FEMA's Hazus Earthquake Modeling

Earthquake Model Data Updates, Methodology Improvements, and Risk Communication

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FEMA

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What is Hazus?

FEMA's Hazus Program provides authoritative **data, tools, methods, and guidance** for risk assessment and communication to the **emergency management community.**

Our mission *is to provide a nationally applicable, standardized methodology for estimating damages and economic loss from natural hazards.*

Our vision *is bringing together experts to drive natural hazard resilience in every community.*

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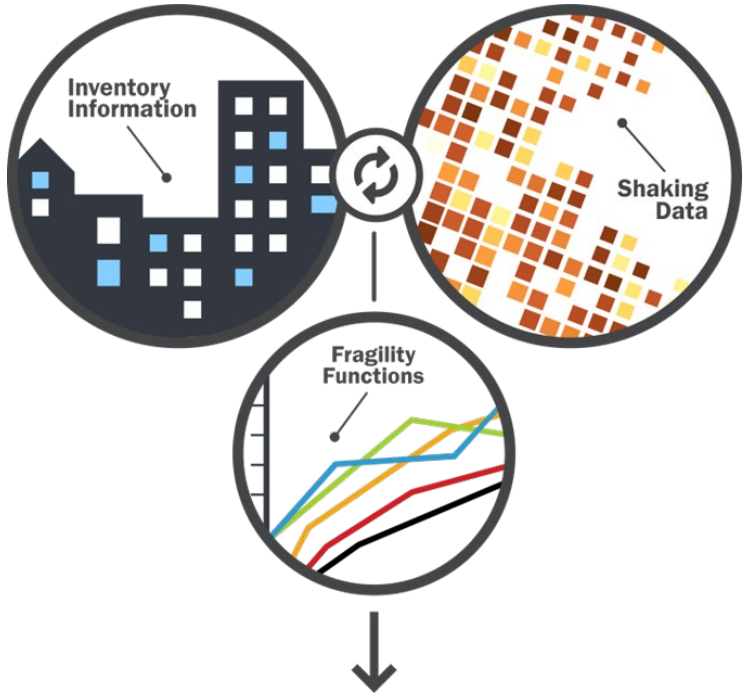
Hazus Earthquake Model

The Hazus Earthquake Model was initially developed in 1997 and continues to evolve through Hazus Program partnerships with seismic experts and engineers.

Partnerships | USGS • NEHRP • EERI • CalOES



Economic Loss, Building Damages, Shelter/Evacuation Needs, Essential Facility Damages, Debris Generation, Infrastructure Damages, Casualties

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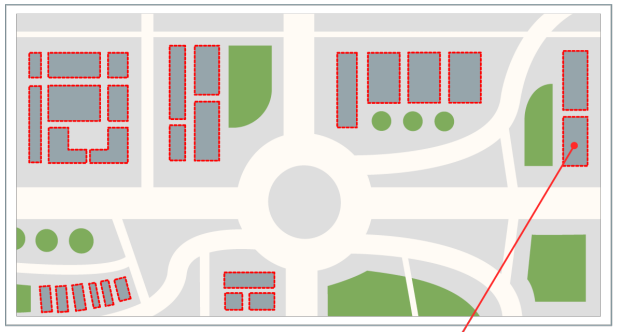
Hazus Inventory Data



Building Vulnerability Attributes

Occupancy Type	Residential	*All Hazards*
Area	2100 SQFT	
Replacement Cost	275K	
Year Built	1984	
Foundation Type	Basement	*Flood*
First Floor Height	4 FT	
Number of Stories	3	
Construction Type	Masonry	*Earthquake*
Seismic Design	High	
Wind Design	Roof Straps + Shutters	*Hurricane*

Risk modeling requires information about the **vulnerability of assets** exposed to natural hazards. Vulnerability attributes drive disaster impacts and **potential mitigation strategies.**

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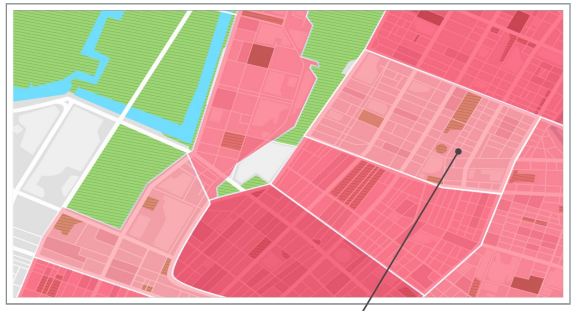
Hazus General Building Stock (GBS)



Census Block: 356 Buildings

30% Residential, 20% Commercial, 10% Industrial

Occupancy Type	Residential	*All Hazards*
Median Year Built	1984	
Replacement Cost	$104/SQFT	
Foundation Type	Basement **25%**, Slab **20%**, Pile **50%**	*Flood*
First Floor Height	4 FT **50%**, 2 FT **20%**	
Number of Stories	3 **30%**, 2 **20%**, 1 **50%**	
Construction Type	Masonry **50%**, Wood **40%**	*Earthquake*
Seismic Design	High	
Wind Design	Roof Straps + Shutters **50%**, No Straps **40%**	*Hurricane*

The Hazus Program provides a nationwide database of **estimated building characteristics,** summarized at the census block level, to facilitate baseline risk assessment in communities without building-level inventory data.

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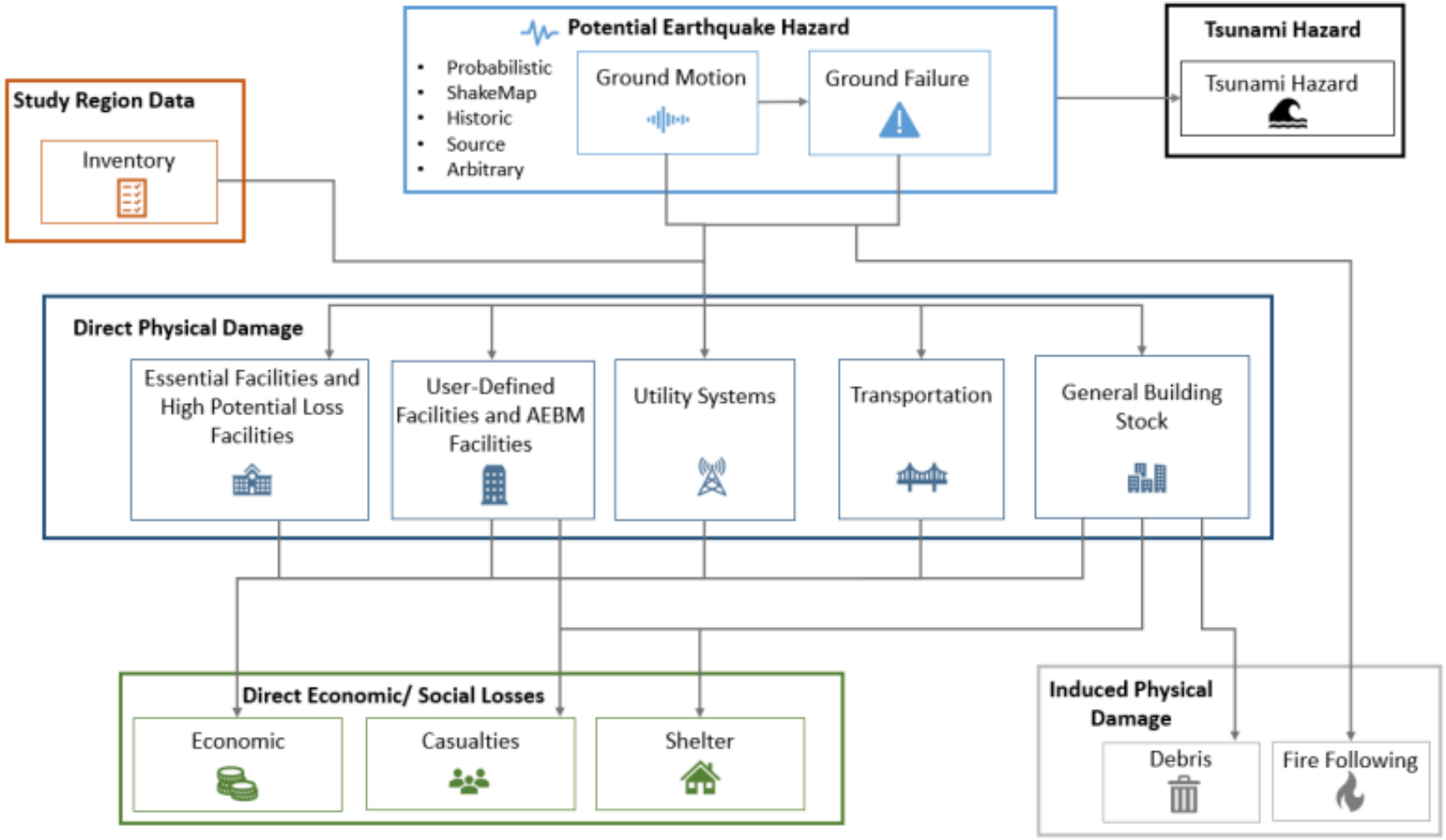
Hazus Earthquake Model Methodology



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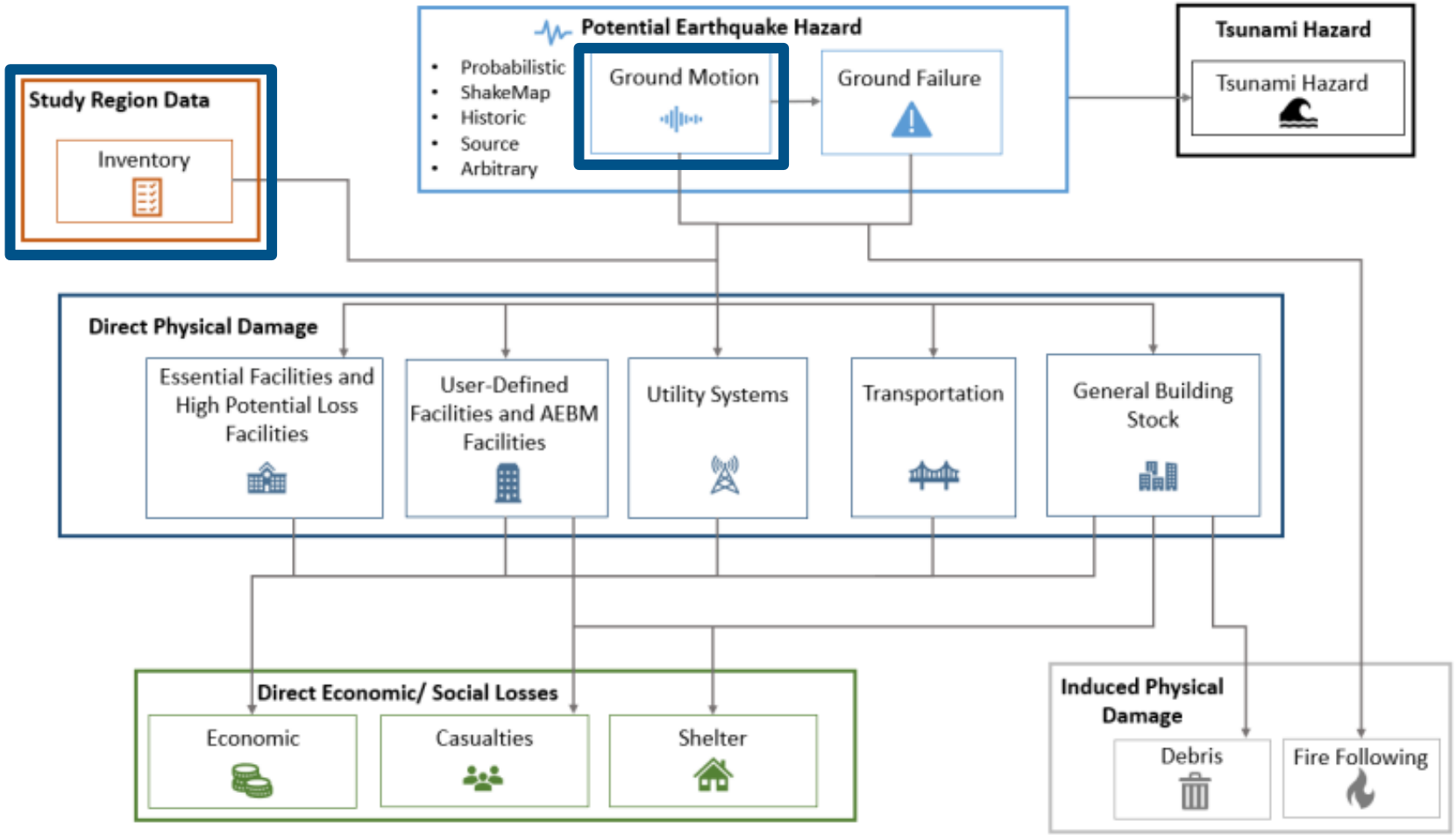
Hazus 6.0 Earthquake Model Data Updates



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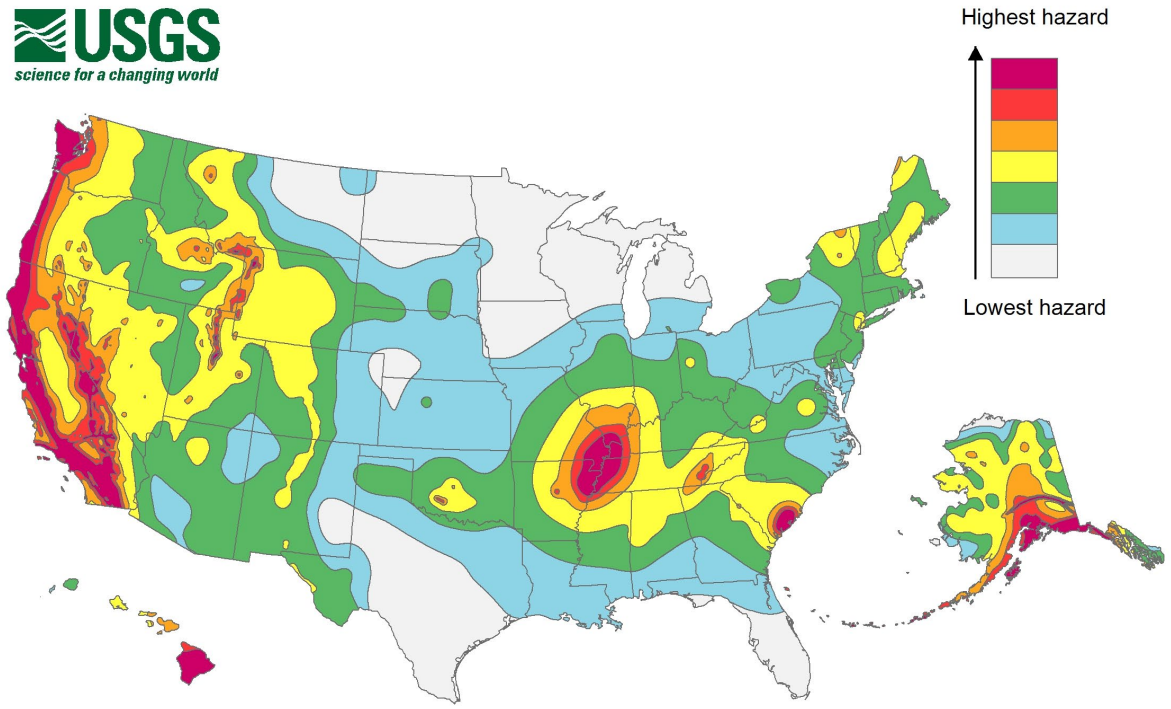
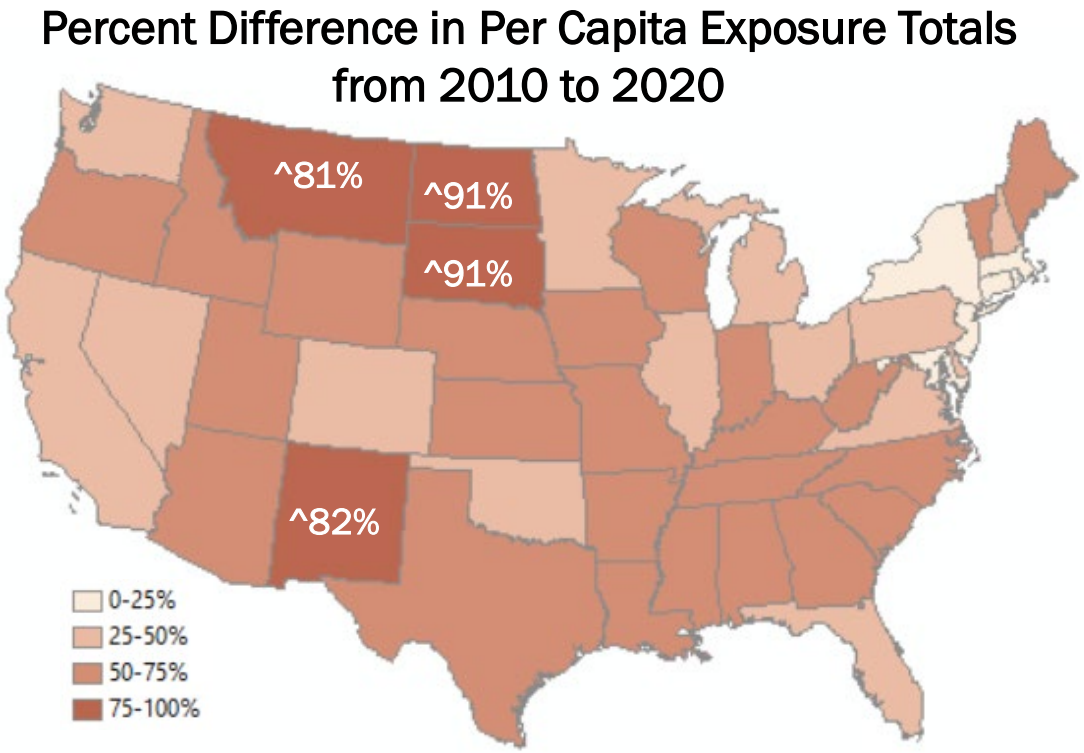
Hazus 6.0 Ground Motion Improvements

- Updated Long-term National Seismic Hazard Model Data
  - B/C soil classification boundaries
  - Soil amplification data (USGS Vs30)
- CONUS data updated from 2014 → 2018
- Hawai'i data updated from 1998 → 2021
- No data updates available for Alaska, Puerto Rico, and U.S. Virgin Islands



Long-term National Seismic Hazard Model Data

Hazus 6.0 Inventory Data Improvements – Demographics



- Updated US Census demographics data from 2010 → 2020
  - Used for Casualty Modeling and Public Shelter Needs
- Time-of-day population by occupancy type is now estimated from Longitudinal Employer and Household Data (LEHD) instead of using regional estimates derived from census data
  - Education and working industrial populations are directly tied to building types at tract level
- 44% increase nationally in per capita exposure

Hazus 6.0 Inventory Data Improvements - NSI

Used Nationwide Structure Inventory (NSI) 2.0 Open Data (USACE) for General Building Stock (GBS)

- Developed from Lightbox Parcel, NGA lidar, ORNL and Bing footprints data

Valuations updated at structure level

- GBS valuation increased ~40% nationally

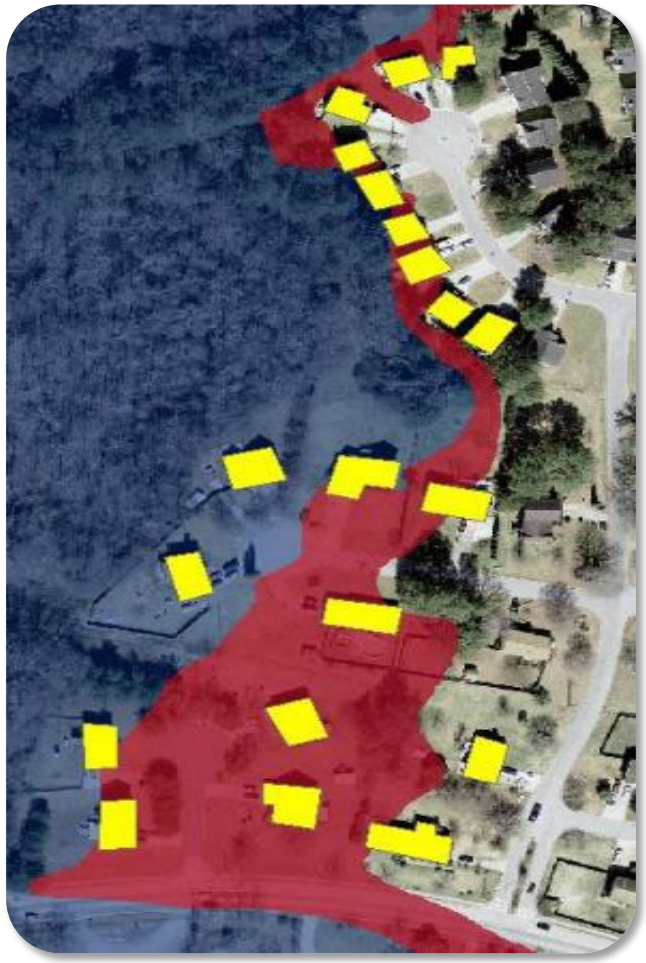
Non-residential building data vastly improved and more complete

Currently, Hazus uses regionally estimated building mapping schemes created from older Applied Technology Council (ATC) studies and applied at the county level based on older NEHRP zone mapping

USACE National Structure Inventory (NSI)

US Army Corps of Engineers

- The NSI is a nationwide building dataset developed from building footprints with parcel attribution – 2022 Attribute List
- Expected to be publicly released with no use restrictions
- The USACE currently has a team dedicated to managing, hosting, and continually improving this dataset
- The USACE plans to host NSI via web services
- Incorporates FEMA ORR's USA Structures, a nationwide footprint dataset derived by Oak Ridge National Lab and other footprint sources
- Parcel information derived from nationwide Lightbox parcels obtained from HIFLD
- Additional multi-hazard attribution planned for development in conjunction with FEMA



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Hazus 6.0 Inventory Data Improvements - HIFLD

Coordinated with CalTrans for more accurate valuation costs & incorporated retrofitting based on available bridge remodeled data

HIFLD college enrollment data using new methods that resulted in the valuation exposure totals 3x higher than what was previously in Hazus for colleges and universities

Hospital bed totals & new methods resulted in a valuation exposure total 6x higher than current Hazus inventory

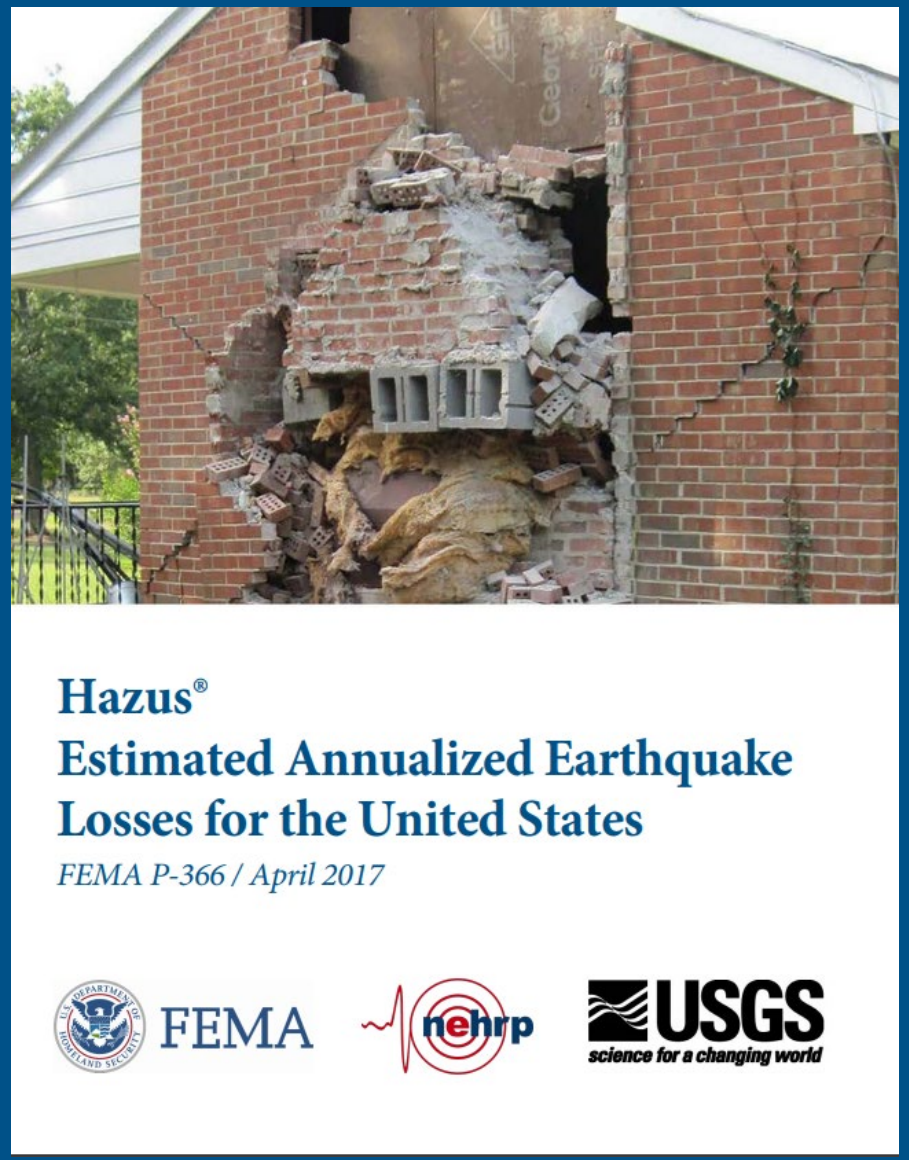
Hazus 6.0 Inventory Data Improvements – HIFLD

- Essential Facilities
  - Emergency care facilities
  - Schools
- Utilities
  - Electric power facilities
  - Wastewater facilities
  - Natural gas pipelines
  - Natural gas facilities
- Highway Bridges
- Transportation Systems
  - Airport facilities
  - Runways
  - Bus facilities
  - Highway tunnel facilities
  - Light rail facilities
  - Light rail segments
  - Railway bridges
  - Railway segments
  - Port facilities

Hazus Earthquake Average Annualized Loss Study Updates

Hazus 366 AAL Study Updates

- Last update in 2017
- Increases expected due to more complete valuation data
- Exposure swings expected
- P-366: Hazus Estimated Annual Earthquake Losses for the United States (fema.gov)



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Hazus 366 AAL Study Updates

- The FEMA 366 Hazus 6.0 2022 Update will include:
  - 2021 HI and 2018 CONUS probabilistic hazard data with site soil amplification included
  - PGV conversions developed with a new method
  - New 2022 NSI based GBS
  - 2020 Census
- The 2022 update using 2018 hazard data by end of this year with latest exposure data will allow the direct comparison to the 2023 mapping next year

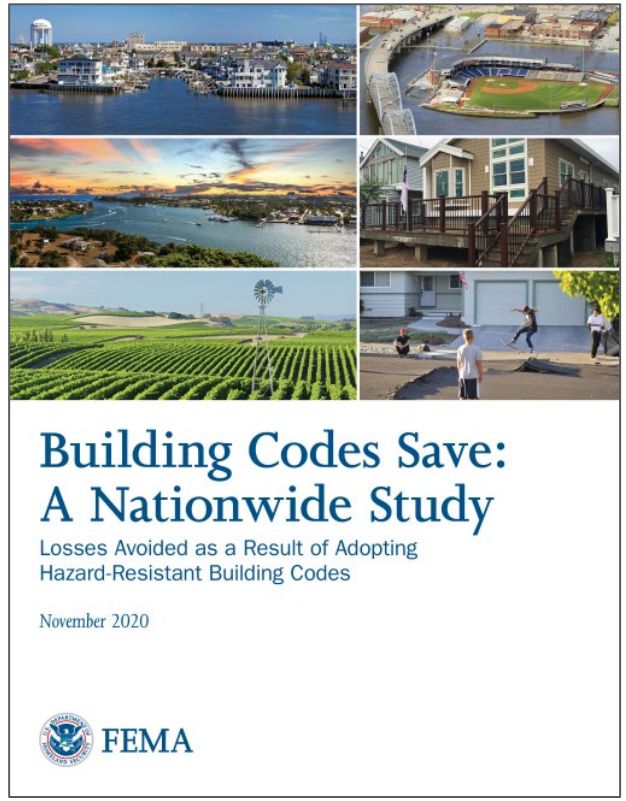
Losses Avoided Study Outcomes for Earthquake Design Levels

- Building Codes Save: A Nationwide Study (fema.gov)

Table ES-1: Data Source, Data Format, and Methodology by Hazard

Data Source / Data Format / Methodology	Flood	Hurricane Wind	Seismic
Main national data sources, by hazard and by land use	CoreLogic parcel database, Microsoft footprint data, ASCE 7, ASCE 24, USACE, CRS, BCEGS	CoreLogic parcel database, Microsoft footprint data, ASCE 7, FBC, CRS, BCEGS	CoreLogic parcel database, Microsoft footprint data, USGS NSHM and on-line design ground motion tools, USGS Vs30 data, BCEGS
Supplemental hazard-specific data sources	Updated DDFs	Modified existing Hazus vulnerability curves and added extensive logic to make applicable building characteristics a function of building code and edition	Discussions with local Structural Engineers to support selection of MBTs, seismic hazard zone maps, near-source fault zone maps
Data format	Simulating Hazus User-Defined Facilities analysis (point data) in cloud database	Standalone Hazus Hurricane Wind Model (SHHWM) format (point data)	Advanced Engineering Building Module (AEBM) analysis (point data)
Hazard map condition nationwide	1 percent-annual-chance flood boundaries from NFHL and CoreLogic.	Published digital ASCE 7 maps and digitized prior versions	USGS on-line design ground motions and digitized maps from 1994/1997 UBC
Probabilistic hazard modeling basis	Used FEMA PELV Curves for flood profile for 5 events based on historic FEMA flood policy.	Full Hazus probabilistic event set (Monte Carlo simulation)	USGS 2014 Probabilistic 100-, 250-, 500-, 750-, 1000-, 1500-, 2000-, and 2500-year return period ground motion data from NSHM
Modeling procedure	Compare code based on freeboard provisions, assigning Hazus flood DDFs by structure and flood zone elevations	Assign hurricane wind damage related building characteristics where known based on parcel data for applicable building code.	Assign Design Levels for building based on strength required in each code edition. Use related Hazus damage functions per occupancy, MBT, and Design Level.
Pre-I-Code	NFIP minimum requirements	BOCA, CABO, SBC, and UBC (Hawaii)	1994 UBC

AEBM = Advanced Engineering Building Module
ASCE = American Society of Civil Engineers
BCEGS = Building Code Effectiveness Grading Schedule
BOCA = Building Officials and Code Administration
CABO = Council of American Building Officials
CRS = Community Rating System
DDF = Depth-Damage Function
FBC = Florida Building Code
FEMA = Federal Emergency Management Agency
ISO = Insurance Services Office
MBT = Model Building Type
NFHL = National Flood Hazard Layer
NFIP = National Flood Insurance Program
NSHM = National Seismic Hazard Maps
PELV = probability of elevation
QA = Quality Assurance
SBC = Standard Building Code
SBC = Standard Building Code
SFHA = Special Flood Hazard Area
SHHWM = Stand-alone Hazus Hurricane Wind Model
UBC = Uniform Building Code
USGS = U.S. Geological Survey
Vs30 = Shear wave velocity in the top 30 meters of soil
WBC = Wind Building Characteristic
WBDR = Wind-Borne Debris Region



Losses Avoided Study Outcomes for Earthquake Design Levels

- Building Codes Save: A Nationwide Study (fema.gov)
- New fragilities developed to represent the IBC strengthening in the western states including the improvements to the post and pier load path in Hawai'i for post 2000 construction would be implemented.

$1.8 BILLION

Estimated reduction in property losses over 20 years associated with California's modern building codes during earthquake and flood events

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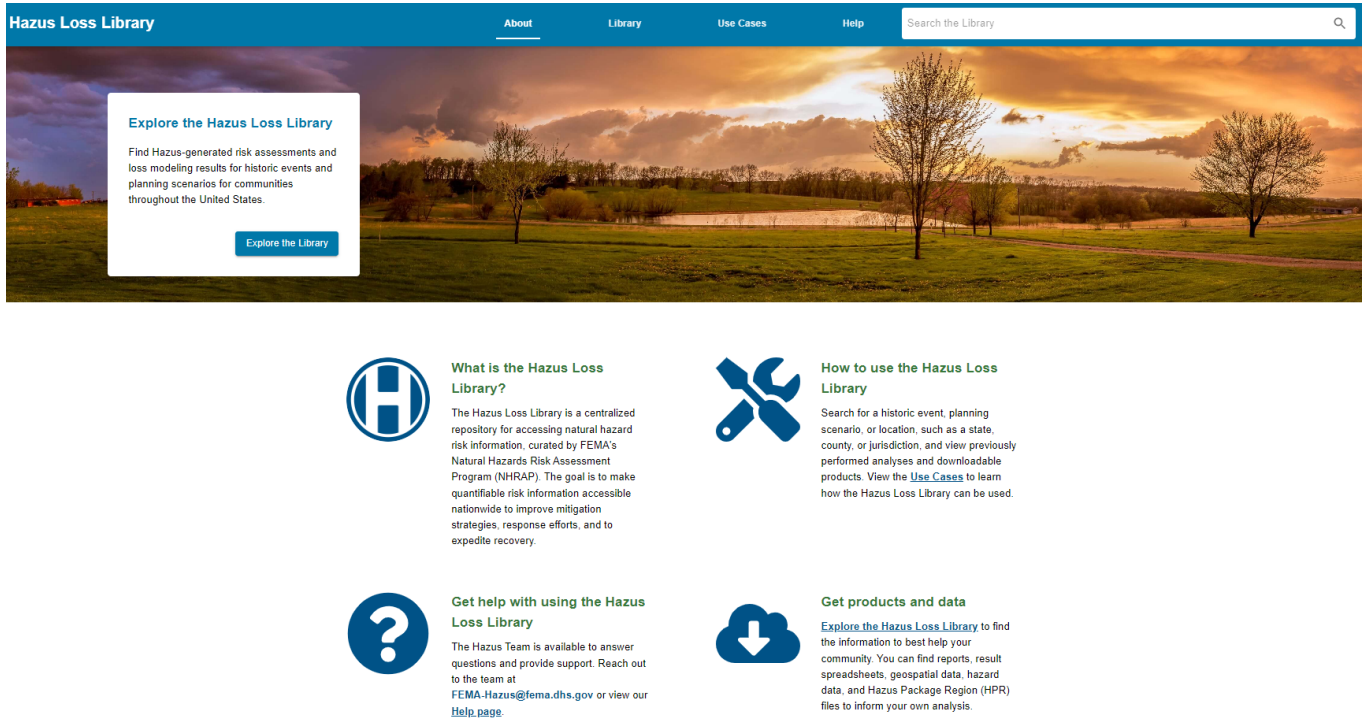
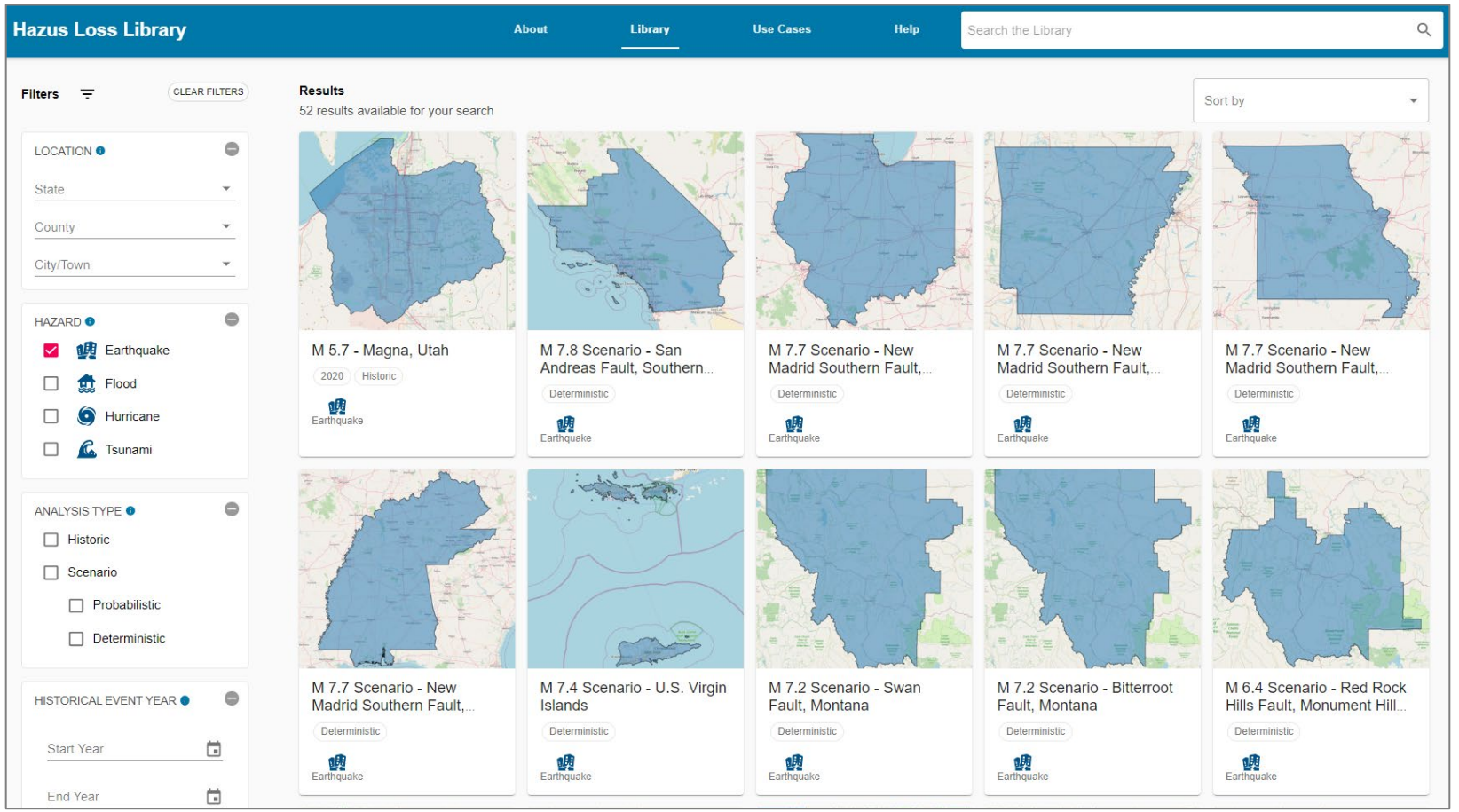
Hazus Loss Library – What is it?

- An online public repository of natural hazard risk information to support all phases of emergency management at local, state, and federal levels
- Search, view, and download risk information for communities across the US
- Hazus Loss Library (fema.gov)



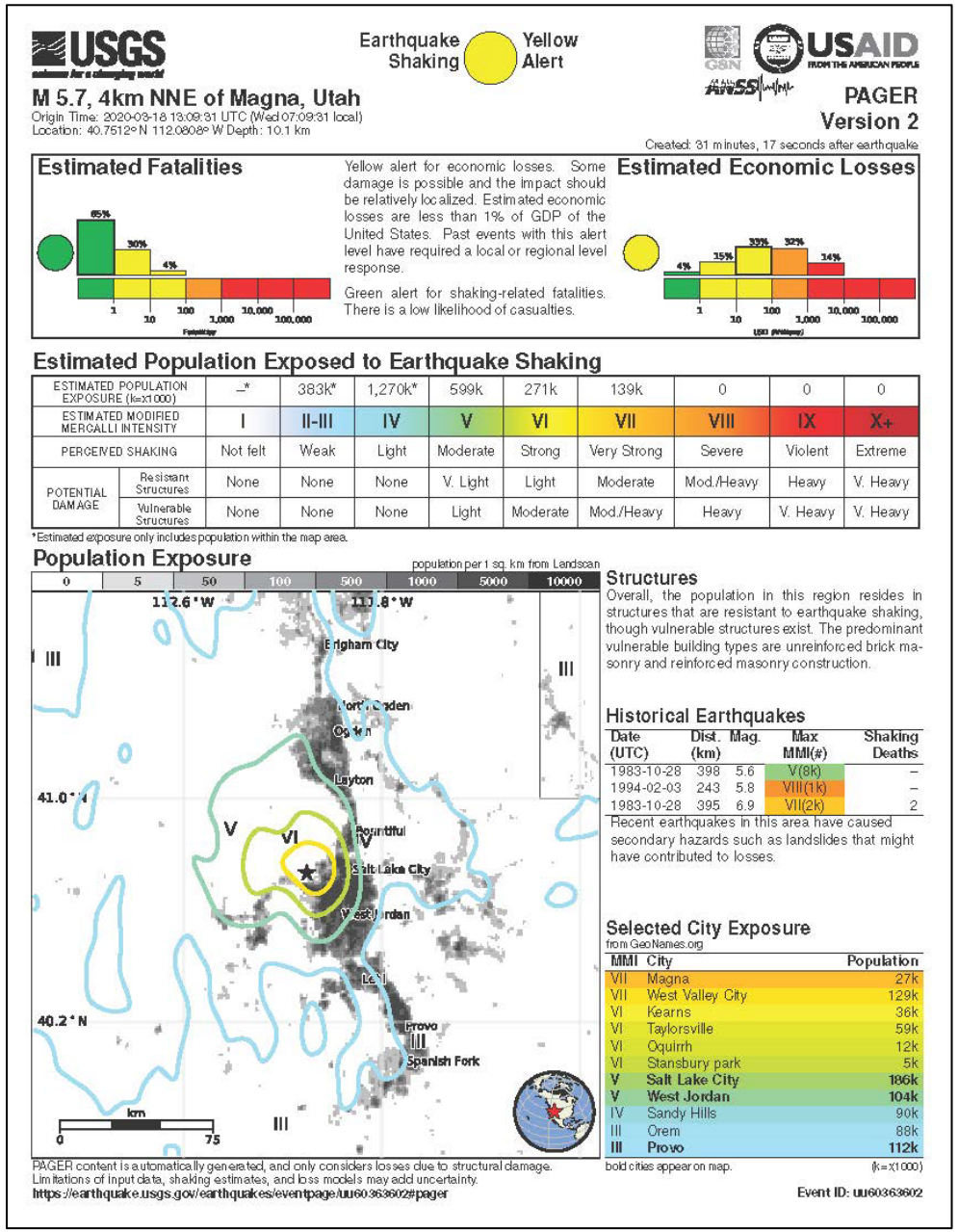
Hazus Loss Library – Earthquake Scenarios



Hazus Loss Library (fema.gov)

FEMA Hazus Program and USGS NEIC Response Product Delivery – 2Pager

- Analyses conducted by FEMA NHRAP team and closely coordinated with USGS NEIC
- Generated 2-4 hours after real events
- 2Pager analyses made available for all domestic earthquakes of a Pager Yellow alert level or higher



USGS

Earthquake Shaking: Yellow Alert

USAID FROM THE AMERICAN PEOPLE

PAGER Version 2

M 5.7, 4km NNE of Magna, Utah

Origin Time: 2020-03-18 13:09:31 UTC (Wed 07:09:31 local)
Location: 40.7512° N 112.0808° W Depth: 10.1 km

Created: 31 minutes, 17 seconds after earthquake

Estimated Fatalities

Yellow alert for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response.

Green alert for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k=x1000)		–*	383k*	1,270k*	599k	271k	139k	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	None	None	None	V. Light	Light	Moderate	Mod./Heavy	Heavy	V. Heavy
	Vulnerable Structures	None	None	None	Light	Moderate	Mod./Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per 1 sq. km from Landscan

0 | 5 | 50 | 100 | 500 | 1000 | 5000 | 10000

Structures

Overall, the population in this region resides in structures that are resistant to earthquake shaking, though vulnerable structures exist. The predominant vulnerable building types are unreinforced brick masonry and reinforced masonry construction.

Historical Earthquakes

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1983-10-28	398	5.6	V(8k)	–
1994-02-03	243	5.8	VIII(1k)	–
1983-10-28	395	6.9	VII(2k)	2

Recent earthquakes in this area have caused secondary hazards such as landslides that might have contributed to losses.

Selected City Exposure

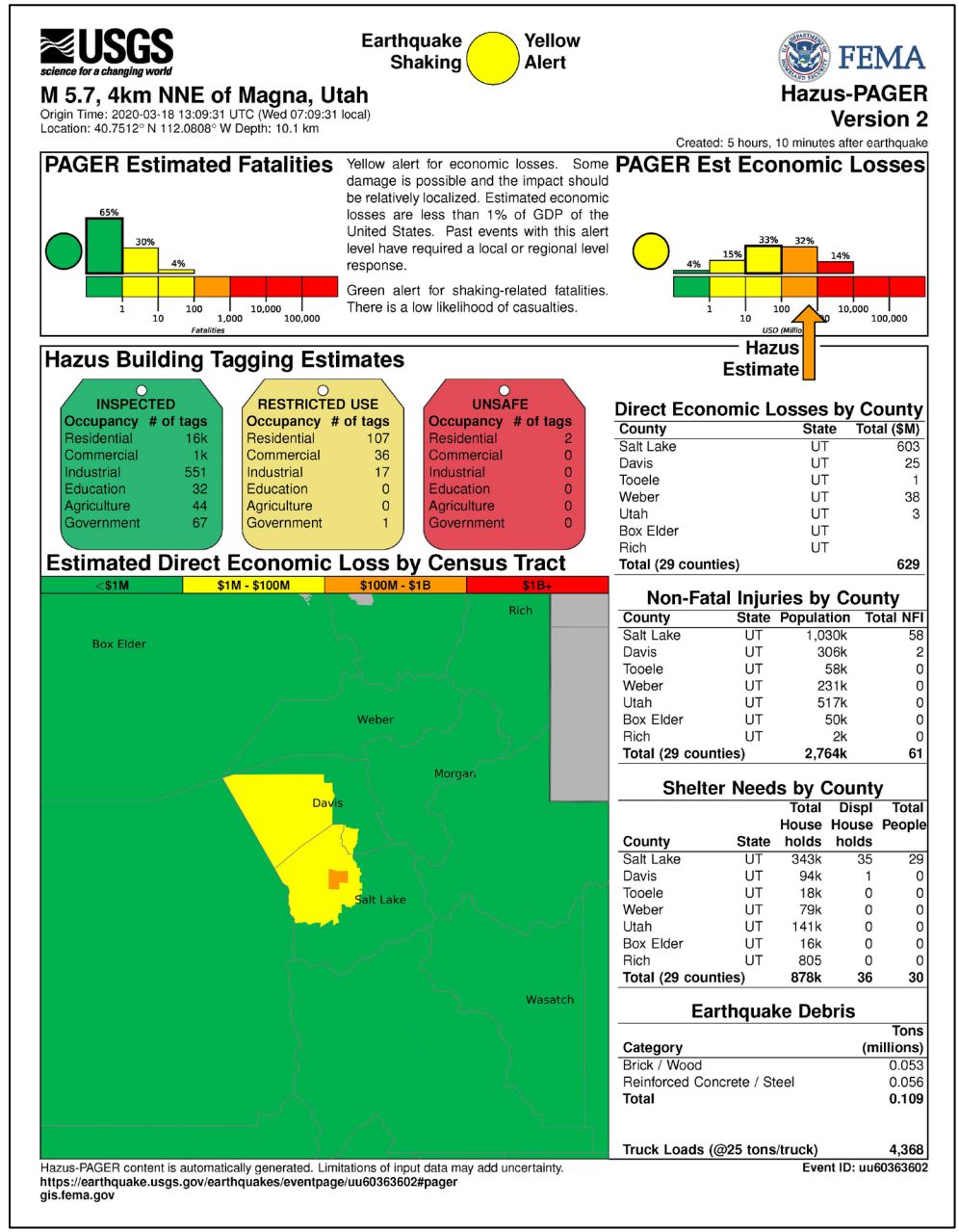
from GeoNames.org

MMI	City	Population
VII	Magna	27k
VII	West Valley City	129k
VI	Kearns	36k
VI	Taylorsville	59k
VI	Oquirrh	12k
VI	Stansbury park	5k
V	**Salt Lake City**	**186k**
V	**West Jordan**	**104k**
IV	Sandy Hills	90k
III	Orem	88k
III	**Provo**	**112k**

bold cities appear on map. (k=x1000)

PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.
https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602#pager

Event ID: uu60363602



USGS science for a changing world

Earthquake Shaking: Yellow Alert

FEMA

Hazus-PAGER Version 2

M 5.7, 4km NNE of Magna, Utah

Origin Time: 2020-03-18 13:09:31 UTC (Wed 07:09:31 local)
Location: 40.7512° N 112.0808° W Depth: 10.1 km

Created: 5 hours, 10 minutes after earthquake

PAGER Estimated Fatalities

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PAGER Est Economic Losses

Hazus Estimate

Hazus Building Tagging Estimates

INSPECTED Occupancy	# of tags
Residential	16k
Commercial	1k
Industrial	551
Education	32
Agriculture	44
Government	67

RESTRICTED USE Occupancy	# of tags
Residential	107
Commercial	36
Industrial	17
Education	0
Agriculture	0
Government	1

UNSAFE Occupancy	# of tags
Residential	2
Commercial	0
Industrial	0
Education	0
Agriculture	0
Government	0

Estimated Direct Economic Loss by Census Tract

Direct Economic Losses by County

County	State	Total ($M)
Salt Lake	UT	603
Davis	UT	25
Tooele	UT	1
Weber	UT	38
Utah	UT	3
Box Elder	UT	
Rich	UT	
Total (29 counties)		**629**

Non-Fatal Injuries by County

County	State	Population	Total NFI
Salt Lake	UT	1,030k	58
Davis	UT	306k	2
Tooele	UT	58k	0
Weber	UT	231k	0
Utah	UT	517k	0
Box Elder	UT	50k	0
Rich	UT	2k	0
Total (29 counties)		**2,764k**	**61**

Shelter Needs by County

County	State	Total House holds	Displ House holds	Total People
Salt Lake	UT	343k	35	29
Davis	UT	94k	1	0
Tooele	UT	18k	0	0
Weber	UT	79k	0	0
Utah	UT	141k	0	0
Box Elder	UT	16k	0	0
Rich	UT	805	0	0
Total (29 counties)		**878k**	**36**	**30**

Earthquake Debris

Category	Tons (millions)
Brick / Wood	0.053
Reinforced Concrete / Steel	0.056
Total	**0.109**
Truck Loads (@25 tons/truck)	**4,368**

Hazus-PAGER content is automatically generated. Limitations of input data may add uncertainty.
https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602#pager
gis.fema.gov

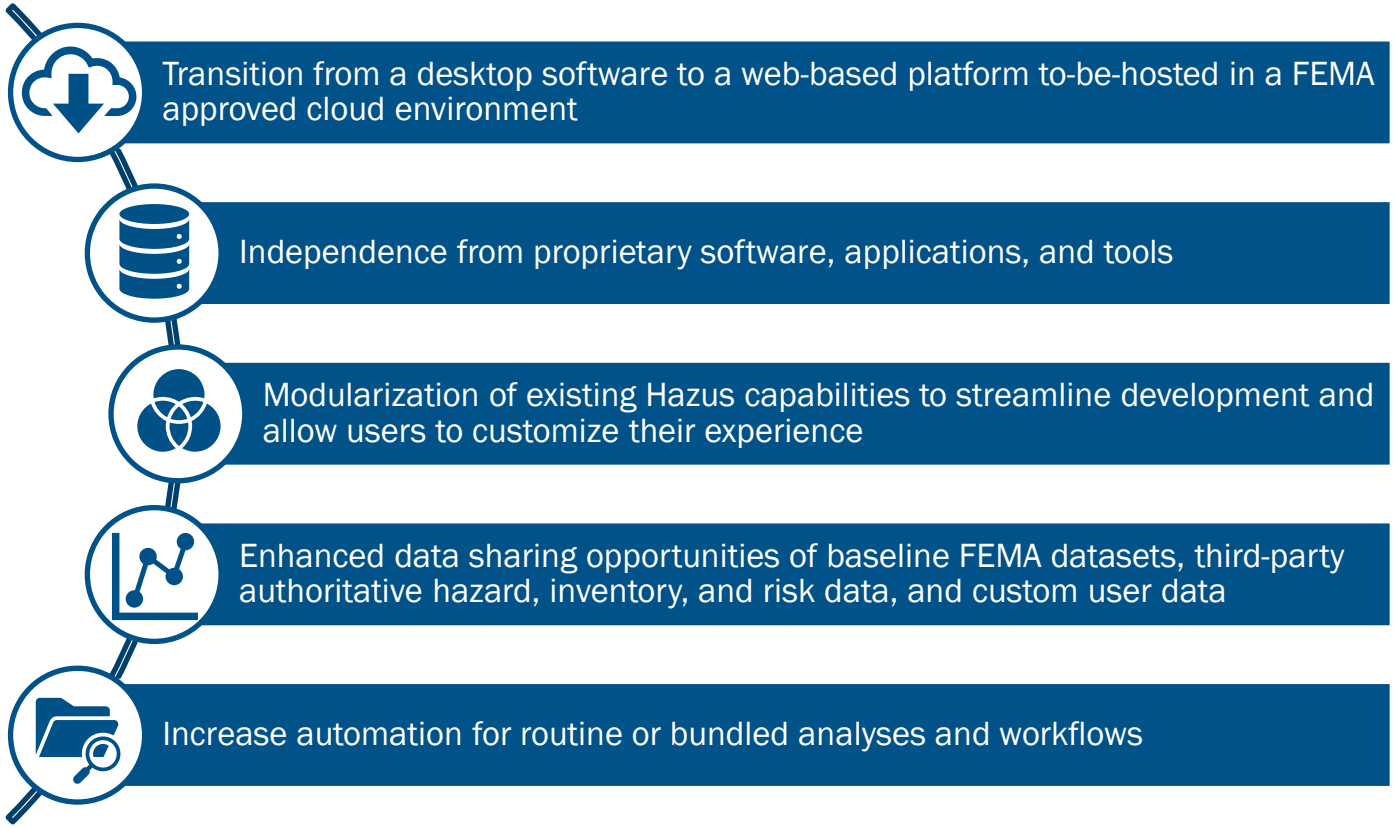
Event ID: uu60363602

FEMA

OpenHazus – Open Science Based Risk Assessment Tool

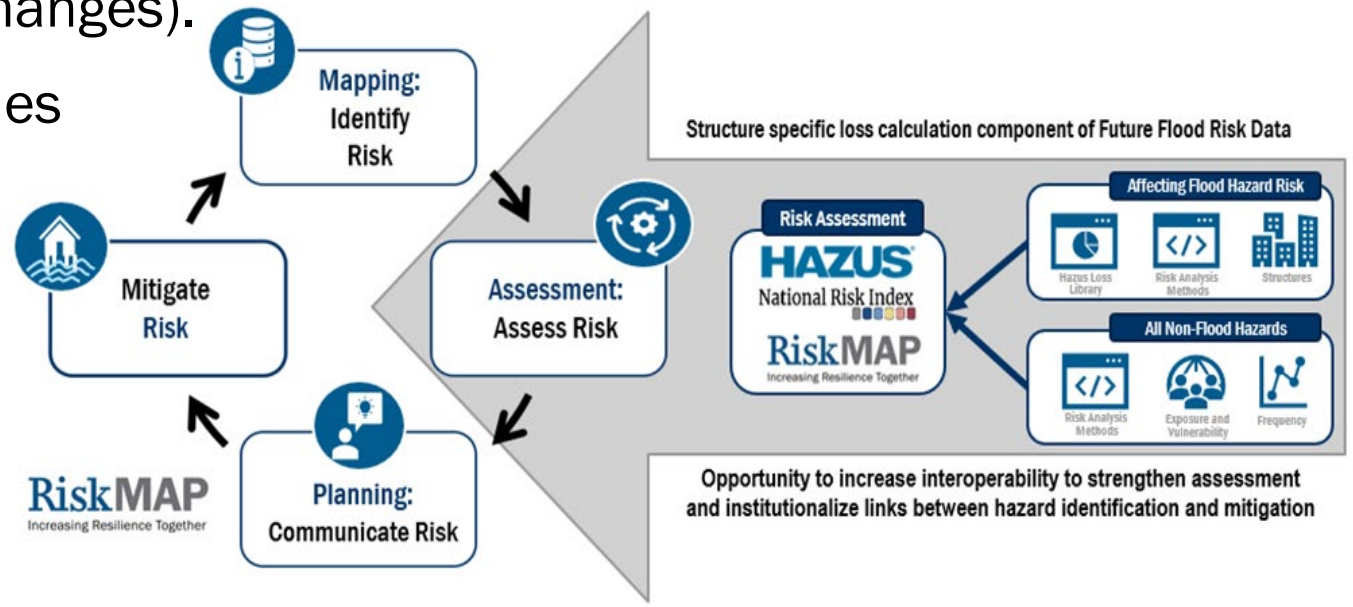
OPEN HAZUS™

Lower the barrier-of-entry to increase access to quality risk assessment information. Establish a risk assessment platform that is truly free to all users and for all use cases.



OpenHazus Innovation

- OpenHazus will be hazard data agnostic (e.g., climate change data can be evaluated if brought in from an authoritative source).
- OpenHazus will be exploring implementable and actionable methodologies for future conditions loss modelling and risk assessments (e.g., probabilistic damage functions and land use and built environment changes).
- OpenHazus will be exploring approaches to evaluating and communicating uncertainty, enabling loss modelling and risk assessment capabilities on varying time horizons with multiple future climate scenarios.



Future Collaborations

- New parcel-based building data has attributes that can be leveraged to create new mapping schemes
  - Building type descriptions, building areas, construction year built, number of stories, foundation type, etc.
- Potential for damage function improvements
- FEMA/USACE National Structure Inventory data collaboration
- OpenHazus

Contact Information

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