LADD TOWER GT_001708

TERRA ASSOCIATES, Inc.

Consultants in Geotechnical Engineering, Geology
and
Environmental Earth Sciences

1310 SW Park Ave
1S1E 04 AD 00100
3128/4

06-145720-EXC-01-CO
06-145720-FND-01-CO

February 12, 2007
Project No. T-5735

Mr. Jeb Koerner
Opus Northwest, LLC
1500 SW First Street, Suite 1100
Portland, Oregon 97209

Subject: Site Specific Seismic Hazard Study
Ladd Tower
Portland, Oregon

Reference: Geotechnical Report, 1300 SW Park Tower, Project No. T-5735, prepared by Terra Associates, Inc., dated January 31, 2006

Dear Mr. Koerner:

As requested, Terra Associates, Inc. has performed a site-specific seismic hazard study for the subject project. The project site is located northeast of the intersection of SW Park Avenue and SW Columbia Street in Portland, Oregon. The approximate site location is shown on Figure 1.

The proposed project is a 22-story residential tower with 4 levels of below-grade parking. The planned elevation for the lower floor will be approximately Elev. 77. Based on current site grades, excavations required to achieve the lower floor and building foundation elevations will be about 50 feet.

The purpose of our study was to evaluate potential seismic hazards at the site due to local and regional seismicity. Our scope of work included the following:

- Review of available literature regarding local and regional geology and seismicity.
- Review of site-specific soil and groundwater information presented in our referenced geotechnical report.
- Determination of a site-specific response spectrum for ground motion having a 10 percent probability of being exceeded in 50 years.
- Evaluation of the potential for damage to the site due to other seismic hazards including earthquake-induced landslides, tsunamis or seiches, regional displacement, or fault displacement.

GEOLOGIC SETTING

The site is located near the southwestern margin of the Portland Basin, a northwest trending structural basin located at the northern end of the Willamette Valley. The basin is underlain by Eocene sedimentary rocks and mid-Miocene volcanic rocks of the Columbia River Basalt Group. The bedrock units are overlain by older consolidated sediments of the Troutdale formation, and Pleistocene alluvial and catastrophic flood deposits.

12525 Willows Road, Suite 101, Kirkland, Washington 98034
Phone (425) 821-7777 • Fax (425) 821-4334

Soils we observed in our geotechnical test borings drilled at the site generally consist of medium dense to dense silty sand to sand with silt to the boring termination depths about 51 to 81 feet below existing surface grades, which we interpreted to be the fine-grained facies of the catastrophic flood deposits (Qff). This is consistent with site geology shown on the *Geologic Map of the Portland Quadrangle, Multnomah and Washington Counties, Oregon, and Clark County, Washington*, by M.H. Beeson and others (1991). One of our site borings encountered very dense sand and gravel approximately 80 feet below the ground surface. This very dense sand and gravel unit may represent the upper horizon of the Troutdale formation, which is described as a friable to moderately strong conglomerate. A cross section included on the referenced geologic map shows the Troutdale formation underlying the Qff unit at a similar depth in the vicinity of the site. The information we reviewed indicates that in the vicinity of the subject site, the Troutdale formation is approximately 70 feet thick, and is underlain by the Sentinel Bluffs unit of the Grande Ronde Basalt formation. The mapped geology of the site and vicinity is shown on Figure 2.

The Portland Basin is bound by northwest-striking steeply-dipping faults, which are believed to have a right-lateral strike-slip sense of displacement. These faults include the Portland Hills fault, which runs through downtown Portland about 1,000 feet east of the subject site and forms the northeastern margin of the Tualatin Mountains (known locally as the Portland Hills); and the East Bank fault, which generally parallels the eastern side of the Willamette River through Portland. The Oatfield fault, located approximately two miles west-southwest of, and generally parallel to the Portland Hills fault, is mapped as a northwest-trending high-angle reverse fault with a right-lateral strike-slip component. The Oatfield fault may be part of the Portland Hills-Clackamas River structural zone described by Beeson and others. No historical earthquakes have been associated with the Portland Hills fault zone, which includes the three faults described above; however, all the structures are believed to be seismogenic, and capable of generating large damaging earthquakes. The locations of the faults described above are shown on Figure 3.

Regionally, the site is located in a very geologically active area situated between the off-shore Cascadia subduction zone (CSZ) to the west, and the volcanically-active Cascade Range to the east, both of which are potential sources of earthquakes in the region. Because the earth's crust between these two features is highly stressed, the region is susceptible to earthquakes on crustal faults. Other potentially damaging earthquakes to the region include thrust earthquakes along the off-shore plate boundary, and deep intraplate earthquakes occurring within the subducting Juan de Fuca plate.

SEISMICITY

There are three major origins of historic seismicity in the Portland area, including great thrust (subduction zone) earthquakes, deep (intraplate) earthquakes, and shallow (crustal) earthquakes. Recent interest has been focused on the CSZ as a structure capable of generating very large (greater than magnitude 8.0), shallow earthquakes. Recently discovered geologic evidence suggests that coastal estuaries in southwestern Washington State underwent rapid subsidence at various times over the last 2,000 years, with the most recent event occurring about 300 years ago. Great subduction earthquakes have been postulated as the cause of this subsidence.

No large subduction earthquakes have occurred in this zone during historical times. A lack of data makes it difficult to define potential earthquake magnitudes, rupture lengths, and recurrence rates for the CSZ. The maximum credible magnitude has been estimated at 8.0 to 9.0 with a recurrence interval of estimates of 300 to 1,000 years. The lack of historical earthquakes in CSZ may indicate that either the tectonic plates are uncoupled and subducting aseismically, or that the Juan de Fuca and North American plates are locked and storing energy to be released in future great earthquakes.

The expected rupture zone for a great subduction earthquake is generally considered to be about 60 mile off-shore from the Oregon coast. Because the epicentral distance from an offshore subduction earthquake would be on the order of 120 to 150 miles from the site, much of the damaging motions would be attenuated prior to reaching the site. Thus, peak ground acceleration at the site is expected to be more severe during a large near-field earthquake than from a greater far-field earthquake. However, the duration of a great far field earthquake could be much greater.

Deep intraplate earthquakes up to M_W (moment magnitude) 7.5 are believed possible in the Portland region; however, none have been recorded in historical times. Major historic earthquakes of this type have occurred in Washington State, including the M_W-7 Olympia earthquake in 1949 and the M_W-6.8 Nisqually earthquake in 2001. Both of these earthquakes had focal depths in excess of 30 miles

Damaging crustal earthquakes in the Portland area have been relatively rare in recent history. However, the seismic activity of the area has been realized by larger crustal events including the November 6, 1962 M_W-5.5 Vancouver, Washington earthquake, located approximately 10 miles north-northeast of Portland, and the March 25, 1993 M_W-5.6 Scotts Mills earthquake located about 30 to 40 miles south of Portland. Recent studies have suggested that crustal movements within the Portland Hills fault zone, and specifically along the Portland Hills fault, have the potential to generate large earthquakes of M_W-6.5 and greater. These earthquakes would be particularly damaging due to their proximity to the city.

For this study, we obtained probabilistic ground motion values for the design earthquake using the United States Geological Survey (USGS) Probabilistic Hazard Lookup by Zip Code web page. For the area where the subject site is located (Zip Code 97201), a peak bedrock acceleration of 0.19 g is given for a seismic event having a 10 percent probability of exceedance over a period of 50 years. Using the subsurface information obtained from our site explorations and available geologic literature, we constructed a geologic model of the subject area. The generalized model criteria are given below:

Soil/Rock Type	Map Unit	Thickness (ft)	Shear Velocity (ft/sec)
Medium dense to dense silty sand, sand with silt (Catastrophic flood deposits - fine grained)	Qff	80	900
Very dense sand and gravel conglomerate (Troutdale formation)	Tt	70	1,800
Volcanic flood basalt (Sentinel Bluffs Unit – Grande Ronde Basalt)	Tgsb	NA	3,500

RESPONSE SPECTRA

Using the above data, we developed elastic response spectra for the subject site using the computer program EduShake. This program computes the soil response to vertical propagation of shear waves originating on the bedrock surface through the soil column to the elevation of interest. For this study, the spectra were developed for the planned foundation elevation of the structure, approximately 50 feet below existing surface grades. The input ground motion used in this analysis was a classic strong motion earthquake record from the 1952 Taft earthquake in southwestern Kern County, California. Computer printouts of the input data and results of the analysis are attached. Vertical ground motion spectra can be conservatively estimated to be two-thirds of the corresponding horizontal ground motion spectra.

CONCLUSIONS

Based on the results of our referenced geotechnical study, the location of the subject site, and the information discussed herein, it is our opinion that the potential for damage due to earthquake-induced landslides, tsunamis and seiches, regional displacement, or fault displacement is low. Based on our current study, it is our opinion that the general design response spectrum curve developed for Site Class D (International Building Code [2003]) will provide the best estimate of potential strong-motion ground shaking for the planned project, except between Periods T=0.77 and T=0.93, where the site-specific spectrum should be used. The IBC and site specific spectrum curves for acceleration have been plotted on the same graph which is attached.

LIMITATIONS

This report is the copyrighted property of Terra Associates, Inc. and was prepared in accordance with generally accepted geotechnical engineering practices. This report is intended for specific application to the Ladd Tower project and for the exclusive use of Opus Northwest, LLC and their authorized representatives. No other warranty, expressed or implied, is made.

We trust this information is sufficient for your current needs. If you have any questions or require additional information, please call.

Sincerely yours,
TERRA ASSOCIATES, INC.

John C. Sadler, R.G., C.E.G.
Project Manager

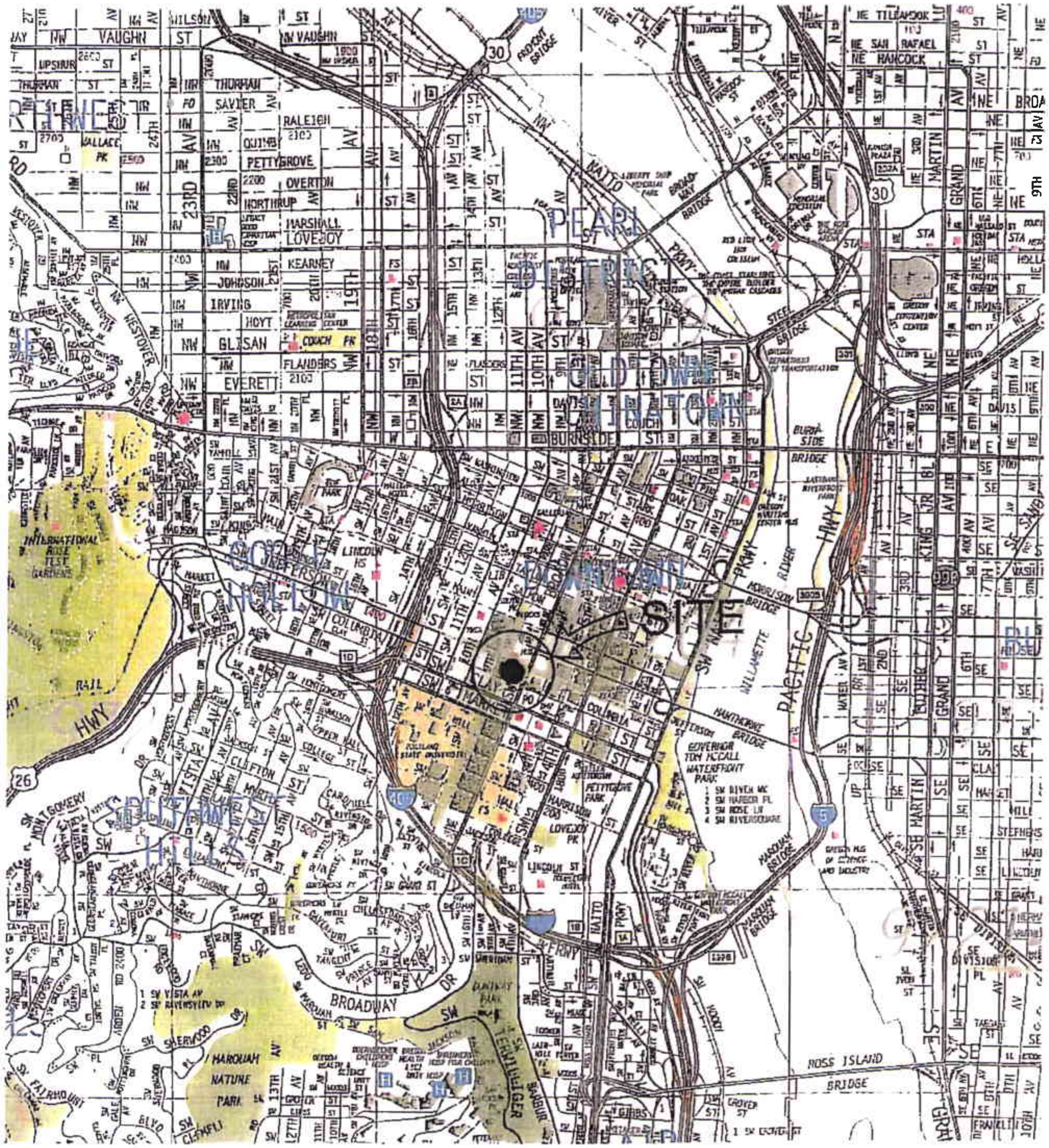
2-12-07

Theodore J. Schepper, P.E.
Principal

EXPIRATION DATE: 06-18-07

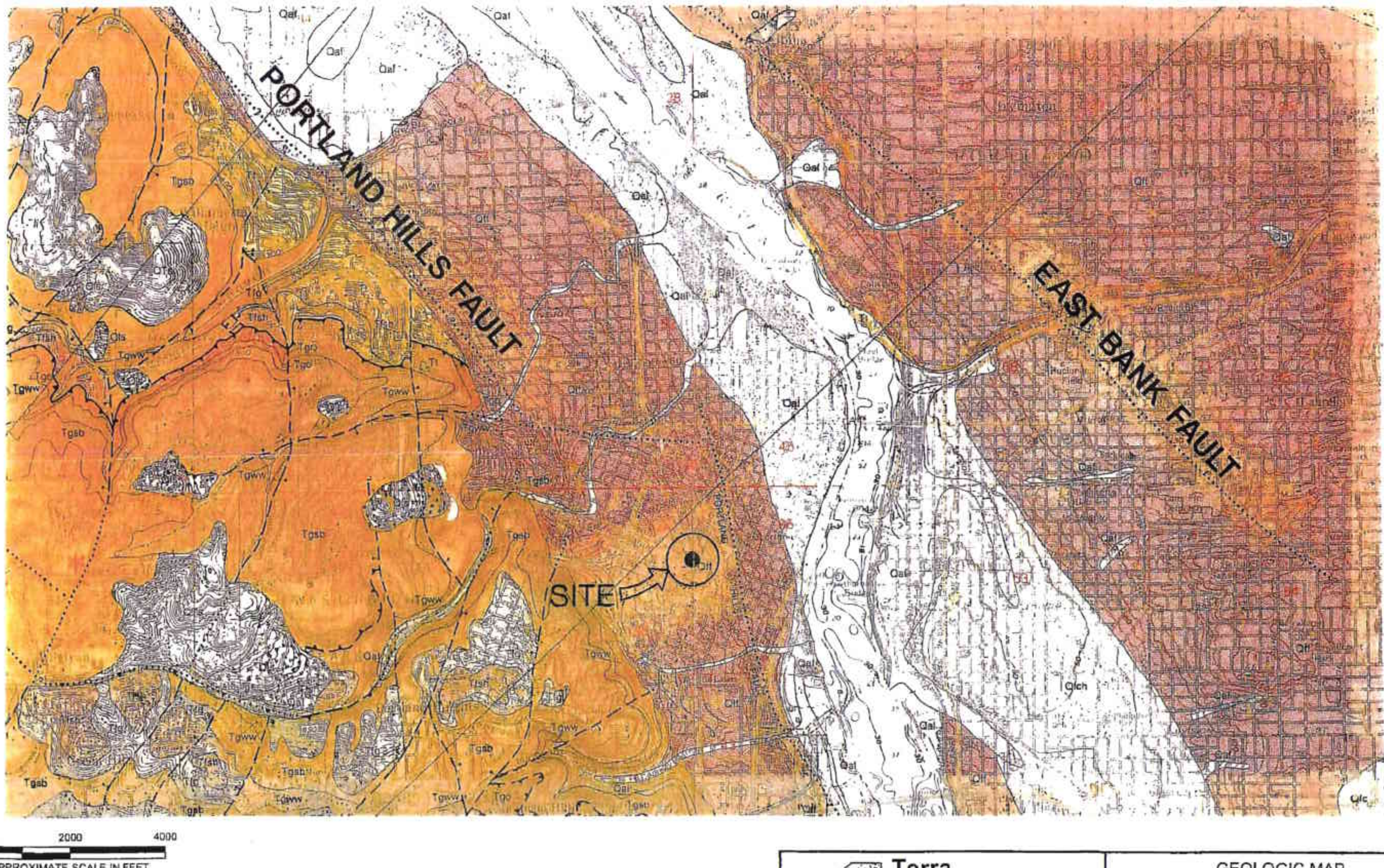
REGISTERED PROFESSIONAL
OREGON
JOHN C. SADLER
G1564
GEOLOGIST

Encl: Figure 1 – Vicinity Map
Figure 2 – Geologic Map
Figure 3 – Portland Area Faults
EduShake Output Data
References



REFERENCE: THE THOMAS GUIDE, PORTLAND METRO AREA, 2003

Terra Associates, Inc. Consultants In Geotechnical Engineering Geology and Environmental Earth Sciences	VICINITY MAP LADD TOWER PORTLAND, OREGON
Proj. No.T-5735	Date FEB 2007
	Figure 1



MAP REFERENCE:
GEOLOGIC MAP OF THE PORTLAND QUADRANGLE, MULTNOMAH AND WASHINGTON COUNTIES, OREGON, AND CLARK COUNTY, WASHINGTON (1991)
STATE OF OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES (DOGAMI) GEOLOGIC MAP SERIES GMS-75

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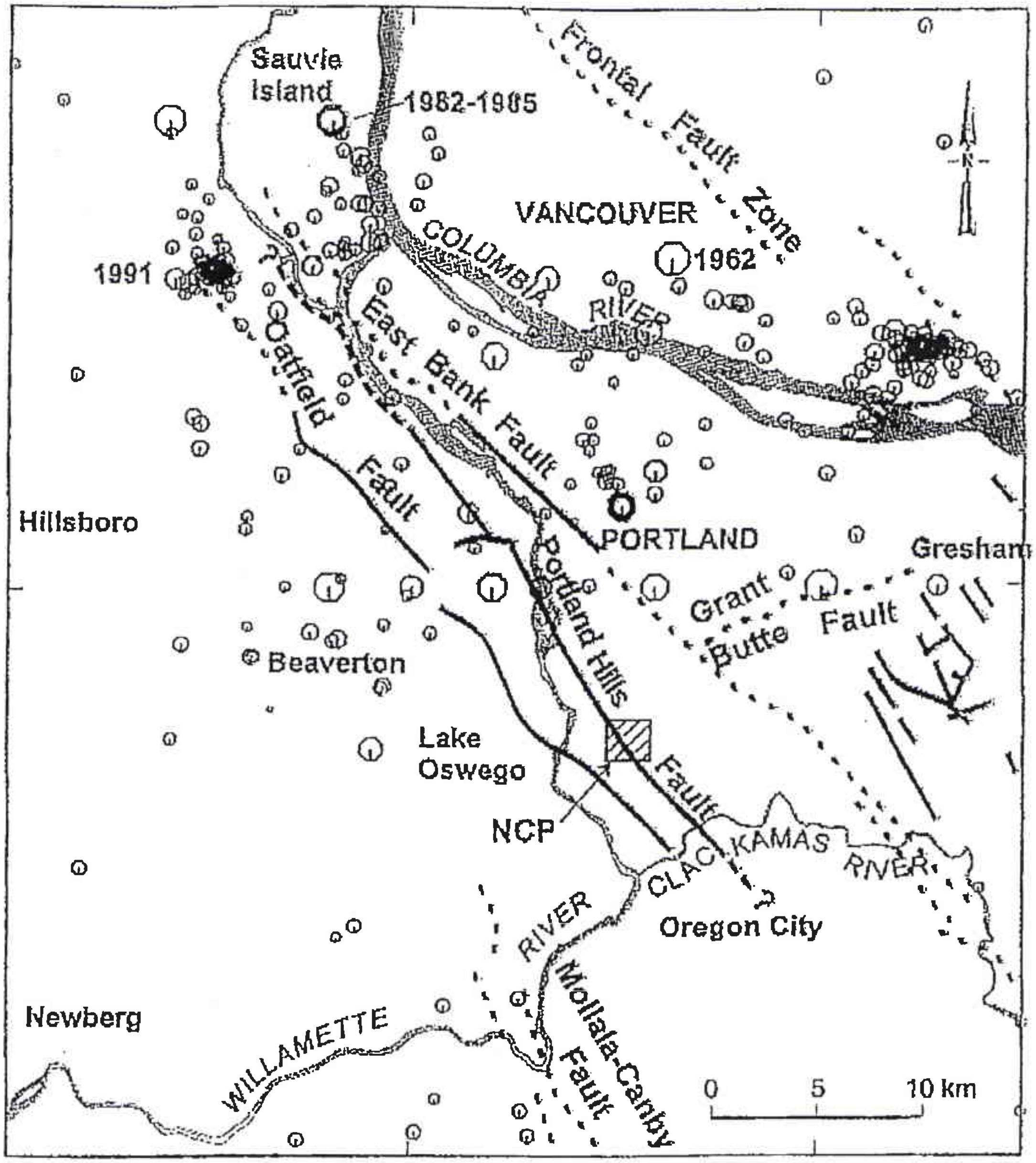
Environmental Earth Sciences

GEOLOGIC MAP
LADD TOWER
PORTLAND, OREGON

Proj. No.T-5735	Date FEB 2007	Figure 2



REFERENCE:
Oregon Geology, Vol. 63, No. 2, 2001.
Compiled by Oregon Department of Geology and Mineral Industries

Terra Associates, Inc. Consultants in Geotechnical Engineering Geology and Environmental Earth Sciences	PORTLAND AREA FAULTS LADD TOWER PORTLAND, OREGON
Proj. No.T-5735	Date FEB 2007 — Figure 3

EDUSHAKE OUTPUT DATA

EduShake Report

Data File: C:\PROGRA~1\PROSHAKE\EDUSHAKE\SWPARK.DAT

Soil Profile

Profile Name: SW Park Tower
Water Table: Not Applicable
Number of Layers: 10

Layer Number	Material Name	Thickness (ft)	Unit Weight (pcf)	Gmax (ksf)	Vs (ft/sec)	Modulus Curve	Damping Curve	Mod. Parameter	Damp. Parameter
1	Qff	10.00	120.00	3,021.07	900.00	Sand (Seed & Idriss) - /	Sand (Seed & Idriss) - Av		
2	Qff	10.00	120.00	3,021.07	900.00	Sand (Seed & Idriss) - /	Sand (Seed & Idriss) - Av		
3	Qff	10.00	120.00	3,021.07	900.00	Sand (Seed & Idriss) - /	Sand (Seed & Idriss) - Av		
4	Qff	10.00	120.00	3,021.07	900.00	Sand (Seed & Idriss) - /	Sand (Seed & Idriss) - Av		
5	Qff	10.00	120.00	3,021.07	900.00	Sand (Seed & Idriss) - /	Sand (Seed & Idriss) - Av		
6	Qff	10.00	120.00	3,021.07	900.00	Sand (Seed & Idriss) - /	Sand (Seed & Idriss) - Av		
7	Qff	10.00	120.00	3,021.07	900.00	Sand (Seed & Idriss) - /	Sand (Seed & Idriss) - Av		
8	Qff	10.00	120.00	3,021.07	900.00	Sand (Seed & Idriss) - /	Sand (Seed & Idriss) - Av		
9	Tt	70.00	130.00	13,091.32	1,800.00	Gravel (Seed et al.)	Gravel (Seed et al.)		
10	Tgsb	Infinite	150.00	57,111.33	3,500.00	Rock	Rock		

Input Motion

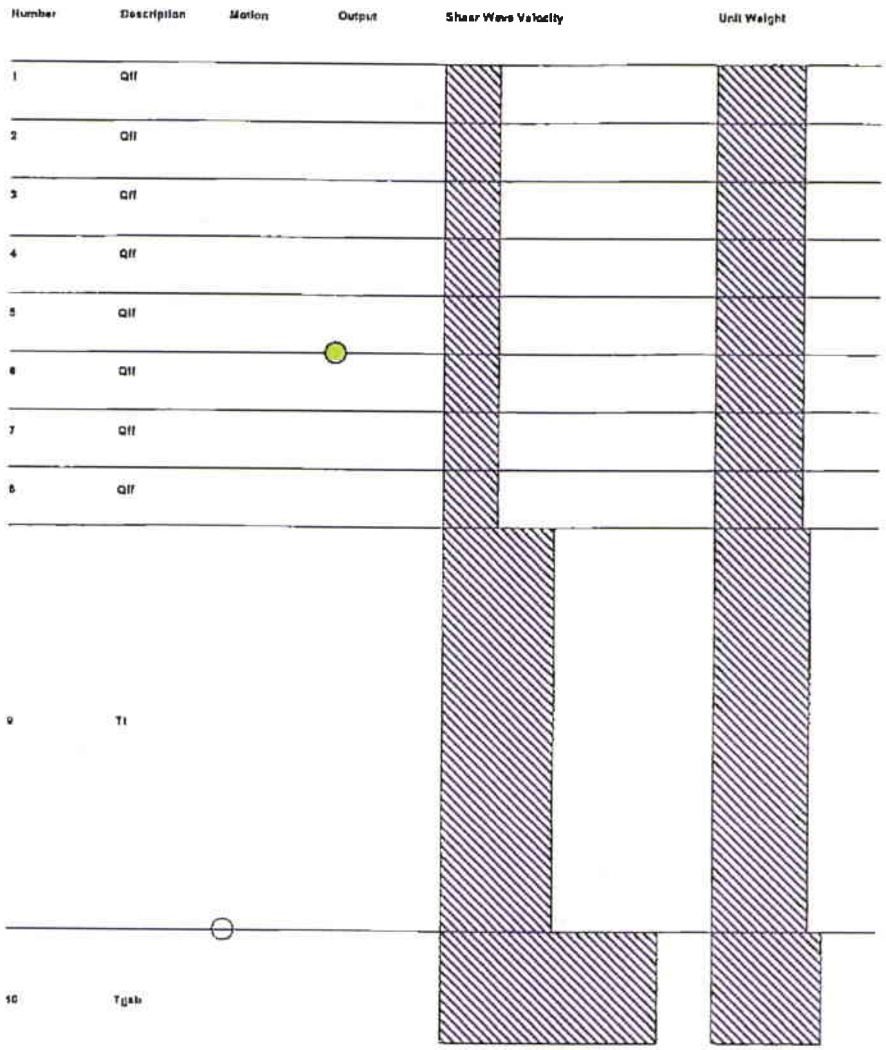
Number of Motions: 1
Numeber of Iterations: 5
Strain Ratio: 0.65
Tolerance: 5.00%

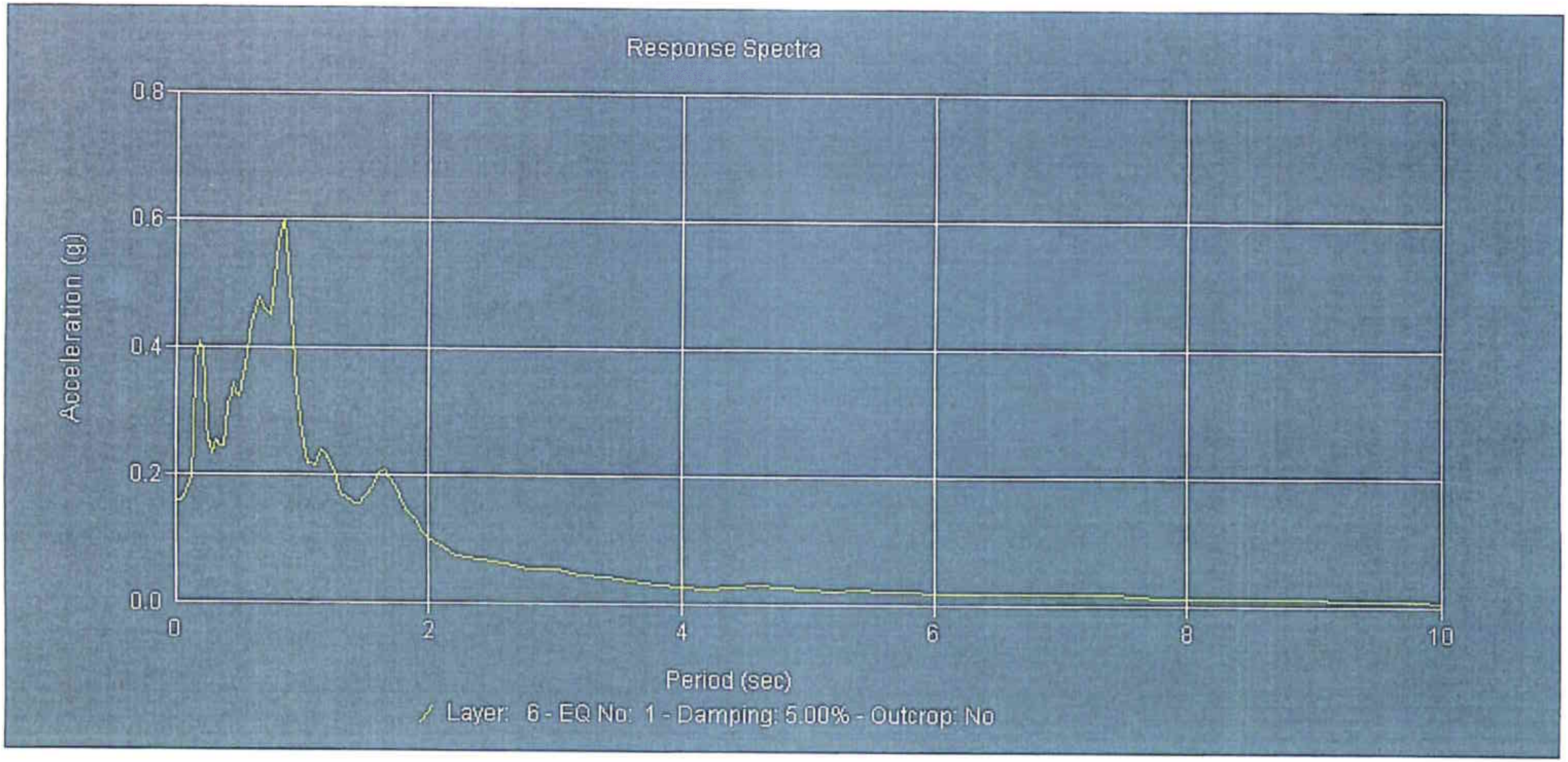
File Name	No of Acc. Values	Max. Acc. (g)	Time Step (sec)	Cuttoff Freq. (Hz)	No of Fourier Terms	Layer	Outcrop
C:\PROGRA~1\PROSHAKI	4220	0.185	0.020	20.00	8192	10	Yes

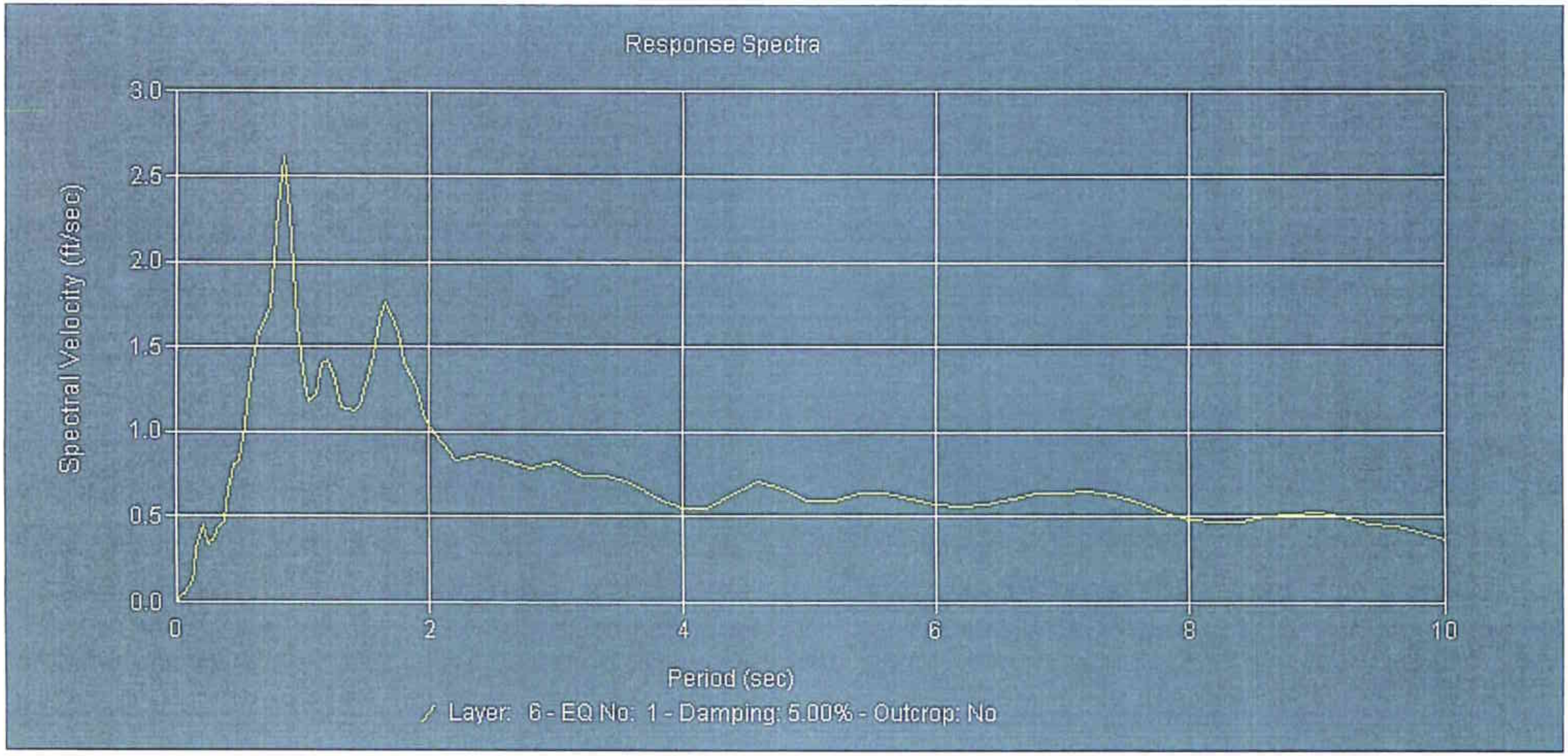
Output Locations

Layer No	Depth (ft)	Outcrop
6	50.00	No

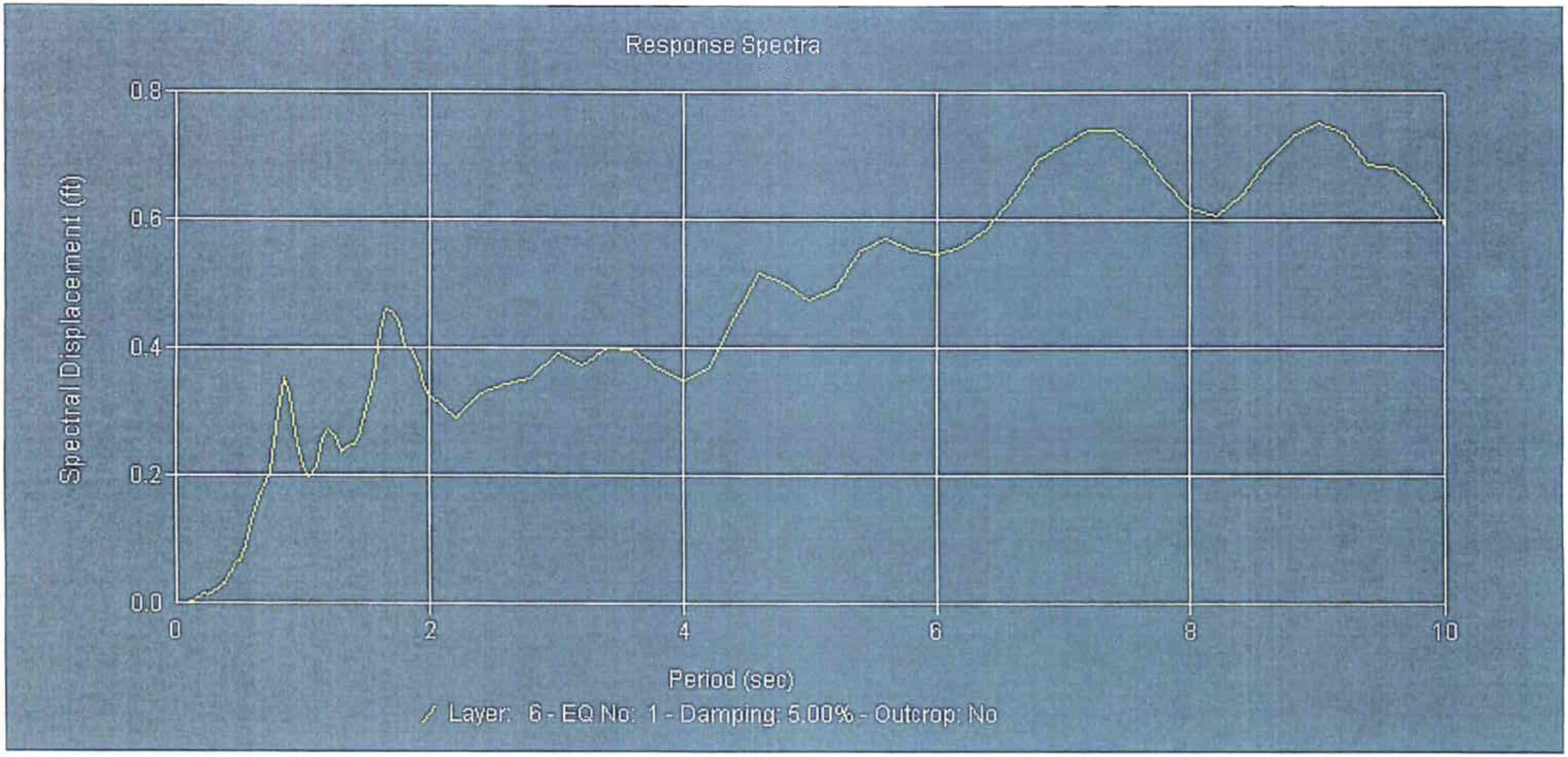
5W Park Tower




Response Spectra
Acceleration (g)
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
Period (sec)
Layer: 6 - EQ No: 1 - Damping: 5.00% - Outcrop: No



Response Spectra
Spectral Velocity (ft/sec)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
Period (sec)
Layer: 6 - EQ No: 1 - Damping: 5.00% - Outcrop: No


Response Spectra
Spectral Displacement (ft)
0.0
0.2
0.4
0.6
0.8
0
2
4
6
8
10
Period (sec)
Layer: 6 - EQ No: 1 - Damping: 5.00% - Outcrop: No

USGS
science for a changing world

```
The input zip-code is 97201.
ZIP CODE                          97201
LOCATION                          45.4983 Lat. -122.6913 Long.
DISTANCE TO NEAREST GRID POINT    0.7042 kms
NEAREST GRID POINT                45.5 Lat. -122.7 Long.
Probabilistic ground motion values, in %g, at the Nearest Grid point are:
                10%PE in 50 yr   5%PE in 50 yr   2%PE in 50 yr
   PGA          19.079370        26.819599       38.896530
0.2 sec SA      43.170101        61.954220      105.315300
0.3 sec SA      40.665310        57.821850       95.987617
1.0 sec SA      17.375460        24.503300       35.159389
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
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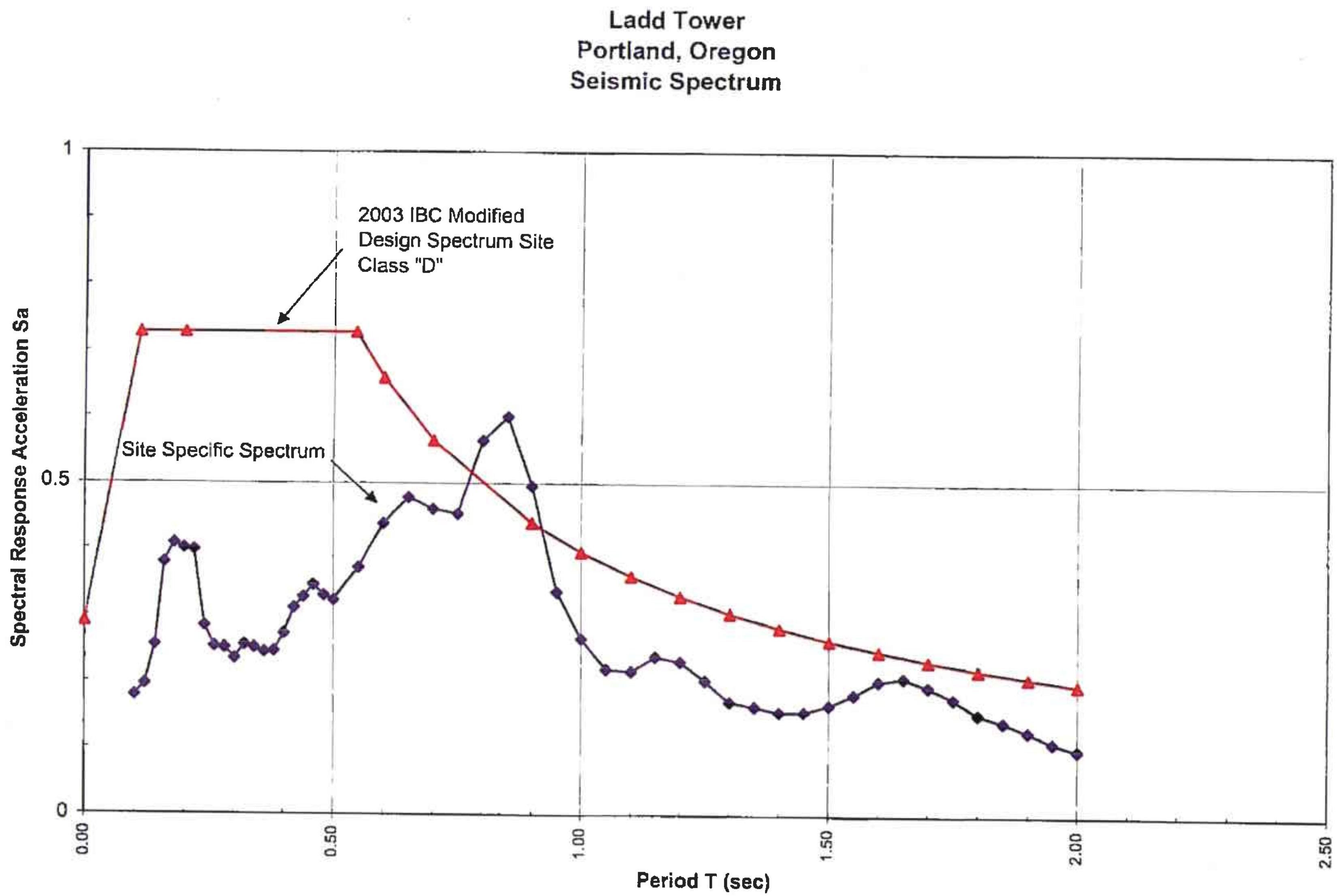
The input zip-code is .
Zip code is zero and we go to the end and stop.

PROJECT INFO: SEISMIC HAZARD: Hazard by Zip Code


Ladd Tower
Portland, Oregon
Seismic Spectrum
2003 IBC Modified
Design Spectrum Site
Class "D"
Site Specific Spectrum
Spectral Response Acceleration Sa
1
0.5
0
0.00
0.50
1.00
1.50
2.00
2.50
Period T (sec)

REFERENCES

REFERENCES

- Geotechnical Report, 1300 SW Park Tower, Project No. T-5735, prepared by Terra Associates, Inc., dated January 31, 2006

- *Geologic Map of the Portland Quadrangle, Multnomah and Washington Counties, Oregon, and Clark County, Washington*, by M.H. Beeson and others (1991). Oregon Department of Geology and Mineral Industries, Geologic Map Series GMS-75.

- *Earthquake-Hazard Geology Maps of the Portland Metropolitan Area, Oregon*, by Ian P. Madin (1990). Oregon Department of Geology and Mineral Industries, Open-File Report 0-90-2.

- *Earthquake Loads-Site Ground Motion*, , Section 1615 - 2003 International Building Code.

- *Map and List of Significant Earthquakes in Washington and Oregon.* Accessed February 6, 2007, from The Pacific Northwest Seismic Network web site: http://pnsn.org/INFO_GENERAL/hist.html.

- *Scotts Mills Earthquake Summary.* Accessed February 5, 2007, from The Pacific Northwest Seismic Network web site: http://pnsn.org/SEIS/EQ_Special/ScottsMills/scottsmills.html.

- *Complete Report for Portland Hills Fault (Class A) No. 877.* Accessed February 5, 2007, from United States Geological Survey (USGS) - Earthquake Hazards Program web site: http://earthquakes.usgs.gov/regional/qfaults.

- *Complete Report for East Bank Fault (Class A) No. 876.* Accessed February 5, 2007, from United States Geological Survey (USGS) - Earthquake Hazards Program web site: http://earthquakes.usgs.gov/regional/qfaults.

- *Complete Report for Oatfield Fault (Class A) No. 875.* Accessed February 7, 2007, from United States Geological Survey (USGS) - Earthquake Hazards Program web site: http://earthquakes.usgs.gov/regional/qfaults.

- *Quaternary Fault and Fold Database, Vancouver 1°x 2° Sheet.* Accessed February 7, 2007, from United States Geological Survey (USGS) - Earthquake Hazards Program web site: http://earthquakes.usgs.gov/regional/qfaults.

- *Oregon Earthquake History.* Accessed February 6, 2007, from United States Geological Survey (USGS) - Earthquake Hazards Program web site: http://earthquakes.usgs.gov/regional/states/oregon/history.php.

- *Airborne Hunt for Faults in the Portland-Vancouver Area.* Accessed February 5, 2007, from United States Geological Survey (USGS) - Earthquake Hazards Program web site: http://quake.wr.usgs.gov/prepare/factsheets/Portland/.

- *Northwest Oregon Fault Zones and Basins.* Accessed February 5, 2007, from United States Geological Survey (USGS) – Geologic Division of the Western Earth Surfaces Processes Team web site: http://geology.wr.usgs.gov/wgmt/pacnw/resfzno.html.

- *The Portland Hills Fault: An earthquake generator or just another old fault?* By Ivan Wong and others, 2001. Oregon Geology (Oregon Department of Geology and Mineral Industries), Volume 63, Number 2, Spring 2001

- *Techtonic Plate Motions, Crustal Blocks, and Shallow Earthquakes in Cascadia.* Accessed February 5, 2007, from United States Geological Survey (USGS) – Geologic Division of the Western Earth Surfaces Processes Team web site: http://geology.wr.usgs.gov/wgmt/pacnw/rescasp1.html.

- *Section 9: Earthquake Hazards, City of Portland Natural Hazard Mitigation Plan,* prepared by ECONorthwest, for the City of Portland Office of Emergency Management, dated August 2005.