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Revision 0

Hanford Seismic Report for Fiscal Year 2014 (October 2013 – September 2014)

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of
Energy under Contract DE-AC06-09RL14728

Box 650
Richland, Washington 99352

Approved for Public Release

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Prepared for Mission Support Alliance

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Executive Summary

The Pacific Northwest Seismic Network (PNSN) and MSA Mission Support Alliance (MSA) continue to provide uninterrupted collection of high-quality raw and processed seismic data from the Hanford Seismic Network (HSN). The HSN includes both onsite and offsite [Eastern Washington Regional Sub-Network (EWRSN)] stations that are operated 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.

During FY2014, seismic activity was relatively quiet throughout eastern Washington. 332 earthquakes were cataloged in the region, of which about 46% (153) took place on or in the immediate vicinity of the Hanford Site. While no damaging earthquakes took place in the region, a handful of notable or significant earthquakes illustrated interesting features of regional seismotectonics. Several earthquakes took place in the historically active area of Entiat and Chelan. Within the vicinity of the Hanford Site, there was typical swarm-type activity, most strongly observed in the Wye Swarm Area.

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 (closest distance from an earthquake epicenter to a station)
DOE	U.S. Department of Energy
Etyp	Event type
EWRSN	Eastern Washington Regional Sub-Network
FY	Fiscal year
g	typical value of gravitational acceleration at Earth's surface (~978 cm/sec/sec)
GPS	Global Positioning System
HLSMP	Hanford Lifecycle Seismic Monitoring Program
HSN	Hanford Seismic Network
Lat	Latitude
Lon	Longitude
Km	kilometer
M_d	coda-duration magnitude
M_L	local magnitude
MAG	Magnitude of earthquake
MMI	Modified Mercalli Intensity
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
WSUR	Washington State University Richland

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1.0 Introduction

This annual report documents the locations, magnitudes, and seismic interpretations of earthquakes recorded for the Hanford monitoring region of south-central Washington during the fiscal year (FY) 2014 (October 2013 through September 2014). The Mission Support Alliance (MSA), Public Safety and Resource Protection (PSRP) program manages seismic monitoring for the Hanford Site with the monitoring work being performed under a sub-contract with the University of Washington (UW), 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 (LAT) and between 119°-120° west longitudes (LON). 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.

1.2 History of Monitoring Seismic Activity at Hanford

The U.S. Geological Survey (USGS) under a contract with the U.S. Atomic Energy Commission initiated monitoring seismic activity at the Hanford Site in 1969. In 1975, the UW assumed responsibility for the network and subsequently expanded it. In 1979, the Basalt Waste Isolation Project (BWIP) became responsible for collecting seismic data for the Hanford Site as part of site characterization activities. Rockwell Hanford Operations, followed by Westinghouse Hanford Company (WHC), operated the local network, and were the contract technical advisors for the EWRSN operated and maintained by UW. Funding ended for BWIP in December 1988; the seismic program (including the UW contract) was transferred to the WHC Environmental Division. Maintenance responsibilities for the EWRSN also were assigned to WHC, who made major upgrades to EWRSN sites. Effective October 1, 1996, all seismic assessment activities were transferred to the Pacific Northwest National Laboratory (PNNL).

The Hanford Strong Motion Accelerometer (SMA) network was constructed during 1997, becoming operational in May 1997. It was shut down in FY 1998 due to lack of funding but became operational again in FY 1999 and has operated continuously since that time. During the third quarter of FY2011, operations of the seismic monitoring networks were assumed by HLSMP.

1.3 Documentation and Reports

The HLSMP issues quarterly reports of local activity, an annual catalog of earthquake activity in southeastern Washington, and special-interest bulletins on local seismic events. This includes information and special reports as requested by DOE and Hanford Site contractors. Earthquake information provided in these reports is subject to revision as new information becomes available. An archive of all cataloged seismic event locations and magnitudes and related waveform data from the HLSMP is maintained by PNSN on computer servers at the UW. Continuous waveform data and associated station metadata from all available seismic stations is permanently archived at the Incorporated Research Institutions in Seismology (IRIS) seismic data archive in Seattle, with backup copies at IRIS facilities in Seattle and in Boulder, Colorado.

2.0 Geology and Tectonic Analysis

The Hanford Site lies within the Columbia Basin, an intermontane basin between the Cascade Range and the Rocky Mountains filled with Cenozoic volcanic rocks and sediments. This basin forms the northern part of the Columbia Plateau physiographic province (Fenneman 1931) and the Columbia River flood-basalt province (Reidel et al. 1989). In the central and western parts of the Columbia Basin, the Columbia River Basalt Group (CRBG) overlies Tertiary continental sedimentary rocks and is overlain by late Tertiary, Quaternary fluvial, and glaciofluvial deposits (Campbell 1989; Reidel et al. 1989, 1994; DOE 1988). In the eastern part, little or no sediment separates the basalt and underlying crystalline basement, and a thin (<10 m) veneer of eolian sediments overlies the basalt (Reidel et al. 1989, 1994).

The Columbia Basin has two structural subdivisions or sub provinces—the Yakima Fold Belt and the Palouse Slope. The Yakima Fold Belt includes the western and central parts of the Columbia Basin and is a series of anticlinal ridges and synclinal valleys with major thrust faults typically along the northern flanks (Figure 3.1) (Reidel and Fecht 1994a, 1994b). The Palouse Slope is the eastern part of the basin and is less deformed than the Yakima Fold Belt, with only a few faults and low-amplitude long-wave-length folds on an otherwise gently westward dipping paleoslope.

2.1 Earthquake Stratigraphy

Seismic studies at the Hanford Site have shown that the earthquake activity is related to crustal stratigraphy (large groupings of rock types) (Rohay et al. 1985; DOE 1988). The main geologic units important to earthquakes at the Hanford Site and the surrounding area are

- Miocene Columbia River Basalt Group
- Sub-basalt sediments of Paleocene, Eocene, Oligocene, and Early Miocene age
- Precambrian and Paleozoic cratonic basement
- Mesozoic accreted terranes forming the basement west of the craton margin

2.2 Geologic Structure Beneath the Monitored Area

Between the late 1950s and the mid-1980s, deep boreholes were drilled for hydrocarbon exploration in the Columbia Basin. These boreholes provided accurate measurements of the physical properties of the Columbia River Basalt Group (CRBG) and the pre-basalt sediments (Reidel et al. 1989, 1994), but the thickness of the sub-basalt sediments and nature of the basement are still poorly understood. Table 3.1, derived from Reidel et al. (1994), was developed for the geologic interpretation in this report. The thicknesses of these units are variable across the monitored area. Table 3.1 summarizes the approximate thickness at the borders of the monitored area.

Table 2.1. Thicknesses of Stratigraphic Units in the Monitoring Area

(from Reidel et al., 1994)

Stratigraphy	North	South	East	West
Columbia River Basalt Group (includes suprabasalt sediments)	3.0 km	4.5 km	2.2 km	4.2 km
Pre-basalt sediments	3.0 km	>4.5 km	0	>6.0 km

The thickness of the basalt and the sub-basalt sediments varies because of different tectonic environments. The western edge of the North American craton (late Precambrian/Paleozoic continental margin and Precambrian craton) is located in the eastern portion of the monitored area (Reidel et al. 1994). The stratigraphy on the craton consists of CRBG overlying basement; the basement is continental crustal rock that underlies much of western North America. The stratigraphy west of the craton consists of 4 to 5 km of CRBG overlying up to 6 km of pre-basalt sediments. This in turn overlies accreted terranes of Mesozoic age. The area west of the craton was subsiding during the Eocene and Oligocene, accumulating great thickness of pre-CRBG sediments. Continued subsidence in this area during the Miocene resulted in thicker CRBG compared to that on the craton. Subsidence continues today but at a greatly reduced rate (Reidel *et al.,* 1994).

2.3 Tectonic Pattern

Studies have concluded that earthquakes can occur in the following six different tectonic environments (earthquake sources) at the Hanford Site (Geomatrix 1996):

Major Geologic Structures. Reverse/thrust faults in the CRBG associated with major anticlinal ridges such as Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge could produce some of the largest earthquakes.

Secondary Faults. These faults are typically smaller (1 to 20 km in length) than the main reverse/ thrust faults that occur along the major anticlinal ridges (up to 100 km in length). Secondary faults can be segment boundaries (tear faults) and small faults of any orientation that formed along with the main structure.

Swarm Areas. Small geographic areas produce clusters of events (swarms); usually located in synclinal valleys not known to contain any mapped geologic faults. These clusters consist of a series of small shocks with no outstanding principal event. Swarms occur over a period of days or months, and the events may number into the hundreds and then quit, only to start again later. This differs from the sequence of foreshocks, mainshock, and trailing-off aftershocks that have the same epicenter or are associated with the same fault system. In the past, swarms were thought to occur only in the CRBG. Most swarm areas are in the basalt, but swarm events also appear to occur in all geologic layers. However, typically a swarm event at a specific time is usually restricted to one layer. It is traditional to regard swarms as occurring within one of seven earthquake swarm areas in the HSN area. The Saddle Mountains, Wooded Island, Wahluke, Coyote Rapids, and Horse Heaven Hills swarm areas are typically active at one time or another during the year (see Figure 5.2 for a map of these swarm areas). The other earthquake swarm areas are active less frequently. There is, however, no compelling theory to suggest a generative mechanism active within these swarm areas. They are deduced purely empirically, are rather conjectural, and will likely be updated or reconfigured as new swarm areas develop.

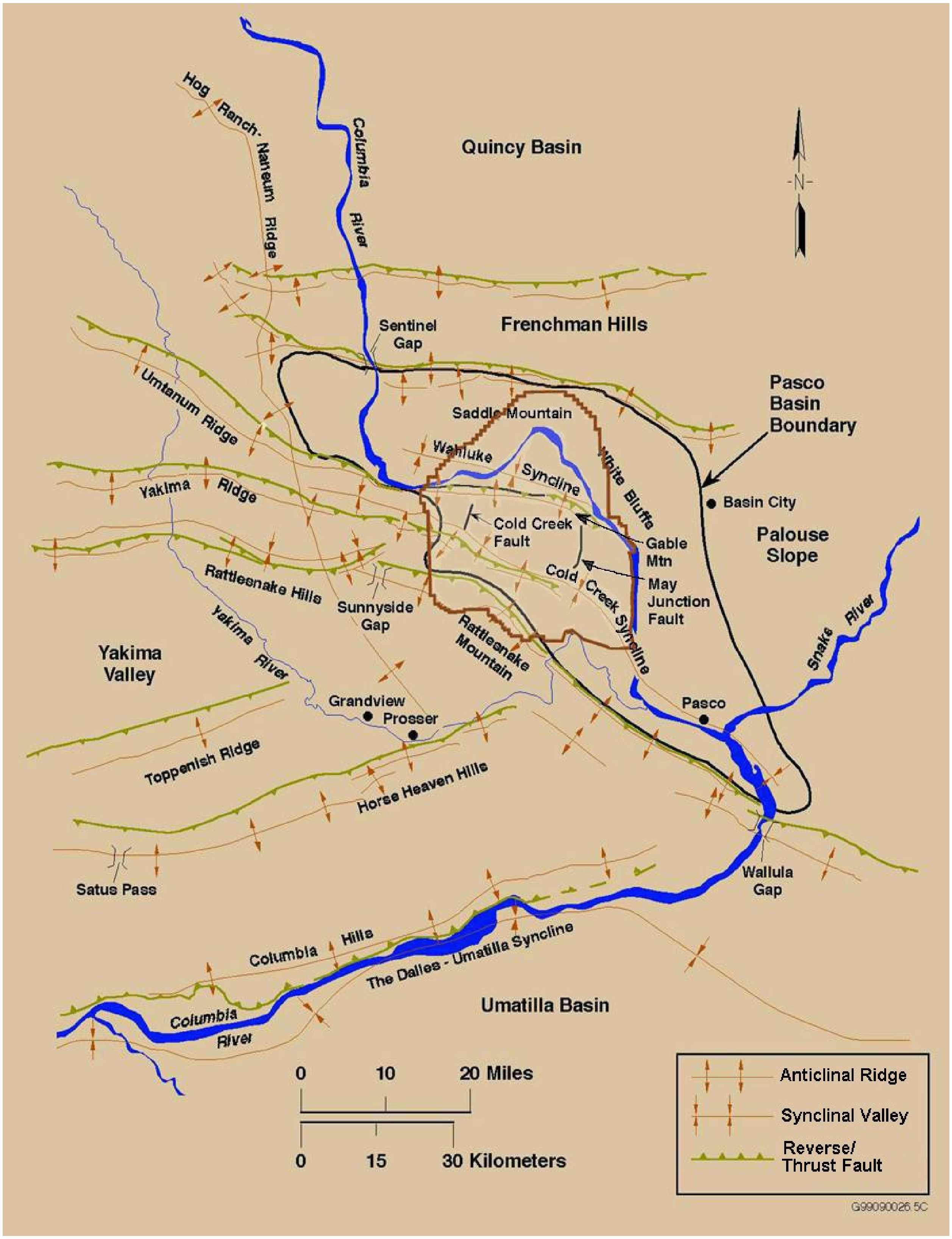
Entire Columbia Basin. The entire basin, including the Hanford Site, could produce a "floating" earthquake. A floating earthquake is one that, for seismic design purposes, can happen anywhere in a tectonic province and is not associated with any known geologic structure. Seismic interpretation classifies it as a random event for purposes of seismic design and vibratory ground motion studies.

Basement Source Structures. Studies (Geomatrix 1996) suggest that major earthquakes can originate in tectonic structures in the basement. Because little is known about geologic structures in the basement beneath the Hanford Site, earthquakes cannot be directly tied to a mapped fault. Earthquakes occurring in the basement without known sources are treated as random events.

Cascadia Subduction Zone. This source has been postulated to be capable of producing a magnitude 9 earthquake. Because this source is along the western boundary of Washington State and outside the HSN, the Cascadia subduction zone is not an earthquake source that is monitored at the Hanford Site, so subduction zone earthquakes are not reported here. Because any earthquake along the Cascadia subduction zone can have a significant impact on the Hanford Site or can be felt like the February 2001 Nisqually earthquake, UW monitors and reports on this earthquake source for the DOE. Ground motion from any moderate or larger Cascadia subduction zone earthquake is detected by Hanford SMAs and reported.

Figure 2.1. Tectonic Features of the Hanford Site within Eastern Washington

(from Rohay et al., 2010b)



3.0 Network Operations

3.1 Seismic Station Overview

The seismic network consists of three types of earthquake sensors—short-period seismometers, broadband seismometers, and strong motion accelerometers (SMAs).

Short-period seismometers are very sensitive passive sensors (they do not use external electric power) designed primarily to detect micro earthquakes. While most short-period stations have a single component, sensitive only to the vertical motion of the ground, several HLSMP short-period stations record the ground in three orthogonal directions. In a regional network like the HLSMP networks, the time of arrival of waves, and the signal duration derived from short-period stations are used to determine the locations and magnitudes of seismic events; the polarities of ground motions may be used to constrain estimates of the geometry of fault that ruptured in an earthquake.

Broadband seismometers are active sensors (they use electricity to power advanced electronic circuitry that is integral to the sensor) that faithfully record ground motions over a wide frequency range. The data they produce are acquired digitally with 24-bit dynamic range; a broadband system will therefore stay "on-scale" over a much broader range of ground motions than a short-period sensor. In addition to locations and magnitudes derived from signal durations, details of the observed waveforms are used to reveal the source processes of small to moderately large earthquakes. HLSMP broadband stations are all 3-component.

Both short-period and broad-band sensors will ultimately "clip", or fail to record properly, if subjected to more than moderate levels of shaking (well below damaging levels). SMA stations, however, are designed to measure even the damaging ground motions from larger earthquakes. They are 3-component stations and must be carefully and strongly anchored to the ground so that the details of ground shaking up to 2g (twice the vertical acceleration of gravity) are accurately recorded. In addition to helping to characterize the earthquake source, they are critically important in measuring the ground motions that impact a particular site. They aid in determining what the built environment has been exposed to for earthquake response activities and engineers and others use them in designing appropriate structures. Because of their importance to seismic monitoring on the Hanford Site, the distribution, design, and operations of SMA stations within the HLSMP is discussed separately in Section 3.2.

We further divide the seismic stations supported by MSA into two geographic sub-networks for discussion: the Hanford Site Network (HSN), which are sites located on the Hanford Site itself, and the Eastern Washington Regional Sub-Network (EWRSN), which includes sites that surround the Hanford Site.

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).

Table 3.1. Hanford Seismic Network Onsite Stations

	Latitude	Longitude	Elevation (m)	Station Name
Strong Motion Accelerometer, 3-Channel Station				
H1K	46.6447	-119.5929	152	100 K Area (SMA)
H2E	46.5578	-119.5345	210	200 East Area (SMA)
H2W	46.5517	-119.6453	201	200 West Area (SMA)
H3A	46.3632	-119.2775	119	300 Area (SMA)
H4A	46.4377	-119.3557	171	400 Area (SMA)
3-Channel Station				
GBB	46.6087	-119.6290	185	Gable Butte
Single Channel Analog Weak Motion				
BEN	46.5186	-119.7185	335	Benson Ranch
MDW	46.6130	-119.7622	330	Midway
MJ2	46.5574	-119.3601	146	May Junction Two
RSW	46.3944	-119.5925	1045	Rattlesnake Mountain
SNI	46.4639	-119.6609	323	Snively Ranch
WA2	46.7552	-119.5668	244	Wahluke Slope
WIW	46.4292	-119.2888	128	Wooded Island

Figure 3.1. Hanford Seismic Network Onsite Stations

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

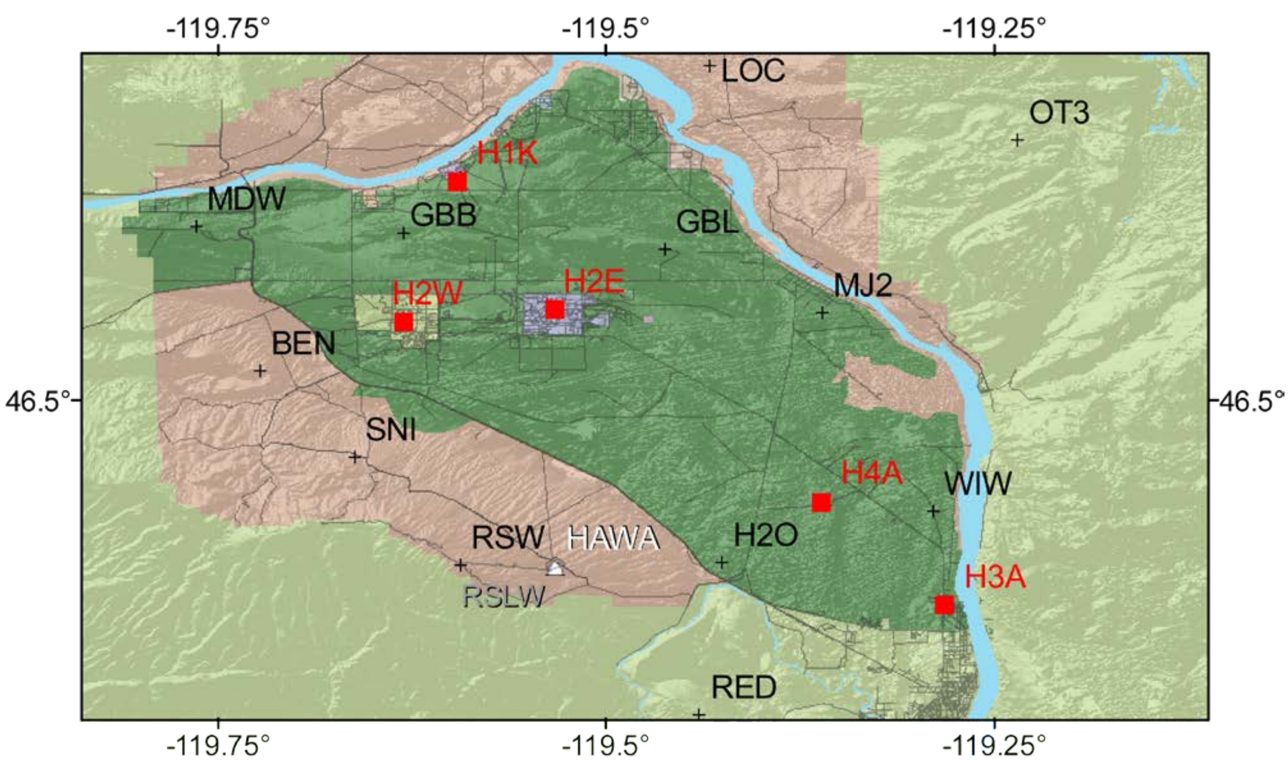
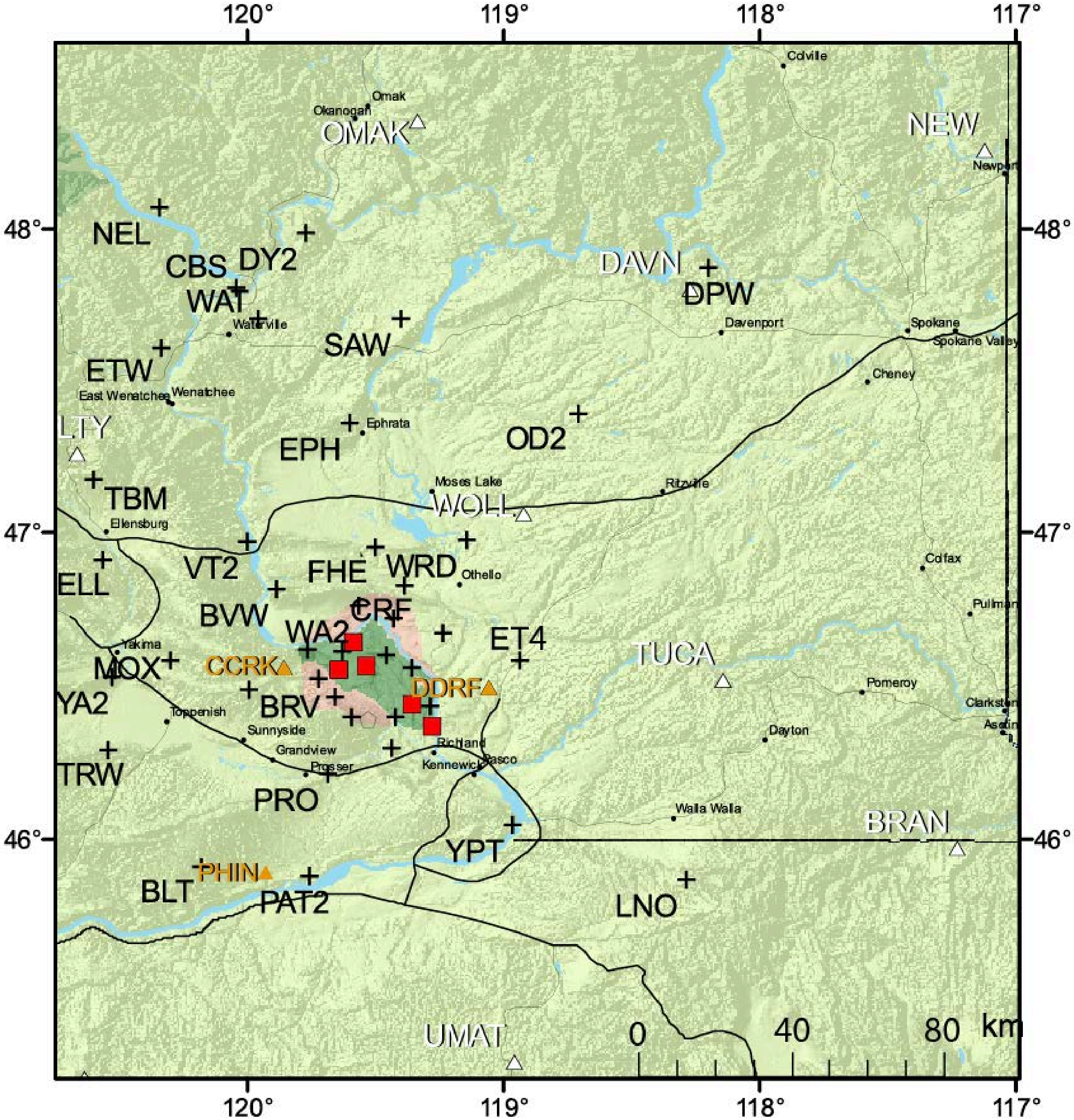


Table 3.2. Hanford Seismic Network Offsite Stations

Station	Latitude	Longitude	Elevation (m)	Station Name
Strong Motion Accelerometer, 3-Channel Station				
CCRK	46.5585	-119.8548	561	Cold Creek
DDRF	46.4911	-119.0595	233	Didier Farms
PHIN	45.8950	-119.9280	227	Phinney Hill
3-Channel Weak Motion Analog (Short Period)				
FHE	*46.9518*	*-119.4981*	*455*	*Frenchman Hills East*
Single-Channel Analog (Short Period)				
BLT	45.9150	-120.1770	659	Bickleton
BRV	46.4852	-119.9923	920	Black Rock Valley
BVW	46.8108	-119.8835	670	Beverly
CBS	47.8047	-120.0429	1067	Chelan Butte South
CRF	46.8249	-119.3881	189	Corfu
DPW	47.8705	-118.2039	892	Davenport
DY2	47.9850	-119.7725	890	Dyer Hill 2
ELL	46.9095	-120.5675	789	Ellensburg
EPH	47.3562	-119.5972	661	Ephrata
ET4	46.5634	-118.9451	236	Eltopia 4
ETW	47.6042	-120.3335	1477	Entiat
LNO	45.8717	-118.2862	771	Lincton Mountain Oregon
MOX	46.5772	-120.2993	501	Moxee City
NAC	46.7330	-120.8249	728	Naches
NEL	48.0700	-120.3414	1500	Nelson Butte
OD2	47.388	-118.7108	553	Odessa 2
OT3	46.6689	-119.2341	322	Othello 3
PAT2	45.8836	-119.7578	259	Paterson 2
PRO	46.2125	-119.6868	553	Prosser
RED	46.2974	-119.4388	330	Red Mountain
SAW	47.7015	-119.4017	701	St. Andrews
TBM	47.1699	-120.5992	1006	Table Mountain
TRW	46.2921	-120.5431	723	Toppenish Ridge
TWW	47.1380	-120.8695	1027	Teanaway
VT2	46.9672	-120.0003	385	Vantage 2
WAT	47.6985	-119.9552	821	Waterville
WRD	46.9699	-119.1460	375	Warden
YA2	46.5265	-120.5312	652	Yakima 2
YPT	46.0487	-118.9634	325	Yellepit

Figure 3.2. Hanford Seismic Network 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.



The EWRSN is used by the HLSMP for two major reasons. 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. Additionally, the characterization of seismicity throughout the surrounding areas, as required for the Probabilistic Seismic Hazard Analysis, supports facility safety assessments at the Hanford Site. Both the HSN and the EWRSN are fully integrated within the Pacific Northwest Seismic Network managed by the University of Washington.

The HSN and EWRSN networks have 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 were acquired from the National Science Foundation funded US Array, "Transportable Arrays (TA)" experiment that is broadband seismometers with digital telemetry via satellite or cellular telephone. GBB and FHE are tri-axial short-period 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 sub-networks to transmit continuously seismogram data to the PNSN in Seattle, Washington, for processing and archiving.

3.2 Strong Motion Accelerometer Stations

3.2.1 Strong Motion Station Location

SMAs provided ground motion observations critical to understand the impacts of strong ground shaking that affect the Hanford Site itself. The Hanford SMA network consists of five free-field SMA stations (see Figure 2.1; Table 2.1). SMAs are located in the 200 East and 200 West Areas, in the 100-K Area adjacent to the K Basins, in the 400 Area near the former Fast Flux Test Facility, and at the south end of the 300 Area.

The locations of SMA stations were chosen based on two criteria: 1) density of workers and 2) sites of hazardous facilities (Moore and Reidel 1996). The 200 East and 200 West Areas contain single-shell and double-shell tanks in which high-level radioactive wastes from past processing of fuel rods are stored. In addition, the Canister Storage Facility (holding encapsulated spent fuel rods) and the new Waste Treatment and Immobilization Plant being constructed are both located in the 200 East Area. The 100-K Area contained the K Basins, where spent fuel rods from the N Reactor were stored prior to encapsulation. The now inactive Fast Flux Test Facility is located in the 400 Area.

3.2.2 Strong Motion Station Design

All free-field SMA stations consist of a four-panel solar array and two 30-gallon galvanized drums that contain equipment. Each panel has a maximum 42-watt output. The two drums are set in the ground such that the base of each drum is about 1 m below the ground surface. One drum houses only the SMA; the other drum, which is connected via a sealed conduit to the SMA drum, contains the batteries. Cellular modems provide communication from all five SMAs. The enclosure serves as a junction box for all cabling that is routed through conduit inside and outside the equipment drums. The antenna for the cell modem is mounted on top of the enclosure. The enclosure permits quick access to check battery conditions and a connection directly to the RS-232 port of the SMA without removing the drum lids.

However, with continuous data telemetry via cell modem, most interrogation of the system is accomplished remotely.

The SMA stations are three-component units consisting of vertical, north-south horizontal, and east-west horizontal seismometers manufactured by Kinemetrics, Inc., Pasadena, California, and known as the Etna system. Each Etna unit contains a digital recorder, a data storage unit, and a Global Positioning System (GPS) receiver with the equipment housed in a watertight box.

The cell modem system provides the Internet address connection to access the system. Stations can be monitored from any computer with appropriate access, and data are continuously telemetered to UW. The data also can be downloaded directly at each site, via a built-in cable connection at the enclosure in case of communication failure. The GPS receiver provides timing of the ground motions accurate to several microseconds, coordinated to Universal Coordinated Time (UTC). The GPS receiver antenna is mounted on the enclosure at the rear of the solar array. The GPS receiver is activated internally approximately every 4 hours and checks the "location of the instrument" and the time. The SMA records any differences between the internal clock and the GPS time. Any corrections to the internal timing are made automatically. Typically, the greatest correction recorded is approximately 4 milliseconds (ms).

The combined operations, data recording, data interpretation, and maintenance facility is located in the PNSN offices at the UW in Seattle.

3.2.3 Strong Motion Operational Characteristics

Signals from the three-accelerometer channels use an 18-bit digitizer with data sampled at 200 samples/s. Data are sent continuously in real-time to the PNSN offices at the UW in Seattle. This permits the recording of ground motion data for smaller, non-damaging earthquakes that can be useful in estimating impacts of larger earthquakes. It also helps confirm the correct operation of the instruments.

For security and robustness, the Etna also stores triggered event files. When one of the accelerometer channels exceeds the trigger threshold (0.02%g), the recorders save information within the data buffers on memory cards within the Etna. Data recording begins 10 s before the actual trigger time, continues until the trigger threshold is no longer exceeded, and ends with an additional 40 s of data. The files created by a triggered event can be retrieved and examined by HLSMP staff, in the event of telemetry failure. The retrieval can be accomplished either remotely when telemetry is re-established, or manually by a technician traveling to the site.

3.3 Data Analysis

Signals from the seismometers are monitored in real time for changes in signal amplitudes and frequency that are expected from earthquakes. The seismic network is subdivided into spatial groupings of stations that are monitored for nearly simultaneous amplitude changes, triggering a permanent recording of the events. The groupings and associated weighting schemes are designed to allow very small seismic events to be recorded and to minimize false triggers. Events are classified as local (south-central Washington near the Hanford Site), regional (western United States and Canada), and teleseisms (from farther distances around the world). Local and regional events are usually earthquakes, but quarry and mining explosions also are recorded. Quarry and mining explosions usually can be identified from wave characteristics and the time of occurrence and may be confirmed with local government agencies and industries. Frequently, military exercises at the U.S. Army Yakima Training Center produce a series of acoustic shocks that trigger the recording system. Sonic booms and thunder also produce acoustic signals that may trigger the recording system. All data, whether triggered or not, is saved in a permanent seismic data archive at the Seattle-based IRIS data management center, and is available for download and analysis.

The HLSMP uses Earthworm, an automated computer-based software system developed by the U.S. Geological Survey (USGS) and used throughout the region by the Pacific Northwest Seismic Network at the UW, to acquire seismic data and automatically detect and locate events. We currently run Earthworm Versions 7.4 through 7.6 on a variety of computer servers. Redundant Earthworm systems run continuously at the PNSN. If one fails, a second one serves as a "backup." Two complete systems are located in different buildings on separate computer servers with redundant power supplies, backed up by different uninterruptable power supplies and a diesel-powered electric generator capable of powering the network until refueling is needed. Seismic data from triggered events are collected on a SUN workstation (Sun Microsystems, Santa Clara, California) for assessment by HLSMP staff. This information is evaluated to determine if the event is "false" (for example, due to a sonic boom) or is an earthquake or ground-surface or underground blast. Earthquake events are evaluated to determine epicenter locations, focal depths, and magnitudes (Section 4).

Data from HLSMP-operated seismic stations are combined at the UW analysis center with seismic data from regional seismic stations operated by other entities and contributed in real-time to PNSN. The earthquake locations and ground motion we report in this catalog include these valuable contributed data. This contributed data improves the accuracy of the seismic products we provide at Hanford, and adds to the robustness of the entire network in the event that any particular portion of the network suffers temporary data loss from environmental or other causes.

3.4 Station Maintenance Activities in Fourth Quarter of FY 2014

Earlier quarterly reports for FY2013 discuss station maintenance activities, so this section will just refer to the fourth quarter.

Seismic station maintenance that took place during the fourth quarter of FY2014 included:

- Repair of station SNI due to elk damage
- Replaced a failed modem at station H4A
- Sited a new location for the work shop and equipment storage space and moved all equipment to a new warehouse

4.0 Earthquake Catalog

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.

4.1 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" (MOD), 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.

Table 4.1. Velocity Model for Eastern Washington
(from Rohay et al. 1985)

Depth to Top of Layer (km)	Layer	Velocity (km/s)
0.0	Saddle Mountains and Wanapum Basalts and intercalated Ellensburg Formation	3.7
0.4	Grande Ronde Basalt and pre-basalt sediments	5.2
8.5	Basement, Layer 1	6.1
13.0	Basement, layer 2	6.4
23.0	Sub-basement	7.1
38.0	Mantle	7.9

4.2 Earthquake Magnitudes

AQMS computes several different magnitude estimates (Mtyp) 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 (in seconds), starting from the P-wave arrival. Many earthquakes yield magnitude determinations that are very small ($M_d < 0$) and highly uncertain. Earthquakes with magnitudes (M_d) smaller than 3.0 are defined 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.

4.3 Quality Factors

Table 4.1 tabulates a two-letter **Quality factor** (Q) 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. If the number of phases exceeds 10 measurements, the depth estimate is considered 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.

4.4 FY 2014 Earthquake Catalog for Eastern Washington

Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
October 2013												
02	17:45:27	46.5338	-120.7532	0.0*	0.7	Md	008/007	140	0.31	CC	C3	px
02	19:32:04	46.9660	-119.0902	0.0*	1.2	Md	009/007	115	0.12	CB	E3	px
02	20:27:05	44.5510	-117.4118	0.0*	2.4	Md	006/008	200	0.35	CD	E3	px
06	18:04:55	46.4998	-119.6863	0.5*	0.1	Md	007/012	157	0.06	CC	E3	le
09	19:03:15	45.8998	-119.3022	0.0*	1.6	Md	011/011	177	0.30	CC	E3	px
10	13:19:28	46.6025	-119.8542	7.3	0.7	Md	009/013	174	0.05	AC	E3	le
11	05:04:12	46.3660	-119.9995	8.5*	0.8	Md	012/016	191	0.06	CD	E3	le
13	10:02:11	47.6768	-120.2262	0.6*	1.1	Md	010/011	133	0.05	CC	N3	le
13	14:23:46	47.7002	-120.0247	5.3	2.1	Md	024/013	107	0.09	AB	N3	le
15	18:04:28	46.5742	-119.6823	8.1	-0.2	Md	006/009	114	0.03	AB	E3	le
17	09:14:27	47.4205	-119.8592	12.1	0.9	Md	006/009	191	0.15	BD	N3	le
19	07:10:29	46.9252	-119.5733	13.9	0.8	Md	015/022	147	0.10	AC	E3	le
19	07:17:29	46.4498	-119.5930	14.4	0.3	Md	008/010	112	0.05	AB	E3	le
22	00:39:29	46.4725	-118.0542	0.0*	1.9	Md	019/019	177	0.18	CD	E3	px
22	04:37:43	47.6860	-120.3458	6.3	0.8	Md	007/010	122	0.07	AB	N3	le
22	04:39:16	47.6947	-120.3412	3.2	0.6	Md	007/010	119	0.06	BB	N3	le
22	12:39:23	46.5462	-121.4103	5.3	0.8	Md	023/025	115	0.16	BC	C3	le
23	01:30:45	47.6612	-120.3823	1.3	1.6	Md	008/010	95	0.08	CB	N3	le
23	01:50:00	45.7630	-120.0830	0.0*	1.7	Md	010/011	129	0.10	CC	E3	px
23	09:42:22	46.6075	-119.8572	7.5	-0.2	Md	004/005	267	0.01	AD	E3	le
23	18:31:29	47.7783	-120.1382	4.8	0.4	Md	007/011	96	0.11	AB	N3	le
25	00:23:07	47.6073	-120.2385	4.2	0.3	Md	004/006	204	0.05	BD	N3	le
29	06:35:59	46.8693	-119.3912	11.3	0.5	Md	007/010	100	0.17	BB	E3	le
29	11:24:40	47.8067	-120.7442	9.3	3.3	Ml	040/024	79	0.14	AB	C3	le
29	11:33:26	47.8290	-120.7455	7.5	1.4	Md	004/006	172	0.10	BC	C3	le
29	13:31:51	47.8365	-120.7383	1.4*	0.3	Md	004/006	164	0.09	CC	C3	le
29	17:43:50	47.8013	-120.7597	10.0	0.9	Md	006/008	180	0.05	AC	C3	le
31	16:38:37	47.1337	-119.4547	14.5	1.5	Md	017/021	103	0.18	BB	N3	le
November 2013												
02	14:08:29	47.6138	-120.2687	7.0	1.0	Md	007/007	150	0.05	AC	N3	le
05	22:06:27	44.6973	-117.4637	5.3	2.7	Ml	008/012	174	0.60	DC	N3	le
06	10:31:37	46.1777	-119.6502	6.8	0.5	Md	006/008	274	0.08	AD	E3	le
06	16:35:31	46.1862	-119.6405	6.3	0.9	Md	009/011	259	0.06	AD	E3	le
06	19:12:13	46.3982	-118.0200	0.0*	1.9	Md	015/020	192	0.25	CD	E3	px
06	22:12:11	46.1608	-119.6565	7.6	0.9	Md	007/011	291	0.10	AD	E3	le
07	23:14:24	46.4547	-118.0812	0.0*	2.1	Md	020/025	165	0.21	CD	E3	px
08	13:59:35	48.0952	-120.9042	4.1	1.7	Md	005/007	174	0.18	BC	C3	le
10	14:00:56	48.0967	-120.8950	5.0*	1.1	Md	004/004	175	0.01	CD	C3	le
12	07:45:21	45.8945	-120.5603	14.8	1.5	Md	013/017	164	0.22	BC	E3	le
12	13:10:45	45.8547	-120.1978	15.8	1.1	Md	010/011	122	0.07	AB	E3	le
12	14:01:05	47.6973	-120.2250	0.8*	0.3	Md	005/008	130	0.06	CC	N3	le
14	00:44:00	45.5450	-119.9412	0.0*	2.0	Md	026/026	109	0.30	CC	E3	px
14	19:15:43	44.1007	-121.3427	0.0*	2.0	Ml	011/014	85	0.24	CA	E3	px
15	23:04:52	47.6378	-120.2240	0.0*	1.2	Md	005/006	148	0.15	CC	N3	px
17	14:47:31	46.4115	-119.2708	0.0	3.2	Ml	047/039	88	0.10	AA	E3	le
17	15:07:17	46.4108	-119.2707	0.0	1.0	Md	012/015	125	0.07	AB	E3	le
17	15:50:31	46.4240	-119.2812	0.0	0.1	Md	006/010	155	0.10	AC	E3	le
17	18:59:41	47.6657	-120.1692	7.7	0.0	Md	004/007	165	0.03	AC	N3	le
18	15:12:42	46.4117	-119.2752	0.5*	1.2	Md	008/008	164	0.04	CC	E3	le
19	04:28:31	47.8612	-120.9642	1.0*	1.4	Md	008/008	103	0.14	CB	C3	le
19	05:20:01	46.5738	-119.8338	8.4	0.8	Md	009/013	128	0.08	AB	E3	le
19	22:46:37	46.4137	-119.2722	0.0	1.2	Md	014/019	123	0.12	AB	E3	le
19	22:58:28	46.4202	-119.2773	0.0	0.5	Md	007/011	159	0.10	AC	E3	le
21	01:02:01	46.5597	-119.5823	17.2	0.2	Md	007/010	103	0.08	AB	E3	le

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Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
22	00:19:03	44.0960	-121.3358	0.0*	1.1	Md	009/008	136	0.27	CC	E3	px
22	19:27:13	46.4153	-119.2712	0.4*	0.8	Md	009/013	163	0.22	CC	E3	le
23	00:25:52	46.4440	-118.0648	0.3	2.1	Ml	029/025	133	0.26	BB	E3	le
23	03:23:58	47.7095	-120.2782	4.5	2.1	Ml	018/015	102	0.07	AC	N3	le
24	10:51:37	46.6008	-119.8590	7.1	1.1	Md	019/021	90	0.06	AA	E3	le
24	21:00:34	45.7013	-120.1682	0.0	1.6	Ml	007/008	112	0.26	BC	E3	le
24	23:04:52	46.4442	-119.9600	0.0*	0.2	Md	003/004	327	0.02	CD	E3	px
24	23:39:35	46.6958	-119.5737	8.2	0.1	Md	006/006	137	0.02	AC	E3	le
25	06:05:56	46.7308	-120.0740	14.9*	0.5	Md	005/005	280	0.31	DD	E3	le
26	05:17:38	46.4098	-119.2710	0.0	0.3	Md	007/012	126	0.16	BB	E3	le
26	22:54:38	45.4168	-120.0905	0.0*	1.6	Md	007/011	265	0.30	CD	E3	px
27	14:24:15	47.6382	-120.1767	3.4	0.4	Md	005/008	186	0.04	BD	N3	le
27	19:57:40	46.4567	-119.4238	0.6*	0.3	Md	008/009	182	0.51	DD	E3	le
28	05:33:13	46.5225	-119.7442	0.8*	-0.8	Md	004/005	194	0.07	CD	E3	le
28	16:16:42	46.4523	-119.2425	0.4*	0.7	Md	006/010	175	0.32	CC	E3	le
28	22:32:50	46.6598	-120.7455	12.3	0.8	Md	013/016	78	0.19	BA	C3	le
29	02:23:52	47.7002	-121.4900	12.7	0.8	Md	006/010	158	0.12	AC	C3	le
29	16:44:10	46.6430	-119.8527	0.8*	-0.4	Md	004/006	293	0.09	CD	E3	le
29	19:06:05	47.8523	-120.7440	1.5*	1.2	Md	003/005	222	0.08	CD	C3	le
30	01:08:51	46.6143	-119.8247	5.8	0.2	Md	007/009	210	0.19	BD	E3	le
December 2013												
02	22:41:29	46.6412	-119.8473	3.1	-0.2	Md	004/008	291	0.14	AD	E3	le
02	22:57:13	46.5997	-119.7887	6.9*	-0.3	Md	002/004	184	0.22	DD	E3	le
03	22:10:35	46.6513	-119.8562	0.7*	0.1	Md	003/005	301	0.14	CD	E3	le
04	05:05:02	47.6885	-120.0995	6.0	0.7	Md	006/010	155	0.11	AC	N3	le
04	23:04:49	46.1787	-120.4932	12.0	1.7	Md	018/019	124	0.23	BB	E3	le
04	23:57:16	46.1745	-120.4710	10.8	2.0	Md	027/032	48	0.37	CB	E3	le
05	00:02:35	44.0177	-121.2290	0.0*	2.0	Ml	020/018	96	0.22	CB	E3	px
05	02:25:28	46.1620	-120.4943	11.3	0.7	Md	005/008	201	0.16	BD	E3	le
05	15:14:22	47.8043	-120.7333	9.7	0.9	Md	006/009	135	0.18	BB	C3	le
05	15:30:58	47.6637	-120.1705	11.4	0.3	Md	004/007	149	0.18	CC	N3	le
07	21:44:19	46.8558	-120.5045	0.0*	0.7	Md	006/010	164	0.32	CC	E3	px
08	07:38:30	46.5745	-119.8307	8.4	0.7	Md	009/013	90	0.06	AA	E3	le
08	08:56:00	46.5777	-119.8347	9.0	-0.1	Md	005/008	197	0.07	AD	E3	le
10	02:05:17	48.5885	-119.6540	1.2*	1.9	Md	008/009	139	0.15	CC	N3	le
10	22:24:57	47.7003	-120.3007	7.6*	0.2	Md	003/005	225	0.07	DD	N3	le
11	22:39:26	46.6100	-118.9352	0.0*	1.8	Md	017/016	210	0.14	CD	E3	px
12	20:38:40	47.3660	-117.9142	0.0*	2.2	Md	009/013	264	0.28	CD	N3	px
12	23:18:16	46.6225	-119.8858	4.8*	-0.3	Md	002/004	295	0.10	DD	E3	le
13	14:38:06	47.7408	-120.1775	3.8	0.6	Md	006/010	124	0.06	AC	N3	le
13	21:21:42	46.7427	-120.9348	7.1	1.0	Md	008/010	124	0.11	AB	C3	le
18	01:23:34	47.7735	-120.1392	6.3	1.0	Md	010/014	94	0.07	AB	N3	le
19	03:17:39	46.4558	-119.5763	14.9	0.8	Md	015/020	74	0.07	AA	E3	le
20	06:56:57	46.0653	-120.4745	13.5	1.6	Md	023/028	76	0.19	BB	E3	le
20	11:13:35	46.5042	-119.9130	9.8	0.1	Md	003/004	335	0.01	CD	E3	le
20	16:37:11	46.6080	-119.8480	6.7	-0.4	Md	005/007	168	0.04	AC	E3	le
20	21:05:09	47.1537	-121.3128	1.4	1.1	Md	014/017	97	0.36	CC	C3	le
20	22:14:00	47.3682	-117.8738	0.0*	1.8	Md	012/021	164	0.51	DD	N3	px
21	00:01:39	46.0655	-120.4747	13.3	2.2	Md	028/034	60	0.19	BB	E3	le
21	03:11:05	46.4098	-119.2648	0.0	1.1	Md	015/020	131	0.17	BB	E3	le
21	07:27:48	46.6027	-119.8573	7.2	-0.2	Md	004/007	264	0.02	AD	E3	le
21	10:34:23	46.4208	-119.2590	0.4*	0.1	Md	005/008	264	0.07	CD	E3	le
21	17:08:52	46.4148	-119.2783	0.0	0.2	Md	007/011	161	0.19	BC	E3	le
23	00:25:41	46.6755	-119.9295	0.6*	0.1	Md	004/004	311	0.04	CD	E3	le
23	02:56:11	45.3602	-118.2060	8.7*	3.0	Md	023/025	147	0.31	CD	E3	le

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Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
24	14:08:01	46.6120	-119.8425	7.1	0.4	Md	009/012	162	0.08	AC	E3	le
24	14:08:12	46.6292	-119.8742	9.2	-0.3	Md	003/005	287	0.05	BD	E3	le
24	14:08:21	46.6108	-119.8345	6.5	-0.4	Md	004/006	252	0.05	BD	E3	le
26	08:23:01	47.8408	-119.9813	10.9	0.7	Md	008/009	90	0.08	AA	N3	le
26	14:23:07	48.3135	-119.0603	1.1*	2.2	Md	012/015	110	0.11	CC	N3	le
26	16:14:17	47.7250	-120.0160	6.2	0.9	Md	006/009	186	0.07	AD	N3	le
28	06:44:06	46.4070	-119.2548	0.0	1.0	Md	009/010	143	0.08	AC	E3	le
28	10:11:59	46.4102	-119.2507	0.4*	0.1	Md	007/008	172	0.10	CC	E3	le
29	22:29:17	46.5992	-119.8703	6.9	0.2	Md	006/009	248	0.13	BD	E3	le
29	22:29:40	46.6007	-119.8585	6.1	-0.4	Md	003/005	263	0.08	BD	E3	le
29	22:29:55	46.6035	-119.8672	7.1	-0.1	Md	004/008	273	0.05	AD	E3	le
29	22:31:08	46.5980	-119.8555	7.6	-0.3	Md	004/006	257	0.09	BD	E3	le
30	15:00:02	48.6043	-119.8108	7.2	3.2	Ml	020/020	117	0.16	BC	N3	le
31	14:09:36	46.4137	-119.7057	6.9	0.8	Md	006/007	253	0.21	BD	E3	le
31	21:46:27	44.3872	-121.0393	0.0*	1.6	Md	010/011	150	0.27	CC	E3	px
January 2014												
02	12:25:22	46.7000	-121.0637	4.7	1.1	Md	018/019	145	0.21	BC	C3	le
02	21:53:04	44.0947	-121.3442	0.0*	1.0	Md	012/013	84	0.26	CA	C3	px
03	13:49:46	46.6108	-119.8308	6.3	1.0	Md	015/019	85	0.35	CA	E3	le
04	06:41:23	47.6743	-120.3905	0.8*	0.8	Md	008/012	94	0.12	CB	N3	le
05	17:03:18	47.6930	-120.3413	2.3	0.3	Md	005/008	123	0.08	CB	N3	le
06	05:37:35	48.0262	-121.1202	6.3	1.3	Md	004/007	146	0.30	DC	C3	le
07	18:59:25	46.9427	-117.3182	3.5	2.2	Md	009/013	171	0.31	CD	E3	le
07	22:40:04	46.6508	-120.5628	6.3	0.7	Md	009/012	98	0.25	BC	E3	le
07	23:44:14	48.4947	-118.6633	0.0	1.8	Ml	011/017	203	0.54	DD	N3	le
10	22:40:06	46.6245	-119.8112	2.8	1.0	Md	010/012	95	0.20	BB	E3	le
13	02:54:51	47.7113	-120.1217	8.3	1.2	Md	006/008	138	0.11	AC	N3	le
14	15:35:26	46.7703	-120.7667	23.4	0.6	Md	003/005	176	0.10	BD	C3	le
16	09:49:29	46.3325	-120.8737	1.8	1.1	Md	015/017	76	0.36	CC	C3	le
21	20:54:47	47.7190	-120.0678	4.0	1.8	Md	006/009	117	0.06	AB	N3	le
21	21:58:26	46.6942	-119.7457	18.3	0.3	Md	006/010	233	0.42	CD	E3	le
22	04:12:51	47.7253	-120.0702	2.2	2.2	Ml	016/013	79	0.09	BB	N3	le
22	05:46:34	46.8562	-120.7180	10.2	0.8	Md	015/014	88	0.08	AB	C3	le
22	15:54:09	47.6522	-120.0818	5.2	1.0	Md	005/008	165	0.06	AC	N3	le
25	23:33:34	46.5860	-121.4340	8.9	0.8	Md	011/010	126	0.11	AB	C3	le
26	03:24:40	46.6062	-119.8513	6.3	0.9	Md	010/012	126	0.08	AB	E3	le
27	16:41:22	46.1922	-119.5598	21.9	1.0	Md	009/013	293	0.07	AD	E3	le
27	22:45:09	44.6502	-121.0418	0.0*	1.7	Md	008/007	154	0.06	CC	E3	px
28	21:50:46	47.3547	-117.9542	0.0*	2.5	Md	009/013	293	0.19	CD	N3	px
31	06:42:00	46.1202	-119.4255	5.0*	0.7	Md	004/005	321	0.13	CD	E3	le
31	19:40:38	47.7803	-118.7443	0.0*	1.5	Md	011/010	99	0.10	CC	N3	px
February 2014												
01	23:49:29	46.1223	-119.4533	9.9	1.5	Md	015/016	193	0.08	AD	E3	le
02	02:44:08	46.1218	-119.4512	8.0	0.6	Md	007/007	280	0.07	BD	E3	le
02	03:59:32	46.1045	-119.4345	8.7	1.5	Md	013/016	145	0.12	BC	E3	le
02	04:09:07	46.1405	-119.4485	7.3	0.6	Md	005/007	291	0.06	AD	E3	le
03	19:26:52	47.7675	-120.0120	4.8*	0.4	Md	002/004	181	0.02	DD	N3	le
04	21:22:09	46.3120	-117.9793	0.0*	2.1	Md	018/020	299	0.21	CD	E3	px
05	10:47:29	46.8637	-119.5647	13.8	0.4	Md	010/012	134	0.03	AB	E3	le
05	18:45:01	47.7988	-118.7205	0.0*	1.8	Md	008/008	101	0.31	CC	N3	px
05	19:34:54	44.0158	-121.2577	0.0*	1.5	Md	019/018	92	0.30	CB	N3	px
06	00:09:35	47.6850	-120.1268	4.7	0.2	Md	005/008	138	0.09	BC	N3	le
06	02:34:44	47.1925	-120.9183	0.0*	1.5	Md	008/011	162	0.12	CC	C3	px
08	23:29:10	46.5745	-119.8358	8.6	1.9	Md	025/024	82	0.08	AA	E3	le
08	23:34:58	46.5765	-119.8403	9.4	-0.3	Md	005/007	205	0.04	AD	E3	le

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Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
08	23:55:32	46.7888	-121.0318	6.0	1.1	Md	016/017	122	0.14	AC	C3	le
09	10:09:35	48.1575	-120.8660	5.4	1.7	Md	009/011	140	0.12	AC	C3	le
10	02:28:48	47.6973	-120.3202	2.1	0.7	Md	006/008	149	0.06	CC	N3	le
11	14:42:51	48.0463	-120.8188	10.1*	1.1	Md	005/005	156	0.09	CD	C3	le
11	20:47:36	47.7795	-119.0247	0.0*	1.8	Md	009/010	106	0.20	CC	N3	px
15	14:36:03	46.4138	-119.2667	0.0	1.0	Md	013/017	144	0.10	AC	E3	le
15	17:24:55	46.1128	-120.5053	19.1	1.5	Md	015/020	122	0.21	BB	E3	le
17	05:49:18	46.9238	-119.4963	20.6	1.5	Md	019/023	91	0.08	AB	E3	le
18	22:28:01	46.1408	-119.1875	0.0*	2.2	Md	013/016	162	0.20	CC	E3	px
19	08:09:05	46.6025	-119.8680	6.9	0.7	Md	007/010	273	0.08	AD	E3	le
20	06:39:23	46.4425	-119.2807	0.0	0.5	Md	004/005	187	0.07	AD	E3	le
20	07:14:20	46.4118	-119.2755	0.5*	0.4	Md	005/006	164	0.11	CC	E3	le
20	19:41:52	46.4288	-119.2713	0.0	0.9	Md	008/011	156	0.10	AC	E3	le
20	22:06:55	44.3473	-121.0395	0.0*	2.4	Ml	007/011	124	0.84	DC	E3	px
21	01:03:43	46.4378	-118.1252	0.0*	2.1	Md	017/021	212	0.44	CD	E3	px
21	21:19:48	46.8045	-119.2242	17.2	2.5	Ml	042/039	71	0.11	AA	E3	le
22	12:20:54	46.4095	-119.2568	1.9	1.9	Md	026/025	91	0.07	AB	E3	le
22	12:25:30	46.4108	-119.2587	0.4*	0.9	Md	012/015	137	0.06	CC	E3	le
23	15:59:20	46.5158	-119.6160	16.5	0.2	Md	011/014	80	0.05	AA	E3	le
23	19:23:11	46.4303	-119.2848	0.0	0.2	Md	005/007	151	0.06	AC	E3	le
24	12:13:07	46.5837	-119.8475	8.0	0.6	Md	008/010	128	0.05	AB	E3	le
24	20:49:10	47.1960	-118.9895	0.0*	1.7	Md	012/014	154	0.30	CC	N3	px
25	20:34:55	46.0557	-118.9132	0.0*	2.0	Md	018/025	116	0.44	CC	E3	px
27	01:45:58	48.6917	-119.5420	0.3	1.8	Md	010/012	160	0.22	BC	N3	le
27	08:27:26	46.4095	-119.2502	0.5*	0.5	Md	007/009	172	0.10	CC	E3	le
28	19:04:35	46.4865	-119.4660	17.4	0.5	Md	013/016	59	0.21	BA	E3	le
28	20:36:01	46.0963	-119.4720	0.0*	0.9	Md	006/008	232	0.39	CD	E3	px
March 2014												
02	01:33:54	46.4303	-119.2703	0.4*	0.4	Md	007/009	155	0.13	CC	E3	le
02	05:48:35	47.6565	-120.2837	4.1	1.6	Md	012/017	90	0.12	AB	N3	le
02	09:29:48	46.6012	-119.8625	7.1	0.1	Md	005/007	268	0.03	AD	E3	le
02	14:04:05	46.6802	-119.2135	17.1	0.7	Md	014/019	113	0.18	BB	E3	le
03	09:58:19	46.4112	-119.2522	2.7	0.5	Md	008/013	171	0.09	AC	E3	le
03	14:21:15	47.7330	-120.1482	4.2	1.7	Md	011/013	114	0.04	AC	N3	le
04	00:40:02	48.3332	-121.3432	7.0	2.2	Ml	016/021	133	0.18	BC	C3	le
04	17:17:45	47.6790	-120.3872	4.3	0.4	Md	006/009	106	0.09	AB	N3	le
04	19:11:18	46.4262	-119.2665	0.6	0.8	Md	008/010	158	0.15	BC	E3	le
04	19:36:03	47.6922	-120.3308	5.5	0.8	Md	005/007	211	0.05	AD	N3	le
05	12:24:19	47.9350	-119.0918	2.5*	1.0	Md	006/007	192	0.16	CD	N3	le
05	14:29:33	48.0125	-119.8875	0.7*	1.8	Md	012/010	125	0.06	CB	N3	le
10	06:37:38	46.4057	-119.2618	0.0	1.0	Md	016/020	137	0.11	AC	E3	le
12	09:05:48	47.7413	-120.0353	4.0	1.3	Md	006/009	187	0.04	AD	N3	le
12	20:27:48	47.0885	-118.8418	0.0*	1.7	Md	015/016	183	0.28	CD	N3	px
14	03:37:33	46.4580	-119.5763	12.3	0.1	Md	007/009	91	0.04	AB	E3	le
14	08:29:33	48.5115	-119.9290	0.3	2.2	Md	015/019	116	0.33	CC	N3	le
16	07:06:25	46.4937	-119.4328	20.9	1.0	Md	020/023	54	0.12	AA	E3	le
16	11:48:01	46.7145	-120.7672	9.2	1.1	Md	021/023	97	0.11	AB	C3	le
17	06:44:40	46.4177	-119.2798	0.4*	0.9	Md	007/009	159	0.19	CC	E3	le
19	16:26:18	45.7455	-120.0190	0.0*	2.3	Md	008/007	172	0.34	CC	E3	px
20	07:31:45	47.7397	-120.2575	3.5	0.7	Md	007/011	141	0.07	BC	N3	le
20	18:00:01	46.9463	-121.1323	2.5	1.5	Md	025/028	71	0.15	BC	C3	le
20	23:44:52	44.3733	-121.0008	0.0*	1.5	Md	008/012	122	0.40	CB	C3	px
22	16:26:24	48.3200	-119.0555	2.0	2.3	Md	014/016	111	0.16	BC	N3	le
24	14:16:24	46.6263	-120.2632	9.5	1.7	Md	015/016	81	0.37	CA	E3	le
25	16:29:21	45.6262	-121.0242	0.0*	1.1	Md	004/004	275	0.02	CD	C3	px

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Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
25	23:36:28	46.6210	-118.9425	0.0*	1.9	Md	018/020	171	0.35	CC	E3	px
26	19:08:45	45.9002	-117.0130	0.0*	2.8	Md	005/009	223	8.46	DD	E3	px
30	14:35:53	47.7255	-120.1938	5.4	0.8	Md	006/008	126	0.06	AC	N3	le
31	08:48:10	48.3687	-119.5862	1.6*	1.7	Md	008/009	119	0.05	CC	N3	le
31	21:24:50	45.8877	-119.6322	0.0*	1.7	Md	013/017	184	0.31	CD	E3	px
April 2014												
03	06:35:14	47.6697	-120.2965	0.0	1.8	Md	012/015	144	0.15	BC	N3	le
04	18:31:28	46.4225	-119.2753	0.0	1.0	Md	013/017	117	0.29	BB	E3	le
04	18:39:31	45.6015	-121.2377	0.0*	0.8	Md	006/007	132	0.34	CC	C3	px
04	19:39:57	47.7738	-118.7303	0.0*	1.8	Md	011/012	118	0.44	CC	N3	px
05	00:44:02	47.5048	-120.3010	0.0*	1.8	Md	013/012	93	0.23	CC	N3	px
05	11:26:43	46.6037	-119.8530	7.0	1.0	Md	015/018	89	0.08	AA	E3	le
05	11:36:59	46.6018	-119.8500	6.7	0.6	Md	012/014	133	0.07	AB	E3	le
07	09:30:41	46.4162	-119.2715	0.0	0.6	Md	010/013	163	0.13	AC	E3	le
07	10:46:13	46.4107	-119.2677	0.0	-0.0	Md	007/008	167	0.08	AC	E3	le
07	19:08:14	46.0635	-119.3385	0.0*	0.9	Md	010/013	155	0.23	CC	E3	px
07	20:56:12	45.9862	-119.3092	0.0*	1.6	Md	011/011	178	0.29	CC	E3	px
07	21:55:25	46.1223	-119.0255	0.0*	2.7	Ml	030/037	107	0.18	CB	E3	px
08	02:34:16	46.4120	-119.2715	0.0	0.5	Md	007/010	165	0.19	BC	E3	le
08	09:46:51	46.4312	-119.2822	2.5	0.1	Md	007/009	167	0.13	BC	E3	le
08	21:06:26	46.8168	-120.9690	0.0*	1.9	Md	007/011	279	4.40	DD	C3	px
10	07:06:03	48.5972	-121.3578	0.7	1.7	Md	007/009	201	0.43	CD	C3	le
10	22:47:27	47.7230	-120.2523	4.8	0.9	Md	007/008	139	0.03	AC	N3	le
11	19:52:03	44.0238	-121.2555	0.0*	2.1	Ml	013/012	145	0.15	CC	N3	px
14	06:02:37	47.6917	-120.2910	4.1	0.2	Md	005/008	156	0.02	BC	N3	le
17	06:14:26	47.7710	-120.1430	5.8	0.4	Md	005/008	119	0.06	AB	N3	le
18	21:04:45	44.0218	-121.2465	0.0*	2.8	Md	009/009	187	0.15	CD	N3	px
20	05:42:48	46.5847	-119.8260	8.9	-0.3	Md	004/006	199	0.04	BD	E3	le
20	19:09:32	46.6025	-119.8417	7.5	0.1	Md	007/009	161	0.03	AC	E3	le
21	22:34:58	46.6430	-120.4902	0.0*	2.4	Md	010/010	101	0.19	CC	E3	px
21	22:53:19	46.4463	-119.2747	1.6	0.6	Md	007/010	313	0.02	AD	E3	le
21	22:53:30	46.4505	-119.2767	0.4*	0.3	Md	005/008	310	0.04	CD	E3	le
22	00:39:38	46.4113	-119.2752	0.4*	0.9	Md	008/010	164	0.05	CC	E3	le
22	03:57:11	46.5848	-119.8287	8.7	-0.2	Md	005/008	203	0.04	AD	E3	le
22	03:57:45	46.5988	-119.8520	9.1	-0.2	Md	004/006	254	0.12	BD	E3	le
22	08:12:39	46.4485	-119.2773	0.8	0.4	Md	004/007	320	0.06	BD	E3	le
22	09:42:52	46.4237	-119.0222	0.0*	0.9	Md	007/006	245	0.05	CD	E3	px
23	02:50:33	47.7348	-120.1982	3.7	0.4	Md	003/006	200	0.01	BD	N3	le
23	08:14:21	48.4797	-120.5412	10.1*	1.9	Md	009/013	98	0.25	CD	C3	le
24	00:25:38	45.8310	-118.3435	0.0*	1.8	Md	009/011	140	0.24	CC	E3	px
24	16:09:36	46.6270	-118.8955	0.0*	2.2	Md	024/023	200	0.08	CD	E3	px
25	21:11:09	46.6065	-119.8680	6.6	-0.3	Md	003/005	275	0.01	BD	E3	le
28	18:10:38	47.6702	-120.1233	2.2	1.8	Md	009/014	91	0.20	CC	N3	le
28	22:36:45	46.3068	-120.0973	0.0*	0.8	Md	018/017	85	0.19	CC	E3	px
30	10:49:48	46.5537	-119.8560	5.6	0.9	Md	012/017	122	0.23	BB	E3	le
30	18:01:52	46.5057	-117.7863	0.0*	2.1	Md	013/013	178	0.21	CC	E3	px
May 2014												
01	23:16:35	46.4348	-119.0058	0.0*	1.6	Md	017/018	228	0.13	CD	E3	px
02	19:20:03	46.5057	-120.5870	16.6	0.3	Md	007/010	190	0.34	CD	E3	le
02	23:49:02	46.4437	-118.0568	0.0*	1.9	Md	018/020	153	0.30	CC	E3	px
04	00:03:43	46.6108	-119.8480	6.7	0.1	Md	008/012	209	0.11	AD	E3	le
04	21:59:02	47.6925	-120.2318	0.6*	1.8	Md	011/008	127	0.05	CC	N3	le
05	16:36:49	47.6912	-120.1660	7.1	0.9	Md	007/010	131	0.11	AC	N3	le
06	22:49:45	47.4227	-120.1962	0.0*	1.8	Md	011/012	105	0.25	CC	N3	px
07	13:38:45	47.5875	-120.2542	6.6	1.6	Md	007/009	117	0.07	AB	N3	le

4.4 FY 2014 Earthquake Catalog for Eastern Washington

Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
07	15:25:44	46.1302	-119.0230	0.0*	2.0	Md	030/032	109	0.15	CB	E3	px
08	01:52:15	47.6743	-120.1225	7.7	0.8	Md	005/008	167	0.08	AC	N3	le
08	23:28:44	46.5985	-119.8530	7.5	0.2	Md	005/007	173	0.05	AC	E3	le
09	19:13:05	46.8345	-119.6967	1.8	1.7	Md	017/019	107	0.16	BC	E3	px
11	00:29:10	46.0880	-118.6008	6.0	1.4	Md	007/011	128	0.33	CC	E3	le
11	18:13:55	47.7422	-120.0910	6.0	0.7	Md	006/010	115	0.06	AB	N3	le
13	06:35:33	46.6100	-119.8427	6.6	0.1	Md	007/009	163	0.06	AC	E3	le
14	21:18:41	46.6465	-120.4925	0.0*	1.7	Md	009/009	98	0.38	CC	E3	px
15	07:04:40	47.7127	-120.3143	8.0	1.0	Md	009/012	99	0.08	AB	N3	le
15	09:03:58	47.6435	-120.2073	6.0	0.6	Md	007/009	122	0.12	AB	N3	le
15	21:33:48	46.5268	-121.4340	5.3	0.8	Md	010/013	260	0.07	AD	C3	le
16	01:14:48	48.4627	-120.0227	10.8	2.1	Md	010/014	131	0.15	BC	N3	le
16	10:32:06	46.6270	-119.8260	8.6	-0.1	Md	004/007	260	0.04	BD	E3	le
21	22:42:34	46.5722	-117.9012	0.0*	1.8	Md	007/009	283	0.20	CD	E3	px
22	15:42:08	47.6625	-120.3160	0.7*	1.8	Md	012/014	106	0.07	CB	N3	le
22	19:51:39	47.5777	-121.3765	9.4	1.4	Md	018/027	69	0.26	BC	C3	le
22	23:22:57	46.2487	-118.5003	8.4	1.6	Md	014/018	116	0.42	CC	E3	le
24	05:05:03	47.7470	-120.1767	7.1	0.6	Md	005/009	125	0.12	AB	N3	le
27	18:16:22	47.6653	-120.3112	0.7*	1.4	Md	007/009	112	0.08	CB	N3	le
28	07:12:41	46.7612	-119.7290	3.0	0.7	Md	012/016	103	0.10	AC	E3	le
28	20:52:04	46.4312	-118.0755	0.0*	1.8	Md	011/012	157	0.36	CC	E3	px
28	20:56:28	48.0122	-117.3422	0.0*	0.5	Md	004/007	158	0.21	CC	N3	px
30	21:49:54	46.0487	-118.8667	0.0*	1.4	Md	008/009	277	0.37	CD	E3	px
31	11:38:32	46.3880	-119.0483	1.2*	0.7	Md	008/012	249	0.16	CD	E3	le
June 2014												
02	03:31:22	44.8148	-117.3002	8.8	2.3	Ml	005/009	209	0.44	CD	E3	le
02	03:55:10	46.7108	-120.9117	6.1	0.9	Md	023/028	82	0.20	BB	C3	le
04	14:14:19	47.6270	-120.2677	6.4	1.9	Md	018/019	66	0.20	BA	N3	le
04	18:00:44	47.6105	-119.6050	13.2	1.6	Md	010/012	92	0.07	AB	N3	le
04	18:41:47	46.7667	-121.0780	4.4	1.2	Md	015/016	132	0.18	BC	C3	le
04	18:52:22	47.6187	-119.5970	13.9	1.4	Md	011/014	95	0.20	BB	N3	le
06	20:00:10	46.4200	-119.2672	0.4*	0.3	Md	006/007	162	0.22	CC	E3	le
08	23:34:52	47.1878	-120.9040	0.0*	1.4	Md	013/019	85	0.18	CB	C3	px
09	03:31:55	46.5823	-119.7877	17.2	0.5	Md	008/011	146	0.06	AC	E3	le
09	06:32:53	47.5763	-120.3888	8.4	0.7	Md	005/008	152	0.11	BC	N3	le
09	21:14:33	47.3663	-117.9752	0.0*	2.1	Md	011/014	156	0.17	CD	N3	px
10	23:18:12	48.0462	-121.4153	7.7	2.5	Ml	023/024	78	0.30	CC	C3	le
11	08:16:57	46.8407	-119.7567	3.1	1.2	Md	019/023	46	0.10	AB	E3	le
13	12:07:08	46.6127	-119.8472	6.6	1.0	Md	013/014	167	0.08	AC	E3	le
13	20:02:24	45.3868	-118.4595	0.0*	2.3	Md	007/009	337	2.10	DD	E3	px
14	13:01:12	46.6075	-119.8390	6.6	0.7	Md	010/013	92	0.08	AB	E3	le
14	16:54:53	48.6037	-120.5507	10.2*	1.6	Md	008/011	206	0.44	CD	C3	le
15	01:13:28	46.7273	-121.0017	2.8	1.1	Md	015/018	106	0.14	AC	C3	le
17	02:13:43	46.5768	-120.2265	15.3	0.5	Md	005/008	164	0.15	BC	E3	le
19	08:42:29	46.6085	-119.8703	7.1	0.2	Md	006/007	279	0.05	AD	E3	le
19	15:16:48	46.5733	-119.8370	8.8	0.6	Md	009/012	122	0.05	AB	E3	le
19	22:56:24	46.5722	-119.8352	8.5	0.6	Md	010/015	121	0.06	AB	E3	le
20	01:23:29	46.6085	-118.9398	0.0*	2.0	Md	023/022	120	0.10	CB	E3	px
21	09:05:27	48.9833	-119.0593	0.5	1.5	Ml	010/014	165	0.37	CD	N3	le
21	18:04:46	48.5812	-117.9545	0.0*	1.5	Md	004/007	174	0.48	CD	N3	px
21	19:27:46	47.4065	-120.5498	0.0	1.7	Md	011/014	151	0.21	BC	N3	le
23	08:26:19	46.2492	-120.7028	11.6	2.1	Ml	020/025	58	0.14	AC	C3	le
24	01:16:02	47.7735	-120.1035	6.6	1.1	Md	008/012	109	0.08	AB	N3	le
24	23:55:25	48.1718	-118.9768	1.5*	2.0	Md	014/020	105	0.21	CC	N3	le
25	08:45:36	46.6025	-119.8592	7.3	0.1	Md	005/007	264	0.04	AD	E3	le

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Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
27	16:22:45	45.6495	-121.0522	0.0*	1.0	Md	006/008	255	0.33	CD	C3	px
29	01:35:04	46.8322	-120.5740	12.9	2.0	Ml	019/020	87	0.11	AA	E3	le
30	02:50:59	47.6837	-120.0262	6.8	1.6	Md	009/008	139	0.04	AC	N3	le
July 2014												
01	03:41:49	45.5370	-118.1530	27.7	1.5	Md	004/006	109	0.24	CC	E3	le
02	08:32:55	47.6887	-120.3187	0.7*	0.8	Md	005/008	120	0.06	CB	N3	le
02	12:20:51	47.6983	-120.1268	0.9*	0.9	Md	007/011	131	0.07	CC	N3	le
05	14:44:04	46.5838	-119.8470	8.3	0.2	Md	008/012	128	0.06	AB	E3	le
07	18:51:30	47.3712	-117.9425	0.0*	1.9	Md	012/015	190	0.24	CD	N3	px
07	19:39:29	44.4107	-121.0385	0.0*	1.5	Md	006/006	109	0.16	CC	N3	px
10	08:42:01	46.5508	-119.5935	14.7	0.3	Md	012/018	59	0.05	AA	E3	le
10	16:55:13	44.1498	-121.3612	0.0*	1.8	Ml	008/010	337	0.77	DD	E3	px
10	23:03:53	46.4192	-119.2700	0.7	0.8	Md	010/013	161	0.04	BC	E3	le
11	01:35:11	47.4930	-118.9223	11.7	1.9	Md	016/016	72	0.17	BB	N3	le
11	03:16:43	46.4318	-119.2727	0.1	0.4	Md	008/010	154	0.07	AC	E3	le
11	12:11:36	46.5402	-119.6000	0.8*	-0.0	Md	007/010	104	0.30	CB	E3	le
11	12:11:39	46.5545	-119.5872	17.2	0.3	Md	011/013	95	0.12	AB	E3	le
11	20:49:25	47.6443	-120.1392	0.9*	1.9	Md	013/014	87	0.06	CC	N3	le
13	15:23:49	48.0252	-120.8150	7.1	1.7	Md	007/009	122	0.09	AB	C3	le
14	17:59:52	47.7057	-120.2015	2.8	0.5	Md	006/008	124	0.03	BC	N3	le
14	18:33:18	44.0645	-121.3648	0.0*	1.4	Md	013/015	85	0.46	CA	N3	px
14	22:35:32	44.0958	-121.3558	0.0*	2.5	Ml	013/013	133	0.30	CB	N3	px
15	17:32:07	46.5852	-118.4878	0.0*	1.6	Md	014/015	116	0.36	CC	E3	px
16	01:20:07	47.6840	-120.0710	0.5*	1.7	Md	010/012	137	0.12	CC	N3	le
16	16:22:16	46.6188	-119.8223	7.0	1.1	Md	015/018	126	0.11	AB	E3	le
16	16:22:31	46.6160	-119.8190	8.1	0.3	Md	007/009	144	0.03	AC	E3	le
16	16:22:55	46.6123	-119.8198	7.5	0.3	Md	008/012	149	0.09	AC	E3	le
16	16:29:51	46.6173	-119.8178	7.2	1.5	Md	020/023	83	0.09	AA	E3	le
16	16:54:12	46.6445	-119.8402	8.7	0.1	Md	007/009	163	0.09	AC	E3	le
16	22:39:29	46.6248	-119.8283	7.7	0.3	Md	006/009	260	0.05	AD	E3	le
18	09:45:10	46.6237	-119.8235	7.9	1.2	Ml	009/012	257	0.07	AD	E3	le
18	09:52:23	46.6273	-119.8240	8.3	-0.3	Md	004/006	259	0.01	BD	E3	le
19	06:13:42	46.8267	-120.5495	11.8	2.0	Ml	059/013	116	0.18	BB	E3	le
21	06:33:06	47.6805	-120.2047	4.5	0.9	Md	007/009	134	0.09	AC	N3	le
21	12:37:06	48.4083	-118.8035	3.8	1.7	Ml	008/010	126	0.35	CC	N3	le
22	17:20:48	44.3787	-121.0005	0.0*	1.4	Md	007/008	111	0.31	CB	N3	px
22	20:29:23	46.5187	-117.9090	0.0*	2.0	Md	009/010	199	0.12	CD	E3	px
24	00:16:27	46.8303	-120.5703	14.4	0.8	Md	005/006	142	0.05	AC	E3	le
24	03:53:45	45.1973	-121.3002	16.5	1.1	Md	009/011	91	0.13	AB	E3	le
24	19:27:03	46.1627	-119.0938	0.0*	1.4	Md	011/014	137	0.21	CC	E3	px
25	16:54:51	45.9690	-119.7870	0.0*	2.2	Md	012/012	110	0.27	CB	E3	px
28	07:57:07	47.6978	-120.2625	6.2	0.2	Md	007/010	119	0.10	AB	N3	le
28	20:37:37	46.5425	-118.2280	0.0*	1.9	Md	010/011	193	0.40	CD	E3	px
29	00:08:09	46.6215	-119.8333	5.3	1.8	Ml	018/023	70	0.31	CB	E3	le
29	03:12:30	47.7058	-120.2768	6.4	0.2	Md	004/006	209	0.02	BD	N3	le
August 2014												
01	02:21:36	48.1337	-117.1523	26.1	2.3	Md	008/012	121	0.76	DB	N3	le
01	08:25:26	45.8430	-121.4122	0.0*	1.7	Md	025/026	76	0.28	CB	C3	ex
02	20:10:47	46.4205	-119.3852	11.2	0.1	Md	008/011	115	0.20	BB	E3	le
04	18:57:49	44.3897	-121.0132	0.0*	1.8	Md	006/006	189	0.23	CD	E3	px
07	19:00:36	46.9460	-119.0992	0.0*	1.5	Md	008/009	117	0.10	CB	E3	px
08	07:38:52	46.7468	-120.7085	5.2	1.3	Md	017/019	96	0.13	AB	C3	le
09	10:45:42	47.6937	-120.0155	4.0	2.0	Ml	018/014	87	0.14	AA	N3	le
09	16:33:21	48.7582	-121.4957	1.1	1.8	Md	010/010	182	0.11	AD	C3	le
10	02:40:55	46.0365	-120.9527	0.0*	1.5	Md	016/016	91	0.12	CC	C3	px

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Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
10	15:30:18	47.6948	-120.0138	2.6	0.5	Md	005/007	142	0.05	AC	N3	le
10	17:03:25	46.4432	-119.5975	16.2	0.4	Md	013/016	120	0.05	AB	E3	le
11	17:19:18	47.2705	-121.2887	10.3*	0.9	Md	008/010	163	0.24	CC	C3	le
12	20:18:36	46.2470	-119.4580	0.0*	2.2	Md	013/015	105	0.20	CB	E3	px
13	05:53:37	46.3510	-119.5775	7.0	0.7	Md	013/015	199	0.04	AD	E3	le
13	14:14:35	47.6670	-120.3343	0.6*	0.3	Md	004/007	205	0.05	CD	N3	le
13	16:28:04	47.6718	-120.3287	6.8	0.9	Md	008/011	97	0.11	AB	N3	le
13	23:46:31	47.8502	-120.7708	9.5	1.7	Md	015/018	111	0.13	AB	C3	le
14	20:03:52	44.0173	-121.2710	0.0*	2.2	Ml	013/013	141	0.50	DC	C3	px
16	07:06:04	45.4418	-117.6717	9.7	2.0	Md	006/009	126	0.67	DD	C3	le
17	06:32:46	46.4470	-119.6180	17.1	0.2	Md	010/014	139	0.06	AC	E3	le
17	18:47:56	46.7927	-121.0903	8.4	0.9	Md	017/021	122	0.29	BC	C3	le
18	07:00:18	47.6500	-121.4093	7.3	0.7	Md	008/011	174	0.08	AC	C3	le
18	09:13:18	47.1717	-120.8855	4.6	1.6	Md	015/014	65	0.14	AA	C3	le
18	10:02:06	46.8963	-121.4882	1.4	0.8	Md	023/021	133	0.15	BC	C3	le
19	04:32:57	45.9050	-120.4898	18.7	2.4	Ml	024/030	56	0.16	BB	E3	le
19	07:49:04	45.9093	-120.4898	17.9	1.6	Md	019/023	73	0.20	BB	E3	le
19	18:10:52	46.4297	-118.0112	0.0*	1.9	Md	015/018	237	0.18	CD	E3	px
20	01:27:20	46.0780	-118.8922	0.0*	1.7	Md	012/013	232	0.45	CD	E3	px
20	11:49:03	45.9040	-120.4865	10.5	1.1	Md	011/012	112	0.16	BC	E3	le
21	12:21:45	46.6285	-119.8280	8.0	0.9	Md	006/009	154	0.09	AC	E3	le
21	19:04:38	48.5823	-121.3502	14.9	0.7	Md	004/007	200	0.06	CD	C3	le
24	02:52:40	45.6310	-120.0130	13.2	1.7	Md	016/019	116	0.12	BB	E3	le
27	19:16:47	44.1003	-121.3407	0.0*	1.1	Md	012/012	85	0.28	CA	E3	px
27	22:01:24	46.3607	-120.0100	0.0*	2.4	Md	012/012	234	0.31	CD	E3	px
28	05:58:22	46.5992	-119.8587	7.1	0.3	Md	007/007	262	0.04	AD	E3	le
28	11:56:09	46.7425	-120.8223	13.9	1.5	Md	007/009	200	0.07	AD	C3	le
28	14:16:47	47.8222	-120.5833	10.9	0.6	Md	006/008	138	0.06	CC	C3	le
September 2014												
01	07:59:52	48.2457	-118.7730	11.6	1.6	Md	008/012	115	0.36	CC	N3	le
01	08:39:10	45.4562	-117.6195	10.7	2.1	Ml	005/007	132	0.37	CD	N3	le
02	13:31:38	47.6740	-120.0935	7.4	0.5	Md	004/006	172	0.06	BC	N3	le
07	06:44:29	46.0940	-119.5743	12.7	0.6	Md	004/004	303	0.00	BD	E3	le
07	06:45:45	46.0930	-119.5437	12.2	1.7	Md	016/018	120	0.12	AB	E3	le
07	08:35:47	46.0763	-119.5495	12.3	0.8	Md	007/008	307	0.10	BD	E3	le
07	13:22:12	46.0868	-119.5598	10.1	1.0	Md	010/012	297	0.15	BD	E3	le
08	11:15:05	48.2425	-121.3448	8.6	1.1	Md	014/014	122	0.17	BC	C3	le
08	11:36:51	45.4467	-117.4715	10.8*	1.6	Md	004/007	151	0.35	CD	C3	le
09	19:03:50	47.7350	-120.4080	1.0*	0.4	Md	004/006	143	0.27	CC	N3	le
12	05:14:04	46.7320	-121.0498	1.6*	1.1	Md	017/021	127	0.15	CC	C3	le
12	20:58:28	46.6547	-120.4770	0.0*	1.5	Md	010/007	124	0.27	CC	E3	px
13	04:55:35	46.2265	-119.0922	11.3	2.2	Ml	023/021	137	0.07	AC	E3	le
15	16:22:04	46.5302	-121.3915	4.8	0.9	Md	015/017	112	0.16	BC	C3	le
17	11:44:39	46.6123	-119.8497	7.0	1.8	Md	026/022	52	0.07	AA	E3	le
19	00:32:47	46.6143	-119.8428	7.0	0.7	Md	012/016	163	0.08	AC	E3	le
19	05:23:07	46.7032	-120.5397	20.9	1.5	Md	010/008	119	0.15	BB	E3	le
19	19:22:18	46.8027	-117.1348	0.0*	2.2	Md	010/012	185	0.33	CD	E3	px
19	20:09:37	46.4275	-119.2808	0.4*	0.8	Md	007/010	186	0.19	CD	E3	le
19	23:46:45	46.4333	-119.2832	0.0	0.6	Md	008/009	150	0.24	BC	E3	le
20	05:58:59	46.6208	-119.8420	6.8	0.7	Md	009/012	163	0.23	BC	E3	le
20	22:08:52	47.2817	-120.9292	6.8	1.1	Md	007/008	145	0.09	BC	C3	le
22	04:57:14	46.6233	-119.8088	0.5*	0.8	Md	004/007	138	0.61	DC	E3	le
23	11:40:38	48.7328	-121.4135	9.2	0.7	Md	004/006	248	0.03	BD	C3	le
25	18:12:06	44.0688	-121.3332	0.0*	2.8	Md	009/008	173	0.14	CC	C3	px
25	18:59:39	45.8937	-119.2918	0.0*	2.0	Md	011/011	177	0.15	CC	E3	px

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Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
26	21:14:24	46.3272	-119.3727	0.0*	1.9	Md	017/016	88	0.94	DB	E3	px
29	02:48:44	46.6538	-119.4590	0.5*	0.6	Md	008/012	106	0.28	CB	E3	le
29	20:38:16	45.6922	-120.1818	0.0*	1.8	Md	007/008	115	0.35	CC	E3	px
29	21:04:45	47.3633	-120.4795	1.1	1.5	Md	007/010	170	0.21	CC	N3	le

typ	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.
Latitude	Latitude of the earthquake epicenter, in decimal degrees
Longitude	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 4.2, "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 section4.1, "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 4.3 of this report, "Quality Factors."

5.0 Discussion of Seismic Activity – FY 2014

5.1 Summary

During FY2014, seismic activity was relatively quiet throughout eastern Washington. 332 earthquakes were cataloged in the region, of which about 46% (153) took place on or in the immediate vicinity of the Hanford Site (Tables 5.1 and 5.2). Several earthquakes took place in the historically active area of Entiat and Chelan. Within the vicinity of the Hanford Site, there was typical swarm-type activity, most strongly observed in the Wye Swarm Area.

Depths of earthquakes during the year also followed the historical pattern of most of the earthquakes at the Hanford Site being located at shallow depths. A similar number of earthquakes located at shallow depths, but there was an increase in the earthquakes at intermediate depths and the basement.

The depth distribution and geographic pattern of the earthquakes for the year are tabulated in Tables 5.1 and 5.2 and plotted on Figures 5.1 and 5.2. Figure 5.3 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. Figures 5.4, 5.5, and 5.6 are the same figures but only including earthquakes for the fourth quarter of FY2014.

There may be differences in the number, depth, and magnitude of earthquakes in the FY2014 Annual Report versus the individual quarterly reports (Wright *et al.*, 2014b, and 2014c) for FY2014. These differences in the text and shown on the following tables are due to events being re-analyzed at later dates. Seismic analysts at PNSN will sometimes re-review locations after internal discussion and/or if more data channels are added, or perhaps omitting data from a particular station if the timing was found to be out of tolerance. Such reanalysis may move them from the preliminary locations, or earthquake types (Etype), that were reported in the quarterly report. Because the FY2014 annual report supersedes the quarterly reports for FY2014, this annual earthquake catalog should be considered the most accurate product.

The FY2014 quarterly reports (Wright *et al.*, 2014b, and 2014c) also contain figures showing data from some of the significant earthquakes, and provide further discussion of the earthquakes.

Table 5.1. Depth Distribution of Eastern Washington Earthquakes for FY 2014

Category	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	FY 2014
Shallow (0-4 km deep)	35	30	24	20	109
Intermediate (4-9 km deep)	42	27	38	30	137
Deep (greater than 9 km deep)	25	18	12	31	86
Total	**102**	**75**	**74**	**81**	**332**
Felt	2	0	0	0	2
Probable Blast	20	22	31	27	100

Table 5.2. Earthquake Counts for FY 2014 for Earthquakes near the Hanford Site

Seismic Sources	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	FY 2014
Frenchman Hills	1	0	0	0	1
Saddle Mountains	1	1	0	0	2
Wahluke Slope	0	1	0	0	1
Coyote Rapids	1	0	0	0	1
Wye	14	13	10	4	41
Cold Creek	4	1	0	2	7
Rattlesnake Mountain	0	0	0	0	0
Horse Heaven Hills	3	0	0	1	4
Total for swarm areas	24	16	10	7	57
Random Events	28	20	22	26	96
Total For All Earthquakes	**52**	**36**	**32**	**33**	**153**

5.1.1 First Quarter FY 2014 Earthquakes

The EWRSN and HSN recorded 102 eastern Washington earthquakes during the first quarter of FY 2014, 52 local to the Hanford Site (local), and 50 off the site (regional). Of the local earthquakes, 21 were located at shallow depths (less than 4 km), 23 at intermediate depths (between 4 and 9 km), most likely in the pre-basalt sediments, and 8 deeper than 9 km, within the basement. Geographically, 14 shallow local earthquakes were located in the Wye swarm area, 4-Cold Creek swarm area, 3-Horse Heaven Hills swarm area, 1-Frenchman Hills swarm area, 1-Saddle Mountains swarm area, and 1-Coyote Rapids swarm area. 28 other local earthquakes were classified as random events. Of the regional earthquakes, 14 were shallow, 19 intermediate, and 17 deep. The network also located 2 events that have been categorized as probable surface explosions within the Hanford Site and another 18 within the region.

There were two earthquakes that were significant (having magnitudes greater than 3.0 and reported felt) for the quarter. The first one occurred on November 17, 2013 in the southeast area of the Hanford Site (M_L = 3.2) at a depth of 0 km. The other significant earthquake of the quarter was a regional event (M_L = 3.2) that took place on December 30, 2013 at depth of 7.2 km with the epicenter located 31.5 km northeast of Okanogan, WA.

5.1.2 Second Quarter FY 2014 Earthquakes

The EWRSN and HSN recorded 75 eastern Washington earthquakes during the second quarter of FY 2014, 36 local to the Hanford Site (local), and 39 off the site (regional). Of the local earthquakes, 14 were located at shallow depths (less than 4 km), 10 at intermediate depths (between 4 and 9 km), most likely in the pre-basalt sediments, and 12 deeper than 9 km, within the basement. Geographically, 13 shallow local earthquakes were located in the Wye swarm area, one in the Saddle Mountains swarm area, one in the Wahluke Slope swarm area, and one in the Cold Creek swarm area. 20 other local earthquakes were classified as random events. Of the regional earthquakes, 16 were shallow, 17 intermediate, and 6 deep. The network also located 2 events that have been categorized as probable surface explosions within the Hanford Site and another 20 within the region.

The largest regional event (M_L = 2.5) took place February 21, 2014 at depth of 17 km with the epicenter located 5 km west-southwest of Othello, WA.

5.1.3 Third Quarter FY 2014 Earthquakes

The EWRSN and HSN recorded 74 eastern Washington earthquakes during the third quarter of FY 2014, 32 local to the Hanford Site (local), and 42 off the site (regional). Of the local earthquakes, 13 were located at shallow depths (less than 4 km), 17 at intermediate depths (between 4 and 9 km), most likely in the pre-basalt sediments, and 2 deeper than 9 km, within the basement. Geographically, 10 shallow local earthquakes were located in the Wye swarm area. 22 other local earthquakes were classified as random events. Of the regional earthquakes, 11 were shallow, 21 intermediate, and 10 deep. The network also located 6 local and 25 regional events that have been categorized as probable surface explosions.

The largest regional event (M_L=2.5) took place on June 10, 2014 at a depth of 8 km with epicenter located 27 km south-southeast of Darrington, WA.

5.1.4 Fourth Quarter FY 2014 Earthquakes

The EWRSN and HSN recorded 81 eastern Washington earthquakes during the fourth quarter of FY 2014, 33 local to the Hanford Site (local), and 48 off the site (regional). Of the local earthquakes, 7 were located at shallow depths (less than 4 km), 16 at intermediate depths (between 4 and 9 km), most likely in the pre-basalt sediments, and 10 deeper than 9 km, within the basement. Geographically, four shallow local earthquakes were located in the Wye swarm area; three in the Cold Creek swarm area, and one in the Horse Heaven Hills swarm area. 26 other local earthquakes were classified as random events. Of the regional earthquakes, 13 were shallow, 14 intermediate, and 21 deep. The network also located 4 local and 23 regional events that have been categorized as probable surface explosions.

The largest regional event (M_L = 2.4) took place on August 19, 2014 at a depth of 19 km with epicenter located 63 km east-northeast of The Dalles, OR.

Figure 5.1. Hanford Seismic Network Offsite Stations Epicenters of Earthquakes Recorded during FY 2014

Red circles stand for shallow earthquakes (0-4 km)
Blue circles for intermediate-depth earthquakes (4 9 km)
Black circles deep earthquakes (>9km).

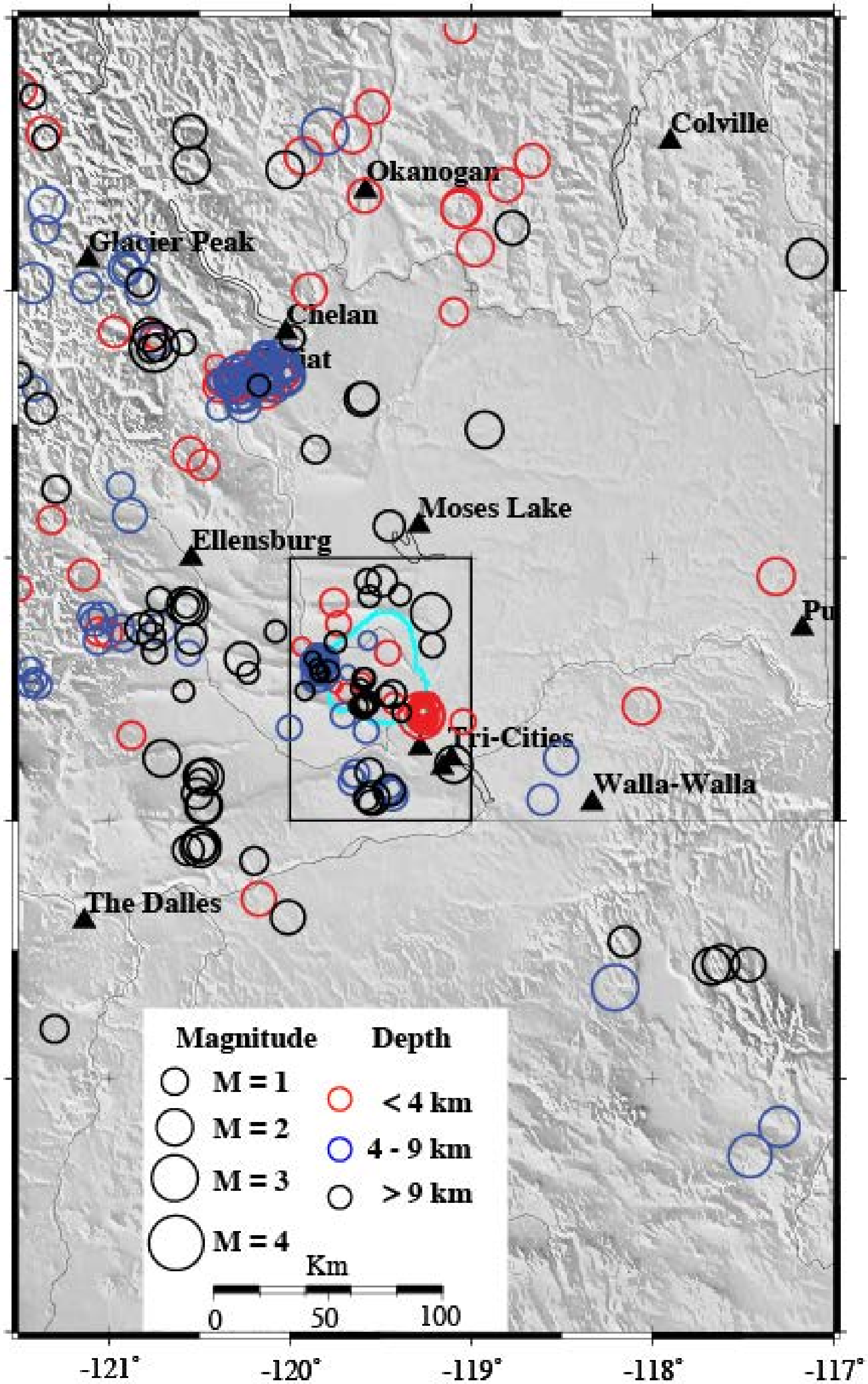


Figure 5.2. Hanford Seismic Network Onsite Stations Epicenters of Earthquakes Occurring during FY 2014

Vicinity of Hanford Site (light blue outline), and their relationship to known structures (red lines), swarm areas (shaded bits), and cultural features. Red circles stand for shallow earthquakes (0-4 km), blue circles for intermediate-depth earthquakes (4-9 km), and black circles deep earthquakes (>9km).

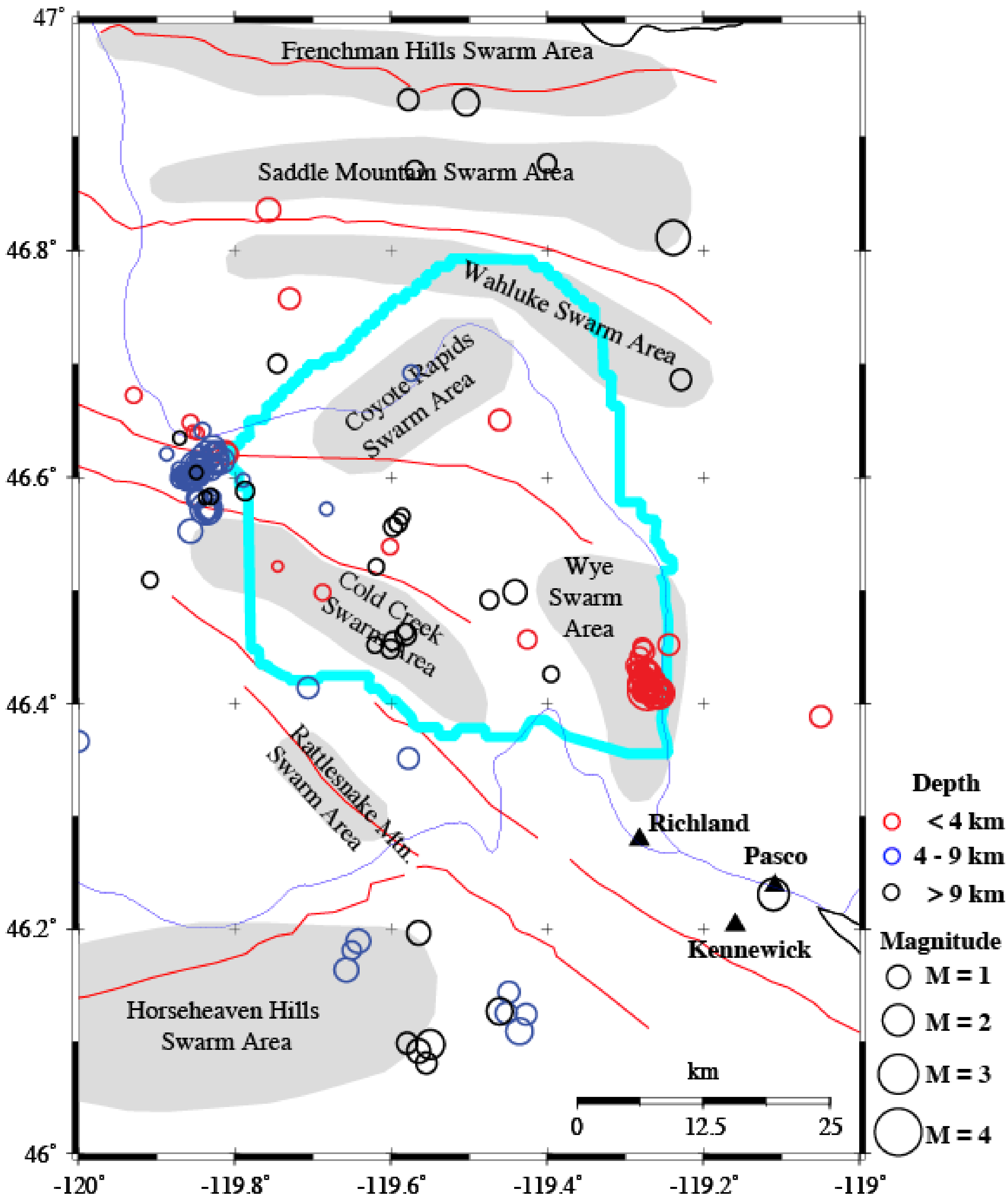


Figure 5.3. Perspective Plot Showing Topography (exaggerated) and Hypocenters

Hypocenters (red dots, connected to epicenter with fine vertical line) of earthquakes occurring during FY2014 in the vicinity of the Hanford Site, both overall (lightly shaded region), and inner (darker shading). Probable blasts are not shown in this figure.

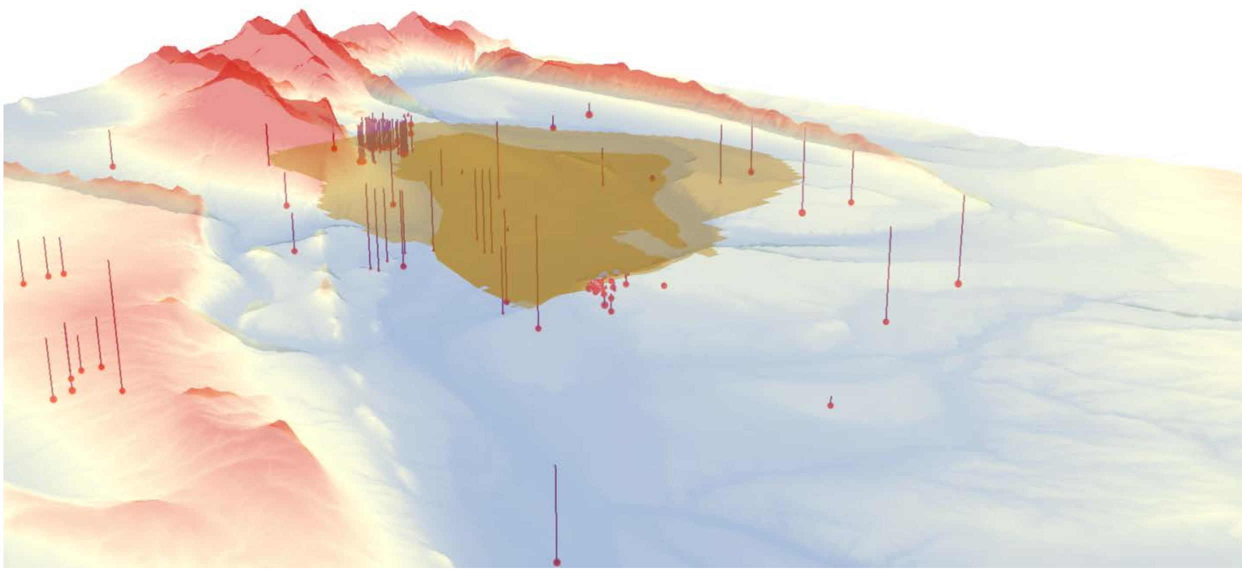


Figure 5.4. Hanford Seismic Network Offsite Stations Epicenters of Earthquakes Recorded during 4th Quarter of FY 2014

Red circles stand for shallow earthquakes (0-4 km), blue circles for intermediate-depth earthquakes (4-9 km), and black circles deep earthquakes (>9km).

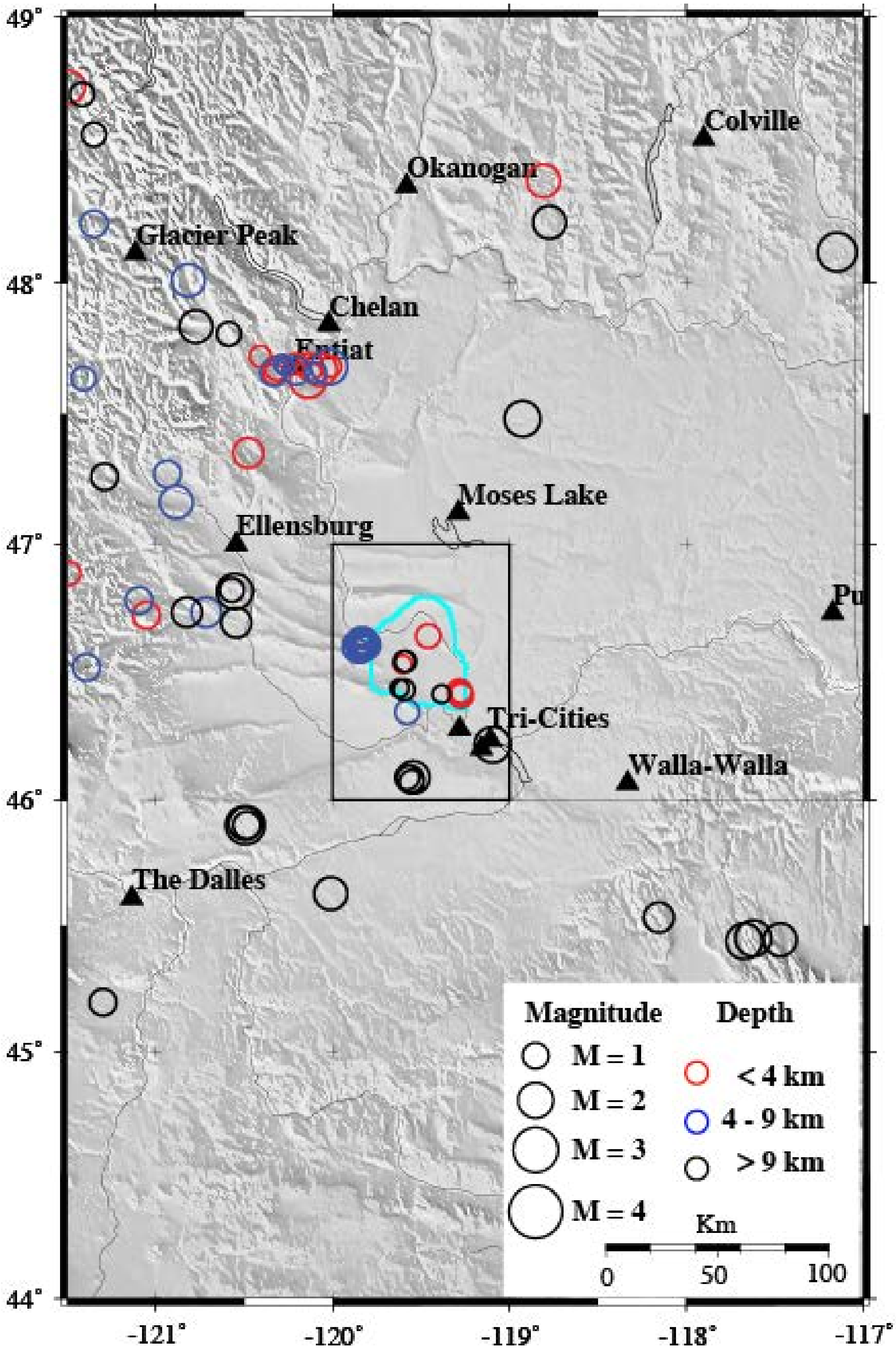


Figure 5.5. Hanford Seismic Network Offsite Stations Epicenters of Earthquakes Recorded during 4th Quarter FY 2014 and their Relationship to Known Structures, Swarm Areas, and Cultural Features

Light Blue Outline: Hanford Site
Red Lines: Structures
Shaded Bits: Swarm Areas

Red Circles: Shallow Earthquakes (0-4 km)
Blue Circles: Intermediate-Depth Earthquakes (4-9 km)
Black circles: Deep Earthquakes (>9km)

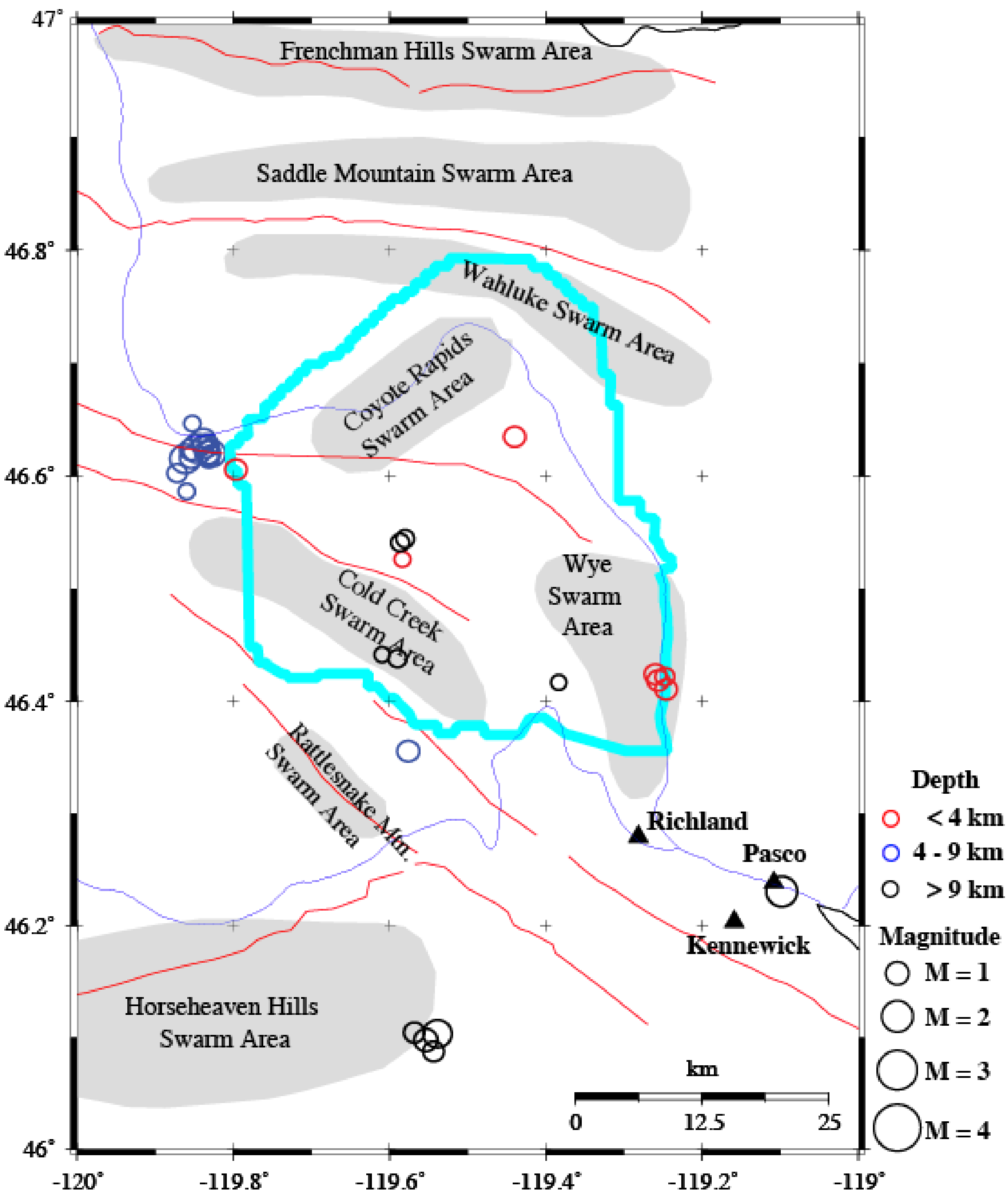
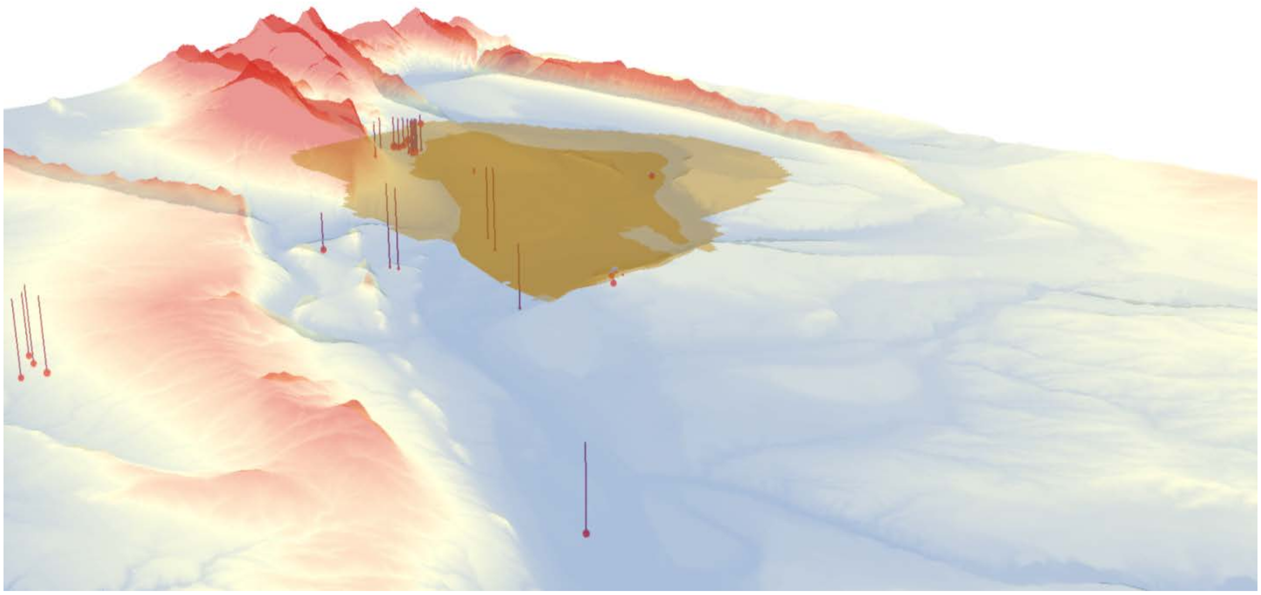


Figure 5.6. Hanford Seismic Network Onsite Stations Perspective Plot Showing Topography and Hypocenters of Earthquakes Occurring during 4th Quarter FY2014

Topography is exaggerated. Hypocenters are red dots, connected to epicenter with fine vertical line of earthquakes. Overall (lightly shaded region), and Inner (darker shading).

Probable blasts are not shown in this figure.



6.0 Status of Monitoring

During the 4th quarter of FY2014, a thorough re-evaluation of the seismic monitoring architecture in eastern Washington took place. While monitoring through FY 2014 was carried out with the networks as described in section 3 of this report, starting with FY2015 there will be some network changes. The goal of these changes is to improve performance and cost efficiency of the seismic monitoring of the Hanford Site. Efficiencies will be gained by modernization of equipment where funding allows, and by refocusing monitoring sites on the seismicity and more complete ground motion observations on and immediately surrounding the Hanford Site proper. Such network changes will lead inevitably to changes in catalog and reporting statistics. However, we anticipate that the evolution of the network will be gradual rather than dramatic and will be carried out in a manner that does not disrupt the basic monitoring function. We will report on the rationale and details of the re-configurations in future reports.

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