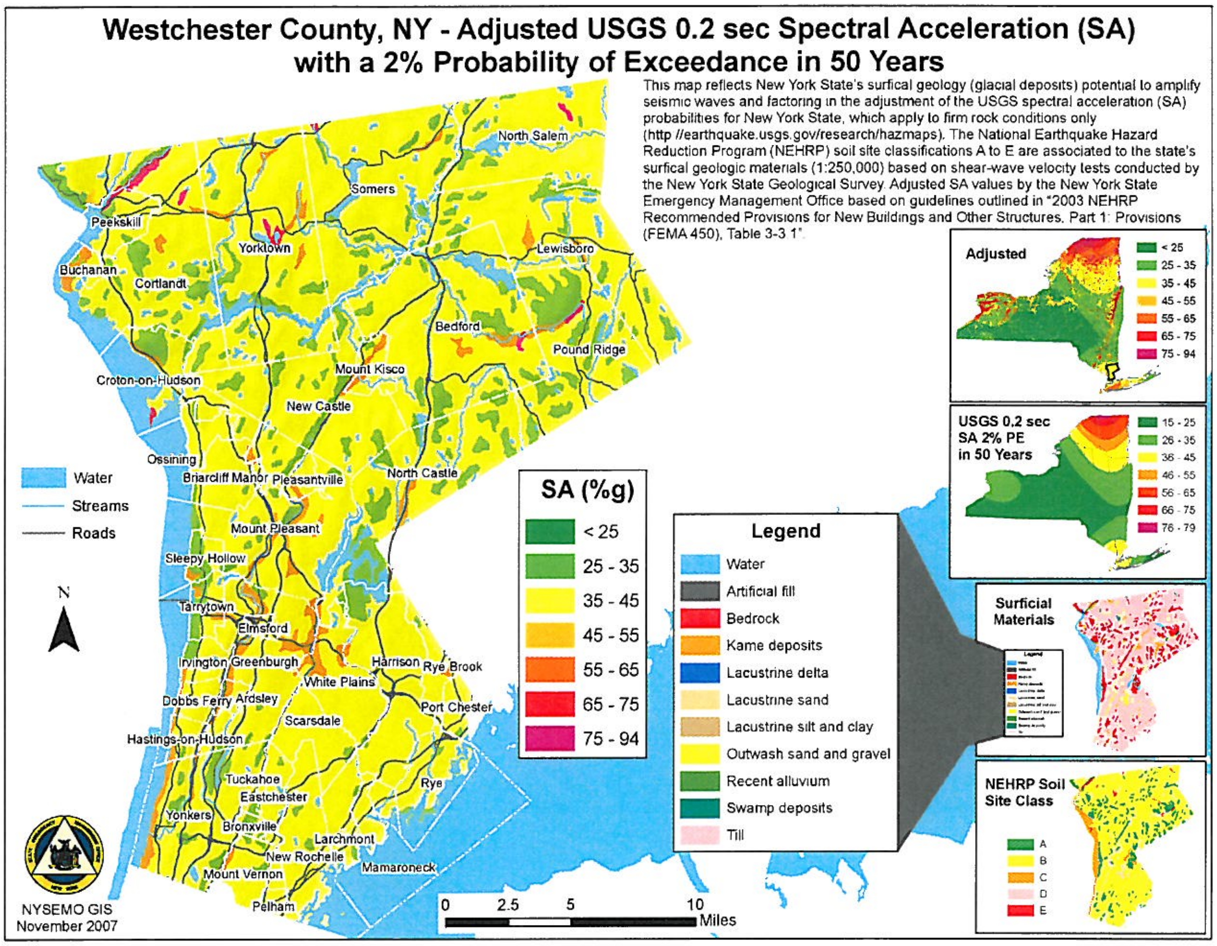
Figure: 5-31 Soils Classification Map for New York State



Source: NYS Hazard Mitigation Plan 2008

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.

Figure 5-32 Westchester County, N.Y. – Adjusted USGS 0.2 sec Spectral Acceleration (SA) with a 2% Probability of Exceedance in 50 Years



Source: 2008 New York State Hazard Mitigation Plan

Previous Occurrences and Losses

While Westchester County and the study area in particular lie within one of three areas of New York State with a higher risk of experiencing an earthquake event (see Figure 5-30) reports of earthquakes of magnitudes which would be noticeable are rare. The most recent and noticeable earthquake to be felt in the study area had its epicenter near Au Sable Forks in upstate New York on April 20, 2002 and measured 5.1 on the Richter Scale. Table 5-42 documents earthquakes having occurred near the study area between 1638 and 2001. Discussions with Department of Public Works staff as well members of the HMPC found that no records existed with respect to any damage to public infrastructure associated with earthquakes felt in the study area from a magnitude 4.0 event occurring on October 19, 1985 near Ardsley, New York or the April 20, 2002, 5.1 magnitude earthquake which occurred near Au Sable Forks in Essex County, New York. The April 20, 2002 earthquake received national attention including the article in the Laredo, Texas Morning Times shown in Figure 5-33.

Figure 5-33 Article from Laredo, Texas Morning Times on April 21, 2002

PAGE 10A   Laredo Morning Times   Sunday, April 21, 2002

NATIONAL

5.1 magnitude earthquake rattles Northeast

BY KRISTA LARSON
Associated Press Writer

AU SABLE FORKS, N.Y. — An earthquake that registered 5.1 on the Richter scale shook the Northeast awake early Saturday, collapsing roads in New York and rattling homes from Maine to Maryland. No injuries were immediately reported.

The quake, centered 15 miles southwest of Plattsburgh, N.Y., left cracks in foundations and chimneys throughout the region, said Ray Thatcher, director of emergency services for Essex County.

"It was shaking pretty good," said Jimmy Mussaw, who said he was standing in a Plattsburgh supermarket just before 7 a.m. when the walls and beams begin to shake. "Everybody was running from the back of the store to the front."

Essex and Clinton counties, near the Vermont and Canada borders, declared states of emergency, and state inspectors were set to the Adirondack region to examine bridges and dams for structural damage. No restrictions were placed on travel, but police were urging drivers to use caution.

William Ott, a seismologist at Weston Observatory at Boston College, said the quake had a magnitude of 5.1, and at least two aftershocks were reported.

He called the earthquake "moderate." A typical magnitude 5.1 earthquake would cause cracked plaster, broken windows and minor structural damage around the epicenter, he said.

The quake broke off a 100-foot section from one road in Ausable, said David Fessette, highway construction supervisor for Clinton County. A crew was filling the area in with limestone Saturday afternoon. Parts of at least two other roads collapsed, and there were several water main breaks in the area.

At Adirondack Mountain Spirits in Ausable, the earthquake rattled liquor bottles off the shelves.

"It was just a mess," said owner Dayle Richards. "Even if they didn't break, they were covered with other debris."

The largest earthquake

SOURCE: ESRI   AP

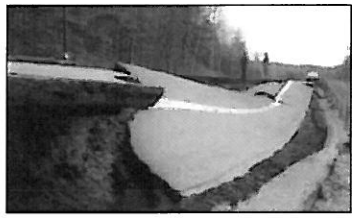
recorded in New York, according to the USGS, was a 5.8 magnitude quake in 1944 that was centered in Massena, about 3 miles from the Canadian border.

Won Young Kim, a seismologist with the Columbia University's Lamont Doherty Earth Observatory, said a magnitude 3.5 quake occurred in the same area on the same day, April 20, two years ago.

"Northern New York is an active area, but most of the earthquakes that occur in the area are smaller," said Frank Revetta, a professor of geology at State University of New York at Potsdam. "Normally you'd got one this big just every 100 years or so.

"During the last two or three years, there haven't been many at all, and I wondered if that meant anything. This might prove the strained energy had not been released, and now it has been."

By several accounts, the



AP Photo/Press-Republican, MIKE DOWD

QUAKE DAMAGE: The collapsed road on Route 9N in the town of Au Sable Forks, N.Y., 12 miles south of Plattsburgh, is shown after an earthquake Saturday.

shaking lasted about 30 seconds.

Amanda Slattery, of Yorktown Heights just north of New York City, said she was in bed when the temblor struck.

"I could hear the frame of the house shaking," Slattery said. "I lay there long enough to realize it was an earthquake ... I was relieved when it stop."

Tremors also were felt in Canada, as far east as Boston and Portland, Maine, and as far south as Baltimore.

Carol McDonald of Downingtown, Pa., about 40 northwest of Philadelphia, said she woke up to find the windows of her home rattling. She and her husband grabbed their baby and waited out the tremors.

"I'm from California and (said), 'This feels like an earthquake.' I didn't think we got those out here," she said.

On the Net: United States Geological Survey's National Earthquake Information Center: http://neic.usgs.gov/

The Albany Times Union Newspaper, in an article dated April 21, 2000 and titled "Adirondack Area Gets A Bit Of A Jolt" reported other earthquakes in New York State in recent times occurring on April 20, 2000 at 4:47 AM centered near Newcomb, Essex County , New York and measuring 3.7 on the Richter Scale; on October 7, 1983 in the same general area which was felt in 12 states and 2 Canadian Provinces and measured 5.1 on the Richter Scale and the largest ever occurring in the State of New York on September 5, 1944 near Messina, New York and measuring 5.8 on the Richter Scale. The September 5, 1944 earthquake caused $2 million in damage in 1944 dollars in a sparsely populated area. That same event in 2000 could be expected to cause 15 to $20 million in damages.

Table: 5-56 Largest Earthquakes in New York City Area (1637-2001)

Date	Location	Magnitude Richter	Max. Intensity	Remarks
December 19, 1737	Greater New York City Area	5.2	VII	Threw down chimneys
November 30, 1783	Northern New Jersey	4.9	VI	Threw down chimneys
October 26, 1845	Greater New York City Area	3.8	VI	NA
1847	Greater New York City Area	4.5	V	Probably Offshore
September 9, 1848	Greater New York City Area	4.4	V	Felt by population
December 11, 1874	Near Nyack, Tarrytown	3.4	VI	Not Applicable
August 10, 1884	Greater New York City Area	5.2	VII	Threw down chimneys, felt From Maine to Virginia
January 4, 1885	Hudson River Valley	3.4	VI	Not Applicable
September 1, 1895	North Central New Jersey	4.3	VI	Location determined by fire and aftershock
June 1, 1927	Near Asbury Park, New Jersey	3.9	VI-VII	Very high intensity in Asbury Park, possible shallow event
July 19, 1937	Western Long Island, New York	3.5	IV	One of few earthquakes beneath Long Island
August 23, 1938	Central New Jersey	3.8	VI	Not Applicable
September 3, 1951	Rockland County, New York	3.6	V	Not Applicable
March 23, 1957	Central New Jersey	3.5	VI	Not Applicable
March 10, 1079	Central New Jersey	3.2	V-VI	Felt by some people in Manhattan
October 19, 1985	Ardsley, New York	4.0	IV	Felt by many people in NYC area
January 1, 2001	Manhattan, New York City	2.4	IV	Felt in upper East Side of Manhattan, Astoria and Queens, NYC
January 17, 2001	Manhattan, New York City	2.4	IV	Felt in upper East Side of Manhattan, Long Island City and Queens, NYC

Source: http://www.ldeo.columbia.edu/LCSN/big-ny-eq.html

While a number of resources were researched for earthquake data for the study area, including the United States Geological Survey, the 2008 New York State Hazard Mitigation Plan, and the Lamont-Doherty Earth Observatory of Columbia University, data was not consistent throughout all the resources utilized. The data provided by Lamont-Doherty was utilized herein because of its close proximity to the study area. Of the 18 earthquakes documented in Table 5-42, two are indicated to have occurred near the study area. The earthquake of December 11, 1874, with a magnitude of 3.4, was located near Tarrytown and Nyack, New York less than 10 miles from the study area. The earthquake of October 19, 1985, with a magnitude of 4.0, originated near Ardsley, New York, also less than 10 miles from the study area.

Probability of Future Events

The NYSHMP notes that New York State can expect a damaging earthquake about once every 22 years, and these events are more likely to occur within one of the three regional areas identified previously. Westchester County and the Town / Village of Harrison are included in the southernmost of these three regions. The State Plan references a NYSGS study by W. Mitrovonas, entitled, "Earthquake Hazard in New York State," which states, "...at present an earthquake of magnitude 3.5 to 4 occurs, on the average every three years somewhere in the State. Such earthquakes do not cause any appreciable damage (except for cracks in plaster, perhaps) but are large enough to be felt strongly by many people near the epicenter."

In the beginning of this plan, the hazards most likely to impact the study were identified by the HMPC and the consultant, discussed as to there impact on the study area, and ranked as to the possibility of an event occurrence. Based on historical records and input from the HMPC, the probability of occurrence for earthquakes in the Town/Village of Harrison is considered occasional (likely to occur less often than once every 5 years, but more often than once every 30 years. While there are no records of damages associated with past earthquake events, future events could affect building stock, critical facilities and infrastructure and the local economy given a severe enough event. There is also a potential for secondary events as a result of an earthquake including fires, utility failures and flooding.

Vulnerability Assessment

A vulnerability assessment is defined as assessing the vulnerability of people and the built environment to a given level of hazard. After identifying types of risk, a vulnerability analysis can help to determine the weak points in the community. This assessment examines the vulnerability of the existing and future built environment, such as structures, utilities, roads and bridges, as well as environmental vulnerability, such as open space that can suffer from erosion. Once the geographic areas of risk are identified in the Town / Village, vulnerability can be assessed for the population, property and resources at risk in those areas. Vulnerability indicates what is likely to be damaged by the identified hazards and how sever the damage may be. If an area is determined to be at risk from an earthquake, vulnerability estimates for that area could include residential property losses, impacts to the tax base and damages to public infrastructure. Earthquake events can impact the entire Town/Village of Harrison. All assets associated with those areas including population, structures, critical facilities and utilities are vulnerable. The following sections evaluate and estimate the potential impact of flooding:

- Overview of vulnerability
- Data and methodology used in the evaluation
- Impact on life, safety and health
- Identifying structures including general building stock, critical facilities and critical infrastructure
- Economic impact
- Addressing Repetitive Loss Properties (NFIP data for floods, other hazards as available)
- Estimating Potential Losses
- Analyzing Development Trends (new buildings, critical facilities and Infrastructure)

- Additional Data and Next Steps
- Overall vulnerability conclusion
- Multi-jurisdictional Risk Assessment

Overview of Vulnerability

Earthquake vulnerability is primarily based upon population and the built environment. Urban areas in high hazard zones are the most vulnerable, while uninhabited areas are less vulnerable. The ability to accurately estimate the timing, location, and severity of future earthquake activity in the Town / Village of Harrison is limited due to the lack of good historical data and the relative infrequent occurrence of earthquakes which generate damage.
Ground shaking, the principal cause of damage, is the major earthquake hazard. Many factors affect the potential damageability of structures and systems from earthquake-caused ground motions. Some of these factors include proximity to the fault, direction of rupture, epicentral location and depth, magnitude, local geologic and soils conditions, types and quality of construction, building configurations and heights, and comparable factors that relate to utility, transportation, and other network systems. Ground motions become structurally damaging when average peak accelerations reach 10 to 15 percent of gravity, and when the Modified Mercalli Intensity Scale is about VII (18-34 percent peak ground acceleration), which is considered to be very strong (general alarm; walls crack; plaster falls).

In general, newer construction is more earthquake resistant than older construction because of improved building codes and their enforcement. Manufactured housing is very susceptible to damage because rarely are their foundation systems braced for earthquake motions. Locally generated earthquake motions, even from very moderate events, tend to be more damaging to smaller buildings, especially those constructed of un-reinforced masonry.
Common impacts from earthquakes include damage to infrastructure and buildings (e.g., crumbling of un-reinforced masonry [brick], failure of architectural facades, rupturing of underground utilities, gas-fed fires, landslides and rock falls, and road closures). Earthquakes can also trigger secondary effects, such as dam failures, explosions, and fires that become disasters themselves.

Data and Methodology

The consultant utilized HAZUS-MH to model earthquake losses for the Town / Village of Harrison. Inventory and risk are from scenarios performed in FEMA's HAZUS software. Scenarios were run to assess potential economic and social losses due to earthquake activity. As previously stated, local historical information is minimal at best and consists principally of institutional knowledge of long tenured municipal staff, comments from the HMPC and public comments.

Assessments were conducted for two Mean Return Periods of 100 and, 500 years which created a range of potential loss estimates. A 100 year Mean Return Period (MRP) indicates that there is a 1% chance that the determined ground motion levels or Peak Ground Acceleration (PGA) will be exceeded in any given year. A 500 year MRP creates a .2% chance that a determined PGA will be exceeded in any given year. For our purposes, **HAZUS –MH utilized an Eathquake**

Magnitude of 5.0 in analyzing potential events. A 4.8-5.4 magnitude event is the point at which people may begin to be awakened and objects begin to fall from shelves.

The 2008 New York State Mitigation Plan's annualized earthquake loss analysis was based on HAZUS model's default soil classification – the National Earthquake Hazard Reduction Program's (NEHRP) soil class "D". This was applied across the entire state. The "D" soil class is next to the worst soil class in terms of ground shaking amplification. Although there are many areas of the state that have been classified with soil class "D" and even worse class "E" in this most recent study, there was overall a better (less amplification) soil class assigned resulting in a significant loss reduction. This demonstrates the significance of soil factors in earthquake risk assessment. For purposes of this study, The class "D" soil will be utilized in all analysis.

Impact on Life, Health and Safety

Impact on life, health and safety combines several factors including the severity of the event as well as one's location and time when the event occurs (e.g. inside a building, adjacent to a building, in open space, driving etc). Based on past history, risk to life, health and safety is minimal. Should an earthquake of sufficient magnitude occur, residents may be displaced and require sheltering or need to seek refuge with relatives and friends outside the earthquake impact area. Low income and senior citizens are particularly susceptible because of their financial or physical condition. According to the 2000 Census, 14% of the study area population is over 65. There are no manufactured type homes in the study area. HAZUS –MH was utilized to develop sheltering and casualty information.

Table: 5-57 Sheltering Requirements

Category	100 Year Event	500 Year Event
Households displaced	0	12
Persons seeking temporary shelter	0	2

Source: HAZUS-MH

HAZUS-MH estimates for casualties are provided for three times of day; (2:00 AM, 2:00 PM and 5:00 PM). These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residency occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and the 5:00 PM represents peak commute time. Table 5-48 provides these estimates. Casualty levels are defined with severities as follows:

- Level 1: Injuries require medical attention but hospitalization is not needed
- Level 2: Injuries will require hospitalization but are not considered life threatening
- Level 3: Injuires will require hospitalization and can become life threatening if not promptly treated
- Level 4: Victims are killed by the earthquake

Table 5-58 Casualty Estimates (number of persons)

Time	Sector	100 Year Level 1	100 Year Level 2	100 Year Level 3	100 Year Level 4	500 Year Level 1	500 Year Level 2	500 Year Level 3	500 Year Level 4
2AM	Commercial	0	0	0	0	0	0	0	0
	Commuting	0	0	0	0	0	0	0	0
	Educational	0	0	0	0	0	0	0	0
	Hotels	0	0	0	0	0	0	0	0
	Industrial	0	0	0	0	0	0	0	0
	Other Residential	0	0	0	0	2	0	0	0
	Single Family	0	0	0	0	2	0	0	0
	Total	0	0	0	0	4	1	1	0
2PM	Commercial	0	0	0	0	5	1	1	0
	Commuting	0	0	0	0	0	0	0	0
	Educational	0	0	0	0	0	0	0	0
	Hotels	0	0	0	0	0	0	0	0
	Industrial	0	0	0	0	1	0	0	0
	Other Residential	0	0	0	0	0	0	0	0
	Single Family	0	0	0	0	0	0	0	0
	Total	0	0	0	0	7	1	1	0
5PM	Commercial	0	0	0	0	3	1	0	0
	Commuting	0	0	0	0	0	0	0	0
	Educational	0	0	0	0	0	0	0	0
	Hotels	0	0	0	0	0	0	0	0
	Industrial	0	0	0	0	1	0	0	0
	Other Residential	0	0	0	0	1	0	0	0
	Single Family	0	0	0	0	1	0	0	0
	Total	0	0	0	0	5	1	0	0

Identifying Structures

According to New York City Consortium for Earthquake Mitigation (NYCEM) most damage and loss to structures and infrastructure is the result of ground shaking. Ground motion and its relationship to gravity are the factors affecting an earthquakes impact on buildings and infrastructure. Data provided by modeling from HAZUS-MH were used to illustrate the earthquake hazard for general building stock in the study area. The following figures represent (PGA) for 100, 500 earthquake events.

Due to the wide ranging impact of an earthquake event, the entire study area is at risk and will be analyzed for structural damage and losses. HAZUS determines the value of the building stock and then assigns a loss value. The analysis considers the age of the building stock, occupancy class, construction composition, examples of structural damage, and building damage based on severity of an event.

Table 5-59 Building Stock Exposure by Occupancy Type

Building Occupancy Class	**Number of Buildings**	**Exposure Value ($1,000)**	**Percent of Total Exposure Value**
Agriculture	57	9,704	.3%
Commercial	673	669,177	23.6%
Education	27	52,876	1.9%
Government	16	18,789	.7%
Industrial	190	180,212	6.3%
Residential	6,618	1,865,990	65.8%
Religion	43	41,243	1.5%
Total	**7,624**	2,837,991	100%

Source: HAZUS-MH

Buildings construction composition is one factor which determines a buildings survivability of an earthquake. Wood and steel constructed buildings are more likely to resist earthquake shaking than un-reinforced masonry structures which would tend to bow out and collapse during and event.

Table 5-60 Building Stock by Construction Type as a Percentage of Study Area Total

Building Construction	**Count**	**Percent of Total**
Wood	5,409	70.95
Steel	498	6.54
Concrete	183	2.40
Precast	32	.42
Reinforced Masonry	234	3.07
Un-reinforced Masonry	1268	16.63
Manufactured Homes	0	0
Total	7,624	

Source: HAZUS-MH

HAZUS –MH maintains an inventory of Critical Facilities; essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations , police stations, emergency operations facilities and public works operations and maintenance facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazard material sites

Table: 5-61 Critical Facility Inventory

Group	Category	Number of Facilities in Study Area
Essential Facilities		
	Hospitals	0
	Medical Clinics	0
	Schools	10
	Fire Stations	3 *
	Police Stations	1
	Emergency Operations	0
	Public Works Operations and Maintenance	2
High Potential Loss Facilities		
	Dams	3*
	Levees	0
	Military Installations	0
	Nuclear Power Plants	0
	Hazard Materials Sites	0

Source: HAZUS-MH and municipal records * HAZUS-MH identifies 2 fire stations in the study area while there are actually 3.
HAZUS-MH identifies 3 dams in the study area where the NYSDEC has 5 in its inventory

Transportation and Utility Lifeline Facilities are those infrastructure both public and privately owned that provide services which allow communities to function and be economically viable. The HAZUS-MH program maintains a local inventory of these facilities including transportation system which include highways, railways, light rail, bus, ports, ferry and airports. Also included in the inventory are utility systems such as potable water, wastewater, natural gas, crude and refined oil, electric power and communications. The total value of the lifeline inventory exceeds $1,209,000,000 and includes 96 kilometers of highways, 43 bridges and 481 kilometers of pipes.

Table:5-62 Transportation System Lifeline Inventory

System	Component	No. of locations / segments	Replacement Value (millions of dollars)
Highway	Bridges	43	655.70
	Segments	19	462.50
	Tunnels	0	0
		Subtotal	1,118.20
Railways	Bridges	1	0
	Facilities	0	0
	Segments	2	11.20
	Tunnels	0	0
		Subtotal	11.20
Light Rail	Bridges	0	0
	Facilities	0	0
	Segments	0	0
	Tunnels	0	0
		Subtotal	0
Bus	Facilities	0	0
		Subtotal	0
Ferry	Facilities		0
		Subtotal	0
Port	Facilities	0	0
		Subtotal	0
Airport	Facilities	1	6.40
	Runways	2	73.30
		Subtotal	79.80
		Total	**1,209.20**

While all of these facilities exist in the study area, only a portion of the highway network is the operating and maintenance responsibility of the Town / Village of Harrison. Highway mileage in the study area is broken down as shown in the Table 5-53

Table: 5-63 Municipal Entity Responsible for Transportation System Lifelines

Municipal Entity Responsible	Mileage
Town/Village of Harrison	81.5
New York State Department of Transportation	23.5
New York State Thruway Authority	6.2
County of Westchester	18.4

Source: New York State Department of transportation Highway Inventory

The railway system is operated and maintained by the Metro-North Commuter Railroad and the Airport is operated and maintained by the County of Westchester.

Table: 5-64 Utility System Lifeline Inventory

System	Component	No. of locations / segments	Replacement Value (millions of dollars)
Potable Water	Distribution Lines	NA	4.80
	Facilities	0	0
	Pipelines	0	0
		Subtotal	4.80
Waste Water	Distribution Lines	NA	2.90
	Facilities	0	0
	Pipelines	0	0
		Subtotal	2.90
Natural Gas	Distribution Lines	NA	1.90
	Facilities	0	0
	Pipelines	0	0
		Subtotal	1.90
Oil Systems	Distribution Lines	0	0
	Facilities	0	0
	Pipelines	0	0
Electric Power	Distribution Lines	0	0
	Facilities	0	0
		Subtotal	0
Communication	Distribution Lines	0	0
	Facilities	0	0
		Subtotal	0
		Total	**9.60**

In order to fully evaluate the potential for damage and loss based on occupancy class, severity of damage to each type of occupancy must also be considered. Table 5-55 provides definitions for damage categories to a light wood framed building.

Table: 5-65 Example of Structural Damage by Category and Description for Light Wood Framed Buildings

Damage Category	Description
None	
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 doors 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, 2005

Economic Impact

There is little local information available locally with respect to how an earthquake event may impact the study area economically since events are few and far between and of a magnitude which creates the need to document economic impact. Damage which closes a commercial, industrial or business establishment or limits access to these type facilities will create a loss of sales tax in the municipality from goods and services provided. HAZUS-MH was utilized to estimate economic losses for buildings, critical facilities and transportation and lifeline systems. Building losses are broken into two categories: direct building losses and business interruption looses. The direct building losses are estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during an earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

Table: 5-66 Building Related Economic Loss Estimates 100 Year MRP Event (Millions of Dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0	0	0	0	0	0
	Capital -Related	0	0	0	0	0	0
	Rental	0	0	0	0	0	0
	Relocation	0	0	0	0	0	0
	Subtotal	0	0	0	0	0	0
Capital Stock Losses	Structural	0	0	0	0	0	0
	Non-Structural	0	0	0	0	0	0
	Content	0	0	0	0	0	0
	Inventory	0	0	0	0	0	0
	Subtotal	0	0	0	0	0	0
	Total	0	0	0	0	0	0

Source: HAZUS-MH

Table: 5-67 Building Related Economic Loss Estimates 500 Year MRP Event (Millions of Dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0	.04	.63	.02	.07	.77
	Capital -Related	0	.02	.63	.01	.01	.67
	Rental	.09	.34	.46	.01	.01	.91
	Relocation	.01	.01	.02	0	.01	.05
	Subtotal	.10	.41	1.75	.04	.10	2.40
Capital Stock Losses	Structural	.92	0	.81	.18	.15	2.52
	Non-Structural	2.81	.47	01.83	.56	.37	7.33
	Content	.80	1.76	.91	.38	.20	2.72
	Inventory	0	.42	.01	.06	0	.08
	Subtotal	4.53	0	3.56	1.18	.72	12.64
	Total	4.63	3.05	5.31	1.22	.82	15.04

Source: HAZUS-MH

For Transportation and Utility Lifeline System Losses, HAZUS-MH computes the direct repair cost for each component only. There are no losses computed by HAZUS-MH for business interruption due to lifeline outages. Long term economic impacts are estimated for 15 years after the earthquake. This information is quantified in terms of income and employment changes within the study area.

Table: 5-68 Transportation System Economic Losses (Millions of Dollars) 100 Year MRP Event (Millions of Dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio(%)
Highway	Segments	462.49	0	0
	Bridges	655.72	0	0
	Tunnels	0	0	0
	Subtotal	1118.20	0	
Railways	Segments	11.20	0	0
	Bridges	.03	0	0
	Tunnels	0	0	0
	Facilities	0	0	0
	Subtotal	11.23	0	
Light Rail	Segments	0	0	0
	Bridges	0	0	0
	Tunnels	0	0	0
	Facilities	0	0	0
	Subtotal	Subtotal	0	
Bus	Facilities	0	0	0
	Subtotal	Subtotal	0	
Ferry	Facilities	0	0	0
	Subtotal	Subtotal	0	
Port	Facilities	0	0	0
	Subtotal	Subtotal	0	
Airport	Facilities	6.43	0	0
	Runways	73.35	0	.04
	Subtotal	79.80	0	0
	Total	**1209.20**	**0**	

Source: HAZUS-MH

Table: 5-69 Transportation System Economic Losses (Millions of Dollars) 500 Year MRP Event (Millions of Dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio(%)
Highway	Segments	462.49	0	0
	Bridges	655.72	.17	.03
	Tunnels	0	0	0
	Subtotal	1118.20	.20	
Railways	Segments	11.20	0	0
	Bridges	.03	0	0
	Tunnels	0	0	0
	Facilities	0	0	0
	Subtotal	11.20	0	
Light Rail	Segments	0	0	0
	Bridges	0	0	0
	Tunnels	0	0	0
	Facilities	0	0	0
	Subtotal	0	0	
Bus	Facilities	0	0	0
	Subtotal	0	0	
Ferry	Facilities	0	0	0
	Subtotal	0	0	
Port	Facilities	0	0	0
	Subtotal	Subtotal	0	
Airport	Facilities	6.43	.28	4.36
	Runways	73.35	0	0
	Subtotal	79.80	.30	0
	Total	**1209.20**	**.50**	

Source: HAZUS-MH

Table: 5-70 Utility System Economic Losses (Millions of Dollars) 100 Year MRP Event (Millions of Dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0	0	0
	Facilities	0	0	0
	Distribution Lines	4.80	0	.01
	Subtotal	4.82	0	
Waste Water	Pipelines	0	0	0
	Facilities	0	0	0
	Distribution Lines	2.90	0	.01
	Subtotal	2.89	0	
Natural Gas	Pipelines	0	0	0
	Facilities	0	0	0
	Distribution Lines	1.90	0	.02
	Subtotal	1.93	0	
Oil Systems	Pipelines	0	0	0
	Facilities	0	0	0
	Subtotal	0	0	
Electric Power	Facilities	0	0	0
	Subtotal	0	0	
Communication	Facilities	0	0	0
	Subtotal	0	0	
	Total	**9.64**	0	

Source: HAZUS-MH

Table: 5-71 Utility System Economic Losses (Millions of Dollars) 500 Year MRP Event (Millions of Dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0	0	0
	Facilities	0	0	0
	Distribution Lines	4.80	.010	.012
	Subtotal	4.82	.01	
Waste Water	Pipelines	0	0	0
	Facilities	0	0	0
	Distribution Lines	2.90	0	.16
	Subtotal	2.89	0	
Natural Gas	Pipelines	0	0	0
	Facilities	0	0	0
	Distribution Lines	1.90	0	.25
	Subtotal	1.93	0	
Oil Systems	Pipelines	0	0	0
	Facilities	0	0	0
	Subtotal	0	0	
Electric Power	Facilities	0	0	0
	Subtotal	0	0	
Communication	Facilities	0	0	0
	Subtotal	0	0	
	Total	**9.64**	.02	

Source: HAZUS-MH

Table: 5-72 Indirect Economic Impact with Outside Aid (Employment as No. of people and Income in millions of dollars) 100 and 500 Year MRP Event

	LOSS	Total 100 Year Event	Percent 100 Year Event	Total 500 Year Event	Percent 500 Year Event
First Year					
	Employment Impact	0	0	0	0
	Income Impact	0	0	0	-.01
Second Year					
	Employment Impact	0	0	0	0
	Income Impact	0	0	0	-.04
Third Year					
	Employment Impact	0	0	0	0
	Income Impact	0	0	0	-.05
Fourth Year					
	Employment Impact	0	0	0	0
	Income Impact	0	0	0	-.05
Fifth Year					
	Employment Impact	0	0	0	0
	Income Impact	0	0	0	-.05
Years 6-15					
	Employment Impact	0	0	0	0
	Income Impact	0	0	0	-.05

Source: HAZUS-MH

Addressing Repetitive Loss Properties (NFIP data for floods, other hazards as available)

The National Flood Insurance Program provides information on payments to homeowners resulting from losses due to flooding where a separate insurance policy for such events has been purchased. Under the earthquake category, flooding may be a secondary or resulting event brought about by a combination of ground motion, overflowing lakes and rivers due to ground motion and dam failures. Flooding events, repetitive loss properties and the associated analysis are discussed elsewhere in this report.

Estimating Potential Losses

Vulnerability in terms of dollar losses provides the study area and the State with a common framework in which to measure the effects of hazards on vulnerable structures.

HAZUS-MH was utilized to develop estimated losses based on three event scenarios. The analysis in Tables 5-63 to 5-70 reflects loss data for 100 and 500 year Mean Return Period earthquake events.

Table: 5-73 Expected Building Damaged by General Occupancy for 100 and , 500 Year Mean Return Period Earthquake Events

Category	**100 Year Event**					**500 Year Event**				
	None	**Slight**	**Moderate**	**Extensive**	**Complete**	**None**	**Slight**	**Moderate**	**Extensive**	**Complete**
Agriculture	0	0	0	0	0	53	2	1	0	0
Commercial	0	0	0	0	0	612	39	19	3	0
Education	0	0	0	0	0	25	2	1	0	0
Government	0	0	0	0	0	15	1	0	0	0
Industrial	0	0	0	0	0	173	11	5	1	0
Other Residential	0	0	0	0	0	1,619	96	33	5	1
Religion	0	0	0	0	0	39	3	1	0	0
Single Family	0	0	0	0	0	4,576	225	54	8	1
Total	0	0	0	0	0	7,111	379	114	17	2

Source: HAZUS-MH

Table:5-74 Expected Building Damage by Building Type (All Design Levels) for 100 and 500 Year Mean Return Period Earthquake Events

		100 Year Event					**500 Year Event**				
		None	**Slight**	**Moderate**	**Extensive**	**Complete**	**None**	**Slight**	**Moderate**	**Extensive**	**Complete**
Wood		0	0	0	0	0	5,195	191	22	1	0
Steel		0	0	0	0	0	456	29	12	1	0
Concrete		0	0	0	0	0	163	14	6	0	0
Precast		0	0	0	0	0	28	2	2	0	0
Reinforced Masonry		0	0	0	0	0	214	12	7	1	0
Unreinforced Masonry		0	0	0	0	0	1,055	132	66	13	2
Manufactured Housing		0	0	0	0	0	0	0	0	0	0
Total		0	0	0	0	0	7,111	379	114	17	2

Source: HAZUS-MH

Table:: 5-75 Expected Damage to Essential Facilities (Number of Facilities) 100 Year Mean Return Period Event

Classification	Total	At least Moderate Damage > 50%	Complete Damage > 50%	With Functionally >50% on day 1
Hospital	0	0	0	0
Schools	10	0	0	10
EOC's	0	0	0	0
Police Stations	1	0	0	1
Fire Stations*	3	0	0	3

*Study Area has 3 Fire Stations (Downtown, West Harrison and Purchase)
Source: HAZUS-NH

Table: 5-76 Expected Damage to Essential Facilities (Number of Facilities) 500 Year Mean Return Period Event

Classification	Total	At least Moderate Damage > 50%	Complete Damage > 50%	With Functionally >50% on day 1
Hospital	0	0	0	0
Schools	10	0	0	10
EOC's	0	0	0	0
Police Stations	1	0	0	1
Fire Stations*	3	0	0	3

* Study Area has 3 Fire Stations (Downtown, West Harrison and Purchase)
Source: HAZUS-MH

Table: 5-77 Expected Damage to the Transportation Systems for 100 and 500 year Mean Return Period Events

System	Component	Number of Locations/Segments	Number of Locations with At Least Moderate Damage	Number of Locations with Complete Damage	Functionality >50% After Day 1	Functionality >50% After Day 7
Highway	Segments	19	0	0	19	19
	Bridges	43	0	0	43	43
	Tunnels	0	0	0	0	0
Railways	Segments	2	0	0	2	2
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	2	0	0	2	2

Source: HAZUS-MH

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these facilities will not be computed

HAZUS-MH performs a simplified system performance analysis for electric power and potable water.

As a result of earthquakes, debris is generated as a result of damage to buildings and infrastructure as well as natural features such as trees and rock formations. HAZUS –MH estimates the amount of debris which can be generated by a particular earthquake event. The model breaks the debris into two general categories; Brick / Wood and Reinforced Concrete / Steel. This distinction is made due to the different types of material handling equipment required to handle the debris. Table: 5-72 shows to amount of debris generated by event scenario.

Table: 5-72 Debris Generated (Tons)

Category	100 Year Earthquake Event	500 Year Earthquake Event
Brick / Wood	0	0
Reinforced Concrete / Steel	0	0
Truck Loads @ 25 tons / Truck	0	0

Source: HAZUS-MH

Analyzing Development Trends (New Buildings, Critical Facilities, Critical Infrastructure)

Section 4 of this plan Municipal Profile – Future Development identifies several areas in the Town / Village of Harrison where the potential for development or redevelopment exists. As of January 1, 2009, construction underway is limited due to the economic turndown. The New York State Building Code contains several sections which discuss construction requirements based on the potential for earthquakes in the State. New development should also take into consideration interior designs which would have greater stability in the event of an earthquake.

Additional Data and Next Steps

On a regional level, sufficient effort exists to monitor earthquake activity in the area.

Overall Vulnerability Conclusion

The Town / Village of Harrison is located in an area that experiences moderate earthquake activity (some shaking). Earthquakes have occurred in the area occasionally and for the most part go undetected by people, and cause minimal or no damage. Future mitigation efforts should include making the public aware of the potential for earthquakes in the study area as well as both passive and active efforts to guard against potential for life threatening and damaging events. The HMPC ranking for earthquakes is "low"