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Overview and Scope of NRC's Seismic Hazard Analyses

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MISSION:

NRC licenses and regulates the Nation's civilian use of radioactive materials to protect public health and safety, promote the common defense and security, and protect the environment.

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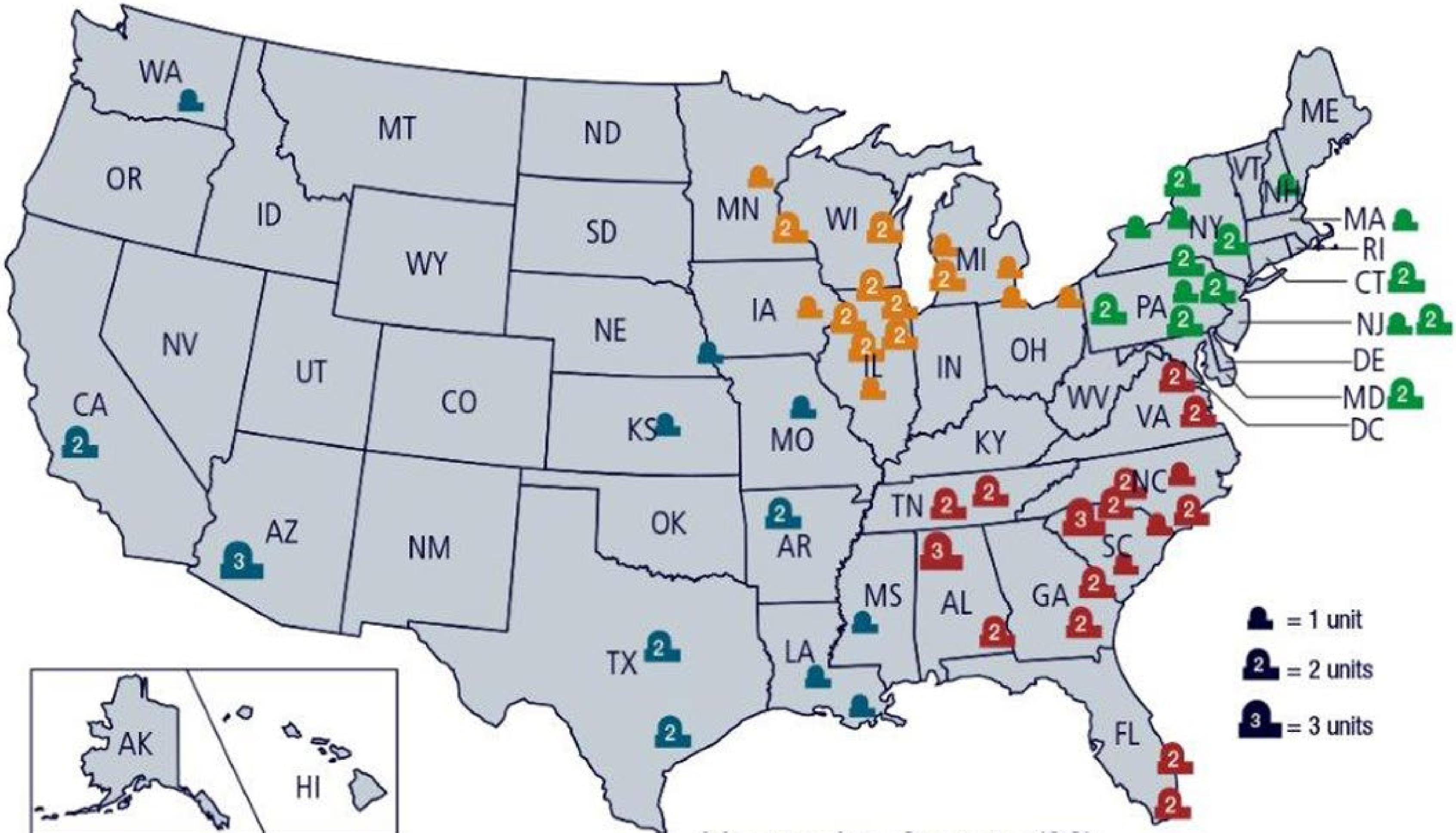
Outline

- US NRC’s Seismic Hazard Analyses and Regulatory Perspectives
- Seismic hazard assessments for NPPs
- Seismic hazard assessments for spent fuel dry storage systems
- Seismic hazard assessments for fuel cycle facilities
- Ongoing research activities at the US NRC

U.S. Operating Commercial Nuclear Power Reactors



Licensed to Operate (98)

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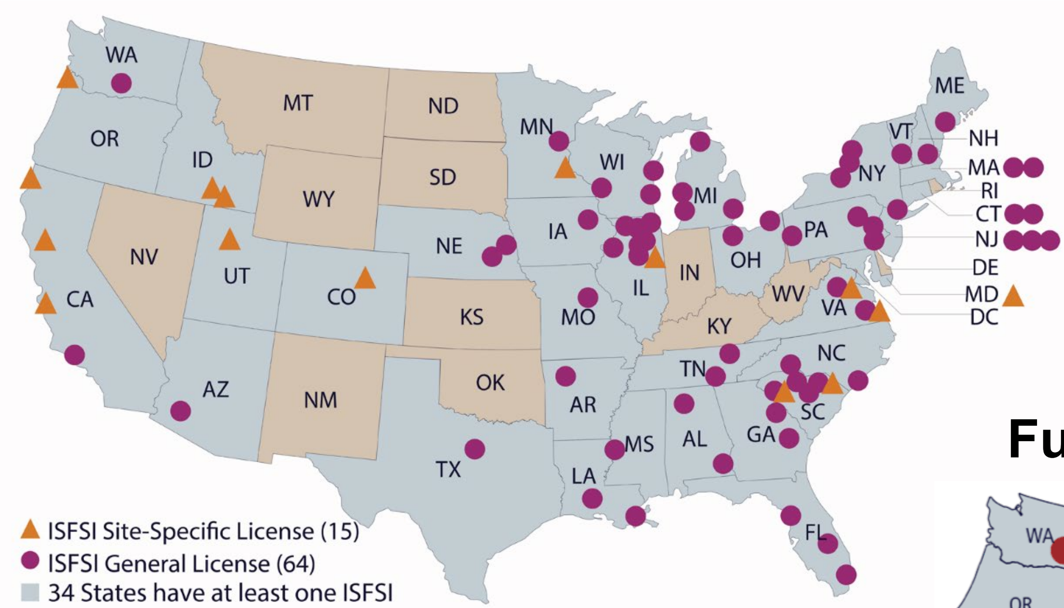
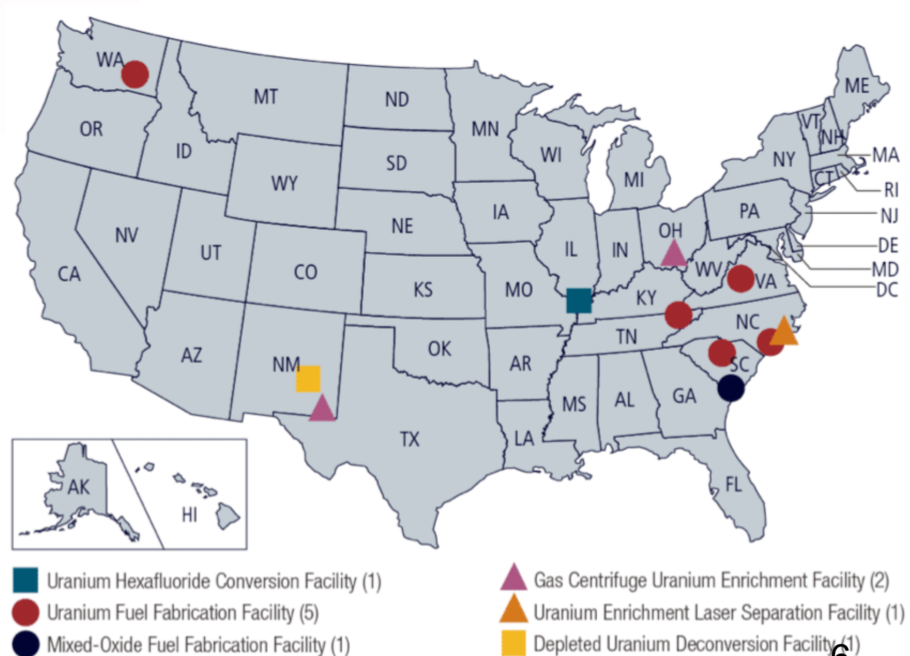
As of Sept. 2018

Independent Spent Fuel Storage Installations



Fuel Cycle Facilities



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Seismic Hazard Analyses for NPPs

- Hazard analyses for NPPs are the most rigorous, requiring in-depth analyses and calculations
- Site-specific
- When available, approved seismic source and ground motion models provide an expedited pathway to acceptable results
- Must conform to established regulations

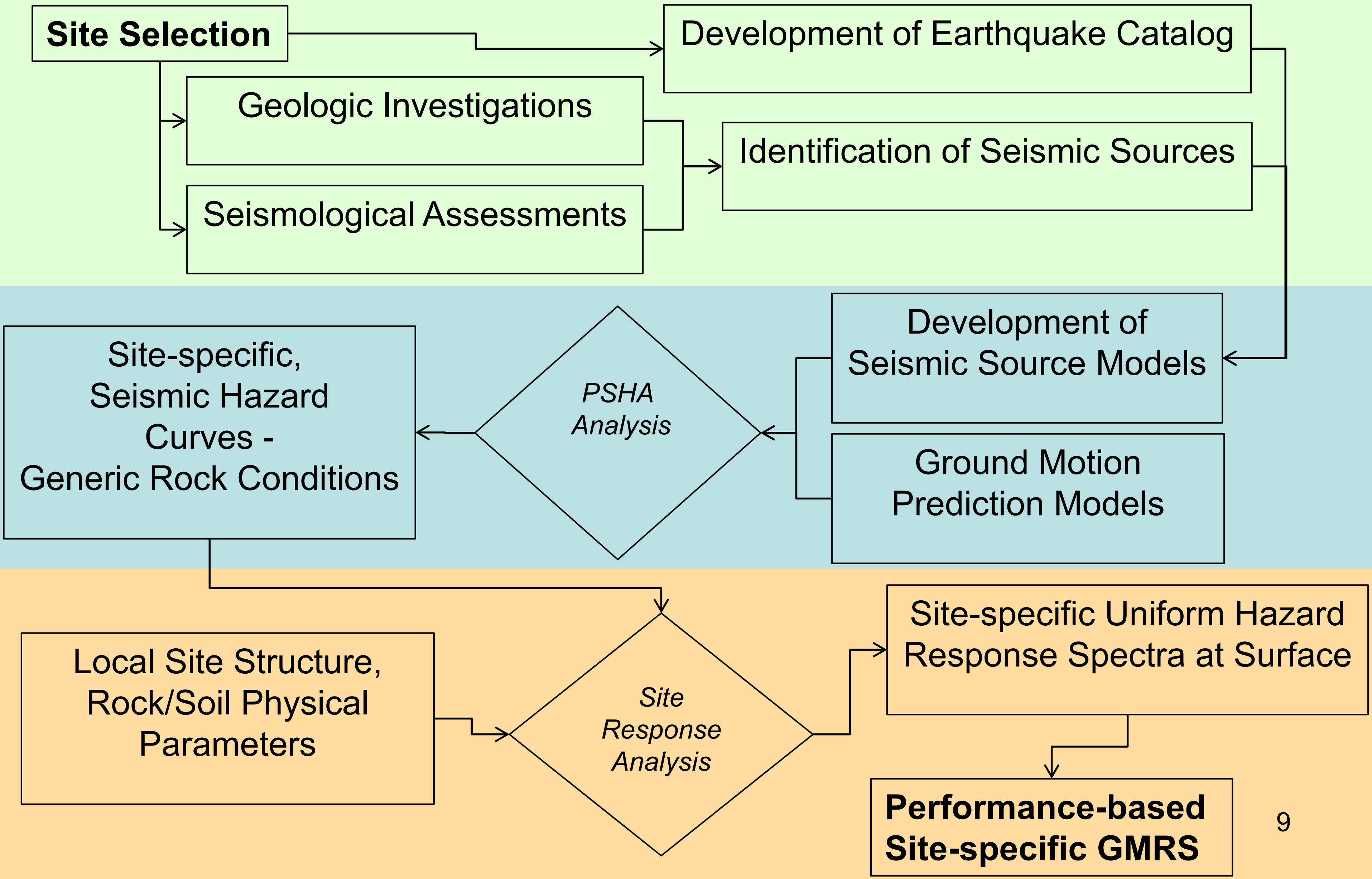
Satisfying the Regulations

Regulatory Guide, RG 1.208 'A Performance-based approach to define the site-specific earthquake ground motion', provides general guidance on procedures acceptable to the NRC staff to satisfy the Geologic and Seismic Siting Criteria outlined in 10 CFR 100.23.

Elements of Seismic hazard Analyses:

- Establish seismic source characterization models
- Establish ground motion prediction models
- Conduct Probabilistic Seismic Hazard Analysis (PSHA)
- Incorporate site response analysis
- Determine Ground Motion Response Spectra (GMRS)

Pathway to GMRS



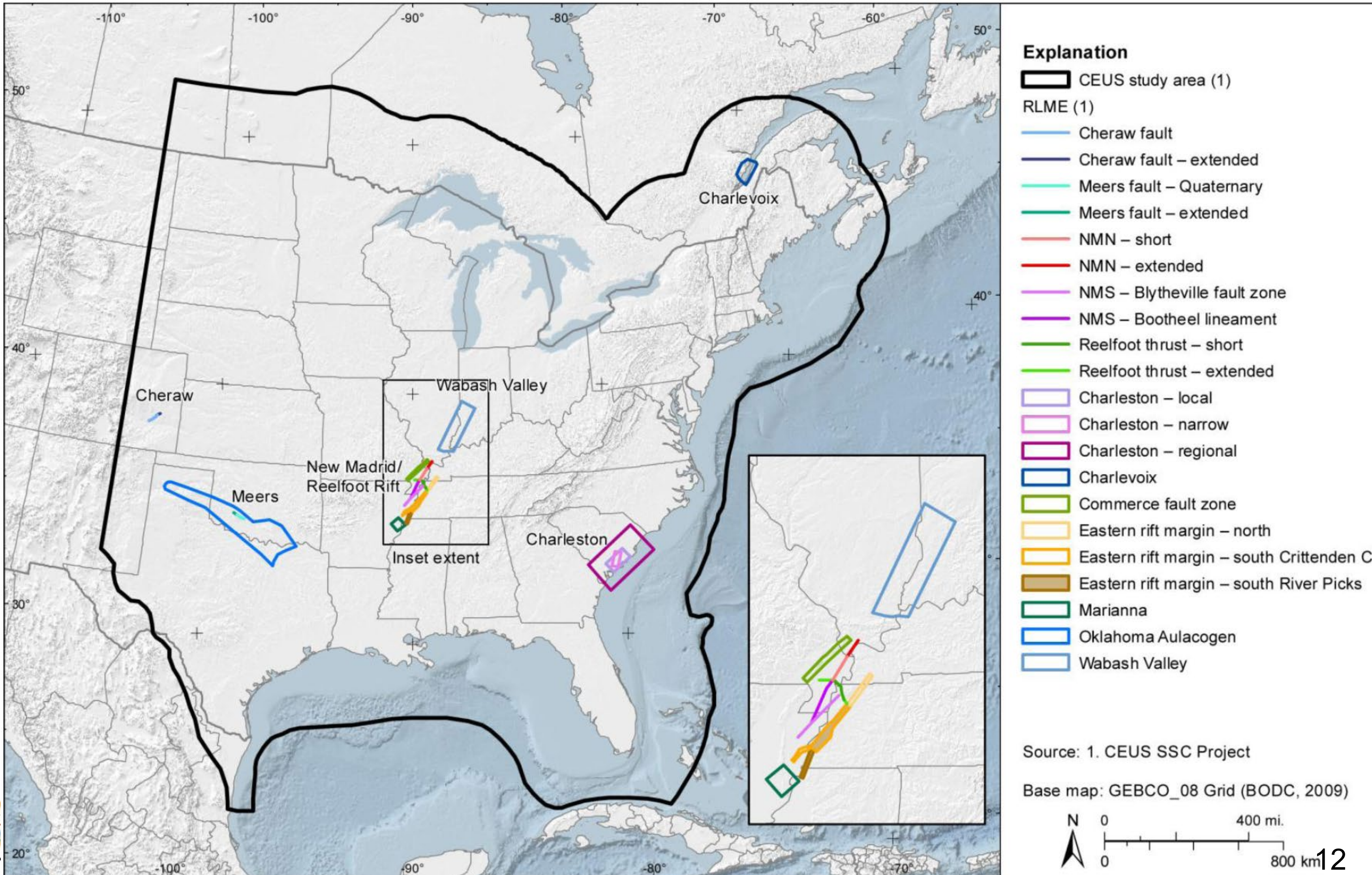
Seismic Source Models

- For the Central and Eastern United States (CEUS) there is an 'NRC approved' seismic source model that can be used as a starting model for any site in this region.
- For sites in the western United States, there are no approved starting seismic source models. Each applicant/licensee needs to develop its own seismic source model using acceptable methodologies (i.e., Senior Seismic Hazard Analysis Committee [SSHAC] processes)

CEUS Seismic Source Model

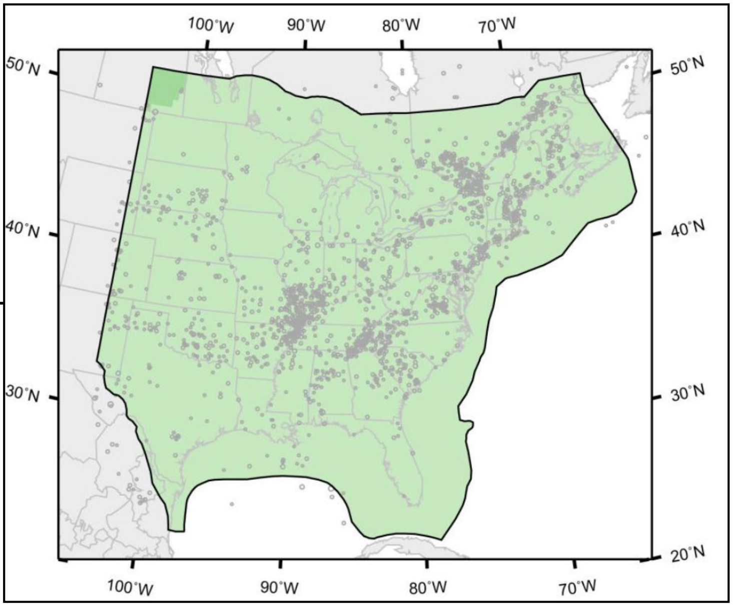
- Published as NUREG 2115 in January 2012
- Joint effort by NRC, DOE, and EPRI
- A generic, starting model applicable to any CEUS site
- Incorporates scientific information on seismic sources capable of producing earthquakes in the CEUS
- Composite model with varying alternatives
- Used in new reactor applications as well as re-assessment of seismic hazards for operating nuclear power plants.

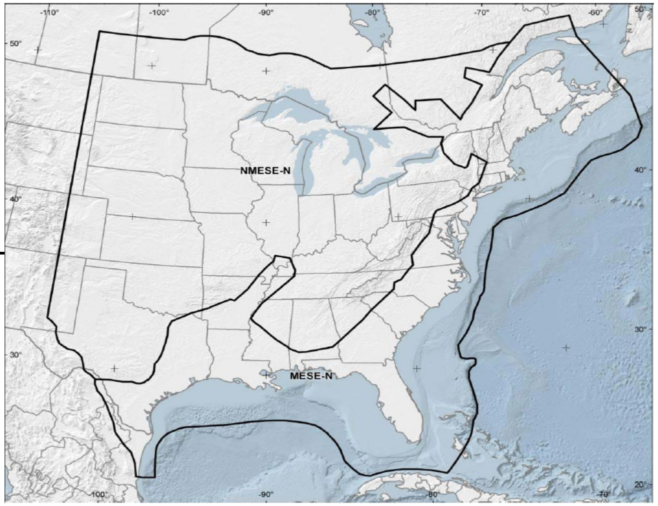
CEUS Seismic Sources – Type 1/3
Repeated Large Magnitude Sources (RMLEs)

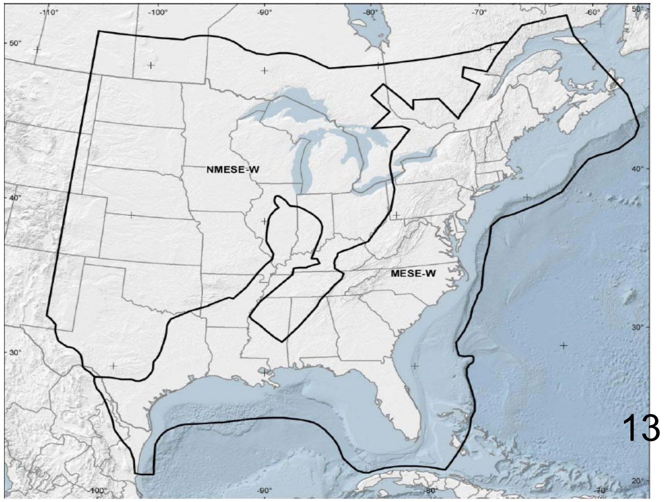


CEUS Seismic Sources – Type 2/3 Maximum Magnitude (Mmax) Sources

Alternative Representations







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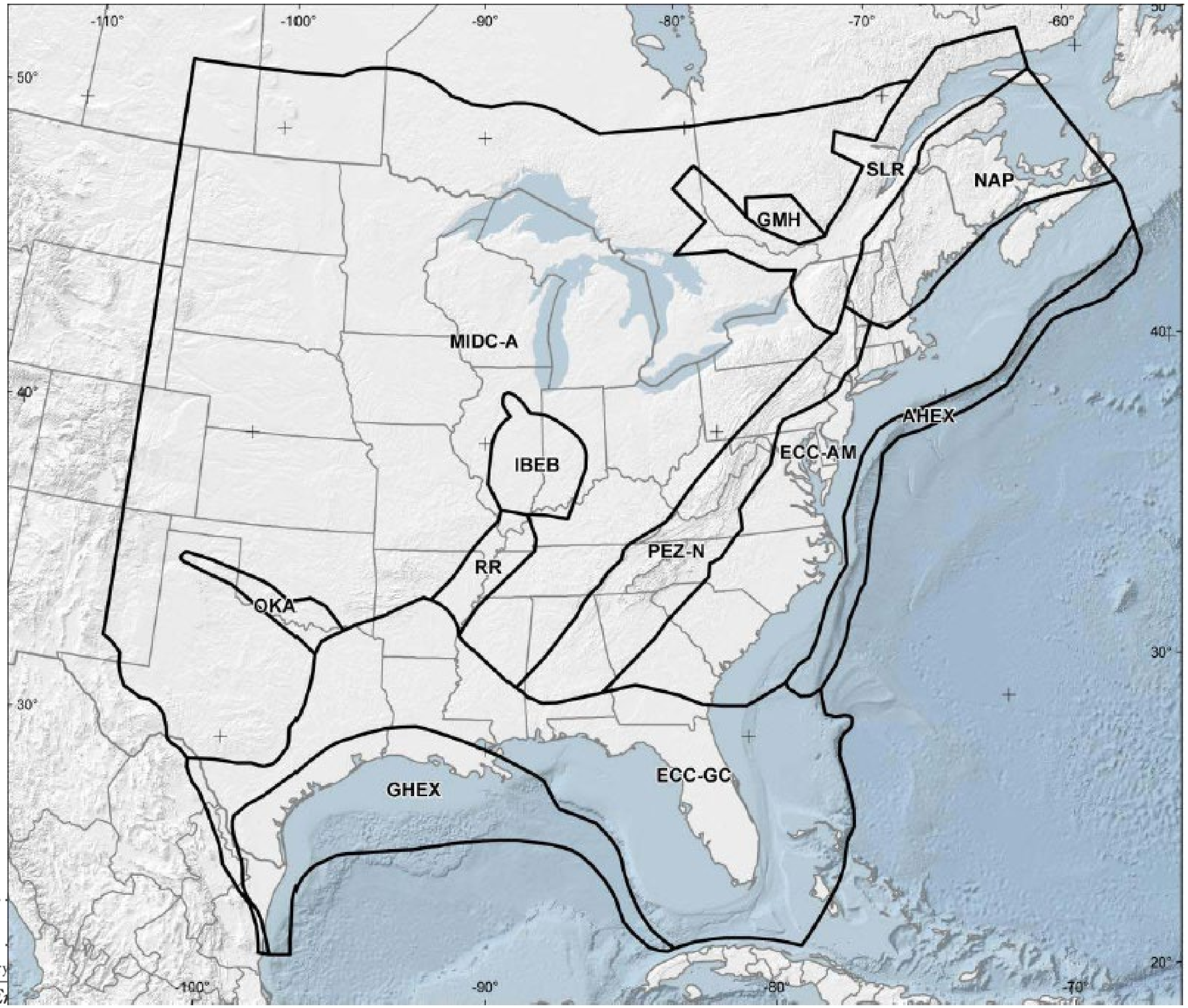
CEUS Seismic Sources – Type 3/3
Seismotectonic Sources
(one of four alternatives shown)



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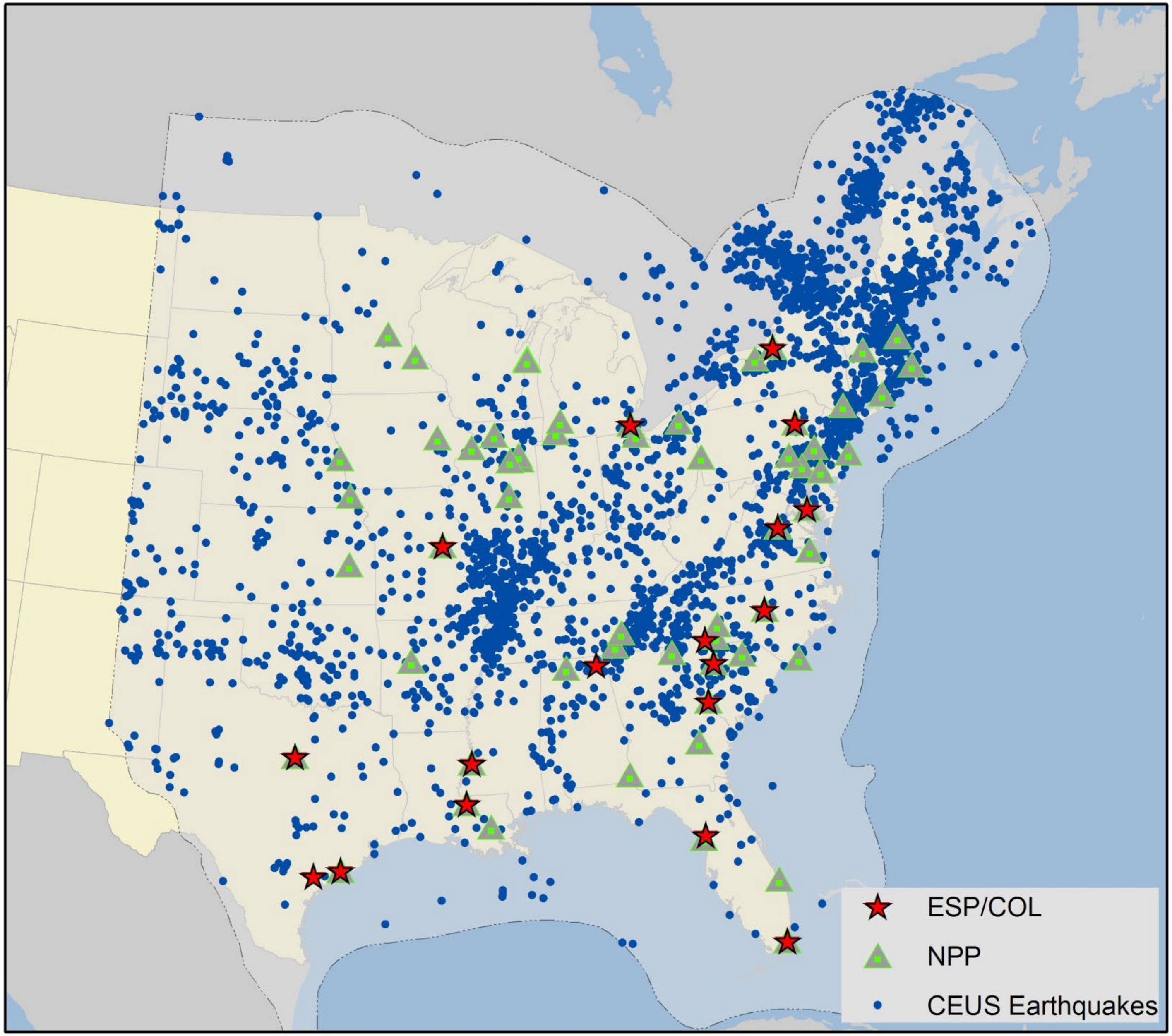
CEUS Earthquake Catalog



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Ground Motion Prediction Models

- For the CEUS, there are approved ground motion models that can use used in PSHA calculations
- As part of the Fukushima seismic re-evaluation, the industry established a working group and updated the EPRI (2004 and 2006) GMPEs in February 2013
- Office of Nuclear Regulatory Research had a major effort to update the existing EPRI GMPEs under a collaborative project (NGA- East). Almost completed, but not yet formally reviewed and endorsed by the NRC.

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Incorporating Local Site Effects into PSHA Calculations

- Local site characteristics are studied using geotechnical, geologic, and geophysical methods
- Dynamic properties of subsurface material are obtained through in-situ and laboratory measurements as well as geophysical methods
- Can be applied to hard-rock PSHA results, or directly incorporated into the PSHA calculations

Developing Performance-based Ground Motion Response Spectra (GMRS)

- Performance is measured in terms of Frequency of Onset of Significant Inelastic Deformation (FOSID), essentially elastic behavior
- Performance Target (P_{FT}) is $1x10^{-5}$ per year
  - IPEEE Seismic PRAs conducted for 25 NPPs during mid/late 1990s determined annual seismic Core Damage Frequency values
  - Median SCDF is $1.2x10^{-5}$/yr

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Performance-Based Approach to Determine the site-specific GRMS

ASCE 43-05 and RG 1.208 define GMRS as:

$$PB\ GMRS = DF \text{ x } UHRS_{10^{-4}}$$

$$DF = \mathrm{Max}\ (0.6 A_R^{\ 0.8}, 1.0)$$

$$A_R = \frac{UHRS_{10^{-5}}}{UHRS_{10^{-4}}}$$

DF: Design Factor
AR: Hazard curve slope
$UHRS_{10-5}$ and $UHRS_{10-4:}$ mean Uniform hazard response spectra with annual probability of exceedance of 10^{-5} and 10^{-4}

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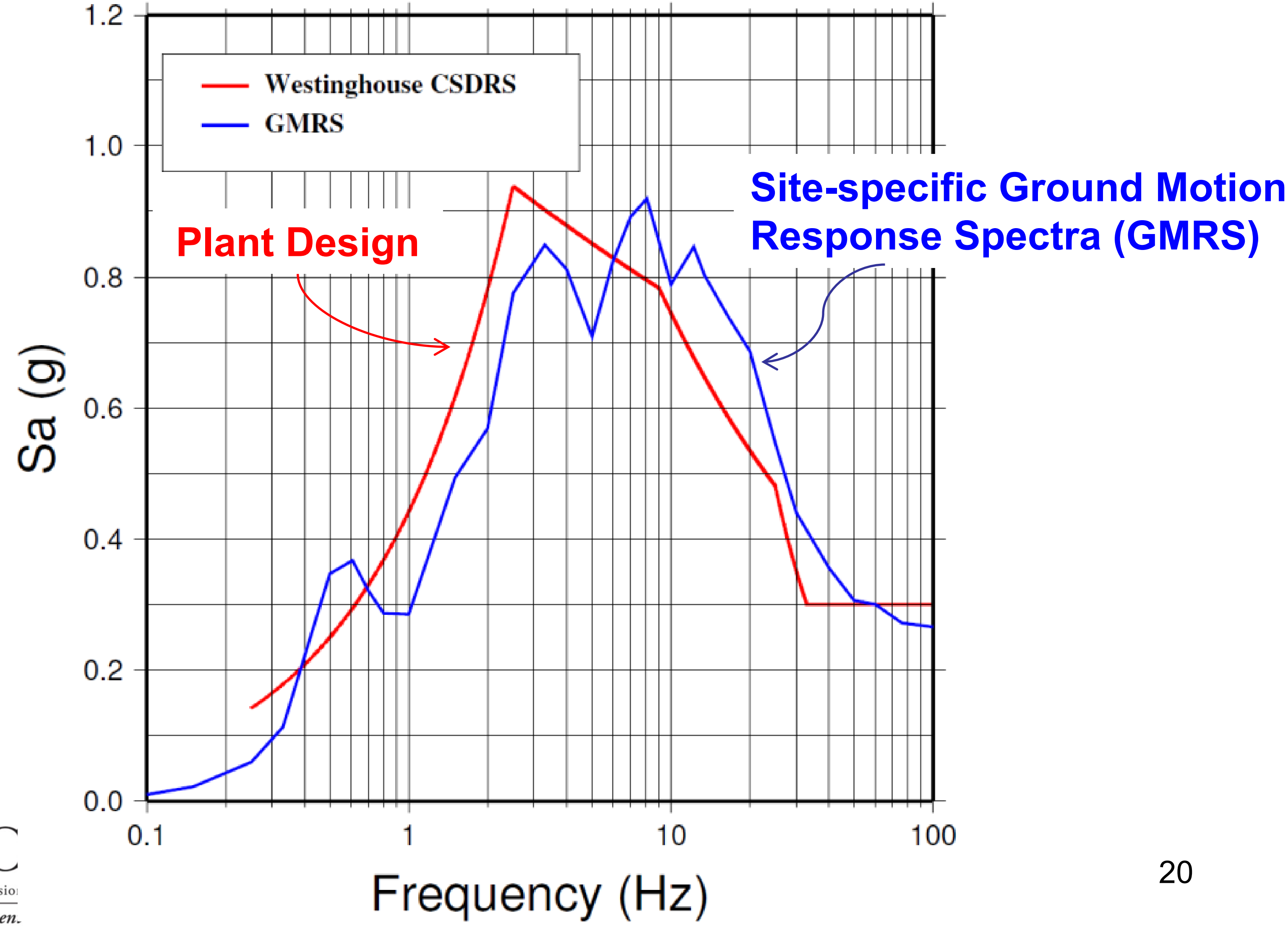
NPP Site Specific Ground Motion vs. Design



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Spent Fuel Dry Storage Facilities

- Must conform to regulations defined in 10 CFR 72.103
- Can be
  - A: Site-specific (similar to NPP analysis)
  - B: General license (under an existing NPP)
- NUREG 1567 '*Standard Review plan for Spent Fuel Dry Storage Facilities*' provides how NRC reviews these seismic hazard studies

Fuel Cycle Facilities

- Must conform to regulations defined in 10 CFR 70.22
- Seismic hazard assessed using established building codes
- NUREG 1520 '*Standard Review Plan for Fuel Cycle Facilities License Applications*' provides how NRC reviews these seismic hazard studies

Current Activities at US NRC

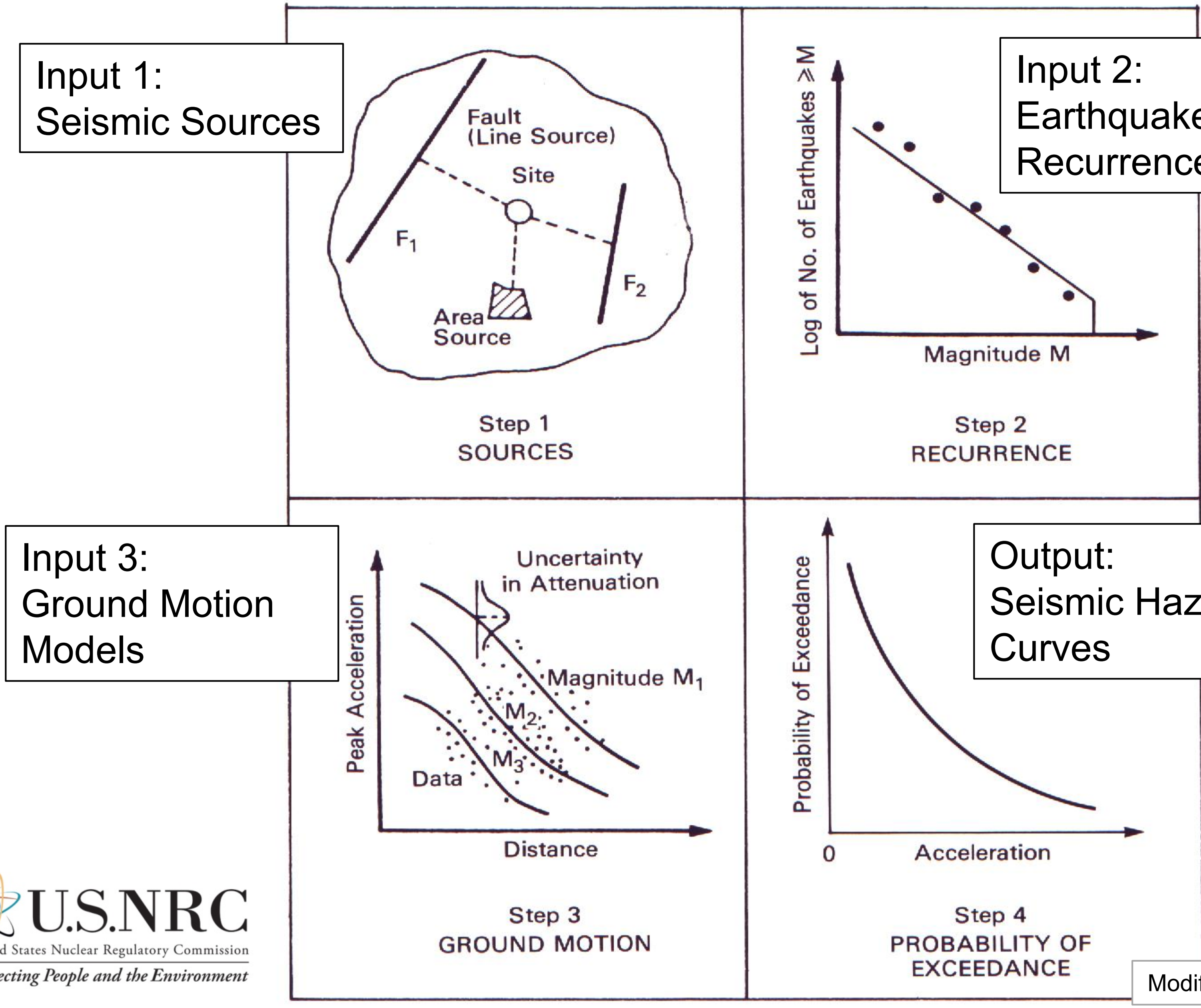
- Under an Interagency agreement with the USGS, assessing existing seismic source and ground motion models to identify areas needing modification/improvement
- Multi-dimensional site response analyses
- Continuous assessments of seismic hazards at the operating nuclear power plants
- Participation in international activities through the IAEA to develop guidance on physics-based simulations, probabilistic fault displacement hazard analyses and PSHA validation methodologies.

Conclusions

- NRC is a key consumer of new data, information, and knowledge gained by the scientific community at large
- NRC conducts its own confirmatory research activities and works with outside partners in government (e.g., USGS) and academia to address regulatory needs
- NRC seismic hazard analyses follow unique sets of requirements that highlight the importance of constant engagement between scientific community and policy makers

Backup Slides

Probabilistic Seismic Hazard Analysis (PSHA)



Modified from Reiter (1990)

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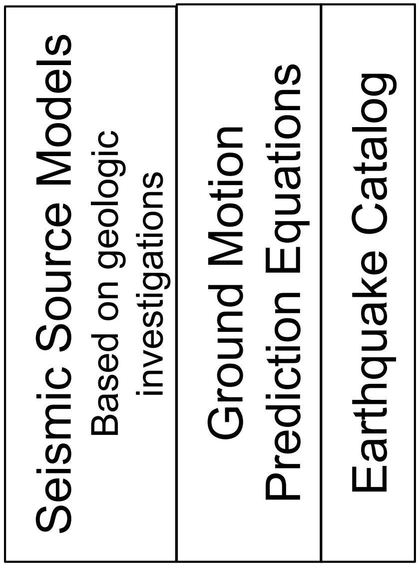
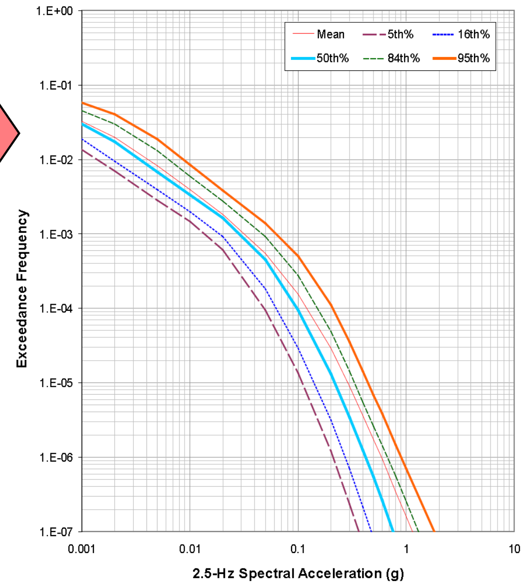
Pathway to Performance-Based GMRS

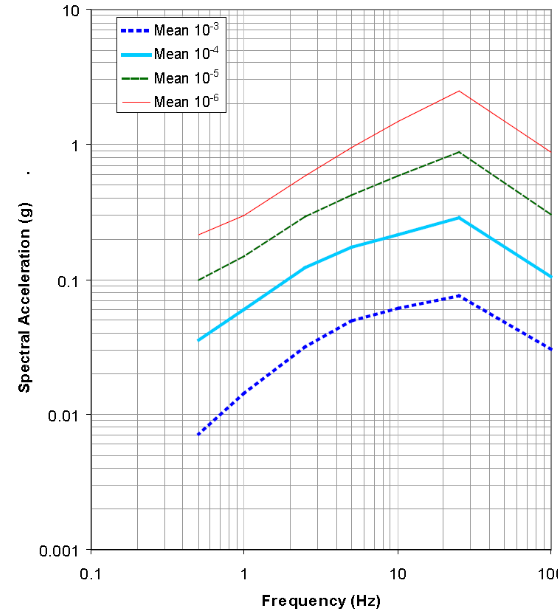


PSHA

Seismic Hazard Curves

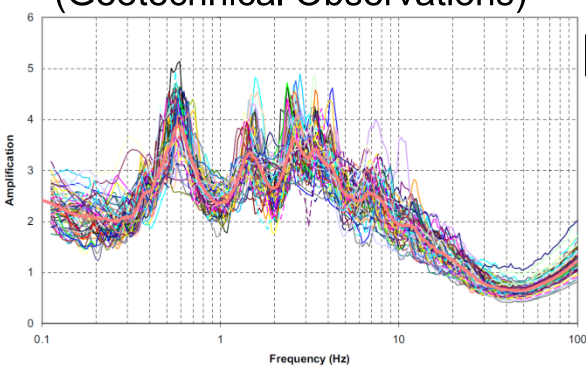


Generic Rock, Uniform Hazard

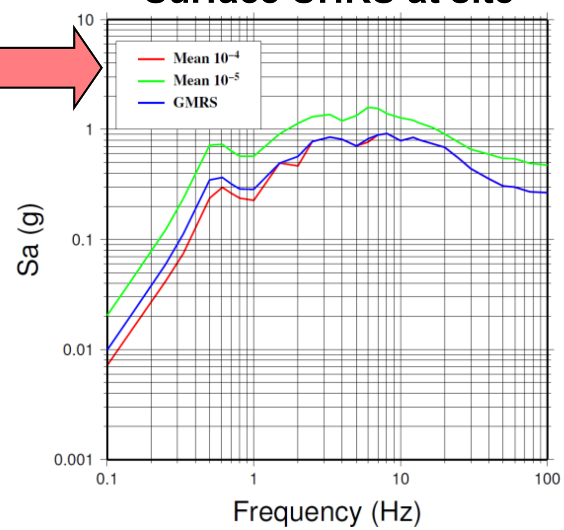


Site-specific Corrections

(Geotechnical Observations)

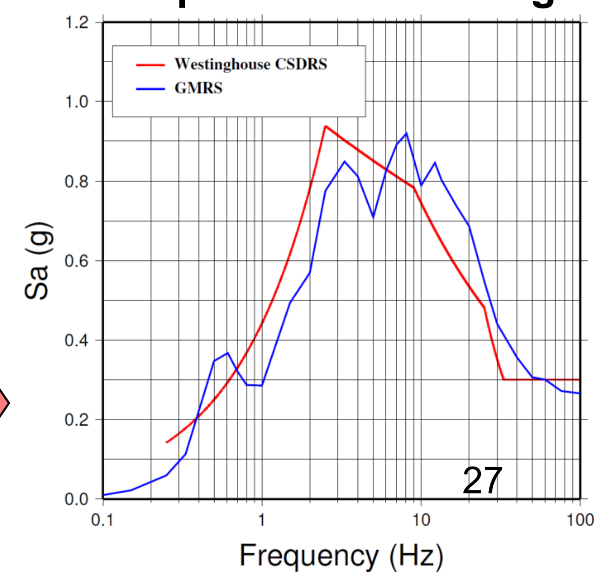


Surface UHRS at site



GMRS

Comparison with Design



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Characterize Seismic Hazard

$$\lambda(S_a > x) = \sum_{i=1}^{n_{sources}} \lambda(M_i > m_{\min}) \sum_{j=1}^{n_M} \sum_{k=1}^{n_R} P(S_a > x \mid m_j, r_k) P(M_i = m_j) P(R_i = r_k)$$

magnitude recurrence curve such as Gutenberg-Richter (G-R)

use ground motion prediction equation for S_a

model distribution of distances from earthquakes to site

develop pdf assuming bounded G-R recurrence with m_{min} and m_{max}

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