



*Twenty-First Annual Undergraduate
Seismic Design Competition (SDC)*



GROUND MOTION SELECTION GUIDE

Organized and Run by:

EERI Student Leadership Council (SLC)

Competition Website:

<https://slc.eeri.org/2024-sdc/>

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1. DISCLAIMER

This Ground Motion Selection Guide has been prepared by the SLC to assist students in understanding the step-by-step process of ground motion selection. While every effort has been made to ensure the accuracy and reliability of the information provided, the SLC does not make any warranties regarding the completeness, accuracy, suitability, or reliability of the content contained within this guide.

The information in this guide is intended for educational purposes only and should not be considered as professional advice. Ground motion selection for seismic design is a complex task that involves various factors, and it is recommended that students consult with qualified professionals or experts in the field for specific and detailed guidance tailored to their projects, while adhering to role expectations for advisors outlined in [Section 3.2](#) of the *Official Rules*.

The SLC shall not be held responsible for any loss, damage, or injury that may arise from the use of this guide or its content in other contexts beyond the SDC.

Additionally, please be aware that the second ground motion used during the shaking day is a simulated version derived from ground motion records available on different databases. It is not an exact replication of any single record. For your analysis, you can use this guide to estimate the intensity of the second ground motion, but we will not disclose the specific details of the record used until Shake Day.

2. TARGET RESPONSE SPECTRUM

A response spectrum is a graphical representation used in structural engineering and seismology to depict the peak structural response of all possible linear single-degree-of-freedom systems to a particular component of ground motion [1]. It illustrates the maximum response of a building (acceleration, velocity, or displacement) plotted against corresponding structural periods (or frequencies). Engineers rely on these spectra to design and evaluate the performance of a structure during an earthquake.

Building codes, such as ASCE 7-22 [2], typically establish a target spectrum for design purposes. This spectrum aligns with a designated hazard or risk level, aiming to achieve a specific level of structural performance. For instance, the structure might be designed to achieve Collapse Prevention during an earthquake event with a return period of 2,500 years. For the 2024 SDC, the client wants to ensure that their structure does not collapse when subject to an earthquake event representative of the Risk-Targeted Maximum Considered Earthquake (MCE_R) as defined in ASCE 7-22. To assess the performance of the proposed design, a structural balsa wood model will be built and tested at the UCIST shake table using two scaled ground motions.

The second ground motion, **GM#2**, will be selected and scaled by the SLC to approximately match the intensity of the MCE_R , subject to the limitations of the shake table. Unlike previous SDC editions, acceleration data for **GM#2** will not be disclosed to the participating teams. Instead, teams are expected to select a ground-motion set from a database of recorded ground motions from different seismograph stations. Students will use the MCE_R spectrum from ASCE 7-22 as a target and assess how closely the recorded ground-motion spectra resemble this target in their selection process. The selected ground motions will serve as an estimate of **GM#2**'s potential characteristics.

The MCE_R , as defined in ASCE 7-22, is determined based on the location, site class, and risk category. To ensure consistency across teams, the following parameters must be used when estimating the MCE_R :

- **Location:** 4th Ave and James, Downtown Seattle.
- **Site Class:** D.
- **Risk Category:** II.

Note that the Site Class enforced in this guide is for ground-motion selection purposes only and does not necessarily reflect the soil conditions reported in the boring logs. Teams are still required to present their geotechnical assessment, including the site class, in their proposals.

2 - Target Response Spectrum

Once these parameters are established, the next step involves consulting seismic hazard maps and engineering standards to define the specific seismic design criteria for the given location. The first step in this process is to use the ASCE 7 hazard tool, an online resource, to estimate the MCER response spectrum. You can access this tool through the following website:

<https://asce7hazardtool.online/>.

Upon visiting the site, you will find a page layout similar to Figure 1.

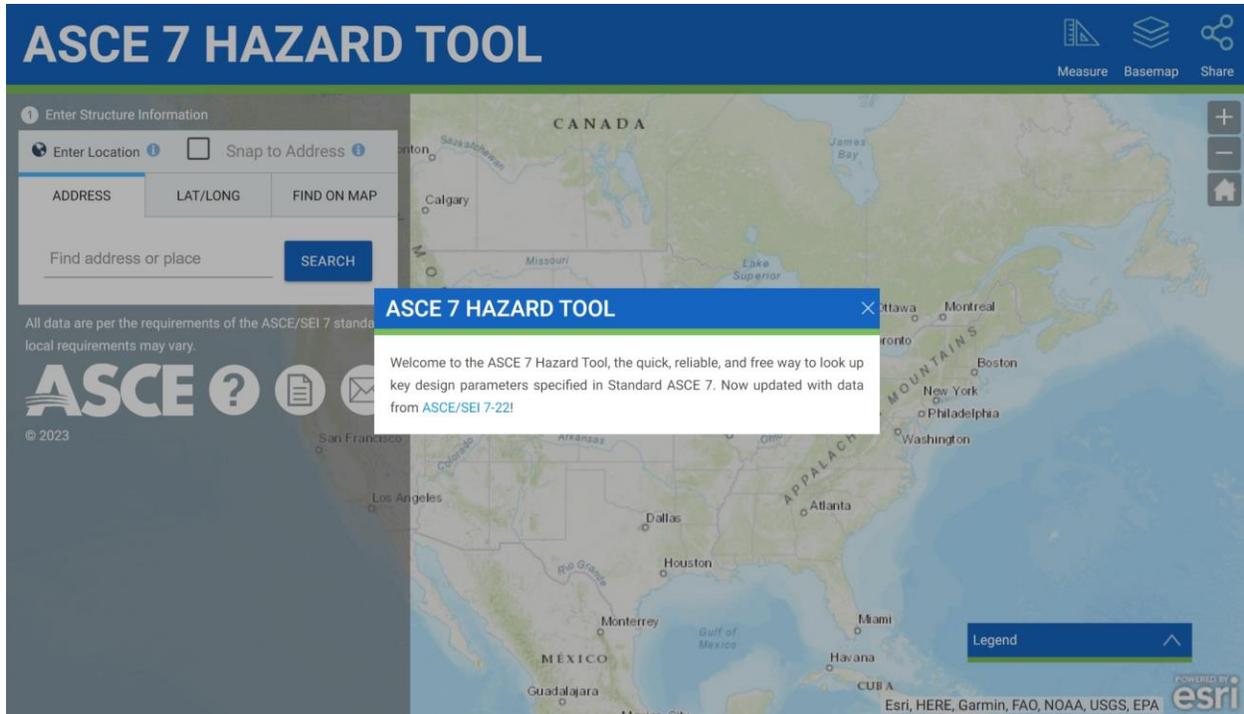


Figure 1 Welcome page of the ASCE 7 hazard tool.

On the top left corner of the website, there are three options to locate a specific site. The first option allows you to enter the address, the second one requires the latitude and longitude coordinates, and the third option lets you pinpoint the location directly on a map. If you enter the address and click on the search button, the tool will precisely locate the area for you. Refer to Figure 2 for a visual representation of these steps.

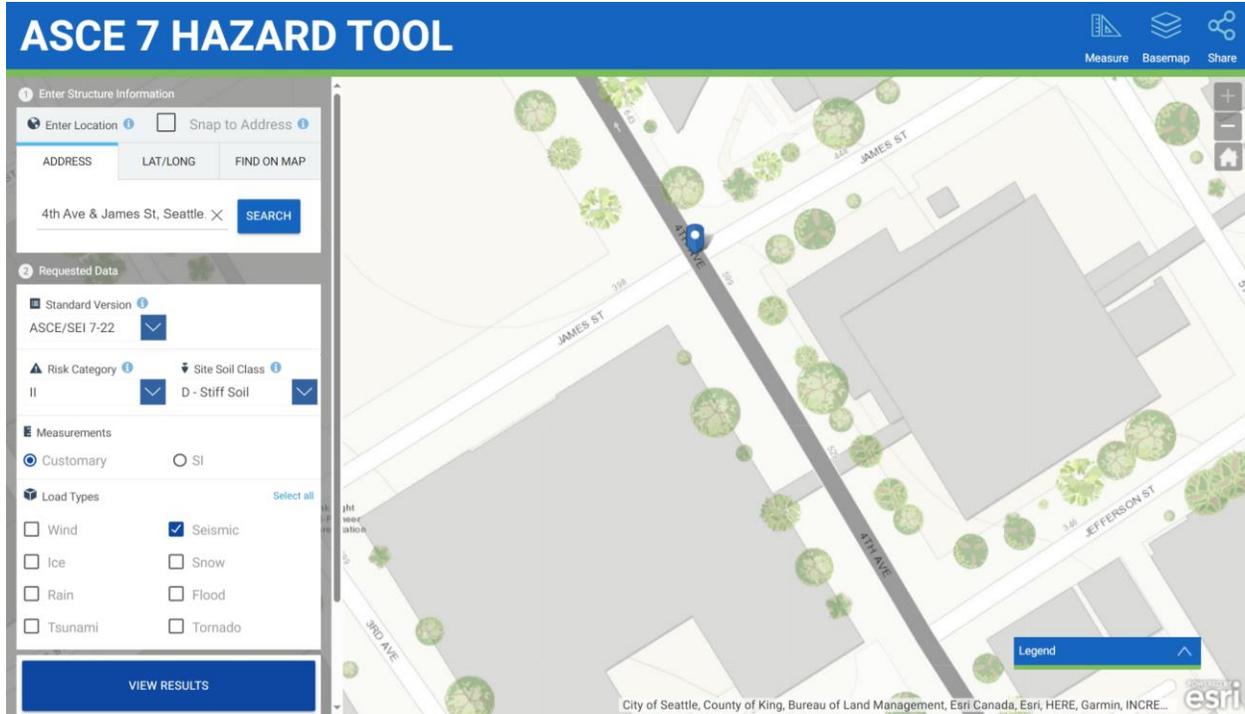


Figure 2 Selecting a site on the ASCE 7 hazard tool.

In the Risk category, specifically, you should choose the second category (**Risk Category II**). Within the Site Class drop-down menu select '**Site Class D**', indicating stiff soil conditions. Under the Load Type category, opt for '**Seismic**', and then proceed to click on '**View Results**'. A window will appear, displaying more detailed information about the latitude and longitude of the site location. This information is depicted in Figure 3.

For a comprehensive analysis, if you click on the '**Full Report**' option, a PDF file will be generated. This document will contain all the essential information necessary for establishing the target spectrum.

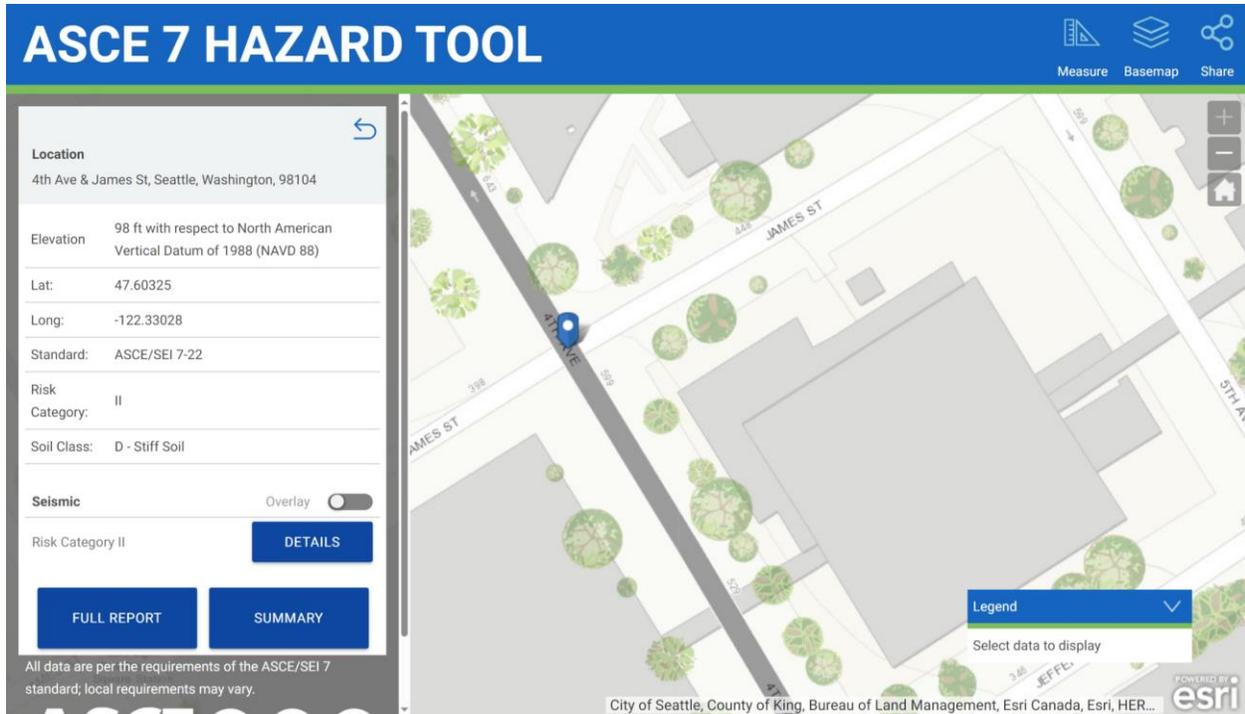


Figure 3 Site detail view before generating the full report.

The PDF file consists of four pages. To view the plots of the MCE_R spectrum and its related seismic design parameters, please turn to [page 2 of the report](#). An illustrative example is provided in Figure 4 for your reference. This information is also available for download in the form of [CSV files](#) if clicking 'Details' in Figure 3.

Note that there you will find two definitions of the MCE_R spectrum in Figure 4. Previous editions of ASCE 7, such as ASCE 7-16, utilized the Two-Period MCE_R spectrum for design. However, the current edition, ASCE 7-22, mandates the use of the Multi-Period MCE_R spectrum. For the 2024 SDC proposal submission, either definition of the MCE_R spectrum will be accepted. Please provide a clear rationale for your choice, explaining why you selected one over the other in your submission.

Ensure you use the MCE_R spectrum, not the Design Spectrum, as your target when selecting ground motions to estimate $GM\#2$. The Design Spectrum aligns with precisely $2/3$ the intensity of the MCE_R . Be mindful of this distinction in your calculations.



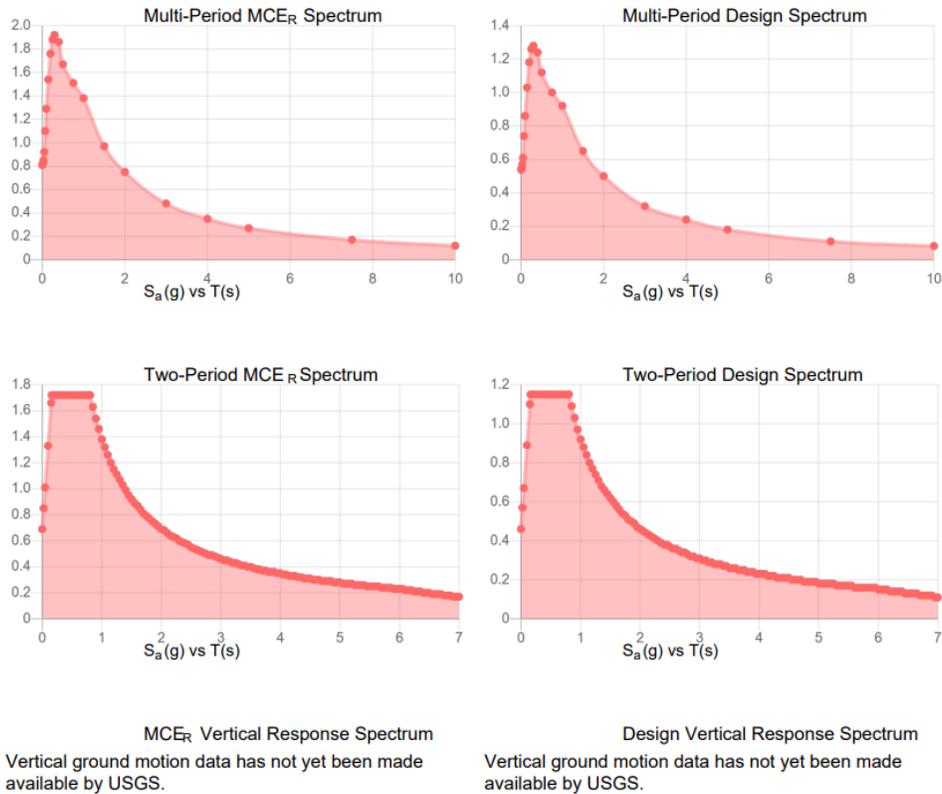
D - Stiff Soil

Site Soil Class:

Results:

PGA _M :	0.71	T _L :	6
S _{MS} :	1.72	S _S :	1.57
S _{M1} :	1.38	S ₁ :	0.66
S _{DS} :	1.15	V _{S30} :	260
S _{D1} :	0.92		

Seismic Design Category: D



<https://asce7hazardtool.online/>

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Sun Oct 15 2023

Figure 4 Target MCE_R spectrum and related seismic design parameters for the selected site.

3. SEISMIC HAZARD DEAGGREGATION

Ground motions are influenced by various factors, including earthquake magnitude, distance, soil type, and fault characteristics. According to ASCE 7-22, factors such as magnitude, site soil conditions, site-to-source distance, and source mechanism should be considered when selecting ground motions for seismic design and performance assessment. In this document, we simplify the analysis by omitting the source mechanism and focusing on other parameters.

To find the expected magnitude and distance for ground motion selection, we will use the seismic hazard deaggregation (also known as disaggregation) provided by the US Geological Survey (USGS) [3]. Visit the following link:

<https://earthquake.usgs.gov/nshmp/hazard/disagg>.

Input the latitude and longitude obtained from Figure 3. Configure the remaining parameters as indicated in Figure 5. For simplicity, we have set the Intensity Measure Type to PGA with an Intensity Measure Level value of $PGA_M = 0.71$ as specified in Figure 4. Scroll down and click on 'Plot'. The results will be displayed. For detailed information, scroll further down to see the results illustrated in Figure 6.

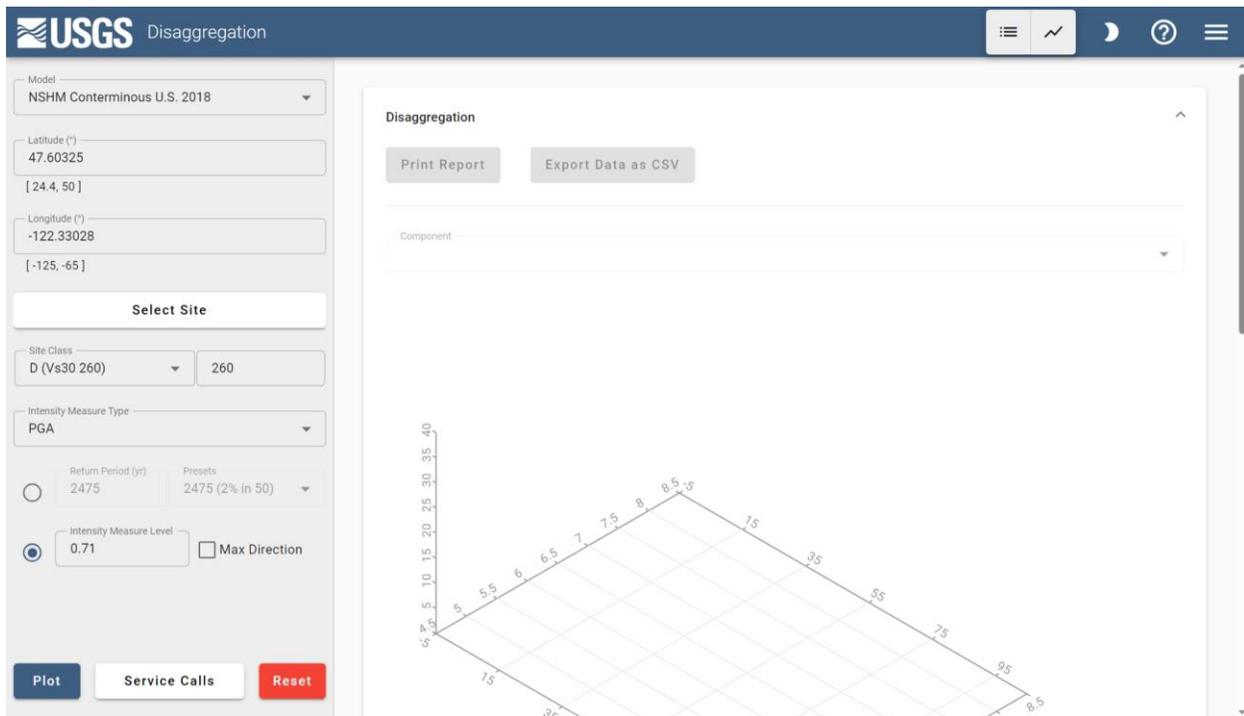


Figure 5 Welcome page for the USGS Disaggregation tool.

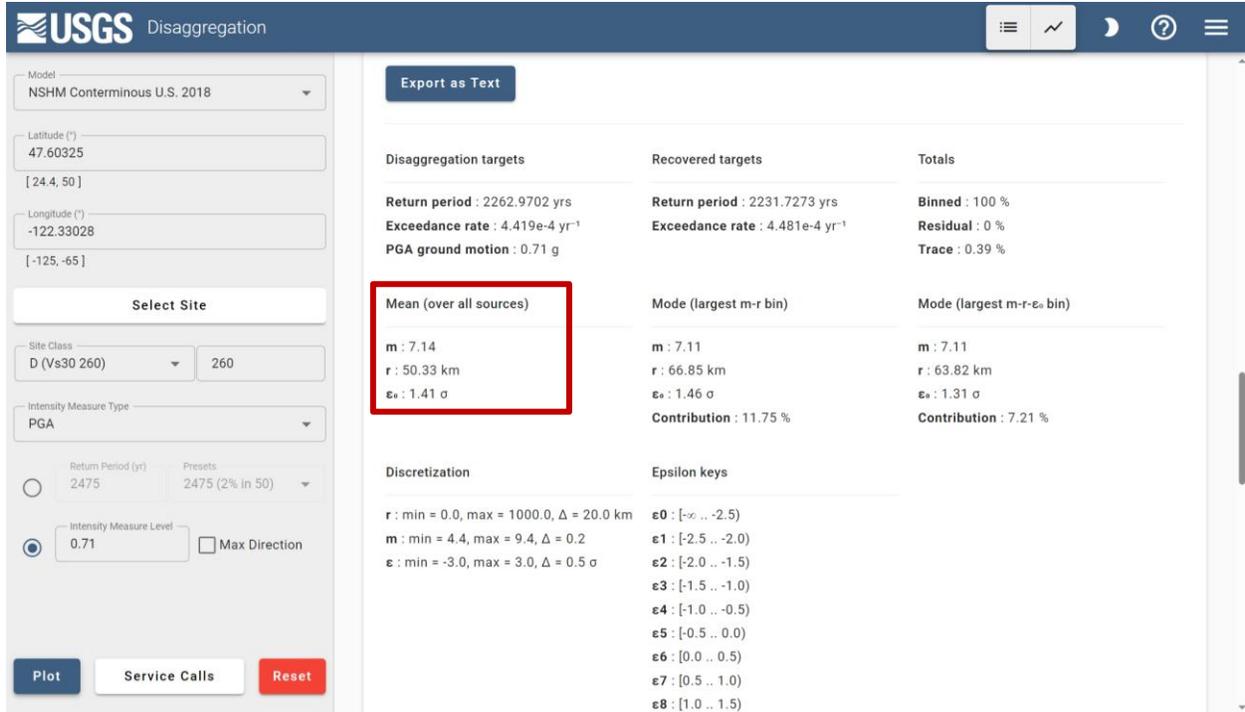


Figure 6 Deaggregation results. Red box added by the SLC.

In the red box highlighted in Figure 6, you will find the estimated mean values, calculated by averaging across all sources, for both magnitude and distance. Specifically, the mean magnitude is **7.14**, and the mean distance is **50.33 km**. For simplicity, we will assume these values represent the most likely earthquake scenario expected at the site.

With these mean values derived from deaggregation and the MCE_R target spectrum in hand, we can proceed to the ground motion selection process. In this final step, we rely on the PEER NGA-West2 web application to choose ground motions that match with the target spectrum (MCE_R) and the expected earthquake scenario.

4. GROUND MOTION SELECTION

Once a specific earthquake scenario, defined by magnitude and distance, has been established, the next step involves selecting ground motions that accurately represent the MCE_R at the site. Seattle, being situated in a complex tectonic setting, is susceptible to both crustal and subduction earthquakes. These two types of earthquakes are fundamentally different, and it is crucial to account for their distinctions when creating a ground motion set. However, for simplicity, our approach will involve selecting ground motions exclusively from the PEER NGA-West2 database [4], focusing solely on crustal earthquakes.

To access this database, please click on the following link:

<https://ngawest2.berkeley.edu/>.

Note: Alternatively, teams have the option to utilize the NHR3 NGA-Subduction Web Portal [5] for ground motion selection:

<http://ec2-35-167-122-9.us-west-2.compute.amazonaws.com/ngasubductions/new>

This web application features a comparable interface to NGA-West2 but includes subduction ground motions, offering a broader range of ground motions for consideration.

Upon clicking, a window similar to the one shown in Figure 7 will appear.

To access the NGA-West2 center depicted on the right side of Figure 7, simply click on it. Upon doing so, the system will prompt you to sign in. If you do not have an existing account, you will need to register on the website. During the registration process, provide your email address (preferably your university email) and set a password. Once your account is created, you can sign in and start using the application.

Similarly, the NHR3 NGA-Subduction website will also require users to sign up.

After signing in, the application will guide you to upload a user-defined target spectrum, allowing you to proceed with the ground motion selection process; see Figure 8. Following the website instructions, we have uploaded a CSV file containing the MCE_R spectrum obtained from Figure 4. Click on **'Submit'**, and you should receive a plotted spectrum, visible in Figure 9, confirming the successful completion of this step.

On the NHR3 application, rather than uploading a CSV file, users just copy and paste the values of the spectrum into the website; see Figure 12.

Next, click on the ‘**Search Records**’ at the bottom of the page (Figure 9), and a new window, as shown in Figure 10, will appear.

To configure the selection criteria, as demonstrated in Figure 10, follow these steps:

- Input a range of (6.14, 8.14) in the magnitude box. This range signifies the minimum and maximum magnitudes of the records to be searched. This selection is based on our estimated mean magnitude from deaggregation shown in Figure 6, which is 7.14. To ensure a comprehensive search around this value, it is advisable to consider a range of 7.14 ± 1 , translating to (6.14, 8.14). This setup ensures that the search includes records falling within this specific magnitude range.
- For the distance parameter, enter (30.33, 70.33), representing 50.33 ± 20 . The value 50.33 is derived from the deaggregation results shown in Figure 6.
- Regarding V_{s30} (m/s), input (180, 360) to consider Site Class D based on ASCE 7-22. V_{s30} denotes the average shear wave velocity of the soil in the top 30 meters.
- Set the maximum number of records to search at 30, ensuring a comprehensive exploration across the databases to match the target spectrum.
- For the scaling factor, use (0.5, 4.0), representing the minimum and maximum values for scaling the ground motions. Note that a maximum scale factor of 4.0 is typically considered very high in practice but will be considered acceptable for our case study.

Adjust the other parameters as illustrated in Figure 10. Upon configuring these settings, clicking on ‘**Search Records**’ at the bottom of the page will display 30 ground motions that best match the target spectrum (MCE_R). These results are detailed in Figure 11.

A similar procedure can be followed for NHR3, resulting in the parameter setting shown in Figure 13. Then, click ‘**Search Database & Compute Scale Factors**’ to obtain a set of ground motions; see Figure 14.

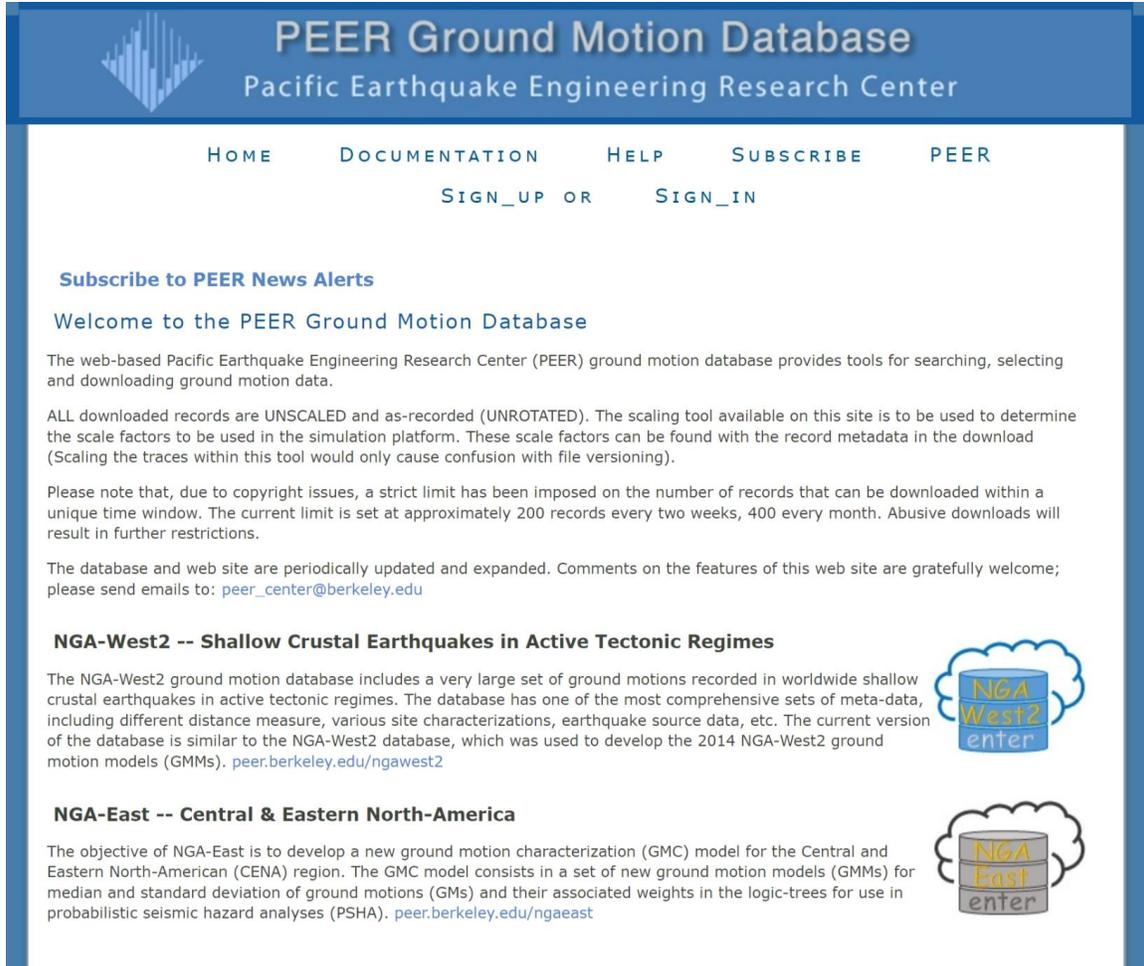
Figure 11 shows the mean of 30 ground motion records that should also align with the target spectrum. The figure displays various parameters corresponding to each ground motion, including Record Number, MSE (mean square error of scaled records), Scale Factor, Duration, Arias Intensity, Event Name, Year of Occurrence, Station Name, Magnitude, Fault Type (Mechanism), Distance, and V_{s30} (m/s). For detailed analysis, you

can download all the time series records, including metadata, spectra, and traces, by clicking on '[Download Time Series Records](#)' at the bottom of the page.

Similarly, on the NHR3 website, you can download all the time series records and their metadata by clicking on '[Download Unscaled Time Series & Metadata](#)' at the bottom of the webpage.

It is important to note that each record has a specific **scaling factor**. If you intend to use any of the 30 ground motion records for your response history analysis, you will need to multiply your time series by the corresponding scale factor of the selected record. Also, note that these records usually have two horizontal components of acceleration (e.g., N-S and E-W, H1 and H2, or 00 and 90 deg.). You can ignore the vertical component of these ground motions for your analyses since we will not be shaking your structural models vertically.

Additionally, please be aware that the acceleration records from PEER NGA-West2 and NHR3 NGA-Subduction are formatted using the .AT2 format. These files should be read line by line, with each line containing groups of 5 consecutive values recorded using a constant time step.



PEER Ground Motion Database
Pacific Earthquake Engineering Research Center

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Welcome to the PEER Ground Motion Database

The web-based Pacific Earthquake Engineering Research Center (PEER) ground motion database provides tools for searching, selecting and downloading ground motion data.

ALL downloaded records are UNSCALED and as-recorded (UNROTATED). The scaling tool available on this site is to be used to determine the scale factors to be used in the simulation platform. These scale factors can be found with the record metadata in the download (Scaling the traces within this tool would only cause confusion with file versioning).

Please note that, due to copyright issues, a strict limit has been imposed on the number of records that can be downloaded within a unique time window. The current limit is set at approximately 200 records every two weeks, 400 every month. Abusive downloads will result in further restrictions.

The database and web site are periodically updated and expanded. Comments on the features of this web site are gratefully welcome; please send emails to: peer_center@berkeley.edu

NGA-West2 -- Shallow Crustal Earthquakes in Active Tectonic Regimes

The NGA-West2 ground motion database includes a very large set of ground motions recorded in worldwide shallow crustal earthquakes in active tectonic regimes. The database has one of the most comprehensive sets of meta-data, including different distance measure, various site characterizations, earthquake source data, etc. The current version of the database is similar to the NGA-West2 database, which was used to develop the 2014 NGA-West2 ground motion models (GMMs). peer.berkeley.edu/ngawest2



NGA-East -- Central & Eastern North-America

The objective of NGA-East is to develop a new ground motion characterization (GMC) model for the Central and Eastern North-American (CENA) region. The GMC model consists in a set of new ground motion models (GMMs) for median and standard deviation of ground motions (GMs) and their associated weights in the logic-trees for use in probabilistic seismic hazard analyses (PSHA). peer.berkeley.edu/ngaeast



Figure 7 PEER NGA welcome page.



Figure 8 Defining Target Spectrum on the PEER NGA-West2 website.



PEER Ground Motion Database

Pacific Earthquake Engineering Research Center

NGA-West2

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If the target spectrum is plotted in the graph, the target spectrum was created successfully. If not, please check the format of the input file. If successful, you may modify your input and recreate it, or you may click Search Records.

Edit Spectra

Select Spectrum Model

Select models to generate target spectrum: User Defined Spectrum

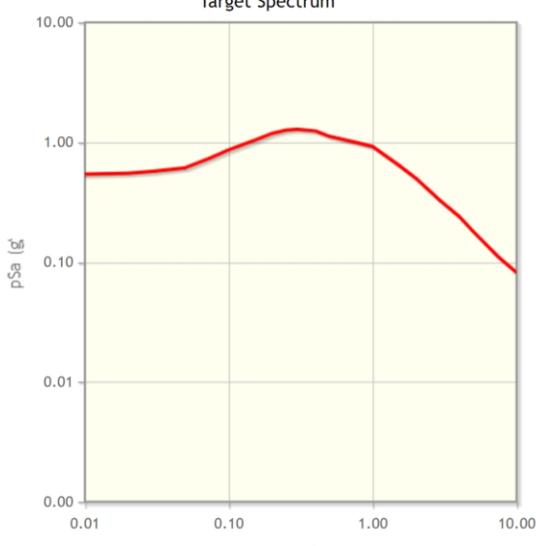
User-Defined Spectrum

As shown in the sample file, start spectra data at row 4 of input file. Spectra data consists of rows of T,pSa comma-separated values.

Filename: my_spectra.csv##e85fca89939 [Upload File](#)

[Download Example file\(.csv\)](#)

Target Spectrum



■ Target Spectrum

Loglog

Click on each label in the legend to toggle its view in the graph. Window Zooming is possible only in Linear plot.

[Show/Hide GMM Notation](#)
[Show/Hide GMM Regions](#)
[Show/Hide GMM Figures](#)

[Recalculate Spectrum](#)
[Download Target Spectra](#)
[Search Records](#)

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Figure 9 MCE_R spectrum successfully loaded to the PEER NGA-West 2 application.



PEER Ground Motion Database

Pacific Earthquake Engineering Research Center

NGA-West2

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Search was successfully created. Please allow time to render the graphics.

Edit Search

Load Sample Input Values
Clear Input Values

Search

These characteristics are defined in the NGA-West2 Flatfile. You need to re-run Search when any of these parameters are updated.

Record Characteristics:

RSN(s) : RSN1,...RSNn

Event Name :

Station Name :

Search Parameters:

Fault Type :

Magnitude :
min,max

R_JB(km) :

min,max

R_rup(km) :
min,max

Vs30(m/s) :
min,max

D5-95(sec) :
min,max

Pulse :

Additional Characteristics:

Max No. Records :
(<=100)

Initial ScaleFactor :
min,max

Suite

Spectral Ordinate :

Damping Ratio :

Suite Average :

Scaling

Scaling Method :

MSE = Computed Weighted Mean Squared Error of record, and suite average, wrt target spectrum.

Weight Function

Used in both search and scaling when computing MSE. Values can be updated for rescaling. Intermediate points are interpolated with $W = f_{xn}(\log(T))$

Period Points : (T1,T2, ... Tn)

Weights : (W1,W2, ... Wn)



The graph shows a weight function W on the y-axis (ranging from 0.00 to 1.00) against Period (sec) on the x-axis (ranging from 0.00 to 10.00). The function is 1.00 for periods between 0.1 and 1.0 seconds, then drops to 0.00 for periods greater than 1.0 seconds.

Controls

Search Records
Rescale Only

Figure 10 Parameter setting for ground motion selection using PEER NGA-West2.

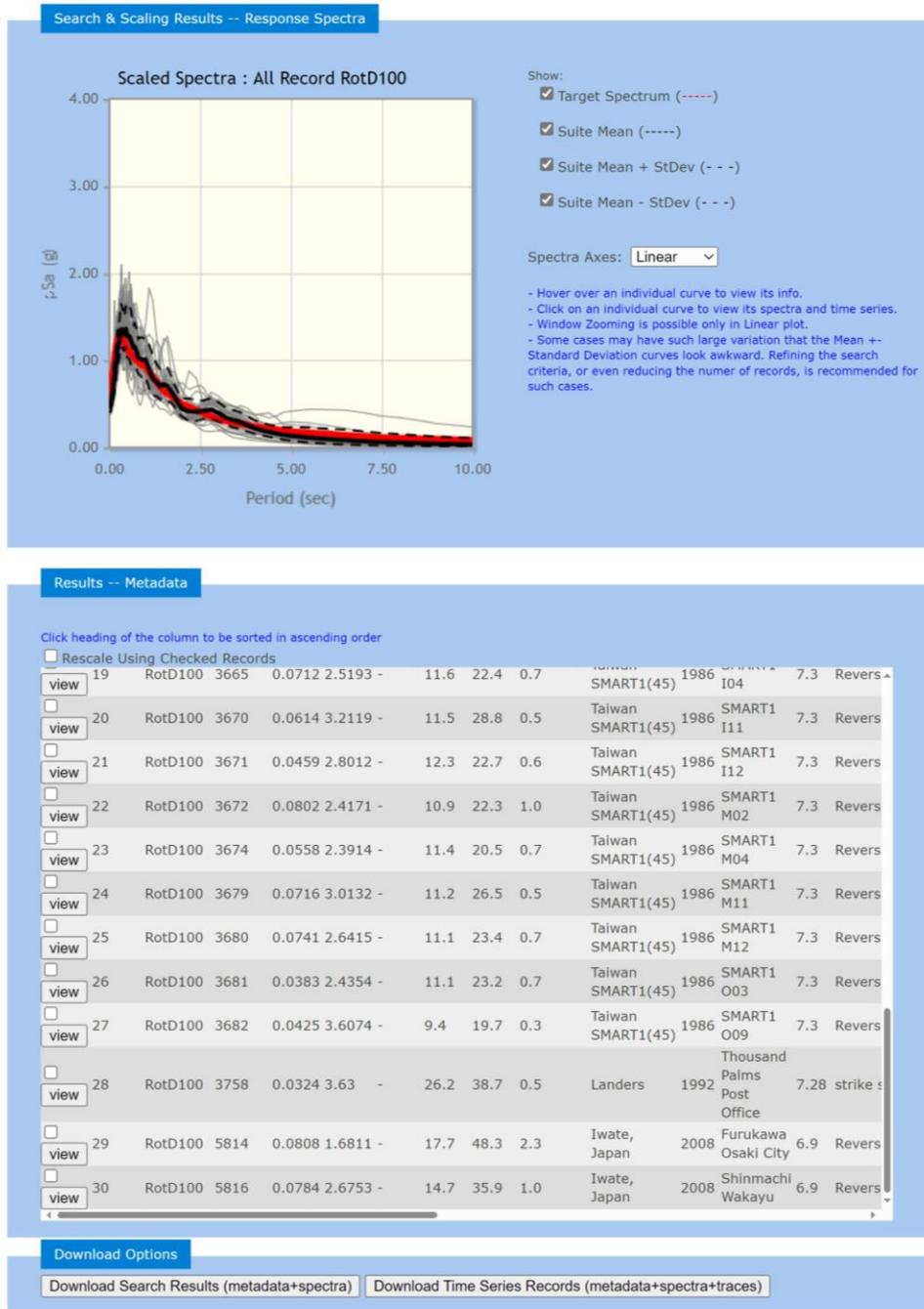


Figure 11 Example of ground motions from PEER NGA-West2 matching the MCE_R.

NGA-Subduction Web Portal: Ground-Motion Record Selection and Download

>>press here to return to NGA-Subduction Portal to START a New Project<<

Target Spectrum

[Show/Hide Target-Spectrum Input](#)

Select Target-Spectrum Model

Target-Spectrum Method

User-Defined Spectrum

[Load Sample Values](#) | You can try copying and pasting each column/row from your excel file

Target-Spectrum Period (T1,T2,...,Tn)

0
0.01
0.02
0.03
0.05

Target-Spectrum PSA (PSA1,PSA2,...,PSAn)

0.54
0.54
0.55
0.57
0.61

Compute Target Spectrum

This web portal was developed by Silvia Mazzoni (smazzoni at ucla dot edu), with the assistance of James Way at the The B. John Garrick Institute for the Risk Sciences at UCLA Engineering (NHR3)
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Figure 12 Defining Target Spectrum on the NHR3 website.

Search and Scale Input

Show/Hide Search Input

Load Sample Values Clear Input

Event

Magnitude (min,max)
6.14,8.14

Earthquake Region
All

Earthquake Name (ex: Tohoku
{2844986 = Maule})

Event Year (min,max)

Hypocenter Lat., deg (min,max)

Hypocenter Long., deg (min,max)

Hypocenter Depth, km (min,max)

Subducting Slab
All

Event Type
All

VolcanicArcFlag of Hypocenter
All

Event NGAsubEQID (EQID1,...)

Station

Vs30 m/s (min,max)
180,360

Station Name (ex: Fukushima)

Network
All

Station Latitude, deg (min,max)

Station Longitude, deg (min,max)

VolcanicArcFlag of Station
All

Cascadia Basin Flag
All

Cascadia Basin Name
All

Station NGAsubSSN (SSN1,...)

Path

Rrup, km (min,max)
30.33,70.33

VolcanicArcFlag of ClosestPoint
All

Record

Useable Period (min,max)

Duration 5-95%, sec (min,max)

PGA (T=0.01s) g (min,max)

NGAsubRSN (RSN1,RSN2,...,RSNn)

Intensity Measure

Spectrum Resultant
RotD100

Damping Ratio (5%)
0.05

Scaling

Record-Scaling Method
Minimize MSE

Target-Spectrum Scale Factor
1.0

Initial Scale Factor (min,max)
0.5,4

MSE = Computed Weighted Mean Squared Error of either record, or suite average, wrt target spectrum.

MSE Weight Function

Period Points (T1,T2,...,Ti)
0.1,1,3

Weights (W1,W2,...,Wi)
1,1,1

The weight function defines the limits for the search and scaling criteria. It is used in both processes to compute the Weighted MSE (= Mean Squared Error of either the record or the suite average, wrt the target spectrum). Interpolation is linear in W and logarithmic in T.

Suite

Suite Average
Arithmetic

Max # of Records (<=100)
30

Search Database & Compute Scale Factors

Compute Scale Factors Only

Fill in only the cells that are needed to constrain the search!

Figure 13 Parameter setting for ground motion selection using NHR3 NGA-Subduction.

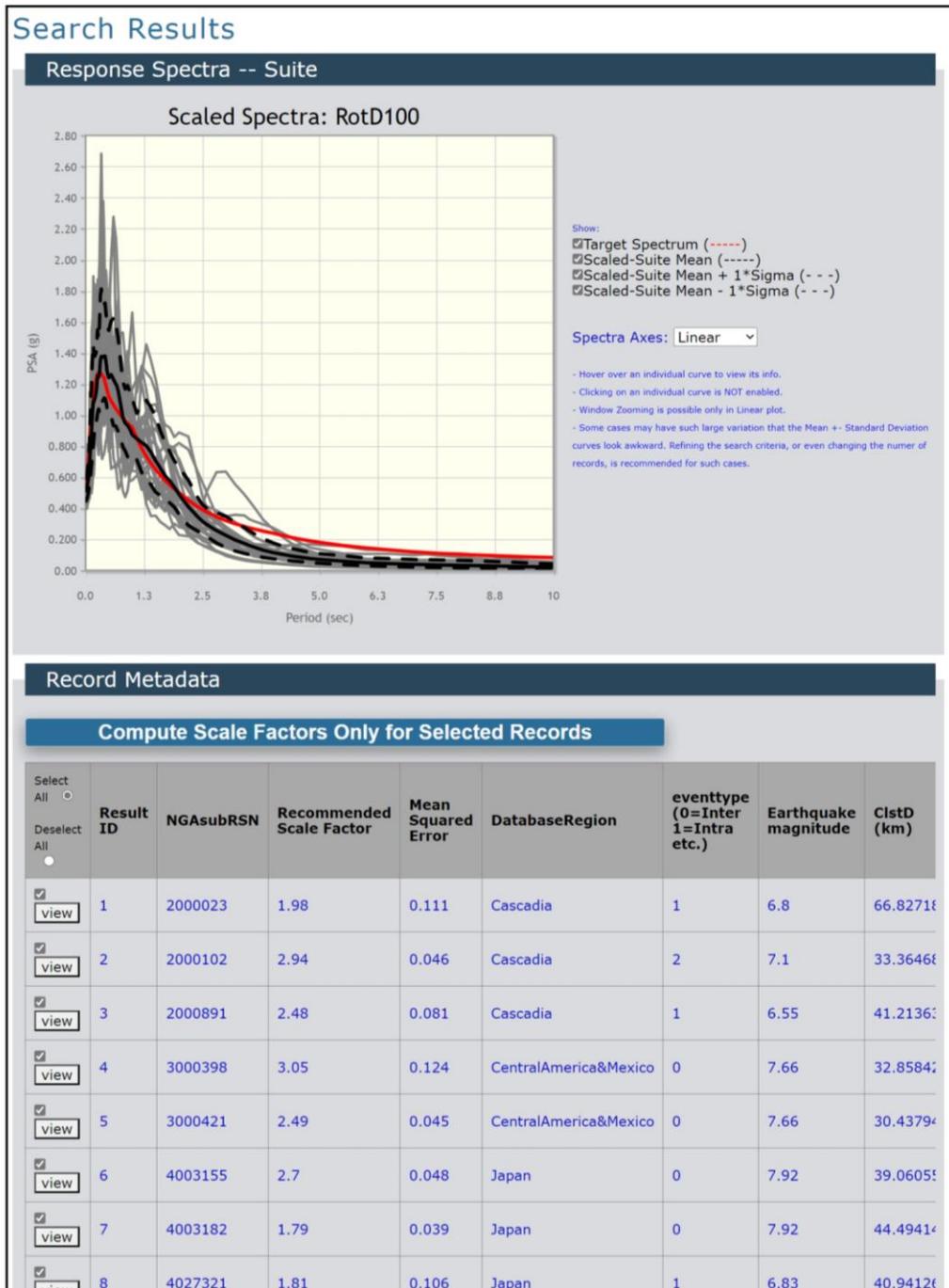


Figure 14 Example of ground motions from NHR3 NGA-Subduction matching the MCE_R .

5. PROPOSAL REQUIREMENTS

Part of the 2024 SDC *Proposal Requirements* is conducting a ground motion selection representative of **GM#2**. For this section, please meet the following requirements:

- Provide a concise overview of the ground motion selection process, focusing on the steps taken by the teams to curate a representative set of **at least 11 ground motions** corresponding to **GM#2**, as defined in the *Official Rules*. The narrative should outline the methodology employed, emphasizing the critical parameters considered, such as magnitude, distance, and site characteristics. Highlight the tools and databases utilized, including PEER NGA-West2 or NHR3 NGA-Subduction, and briefly discuss any criteria or constraints applied during the selection process. Important to note, the proposal should address the potential removal of ground motions from the 30 records initially suggested by the NGA websites. Ground motions that individually do not match the target spectrum very well might be considered for removal to improve the selected ground motion set.
- Present a detailed table listing the selected ground motions. Include essential metadata for each motion, such as earthquake details (name, date), station information, year of occurrence, magnitude, and distance from the epicenter. Also, provide the corresponding scale factors applied to each motion.
- Include a figure displaying the RotD100 response spectra of the chosen ground motions. Clearly illustrate these spectra alongside the target spectrum for **GM#2**.

6. REFERENCES

- [1] A. K. Chopra, «Elastic response spectrum: a historical note,» *Earthquake Engineering & Structural Dynamics*, vol. 36, pp. 3-12, 2007.
- [2] ASCE 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, ASCE/SEI 7-22, Reston, Virginia: American Society of Civil Engineers, 2022.
- [3] USGS, «USGS Earthquake Hazard Toolbox, Version 1.0.3,» US Geological Survey, 2022. [En línea]. Available: <https://earthquake.usgs.gov/nshmp/>.
- [4] T. D. Ancheta, R. B. Darragh, J. P. Stewart, E. Seyhan, W. J. Silva, B. S.-J. Chiou, K. E. Wooddell, R. W. Graves, A. R. Kottke, D. M. Boore, T. Kishida y J. L. Donahue, «PEER NGA-West2 Database,» Pacific Earthquake Engineering Research Center, Berkeley, CA, United States., 2013.
- [5] S. Mazzoni, «NGA-Subduction Portal: Ground-Motion Record Selection and Download,» The B. John Garrick Institute for the Risk Sciences., 2022. [En línea]. Available: <https://doi.org/10.34948/N3D59V>.