5.4.2 Earthquake

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

5.4.2.1 Hazard Profile

This section provides profile information including description, extent, location, previous occurrences and losses, climate change projections and the probability of future occurrences for the earthquake hazard.

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] 2001, Shedlock and Pakiser 1995). Most earthquakes occur at the boundaries where the Earth's tectonic plates meet (faults); less than 10 percent of earthquakes occur within plate interiors. As plates continue to move and plate boundaries change geologically over 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 1995).

The location of an earthquake is commonly described by its focal depth and the geographic position of its epicenter. Focal depth of an earthquake is depth from 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 a great distance from the epicenter (FEMA 2001).

According to the U.S. Geological Society (USGS) Earthquake Hazards Program, an earthquake hazard is any disruption associated with an earthquake that may affect residents' normal activities. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunamis, and seiches; each of these terms is defined below:

- *Surface faulting*: Displacement that reaches the earth's surface during a 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 a 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 the wet sand near the water at the beach. Earthquake shaking can cause this effect. Liquefaction susceptibility is determined by the geological history, depositional setting, and topographic position of the soil. Liquefaction effects may occur along the shorelines of the ocean, rivers, and lakes and they can also happen in low-lying areas away from water bodies in locations where the ground water is near the earth's surface.
- *Tectonic Deformation*: A change in the original shape of a material caused by stress and strain.
- *Tsunami*: A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major sub-marine slides, or exploding volcanic islands.
- *Seiche*: The sloshing of a closed body of water, such as a lake or bay, from earthquake shaking (USGS 2012a).

Extent

An earthquake's magnitude and intensity are used to describe the size and severity of the event. Magnitude describes the size at the focus of an earthquake and intensity describes the overall felt severity of shaking during the event. The earthquake's magnitude is a measure of the energy released at the source of the earthquake. Magnitude was formerly expressed by ratings on the Richter scale but is now most commonly expressed using the moment magnitude (Mw) scale. This scale is based on the total moment release of the earthquake (the product of the distance a fault moved, and the force required to move it). The scale is as follows:

- Great Mw > 8
- Major Mw = 7.0 – 7.9
- Strong Mw = 6.0 – 6.9
- Moderate Mw = 5.0 – 5.9
- Light Mw = 4.0 – 4.9
- Minor Mw = 3.0 – 3.9
- Micro Mw = 3.0 – 3.9

The most commonly used intensity scale is the modified Mercalli intensity scale. Ratings of the scale, as well as the perceived shaking and damage potential for structures, are shown in Table 5.4.2-1 The modified Mercalli intensity scale is generally represented visually using shake maps, which show the expected ground shaking at any given location produced by an earthquake with a specified magnitude and epicenter. An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region. This shaking depends on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust. A USGS shake map shows the variation of ground shaking in a region immediately following significant earthquakes. Table 5.4.2-2 displays the MMI scale and its relationship to the areas peak ground acceleration.

Table 5.4.2-1 Modified Mercalli Intensity Scale

Mercalli Intensity	Shaking	Description
I	Not Felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	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	Light	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	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very Strong	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	Severe	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	Violent	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	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Source: USGS 2016c

Table 5.4.2-2 Modified Mercalli Intensity and PGA Equivalents

Modified Mercalli Intensity	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	< 0.17	Not Felt	None
II	0.17–1.4	Weak	None
III	0.17–1.4	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

Source: Freeman et al. (Purdue University) 2004
Note: PGA Peak Ground Acceleration

The ground experiences acceleration as it shakes during an earthquake. The peak ground acceleration (PGA) is a measure of how hard the earth shakes in a given geographic area. It is expressed as a percentage of the acceleration due to gravity (percent g). Horizontal and vertical PGA varies with soil or rock type. Earthquake hazard assessment involves estimating the annual probability that certain ground accelerations will be exceeded, and then summing the annual probabilities over a period of interest. Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures, as noted in Table 5.4.2-3.

Table 5.4.2-3 Damage Levels Experienced in Earthquakes

Ground Motion Percentage	Explanation of Damages
1-2%g	Motions are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
Below 10%g	Usually causes only slight damage, except in unusually vulnerable facilities.
10 - 20%g	May cause minor-to-moderate damage in well-designed buildings, with higher levels of damage in poorly designed buildings. At this level of ground shaking, only unusually poor buildings would be subject to potential collapse.
20 - 50%g	May cause significant damage in some modern buildings and very high levels of damage (including collapse) in poorly designed buildings.
≥50%g	May causes higher levels of damage in many buildings, even those designed to resist seismic forces.

Source: NJOEM 2014
Note: %g Peak Ground Acceleration

National maps of earthquake shaking hazards provide information for creating and updating seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities, and land use planning. 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 updated the National Seismic Hazard Maps in 2014. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these revised maps. The 2014 map represents the best available data, as determined by the USGS.

The HAZUS-MH earthquake model was run for 2 mean return period (MRP) events in Broome County to provide a range of potential scenarios and associated impacts—the 250-year MRP event and the 1,000-year MRP event. Conklin. Figure 5.4.2-1 and Figure 5.4.2-2 illustrate geographic distributions of the Modified Mercalli Scale based on PGAs (*g*) across Broome County at the census-tract level for these two events. A 250-year MRP event is an earthquake with a 0.4 percent chance that mapped ground motion levels (PGA) will be exceeded in any given year. Broome County is estimated to experience light shaking during a 250-year event. A 1,000-year

MRP is an earthquake with 0.1 percent chance that mapped PGAs will be exceeded in any given year. HAZUS-MH estimates Broome County will experience light shaking during the 1,000-year event with moderate shaking and light damage. Moderate shaking is projected for the eastern half of the Town of Chenango, the southern portion of the Town of Union, the Village of Endicott, the northern portion of the Town of Vestal, the Town of Dickinson, the City of Binghamton, and the Town of Conklin. Figure 5.4.2-1. Peak Ground Acceleration 250-Year Mean Return Period for Broome County

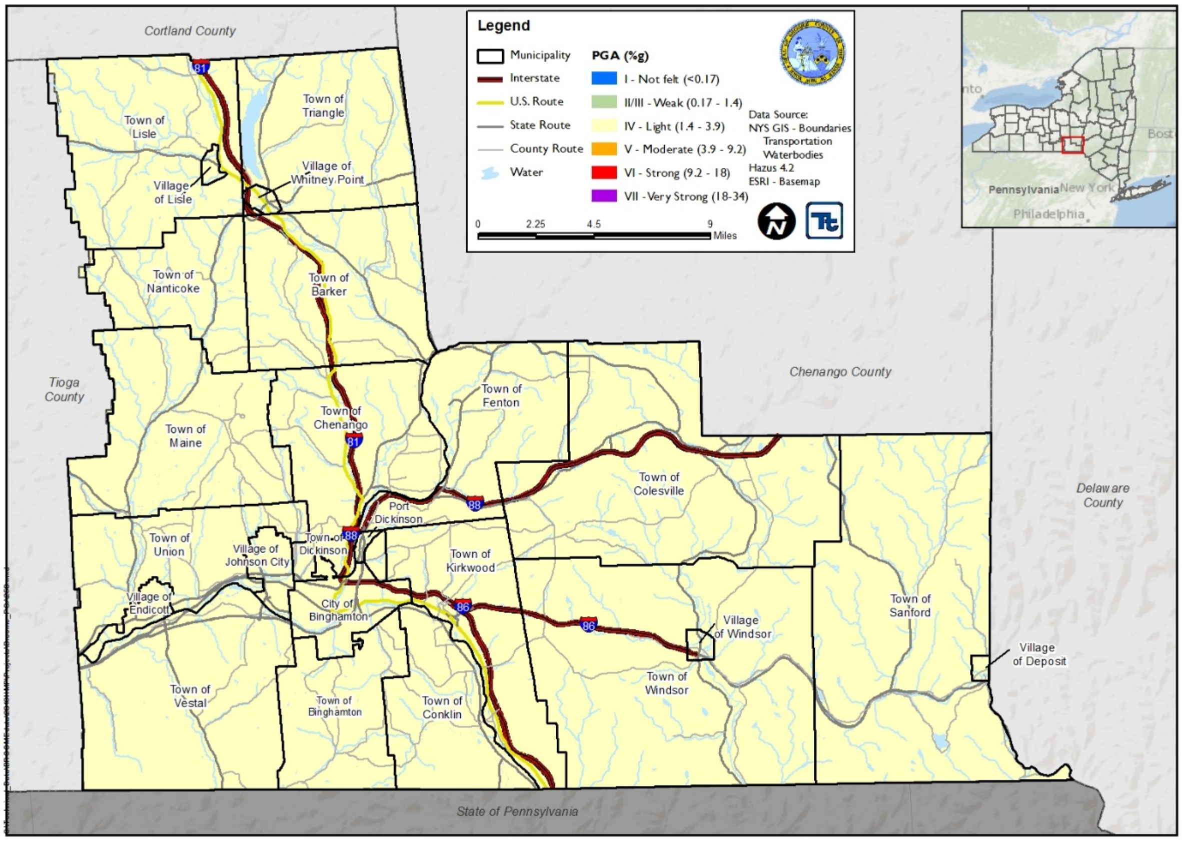
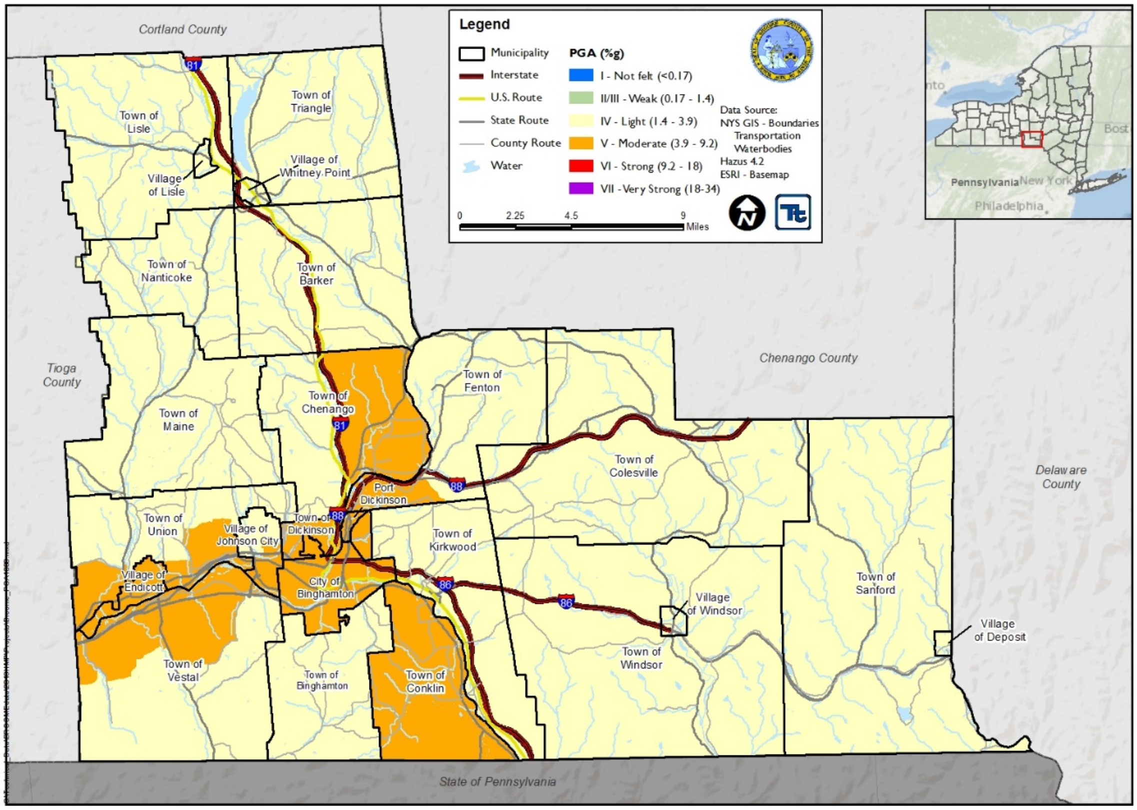


Figure 5.4.2-2. Peak Ground Acceleration 1,000-Year Mean Return Period for Broome County



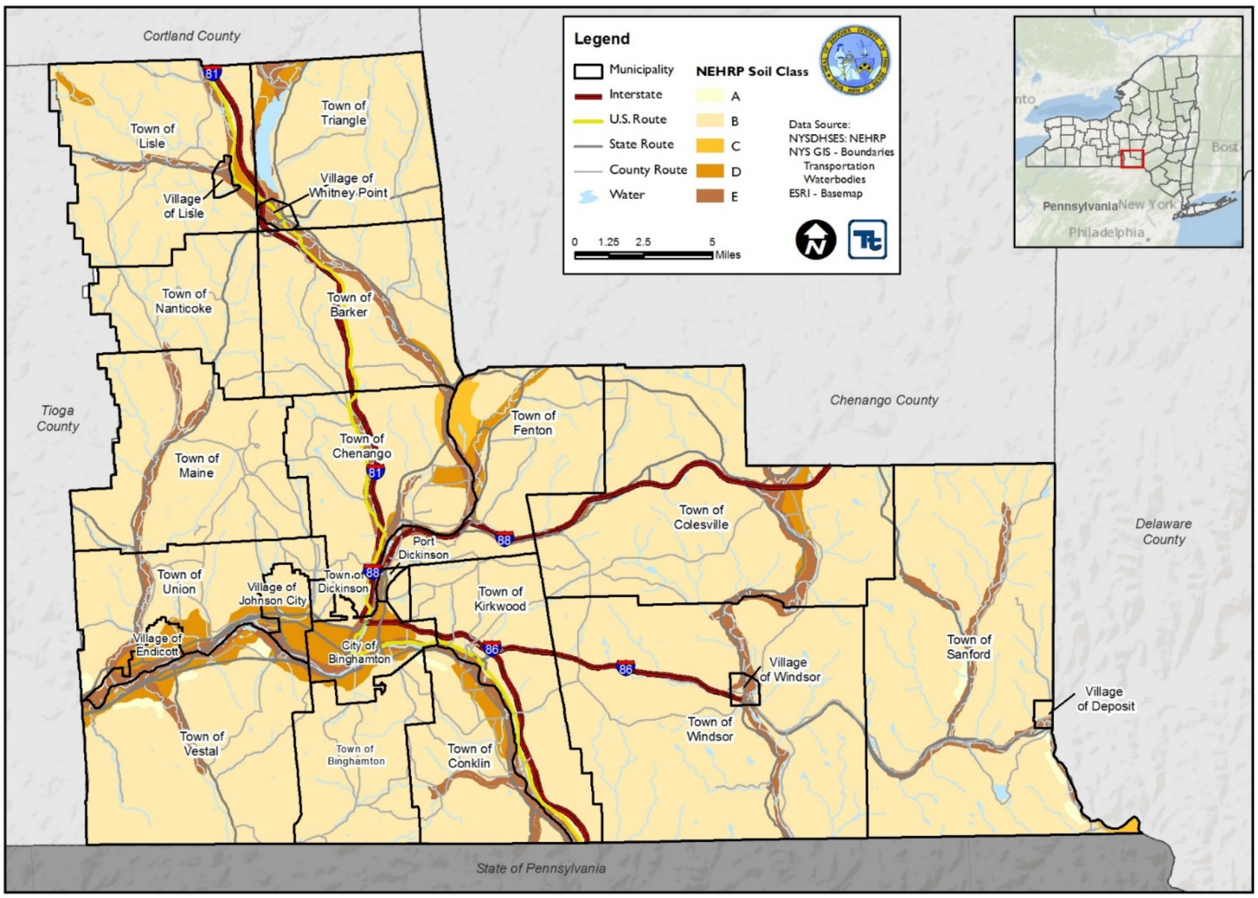
The New York State Geological Survey conducted seismic shear-wave tests of the state's surficial geology (glacial deposits). Based on these test results, the surficial geologic materials of New York State were categorized according to the National Earthquake Hazard Reduction Program's (NEHRP) Soil Site Classifications (Table 5.4.2-4). The NEHRP developed five soil classifications defined by their shear-wave velocity that impact the severity of an earthquake. The soil classification system ranges from *Class A to Class E,* as noted in Table 5.4.2-4, where Class A represents hard rock that reduces ground motions from an earthquake and Class E represents soft soils that amplify and magnify ground shaking and increase building damage and losses. Class E soils include water-saturated mud and artificial fill. The strongest amplification of shaking due is expected for this soil type. Seismic waves travel faster through hard rock than through softer rock and sediments. As the waves pass from harder to softer rocks, the waves slow down, and their amplitude increases. Shaking tends to be stronger at locations with softer surface layers where seismic waves move more slowly. Ground motion above an unconsolidated landfill or soft soils can be more than 10 times stronger than at neighboring locations on rock for small ground motions (FEMA 2016).

Table 5.4.2-4 NEHRP Soil Classifications

Soil Classification	Description
A	Hard rock
B	Rock
C	Very dense soil and soft rock
D	Stiff soils
E	Soft soils

Source: FEMA 2013

As illustrated in Figure 5.4.2-3 soils in Broome County are primarily NEHRP Soil Classes B, D, and E. The vast majority of the county has Class B soils with areas of Class D and E along majority waterways. Smalls areas of Classes A and C are located throughout the county. Figure 5.4.2-3. NEHRP Soil Classification in Broome County



Location

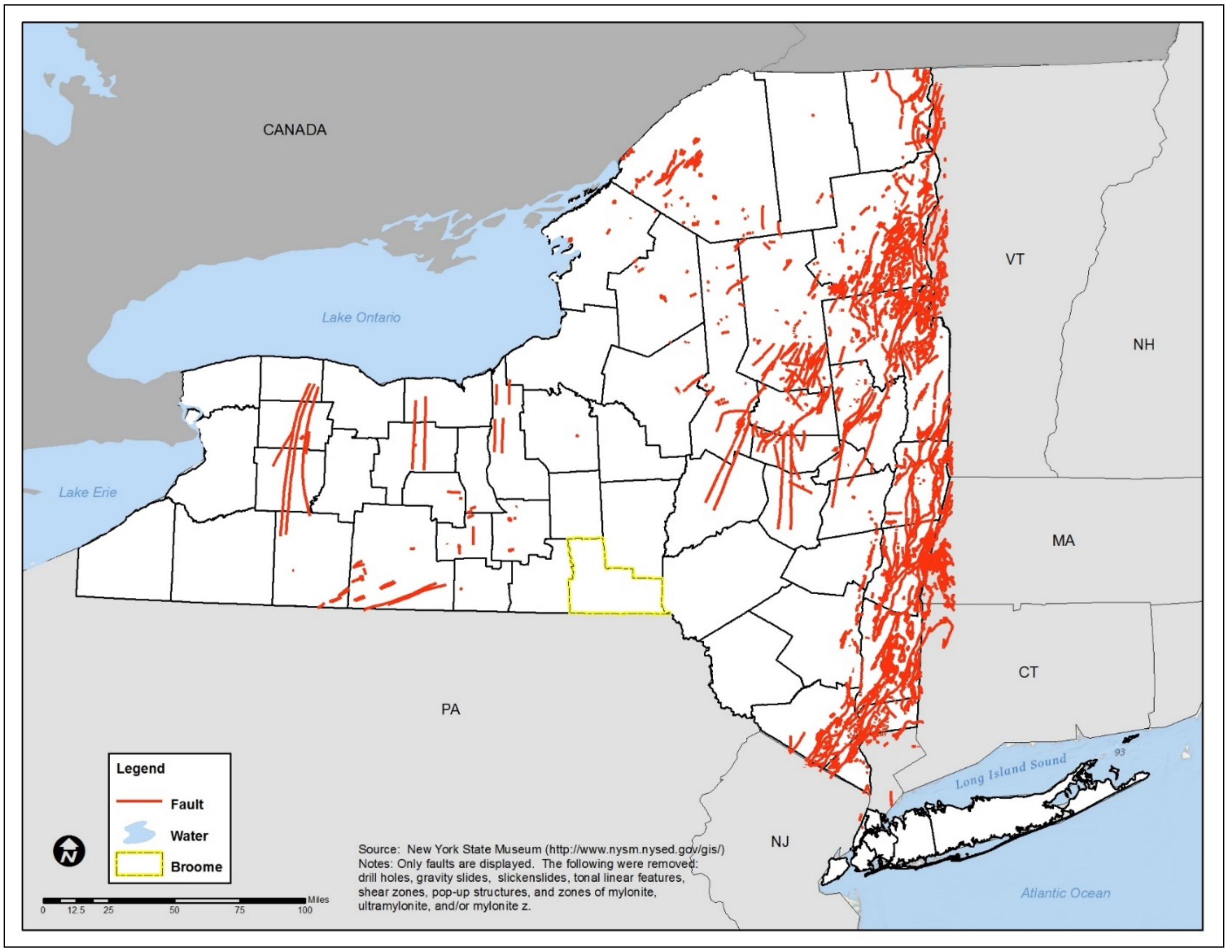
There are three general regions in New York State that have a higher seismic risk compared to other parts of the state including the following:

1) The north and northeast third of the state, which includes the North Country/Adirondack region and a portion of the greater Albany-Saratoga region.
2) The southeast corner, which includes the greater New York City area and western Long Island.

3) The northwest corner, which includes Buffalo and its surrounding area.

Broome County is not located in a region identified as high risk (NYS DHSES 2014). Figure 5.4.2-4 shows the known faults within New York State with the Broome County study area highlighted in yellow. According to this figure, there are no fault lines in the county

. Figure 5.4.2-4. Faults in New York State



The Lamont-Doherty Cooperative Seismographic Network (LCSN) monitors earthquakes that occur primarily in the northeastern United States. The goal of the project is to compile a complete earthquake catalog for this region, to assess the earthquake hazards, and to study the causes of the earthquakes in the region. The LCSN operates 52 seismographic stations in seven states, including New York. There are no seismic stations in Broome County; however, there are several in the region that service the county (LCSN 2014). In addition to the Lamont-Doherty Seismic Stations, the USGS operates a global network of seismic stations (GSN) to monitor seismic activity. While no seismic stations are located in New York State, nearby stations are positioned in State College, Pennsylvania and Oak Ridge, Massachusetts.

The Advanced National Seismic System (ANSS) is run by USGS. When earthquakes strike, ANSS delivers real-time information, providing situational awareness for emergency-response personnel. In regions with sufficient seismic stations, that information includes –within minutes–a ShakeMap showing the distribution of potentially damaging ground shaking, information used to target post-earthquake response efforts. ANSS stations are operated within the state at Lake Ozonia (St. Lawrence County) and the City of Binghamton (Broome County) (USGS 2018).

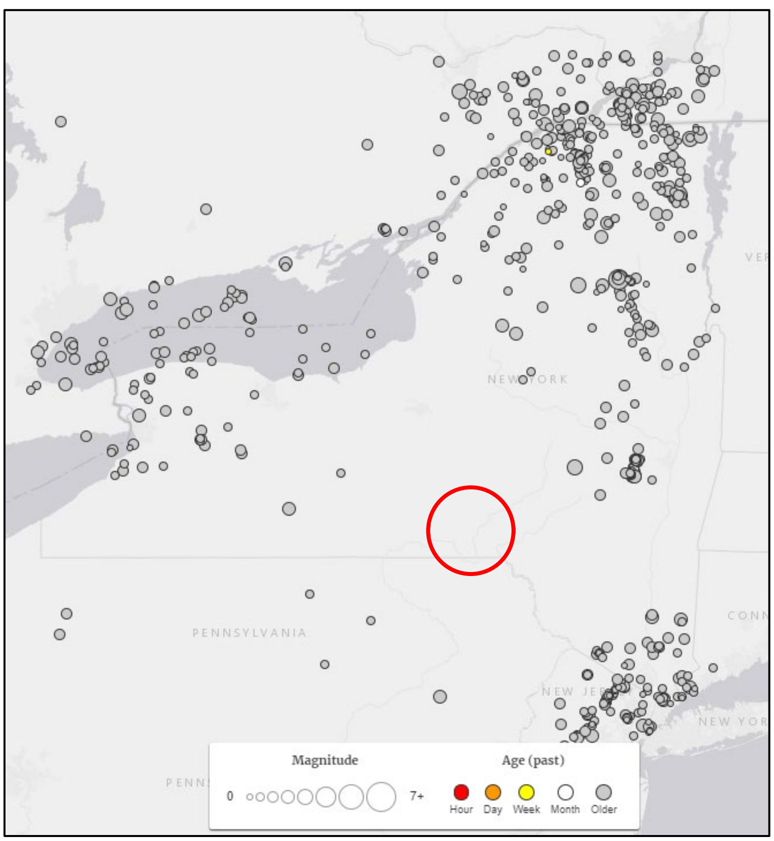
Previous Occurrences and Losses

New York State has a history of earthquake occurrences. According to the USGS earthquake catalog search, between 1950 and January 2019, the state has experienced over 450 earthquakes. Of those events, no earthquake epicenters were recorded in Broome County (USGS 2019). Figure 5.4.2-5 illustrates the epicenters of earthquakes with epicenters within New York State and outside of the state. The earthquakes originating outside of the state have also been felt within the state. According to the NYS HMP, these events are considered significant for hazard mitigation planning because earthquakes such as those could inflict damage within the state in certain situations (NYS DHSES 2014).

Between 1954 and 2018, New York State was included in one earthquake-related major disaster (DR) or emergency (EM) declaration (DR-1415). Generally, these disasters cover a wide region of the state; therefore, they may have impacted many counties. However, not all counties were included in the disaster declaration. Broome County was not included in any DRs or EMs (FEMA 2018).

Known earthquakes events that have impacted New York State and Broome County between 2005 and 2018 are identified in Table 5.4.2-5. For events prior to 2005, refer to Appendix E (Supplemental Data). Please note that many sources were researched for historical information regarding earthquake events in Broome County; therefore, Table 5.4.2-5 might not include all earthquake events that impacted the county.

Figure 5.4.2-5. Earthquake Epicenters in the Northeast United States, January 1950 to January 2019



Source: USGS 2019
Note: The red oval indicates the approximate location of Broome County.

Table 5.4.2-5 Earthquake Events Impacting Broome County, 2005 to 2018

Dates of Event	Event Type	Location	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
June 23, 2010	Earthquake	Ontario-Quebec border	N/A	N/A	A magnitude 5.4 earthquake at the Ontario-Quebec border region in Canada was felt throughout the northeast, including Broome County.
August 23, 2011	Earthquake	Richmond, Virginia	N/A	N/A	A magnitude 5.8 earthquake centered northwest of Richmond, Virginia was felt throughout the East Coast. Shaking was felt in Broome County.
September 27, 2015	Earthquake	Stamford, NY	N/A	N/A	A magnitude 2.8 earthquake struck near Stamford, NY. Slight shaking was felt in the eastern portion of Broome County.

Source(s): NYS DHSES, 2014; USGS 2018d; FEMA 2018
**Many sources were consulted to provide an update of previous occurrences and losses; event details and loss/impact information may vary and has been summarized in the above table.*

DR	*Major Disaster Declaration (FEMA)*
FEMA	*Federal Emergency Management Agency*
N/A	*Not Applicable*
NY	*New York*
USGS	*U.S. Geological Survey*

Climate Change Projections

The impacts of global climate change on earthquake probability are unknown. Some scientists say that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (Andersen et al. 2004).

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

Probability of Future Events

The New York City Area Consortium for Earthquake Loss Mitigation (NYCOEM) ranks New York State as having the third highest earthquake activity level east of the Mississippi River (Tantala et al. 2003). The New York State Disaster Preparedness Commission (NYS DPC) and probabilistic maps for Broome County indicate that the potential for earthquakes does exist in Broome County (NYS DHSES 2014). The location of Broome County and past events indicate that earthquakes will continue to occur even though impacts to Broome County might be small. The probability of occurrence for earthquakes in the county is considered *rare* (having between a 1 and 10 percent annual probability) but possible. Refer to Section 5.3 for additional information on the hazard ranking methodology and probability criteria.

5.4.2.2 Vulnerability Assessment

A probabilistic assessment was conducted for the 250- and 1,000-year MRPs through a Level 2 analysis in HAZUS-MH v4.2 to analyze the earthquake hazard and provide a range of loss estimates.

Impacts on Life, Health, and Safety

The entire population of Broome County is exposed to the direct and indirect impacts from earthquakes. The degree of exposure is dependent on many factors, including the age and type of construction people live/work in, the soil types their homes are located on, the intensity of the earthquake. Whether directly or indirectly impacted, residents could be faced with business closures, road closures that could isolate populations, and loss of function of critical facilities and utilities.

According to the 2010 U.S. Census, Broome County had a population of 200,600 people. Overall, risk to public safety and loss of life from an earthquake in the county is minimal. However, there is a higher risk to public safety for those inside buildings due to structural damage or people walking below building ornamentations and chimneys that may be shaken loose and fall because of an earthquake.

An exposure analysis was performed, based on NEHRP soils data and 2010 U.S. Census population data. As noted earlier, NEHRP soil classes D and E can amplify ground shaking to damaging levels, even during a moderate earthquake, and thus increase risk to the population. Populations within municipalities on NEHRP Class D and E soils were calculated and are listed in Table 5.4.2-6 below. Overall, approximately 48.8-percent of the county's population resides on NEHRP Class D and E soils. The City of Binghamton and Villages of Endicott and Lisle have over 80 percent population located on NEHRP Class D and E soils and represent areas within Broome County having higher vulnerability to this hazard.

Table 5.4.2-6. Approximate Populations on NEHRP "D" and "E" Soils

Municipality	Total Population (2010 U.S. Census)	Population NEHRP Class "D" and "E" Soils	
		Total Population Exposed	Percent of Population Exposed
Barker (T)	2,732	243	8.9%
Binghamton (C)	47,376	42,343	89.4%
Binghamton (T)	4,942	105	2.1%
Chenango (T)	11,252	3,302	29.3%
Colesville (T)	5,232	798	15.3%
Conklin (T)	5,441	2,628	48.3%
Deposit (V)	819	80	9.8%

Municipality	Total Population (2010 U.S. Census)	Population NEHRP Class "D" and "E" Soils	
		Total Population Exposed	Percent of Population Exposed
Dickinson (T)	3,637	1,135	31.2%
Endicott (V)	13,392	11,478	85.7%
Fenton (T)	6,674	1,223	18.3%
Johnson City (V)	15,174	11,402	75.1%
Kirkwood (T)	5,857	108	1.8%
Lisle (T)	2,431	570	23.4%
Lisle (V)	320	260	81.3%
Maine (T)	5,377	986	18.3%
Nanticoke (T)	1,672	0	0.0%
Port Dickinson (V)	1,641	1,106	67.4%
Sanford (T)	1,588	243	15.3%
Triangle (T)	1,982	119	6.0%
Union (T)	27,780	10,331	37.2%
Vestal (T)	28,043	8,051	28.7%
Whitney Point (V)	964	751	77.9%
Windsor (T)	5,358	207	3.9%
Windsor (V)	916	421	46.0%
Broome County	**200,600**	**97,890**	**48.8%**

Sources: NYS DHSES 2008, U.S. Census 2010.

Note: NEHRP National Earthquake Hazard Reduction Program

Notes: The NEHRP boundaries were overlaid on the U.S. Census blocks; the blocks with their centroids within hazard areas were totaled for each municipality.

Populations considered most vulnerable are those located in/near the built environment, particularly those near unreinforced masonry structures. Of these most vulnerable populations, socially vulnerable populations, including the elderly (persons over age 65) and individuals living below the census poverty threshold, are most susceptible. Populations with decreased mobility and financial ability to react or respond during a hazard, and the location and construction quality of their housing may also increase vulnerability. There are 15,939 people over the age of 65 and 28,550 people considered low-income populations that reside on NEHRP Class D and E soils, which can amplify ground shaking.

Residents could be displaced or require temporary to long-term sheltering because of an earthquake event. The number of people requiring shelter is generally less than the number displaced because some displaced persons use hotels or stay with family or friends following a disaster event. Table 5.4.2-7 estimates the number of households displaced, and population that may require short-term sheltering as a result of the 250- and 1,000-year MRP earthquake events.

Table 5.4.2-7. Summary of Estimated Sheltering Needs for Broome County

HAZUS-MH Mean Return Period Event	Displaced Households	Persons Seeking Short-Term Shelter
250-Year Earthquake	6	4
1,000- Year Earthquake	46	30

Source: HAZUS-MH v4.2

According to the 1999-2003 NYCOEM Summary Report (Earthquake Risks and Mitigation in the New York / New Jersey / Connecticut Region), a strong correlation exists between structural building damage and number of injuries and casualties from an earthquake event. Further, time of day also exposes different sectors of the community to the hazard. For example, HAZUS-MH v4.2 considers residential occupancy at its maximum at 2:00 AM, whereas educational, commercial, and industrial sectors are at their maximum at 2:00 PM, and peak commute time is at 5:00 PM. Whether directly or indirectly impacted, the entire population will be affected to some degree. Business interruption could prevent people from working, road closures could isolate populations, and loss of utilities could impact populations that suffered no direct damage from an event.

Table 5.4.2-8 summarizes countywide injuries and casualties estimated for the 250- and 1,000-year MRP earthquake events.

Table 5.4.2-8. Estimated Number of Injuries and Casualties from the 250- and 1,000-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
250-year			
Injuries	1	1	1
Hospitalization	0	0	0
Casualties	0	0	0
1,000-Year			
Injuries	10	10	8
Hospitalization	1	1	1
Casualties	0	0	0

Source: HAZUS-MH v4.2

Impact on General Building Stock

The entire county's general building stock is considered at risk and exposed to this hazard. As stated earlier, soft soils (NEHRP Soil Classes D and E) can amplify ground shaking to damaging levels even during a moderate earthquake (NYCOEM 2003); therefore, buildings located on NEHRP Classes D and E soils are at increased risk of damage from an earthquake. Table 5.4.2-9 summarizes the number and replacement cost value of buildings located on NEHRP soils classes D and E.

Table 5.4.2-9. Number and Replacement Cost Value of Buildings Located on NEHRP Class 'D' and 'E' Soils

Municipality	Total Number of Buildings	Total Replacement Cost Value (Structure and Contents)	Buildings on NEHRP Class "D" and "E" Soils			
			Number of Buildings	% of Total Buildings	RCV	% of Total RCV
Barker (T)	1,265	$688,813,868	194	15.3%	$140,802,681	20.4%

Table 5.4.2-9. Number and Replacement Cost Value of Buildings Located on NEHRP Class 'D' and 'E' Soils

Municipality	Total Number of Buildings	Total Replacement Cost Value (Structure and Contents)	Buildings on NEHRP Class "D" and "E" Soils			
			Number of Buildings	% of Total Buildings	RCV	% of Total RCV
Binghamton (C)	25,243	$77,847,328,827	22,842	90.5%	$74,974,010,408	96.3%
Binghamton (T)	2,121	$1,228,624,612	71	3.3%	$44,287,893	3.6%
Chenango (T)	5,183	$4,543,298,114	1,865	36.0%	$2,444,438,361	53.8%
Colesville (T)	2,476	$2,981,791,633	439	17.7%	$273,996,369	9.2%
Conklin (T)	2,520	$1,795,243,811	1,316	52.2%	$1,053,263,815	58.7%
Deposit (V)	468	$459,195,313	114	24.4%	$177,075,319	38.6%
Dickinson (T)	1,446	$1,446,559,666	349	24.1%	$337,787,105	23.4%
Endicott (V)	7,011	$11,814,240,767	6,215	88.6%	$11,362,321,933	96.2%
Fenton (T)	3,166	$1,763,698,720	595	18.8%	$345,334,886	19.6%
Johnson City (V)	7,904	$31,593,599,188	5,814	73.6%	$13,291,857,729	42.1%
Kirkwood (T)	2,628	$3,589,691,107	114	4.3%	$306,176,822	8.5%
Lisle (T)	1,108	$568,905,916	385	34.7%	$215,848,696	37.9%
Lisle (V)	135	$107,968,636	114	84.4%	$97,463,094	90.3%
Maine (T)	2,431	$1,702,703,387	521	21.4%	$264,049,713	15.5%
Nanticoke (T)	762	$395,739,757	1	0.1%	$287,731	0.1%
Port Dickinson (V)	845	$525,142,613	589	69.7%	$391,195,253	74.5%
Sanford (T)	1,399	$770,815,458	197	14.1%	$111,239,831	14.4%
Triangle (T)	915	$576,956,692	58	6.3%	$107,138,801	18.6%
Union (T)	12,997	$30,465,363,557	5,300	40.8%	$6,214,943,361	20.4%
Vestal (T)	9,532	$21,589,049,741	4,075	42.8%	$14,026,814,383	65.0%
Whitney Point (V)	439	$519,433,248	391	89.1%	$491,368,477	94.6%
Windsor (T)	2,685	$1,424,173,576	204	7.6%	$115,440,374	8.1%
Windsor (V)	435	$719,873,967	247	56.8%	$527,423,353	73.3%
Broome County	**95,114**	**$199,118,212,175**	**52,010**	**54.7%**	**$127,314,566,389**	**63.9%**

Sources: NYS DHSES 2008, HAZUS v4.2
Note: RCV is the estimated replacement cost value of both structure and contents.
Note: The NEHRP boundaries were overlaid on the custom general building stock inventory; the structures with their centroids within hazard areas were totaled for each municipality.
Notes:
C City
T Town
V Village

There is a strong correlation between PGA and damage a building might undergo (NYCOEM 2003). The HAZUS-MH model is based on best available earthquake science and aligns with these statements. The HAZUS-MH probabilistic model was applied to analyze effects from the earthquake hazard on general building stock in Broome County. See Figures 5.4.2-1 through Figure 5.4.2-2 earlier in this profile which illustrate the geographic distribution of PGA (percent g) across the county for 250- and 1,000-year MRP events at the Census-Tract level.

A building's construction determines how well it can withstand the force of an earthquake. The NYCOEM report indicates that unreinforced 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 affect a building's capability to withstand an earthquake's force include its age, number of stories, and quality of construction. HAZUS-MH v4.2 considers building construction and age of building as part of the analysis. Because a custom general building stock was used for this HAZUS-MH v4.2 analysis, the building ages and building types from the inventory were incorporated into the HAZUS-MH v4.2 model.

Potential building damage was evaluated via HAZUS-MH v4.2 across damage categories of none, slight, moderate, extensive, and complete. Table 5.4.2-10 lists definitions of these five categories of damage to a light wood-framed building; definitions of categories of damage to other building types appear in HAZUS-MH technical manual documentation.

Table 5.4.2-10. Example of Structural Damage State Definitions for a Light Wood-Framed Building

Damage Category	Description
None	No damage recorded.
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 might have large permanent lateral displacement, collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures can slip and fall off the foundations; large foundation cracks.

Source: HAZUS-MH Technical Manual

Building damage as a result of the 250- and 1,000-year MRP earthquake events was estimated using HAZUS-MH. In addition, annualized losses were calculated. Table 5.4.2-11 below lists the estimated numbers of buildings damaged (within general occupancy categories) as a result of the 250- and 1,000-year MRP earthquake events. Damage loss estimates include structural and non-structural damage to the building and loss of contents. Table 5.4.2-12 lists estimated replacement cost values (RCVs) of buildings and contents damaged by 250- and 1,000-year MRP earthquake events. The annualized total estimated damages are less than 1 percent of the total building replacement cost value for all municipalities.

Table 5.4.2-11. Estimated Number of Buildings Damaged by the 250-year and 1,000-year MRP Earthquake Events

Category	Expected Building Damage by Occupancy									
	250-Year MRP					1,000-Year MRP				
	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Residential	88,508 (93.1%)	277 (<1%)	75 (<1%)	8 (<1%)	1 (<1%)	86,397 (90.8)	1,871 (2.0%)	528 (<1%)	66 (<1%)	6 (<1%)
Commercial	4,381 (4.6%)	30 (<1%)	8 (<1%)	1 (<1%)	0 (0%)	4,202 (4.4%)	157 (<1%)	54 (<1%)	7 (<1%)	0 (0%)
Industrial	502 (<1%)	3 (<1%)	1 (0.8%)	0 (0%)	0 (0%)	483 (<1%)	16 (<1%)	5 (<1%)	1 (<1%)	0 (0%)

Category	Expected Building Damage by Occupancy									
	250-Year MRP					1,000-Year MRP				
	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Education, Government, Religious and Agricultural	1,313 (1.4%)	5 (<1%)	2 (1.81%)	0 (0%)	0 (0%)	1,268 (1.3%)	38 (<1%)	13 (<1%)	2 (<1%)	0 (0%)

Source: HAZUS-MH v4.2

Table 5.4.2-12. Estimated Building and Content Loss for the 250- and 1,000-Year MRP Earthquake Events

Municipality	Total Replacement Cost Value (Structure and Contents)	Annualized Loss	Estimated Total Damages*	
			250-Year	1,000-Year
Barker (T)	$688,813,868	$790.65	$0.00	$226,243
Binghamton (C)	$77,847,328,827	$715,221	$22,442,665	$164,420,96
Binghamton (T)	$1,228,624,612	$845	$49.23	$245,579
Chenango (T)	$4,543,298,114	$7,350	$93,529	$2,008,881
Colesville (T)	$2,981,791,633	$4,040	$0.00	$1,164,431
Conklin (T)	$1,795,243,811	$3,167	$0.00	$903,538
Deposit (V)	$459,195,313	$535	$0.00	$150,921
Dickinson (T)	$1,446,559,666	$2,330	$1,246	$661,264
Endicott (V)	$11,814,240,767	$84,921	$2,660,785	$19,024,650
Fenton (T)	$1,763,698,720	$2,758	$0.00	$800,330
Johnson City (V)	$31,593,599,188	$93,481	$2,127,325	$23,615,437
Kirkwood (T)	$3,589,691,107	$3,605	$0.00	$1,013,778
Lisle (T)	$568,905,916	$707	$0.00	$204,474
Lisle (V)	$107,968,636	$134	$0.00	$38,797
Maine (T)	$1,702,703,387	$1,708	$0.00	$485,235
Nanticoke (T)	$395,739,757	$332	$0.00	$98,164
Port Dickinson (V)	$525,142,613	$842	$0.00	$239,390
Sanford (T)	$770,815,458	$898	$0.00	$253,212
Triangle (T)	$576,956,692	$830	$0.00	$239,583
Union (T)	$30,465,363,557	$58,216	$758,172	$15,384,549
Vestal (T)	$21,589,049,741	$35,77	$279,688	$9,836,567
Whitney Point (V)	$519,433,248	$748	$0.00	$215,750
Windsor (T)	$1,424,173,576	$1,423	$0.00	$405,404
Windsor (V)	$719,873,967	$719	$0.00	$204,946
Broome County	**$199,118,212,175**	**$1,021,375**	**$28,363,459**	**$241,842,090**

Source: HAZUS-MH v4.2
**Total Damages is sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious, and government).*
C City
T Town
V Village

HAZUS-MH v4.2 estimates approximately $28.4 million in building damage due to a 250-year earthquake event. This includes structural damage, non-structural damage, and loss of contents representing less than 1 percent of total RCV of general building stock in Broome County. HAZUS-MH estimates approximately $241.8 million in building damage (less than 1 percent of the total general building stock RCV) due to a 1,000-year MRP earthquake event. Residential and commercial buildings account for greatest damage due to these earthquake events, with residential buildings accounting for 79.7 percent and 76.7 percent of the total losses for the 250- and 1,000-year MRP events, respectively and with commercial losses accounting for approximately 14.4 percent and 16.3 percent of the total losses for the 250- and 1,000-year MRP events, respectively.

Historically, Building Officials Code Administration (BOCA) regulations in the northeast states were developed to address local concerns, including heavy snow loads and wind. Seismic requirements for design criteria are not as stringent as those of the west coast of the United States, which rely on the more seismically focused Uniform Building Code. As such, a smaller earthquake in the northeast can cause more structural damage than if it would occur in the west.

Impacts on Critical Facilities

All critical facilities in Broome County are considered exposed and vulnerable to the earthquake hazard. Refer to Section 4.7 (Critical Facilities) in the County Profile for a complete inventory of critical facilities in Broome County. in Appendix F summarizes the number of critical facilities, by type, located on NEHRP soil Classes D or E. Of the 1,294 critical facilities exposed countywide, the City of Binghamton has the greatest number of critical facilities located on Class D or E soils (580 facilities), followed by the Town of Vestal with 283 facilities. Because of their locations on softer soils, these critical facilities have increased risk of damage from an earthquake.

The HAZUS-MH v4.2 earthquake model was used to assign a probability of each damage category, as defined in Table 5.4.2-10, to every critical facility in the planning area, which was then averaged across the facility category. In addition, HAZUS-MH v4.2 estimates the time to restore critical facilities to fully functional use. Results are presented as probability of being functional at specified time increments (days after the event). For example, HAZUS-MH v4.2 might estimate that a facility has 5 percent chance of being fully functional at Day 3, and a 95-percent chance of being fully functional at Day 90. Results for the 250- and 1,000-year events are summarized in Table 5.4.2-13 and Table 5.4.2-14. For percent probability of sustaining damage, the minimum and maximum damage estimated value for that facility type is presented.

Table 5.4.2-13. Estimated Damage and Loss of Functionality for Critical Facilities and Utilities for the 250-Year MRP Earthquake Event

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Critical Facilities									
Medical	92-96	3-5	0-2	<1	0	92-96	97-99	100	100
Police	91-99	0-6	0-2	<1	0	91-99	97-100	100	100
Fire	92-99	1-6	0-2	<!	0	91-99	97-100	100	100
EOC	98.9	1	<1	0	0	99	100	100	100
School	91-99	0-6	0-2	<!	0	91-99	97-100	100	100
Utilities									
Potable Water	99-100	0-1	<1	0	0	100	100	100	100
Wastewater	99-100	0-1	<1	0	0	100	100	100	100
Communication	98-100	0.2-2	<1	0	0	100	100	100	100

Source: HAZUS-MH v4.2

Table 5.4.2-14. Estimated Damage and Loss of Functionality for Critical Facilities and Utilities for the 1,000-Year MRP Earthquake Event

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Critical Facilities									
Medical	79-87	8-13	4-7	0-2	<1	79-87	91-95	98-99	99-100
Police	77-95	4-14	1-8	0-2	<1	77-95	90-98	98-100	99-100
Fire	77-95	4-13	1-7	0-2	<1	77-95	90-99	98-100	99-100
EOC	87.2	8.2	3.8	<1	<1	90	97	100	100
School	77-95	4-14	1-8	0-2	<1	77-95	90-99	98-100	99-100
Utilities									
Potable Water	92-100	0-6	0-2	<1	0	98-100	100	100	100
Wastewater	92-100	0-6	0-2	<1	0	94-100	100	100	100
Communication	93-100	0-5	0-2	0	0	99-100	100	100	100

Source: HAZUS-MH v4.2

Levees

According to EC 1110-2-6067 *USACE Process for the National Flood Insurance Program Levee System Evaluation*, if the PGA is less than 0.10g (10 percent g) for a seismic event with a 100-year MRP, then a seismic evaluation is not required for a levee. HAZUS-MH v4.2 was used to generate the PGA in Broome County for a 100-year MRP event. The PGA for Broome County ranges from 0.0079g to 0.0216g and is well below the 0.10g standard in EC 1110-2-6067. Based on this guidance, no seismic evaluations are required for the levee system accreditation in the county, and no levees are at an increased risk of structural failure due to a 100-year MRP seismic event.

Impact on Economy

Earthquakes also impact the economy, including causing loss of business function, damage to buildings and infrastructure, relocation costs, wage loss, and rental loss due to repair and replacement of buildings. HAZUS-MH v4.2 estimates building-related economic losses, including income losses (wage, rental, relocation, and capital-related losses) and capital stock losses (structural, non-structural, content, and inventory losses). Economic losses estimated by HAZUS-MH v4.2 are summarized in Table 5.4.2-15.

Table 5.4.2-15. Building-Related Economic Losses from the 250 and 1,000-Year MRP Earthquake Event

Level of Severity	Mean Return Period	
	250-year	1,000-year
Income Losses		
Wage	$751,100	$8,419,000
Capital Related	$460,000	$17,319,200
Rental	$1,038,300	$2,624,600
Relocation	$1,165,500	$16,400
Subtotal	**$3,414,900**	**$8,379,200**
Capital Stock Losses		
Structural	$5,952,200	$52,164,500
Non-Structural	$3,486,100	$151,514,400

Level of Severity	Mean Return Period	
	250-year	1,000-year
Content	$7,150,200	$38,162,400
Inventory	$9,073,500	$405,300
Subtotal	**$25,662,000**	**$242,246,600**

Source: HAZUS-MH v4.2

Although the HAZUS-MH v4.2 analysis did not compute estimates of damage to roadway segments and railroad tracks, assumedly these features would undergo damage due to ground failure—resulting in interruptions of regional transportation and of distribution of materials. Losses to the community that would result from damage to lifelines could exceed costs of repair (FEMA 2012).

Earthquake events can significantly affect road bridges, many of which provide the only access to certain neighborhoods. Because softer soils generally follow floodplain boundaries, bridges that cross watercourses should be considered vulnerable to earthquake events. Another key factor in degree of vulnerability is age of facilities and infrastructure, which correlates with standards in place at times of construction of these. HAZUS-MH v4.2 estimated economic impacts on Broome County for 15 years after an earthquake event— for the repair of highway bridges after an earthquake, less than $500,000 in damages were estimated as a result of a 250-year event and $9.9 million as a result of a 1,000-year event.

HAZUS-MH v4.2 estimates volume of debris that might be generated as a result of an earthquake event to enable the study region to prepare for and rapidly and efficiently manage debris removal and disposal, which can be costly. Debris estimates were divided into two categories: (1) reinforced concrete and steel that require special equipment to break up before transport can occur, and (2) brick, wood, and other debris that can be loaded directly onto trucks by use of bulldozers (HAZUS-MH Earthquake User's Manual).

HAZUS-MH v4.2 estimated the generation of more than 6,000 tons of debris during the 250-year MRP event, and over 42,000 tons of debris during the 1,000-year MRP event. Table 5.4.2-16 below lists estimated countywide debris amounts by MRP event.

Table 5.4.2-16. Estimated Debris Generated by the 250- and 2,500-year MRP Earthquake Events

Mean Return Period	Brick/Wood (tons)	Concrete/Steel (tons)
250-Year	5,006.9	1,392.6
1,000-Year	30,540.3	11,521.9

Source: HAZUS-MH v4.2

Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in the county can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. Broome County considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Projected Development

Generally, new development will be more resistant to damage from earthquake events than older construction, as building code seismic design standards have improved over time and modern codes, such as the International Building Code, include provisions for classifying soils.

NEHRP Class D and E soil areas were overlain on areas that have been developed over the performance period of the plan as identified by the county. A total of 122 new and recent developments are exposed to the NEHRP Class D and E soils; this represents approximately 60.7 percent of the 201 developments provided. The City of Binghamton has the greatest number of recent developments located on Class D and E soils (49 developments). Refer to each annex in Section 9 (Jurisdictional Annexes) for the results of each exposure analysis on new development.

Broome County GIS & Mapping Services conducted a developable land analysis to determine potential locations for relocating homes out of hazard areas or building homes once properties in hazard areas have been acquired. The criteria for determining potential locations is detailed in Section 4.6.8 (Housing and Relocation) in the County Profile. The spatial layers used to determine potential locations for development were used to calculate a percent of developable area for each vacant parcel. Of the 15,751 vacant parcels, 14,802 are considered developable. A total of 4,162 parcels are located on NEHRP Class D and E soil areas. The City of Binghamton has the greatest number of developable parcels located on Class D and E soils (984 parcels).

Projected Changes in Population

According to population projections from the Cornell Program on Applied Demographics, Broome County will experience a continual population decrease through 2040 (over 17,400 people in total by 2040). This decrease will reduce the overall vulnerability of the county’s population over time. While less people will reside in the county, those that remain may move into locations that are more susceptible than others due to aging buildings and infrastructure. Refer to Section 4.4.2 (Population Trends) in the County Profile for a discussion on trends for the county.

Climate Change

Because the impacts of climate change on the earthquakes are not well understood, an increase or decrease in the county’s vulnerability is difficult to determine. However, climate change has the potential to magnify secondary impacts of earthquakes. As a result of the climate change projections discussed above, the county’s assets located on areas of saturated soils and on or at the base of steep slopes, are at a higher risk to landslides and mudslides because of seismic activity. Failure of a dam storing increased volumes of water would result in flooding of the county’s assets located in the inundation area.

Changes in Vulnerability Since the 2013 HMP

The 2013 HMP conducted a HAZUS-MH analysis using version 2.1 for the 100-, 500-, and 2,500-year MRP events. HAZUS-MH 2.1 used 2000 U.S. Census data for its loss estimations. This HMP update used HAZUS-MH v4.2 for the 250- and 1,000-year MRP events. The analysis relied on 2010 U.S. Census data and was updated with the current custom-building stock and critical facility inventory using 2018 RS Mean valuations (2011 RS Means valuations were used in the 2013 HMP). HAZUS-MH v4.2 estimated greater losses due to the 1,000-year MRP event than HAZUS-MH v2.1 estimated for the 2,500-year MRP event. An additional 21,400 structures are included in the general building stock inventory for the 2019 HMP due to an increase in the number of features in the county’s spatial data; 10,400 of these structures are in the City of Binghamton, where the greatest ground shaking is predicted to occur. The increase in the number of structures and increases in RS Means valuations between 2011 and 2018 resulted in greater losses for a more probable MRP event. Overall, the county continues to be vulnerable to earthquake events.

Issues Identified

Important issues associated with an earthquake in Broome County include the following:

- Critical facility owners should be encouraged to create or enhance a continuity of operations plan using the information on risk and vulnerability contained in this plan update.
- Identifying assets built prior to the uniform application of seismic provisions in the state will provide a basis to better understand the vulnerability of building stock in the county.
- A number of levees/earthen dams are found within Broome County. Dam failure warning and evacuation plans, and procedures should be reviewed and updated to reflect the dams' risk potential associated with earthquake activity in the region.
- Earthquakes could trigger other natural hazard events, such as levee/dam failures and landslides, which could impact Broome County.
- The number of unreinforced masonry structures in Broome County is currently unknown. An inventory is needed to identify the number and location of these structures, and then the structure owners should be notified to educate them about retrofitting their structure.
- Over 48 percent of the county's population lives in Class D and E soils. These soils are more susceptible to earthquake damages. The population living in these areas need to be educated on taking appropriate action when earthquakes occur.
- The current Broome County GIS portal does not have NEHRP soil layer option. This layer would provide guidance for communities as to where to limit development in these areas or require more stringent seismic requirements for new buildings.

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