

Pacific Northwest Seismograph Network Operations  
1434-92-A-0963 R.S. Crosson, S.D. Malone and A.I. Qamar, P.I.s

1994

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Oct. 1, 1993 - Sept. 30, 1994

Operation of 96 stations west of 120 degrees west longitude by the Pacific Northwest Seismograph Network (PNSN) (formerly known as the Washington Regional Seismograph Network or WRSN), and preliminary analysis of earthquakes in Washington and Oregon are funded under this agreement. In addition to monitoring earthquake activity, the PNSN provides earthquake and earthquake hazards information to emergency managers, the press, and the public.

The PNSN processed 8,457 events between Oct. 1, 1993 and Sept. 30, 1994. Of these, 7,588 were earthquakes or blasts within the network (1,701 of which were too small to locate). The remaining events were regional earthquakes (274) or teleseisms (595). Within our network area, 5,305 earthquakes were located west of 120.5 degrees west longitude, (including 383 near Mount St. Helens, which has not erupted since 1986), and 187 east of 120.5 degrees west longitude.

During this reporting period there were 21 earthquakes reported felt west of the Cascades, and 4 reported felt east of the Cascades. The largest earthquake was magnitude 5.1, and occurred on December 4, 1993 (22:15 UCT) near Klamath Falls, Oregon. This was the largest aftershock following a main-shock pair (magnitudes 5.9 and 6.0) on September 21, 1993 (UCT). The sequence, which had diminished rapidly after the September, 1993 mainshocks, resurged following the December 4 aftershock. Following the December 4 aftershock, five additional shocks of magnitude 4 or larger in the Klamath Falls area followed during December 1993 and January 1994, and smaller earthquakes continued throughout this reporting period.

Two other notable felt earthquakes, magnitudes 4.0 and 4.3, occurred within a few days of one another in June. The earlier event, on June 15 at 8:22 UCT, was a deep earthquake (about 45 km) west south-west of Bremerton, Washington. It was widely felt around the south Puget Sound region. Earthquakes of this type (deeper than 30 km and within the subducting Juan de Fuca plate) are well known, and include the damaging earthquakes of 1949 and 1965 (magnitudes 7.1 and 6.5 respectively). Magnitude 4 or larger earthquakes within the subducting plate have occurred about every two years, on average, since 1970. The other earthquake, magnitude 4.3 on June 18th at 07:01 UCT, was located near Skykomish, Washington with an estimated depth of 6 km, and was followed by 8 aftershocks within the next few days. This event was unusual because, historically, Skykomish is not known to be the source of any significant earthquakes, and no other felt earthquakes, nor any larger than magnitude 2.5, have been located within 10 km of the mainshock since we began locating earthquakes with our regional network in 1970.

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### Investigations

Operation of the Pacific Northwest Seismograph Network (PNSN) (formerly known as the Washington Regional Seismograph Network or WRSN) and preliminary analysis of earthquakes in Washington and Oregon continues under this agreement. Quarterly bulletins which provide operational details and descriptions of seismic activity in Washington and Oregon are available from 1984 through the third quarter of 1994. Final published catalogs are available from 1970, when the network began operation, though 1989.

The University of Washington operates 96 stations west of 120 degrees west longitude under this agreement. This report includes a brief summary of significant seismic activity. Additional details are included in our Quarterly bulletins.

### Information - Emergency Notification and Public Education and Outreach

In addition to monitoring earthquake activity in Washington and much of Oregon, the staff of the PNSN participates in outreach projects to inform and educate the public about seismicity and natural hazards. Our outreach includes lab tours, lectures, educational classes and workshops, TV and radio interviews, field trips, and participation in regional earthquake planning efforts. We answer from 5-40 questions per day on Pacific Northwest seismicity and seismic hazards, and give about a half-dozen lab tours or presentations each month for a wide variety of groups, including elementary through post-graduate students, retirees, science teachers, emergency educators, and many others. We provide a taped telephone message describing the seismic hazards in Washington and Oregon and a separate taped message on current seismic activity ((206) 543-7010). Both these services are heavily used. We provide a one-page information and resource sheet on seismic hazards in Washington and Oregon that we encourage others to reproduce and further distribute.

For significant local events, our automatic processing includes an alarm that initiates electronic mail (e-mail) or faxes to local emergency response agencies, operators of adjacent seismograph networks, and the National Earthquake Information Center in Colorado. When the event has been fully processed, updated final information on it is also faxed or e-mailed.

Locations of recent earthquakes of magnitude 2 or larger can be obtained via modem by dialing (206)685-0889 and logging in as **quake** with password **quake**, by sending e-mail to **quake@geophys.washington.edu** or via ethernet using the UNIX utility **finger quake@geophys.washington.edu**. Summary lists for all earthquakes located by the PNSN since 1969 are available via anonymous ftp on **ftp.geophys.washington.edu** in the *pub/seis\_net* sub-directory. In addition, special sub-directories; *pub/kfalls* and *pub/woodburn*; include locations, focal mechanisms, and local station lists for the Klamath Falls and Scotts Mills, Oregon earthquake sequences. This information is also available via the **World-Wide-Web (WWW)** which provides text and graphics for anyone connected to the Internet running a version of "Mosaic" (available for workstations, PC-Windows, and Macintoshes with anonymous ftp at **ftp.ncsa.uiuc.edu**). Our **WWW** server contains text about earthquakes in the Pacific Northwest, maps of stations, catalogs and maps of recent earthquake activity, and maps and text about recent interesting sequences. It

also contains links into other sources of earthquake information around the country and world. To access it use mosaic <http://www.geophys.washington.edu>.

Seismic trace data are being reformatted to the IRIS-SEED format, and submitted to the IRIS Data Management Center, where they will be made available over Internet through the IRIS database system. We have also recently acquired a very large (18 gigabyte) on-line storage disk, which will allow us to store all PNSN digital seismic trace data (since 1980).

### Network Operations

A station map and a discussion of recently installed three-component broad-band instrumentation is included in the summary for agreement 1434-92-G-2195.

This year, we modified both our seismic trace data and pickfile (phase arrival times) formats (and associated data-processing software). The old formats, in use since 1980, did not allow broad-band data to be merged into our network data stream. The modifications were developed and tested in the context of SNAPS (Seismic Network Automated Processing System), a software package for processing network data that allows automated processing steps to be integrated with steps controlled by an analyst.

Our new working seismic trace data format (UW-2) allows us to accommodate data of varying durations, sample rates, start times, and formats; is extensible without affecting existing processing programs; and is backward-compatible with our original (UW-1) format. Conversion programs allow easy conversion between UW-2 and other commonly used trace-data formats such as AH and SEED. The new UW-2 pickfile format provides full support for three-component stations, flexibility to represent arbitrary phase types (our old UW-1 format could only represent P and S phases) such as Pn and PmP, and a number of other advantages, and is also backward compatible. Interactive viewing of both trace and pickfile data is provided through *Xped* (X pick editor), an X window application that allows the user to display trace and pick information, modify picks, run location programs, and perform other data analysis functions.

In addition to the extensive modifications of data-processing software required by the change to UW-2 data formats, we are also updating our data acquisition hardware and software. Since 1988, we have used a Concurrent 5600 computer running *HAWK* software, a derivative of the *CEDAR* system developed at Cal Tech by Carl Johnson. Now, in 1994, rapid advances in computer speed enable us to enhance and streamline data acquisition while lowering our computer costs. The new data acquisition software is called *SUNWORM*. It is being developed in cooperation with the *EARTHWORM* project at the USGS in Menlo Park, and is currently running in test mode on a SUN-SparcStation-5 workstation. *SUNWORM* will replace the *HAWK* system by the end of 1994.

### Seismicity

Figure 1 shows earthquakes of magnitude 2.0 or larger located in Washington and Oregon during this reporting period. The PNSN processed 8,457 events between Oct. 1, 1993 and Sept. 30, 1994. Of these, 7,588 were earthquakes or blasts within the network (1,701 of which were too small to locate). The remaining events were regional earthquakes (274) or teleseisms (595). Within our network area, 5,305 earthquakes were located west of 120.5 degrees west longitude, (including 383 near Mount St. Helens, which has not erupted since 1986), and 187 east of 120.5 degrees west longitude.

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Articles on the Klamath Falls, Oregon sequence have been published in the USGS publication **Earthquakes and Volcanos** (Vol. 24, No. 3, 1993) which can be ordered from: USGS Map Distribution, Box 25286, Bldg. 810, Denver Federal Center, Denver, CO 80 225.

<b>Month</b>	<b>Number of events</b>
September, 1993	105
October, 1993	16
November, 1993	12
December, 1993	112
January, 1994	110
February, 1994	11
March, 1994	15
April, 1994	12
May, 1994	10
June, 1994	6
July, 1994	3
August, 1994	4
September, 1994	1
October, 1994	1

Two other notable felt earthquakes, magnitudes 4.0 and 4.3, occurred within a few days of one another in June and are apparent in Fig. 1. The earlier event, on June 15 at 8:22 UCT, was a deep earthquake (about 45 km) west south-west of Bremerton, Washington. It was widely felt around the south Puget Sound region. Earthquakes of this type (deeper than 30 km and within the subducting Juan de Fuca plate) are well known, and include the damaging earthquakes of 1949 and 1965 (magnitudes 7.1 and 6.5 respectively). Magnitude 4 or larger earthquakes within the subducting plate have occurred about every two years, on average, since 1970 (preceeding this event, the last such earthquakes were in 1989, when two deep events larger than magnitude 4 occurred). The other earthquake, magnitude 4.3 on June 18th at 07:01 UCT, was located near Skykomish, Washington with an estimated depth of 6 km, and was followed by 8 aftershocks within the next few days. This event was unusual because, historically, Skykomish is not known to be the source of any significant earthquakes, and no other felt earthquakes, nor any larger than magnitude 2.5, have been located within 10 km of the mainshock since we began locating earthquakes with our regional network in 1970.

PNSN Quarterly Reports for 1994 have included moment-tensor focal mechanisms for earthquakes larger than magnitude 3.5. These have been provided to us by Dr. John Nabelek of Oregon State University (OSU) under support from USGS NEHRP Grant 1434-93-G-2326. OSU also provides broad-band data from station COR, which we archive with our trace-data files. The University of Oregon (UO) also provides broad-band data (from stations PIN and DBO), which is likewise archived.

#### **Reports and Articles**

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- Jonientz-Trisler, C. B. Myers, and J. Power, 1994, Seismic identification of gas-and-ash explosions at Mount St. Helens: capabilities, limitations, and regional application, in *Proceeding Volume, First International Symposium on Volcanic Ash and Aviation Safety*, T.J. Casadevall, editor, USGS Bulletin 2047.
- Ludwin, R.S., A.I. Qamar, S.D. Malone, C. Jonientz-Trisler, R.S. Crosson, R. Benson, and S. Moran, 1994, Earthquake Hypocenters in Washington and Northern Oregon, 1987-1989 and the Washington Regional Seismograph Network; Operations and Data Processing, Washington State Dept. of Natural Resources, Information Circular 89, 40 p.
- Ludwin, R.S., A.I. Qamar, S.D. Malone, R.S. Crosson, S. Moran, G.C. Thomas, and W.P.

- Steele (in preparation), Earthquake Hypocenters in Washington and Oregon, 1990-1994, Washington State Dept. of Natural Resources Information Circular
- Qamar, A.I. and K. L. Meagher, 1993, Precisely Locating the Klamath Falls, Oregon, Earthquakes, Earthquakes and Volcanos, V. 24, N. 3, pp. 129-139.
- Thomas, G.T, and R.S. Crosson, (in preparation), The 25 March 1993 Scotts Mills, Oregon earthquake and aftershock sequence; spatial distribution, focal mechanisms, and the Mount Angel Fault Zone, to be submitted to BSSA.
- Univ. of Wash. Geophysics Program, 1994, Quarterly Network Reports; 93-D, 94-A,94-B, and 94-C; Seismicity of Washington and Western Oregon
- Wiley, T.J., D.R. Sherrod, D.K. Keefer, A.I. Qamar, R.L. Schuster, J.W. Dewey, M.A. Mabey, G. E. Black, and R.E. Wells, 1993, Klamath Falls earthquakes, September 20, 1993 - including the strongest quake ever measured in Oregon, Oregon Geology, Vol. 55, No. 6, pp. 127-134.

#### Abstracts

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- Ludwin, R.S., S.D. Malone, A.I. Qamar, and R.S. Crosson, 1993, Operation of the Washington Regional Seismograph Network, Seis. Res. Lett., V. 64, No. 3, p. 262.
- Malone, S.D., 1994, A review of seismic data access techniques over the Internet, EOS, Vol. 75, Supplement to No. 44, p. 429.
- Moran, S.C., and S.D. Malone, 1994, A Seismic refraction profile across the central Washington Cascades: Preliminary Results, EOS, Vol. 75, Supplement to No. 44, p. 621.
- Qamar, A.I., and K.L. Meagher, 1993, The 1993 Klamath Falls, Oregon Earthquake Sequence, Special Session, Fall 1993 AGU meeting at-meeting program, p. 219.

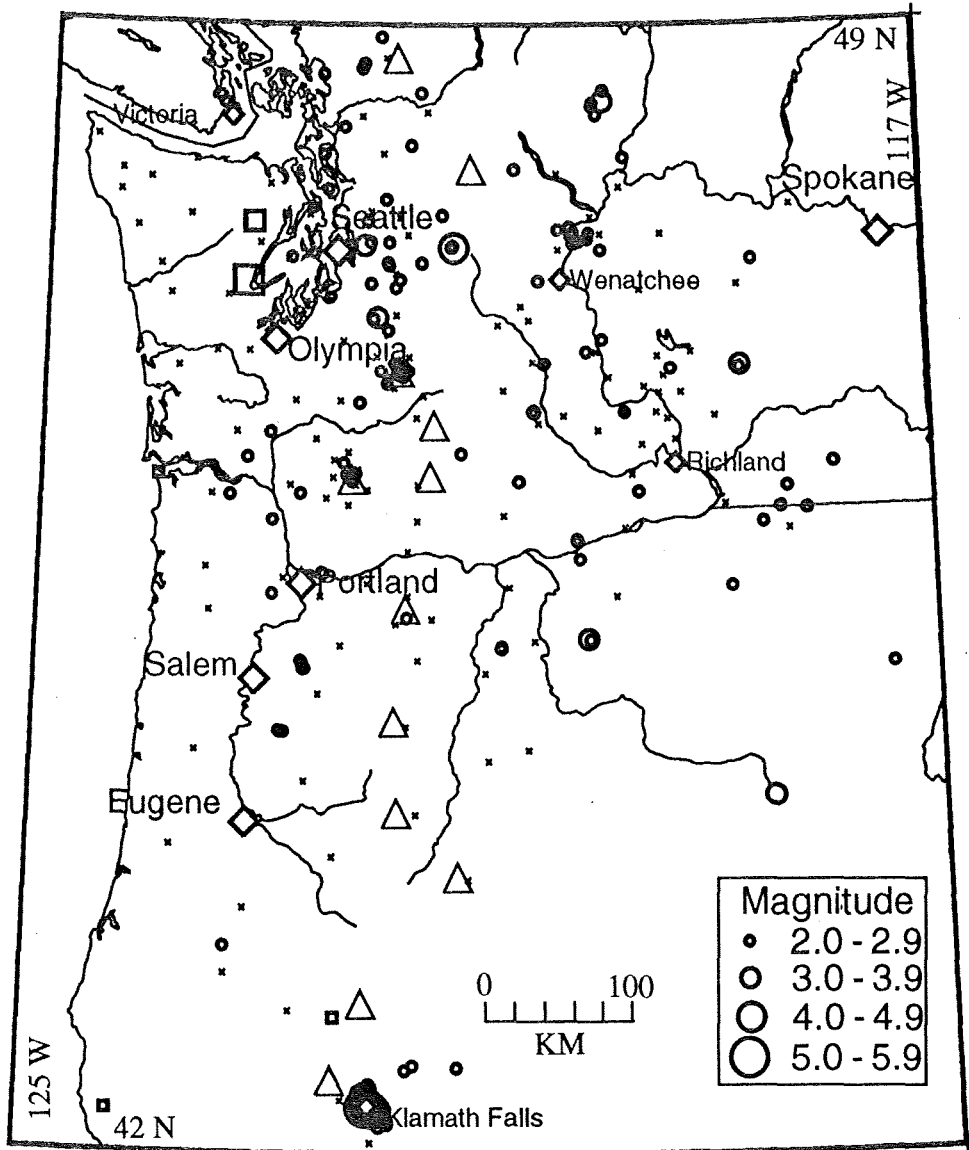


Figure 1. Earthquakes larger than magnitude 2.0 between Oct. 1, 1993 and Sept. 30, 1994. Locations of a few cities are shown as white-filled diamonds. Earthquakes are indicated by filled circles or squares; circles represent earthquakes at depths shallower than 30 km, and squares represent earthquakes at 30 km or deeper. Small "x" symbol indicate locations of seismometers operated by the PNSN at the end of Sept. 1994. More information on stations is included in the report on grant 1434-92-G-2195 in this volume.