UPDATE TO FEMA 366: ESTIMATED ANNUALIZED EARTHQUAKE LOSSES FOR THE UNITED STATES

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Briefing at Subcommittee on Disaster Reduction (SDR) meeting

Nov 2, 2017

FEMA nehrp USGS science for a changing world

Outline

- Significance
- Previous Studies… , Why an update?
- Data/Models Enhancements
- Results & Discussion
- Summary

Significance of FEMA 366…

- Improving our understanding of the seismic risk for the Nation,
- Providing a baseline for earthquake policy development, the promotion of risk awareness, and comparison of mitigation actions in high risk local communities,
- Adoption of seismic provisions of building codes,
- Comparing the seismic risk with those due to other natural hazards (e.g., flood, hurricane), and
- Supporting pre-disaster planning for earthquake response and recovery.

Previous Studies…

FEMA 366 (2001)

Hazus 99 Version

- **1996 national seismic hazard maps**
- Loss estimates based on **1990 census** Data
- **1994 building inventory** and occupancy to building type distributions
- Building and content exposure based on square footage from pre-defined regions
- Losses reported in **1994 values of dollars**

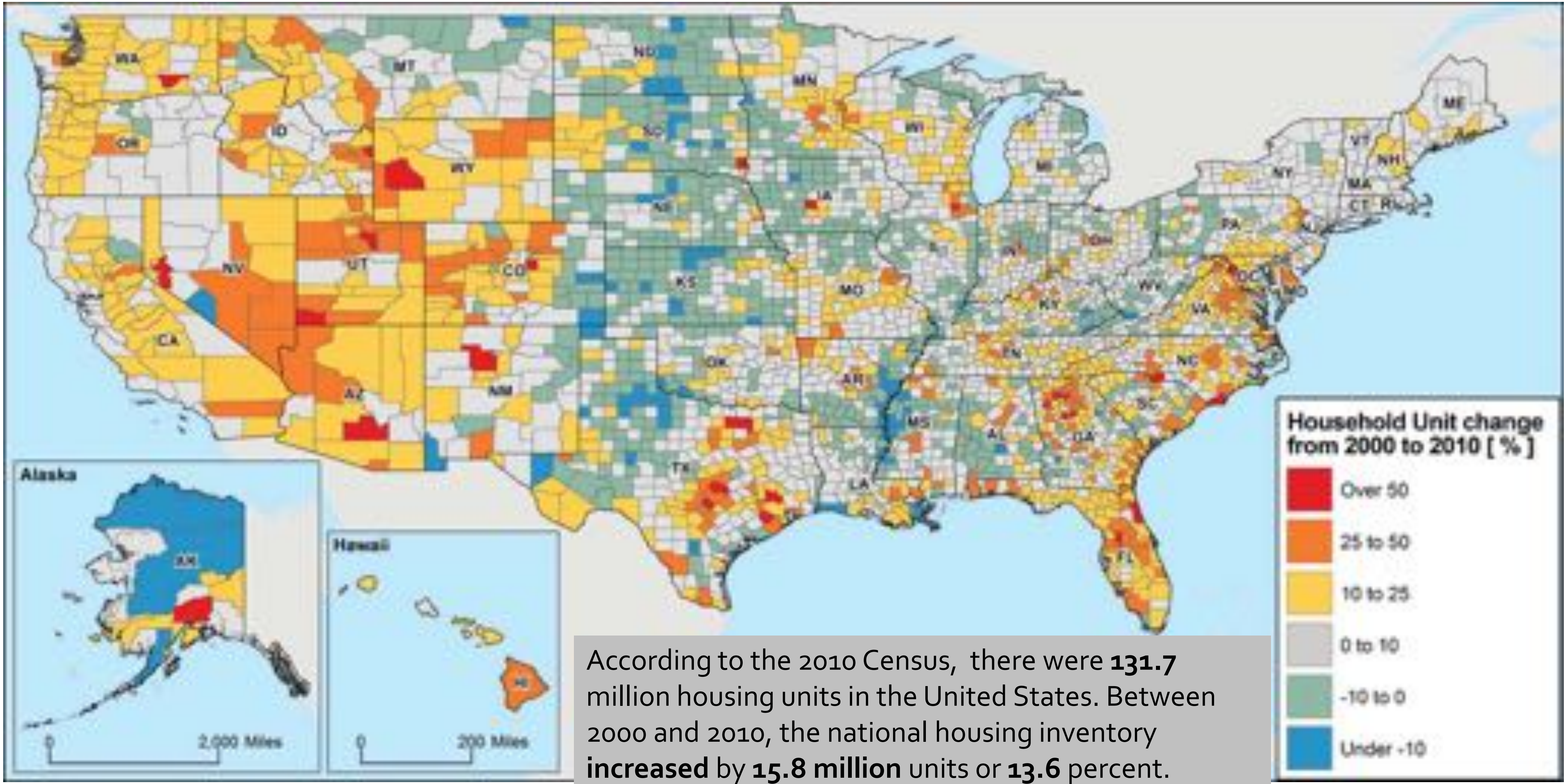
FEMA 366b (2008)

Hazus-MH MR2 Version

- **2002 USGS national seismic hazard maps**
- Loss estimates based on **2000 census** data
- **2002 building inventory** (Dun and Bradstreet) **2005 RS Means**, and updated occupancy to building type distributions
- Building and content exposure based on **general building stock** datasets in the study region.
- Losses reported in **2005 values of dollars**

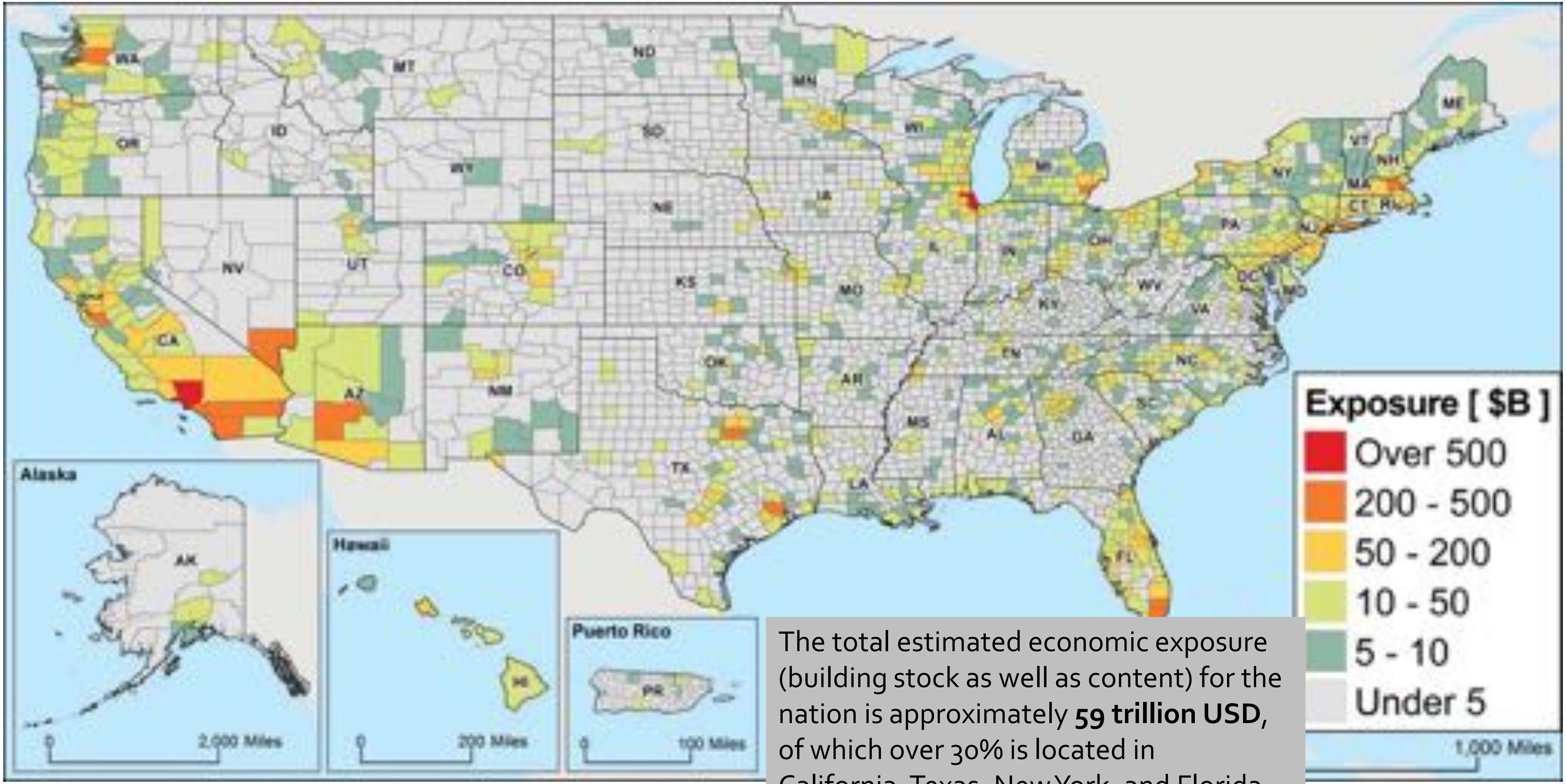
New Data/ Models

- ✓ 2010 Census Data (Population, dwelling counts)
- ✓ 2006 Dun and Bradstreet Commercial Inventory Data
- ✓ 2014 R.S. Means Costs Data
- ✓ 2014 USGS National Seismic Hazard Models (2017 1- Yr Forecast Maps were **not** used!)
- ✓ Site Soil Characterization



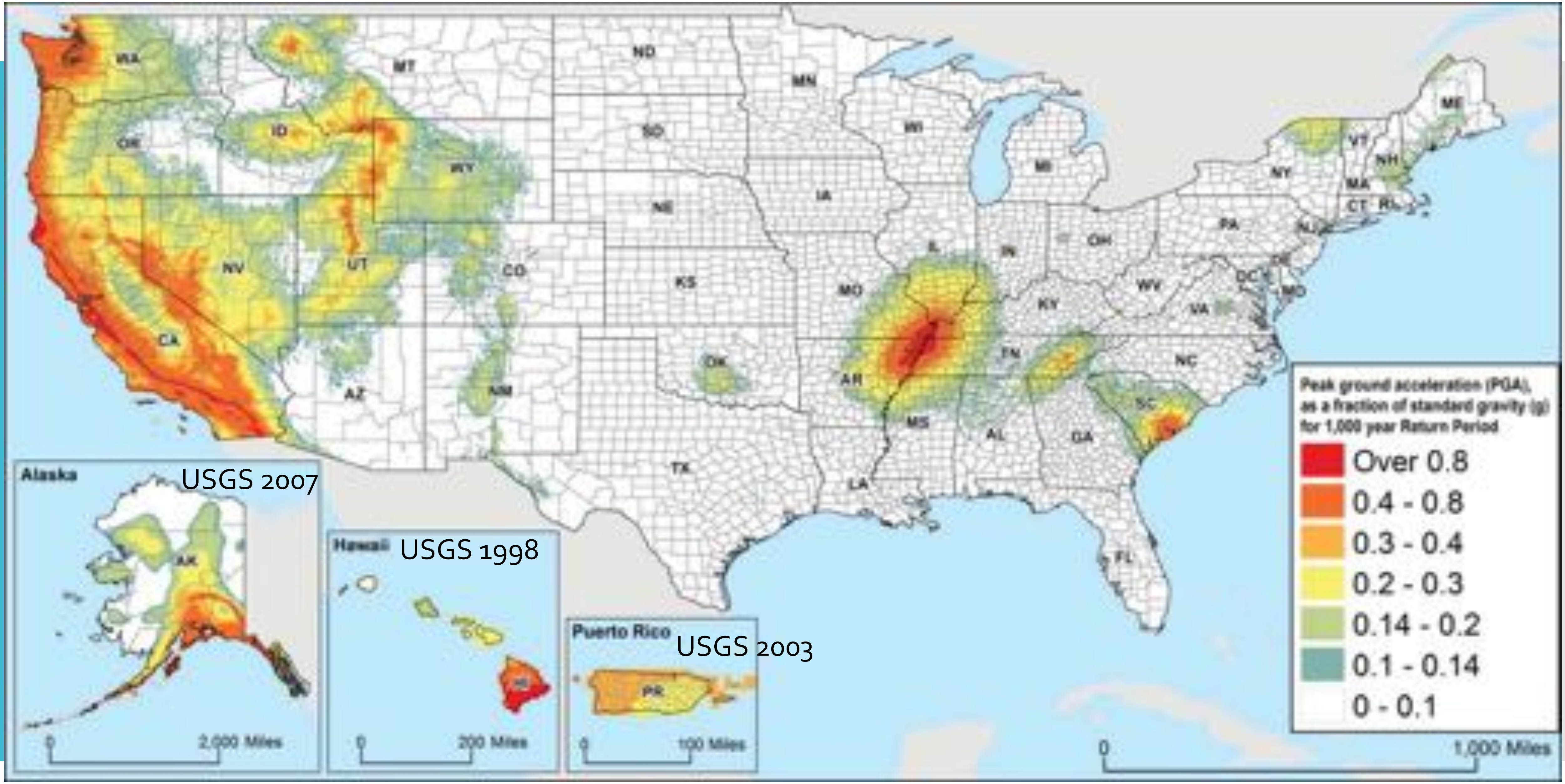
According to the 2010 Census, there were **131.7** million housing units in the United States. Between 2000 and 2010, the national housing inventory **increased** by **15.8 million** units or **13.6** percent.

Comparison of Household Population Demographics between 2000 and 2010

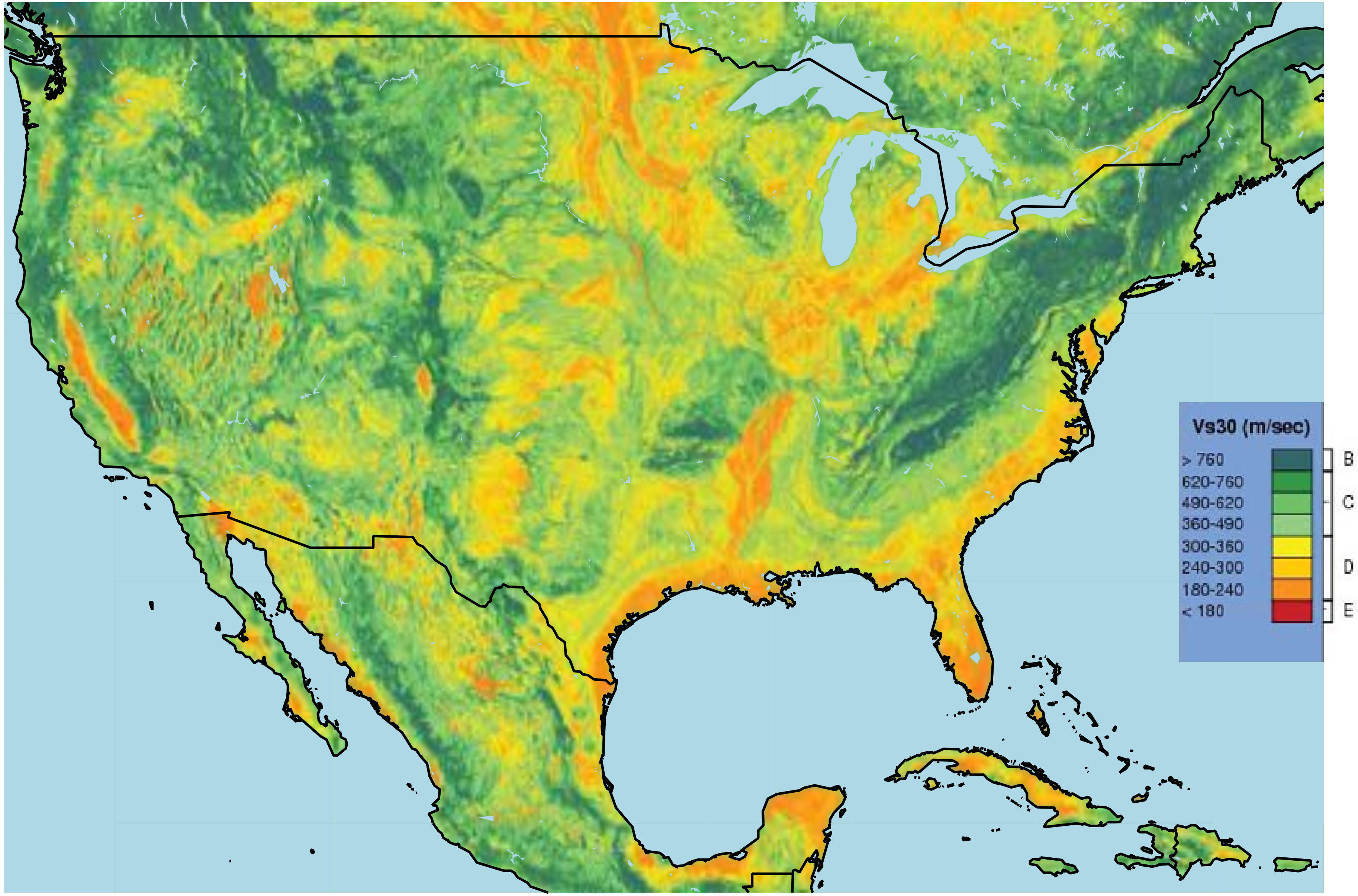


The total estimated economic exposure (building stock as well as content) for the nation is approximately **59 trillion USD**, of which over 30% is located in California, Texas, New York, and Florida.

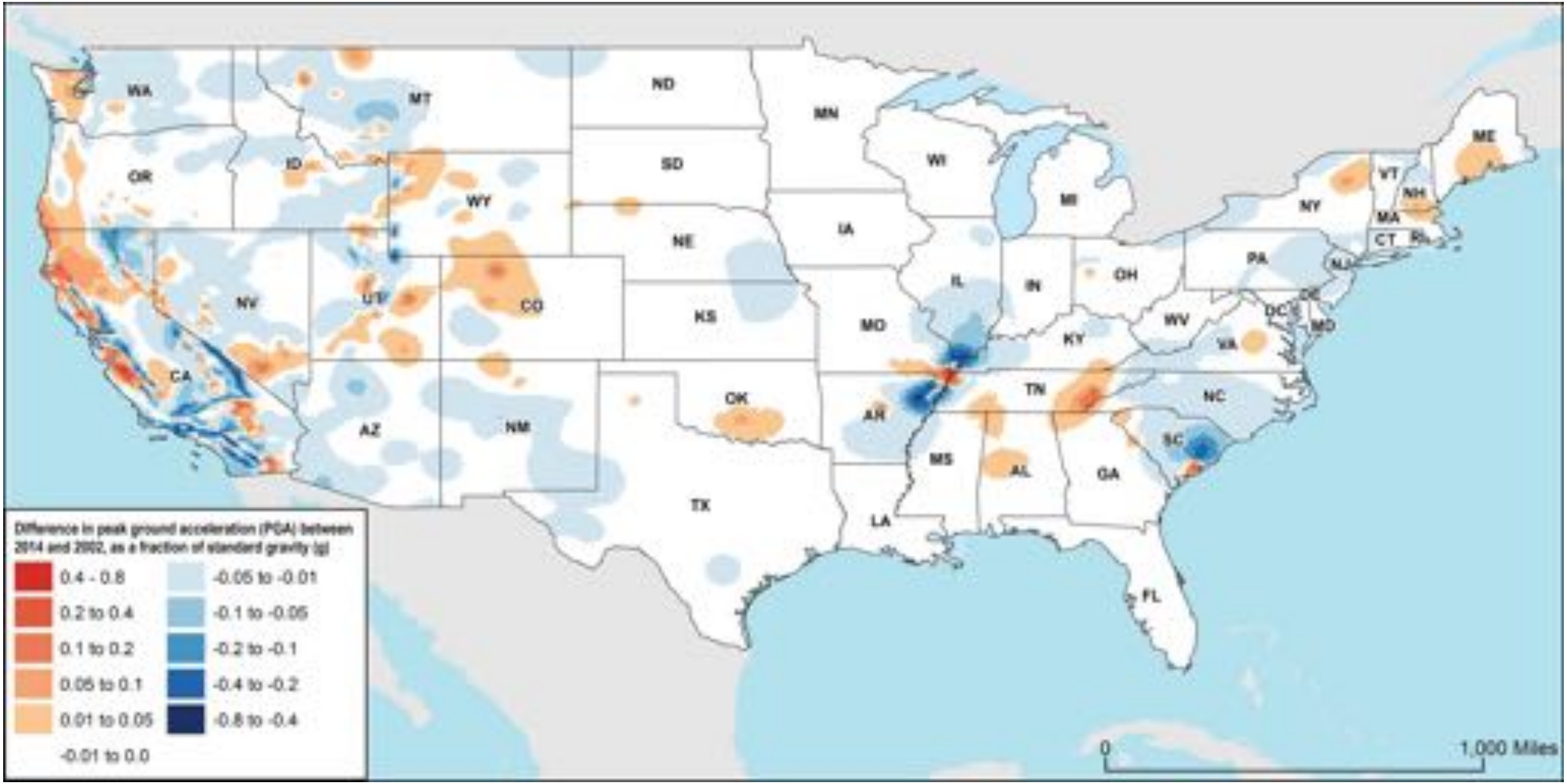
Replacement Value (2014 U.S. dollars) of Hazus 3.0 Building Inventory by County



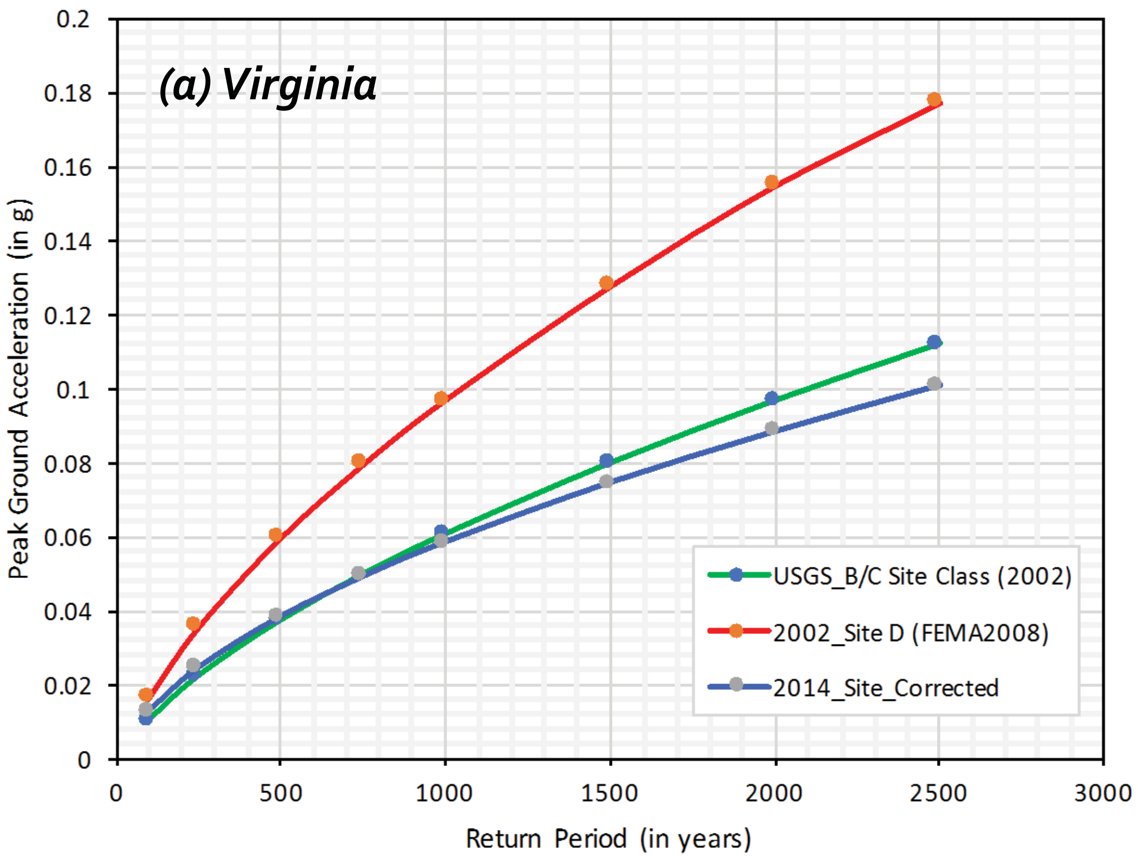
USGS 2014 Site-Corrected Seismic Hazard Map in terms of Peak Ground Acceleration for the 1000-year Return Period



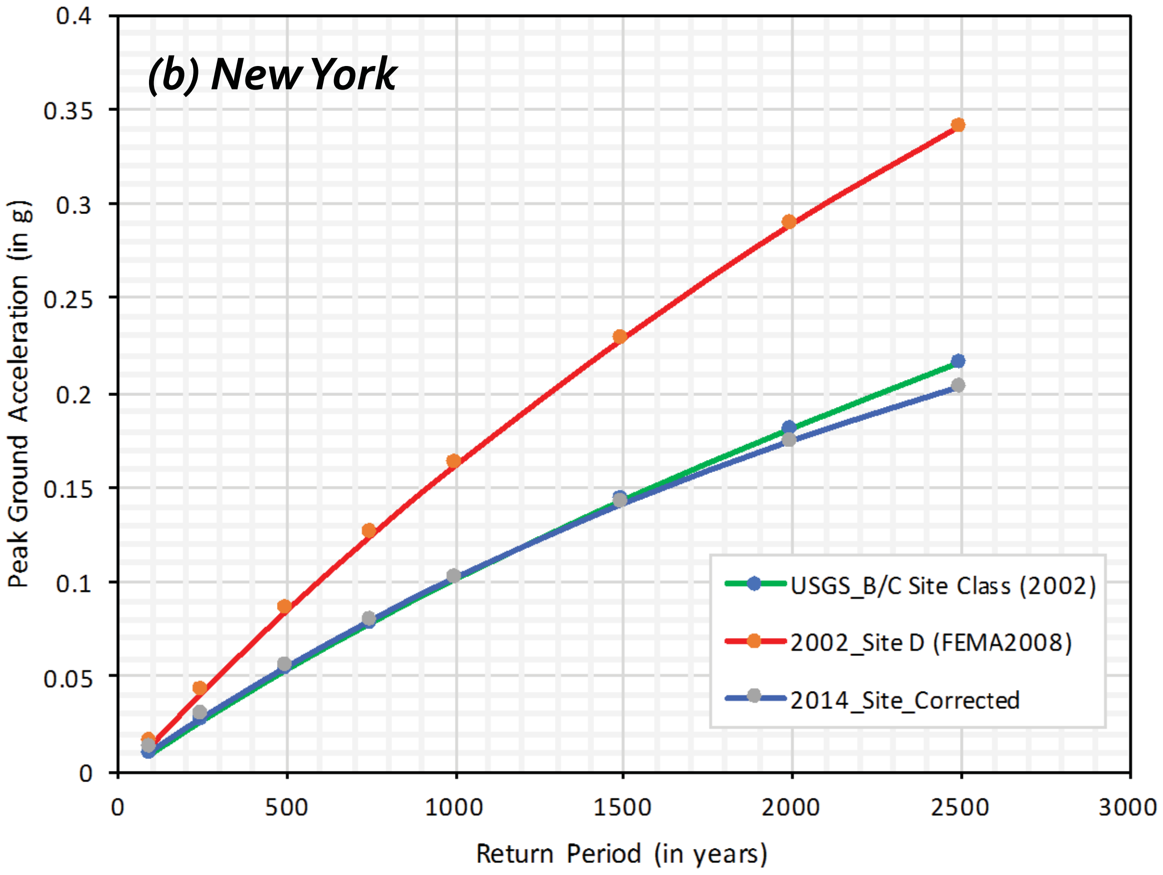
Site categorization using Global topo-based Vs30 approximation obtained using the USGS Global Vs30 Model (https://earthquake.usgs.gov/data/vs30/)



Difference in ground motions between [2014] and [2002] USGS seismic hazard model for the 1,000-year return period *(a) 42.00° N, 72.00° W; Vs30 ~ 770 m/s (Rock); Site Class B-C*

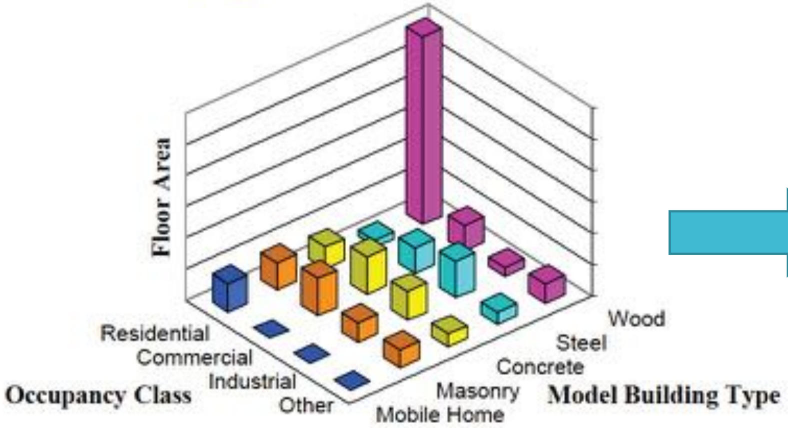


(b) 40.70° N, 74.00° W; Vs30 ~ 600 m/s (Rock); Site Class B-C



Comparison of the hazard curves for locations in (a) Virginia and (b) New York using 2002 and 2014 USGS National Seismic Hazard Model (NSHM).

FEMA/NIBS Earthquake Loss Methodology



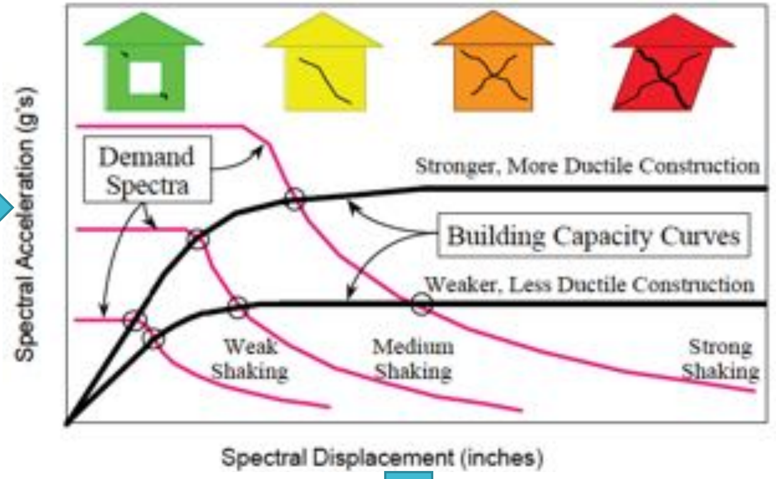
1. Classification of MBT

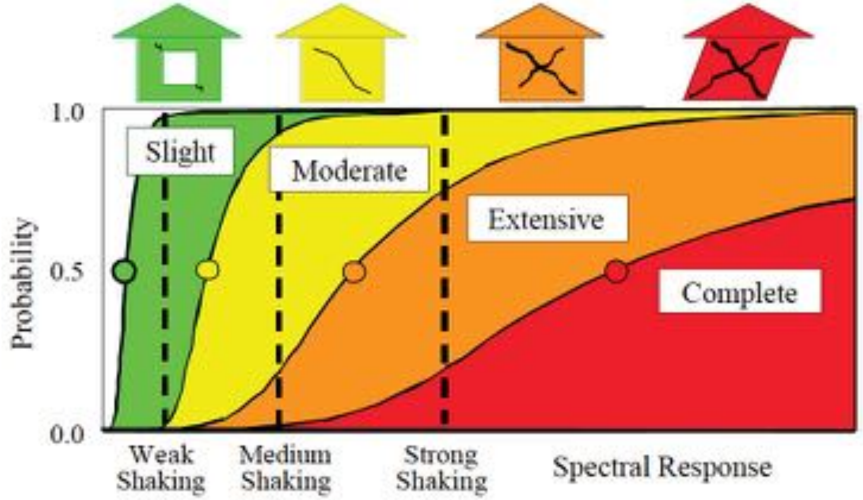
UBC Seismic Zone (NEHRP Map Area)	Design Vintage		
	Post-1975	1941 - 1975	Pre-1941
Zone 4 (MA 7)	High-Code	Moderate-Code	Pre-Code[1]
Zone 3 (MA 6)	Moderate-Code	Moderate-Code	Pre-Code[1]
Zone 2B (MA 5)	Moderate-Code	Low-Code	Pre-Code[2]
Zone 2A (MA 4)	Low-Code	Low-Code	Pre-Code[2]
Zone 1 (MA 2/3)	Low-Code	Pre-Code[2]	Pre-Code[2]
Zone 0 (MA 1)	Pre-Code[2]	Pre-Code[2]	Pre-Code[2]

Construction Quality	Seismic Design Level			
	High-Code	Moderate-Code	Low-Code	None
Superior	Special[1]	High-Code	Moderate-Code	Low-Code
Ordinary	High-Code	Moderate-Code	Low-Code	Pre-Code
Inferior	Moderate-Code	Low-Code	Pre-Code	Pre-Code

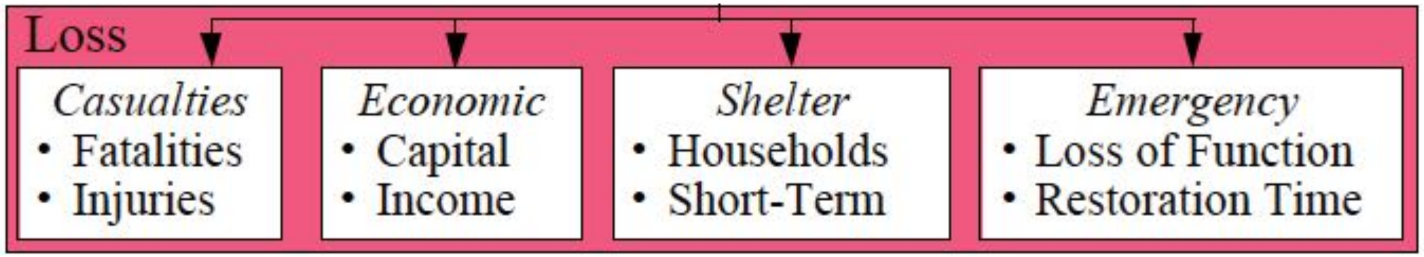
2. Exposure Mapping Schemes

3. Structural Analysis



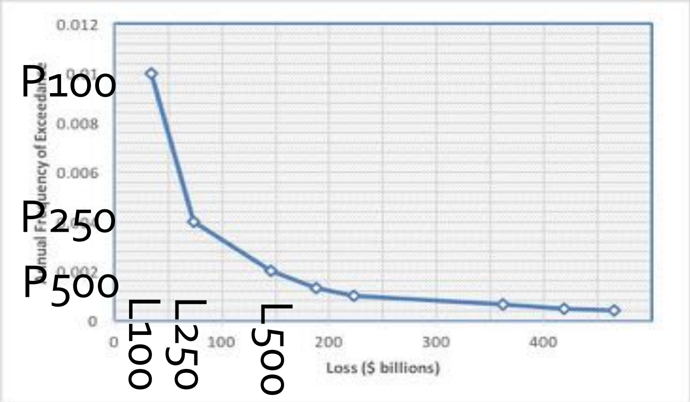


4. Damage and Loss Analysis



5. Loss Metric

Methodology

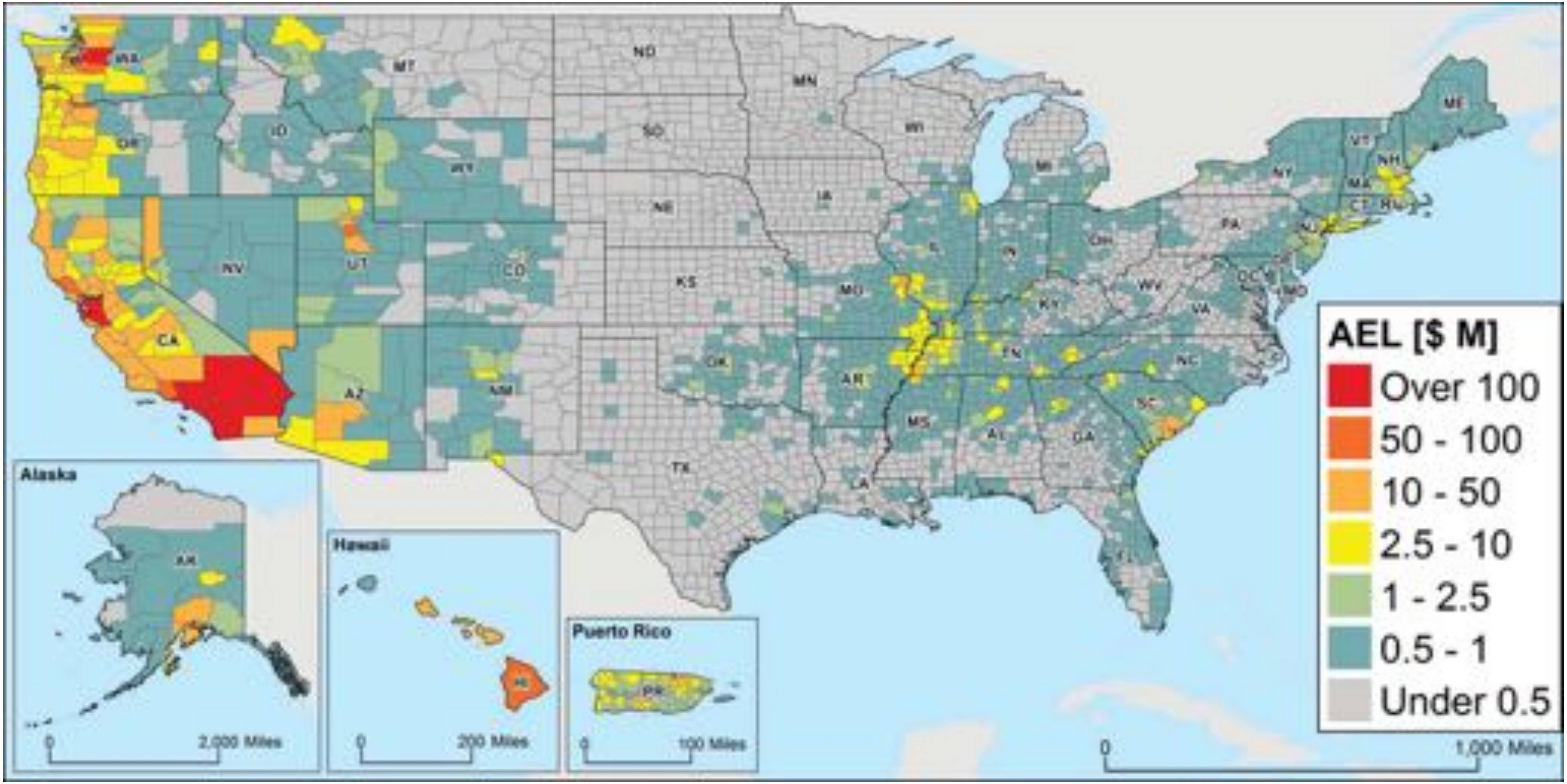


- Step 1: Compute the PGA, SA@0.3 and SA@1.0 at each grid point for the eight return periods
- Step 2: Modify the PGA, SA@0.3 and SA@1.0 at each grid point to represent site-soil conditions
- Step 3: Compute the PGA, SA@0.3 and SA@1.0 at each census tract centroid for the eight return periods
- Step 4: Hazus computes annual losses for eight probabilistic return periods

#	Return Period	Annual Probabilities	Differential Probabilities		Annual Losses	Average Losses	Annualized Loss
			Formula	Values			
1	2500	0.00040	P2500	0.00040	L2500	L2500	P2500 x L2500
2	2000	0.00050	P2000 - P2500	0.00010	L2000	(L2500+L2000)/2	(P2000 - P2500) x (L2500+L2000)/2
3	1500	0.00067	P1500 - P2000	0.00017	L1500	(L2000+L1500)/2	(P1500 - P2000) x (L2000+L1500)/2
4	1000	0.00100	P1000 - P1500	0.00033	L1000	(L1500+L1000)/2	(P1000 - P1500) x (L1500+L1000)/2
5	750	0.00133	P750 - P1000	0.00033	L750	(L750+L1000)/2	(P750 - P1000) x (L750+L1000)/2
6	500	0.00200	P500 - P750	0.00067	L500	(L750+L500)/2	(P500 - P550) x (L750+L500)/2
7	250	0.00400	P250 - P500	0.00200	L250	(L250+L500)/2	(P250 - P500) x (L250+L500)/2
8	100	0.01000	P100 - P250	0.00600	L100	(L100+L250)/2	(P100 - P250) x (L100+L250)/2
							Σ ( )

Assumption: The losses associated with ground motion with return periods **greater than 2,500 years** were assumed to be no worse than the losses for a 2,500-year event as per the AEL computation engine implemented within Hazus. Similarly the losses for ground motion with **less than a 100-year** return period were assumed to be generally small enough to be negligible

Some Results…



We estimate a national AEL of $6.1 billion (2014 dollars), which also includes the losses estimated for Puerto Rico. The new estimate (w.o. Puerto Rico) is $5.8 billion which reflect a 10% increase over the 2008 FEMA 366 estimate of $5.3 billion (2005 $).

#	Metropolitan Areas with AEL over 10 million.	#		#		#	
1	Aguadilla-Isabela, PR	15	Evansville, IN-KY	29	Oxnard-Thousand Oaks-Ventura, CA	43	San Francisco-Oakland-Hayward, CA
2	Albuquerque, NM	16	Fresno, CA	30	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	44	San Germain, PR
3	Anchorage, AK	17	Kahului-Wailuku-Lahaina, HI	31	Phoenix-Mesa-Scottsdale, AZ	45	San Jose-Sunnyvale-Santa Clara, CA
4	Arecibo, PR	18	Knoxville, TN	32	Ponce, PR	46	San Juan-Carolina-Caguas, PR
5	Atlanta-Sandy Springs-Roswell, GA	19	Las Vegas-Henderson-Paradise, NV	33	Portland-Vancouver-Hillsboro, OR-WA	47	San Luis Obispo-Paso Robles-Arroyo Grande, CA
6	Bakersfield, CA	20	Little Rock-North Little Rock-Conway, AR	34	Provo-Orem, UT	48	Santa Cruz-Watsonville, CA
7	Bellingham, WA	21	Los Angeles-Long Beach-Anaheim, CA	35	Redding, CA	49	Santa Maria-Santa Barbara, CA
8	Boston-Cambridge-Newton, MA-NH	22	Memphis, TN-MS-AR	36	Reno, NV	50	Santa Rosa, CA
9	Bremerton-Silverdale, WA	23	Modesto, CA	37	Riverside-San Bernardino-Ontario, CA	51	Seattle-Tacoma-Bellevue, WA
10	Charleston-North Charleston, SC	24	Napa, CA	38	Sacramento--Roseville--Arden-Arcade, CA	52	St. Louis, MO-IL
11	Chicago-Naperville-Elgin, IL-IN-WI	25	Nashville-Davidson--Murfreesboro--Franklin, TN	39	Salem, OR	53	Stockton-Lodi, CA
12	Chico, CA	26	New York-Newark-Jersey City, NY-NJ-PA	40	Salinas, CA	54	Urban Honolulu, HI
13	El Centro, CA	27	Ogden-Clearfield, UT	41	Salt Lake City, UT	55	Vallejo-Fairfield, CA
14	Eugene, OR	28	Olympia-Tumwater, WA	42	San Diego-Carlsbad, CA		

More than 60% of the annualized losses in California are contributed by the three metropolitan areas of **San Francisco, Los Angeles and San Diego**.

Row Labels	Sum of AEL_1mil
Los Angeles-Long Beach-Anaheim, CA	1,352.9
San Francisco-Oakland-Hayward, CA	794.2
Riverside-San Bernardino-Ontario, CA	414.9
San Jose-Sunnyvale-Santa Clara, CA	342.8
Seattle-Tacoma-Bellevue, WA	284.2
Portland-Vancouver-Hillsboro, OR-WA	168.5
San Juan-Carolina-Caguas, PR	157.8
San Diego-Carlsbad, CA	132.4
Oxnard-Thousand Oaks-Ventura, CA	84.4
Santa Rosa, CA	75.9
Charleston-North Charleston, SC	74.7
Sacramento--Roseville--Arden-Arcade, CA	71.2
New York-Newark-Jersey City, NY-NJ-PA	70.1
Anchorage, AK	69.2
Salt Lake City, UT	65.5
Memphis, TN-MS-AR	64.4
St. Louis, MO-IL	60.7

#	Metropolitan Areas with AEL over 10 million.	#		#		#	
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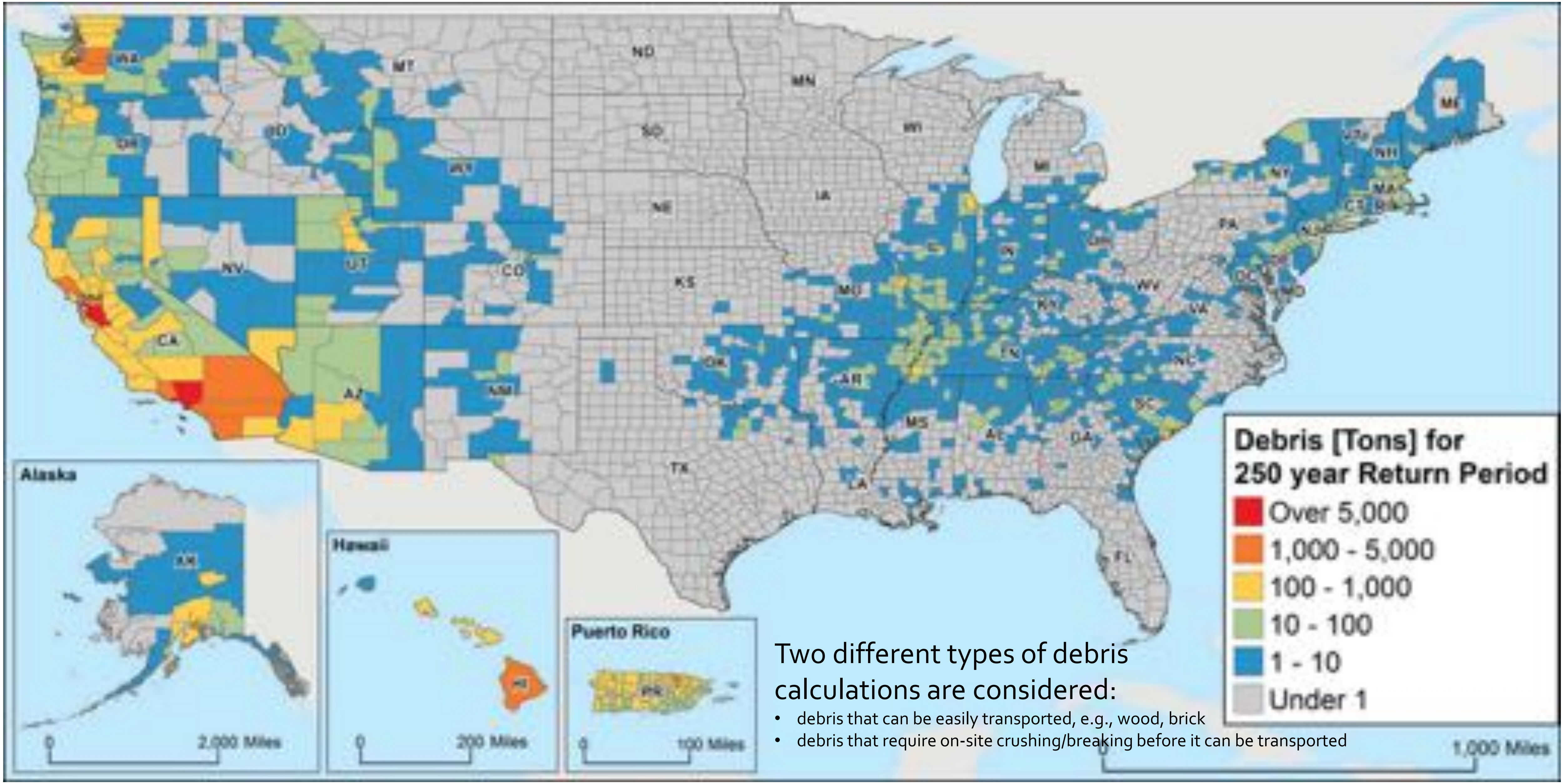
Annualized Earthquake Loss Ratio (AELR) expresses estimated annualized loss as a fraction of the building inventory replacement value

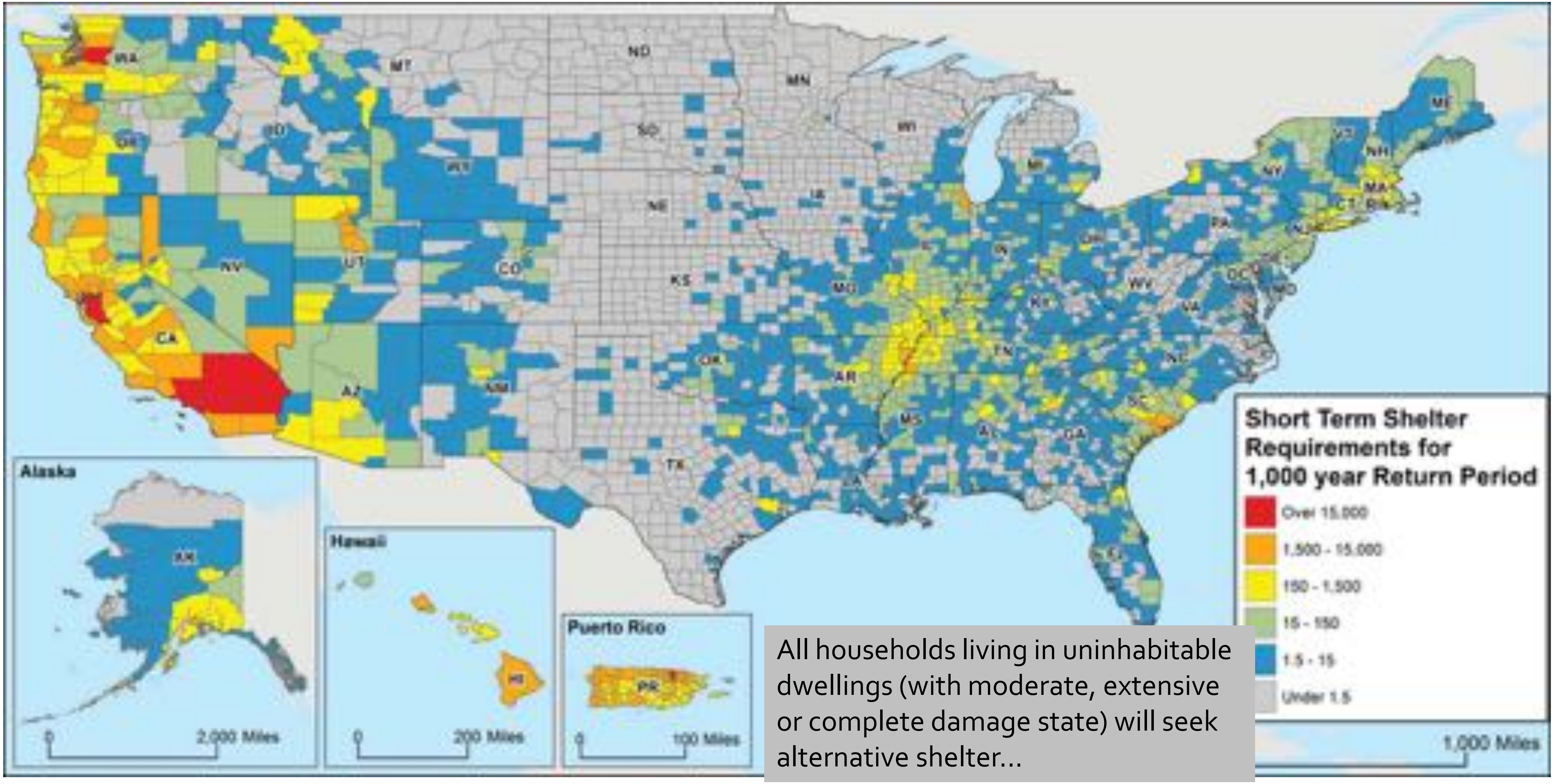
Row Labels	SUM_AELR_ $ per Million
El Centro, CA	2,043.8
San Jose-Sunnyvale-Santa Clara, CA	1,594.5
Anchorage, AK	1,477.5
San Francisco-Oakland-Hayward, CA	1,437.3
San Germán, PR	1,328.8
Aguadilla-Isabela, PR	1,316.6
Santa Cruz-Watsonville, CA	1,284.0
Napa, CA	1,273.6
Santa Rosa, CA	1,258.3
Arecibo, PR	1,142.0
Riverside-San Bernardino-Ontario, CA	1,090.0
Los Angeles-Long Beach-Anaheim, CA	1,054.2
San Juan-Carolina-Caguas, PR	1,050.2
Ponce, PR	1,033.6
Vallejo-Fairfield, CA	982.5
Charleston-North Charleston, SC	977.1
Salinas, CA	960.5



Two different types of debris calculations are considered:

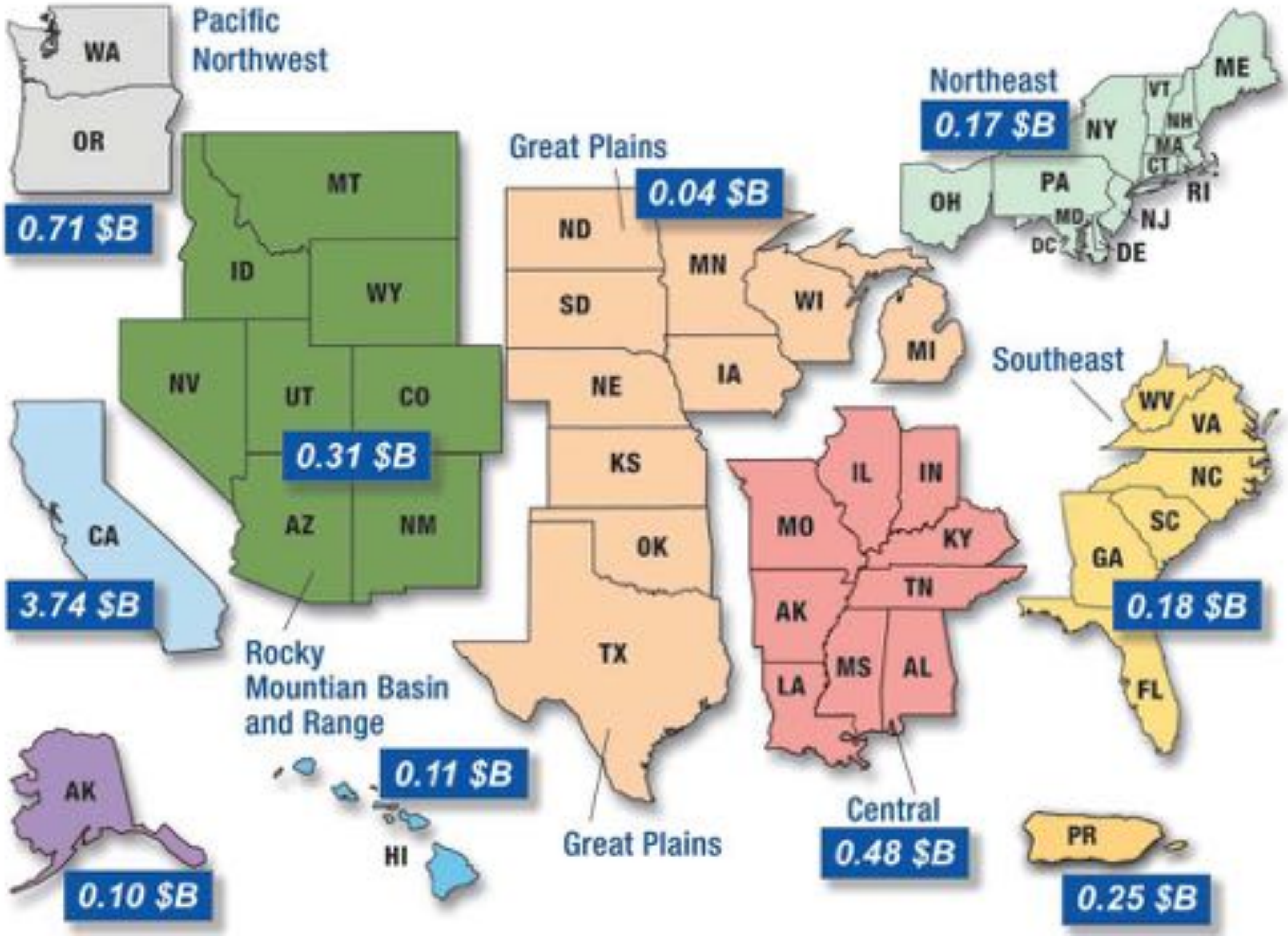
- debris that can be easily transported, e.g., wood, brick
- debris that require on-site crushing/breaking before it can be transported

Estimates of Debris Generated for 250 Year Return Period



All households living in uninhabitable dwellings (with moderate, extensive or complete damage state) will seek alternative shelter…

Estimates of shelter requirements for 1000-year return period



Distribution of Average Annualized Earthquake Loss by Seismic Region

Summary

- Annualized earthquake loss (AEL) to the national building stock is **$6.1 billion** per year
- The majority of average annual loss **61 percent** ($3.7 billion per year) is concentrated in the State of California and overall, the west coast (California, Oregon, and Washington) accounts for **73 percent** of the total average estimated annual loss in U.S.
- **Fifty-five** metropolitan areas, led by the Los Angeles and San Francisco Bay areas, account for **80 percent** of the total estimated annualized earthquake loss (AEL).
- The study highlight the needs to improve **site soil hazard categorization** and **building exposure data.** This is key to identifying and implementing realistic public and private mitigation activities.

Some Open Questions…

- **Detailed site-specific probabilistic risk estimates are necessary for improving assessments on retrofit priorities (i.e., detailed structure-specific information, site soil characterization, improved vulnerability/fragility models).**
- **Default Hazus GBS Inventory and Exposure data ($) requires constant improvement.**
- **Losses to Non-building Infrastructure such as Transportation (Roads, Bridges, Tunnels, Airports), Utility (water, sewer, electric), Telecommunication/Cyber infrastructure facilities are not included.**
- **A comprehensive assessment on "Earthquake Losses to the Nation's Infrastructure" is needed to help prioritize future infrastructure investments. Assets that are deemed as structurally deficient* (undergone deterioration and require significant maintenance) and are located at high hazard areas are at highest risk.**

* https://www.fhwa.dot.gov/policy/2015cpr/pdfs/2015cpr.pdf

FEMA/USGS Hazus Earthquake Analysis on the Nation’s Infrastructure Study - 2018

ASCE U.S. Infrastructure Report Card*

- ASCE Infrastructure Report Card Ranks the U.S. Infrastructure at D+ (Note: it does not account for risk to natural hazards!!)
- A comprehensive “Hazus Earthquake Analysis on the Nations Infrastructure” study could provide actionable information on the infrastructure elements at greatest risk of collapse/damage during an earthquake.
- The analysis could help target mitigation investments to those infrastructure elements that are at greatest risk.

* https://www.infrastructurereportcard.org/americas-grades/

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https://tinyurl.com/FEMAP366


Hazus®
Estimated Annualized Earthquake Losses for the United States

FEMA 366 - April 2017

FEMA nehrp USGS

Thank you!

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UPDATE TO FEMA HAZUS HURRICANE WIND MODEL - PUERTO RICO

Jesse Rozelle (FEMA), Casey Zuzak (FEMA)

Hazus Hurricane Wind Model Loss Estimation Capabilities

Direct Damage

- General Building Stock
- Essential Facilities

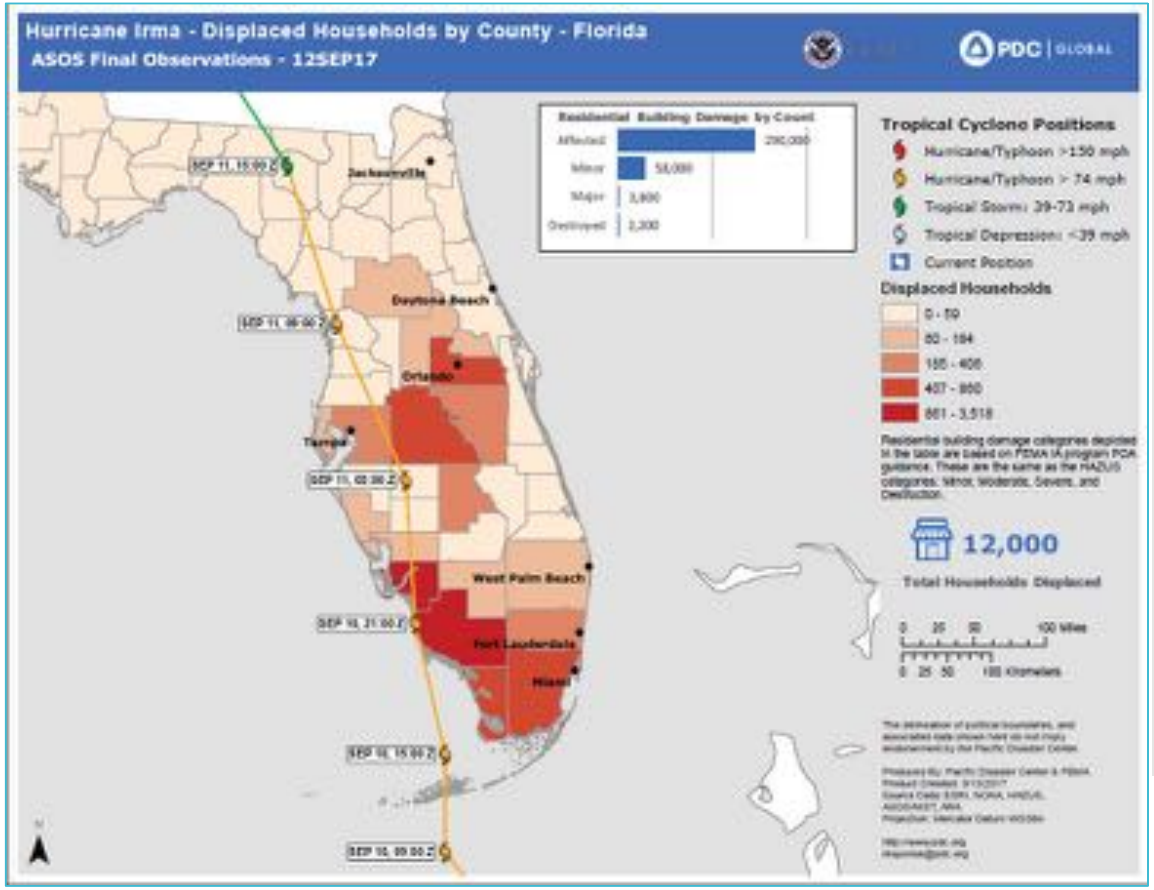
Induced Damage

- Debris Generation

Direct Losses

- Cost of Repair
- Income Loss
- Shelter Needs

Hazus model currently only capable of flood and earthquake loss estimation in Puerto Rico



Next Steps for Adding Hazus Hurricane Wind Capability for Puerto Rico

Work Completed in 2012 (FEMA Region 2 and Puerto Rico Planning Board

- Hurricane Wind Parameters
  - Tree stem estimates
  - Surface roughness
  - Historic tracks
- Built Environment Information
  - Critical facility locations
  - General building stock updates
  - Parcel database integration

Future Work Planned for Complete Integration of Hazus Wind for PR

- Update General Building Stock Information from 2000 to 2010 census
- Add Probabilistic Storms Capability
- Develop Puerto Rico Specific Wind Damage Functions
- Develop Puerto Rico Specific Model Building Types

Questions?

Thank you!

https://www.fema.gov/hazus

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