FINAL TECHNICAL REPORT

Cooperative Regional/Urban Seismic Monitoring—Wasatch Front, Utah, and Neighboring ANSS-Intermountain West Area

February 1, 2007–January 31, 2010

U.S. Geological Survey Cooperative Agreement No. 07HQAG0022

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ANSS Region:	Intermountain West Region

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ABSTRACT

This report is the final technical report for USGS Cooperative Agreement No. 07HQAG0022, covering the period from February 1, 2007, through January 31, 2010. This cooperative agreement, combined with funding from the State of Utah, provided major support for the operation of (1) the University of Utah Seismograph Stations' (UUSS) regional and urban seismic network, an ANSS Tier-1 network, and (2) a regional earthquake-recording and information center on the University of Utah campus in Salt Lake City.

On January 31, 2010, UUSS operated and/or recorded 247 stations (49 broadband, 99 strong-motion, and 99 short-period, with some stations having multiple sensor types); a total of 649 channels were being recorded. Of the 247 stations, 129 stations (378 channels) were operated and maintained in the Utah region (36° 45'–42° 30' N, 108° 45'–114° 15' W) with full or partial support from the USGS as part of the Advanced National Seismic System (ANSS). These include 14 broadband stations, 81 strong-motion stations, and 34 short-period stations. USGS support is focused on the seismically hazardous Wasatch Front urban corridor of north central Utah but also encompasses neighboring areas of the Intermountain Seismic Belt.

At the beginning of the report period, we operated and maintained 127 stations in the Utah region with full or partial support from ANSS. The change to 129 stations by the end of the report period does not include 20 new ANSS-contributing stations added with state funds in earthquake-prone parts of southwestern and central Utah. The additions include 12 urban strong-motion stations, notably in the rapidly growing St. George and Cedar City areas, and eight broadband/strong-motion regional stations. Also during the report period, Transportable Array (TA) stations of EarthScope's USArray rolled through Utah. While they were operating, we recorded up to 84 TA stations within or near our study region and integrated these data into our routine earthquake processing. We adopted three TA stations with non-USGS funds and now operate them as ANSS-contributing stations. We also adopted four strategically located TA vaults for future ANSS use.

A significant episode of development, modernization, and expansion (DME) of our regional/urban seismic network occurred during the report period. A total DME investment of $2.7 million—chiefly with private and state funds—was made in space, furnishings, and equipment to: (1) create a modern earthquake information center and seismically hardened, state-of-the-art facilities for network operations in a new building; (2) restructure our network's telemetry architecture to ensure continuity of operations; (3) and expand seismic instrumentation and capabilities for providing real-time earthquake information products outside the Wasatch Front area. Of the $2.7 million DME investment, 62 percent came from private funds, 33 percent from state funds, and 5 percent from federal funds (including 2.3 percent from ANSS). The next major DME step for our network, now under way from October 2009 to September 2011, will be made with USGS funding under the American Recovery and Reinvestment Act. In the Utah region, we will upgrade 24 existing ANSS stations (10 broadband and 14 short-period) and install triaxial accelerographs in four adopted TA vaults to create new UUSS-ANSS cooperative stations.

Other notable accomplishments during the report period (not an exhaustive list) included: (1) taking steps toward greater coordination with the USGS National Earthquake Information Center in terms of continuity-of-operations planning, post-event coordinated response, and post-event coordination of field recording; (2) starting the upgrading of our UUSS data-processing systems to the ANSS Quake Monitoring System (AQMS); (3) collaborating with the USGS in using spatial autocorrelation of noise to characterize site amplification in urban areas in Utah; (4) responding to and studying the August 2007 Crandall Canyon Mine disaster; (5) improving the monitoring of mining-induced seismicity in Utah to aid

mine safety; (6) collaborating with scientists from Southern Methodist University in seismo-acoustic studies of data from three permanent infrasound arrays in the Wasatch Front area; (7) partnering with the Utah Division of Homeland Security and FEMA Region VIII to enhance the use of ShakeMap and derivative products by emergency managers in Utah; (8) coordinating, planning, and becoming involved in the initial field deployment of instruments in the epicentral area of the M6.0 Wells, Nevada, earthquake in February 2008 (because the earthquake was closer to Salt Lake City than Reno); (9) contributing significantly to creating a Utah version of *Putting Down Roots in Earthquake Country* for local earthquake awareness; and (10) participating in many ANSS implementation activities—local, regional, and national.

Additionally, we reported our work relating to seismic monitoring and associated earthquake research in Utah (including collaborative work in seismo-acoustic monitoring, remote earthquake triggering, and studies of mining-induced seismicity) in more than 50 reports, abstracts, and scientific articles. This includes papers (either published or submitted) describing (a) seismicity and seismotectonics in central and western Utah, (b) use of ANSS strong-motion data to analyze small local earthquakes, (c) local magnitude determinations for earthquakes in our study region using broadband digital data, (d) a detailed seismological report on the August 2007 Crandall Canyon Mine collapse in Utah, (e) improving spatial resolution of mining-induced seismicity in Utah with double-difference relocations, (f) studies of the 2008 Wells, Nevada, earthquake sequence and associate ground motions, and (g) seismo-acoustic monitoring of explosions and earthquakes in Utah.

During the three-year period January 2007–December 2009, we detected and analyzed nearly 22,000 seismic events, including local earthquakes, teleseismic and regional earthquakes, and blasts. Approximately 13,000 earthquakes were located within and near our regional seismic network—including 7,330 within the Utah region, of which 5,943 were within the Wasatch Front area (38° 55'–42° 30' N, 110° 25'–113° 10' W). Thirty-eight earthquakes of magnitude 3.0 and larger occurred in the Utah region during the report period, and 35 earthquakes were documented as felt. The largest earthquake was a shock of magnitude (M_L) 4.0 that occurred at 21:47 UTC on June 3, 2009, 8 km (5 mi) northwest of Garland, Utah.

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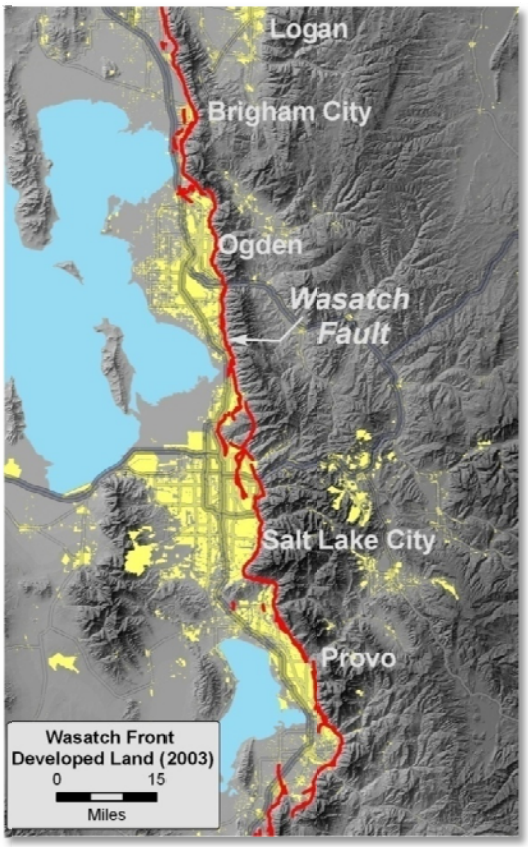
INTRODUCTION

This final technical report summarizes network-related activities and accomplishments during the three-year period of this cooperative agreement from February 1, 2007 through January 31, 2010. Annual reports were previously submitted to the USGS for Year One on December 13, 2007, and for Year Two on December 12, 2008. In this report, we give an overview for the three-year period, without attempting to repeat all details included in the earlier reports.

General Background

This cooperative agreement, combined with funding from the State of Utah, provided major support for the operation of (1) the University of Utah Seismograph Stations' (UUSS) regional and urban seismic network (Figs. 1 and 2), an ANSS Tier-1 network, and (2) a regional earthquake-recording and information center on the University of Utah campus in Salt Lake City.



At the end of January 31, 2010, UUSS operated and/or recorded 247 stations; a total of 649 data channels were being recorded (more detail is provided in a later section). USGS support is focused on the seismically hazardous Wasatch Front urban corridor of north central Utah (inset, right), but also encompasses neighboring areas of the Intermountain Seismic Belt. State funds contribute significantly to network-operation costs in the Wasatch Front area, and they support network operations in Utah outside this area.

Earthquake Hazard and Risk in Our Study Region

Earthquakes pose the greatest natural threat for destruction of life and property in Utah. On a national level, the relative hazard and risk of Utah's Wasatch Front area led the USGS to target it for an urban strong-motion network of 500 instruments in its 1999 report to Congress for an Advanced National Seismic System (ANSS) (USGS, 1999). Nearly 80 percent of our state's population of 2.7 million and more than 75 percent of Utah's economy are concentrated in the Wasatch Front area, literally astride the five most active segments of the Wasatch fault (inset, above). During the past 6,000 years, at least 20 surface-faulting earthquakes have occurred on these five segments between Brigham City and Nephi, just below the edge of the figure (Utah Seismic Safety Commission, 2008). One of the most active segments is the Salt Lake City segment, which has produced large, M~7, surface-faulting earthquakes on the average of 1,300 ± 400 years during the past 5,300 years, with the last one occurring 1,300 ± 650 years ago (see Lund, 2005). Loss estimates for a scenario M7 earthquake on the Salt Lake City segment include $42 billion in building losses and 9,000 life-threatening injuries and fatalities (Utah Seismic Safety Commission, 2008).

Partnerships

State-federal — The state of Utah provides nearly half of the support for seismic network operations and associated earthquake research in the Utah region. Under this long-standing state-federal partnership, USGS support is focused on the seismically hazardous Wasatch Front urban corridor of north central Utah but also encompasses neighboring areas of the Intermountain Seismic Belt. About half of the annual funding from the state of Utah contributes to seismic-network operations in the Wasatch Front area; the remainder, towards network operations in Utah outside the Wasatch Front area and for general earthquake research in Utah. Separate support is provided to the University of Utah by the USGS Volcano Hazards Program for the Yellowstone seismic network; the latter support typically represents less than 10 percent of our total UUSS budget for seismic network operations.

The strength of the combined state-federal funding of our network is that it allows us to balance the practical necessities of a regional seismological approach (Fig. 1) along with careful attention to Utah's urban corridor. Federal funding also gives us essential flexibility to respond to and study significant earthquakes in other parts of the ISB outside of Utah, where our state funds can't appropriately be used. We routinely monitor virtually the entire ISB from Yellowstone National Park to the Utah-Arizona border (Fig. 1). However, our responsibility for producing earthquake catalogs is limited to the Utah and Yellowstone regions.

Institutional & Private — The University of Utah has a longstanding and ongoing commitment to support seismic monitoring sponsored by the USGS under this cooperative agreement and earlier agreements dating back to the 1970s. An indication of the University's commitment to partnership was providing seismically strengthened space for our seismic-network operations in the new Frederick A. Sutton Building (inset, upper right), designed for the Department of Geology and Geophysics and completed in early 2009. Kennecott Utah Copper, part of the global Rio Tinto Company, generously donated $600,000 for creating a state-of-the art earthquake information center in the new building. Two thirds of the donation went toward space costs and the rest for equipment and technologies.

Host facilities for seismic instrumentation — Currently, 83 siting partners (listed in Appendix A) are providing host facilities and/or space for the operation of ANSS seismic instrumentation and communications equipment in Utah, predominantly for urban strong-motion monitoring in the Wasatch Front area. These include: 44 cities, towns, and counties; 18 school districts and institutions of higher education; and 21 other private and public partners ranging from the Church of Jesus Christ of Latter-Day Saints to the Utah Highway Patrol. Some of the partners are providing free access to their communication networks. Dozens of other private individuals graciously allow use of their land for instrument siting. In-kind financial support provided by these partners is estimated to be about $10,000 annually.

Contributions and Benefits to NEHRP

Both NEHRP and the USGS benefit greatly from this ongoing project in the form of (a) significant sharing of costs by the state of Utah under this state-federal partnership and (b) wide-ranging activities by the University of Utah seismologists, which effectively relieve the USGS from having to meet the same first-order needs in this region. (Unlike other NEHRP focus regions such as southern and northern California, the Pacific Northwest, and New Madrid, there are no collocated USGS earthquake scientists here.) Data and information from our regional/urban network provide essential underpinnings for earthquake engineering, emergency response, and science in our region. The USGS also benefits from the

leadership role we are playing in implementing ANSS both in the Intermountain West region and nationally.

Information products and services produced under this cooperative agreement include:

- rapid earthquake alerts
- a Web site with near-real-time earthquake information
- earthquake catalogs (issued on a quarterly basis in preliminary form and periodically in finalized form)
- automated transfer of hypocenters, waveforms, arrival-time data, and ShakeMaps to other outlets prescribed by the USGS for broad access, and
- extensive expert assistance to individuals and groups in earthquake education and awareness, public policymaking, planning and design, and hazard and risk assessment

(see Appendix C for more details on our network's products and services).

Scientific contributions from our seismic monitoring include the characterization of tectonic framework and earthquake potential, surveillance of space-time seismicity and characteristics of small-to-moderate earthquakes (for understanding the nucleation of large earthquakes in the region), improved ground-motion modeling for engineering applications, and the documentation and evaluation of various earthquake-related parameters for accurate hazard and risk analyses. Some of our scientific results are reported to the USGS under separate research awards.

UNIVERSITY OF UTAH REGIONAL/URBAN SEISMIC NETWORK

Network Overview

Figures 1 and 2 together with Tables 1 and 2 and Appendix B summarize essential information for the University of Utah's urban/regional seismic network. The regional distribution of conventional broadband and short-period stations is effectively shown in Figure 1. Figure 2 shows our real-time urban strong-motion network in the Wasatch Front urban corridor and in the SW Utah. A representative seismicity map of the Utah region for the period January 1, 2007–December 31, 2009, is shown in Figure 3.

- **247** — Number of stations (649 channels) we operate and/or record (Table 1): 49 broadband (BB), 99 strong-motion (SM), and 99 short-period (SP) stations, with some stations having multiple sensor types.
- **205** — Number of stations (571 channels) we operate and maintain (Table 1): 31 BB, 99 SM, 75 SP stations. All data are contributed to ANSS. We import data from 42 stations (78 channels) and, excluding data export to the IRIS DMC, we export data from 98 stations (194 channels) to other seismic networks and NEIC.
- **129 —** Number of stations (378 channels) <u>we operate and maintain with full or partial ANSS support</u> (Table 2): 14 BB, 81 SM, and 34 SP stations. Currently, all our ANSS O&M stations are within the Utah region.

Summary of Recorded Seismicity

During the three-year period January 2007–December 2009, we detected and analyzed nearly 22,000 seismic events, including local earthquakes, teleseismic and regional earthquakes, and blasts. Approximately 13,000 earthquakes were located within and near our regional seismic network—including 7,330 within the Utah region, of which 5,943 were within the Wasatch Front area (38° 55'–42° 30' N, 110° 25'–113° 10' W). Thirty-eight earthquakes of magnitude 3.0 and larger occurred in the Utah region during the report period, and 35 earthquakes were documented as felt. The largest earthquake was a

shock of magnitude (M_L) 4.0 that occurred at 21:47 UTC on June 3, 2009, 8 km (5 mi) northwest of Garland, Utah.

From January 1, 2007 through December 31, 2009, thirty five earthquakes in the Utah region were documented as felt and/or generating a ShakeMap (Table 4). During this same period, we issued fourteen press releases immediately after earthquakes in the Utah region that were either felt by many or were larger than a set threshold magnitude of 3.5. Mining-induced seismicity accounted for about 69 percent of the earthquakes located in the Utah region during this period. A total of 5,080 shocks ($M \leq 3.9$) were located in known areas of underground coal-mining within an arcuate zone extending counterclockwise from east of Price to 100 km southwest of it (Fig. 3).

ANSS PERFORMANCE

Data Management Practices

Data management practices in our regional/urban seismic network are consistent with ANSS data policy, and we have agreed to adhere to the "Advanced National Seismic System Elements of Data Policy" adopted by the ANSS National Implementation Committee in December 2003. In particular:

- All digitally-recorded waveforms from stations we maintain and operate (channel types EH, EN, HH, HN, EL) are archived at the IRIS DMC. From 1981 to the beginning of continuous archiving, the archived waveforms are the recorded segments containing seismic events.
- Continuous archiving of waveform data at the IRIS DMC from our broadband stations began on June 19, 2001, and from our strong-motion stations on April 19, 2001. Since June 2002, continuous waveform data from all stations we maintain and operate (EH, EN, HH, HN, EL) have been submitted to the IRIS DMC on a daily basis. Currently, the IRIS DMC retrieves data from our Earthworm System wavetanks several times per day.
- All UUSS instrument responses, dating back to the start of digital recording in 1981, are archived at the IRIS DMC in SEED format.
- All UUSS station locations are available at the IRIS DMC and at http://www.seis.utah.edu/EQCENTER/QUARTERLY/quarterly.htm as part of our quarterly reports.
- For our UUSS strong-motion stations, information including site-class, building type, and telemetry are available at http://www.seis.utah.edu/urban/smstations.shtml
- Our standard practice is to calibrate new and changed broadband stations with a step-function calibration (Guralp models following Pechmann et al., 1999), before including their responses in a dataless SEED volume. For the Kinemetrics K2s, we use a calibration procedure similar to that for the broadband instruments. For all other strong-motion stations, we develop the response files using information provided by the manufacturers and verify that the response remains stable by comparing repeated step-function tests. Response files for the analog stations are constructed from the nominal responses for each individual component; some *in situ* calibrations were done on analog telemetry stations using a random binary sequence method (Berger et al., 1979).
- Our network promptly reports automated and analyst-reviewed earthquake locations into the QDDS (we recently moved to EIDS); earthquake catalog updates are automatically submitted to the CNSS/ANSS catalog four times per day (Monday through Friday).
- The automatic locations and magnitudes are very reliable for real earthquakes. However, we generate a few false alarms per year, and closely spaced events are not always distinguished.

- ShakeMaps are posted to both our Web site and the USGS Web site within 7 to 9 minutes of the event and JPEG images of the intensity maps are emailed to critical users within this same time window.

All seismic waveform data archived by the University of Utah Seismograph Stations can be retrieved from the IRIS DMC (for information about data availability and request tools please check the IRIS webpage at http://www.iris.edu/data/). Alternatively, the data can be obtained upon request directly from our office (typically delivered to the user in SAC ASCII or binary format). Earthquake catalog data for the Utah region are available (1) by e-mail request to webmaster@seis.utah.edu, or (2) via the Advanced National Seismic System's composite earthquake catalog, <http://www.ncedc.org/anss/catalog-search.html>. See also the University of Utah Seismograph Stations homepage at http://www.seis.utah.edu. The contact person for data requests is Relu Burlacu, tel: (801) 585-7972; e-mail: burlacu@seis.utah.edu.

Continuity of Operations and Response Planning

Beginning in 2007, we have developed a formal plan for continuity of operations. The plan can be divided into two parts: (1) continuity of data collection and (2) continuity of routine and response operations. To improve data recovery, the entire schema for our seismic network has been redesigned. The major changes include digitizing the analog stations at mountaintops, collecting the digital data at six data collection nodes dispersed throughout the state, and pulling all data to both the University of Utah and to a hot site in a state-owned backup facility in Richfield, Utah. Data transmission from the nodes and hot site is done through the State of Utah microwave network (internet protocol) and the Utah Education Network. The next step in our planning is to send all data to NEIC from either or both the University of Utah and the hot site. We have been in discussion with NEIC personnel and are waiting for software upgrades at NEIC that will allow them to receive the data. In addition to sending raw data to NEIC, we are working with NEIC to send the ShakeMap data file. We are currently working through firewall issues.

The hot site in Richfield currently is a data collection site. It has 12 TB mass storage. However, it was designed with two redundant Earthworm servers including Oracle database functionality. The plan is to build out functionality to the hot site to include processing. This will happen with the change in software to AQMS.

For continuity of routine operations and response operations, we developed and submitted to the USGS in 2007 a plan modeled after an existing NEIC plan. Key elements of this plan include an incident command structure and communication protocols. In September of 2007, we conducted a tabletop exercise to familiarize core staff with elements of the plan. In September of 2009, we conducted an active exercise to test our core staff's ability to work from home and use alternative forms of communication including a call-down phone list, posting to a wiki, and internet relay chat.

UUSS Response Plan

Elements of our current UUSS response plan include:

- the designation of a primary duty seismologist
- e-mail alarms to UUSS-staff and designees at the Utah Geological Survey and State of Utah Department of Homeland Security
- a duty seismologist checklist
- contact information for NEIC in the event that operations fail at UUSS

- immediate deployment of at least one or two digital seismographs with real-time data streaming in the epicentral area if the magnitude or regional station coverage suggest additional data is needed

While this plan has served us well in the past, we recognize the need to review and update our procedures and to exercise them routinely. As part of updating our plan we have been discussing formal coordination with NEIC. Major elements of this coordination will include: 24/7 backup (actions depend on functional status of the RSN), post-event response coordination, and post-event coordination of field recording.

Metadata Availability

The metadata for *all* UUSS stations—including UUSS strong-motion stations, UUSS/NSMP cooperative stations in Utah, and a UUSS infrasound array—are available through the IRIS Web site and our UUSS sftp site. Updates are made in a timely fashion using the IRIS PDCC software.

The USGS has recently developed a Station Metadata Server, designed to host station information for regional networks. For seismic stations with our network codes UU and WY, the USGS database for the Station Metadata Server was populated in early 2010 using information from our dataless SEED volume. A project, discussed and approved by Harley Benz of the USGS, is under way and involves the development of a spreadsheet with metadata for all of the UUSS seismic stations, containing the *full* information required by the data entry fields in the USGS metadata server (not all required data are contained in the dataless SEED volume). The spreadsheet is now complete as of this writing and will soon be submitted to the USGS.

CHANGES AND ACCOMPLISHMENTS IN NETWORK OPERATIONS

The purpose of this section is to document changes that have taken place in our network's operations during the three years of this cooperative agreement (from February 2007 through January 2010) in terms of new stations, new procedures, new partnerships, and major objectives accomplished.

For convenience, we incorporate detailed progress reports that were submitted to the USGS in December 2008 for Year Two and in December 2007 for Year One. We begin with a report for Year Three, using a similar format.

Report for Year Three

New Stations (and Changes)

- At the beginning of Year three, we maintained and operated 129 stations with full or partial ANSS support. **The only changes to our ANSS stations during Year Three were the upgrading of two broadband stations**, HVU and BGU, in November 2009 with funding from the American Recovery and Reinvestment Act (ARRA). Upgrading of station HVU included a new data logger, a new broadband sensor, and the addition of a triaxial accelerometer; for BGU, a new data logger and broadband sensor. After the writing of our Year-Two report, we began continuous recording from station KNB, a new ANSS cooperative broadband/strong-motion station, on January 28, 2009 (see Year-Two report, *New Stations*, for other details).

- A significant change to our network in Year Three was the start of recording of **20 new ANSS-contributing stations**, funded by the state of Utah and installed in southwestern and central Utah. These included **12 urban strong-motion stations** (six in the Greater St. George Area, three in the Cedar City area, one in Richfield, one in Beaver, and one in Kanab) and **eight broadband/strong-motion regional stations**. Up to four more regional broadband stations will be added as part of this same project.

- The moving of Transportable Array (TA) stations of EarthScope's USArray out of the Utah region during Year Three diminished the seismographic coverage of our study area. USArray began rolling into Utah in about mid-2007. While the temporary TA stations were here, we recorded up to 84 stations within and near the Utah region and integrated these data into our routine processing of earthquake locations. **Except for three stations that we adopted with non-ANSS funds, all the rest of the 84 TA stations we were recording were decommissioned** between about August 2008 and October 2009. The three retained stations were stations Q16A (now renamed CVRU), P17A (now BRPU), and P18A (now PNSU). Besides adopting these three TA stations as operating stations, we have also negotiated with IRIS/NSF to adopt the instrument vaults at four decommissioned stations (L17A, O16A, N16A, and R19A). As part of our ARRA project, triaxial accelerographs with continuous real-time telemetry will be installed in these four strategically located vaults.

- **Two NetQuakes accelerographs** (see http://earthquake.usgs.gov/earthquakes/waveforms/netq/) were shipped to us by the USGS in early 2009 for testing and local installation. Both have been installed at the homes of UUSS technical staff in the Salt Lake Valley, one in January 2009 and the other in February 2010. (**In early 2010 we received an additional ten NetQuakes** instruments from the USGS for local installation; the first was installed in March.)

Major Accomplishments (and Partnering)

Our efforts and accomplishments during Year Three were dominated by three activities: (1) completion of a major restructuring of our network telemetry; (2) continued work on expanding our seismic network in earthquake-prone parts of central and southwestern Utah; and (3) moving our entire facilities for network operations into a new building. Another time-consuming, network-related activity was the planning and writing of two major proposals to the USGS—one for the significant upgrading of 28 of our stations with ARRA funds and the other for a new five-year cooperative agreement for operating our regional/urban seismic network (two companion proposals were also written for ARRA upgrading and cooperative funding of the Yellowstone seismic network).

- **Major restructuring of our telemetry network — In 2009 we continued and finished a major restructuring of our network's telemetry architecture** that variously involved building (1) seven mountain-top data concentrators for our legacy short-period stations, (2) six remote Earthworm nodes, (3) a redundant hot site outside the Wasatch Front area in Richfield, Utah, and (4) a data access point at the Salt Lake County emergency operations center. The primary motivation for this restructuring was continuity-of-operations planning (see earlier section on *Continuity of Operations and Response Planning*). We wanted to ensure throughput of our network data to the USGS National Earthquake Information Center (NEIC) in case our network operations center were to fail due to a strong earthquake or other serious impact. Also we wanted to enable remote access to our network data if our earthquake information center were inaccessible.

- **Network Development and Expansion — A significant episode of development, modernization, and expansion (DME) of our regional/urban seismic network, carried out primarily with state funding, culminated during 2009**. The focus of this DME was on earthquake-prone parts of Utah outside the Wasatch Front urban corridor, notably in southwestern Utah, but the DME was solidly part of the state-federal partnership for seismic monitoring in Utah that underpins our USGS cooperative agreement. Excluding personnel costs, the DME totaled $717K. This included: $160K in state funds for restructuring our telemetry network; $131K in state funds for 12 new urban strong-motion stations; $326K in state funds for equipment for 12 new broadband/strong-motion stations plus upgrading one broadband station; and a combination of $33K in state funds and $67K from the National Institute for Occupational Safety and Health for adopting three EarthScope TA stations

(located in a region of mining-induced seismicity) and upgrading them to broadband/strong-motion stations. The next stage of development and expansion of our network, now under way from October 2009 to September 2011, will be with ARRA funds from the USGS. In the Utah region, this will involve upgrading 24 existing ANSS stations (10 broadband and 14 short-period) and installing triaxial accelerographs in four adopted TA vaults to create new UUSS-ANSS cooperative stations.

- **New Network Operations Facilities — In April 2009 our UUSS group completed months of effort to move nearly all our network-related facilities into a new building** (see earlier description of *Institutional and Private Partnerships*). This included (1) facilities for engineering and field operations, (2) data acquisition and computing facilities, (3) our earthquake information center, and (4) staff offices. A breakdown of the dollar investment gives some sense of what this involved in terms of securing funding for, planning, and creating these new facilities. The total investment of approximately $2 million included: $1.46 million for space (100 percent private funding from two sources), $196K for furnishings (59 percent private funding, 41 percent state), and $327K for computer systems (49 percent state funding, 26 percent private, 19 percent ANSS, and 6 percent USGS Volcano Hazards Program). We noted earlier that a private donation of $600,000 from Kennecott Utah Copper/Rio Tinto enabled the creation of a state-of-the-art earthquake information center. As part of our new computer facilities, state funds totaling $51.6k were used to acquire and install a new data storage system with a robotic tape library, configured with 20 TB of data storage capacity.

- **Steps Toward Greater Coordination with NEIC —** Greater coordination between NEIC and regional seismic networks, including ours, is a key imperative for ANSS system performance. This includes 24/7 backup by NEIC, with emphasis on **continuity-of-operations planning, post-event coordinated response, and post-event coordination of field recording**. Examples of our successful coordination with NEIC in post-event response and post-event field recording include the 2007 Crandall Canyon mine collapse in Utah and the 2008 Wells earthquake in northeastern Nevada. In 2009 we continued coordination with NEIC in our continuity-of-operations planning, in site visits to NEIC (including sending one of our seismic analysts to NEIC for one week), and in acquiring two digital recorders together with external triaxial accelerometers for rapid field response. These portable instruments are now available for immediate field deployment (while USGS/ANSS instruments are being shipped) when significant seismic events occur in our region of monitoring. For maximum flexibility in aftershock monitoring, the new instruments have 6-channel recorders to allow the addition of a broadband sensor.

- **Upgrading of our UUSS data-processing systems to AQMS —** In Year Three **we began the first phase of switching our regional network processing to CISN software, now designated as AQMS**, for "ANSS Quake Monitoring System." This is a major—and complicated—software upgrade for UUSS. In June 2009 we received and installed in our new network operations center three USGS-furnished computers—two fully redundant real-time servers and a post-processing Oracle server. Software installation proceeded throughout the summer with the help of Instrumental Software Technologies, Inc. (ISTI), a USGS contractor. The summer was also spent working with ISTI to get our dataless SEED volume formatted for AQMS. By September ISTI could view catalogs using Jiggle, and in December Paul Friberg visited UUSS to demonstrate the new software. In parallel with installing AQMS, we have been configuring and testing *carl*trig* modules (CarlTrig is an Earthworm event-detection algorithm which is also used in AQMS). This is now mostly complete. We have also purchased (with ARRA monies) and installed a backup Oracle server for AQMS. Configuring AQMS and incorporating Utah-specific velocity models and magnitude relations will be done as part of our ARRA project**.**

- **Characterizing Vs30 in the St. George and Cedar City areas —** In June 2009 **microtremor data were collected with small arrays of broadband seismographs at eight sites** in southwestern Utah near the rapidly growing urban areas of St. George and Cedar City. With state funding, UUSS recently installed 12 urban strong-motion stations as ANSS-contributing stations in these areas. Sites for the Vs30 experiment were chosen to sample different geologic surface units and to be close to the new strong-motion stations. At present there are no geotechnical data available to characterize site-response conditions near these stations. The field data collected during the experiment are being processed in collaboration with Bill Stephenson of the USGS using both the traditional spatial autocorrelation (SPAC; Aki, 1957) method and the multi-mode spatial autocorrelation (MMSPAC; Asten, 2006) method. For creating ShakeMaps, we have used Vs30 information from northern Utah to characterize the soil sites in southwestern Utah. The new data should greatly improve the understanding of site amplification in southwestern Utah, particularly in the Greater St. George area, where the pattern of damage that occurred during the magnitude 5.9 St. George earthquake in September 1992 was enigmatic to structural engineers.

- **Seismic Monitoring of Mining-Induced Seismicity (MIS) —** Seismic monitoring of MIS in Utah and elsewhere in the U.S. became an important issue after the Crandall Canyon mine collapse in Utah in August 2007, which resulted in the deaths of six miners and , ten days later, the deaths of three rescue workers. In collaboration with the University of Utah's Department of Mining Engineering, and with funding from the National Institute for Occupational Safety and Health, **we completed work on three MIS-related projects in 2009**: (1) an assessment of the current state of practice of seismic monitoring in U.S. underground coal mines and its practical value for mine safety, (2) the adoption and incorporation into our network of two TA stations in Utah's coal-mining region, and (3) research on improved locations for MIS. Project (1) was carried out with the help of an expert panel of 16 national and international experts experienced in issues relevant to seismic monitoring of MIS.

- **Infrasound arrays and partner projects —** During the past year, we continued our collaboration with scientists from **Southern Methodist University** in the analysis of data recorded at three permanent infrasound arrays in the Wasatch Front area with funding from the **Air Force Research Laboratory.** Last year, we received a new three-year contract that will allow the continued operation of the original three infrasound arrays and the installation of six new arrays.

Report for Year Two (reproduced from report submitted December 12, 2008)

PROGRESS REPORT – USGS COOPERATIVE AGREEMENT FOR SEISMIC NETWORK OPERATIONS

December 12, 2008

Network Name:	**University of Utah Regional/Urban Seismic Network**		
Cooperative Agreement No:	07HQAG0022	Project Start Date:	02/01/2007
Principal Investigator:	Walter J. Arabasz	Email Address:	arabasz@seis.utah.edu
Co-Principal Investigator:	Kristine L. Pankow	Email Address:	pankow@seis.utah.edu
Institution and Address:	University of Utah, Office of Sponsored Projects 1471 Federal Way, Salt Lake City, UT 84102-1870		
Project Web Site:	http://www.seis.utah.edu		
Report Period:	Year Two to Date — 02/01/2008–12/01/2008		

Changes Implemented in this Reporting Period

The cooperative agreement identified here, combined with funding from the State of Utah, provides major support for the operation of (1) the University of Utah Seismograph Stations' (UUSS) regional and urban seismic network and (2) a regional earthquake-recording and information center on the University of Utah campus in Salt Lake City. USGS support is focused on the seismically hazardous Wasatch Front urban corridor of north central Utah but also encompasses neighboring areas of the Intermountain Seismic Belt. During the report period, changes and accomplishments included the following:

New Stations

- At the beginning of Year 2 we maintained and operated 127 stations with full or partial ANSS support. **The only change** was the closing of the three-component short-period station BBU (Bumble Bee, Salt Lake City, UT) in October 2008, due to increased cultural noise in the area. [Note: Station LKC, an ANSS strong-motion station, is 2 miles SW of where station BBU was located.]

- **We recorded up to 84 Transportable Array (TA) stations** of EarthScope's USArray (see Figure 1) and integrated these data into our routine processing of earthquake locations—including their use in automated picking (in Earthworm) and post-processing. At the beginning of Year 2 we were recording 65 TA stations. Since then, we've added the recording of 19 more TA stations, and 23 TA stations in the Utah region have been decommissioned. At this writing, we are recording 61 TA stations. **We have secured funding to adopt three TA stations** in central Utah (see *New Partnerships* below). As USArray rolls out of Utah, these stations will be retained and upgraded to six-component BB/SM stations, and they will be ANSS contributing stations.

- **New ANSS cooperative station KNB (Kanab)** — We have partnered with Lawrence Livermore National Lab (LLNL) and the USGS/Golden to upgrade and reactivate station KNB in southwestern Utah, a broadband station with a long history of recording. By mutual agreement: LLNL is paying a sharply increased site-use permit of approximately two thousand dollars per year plus utility costs; the USGS provided a RefTek datalogger and broadband/strong-motion sensors; and the University of

Utah implemented continuous real-time telemetry, is handling data acquisition and export, and is maintaining the station. The station was reactivated in September 2008, but there are still unresolved problems relating to calibration of the broadband sensor.

- During the report period, we installed **ten new urban strong-motion stations** in the St. George-Cedar City area of southwestern Utah (one of the fastest growing areas in Utah and the U.S.) and in other earthquake-prone parts of Utah outside the Wasatch Front urban corridor. These ten stations were installed with state funds (see *State of Utah Network Expansion Project & Continuity of Operations*); two more strong-motion stations will soon be installed as part of this same project. The stations are using Kinemetrics ETNA and Geotech SMART-24A accelerographs. Data are being recording onsite but not yet streaming reliably to our network operations center. When complete, all 12 stations will be ANSS contributing stations.

New Partnerships

- **New collaboration in monitoring mining-induced seismicity and adoption of three EarthScope TA stations** — In the aftermath of the August 2007 Crandall Canyon mine accident in Utah, we secured funding from the **National Institute for Occupational Safety and Health (NIOSH)** for a multifaceted project aimed at improving coal mine safety in Utah. The project is a collaborative one between UUSS and the University of Utah's Department of Mining Engineering. Parts of the project include NIOSH funding for UUSS to adopt two EarthScope Transportable Array (TA) stations in central Utah and research to improve the spatial resolution of mining-induced seismicity in Utah by applying double-difference relocation techniques to our regional-network data. UUSS will adopt a third TA station in central Utah with split support from UUSS state funds and funding from the **State of Utah School and Institutional Trust Lands Administration**. All three TA stations will be upgraded to six-component broadband/strong-motion stations and will operate as contributed high-quality ANSS stations.

- We are partnering with **URS Corporation** and a Wasatch Front **ShakeMap/HAZUS Working Group**, which includes representatives from the **Utah Division of Homeland Security**, **FEMA Region VIII**, the **Utah Geological Survey**, and engineers from the University of Utah and local practice. The group is working on a FEMA-sponsored project to produce a catalog of loss-estimation map products that are based on earthquake-scenario ShakeMaps and FEMA's risk analysis software HAZUS-MH. We provided fifteen ShakeMap scenarios (see http://www.quake.utah.edu/shake/archive/scenario.html), ranging from **M** 5.5 to **M** 7.0, based on rupture of various segments of the Wasatch fault and other Utah faults in the Intermountain Seismic Belt. The results of the collaborative loss-estimation work will be presented at the February 2009 EERI-WSSPC annual meeting in Salt Lake City (Terra et al., 2009).

- During the past year, we continued our collaboration with scientists from **Southern Methodist University** in the analysis of data recorded at three permanent infrasound arrays in the Wasatch Front area with funding from the **Air Force Research Laboratory.** We also collaborated with scientists from the **Los Alamos National Laboratory**. Work included development of an event locator using infrasound data (Arrowsmith et al., 2008a), analysis of infrasound energy generated by the 2008 Wells, Nevada, earthquake (Burlacu et al., 2010, *submitted*), and analysis of acoustic-to-seismic coupled energy (Hayward et al., 2008).

- **Rio Tinto/Kennecott Copper of Utah** has committed $600,000 to the University of Utah's College of Mines and Earth Sciences to establish **The Rio Tinto Earthquake Information Center** in the new Frederick A. Sutton Building being built for the Department of Geology and Geophysics. The

building will be occupied in January 2009, with a Grand Opening on April 17, 2009. The generous private donation is helping to pay for necessary space costs for UUSS to move its facilities into the seismically designed Sutton Building and for part of the costs to equip and furnish the new earthquake center.

Major Accomplishments

Besides some achievements already mentioned, our efforts and accomplishments to date in Year 2 of this cooperative agreement have been influenced by four circumstances that have had a major impact on our seismic network: (1) continuing developments from the August 2007 Crandall Canyon mine disaster; (2) the M 6.0 Wells, Nevada, earthquake of February 21, 2008; (3) our $1 million state network expansion project; and (4) preparations for moving our network center into a new building in the next few months. Some accomplishments relating to improved network operations are grouped into a fifth category.

Crandall Canyon aftermath

- We wrote and published a **seismological report on the Crandall Canyon mine accident** (Pechmann et. al, 2008; see also Warner et al., 2009).

- We wrote and published a paper on **new approaches to monitoring mine seismicity in Utah** (Pankow et al., 2008b). The ability to achieve fine spatial resolution of mine seismicity recorded by the University of Utah Seismograph Stations (UUSS) regional network—and the possibility of producing calibrated hypoDD locations on the fly—are of increasing interest to the coal mining community in Utah. This research also benefits our monitoring of natural earthquake activity.

- **Funding for a multifaceted project relating to mining seismicity —** UUSS and the University of Utah Department of Mining Engineering received joint funding from the National Institute for Occupational Safety and Health (NIOSH) to: (1) convene a panel of 16 international and national experts to address issues of monitoring mining-induced seismicity in "bump-prone" U.S. coal mines, (2) **adopt two USArray TA stations** in Utah's coal-mining region, and (3) improve locations for mining-induced seismicity in Utah using hypoDD. The expert panel meeting and workshop was held October 20–22, 2008 (see http://www.seis.utah.edu/expertpanel.htm).

- Besides adopting two TA stations with NIOSH funding, **we secured funds to adopt a third TA station** in Utah's coal-mining region by cost-sharing with a Utah state agency that leases coal tracts on state trust lands (see *New Partnerships*).

The M 6.0 Wells, Nevada, earthquake of February 21, 2008

The Wells earthquake was widely felt in western Utah and along Utah's Wasatch Front urban corridor, prompting routine response efforts and media interactions. Because the earthquake was closer to Salt Lake City than Reno, UUSS became heavily involved in the early field deployment of instruments and in coordination and planning—not only with the USGS and the University of Nevada, Reno (UNR), but also with supportive response efforts by the Utah Geological Survey and the Utah Department of Homeland Security.

- UUSS technicians **installed and operated five strong-motion instruments and a four-station short-period telemetry array** in the epicentral and aftershock area of the Wells earthquake. Two instruments were installed the same day as the mainshock and all nine UUSS stations operated for ~5½ weeks. A total of 27 stations were deployed by UNR, the USGS, and UUSS.

One of the clear lessons from the Wells earthquake is the need for advance ANSS planning to implement real-time data acquisition and processing from temporary stations following a damaging earthquake in an un-instrumented area. Expectations and needs from ANSS for real-time earthquake information products are compelling.

- For the 2008 AGU Fall Meeting in San Francisco, **a special session on "The 2008 M 6.0 Wells, Nevada Earthquake"** has been organized and convened by Kris Pankow of UUSS and Glenn Biasi of UNR. Petersen et al. (2008) report results of one of our collaborative studies in this session; see also Burlacu et al. (2010).

State of Utah Network Expansion Project & Continuity of Operations

In July 2007, after two years of efforts, UUSS received an appropriation of approximately $1 million from the Utah State Legislature to expand seismic instrumentation and real-time earthquake information products in the St. George-Cedar City area and in parts of rural Utah outside the Wasatch Front area. Funding was also provided to achieve continuity of operations in event of a large Wasatch fault earthquake.

- During the report period, **we planned and nearly completed the installation of 12 urban strong-motion stations** in the St. George-Cedar City area as well as in Beaver, Kanab, and Richfield (see *New Stations*). Site selection was overseen by the Utah Strong-Motion Advisory Committee, and candidate sites—based on geologic site conditions—were identified with help from the Utah Geological Survey.

- **Siting and prep work for 12 new BB/SM stations** — The state appropriation included funds for ten regional stations. Funds were managed to ensure that all ten stations would have both broadband (BB) and strong-motion (SM) sensors. Also, cost savings in the project budget were used to buy equipment for an additional two BB/SM stations. Federal site-use permits are still pending for five of the first ten stations; installations are planned for 2009.

- A design for **a robust, fault-tolerant, statewide seismic network in Utah** (both in terms of telemetry and data processing) was developed beginning in late 2007 with help from USGS scientists and engineers. Key elements include: (a) six to seven regionally distributed nodes with Earthworm systems; (b) a "hot site" outside the Wasatch Front urban corridor in Richfield, Utah, which will receive the same data as our primary UUSS network center and serve as a backup collection/processing site; and (c) a" point-of-presence" in the Salt Lake County Emergency Operations Center to allow emergency access to data stored at the hot site or the regional Earthworm nodes. All of the regional nodes and the backup hot site have been installed, and the point of presence has also been completed.

- As part of our Continuity of Operations planning and the build-out to nodes, **the entire telemetry schema for our seismic network has been redesigned**. One of the major changes that is currently being implemented is to digitize the analog telemetry data at spatially close mountaintops and then send the data to one or multiple nodes (our network currently operates 64 legacy short-period stations in the Utah region). This has advantages such as cleaner data streams and allowing us to discontinue some expensive microwave circuits. To make it work has involved a great deal of engineering: Greg Steiner of VLF Designs (formerly with the University of Memphis) designed and built new discriminator racks to be deployed on the mountaintops, and

we ported Earthworm PsnAdSend from Linux to Solaris in order to use a special digitizer designed by Larry Cochrane of California's Public Seismic Network.

Because all data arriving at our network operation center will soon be digital, we will be retiring our Masscomp data-processing computer, which for years has generated triggers and UW1 format data for use with the routine analysis software, *uping*. This change will not be an issue once CISN software is installed. However, to fill the gap before CISN software is implemented, we have written code to use the output from Earthworm modules *carl*trig* and *trig2disk* to generate UW1 format files. We are in the final stages of testing the software.

New Building and Move of UUSS's Network Operations Center

As noted under *New Partnerships*, a new building for the University of Utah's Department of Geology and Geophysics will soon be occupied. The $26 million building was built with private funds and will provide ~5,000 square feet (at more than $200/sq ft) for UUSS's network operations center, its earthquake information center, and its technical staff—including the "Rio Tinto Earthquake Information Center." Among the time-consuming planning for such a move, **we made major efforts to avoid significant down time when we move our data acquisition and processing systems**.

Improved Network Operations

- Using our state funds, **we have purchased equipment for and implemented a new data storage system** using a Sun Server with over six months of internal online disk storage (compressed) and a Storagetek tape library system capable of retaining six months of data internally. The Sun Server has been configured with Solaris 10 and Symantec Veritas NetBackup 6.5 as the operating and application platform. The tape library is configured with 20 TB of tape storage internally, and library modules can be added for an internal storage of 230TB of data. Infrastructure services (Fiber connections, Network) were set up to accommodate easy expansion for either or both components. The NetBackup software is configured to backup both staff workstations and our Earthworm system data on a regular interval as well as daily incremental backups. With the large amount of data storage available in the backup system, restores can be done quickly.

- **SeisNetWatch and INV (Status) —** We first installed SeisNetWatch in 2005 with the help of Instrument Software Technologies, Inc. (ISTI). Currently, we are running version 1.52 of the Network Station Info (NSI) server and version 1.75 of the GUI client software. We still need to work with the USGS to make the necessary configuration adjustments to allow the USGS to access state-of-health information for UUSS stations. We continue to use Nagios, an open-source host, service, and network monitoring program, to monitor critical systems (e.g., telemetry links, sensors, computer hardware) in our network. Email and pager notifications are configured to alert when there are problems. We also have installed MRTG (multi-router traffic grapher) to monitor local network traffic (LAN) as well as telemetry traffic & health (error rates) both locally and for our Earthworm nodes. This allows us to see short-term statistics, as well as long-term trends in network behavior.

  During the past year, **we have continued to work with ISTI** (including a site visit by Sid Hellman in May 2008) to make INV work at UUSS. We have had difficulty populating the database with the available tools (INV directly or DIGIT) and with the MySQL database. We are now trying a spreadsheet template provided by David Oppenheimer as a means of organizing the

metadata for import into CISN software. It is also our understanding that INV can be populated from the spreadsheet.

- **False alarms from teleseisms —** Recognizing the need to limit false alarms of local earthquakes generated by teleseisms, **we have explored many options** this year, including current Earthworm parameters and parametric filters. From these options, we have not determined a reliable means to discriminate the false alarms. Currently, we are looking into the possibility of discriminating events based on frequency content. If this turns out to be a reliable option, minimal coding to existing software will be necessary.

Other

- **Utah Version of *Putting Down Roots in Earthquake Country* —** We contributed significantly to creating a Utah version of *Putting Down Roots in Earthquake Country* in collaboration with the Utah Seismic Safety Commission, the Utah Division of Homeland Security, the Utah Geological Survey, and the Structural Engineers Association of Utah. Printing of the 34-page earthquake-awareness document is now under way, with partial support from the USGS and FEMA. The brochure will be published online within the next month, and mass-media distribution is planned for April 2009—Utah's Earthquake Awareness Month.

- **Quarterly Earthquake Summaries —** Within 30–60 days of each calendar quarter we submitted to the USGS and distributed to stakeholders a report on *Earthquake Activity in the Utah Region, Preliminary Epicenters*. Besides an earthquake catalog and seismicity map, the reports include a narrative summary, a table of earthquakes felt and/or generating a ShakeMap in the Utah region, and an up-to-date table and maps for operating stations in the University of Utah Regional/Urban Seismic Network. The reports are available online at: http://www.quake.utah.edu/EQCENTER/QUARTERLY/quarterly.htm.

Report for Year One (reproduced from report submitted December 13, 2007)

PROGRESS REPORT – USGS COOPERATIVE AGREEMENT FOR SEISMIC NETWORK OPERATIONS

December 13, 2007

Cooperative Agreement No:	07HQAG0022	Project Start Date:	02/01/2007
Network Name:	**University of Utah Regional/Urban Seismic Network**		
Project Start Date:	02/01/2007		
Institution and Address:	University of Utah, Office of Sponsored Projects 1471 Federal Way, Salt Lake City, UT 84102-1870		
Principal Investigator:	Walter J. Arabasz	Email Address:	arabasz@seis.utah.edu
Co-Principal Investigator:	Kristine L. Pankow	Email Address:	pankow@seis.utah.edu
Project Web Site:	http://www.seis.utah.edu		

Changes Implemented in this Reporting Period

The cooperative agreement identified here, combined with funding from the State of Utah, provides major support for the operation of (1) the University of Utah Seismograph Stations' (UUSS) regional and urban seismic network and (2) a regional earthquake-recording and information center on the University of Utah campus in Salt Lake City. USGS support is focused on the seismically hazardous Wasatch Front urban corridor of north central Utah but also encompasses neighboring areas of the Intermountain Seismic Belt. During the report period, changes and accomplishments included the following:

New Stations

- Among our 127 stations maintained and operated with full or partial ANSS support, **the only change** was the closing of urban strong-motion station GAS in the Salt Lake Valley in April 2007, due to demolition of the host site, and reinstallation of equipment at a new station RPF in October 2007.

- The most significant change to our network was **the added recording of 65 Transportable Array (TA) stations** of EarthScope's USArray (see Figure 1) and the integration of these data into our routine processing of earthquake locations—including their use in automated picking (in Earthworm) and post-processing. Incorporation of the TA data into our network first required upgrading our Earthworm data acquisition and processing systems (discussed below under *Major Accomplishments*). Our next milestone is to fully utilize the TA stations as part of subnets in the *carl*trig* Earthworm modules, with emphasis on parts of the Utah region where UUSS station coverage is poor.

- On July 1 we received one-time as well as ongoing funding from our state legislature to install and operate **12 new urban strong-motion stations and 10 new 6-component regional stations in southwestern Utah**—one of the fastest growing areas in Utah and the U.S.—and in other parts of Utah outside the Wasatch Front urban corridor. We've started the site selection and permitting process, have ordered a combination of Kinemetrics ETNAs and Geotech SMART-24A accelerographs for the urban installations, and we are working with the USGS/ASL to test and select suitable broadband sensors for the regional stations. All stations will be ANSS contributing stations.

- Funding from our state legislature was also appropriated in 2007 to install **a 36-channel array in our Utah State Capitol for seismic structural response monitoring**. The installation will be done by Mehmet Celebi and technicians of the USGS National Strong Motion Project and is expected to be completed in early 2008.

New Partnerships

- **New ANSS cooperative station KNB (Kanab)** — We are partnering with Lawrence Livermore National Lab (LLNL) and the USGS/Golden to upgrade and reactivate station KNB in southwestern Utah, a broadband station with a long history of recording. By mutual agreement: LLNL will be paying a sharply increased site-use permit of approximately two thousand dollars per year plus utility costs; the USGS is providing a RefTek datalogger and broadband/strong-motion sensors; and the University of Utah will enable continuous real-time telemetry, handle data acquisition and export, and maintain the station. We are currently awaiting delivery of the datalogger from the USGS.

- We have extended our partnering with the **Utah Division of Homeland Security** to include Doug Bausch, **FEMA Region VIII**, in a collaborative effort to (1) enhance the use of ShakeMap and derivative products by emergency managers in the Utah region and (2) link data from ShakeMap in the Utah region with HAZUS loss-estimation software in near-real-time for rapid impact assessment. Details are described in an abstract for the 2007 Fall AGU meeting by Pankow et al. (2007a).

- During the past year, in collaboration with scientists from **Southern Methodist University and Ensco**, and with funding from the **Air Force Research Laboratory**, we have installed and are continuously recording data from three permanent infrasound arrays in the Wasatch Front area. The arrays are primarily recording detonations by the U.S. Air Force in a desert area west of the Great Salt Lake, but our plan is to develop capabilities to use the arrays for routine discrimination of blasts within our seismic network out to regional distances.

- On June 14, 2007, an announcement was made that **Kennecott Copper of Utah** had committed $600,000 to the University of Utah's College of Mines and Earth Sciences to establish the Kennecott Earthquake Information Center. The center will be housed in the new Frederick A. Sutton Building, now being built for the Department of Geology and Geophysics and scheduled for occupancy in early 2009. Kennecott's generous donation will pay for necessary space costs for UUSS to move its facilities into the seismically designed Sutton Building and for part of the costs to equip and furnish the new earthquake information center.

Major Accomplishments

Our accomplishments to date in Year 1 of this cooperative agreement relate not only to planned tasks but also to (a) aggressive leveraging of our ANSS funding and (b) response to a significant mining-induced seismic event—the August 6, 2007, Crandall Canyon mine disaster.

- In March 2007 we succeeded in getting a **$1 million special appropriation from the 2007 State Legislature**. The funding success, which came after more than two years of effort, was facilitated by the Utah League of Cities and Towns and the Utah Seismic Safety Commission. The money includes: (a) $420,000 one-time for bolstering seismic monitoring outside the Wasatch Front area (described above under *New Stations*); (b) $300,000 one-time for backup systems and re-engineering of our network telemetry to ensure continuity of operations following a large earthquake—a vital

reinforcement, at state expense, of our ANSS-supported network operations; and (c) $327,000 per year ongoing funds added to our UUSS state line-item appropriation.

- **Leveraged Upgrading of Earthworm Computer Systems** — Another example of leveraging ANSS funding was our success in patching together funds and/or new equipment from the state of Utah, the Yellowstone Volcano Observatory, and IRIS to achieve much of what we had asked for in two non-funded DME requests included in our September 2006 ANSS network renewal proposal. The needed funding was to address critical problems with our Earthworm computer systems, installed in 2001, due to aging and undercapacity in the face of vastly expanded recording/processing load. The funding package we put together for our highest-priority computer upgrades included $17K in ANSS funds (from year-end spending, with USGS approval, in our FY2006 cooperative agreement) and more than $46K from the other sources.

- **Response to (and Study of) the August 2007 Crandall Canyon Mine Disaster —** A large and tragic collapse occurred in the Crandall Canyon coal mine in east-central Utah at 2:48 a.m. (MDT) on August 6, 2007, entombing six miners and generating national attention. The collapse caused a seismic event of local magnitude (M_L) 3.9. Ten days later an "aftershock" of $M_L = 1.6$, due to a violent burst of coal from the mine walls, killed three rescuers and injured six others. Our involvement with the Crandall Canyon disaster began within minutes of the August 6 mine collapse (with pager alerts triggered by the magnitude 3.9 shock), intensified during the early days and weeks, and still continues vis-à-vis ongoing investigations by three congressional committees, the Mine Safety and Health Administration, and the Utah Mine Safety Commission, among others. We worked closely with the USGS during the response phase. Timely information was provided on our Web site (http://www.seis.utah.edu/), including public statements, seismicity maps and data, FAQs, and scientific and technical information. Seismological findings were reported in an abstract for the 2007 Fall AGU meeting by J. C. Pechmann et al. (2007a). See link at http://www.seis.utah.edu/MONRESEARCH/CM/tech_rep.htm to view the corresponding poster presentation. A scientific manuscript will be submitted soon to *Seismological Research Letters.*

- **SeisNetWatch and INV (Status) —** We first installed SeisNetWatch in 2005 with the help of Instrument Software Technologies, Inc. (ISTI). Currently, we are running version 1.52 of the Network Station Info (NSI) server and version 1.75 of the GUI client software. We still need to work with the USGS to make the necessary configuration adjustments to allow the USGS to access state-of-health information for UUSS stations. We also have installed Nagios, an open-source host, service, and network monitoring program, to monitor critical systems (e.g., telemetry links, sensors, computer hardware) in our network and we are experimenting with the software. We have worked with ISTI to make INV work at UUSS but may still need further help from them. After several interactions with ISTI, we received a modified copy of our INV table structure that we need to insert into our UUSS MySQL database. We also need to finish populating our station-inventory database.

- **Web Pages —** We redesigned our UUSS Web site (http://www.seis.utah.edu) in time for the celebration of 100 year of earthquake recording at the University of Utah on June 29, 2007. The redesign followed the basic structure of the USGS model but with constraints imposed by our University for Web page design. For the new design we focused on improving layout and the navigation structure, and we paid particular attention to ANSS requirements for content. Our Web site revision is still ongoing; some of the non-ANSS content still has to be updated.

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TABLES AND FIGURES

Table 1. Overview of the University of Utah Regional/Urban Seismic Network
January 31, 2010

Networks Forming Part of Regional Operation:	CODE	Stations/channels
Utah Region Seismic Network	UU	169/493
ANSS-NSMP stations with real-time telemetry maintained and operated by University of Utah	NP	12/36
Yellowstone National Park Seismograph Network (YSN)	WY	24/42

TOTAL Stations/Channels Operated: 205/571

Import data from:	*CODE*	*Stations/channels*
Montana Regional Seismic Network	MB	6/6
Idaho National Engineering and Environmental Laboratory Seismic Network	IE	7/7
Western Great Basin/Eastern Sierra Seismic Network University of Nevada, Reno	NN	6/6
US Bureau of Reclamation Paradox Valley Seismic Network	RE	2/2
US National Seismic Network	US	11/33
USGS National Strong Motion Project (via EW module getfile; triggered data from instruments in Wasatch Front area)	NP	Variable (.evt and xml files)
Sandia National Laboratory—Leo Brady Network	LB	1/3
USGS Albuquerque Seismological Laboratory	IU	1/3
Northern Arizona University Seismic Network	AR	3/3
Jackson Wyoming Regional Seismic Network	IW	5/15
Total Stations/Channels Imported:		**42/78**

TOTAL Stations/Channels Recorded: 247/649

Export Data To:	Stations/Channels
Brigham Young University (Idaho) Seismic Network (formerly Ricks College)	21/29
Montana Regional Seismic Network	8/8
Idaho National Engineering and Environmental Laboratory Seismic Network	7/7
Northern Arizona University Seismic Network	7/21
Yellowstone Volcano Observatory/USGS	29/53
USGS/NEIC	Export HYP, MAG, SMII messages
USGS/NEIC	26/76
IRIS Data Management Center (via ew2mseed)	248/539
Total Stations/Channels Exported:	**346/733**

Table 2. Summary Statistics for UU Regional/Urban Seismic Network (as of January 31, 2010)

Total no. of stations operated and/or recorded	247
Total no. of channels recorded	649
No. of short-period (SP) stations	99 (34 ANSS)
No. of short-period (SP) stations with metadata	99
No. of broadband (BB) stations	49 (14 ANSS)
No. of broadband (BB) stations with metadata	49
No. of strong-motion (SM) stations	99 (81 ANSS)
No. of strong-motion (SM) stations with metadata	99
No. of stations maintained & operated by network	205
-same, with full metadata	205
No. of stations maintained & operated as part of ANSS	129
-same, with full metadata	129
Total data volume archived (mbytes/day)	*

** Approx. 23,000 mbytes/day for all data we record in SAC Format; estimated UU data volume being recorded in the IRIS DMC in MiniSeed format is ~4000 mbytes/day*

Table 3. Earthquakes in the Utah Region of Magnitude 3.0 and Larger: January 1, 2007 – December 31, 2009

NO.	DATE	ORIGIN TIME	LATITUDE	LONGITUDE	DEPTH	MAG	NO	GAP	DMN	RMS
1	070208	08:58:29.26	38º 18.79′	112º 36.39′	2.5*	3.1W	19	71	31	0.44
2	070225	03:52:20.45	42º 26.92′	110º 41.28′	0.2*	3.8W	14	133	49	0.22
3	070605	03:28:42.45	41º 41.56′	109º 58.36′	1.1*	3.1W	11	173	109	0.22
4	070605	03:29:06.92	41º 35.29′	109º 54.50′	5.3*	3.4W	8	259	117	0.31
5	070611	01:03:46.65	37º 29.66′	114º 00.98′	1.5*	3.9W	18	96	39	0.34
6	070704	04:03:24.46	37º 32.79′	112º 31.78′	2.4*	3.1W	16	67	53	0.19
7	070704	18:31:58.40	37º 32.31′	112º 31.74′	1.1*	3.1W	17	68	30	0.36
8	070806	08:48:40.01	39º 27.81′	111º 13.66′	0.4*	3.9W	43	36	19	0.31
9	070818	13:16:30.46	38º 04.18′	113º 19.40′	0.6*	3.9W	14	132	37	0.36
10	070901	18:32:02.06	41º 38.61′	112º 18.86′	5.8	3.9W	42	62	8	0.21
11	071105	21:48:00.61	39º 20.75′	111º 38.85′	5.5	3.9W	48	35	10	0.30
12	071122	02:29:36.46	41º 37.98′	109º 44.17′	4.7*	3.4W	13	224	73	0.21
13	071210	05:46:13.71	37º 31.85′	112º 19.33′	1.9*	3.0W	30	55	17	0.27
14	071212	18:07:24.32	37º 21.64′	114º 06.78′	1.1*	3.1W	18	94	29	0.35
15	071213	07:54:45.26	37º 21.69′	114º 06.63′	0.5*	3.5W	19	101	29	0.31
16	080201	06:52:28.54	38º 11.78′	112º 12.40′	0.2*	3.6W	41	32	35	0.25
17	080201	21:36:54.23	41º 48.52′	112º 13.10′	6.2*	3.5W	48	33	16	0.20
18	080209	17:41:49.85	41º 40.06′	109º 53.32′	1.7*	3.3W	11	94	31	0.39
19	080521	23:57:07.43	37º 32.06′	112º 19.05′	1.2*	3.0W	20	56	16	0.25
20	080606	20:09:59.03	37º 21.47′	109º 28.09′	9.6*	3.7W	23	74	44	0.16
21	080615	19:27:22.19	41º 44.26′	112º 36.58′	7.0	3.1W	35	46	13	0.21
22	080816	02:24:23.11	42º 28.73′	111º 35.20′	4.5*	3.3W	32	65	39	0.22
23	080828	19:26:27.80	37º 32.12′	112º 19.01′	0.1*	3.3W	20	59	16	0.19
24	080830	22:06:15.57	41º 40.42′	111º 08.73′	2.8*	3.3W	26	86	24	0.24
25	080907	02:12:12.02	41º 42.71′	112º 22.77′	2.4*	3.1W	37	91	17	0.19
26	081012	03:26:01.41	41º 41.42′	111º 08.55′	8.6*	3.4W	29	48	25	0.22
27	090131	13:43:37.21	42º 20.27′	111º 11.02′	1.1*	3.1W	28	51	37	0.21
28	090307	02:45:10.18	41º 40.21′	109º 55.39′	4.5*	3.5W	13	62	30	0.22
29	090309	03:20:23.97	38º 49.09′	111º 44.11′	2.8*	3.0W	32	41	27	0.21
30	090323	05:43:26.10	37º 25.20′	113º 09.90′	3.5*	3.2	16	65	23	0.33
31	090331	02:36:10.64	37º 39.72′	110º 27.22′	7.2*	3.0W	7	169	40	0.19
32	090411	10:34:34.92	39º 24.76′	111º 05.12′	6.1	3.0W	31	48	11	0.21
33	090603	21:47:01.86	41º 48.24′	112º 12.85′	7.5*	4.0W	34	60	17	0.15
34	090606	11:14:10.84	41º 48.20′	112º 13.03′	6.8*	3.0W	28	60	17	0.18
35	090713	03:40:37.95	37º 00.72′	110º 46.31′	3.0*	3.3W	9	177	103	0.07
36	090904	06:01:01.45	36º 59.15′	112º 22.37′	15.5	3.0W	15	114	15	0.32
37	091113	13:22:37.68	38º 59.54′	111º 23.51′	0.5*	3.2W	24	46	21	0.17
38	091119	12:24:52.09	40º 52.85′	111º 32.36′	8.2*	3.0W	46	55	25	0.22

number of earthquakes = 38

* indicates poor depth control
W indicates Wood-Anderson data used for magnitude calculation

Table 4. Earthquakes Felt and/or Generating a ShakeMap in the Utah Region
January 1, 2007 to December 31, 2009

Date	Time†	Felt Information‡	Latitude	Longitude	Magnitude§
2007					
Feb 08	01:58 MST 08:58 UTC	Utah. *CIIM*. Felt (III) at Beaver and Sandy, UT and (II) at Syracuse, UT.	38º 18.79′	112º 36.39′	M_L 3.1
Feb 24 (MDT) Feb 25 (UTC)	20:52 MST 03:52 UTC	Utah. *CIIM*. Felt (III) at Big Piney, La Barge, Green River, WY and Tremonton, UT and (II) at Smoot and Rock Springs, WY.	42º 26.92′	110º 41.28′	M_L 3.8
May 28 (MDT) May 29 (UTC)	21:05 MDT 03:05 UTC	Utah. *CIIM*. Felt (III) at South Jordan, West Jordan, Midvale, Salt Lake City, Draper, Riverton, UT and (II) at Salt Lake City, UT.	40º 34.11′	111º 56.15′	M_L 2.3
June 10 (MDT) June 11 (UTC)	19:03 MDT 01:03 UTC	Utah. *CIIM*. Felt (IV) at Central, UT; (III) at Dammeron Valley, UT, Mesquite, NV and (II) at Saint George, Ivins UT, Caliente, NV.	37º 29.66′	114º 00.98′	M_L 3.9
July 04	12:31 MDT 18:31 UTC	Utah. *CIIM*. [Reportedly felt (III) at Nampa, ID and (II) at Soda Springs, ID].	37º 32.31′	112º 31.74′	M_L 3.1
August 06	02:48 MDT 08:48 UTC	Utah. *CIIM*. *ShakeMap*. Felt (III) at Huntington, UT and (II) at Mount Pleasant, Orem, Sandy, South Jordan, Salt Lake City, Tooele, Roy, UT [and reportedly at Gypsum, CO, Rupert, ID].	39º 27.81′	111º 13.66′	M_L 3.9
August 18	07:16 MDT 13:16 UTC	Utah. *CIIM*. *ShakeMap*. Felt (III) at Cedar City, UT.	38º 04.18′	113º 19.40′	M_L 3.9

September 01	12:32 MDT 18:32 UTC	Utah. *CIIM*. *ShakeMap*. Felt (IV) at Garland, UT, (III) at Tremonton, Honeyville, Corinne, Mendon, Plymouth, UT, Pocatello, ID, and (II) at Brigham City, UT, Malad City, ID, Salt Lake City, Sandy, UT.	41º 38.61′	112º 18.86′	M_L 3.9
November 05	14:48 MST 21:48 UTC	Utah. *CIIM*. *ShakeMap*. Felt (IV) at Mount Pleasant, UT, (III) at Ephraim, Fayette, Manti, Salina, Huntington, Orem, Lehi, UT, and (II) at Nephi, Ferron, UT.	39º 20.75′	111º 38.85′	M_L 3.9
November 21 November 22	19:29 MST 02:29 UTC	Wyoming. *CIIM*. Felt (II) at Green River, WY.	41º 37.98′	109º 44.17′	M_L 3.4
2008					
Date	**Time†**	**Felt Information‡**	**Latitude**	**Longitude**	**Magnitude§**
January 31 (MST) February 01 (UTC)	23:52 MST 06:52 UTC	Utah. *CIIM*. *ShakeMap*. Felt (III) at Kingston, UT and (II) at Washington, UT.	38º 11.78′	112º 12.40′	M_L 3.6
February 01	14:36 MST 21:36 UTC	Utah. *CIIM*. *ShakeMap*. Felt (IV) at Portage, UT and Malad City, ID; (III) at Garland, Fielding, Plymouth, Tremonton, Clarkston, Cornish, Logan, UT, Idaho Falls, ID (?) and (II) at Mendon, Smithfield, Logan, Brigham City, Corinne, Clearfield, UT.	41º 48.52′	112º 13.10′	M_L 3.5

February 21	07:16 MST 14:16 UTC	Nevada. *CIIM*. *ShakeMap*. Reported felt by more than 1300 people in Utah, ranging from (V) in Groose Creek, UT (113 km) to (II) in Dutch John, UT (474 km). See CIIM for details, including felt reports in Utah for several aftershocks (3.7≤ M ≥4.6), February 21-27, 2008.	41º 09.18′	115º 52.02′	M_W 6.0 (NEIS)
March 07	04:21 MST 11:21 UTC	Utah. *CIIM*. Felt (III) at Salt Lake City, UT and (II) at Salt Lake City, Bountiful, Sandy, South Jordan, UT.	40º 48.85′	111º 46.50′	M_L 2.5
April 20	16:17 MDT 22:17 UTC	Utah. *CIIM*. Felt (III) at Cedar Valley, UT and (II) at Payson, Santaquin, UT.	39º 58.83′	111º 53.37′	M_L 2.8
June 06	14:09 MDT 20:09 UTC	Utah. *CIIM*. *ShakeMap*. Felt (III) at Blanding, UT.	37º 21.47′	109º 28.09′	M_L 3.7
June 15	13:27 MDT 19:27 UTC	Utah. *CIIM*. [Reportedly felt (II) at Twin Falls, ID.]	41º 44.26′	112º 36.58′	M_L 3.1
July 14*	16:06 MDT 22:06 UTC	Utah. *CIIM*. Felt (II) at Vernal, UT.	40º 39.00′	109º 28.80′	M 3.0
August 11	00:05 MDT 06:05 UTC	Utah. *CIIM*. Felt (III) at Salt Lake City, Magna, Riverton, UT and (II) at Hooper, UT.	40º 42.77′	112º 04.33′	M_L 2.3
August 15 August 16	20:24 MDT 02:24 UTC	Utah. *CIIM*. Felt (II) at Grace, ID.	42º 28.73′	111º 35.20′	M_L 3.3
August 30	01:15 MDT 07:15 UTC	Utah. *CIIM*. Felt (II) at Bryce Canyon, UT.	37º 32.52′	112º 18.97′	M_L 2.8
August 30	16:06 MDT 22:06 UTC	Utah. *CIIM*. *ShakeMap*. Felt (III) at Randolph, UT and Las Vegas, NV (?) and (II) at Clearfield, UT.	41º 40.42′	111º 08.73′	M_L 3.3

September 6 September 7	20:12 MDT 02:12 UTC	Utah. *CIIM*. *ShakeMap*. Felt (III) at Garland, Snowville, UT and (II) at Tremonton, Fielding, Magna, UT.	41º 42.71′	112º 22.77′	M_L 3.1
September 26	16:11 MDT 22:11 UTC	Utah. [Reportedly felt at Lehi, South Jordan; phone call.]	40º 21.39′	111º 53.87′	M_L 1.7
October 11 October 12	21:26 MDT 03:26 UTC	Utah. *CIIM*. *ShakeMap*. Felt (IV) at Woodruff, UT, (III) at Randolph, UT and (II) at Rock Springs, WY.	41º 41.42′	111º 08.55′	M_L 3.4
2009					
Date	**Time†**	**Felt Information‡**	**Latitude**	**Longitude**	**Magnitude§**
January 31	06:43 MST 13:43 UTC	Idaho. *CIIM*. Felt (II) at Afton, WY and American Falls, ID.	39º 37.90′	111º 11.02′	M_L 3.1
March 08 March 09	21:20 MDT 03:20 UTC	Utah. *CIIM*. Felt (III) at Salina, UT and (II) at Centerfield, Magna, Ibapah, UT and Bozeman, MT (?).	38º 49.09′	111º 44.11′	M_L 3.0
March 22 March 23	23:43 MDT 05:43 UTC	Utah. *CIIM*. Felt (II) at New Harmony, Virgin, Hurricane, Springdale, Kanarraville, Cedar City, Saint George, UT.	37º 25.20′	113º 09.90′	M_L 3.2
April 01 April 02	21:59 MDT 03:59 UTC	Utah. *CIIM*. Felt (III) at Park City, Salt Lake City, UT and (II) at Sandy, Morgan, Monroe (?), Washington (?), UT.	40º 34.88′	111º 30.45′	M_L 2.5

June 03	15:47 MDT 21:47 UTC	Utah. *CIIM*. *ShakeMap*. Felt (V) at Fielding, UT, (IV) at Garland, Plymouth, Wellsville, UT, (III) at Collinston, Tremonton, Portage, Deweyville, Mendon, Honeyville, Smithfield, Trenton, Hyde Park, Providence, Corinne, UT and (II) at Cornish, Logan, Brigham City, Richmond, Willard, Preston, Magna, Salt Lake City, South Jordan, UT and Weston, Malad City, Clifton, Preston, Blackfoot, ID .	41º 48.24′	112º 12.85′	M_L 4.0
June 06	05:14 MDT 11:14 UTC	Utah. *CIIM*. Felt (II) at Garland, UT.	41º 48.20′	112º 13.03′	M_L 3.0
September 04	00:01 MDT 06:01 UTC	Arizona. *CIIM*. Felt (II) at Fredonia, AZ.	36º 59.15′	112º 22.37′	M_L 3.0
January 31	06:43 MST 13:43 UTC	Idaho. *CIIM*. Felt (II) at Afton, WY and American Falls, ID.	39º 37.90′	111º 11.02′	M_L 3.1
March 08 March 09	21:20 MDT 03:20 UTC	Utah. *CIIM*. Felt (III) at Salina, UT and (II) at Centerfield, Magna, Ibapah, UT and Bozeman, MT (?).	38º 49.09′	111º 44.11′	M_L 3.0
March 22 March 23	23:43 MDT 05:43 UTC	Utah. *CIIM*. Felt (II) at New Harmony, Virgin, Hurricane, Springdale, Kanarraville, Cedar City, Saint George, UT.	37º 25.20′	113º 09.90′	M_L 3.2

† Times are listed both as Local Time—Mountain Standard Time (MST) or Mountain Daylight Time (MDT)—and as Universal Coordinated Time (UTC).

‡ *CIIM* indicates the availability of a Community Internet Intensity Map (*http://pasadena.wr.usgs.gov/shake/imw /archives.html*), compiled by the U.S. Geological Survey (USGS); *ShakeMap* indicates the availability of computer-generated maps of ground-shaking (*http://www.seis.utah.edu/shake/archive*), produced by the University of Utah Seismograph Stations (UUSS). Roman numerals correspond to the Modified Mercalli intensity scale. Unless otherwise indicated, felt information is from the USGS′s (1) CIIM reports and/or (2) PDE Monthly (or) Weekly Listing Files (*http://neic.usgs.gov/neis/data_services/ftp_files.html*). For a complete list of reported information see the *CIIM* website.

§ Richter local magnitude (M_L) or coda magnitude (M_C) determined by UUSS. If labeled "NEIS," data are from the National Earthquake Information Service of the USGS.

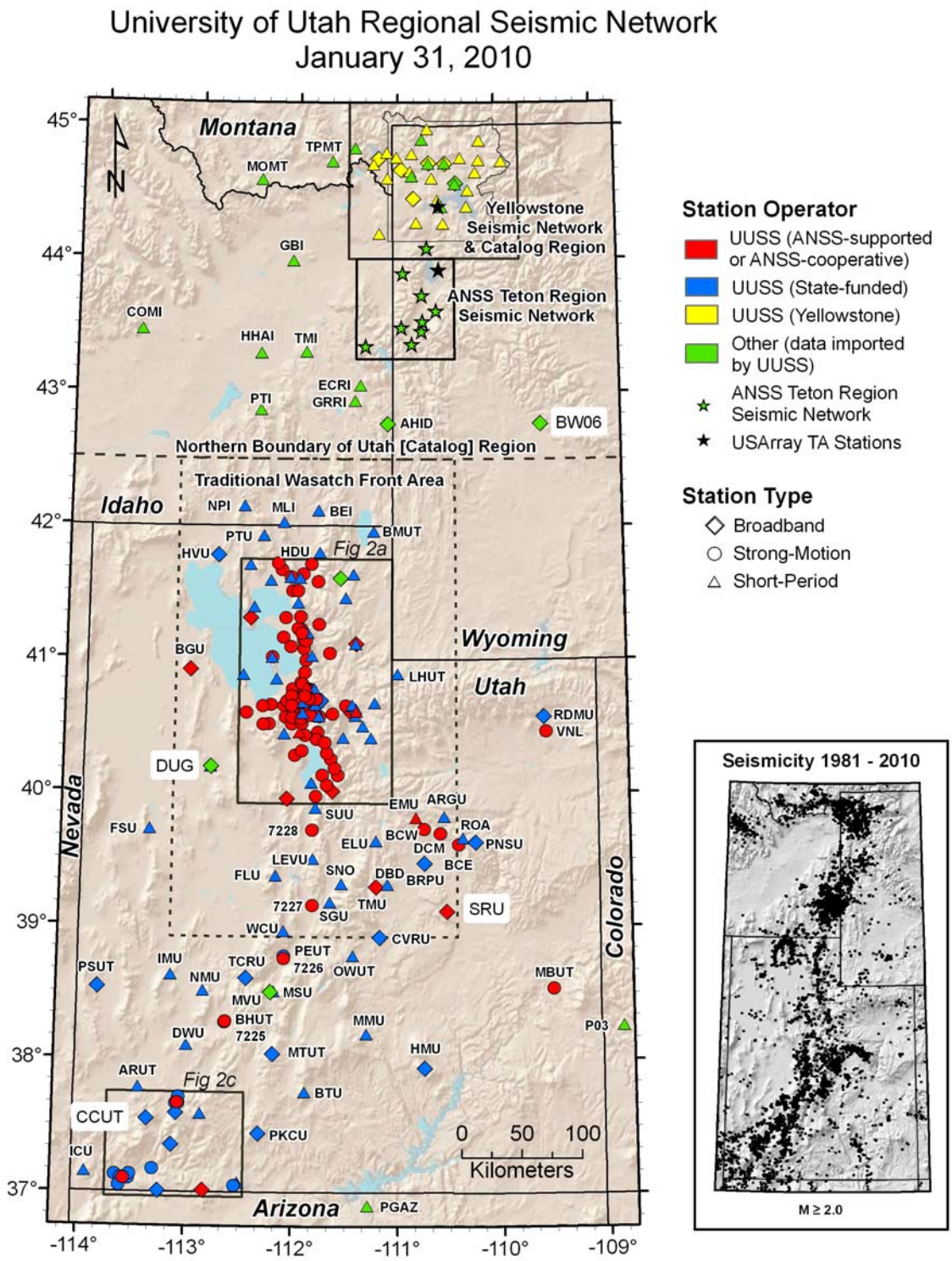

Figure 1. **Seismic stations operated and/or recorded as part of the University of Utah regional/urban seismic network (for list, see Appendix B or** http://www.seis.utah.edu/STATION_MAP/station_table.htm**). Inset dashed rectangle outlines our traditional Wasatch Front study area; our authoritative Utah catalog region extends from 36.75° to 42.5°N. Smaller map (right) shows representative seismicity for the same area. Locations of Figures 2a and 2c also shown.**

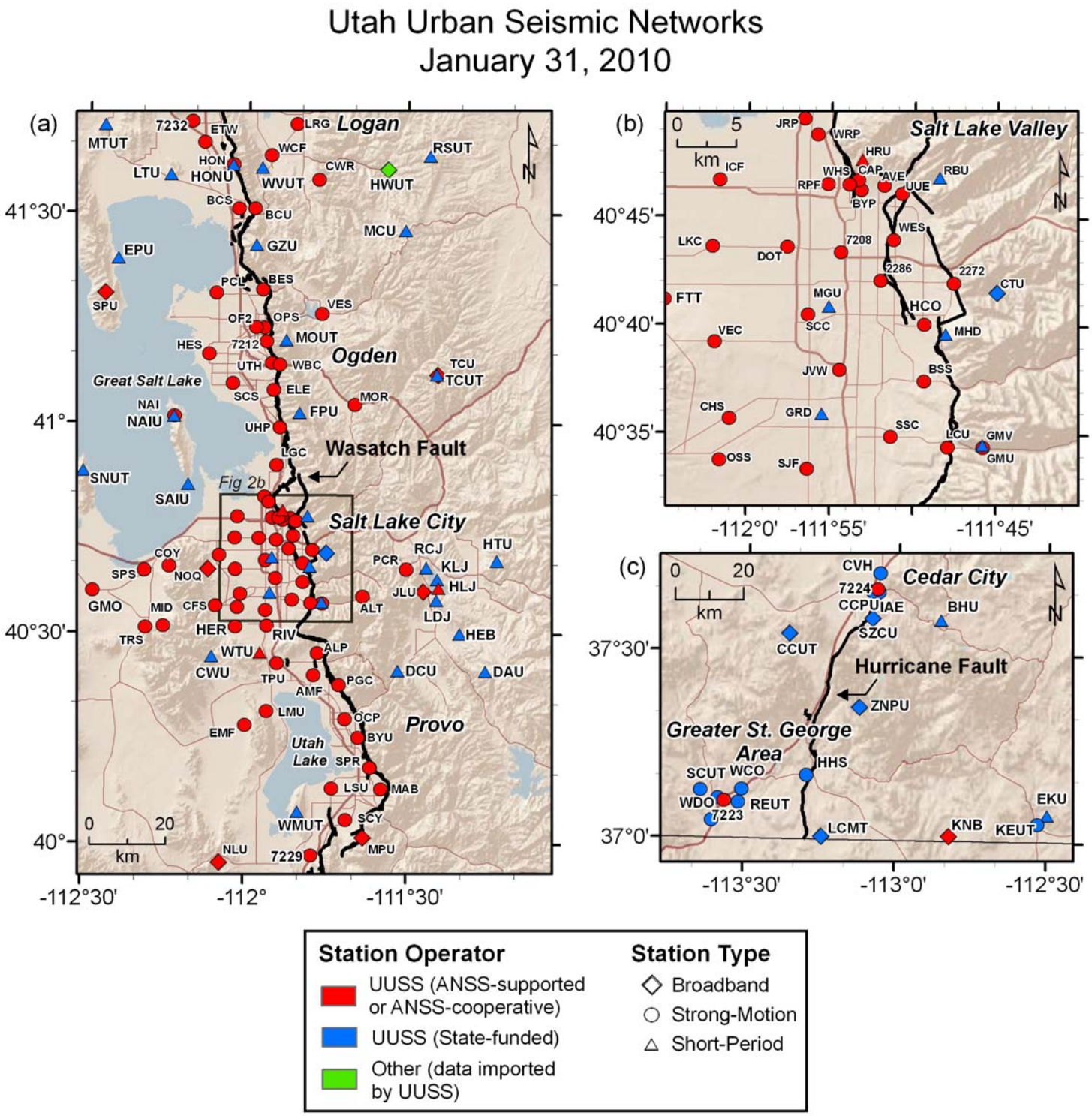

Figure 2. Real-time urban strong-motion networks in the Wasatch Front urban corridor and in SW Utah.

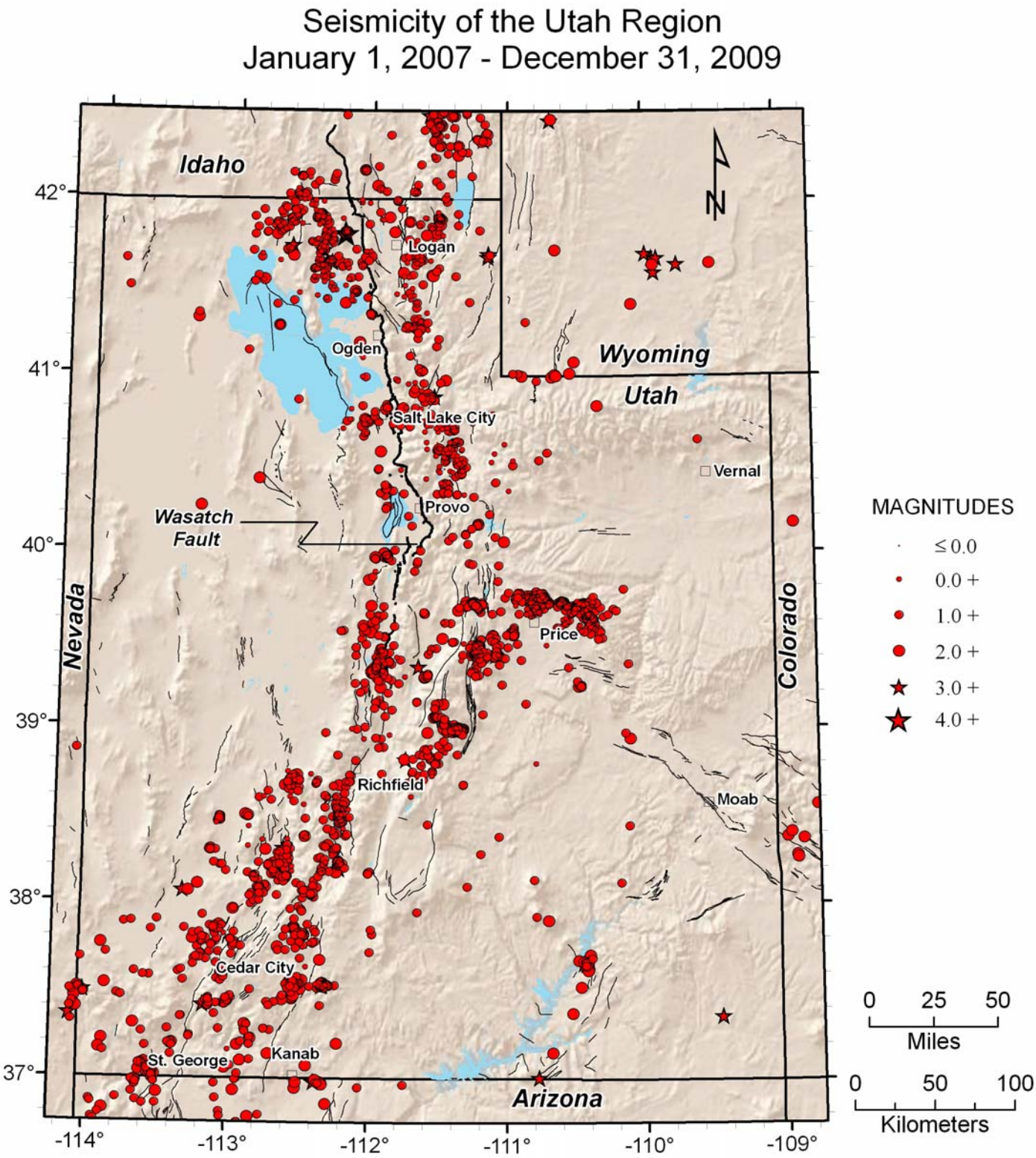

Figure 3. Epicenter map of earthquakes located by the University of Utah Seismograph Stations in the Utah region; base map of Quaternary (geologically young) faults from the Utah Geological Survey. The Wasatch fault is shown in bold.

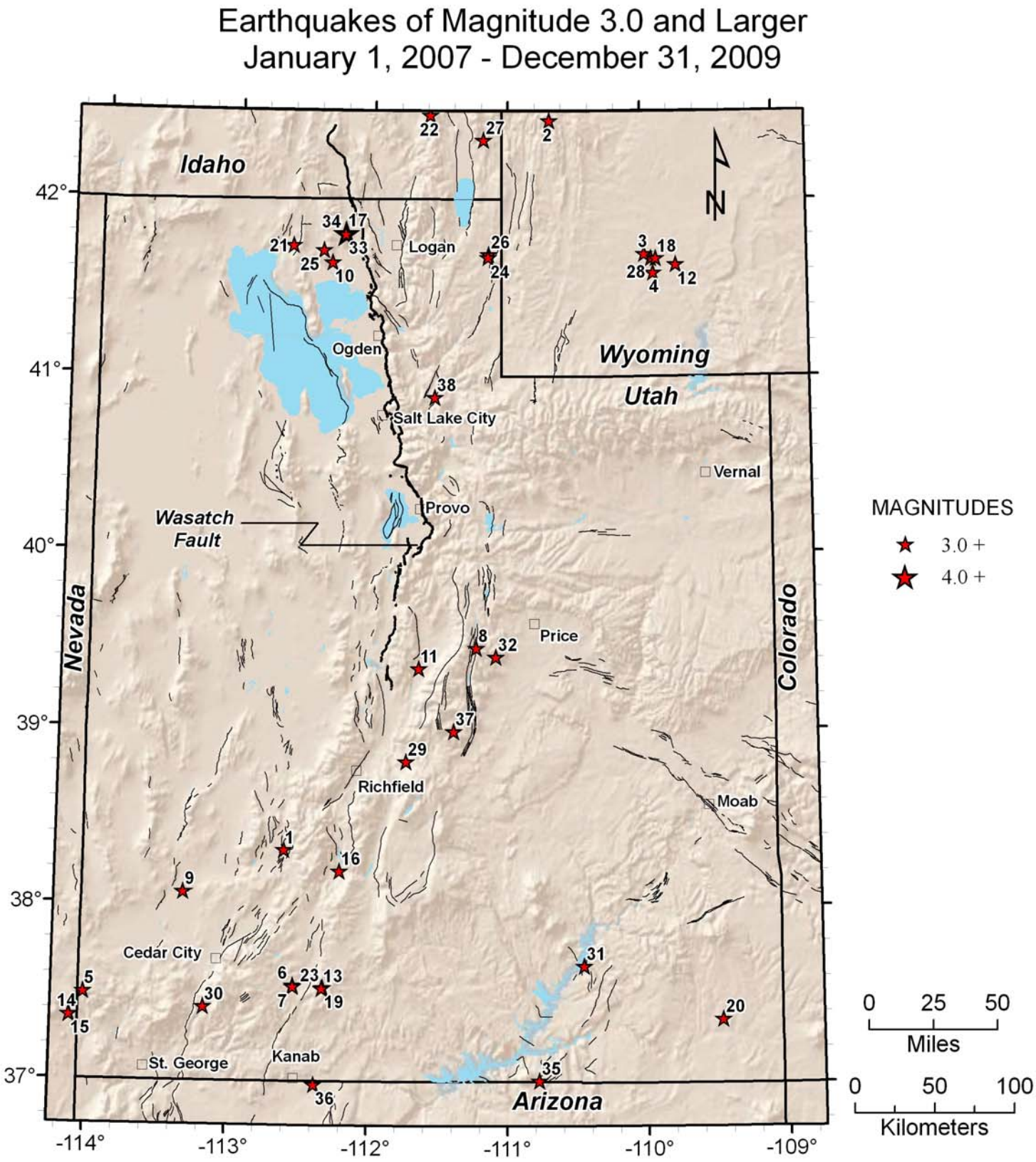

Figure 4. Epicenter map of earthquakes of magnitude 3.0 and larger in the Utah region during the period January 1, 2007 – December 31, 2009 (base map as in Figure 3). Epicenters, keyed to Table 3, are labeled by number.

APPENDICES

APPENDIX A

Siting Partners for ANSS Seismic Instrumentation

K-12 Schools and Colleges

Beaver School District
College of eastern Utah
Davis School District
Dixie State College
Granite School District
Jordan School District
Juab School District
Nebo School District
Salt Lake School District
Weber School District
Brigham Young University
Salt Lake Community College
Southern Utah University
University of Utah
Utah State University
Utah Valley University
Weber State College
Westminster College

Utah Cities, Towns & Counties

Alpine
Alta
American Fork
Beaver
Bountiful
Brigham City
Copperton
Eagle Mountain
Elwood
Grantsville
Gunnison
Holladay
Herriman
Lehi
Logan
Magna
Mapleton
Morgan
Murray
Ogden
Orem
Park City
Patson
Plain City
Pleasant Grove
Richfield
Riverton
Salem
Salt Lake City
Sandy
Santaquin
South Jordan
Stansbury Park
Syracuse
Tooele
Tremonton
Uintah
Wellsville
West Valley City

Cache County
Davis County
Salt Lake County
Utah County
Weber County

Other Siting Partners

Church of Jesus Christ of Latter-Day Saints
John Youd
Jordan River Park
Jordan Valley Water District
Kennecott Corporation
Lakeside Golf Course
Lee Kay Hunter Education Center
Rocky Mountain Power
Thanksgiving Point
Unified Fire Authority
US Bureau of Reclamation
US Bureau of Land Management
Utah Communications Agency Network
US Department of the Army
US Forest Service
Utah Department of Transportation
Utah Department of Information Technology Services
Utah Highway Patrol
Utah School and Institutional Trust Lands Administration
Utah State Army National Guard

APPENDIX B
UNIVERSITY OF UTAH REGIONAL/URBAN SEISMIC NETWORK

Operating Seismograph Stations
January 31, 2010

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
2272	Eastwood Elementary School Salt Lake City, UT	2272	HN[ZEN]	3	NP	40° 41.98′	111° 47.62′	1515	FBA23	Etna	Digital	NSMP, ANSS
2286	Roosevelt Elementary School Salt Lake City, UT	2286	HN[ZEN]	3	NP	40° 42.08′	111° 52.01′	1314	EpiSensor	K2	Digital	NSMP, ANSS
7208	SR 201/I-80 Bridge Array, Salt Lake City, UT	7208	EN[ZEN]	3	NP	40° 43.38′	111° 54.43′	1291	EpiSensor	K2	Digital	NSMP, ANSS
7212	Annex Bldg., Weber State University, Ogden, UT	7212	HN[ZEN]	3	NP	41° 11.75′	111° 56.50′	1422	EpiSensor	K2	Digital	NSMP, ANSS
7223	Dixie State College St. George, UT	7223	HN[ZEN]	3	NP	37° 06.02′	113° 33.94′	815	EpiSensor	Etna	Digital	NSMP, ANSS
7224	Southern Utah University Cedar City, UT	7224	HN[ZEN]	3	NP	37° 40.35′	113° 04.29′	1782	EpiSensor	Etna	Digital	NSMP, ANSS
7225	City Maintenance Yard Beaver, UT	7225	HN[ZEN]	3	NP	38° 17.01′	112° 38.32′	1808	EpiSensor	Etna	Digital	NSMP, ANSS
7226	UDOT IT Radio Shop Richfield, UT	7226	HN[ZEN]	3	NP	38° 45.43′	112° 05.26′	1616	FBA23	Etna	Digital	NSMP, ANSS
7227	City Maintenance Yard Gunnison, UT	7227	HN[ZEN]	3	NP	39° 09.35′	111° 49.17′	1568	EpiSensor	Etna	Digital	NSMP, ANSS
7228	Juab School District Nephi, UT	7228	HN[ZEN]	3	NP	39° 43.27′	111° 49.49′	1576	EpiSensor	Etna	Digital	NSMP, ANSS
7229	City Maintenance Shop Santaquin, UT	7229	HN[ZEN]	3	NP	39° 58.35′	111° 47.58′	1520	EpiSensor	Etna	Digital	NSMP, ANSS
7232	City Parks & Recreation Office Tremonton, UT	7232	HN[ZEN]	3	NP	41° 43.13′	112° 10.91′	1320	EpiSensor	Etna	Digital	NSMP, ANSS
AHI	Auburn, ID	AHID	BH[ZEN]	3	US	42° 45.92′	111° 06.02′	1960	*	*	Digital	USGS
ALP	Alpine Fire Station, Alpine, UT	ALP	EN[ZEN]	3	UU	40° 27.26′	111° 46.61′	1510	EpiSensor	K2	Digital	ANSS

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
ALT	Alta City Offices, Alta, UT	ALT	EN[ZEN]	3	UU	40° 35.42′	111° 38.25′	2635	Applied Mems	ANSS-130	Digital	ANSS
AMF	Tri-Cities Golf Course American Fork, UT	AMF	EN[ZEN]	3	UU	40° 24.11′	111° 47.27′	1445	EpiSensor	K2	Digital	ANSS
ANMO	Albuquerque, NM	ANMO	BH[ZEN]	3	IU	34° 57.01′	106° 27.61′	1743	*	*	Digital	USGS
ARGU	Argyle Ridge, UT	ARGU	EHZ	1	UU	39° 49.37′	110° 32.62′	2828	S13	Masscomp	Analog	Utah
ARUT	Antelope Range, UT	ARUT	EHZ	1	UU	37° 47.28′	113° 26.42′	1646	L4C	Masscomp	Analog	Utah
AVE	Avenues, Salt Lake City, UT	AVE	EN[ZEN]	3	UU	40° 46.47′	111° 51.83′	1387	Applied Mems	ANSS-130	Digital	ANSS
BCE	Book Cliffs East, UT	BCE	EHZ EN[ZEN]	4	UU	39° 36.79′	110° 24.51′	2666	L4C EpiSensor	K2	Digital	Utah
BCS	Brigham City Maintenance Shop Brigham City, UT	BCS	EN[ZEN]	3	UU	41° 30.71′	112° 01.98′	1303	EpiSensor	K2	Digital	ANSS
BCU	Brigham City, UT	BCU	EN[ZEN]	3	UU	41° 30.74′	111° 58.93′	1676	EpiSensor	K2	Digital	ANSS
BCW	Book Cliffs West, UT	BCW	EHZ EN[ZEN]	4	UU	39° 43.82′	110° 44.55′	2614	L4C EpiSensor	K2	Digital	Utah
BEI	Bear River Range, ID	BEI	EHZ	1	UU	42° 07.00′	111° 46.94′	1859	L4C	Masscomp	Analog	USGS
BES	Bates Elementary School Ogden, UT	BES	EN[ZEN]	3	UU	41° 19.10′	111° 57.26′	1455	EpiSensor	K2	Digital	ANSS
BGMZ	Barton Gulch, MT	BGMT	EHZ	1	MB	45° 14.00′	112° 02.43′	2172	*	*	Analog	MBMT
BGU	Big Grassy Mountain, UT	BGU	EN[ZEN] HH[ZEN]	3 3	UU	40° 55.53′	113° 01.79′	1640	EpiSensor 3ESP	72A-08	Digital	ANSS
BHU	Blowhard Mountain, UT	BHU	EH[ZEN]	3	UU	37° 35.55′	112° 51.42′	3230	S13	Masscomp	Analog	Utah
BHUT	Beaver High School, UT	BHUT	EN[ZEN]	3	UU	38° 16.61′	112° 38.42′	1799	PA-23	SMART-	Digital	Utah
BMN	Battle Mountain, NM	BMN	BHZ	1	NN	40° 25.89′	117° 13.31′	1594	*	*	Digital	UNR
BMUT	Black Mountain, UT	BMUT	EHZ	1	UU	41° 57.49′	111° 14.05′	2243	S13	Masscomp	Analog	USGS
BON	Boundary Peak, NV	BONR	SHZ	1	NN	37° 57.31′	118° 18.10′	2582	*	*	Digital	UNR
BOZ	Bozeman, MT	BOZ	BH[ZEN]	3	US	45° 38.82′	111° 37.78′	1589	*	*	Digital	USGS
BSS	Butlerville Substation Salt Lake City, UT	BSS	EN[ZEN]	3	UU	40° 37.45′	111° 49.37′	1411	EpiSensor	K2	Digital	ANSS
BTU	Barney Top, UT	BTU	EHZ	1	UU	37° 45.34′	111° 52.46′	3235	S13	Masscomp	Analog	Utah
BW0	Boulder, WY	BW06	BH[ZEN]	3	US	42° 46.00′	109° 33.50′	2224	*	*	Digital	USGS

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
BYP	Brigham Young Park Salt Lake City, UT	BYP	EN[ZEN]	3	UU	40° 46.26′	111° 53.23′	1323	Applied Mems	ANSS-130	Digital	ANSS
BYU	Brigham Young University Provo, UT	BYU	EN[ZEN]	3	UU	40° 15.17′	111° 38.97′	1421	EpiSensor	K2	Digital	ANSS
BZMZ	Bozeman Pass, MT	BZMT	EHZ	1	MB	45° 38.89′	110° 47.80′	1905	*	*	Analog	MBMT
CAPU	Capitol, Salt Lake City, UT	CAP	EN[ZEN]	3	UU	40° 46.71′	111° 53.40′	1384	Applied Mems	ANSS-130	Digital	ANSS
CCPU	Cedar City Park, UT	CCPU	EN[ZEN]	3	UU	38° 16.61′	112° 38.42′	1799	PA-23	SMART-24	Digital	Utah
CCUT	Cedar City, UT	CCUT	HH[ZEN]	3	UU	37° 33.04′	113° 21.77′	2124	STS-2	ANSS-130	Digital	USGS
			EN[ZEN]	3					Applied Mems			
CFS	Copperton Fire Station Copperton, UT	CFS	EN[ZEN]	3	UU	40° 33.96′	112° 05.61′	1654	EpiSensor	K2	Digital	ANSS
CHS	Copper Hills High School, West Jordan, UT	CHS	EN[ZEN]	3	UU	40° 35.68′	112° 01.03′	1460	Applied Mems	ANSS-130	Digital	ANSS
COM	Craters of the Moon, ID	COMI	EHZ	1	IE	43° 27.72′	113° 35.64′	1890	*	*	Digital	INEEL
COY	Coyote Canyon, Tooele Valley, UT	COY	EN[ZEN]	3	UU	40° 39.56′	112° 14.34′	1572	Applied Mems	ANSS-130	Digital	ANSS
CRMZ	Chrome Mountain, MT	CRMT	EHZ	1	MB	45° 27.35′	110° 08.41′	2941	*	*	Analog	MBMT
CTU	Camp Tracy, UT	CTU	HH[ZEN]	3	UU	40° 41.55′	111° 45.02′	1731	40T	72A-07	Digital	USGS
CVH	Cedar City, Canyon View High School, UT	CVH	EN[ZEN]	3	UU	37° 42.91′	113° 03.85′	1724	PA-23	SMART-24	Digital	Utah
CWR	Coldwater Ranch, Paradise, UT	CWR	EN[ZEN]	3	UU	41° 34.90′	111° 46.89′	1837	Applied Mems	ANSS-130	Digital	ANSS
CWU	Camp Williams, UT	CWU	EHZ	1	UU	40° 26.75′	112° 06.13′	1945	L4C	Masscomp	Analog	USGS
DAU	Daniels Canyon, UT	DAU	EHZ	1	UU	40° 24.75′	111° 15.35′	2771	S13	Masscomp	Analog	USGS
DBD	Des Bee Dove, UT	DBD	EHZ	1	UU	39° 18.82′	111° 05.55′	2265	L4C	Masscomp	Analog	Utah
DCM	Dugout Coal Mine, UT	DCM	EHZ	1	UU	39° 41.70′	110° 35.00′	2537	L4C	K2	Digital	Utah
			EN[ZEN]	3					EpiSensor			
DCU	Deer Creek Reservoir, UT	DCU	EHZ	1	UU	40° 24.82′	111° 31.61′	1829	L4C	Masscomp	Analog	USGS
DOT	Utah Dept. of Transportation Region II Offices, Salt Lake City, UT	DOT	EN[ZEN]	3	UU	40° 43.61′	111° 57.65′	1282	Applied Mems	ANSS-130	Digital	ANSS

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
DUG	Dugway, UT	DUG	BH[ZEN]	3	US	40° 11.70′	112° 48.80′	1477	*	*	Digital	USGS
			EH[ZEN]	6	UU				S13	Masscomp	Analog	Utah, USGS
			EL[ZEN]									
DWU	Dry Willow, UT	DWU	EHZ	1	UU	38° 06.32′	112° 59.85′	2270	S13	Masscomp	Analog	Utah
ECR	Eagle Creek, ID	ECRI	EHZ	1	IE	43° 03.24′	111° 22.26′	2086	*	*	Digital	INEEL
EKU	East Kanab, UT	EKU	EHZ	1	UU	37° 04.48′	112° 29.81′	1829	S13	Masscomp	Analog	Utah
ELE	East Layton Elementary School, East Layton, UT	ELE	EN[ZEN]	3	UU	41° 04.84′	111° 55.09′	1444	Applied Mems	ANSS-130	Digital	ANSS
ELK	Elko, NV	ELK	BH[ZEN]	3	US	40° 44.69′	115° 14.33′	2210	*	*	Digital	USGS
ELU	Electric Lake, UT	ELU	EHZ	1	UU	39° 38.41′	111° 12.23′	2970	L4C	Masscomp	Analog	Utah
EMF	Eagle Mountain Gas Tap, UT	EMF	EN[ZEN]	3	UU	40° 16.89′	111° 59.92′	1487	Applied Mems	ANSS-130	Digital	ANSS
EMU	Emma Park, UT	EMU	EH[ZEN]	4	UU	39° 48.84′	110° 48.92′	2268	S13	Masscomp	Analog	USGS
			ELZ									
			EN[ZEN]	3					FBA23	K2	Digital	Utah
EPU	East Promontory, UT	EPU	EHZ	1	UU	41° 23.49′	112° 24.53′	1436	L4C	Masscomp	Analog	USGS
ETW	Elwood Town Hall, Elwood, UT	ETW	EN[ZEN]	3	UU	41° 40.15′	112° 08.53′	1305	Applied Mems	ANSS-130	Digital	ANSS
FLU	Fool′s Peak, UT	FLU	EHZ	1	UU	39° 22.69′	112° 10.29′	1951	18300	Masscomp	Analog	USGS
FPU	Francis Peak, UT	FPU	EHZ	1	UU	41° 01.58′	111° 50.21′	2816	L4C	Masscomp	Analog	USGS
FSU	Fish Springs, UT	FSU	EHZ	1	UU	39° 43.35′	113° 23.48′	1487	18300	Masscomp	Analog	Utah
FTT	Fire Training Tower, Magna, UT	FTT	EN[ZEN]	3	UU	40° 41.16′	112° 04.99′	1381	Applied Mems	ANSS-130	Digital	ANSS
FLWY	Flagg Ranch, WY	FLWY	BH[ZEN]	3	IW	44° 04.96′	110° 41.96′	2078	3ESP	RT-130	Digital	ANSS
GBI	Big Grassy Butte, ID	GBI	EHZ	1	IE	43° 59.22′	112° 03.78′	1541	*	*	Digital	INEEL
GCN	Grand Canyon, AZ	GCN	EHZ	1	AR	36° 02.64′	112° 07.68′	2294	*	*	Analog	NAU
GMO	Grantsville Maintenance Office, Grantsville, UT	GMO	EN[ZEN]	3	UU	40° 36.04′	112° 28.48′	1320	Applied Mems	ANSS-130	Digital	ANSS
GMU	Granite Mountain, UT	GMU	EH[ZEN]	4	UU	40° 34.53′	111° 45.79′	1829	S13	Masscomp	Analog	USGS
			ELZ									
GMV	Granite Mountain Vault Sandy, UT	GMV	EN[ZEN]	3	UU	40° 34.40′	111° 45.79′	1829	EpiSensor	K2	Digital	ANSS
GRD	Gardner Farm, UT	GRD	EHZ	1	UU	40° 35.93′	111° 55.47′	1323	Ranger	Masscomp	Analog	USGS
GRR	Grays Lake, ID	GRRI	EHZ	1	IE	42° 56.28′	111° 25.32′	2207	*	*	Digital	INEEL

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
GZU	Grizzly Peak, UT	GZU	EH[ZEN]	4	UU	41° 25.53′	111° 58.50′	2646	S13	Masscomp	Analog	USGS
			ELZ									
HCO	Holladay City Offices Holladay, UT	HCO	EN[ZEN]	3	UU	40° 40.07′	111° 49.38′	1362	EpiSensor	K2	Digital	ANSS
HDU	Hyde Park, UT	HDU	EHZ	1	UU	41° 48.18′	111° 45.99′	1807	L4C	Masscomp	Analog	USGS
HEB	Heber, UT	HEB	EHZ	1	UU	40° 30.09′	111° 20.15′	1925	S13	Masscomp	Analog	Utah
HER	Herriman Fire Station Herriman, UT	HER	EN[ZEN]	3	UU	40° 30.94′	112° 01.85′	1502	EpiSensor	K2	Digital	ANSS
HES	Hooper Elementary School Hooper, UT	HES	EN[ZEN]	3	UU	41° 09.89′	112° 07.30′	1292	EpiSensor	K2	Digital	ANSS
HHA	Hell′s Half Acre, ID	HHAI	EHZ	1	IE	43° 17.70′	112° 22.74′	1371	*	*	Digital	INEEL
HHS	Hurricane High School, UT	HHS	EN[ZEN]	3	UU	37° 10.43′	113° 17.74′	987	EpiSensor	Etna	Digital	Utah
HLI	Hailey, ID	HLID	BH[ZEN]	3	US	43° 33.75′	114° 24.83′	1772	*	*	Digital	USGS
HLJZ	Hailstone, UT	HLJ	EHZ	1	UU	40° 36.64′	111° 24.05′	1931	S13	Masscomp	Analog	Utah
			EN[ZEN]	3					FBA23	K2	Digital	
HMU	Henry Mountain, UT	HMU	HH[ZEN]	3	UU	37° 56.28′	110° 44.51′	2430	3T	72A-07	Digital	Utah
HON	Honeyville, UT	HON	EN[ZEN]	3	UU	41° 36.97′	112° 03.05′	1528	Applied Mems	ANSS-130	Digital	ANSS
HONU		HONU	EHZ	1					L4C	Masscomp	Analog	USGS
HRU	Hogsback Ridge, UT	HRU	EHZ	1	UU	40° 47.67′	111° 53.14′	1620	Ranger	Masscomp	Analog	USGS
			EN[ZEN]	3					Applied Mems	ANSS-130	Digital	ANSS
HTU	Hoyt, UT	HTU	EHZ	1	UU	40° 40.52′	111° 13.21′	2576	L4C	Masscomp	Analog	USGS
HVU	Hansel Valley, UT	HVU	HH[ZEN]	3	UU	41° 46.78′	112° 46.50′	1609	40T	72A-07	Digital	USGS
HWU	Hardware Ranch, UT	HWUT	BH[ZEN]	3	US	41° 36.41′	111° 33.91′	1830	*	*	Digital	USGS
IAE	Cedar City, Iron County Adult Education, UT	IAE	EN[ZEN]	3	UU	37°39.91′	113° 40.02′	1807	EpiSensor	Etna	Digital	Utah
ICF	International Center Fire Station, Salt Lake City, UT	ICF	EN[ZEN]	3	UU	40° 46.69′	112° 01.72′	1281	EpiSensor	K2	Digital	ANSS
ICU	Indian Springs Canyon, UT	ICU	EHZ	1	UU	37° 08.98′	113° 55.41′	1451	S13	Masscomp	Analog	Utah
IMU	Iron Mountain, UT	IMU	EHZ	1	UU	38° 37.99′	113° 09.50′	1833	L4C	Masscomp	Analog	Utah
IMW	Indian Meadows, WY	IMW	BH[ZEN]	3	IW	43° 53.58′	110° 56.58′	2670	3ESP	RT-130	Digital	ANSS
JLU	Jordanelle, UT	JLU	EN[ZEN]	3	UU	40° 36.12′	111° 27.00′	2285	EpiSensor	ANSS-130	Digital	ANSS
			HH[ZEN]	3					3ESP			

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
JRP	Jordan River State Park Salt Lake City, UT	JRP	EN[ZEN]	3	UU	40° 49.54′	111° 56.66′	1284	EpiSensor	K2	Digital	ANSS
JVW	Jordan Valley Water District Well, Murray, UT	JVW	EN[ZEN]	3	UU	40° 37.95′	111° 54.46′	1315	Applied Mems	ANSS-130	Digital	ANSS
KEUT	Kanab Elementary School, UT	KEUT	EN[ZEN]	3	UU	37° 03.02′	112° 31.76′	1514	PA-23	SMART-24	Digital	Utah
KLJ	Keetley, UT	KLJ	EHZ	1	UU	40° 37.85′	111° 24.30′	1992	S13	Masscomp	Analog	Utah
KNB	Kanab, UT	KNB	HH[ZEN]	3	UU	37° 01.00′	112° 49.34′	1715	3T	ANSS-130	Digital	Utah. ANSS, LLNL
			EN[ZEN]	3					Episensor			
LCMT	Little Creek Mountain, UT	LCMT	HH[ZEN]	3	UU	37° 00.71′	113° 14.63′	1411	3T	SMART-24	Digital	Utah
			EN[ZEN]	3					PA-23			
LCU	Little Cottonwood, UT	LCU	EN[ZEN]	3	UU	40° 34.41′	111° 47.91′	1571	Applied Mems	K2	Digital	ANSS
LDJ	Lady, UT	LDJ	EHZ	1	UU	40° 34.89′	111° 24.52′	2217	S13	Masscomp	Analog	Utah
LEVU	Levan, UT	LEVU	EHZ	1	UU	39° 30.39′	111° 48.88′	1996	L4C	Masscomp	Analog	USGS
LGC	Lakeside Golf Course Bountiful, UT	LGC	EN[ZEN]	3	UU	40° 54.04′	111° 54.51′	1292	EpiSensor	K2	Digital	ANSS
LHUT	Little Humpy Peak, UT	LHUT	EHZ	1	UU	40° 53.49′	110° 59.78′	3084	S13	Masscomp	Analog	Utah
LKC	Lee Kay Hunter Education Center Magna, UT	LKC	EN[ZEN]	3	UU	40° 43.62′	112° 02.14′	1289	EpiSensor	K2	Digital	ANSS
LKW	Lake, WY	LKWY	BH[ZEN]	3	US	44° 33.91′	110° 24.00′	2424	*	*	Digital	USGS
LMU	Lake Mountain, UT	LMU	EN[ZEN]	3	UU	40° 18.91′	111° 55.92′	1593	EpiSensor	K2	Digital	ANSS
LOHW	National Elk Refuge, WY	LOHW	BH[ZEN]	3	IW	43° 36.76′	110° 36.30′	2245	3ESP	RT-130	Digital	ANSS
LRG	Logan River Golf Course	LRG	EN[ZEN]	3	UU	41° 42.82′	111° 51.08′	1362	Applied Mems	ANSS-130	Digital	ANSS
LSU	Lake Shores, UT	LSU	EN[ZEN]	3	UU	40° 07.94′	111° 43.80′	1375	EpiSensor	K2	Digital	ANSS
LTU	Little Mountain, UT	LTU	EHZ	1	UU	41° 35.51′	112° 14.83′	1585	L4C	Masscomp	Analog	USGS
MAB	Mapleton Ambulance Building Mapleton, UT	MAB	EN[ZEN]	3	UU	40° 07.85′	111° 34.67′	1440	EpiSensor	K2	Digital	ANSS
MBUT	Moab, UT	MBUT	EN[ZEN]	3	UU	38° 32.00′	109° 30.59′	1376	FBA23	Etna	Digital	Utah
MCID	Moose Creek, ID	MCID	EHZ	1	WY	44° 11.45′	111° 11.03′	2137	L4C	Masscomp	Analog	USGS
MCU	Monte Cristo Peak, UT	MCU	EHZ	1	UU	41° 27.70′	111° 30.45′	2664	18300	Masscomp	Analog	USGS

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
MGU	Meadow Brook Golf Course Salt Lake City, UT	MGU	EHZ	1	UU	40° 40.89′	111° 55.09′	1291	Ranger	Masscomp	Analog	USGS
MHD	Mile High Drive, UT	MHD	EHZ	1	UU	40° 39.64′	111° 48.05′	1597	Ranger	Masscomp	Analog	USGS
MID	Middle Canyon, UT	MID	EN[ZEN]	3	UU	40° 31.04′	112° 15.28′	1722	Applied Mems	ANSS-130	Digital	ANSS
MLI	Malad Range, ID	MLI	EHZ	1	UU	42° 01.61′	112° 07.53′	1896	L4C	Masscomp	Analog	USGS
MMU	Miners Mountain, UT	MMU	EHZ	1	UU	38° 11.57′	111° 17.66′	2387	S13	Masscomp	Analog	Utah
MOMZ	Monida, MT	MOMT	EHZ	1	MB	44° 35.60′	112° 23.66′	2220	*	*	Analog	MBMT
MOR	Morgan,UT	MOR	EN[ZEN]	3	UU	41° 02.77′	111° 39.94′	1633	Applied Mems	ANSS-130	Digital	ANSS
MOUT	Mount Ogden, UT	MOUT	EHZ	1	UU	41° 11.94′	111° 52.73′	2743	S13	Masscomp	Analog	USGS
MPU	Maple Canyon, UT	MPU	EN[ZEN]	3	UU	40° 00.93′	111° 38.00′	1909	EpiSensor	K2	Digital	ANSS
			HH[ZEN]	3					40T	72A-07	Digital	USGS
MSU	Marysvale, UT	MSU	EHZ	1	UU	38° 30.74′	112° 10.63′	2105	18300	Masscomp	Analog	Utah
MTLO	Mt. Logan, AZ	MTL	EHZ	1	AR	36° 21.18′	113° 11.94′	2418	*	*	Analog	NAU
MTPU	Mt. Pierson, UT	MTPU	HH[ZEN]	3	UU	38° 02.49′	112° 11.06′	3112	Trillium 120	Q330	Digital	Utah
			EN[ZEN]	3					EpiSensor			
MTUT	Morton Thiokol, UT	MTUT	EHZ	1	UU	41° 42.55′	112° 27.28′	1373	L4C	Masscomp	Analog	USGS
MVCO	Mesa Verde, CO	MVCO	BH[ZEN]	3	US	37° 12.62′	108° 29.92′	2170	STS-2	Q330	Digital	ANSS
MVU	Marysvale, UT	MVU	BH[ZEN]	3	LB	38° 30.22′	112° 12.74′	2240	*	*	Digital	Sandia
NAI	North Antelope Island, UT	NAI	EN[ZEN]	3	UU	41° 00.97′	112° 13.68′	1472	EpiSensor	K2	Digital	ANSS
NAIU		NAIU	EHZ	1					L4C	Masscomp	Analog	USGS
NLU	North Lily Mine, UT	NLU	EN[ZEN]	3	UU	39° 57.29′	112° 04.50′	2036	Episensor	72A-08	Digital	ANSS
			HH[ZEN]	3					3ESP			
NMU	North Mineral Mountain, UT	NMU	EH[ZEN]	4	UU	38° 30.99′	112° 51.00′	1853	S13	Masscomp	Analog	Utah
			ELZ									
NOQ	North Oquirrh Mountains, UT	NOQ	EN[ZEN]	3	UU	40° 39.16′	112° 07.26′	1628	EpiSensor	K2	Digital	ANSS
			HH[ZEN]	3					40T	72A-07	Digital	USGS
NPI	North Pocatello, ID	NPI	EHZ	1	UU	42° 08.84′	112° 31.10′	1640	L4C	Masscomp	Analog	USGS
OCP	Orem City Park, Orem, UT	OCP	EN[ZEN]	3	UU	40° 17.87′	111° 41.44′	1464	EpiSensor	K2	Digital	ANSS
OF2	Ogden Fire Station º 2 Ogden, UT	OF2	EN[ZEN]	3	UU	41° 13.70′	111° 56.92′	1358	EpiSensor	K2	Digital	ANSS

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
OPS	Ogden Public Safety Building, Ogden, UT	OPS	EN[ZEN]	3	UU	41° 13.72′	111° 58.54′	1317	Applied Mems	ANSS-130	Digital	ANSS
OSS	Oquirrh Sub Station, UT	OSS	EN[ZEN]	3	UU	40° 33.77′	112° 01.61′	1503	Applied Mems	ANSS-130	Digital	ANSS
OWUT	Old Woman Plateau, UT	OWUT	EHZ	1	UU	38° 46.80′	111° 25.42′	2568	L4C	Masscomp	Analog	Utah
P03	Wild Steer, Paradox Basin, CO	PV03	EHZ	1	RE	38° 15.26′	108° 50.88′	1975	*	*	Analog	USBR
P15	Potato Mountain Paradox Basin, CO	PV15	EHZ	1	RE	38° 20.51′	108° 28.86′	2280	*	*	Analog	USBR
P17A	Butcher Ranch, Price, UT	P17A	HH[ZEN]	3	UU	39° 37.67′	110° 14.56′	1687	Trillium 240	Q330	Digital	Utah
			EN[ZEN]	3					EpiSensor			
P18A	Preston Nutter Ranch, Sunnyside, UT	P18A	HH[ZEN]	3	UU	39° 28.38′	110° 44.40′	2743	Trillium 240	Q330	Digital	Utah
PCL	Plain City Landfill Plain City, UT	PCL	EN[ZEN]	3	UU	41° 18.60′	112° 06.00′	1290	Applied Mems	ANSS-130	Digital	ANSS
PCR	Park City Recreation Center Park City, UT	PCR	EN[ZEN]	3	UU	40° 39.25′	111° 30.19′	2100	EpiSensor	K2	Digital	ANSS
PEUT	Richfield, Pahvant Elementary School, UT	PEUT	EN[ZEN]	3	UU	38° 46.55′	112° 05.32′	1644	PA-23	SMART-24	Digital	Utah
PGAZ	Page, AZ	PGA	EHZ	1	AR	36° 54.34′	111° 16.86′	1272	*	*	Analog	NAU
PGC	Pleasant Grove Creek, UT	PGC	EN[ZEN]	3	UU	40° 22.71′	111° 42.62′	1707	EpiSensor	K2	Digital	ANSS
PKCU	Pink Cliffs, UT	PCUT	HH[ZEN]	3	UU	37° 26.63′	112° 18.66′	2834	Trillium 120	SMART-24	Digital	Utah
			EN[ZEN]	3					PA-23			
PRN	Pahroc, Range, NV	PRN	SHZ	1	NN	37° 24.40′	115° 03.05′	1402	*	*	Digital	UNR
PSUT	Pine Spring, UT	PSUT	HH[ZEN]	3	UU	38° 32.02′	113° 51.28′	1999	Trillium 120	Q330	Digital	Utah
			EN[ZEN]	3					EpiSensor			
PTI	Pocatello, ID	PTI	EHZ	1	IE	42° 52.20′	112° 22.21′	1670	*	*	Digital	INEEL
PTU	Portage, UT	PTU	EHZ	1	UU	41° 55.76′	112° 19.48′	2192	L4C	Masscomp	Analog	USGS
Q16A	Castle Valley Ranch, Emery, UT	Q16A	HH[ZEN]	3	UU	38° 55.06′	111° 10.30′	1912	STS-2	Q330	Digital	Utah
			EN[ZEN]	3					EpiSensor			
QLMZ	Earthquake Lake, MT	QLMT	EHZ	1	MB	44° 49.84′	111° 25.80′	2064	*	*	Analog	MBMT
RBUZ	Red Butte Canyon, UT	RBU	EHZ	1	UU	40° 46.85′	111° 48.50′	1676	L4C	Masscomp	Analog	USGS
RCJZ	Ross Creek, UT	RCJ	EHZ	1	UU	40° 39.51′	111° 26.36′	2090	S13	Masscomp	Analog	Utah

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
RDMU	Red Mountain, UT	RDMU	HH[ZEN]	3	UU	40° 34.25′	109° 34.17′	2087	Trillium 120	SMART-24	Digital	Utah
			EN[ZEN]	3					PA-23			
REDW	Red-Top Meadows, WY	REDW	BH[ZEN]	3	IW	43° 21.74′	110° 51.18′	2322	3ESP	RT-130	Digital	ANSS
REUT	Washington Fields, Riverside Elementary School, UT	REUT	EN[ZEN]	3	UU	37° 05.86′	113° 31.16′	791	PA-23	SMART-24	Digital	Utah
RIV	Public Works Building Riverton, UT	RIV	EN[ZEN]	3	UU	40° 31.16′	111° 56.05′	1347	EpiSensor	K2	Digital	ANSS
ROA	Roan Cliffs, UT	ROA	EHZ	1	UU	39° 39.69′	110° 21.88′	2962	S13	Masscomp	Analog	Utah
RPF	Rose Park Fire Station, Salt Lake City, UT	RPF	EN[ZEN]	3	UU	40° 46.52′	111° 55.22′	1287	Applied Mems	ANSS-130	Digital	ANSS
RRI2	Red Ridge, ID	RRI2	BH[ZEN]	3	IW	43° 20.84′	111° 19.20′	2547	3ESP	RT-130	Digital	ANSS
RSUT	Red Spur, UT	RSUT	EHZ	1	UU	41° 38.31′	111° 25.90′	2682	S13	Masscomp	Analog	USGS
SAIU	South Antelope Island, UT	SAIU	EHZ	1	UU	40° 51.29′	112° 10.89′	1384	L4C	Masscomp	Analog	USGS
SCC	Salt Lake Community College	SCC	EN[ZEN]	3	UU	40° 40.49′	111° 56.37′	1306	EpiSensor	K2	Digital	ANSS
SCS	Syracuse City Cemetery Shop Syracuse, UT	SCS	EN[ZEN]	3	UU	41° 05.73′	112° 02.81′	1321	EpiSensor	K2	Digital	ANSS
SCUT	Santa Clara, UT	SCUT	EN[ZEN]	3	UU	37° 07.69′	113° 38.68′	837	EpiSensor	Etna	Digital	Utah
SCY	Salem City Yard, Salem, UT	SCY	EN[ZEN]	3	UU	40° 03.47′	111° 41.14′	1386	Applied Mems	ANSS-130	Digital	ANSS
SGSU	St. George Fire Station #4, UT	SCSU	EN[ZEN]	3	UU	38° 16.61′	112° 38.42′	1799	PA-23	SMART-24	Digital	Utah
SGU	Sterling, UT	SGU	EHZ	1	UU	39° 10.94′	111° 38.68′	2357	18300	Masscomp	Analog	USGS
SHP	Sheep Range, NV	SHP	EHZ	1	NN	36° 30.33′	115° 09.61′	1590	*	*	Digital	UNR
SJF	South Jordan Fire Station, South Jordan, UT	SJF	EN[ZEN]	3	UU	40° 33.37′	111° 56.34′	1356	Applied Mems	ANSS-130	Digital	ANSS
SNO	Snow College, UT	SNO	EHZ	1	UU	39° 19.18′	111° 32.33′	2503	Ranger	Masscomp	Analog	Utah
SNUT	Stanbury North, UT	SNUT	EHZ	1	UU	40° 53.10′	112° 30.52′	1652	18300	Masscomp	Analog	USGS
SPR	Wildlife Resource Center Springville, UT	SPR	EN[ZEN]	3	UU	40° 10.94′	111° 36.71′	1379	EpiSensor	K2	Digital	ANSS
SPS	Stansbury Park Sewage Lagoon Stansbury Park, UT	SPS	EN[ZEN]	3	UU	40° 38.97′	112° 18.95′	1293	Applied Mems	ANSS-130	Digital	ANSS
SPU	South Promontory Point, UT	SPU	EN[ZEN]	3	UU	41° 18.52′	112° 26.95′	2086	EpiSensor	72A-08	Digital	ANSS
			HH[ZEN]	3					3ESP			

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
SRU	San Rafael Swell, UT	SRU	EHZ	1	UU	39° 06.65′	110° 31.43′	1804	S13	Masscomp	Analog	Utah, ANSS, IRIS
			HH[ZEN]	6					STS-2	ANSS-130	Digital	
			EN[ZEN]						EpiSensor			
SSC	Sandy Senior Center Sandy, UT	SSC	EN[ZEN]	3	UU	40° 34.89′	111° 51.35′	1414	EpiSensor	K2	Digital	ANSS
SUU	Santaquin Canyon, UT	SUU	EHZ	1	UU	39° 53.29′	111° 47.45′	2024	18300	Masscomp	Analog	USGS
SZCU	Shurtz Canyon, UT	SZCU	HH[ZEN]	3	UU	37° 35.72′	113° 05.25′	2026	3T	SMART-24	Digital	Utah
			EN[ZEN]	3					PA-23			
TCRU	Three Creeks Reservoir, UT	TCRU	HH[ZEN]	3	UU	38° 36.57′	112° 26.83′	2293	Trillium 120	SMART-24	Digital	Utah
			EN[ZEN]	3					PA-23			
TCU	Toone Canyon, UT	TCU	EN[ZEN]	3	UU	41° 07.04′	111° 24.47′	2269	EpiSensor	72A-08	Digital	ANSS
			HH[ZEN]	3					3ESP			
TCUT	Toone Canyon, UT	TCUT	EHZ	1	UU	41° 07.07′	111° 24.51′	2320	L4C	Masscomp	Analog	USGS
TMI	Taylor Mountain, ID	TMI	EHZ	1	IE	43° 18.30′	111° 55.08′	2179	*	*	Digital	INEEL
TMU	Trail Mountain, UT	TMU	HH[ZEN]	3	UU	39° 17.79′	111° 12.49′	2731	40T	72A-08	Digital	Utah, ANSS
			EN[ZEN]	3					EpiSensor			
TPMZ	Teepe Creek, MT	TPMT	EHZ	1	MB	44° 43.79′	111° 39.94′	2518	*	*	Analog	MBMT
TPNV	Topopah Spring, NV	TPNV	BH[ZEN]	3	US	36° 56.93′	116° 14.97′	1600	*	*	Digital	USGS
TPU	Thanksgiving Point, Lehi, UT	TPU	EN[ZEN]	3	UU	40° 25.81′	111° 54.13′	1383	EpiSensor	K2	Digital	ANSS
TRC	Troy Canyon, NV	TRC	BHZ	1	NN	38° 20.98′	115° 35.11′	1815	*	*	Digital	UNR
TRS	Tooele County Radio Shop, Tooele, UT	TRS	EN[ZEN]	3	UU	40° 30.83′	112° 18.63′	1568	EpiSensor	K2	Digital	ANSS
TUC	Tucson, AZ	TUC	BH[ZEN]	3	US	32° 18.58′	110°47.05′	906	*	*	Digital	USGS
UHP	Utah Highway Patrol Farmington, UT	UHP	EN[ZEN]	3	UU	40° 59.47′	111° 53.88′	1295	EpiSensor	K2	Digital	ANSS
UTH	Uintah Town Hall, Uintah, UT	UTH	EN[ZEN]	3	UU	41° 08.65′	111° 55.52′	1389	EpiSensor	K2	Digital	ANSS
UUE	University of Utah EMCB Bldg. Salt Lake City, UT	UUE	EN[ZEN]	3	UU	40° 46.09′	111° 50.77′	1449	EpiSensor	K2	Digital	ANSS
VEC	Valley Emergency Communications Center West Valley City, UT	VEC	EN[ZEN]	3	UU	40° 39.21′	112° 01.95′	1480	EpiSensor	K2	Digital	ANSS

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
VES	Valley Elementary School, Huntsville, UT	VES	EN[ZEN]	3	UU	41° 15.72′	111° 46.20′	1501	Applied Mems	ANSS-130	Digital	ANSS
VNL	Vernal, UT	VNL	EN[ZEN]	3	UU	40° 27.48′	109° 32.89′	1648	FBA23	Etna	Digital	Utah
WBC	Weber Canyon, UT	WBC	EN[ZEN]	3	UU	41° 08.38′	111° 54.05′	1602	EpiSensor	K2	Digital	ANSS
WCF	Wellsville Fire Station, Wellsville, UT	WCF	EN[ZEN]	3	UU	41° 38.37′	111° 55.94′	1387	Applied Mems	ANSS-130	Digital	ANSS
WCN	Washoe, NV	WCN	HHZ	1	NN	39° 18.10′	119° 45.38′	1500	*	*	Digital	UNR
WCO	Washington City Office Building, UT	WCO	EN[ZEN]	3	UU	37° 07.91′	113° 30.56′	837	EpiSensor	Etna	Digital	Utah
WCU	Willow Creek, UT	WCU	EHZ	1	UU	38° 57.88′	112° 05.44′	2673	18300	Masscomp	Analog	USGS
WDO	Saint George, Washington County School District Office, UT	WDO	EN[ZEN]	3	UU	37° 06.46′	113° 35.19′	831	PA-23	SMART-24	Digital	Utah
WES	Westminster College Salt Lake City, UT	WES	EN[ZEN]	3	UU	40° 43.97′	111° 51.26′	1341	EpiSensor	K2	Digital	ANSS
WHS	West High School	WHS	EN[ZEN]	3	UU	40° 46.51′	111° 53.93′	1301	EpiSensor	K2	Digital	ANSS
WMUT	West Mountain, UT	WMUT	EHZ	1	UU	40° 04.60′	111° 50.00′	1981	L4C	Masscomp	Analog	USGS
WRP	Water Reclamation Plant Salt Lake City, UT	WRP	EN[ZEN]	3	UU	40° 48.82′	111° 55.87′	1286	Applied Mems	ANSS-130	Digital	ANSS
WTU	Western Traverse Mountains, UT	WTU	EH[ZEN]	4	UU	40° 27.29′	111° 57.21′	1552	S13	Masscomp	Analog	USGS
			ELZ									
			EN[ZEN]	3					Applied Mems	ANSS-130	Digital	ANSS
WUAZ	Wupatki, AZ	WUAZ	BH[ZEN]	3	US	35° 31.01′	111° 22.43′	1592	*	*	Digital	USGS
WVUT	Wellsville, UT	WVUT	EHZ	1	UU	41° 36.61′	111° 57.55′	1828	L4C	Masscomp	Analog	USGS
YDC	Denny Creek, MT	YDC	EHZ	1	WY	44° 42.51′	111° 14.60′	2025	L4C	Masscomp	Analog	USGS
YFT	Old Faithful (YNP), WY	YFT	HH[ZEN]	3	WY	44° 27.05′	110° 50.24′	2292	40T	72A-07	Digital	USGS
			EHZ	1					L4C	None	None	
YGC	Grayling Creek, MT	YGC	EHZ	1	WY	44° 47.77′	111° 06.45′	2075	L4C	Masscomp	Analog	USGS
YHB	Horse Butte, MT	YHB	EHZ	1	WY	44° 45.07′	111° 11.71′	2157	L4C	Masscomp	Analog	USGS
			HH[ZEN]	3					40T	ANSS-130	Digital	
YHH	Holmes Hill (YNP), WY	YHH	EH[ZEN]	3	WY	44° 47.30′	110° 51.03′	2717	S13	Masscomp	Analog	USGS
YJCZ	Joseph′s Coat (YNP), WY	YJC	EHZ	1	WY	44° 45.33′	110° 20.95′	2684	S13	Masscomp	Analog	USGS
YLAZ	Lake Butte (YNP), WY	YLA	EHZ	1	WY	44° 30.76′	110° 16.12′	2580	L4C	Masscomp	Analog	USGS
YLT	Little Thumb Creek (YNP), WY	YLT	EHZ	1	WY	44° 26.25′	110° 35.28′	2439	L4C	Masscomp	Analog	USGS

UURSN Code	Location	SEED Station	SEED Channel	No. of Channels	Network Code	Latitude	Longitude	Elevation (meters)	Sensor	Digitizer	Telemetry	Sponsor
YMC	Maple Creek (YNP), WY	YMC	EHZ	1	WY	44° 45.53′	111° 00.41′	2073	S13	Masscomp	Analog	USGS
YML	Mary Lake (YNP), WY	YML	EHZ	1	WY	44° 36.20′	110° 38.63′	2653	L4C	Masscomp	Analog	USGS
YMP	Mirror Plateau (YNP), WY	YMP	EH[ZEN]	3	WY	44° 44.38′	110° 09.40′	2774	S13	Masscomp	Analog	USGS
YMR	Madison River (YNP), WY	YMR	HH[ZEN]	3	WY	44° 40.12′	110° 57.90′	2149	40T	72A-07	Digital	USGS
YMS	Mount Sheridan (YNP), WY	YMS	EHZ	1	WY	44° 15.84′	110° 31.67′	3106	L4C	Masscomp	Analog	USGS
YMV	Mammoth Vault (YNP), WY	YMV	EHZ	1	WY	44° 58.42′	110° 41.33′	1829	L4C	Masscomp	Analog	USGS
YNR	Norris Junction (YNP), WY	YNR	HH[ZEN]	3	WY	44° 42.93′	110° 40.75′	2336	40T	RT-130	Digital	USGS
YPC	Pelican Cone (YNP), WY	YPC	EHZ	1	WY	44° 38.88′	110° 11.55′	2932	L4C	Masscomp	Analog	USGS
YPK	Parker Peak (YNP), WY	YPK	EH[ZEN]	3	WY	44° 43.91′	109° 55.32′	2897	L4C	Masscomp	Analog	USGS
YPM	Purple Mountain (YNP), WY	YPM	EHZ	1	WY	44° 39.43′	110° 52.12′	2582	L4C	Masscomp	Analog	USGS
YPP	Pitchstone Plateau (YNP), WY	YPP	EHZ	1	WY	44° 16.26′	110° 48.27′	2707	S13	Masscomp	Analog	USGS
YSB	Soda Butte (YNP), WY	YSB	EHZ	1	WY	44° 53.04′	110° 09.06′	2072	L4C	Masscomp	Analog	USGS
YTP	The Promontory (YNP), WY	YTP	EHZ	1	WY	44° 23.51′	110° 17.10′	2384	L4	Masscomp	Analog	USGS
YUF	Upper Falls (YNP), WY	YUF	HH[ZEN]	3	WY	44° 42.76′	110° 30.71′	2394	3ESP	ANSS-130	Digital	USGS
YWB	West Boundary (YNP), WY	YWB	EHZ	1	WY	44° 36.35′	111° 06.05′	2310	L4C	Masscomp	Analog	USGS
ZNPU	Zion National Park, UT	ZNPU	HH[ZEN]	3	UU	37° 21.37′	113° 07.52′	1953	Trillium 120	Q330	Digital	Utah
			EN[ZEN]	3					EpiSensor			

* Indicates station operated by another agency and recorded as part of University of Utah regional seismic network

Network Statistics: 649 data channels from 247 stations were being recorded at the end of this report period (excluding temporary TA stations)

EXPLANATION OF TABLE

UURSN Code: Station code used in routine processing. Due to processing software limitations, the station code may not be the station code used by the original operator. For multi-component stations, the vertical, east-west, and north-south high gain (low gain) components are identified by an appended Z(V), E(L), and N(M), respectively, in UUSS phase files.

Location: General description of station location. YNP = Yellowstone National Park.

SEED Station: The SEED (Standard for the Exchange of Earthquake Data) station code used by the original operator.

SEED Channel: The SEED format uses three letters to name seismic channels. See <<http://www.iris.edu/manuals/SEED_appA.htm>> for information about the SEED channel naming convention. Relevant sections are reproduced below. In the SEED convention, each letter describes one aspect of the instrumentation and its digitization. The first letter specifies the general sampling rate and the response band of the instrument. Band codes used in this table include:

Band Code	Band Type	Sample Rate	Corner Period
E	Extremely short period	≥ 80 Hertz	< 10 seconds
H	High broadband	≥ 80 Hertz	≥ 10 seconds
B	Broadband	≥ 10 to < 80 Hertz	≥10 seconds
S	Short period	≥ 10 to < 80 Hertz	< 10 seconds

The second letter specifies the family to which the sensor belongs. Sensor families used in this table are:

Instrument Code	Description
H	High gain seismometer
L	Low gain seismometer
N	Accelerometer

The third letter specifies the physical configuration of the members of a multiple axis instrument package. Channel orientations used in this table are:

Z E N Traditional (Vertical, East-West, North-South)

Number of Channels: Total number of waveform channels recorded.

Network Code: The FDSN (Federation of Digital Seismographic Networks) registered network code. See <<http://www.iris.edu/stations/networks.txt>> for information about registered seismograph network codes. Network codes referenced in this table:

Network Code	Network name; Network operator or responsible organization
AR	Northern Arizona Seismic Network, Northern Arizona University
LB	Leo Brady Network; Sandia National Laboratory
IE	Idaho National Engineering and Environmental Laboratory

IU	IRIS/USGS Network; USGS Albuquerque Seismological Laboratory
IW	Intermountain West Network
MB	Montana Regional Seismic Network; Montana Bureau of Mines and Geology
NN	Western Great Basin; University of Nevada, Reno
NP	National Strong Motion Program; U.S. Geological Survey
RE	U.S. Bureau of Reclamation Seismic Networks; U.S. Bureau of Reclamation, Denver Federal Center
UU	University of Utah Regional Network; University of Utah
US	US National Network; USGS National Earthquake Information Center
WY	Yellowstone Wyoming Seismic Network; University of Utah

Latitude, Longitude: Sensor location in degrees and decimal minutes; North latitude, West longitude.

Elevation: Sensor altitude in meters above sea level.

Sensor	**Description**
L4, L4C	Mark Products short-period seismometer
S13, 18300	Geotech S13 or 18300 short-period seismometer
Ranger	Kinemetrics Ranger short-period seismometer
40T	Guralp CMG-40T broadband seismometer
3T	Guralp CMG-3T broadband seismometer
3ESP	Guralp CMG-3ESP broadband seismometer
STS-2	Streckheisen STS-2 broadband seismometer
FBA23	Kinemetrics accelerometer
EpiSensor	Kinemetrics accelerometer
Applied Mems	Applied Mems accelerometer
PA-23	Geotech PA-23
Trillium 120	Nanometrics Trillium 120 broadband seismometer
Trillium 240	Nanometrics Trillium 240 broadband seismometer

Digitizer	**Description**
Masscomp	Concurrent Computer Corporation (formerly Masscomp) 7200C computer (with 12-bit digitizer)
K2	Kinemetrics Altus Series K2 (19-bit resolution field digitizer)
Etna	Kinemetrics Altus Series Etna (19-bit resolution field digitizer)
72A-07	Refraction Technology (REF TEK) model 72A-07 (24-bit field digitizer)
72A-08	Refraction Technology (REF TEK) model 72A-08 (24-bit field digitizer)
ANSS-130	Refraction Technology (REF TEK) model 130-ANSS/02 (24-bit resolution field digitizer)
RT-130	Refraction Technology (REF TEK) model RT-130 (24-bit resolution field digitizer)
Q330	Quanterra, Inc (24-bit resolution field digitizer)
SMART-24	Geotech SMART-24 digitizer (24-bit resolution field digitizer)

Telemetry	**Description**
Analog	Data transmission is analog along part of the transmission pathway

Digital	Data are converted to digital form at the station site
None	On-site recording system

Sponsor (or Operator for stations marked by * in preceding columns)

USGS	U.S. Geological Survey
Utah	State of Utah
ANSS	Advanced National Seismic System
INEEL	Idaho National Engineering and Environmental Laboratory
USBR	U.S. Bureau of Reclamation
LLNL	Lawrence Livermore National Laboratory
Sandia	Sandia National Laboratory
BYU-I	Brigham Young University, Idaho (formerly Ricks College)
MBMT	Montana Bureau of Mines and Geology
NSMP	National Strong Motion Project, U.S. Geological Survey
UNR	University of Nevada, Reno

Appendix C: Earthquake Data and Information Products

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Primary EQ Parameters		
Picks	Yes	Automatic phase picks are exported in near-real-time to USGS/NEIC via Earthworm export. UUSS analyst phase picks are archived internally and are available on request
Hypocenters	Yes	
Magnitudes (& Amplitudes)	Yes	Magnitudes are posted at www.quake.utah.edu. Magnitudes and peak ground motions (for ShakeMap) automatically determined by Earthworm are exported in near-real-time to USGS/NEIC via Earthworm export. Analyst-determined amplitudes for local magnitude determinations are archived internally at UUSS.
Focal mechanisms	Yes	These are not done real-time. For events with M ≥ 3 in the Utah region and M ≥ 2.5 in the Wasatch Front region, we attempt to determine first-motion focal mechanisms within a few days of the event.
Moment Tensor(s)	No	
Other EQ Parameters/Products		
ShakeMap	Yes	Shake maps are posted to our web site at http://www.quake.utah.edu/shake/ and sent to USGS computers.
Finite Fault	No	
Supplemental Information		
Felt Reports	Yes	We provide links on our Web site to the "Did You Feel It?" webpage. We also summarize felt reports and USGS-estimated intensities in our quarterly earthquake reports.
Event Summary	No	Not routinely provided. We occasionally provide an event summary for significant earthquakes.
Tectonic Summary	Yes	We submitted tectonic summaries for 7 subdivisions of the Utah region to the USGS for review on March 23, 2010. Revisions are underway based on the USGS comments received.
Collated Maps	No	
Refined Hypocenters (e.g. double-difference)	Yes	Not done routinely. We compute refined hypocenters (including double-difference) for sequences of special interest and for research purposes.
Web Content		
Recent EQ Maps	Yes	http://www.quake.utah.edu/EQCENTER/recent.htm
Station Helicorder	Yes	http://www.quake.utah.edu/helicorder/
Station noise PDFs	Yes	http://www.iris.edu/servlet/quackquery/ (produced by IRIS)

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Station Performance Metrics	Yes	http://www.iris.edu/servlet/quackquery/ (produced by IRIS)
Network Description	Yes	http://www.quake.utah.edu/ABOUT/uussanss.htm and http://www.quake.utah.edu/ABOUT/monitoring_scope.htm
Station List	Yes	http://www.quake.utah.edu/MONRESEARCH/seisnet.htm http://www.quake.utah.edu/EQCENTER/QUARTERLY/quarterly.htm
Station Metadata	Yes	http://www.iris.edu/mda/UU
Email Notification Services	Yes	Only to selected state and federal agencies. We direct other users to the USGS ENS Web site (https://sslearthquake.usgs.gov/ens/)
Contact Info	Yes	http://www.quake.utah.edu/ABOUT/about.htm (general contact info provided at bottom of all higher-level pages on our Web site)
Region-specific FAQs	Yes	http://www.quake.utah.edu/REGIONAL/eqfaq.htm
Region-specific EQ info	Yes	http://www.quake.utah.edu/REGIONAL/regional.htm
Waveforms		
Triggered	Yes	Triggered waveform data are archived in-house and are available upon request.
Continuous	Yes	All continuous waveform data are archived at the IRIS DMC and publicly available from this data center.
Processed	Yes	Synthetic Wood-Anderson seismograms are generated both automatically and as part of post-processing, but these processed waveforms are not permanently archived. Other processed waveforms are generated for special projects.
Summary Products		
Catalogs	Yes	Posted on our web site at http://www.quake.utah.edu/EQCENTER/quakelists.htm and incorporated into the ANSS catalog.
Metadata		
Instrument Response	Yes	Archived at http://www.iris.edu/mda/UU and at UUSS.
Site Info (e.g. surface geology, Vs30)	Yes	Vs30 information (mostly from generalized Vs30 maps) for our Utah region stations is available on our Web site at http://www.quake.utah.edu/MONRESEARCH/seisnet.htm. See also http://www.quake.utah.edu/urban/Avg_Shear_Wave_Velocity_Maps/shear_wave_2001.html.

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Descriptions:		
***Tectonic Summary*: Text and/or figures describing the tectonic setting of the event and related activity**		
***Event Summary*: Text and/or figures (press releases, collated media/disaster agencies info) that describes the earthquake and its effects**		
***Collated Maps*: Any map or set of maps that illustrates the event properties, tectonics, hazards, etc**		
***Processed Waveforms*: Specialized processing that is required by some portion of the community, e.g. processed strong motion records for the engineering community**		
***Catalogs*: Lists of parameters that describe an earthquake(s) or information used to describe an earthquake (e.q., picks, locations, amps,..)**		
***Region-specific earthquake information*: Description (text and/or maps) of historical earthquakes, faults/geology, etc.**		

Appendix D: ANSS Performance Self-Rating

Question	Answer	Explanation (if needed)
1. What is the minimum magnitude detection threshold for the best instrumented part of your network?	M ≥ 1.2 (in the Wasatch Front urban corridor, along the main seismic belt; see Pankow et al., 2004, BSSA 94, S332-S347)	
2. What is the typical hypocentral location accuracy for earthquakes occurring within your network? Is it the same for automated vs reviewed?	Based on a review of earthquake locations from January 2007 through November 2007, epicentral accuracy is similar for automatic and reviewed locations, but the latter have more accurate depths. In the Utah (UT) region, the median ERH is 0.8 km for reviewed locations versus 0.9 km for automatic, and the median ERZ is 1.8 km for reviewed locations versus 6.9 km for automatic. In the Yellowstone Park (YP) region, the median ERH is 0.6 km for reviewed locations versus 0.8 for automatic, and the median ERZ is 1.5 km for reviewed locations versus 5.0 km for automatic. For the 4.4-year period July 2003 through November 2007, 28% of the reviewed locations in the UT region and 46% of those in the YP region have good focal-depth control: DMIN ≤ DEPTH or 5.0 km and ERZ ≤ 2.0 km.	
3. Does your network report automated earthquake locations into EIDS? If yes, how long does it take?	Automated locations are currently reported into EIDS for M ≥ 3.0 events in the Utah region and M ≥ 2.5 events in the Wasatch Front urban corridor and the Yellowstone region. Based on the Earthworm system logs for 10 earthquakes meeting these criteria, the first EIDS message is typically sent out 4.0 ± 0.5 min. after the origin time. However, it can take as long as 6 min., even in well-instrumented areas. A live Internet connection must be available for the EIDS message to be sent out.	
4. Does your network report analyst-reviewed earthquake locations for all quakes into EIDS (i.e., the little ones)?	Yes. All locations for earthquakes in our authoritative regions are submitted to EIDS following analyst review. The delay is typically next business day. If there is significant earthquake activity, then the analysts process the largest events first. In such situations, processing delays for smaller events can be a week or longer (depending on staff resources at the time).	If yes, what is the typical processing delay?

5. Does your network have 24/7 duty seismologists who review real-time earthquake locations above some magnitude?	Yes. Real-time locations/magnitudes for earthquakes of $M \geq 3.5$ in the Utah and Yellowstone monitoring regions are human-reviewed as quickly as feasible. For smaller events, the automatic locations/magnitudes posted on the UUSS web site are usually reviewed within a half a day. The review can be completed in 15 minutes but occasionally takes up to one hour due to the slow speed and inefficient user interface of our current reviewing software and problems caused by its bugs. Currently the 24/7 duty-seismologist responsibilities are carried out for Utah by volunteers from among the four UUSS seismologists and for Yellowstone by one post-doc and one graduate student. The duty seismologist is expected to begin the review process within a half an hour after receiving a page about an $M \geq 3.5$ earthquake. We are considering enlarging our pool of trained responders.	If yes, what magnitude and how long does it take?
6. Describe the velocity model used to locate earthquakes in your network (1-D, multiple models, 3-D). Does it differ for automated vs. reviewed?	Three different 1-D velocity models are used for analyst-reviewed locations in the Utah region. A single 1-D velocity model is used for analyst-reviewed locations in the Yellowstone region. Automatic solutions use a single Utah 1-D model for all regions, including Yellowstone.	
7. What software/program does your network use to locate earthquakes? Does it differ for automated vs. reviewed?	Automated locations are computed using the Hypoinverse-2000 version that comes with Earthworm. Analyst-reviewed locations are computed using Hypoinverse-1978.	
8. What magnitudes does your network routinely report in real time (Md, ML, Me, Mw, Ms etc.)? How long does it take to compute them?	Our Earthworm system initially reports an automated coda-duration magnitude, M_C (calibrated to M_L), and subsequently reports an M_L if one can be determined. The system computes the M_C along with the location and reports it to the EIDS system in the time frame described under (3). If an M_L is successfully computed, then a second EIDS message with this M_L is sent 20-35 sec after the first message and the M_L will supersede the M_C. Note that the EIDS messages are only sent if the criteria described under (3) are satisfied. Therefore, M_C and/or M_L may be reported for any given earthquake, with preference given to the latter if available.	
9. Does your network archive phase information at a datacenter?	Phase data from July 1962 through 1988 were submitted to NOAA some time ago. The post-1988 data have not been archived at a data center but are archived in-house.	If yes, how long is the delay to report? Where is the information archived?
10. What is the date of the most recent event you have contributed to the ANSS catalog?	Today (April 29, 2010). Updates to the ANSS catalog are automatically submitted four times per day (Monday through Friday). The submitted catalogs date back to 1962 for the Utah region and 1973 for the Yellowstone region (the pre-1982 Yellowstone catalog is from the USGS).	If yes, how long is the delay to report? In what year does archiving begin?

11. Where is the permanent archive of seismic waveform data from your network?	The IRIS DMC. Continuous waveform data from all stations we maintain and operate (EH, EN, HH, and EL) have been submitted to the IRIS DMC on a daily basis since June 2002. Currently, the IRIS DMC continuously pulls data from our Earthworm system wave tanks. Submission of continuous waveform data from our broadband stations began on June 19, 2000, and submission of data from our strong-motion stations began on April 19, 2001. Archived event-segment waveforms date back to 1981. All digitally-recorded waveforms from stations we maintain and operate have been sent to the IRIS DMC. We stopped sending segmented waveform data to IRIS when we began submitting continuous data streams. However, the segmented waveform data are archived on site on optical disks, 9-mm tapes, DVDs, and/or hard disks.	If yes, describe what type of channels (e.g., EH, HH, HN) and how long is the delay to report? In what year does archiving begin?
14. Does your system compute focal mechanisms?	We do not compute automated focal mechanisms in real time. Some focal mechanisms from P-wave first motions are determined as parts of research projects. Since September 2005 we have been systematically attempting to determine P-wave first motion mechanisms for earthquakes of $M \geq 3.0$ in the Utah region and $M \geq 2.5$ in the Wasatch Front region within a few days after their occurrence. These focal mechanisms are not archived at a public datacenter.	If yes, what type (first motion, moment tensor). In real-time? Do you archive them at a public datacenter?
15. Does your system automatically distribute email to the public in near real-time for significant events?	We do not provide earthquake email notifications to the general public; we instead direct interested persons to the USGS ENS service. Automatic email alerts are distributed to the following State of Utah agencies following significant earthquakes in the Utah region: (a) the Utah Division of Emergency Services and Homeland Security, for $M \geq 3.0$ events; (b) the Utah Geological Survey, for $M \geq 3.0$ events; and (c) the Dept. of Natural Resources, for $M \geq 5.0$ events. Email notifications are also sent to (a) and (b) after the creation of a ShakeMap in the Utah region. Following $M \geq 2.5$ earthquakes in the Yellowstone region, email notifications are sent to (1) the Yellowstone Volcano Observatory Scientist-in-Charge and (2) a National Park Service geologist in Yellowstone Park.	If yes, Do you offer a website where they can sign up? What is the URL?
16. Does your system automatically distribute alphanumeric pages to the public in near real-time for significant events?	Currently, automatic alphanumeric pages are sent only to our internal staff and to a few emergency responders. Following $M \geq 3.5$ earthquakes in the Utah region, alphanumeric pages are sent to the earthquake specialist at the Utah Division of Emergency Services and Homeland Security. Following $M \geq 2.5$ earthquakes in the Yellowstone region, alphanumeric pages are sent to (1) the Yellowstone Volcano Observatory Scientist-in-Charge and (2) a National Park Service geologist in Yellowstone Park.	If yes, Do you offer a website where they can sign up?

17. Does your system automatically compute ShakeMaps and make them publicly available? If so, how long does it take?	Yes, for Utah region earthquakes of M ≥ 3.0 to M ≥ 3.5, depending on the location. Automatically generated ShakeMaps are posted publicly on our web site and submitted to the USGS, usually within 7-9 minutes after the origin time. The web posting could take longer if the web server is being overwhelmed with hits. A live Internet connection is assumed.	
18. Is your processing system hardened? (i.e., fault-tolerant, with redundant computers, UPS, back-up generator & fuel)?	It is to a large extent, but improvements are still underway. We operate redundant computer systems—including dual Earthworm systems and a parallel Concurrent 7200-C computer system running HAWK data acquisition software for analog telemetry data. We are in the process of replacing our centralized analog telemetry data acquisition systems, HAWK and Earthworm, by a distributed network of remote digitizers and Earthworm nodes. This new distributed system should be much more resistant to major failures. It will be completed by June 1, 2010. In March 2009, UUSS moved into a new building that was built for the Geology and Geophysics department. This building has a UPS system and back-up generator that provides backup power for the UUSS network operations center, including the air conditioning. Some of our computer equipment has still not been moved from our old computer room, which has a UPS system but no back-up generator. The remaining computer equipment will be moved or retired within the next few months after the remote digitizers and Earthworm nodes are fully operational.	
19. What is your network's total data volume (mbytes/day)?	The total volume of data that our network records is currently about 23,000 mbytes/day, uncompressed. This estimate is from data rate calculations for the 649 data channels from 247 stations that we record, assuming 10% overhead for disk storage with header information.	Specify how the estimate was made (e.g., data rate or disk storage) and if the data is compressed or not.
20. What is your network's total data volume (mbytes/year to archive)?	Our network's total data volume to archive every year is about 7.6 million mbytes/year, uncompressed (7.2 terrabytes/year). This estimate is from data rate calculations for the 571 data channels from 205 stations that we operate and maintain, assuming 10% overhead for disk storage with header information. This rate is slightly lower than the daily volume times 365 because it does not include data that we record from stations operated by other institutions.	If different from the daily volume times 365, explain the difference (e.g., reformatted, compressed, or edited).