UTILIZING STRONG-MOTION DATA AFTER EARTHQUAKES: UPDATE ON THE CISN ENGINEERING DATA CENTER, INTERNET QUICK REPORT, SHAKEMAP AND CISN DISPLAY

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Introduction

The California Integrated Seismic Network (CISN) is a consortium of institutions engaged in statewide earthquake monitoring. The five core members are the California Geological Survey, the California Institute of Technology, the U.S. Geological Survey Offices at Pasadena and Menlo Park, and UC Berkeley. The California Office of Emergency Services (OES) participates as an ex-officio participant. The TriNet project initiated in southern California with FEMA support was a prototype for the statewide CISN project.

The CISN has a statewide Engineering Data Center, a southern California seismic Data Center at Pasadena, and a northern California seismic Data Center in the Bay area. The CISN Engineering Data Center is operated by the CGS Strong Motion Instrumentation Program (CSMIP) in cooperation with the USGS National Strong Motion Program (NSMP).

A primary goal of the Engineering Data Center as well as the other two Data Centers is to provide robust and rapid information products after an earthquake, with products ranging from the ShakeMap to strong-motion data and calculated parameters. A high-speed T-1 computer communication network, or Intranet, which connects all CISN partner agencies has been recently established, depicted in Figure 1. The T-1 communication ring consists of dedicated segments connecting each center and OES, and is completely independent of the Internet. The ring became operational early in 2003. The Internet is also used in communication between the centers, but the T-1 ring provides the secure, reliable backup to the Internet that is needed. A second level of backup, using OES satellite communication channels, is also planned.

Effective communication requires standardized protocols. Data packets and formats for the exchange of parametric data and waveforms are being finalized by the CISN Program Management Committee and its Standards Committee. With the completion of the T-1 ring, the CISN partners have begun routine exchange of strong-motion parametric data between centers while the protocols for exchange of waveforms are being standardized. When routine waveform exchange begins, planned for later in 2003, it will be possible to assemble the strong-motion data for all strong-motion stations in the State at CISN, in forms convenient for use by the earthquake engineering or seismology communities, an unprecedented advance.

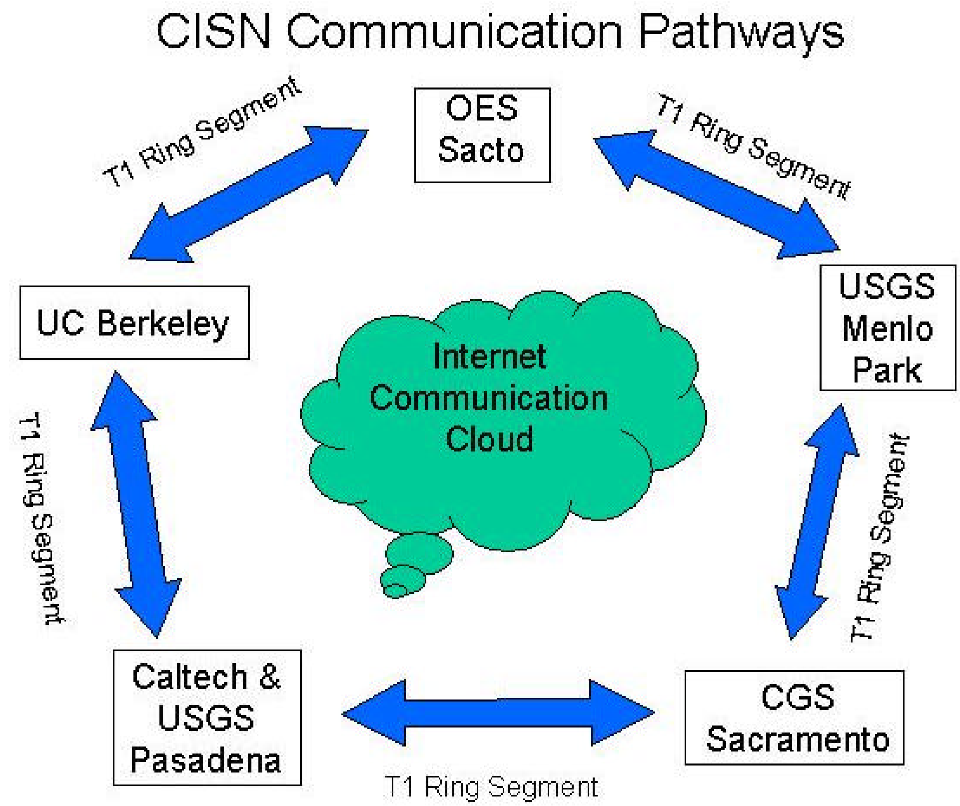


Figure 1. Communication pathways between seismic centers within the CISN system. The dedicated T1 segments form a robust ring, with communication allowed in both directions in the event one segment is damaged. Normal communication tunnels through the Internet cloud are also used, but as backup to each link of the robust system.

The Engineering Data Center

The Engineering Data Center is at URL **http://www.cisn-edc.org** (Figure 2) and additional mirror sites are planned at CGS and USGS in the future. These will provide the critically needed robustness and redundancy, in the case of a major earthquake or other disabling event at either Sacramento or Menlo Park, a central goal of the CISN and of OES.

The Internet Quick Report

The EDC uses the Internet Quick Report (IQR) to rapidly disseminate strong-motion data for engineering applications after major earthquakes. The IQR is based on the concept of the traditional Quick Report, streamlined for automated generation. A total of 13 IQRs have been released after earthquakes of M~4 and larger since August 2001. In addition, a search function

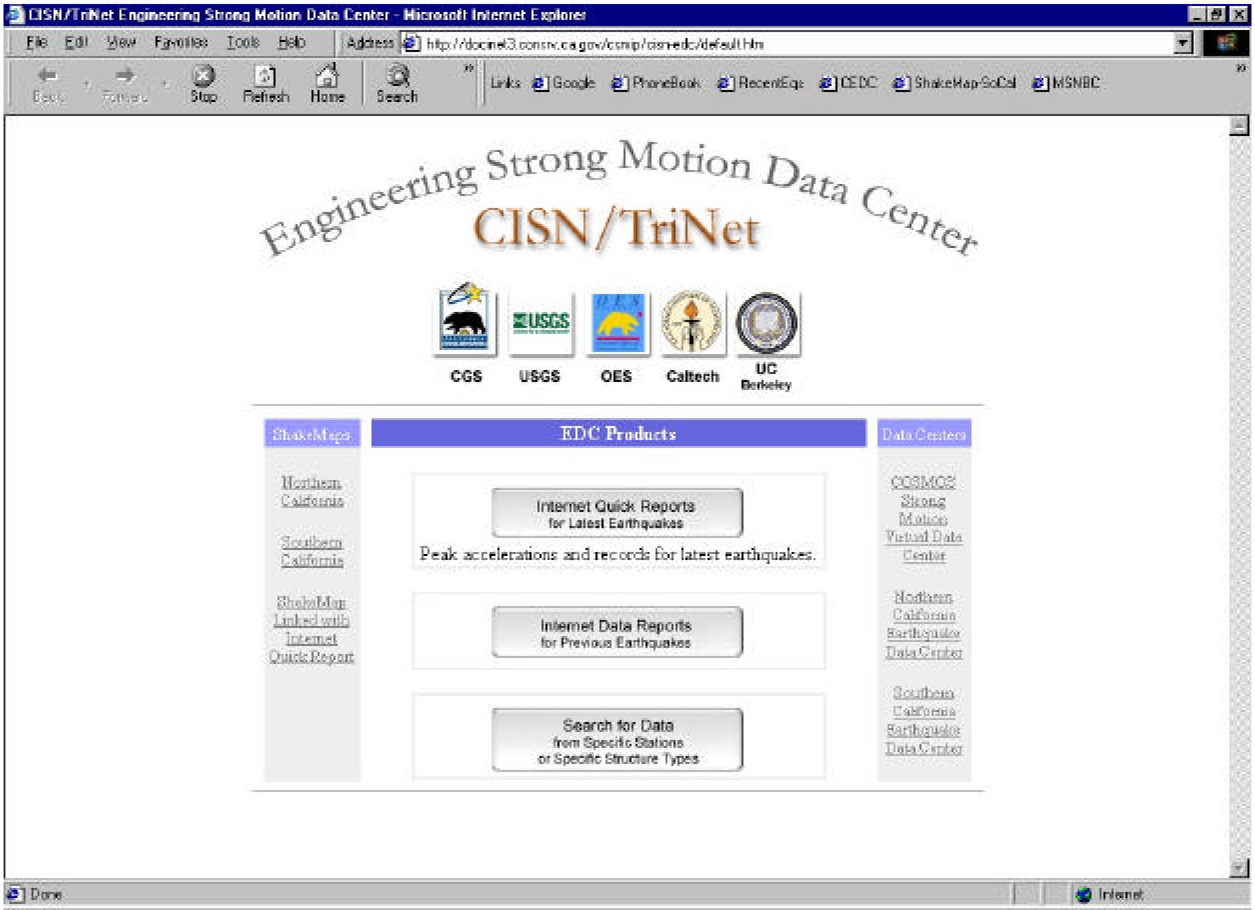
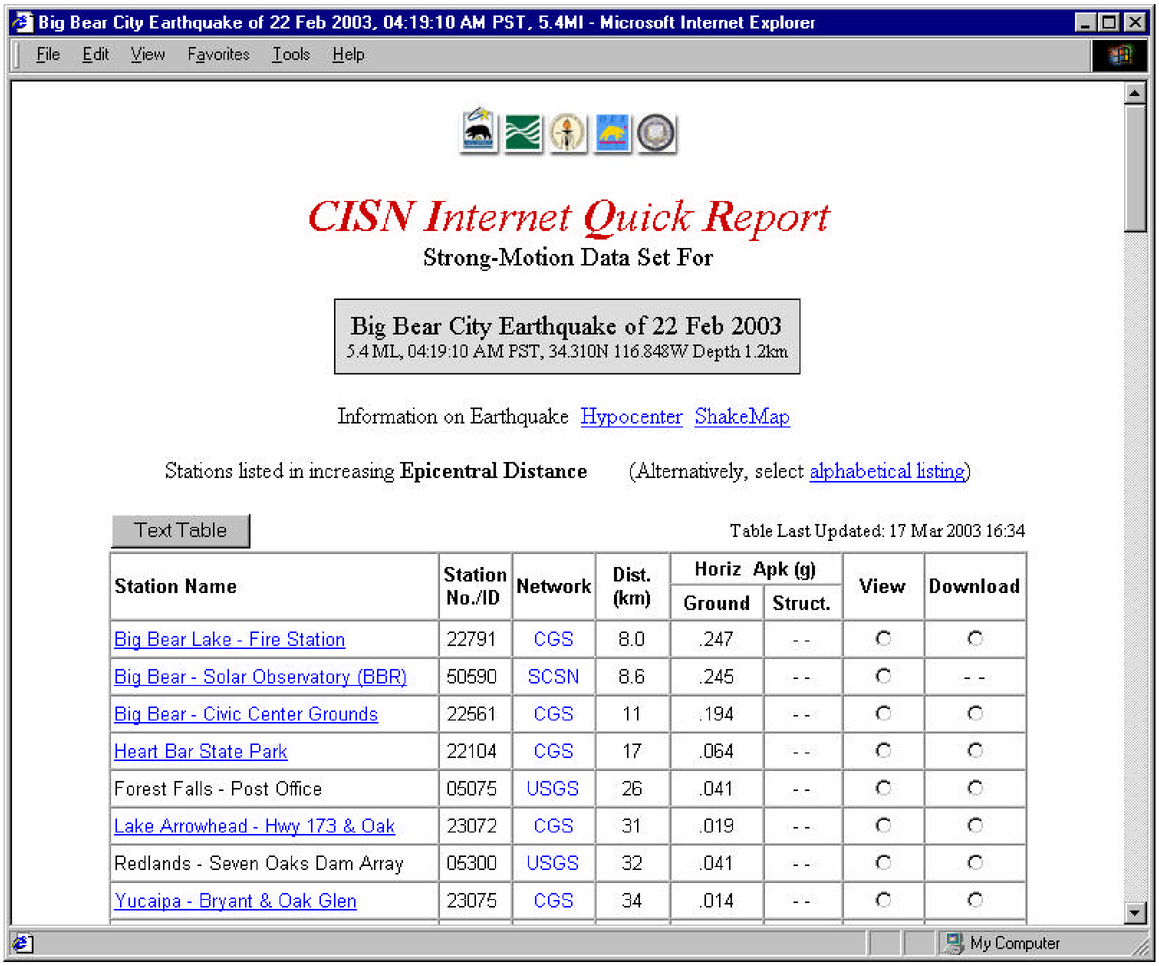


Figure 2. CISN Engineering Strong Motion Data Center, with links to Internet Quick Reports, Data Reports, and data searches by station or structure type, as well as links to the other two CISN Data Centers, the COSMOS data center, and ShakeMaps for northern and southern California.

has been developed to provide users a simple but versatile tool to locate strong-motion data of specific interest. The design of the search function allows access to the strong-motion data at the EDC according to the parameters of the instrumented station or structure. The search provides two essentially orthogonal paths to request data, one by earthquake for all stations, and the other by station/structure types independent of earthquakes. This approach allows users to quickly locate the specific data of interest for their engineering applications.

An Internet Quick Report is generally prepared for earthquakes over magnitude 4.0, for which a ShakeMap is also released by CISN. The content of the IQR is dynamic and cumulative after an earthquake, expanding as new data continues to be recovered. Initial work on the IQR is described in Shakal and Scrivner (2000) and Lin et al. (2001, 2002). An example of a recent IQR, for the Big Bear City earthquake in southern California in February 2003, is shown in Figure 3. It lists data recovered from the CGS and USGS strong-motion stations, as well as stations of Caltech/USGS Pasadena's Southern California Seismic Network (SCSN), in order of increasing epicentral distance. At the top of the IQR web page is given the name and date of the earthquake, links to related information about the event at other CISN sites (location, magnitude and ShakeMap), and the time of last modification of the table. The table lists peak acceleration values and station distances for the strong-motion records recovered. Each row of the table includes, for one record, the station name and number, network, epicentral distance, and peak horizontal acceleration, on the ground and the structure (if applicable). The row also includes buttons for viewing and/or downloading the data once the data itself is available at the EDC. Information regarding the station or instrumented structure is accessible directly using the Internet link under the station name.


Big Bear City Earthquake of 22 Feb 2003, 04:19:10 AM PST, 5.4Ml - Microsoft Internet Explorer

File Edit View Favorites Tools Help

CISN Internet Quick Report

Strong-Motion Data Set For

Big Bear City Earthquake of 22 Feb 2003

5.4 ML, 04:19:10 AM PST, 34.310N 116.848W Depth 1.2km

Information on Earthquake Hypocenter ShakeMap

Stations listed in increasing **Epicentral Distance** (Alternatively, select alphabetical listing)

Text Table

Table Last Updated: 17 Mar 2003 16:34

Station Name	Station No./ID	Network	Dist. (km)	Horiz Apk (g) Ground	Horiz Apk (g) Struct.	View	Download
Big Bear Lake - Fire Station	22791	CGS	8.0	.247	- -	○	○
Big Bear - Solar Observatory (BBR)	50590	SCSN	8.6	.245	- -	○	- -
Big Bear - Civic Center Grounds	22561	CGS	11	.194	- -	○	○
Heart Bar State Park	22104	CGS	17	.064	- -	○	○
Forest Falls - Post Office	05075	USGS	26	.041	- -	○	○
Lake Arrowhead - Hwy 173 & Oak	23072	CGS	31	.019	- -	○	○
Redlands - Seven Oaks Dam Array	05300	USGS	32	.041	- -	○	○
Yucaipa - Bryant & Oak Glen	23075	CGS	34	.014	- -	○	○

My Computer

Figure 3. Internet Quick Report (partial) for the M5.4 earthquake near Big Bear City, CA on February 22, 2003. The table is sorted in epicentral distance order; alphabetical order can be selected at the top. A text table of the data can be downloaded for analysis via the 'Text Table' link. Stations with strong-motion data available for viewing and/or downloading are indicated by the presence of buttons in the right columns. For underlined stations, a linked page contains station photographs and site information. The network column indicates this IQR includes data from the CGS, the USGS, and the NCSN (Caltech/USGS Pasadena).

The table shown, designed for viewing using Internet browsers, is complemented by a more comprehensive table available as an ASCII text file using a link at the top of the page. A user can easily import this table into a spreadsheet program for analysis. Both the web table and the text table have a date-time stamp to indicate when they were last modified by the update or addition of data.

Linking the Internet Quick Report and ShakeMap

The ShakeMap and the Internet Quick Report are CISN products that use the data from the same strong motion stations. The data inputs for the ShakeMap consist of parametric data (peak ground acceleration, velocity, and spectral accelerations) for the record from a station, while the IQR also includes time history data. In an effort to provide users easy access to both CISN products, the EDC has developed links to the time history plots of the IQR from within the ShakeMap.

Figure 4 shows the ShakeMap for the Big Bear City earthquake of February 22, 2003. As shown in the figure, the pop-up window in the upper left corner contains values of peak ground motion and station related information from a specific station as in the standard ShakeMap. In addition, an EDC extension includes a hypertext link for the station for direct access to the time history plot for the same station in the IQR. Clicking the hypertext link causes a new window to appear on the screen with the IQR time history plot displayed side by side with the ShakeMap. In the example this has been done for two different stations on the same screen. This implementation allows engineering users to navigate between the two products more efficiently.

The creation and update of the station links inside the ShakeMap is an add-on process of the IQR. This means that the update is also dynamic and cumulative like the update of the IQR. Not all ShakeMaps will contain links to the time history plots at the EDC since the criteria for the production of ShakeMaps and IQRs may be different.

Data for Previous Earthquakes – Internet Data Reports

The discussion above is focused on data in the immediate post-earthquake period. Earthquake data is also important for longer-term analysis, beyond the immediate earthquake response time frame. In the past, paper-copy Quick Reports (e.g., CSMIP, 1994) were the pre-Internet analog to the Internet Quick Reports, and those Quick Reports were followed by a final, hard-copy report on the event's strong motion data, which was usually released one month after the event (e.g., Shakal et al., 1994; Porcella et al., 1994). In many ways, the IQR is as comprehensive as that report; thus, using new technology, a product is being produced in 30 minutes, which is very comparable to what was available only after 30 days. For a given event, the Internet Quick Report will transition to the Internet Data Report, to reflect its more final nature, after enough time has gone by for all data (including that from any analog instruments) to be included and quality controlled.

The EDC has created Internet Data Reports for four major historical earthquakes, to provide users the same access to the earlier strong-motion data as for new data. More historical earthquakes are being added. An example showing part of the Internet Data Report for the 1994 Northridge earthquake is shown in Figure 5. The Internet Data Reports have the same format as the IQR and are placed in the archive section of the EDC, paralleling the way the CISN ShakeMaps are archived. Internet Data Reports are being created for additional historical earthquakes as current data work allows.

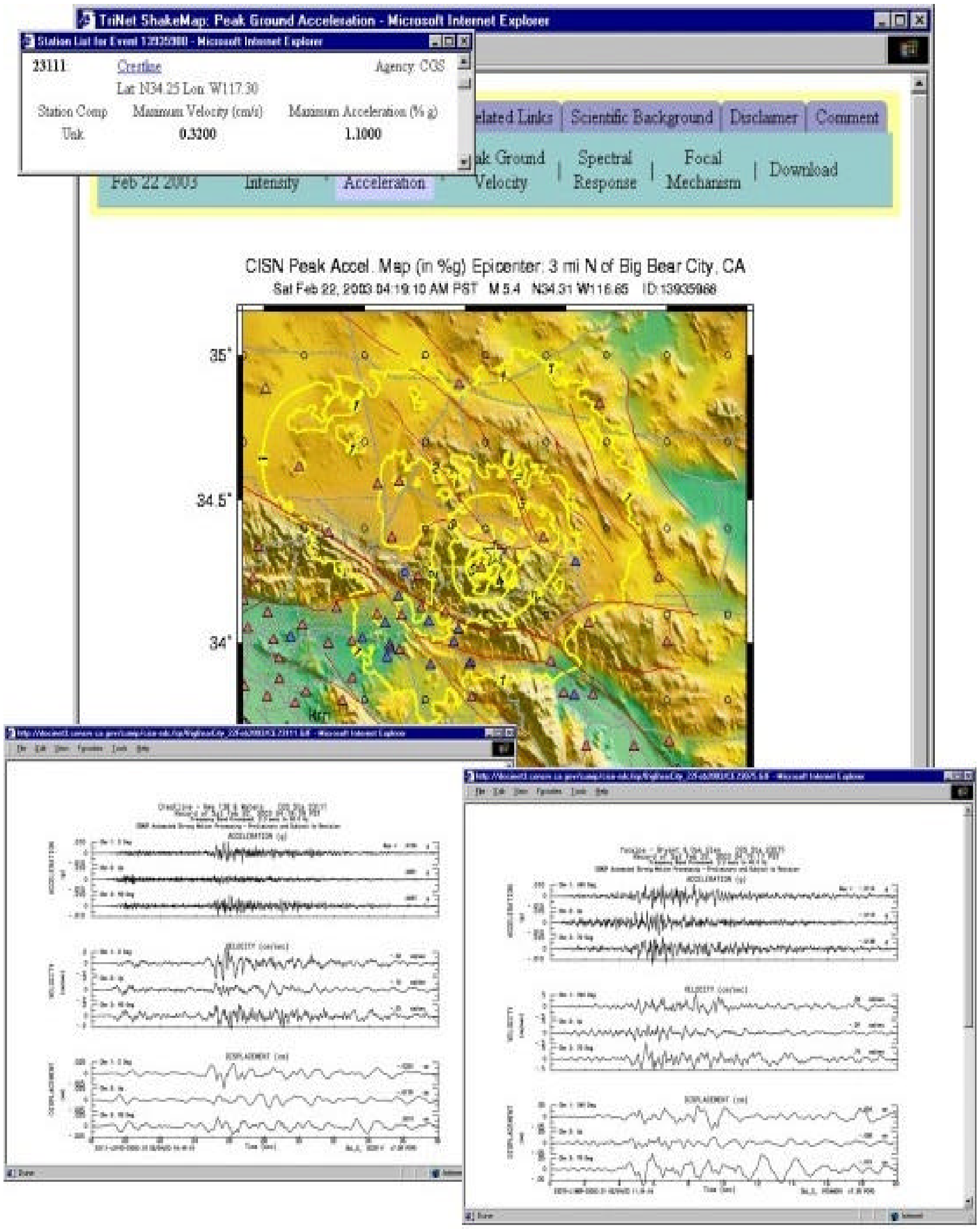
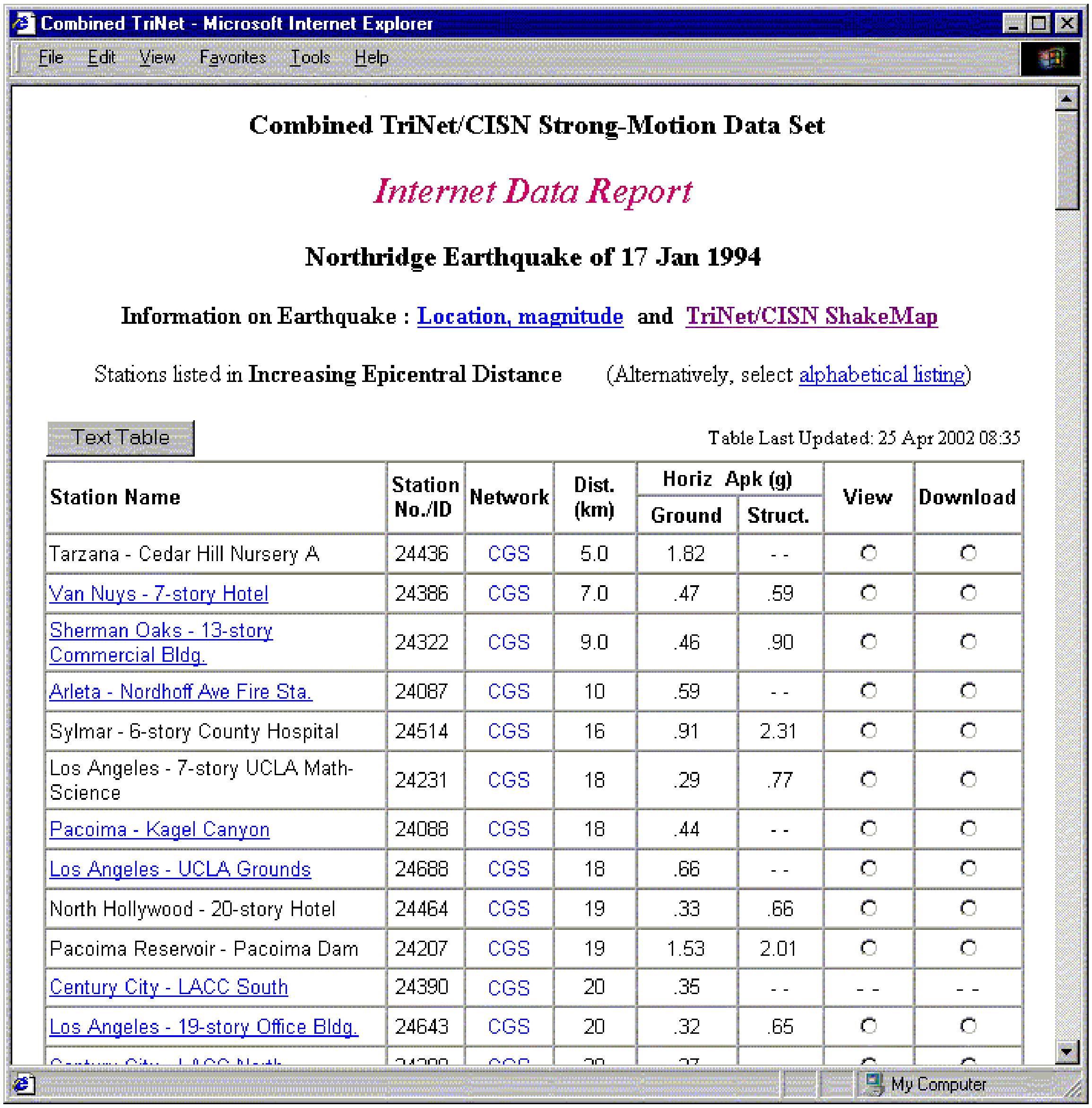


Figure 4. The ShakeMap for the Big Bear City earthquake of February 22, 2003 at the CISN Engineering Data Center. The ShakeMap is linked with the Internet Quick Report (IQR) and screens with the time history plots from the IQR can be accessed directly from within the ShakeMap.



Combined TriNet/CISN Strong-Motion Data Set

Internet Data Report

Northridge Earthquake of 17 Jan 1994

Information on Earthquake : Location, magnitude and TriNet/CISN ShakeMap

Stations listed in **Increasing Epicentral Distance** (Alternatively, select alphabetical listing)

Text Table

Table Last Updated: 25 Apr 2002 08:35

Station Name	Station No./ID	Network	Dist. (km)	Horiz Apk (g)		View	Download
				Ground	Struct.		
Tarzana - Cedar Hill Nursery A	24436	CGS	5.0	1.82	- -	○	○
Van Nuys - 7-story Hotel	24386	CGS	7.0	.47	.59	○	○
Sherman Oaks - 13-story Commercial Bldg.	24322	CGS	9.0	.46	.90	○	○
Arleta - Nordhoff Ave Fire Sta.	24087	CGS	10	.59	- -	○	○
Sylmar - 6-story County Hospital	24514	CGS	16	.91	2.31	○	○
Los Angeles - 7-story UCLA Math-Science	24231	CGS	18	.29	.77	○	○
Pacoima - Kagel Canyon	24088	CGS	18	.44	- -	○	○
Los Angeles - UCLA Grounds	24688	CGS	18	.66	- -	○	○
North Hollywood - 20-story Hotel	24464	CGS	19	.33	.66	○	○
Pacoima Reservoir - Pacoima Dam	24207	CGS	19	1.53	2.01	○	○
Century City - LACC South	24390	CGS	20	.35	- -	- -	- -
Los Angeles - 19-story Office Bldg.	24643	CGS	20	.32	.65	○	○

Figure 5. An example of the Internet Data Report table, sorted in epicentral distance order, for the M6.7 Northridge of Jan 17, 1994. The table parallels the functionality of the Internet Quick Report, but is permanently available, beyond the time of post-earthquake response, and includes records from analog film stations and other records that may be recovered manually (this is an example and only includes CGS data).

Searching for Strong-Motion Data at the CISN Engineering Data Center

The design goal of the EDC search function is the distribution of strong-motion data from stations of the CISN network in a rapid manner and the provision of station information and associated structural information, as applicable. It complements the worldwide ground-response database available through the COSMOS virtual data center (e.g., Archuleta, 2000) and the newly completed Internet Site for European Strong Motion Data (Ambraseys, 2000).

The layout of the EDC search function is a typical top-down tier approach that guides the user through a series of choices. The user can further confine the search criteria by entering keywords in appropriate fields anytime during the search process. Results of a given search are presented in a table listing all stations that matched the search criteria. Each station has a direct link in the result table that leads the user to a list of readily accessed strong-motion data for the station.

In 2002-2003, more earthquakes and station data were added to the EDC. The functionality of the search feature was improved to incorporate the newly added data. Currently, data for all 13 Internet Quick Reports and four Internet Data Reports of historic earthquakes have been entered into the database. In addition, station information on all ground response stations and approximately one third of the building stations has been loaded into the EDC search feature. The EDC is continuing to work with the CISN partners to increase the inventory of information for the CISN stations.

With the inventory of the ground response stations nearly complete, it is now possible to search for station information for most ground response stations and for the earthquake data associated with the stations. Users can take advantage of the search feature to obtain information on a single station or group of stations based on the geographical location, such as city name. Figure 6 shows the result of a sample search that lists the ground response stations in the city of Los Angeles.

ShakeMap Utilization

The ShakeMap product, developed under TriNet, provides a graphical portrayal of the regional shaking (Wald et al., 1999) for use in rapid post event response. Another level of utilization of the ShakeMap by engineers is in guiding the assessment of structural performance and structural safety after an event. The strong motion data itself, in addition to the information captured in ShakeMaps, is also important. Rojahn et al (2003) describe the ATC-54 report by the Applied Technology Council focused on these engineering applications. This is an important progression in increasing the usefulness of ShakeMap.

Another important application of ShakeMap is in engineering loss estimation. HAZUS, a project of FEMA and the National Institute of Building Sciences (NIBS) is an advanced computational methodology to estimate loss after a significant earthquake. With the introduction of ShakeMap, is becomes possible to do loss estimation in near real time. HAZUS was conceived in a time when rapid data was not available, so ShakeMap expands its value, as well as increases the importance of calibration of methodology and inventory in order for the results, produced rapidly and possibly without human intervention, to be credible. Kircher (2003) discusses aspects of calibration of HAZUS to the 1994 Northridge data, a key step toward its general application.

Figure 6. An example of a search for ground response stations in Los Angeles (first screen). A similar search can be made for buildings, and specific structural types. This allows searching for data by stations or within certain areas, regardless of what earthquakes were recorded at the stations.

CISN Display

The CISN is developing an Internet application, CISN Display, to provide statewide real-time earthquake information. The development efforts are concentrated at the Caltech/USGS Pasadena Center. The CISN Display is an integrated 24 x 7 Web-enabled earthquake notification client-server application. The application provides users with real-time seismicity information, and following a large earthquake it will automatically provide links to the earthquake information products such as ShakeMap and the Internet Quick Report.

A sample screen is shown in Figure 7. After a significant earthquake, the link to products, including the ShakeMap and Internet Quick Report for that event, will appear in the lower right. The key benefit is that engineering users and others with event response responsibilities can have CISN Display running as one of the processes on their PC. They will have updated information which until recently was only possible for network operators and others with specialized communication systems set up. The product is in beta testing, and the Pasadena Center expects it to be available to CISN customers later in 2003.

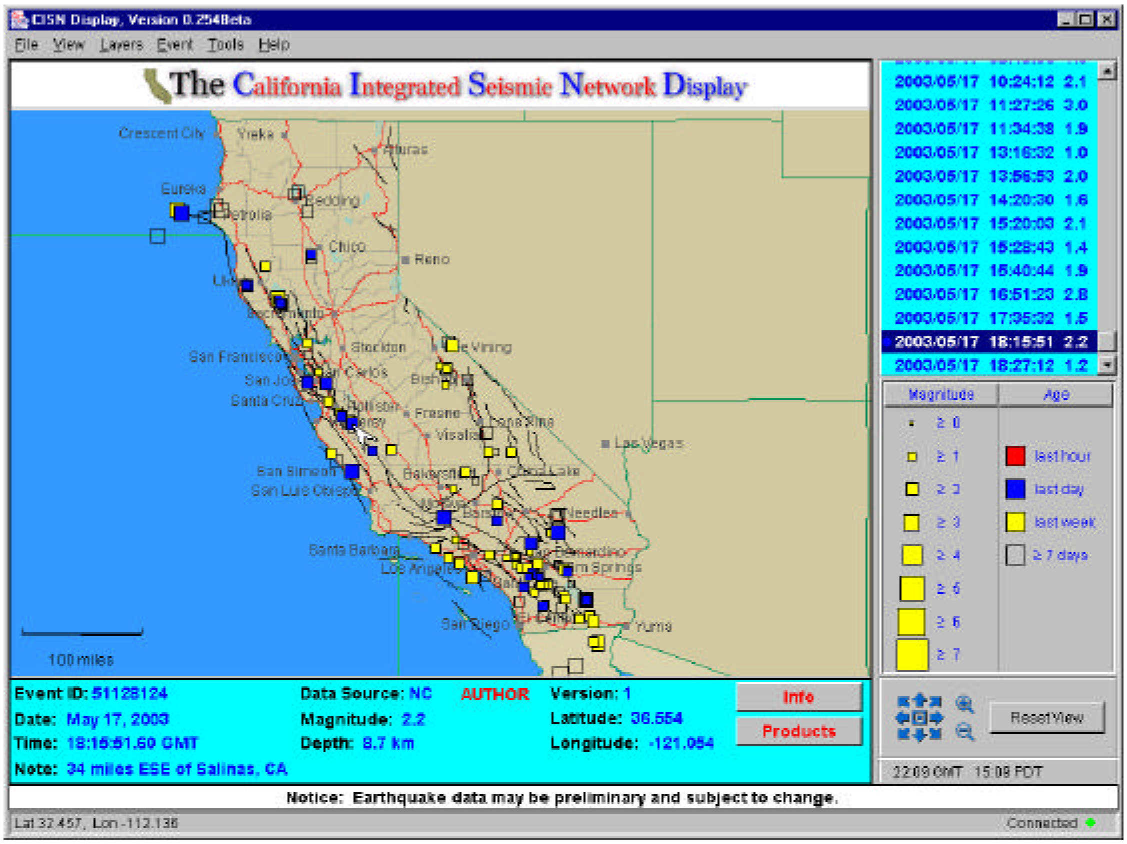


Figure 7. The CISN Display being developed by the Caltech/USGS Pasadena Data Center is a powerful, convenient way for engineering and other users to keep abreast of seismic activity in California. In the event of earthquakes large enough to be of engineering significance, the ShakeMap and Internet Quick Report generated by CISN can be accessed from this screen through the 'Products' link.

Continuing Development of CISN and the EDC

The CISN dedicated high-speed T1 data network ring, or Intranet, allows rapid and robust post-earthquake data exchange among the CISN networks. The level of data exchange for strong-motion waveform and parameter data among CISN partner agencies will increase greatly as this network comes to full operational usage later during 2003. At that time the IQR process of the EDC will serve strong-motion data from all CISN agencies in a fully automatic mode.

CISN is one region of the nationwide Advanced National Seismic System. The tools and techniques developed for the CISN Engineering Data Center, in the most seismically active region in the ANSS, may be similarly employed, with local adjustments, in other regions with less frequent, though very similar, needs for engineering information after significant earthquake shaking.

Summary

The CISN Engineering Data Center greatly accelerates access to data after earthquakes and allows users to conveniently obtain data for specific structures and structure types. The development of the EDC is continuing and will focus on the following areas:

- Fully automating the Internet Quick Report, to be available routinely within 15 minutes or less after M>4 earthquakes by later in 2003; until then it is partly manual and will be available within minutes to hours after a significant earthquake.

- Continuing to expand the search capability, to allow users to conveniently access strong-motion earthquake data and detailed information on instrumented structures and other stations, including location, site geology, structural system, sensor layouts, and other information. The data archives are being populated to include strong-motion data and station/structure information from previous earthquakes, from the CSMIP and NSMP networks and the other partners.

- Expanding the linking between the Internet Quick Report and the ShakeMap for an earthquake, allowing users to see the regional and the very local shaking associated with an earthquake, in forms customarily used in earthquake engineering.

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