Understanding Ground Motion Variations at the Van Norman Dam Complex Site

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October 16,1998

Abstract

During the 1994 Northridge event, seismic stations at the Van Norman Dam Complex recorded peak accelerations that significantly varied over short distances. In an effort to gain further understanding of this behavior, this project focused on comparing weak ground motion at six different sites around the dam. The first station was an existing SCEC borehole at the Jensen Generator Building. The other stations were placed at the Jensen Administration Lawn, Sylmar Converter Station West and East, the Los Angeles Dam, and the Rinaldi Station. Over the course of two months, a few weak motion events yielded enough data to begin a comparison of the array stations to data recorded at the borehole station during the previous seven months. The weak motion data recorded during this project have shown ground motion variation similar to those observed during the Northridge earthquake.

Introduction

The Los Angeles Dam, which survived the 1994 Northridge event gave seismologists a good opportunity to observe site responses at different points around the dam during strong ground motion events. With this project I attempted to observe similar site response variation at six weak motion stations around at the dam complex. The reason that the Van Norman Dam Complex in Los Angeles County was chosen for the location of this study is that the stability of the structures around the dam are important to the safety of the population of the San Fernando Valley. The near failure of the San Fernando dam in the 1971 San Fernando earthquake prompted engineers to construct the LA Dam and sparked much interest in the site response of the area

I chose to work on this project to gain a deeper understanding of seismology. What made the project most interesting to me was that working with Jamie Steidl would give me the opportunity to get out into the field and undertake the enjoyable task of putting out and maintaining the array. It would also be a project through which I would learn how to assemble and operate seismic equipment. It would also be an opportunity to tackle a problem that affected the local community and that was not purely focused on academic interests.

Experimental Methods and Procedure

To collect data for the project a seismic array consisting of five surface stations were set up in addition to a downhole accelerometer and uphole weak motion sensor Jamie already had in place at the Jensen Generator building. The other stations were located at the Jensen Administration Building lawn, Sylmar Converter Stations West and East, the Los Angeles Dam, and the Rinaldi Power Station. Data was collected from these stations on a weekly basis for approximately a month and a half. After copying the data onto computers at ICS, seismic events were separated from false data and processed in SAC format in order to compare site response at different stations.

The first step of the project was to meet with Jamie and discuss the setup of the seismic stations. L4C3d sensors were used to collect weak motion data and FBA accelerometers were used to collect strong motion data. Reftek 72A-08 data acquisition system (DAS) computers would process the data from these sensors, an external GPS clock and a 12V gel cell battery. The data would be recorded via a SCSI connection onto an external hard disk. After learning the use of the RefTek station and it's components, a test station was set up near the Portable Broadband Instrument Center (PBIC) at the Institute for Crustal Studies office. This experiment did not yield any seismic data but it did teach me the fundamental skills required to set up, maintain, and disassemble a seismic station.

The next step was to put low noise module chips into the DASs in order to maximize the resolution of the strong motion data. This required learning to open up the computers and carefully work with the cards inside. Once this was completed, final step in preparing the seismic stations was begun. The five seismic stations were set up one at a time on the UCSB campus and tested to see that their individual components properly functioned together. Sometimes, for inexplicable reasons a certain DAS may not read the data from a certain GPS unit or may have difficulty writing to a particular hard disk with a particular cable. Therefore this step was necessary in order to ensure an efficient field deployment.

One of the most fundamental steps in setting up seismic stations in obtaining permission to use the land. Fortunately Jamie had made contact with the Los Angeles Department of Water and

Power, as well as the owners of the Jensen Filtration Plant, the Metropolitan Water District. We deployed the Jensen lawn station first, it was a good lesson. This trip also allowed me to practice a site visit to the Jensen Generator Borehole. The remaining four stations were deployed all on the same day under the supervision of LA Department of Water and Power Geologist Jeff Owen.

Once the deployment was complete it was time to focus on the laboratory aspect of the project and gain some insight into the behavior of earthquake waves. I studied from Geotechnical Earthquake Engineering by Steven L. Kramer. This helped me gain on understanding of why ground motion is important to engineering. If sesimology can predict how the ground will move, then engineers can design buildings that stand up to it. This is common sense, but studying the different types of ground motion and the types of damage they cause was something that I had never explored in depth. I also read from Digital Spectral Analysis with Applications by S.Marple. It explained the some of the theories behind the mathematical analysis of seismic data. It was more advanced than I was prepared for but it did present a number of different theories. It also helped me to understand the fast fourier transform operation. Something else that was important was practicing working in the UNIX operating system. This would prove to be very useful once I began receiving data from the field.

In order to collect the field data on a regular basis weekly visits were made to the Van Norman Dam Complex. It was important to assure that all of my sites were running properly to collect as much data as possible (see challenges). This required copying the contents of the hard disks onto a transfer disk. This is a hard disk that is designed to be carried into the field for the purposes of downloading the contents of hard disks at multiple stations. If the transfer proved unsuccessful the hard disk at the station could be exchanged for one that was blank. I made four solo site visits to the complex. Due to the dangerous nature of working in power stations, I took a short safety course to make unsupervised visits to the Sylmar stations. This saved Jeff Owen considerable time as he would no longer need to supervise my visits.

The final step in the project was the data analysis. Information from the transfer disk or swapped station disk was transferred to the UNIX computers at ICS. Once this was done the data would have to be changed from the RefTek format to what is called SEGY format. This allowed it to be viewed using the XQR program from the designed by SCEC PBIC computer engineer Aaron Martin. Using this program, Jamie showed me how to separate seismic events from false triggers. The sensors pick up the shaking in the up-down, north-south, and east-west directions and the DAS records them as separate files. I picked through all of 1998 borehole data and managed to pick out 21 distinct earthquakes, including some with multiple events. The data from the array set up for my project yielded five events, but only four that were also recorded at the borehole site (figure 1). The data were then converted into SAC format. In SAC format the data could be analyzed mathematically identify site response.

In order to understand which of the events in the data were verified and recorded in SCEC earthquake catalogs, an event association was necessary. Available on the internet at http://scec.gps.caltech.edu/catalog-search.html. The next step was to use log files, records the DAS keeps independent of event files, in an event association program. The program looked for close time matches between events in the catalog and events in the log file. Once this is done directories can be made, grouping all of the event files in UNIX under folders displaying their Julian day and magnitude.

At this point the SAC program was used to convert data to ground motion. The data was in counts and had to be converted to volts and then to velocity. The data from the L4C3d files was converted to velocity (figures 2&3) using a volt to count ratio and assuming 4.1 cm/s per volt. The downhole accelerometer recorded data in terms of the gravity constant, g. The accelerometer data was converted to ground motion using 10 V/g with 1g=980.6 cm/s^2. The file was then integrated in SAC to change it from acceleration to velocity (figure 4). The next step in the mathematical analysis was to perform a complex fourier transform (ffc) on the two horizontal shaking direction files from each sensor during each event. Once this was accomplished, the L4C3d ffc files were divided by those from the borehole and a site response ratio could be established. Through plotting the data (figure 5) amplification at each site could be determined. In this way, it could be understood whether or not the site response was noticeable even for weak motion events.

Challenges

My first challenge in the execution of this project was learning the basics of operating UNIX. I practiced many of the commands but did not have an immediate task to accomplish with the system. It was not until I started to actually sort out seismic data that I began to feel comfortable with UNIX.

The other challenge that was presented to me was the maintenance of the array. After completely deploying all of the seismic stations, they would still require visitation. The challenge in this is that a field visit is never the same as what was practiced in the laboratory with Jamie and Aaron. The first time I planned and executed a field visit on my own the Rinaldi station was not working and was presenting me with a number of computer and disk problems. I called Jamie back at ICS quite a few times before I could get the station functioning properly. However, troubleshooting seismic stations in the field is something that requires experience. Batteries die and wires come loose. An important fact to keep in mind is that there may come a point where a site will not work and the only option is start from scratch with your spares. Although this is rare, I have had to replace as much as half of the equipment at a site during one visit.

A challenge specific to the Van Norman Dam Complex is related to the high level of security around the dam. Half of the power used by the city of Los Angeles travels through the Rinaldi station and the security of a dam and reservoir near a populated area is understandable; it is part of the reason this research project is interesting. With all of this to consider, it was important for me to call ahead before a site visit to gain access, be prepared to explain my business, wear a hardhat and maintain a high level of respect towards these secure areas. This was not so much a difficult task as something to note for any future interns considering field projects in high security areas.

One of the main challenges that I have paced in the final days of my internship period is in processing the data correctly. The SAC program for UNIX has a very easy to use manual page on the internet. However, understanding how to utilize the program most efficiently is the responsibility of the researcher. In order to learn the SAC system, I did processed most of the data event after event, each by hand. This meant that any error that I consistently made would have to be corrected later on. Therefore, I would recommend to anyone working with SAC, that designing macros is the most efficient means of utilizing the program.

Results and Conclusions

The final analyses of the weak motion data from the Van Norman Dam Complex array shows that there is significant site response and amplification throughout the area. The exception to this is the Los Angeles Dam site, which may experience wave dampening due to its position between two large bodies of water, the Los Angeles Reservoir and the Van Norman Bypass Reservoir. The Sylmar stations show peaks around 12 Hz, which can be explai subharmonics of the interference from the 60 Hz background noise found stations.

During my SCEC internship I acquired some skills that I feel will be important to me as I move on to study geology. Jamie Steidl and Aaron Martin taught me a lot about planning, assembling and maintaining portable seismic stations. I also learned how to use UNIX to manage files and analyze data. This included using aforementioned programs such as XQR, XQuakes, and SAC. One thing that was especially enriching about working at ICS was learning the importance of communication. There were many good people and resources around me every day. I asked questions to just about every researcher at ICS and everyone was always willing to help. However, a skill that I am still working on is being concise in my questions. That is the goal of communication in science.

Applications

The results of this project can be used to understand the ways in which the important water and power stations surrounding Los Angeles Dam can be affected by even weak motion seismic events. By understanding the way that the near surface soils affect the motion of the ground, engineers can better understand the kinds of shaking that their structures must withstand. Such and understanding can also help legislators improve building codes for public works stations as well as residential structures throughout California. What is most important in ground motion research is the safety of the community.

Figures and Appendix Guide

Figure 1

Directory of Events Used in Data Analysis-a guide to the magnitude and locations of the events as well as the stations where they were recorded.

Figures 2 & 3

The August 26th event was recorded by all but one of the stations in the array. It is this event which allowed for comparing the site response of all the stations to the borehole. The computer (DAS) id numbers appear above the data for each plot. The guide is as follows:

0593: Jensen Administration Building Lawn
0630: Los Angeles Dam
0631: Jensen Generator Borehole
0883: Sylmar Converter Station East
0884: Sylmar Converter Station West

Figure 4

This is a plot of the horizontal components recorded by the accelerometer in the borehole.

Figure 5

This plot shows the site response vs. frequency for all of the data.

Appendix A

Copy of webpage (http://magic.geol.ucsb.edu/~jds/scecjour.html). This was my daily progress journal during my project.

Directory of Events Used in Data Analysis[1]

Day (1998)	Richter Scale	latitude	longitude	Jensen Borehole	Jensen Lawn	Rinaldi *	Sylmar West	Sylmar East
3/2	2.8	34.2410	-118.6770	X				
3/6	4.8	36.0610	-117.6300	X				
3/7	4.8	36.0740	-117.6300	X				
3/11	Unknown	unknown	unknown	X				
3/17	Unknown	unknown	unknown	X				
4/15	3.2	34.1020	-118.4610	X				
4/25	1.6	34.3220	-118.4610	X				
4/26	3.8	34.0750	-118.1070	X				
4/27	1.7	34.2770	-118.4690	X				
4/28	2.4	34.2970	-118.4590	X				
4/29	2.1	34.1720	-118.5630	X				
5/1	3.8	34.3520	-118.6670	X				
5/18	1.9	34.2900	-118.4580	X				
6/3	3.0	34.1240	-118.4820	X				
6/14	2.3	34.3170	-118.4590	X				
6/17	3.2	34.2710	-118.5780	X				
6/20	Unknown	unknown	unknown	X				
7/14	Unknown	unknown	unknown	X				
8/8	1.9	34.3200	-118.4800	X				
8/8	Unknown	unknown	unknown	X				
8/16	Unknown	unknown	unknown	X	X			
8/20	4.4	34.3740	-117.6480	X	X			
8/21	1.9	34.2870	-118.4650	X	X			
8/26	3.3	34.2850	-118.4340	X	X		X	X
9/1	Unknown	unknown	unknown	X				

1 *Source: Southern California Earthquake Center Data Center Earthquake Hypocenter and Phase Database*

*Rinaldi Station was inoperative during this period.