Expanded Earthquake Monitoring and Rapid Event Notification in Nevada

a project proposed to the

Union Pacific Foundation

by the

Seismological Laboratory of the Mackay School of Mines,
The University of Nevada, Reno

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Project Summary

The Seismological Laboratory of the Mackay School of Mines, The University of Nevada, Reno (UNR), is a state-wide research institute chartered to investigate the origins and effects of earthquakes within Nevada, and to inform the State and the public on seismic hazards. The Laboratory seeks funds from the Union Pacific Foundation to continue to expand earthquake monitoring to areas of Nevada not of interest to current Federally-supported projects, that the State has also been unable to support. This project will increase the Lab's cooperative efforts with the operators of other regional seismic networks assessing eastern and southernmost Nevada, allowing more accurate characterization of earthquake hazards in these areas. In addition, this project will continue development of the Nevada Seismic Research Affiliates (NSRA) program of the UNR Foundation. The NSRA seeks to disseminate information on earthquake occurrence much more rapidly than has been possible in the past, and to jointly research with public agencies and lifeline industries methods of reducing the economic and social impacts of earthquakes. Continued support from the Union Pacific Foundation will enable the UNR Seismological Laboratory to develop additional government and private funding for these publicly-beneficial programs.

Project Description

The UNR Seismological Laboratory

The Seismological Laboratory at The University of Nevada, Reno (UNR) is a state-wide public research laboratory, created in 1974 by action of the University of Nevada Board of Regents. The Laboratory is responsible for monitoring seismicity and carrying out research on seismic hazard, tectonics, and earth structure in Nevada. In addition, the Laboratory carries out research nationally and worldwide through Federal funding. Our research activities contribute to the understanding not only of earthquake hazard, but also of natural resource occurrence, environmental hazards and waste containment, geothermal energy, water resources, and international efforts to monitor underground nuclear explosions. Although quite small in terms of state-funded personnel and operating budget, the Laboratory has been one of the most successful units of the University in terms of obtaining government grant support. Our academic and research staff are recognized worldwide.

The Seismological Laboratory plays an important role in graduate education. We provide graduate training in seismology and seismic hazard. In recent years six Ph.D. and four M.S. students have graduated from our program. These students and their research contribute to the activities of the UNR Geological Sciences Department, especially to studies of tectonics and earth structure.

Governance— The Seismological Laboratory is directed by Professor James N. Brune, on behalf of the UNR President and the Dean of the Mackay School of Mines. Professor John G. Anderson has been appointed Acting Director for the 1994-1995 academic year. A committee of noted seismologists from outside Nevada provides scientific oversight (Attachment A, page 6).

Resources— The third academic faculty member in the Seismological Laboratory is Associate Professor John N. Louie. The Laboratory also employs four Research Professors, two Postdoctoral Scholars, five management and engineering professionals, eight technical and administrative staff, eight graduate students, and seven undergraduate students (Attachment A, pages 73-78). Laboratory staff are supported by an extensive network of seismic

instruments in Nevada and eastern California to monitor and catalogue earthquakes. Including twenty-two broad-band digital stations and over 130 short-period stations, this monitoring network is the Lab's primary tool for research and public service.

Figure 1 shows the distribution of UNR seismic stations in Nevada and eastern California, as well as regional stations of the U.S. National Seismic Network. Data from these stations is transmitted to the Laboratory almost exclusively through microwave facilities built by UNR personnel (Figure 3). A network of computers running the UNIX and VMS operating systems, with 25 graphic workstations and servers from Sun Microsystems and Digital Equipment, allows our staff to collect and interpret data from the Laboratory's seismic network. All of these computers have fast connections to the Internet. One of the principal results of our personnel's analysis of the seismic network's data is a catalogue of earthquakes occurring in the region. Within the area covered by the monitoring network, this catalog is continuous and complete for events as small as Richter magnitude 2.5. Figure 2 is a map showing the distribution of the nearly three thousand earthquakes of various magnitudes located by the UNR Seismological Laboratory during 1994.

The 1994 calendar year was particularly notable because of the occurrence on Sept. 12 of the largest earthquake in the eastern Sierra Nevada in 28 years. The magnitude 6.0 Double Spring Flat event was widely felt in the urban areas of western Nevada, and as far west as Sacramento, and generated intense interest by the public and the press in earthquakes and hazard reduction. The public feedback to the UNR Seismological Lab that resulted from this interest drove the Lab's staff to significantly increase outreach efforts to the public, the press, and regional industries and governments. In addition, the earthquake presented new opportunities for investigations of seismic hazard in western Nevada and eastern California. The Lab began several field and laboratory efforts that, when completed, should better characterize local variations in potential ground motion.

The Yucca Mountain Seismic Monitoring and Analysis program, sponsored at the Seismological Laboratory by the U.S. Department of Energy (DOE), is a further example of the result of the Lab's strong history in seismic research, and its faculty with world-wide reputations. For this project we undertook a major expansion of our facilities and personnel to operate the Southern Great Basin Seismic Network for DOE's Yucca Mountain Project. Funding for this project will continue above $0.8 million per year over the next five to ten years, including both operations and research. The project is developing one of the most sophisticated seismic monitoring networks in existence, and provides a research facility for obtaining funds for a wide range of research projects in addition to those directly related to the Yucca Mountain Project.

Although the Seismological Laboratory has been very successful, its research and public service activities in the State of Nevada are limited and not well-balanced. This stems from the small amount of State funding we receive, and our consequent responsibility to concentrate our seismic research activities in areas of current interest to Federal funding agencies. These areas have shifted with time, and have left the northern, eastern, and southernmost parts of the state poorly covered, resulting in a lack of uniformity in our understanding of earthquake hazard throughout Nevada.

The Nevada Seismic Research Affiliates— To address this imbalance created by the Seismological Laboratory's heavy reliance on Federal projects, the Seismological Laboratory initiated the Nevada Seismic Research Affiliates (NSRA) as a project within the UNR Foundation. Attachments C, D, E, and F describe the UNR foundation. The purpose of the NSRA is to

promote research in seismology and earthquake hazard reduction activities in cooperation with public and private institutions and individuals. One of the immediate functions of this program is to extend the Seismological Laboratory's high-quality earthquake monitoring and hazard-characterization activities to the areas of Nevada that are not of Federal interest. The northern and eastern region of Nevada may be of interest to the transportation, lifeline, and mining industries. Of interest to the public and to the tourism industry as well is the populous and rapidly-growing southernmost region of Nevada encompassing Clark County. Neither region is currently covered by Federally-funded monitoring projects, but new private funds have allowed modest efforts at expansion to begin. In addition, some regions that can only be poorly monitored by UNR alone can be better-characterized by increasing the sharing of data with other regional seismic networks. We have begun rapid data exchanges with the networks in southern and northern California.

A Seismological Laboratory team comprised of J. Anderson, J. Brune, J. Louie, C. Middlebrooks, K. Smith, S. Jaume, and D. Von Seggern will manage the activities of the Nevada Seismic Research Affiliates. One of the initial activities of the NSRA was to implement methods of rapidly disseminating earthquake information to affiliated researchers, and to the public. Such data are available at no charge. Some of the activities of the NSRA, such as joint research projects, development of the Nevada Broadcast of Earthquakes (described below), technology transfer, internships, and student fellowships, are costly. Thus the Seismological Laboratory invites industries and individuals to contribute toward these costs to the Nevada Seismic Research Affiliates. All of the activities of the NSRA will be to the general and public benefit.

This proposal describes a $10,000 one-year continuation of a seismic research project to improve seismic network data quality, cooperation efforts, and the dissemination of earthquake information in Nevada. The UNR Seismological Laboratory respectfully requests continued support from the Union Pacific Foundation toward this publicly-desirable effort. Any contributions may be made to the UNR Foundation, on behalf of the Nevada Seismic Research Affiliates, or on behalf of the Seismological Laboratory. In either case, the NSRA Management Team will assure that all funds are dedicated to these seismic research and outreach purposes.

Accomplishments from previous award

In March of 1995 the Union Pacific Foundation generously granted $10,000 to the UNR Foundation, on behalf of the Seismological Laboratory, to underwrite seismic research and the development of rapid earthquake response. This grant has allowed significant broadening in the activities of the Seismological Laboratory beyond the interests of Federal agencies. The Nevada Seismic Research Affiliates Management Team has planned several activities for the one-year period following the donation. Some of these activities have been completed, or are underway.

Monitoring network expansion— The Seismological Laboratory's work on the Fairview Peak microwave relay station is underway. The start of transmissions is waiting for the State of Nevada to complete the building at the site. The State's work was delayed by the extended period of snow cover in the winter of 1994-95. This relay will allow improved seismic station coverage of eastern Nevada. It is the first leg of three that will allow

continuous data reception from seismic monitoring stations hundreds of miles from UNR in eastern Nevada, without the expense of leased telephone lines. The Fairview peak relay will also improve the reliability of our broadband digital data from the nearby stations WHR, KVN, and BMN (Figure 1).

The UNR work on a relay station on Mt. Lewis near Battle Mountain (Figure 3) is underway with expectations that it will be completed by the end of October. This is a second leg of the microwave data transmission link for the UNR seismic monitoring network planned for eastern Nevada. With the Mt. Lewis microwave relay in place, the Seismological Laboratory will consider installing one or two additional short-period, high-gain seismic monitoring stations in eastern Nevada. Funds currently available from the previous grant will be used to assist the establishment of new stations. Laboratory Engineer Walter Nicks and his staff are building the entire microwave network.

An earthquake having a Richter magnitude of almost 5, in an area west of Ely having no station coverage, did occur in 1993. Figure 2 shows further such events during 1994 in the magnitude 3 range. Expanding coverage in this area is important for a complete assessment of the tectonics and seismic potential of Nevada, and for characterizing the earthquake hazard to lifelines, utilities, and rapidly-growing small urban areas such as Elko.

Data exchange— One goal of the previously-funded project was to improve communication with the U.S. Geological Survey (USGS) and the National Seismic Network (NSN), by integrating real-time data from NSN stations (squares with crosshairs on Figure 1) into the event detection and location procedures we use. Routine inclusion of data from the ELK and WVOR National Seismic Network stations (Figure 1) would greatly increase our ability to detect and locate earthquakes in northern and eastern Nevada.

However, the limited nature of the data input interfaces of our existing DEC VAX-based seismic processing system currently prevents routine merging of outside data. Implementation of the UNIX-based processing system (described below) will allow, perhaps later this year, tests of location and magnitude estimation procedures that incorporate real-time data from the NSN stations (Figure 1). As an additional benefit, the UNIX-based system will more easily and more quickly accommodate real-time transmission of UNR seismic data to other regional seismic networks, and to the USGS. For these reasons we propose below to develop some test transitions of Western Great Basin Seismic Network stations to the UNIX-based processing system.

Nevada Broadcast of Earthquakes— Effective implementation of the Nevada Broadcast of Earthquakes (NBE) has been a top priority during the previously-funded project. One issue being investigated, in the effort to broaden the availability of NBE to public, industrial, and government users is how to disseminate the notice of earthquake events in a form that will be most effective. Such notices, generated automatically, must reach remote subscribers over a medium that is both instantaneous and reliable during natural-disaster situations.

David Von Seggern, Charlotte Middlebrooks, and Ken Smith have been communicating with various constituencies, developing specifications, and implementing procedures associated with the current NBE capabilities that can be delivered with the existing analog seismic data collection environment. Investigations and efforts in providing integrated rapid broadcast of earthquakes with other seismic laboratories continue. In May of 1995 a test was run

where NBE locations were made available to the public on the Internet via our World-Wide Web server (Figure 4; described below). This test showed that further developments needed to cull old event notices out of the list, after correction. Although the current NBE is not suited for public consumption on-line, we are implementing secure servers that will carry the NBE, at the current error rate, for Nevada Seismic Research Affiliates partners.

Improved tools for the rapid availability of earthquake information for the seismologists at the UNR Seismological Laboratory from the seismic data collection computing systems provides the capability for generally enhanced response to the public. This provides another reason to begin tests of the application of the new UNIX-based processing system to the Western Great Basin Seismic Network. Since there are currently no Federal or State sources of funds to support NBE subscriptions by industries, State entities, the press, or individuals, we propose below to integrate the NBE as well into the new UNIX-based processing system. Moving the NBE as well from the microVAX-based system will provide enhanced flexibility, reliability, and rapid response.

Internet services— To provide better outreach to other educational institutions, government agencies, industry, and individuals, the Seismological Laboratory has greatly improved its Internet accessibility. During the past year, the Seismological Lab hired two students to create, maintain, and administrate a World Wide Web server, (web server). Briefly, a web server is a program that is connected to the Internet that provides users with textual, graphical, and auditory information. In the Seismological Lab's case, we provide information related to the investigation of earthquakes and their effects in Nevada and eastern California (Figure 4). This information is thus available worldwide, and over the past year the number of people with access to our services has grown exponentially. For example, subscribers to Compuserve and America On-Line, currently numbering more than five million, can now view, download, and search our data bases.

For those with relatively good Internet connections, the Mosaic and Netscape programs provide a user-friendly, interactive multimedia interface to explore our data bases (Figure 4). The address of our services is "http://www.seismo.unr.edu". For those with more indirect connections, electronic-mail and finger requests allow interested parties to make inquiries, now more easily filled by Lab staff, who also have access to the newly-organized data bases. Inquiries can be directed by e-mail to "webmaster@seismo.unr.edu".

John Louie hired and supervised an undergraduate student (Douglas Ring) who implemented the World-Wide Web server software, and assisted in developing the on-line data bases from previously-published sources. An additional Geophysics undergraduate major (Russell Brigham) updates the data bases as new events occur in Nevada and around the world. Our publicly-available data bases now include over 480 distinct ''pages'' (topical displays of information), and 236 separate graphical elements (most displaying interpreted earthquake data), and with accessible data archives encompass over 459 megabytes. Over the past eight months, since our service was announced, we have averaged between 4000 and 6000 ''hits'' each week. This data rate boils down to perhaps several hundred people each week who access our services. We have no other method of serving so many in any direct way.

This semester, Douglas Ring, the Lab's Webmaster, has developed and implemented a graphical interface between the UNRSL Earthquake Helicorder display and the World Wide Web (WWW). The UNRSL Earthquake Helicorder display is where raw seismic station data

traces are displayed as they enter the lab. The graphical interface now allows Internet users in Nevada and eastern California, who believe they may have felt an earthquake, to look at the UNRSL web site, 24 hours a day, to see if the Lab has recorded a seismic event. Live images of this data are captured once every 90 seconds and sent to the web server. UNRSL researchers who are viewing these images, via this interface, now have up to the minute images of their raw data, even if they are not physically at the Laboratory.

Russell Brigham, a graduate student, has been working a seismic analysis program to produce the UNRSL Record of the Day. Russell searches for seismic events which may be of interest to researchers around the world. He selects a local, a domestic, and an international event, interprets raw data relevant to each event and places it on the web in the form of seismograms. Researchers are also provided the raw data and analysis code in the event they wish to further analyze it.

Another project currently under construction is the UNRSL Virtual Tour. This project is aimed at prospective students and researchers who may wish to visit or attend the Seismological Lab.

The previous grant provides all of the $3000 needed to employ such students about 7 hours/week during the 1995 calendar year. There is no other source of support for such outreach activities.

Technology transfer— Finally, it is necessary to inform the community in Nevada having seismological interests of the results of the activities above, and to transfer the technology needed to benefit from them. Although we originally intended to schedule a Nevada Seismic Conference, the occurrence of the Double Spring Flat earthquake made it clear that informational and technology-transfer activities needed to take place continuously. Thus the Management Team of the Nevada Seismic Research Affiliates decided to put the resources of the previous grant into the development and maintenance of the World-Wide Web service (Figure 4; described above), rather than into a one-time conference. In fact, several consultants and university researchers have already taken advantage of our facility to sort and obtain portions of UNR's seismic event catalog via the Internet. These contacts have led some of them to join the Affiliates.

Proposed Project

The UNR Seismological Laboratory proposes to essentially continue and expand the above activities, made possible by the previous grant from the Union Pacific Foundation. Continued funding will make possible some critically-needed tasks that have no other source of support, during the proposed project period from April 1996 through March 1997. All of these tasks will contribute to the goals of expanded network coverage and rapid earthquake response articulated by the Nevada Seismic Research Affiliates.

Integration of WGBSN into upgraded UNIX processing system— We propose to begin transition of Western Great Basin Seismic Network stations to a newly-developed UNIX-based processing system. The Western Great Basin Seismic Network currently records signals from over 100 seismic monitoring stations in Nevada and eastern California (Figure 1). The seismic signals are processed on VAX workstations from the Digital Equipment Corp. (DEC)

using the Caltech-USGS Seismic Processing (CUSP) software system. This software is responsible for real-time archiving of the seismogram data, interpreting the seismic waves arriving at each station, and estimating event locations and magnitudes (e.g. Figure 2 for 1994 locations).

The CUSP system was developed during the 1970s and 1980s by seismologists, principally at Caltech and partly as a thesis project. At the time, the DEC software environment offered the only available real-time processing capabilities, and the entire CUSP system was built around the intricacies and idiosyncracies of the proprietary VAX operating system. Considering the system's complete reliance on this obsolete hardware and software platform, it has achieved remarkable reliability and capability at several current seismic monitoring operations. However, DEC VAX hardware and software is now very expensive to acquire and maintain. Further, programming shortcuts needed in the 1970s computing environment are at the foundation of CUSP, and prevent its adaptation to the new needs of rapid notification and data exchange.

To address the systemic shortcomings of the VAX-based CUSP system, the Seismological Laboratory has over the past year developed an entirely new seismic processing system based on computers running the widely-portable UNIX operating system. The Department of Energy funded this development as part of the creation of a new network of broadband digital seismometers to monitor the proposed high-level nuclear waste repository at Yucca Mountain, in southern Nevada. The UNIX-based system is more robust, easier to adapt to new needs, portable to a large range of computer hardware, and much cheaper to maintain than the DEC VAX-based system.

The Seismological Laboratory's new system has been in operation almost a year, and currently records twelve seismic stations with exceptionally high quality and reliability. At the Laboratory, David Von Seggern, Ken Smith, and Charlotte Middlebrooks lead the development of the new system, and Bruce Crawford is the UNIX software engineer. Implementation of the UNIX-based processing system will allow incorporation of real-time data from other sources, such as the NSN stations (Figure 1). As an additional benefit, the UNIX-based system will more easily and more quickly accommodate real-time transmission of UNR seismic data to other regional seismic networks, and to the USGS. For these reasons we propose to develop some test transitions of Western Great Basin Seismic Network stations to the UNIX-based processing system.

The transition of WGBSN stations to the UNIX-based processing system consists of two steps. First, Bruce Crawford, our software engineer, must import existing software into the system that provides for seismic wave arrival detection and measurement. The new system, as currently running, includes all other necessary components such as data gathering, real-time archiving, and location and magnitude estimation. Crawford has already built the UNIX-based system over the last year with similar imports and adaptations, so we believe only two weeks of his software engineering time are needed for this task. Charlotte Middlebrooks will supervise this development.

The second step is to provide for the physical acquisition of WGBSN network data by the UNIX system. We propose to spend $1000 to design and build the isolation amplifiers needed to integrate between three and ten WGBSN analog stations into the UNIX system. Laboratory Engineer Walter Nicks and his staff have much experience in the design and construction of such amplifiers. In this test, the output of the isolation amplifiers will go to IBM-PC-based digitizing boards already available from another DOE-supported project that is

ending. That project already has developed the data-transfer methods that make the real-time data available to a previously-acquired UNIX workstation from Sun Microsystems, which is available to run the new seismic processing system.

With these two simple steps of software engineering and amplifier construction, we will be able to record and analyze WGBSN data on the new UNIX-based seismic processing system. The Foundation would thus seed an important improvement in the reliability and flexibility of our seismic monitoring operations. Once the seismic arrival detection and measurement software has been written, and the isolation amplifiers designed, the cost of adding additional monitoring stations to the new system may be as low as $20 each. Thus modest industrial and State contributions over the next few years could allow the entire WGBSN to move to this system, with its enhanced capabilities.

NBE development on UNIX processing system— At present, the Nevada Broadcast of Earthquakes is also tied to the VAX-based seismic processing system, with the shortcomings described above. As we move our operations to the UNIX-based systems for improved reliability and flexibility, it is imperative to also develop an equivalent system on the UNIX platform that will supply the NBE data stream. This will have the additional advantage that the NBE data will not need to suffer the delays of translation between the VAX and UNIX systems that it currently does. Importing the NBE facilities to UNIX will have the NBE data available immediately and natively in the Internet e-mail and World-Wide Web formats that we will use to disseminate the data to users, and to paging systems.

The NBE software system is built of several components. Some, such as the real-time data examination facilities, are currently designed for the VAX-based system and will require extensive re-configuration to work with the new UNIX-based system. Others, such as the notification modules, are easily re-configured for UNIX. Thus we propose to use one month of Bruce Crawford's software engineering time, for him to develop the NBE data stream on top of the existing UNIX-based seismic processing system. Charlotte Middlebrooks will supervise this development. Funding of this effort will assure the continued availability and improve the reliability of the Nevada Broadcast of Earthquakes.

Internet services— We propose to continue and expand our Internet services to industry and the public. Several of the services already implemented (Figure 4), such as the UNRSL Record of the Day, the Helicorder Camera, the earthquake catalog sorting facility, and the weekly maps of seismic activity, require periodic updating and maintenance. In addition, the services require constant supervision to assure availability, and corrections for accuracy. We would like to continue to employ our undergraduates, such as Douglas Ring and Russell Brigham, who are already adept at developing and maintaining these services.

In addition, we would like to expand and improve our Internet services. For example, on-line searches of the earthquake catalog now produce simple ASCII lists of earthquake locations and magnitudes. We would like to enhance this interface to allow both simpler and more in-depth catalog analysis. Users should be able to make very simple queries (e.g.: ''get major events near Las Vegas'') as well as quite sophisticated ones (e.g.: ''get events within the stated region having the stated quality and station coverage''). This flexibility is needed because the users of the World-Wide Web interface range from school children to fellow seismologists. The output of a catalog search should be more flexible as well, ranging from simple maps to cross sections, volume visualizations, cross-plots with geologic and

geophysical data maps, data bases of seismograms and time picks, etc. The serving of such data products, given the present access load, will likely require the implementation of distributed processing capabilities. Guided by John Louie, the undergraduates have shown themselves capable of such developments, and we expect to announce new services frequently.

Other enhancements are needed in the quality and interpretability of most of the other maps (geological, seismicity, hazard, zoning, etc.). Russell Brigham has the background now to prepare maps that are functional and easy to interpret, from available data sources with existing software. Further improvements need to be made in the range of topics covered by tutorials, examples, and lessons in seismology. We do not have enough material geared toward the K-12 audience, nor do we have detailed-enough descriptions of our operations and research methods for our seismological colleagues. John Louie will oversee the conversion of existing Seismological Lab materials into the World-Wide Web databases, in a manner similar to the on-line offering of our Lab brochure (Figure 4). Additional explanatory materials on the Internet will assist us in our task of informing the public, and of transferring seismic knowledge and technology to regional industries and agencies. The Foundation, by supporting this activity, will be making an essential contribution to the welfare of the people and the industries of Nevada.

Proposed Project Budget, 4/96-3/97

Item	Amount
Software Engineer (Bruce Crawford, 1.5 mos. incl. benefits)	$6000
Undergraduate Wages (D. Ring and R. Brigham)	3000
Isolation Amplifier Materials and Supplies	1000
Total Requested	$10,000

Project Staff— The proposed project will partially employ one UNR Seismological Laboratory Software Engineer and two undergraduate students. A number of Seismological Laboratory personnel will also contribute. While the projects employing the non-academic personnel do not provide for direct support of this project, their duties are consistent with some work on its behalf. David Von Seggern, Ken Smith, Steve Jaume, and Charlotte Middlebrooks are in such positions and can supervise the student, benefiting the project with their experience in technical and scientific oversight. Walter Nicks is employed by the State and is thus available to design and supervise station integration into the UNIX system.

Seismological Laboratory Budgets

The following tables give for the Seismological Laboratory a very general assessment of actual and projected categories of income for the previous and current fiscal years, and approximate categories of expenditures for both years. While not audited or independently verified, these tables give the best picture of income sources and expenditures for seismic research in Nevada. Attachment A contains on page 98 additional information on the operating and research budgets of the Mackay School of Mines and the Seismological Laboratory for the 1992-1993 fiscal year. Attachment B is a more recent summary of State operating funds and expenses for the entire University and the Mackay School of Mines. Attachment D is the financial statement of the UNR Foundation, which has a budget separate from the University in general.

Seismological Laboratory Income

	1994-1995	1995-1996 (projected)
Federal Research Grants and Contracts	$2,005,741	$1,565,741
State Operating Funds	267,680	267,680
Industrial Support (UNR Foundation)	10,200	10,500
Totals	$2,283,621	$1,843,921

Seismological Laboratory Expenditures

	1993-1994 (approximated)	1994-1995 (projected)
Salaries and Wages	$1,076,634	$876,934
Major Equipment Acquisition	70,000	10,000
Benefits, Administration, Operations	1,138,110	936,987
Totals	$2,283,621	$1,823,921

Corporate Support of the Seismological Laboratory

As the tables above show, corporate support of seismic research in Nevada has been quite limited to date. Corporate benefactor to the Seismological Laboratory (through the the UNR Foundation) in the last two years have been the Union Pacific Foundation, and Lettis and Associates of California. The Nevada Seismic Research Affiliates is channeling new outreach and seismic information products to the public as well as to interested corporations, and the NSRA will gain new participants in time.

Corporate support for other activities within the Mackay School of Mines has been continually strong, as outlined on pages 93-97 of Attachment A. The UNR Foundation has also garnered much additional corporate support, as reported in Attachment D.

Attachment A: Mackay School of Mines Annual Report
Attachment B: UNR Operating Budgets
Attachment C: Directors of the UNR Foundation
Attachment D: Financial Statements of the UNR Foundation (2 parts)
Attachment E: IRS 501(c)3 Letter of the UNR Foundation
Attachment F: IRS 990 Report of the UNR Foundation