# SOFTWARE VALIDATION TEST PLAN AND REPORT
# EZ-FRISK™, Versions 6.22 and 7.20

*Prepared for*

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*Prepared by*


## Sarah Gonzalez

## Center for Nuclear Waste Regulatory Analyses
## San Antonio, Texas


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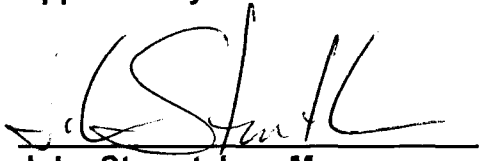
**Approved by:**



**John Stamatakos, Manager**
**Geology and Geophysics**

10/30/2006
**Date**

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# 1 SCOPE OF VALIDATION

The software EZ-FRISK™ was developed by Risk Engineering, Inc. EZ-FRISK calculates the probabilistic earthquake hazard at a site based on user-defined inputs. The user must specify the location and characteristics of seismic sources in the region and select one or more ground motion attenuation models applicable to the region. Seismic sources and attenuation models can either be selected from the EZ-FRISK database or defined by the user. The results of the program's probabilistic calculations are annual frequencies of exceedance of various ground motion levels at the site of interest. In addition, EZ-FRISK (Version 7.20) can spectrally match the response spectrum of an input acceleration time history to a specified target response spectrum.

This validation test plan and report documents the validation of EZ-FRISK Version 6.22 and 7.20. The validation test plan of EZ-FRISK Version 6.22 is identical to that used for the validation of EZ-FRISK Version 6.10 (Gonzalez, 2004). The seismic hazard for a rock site in San Diego, California was calculated in EZ-FRISK. This calculation required input of the relevant seismic sources and attenuation models from the EZ-FRISK database. The results were then compared with those obtained from the U.S. Geological Survey (2006) and the California Geological Survey (2006) websites for the same location. In performing the above calculation, the full capabilities of EZ-FRISK Version 6.22 were tested. The validation of EZ-FRISK Version 7.20 only focused on the spectral matching module. The probabilistic hazard calculations were not validated because they have not been used for any analyses to date, and a newer version of this software is now available.

Based on the presented results, this validation test was successful. The specified spectral matching criteria were satisfied for the validation of EZ-FRISK Version 7.20. The spectral matching criteria were based on those recommended in Section 5 of NUREG/CR–6728 (McGuire, et al., 2001). In addition, the validation of EZ-FRISK Version 6.22 yielded results that were within 10 percent of those obtained in the validation of EZ-FRISK Version 6.10 (Gonzalez, 2004).

# 2 REFERENCES

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# 3 ENVIRONMENT

## 3.1 Software

EZ-FRISK was built to operate within the Microsoft® Windows® (98/NT/2000/XP) family of operating systems.

## 3.2 Hardware

The following is a list of minimum requirements needed to run the application:

- PC with Pentium processor (or compatible) and 64 MB of memory (128 MB recommended) with 300 MB of free disk space
- A VGA monitor is required (a SVGA monitor is recommended)
- An available internet connection

# 4 PREREQUISITES

Not applicable.

# 5 ASSUMPTIONS AND CONSTRAINTS

Assumptions of this validation are presented in Section 6.1.4.

# 6 TEST CASES

## 6.1 Seismic Hazard Calculation

### 6.1.1 Objective

The objective of this validation was to demonstrate that EZ-FRISK Version 6.22 can correctly calculate the seismic hazard at a specified site and that EZ-FRISK Version 7.20 can successfully match the response spectrum of an acceleration time history to a specified target response spectrum. The acceptance criteria for the validation of EZ-FRISK Version 7.20 was based on the recommended criteria provided in Section 5 of NUREG/CR–6728 (McGuire, et al., 2001) for developing and evaluating artificial ground motions used to estimate the seismic response of nuclear power plants and other critical facilities.

Based on several of the recommended criteria in NUREG/CR–6728 (McGuire, et al., 2001), this software validation is successful if the computed 5 percent damped response spectrum of the artificial accelerogram does not fall more than 10 percent below the target spectrum at any one frequency point, and no more than 9 adjacent spectral points fall below the target spectrum at any frequency. In addition, the computed 5 percent damped response spectrum of the accelerogram should not exceed the target spectrum at any frequency by more than 30 percent in the frequency range between 0.2 Hz and 25 Hz. Furthermore, to ensure that the artificial accelerogram is not biased high with respect to the target, the average ratio of the spectral acceleration calculated from the artificial accelerogram to the target should only be slightly greater than one. Note that the ratio is calculated frequency by frequency.

An additional recommendation by McGuire, et al. (2001) is that, in general, artificial motions should have durations (5–75 percent Arias intensity) and ratios (PGV/PGA and $PGA \cdot PGD/PGV^2$) that are generally consistent with bin average values. This recommendation was not considered in this validation because it is dependent upon the particular time history and target response spectrum selected for the spectral matching.

For this validation, the target response spectrum was compared with the response spectrum of the artificial motion at each frequency in the 0.2 to 25 Hz range. As recommended in NUREG/CR–6728 (McGuire, et al., 2001), spectral accelerations were calculated at a minimum of 100 points per frequency decade and uniformly spaced over the log frequency scale from 0.1 to 50 Hz (or the Nyquist frequency).

The acceptance criteria for the validation of EZ-FRISK Version 6.22 was based on a comparison with the results of the Version 6.10 validation. If the two results agree to within 10 percent, this part of the validation is successful.

### 6.1.2 Test Input

A probabilistic seismic hazard analysis for San Diego, California (latitude 32.712°, longitude -117.16°) was performed in EZ-FRISK Version 6.22. For this validation, a shear wave velocity of 1000 m/s was assumed for the site. In addition, all seismic sources and

attenuation equations were selected from the EZ-FRISK Version 6.22 database. The results from this calculation will then be compared to those obtained from both the U.S. Geological Survey and California Geological Survey hazard mapping websites for the same location.

The validation of EZ-FRISK Version 7.20 involved spectrally matching two earthquake time histories to two target response spectra obtained from Bechtel SAIC Company, LLC (2004). The target spectra correspond to one of the 2,000-year return period deaggregation earthquakes (hereafter referred to as Test 1) and one of the 10,000-year return period deaggregation earthquakes (hereafter referred to as Test 2) developed for the Yucca Mountain, Nevada, site (Bechtel SAIC Company, LLC, 2004).

The target response spectra are provided in Tables 1 and 2. The target response spectrum in Table 1 corresponds to an earthquake with a magnitude $M_w$ = 5.9 located 9 km [5.6 mi] away. The target response spectrum in Table 2 corresponds to an earthquake with a magnitude $M_w$ 5.4 located 5 km [3.1 mi] away and represents the 10,000-year return period. Time histories with similar magnitudes and distances to the deaggregation earthquakes were selected. The time history selected to match the 2,000-year return period deaggregation response spectrum was obtained from the European Strong-Motion database (Ambraseys, et al., 2002). The time history selected to match the 10,000-year return period deaggregation response spectrum was obtained from NUREG/CR–6728 (McGuire, et al., 2001).

The electronic files related to this validation are on the attached CD in the directory EZ-FRISK Version 6.22 and EZ-FRISK Version 7.20.

**Table 1. Target Response Spectrum for Test 1***

| Frequency (Hz) | Spectral Acceleration (g) |
|---|---|
| 0.3 | 0.033 |
| 0.5 | 0.075 |
| 1.0 | 0.185 |
| 2.0 | 0.348 |
| 5.0 | 0.499 |
| 10.0 | 0.530 |
| 20.0 | 0.449 |
| 100.0 | 0.255 |

*Bechtel SAIC Company, LLC. "Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, Nevada." MDL–MGR–GS000003. Rev. 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2004.

| Table 2. Target Response Spectrum for Test 2* | |
|---|---|
| **Frequency (Hz)** | **Spectral Acceleration (g)** |
| 0.3 | 0.070 |
| 0.5 | 0.167 |
| 1.0 | 0.416 |
| 2.0 | 0.854 |
| 5.0 | 1.362 |
| 10.0 | 1.534 |
| 20.0 | 1.292 |
| 100.0 | 0.689 |
| *Bechtel SAIC Company, LLC. "Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, Nevada." MDL-MGR-GS000003. Rev. 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2004. | |

### 6.1.3 Test Procedures

The test procedure for performing the validation of EZ-FRISK Version 6.22 is identical to the procedure used for the validation of EZ-FRISK Version 6.10 (Gonzalez, 2004). Refer to Gonzalez (2004) for more detail.

This validation of EZ-FRISK Version 7.20 involved spectrally matching two earthquake time histories to two target response spectra obtained from Bechtel SAIC Company, LLC (2004). The target spectra correspond to one of the 2,000-year return period deaggregation earthquakes and one of the 10,000-year return period deaggregation earthquakes developed for the Yucca Mountain, Nevada, site. The test procedure is outlined below.

1. Start EZ-FRISK.

2. From the horizontal toolbar select **New > EZ-FRISK Project**. The "Project 1.ezf" window will appear. From the horizontal toolbar at the top of this window, click on "New Spectral Matching Run."

3. The "Execute Spectral Matching" window will then appear. Under "Target Spectrum," click on "Edit." The "Response Spectrum Editor" window will appear. In this editor, enter the values provided in Table 1.

4. Next, in the "Execute Spectral Matching" window under "Input Accelerogram File," click on "Import." Open the earthquake time history 000242YA.EQ.

5. In the "Execute Spectral Matching" window, click on "Matching Options." Under the "Basic" tab, make sure that "Minimum Frequency to Match, Hz" is set to 0.1, and "Maximum Frequency to Match, Hz" is set to 50 Hz (corresponding to the

Nyquist frequency of the input acceleration time history 000242YA.EQ). Also make sure that the option for "Apply Internal Baseline Correction is unchecked. In addition, set the "Maximum Number of Iterations" to 100 and "Tolerance for Spectral Match" to 0.01.

6. Under the "Target Spectrum" tab, set the "Maximum Frequency, Hz" to 50 Hz and the "Maximum Frequency, Hz" to 0.1.

7. Click on "OK." In the "Execute Spectral Matching" window, click on "Run."

8. When the matching run is complete, click on **File > Export > Adjusted Accelerogram** in the horizontal toolbar of the main program window.

9. Save as Project 1.ezf in the directory Test 2.

10. Repeat for the target response spectrum in Table 2 and the acceleration time history C-TSM360.AT2. Save as Project 1.ezf in the directory Test 2. Set the maximum frequency to 100 Hz for this input time history (corresponding to the Nyquist frequency).

### 6.1.4 Test Results

Tables 3 and 4 compare results obtained from EZ-FRISK Version 6.10 and Version 6.22 with those obtained from the U.S. Geological Survey and California Geological Survey websites. Ground motion values from the EZ-FRISK calculations are very close to those obtained from the U.S. Geological Survey and California Geological Survey websites. The maximum difference between the results from EZ-FRISK Version 6.22 and 7.20 is 2.34 percent. Possible reasons for the small observed differences are discussed in Gonzalez (2004). Based on this comparison, the validation test for EZ-FRISK Version 6.22 was successful.

**Table 3. Comparison of Probabilistic Ground Motion Values for an Annual Frequency of Exceedance of 0.0021**

| Model | PGA | 0.2 sec Spectral Acceleration | 1.0 sec Spectral Acceleration |
|---|---|---|---|
| EZ-FRISK 6.22 (Mean) | 0.256 | 0.604 | 0.239 |
| EZ-FRISK 6.10 (Mean) | 0.25 | 0.60 | 0.24 |
| California Geological Survey Website | 0.274 | 0.639 | 0.240 |
| U.S. Geological Survey Website | 0.273 | 0.635 | 0.238 |

| Table 4. Comparison of Probabilistic Ground Motion Values for an Annual Frequency of Exceedance of 0.00040 | | | |
|---|---|---|---|
| **Model** | **PGA** | **0.2 sec Spectral Acceleration** | **1.0 sec Spectral Acceleration** |
| EZ-FRISK 6.22 (Mean) | 0.731 | 1.614 | 0.678 |
| EZ-FRISK 6.10 (Mean) | 0.73 | 1.6 | 0.68 |
| California Geological Survey Website | N/A | N/A | N/A |
| U.S. Geological Survey Website | 0.68 | 1.575 | 0.619 |

The results of the spectral matching using EZ-FRISK Version 7.20 are shown in Figures 1 through 4. Figures 1 and 2 compare the output response spectra with target response spectra for Tests 1 and 2. The percentage differences between the output response spectrum and the target response spectrum for Tests 1 and 2 are shown in Figures 3 and 4, respectively. No more than 9 adjacent spectral points fall below the target spectrum, nor do any points fall more than 10 percent below the target spectrum and exceed the target spectrum by more than 30 percent in the frequency range between 0.1 and 50 Hz for Test 1 and 0.1 and 100 Hz for Test 2. Furthermore, the average ratio of the spectral acceleration calculated from the artificial accelerogram to the target should only be slightly greater than 1. For Test 1, the calculation ratio was 0.9996, and for Test 2, the calculated ratio was 1.0016. Both values are close to 1, which suggests that the artificial accelerogram is not biased high with respect to the target. Based on this comparison, the validation test for EZ-FRISK Version 7.20 was successful because the criteria recommended in NUREG/CR–6728, as discussed in Section 6.1.1 of this report, are satisfied.

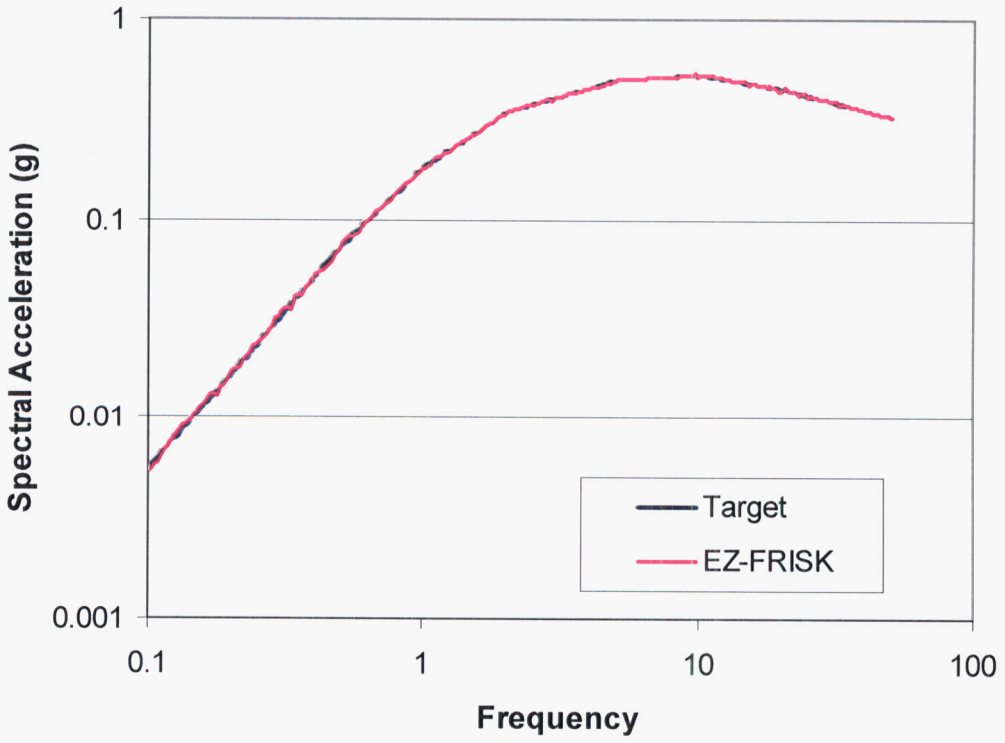


**Figure 1. Comparison of Target Response Spectrum and EZ-FRISK Output Response Spectrum for Test 1**

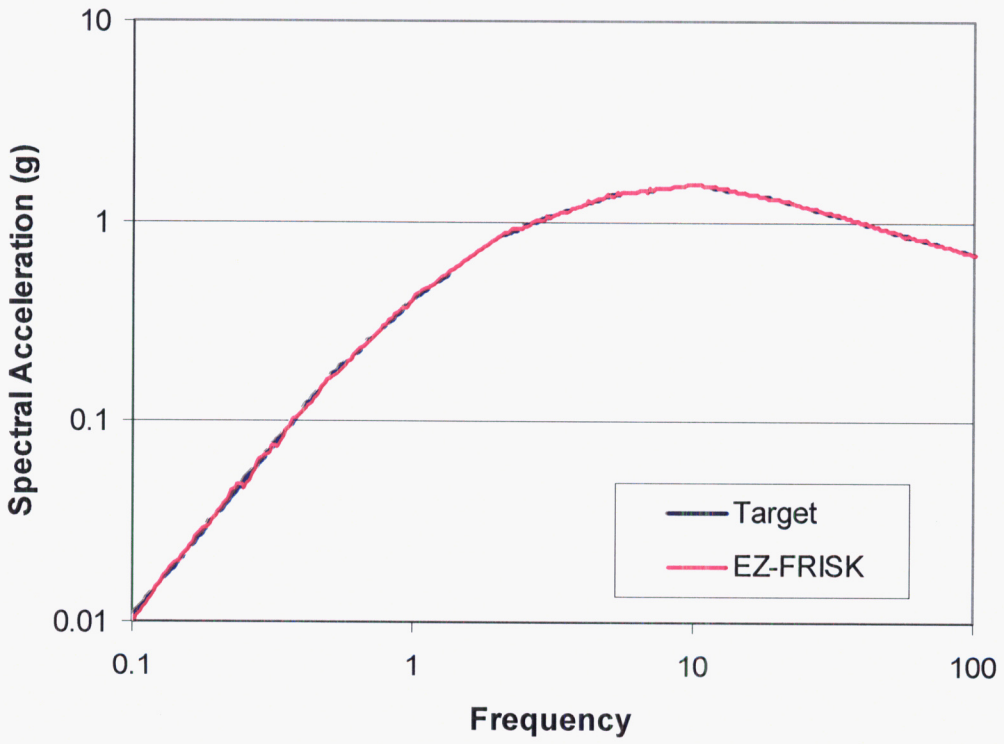


**Figure 2. Comparison of Target Response Spectrum and EZ-FRISK Output Response Spectrum for Test 2**

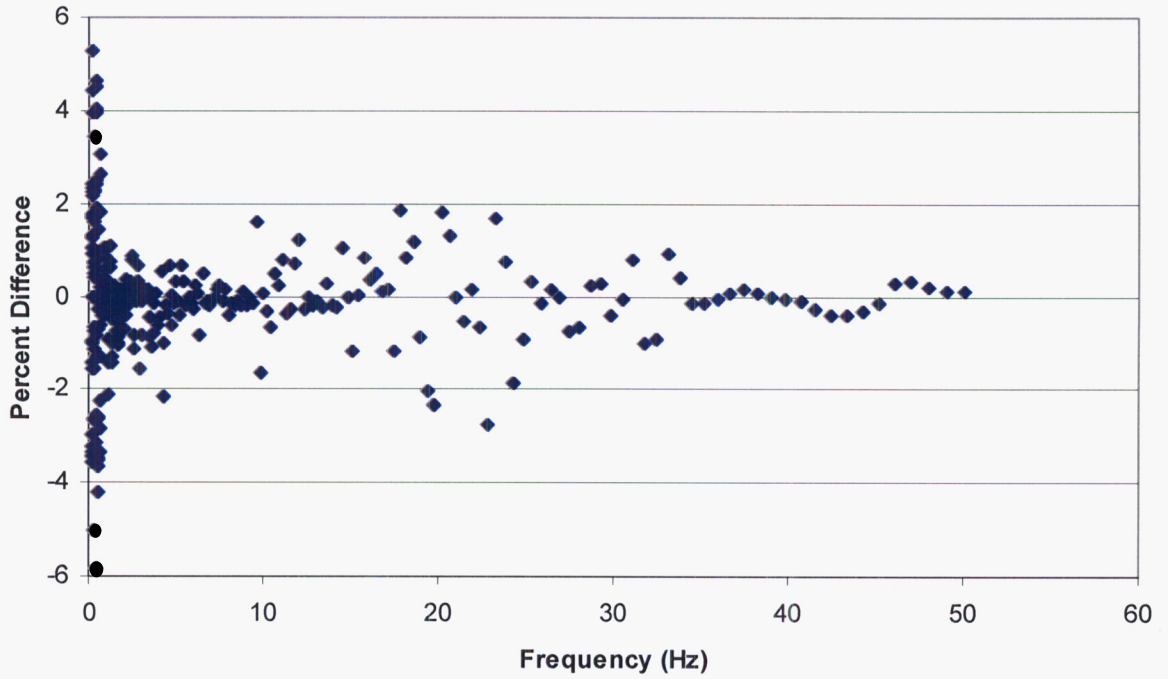


**Figure 3. Percent Difference Between Target Response Spectrum and EZ-FRISK Output Response Spectrum for Test 1**

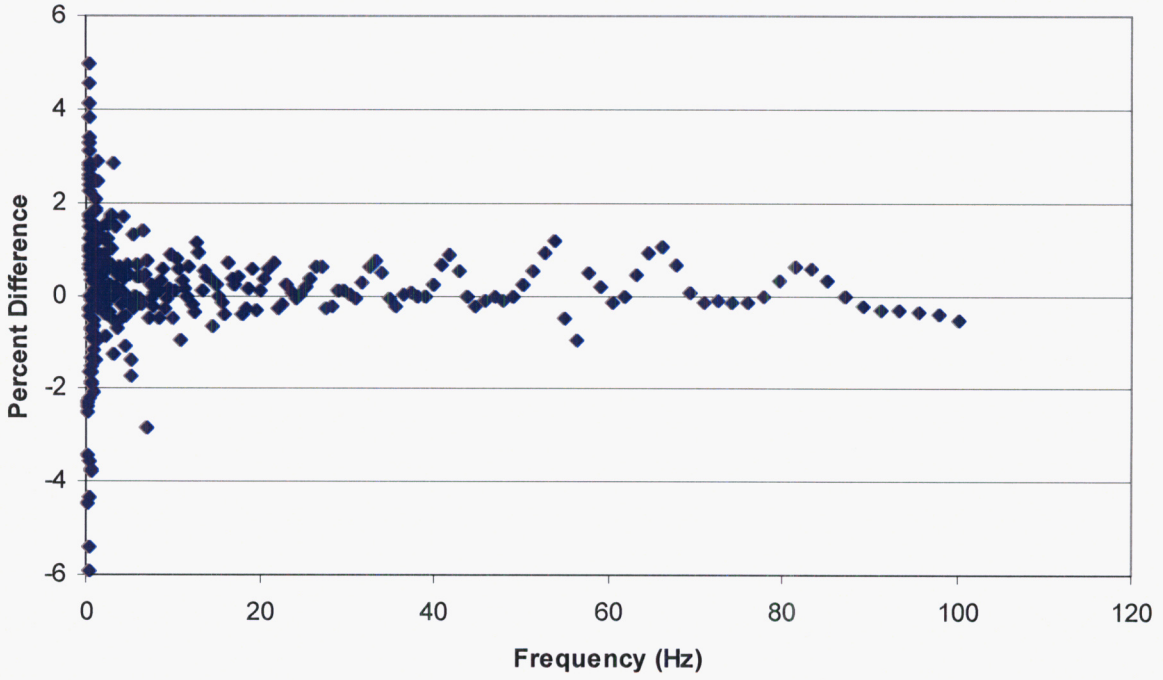


**Figure 4. Percent Difference Between Target Response Spectrum and EZ-FRISK Output Response Spectrum for Test 2**