EARTHQUAKE LOSS ESTIMATION STUDY

FOR

HUDSON COUNTY, NEW JERSEY:

GEOLOGIC COMPONENT

Prepared for the
New Jersey State Police
Office of Emergency Management

by the
New Jersey Geological Survey

December 1999

CONTENTS

FINAL REPORT

GEOLOGIC COMPONENT OF THE EARTHQUAKE LOSS ESTIMATION STUDY FOR HUDSON COUNTY, NEW JERSEY

Prepared for the New Jersey State Police, Office of Emergency Management

by
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New Jersey Geological Survey

December 31, 1999

Summary: Geologic and topographic data were acquired and analyzed in order to compile maps of seismic soil class, liquefaction susceptibility, and landslide susceptibility for Hudson County (folded in pocket). The soil class, liquefaction susceptibility, and landslide susceptibility data were entered into the HAZUS model for each census tract in the county. The HAZUS model was run with the upgraded geologic data and with the default geologic data for earthquake magnitudes of 5, 5.5, 6, 6.5, and 7. Selected outputs from these runs are attached in Appendices A through K. The upgraded geology produced significant changes in both the spatial distribution of damage and the total damage estimates. The upgraded geology produced greater building damage in the Hudson waterfront and Hackensack Meadowlands areas of the county, where soils are softer and more liquefiable than the default, and less building damage on the Palisades Ridge and on uplands in Kearny and Secaucus, where soils are stronger than the default. Because most building in the county is concentrated on these ridges, the total estimated building damage is somewhat less with the upgraded geologic data than with the default data at all magnitudes.

In addition to the HAZUS data upgrades and runs, shear-wave velocity was measured on the three softest soil types at a total of nine locations. These measurements were made to check the soil-class assignments, which use test-drilling data as a proxy for shear-wave velocity. The measured velocities confirmed the assignments.

Geologic Data Acquired: Six distinct units of surficial material were identified and mapped in Hudson County. These include glacial till, glacial-lake sand and gravel deposits, glacial-lake silt and clay deposits, postglacial river sand, peat and organic silt deposited in estuaries and salt marshes, and outcropping bedrock. The distribution and thickness of these materials were mapped at 1:24,000 scale using stereo-airphoto interpretation, field observations, archival geologic map data on file at the NJGS, and logs of about 500 test borings. Till is a compact pebbly, cobbly silty sand to sandy silt sediment deposited directly beneath glacial ice. It veneers the bedrock surface and is as much as 50 feet thick in the county. On parts of the Palisades Ridge, and on Snake Hill in the Meadowlands, till is thin or absent and diabase bedrock is exposed or is within 10 feet of the surface (Figure 1). Glacial-lake deposits overlie the till in the lowlands along the Hudson River, and the Newark Bay-Hackensack Meadowlands. These deposits include sand and gravel as much as 100 feet thick and silt and clay as much as 200 feet thick. The sand and gravel deposits form low uplands along the Hudson waterfront, the east edge

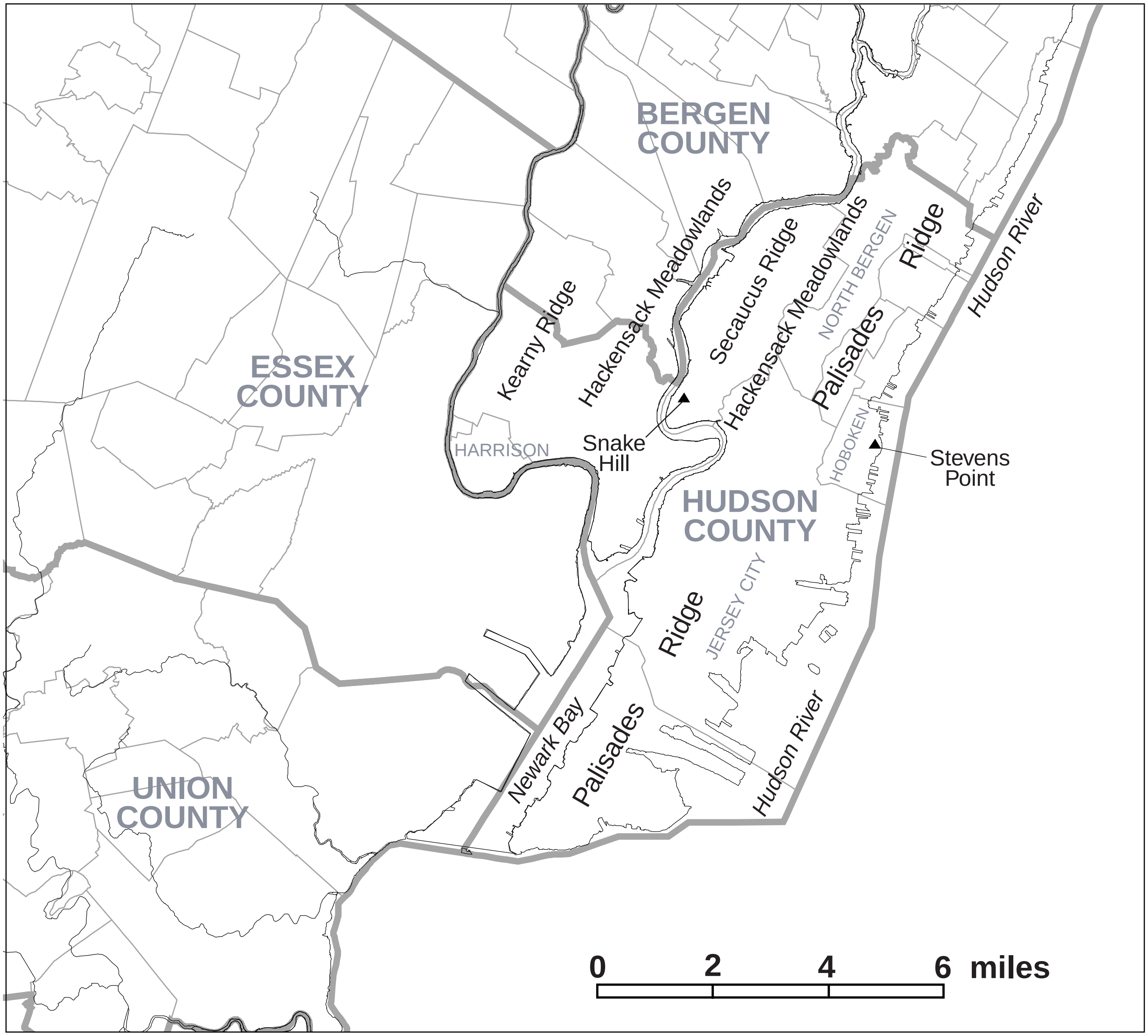


Figure 1. Hudson County and vicinity, showing features named in text.

of the Hackensack Meadowlands, and in Harrison, and occur in the subsurface in places beneath the silt and clay. The silt and clay underlie the salt-marsh and alluvial deposits. Alluvial sand was deposited by streams in the Hackensack Meadowlands lowland after the glacial lakes drained but before rising sea level entered the lowland. It is as much as 20 feet thick and occurs sporadically between the glacial-lake deposits and the salt-marsh deposits. The salt-marsh and estuarine deposits are as much as 300 feet thick beneath the Hudson River but are generally less than 20 feet thick in the Hackensack Meadowlands-Newark Bay lowland. The extent of the these deposits is important because they are loose, saturated soils that are especially susceptible to seismic shaking. Archival maps at the NJGS dating back to 1841 were used to delineate the former extent of the marshes, which are now completely covered by fill over much of the county.

Data Analysis: Shaking behavior and liquefaction susceptibility of soils are determined by their grain size, thickness, compaction, and degree of saturation. These properties, in turn, are determined by the geologic origin of the soils and their topographic position. Soils can be classed into the HAZUS categories using Standard Penetration Test (SPT) data, which are acquired during the drilling of test borings and report the number of blows of a 140-pound hammer falling 30 inches that are required to drive a sampling tube 12 inches into the test material. Approximately 300 borings in the Hudson County-Newark area contained engineering data usable for HAZUS soil classification. These borings reported a total of 4,777 SPT tests on the 5 types of surficial material, and man-made fill, underlying Hudson County (Table 1). For each surficial unit, a mean SPT value, and standard deviation, were calculated. This mean value is then applied to the mapped extent of the surficial unit to prepare the soil class map. Fill includes a variety of materials ranging from demolition debris and excavated bedrock to trash and dredged silt and sand. Because of the variable composition of fill it is inappropriate to apply a mean SPT value, and fill was not included in the soil classification determinations. The behavior of fill under seismic shaking should be assessed on a site-specific basis. The boring logs also report the depth of the water table, which marks the upper limit of saturation. This information, along with the grain size and compaction of the soil, is used to map liquefaction susceptibility. HAZUS soil classes were assigned according to the procedures described in sections 4.1.2.1, 4.1.2.2, and 4.1.2.3 of the 1997 National Earthquake Hazards Reduction Program (NEHRP) Provisions. These procedures assign a soil class by using a weighting formula to sum the soil and rock layers to a depth of 100 feet. Liquefaction susceptibility was assigned based on Table 9.1 of the HAZUS Users Manual. The resulting maps are attached (folded in pocket).

Table 1.--Standard Penetration Test (SPT) data for surficial materials in the Hudson County-Newark area.

Material	Number of Borings	Number of Tests	Range of SPT Values	Mean ± Standard Deviation	Percentage of Zero Values
fill	223	737	0-191	17.8±19.2	1.2%
salt-marsh deposits	218	647	0-38	2.8±4.5	45.9%
alluvial sand	67	221	0-89	24.0±13.9	1.8%
glacial-lake sand	79	573	2-139	27.3±17.3	0%
glacial-lake silt and clay	224	1559	0-157	13.7±13.9	11.4%
till	247	723	3-330	67.4±57.8	0%

Landslide susceptibility depends on slope angle and the geologic material underlying the slope. Slope angles for Hudson County were calculated from 1:24,000 topographic maps with 10-foot contour interval (20 foot interval for the Harrison-Kearny area), and slope materials were determined in the field. Landslide susceptibility was assigned according to the classification in Table 9.2 of the HAZUS User's Manual (refer to map folded in pocket). Areas of potential landsliding include cliffs and steep slopes in diabase bedrock on the east slope of the Palisades Ridge north of Jersey City, several small areas of steep slope on the west slope of the Palisades Ridge, bluffs in serpentinite bedrock at Stevens Point in Hoboken, and the cliffs in diabase on Snake Hill in Secaucus.

Shear-wave Velocity Measurements: To test the accuracy of using SPT data as a proxy for shear-wave velocity, seismic data were collected at nine sites in the Hudson County area. The tested soil types include glacial-lake sand and gravel (4 sites), alluvial sand (3 sites) and salt-marsh deposits (2 sites) (Table 2). The measurements were made at sites where the natural deposit was undisturbed and not covered or mixed with man-made fill. At each site, hand-auger holes were drilled to a depth of 5 feet to test for soil disturbance and fill. The seismic data were collected using a Bison 9000 digital engineering seismograph. Both shear wave (horizontal component) and compression (P) wave data were acquired (Appendix L). P-wave data allows for the interpreter to readily discriminate between the shear and P-waves using the large velocity difference. An example of P-wave data is shown from the Kenilworth and DeKorte sites (Appendix L); at all the other sites the raw data was interpreted but not shown in this report.

Table 2. Shear-wave velocity measurements. Data provided in Appendix L.

Site	Location (latitude; longitude)	Material	Measured shear-wave velocity (feet/second)	Shear-wave velocity range predicted from SPT data (feet/second)	Comments
Harrison	40°50'; 74°9'12"	glacial-lake sand and gravel	1397	600-1200	slightly higher than predicted; gravel increases velocity
Hillside	40°41'15"; 74°16'26"	glacial-lake sand and gravel	1181	600-1200	at high end of predicted range; gravel increases velocity
Kenilworth	40°40'25"; 74°18'37"	glacial-lake sand	925	600-1200	agrees
Black Brook	40°41'2"; 74°17'52"	glacial-lake sand	916	600-1200	agrees
Teterboro	40°50'15"; 74°4'13"	alluvial sand	995	600-1200	agrees
Moonachie# 1	40°50'10"; 74°3'18"	alluvial sand	705	600-1200	agrees
Moonachie# 2	40°50'2"; 74°2'47"	alluvial sand	629	600-1200	agrees
DeKorte	40°47'32"; 74°6'5"	salt-marsh mud	not determined	<600	material too fluid to transmit shear waves
Sabretts	40°49'7"; 74°5'16"	salt-marsh mud	not determined	<600	material too fluid to transmit shear waves

Twelve shear geophones were used with a 3 or 6-foot spacing. The source was located 6 feet from the first geophone. The geophone spacing was decreased to 3 feet at the Teterboro, Moonachie#1 and Moonachie#2 sites due to higher background noise. Each geophone was oriented with the axis of movement parallel to the generating source. The source is 6-inch channel steel beam that is 5 feet long and has triangular teeth welded to the bottom. A 10-pound sledgehammer is used to impact either side of the source. Two people stand on the source while it is being hit to improve ground coupling. A comparison of a dug-trench type source to the steel beam source is shown in the Hillside data. The velocities are similar for both sources indicating that the visual first-break picking interpretation is comparable. A trench type source is simply a rectangular 18-inch-deep ditch oriented parallel to the shear geophone axis; a sledgehammer is used to hit a steel plate against one wall of the ditch to generate a shear wave.

Compressional (P-wave) data was collected using the standard seismic refraction line type setup. Twelve 8-hertz geophones were used in-line at 6-foot spacing. A 10 pound sledgehammer and a strike plate are used as a source.

The first seismic break on the raw records from both the shear and compressional data is picked on the records much like picking first breaks for seismic refraction data. The regression velocity is calculated using the inverse slope on the time-distance curves. The data is also presented numerically as the interval velocity between consecutive geophones along each line and is shown as an average of the interval velocities. This is done to check for lateral velocity variation along each seismic line. A large difference in the average velocity and the regression velocity is indicative of lateral inhomogeneities within the soil; however, the regression velocity is statistically more accurate as a bulk soil property. The shear wave data shows no coherent signal in the raw records that were collected at two sites in the salt marsh mud (DeKorte and Sabretts sites). The saturated mud behaves (acoustically) like a liquid; thus, shear waves will be attenuated. Also, the liquid nature of the mud made for bad ground coupling with the source and receivers that further degraded the data quality. However, P-wave data was collected with marginal quality at the DeKorte site and is presented in this report. No coherent data of (shear or compressional) could be observed in the raw records from the Sabretts site, suggesting very poor ground coupling.

Table 2 shows that, with the exception of the test at the Harrison site, all the measured shear-wave velocities fall within the range predicted from the SPT data. The glacial-lake deposit at the Harrison site was more gravelly than other glacial-lake deposits in the study area. In soils, shear-wave velocity generally increases with mean grain size (Fumal and Tinsley, 1985), so gravels will be faster than sands. The gravelly deposits at Harrison and Hillside show this effect, as they yielded higher velocities than the glacial-lake sands at Kenilworth and Black Brook and the alluvial sands at Teterboro and Moonachie#1 and Moonachie#2. The salt-marsh muds at the DeKorte and Sabretts sites were too loose and watery to transmit shear waves. Shear waves do not propagate through fluids because there is no rigidity in the material to permit particle motion transverse to the travel direction of the seismic wave. This fluid condition is consistent with the SPT data collected for the salt-marsh deposits. Nearly 46% of the SPT tests on the marsh deposits had a zero value, indicating no resistance to the sampling tube (Table 1). Engineering tests on the marsh muds in the Newark Bay area (U. S. Army Corps of Engineers, 1995; Port Authority of New York and New Jersey, 1996) show that the muds consistently have water contents of greater than 40% and plasticity indices of greater than 20 (the plasticity index is the range of water content over which the material behaves as a plastic). Such highly saturated, loose muds are classified as E soils in the NEHRP Provisions, which correspond to shear-wave velocities of less than 600 feet per second. Thus, although shear waves could not be measured in the marsh mud, the other engineering properties confirm the E classification.

HAZUS Simulations: To evaluate the effect of upgraded geology, a total of ten simulations were run. Earthquake magnitudes of 5, 5.5, 6, 6.5, and 7, with an epicenter at the centroid of Hudson County and a focal depth of 10 km, were simulated for both the default and the upgraded geology. The selected magnitudes span the range of potential damaging earthquakes in the region. The largest local earthquake in historic records was an estimated magnitude 5.2 event in 1884 with an epicenter offshore from Brooklyn, and earthquakes with magnitudes between 6 and 7 have been recorded or estimated from historical accounts in the Boston area, southern Quebec, and the St. Lawrence Valley.

To upgrade the geologic data, soil type, liquefaction susceptibility, and landslide susceptibility were modified for each census tract using the seismic soil class, liquefaction susceptibility, and landslide susceptibility maps (folded in pocket). A number of census tracts spanned two or more soil types. In these cases, the dominant soil under the most densely built part of the census tract was selected. Also, areas subject to landsliding cover only a small part of the census tracts that were assigned a landslide hazard. The default geology assigned a uniform soil type (class D), and no liquefaction or landslide susceptibility, for the entire county. Maps of the upgraded and default geology, by census tract, are provided in Appendix A. It was determined that building damage was the output parameter that would most directly illustrate the effect of geology on the simulations, because it does not directly incorporate economic and demographic patterns. Appendices B through K provide tables showing the number of the buildings (classed by use) in various states of damage, and the probability of a given damage state for a given use class. The appendices also provide maps showing the percent moderate or greater building damage by census tract for the various simulations, and the total economic loss by census tract. The moderate-or-greater cutoff was used because buildings with moderate damage must be evacuated and inspected prior to reoccupancy. Thus, moderate damage requires significant population disruptions and emergency response. The total economic loss includes repair and replacement costs, contents damage, business inventory damage, relocation costs, capital-related income costs, wage loss, and rental loss.

Evaluation of Simulations: The upgraded geologic data produced increased damage estimates in the Hudson waterfront and Hackensack Meadowlands areas of the county and decreased damage estimates on the Palisades Ridge and Kearny ridge for all of the magnitudes, although the effect is most pronounced at magnitudes 5.5, 6, and 6.5. This pattern reflects the softer salt-marsh and glacial-lake soils beneath the Hudson waterfront and Hackensack Meadowlands, which are of less stable soil class and are more liquefiable than the default conditions, and the compact glacial till soil on the Palisades and Kearny ridges, which are of stronger soil class than the default. The effect of the stronger upgrade soils is best shown on the northern end of the Palisades Ridge in North Bergen, where thin till and exposed diabase bedrock give an upgrade soil class of A, and the number of buildings experiencing moderate or greater damage is about 30% less than in the default runs, which use a soil class of D.

Because the Palisades and Kearny ridges are more densely built than the Hackensack Meadowlands and southern parts of the Hudson waterfront, the total number of buildings with moderate or greater damage is less with the upgraded geologic data than with the default data. Thus, county-wide structural damage to buildings is greater with the default geology than with the upgraded geology, again reflecting the stronger upland soils in the upgraded case.

References Cited (additional references are provided on the map plates)

Fumal, T. E., and Tinsley, J. C., 1985, Mapping shear-wave velocities of near-surface geologic materials, *in* Ziony, J. I., ed., Evaluating earthquake hazards in the Los Angeles region--an earth-science perspective: U. S. Geological Survey Professional Paper 1360, p. 127-149.

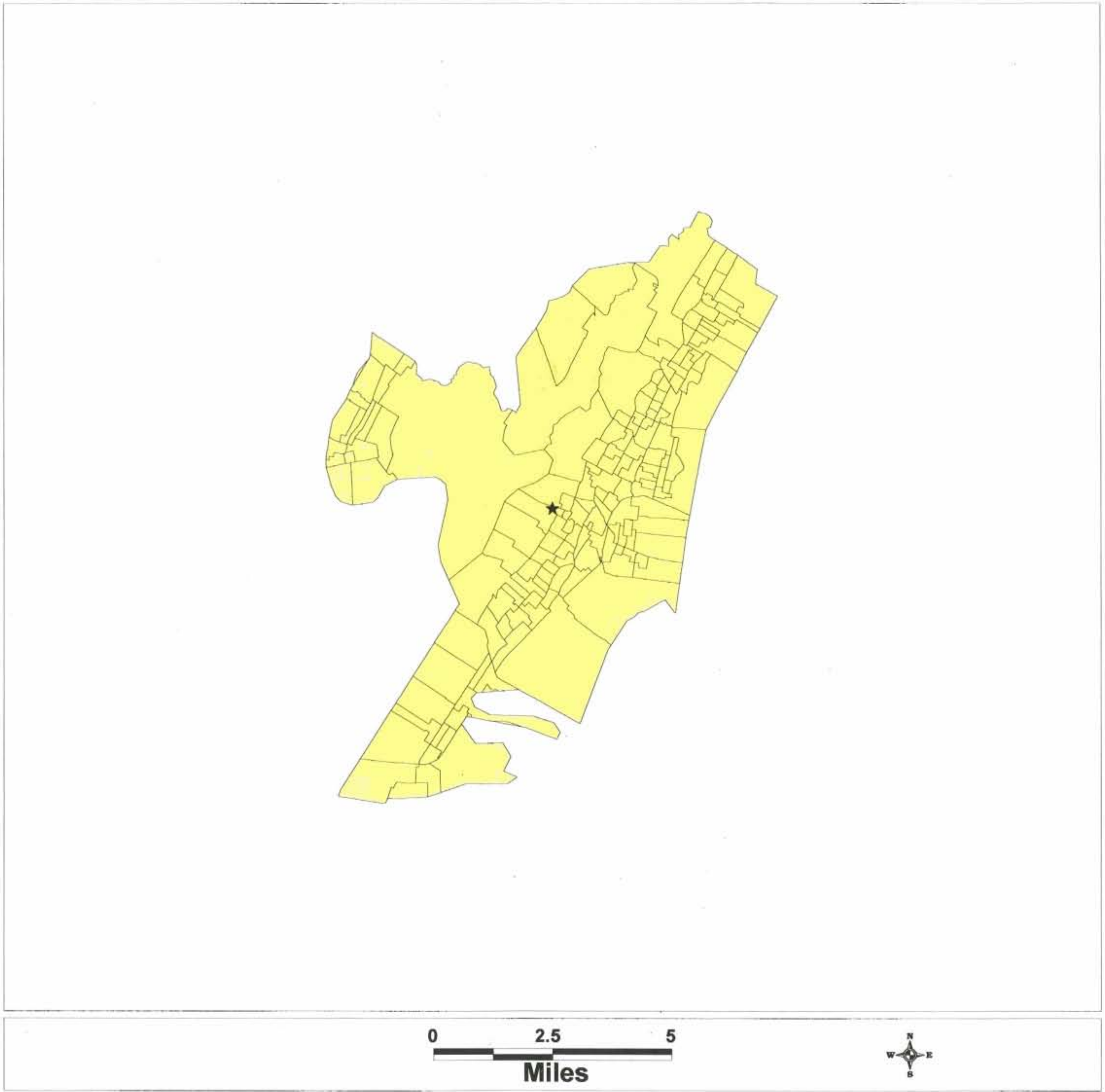
Port Authority of New York and New Jersey, 1996, Newark Bay confined disposal facility: subsurface and laboratory investigation report: prepared by the Geotechnical Unit, Engineering/Architecture Design Division, Engineering Department, 5 p. plus appendices.

U. S. Army Corps of Engineers, 1995, Passaic River flood damage reduction project, design memorandum: prepared by the New York District, 3 volumes.

APPENDIX A

Maps of Hudson County, with census tracts, showing:

- Epicenter location
- Default soil type
- Default liquefaction susceptibility
- Default landslide susceptibility
- Upgraded soil type
- Upgraded liquefaction susceptibility
- Upgraded landslide susceptibility
- Total value of building stock



Study region:
Hudson County

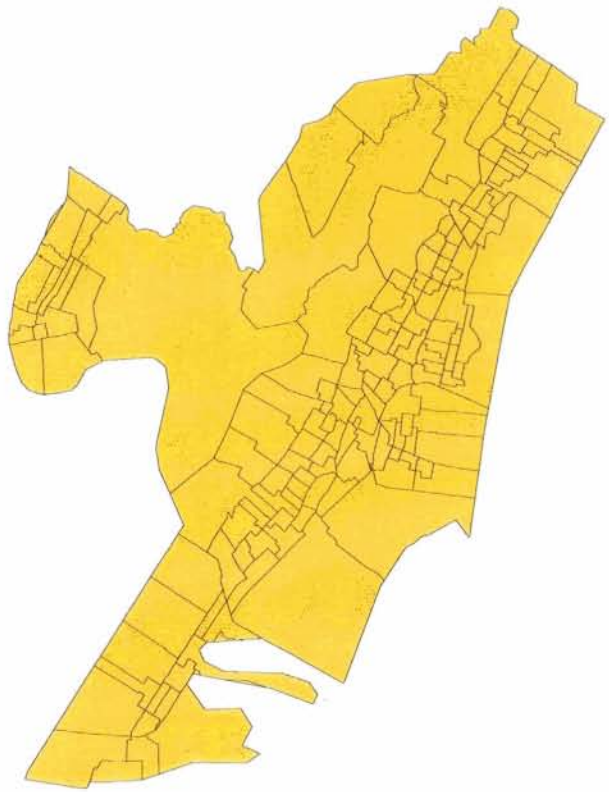
Table Description:
Study Region Epicenter

Scenario Description:

★ Epicenter (County Centroid)
74.0759 degrees longitude
40.7325 degrees latutude

New Jersey Geological Survey
1835

Data from the HAZUS GIS software
October 26, 1999



0 2.5 5
Miles

Study region:
Hudson County

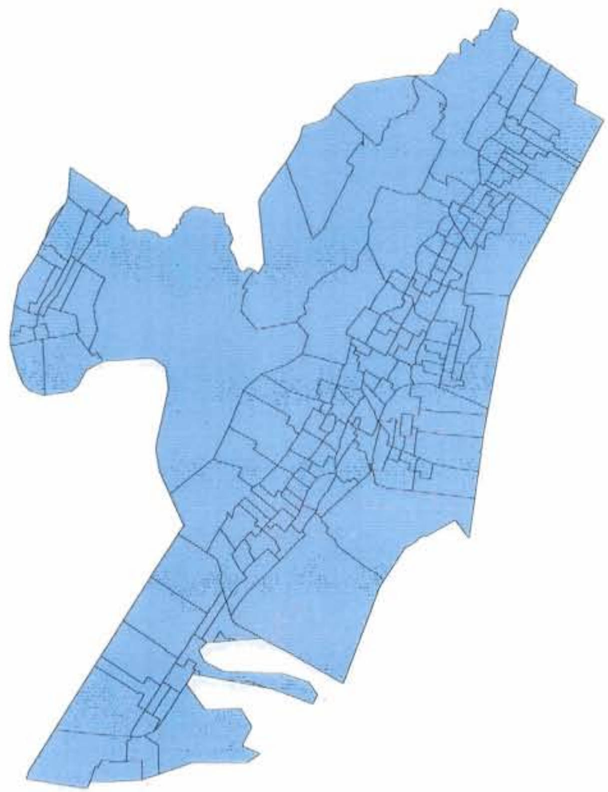
Table Description:
Default Soil Map

Scenario Description:

Soil Type

Class D

Data from the HAZUS GIS software.
October 26, 1999.



0 2.5 5
Miles

Study region:
Hudson County

Table Description:
Default Liquefaction Map

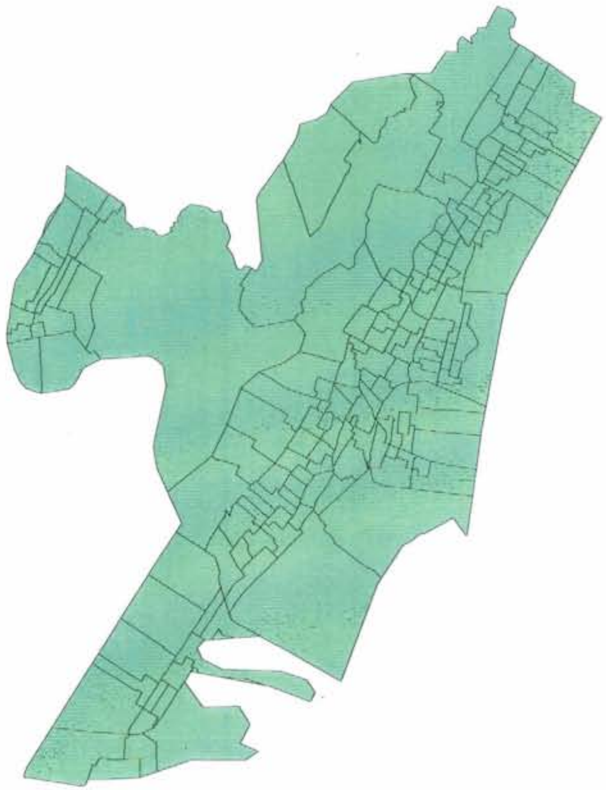
Scenario Description:

Liquefaction Susceptibility

None

New Jersey Geological Survey
1835

Data from the HAZUS GIS software.
October 26, 1999



0 2.5 5
Miles

Study region:
Hudson County

Table Description:
Default Landslide Map

Scenario Description:

Landslide Susceptibility

None

New Jersey Geological Survey
1835

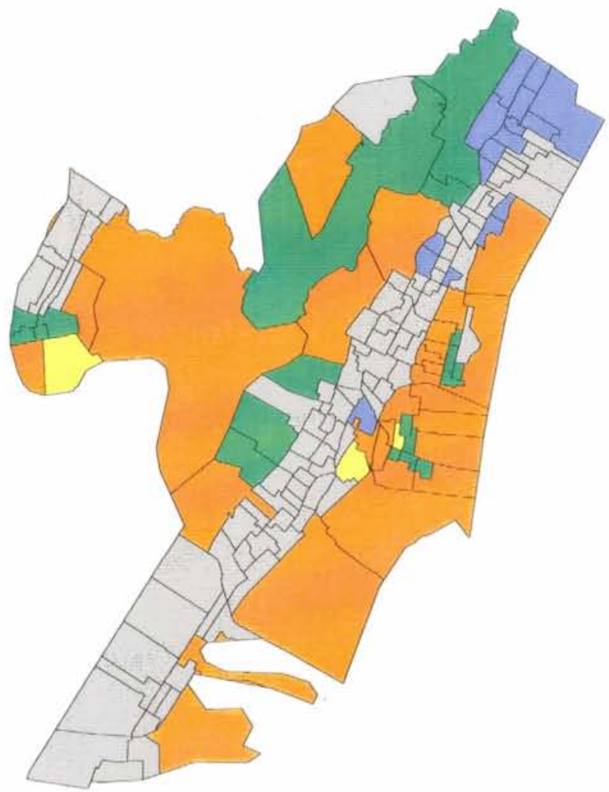
Data from the HAZUS GIS software.
October 26, 1999

Study region:
Hudson County

Table Description:
New Jersey Geological Survey
Soil Map

Scenario Description:

Data generated by the New Jersey Geological Survey.
October 27, 1999.



0 2.5 5
Miles

Study region:
Hudson County

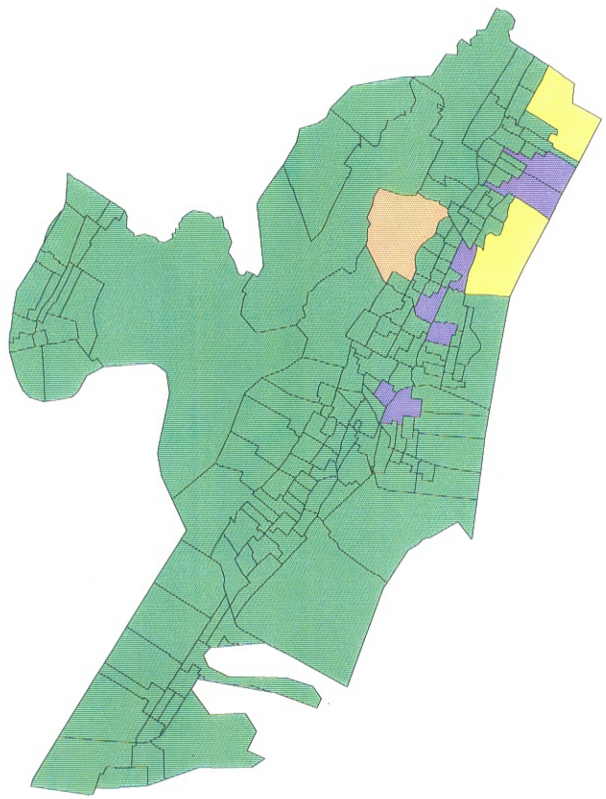
Table Description:
New Jersey Geological Survey Liquefaction Map

Scenario Description:

Liquefaction Susceptibility

- None
- Very low
- Low
- Medium
- High
- Very high

Data Generated by the New Jersey Geological Survey.
October 27, 1999



Study region:
Hudson County

Table Description:
New Jersey Geological Survey Landslide Map

Scenario Description:

Landslide Susceptibility

- None
- Susceptibility I
- Susceptibility II
- Susceptibility III
- Susceptibility IV
- Susceptibility V
- Susceptibility VI
- Susceptibility VII
- Susceptibility VIII
- Susceptibility IX
- Susceptibility X

0 2.5 5
Miles

Data generated by the New Jersey Geological Survey.
October 27, 1999

Building Stock Exposure By General Occupancy

December 09, 1999

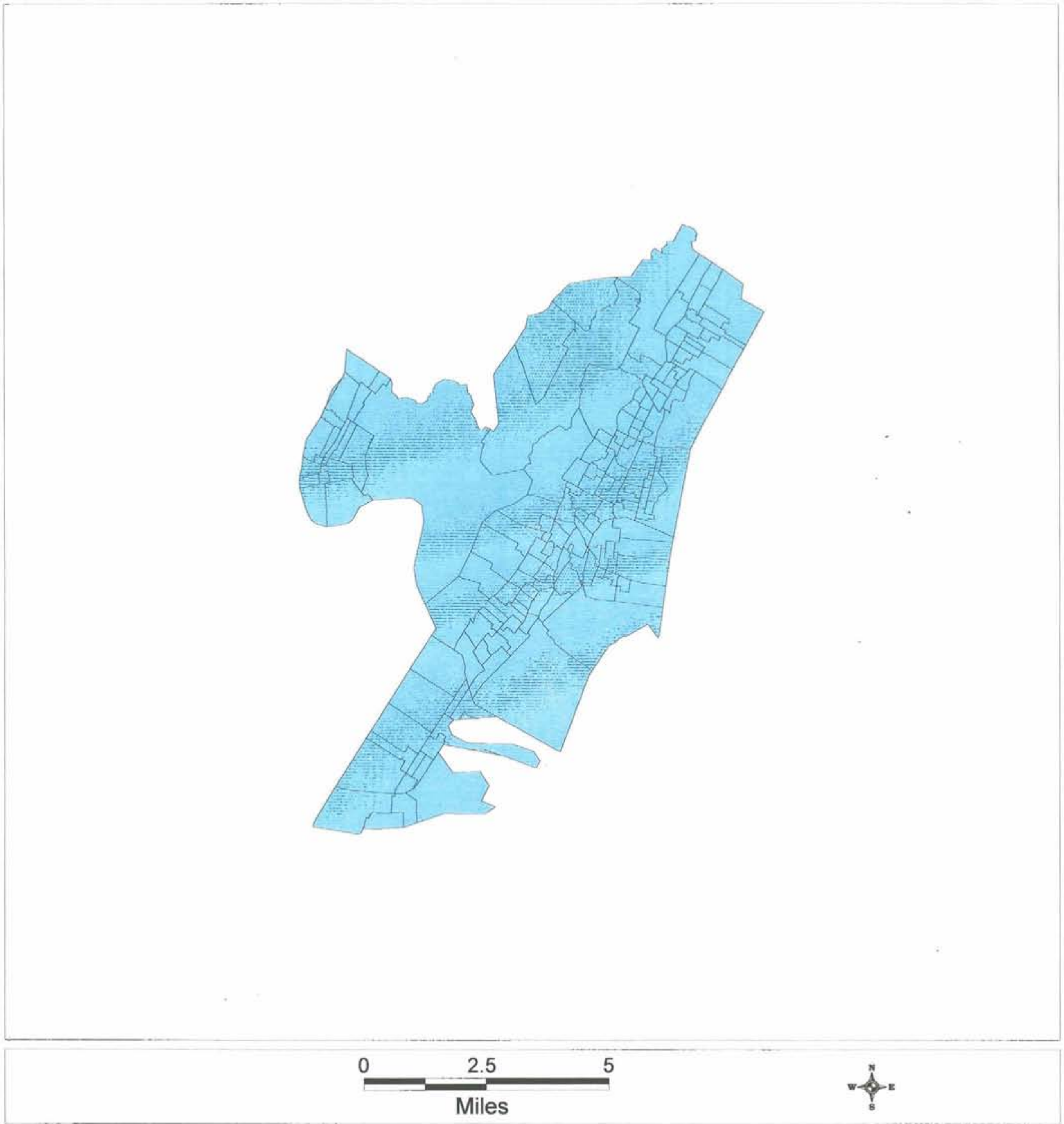
All values are in thousands of dollars

	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
New Jersey								
Hudson	21,425,763	7,613,387	1,893,237	1,920	323,422	86,194	247,508	31,591,420
Total State	**21,425,763**	**7,613,387**	**1,893,237**	**1,920**	**323,422**	**86,194**	**247,508**	**31,591,420**
Total Study Region	**21,425,763**	**7,613,387**	**1,893,237**	**1,920**	**323,422**	**86,194**	**247,508**	**31,591,420**

Study Region : hud1
Scenario : N/A

APPENDIX B

Magnitude 5 with default geology



Study region:
Hudson County

Scenario Description:
5.0 Default Scenario

Percentage Of Buildings With Moderate and Greater Damage

0 to 10

New Jersey Geological Survey
1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 2, 1999

Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
5.0 Default Scenario

Total Loss
(Thousands of Dollars)

☐ 0 to 100,000

0 2.5 5
Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 8, 1999

Building Damage By General Occupancy

December 09, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	20.48	3.30	1.37	0.25	0.00
Commercial	118,728	77.57	12.37	6.50	0.99	0.00
Education	2,916	58.53	9.01	4.78	0.73	0.00
Government	1,131	79.34	11.24	6.21	0.98	0.00
Industrial	32,998	77.15	11.54	6.63	1.18	0.00
Religion	3,356	66.98	11.75	6.18	1.57	0.00
Residential	247,502	79.70	13.01	5.25	0.97	0.00
State Average	406,763	65.68	10.32	5.27	0.95	0.00
Study Region Average	406,763	65.68	10.32	5.27	0.95	0.00

Building Damage by Count by General Occupancy

December 09, 1999

	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	3	0	0	0	0	3
Commercial	4,179	442	168	7	0	4,796
Education	147	3	2	0	0	152
Government	9	0	0	0	0	9
Industrial	1,237	125	49	1	0	1,412
Religion	196	12	5	0	0	213
Residential	36,183	5,603	1,700	141	28	43,655
Total State	41,954	6,185	1,924	149	28	50,240
Study region	41,954	6,185	1,924	149	28	50,240

Study Region : hud1

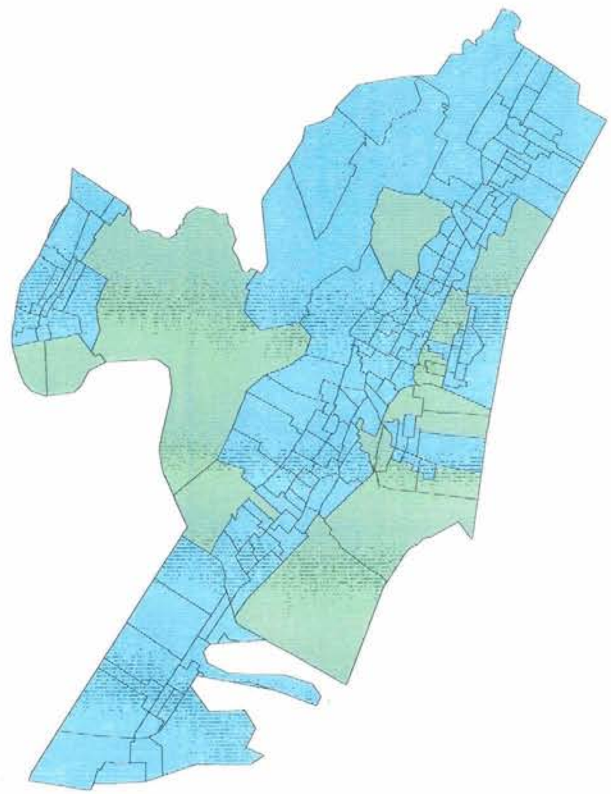
Scenario : def5

APPENDIX C

Magnitude 5 with upgraded geology

Study region:
Hudson County

Scenario Description:
5.0 Upgrade Scenario



Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20

New Jersey Geological Survey
1835

0 2.5 5
Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
November 16, 1999

Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
5.0 Upgrade Scenario

Total Loss
(Thousands of Dollars)

☐ 0 to 100,000

0 2.5 5
Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 13, 1999

Building Damage By General Occupancy

December 13, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	21.93	2.37	0.94	0.14	0.00
Commercial	118,728	82.04	9.56	4.96	1.35	0.13
Education	2,916	62.16	6.78	3.52	0.97	0.10
Government	1,131	83.56	8.75	4.81	0.92	0.00
Industrial	32,998	81.54	8.87	5.01	1.11	0.04
Religion	3,356	71.64	8.80	4.41	1.27	0.14
Residential	247,502	84.07	10.10	3.96	0.62	0.00
State Average	406,763	69.56	7.89	3.94	0.91	0.06
Study Region Average	406,763	69.56	7.89	3.94	0.91	0.06

Building Damage by Count by General Occupancy

December 13, 1999

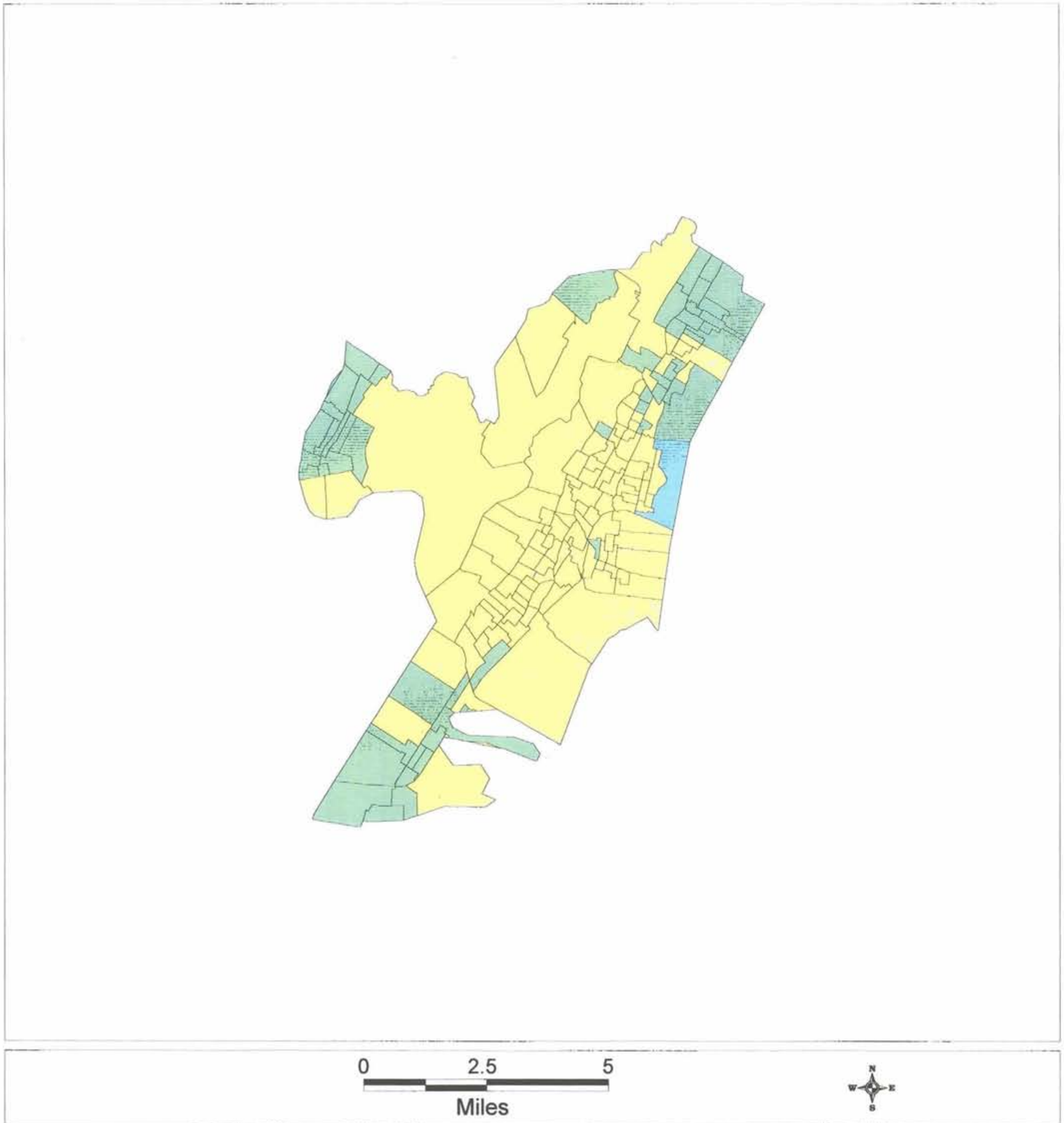
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	3	0	0	0	0	3
Commercial	4,156	423	219	41	1	4,840
Education	146	3	1	0	0	150
Government	9	0	0	0	0	9
Industrial	1,200	125	78	11	0	1,414
Religion	199	12	5	1	0	217
Residential	38,457	3,751	1,169	229	15	43,621
Total State	44,170	4,314	1,472	282	16	50,254
Study region	44,170	4,314	1,472	282	16	50,254

Study Region : hud1

Scenario : hudnj5

APPENDIX D

Magnitude 5.5 with default geology



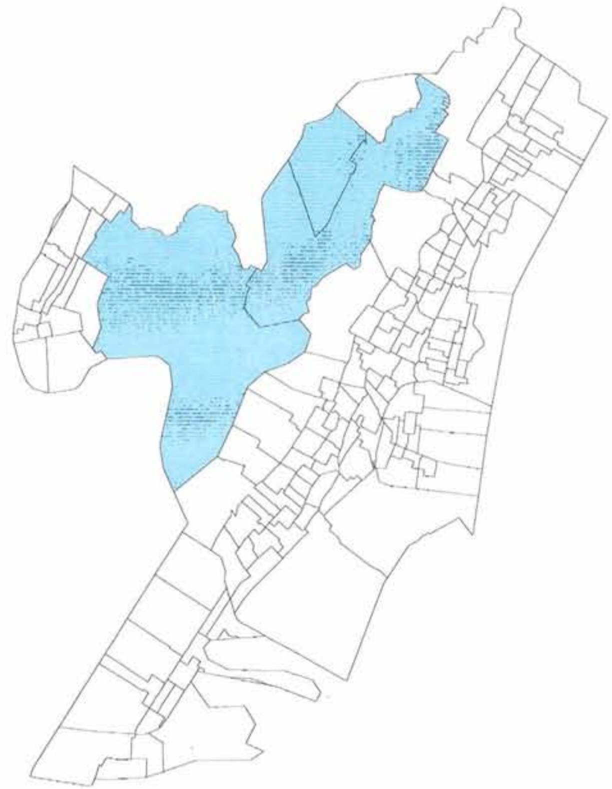
Study region:
Hudson County

Scenario Description:
5.5 Default Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 1, 1999



Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
5.5 Default Scenario

Total Loss
(Thousands of Dollars)

- 0 to 100,000
- 100,000 to 200,000

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 8, 1999

Building Damage By General Occupancy

December 09, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	12.66	6.48	4.71	1.36	0.25
Commercial	118,728	46.89	22.14	20.83	6.84	1.35
Education	2,916	35.78	16.11	15.38	4.76	1.03
Government	1,131	48.71	21.07	20.91	6.31	0.99
Industrial	32,998	46.75	20.76	21.11	7.08	1.13
Religion	3,356	38.71	22.07	17.80	6.29	1.51
Residential	247,502	46.22	28.49	18.01	5.14	0.96
State Average	406,763	39.39	19.59	16.96	5.40	1.03
Study Region Average	406,763	39.39	19.59	16.96	5.40	1.03

Building Damage by Count by General Occupancy

December 09, 1999

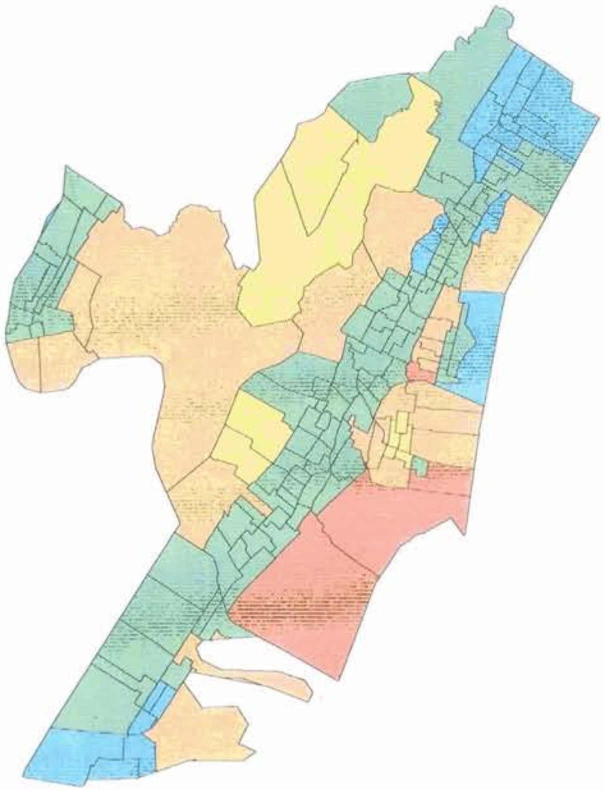
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	2	0	0	0	0	2
Commercial	2,554	983	924	181	18	4,660
Education	91	12	10	2	0	115
Government	5	0	0	0	0	5
Industrial	767	262	276	59	3	1,367
Religion	88	44	24	5	0	161
Residential	21,009	13,619	7,405	1,705	232	43,970
Total State	24,516	14,920	8,639	1,952	253	50,280
Study region	24,516	14,920	8,639	1,952	253	50,280

Study Region : hud1

Scenario : HUD55

APPENDIX E

Magnitude 5.5 with upgraded geology



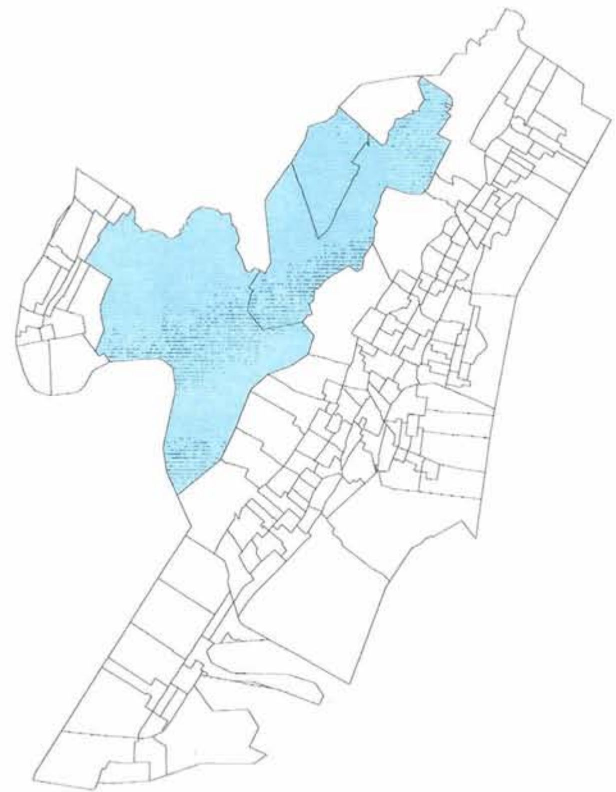
Study region:
Hudson County

Scenario Description:
5.5 Upgrade Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50

Data from the HAZUS GIS software and the New Jersey Geological Survey.
November 16, 1999



Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
5.5 Upgrade Scenario

Total Loss
(Thousands of Dollars)

0 to 100,000
100,000 to 200,000

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 13, 1999

Building Damage By General Occupancy

December 13, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	15.43	5.35	3.50	0.96	0.11
Commercial	118,728	55.82	19.14	16.43	5.48	1.06
Education	2,916	43.16	13.73	11.83	3.76	0.86
Government	1,131	57.84	17.93	16.28	5.11	0.92
Industrial	32,998	55.66	17.74	16.57	5.60	1.01
Religion	3,356	47.52	18.71	13.93	4.98	1.26
Residential	247,502	55.77	23.89	14.16	4.02	1.01
State Average	406,763	47.31	16.64	13.24	4.27	0.89
Study Region Average	406,763	47.31	16.64	13.24	4.27	0.89

Building Damage by Count by General Occupancy

December 13, 1999

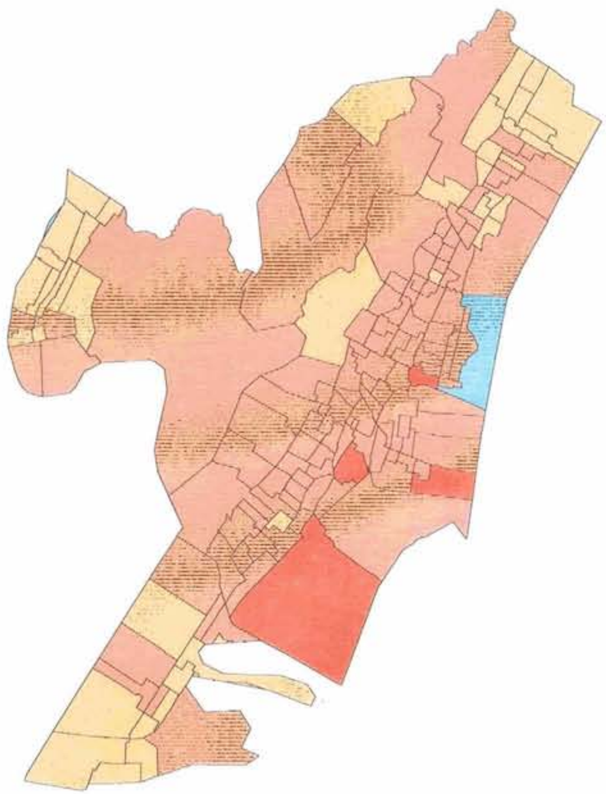
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	2	0	0	0	0	2
Commercial	2,707	865	822	258	46	4,698
Education	106	11	10	1	0	128
Government	8	0	0	0	0	8
Industrial	793	230	263	92	11	1,389
Religion	128	31	23	7	1	190
Residential	26,433	10,776	5,264	1,186	192	43,851
Total State	30,177	11,913	6,382	1,544	250	50,266
Study region	30,177	11,913	6,382	1,544	250	50,266

Study Region : hud1

Scenario : hudnj55

APPENDIX F

Magnitude 6 with default geology



0 2.5 5

Miles

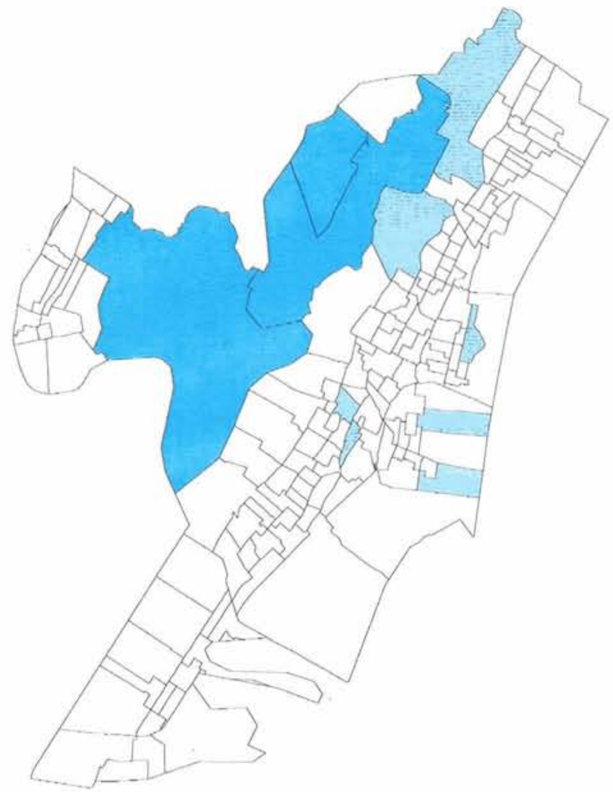
Study region:
Hudson County

Scenario Description:
6.0 Default Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 30 to 40
- 40 to 50
- 50 to 60

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 2, 1999



Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
6.0 Default Scenario

Total Loss
(Thousands of Dollars)

0 to 100,000
100,000 to 200,000
200,000 to 300,000

0 2.5 5
Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 8, 1999

Building Damage By General Occupancy

December 09, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%) None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	6.04	6.42	8.30	3.59	1.13
Commercial	118,728	22.45	20.51	32.09	17.22	6.05
Education	2,916	17.53	15.07	23.78	12.44	4.50
Government	1,131	23.08	19.24	32.53	17.52	5.84
Industrial	32,998	22.25	18.68	31.98	18.14	6.01
Religion	3,356	19.62	21.70	26.20	13.79	5.48
Residential	247,502	23.94	30.25	29.37	11.67	3.99
State Average	406,763	19.27	18.84	26.32	13.48	4.71
Study Region Average	406,763	19.27	18.84	26.32	13.48	4.71

Building Damage by Count by General Occupancy

December 09, 1999

	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	0	0	0	0	0	0
Commercial	1,191	905	1,607	732	151	4,586
Education	24	11	41	8	1	85
Government	0	0	0	0	0	0
Industrial	329	232	433	223	41	1,258
Religion	32	36	61	18	5	152
Residential	11,323	14,717	12,738	4,254	1,199	44,231
Total State	12,899	15,901	14,880	5,235	1,397	50,312
Study region	12,899	15,901	14,880	5,235	1,397	50,312

Study Region : hud1

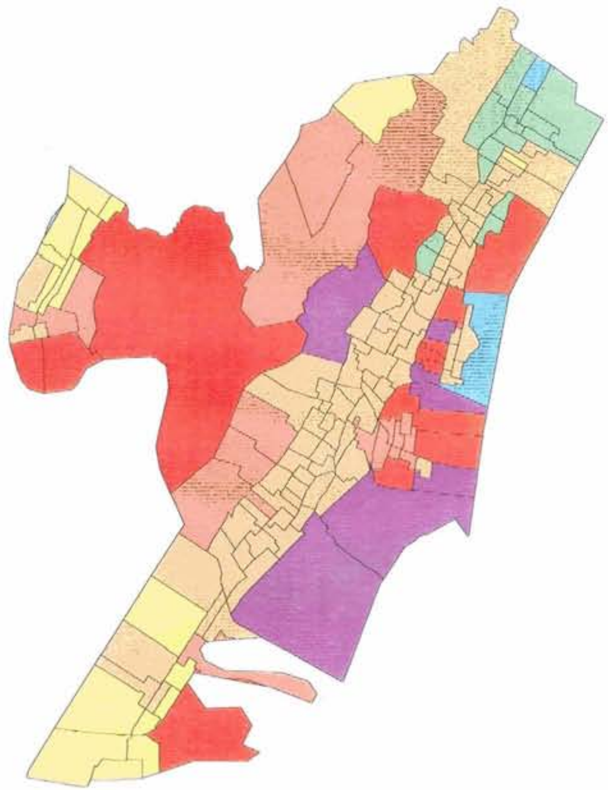
Scenario : hud6d

APPENDIX G

Magnitude 6 with upgraded geology

Study region:
Hudson County

Scenario Description:
6.0 Upgrade Scenario

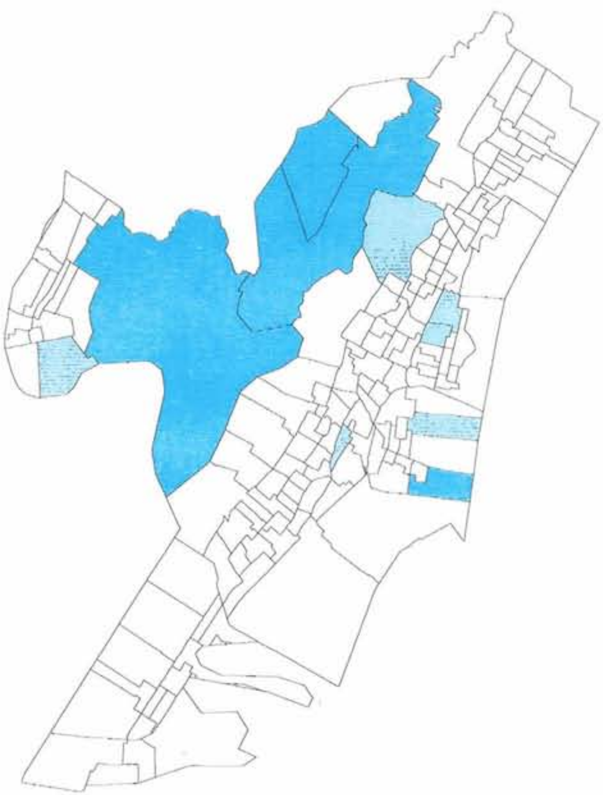


Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70

0 2.5 5
Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
November 16, 1999



Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
6.0 Upgrade Scenario

Total Loss
(Thousands of Dollars)

0 to 100,000
100,000 to 200,000
200,000 to 300,000

0 2.5 5
Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 13, 1999

Building Damage By General Occupancy

December 13, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	8.40	6.32	6.97	2.86	0.98
Commercial	118,728	29.22	20.20	27.98	14.93	5.81
Education	2,916	23.35	14.88	20.43	10.45	4.04
Government	1,131	30.52	18.94	28.17	14.95	5.68
Industrial	32,998	29.24	18.58	27.75	15.50	5.83
Religion	3,356	26.12	21.22	22.72	11.51	4.68
Residential	247,502	31.39	29.44	24.97	9.68	3.37
State Average	406,763	25.46	18.51	22.71	11.41	4.34
Study Region Average	406,763	25.46	18.51	22.71	11.41	4.34

Building Damage by Count by General Occupancy

December 13, 1999

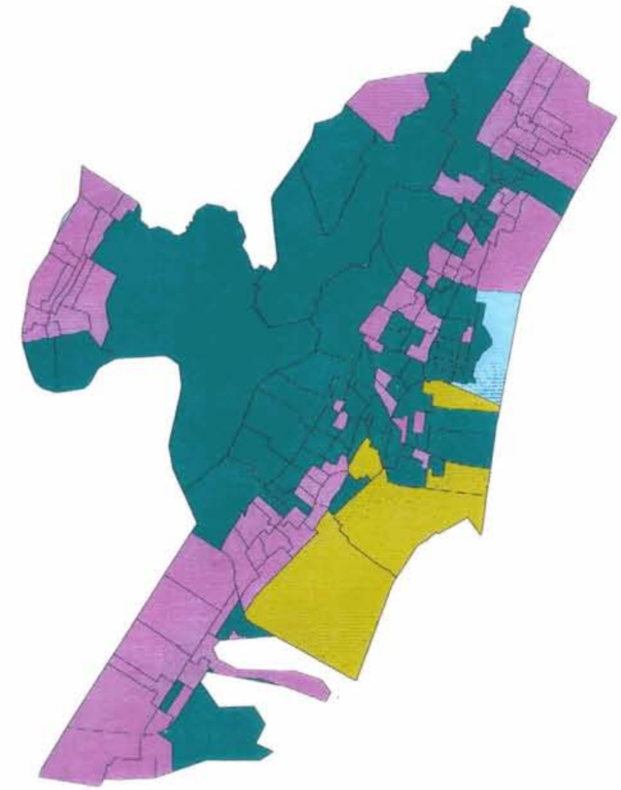
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	0	0	0	0	0	0
Commercial	1,285	807	1,411	750	330	4,583
Education	45	11	32	9	3	100
Government	2	0	0	0	0	2
Industrial	336	188	386	254	118	1,282
Religion	60	40	55	14	6	175
Residential	15,587	14,152	10,363	3,200	862	44,164
Total State	17,315	15,198	12,247	4,227	1,319	50,306
Study region	17,315	15,198	12,247	4,227	1,319	50,306

Study Region : hud1

Scenario : hudnj6

APPENDIX H

Magnitude 6.5 with default geology



Study region:
Hudson County

Scenario Description:
6.5 Default Scenario

Percentage Of Buildings With Moderate and Greater Damage

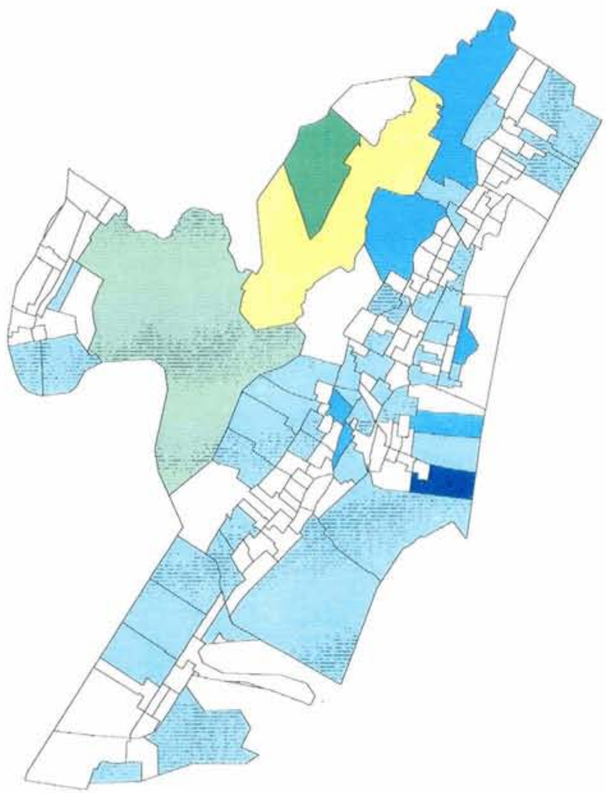
0 to 10
60 to 70
70 to 80
80 to 90

New Jersey Geological Survey
1835

0 2.5 5
Miles

N W E S

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 2, 1999



Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
6.5 Default Scenario

Total Loss
(Thousands of Dollars)

- 0 to 100,000
- 100,000 to 200,000
- 200,000 to 300,000
- 300,000 to 400,000
- 400,000 to 500,000
- 500,000 to 600,000
- 600,000 to 700,000

0 2.5 5
Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 8, 1999

Building Damage By General Occupancy

December 09, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	1.22	2.88	8.27	7.16	6.01
Commercial	118,728	3.91	8.05	25.70	31.16	29.41
Education	2,916	3.10	5.91	19.20	23.70	21.43
Government	1,131	3.70	6.57	23.45	33.20	31.56
Industrial	32,998	3.58	6.62	23.18	32.05	31.50
Religion	3,356	5.17	12.94	25.85	23.09	19.56
Residential	247,502	7.12	20.71	35.01	22.12	13.97
State Average	406,763	3.97	9.10	22.95	24.64	21.92
Study Region Average	406,763	3.97	9.10	22.95	24.64	21.92

Building Damage by Count by General Occupancy

December 09, 1999

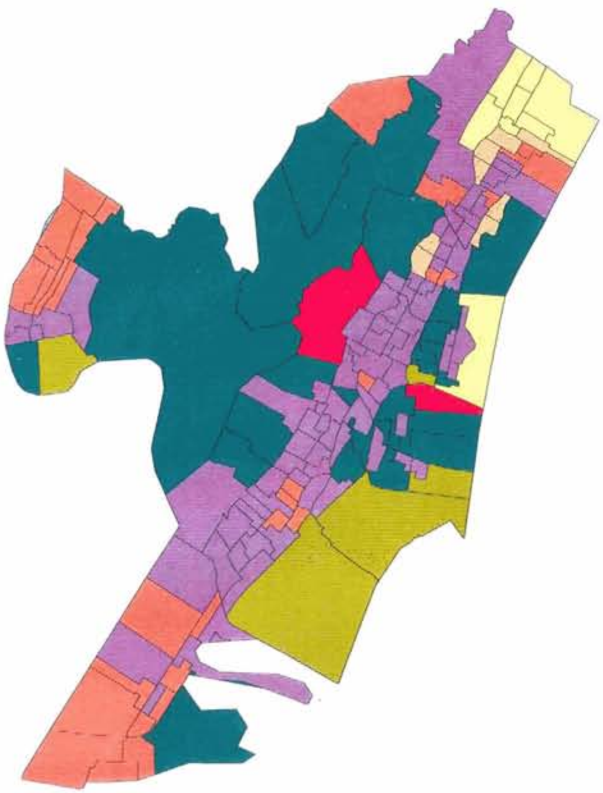
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	0	0	0	0	0	0
Commercial	146	239	1,279	1,525	1,381	4,570
Education	7	2	26	34	31	100
Government	0	0	0	0	0	0
Industrial	40	53	310	434	410	1,247
Religion	7	13	58	54	27	159
Residential	3,748	10,712	16,726	8,771	4,279	44,236
Total State	3,948	11,019	18,399	10,818	6,128	50,312
Study region	3,948	11,019	18,399	10,818	6,128	50,312

Study Region : hud1

Scenario : hud65

APPENDIX I

Magnitude 6.5 with upgraded geology



0 2.5 5

Miles

Study region:

Hudson County

Scenario Description:

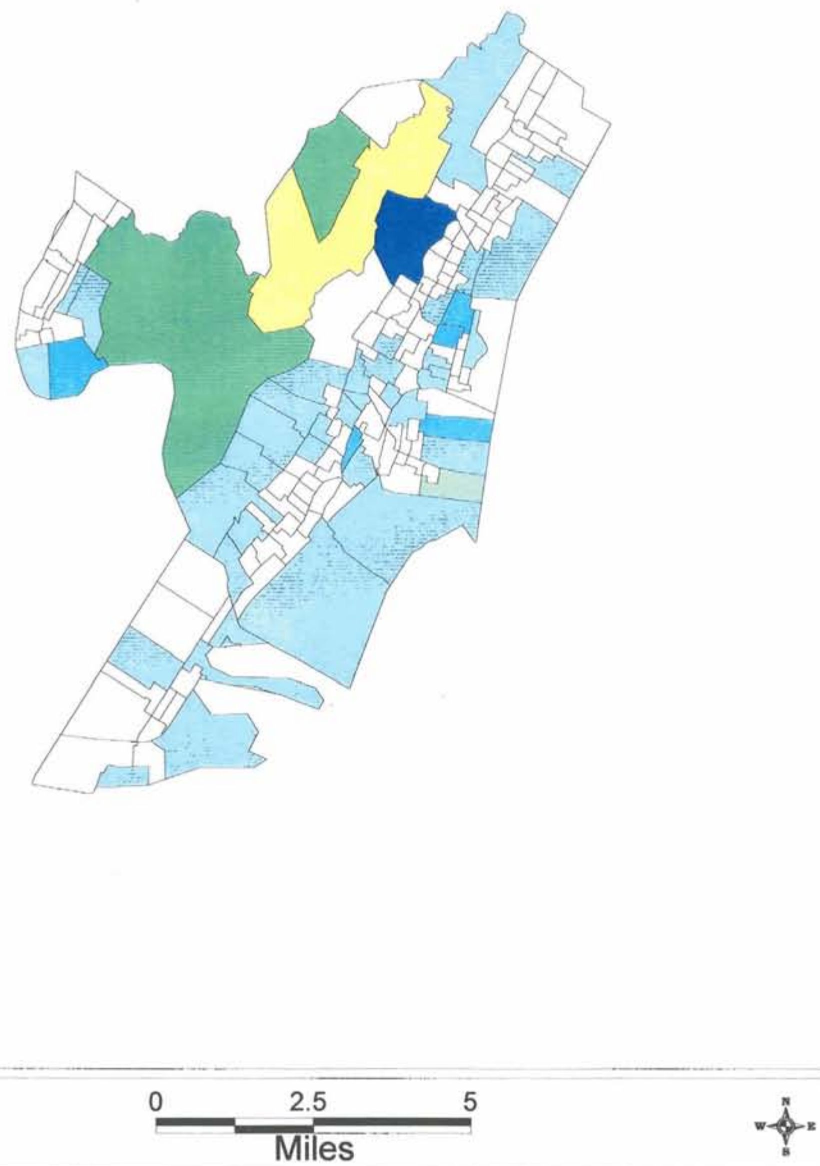
6.5 Upgrade Scenario

Percentage Of Buildings With Moderate and Greater Damage

0 to 10
20 to 30
30 to 40
50 to 60
60 to 70
70 to 80
80 to 90
90 to 100

New Jersey Geological Survey
1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 1, 1999



Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
6.5 Upgrade Scenario

Total Loss
(Thousands of Dollars)

- 0 to 100,000
- 100,000 to 200,000
- 200,000 to 300,000
- 300,000 to 400,000
- 400,000 to 500,000
- 500,000 to 600,000
- 600,000 to 700,000

Data from the HAZUS GIS software and the New Jersey Geological Survey. December 13, 1999

Building Damage By General Occupancy

December 13, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	2.50	3.77	8.03	6.12	5.05
Commercial	118,728	7.68	10.38	26.05	27.22	26.80
Education	2,916	6.48	7.93	19.66	20.44	18.80
Government	1,131	7.57	8.97	24.76	28.78	28.02
Industrial	32,998	7.33	8.96	24.27	28.04	28.13
Religion	3,356	9.07	15.25	25.05	20.03	16.98
Residential	247,502	12.18	23.49	32.49	18.61	12.10
State Average	406,763	7.54	11.25	22.90	21.32	19.41
Study Region Average	406,763	7.54	11.25	22.90	21.32	19.41

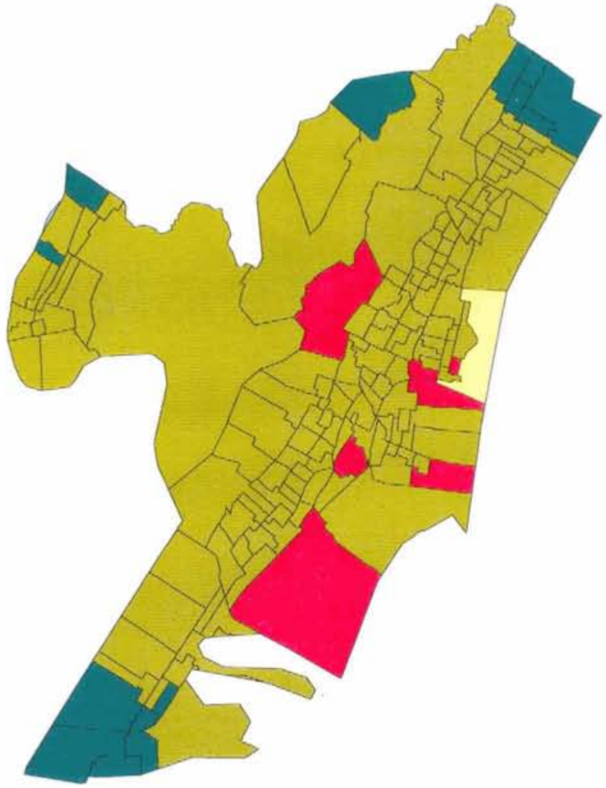
Building Damage by Count by General Occupancy

December 13, 1999

	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	0	0	0	0	0	0
Commercial	264	281	1,111	1,312	1,581	4,549
Education	10	2	26	30	29	97
Government	0	0	0	0	0	0
Industrial	70	61	245	357	538	1,271
Religion	10	17	53	34	28	142
Residential	6,645	12,216	15,158	6,976	3,259	44,254
Total State	6,999	12,577	16,593	8,709	5,435	50,313
Study region	6,999	12,577	16,593	8,709	5,435	50,313

APPENDIX J

Magnitude 7 with default geology

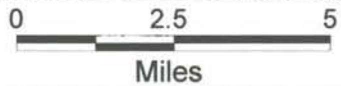


Study region:
Hudson County

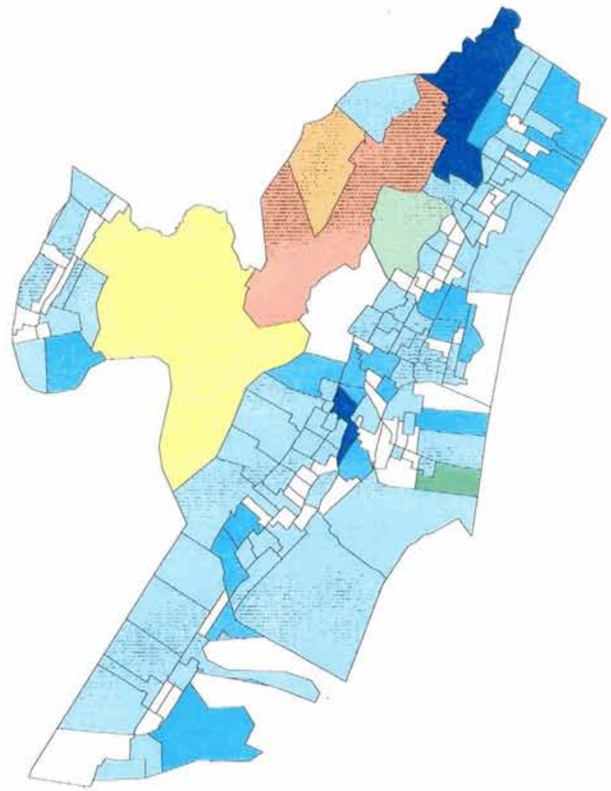
Scenario Description:
7.0 Default Scenario

Percentage Of Buildings With Moderate and Greater Damage

	0 to 10
	20 to 30
	70 to 80
	80 to 90
	90 to 100



Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 2, 1999



Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
7.0 Default Scenario

Total Loss
(Thousands of Dollars)

	0 to 100,000
	100,000 to 200,000
	200,000 to 300,000
	300,000 to 400,000
	400,000 to 500,000
	500,000 to 600,000
	600,000 to 700,000
	700,000 to 800,000
	900,000 to 1,000,000

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 13, 1999

Building Damage By General Occupancy

December 09, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	0.27	0.96	5.01	7.42	11.73
Commercial	118,728	0.96	2.48	13.49	26.94	54.39
Education	2,916	0.76	1.86	9.82	20.61	40.32
Government	1,131	0.84	1.97	10.77	26.60	58.17
Industrial	32,998	0.86	2.08	11.07	25.93	57.30
Religion	3,356	1.78	6.95	20.04	22.45	35.42
Residential	247,502	2.42	12.47	31.61	25.81	26.53
State Average	406,763	1.13	4.11	14.55	22.25	40.55
Study Region Average	406,763	1.13	4.11	14.55	22.25	40.55

Building Damage by Count by General Occupancy

December 09, 1999

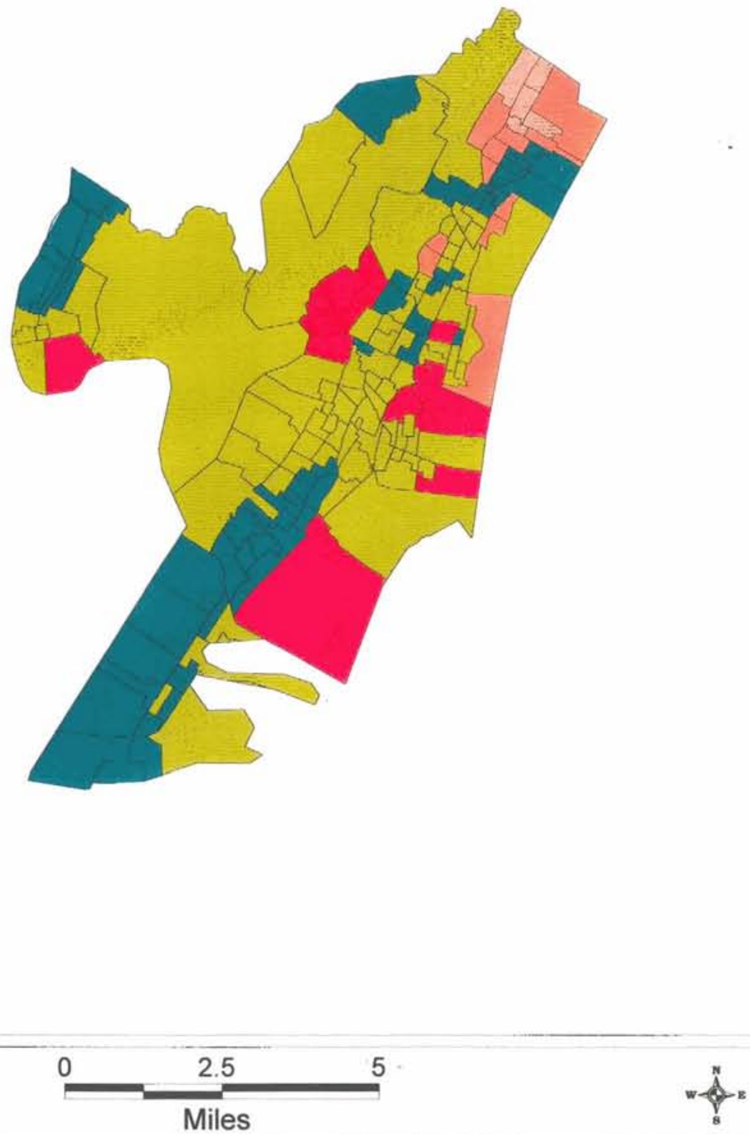
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	0	0	0	0	1	1
Commercial	9	57	541	1,303	2,885	4,795
Education	0	0	4	27	105	136
Government	0	0	0	0	7	7
Industrial	1	12	124	354	919	1,410
Religion	0	6	25	52	71	154
Residential	1,324	6,636	16,169	11,540	8,141	43,810
Total State	1,334	6,711	16,863	13,276	12,129	50,313
Study region	1,334	6,711	16,863	13,276	12,129	50,313

Study Region : hud1

Scenario : hud7

APPENDIX K

Magnitude 7 with upgraded geology



Study region:
Hudson County

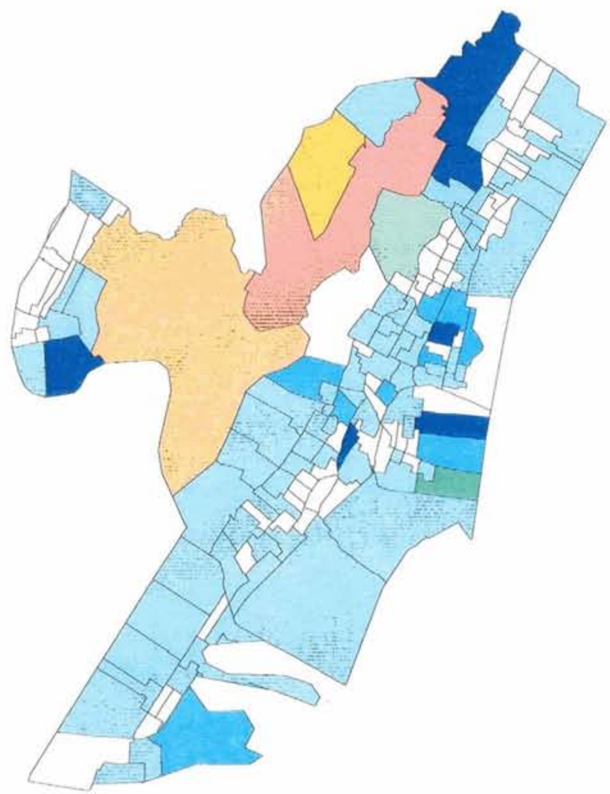
Scenario Description:
7.0 Upgrade Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 40 to 50
- 50 to 60
- 70 to 80
- 80 to 90
- 90 to 100

New Jersey Geological Survey
1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 1, 1999



Study region:
Hudson County

Table Description:
Loss - GBS - Total Loss

Scenario Description:
7.0 Upgrade Scenario

Total Loss
(Thousands of Dollars)

0 to 100,000
100,000 to 200,000
200,000 to 300,000
300,000 to 400,000
400,000 to 500,000
500,000 to 600,000
700,000 to 800,000
800,000 to 900,000
900,000 to 1,000,000

0 2.5 5
Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
December 13, 1999

Building Damage By General Occupancy

December 13, 1999

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Hudson						
Agriculture	131	0.76	1.75	5.91	7.01	9.97
Commercial	118,728	2.04	4.30	16.52	26.62	48.39
Education	2,916	1.84	3.39	12.60	20.43	34.91
Government	1,131	2.04	3.51	14.23	26.89	51.18
Industrial	32,998	1.99	3.63	14.36	26.24	50.64
Religion	3,356	3.18	9.20	21.52	21.74	30.78
Residential	247,502	4.53	15.30	32.11	23.95	23.02
State Average	406,763	2.34	5.87	16.75	21.84	35.56
Study Region Average	406,763	2.34	5.87	16.75	21.84	35.56

Building Damage by Count by General Occupancy

December 13, 1999

	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Hudson						
Agriculture	0	0	0	0	0	0
Commercial	50	85	565	1,203	2,784	4,687
Education	0	1	8	29	76	114
Government	0	0	0	0	5	5
Industrial	14	16	117	297	901	1,345
Religion	1	7	34	49	80	171
Residential	2,592	8,376	16,084	10,233	6,706	43,991
Total State	2,657	8,485	16,808	11,811	10,552	50,313
Study region	2,657	8,485	16,808	11,811	10,552	50,313

Study Region : hud1

Scenario : hudnj7

APPENDIX L

Shear-wave velocity data

Abbreviations are:

gp spc = distance of geophone from source (feet)
pick = arrival time of wave at geophone (milliseconds)
int time = interval travel time between geophone (milliseconds)
int vel = calculated wave velocity between geophone (feet/second)

HARRISON PARK SHEAR WAVE						REGRESSION
gp spc	pick	int time	int vel	**AVG VEL**	slope	**VELOCITY**
0	7.9			ft/sec		ft/sec
6	13.8	5.9	1016.949	**1459.024**	0.715909	**1396.825397**
12	18.6	4.8	1250			
18	23.9	5.3	1132.075			
24	28.7	4.8	1250			
30	32.7	4	1500			
36	37.1	4.4	1363.636			
42	41.7	4.6	1304.348			
48	45.4	3.7	1621.622			
54	49	3.6	1666.667			
60	52.2	3.2	1875			
66	55.1	2.9	2068.966			

HILLSIDE PARK SITE, ON DIRT RD NEAR RR
SHEAR WAVE

	STEEL BEAM SOURCE					**REGRESSION**
gp spc	pick	int time	int vel	**AVG VEL**	SLOPE	**VELOCITY**
0	10.3			ft/sec		ft/sec
6	19.5	9.2	652.17391	**1231.473**	0.846387	**1181.492702**
12	24.8	5.3	1132.0755			
18	29.4	4.6	1304.3478			
24	35.9	6.5	923.07692			
30	41.2	5.3	1132.0755			
36	44.8	3.6	1666.6667			
42	50.3	5.5	1090.9091			
48	54.5	4.2	1428.5714			
54	60.3	5.8	1034.4828			
60	63.6	3.3	1818.1818			
66	68	4.4	1363.6364			
	TRENCH SOURCE					
0	11.9					
6	18.2	6.3	952.38095	**1239.679**	0.838986	**1191.914982**
12	24.4	6.2	967.74194			
18	28.8	4.4	1363.6364			
24	36.1	7.3	821.91781			
30	41.1	5	1200			
36	44.9	3.8	1578.9474			
42	49.7	4.8	1250			
48	54.8	5.1	1176.4706			
54	59.3	4.5	1333.3333			
60	62.2	2.9	2068.9655			
66	68.7	6.5	923.07692			

KENILWORTH PARK ALONG RT 509

P-WAVE

gp spc	pick	int time	int vel.	**AVG VEL**	SLOPE	**REGRESSION VELOCITY**
				ft/sec		ft/sec
0	13.9					
6	18.3	4.4	1363.636364	**3898.331467**	0.28776	**3475.09113**
12	20.9	2.6	2307.692308			
18	23.6	2.7	2222.222222			
24	25.2	1.6	3750			
30	26.6	1.4	4285.714286			
36	28	1.4	4285.714286			
42	30	2	3000			
48	31.2	1.2	5000			
54	32.1	0.9	6666.666667			
60	33.3	1.2	5000			
66	34.5	1.2	5000			

S-WAVE

0	14.5					
6	21.7	7.2	833.3333333	**942.2977481**	1.08153	**924.6187833**
12	28.7	7	857.1428571			
18	33.2	4.5	1333.333333			
24	39.5	6.3	952.3809524			
30	45.6	6.1	983.6065574			
36	53	7.4	810.8108108			
42	58.3	5.3	1132.075472			
48	67	8.7	689.6551724			
54	73.2	6.2	967.7419355			
60	78.7	5.5	1090.909091			
66	87.1	8.4	714.2857143			

BLACK BROOK PARK SHEAR WAVE

gp spc	pick	int time	int vel	**AVG VEL**	slope	**REGRESSION VELOCITY**
0	18			ft/sec		ft/sec
6	31.8	13.8	bad pick	**955.5909**	1.090707	**916.8364512**
12	38.8	7	857.1429			
18	44.4	5.6	1071.429			
24	50.9	6.5	923.0769			
30	56.7	5.8	1034.483			
36	63	6.3	952.381			
42	70.5	7.5	800			
48	77	6.5	923.0769			
54	85.3	8.3	722.8916			
60	90.9	5.6	1071.429			
66	95.9	5	1200			

TETERBORO AIRPORT SHEAR WAVE

gp spc	pick	int time	int vel	AVG VEL	slope	REGRESSION VELOCITY
3	11			ft/sec		ft/sec
6	14.8	6.3	bad pick	**1041.787**	1.005455	**994.5750452**
9	21.1	3	1000			
12	24.1	3.3	909.0909			
15	27.4	2.9	1034.483			
18	30.3	3.1	967.7419			
21	33.4	3.2	937.5			
24	36.6	2.3	1304.348			
27	38.9	3.4	882.3529			
30	42.3	3.4	882.3529			
33	45.7	2.4	1250			
36	48.1	2.4	1250			

MOONACHIE #1 SITE SHEAR WAVE

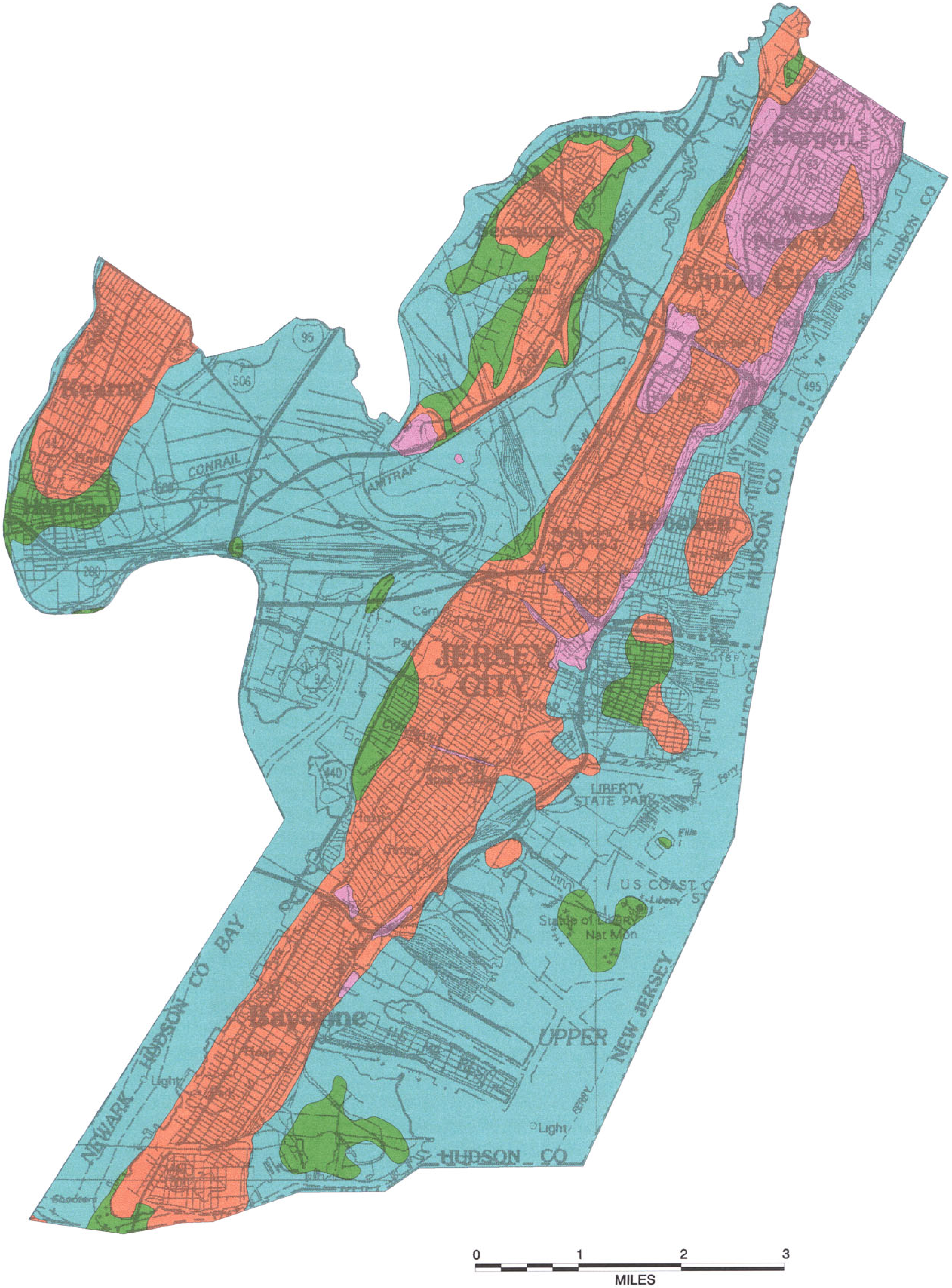
gp spc	pick	int time	int vel	**AVG VEL**	slope	**REGRESSION VELOCITY**
0	10.8			ft/sec		ft/sec
3	18.4	7.6	394.7368	**740.737**	1.417576	**705.4296708**
6	25.4	7	428.5714			
9	29.2	3.8	789.4737			
12	35.7	6.5	461.5385			
15	37.5	1.8	1666.667			
18	42.2	4.7	638.2979			
21	47.3	5.1	588.2353			
24	50.2	2.9	1034.483			
27	54.2	4	750			
30	58.4	4.2	714.2857			
33	62.8	4.4	681.8182			

MOONACHE #2 SITE SHEAR WAVE

gp spc	pick	int time	int vel.	**AVG VEL** ft/sec	slope	**REGRESSION VELOCITY** ft/sec
3	22					
6	24.7	2.7	1111.111	**725.689926**	1.589091	**629.2906178**
9	29.2	4.5	666.6667			
12	33.1	3.9	769.2308			
15	37.7	4.6	652.1739			
18	43.9	6.2	483.871			
21	50.5	6.6	454.5455			
24	55.5	5	600			
27	59.7	4.2	714.2857			
30	63.1	3.4	882.3529			
33	65.9	2.8	1071.429			
36	71.1	5.2	576.9231			

DEKORT SALT MARSH ***P-WAVE***						**REGRESSION**
gp spc	pick	int time	int vel	**AVG VEL**	slope	**VELOCITY**
0	2			ft/sec		ft/sec
6	4.6	2.6	2307.7	**2386.408**	0.4542	**2201.83486**
12	6.6	2	3000			
18	9.2	2.6	2307.7			
24	13.8	4.6	1304.3			
30	15.7	1.9	3157.9			
36	18.3	2.6	2307.7			
42	21	2.7	2222.2			
48	23.2	2.2	2727.3			
54	26	2.8	2142.9			

*NO SHEAR WAVE DATA COULD BE OBTAINED AT THIS SITE



SEISMIC SOIL CLASS MAP

FOR

HUDSON COUNTY, NEW JERSEY

Prepared by Scott D. Stanford, New Jersey Geological Survey

for the

New Jersey State Police, Office of Emergency Management

1999

- Soil Class A--hard rock with less than 10 feet of soil cover. Shear wave velocity greater than 1500 m/s (HAZUS number 1).
- Soil Class C--very dense soil and soft rock. Shear wave velocity between 360 and 760 m/s (HAZUS number 3).
- Soil Class D--stiff soil. Shear wave velocity between 180 and 360 m/s (HAZUS number 4).
- Soil Class E--soft soil. Shear wave velocity less than 180 m/s (HAZUS number 5).

The soil class designations are defined in the 1997 National Earthquake Hazards Reduction Program (NEHRP) Provisions. Soil classes were assigned using Standard Penetration Test data and geologic map data from Stanford (1993, 1995, 1998 a, b) according to the procedures described in sections 4.1.2.1, 4.1.2.2., and 4.1.2.3 of the NEHRP Provisions (Federal Emergency Management Agency, 1998). Equation 4.1.2.3-2 was used to assign soil class in layered cases.

This map shows the extent of natural soils. Man-made fill overlies these soils (particularly soil class E) over much of the county. This fill includes a wide range of materials. The behavior of fill during seismic shaking should be assessed on a site-specific basis.

REFERENCES CITED

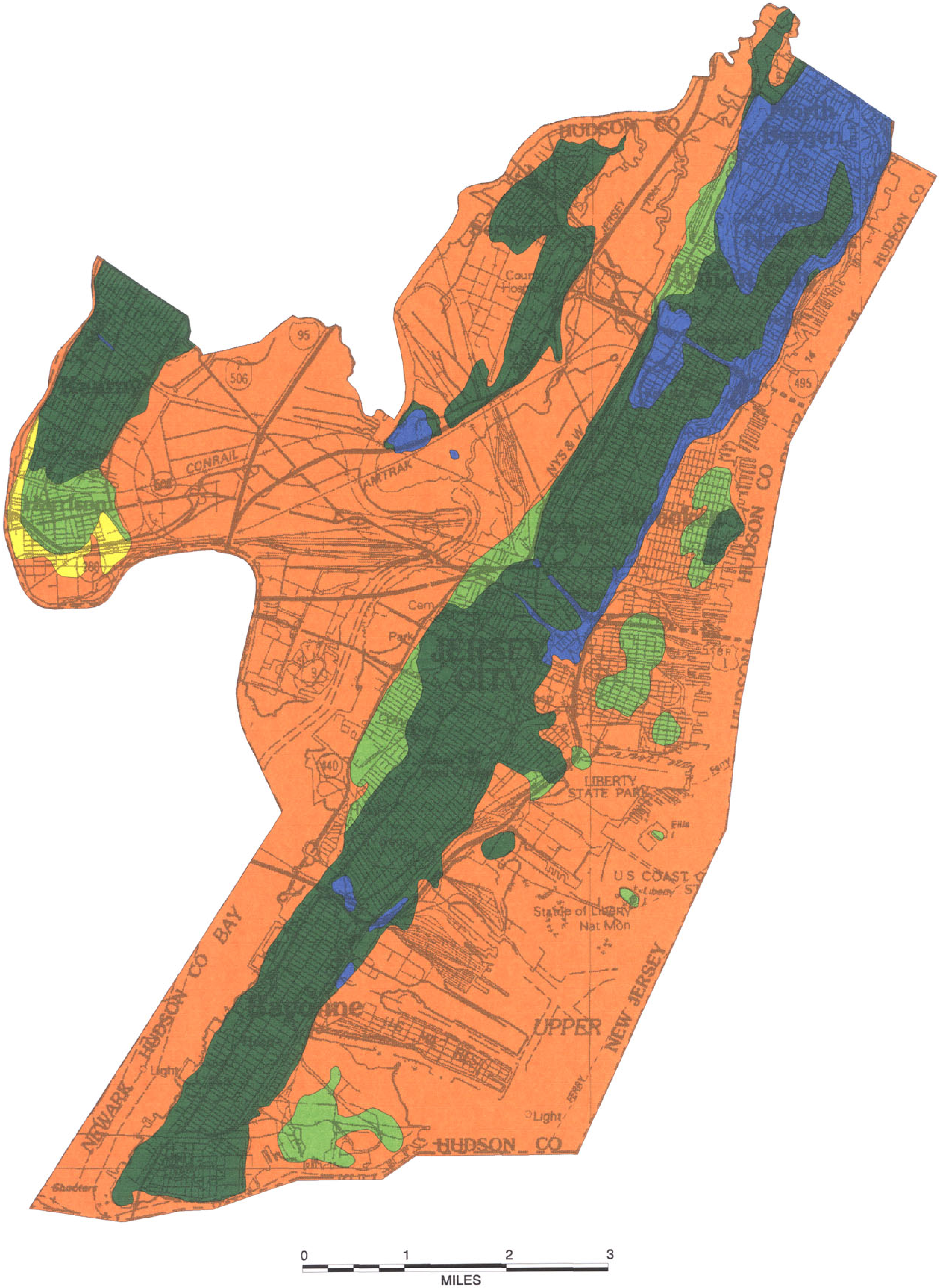
Federal Emergency Management Agency, 1998, NEHRP recommended provisions for seismic regulations for new buildings and other structures, part 1--provisions: prepared by the National Institute of Building Sciences, FEMA 302, p. 33-41.

Stanford, S. D., 1993, Surficial geology of the Weehawken and Central Park quadrangles, Bergen, Hudson, and Passaic counties, New Jersey: N. J. Geological Survey Open File Map 13, scale 1:24,000.

Stanford, S. D., 1995, Surficial geology of the Jersey City quadrangle, Hudson and Essex counties, New Jersey: N. J. Geological Survey Open File Map 20, scale 1:24,000.

Stanford, S. D., 1998a, Surficial geology of the Elizabeth quadrangle, Essex, Hudson, and Union counties, New Jersey: N. J. Geological Survey Open File Map (in review), scale 1:24,000.

Stanford, S. D., 1998b, Surficial geology of the Orange quadrangle, Essex, Passaic, Hudson, and Bergen counties, New Jersey: N. J. Geological Survey Open File Map (in review), scale 1:24,000.



SOIL LIQUEFACTION SUSCEPTIBILITY

FOR

HUDSON COUNTY, NEW JERSEY

Prepared by Scott D. Stanford, New Jersey Geological Survey

for the

New Jersey State Police, Office of Emergency Management

1999

- Category 0--none
- Category 1--very low
- Category 2--low
- Category 3--moderate
- Category 4--high

Categories are from the HAZUS User's Manual, Table 9.1 (National Institute of Building Sciences, 1997). Geologic data are from Stanford (1993, 1995, 1998a, b). Liquefaction susceptibility is based, in part, on soil-saturation and penetration-test data in Stanford (1997).

This map shows the liquefacton susceptiblity of natural soils. Man-made fill overlies these soils (particularly those in Category 4) over much of the county. While most fill has a low liquefaction susceptiblity, uncompacted sand and silt fill may liquefy. The behavior of fill during seismic shaking should be assessed on a site-specific basis.

REFERENCES CITED

National Institute of Building Sciences, 1997, HAZUS user's manual: Washington, D. C., National Institute of Building Sciences Publication 5200.

Stanford, S. D., 1993, Surficial geology of the Weehawken and Central Park quadrangles, Bergen, Hudson, and Passaic counties, New Jersey: N. J. Geological Survey Open File Map 13, scale 1:24,000.

Stanford, S. D., 1995, Surficial geology of the Jersey City quadrangle, Hudson and Essex counties, New Jersey: N. J. Geological Survey Open File Map 20, scale 1:24,000.

Stanford, S. D., 1997, Distribution and thickness of surficial geologic materials subject to potential earthquake-induced ground-shaking amplification and liquefaction in the New Jersey part of the Weehawken and Jersey City quadrangles: report prepared for the U. S. Geological Survey, National Earthquake Hazards Reduction Program, by the N. J. Geological Survey, 8 p.

Stanford, S. D., 1998a, Surficial geology of the Elizabeth quadrangle, Essex, Hudson, and Union counties, New Jersey: N. J. Geological Survey Open File Map (in review), scale 1:24,000.

Stanford, S. D., 1998b, Surficial geology of the Orange quadrangle, Essex, Passaic, Hudson, and Bergen counties, New Jersey: N. J. Geological Survey Open File Map (in review), scale 1:24,000.

LANDSLIDE SUSCEPTIBILITY

OF

HUDSON COUNTY, NEW JERSEY

Prepared by Scott D. Stanford, New Jersey Geological Survey

for the

New Jersey State Police, Office of Emergency Management

1999

None--HAZUS number 0

Landslide Class A I--strongly cemented rock, slope angle 15-20 degrees (HAZUS number 1)

Landslide Class A II--strongly cemented rock, slope angle 20-30 degrees (HAZUS number 2)

Landslide Class A IV--strongly cemented rock, slope angle 30-40 degrees (HAZUS number 5)

Landslide Class B IV--weakly cemented rock and soil, slope angle 15-20 degrees (HAZUS number 4)

Landslide classes are from the HAZUS User's Manual, Table 9.2 (National Institute of Building Sciences, 1997). Slope angles were measured from the following U. S. Geological Survey 7.5 minute quadrangles: Jersey City, Weehawken, Central Park (all with 10 foot contour interval), and Orange (20 foot contour interval). Slope materials were determined in the field (Stanford, 1993, 1995, 1998).

REFERENCES CITED

National Institute of Building Sciences, 1997, HAZUS user's manual: Washington, D. C., National Institute of Building Sciences Publication 5200.

Stanford, S. D., 1993, Surficial geology of the Weehawken and Central Park quadrangles, Bergen, Hudson, and Passaic counties, New Jersey: N. J. Geological Survey Open File Map 13, scale 1:24,000.

Stanford, S. D., 1995, Surficial geology of the Jersey City quadrangle, Hudson and Essex counties, New Jersey: N. J. Geological Survey Open File Map 20, scale 1:24,000.

Stanford, S. D., 1998, Surficial geology of the Orange quadrangle, Essex, Passaic, Hudson, and Bergen counties, New Jersey: N. J. Geological Survey Open File Map (in review), scale 1:24,000.