NEAR-REAL-TIME STRONG MOTION, TRINET DATA, AND DATA DISSEMINATION THROUGH THE INTERNET

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Abstract

Recent developments in near-real-time recovery of strong-motion data have been expanded to include new means to disseminate and rapidly utilize the data. The TriNet project, a cooperative project in southern California involving CDMG, Caltech and the USGS, will disseminate earthquake data and information rapidly for use by emergency responders. In another development, the release of strong-motion data by CSMIP will include simple descriptors of the shaking level (Light, Moderate, Strong and Extreme Shaking). These descriptors, designed to be easily understood by the non-specialist, will be complemented by more customary quantitative characterizations (time-history and spectral levels). To make strong-motion data widely available for use in earthquake engineering and engineering seismology, the data will be available for access by any current Web browser at the Internet site http://www.consrv.ca.gov/dmg/csmip. All strong-motion data released by CSMIP over the years are or will soon be available at this location. For future significant earthquakes, strong-motion data will also be available rapidly at the site.

Developments in Near-Real-Time Strong Motion

Near-real-time strong motion record recovery by the California Strong Motion Instrumentation Program (CSMIP) was first described at the SMIP95 conference (Shakal and others, 1995). The system has continued to evolve since then. A total of 70 stations are now configured with appropriate accelerographic and communication equipment to transmit strong-motion data automatically to a bank of computers in Sacramento. One new development is that summary parameters of the recorded motion (peak acceleration, etc.) are now being automatically uploaded to the Internet. In addition, the data recovery software and protocols in Sacramento have evolved to become increasingly robust, in order to withstand known error situations in a fail-safe mode. Experience has indicated that, for a successful automated strong motion communication system, developing fail-safe robustness is as challenging as initially establishing the capability. On a related front, a significant development in rapid utilizing near-real-time strong-motion data is the introduction of the data into the cooperative TriNet system.

TriNet: A Multi-Network Earthquake Measuring and Data Utilization Consortium

One outgrowth of the Northridge earthquake was an initiative to increase the measurement of ground shaking data and to accelerate the distribution and utilization of that information. This eventually led to a cooperative project in southern California among the principal agencies recording earthquake motion in the area. The California Institute of Technology (Caltech) and the Pasadena office of the U.S. Geological Survey operate the Southern California Seismic Network (SCSN), a weak-motion network well known for recording and rapidly determining the location of earthquakes in southern California, for magnitude 1 and larger events. The earthquake locations and magnitudes reported in newspapers and on radio or television after events in southern California are determined by this network. For larger earthquakes, the CSMIP network of the California Division of Mines and Geology (CDMG) is the primary strong motion network in the area, and it recovers and disseminates strong-motion data after moderate and larger earthquake (typically magnitude 5 and above).

TriNet, a cooperative project among these three institutions, was established with funding for 5 years from the Federal Emergency Management Agency (FEMA), co-sponsored by the California Office of Emergency Services (OES). One focus of the CSMIP part of TriNet is a data interpretation project which will fund studies to improve seismic design codes.

Joint products of the TriNet project will include rapid determination and characterization of the earthquake shaking. A map of the shaking, called ShakeMap, will be produced by TriNet that shows the areal distribution of shaking intensity. This can be used by emergency responders to direct their resources most effectively to areas of the greatest shaking and damage. A prototype of ShakeMap has been prepared for several recent small events by the USGS Pasadena Office. The ongoing processing and release of strong-motion data by CSMIP to the earthquake engineering and seismological community, in forms customary to them, will continue unaltered. In fact this will be improved, and more data will be available, more rapidly, since part of the TriNet project will include the upgrade of CSMIP instruments in southern California from analog (film) recorders to digital instruments with telephone communications, and they will become part of the near-real-time data recovery discussed above. Another aspect of the TriNet project is that new instruments to be installed at stations of the weak-motion seismographic network of Caltech and USGS will also be able to record strong shaking, and these data will be processed along with the CSMIP strong-motion data. Similarly, for smaller events of little engineering interest, any low-level records obtained by CSMIP will be provided to the Caltech/USGS network to improve their accuracy in locating the event and determining magnitude and other seismological characteristics.

The net effect of the TriNet project in terms of strong-motion data should be the provision of more data, more rapidly, for the earthquake engineering community, while also expanding the capability of the seismic networks in southern California to understand earthquake generation and shaking distribution. Caltech and the USGS also intend to develop a prototype warning system as part of the project. In northern California, an effort paralleling the southern California TriNet project is in the discussion stage among CDMG, UC Berkeley and the USGS at Menlo Park.

Shaking-Level Descriptors for Use in Response: Light, Moderate, Strong and Extreme Shaking

The customary use of strong-motion data is to quantitatively describe the level of shaking, in a precise and definite way. For example, the motion at the Arleta station during the Northridge earthquake had a peak horizontal acceleration of 0.34 g and a peak velocity of 40 cm/sec. There are several reasons to accompany this traditional characterization with short descriptive words. First, from a human factors perspective, rapid response to strong shaking information requires a more easily recognizable characterization than a series of quantities which must be interpreted and considered. Second, peak acceleration is known to correlate poorly with damage, in general. A striking example is the Tarzana station, which in the Northridge earthquake had a peak acceleration of over 1.8 g, and yet damage in the area was not great. Third and most importantly, most emergency responders are not accustomed to the usage of the technical quantities used by seismologists and engineers. However, conventional vernacular already includes well-understood descriptive words, that while normally applied to other phenomena or situations, can be brought forward to help make shaking levels more quickly understood by nonspecialists.

Since we wish to describe the shaking at a location it is natural to incorporate concepts from the Modified Mercalli Intensity scale. This scale was developed to characterize shaking and damage at various locations in the vicinity of an earthquake before instrumental measurements were available. Richter (1956) describes the scale and its evolution in detail. The MMI scale is also considered in the contemporary book Earthquakes by B.A. Bolt (1993). Bolt (1993) includes a correlation between the MMI Intensity level and instrumentally-measured acceleration and velocity. Other correlations are also available and can be considered for reference. With a tie between instrumental measurements and the effects of shaking embodied in the MMI scale, a useful set of descriptors can be used.

The descriptive words characterizing shaking levels are shown in Table 1, along with the MMI Intensity level range and the structural damage descriptions, ranging from none (Light Shaking) through significant destruction (Extreme Shaking). Although this approach capitalizes on an accepted, description-based system like Mercalli Intensity, it must be noted that the MMI scale has limitations because of its introduction before modern design and construction methods. However, it is still an effective scale to use, which may be improved as new events occur. This characterization will be used as part of the post-earthquake data released by CSMIP, accompanied by the customary quantities (time and spectral domain). These descriptors have been found to be very useful in quickly interpreting the pager messages described in Shakal and others (1995).

TABLE 1

SHAKING LEVEL DESCRIPTORS
STRONG MOTION MONITOR SYSTEM

Light Shaking
(Intensity V-VI MMI)

Structural Damage

- None or slight.

Other Aspects

- Felt by nearly everyone, some frightened.
- A few cases of cracked or fallen plaster and chimney damage.
- Unstable objects overturned, some heavy furniture moved and dishes/windows broken.
- Movement of trees, poles, etc. sometimes noticed.

Corresponding motion to be measured (at ground level)

- Sustained acceleration of .02 to .10 g, or velocity of 2 to 10 cm/sec.

Moderate Shaking
(Intensity VII MMI)

Structural Damage

• Buildings of good design and construction:	Negligible
• Well-built ordinary structures:	Slight to moderate
• Poorly built or badly design structures:	Considerable

Other Aspects

- Everybody runs outdoors; some chimneys broken; noticed by people driving cars.

Corresponding motion to be measured (at ground level)

- Sustained acceleration of .10 g to .25 g, or velocity of 10 to 25 cm/sec.

Strong Shaking
(Intensity VIII-IX MMI)

Structural Damage

• Specially designed structures:	Slight to considerable.
• Ordinary substantial buildings:	Considerable to great, with partial collapse.
• Poorly built structures:	Great.

TABLE 1 (Continued)

Other Aspects

- Fall of chimneys, factory stacks, columns, monuments, walls.
- Panel walls thrown out of frame structures.
- Heavy furniture overturned; people driving cars disturbed.
- Underground pipes may be broken; sand and mud ejected in small amounts.

Corresponding motion to be measured (at ground level)

- Sustained acceleration of .25 g to .60 g, or velocity of 25 to 60 cm/sec.

Extreme Shaking

(Intensity X-XII MMI)

Structural Damage

- Well-built wooden structures: Some destroyed.
- Masonry and frame structures: Destroyed.
- Bridges: Some destroyed.

Other Aspects

- Landslides considerable.
- Rails bent.
- Fissures in ground.

Corresponding motion to be measured (at ground level)

- Sustained acceleration greater than .60 g, or velocity greater than 60 cm/sec.

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Accessing Strong-Motion Data Through the Internet

The most effective means for distributing the digital version of strong-motion records has evolved over the last 20 years. The traditional means was based on the nine-track computer tape; a particular tape would be requested, and shipped in a specified format. In the last decade, the most common means of distribution became the floppy disk. As personal computers became more common, people could now request records and load them into the computer at their own desk. The next step of evolution is the Internet and the World Wide Web, which can revolutionize the distribution and use of strong-motion data even more than floppy disks did.

CSMIP has developed a Strong Motion Data Center site on the Internet. The site allows a user to request specific records, as desired, without submitting request forms or waiting for package delivery. Usage of the Data Center is quite straightforward, as described below. The Web site is operational and available, although an improved phase is underway.

The home page of the Data Center is shown in Figure 1. The site, at address http://www.consrv.ca.gov/dmg/csmip, can be accessed by any of the current browsers, such as Netscape, America Online, or Microsoft Internet Explorer. Some of the earliest browsers (such as early Mosaics), may not portray the tables well, but should still work.

The Web site has two pathways for requesting data. The most common data request received by CSMIP is a request for the strong-motion record from a specific earthquake from one more stations. A similarly common request is for the records from a specific station, for several earthquakes. Accordingly, the Web site is designed so that these requests are the most convenient, and the flow path for the request is shown schematically in Figure 2. The first action button on the home page is "View/Download Strong Motion Data". Clicking on this button with a mouse brings up screen (2) in Figure 2, which allows the user to choose between requesting data for an earthquake or for a station. If the user wishes to request data for an earthquake, the left panel allows the selection of one of the listed earthquakes. After the cursor bar is moved to that selection, the "Submit Selection" button must be clicked to transmit that request to the server through the user's local Internet connection.

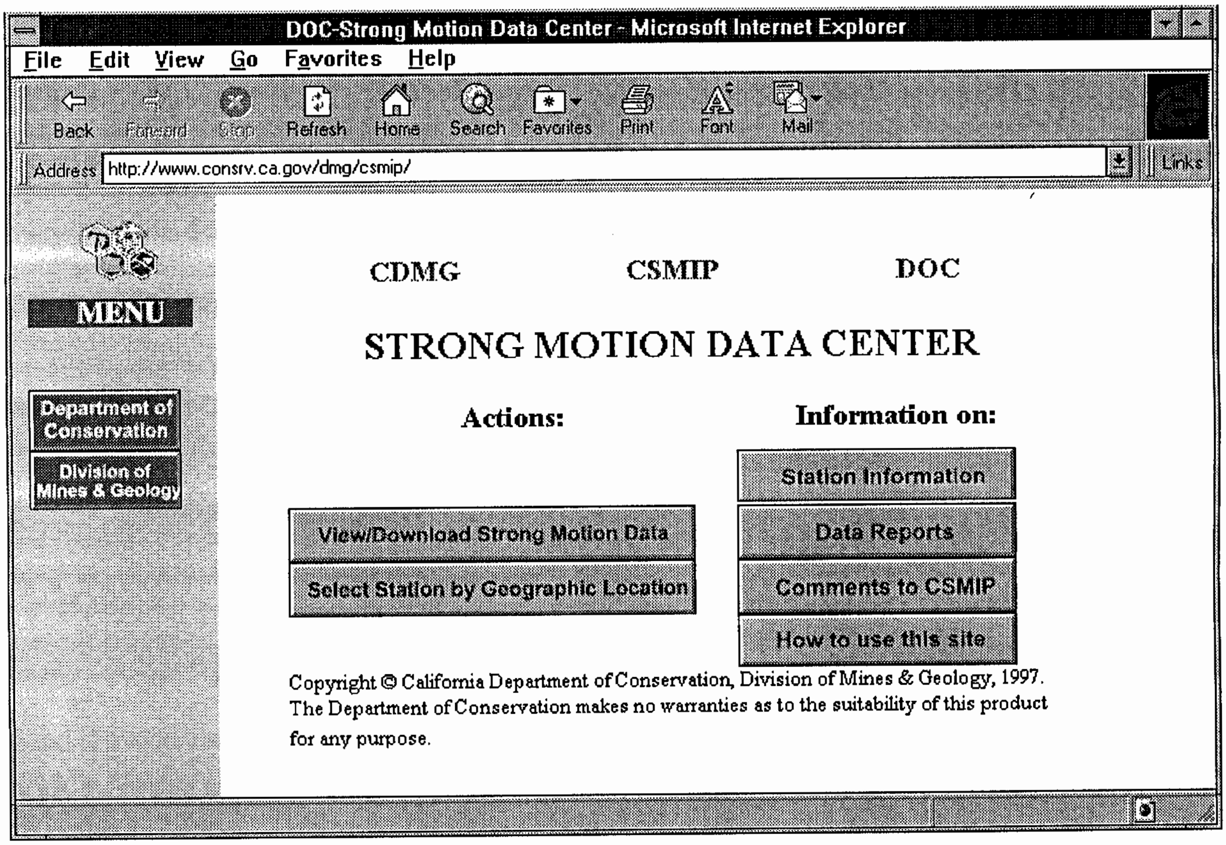

Figure 1. The Strong Motion Data Center home page on the Internet at http://www.consrv.ca.gov/dmg/csmip.

Selection of Records from a Specific Earthquake

Once the user selects an earthquake, Northridge for example, the following screen (3) lists all stations that have recorded data for that event in the database. These are listed alphabetically by station name in the left panel, and numerically by station number on the right, in case the user only knows the station number. The user may choose from either list, and then again "Submit" the selection. In the example, the user is about to request to view the data from the Obregon Park station in Los Angeles. Once that selection is submitted, the next screen (5) displays the retrieved time-history of the specified record, including the acceleration, velocity and displacement. This particular screen is long, and the user can scroll the display up to also obtain a display of the response spectra (screen 6). Other graphic representations of the data (additional spectral or time-history representations) will be added here in the future. If the user now desires, the record itself can be downloaded directly to his/her computer, simply by clicking on the "Download Record" button. The data files will be downloaded in a compressed format (PKZIP), and can be auto-uncompressed on PCs by simply executing the file. (A few users have Sun or other computers using Unix; a slightly different compression is needed, which can also be requested over the Internet). The format of these ASCII files is standard, conforming to the format CSMIP has adhered to for 15 years (Shakal and Huang, 1985). If the user does not wish to download at this point, he/she can just go back one screen and view other records in order to find one with the particular time-history or spectral properties desired.

Selection of Records from a Specific Station

A second pathway for obtaining data allows the user to request data from a particular station. In that case, the right panel of screen 2 in Figure 2 is used. There, the user can select from an alphabetical list of all stations in the network, statewide, scrolling down in the list as needed. Once a particular station is selected, the next screen (7) lists all earthquakes which were recorded at the station and are in the data base at the present time. In the example, Obregon Park has been selected, which has the recorded accelerogram from five earthquakes currently loaded into the Web site. The inset map on the left in screen (7) shows the locations of the station and the earthquake epicenters. At this point, the user can select the earthquake for which the record from this station is desired. This will result in screens identical to (5) and (6) discussed in the above example, and the same choice to download is available. (Note that the same station was used in these two examples simply to reduce the number of screens).

Searching for a Record from a Geographic Location

A very different application is provided by the option, "Select Station by Geographic Location" on the home page (Figure 1). This option ties to a second type of request from users, less common than the first. In this request, the user has an unfocused request, and may not be familiar with the data available. The user basically asks "Is there data from any station near my site (building, development, etc.)?" This can be a time consuming request for CSMIP staff to respond to. However, the example in Figure 3 shows the screen (2) that

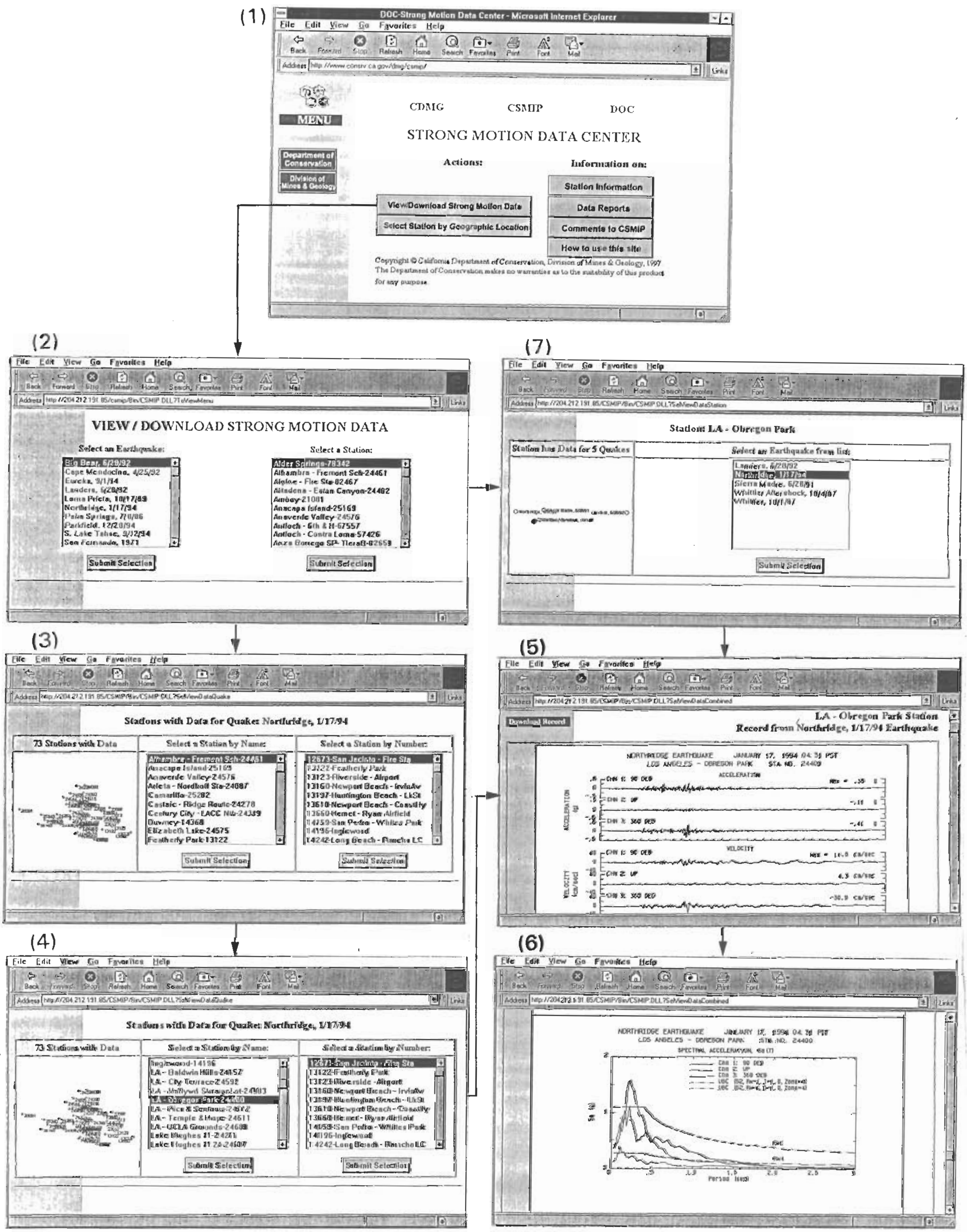

Figure 2. The flow path for accessing strong motion data using the upper action button "View/Download Strong Motion Data", as described in the text.

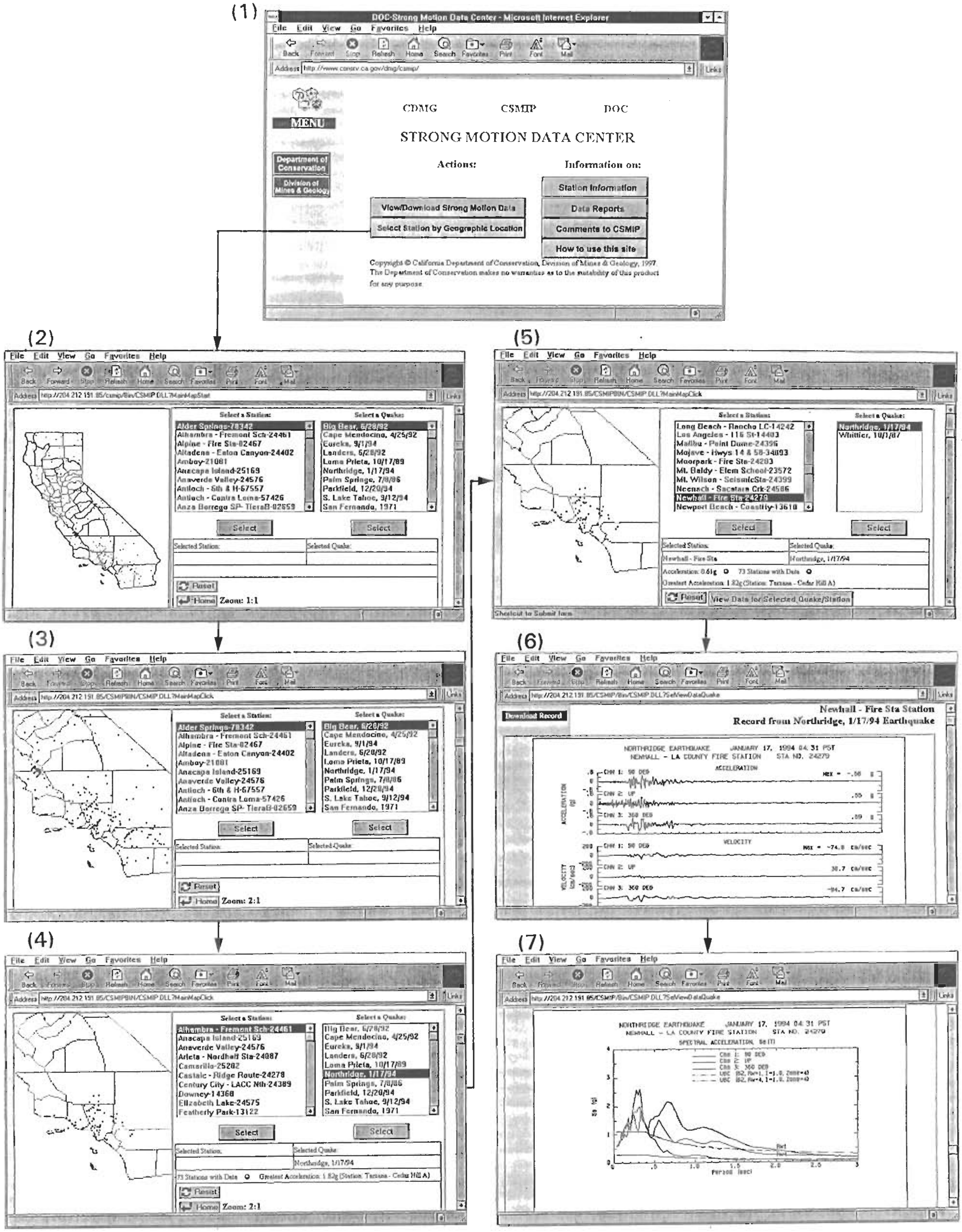

Figure 3. The flow path for accessing strong motion data using the lower action button "Select Station by Geographic Location", as described in the text.

the user is presented with if this option is selected. In this example, the user is interested in southern California stations, and so clicks on the southern California area to zoom in on the map (screen 3). If the user now restricts the request to data recorded in the Northridge earthquake, a map of just the stations that recorded Northridge appears (screen 4), which indicates that records from 73 stations are available on the Web site for this event. By studying the map, the users may localize their request further, zooming in again and again. (In the current version county boundaries are dropped at the third zoom level. Also, some intermediate re-zoom steps are necessary in going from screen 3 to 4 and 4 to 5). Finally, users may identify the station they want to know about the data for; and in this example the Newhall station has been selected (screen 5). The user learns that the station had a peak acceleration of 0.61 g in Northridge. If desired, the user then selects "View Data for Selected Quake/Station", and panels identical to screens 5 and 6 of the first application (Figure 2) appear, and the user may then elect to download the data after viewing the time-histories and spectra, or consider other stations in the vicinity of the user's building or site.

This application of Web site and database technology has recently been made operational. Dynamically creating screens, as in this application, is significantly more complex than presenting fixed screens with company logos, etc, which is most common on the Web. The present version is not as powerful as CSMIP desires, nor as powerful as some users will want once they begin using it regularly. The site is fully operational now, and additional data are being added weekly. CSMIP intends to discontinue the FTP site that has been maintained since 1994 once this site incorporates all the data. The site only includes data from freefield or ground reference stations at the present time, as these constitute the greatest volume of requests to CSMIP. Data from buildings and other structures data will be added in the next phase. Some improvements now being addressed include allowing the download of records without viewing under option 1, and improving the map-zooming operation under option 2 (which turns out to be significantly more complex over the Web than expected). Additional, non-CSMIP data will be added, always with full attribution of the data source, if the source network agrees to their data being added and it appears that there would be significant demand for the data. Old data, for example the 1971 San Fernando earthquake data collected by the Coast and Geodetic Survey and digitized by Caltech, are being added, with attribution, as the data are converted to standard format.

Distribution Policies and Security

There are no charges for downloading data from the Strong Motion Data Center site at this time. The only request of the Department of Conservation's Division of Mines and Geology is that appropriate credit of the source of the data be given in reports and citations so that the value of the data and its utilization can be demonstrated to the agencies funding the data collection and dissemination. Other Web sites, either commercial or private, may desire to download all the records from this site, and distribute the data from a site they set up themselves. Several aspects discourage that. First, only the data at this site will be maintained by CSMIP. As better instrument-correction algorithms or noise removal techniques become available, CSMIP will re-process and update the records in the data base as appropriate. If there were to be an error in sensor orientation or scaling constants for a record, something that networks like CSMIP work hard to prevent but is still a possibility, the early data would be replaced by the corrected data. Any copies at other Web sites would still be the old version. (This ability to improve the data is an advantage of archiving data through the Web versus using CDROMs. Once a CDROM is made, it is permanent and files can not be changed.)

The second aspect is that the processed data at the Web site are copyrighted by the State of California as part of the quality assurance effort, and legal issues would probably need to be resolved before the data are copied for redistribution. Finally, from the user's perspective, data archived at the CSMIP Web site is virus-free, and anti-virus security programs are automatically run at frequently scheduled times to ensure that the data remain virus-free.

In general, an effective approach for an independent site is to develop and archive information about data and earthquakes, useful for users and reflecting the mission of the organization, but then to simply have an Internet link which passes the user through to this Data Center site when an actual record is desired.

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