

Fourth Quarter Hanford Seismic Report for Fiscal Year 2012 (July-September 2012)

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Summary

The PNSN/MSA team continues to provide uninterrupted collection of high-quality raw and processed seismic data from the combined Hanford Seismic Network (HSN) and Eastern Washington Regional Sub-Network (EWRSN) for the U.S. Department of Energy and its contractors. The team is responsible for identifying and locating sources of seismic activity that might affect the Hanford site, monitoring changes in the historical pattern of seismic activity surrounding the Hanford Site, and monitoring ground motion to provide data to constrain studies of earthquake effects on the Hanford site. Seismic data are compiled, archived, and published for use by the Hanford Site for waste management, natural phenomena hazards assessments, and engineering design and construction. In addition, the team works with the Hanford Site Emergency Services Organization to provide assistance in the event of a significant earthquake on the Hanford Site. The HSN and the EWRSN together consist of 49 individual sensor sites and 15 radio relay sites maintained by the PNSN.

Overall, the seismicity throughout the 4th quarter of FY2012 was very similar to the 3rd quarter, with no significant increase or decrease. In the vicinity of the Hanford site, there was an increase in earthquake occurrence in the Wye Swarm Area.

The networks detected one (1) event within the Hanford vicinity that has been categorized as a probable surface explosion.

The largest event ($M_L = 3.4$) took place on 13 September 2012 at a depth of 10.2 km with epicenter located 24 km east-southeast of Wenatchee, WA.

Abbreviations and Acronyms

ANSS - Advanced National Seismic System
AQMS - ANSS Quake Management System
BPA - Bonneville Power Administration
CRBG - Columbia River Basalt Group
Dmin - Minimum distance (of nearest seismic station to earthquake)
DOE - U.S. Department of Energy
Etyp - Event type
EWRSN - Eastern Washington Regional Sub-Network
FY - Fiscal year
GPS - Global Positioning System
HLSMP - Hanford Lifecycle Seismic Monitoring Program
HSN - Hanford Site Network
Lat - Latitude
Lon - Longitude
km - kilometer
 M_d - coda-duration magnitude
 M_L - local magnitude
MAG - Magnitude of earthquake
MOD - Velocity model
Mtyp - Magnitude type
NS/NP - Number of stations/number of phases
PNSN - Pacific Northwest Seismic Network
Q - Quality factor (of earthquake location)
Rms - Root Mean Square (error of earthquake location)
RSLW – Lower Rattlesnake (Mountain) data acquisition/telemetry site
SMA - strong motion accelerometer
USGS - U.S. Geological Survey
UTC - Coordinated Universal Time
UW - University of Washington
 V_p - p-wave velocity
 V_s - s-wave velocity

1.0 Introduction

This quarterly report documents the locations, magnitudes, and seismic interpretations of earthquakes recorded for the Hanford monitoring region of south-central Washington during the fourth quarter of fiscal year (FY) 2012 (July 2012 through September 2012). Since April 1st, 2011, seismic monitoring for Public Safety and Resource Protection (PSRP) at the Hanford site has been carried out by the Hanford Lifecycle Seismic Monitoring Program (HLSMP). HLSMP is managed by Mission Support Alliance (MSA) with the monitoring work being performed under a sub-contract to the Pacific Northwest Seismic Network (PNSN).

1.1 Mission

The mission of the HLSMP is to maintain seismic stations, report data from measured events, and provide assistance in the event of an earthquake. This mission supports the U.S. Department of Energy (DOE) and the other Hanford Site contractors in their compliance with DOE Order 420.1B, Chapter IV, Section 3.d “Seismic Detection” and DOE Order G 420.1-1, Section 4.7, “Emergency Preparedness and Emergency Communications.” DOE Order 420.1B requires facilities or sites with hazardous materials to maintain instrumentation or other means to detect and record the occurrence and severity of seismic events. The HLSMP maintains the seismic network located on and around the Hanford Site. The data collected from the seismic network can be used to support facility or site operations to protect the public, workers, and the environment from the impact of seismic events.

In addition, the HLSMP provides an uninterrupted collection of high-quality raw seismic data from the Hanford Site Network (HSN) and the Eastern Washington Regional Sub-Network (EWRSN) and provides interpretations of seismic events from the Hanford Site and the vicinity. The program locates and identifies sources of seismic activity, monitors changes in the historical pattern of seismic activity, and builds a “local” earthquake database (processed data) that is permanently archived. The focus of this report is the precise location of earthquakes and explosions proximal to or on the Hanford Site, specifically, between 46-47° north latitudes and between 119-120° west longitudes. Data from the EWRSN and other seismic networks in the Northwest provide the HLSMP with necessary regional input for the seismic hazards analysis at the Hanford Site. These seismic data are used to support Hanford Site contractors for waste management activities, natural phenomena hazards assessments, and engineering design and construction.

2.0 Network Operations During the 4th Quarter of FY2012

2.1 Description of Seismic Stations

HLSMP seismic stations supported by MSA are divided into two geographic sub-networks, the Hanford Site Network (HSN), comprised by stations located on the Hanford site itself, and the Eastern Washington Regional Sub-Network (EWRSN), which includes stations that surround the Hanford site.

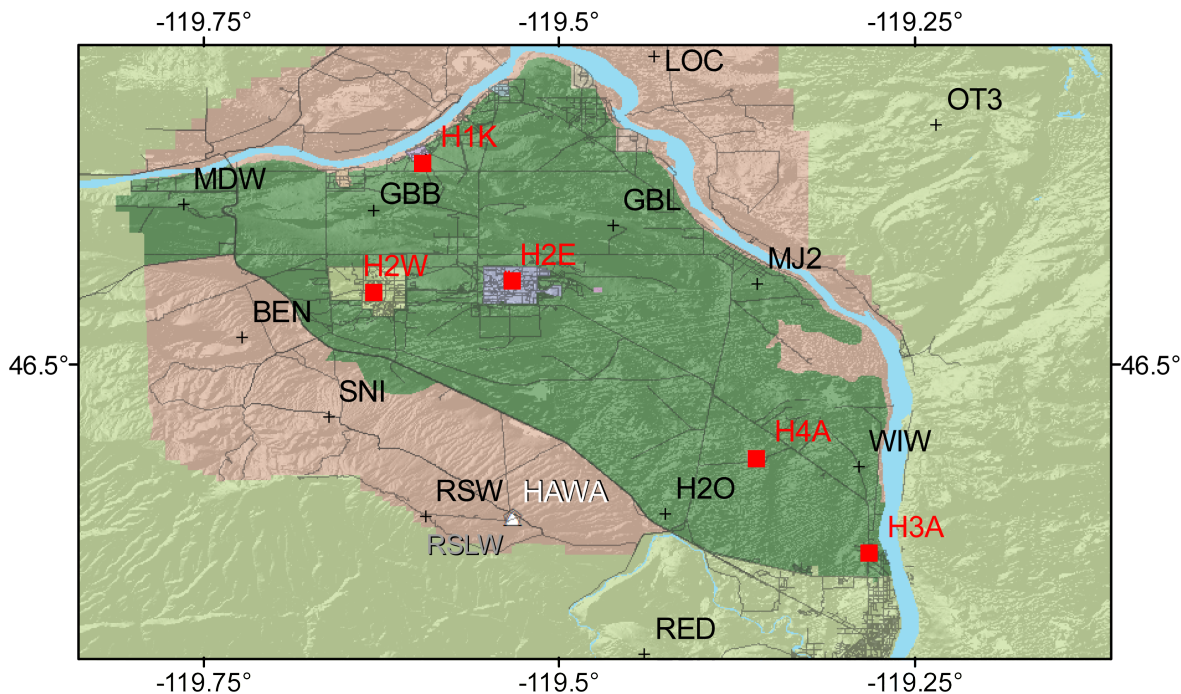


Figure 2.1 Seismic monitoring stations of the Hanford Seismic Network, on the Hanford site. Red squares and text are strong motion accelerographs (SMA) stations. Black text and plusses are short period stations. HAWA is a broadband and SMA US National Seismic Network Station operated by the US Geological Survey (USGS). RSLW is the data collection/telemetry node at Rattlesnake Mountain.

Combined, the HSN and the EWRSN include 49 stations. Most stations reside in remote locations and require solar panels and batteries for power. The HSN includes 16 stations (Table 2.1 and Figure 2.1), and the EWRSN consists of 33 stations (Table 2.2 and Figure 2.2).

Two major reasons compel the HLSMP to use the regional capabilities of the EWRSN. A large earthquake located in the Pacific Northwest outside of Hanford could produce significant ground motion and damage to structures at the Hanford Site. For example, the magnitude 7.0 earthquake that occurred in 1872 near Chelan/Entiat or other earthquakes located in the region (*e.g.*, eastern Cascade mountain range) could have such an effect. The EWRSN would provide valuable information to help determine the impacts of such an event. Moreover, the characterization of seismicity throughout the surrounding areas, as required for the Probabilistic Seismic Hazard Analysis, supports facility safety assessments at the Hanford Site.

The HSN and EWRSN networks provide a total of 69 combined data channels because the 5 three-component seismometer sites (GBB, FHE, CCRK, DDRF, and PHIN), and the 5 SMA sites in the HSN (H1K, H2E, H2W, H3A, and H4A) require two additional data channels per station. The tri-axial

stations record motion in the vertical, north-south horizontal, and east-west horizontal directions. Stations CCRK, DDRF, and PHIN are broad-band seismometers with digital telemetry via cellular telephone. GBB and FHE are tri-axial sites with 1-Hz seismometers and analog radio telemetry. The other 39 stations are single vertical component seismometers. Fifteen radio telemetry relay sites are used by both networks to continuously transmit seismogram data to the PNSN in Seattle, Washington, for processing and archiving.

Table 1. Hanford Site Network (HSN) Stations. *Italic font indicates a 3-channel station, bold font indicates a Strong Motion Accelerometer*

	Latitude	Longitude	Elevation (m)	Station Name
BEN	46.52	-119.72167	335	Benson Ranch
<i>GBB</i>	<i>46.60814</i>	<i>-119.62898</i>	<i>185</i>	<i>Gable Butte</i>
GBL	46.59819	-119.46097	330	Gable Mountain
<i>H1K</i>	<i>46.64468</i>	<i>-119.59287</i>	<i>152</i>	<i>100 K Area (SMA)</i>
<i>H2E</i>	<i>46.55780</i>	<i>-119.53450</i>	<i>187</i>	<i>200 East Area (SMA)</i>
H2O	46.39555	-119.42411	175	Water Station
<i>H2W</i>	<i>46.5517</i>	<i>-119.64532</i>	<i>129</i>	<i>200 West Area (SMA)</i>
<i>H3A</i>	<i>46.36322</i>	<i>-119.27747</i>	<i>99</i>	<i>300 Area (SMA)</i>
<i>H4A</i>	<i>46.46835</i>	<i>-119.35441</i>	<i>147</i>	<i>400 Area (SMA)</i>
LOC	46.71686	-119.43197	210	Locke Island
MDW	46.61302	-119.76215	330	Midway
MJ2	46.55736	-119.36013	146	May Junction Two
RSW	46.39436	-119.59247	1045	Rattlesnake Mountain
SNI	46.46386	-119.66089	323	Snively Ranch
WA2	46.75519	-119.56681	244	Wahluke Slope
WIW	46.42919	-119.2888	128	Wooded Island

Table 2. Eastern Washington Regional Sub-Network (EWRSN) Stations. *Italic font indicates a 3-channel station.*

	Latitude	Longitude	Elevation (m)	Station Name
BLT	45.915	-120.177	659	Bickleton
BRV	46.48519	-119.992	920	Black Rock Valley
BVW	46.81083	-119.883	670	Beverly
CBS	47.80469	-120.043	1067	Chelan Butte South
<i>CCRK</i>	<i>46.5585</i>	<i>-119.855</i>	<i>561</i>	<i>Cold Creek</i>
CRF	46.82486	-119.388	189	Corfu
<i>DDRF</i>	<i>46.4911</i>	<i>-119.06</i>	<i>233</i>	<i>Didier Farms</i>
DPW	47.87052	-118.204	892	Davenport
DY2	47.98503	-119.773	890	Dyer Hill Two
ELL	46.90951	-120.568	789	Ellensburg
EPH	47.35619	-119.597	661	Ephrata
ET4	46.56342	-118.945	236	Eltopia Four
ETW	47.60418	-120.334	1477	Entiat
<i>FHE</i>	<i>46.95178</i>	<i>-119.498</i>	<i>455</i>	<i>Frenchman Hills East</i>
LNO	45.87169	-118.286	771	Linton Mountain Oregon

MOX	46.57718	-120.299	501	Moxee City
NAC	46.73301	-120.825	728	Naches
NEL	48.07003	-120.341	1500	Nelson Butte
OD2	47.38754	-118.711	553	Odessa Two
OT3	46.66886	-119.234	322	Othello Three
PAT2	45.88362	-119.75775	262	Paterson Two
PHIN	45.8951	-119.928	227	Phinney Hill
PRO	46.21252	-119.687	553	Prosser
RED	46.29736	-119.43880	330	Red Mountain
SAW	47.70153	-119.402	701	St. Andrews
TBM	47.16985	-120.599	1006	Table Mountain
TRW	46.29207	-120.543	723	Toppenish Ridge
TWW	47.13801	-120.87	1027	Teanaway
VT2	46.96719	-120	385	Vantage Two
WAT	47.69852	-119.955	821	Waterville
WRD	46.96986	-119.146	375	Warden
YA2	46.52652	-120.531	652	Yakima Two
YPT	46.04869	-118.963	325	Yellepit

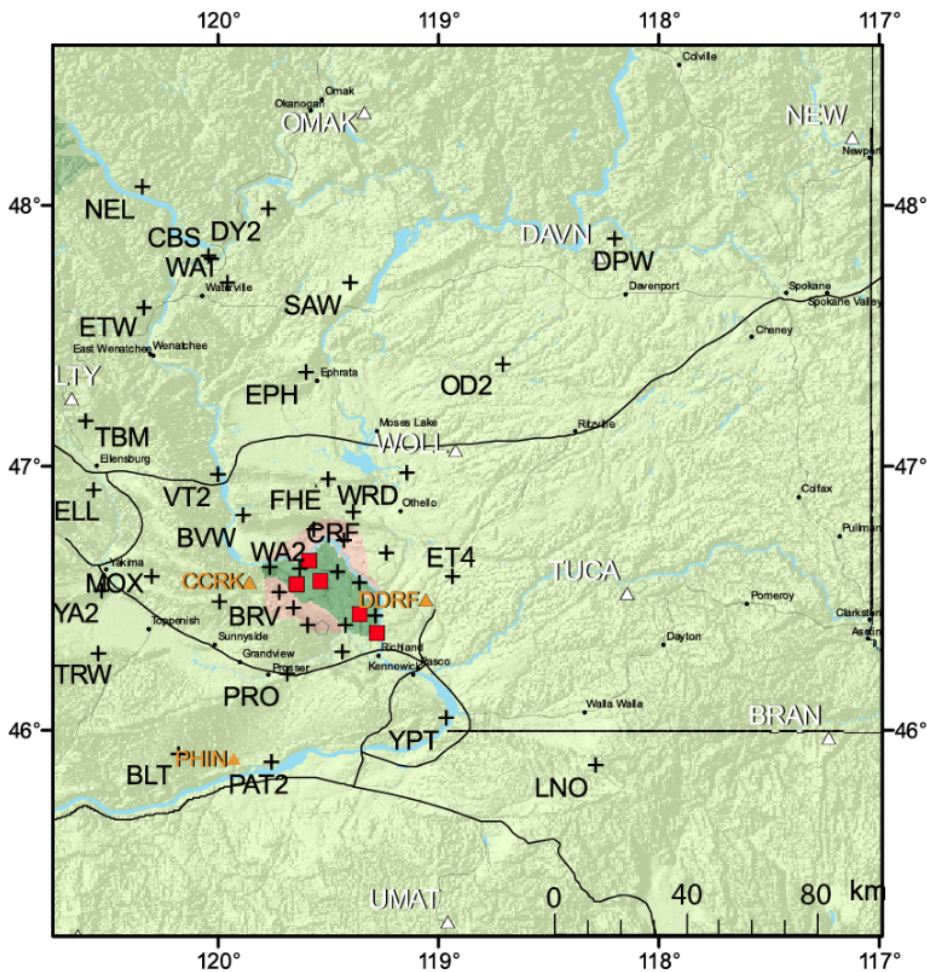


Figure 2.2 Seismic stations of the Eastern Washington Region Sub-Network. Black font and pluses are short-period EWRSN stations. Gold font and triangles are EWRSN broadband stations. White font and triangles are broadband stations contributed by other agencies to the PNSN data collection in eastern Washington.

2.2 Station Maintenance During the 4th Quarter of FY2012

During the 3rd quarter of FY2012, there were many false noise triggers on the Ashe line, this includes stations OT3, WA2, H2O, MDW, RED, LOC, WIW, GBL. The noise was coming in at the receiving site at Ashe Bonneville Power Administration (BPA) and a quick remedy for the issue was not possible. Instead, the “Glowworm” remote Earthworm data acquisition node was re-tasked to receive all of the Ashe line. Because of that change, the line is now being digitized at Hanford. In the 4th quarter of FY2012, the old Ashe became a functional backup, but not operational. The noise is still present and is due to electromagnetic discharge (corona) during high-peak hours from the BPA station itself.

As a result of the Ashe line change during the 3rd quarter, station SNI went down in May 2012. It became operational in August 2012.

Station ET3 was moved about 2 km and renamed ET4.

Several issues have intermittently affected performance of individual sites that we are still in the process of resolving. Near-record drought and, thus, extreme fire hazard dogged our ability to visit stations during the quarter. Stations YA2 and MOX went down in August 2012 and remained down through the 4th quarter for reasons unknown. Station RED is receiving sporadic radio frequency interference that we are trying to diagnose and fix. Station WRW is in need of a new battery. Station CCRK needs an antenna system upgrade. The needed equipment for stations WRW and CCRK will most likely be installed in the summer of 2013. Despite these problems, the performance of the network and capability to carry out its mission has improved overall.

A new digital telemetry link was installed during 4th quarter. Station data we were receiving from a cell modem at the Rattlesnake repeater is now being received from WSUR (Washington State University Richland).

2.3 Other Network Activities during the 4th Quarter of FY2012

In the 4th quarter of FY2012, we began producing a high-resolution ShakeMap for the Hanford site that uses Washington Department of Natural Resources data to represent the shallow geology in the area. These ShakeMaps are currently available on the PNSN website. We are working on automatic delivery of the ShakeMaps to the emergency managers at the Hanford site.

Also, in the 4th quarter of FY2012, MSA purchased seismic equipment in order to upgrade the five strong motion stations on the Hanford site (H1K, H2E, H2W, H3A, and H4A) while deploying accelerometers at five additional sites. We are planning the installation of the newly acquired equipment.

3.0 Earthquake Catalog Description

Within the Advanced National Seismic System (ANSS) Quake Management System (AQMS) seismic network processing software, an interactive program called Jiggle is used to manually review and revise automatic phase arrival picks and signal durations, as well as their polarities, uncertainties and quality factors. Arrival and duration times and uncertainties are used as input to an earthquake location program (Klein, 2002) to compute locations and magnitudes of the seismic events. Resulting locations for local earthquakes (46-47° north latitude, 119-120° west longitude) are reported in Table 4.1. Additional seismic events located outside the reporting region for this report are also evaluated. These surrounding events are not reported in this document, but are used as a check to confirm that the HSN and EWRSN are functioning properly (*e.g.*, quality checks on data recording). All processing results are available through the PNSN at www.pnsn.org.

3.1 Velocity Models

Earthquake location uses the arrival times of seismic phases at seismic stations and a model of the seismic wave speeds of crustal rocks of eastern Washington (called a “velocity model”) to solve for the most likely location for the earthquake source. AQMS divides the eastern Washington region into 4 sub-regions. The velocity models for each sub-region were developed using available geologic information and calibrated from seismic data recorded from accurately located earthquake and blast events in eastern Washington. Time corrections (delays) are incorporated into the velocity models to account for significant deviations in station elevations or stations situated on sedimentary layers. Station delays also are determined empirically from accurately located earthquakes and blast events in the region.

3.2 Earthquake Magnitudes

AQMS computes several different magnitude estimates for earthquakes. Table 4.1 shows the analyst-preferred value of either: 1) the coda-duration magnitude (M_d), or 2) the local magnitude (M_L) (Richter 1958). We report the median magnitude provided by all stations contributing estimates for an event.

The coda duration magnitude is based on a relationship developed for Washington State by Crosson (1972), modified for application within the AQMS software. The formula we use for M_d is:

$$M_d = -1.61 + 2.82 \log(D) - 2.46$$

where D is the duration of the observed event, starting from the P-wave arrival. Many earthquakes yield magnitude determinations that are very small ($M_d < 0$) and highly uncertain. We define earthquakes with magnitudes (M_d) smaller than 3.0 as “minor”. Coda-duration magnitudes for events classified as explosions are reported although they may be biased by a prominent surface wave that extends the apparent duration in a way inconsistent with coda-length measurement.

M_L is computed from the maximum amplitudes of the signals on the horizontal components recording an event, filtered to mimic the instrument response of a Wood-Anderson torsion seismograph. The formula is:

$$M_L = \log(A) - \log(A_0) + S$$

where A is the average zero-to-peak amplitude of the two horizontal components at a station after they have been converted to pseudo-Wood-Anderson traces. $\log(A_0)$ is a distance correction, for which we use the Jennings and Kanamori (1983) values, and S is a site correction term that accounts for differences in local geological conditions amongst stations.

The choice of preferred magnitude type involves some subjectivity, as the relative strength of each depends on conditions that differ from event to event. In general, M_L is preferred for an event that is well recorded on a sufficient number of suitable channels. [This is because there may be subjectivity in determining the durations used by the M_d algorithm (although AQMS does this in a largely automatic, and hence objective, way), and because the determination of the duration is biased by background noise levels.] In practice, this usually means that M_L is preferred for earthquakes sufficiently large to be observed at several regional broadband stations (CCRK, DDRF, PHIN, HAWA), or approximately $M2.5$. Although occasionally smaller earthquakes yield robust M_L estimates, depending on the background noise level at the time of the earthquake. M_d , on the other hand can be obtained from smaller earthquakes, even if the recording should “clip”. For earthquakes larger than about $M4.5$, only the M_L should be used. The two magnitude scales are defined to be consistent for the events for which they overlap.

3.3 Quality Factors (Q)

Table 4.1 tabulates a two-letter **Quality factor** for each event that indicates the general reliability of the solution (**A** is best quality, **D** is worst). The first letter of the quality code is a measure of the hypocenter quality based primarily on arrival time residuals. For example: Quality **A** requires a root-mean-square residual (**RMS**) less than 0.15 s, while a **RMS** of 0.5 s or more is **D** quality (other estimates of the location uncertainty also affect this quality parameter). The second letter of the quality code is related to the spatial distribution of stations that contribute to the event location, including the number of stations (**NS**), the number of p-wave and s-wave phases (**NP**), the largest gap in event-station azimuth distribution (**GAP**), and the closest distance from the epicenter to a station (**Dmin – not shown**). Quality **A** requires a solution with **NP** > 8, **GAP** < 90°, and **Dmin** < 5 km (or the hypocenter depth if it is greater than 5 km). If **NP** ≤ 5, **GAP** > 180°, or **Dmin** > 50 km, the solution is assigned Quality **D**. Uncertainties associated with estimated depths depend upon the number of stations and number of phase measurements (**NS/NP**) utilized by the Hypoinverse location program. Generally speaking, if the number of phases exceeds 10 measurements, the depth estimate is considered to be reliable. In this case, the second letter in the quality evaluation is either “A” or “B” (*cf.* Table 4.1). For example, the number of phase measurements from earthquakes ultimately classified as “deep” events typically falls within the 10-20 measurement range; these depth estimates are considered reliable. However, the number of phase measurements from earthquakes classified as “shallow” or “intermediate” may be less than 10 readings; in this case the depth estimate is less certain and the event could be classified as occurring in the CRBG or pre-basalt layers.

4.0 Seismic Activity – Fourth Quarter FY 2012

4.1 Catalog of Seismic Events

Table 4.1. Regional Seismic Data, July 1 – September 30, 2012

July 2012												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Etyp
03	21:48:40	45.8732	-119.2983	0.0*	1.9	Md	009/012	134	0.21	CC	E3	px
06	17:21:36	46.4148	-119.2665	1.7	1.1	Md	011/014	200	0.06	AD	E3	le
06	17:32:20	46.4162	-119.2655	1.0	0.8	Md	007/010	198	0.07	AD	E3	le
06	18:01:56	46.4140	-119.2683	0.0	0.9	Md	008/013	127	0.08	AB	E3	le
06	19:11:09	44.2907	-121.0812	0.0*	1.4	Md	005/005	316	0.35	DD	E3	px
06	19:59:31	46.4233	-119.2727	1.8	0.4	Md	005/008	191	0.12	AD	E3	le
06	22:29:39	46.7122	-120.7107	10.5	0.5	Md	006/008	199	0.08	BD	C3	le
06	22:50:34	46.4545	-119.2835	1.0*	0.5	Md	004/007	185	0.05	CD	E3	le
07	00:18:53	46.4088	-119.2597	0.5*	0.6	Md	005/007	205	0.06	CD	E3	le
07	06:50:32	46.4130	-119.2603	0.1	0.9	Md	009/012	202	0.04	AD	E3	le
07	06:55:17	46.4133	-119.2607	1.1	0.6	Md	005/008	202	0.05	BD	E3	le
07	07:44:47	46.4060	-119.2692	0.0	1.1	Md	008/013	206	0.17	BD	E3	le
07	07:49:12	46.4112	-119.2598	0.4*	0.9	Md	008/010	204	0.05	CD	E3	le
07	08:18:07	46.4112	-119.2602	0.5*	1.1	Md	008/009	204	0.06	CD	E3	le
07	08:22:28	46.4172	-119.2633	0.3	0.9	Md	011/015	129	0.10	AB	E3	le
07	08:29:20	46.6695	-120.6367	6.1	0.4	Md	008/008	100	0.05	AC	E3	le
07	09:58:08	46.4182	-119.2725	0.6	1.6	Md	020/024	86	0.14	AA	E3	le
07	10:14:40	46.4172	-119.2680	0.0	0.6	Md	005/009	197	0.15	BD	E3	le
08	00:52:17	46.4115	-119.2620	0.7	0.4	Md	006/009	202	0.08	BD	E3	le
09	14:41:24	48.6800	-119.4165	0.9	2.3	Md	012/014	115	0.40	CC	N3	le
10	13:12:12	46.6018	-119.8562	6.4	0.8	Md	007/008	177	0.08	AC	E3	le
11	16:47:27	48.8037	-118.9157	0.0*	1.1	Md	006/010	238	0.50	DD	N3	px
11	19:25:32	46.6240	-120.6692	0.0*	1.7	Md	019/027	58	1.03	DC	E3	px
14	03:52:13	45.7438	-120.7878	0.3	1.3	Md	010/011	147	0.13	AC	C3	le
18	02:09:44	47.7262	-120.1995	0.6*	2.2	Md	024/014	64	0.07	CC	N3	le
20	19:54:40	48.1028	-120.7350	1.6	1.9	Md	011/013	144	0.12	AC	C3	le
21	11:29:34	46.4085	-119.2680	1.9	1.0	Md	011/012	204	0.04	AD	E3	le
21	23:29:31	46.6437	-119.3823	13.9	0.3	Md	009/015	164	0.08	AC	E3	le
27	16:22:47	46.7002	-120.4970	19.6	1.6	Md	011/014	81	0.23	BA	E3	le
30	07:37:30	46.5598	-119.2068	16.1	0.7	Md	015/021	93	0.12	AB	E3	le
30	20:58:56	48.3622	-120.8275	5.2	1.7	Md	019/025	87	0.39	CC	C3	le
31	21:27:54	46.1430	-119.2080	0.0*	2.3	Md	015/016	164	0.17	CC	E3	px
August 2012												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Etyp
07	23:59:45	47.6903	-120.3022	8.9	3.2	Ml	028/030	46	0.14	AC	N3	le
09	12:36:35	46.8205	-119.4062	17.8	0.4	Md	006/010	261	0.10	AD	E3	le
15	17:51:15	47.6320	-120.1140	3.1	1.0	Md	007/009	145	0.09	BC	N3	le
17	04:23:13	46.6625	-121.4470	7.2	0.7	Md	017/024	252	0.08	AD	C3	le
19	13:28:31	47.6793	-120.0500	5.5	2.1	Ml	010/011	119	0.04	AB	N3	le
21	19:22:28	48.1295	-120.3692	3.4	2.0	Md	014/018	88	0.40	CB	N3	le
22	04:55:44	46.4128	-119.2685	0.0	1.0	Md	009/013	106	0.11	AB	E3	le
31	23:34:09	47.6658	-120.3302	1.7*	1.3	Md	005/008	128	0.08	CC	N3	le
September 2012												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Etyp
02	08:25:39	46.2438	-120.7248	17.7	1.7	Md	027/036	53	0.40	CA	C3	le
02	11:30:00	46.5680	-119.6682	12.4	0.4	Md	009/015	162	0.25	BC	E3	le
02	19:15:30	46.5938	-119.8278	6.1	1.0	Md	015/019	76	0.40	CA	E3	le
04	09:06:49	48.9025	-120.6897	10.1*	1.5	Md	008/012	152	0.30	CD	C3	le
06	03:56:02	48.0595	-120.8233	5.6	0.8	Md	006/007	130	0.06	AC	C3	le

11	19:29:23	47.3370	-117.8560	0.0*	2.2	Md	011/016	205	0.53	DD	N3	px
13	17:34:10	47.3425	-120.0190	10.2	3.4	Ml	037/038	61	0.21	BC	N3	le
15	02:37:50	46.4853	-119.8057	0.6*	1.5	Md	009/011	149	0.36	CC	E3	le
15	07:25:45	48.8770	-120.6848	10.0*	1.6	Md	009/011	137	0.14	CD	C3	le
19	21:10:32	46.5780	-119.7833	8.1	0.8	Md	005/008	133	0.22	BB	E3	le
22	19:26:19	46.6600	-120.5885	6.7	1.2	Md	012/010	141	0.12	AC	E3	le
23	18:15:49	47.6873	-120.3332	5.5	0.3	Md	004/007	210	0.07	BD	N3	le
25	02:16:03	46.7433	-121.0363	3.8	2.3	Ml	044/050	53	0.26	BC	C3	le
25	22:06:58	46.6510	-120.5165	0.0*	1.5	Md	011/013	76	0.35	CC	E3	ex
26	20:31:21	48.2073	-121.3183	8.9	1.2	Md	014/019	120	0.29	BB	C3	le
28	19:40:37	47.8067	-117.4277	0.0*	2.4	Md	015/021	115	0.58	DD	N3	px
30	15:46:33	47.7490	-120.2012	4.7	2.0	Md	017/013	106	0.06	AC	N3	le

Explanation of Table 4.1 – also see section 3.3 of this report

Etyp	Event Type. le is local earthquake, px is Probable Blast; ex is Confirmed Blast
Day	The year and date in Universal Time Coordinated (UTC). UTC is used throughout this report unless otherwise indicated.
Time	The origin time of the earthquake given in Coordinated Universal Time (UTC). To covert UTC to Pacific Standard Time, subtract eight hours; to Pacific Daylight Time, subtract seven hours.
Lat	Latitude of the earthquake epicenter, in decimal degrees
Lon	Longitude of the earthquake epicenter, in decimal degrees
Depth	The depth of the earthquake in kilometers (km). * = Depth constrained by location program, \$ = location program had trouble converging and constrained both location and depth.
Mag	The analyst-preferred magnitude. If magnitude is blank, a determination was not made.
Mtype	Preferred magnitude type (see section 3.2, “Earthquake Magnitudes”)
NS/NP	Number of stations/number of phases used in the location.
Gap	Azimuthal gap; the largest horizontal angle (relative to the epicenter) containing no stations.
Mod	Primary velocity model used in the location. (see section 3.1, “Velocity Models”)
Rms	Average misfit, in seconds, between the model-predicted and observed travel time. Computed as the square root of the summed squares of individual phase time residual (observed phase arrival time minus predicted arrival time) of all phases used to locate the earthquake. It is a meaningful measure of quality of the solution only when five or more well-distributed stations are used in the solution. Good solutions are normally characterized by Rms values smaller than ~ 0.3 s.
Q	Quality factors; indicate the general reliability of the solution/location (A is best quality, D is worst). See Section 3.3 of this report, “Quality Factors.”

4.2 Summary

Overall, the seismicity throughout the 4th quarter of FY2012 was very similar to the 3rd quarter, with no significant increase or decrease between quarters. Within the vicinity of the Hanford site, there was an increase in earthquake occurrence in the Wye Swarm Area.

4.3 Discussion of Fourth Quarter FY 2012 Earthquakes

The EWRSN and HSN recorded 58 eastern Washington earthquakes during the fourth quarter of FY 2012, 26 local to the Hanford site (local), and 32 off of the site (regional). Of the local earthquakes, 19 were located at shallow depths (less than 4 km), 3 at intermediate depths (between 4 and 9 km), most likely in the pre-basalt sediments, and 4 deeper than 9 km, within the basement. Geographically, 17 shallow local earthquakes were located in the Wye swarm area. Nine other local earthquakes were classified as random events. Of the regional earthquakes, 15 were shallow, 11 intermediate, and 6 deep. The network also located eight local and regional events that have been categorized as probable surface explosions. (Tables 4.1 & 4.2).

The largest event ($M_L = 3.4$) took place on 13 September 2012 at a depth of 10.2 km with epicenter located 24 km east-southeast of the Wenatchee, WA.

Epicenters of the earthquakes in Table 4.1 are plotted in Figures 4.1 and 4.2. The depth distribution and geographic pattern of the earthquakes are tabulated in Table 4.2. Epicenters of earthquakes in the immediate vicinity of the Hanford site, and their relationship to known faults and swarm areas are shown on Figure 4.2. Figure 4.3 is a perspective plot showing the hypocenters in the vicinity of the Hanford site and their location at depth and their relationship to the surface topography.

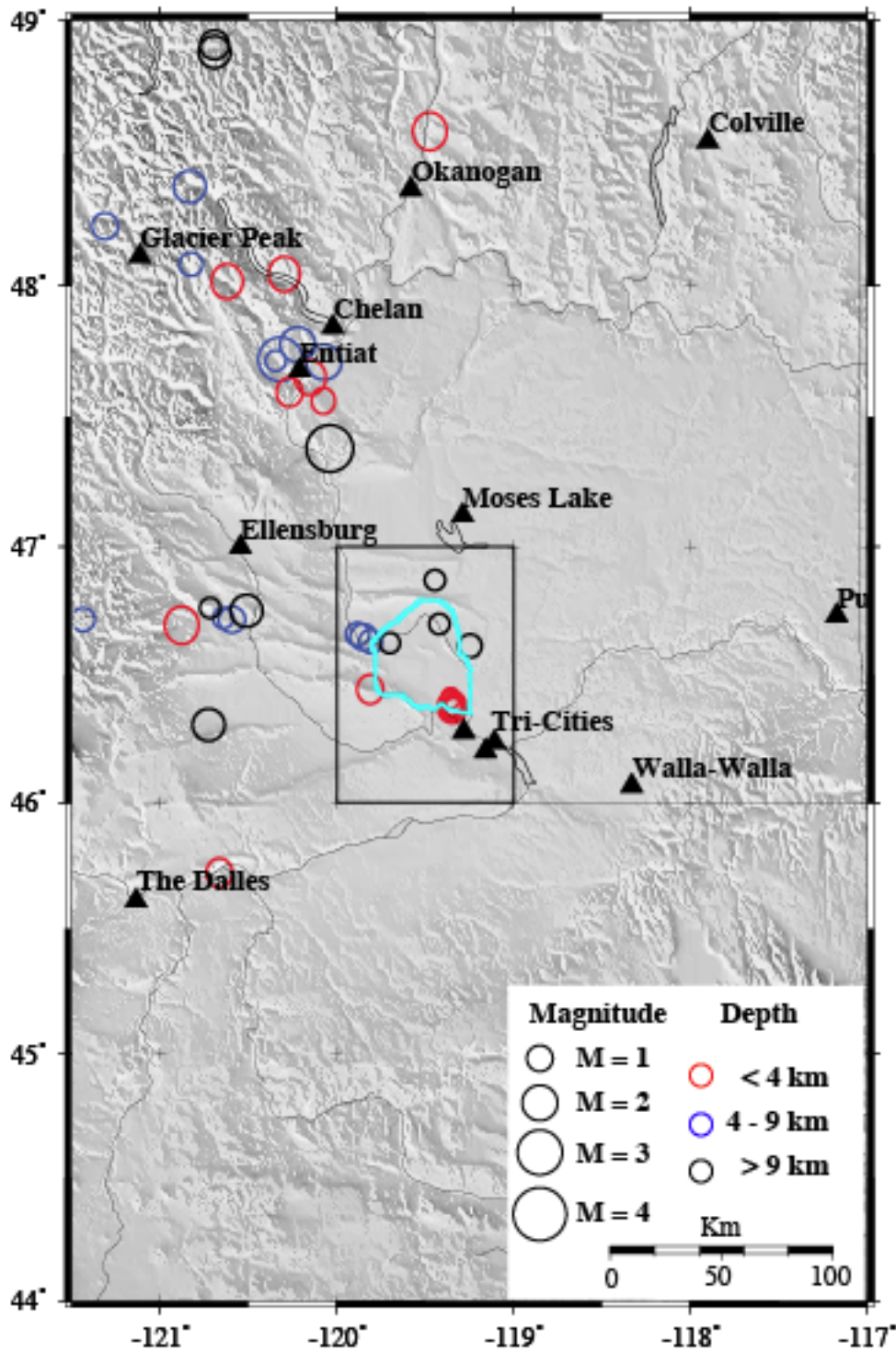


Figure 4.1 Epicenters of earthquakes recorded in the Eastern Washington region during the 4th Quarter of FY2012. Black triangles show locations of cities, towns, and volcanoes. Light blue line is the outline of the Hanford site. Black rectangle outlines area mapped in Figure 4.2. Circles are earthquake epicenters, with size scaled by magnitude [radius(in inches) = 0.05*M + 0.1]. Representative symbols for magnitudes 1-4 are shown in the legend. Epicenter symbols are colored by depth, as shown in legend.

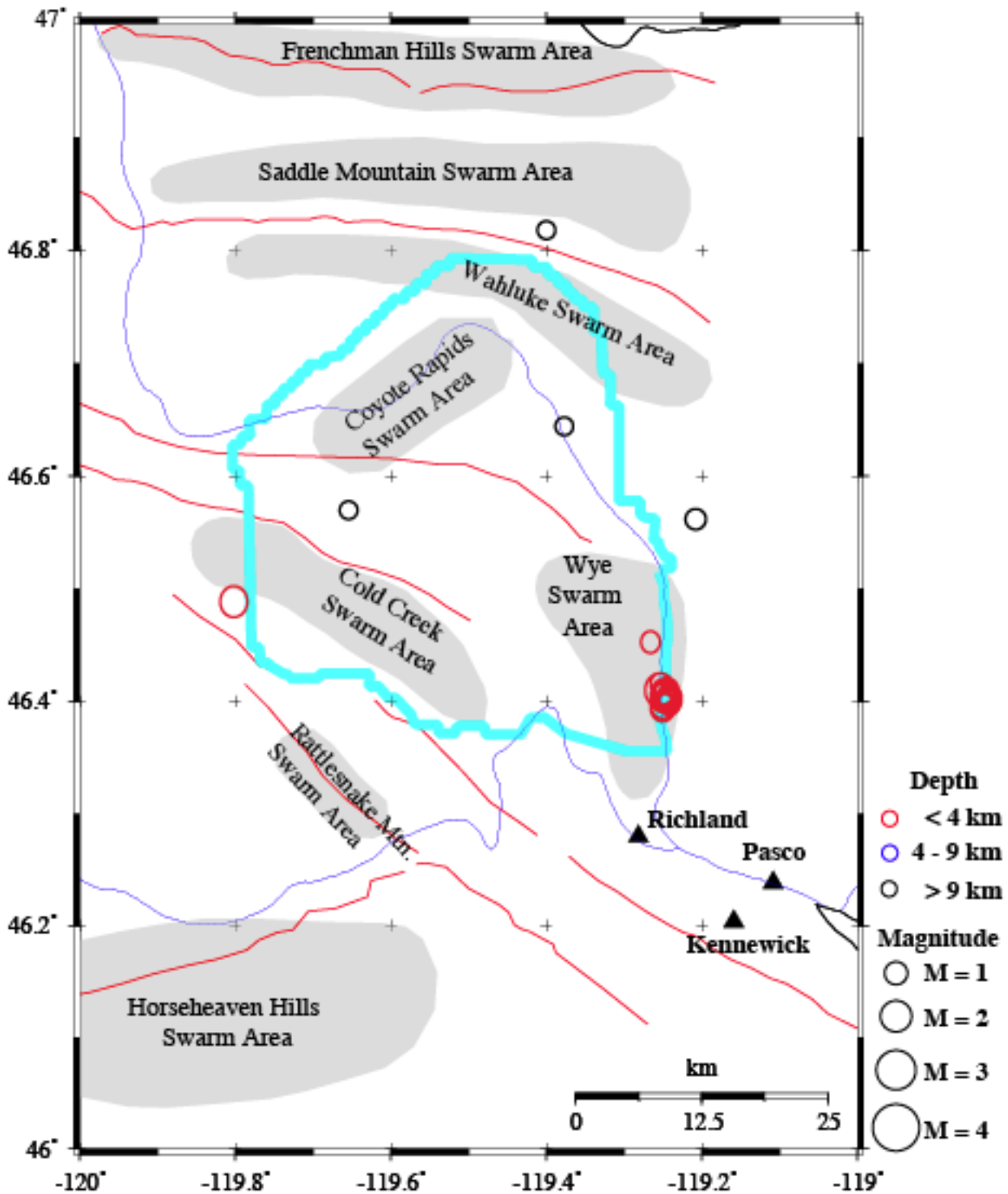


Figure 4.2 Epicenters of earthquakes occurring during the 4th Quarter of FY2012 in the vicinity of the Hanford site (blue outline), and their relationship to known structures (red lines), swarm areas (shaded regions), and cultural features and cities (black triangles). Circles are earthquake epicenters, with size scaled by magnitude [radius(in inches) = $0.05 * M + 0.1$]. Representative symbols for magnitudes 1-4 are shown in the legend. Epicenter symbols are colored by depth, as shown in legend.

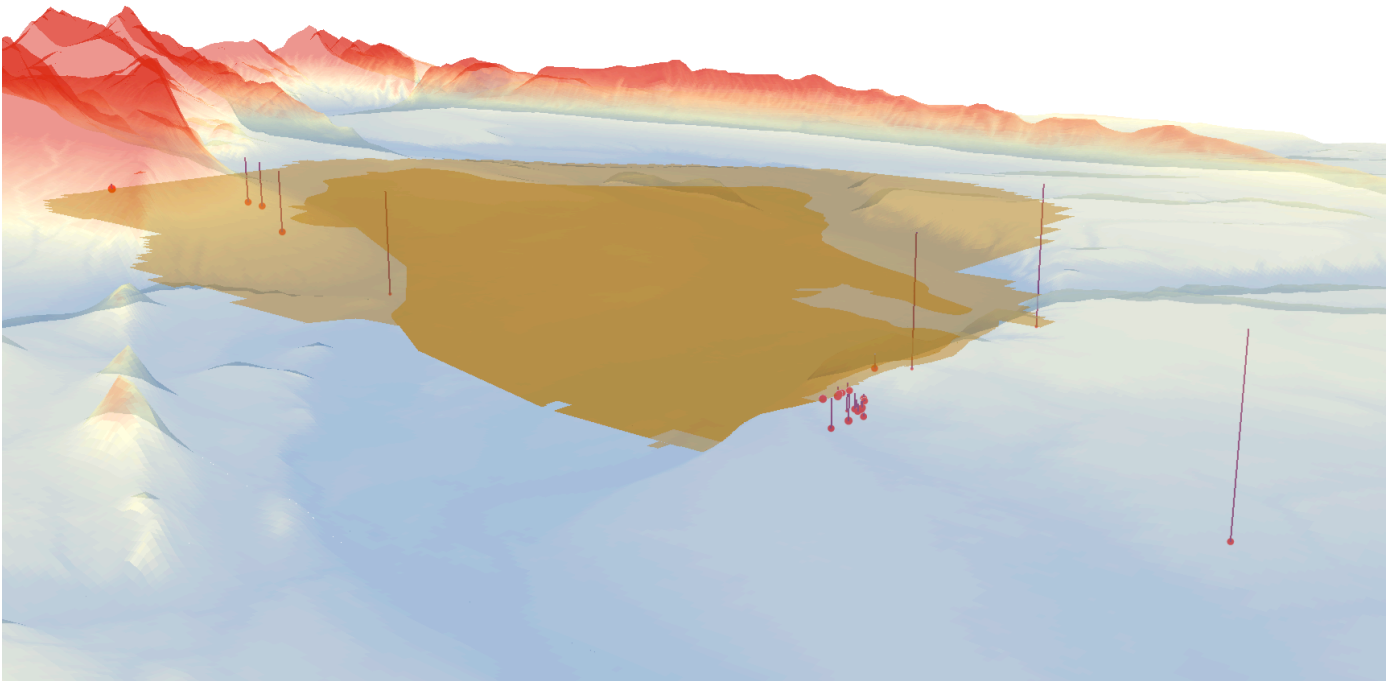


Figure 4.3 Perspective plot showing topography (exaggerated) and hypocenters (red dots, connected to epicenter with fine vertical line) of earthquakes occurring during the 4th Quarter of FY2012 in the vicinity of the Hanford site, both overall (lightly shaded region), and inner (darker shading). Probable blasts are not shown in this figure.

Table 4.2 Summary Table of the Distribution of Earthquakes for 4th Quarter, FY 2012

Event Category		4th Quarter	
		Hanford	Region
Depth	< 4 km	19	15
	4-9 km	3	11
	>9 km	4	6
Sub-total		26	32
Total		58	
Geographic Area	FHS	0	0
	SMS	0	0
	WAHS	0	0
	CRS	0	0
	CCS	0	0
	WYES	17	0
	RMS	0	0
	Horse Heaven Hills Structure	0	0
Random Event		9	0
Sub-total		26	0
Total		26	0
Felt		0	2
Probable Blast		1	7

5.0 Significant or Notable Seismic Events

5.1 Significant Earthquakes

We consider earthquakes that were felt widely, generated public interest, or produced notable shaking on the Hanford site to be significant earthquake events. We generally include any earthquake exceeding $M3.0$ to fall into this category. There were two $M \geq 3.0$ earthquakes in the 4th quarter of FY2012. Neither of these earthquakes was located in the Hanford site, however.

The first significant earthquake occurred on August 7, 2012, 6.5 km west-northwest of Entiat at 8.9 km depth and with $3.2 M_L$. Figure 5.1 shows the waveforms for this earthquake.

The second significant earthquake occurred on September 13, 2012, 24 km east-southeast of Wenatchee at 10 km depth and a $M_L = 3.4$. Figure 5.2 shows the waveforms for this earthquake. Figure 5.3 shows the regional ShakeMap for this earthquake and Figure 5.4 shows the new Hanford area ShakeMap. This is the first high-resolution ShakeMap produced by the PNSN for the Hanford area.

Figure 5.1 Waveforms for the 7 August 2012 $M_L=3.2$ earthquake from the event page at www.pnsn.org.

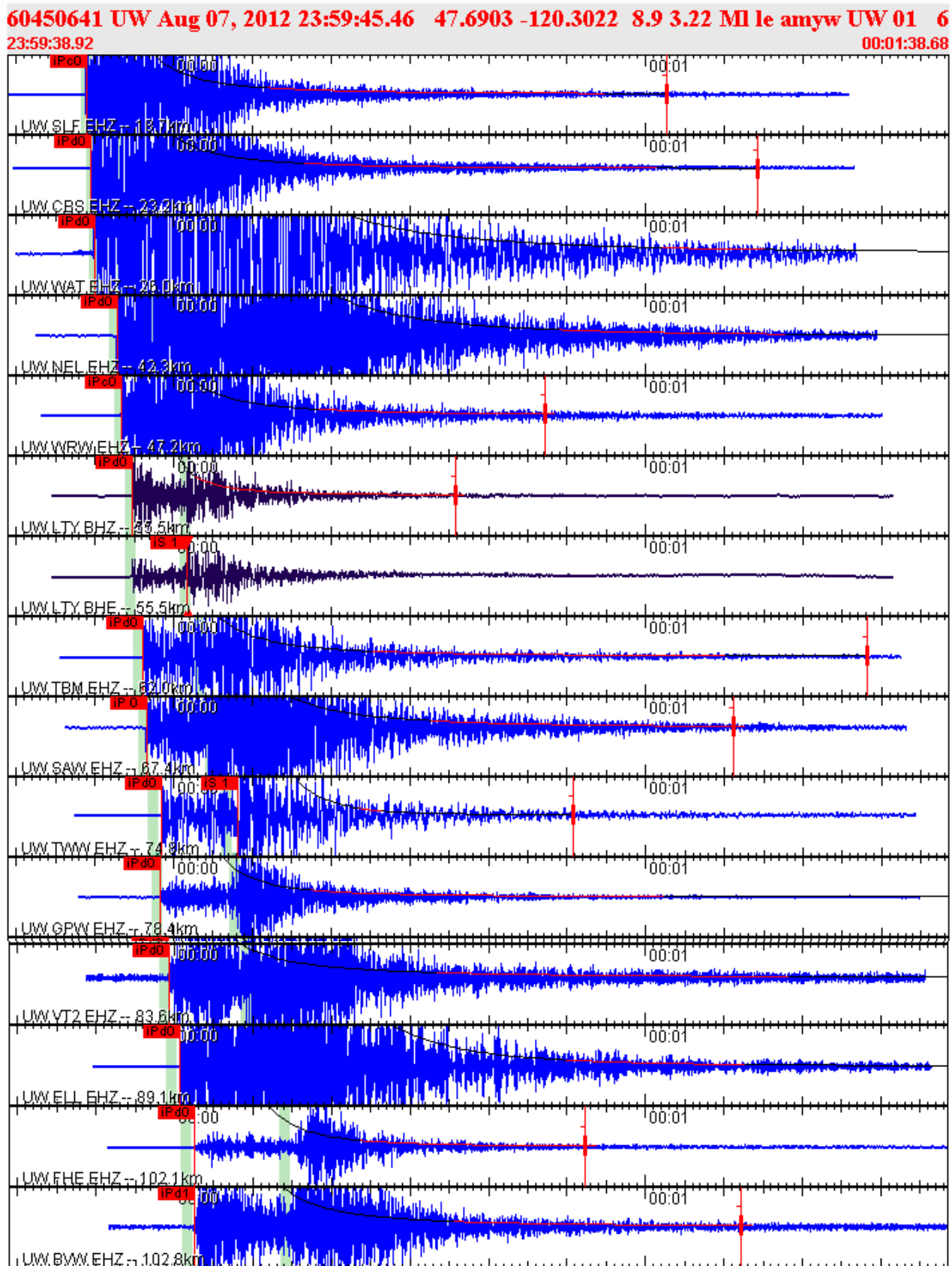


Figure 5.2 Waveforms for the 13 September 2012 $M_L=3.4$ earthquake from the event page at www.pnsn.org.

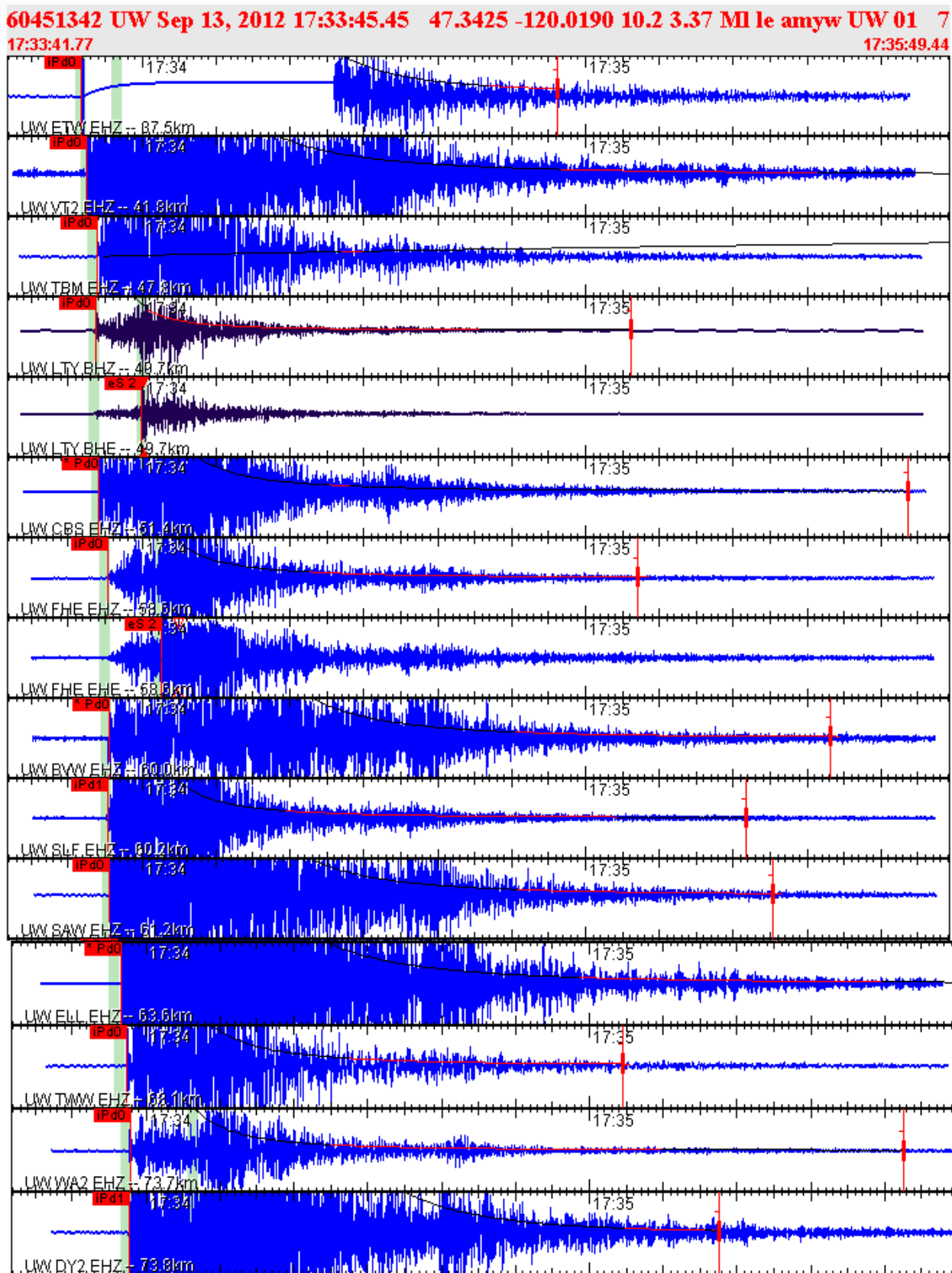
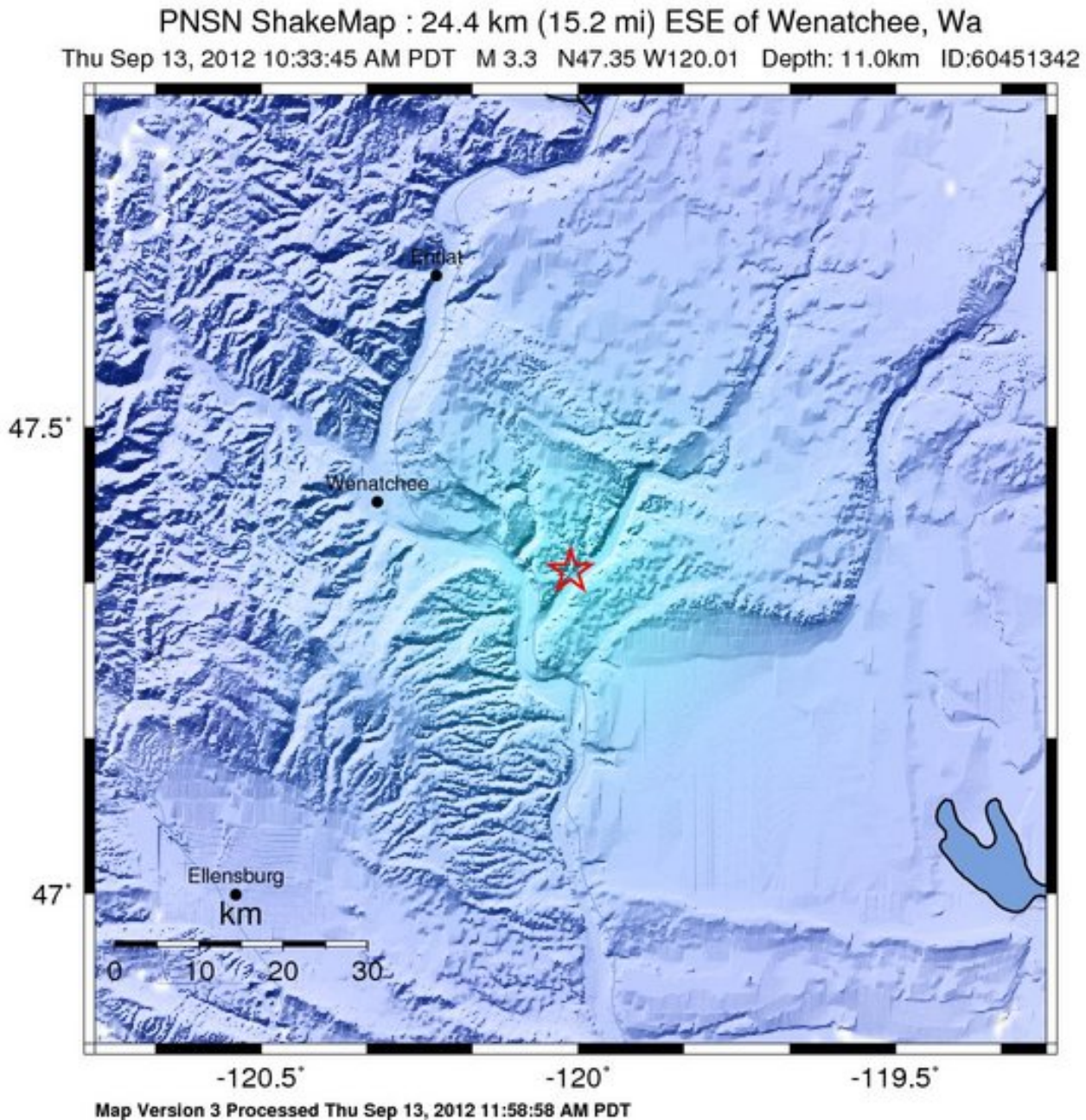


Figure 5.3 Regional ShakeMap for the 13 September 2012 $M_L=3.4$ earthquake from the event page at www.pnsn.org.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2011)

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