Second Quarter Hanford Seismic Report for Fiscal Year 2012 (January-March 2012)

P. Bodin,[1] J. Vidale,[1] A. Wright[1]

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[1] Pacific Northwest Seismic Network
University of Washington
Seattle, Washington 98195

Summary

The PNSN/MSA team continues to provide uninterrupted collection of high-quality raw and processed seismic data from the 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 Hanford Seismic Network and the Eastern Washington Regional Network consist of 49 individual sensor sites and 15 radio relay sites maintained by the PNSN.

The first three months of 2012 were seismically very quiet in eastern Washington. A few background earthquakes and a handful of swarm-type events took place. Perhaps the most notable event was the 2.4 M_d earthquake that took place on the 7th of January 2012 at a depth of 24.6 km directly beneath area 200E in the Hanford site. This earthquake produced very low levels of ground motion on the site, but is a reminder that larger earthquakes may take place on site. Instrumentation also detected eight (8) events that have been categorized as probable surface explosions.

The largest event (M_L = 2.5) took place 5 February 2012 at depth of 18.2 km with epicenter located in the 2009 Maupin, Oregon, deep 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 (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
IRIS - Incorporated Research Institutions in Seismology
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
PNNL - Pacific Northwest National Laboratory
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
Vp - p-wave velocity
Vs - 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 second quarter of fiscal year (FY) 2012 (January 2012 through March 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 the seismic event. 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 latitude and between 119-120° west longitude. 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 2nd 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.

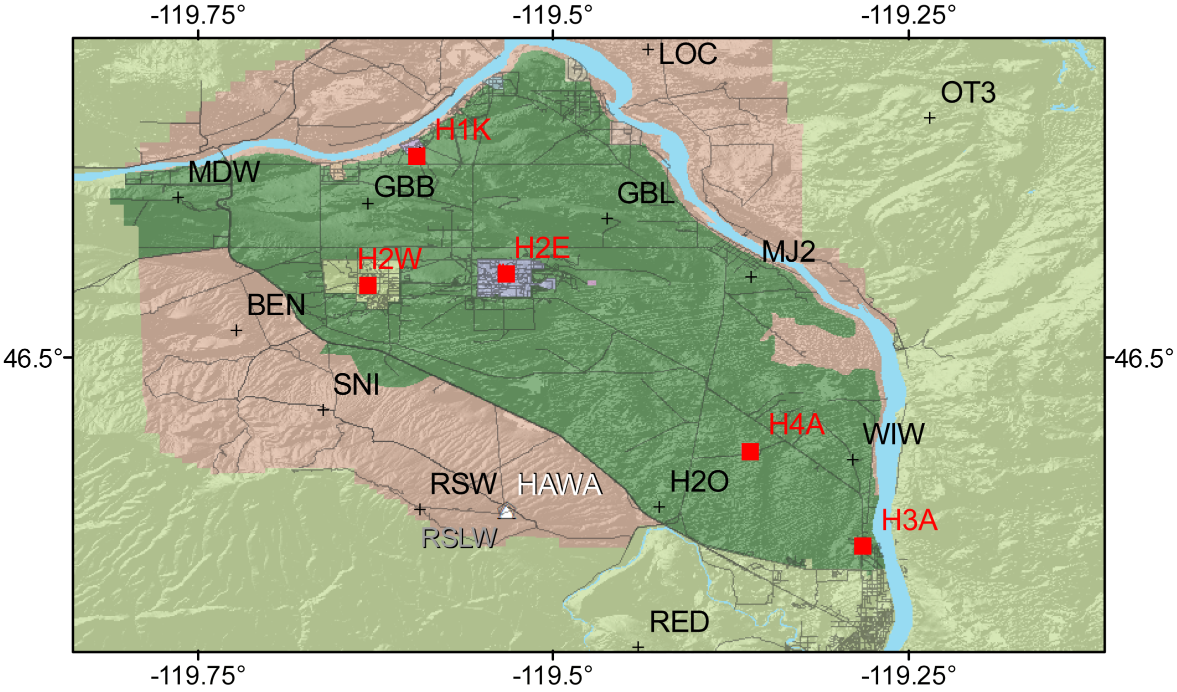

Figure 2.1 Seismic monitoring stations of the Hanford Seismic Network, on the Hanford site. Red squares and text are strong motion accelerographs (SMA) stations. Black text and plusses are short period stations. HAWA is a broadband and SMA US National Seismic Network Station operated by the US Geological 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.

Station	Latitude	Longitude	Elevation (m)	Station Name
BEN	46.52	-119.72167	335	Benson Ranch
GBB	*46.60814*	*-119.62898*	*185*	*Gable Butte*
GBL	46.59819	-119.46097	33	Gable Mountain
H1K	***46.64468***	***-119.59287***	***152***	***100 K Area (SMA)***
H2E	***45.55780***	***-119.53450***	***187***	***200 East Area (SMA)***
H2O	46.39555	-119.42411	175	Water Station
H2W	***46.5517***	***-119.64532***	***129***	***200 West Area (SMA)***
H3A	***46.36322***	***-119.27747***	***99***	***300 Area (SMA)***
H4A	***46.46835***	***-119.35441***	***147***	***400 Area (SMA)***
LOC	46.71686	-119.43197	21	Locke Island
MDW	46.61302	-119.76215	33	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 1. Hanford Site Network (HSN) Stations. Italic font indicates a 3-channel station, ***bold font*** *indicates a Strong Motion Accelerometer.*

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

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
CCRK	*46.5585*	*-119.855*	*561*	*Cold Creek*
CRF	46.82486	-119.388	189	Corfu
DDRF	*46.4911*	*-119.06*	*233*	*Didier Farms*
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
ET3	46.57719	-118.939	286	Eltopia Three
ETW	47.60418	-120.334	1477	Entiat
FHE	*46.95178*	*-119.498*	*455*	*Frenchman Hills East*
LNO	45.87169	-118.286	771	Lincton 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

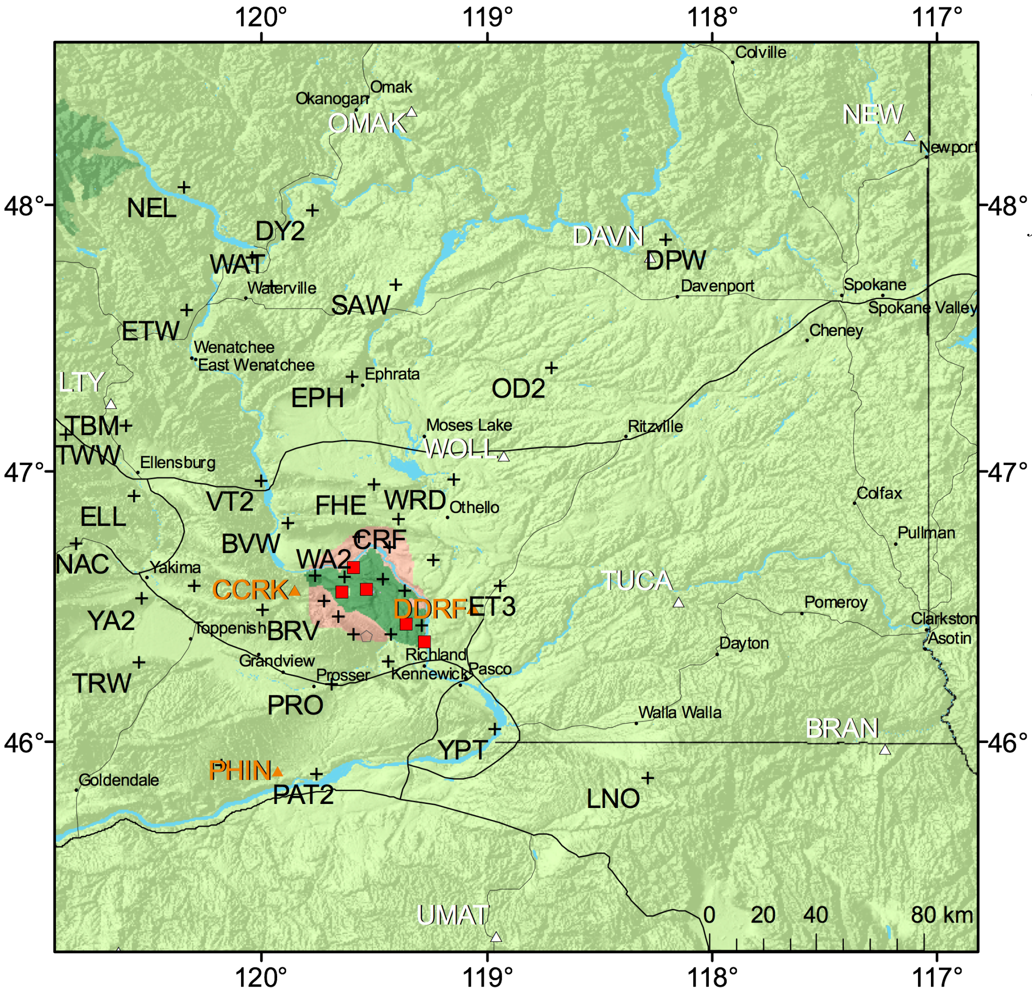

Figure 2.2 Seismic stations of the Eastern Washington Region Sub-Network. Black font and plusses are short-period EWRSN stations. Gold font and triangles are EWRSN broadband stations. White font and triangles are broadband stations contributed by other agencies to the PNSN data collection in eastern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

2.2 Station Maintenance During the 2nd Quarter of FY2012

Fieldwork during the 2nd quarter of FY2012 focused on problems related to the RSLW site on the slopes of Rattlesnake Mountain. Several issues demanded site visits to rectify conditions that took stations that pass data through this site off-line. In January, both the RSLW “Glowworm” remote Earthworm data acquisition node, and the co-located USGS seismic station HAWA went off-line. A site visit by PNSN and MSA staff ascertained that an electrical power breaker that provided power to both sites, located in the silo, had been turned off by mistake. Once power was restored, the site became operational. The power switch was labeled clearly to prevent future occurrences.

Then on March 20th a wind gust exceeding 70 mph at a nearby meteorology station, blew over the small shed that houses the radio telemetry equipment and the data acquisition node (Figure 2.3). The solar panel that provided power for the station was blown 100 meters away and broken, also. On March 22nd PNSN staff visited the site and righted the shed, restoring the site to operating conditions. Since that time, PNSN and MSA have been planning how to move the equipment off of the surface and into the nearby bunker. Work on this is planned for summer 2012.

Figure 2.3 Instrument shed at RSLW blown over by high wind.

2.3 Other Network Activities during the 2nd Quarter of FY2012

As of January 1st 2012, the PNSN’s AQMS software became the sole source of catalog information. This is the first reporting period for which the AQMS/Hypoinverse/Jiggle software was employed exclusively.

Negotiations between the USGS and PNSN for continued transmission of seismic data for the PNSN through Bonneville Power Administration (BPA) telemetry infrastructure were pursued vigorously by PNSN staff and BPA representatives. The recently concluded negotiations will provide telemetry bandwidth of analog-type signals through the new BPA digital system. This will necessitate site visits to many EWRSN stations and BPA data relay sites in the Spring and Summer of 2012. We plan to perform needed but long-deferred station upkeep and maintenance during these station visits that are critical to flow of seismic data from EWRSN stations.

3.0 Earthquake Catalog Description

Within the 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 in the XPED calculation. 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 – Second Quarter FY 2012

4.1 Catalog of Seismic Events

Table 4.1 *Local Seismic Data, January 1 – March 31, 2012*

January 2012

Day	Time	Lat	Lon	Depth	M	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
04	16:02:10	47.7460	-120.2397	0.8*	2.4	Md	025/024	55	0.13	CC	N3	le
07	10:48:24	48.4098	-120.6053	10.8*	1.5	Md	006/007	171	0.18	CC	C3	le
07	14:47:50	46.5652	-119.5487	24.6	2.4	Md	031/021	78	0.08	AA	E3	le
10	19:56:30	46.6493	-120.4782	0.0*	1.7	Md	011/005	133	0.11	CD	E3	px
14	00:21:52	46.3988	-119.2732	0.4*	1.3	Md	007/009	128	0.24	CB	E3	le
16	19:18:01	46.5603	-121.4555	6.0	0.8	Md	009/012	268	0.10	BD	C3	le
18	18:30:06	46.9145	-119.2928	0.3	1.7	Md	009/010	110	0.11	AC	E3	le
25	14:29:47	46.6307	-119.2878	15.7	0.8	Md	008/008	87	0.08	AA	E3	le
29	01:18:31	46.4100	-119.2540	0.0	1.1	Md	008/010	142	0.29	BC	E3	le
29	16:14:13	46.4032	-119.2685	0.4*	0.6	Md	006/006	268	0.08	CD	E3	le

February 2012

Day	Time	Lat	Lon	Depth	M	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
01	11:59:13	48.4592	-119.6138	0.0	2.5	Md	011/013	225	0.14	BD	N3	le
02	06:59:47	47.1127	-119.3878	13.2	2.1	Md	022/026	70	0.22	BB	N3	le
02	07:00:13	47.0987	-119.3713	14.3	1.2	Md	004/006	246	0.07	BD	N3	le
03	19:49:30	46.4115	-119.2492	0.3	1.8	Md	014/017	122	0.14	AB	E3	le
05	03:50:56	46.5555	-119.3328	18.8	1.0	Md	013/012	163	0.08	AC	E3	le
05	17:28:16	45.1240	-120.9500	18.2	2.5	M_L	015/018	129	0.26	BB	E3	le
07	23:20:52	45.7097	-119.1590	0.0*	1.6	Md	012/016	155	0.52	DC	E3	px
17	20:14:31	47.6643	-120.2962	1.3*	0.7	Md	005/009	131	0.09	CC	N3	le
19	22:18:37	47.6860	-120.2988	1.2*	0.6	Md	006/010	123	0.08	CC	N3	le
29	01:41:36	44.0577	-120.9385	0.0	2.4	Md	014/022	93	0.75	DC	N3	px

March 2012

Day	Time	Lat	Lon	Depth	M	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
02	08:52:57	46.9315	-120.7350	8.1	0.8	Md	012/015	98	0.19	BB	C3	le
03	05:03:36	46.4080	-119.2595	0.0	1.9	Md	017/021	115	0.22	BB	E3	le
03	08:51:00	46.4193	-119.2600	0.5*	0.7	Md	004/006	197	0.07	CD	E3	le
04	04:03:29	46.4212	-119.2657	0.5*	0.9	Md	004/006	194	0.07	CD	E3	le
04	04:15:41	46.4037	-119.2657	0.0	1.2	Md	013/015	134	0.20	BB	E3	le
08	17:25:31	46.4122	-119.2600	0.5*	1.0	Md	007/011	134	0.16	CB	E3	le
09	19:03:17	46.7392	-121.2003	1.4*	0.7	Md	004/004	170	0.35	DD	C3	le
10	18:37:52	46.5593	-119.8218	11.0	0.5	Md	004/008	199	0.17	BD	E3	le
12	18:59:39	46.1648	-119.1712	0.0*	2.6	Md	010/012	108	0.31	CC	E3	px
12	19:38:35	46.6462	-120.6958	0.0*	1.3	Md	005/005	152	0.45	CD	E3	px
14	20:31:06	47.3777	-117.8732	0.0*	1.7	Md	006/008	164	0.27	CD	N3	px
16	18:53:09	44.4037	-121.0125	0.0*	1.7	Md	008/010	139	0.25	CC	N3	px
17	23:59:09	46.4645	-120.0320	10.4	1.2	Md	010/011	75	0.33	CC	E3	le
20	10:05:15	46.8298	-121.1982	9.1	0.8	Md	014/017	115	0.20	BC	C3	le
21	19:55:33	47.0015	-119.1490	0.0*	0.8	Md	011/013	81	1.66	DC	N3	px
23	19:46:57	46.6652	-119.1092	5.9	1.2	Md	013/014	108	0.13	AB	E3	le
26	04:10:56	48.5498	-120.0202	6.0	1.7	Md	010/013	100	0.31	CD	N3	le
26	19:32:06	47.8758	-120.8993	10.3*	2.1	Md	008/012	95	0.36	CC	C3	le
27	01:01:47	47.8978	-120.8872	8.2	2.2	Md	008/011	101	0.09	AC	C3	le
28	08:50:13	46.7098	-120.9058	8.1	1.1	Md	016/017	105	0.16	BB	C3	le
30	07:39:39	47.6377	-119.7222	12.6	1.0	Md	005/008	167	0.09	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

The first three months of 2012 were seismically very quiet in eastern Washington. A few background earthquakes and a handful of swarm-type events took place. The most notable earthquake was an M_d = 2.4 earthquake 24.6 km beneath the 200E area on the site, which produced very low levels of ground motion on the site, but serves as a reminder that larger earthquakes may take place on site.

4.3 Discussion of Second Quarter FY 2012 Earthquakes

The EWRSN and HSN recorded 33 eastern Washington earthquakes during the first quarter of FY 2012, 15 local to the Hanford site (local), and 18 off of the site (regional). Of the local earthquakes, 10 were located at shallow depths (less than 4 km), 1 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, 9 shallow local earthquakes were located in the Wye swarm area, and one in the Cold Creek swarm area. Five other local earthquakes were classified as random events. Of the regional earthquakes 5 were shallow, 5 intermediate, and 8 deep. The network also located eight (8) events that have been categorized as probable surface explosions. (Tables 4.1 & 4.2).

The largest event (M_L = 2.5) took place 5 February 2012 at depth of 18.2 km with epicenter located in the 2009 Maupin, Oregon, deep swarm area. Of greatest seismological interest, probably was the M_d = 2.4 earthquake that took place on the 7th of January 2012 at a depth of 24.6 km directly beneath area 200E in the Hanford site.

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.

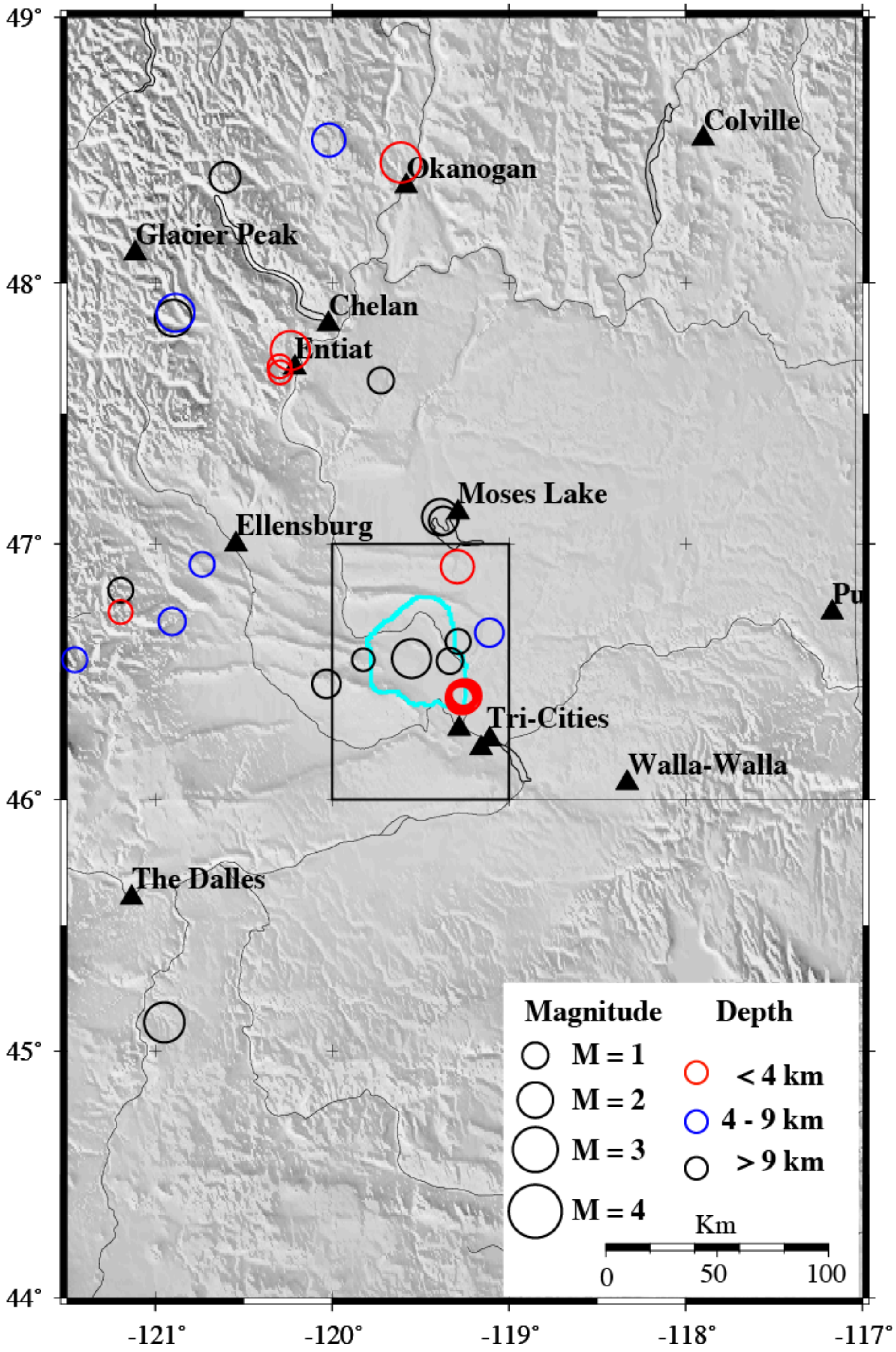

*Figure 4.1 Epicenters of earthquakes recorded in the Eastern Washington region during the 2nd Quarter of FY2012. Black triangles show locations of cities, towns, and volcanoes. Light blue line is the outline of the Hanford site. Black rectangle outlines area mapped in Figure 4.2. Circles are earthquake 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.*

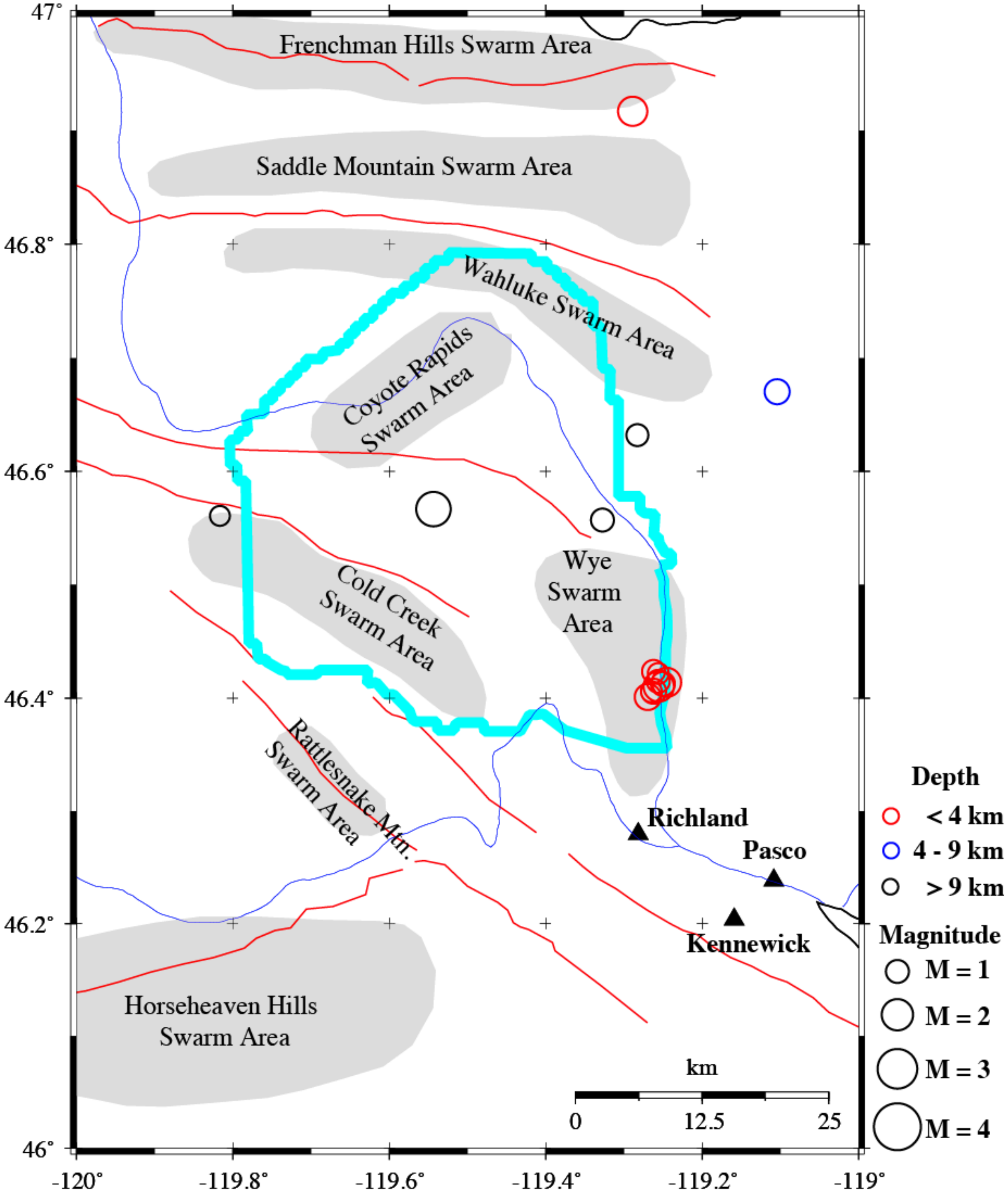

*Figure 4.2 Epicenters of earthquakes occurring during the 2nd Quarter of FY2012 in the vicinity of the Hanford site (blue outline), and their relationship to known structures (red lines), swarm areas (shaded regions), and cultural features and cities (black triangles). Circles are earthquake epicenters, 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.*

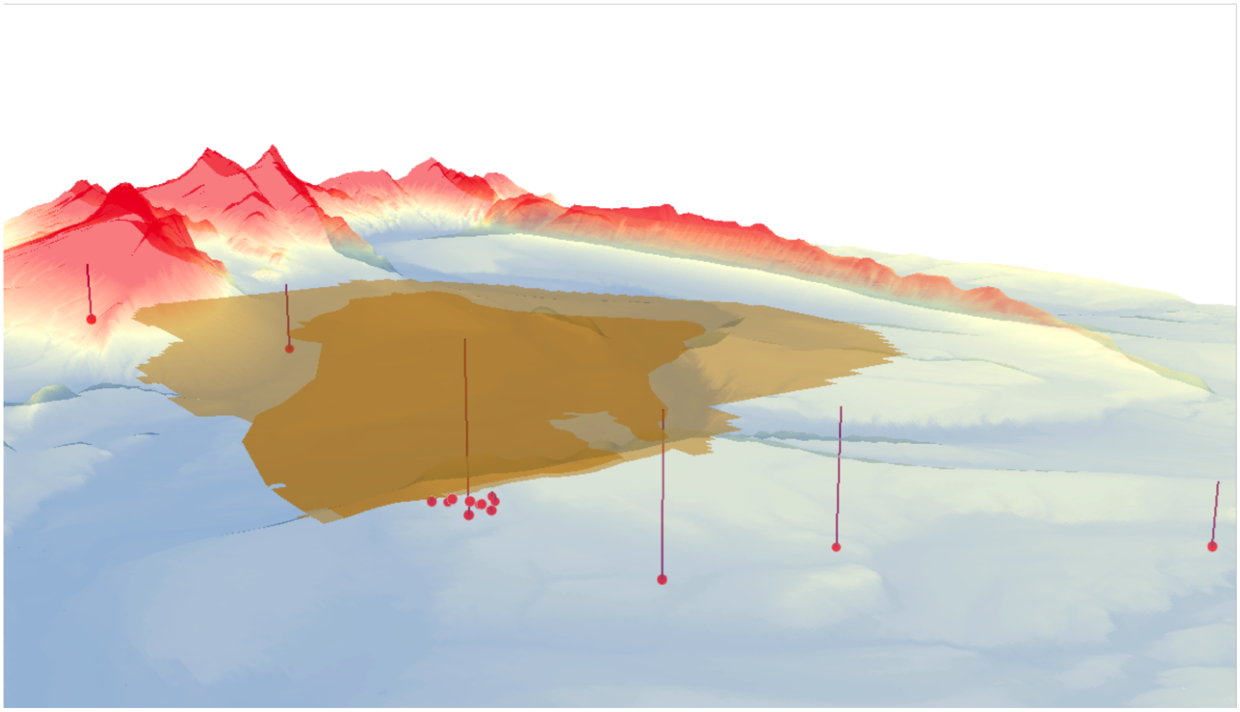

Figure 4.3 Perspective plot showing topography (exaggerated) and hypocenters (red dots, connected to epicenter with fine vertical line) of earthquakes occurring during the 2^{nd} Quarter of FY2012 in the vicinity of the Hanford site, both overall (lightly shaded region), and inner (darker shading). Probable blasts are not shown in this figure.

Table 4.2 Summary Table of the Distribution of Earthquakes for 2nd Quarter, FY 2012

Event Category		2nd Quarter	
		Hanford	Region
Depth	< 4 km	10	5
	4-9 km	1	5
	>9 km	4	8
Sub-total		15	18
Total		33	
Geographic Area	FHS	0	0
	SMS	0	0
	WAHS	0	0
	CRS	0	0
	CCS	1	0
	WYES	9	0
	RMS	0	0
	Horse Heaven Hills	0	0
	Structure	1	0
Random Event		5	0
Sub-total		16	0
Total		16	0
Felt		0	0
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. No earthquakes of significance took place in the EWRSN region during the first three months of 2012.

5.2 Notable Earthquakes

The most notable earthquake was the 24.6 km deep, Md=2.4, earthquake on the 7th of January 2012. This was not only one of the largest events of the quarter, but also reminded us of the potential for even larger earthquakes on the Hanford site. This earthquake was directly beneath area 200E. Figure 5.1 shows the waveforms on the event page at www.pnsn.org. The focal mechanism suggests a reverse sense of slip on a WNW-striking fault, *i.e.,* resulting from NNW-oriented horizontal compression (http://www.pnsn.org/event/60379986#technical-data). So the earthquake probably took place on a fault that participates in the regional fold-and-thrust tectonics of the area. Ground motions were quite weak on the site, despite the earthquake's proximity. One reason, of course, is that it is quite a small earthquake. Another reason is that the earthquake was quite deep, so that even station H2E, pretty much directly above the earthquake, was almost 25 km removed from the buried source. However, Figure 5.2 reveals another interesting observation: ground motions appear to have been larger locally, as gauged by their emergence from the seismic background noise, as one gets farther from the earthquake. We suspect this is a combined effect of the focal mechanism and the geometry of the stations, such that stronger (particularly shear wave) radiation was directed toward these stations.

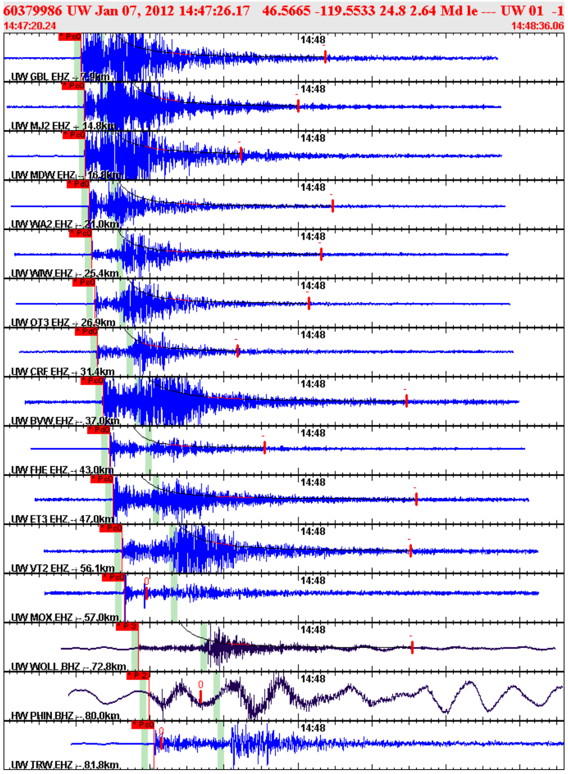

Figure 5.1 Waveforms for the 7 January, 2012 M=2.4 earthquake on the Hanford site. This well-recorded earthquake was located using 31 phases timed from 21 stations in the seismic network. These waveforms were used by the automatic location algorithm in AQMS that provided a location within 2 minutes of the earthquake origin time.

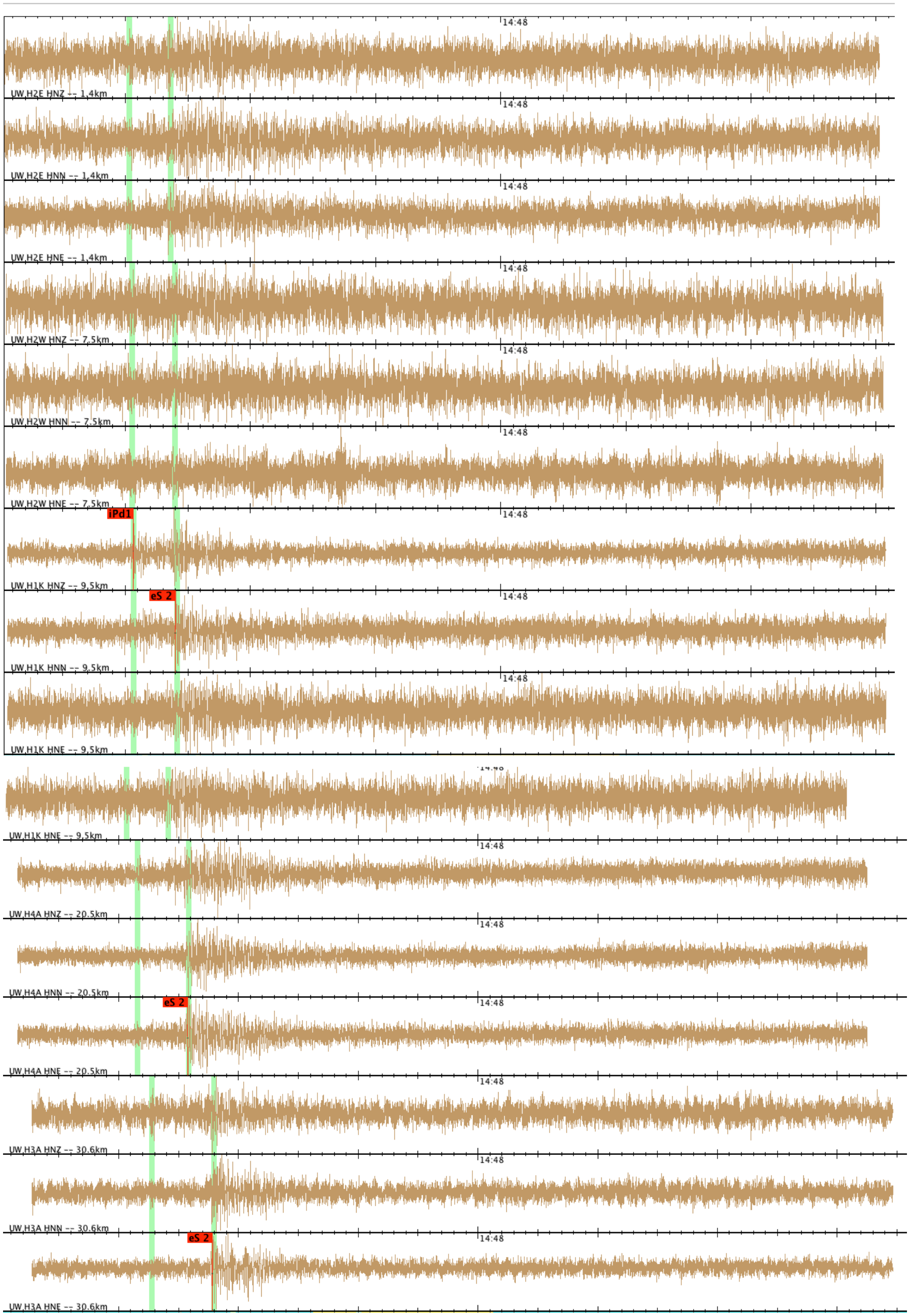

Figure 5.2 Waveforms from HSN strong motion stations on the Hanford site for the 7 January 2012 M2.4 earthquake. Note the emergence of signal from background noise for stations H4A and H3A at a distance of 20.5 and 30.6 km from the earthquake (bottom 6 traces), while for the other 3 stations (all within 10 km of the earthquake) the waves are difficult to detect in these raw accelerograms. The traces must be filtered to see the earthquake. Data channels are individually labeled at lower left of trace. Red "flags" reveal analysts' phase picks used to locate the earthquake. Vertical green bands show predicted phase arrival times from the earthquake location, using the E3 velocity model.

6.0 References

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