NUREG/CR-6625
Addendum 1

Automated Seismic Event Monitoring System

Addendum 1

Multimax, Inc.

U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
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Prepared by
I. Henson, R. Wagner, W. Rivers, Jr.

Multimax, Inc.
1441 McCormick Drive
Largo, MD 20174

E. Zurflueh, S. Pullani, NRC Project Managers

Prepared for
Division of Engineering Technology
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
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ABSTRACT

Original NUREG/CR-6625

The U.S. Nuclear Regulatory Commission (NRC), as part of its actions for insuring public safety, wishes to be able to monitor seismic activity in near-real time. To help achieve this capability, a data recording, processing, and archiving system was constructed to detect seismic signal arrivals, calculate epicenters and seismic magnitudes, and issue alerts whenever a strong earthquake is determined to have occurred near the site of a nuclear power plant. This system takes as its input raw waveforms that have triggered signal detectors at stations of the U.S. National Seismographic Network (SNSN) and that have been re-broadcast via satellite from the U.S. Geological Survey (USGS) to a Very Small Aperture Terminal receiver at NRC, so the system is able to perform its calculations within minutes of the earthquake. The epicenters that are calculated by the system are crude, however, so as soon as improved event locations are calculated by USGS they are downloaded via the Internet and used in place of the epicenters that had been calculated at NRC in near-real time. Seismograms that were not received at NRC via the satellite link are also retrieved via the Internet, sometimes months after the event, and they are then added to the permanent seismogram archive.

In addition to determining earthquake epicenters and magnitudes automatically, the software system permits the seismograms to be studied off-line by means of stand-alone seismic data analysis packages that are operated by a scientist or data analyst using interactive graphics on a UNIX workstation. One of these stand-alone packages permits the seismograms recorded at the USNSN stations to be used to estimate the Cumulative Absolute Velocity (CAV) at nearby nuclear power plant sites. These calculations make use of tables of frequency-dependent site effects that were computed for power plant sites on the basis of local geologic structures. Another part of the off-line software is a Geographic Information System that permits the newly computed epicenters, the locations of the seismic stations, and the power plant sites all to be displayed on the workstation in interactive maps that show a detailed context of the geologic and geophysical data sets which affect seismic wave propagation and other important physical phenomena.

The software for near-real time seismic analysis has recently been re-written in the Java programming language. As a part of this re-writing of the code, a graphical interface has been developed that permits information about recent and archived events to be displayed via tables and that permits the raw waveforms to be viewed and manipulated graphically in both the time and frequency domains. The seismograms can be displayed as soon as they are received from the satellite or after the events have been detected and located. Because both the analysis and system is platform-independent.

Addendum 1

This addendum documents the results of additional work performed on the Automatic Seismic Event Monitoring System following the original publication of NUREG/CR-6625 in May 2000.

CONTENTS

This document contains 37 pages reflecting revisions or additions to NUREG/CR-6625, Automatic Seismic Event Monitoring System, as a result of additional work performed by Multimax, Inc., under terms of NRC Purchase Order No. DR-98-0370, Job Code Y6063.

14 pages of this updated documentation replace 13 pages of NUREG/CR-6625:

- The 7 pages (13 through 19) replace pages 13 through 19 of NUREG/CR-6625 by expanding the total number of seismic events in Table 1 from 232 to 277 and by incorporating data from additional stations for many of the original 232 events.
- The 7 pages (21 through 26 and 26a) replace pages 21 through 26 of NUREG/CR-6625 by expanding the total number of seismic stations in Table 2 from 219 to 240 and by showing that many of the original 219 stations have now contributed data to the archive for more events than they did before.

23 pages of this updated documentation are addenda to the text of NUREG/CR-6625:

- The 3 pages (7a, 7b, and 7c) contain Section 1.7 of this Addendum, which follows immediately after page 7 of NUREG/CR-6625.
- The 20 pages (70a through 70t) contain Sections 3.2.24 through 3.2.27, Section 3.3, and Section 3.4 of this Addendum, all of which follow immediately after page 70 of NUREG/CR-6625.

1.7 Subsequent Changes to the Hardware and Software Configuration

Section 1.5 described the ArcView Geographic Information System (GIS) that Multimax has installed at NRC to display, and perform interactive queries of, the geographic, geological, and geophysical data sets that we have installed there. That GIS was version 3.0 of the commercial ArcView software, but Multimax has subsequently updated it by installing ArcView version 3.2 and porting all the data sets to this new software package. The supplementary software products ArcView Spatial Analyst Extension and ArcView 3-D Analyst Extension were re-installed to work within the ArcView version 3.2 operating environment, and the GIS analysis of the data sets described in Section 3 can thus continue to make use of those extensions.

Environmental Sciences Research Institute (ESRI) Corp., the vendor of the commercial ArcView product, has announced that version 3.2 will be the final version of ArcView that is built using the original code base. In June 2001 ESRI introduced version 8.1 of ArcView (skipping versions numbered 4 through 7), a product that has both a completely different code base and a radically different software architecture from version 3.2. It is, however, backwards-compatible in that it can read the same data files that were read by version 3.2. The UNIX version of ArcView 8.1 is less functional than the Windows NT or Windows 2000 version, since the UNIX version cannot be modified by running scripts, as version 3.2 could. In going from version 3.2 to version 8.1, the scripting language was changed from ESRI's own Avenue language to Microsoft's Visual Basic for Applications, which runs only within the Windows environment. ESRI does not plan to change this significant limitation of the capability of the UNIX version in subsequent releases. Indeed, the UNIX version is being issued primarily to allow customers to transition legacy ArcView UNIX installations either to ArcView on the Windows platform or to the more powerful ArcInfo product, which will remain fully functional under UNIX. We therefore do not recommend that NRC upgrade the GIS on the workstation *res11* to any release beyond the final one that we have installed there.

Reference was made in Sections 1.3 and 1.6 to the ASEMS software's running on workstation *res18*. During the year 2000 the software was modified so that almost all ASEMS processes could be initiated and run from either workstation *res11* or workstation *res18*. The two exceptions to this rule were the Geographic Information System, which was completely transferred from *res18* to *res11*, and the *readsat* process that downloads data from the VSAT, which remained running exclusively on *res18*, the machine to which the data cable to the VSAT was physically attached. In order for the same software to run on both machines, it had to be modified so that it always took into account the workstations' file-naming configurations. Even though the same disks were remote-mounted from one workstation to the other, NRC's Systems Administration policy assigned them different names on the two machines, and so the ASEMS software checked to see on which machine it was being run, and then it used the correct nomenclature for that machine in order to access the data files.

However, in 2001 the decision was made that the older workstation, *res18*, would soon be removed from operational status. The ASEMS software was therefore modified to run only on *res11*. These modifications included removing the features that checked to determine on which workstation the software was running and accordingly changed the top-level disk-partition names in the directory path structure to compensate for the differences in the names of the same physical files on the machines to which they were either locally or remotely mounted. Another critical modification was changing the software to read the input data stream from a port on *res11* instead of one on *res18*, since the cable from the VSAT was now physically connected to the newer, faster workstation instead of the older one to which it was originally attached. As a result of this new hardware configuration, it was possible to delete from the system the "black box" data buffer that had been connected between the VSAT data stream and the I/O port on *res18*, to hold the data long enough for *res18* to download them without suffering data dropouts due to overload.

Because *res11* is a faster machine, it is able to download the VSAT data stream at the same rate that the data are transmitted over the cable from the satellite receiver to the workstation, and so no external data buffering is required.

As part of the final software modification performed for delivery in June 2001, one feature of the data-processing pipeline that was described in Section 1.3 and again in Sections 6.3.4 and 6.4 has now been disabled. As the second paragraph of page 2 of NUREG/CR-6625 explains, the ASEMS signal detection system records many "false alarms", since it is intended to be an "early warning" system that reports seismic wave energy as soon as it is detected by a single station. Because it is designed to perform single-station seismic signal detection and event location, most of the "events" that it reports are in fact either very small tremblors that are purely local to the single detecting station and that are far too low in seismic magnitude to be regarded as significant, or they are due to anomalously large excursions in the ambient seismic noise background at the single detecting station, or they are due to misidentified seismic wave arrivals from large but distant events outside the Eastern and Central USA area of interest. For example, PKP waves (P-type seismic waves that travel from a distant earthquake downward through the earth's mantle, then through the earth's core, and then up through the mantle again to the detecting station), will likely be identified as direct P-waves from a (fictitious) near-by event instead, since these two scenarios are generally indistinguishable on the basis of single-station data alone, unless the event is in fact an especially large one. Furthermore, even for signals that are correctly identified by the single-station data processing as being direct seismic wave arrivals from events within the Eastern and Central USA area of interest, the epicenters determined on the basis of single-station data are well known to be highly unreliable for all but the largest events or moderate-sized events that are fairly close to the detecting station.

Although for an early-warning system such as ASEMS it is important that all such "events" be reported as soon as they are "detected" and "located" (and thus they all appear in the directory /SAT/Events/recent and can be viewed immediately using the "EventMap" program that is described in Sections 6.3.5 and 6.3.6), it would be unnecessary (and misleading!) to store these preliminary single-station event locations in the permanent archives of event detections and waveform data. For this reason, ASEMS attempts to confirm all single station event detections by checking them against the lists of events located by USGS using multiple stations within their global seismic network. Of necessity, these multi-station seismic event locations can be performed only later than single-station event locations can be, so they are usually insufficient to serve as early-warning alarms, but they should be regarded as being much more nearly reliable than the single station event locations. ASEMS therefore was designed to verify the events in the /SAT/Events/recent directory against the network-detection event list posted online by USGS, and only if an event was posted there within the next week that could be associated with the single-station location and origin time well enough to be considered a match, and only if USGS located the event as having occurred in the Central or Eastern USA, would the seismic waveforms from that event then be stored in the permanent event data archive. Furthermore, the event locations that would be stored in the "monthly archive" subdirectories of directory /SAT/Events/archive would be the multi-station locations that were computed by USGS, since they would always be more nearly reliable than the single-station (and thus only preliminary) event locations computed by ASEMS would be. It is this event verification procedure that we have now disabled in the final software configuration, for a reason that we shall now explain.

The procedure for verifying a single-station event detection against the list of epicenters determined by multi-station event detection involved using the UNIX "finger" command to retrieve data from a server at USGS in Golden, CO. This "finger" process no longer works from *res11*, due to the firewall that has been installed to protect the local-area network against intrusion. The "finger" command transmits its data to USGS, but the USGS reply is never received back by *res11* on account of the firewall. The ASEMS software thus waits for an event confirmation, but then it fails to receive one within one week, and so the event location and detecting seismograms are then deleted from the /SAT/Events/recent directory without ever being written to the current "monthly" subdirectory within the /SAT/Events/archive directory. Consequently, no data were being archived. In order for single-station event detection reports and the detecting seismograms to be stored permanently, the event verification system has been disabled, and so now *all* data that are written into the directory /SAT/Events/recent are, after one week has elapsed, deleted from that directory and copied into the current "monthly" subdirectory within the /SAT/Events/archive directory, even though these "events" are at best, poorly located, and at worst (and far more likely), spurious "detections" based on misidentified signals from distant events outside the area of interest, or very small and thus unimportant purely local events, or simply seismic noise excursions.

When the "finger" command was still operational, ASEMS typically entered at most a half dozen USGS-verified events, and sometimes only a single event, into the permanent data archives each month. Once the "finger" command ceased to be operational due to the firewall, of course no data were archived at all. Now that the event verification system has been removed from the data-processing pipeline, however, "events" (however unreliable or purely spurious they may be) are being archived at a rate of between 250 and 300 "events" per month. These "events" and the associated seismograms will add from 500 to 700 megabytes of data to the archive annually. Of course, there is no harm in this, provided it is understood that the archive is in fact now an archive of all the preliminary possible alarms determined by ASEMS and not an archive of "genuine" seismic events within the Central and Eastern USA area of interest, as it was originally intended to be. Since there is currently some 4.6 gigabytes of free disk space available within the disk partition /local3 on which the data archive resides [either one of the alternate pathnames /SAT/Events/archive or /local3/SAT/Events/archive will serve to access the archive], even though the volume of data currently being archived is some 50 times greater than it was when the event verification system was functional, there is still sufficient disk space for the system to continue archiving data for the next several years without having to be removed from disk and retained only on backup tapes.

The final configuration of the ASEMS hardware and software appears to be operating stably, since the system has continued to operate without interruption for nearly a full month since the installation was completed in June 2001. We anticipate, then, that the system can continue to operate until *res11* is rebooted for some reason or another. When that happens, a user can start the data pipeline flowing again by using the **start_vsat** command described in Section 6.3.2. In addition, using the ArcView GIS software after a system reboot may require that the System Administrator re-start the ArcView license manager. The necessary procedure (which consists of a single UNIX command-line entry) is described in ESRI's *ArcView License Manager* booklet. A copy of that document is stored in the file cabinet underneath the console of *res11*.

Finally, it is important to note that as a result of the file system nomenclature that is used on *res11*, the filenames shown in Section 6 of NUREG/CR-6625 are now out-of-date, since they are the filenames by which *res18* accessed those same data files. Now all pathnames mentioned in Section 6 as beginning with the root directory /local1/Loc_Sys should be interpreted as beginning with the root directory /local3/Loc_Sys instead. Similarly, the pathnames mentioned as beginning with the root directory /local1/Events should be interpreted as beginning with the root directory /SAT/Events (or, equivalently, /local3/SAT/Events) instead. The analogous changes to the directory and filename structure of the GIS software and data are explained in detail in Section 3.4 of the present Addendum to NUREG/CR-6625.

Table 1

The 277 Events in the Seismic Waveform Archive at NRC

Epoch	Date	Origin	Lat	Lon	Depth	Mag		Src	#Sta
789998721	01/13/95	12:05:21	43.37	-70.94	7.2	2.6	Ml	MIT	5
790444299	01/18/95	15:51:39	34.77	-97.60	5.0	4.2	Ml	USGS	11
792607471	02/12/95	16:44:31	44.27	-70.25	5.0	2.8	Md	USGS	21
792863637	02/15/95	15:53:57	45.90	-75.04	18.0	3.5	Ml	USGS	18
792983596	02/17/95	01:13:16	44.17	-70.24	8.0	2.7	Md	USGS	19
793198626	02/19/95	12:57:06	39.12	-83.47	10.0	3.6	Ml	USGS	27
793531933	02/23/95	09:32:13	41.87	-80.83	5.0	2.9	Ml	USGS	21
794505997	03/06/95	16:06:37	29.18	-101.33	0.0	3.9	Mb	IDC	4
794909752	03/11/95	08:15:52	36.96	-83.13	1.0	3.7	Mb	USGS	28
794915404	03/11/95	09:50:04	37.00	-83.19	5.0	3.3	Lg	USGS	2
795536670	03/18/95	14:24:30	43.33	-71.61	8.1	2.8	Ml	MIT	5
797615976	04/11/95	15:59:36	43.83	-68.44	13.3	3.1	Ml	MIT	5
797819576	04/14/95	00:32:56	30.29	-103.35	18.0	5.6	Mb	USGS	14
797821908	04/14/95	01:11:48	30.30	-103.35	10.0	2.7	Ml	USGS	5
797825666	04/14/95	02:14:26	30.30	-103.35	10.0	2.8	Ml	USGS	9
797825978	04/14/95	02:19:38	30.30	-103.35	10.0	3.3	Ml	USGS	8
797831322	04/14/95	03:48:42	30.30	-103.35	10.0	2.6	Ml	USGS	6
797832676	04/14/95	04:11:16	30.30	-103.35	10.0	2.4	Ml	USGS	8
797838819	04/14/95	05:53:39	30.30	-103.35	10.0	2.7	Ml	USGS	9
797845176	04/14/95	07:39:36	30.30	-103.35	10.0	2.4	Ml	USGS	7
797848032	04/14/95	08:27:12	30.30	-103.35	10.0	2.8	Ml	USGS	8
797853778	04/14/95	10:02:58	30.30	-103.35	10.0	2.9	Ml	USGS	8
797857040	04/14/95	10:57:20	30.30	-103.35	10.0	2.3	Ml	USGS	8
797956409	04/15/95	14:33:29	30.27	-103.32	10.0	4.0	Ml	USGS	11
798126357	04/17/95	13:45:57	32.95	-80.07	10.0	3.9	Ml	USGS	21
799746695	05/06/95	07:51:35	47.00	-66.60	5.0	3.9	Mb	USGS	11
799827310	05/07/95	06:15:10	43.38	-70.95	5.8	2.8	Ml	MIT	5
801411752	05/25/95	14:22:32	42.99	-78.83	5.0	3.0	Ml	USGS	27
801604270	05/27/95	19:51:10	36.17	-89.43	6.0	3.8	Ml	USGS	23
802219472	06/03/95	22:44:32	47.02	-76.29	18.0	3.4	Mb	USGS	22
802474031	06/06/95	21:27:11	36.22	-89.47	5.0	3.6	Ml	USGS	21
803304791	06/16/95	12:13:11	44.29	-71.92	5.0	3.8	Ml	USGS	24
804126977	06/26/95	00:36:17	36.75	-81.45	5.0	3.1	Mb	USGS	34
804418040	06/29/95	09:27:20	36.55	-89.78	10.0	3.1	Lg	USGS	1
804830344	07/04/95	03:59:04	36.25	-104.81	5.0	3.8	Ml	USGS	26
804953804	07/05/95	14:16:44	35.37	-84.21	10.0	3.7	Ml	USGS	28
804955321	07/05/95	14:42:01	43.34	-71.44	4.0	2.2	Ml	MIT	4
805150867	07/07/95	21:01:07	36.35	-81.33	5.0	3.0	Lg	USGS	1
806206234	07/20/95	02:10:34	36.50	-89.67	5.0	3.2	Lg	USGS	2

Table 1 (Continued)

Epoch	Date	Origin	Lat	Lon	Depth	Mag		Src	#Sta
807455224	08/03/95	13:07:04	37.40	-76.68	5.0	2.9	Ml	USGS	25
807464873	08/03/95	15:47:53	48.09	-92.34	0.0	-1.0	u	IDC	11
808701530	08/17/95	23:18:50	36.10	-89.41	5.0	3.1	Ml	USGS	23
808935326	08/20/95	16:15:26	45.41	-73.28	18.0	3.3	Ml	USGS	16
810342081	09/05/95	23:01:21	38.36	-89.04	4.0	2.9	Ml	USGS	22
810878345	09/12/95	03:59:05	45.61	-74.43	18.0	3.7	Ml	USGS	21
811125093	09/15/95	00:31:33	36.87	-98.69	5.0	4.1	Ml	USGS	21
811724607	09/21/95	23:03:27	45.08	-74.21	18.0	3.1	Ml	USGS	19
812431061	09/30/95	03:17:41	43.28	-71.59	6.9	2.9	Ml	MIT	5
813309560	10/10/95	07:19:20	46.42	-78.77	18.0	3.5	Ml	USGS	21
814149202	10/20/95	00:33:22	28.38	-100.60	0.0	4.2	Ml	IDC	5
814156181	10/20/95	02:29:41	44.40	-70.84	8.7	2.8	Ml	MIT	5
814204638	10/20/95	15:57:18	45.79	-96.86	5.0	3.7	Ml	USGS	12
814219481	10/20/95	20:04:41	38.05	-81.41	0.0	2.9	Mb	IDC	31
814295065	10/21/95	17:04:25	42.85	-77.92	5.0	-1.0	u	USGS	6
814667848	10/26/95	00:37:28	37.05	-83.12	1.0	3.9	Mb	USGS	32
816198359	11/12/95	17:45:59	30.30	-103.35	10.0	3.6	Ml	USGS	10
816221523	11/13/95	00:12:03	44.30	-68.00	5.0	3.0	Ml	MIT	5
816686614	11/18/95	09:23:34	43.01	-71.92	0.9	2.5	Ml	MIT	5
817329332	11/25/95	19:55:32	42.83	-70.74	0.9	2.2	Ml	MIT	5
817679311	11/29/95	21:08:31	38.38	-80.66	0.0	2.7	Lg	USGS	32
817828660	12/01/95	14:37:40	35.06	-99.34	5.0	2.9	Ml	USGS	14
817940928	12/02/95	21:48:48	37.81	-82.20	33.0	2.9	Lg	USGS	30
818387006	12/08/95	01:43:26	44.09	-71.24	13.0	2.9	Ml	MIT	5
819022600	12/15/95	10:16:40	36.07	-83.64	5.0	2.6	Lg	USGS	21
819701508	12/23/95	06:51:48	38.73	-104.92	5.0	3.5	Mb	USGS	19
820370258	12/31/95	00:37:38	38.72	-104.91	5.0	2.8	Ml	USGS	17
821139327	01/08/96	22:15:27	38.03	-81.68	0.0	3.6	Lg	USGS	29
823603562	02/06/96	10:46:02	42.82	-71.37	7.1	-1.0	u	MIT	5
823619428	02/06/96	15:10:28	42.51	-97.54	5.0	3.6	Ml	USGS	34
823622917	02/06/96	16:08:37	43.98	-103.73	5.0	3.7	Lg	USGS	24
824322541	02/14/96	18:29:01	38.00	-81.62	0.0	3.9	Lg	USGS	39
824796797	02/20/96	06:13:17	45.96	-74.78	18.0	-1.0	u	USGS	3
826800146	03/14/96	10:42:26	45.99	-74.43	18.0	-1.0	u	USGS	48
827526132	03/22/96	20:22:12	41.69	-71.24	12.0	3.5	Lg	USGS	36
827736227	03/25/96	06:43:47	35.61	-102.60	5.0	-1.0	u	USGS	35
827763350	03/25/96	14:15:50	32.13	-88.67	5.0	3.5	Lg	USGS	30
828193541	03/30/96	13:45:41	44.92	-73.48	10.0	-1.0	u	USGS	8
828338407	04/01/96	06:00:07	42.11	-70.56	6.9	-1.0	u	MIT	5
829018088	04/09/96	02:48:08	43.07	-104.10	5.0	3.7	Ml	USGS	26

Table 1 (Continued)

Epoch	Date	Origin	Lat	Lon	Depth	Mag		Src	#Sta
829259698	04/11/96	21:54:58	34.97	-91.16	5.0	3.3	Ml	USGS	20
829903814	04/19/96	08:50:14	36.98	-83.02	0.0	3.9	Mb	USGS	25
830169870	04/22/96	10:44:30	41.68	-71.06	5.0	2.6	Ml	USGS	13
830931231	05/01/96	06:13:51	44.42	-69.98	19.0	-1.0	u	MIT	5
830999980	05/02/96	01:19:40	42.55	-71.47	6.7	-1.0	u	MIT	5
831109672	05/03/96	07:47:52	43.05	-104.02	5.0	3.1	Ml	USGS	28
831145140	05/03/96	17:39:00	44.40	-69.95	18.4	-1.0	u	MIT	5
833348823	05/29/96	05:47:03	43.71	-71.20	5.0	-1.0	u	MIT	5
835063109	06/18/96	01:58:29	42.16	-71.06	9.5	-1.0	u	MIT	5
836076643	06/29/96	19:30:43	37.19	-81.95	1.0	4.1	Mb	USGS	19
836602630	07/05/96	21:37:10	35.20	-84.00	5.0	2.8	Ml	USGS	4
838084800	07/23/96	01:20:00	44.45	-74.03	5.0	2.8	Ml	USGS	14
838333756	07/25/96	22:29:16	37.30	-98.50	5.0	2.2	Ml	USGS	13
838878263	08/01/96	05:44:23	37.40	-104.25	5.0	3.8	Ml	USGS	23
838878954	08/01/96	05:55:54	37.38	-104.20	5.0	3.2	Ml	USGS	20
839787470	08/11/96	18:17:50	33.58	-90.87	10.0	3.5	Ml	USGS	9
840171406	08/16/96	04:56:46	49.21	-82.92	18.0	3.6	Ml	USGS	10
840305923	08/17/96	18:18:43	37.94	-81.45	0.0	3.0	Mb	IDC	17
840614054	08/21/96	07:54:14	44.18	-71.35	10.0	3.8	Ml	USGS	32
843012988	09/18/96	02:16:28	33.74	-82.10	5.0	2.8	Ml	USGS	13
843183353	09/20/96	01:35:53	42.43	-72.22	7.0	-1.0	u	MIT	5
843269040	09/21/96	01:24:00	35.70	-84.00	5.0	2.0	Ml	USGS	9
843853300	09/27/96	19:41:40	37.63	-81.20	0.0	3.0	Mb	IDC	20
844290731	10/02/96	21:12:11	37.80	-81.03	0.0	3.2	Mb	IDC	20
844372087	10/03/96	19:48:07	42.67	-104.35	0.0	3.6	Mb	IDC	20
845205084	10/13/96	11:11:24	35.88	-89.99	5.0	2.8	Ml	USGS	14
845552608	10/17/96	11:43:28	39.74	-76.05	5.0	2.3	Ml	USGS	9
846485979	10/28/96	06:59:39	40.27	-76.14	5.0	2.6	Ml	USGS	12
846611423	10/29/96	17:50:23	43.43	-71.54	6.0	-1.0	u	MIT	5
846817768	11/01/96	03:09:28	37.35	-104.23	5.0	3.2	Ml	USGS	23
846954487	11/02/96	17:08:07	37.41	-79.84	0.0	3.1	Mb	IDC	23
847764213	11/12/96	02:03:33	38.00	-90.40	5.0	2.7	Ml	USGS	12
848746458	11/23/96	10:54:18	35.04	-100.50	5.0	3.0	Ml	USGS	10
849132348	11/27/96	22:05:48	38.31	-81.42	0.0	3.4	Mb	IDC	20
849246094	11/29/96	05:41:34	35.92	-89.93	20.0	4.3	Ml	USGS	22
849264429	11/29/96	10:47:09	36.29	-89.37	5.0	3.6	Ml	USGS	18
850418025	12/12/96	19:13:45	43.58	-71.29	7.3	-1.0	u	MIT	5
850634397	12/15/96	07:19:57	36.03	-89.84	1.0	2.8	Ml	USGS	9
850701511	12/16/96	01:58:31	39.50	-87.40	5.0	3.1	Ml	USGS	13
851012998	12/19/96	16:29:58	35.08	-97.65	5.0	2.5	Ml	USGS	9

Table 1 (Continued)

Epoch	Date	Origin	Lat	Lon	Depth	Mag		Src	#Sta
851234177	12/22/96	05:56:17	39.20	-76.90	5.0	2.3	Ml	USGS	9
851761728	12/28/96	08:28:48	43.32	-69.74	6.1	-1.0	u	MIT	5
852029804	12/31/96	10:56:44	46.54	-75.95	10.0	-1.0	u	USGS	8
852385082	01/04/97	13:38:02	43.71	-69.43	5.0	-1.0	u	MIT	5
852779246	01/09/97	03:07:26	33.20	-92.60	5.0	2.8	Ml	USGS	6
853625078	01/18/97	22:04:38	39.25	-104.50	0.0	3.3	Mb	IDC	1
853627550	01/18/97	22:45:50	39.21	-104.27	0.0	2.5	Mb	IDC	8
853648573	01/19/97	04:36:13	39.42	-104.49	0.0	3.2	Mb	IDC	10
855432792	02/08/97	20:13:12	43.35	-104.97	0.0	3.6	Mb	IDC	16
855531133	02/09/97	23:32:13	42.62	-72.27	5.0	-1.0	u	USGS	5
855791591	02/12/97	23:53:11	34.95	-100.89	5.0	3.0	Ml	USGS	12
855997740	02/15/97	09:09:00	34.93	-100.96	0.0	3.5	Mb	IDC	11
858087031	03/11/97	13:30:31	34.72	-97.50	5.0	2.5	Ml	USGS	14
858539248	03/16/97	19:07:28	34.21	-93.44	5.0	3.4	Ml	USGS	15
859242695	03/24/97	22:31:35	27.58	-98.03	0.0	3.9	Mb	IDC	4
860042652	04/03/97	04:44:12	45.98	-72.33	5.0	3.5	Ml	USGS	14
860674076	04/10/97	12:07:56	41.02	-69.53	18.2	-1.0	u	MIT	5
860829701	04/12/97	07:21:41	48.14	-79.93	0.0	3.5	Mb	IDC	10
860847096	04/12/97	12:11:36	48.19	-79.82	5.0	3.6	Mb	USGS	9
861375464	04/18/97	14:57:44	26.51	-87.08	28.2	3.7	Mb	IDC	7
862305831	04/29/97	09:23:51	44.48	-70.34	18.9	-1.0	u	MIT	5
862717153	05/04/97	03:39:13	31.00	-87.40	5.0	3.1	Ml	USGS	9
864071134	05/19/97	19:45:34	34.78	-85.44	5.0	2.9	Ml	USGS	5
864392700	05/23/97	13:05:00	43.25	-71.17	1.5	-1.0	u	MIT	5
864499927	05/24/97	18:52:07	46.08	-74.49	0.0	3.5	Mb	IDC	25
865049201	05/31/97	03:26:41	33.18	-95.97	5.0	3.4	Ml	USGS	12
867347731	06/26/97	17:55:31	36.61	-89.64	10.0	2.5	Lg	USGS	20
868543071	07/10/97	13:57:51	45.04	-74.83	18.0	2.8	Lg	USGS	15
869331994	07/19/97	17:06:34	35.06	-84.81	10.0	3.5	Lg	USGS	25
870016236	07/27/97	15:10:36	38.67	-78.39	5.0	2.4	Lg	USGS	19
870265763	07/30/97	12:29:23	36.44	-83.51	5.0	3.8	Lg	USGS	20
870333330	07/31/97	07:15:30	43.62	-75.37	5.0	3.2	Lg	USGS	12
871148764	08/09/97	17:46:04	41.80	-97.19	5.0	3.4	Lg	USGS	49
871927912	08/18/97	18:11:52	44.06	-104.87	0.0	4.0	Ml	IDC	49
872068324	08/20/97	09:12:04	47.53	-70.29	18.0	3.2	Lg	USGS	10
873589081	09/06/97	23:38:01	34.66	-96.44	5.0	4.2	Lg	USGS	16
874180232	09/13/97	19:50:32	38.29	-89.71	16.0	2.5	Lg	USGS	14
874520192	09/17/97	18:16:32	35.62	-90.46	5.0	3.8	Lg	USGS	18
874734950	09/20/97	05:55:50	37.18	-90.92	5.0	3.1	Lg	USGS	16
875074825	09/24/97	04:20:25	36.55	-89.82	5.0	3.2	Ml	USGS	14

Table 1 (Continued)

Epoch	Date	Origin	Lat	Lon	Depth	Mag		Src	#Sta
875362449	09/27/97	12:14:09	36.20	-89.48	5.0	3.1	Lg	USGS	17
875555110	09/29/97	17:45:10	38.70	-77.50	5.0	1.4	Md	USGS	20
876644902	10/12/97	08:28:22	44.91	-74.55	14.0	2.5	Lg	USGS	8
876784000	10/13/97	23:06:40	44.36	-74.97	4.0	2.7	Lg	USGS	10
877259532	10/19/97	11:12:12	32.33	-103.40	0.0	3.3	Mb	IDC	47
877682118	10/24/97	08:35:18	31.12	-87.34	10.0	4.8	Mb	USGS	19
877908432	10/26/97	23:27:12	31.10	-87.30	10.0	3.7	Lg	USGS	17
878029211	10/28/97	09:00:11	31.10	-87.30	10.0	3.0	Lg	USGS	11
878035006	10/28/97	10:36:46	37.16	-82.03	1.0	3.4	Lg	USGS	22
878039058	10/28/97	11:44:18	47.67	-69.91	12.0	4.8	Mb	USGS	12
878193743	10/30/97	06:42:23	36.70	-80.92	10.0	2.0	Lg	USGS	19
878227180	10/30/97	15:59:40	36.72	-80.93	9.0	1.8	Lg	USGS	16
878418070	11/01/97	21:01:10	42.78	-70.01	12.1	-1.0	u	MIT	5
878783673	11/06/97	02:34:33	46.80	-71.41	23.0	4.8	Mb	USGS	22
878784939	11/06/97	02:55:39	46.78	-71.39	18.0	2.8	Ml	USGS	11
878785557	11/06/97	03:05:57	46.76	-71.37	18.0	2.9	Ml	USGS	6
879000566	11/08/97	14:49:26	46.78	-71.37	23.0	2.3	Lg	USGS	9
879479051	11/14/97	03:44:11	40.15	-76.25	5.0	2.8	Lg	USGS	13
880712924	11/28/97	10:28:44	36.01	-89.72	5.0	2.3	Lg	USGS	13
881106076	12/02/97	23:41:16	36.53	-89.47	10.0	2.8	Lg	USGS	17
881434166	12/06/97	18:49:26	42.88	-104.65	0.0	3.8	Mb	IDC	30
881840097	12/11/97	11:34:57	37.10	-98.48	5.0	2.7	Lg	USGS	9
881916138	12/12/97	08:42:18	33.38	-87.29	1.0	3.8	Mb	USGS	21
882911357	12/23/97	21:09:17	43.37	-104.72	0.0	4.1	Ml	IDC	33
882988332	12/24/97	18:32:12	33.20	-92.75	5.0	2.6	Lg	USGS	9
883756036	01/02/98	15:47:16	37.83	-103.41	5.0	3.4	Ml	USGS	26
883887922	01/04/98	04:25:22	36.46	-83.33	0.0	2.7	u	VTECH	4
884234052	01/08/98	04:34:12	42.85	-70.04	25.0	2.9	Ml	USGS	14
886025112	01/28/98	22:05:12	36.10	-89.76	11.0	2.7	Ml	USGS	23
886488444	02/03/98	06:47:24	37.31	-80.50	0.0	0.5	Md	VTECH	3
887276269	02/12/98	09:37:49	36.12	-89.71	10.0	3.0	Ml	USGS	26
887390170	02/13/98	17:16:10	43.85	-71.26	8.0	2.7	Ml	USGS	22
887897127	02/19/98	14:05:27	36.54	-89.58	9.0	2.6	Ml	USGS	21
888459027	02/26/98	02:10:27	36.38	-89.58	10.0	2.5	Ml	USGS	18
888502831	02/26/98	14:20:31	46.07	-76.36	18.0	3.7	Ml	USGS	12
889419958	03/09/98	05:05:58	46.49	-81.07	1.0	3.9	Mb	USGS	12
889945006	03/15/98	06:56:46	36.43	-89.52	5.0	2.6	Ml	USGS	21
890252528	03/18/98	20:22:08	35.20	-84.20	5.0	2.5	Ml	USGS	18
891021595	03/27/98	17:59:55	47.44	-93.46	0.0	3.2	Mb	IDC	5
892059409	04/08/98	18:16:49	36.94	-89.02	14.0	3.2	Ml	USGS	24

Table 1 (Continued)

Epoch	Date	Origin	Lat	Lon	Depth	Mag		Src	#Sta
892098821	04/09/98	05:13:41	36.40	-89.50	7.0	2.7	Lg	USGS	19
892310552	04/11/98	16:02:32	43.09	-104.66	0.0	3.3	Mb	IDC	19
892461371	04/13/98	09:56:11	34.61	-80.47	5.0	3.9	Ml	USGS	29
892636422	04/15/98	10:33:42	30.19	-103.30	10.0	3.6	Ml	USGS	10
892839916	04/17/98	19:05:16	43.23	-104.64	0.0	3.5	Mb	IDC	33
892916572	04/18/98	16:22:52	45.57	-74.99	18.0	4.1	Ml	USGS	32
893201306	04/21/98	23:28:26	38.17	-78.57	8.0	2.6	Ml	USGS	31
893438802	04/24/98	17:26:42	47.48	-92.78	0.0	3.2	Ml	IDC	5
893690566	04/27/98	15:22:46	35.45	-102.38	5.0	3.2	Ml	USGS	19
893772782	04/28/98	14:13:02	34.78	-98.42	5.0	4.2	Ml	USGS	17
894543881	05/07/98	12:24:41	32.37	-88.11	10.0	2.8	Ml	USGS	13
894874034	05/11/98	08:07:14	36.88	-89.07	8.0	2.6	Ml	USGS	19
895629208	05/20/98	01:53:28	38.76	-78.42	3.0	2.4	Ml	USGS	23
896111222	05/25/98	15:47:02	46.46	-81.17	1.0	3.9	Ml	USGS	11
896249092	05/27/98	06:04:52	36.11	-89.01	5.0	2.4	Ml	USGS	20
897013862	06/05/98	02:31:02	35.48	-80.82	5.0	3.2	Ml	USGS	24
897382431	06/09/98	08:53:51	44.75	-73.72	5.0	3.4	Ml	USGS	9
898070423	06/17/98	08:00:23	35.93	-84.41	10.0	3.6	Ml	USGS	26
898187198	06/18/98	16:26:38	42.62	-103.00	5.0	3.4	Ml	USGS	31
898701601	06/24/98	15:20:01	32.50	-87.95	5.0	3.4	Ml	USGS	18
898805307	06/25/98	20:08:27	42.93	-104.67	0.0	3.5	Mb	IDC	28
899708044	07/06/98	06:54:04	25.02	-93.63	10.0	3.4	Mb	USGS	4
899837084	07/07/98	18:44:44	34.72	-97.59	5.0	3.2	Ml	USGS	19
899949133	07/09/98	01:52:13	44.73	-73.68	0.0	2.5	Ml	USGS	4
900260930	07/12/98	16:28:50	43.55	-101.11	5.0	3.1	Ml	USGS	23
900394729	07/14/98	05:38:49	35.34	-103.47	5.0	3.0	Ml	USGS	17
900476691	07/15/98	04:24:51	36.69	-89.52	13.0	3.1	Ml	USGS	21
900486484	07/15/98	07:08:04	47.02	-66.61	5.0	4.0	Ml	USGS	5
901145517	07/22/98	22:11:57	37.65	-90.20	18.0	2.7	Ml	USGS	19
901216337	07/23/98	17:52:17	48.59	-104.15	0.0	3.5	Mb	IDC	19
901683119	07/29/98	03:31:59	48.37	-104.71	5.0	3.8	Mb	USGS	19
901789041	07/30/98	08:57:21	46.17	-74.72	18.0	4.0	Lg	USGS	15
903114312	08/14/98	17:05:12	27.74	-99.86	0.0	3.8	Mb	IDC	4
906753172	09/25/98	19:52:52	41.49	-80.39	5.0	5.2	Ml	USGS	4
908444842	10/15/98	09:47:22	35.62	-90.45	12.0	2.9	Ml	USGS	3
908949407	10/21/98	05:56:47	37.38	-78.37	13.0	3.8	Ml	USGS	5
909049415	10/22/98	09:43:35	49.34	-66.88	18.0	4.1	Ml	USGS	4
909361792	10/26/98	00:29:52	37.00	-90.88	5.0	2.6	Ml	USGS	3
909769282	10/30/98	17:41:22	36.80	-97.60	5.0	3.5	Ml	USGS	3
909796344	10/31/98	01:12:24	36.12	-83.70	9.0	2.6	Ml	USGS	3

Table 1 (Continued)

Epoch	Date	Origin	Lat	Lon	Depth	Mag		Src	#Sta
910762701	11/11/98	05:38:21	34.81	-93.18	5.0	2.6	Ml	USGS	2
910785578	11/11/98	11:59:38	48.55	-104.03	5.0	3.5	Ml	USGS	3
911962506	11/25/98	02:55:06	41.07	-82.41	5.0	2.7	Ml	USGS	4
913805134	12/16/98	10:45:34	35.85	-89.94	8.0	2.4	Ml	USGS	2
914592626	12/25/98	13:30:26	43.83	-77.93	18.0	3.6	Ml	USGS	5
915686187	01/07/99	05:16:27	38.67	-99.38	5.0	3.0	Ml	USGS	5
915965536	01/10/99	10:52:16	42.84	-70.98	2.0	3.1	Ml	USGS	3
915981644	01/10/99	15:20:44	42.84	-71.00	2.0	3.0	Ml	USGS	3
916598285	01/17/99	18:38:05	36.85	-83.69	5.0	3.0	Ml	USGS	4
916642853	01/18/99	07:00:53	33.41	-87.25	1.0	4.8	Mb	USGS	4
917295150	01/25/99	20:12:30	42.73	-77.85	3.0	2.7	Ml	USGS	5
917907726	02/01/99	22:22:06	49.27	-80.94	18.0	3.4	Ml	USGS	3
919908689	02/25/99	02:11:29	34.10	-89.87	5.0	2.9	Ml	USGS	4
920000323	02/26/99	03:38:43	44.48	-69.52	3.0	3.8	Ml	USGS	3
920275223	03/01/99	08:00:23	32.57	-104.66	1.0	2.9	Ml	USGS	7
920981225	03/09/99	12:07:05	44.76	-73.80	10.0	2.9	Ml	USGS	2
921451398	03/14/99	22:43:18	32.59	-104.63	1.0	4.0	Ml	USGS	24
921588648	03/16/99	12:50:48	49.61	-66.32	18.0	5.1	Ml	USGS	8
921673763	03/17/99	12:29:23	32.58	-104.67	1.0	3.5	Ml	USGS	17
922718976	03/29/99	14:49:36	33.00	-80.20	5.0	2.9	Ml	USGS	17
926591940	05/13/99	10:39:00	35.09	-87.03	22.0	2.8	Ml	USGS	11
926605103	05/13/99	14:18:23	39.10	-94.70	5.0	3.0	Ml	USGS	3
927833284	05/27/99	19:28:04	34.83	-82.00	5.0	2.4	Ml	USGS	12
928091066	05/30/99	19:04:26	32.58	-104.66	10.0	3.9	Ml	USGS	23
931253340	07/06/99	09:29:00	37.02	-88.78	5.0	2.1	Ml	USGS	19
934181483	08/09/99	06:51:23	32.57	-104.59	5.0	2.9	Ml	USGS	10
935026244	08/19/99	01:30:44	36.14	-89.69	12.0	2.3	Ml	USGS	1
935410361	08/23/99	12:12:41	36.26	-89.50	9.0	3.1	Ml	USGS	16
936289050	09/02/99	16:17:30	41.72	-89.43	5.0	3.5	Ml	USGS	21
937994542	09/22/99	10:02:22	41.83	-81.48	18.0	2.8	Ml	USGS	12
939809340	10/13/99	10:09:00	42.55	-71.44	2.0	2.7	Ml	USGS	9
940493880	10/21/99	08:18:00	36.49	-91.02	19.0	3.9	Ml	USGS	18
940495788	10/21/99	08:49:48	36.51	-91.05	12.0	3.1	Ml	USGS	17
941273847	10/30/99	08:57:27	34.90	-82.30	5.0	2.3	Lg	USGS	21
941274620	10/30/99	09:10:20	34.90	-82.30	5.0	2.2	Lg	USGS	21
941400850	10/31/99	20:14:10	45.85	-74.32	18.0	4.2	Lg	USGS	10
943599300	11/26/99	06:55:00	36.34	-92.41	0.0	2.6	Md	USGS	16
943655581	11/26/99	22:33:01	43.71	-79.00	13.0	3.8	Lg	USGS	15

Table 2

The 240 Stations Contributing to the Seismic Waveform Archive at NRC

Sta	Lat	Lon	Elev	Type	#Evt
AAM	42.299721	-83.656110	0.249	3C	41
ABL	34.850811	-119.220800	1.981	1C	2
AHID	42.765388	-111.100300	1.960	3C	10
ALQ	34.942501	-106.457400	1.849	3C	48
AAM	42.299721	-83.656110	0.249	3C	50
ABL	34.850811	-119.220800	1.981	1C	2
AHID	42.765388	-111.100300	1.960	3C	10
ALQ	34.942501	-106.457400	1.849	3C	48
ANMO	34.946201	-106.456700	1.840	3C	61
ARN	37.349331	-121.532600	0.628	1C	2
ARNY	41.303200	-74.114500	0.430	-	4
ARUT	37.787998	-113.440300	1.646	1C	16
BGR	44.828800	-74.374200	0.297	-	7
BINY	42.199310	-75.986100	0.498	3C	70
BLA	37.211300	-80.420990	0.634	3C	93
BLO	39.171940	-86.522210	0.246	3C	5
BLUE	43.894001	-74.454000	0.601	3C	9
BMN	40.431469	-117.221700	1.500	3C	3
BMW	46.474998	-123.228000	0.870	1C	1
BONR	37.955189	-118.301600	2.582	1C	2
BRC	44.427500	-75.583000	0.083	-	4
BW06	42.777779	-109.555500	2.200	3C	15
CALA	40.113400	-108.535800	2.345	-	3
CALI	40.365299	-108.567000	2.085	-	3
CBKS	38.813999	-99.737380	0.677	3C	61
CCM	38.055672	-91.244580	0.223	3C	108
CEH	35.890831	-79.092780	0.152	3C	65
CHIP	44.798000	-75.195000	0.097	-	3
CLER	44.383999	-74.245000	0.498	3C	5
COW	33.381672	-80.699330	0.060	1C	2
CRNY	41.311800	-73.548200	0.293	-	4
CSD	40.436401	-108.279100	1.931	-	3
CSP	34.298031	-117.357400	1.268	1C	1
CTU	40.692501	-111.750300	1.731	3C	12
CVL	37.981392	-78.460830	0.167	1C	69
CWPT	36.009109	-89.626380	0.076	1C	16
DAN	34.637100	-115.380500	0.398	3C	4
DAU	40.412498	-111.255800	2.771	1C	18
DLAR	35.809700	-90.008000	0.067	1C	13

Table 2 (Continued)

Sta	Lat	Lon	Elev	Type	#Evt
DNH	43.122500	-70.894800	0.024	-	42
DOUG	40.570301	-108.688600	2.153	-	3
DPW	47.870640	-118.202800	0.892	1C	6
DRLN	49.256001	-57.504200	0.238	3C	8
DRY	40.699501	-108.536600	2.059	-	3
DUG	40.195000	-112.813300	1.477	3C	20
DWPF	28.110201	-81.432700	0.020	-	8
DXB	42.061000	-70.699200	0.008	-	34
EBZ	35.141331	-89.350510	0.169	1C	1
EDIT	35.862999	-89.554310	0.148	1C	8
ELK	40.744831	-115.238700	2.210	3C	10
ELN	37.228300	-80.751700	0.634	-	10
EMUT	39.813999	-110.815300	2.268	1C	19
EYMN	47.946190	-91.495000	0.475	3C	14
FFC	54.724998	-101.978300	0.338	3C	4
FINE	44.265000	-75.167000	0.000	-	1
FLET	44.722700	-72.951700	0.366	-	6
FRD	33.494701	-116.602200	1.164	-	1
FVM	37.984001	-90.426000	0.310	3C	5
FWGP	40.964199	-108.768000	2.077	-	3
FWV	37.581700	-80.811700	0.756	-	10
GAC	45.703300	-75.478300	0.062	5C	58
GHV	37.794170	-78.107330	0.107	1C	44
GLA	33.049999	-114.830000	0.000	-	1
GLD	39.750561	-105.221300	1.762	1C	57
GLO	42.640300	-70.727200	0.015	-	42
GLST	36.269112	-89.287690	0.122	1C	35
GMW	47.547920	-122.786300	0.506	1C	2
GOGA	33.411190	-83.466610	0.150	3C	83
GPD	41.017700	-74.460800	0.360	-	2
GRAI	43.809310	-111.335700	2.231	1C	4
GRAN	41.108398	-108.641900	2.164	-	3
GWDE	38.825611	-75.617110	0.019	3C	31
HAWT	36.225609	-89.659600	0.081	1C	13
HAYW	43.639580	-110.332500	2.835	1C	11
HBF	32.933060	-80.377670	0.010	1C	48
HBVT	44.362300	-73.065000	0.342	-	5
HELL	41.047001	-108.576600	2.153	-	3
HIAW	41.014801	-108.734400	2.105	-	3
HKSI	40.596700	-74.122000	0.107	-	1

Table 2 (Continued)

Sta	Lat	Lon	Elev	Type	#Evt
HKT	29.950001	-95.833340	-0.121	3C	67
HMR	38.154671	-121.800300	0.065	1C	2
HRV	42.506390	-71.558320	0.180	3C	71
HVU	41.779671	-112.775000	1.609	1C	8
HWUT	41.607310	-111.565000	1.720	3C	12
IKP	32.648830	-116.108000	0.957	1C	2
ISCO	39.799720	-105.613400	2.743	3C	28
JCS	33.085899	-116.595900	1.258	3C	4
JCT	30.479441	-99.802220	0.591	3C	1
JFWS	42.914890	-90.248800	0.318	3C	38
JNMT	40.459202	-108.020300	2.231	-	3
JSC	34.278889	-81.258050	0.120	1C	69
JWM	40.571701	-108.603800	2.077	-	3
KEEN	44.264999	-73.821990	0.485	3C	12
KINN	41.180099	-108.592500	2.292	-	3
KNB	37.016609	-112.822400	1.715	3C	8
KNW	33.714100	-116.711800	1.507	-	1
KVN	39.050999	-118.099900	1.829	1C	2
LANG	40.873100	-108.290600	2.258	-	3
LBFM	41.347000	-121.890300	1.982	1C	2
LBNH	44.240108	-71.925880	0.367	3C	58
LDS	37.242500	-113.351400	1.102	3C	7
LGPM	40.912498	-122.828600	1.290	1C	2
LHS	34.479172	-80.808320	0.120	1C	72
LIME	40.871399	-108.785800	2.371	-	3
LKWY	44.565189	-110.400000	2.424	3C	10
LNOR	45.871059	-118.285000	0.768	1C	2
LON	46.750000	-121.809900	0.854	1C	2
LOOK	40.863400	-108.482300	2.415	-	3
LOZ	44.620000	-74.580000	0.482	-	8
LSC	40.532799	-108.441300	1.802	-	3
LSCT	41.678391	-73.224380	0.318	3C	46
LTX	29.333891	-103.666900	1.013	3C	24
LVA2	33.351601	-116.561500	1.435	-	1
MANY	41.222000	-73.868600	0.133	-	4
MAYB	40.482800	-108.192800	1.888	-	3
MCW	48.679668	-122.832300	0.693	1C	1
MCWV	39.658112	-79.845610	0.280	3C	81
MDV	43.999200	-73.181200	0.134	-	4
MEMM	37.666328	-118.939100	0.000	1C	5

Table 2 (Continued)

Sta	Lat	Lon	Elev	Type	#Evt
MIAR	34.545700	-93.572990	0.207	3C	105
MIV	44.074700	-73.534000	0.317	-	6
MM01	42.317501	-72.711700	0.122	-	19
MM02	42.166000	-73.718690	0.134	-	22
MM03	42.038799	-74.846190	0.670	-	24
MM04	41.853001	-76.197990	0.473	-	21
MM05	41.653000	-76.921990	0.701	-	25
MM06	41.391499	-78.126190	0.647	-	23
MM07	41.257130	-79.135000	0.518	-	28
MM08	41.109501	-80.068190	0.381	-	29
MM09	40.791100	-81.205590	0.357	-	30
MM10	40.614700	-82.303100	0.346	-	23
MM11	40.221401	-83.194700	0.283	-	26
MM12	40.043900	-84.372490	0.305	-	25
MM13	39.831699	-85.311400	0.337	-	24
MM14	39.549435	-86.394760	0.290	-	21
MM15	39.294521	-87.313460	0.191	-	15
MM16	38.921902	-88.304570	0.165	-	21
MM17	38.669441	-89.325540	0.144	-	21
MM18	38.528679	-90.568600	0.186	-	17
MNV	38.432800	-118.153100	1.524	3C	1
MO18	38.514381	-90.564370	0.161	-	3
MPU	40.015499	-111.633300	1.909	3C	1
MRCM	37.671669	-118.506300	2.030	1C	1
MSAR	35.784170	-90.146860	0.069	1C	6
MSNY	44.998300	-74.862000	0.055	-	7
MSU	38.513329	-112.174100	2.141	1C	22
MTPC	35.484830	-115.553300	1.582	3C	2
MTUM	37.353329	-118.563400	1.810	1C	1
MYNC	35.073891	-84.127890	0.550	3C	58
NA12	37.983060	-77.879450	0.125	1C	18
NAV	37.316669	-80.793050	0.610	1C	25
NCB	43.970798	-74.223500	0.500	3C	1
NDH	40.370602	-108.136300	1.957	-	3
NEE	34.823002	-114.596000	0.139	-	10
NEW	48.263329	-117.120000	0.760	3C	4
NMMO	36.588001	-89.552000	0.090	1C	4
NOQ	40.652500	-112.120300	1.622	3C	7
ONH	43.279200	-71.505600	0.280	-	41
OXF	34.511810	-89.409180	0.101	3C	63

Table 2 (Continued)

Sta	Lat	Lon	Elev	Type	#Evt
PACK	43.535000	-73.818030	0.287	3C	4
PAL	41.004200	-73.909200	0.091	3C	5
PD06	42.766701	-109.558200	2.224	-	1
PD31	42.766701	-109.557800	2.214	-	21
PEC	33.891941	-117.160600	0.616	1C	1
PFO	33.609169	-116.455200	1.280	3C	7
PHAM	35.835999	-120.398400	0.455	1C	1
PINI	43.507600	-111.345700	1.932	1C	3
PINR	40.363400	-108.368400	2.097	-	3
PIT	44.169200	-74.241700	0.311	-	1
PKEM	36.061501	-120.109000	0.288	1C	3
PLAL	34.982361	-88.075470	0.165	3C	7
PLG	41.004200	-73.909200	0.091	-	3
PLM	33.353439	-116.861600	1.692	1C	3
PLVA	36.667332	-81.158150	1.353	1C	4
PNH	43.094200	-72.135800	0.659	-	6
PNY	44.834200	-73.555000	0.177	-	5
PRM	34.083328	-82.363320	0.254	1C	12
PTI	42.870331	-112.370100	1.670	1C	8
PTN	44.570000	-74.981900	0.197	-	8
PV08	38.576309	-108.647000	2.940	1C	38
PV09	38.498661	-109.133400	2.652	1C	41
PV10	38.376339	-109.038800	2.316	1C	44
PWLA	34.979970	-88.063670	0.204	1C	25
QUAR	35.643940	-90.649140	0.115	1C	25
REDW	43.362390	-110.851800	2.192	1C	10
RELT	36.033199	-89.302190	0.107	1C	13
RMW	47.459690	-121.805300	1.024	1C	2
RRE	41.168701	-108.732300	2.353	-	3
RRW	41.138901	-108.858900	2.320	-	3
RSNY	44.548328	-74.529990	0.396	3C	6
RSSD	44.120419	-104.036100	2.060	3C	32
RW3	38.250170	-107.687000	2.603	1C	10
RW4	38.156830	-107.615700	2.739	1C	11
RW5	38.080000	-107.832500	2.991	1C	4
SADO	44.769402	-79.141700	0.243	4C	21
SCHQ	54.831902	-66.833600	0.501	3C	12
SFTN	35.357498	-90.018750	-0.022	1C	29
SGS	33.192670	-80.511830	0.024	1C	32
SIUC	37.714890	-89.217640	0.137	3C	8

Table 2 (Continued)

Sta	Lat	Lon	Elev	Type	#Evt
SLM	38.636108	-90.236100	0.161	1C	8
SMR	40.721699	-108.302800	1.900	-	3
SND	33.551899	-116.612900	1.358	-	1
SRU	39.110828	-110.523800	1.804	1C	23
SSK	34.210670	-117.693000	1.683	1C	2
SSPA	40.635811	-77.888000	0.158	3C	106
STEW	44.049720	-110.681700	2.316	1C	9
STLK	44.223500	-75.015000	0.513	-	1
SUTT	40.578701	-108.285800	1.852	-	3
SWB	40.654202	-108.380600	1.815	-	3
TANK	40.405300	-108.737000	2.441	-	3
TBR	41.141700	-74.222200	0.261	-	4
TKL	35.658001	-83.774000	0.351	-	16
TMI	43.305561	-111.918000	2.179	1C	13
TNP	38.082001	-117.218000	1.932	1C	2
TPH	38.075000	-117.222500	1.884	3C	1
TPNV	36.928669	-116.223600	1.600	3C	1
TRO	33.523399	-116.425600	2.628	-	1
TUC	32.309719	-110.784100	0.906	3C	35
TWAR	35.361389	-90.559690	0.061	1C	17
TWIN	40.755600	-108.384400	1.883	-	3
TX00	29.333799	-103.667000	1.013	-	26
TX03	29.330999	-103.674000	0.990	-	3
TX04	29.339701	-103.667100	1.013	-	3
TX31	29.334200	-103.667800	1.025	-	3
TYS	38.526001	-90.566000	0.195	1C	10
UALR	34.775311	-92.343610	0.138	3C	6
ULM	50.249901	-95.875000	0.281	3C	18
UTMT	36.342300	-88.864190	0.120	3C	8
VGB	45.515671	-120.777400	0.729	1C	1
VMCK	41.078899	-108.709800	2.136	-	3
VMSC	40.928398	-108.648300	2.006	-	2
WADM	36.366112	-89.795890	0.078	1C	17
WCC	41.058500	-73.791800	0.100	-	1
WCI	38.229000	-86.293800	0.500	3C	51
WFM	42.610600	-71.490600	0.088	-	42
WMC	33.573601	-116.674600	1.271	-	1
WMOK	34.737888	-98.780990	0.486	3C	70
WMV	37.108500	-80.970500	0.000	-	10
WUAZ	35.516891	-111.373800	0.000	3C	2

Table 2 (Continued)

Sta	Lat	Lon	Elev	Type	#Evt
WVOR	42.433941	-118.636700	1.344	3C	3
WVT	36.130000	-87.830000	0.153	3C	62
YSCF	40.428902	-108.430000	1.966	-	3
YSNY	42.475811	-78.537490	0.628	3C	54
ZENO	40.602798	-108.824500	2.302	-	3

3.2.24 DRG Topographic Maps, UTM Projection

Digital Raster Graphics (DRG) of topographic maps for 60 regions containing nuclear power plants in the eastern and central U.S. were downloaded as TIFF files from the following "GIS Data Depot" web site:

http://www.gisdatadepot.com

The map scale is 1:24000 based on a 7.5 minute quadrangle. Maps are all projected in the Universal Transverse Mercator (UTM) coordinate system and have been sorted by zone depending on the longitude. Views are available for UTM Zones 14, 15, 16, 17, 18, and 19, in which each zone projection covers three degrees longitude east and west of the Central Meridian (*i.e.*, a width of six degrees longitude). Maps named for the nuclear power plant contained therein can be found in the appropriate zone covering the same longitude.

Two earlier views described in NUREG/CR-6625 have been deleted due to reorganization of DRG topographic maps into views sorted by UTM zone since we were now able to collect a far greater number of maps. The deleted views are 1) "Topographic Maps (DRG) Nebraska" (section 3.2.19, on p. 63) and 2) "Topographic maps (DRG) TEXAS" (section 3.2.21, on p.64). The corresponding map themes were placed in the appropriate UTM zone view.

Note that the five Pennsylvania maps are displayed in a separate view using Albers Equal Area projection. In all cases, it should be noted, DRG topographic maps are images which will display the same way regardless of how the View projection is set. However, it is necessary to set the View projection parameters the same as the DRG (tiff) image so that other themes (e.g., Nuclear Power Plants) which have geographic coordinates (decimal degrees) will align properly.

Also note that DRG maps in the UTM projection are based either on GRS80 or Clarke 1866 spheroids. So to ensure proper alignment, it will be necessary to adjust the View projection to correspond to the correct spheroid. Projection parameters are usually given in the metadata files

In /local3/arc/sdaes_gis/gis/drg in the subdirectory named for the nuclear plant, the files may have suffixes such as ".fgd", ".met", ".txt", or ".text" and should contain a line with the string "ELLIPSOID NAME".

A list of the 60 nuclear power plant sites for which DRG topographic maps are available in UTM projection, and the corresponding TIFF filenames, follows:

```
Arkansas            o35093b2.tif
bellefonte          o34085f8.tif
bigrockpoint        145085c2.tif
braidwood           o41088b2.tif
brownsferry         o34087f1.tif
brunswick           o33078h1.tif
byron               o42089a3.tif
callaway            o38091g7.tif
calvertcliffs       o38076d4.tif
catawba             o35081a1.tif
clinton             o40088b7.tif
comanche_peak        32097c7.tif
cook                o41086h5.tif
cooperstation       o40095c6.tif
crystalriver        o28082h6.tif
davis_besse         o41083e1.tif
dresden             o41088d3.tif
duanearnold         o42091a7.tif
enrico_fermi        o41083h3.tif
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farley	o31085b1.tif
Fitzpatrick	o43076e4.tif
Fortcalhoun	o41096e1.tif
ginna	o43077c3.tif
grandgulf	o32091a1.tif
haddamneck	o41072d4.tif
harris	o35078f8.tif
hatch	o31082h3.tif
hopecreek	o39075d5.tif
indianpoint	o41073c8.tif
kewaunee	o44087c5.tif
lacrosse	o43091e2.tif
lasalle	o41088b6.tif
maineyankee	o43069h6.tif
mcguire	o35080d8.tif
millstone	o41072c2.tif
monticello	o45093c7.tif
northanna	o38077a7.tif
oconee	o34082g8.tif
oystercreek	o39074g2.tif
palisades	o42086c3.tif
perry	o41081g2.tif
pilgrim	141070h5.tif
prairie_island	o44092e6.tif
quadcities	o41090f3.tif
riverbend	o30091g3.tif
robinson	o34080d2.tif
salem	o39075d5.tif
sequoyah	o35085b1.tif
shoreham	o40072h7.tif
south_texas	28096g1.tif
st_lucie	o27080c2.tif
surry	o37076b6.tif
turkeypoint	o25080d3.tif
vermontyankee	k42072g5.tif
virgil_summer	o34081c3.tif
vogtle	o33081b7.tif
waterford	o29090h4.tif
wattsbar	o35084e7.tif
wolfcreek	1152.tif
zion	o42087d7.tif

3.2.25 JPEG Aerial Photos (from Digital Orthophoto Quads)

This view consists of aerial or satellite photos in JPEG format of each of 34 nuclear power plants. The photos were derived from those posted on Microsoft's Terraserver web site:

http://www.microsoft.terraserver.com

and are based on digital orthophoto quads (DOQ) available from USGS. The images may have a resolution of one or two meters. Photos at a smaller scale (*i.e.*, zoomed out further) may be retrieved from the above web site.

The 34 JPEG files, named for each nuclear power plant, are listed below:

```
beavervalley.jpg
braidwood.jpg
```

JPEG Image of Watts Bar Nuclear Plant, Tennessee

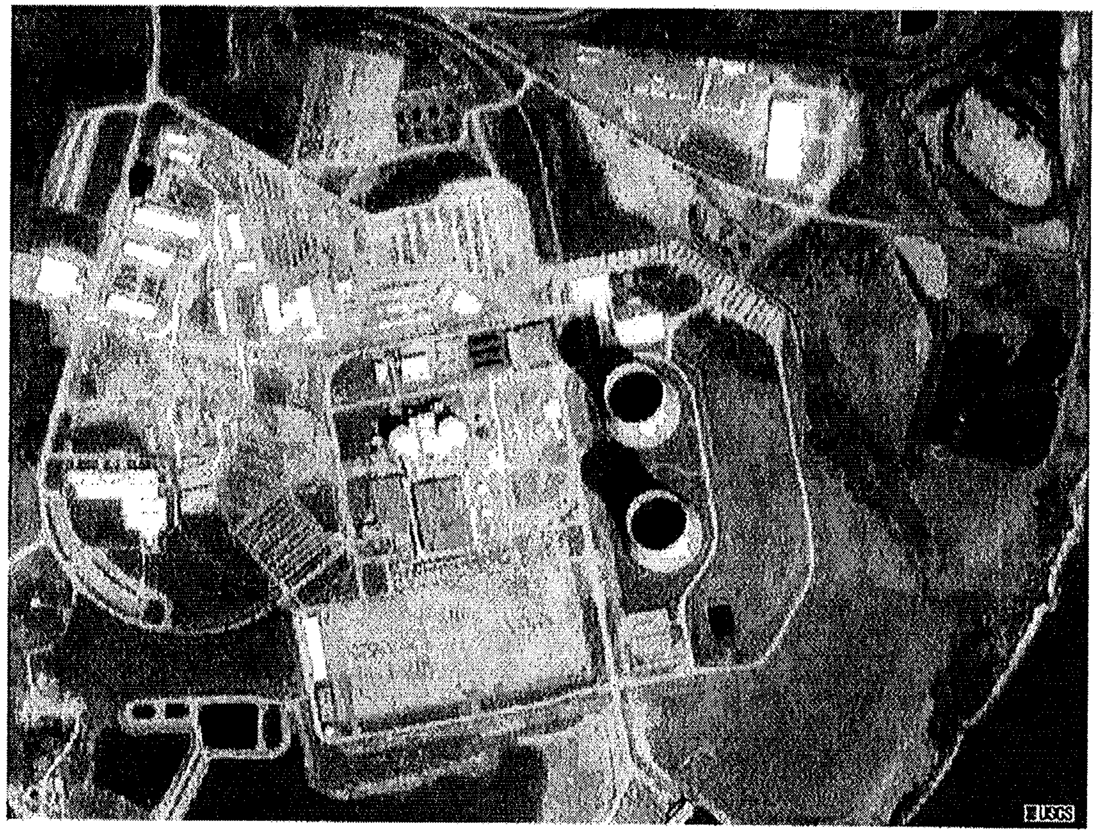

Figure 18(a). Aerial photo image in JPEG format of the Watts Bar nuclear power plant in Tennessee. Images were downloaded from the Microsoft Terraserver website http://terraserver.homeadvisor.msn.com/default.asp, and they are derived from digital orthophoto quads (DOQ) with a resolution of 1 or 2 meters.

```
callaway.jpg
catawba.jpg
comanchepeak.jpg
cooperstation.jpg
duanearnold.jpg
fermi.jpg
fitzpatrick.jpg
fortcalhoun.jpg
ginna.jpg
harris.jpg
hatch.jpg
indianpoint.jpg
kewaunee.jpg
lacrosse.jpg
limerick.jpg
mcguire.jpg
monticello.jpg
ninemilepoint.jpg
peachbottom.jpg
perry.jpg
pointbeach.jpg
prairie_island.jpg
salem.jpg
seabrook.jpg
stlucie.jpg
surry.jpg
threemileis.jpg
turkeypoint.jpg
wattsbar.jpg
wolfcreek.jpg
yankeerowe.jpg
zion.jpg
```

3.2.26 Geophysics of North America

The Geophysics of North America (GNA) data resource consists of a CD-ROM and a User's Manual, both published by the National Oceanic and Atmospheric Administration (NOAA) of \the U.S. Department of Commerce. Datasets within this resource include gravity, magnetics, topography, crustal stress, thermal aspects, and seismicity. These datasets were compiled through the research efforts of the Geological Society of America (GSA), the Society of Exploration Geophysicists (SEG), and the governments of the United States, Canada, and Mexico. While any of the datasets can be viewed on a PC in DOS mode by following instructions in the User's Manual, GIS software such as ArcView provides a more thoroughly capable environment within which to display and analyze these data. However, a given dataset must first be extracted from the CD-ROM either by using the software provided or by writing a computer program specifically for that purpose. For this SDAES project, four datasets (DNAG magnetics, DNAG gravity, SEG gravity, and ETOPO5 topography) were extracted and processed in ArcView using Spatial Analyst 1.0 to generate interpolated surfaces. More recent thermal and stress datasets were downloaded from the Internet and displayed on the two separate views "Heat Flow and Sediment Thickness" and "World Stress Map (1997)", so they are thus not considered in the "Geophysics of North America" view.

Magnetic anomaly and gravity data were compiled under the Decade of Noth American Geology (DNAG) project which represents a major effort of the Geological Society of America (GSA) prior to 1990. The Society of Exploration Geophysicists (SEG) produced the second gravity dataset. Elevation data are gridded at 5-minute intervals and represent a subset of the global ETOPO5 data available from the National Geophysical Data Center (NGDC).

The "DNAG Magnetic Anomaly" grid theme was produced in ArcView by using the "Interpolate Grid" option of Spatial Analyst's "Surface" menu. The original data from the GNA CDROM, with grid spacing at 2 km intervals, were first decimated by a factor of two to resample at 4 km grid spacing in order to improve the performance of the surface interpolation. The data were then converted from Spherical Transverse Mercator projection to geographic coordinates (decimal degrees) using software provided by NOAA. The resulting ASCII file, containing longitude, latitude, and magnetic anomaly (in units of nanoteslas or gammas) was added in the Project window with the "Add Table" option and to the view as an Event Theme. A mask grid was created to clip the areas outside of the data coverage. The Inverse Distance Weighting (IDW) method of interpolation was used with the following parameters: a) cell size = 4000 m; b) Nearest Neighbors = 12; c) power of 3; d) No Barriers. The resulting theme, saved as a permanent floating-point grid in ARC/INFO format, can be found in the directory

/local3/arc/sdaes_gis/gis/gna

as "dnagmag". The legend file "dnagmag.avl" contains the symbolized table of contents shown in the view. The User's Manual and the text file "dnagmag.doc" in

/local3/arc/sdaes_gis/gis/gna

provide additional documenation.

The "DNAG Gravity" grid theme is based on Bouger gravity anomalies on land and free-air gravity anomalies over the oceans, both with grid spacing of 6 km. The file "dnaggrav.txt" consists of a subset of grid points converted to geographic coordinates (decimal degrees) that were used as input for interpolation. A mask grid was created to clip the areas outside of the data coverage. The Inverse Distance Weighting (IDW) method of interpolation was used with the following parameters: a) cell size = 6000 m; b) Nearest Neighbors = 12; c) Power of 3; d) No Barriers. Gravity units are mgals. The permanent floating point grid theme "dnaggrav" is stored in directory

/local3/arc/sdaes_gis/gis/gna

with legend file "dnaggrav.avl" and additional documentation in text file "dnaggrav.doc" which describes the format of data on the CDROM.

The "SEG Gravity" grid theme is based on Bouger gravity anomaly values on land and free-air gravity values offshore. The compilation of these data was supported by the Society of Exploration Geophysicists (SEG). The file "seggrav.txt", used as input to the surface interpolation, contains a subset of data converted to geographic coordinates (decimal degrees). The data in this subset were first decimated so that grid spacing is equivalent to 8 km, whereas the original data has a grid spacing of 4 km. A mask grid was created to clip the areas outside of the data coverage. The Inverse Distance Weighting (IDW) method of interpolation with the following parameters was used: a) cell size = 8000 m; b) Nearest Neighbors; c) Power of 3; d) No Barriers. Units of gravity are mgals. Additional documentation is contained in the User's Manual and the file "seggrav.doc" in directory

local3/arc/sdaes_gis/gis/gna.

The latter data file describes the format of the original CDROM data.

The "ETOPO5 Elevation" grid theme shows topographic elevation in meters with grid spacing at 5 minute intervals. The file "etopo5.txt" in directory

Geophysics of North America - DNAG Gravity

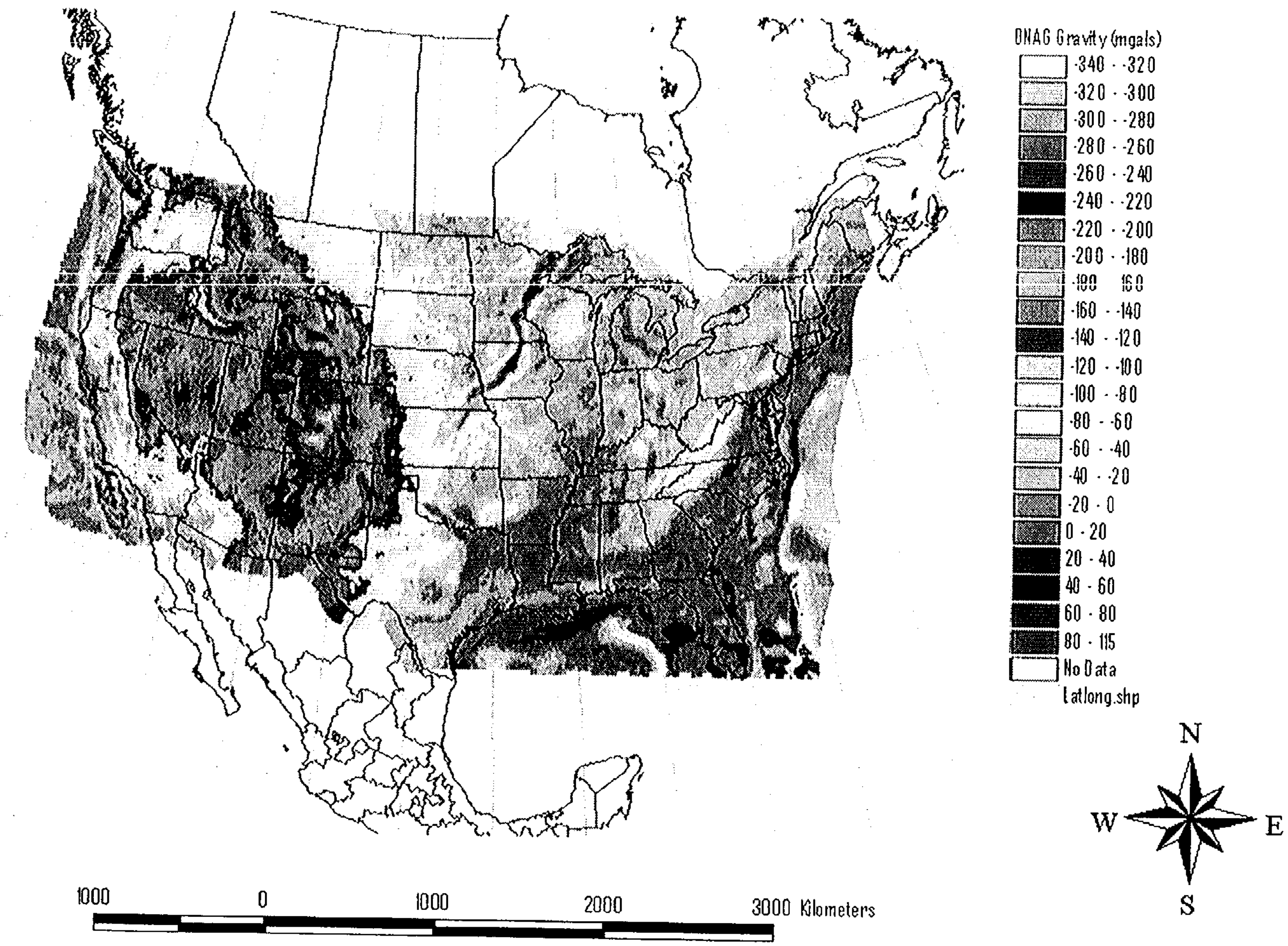

Figure 18(b). Interpolated grid surface showing Bouger gravity anomalies from the Geophysics of North America view. The surface was created using the Spatial Analyst 1.0 extension to ArcView and a grid spacing of 6 km. The Inverse Distance Weighting (IDW) method of interpolation was applied with the following parameters: a) cell size of 6000 m; b) Nearest Neighbors = 12; c) Power = 3; d) No Barriers. Gravity anomaly units are mgals.

Geophysics of North America - DNAG Magnetic Anomaly

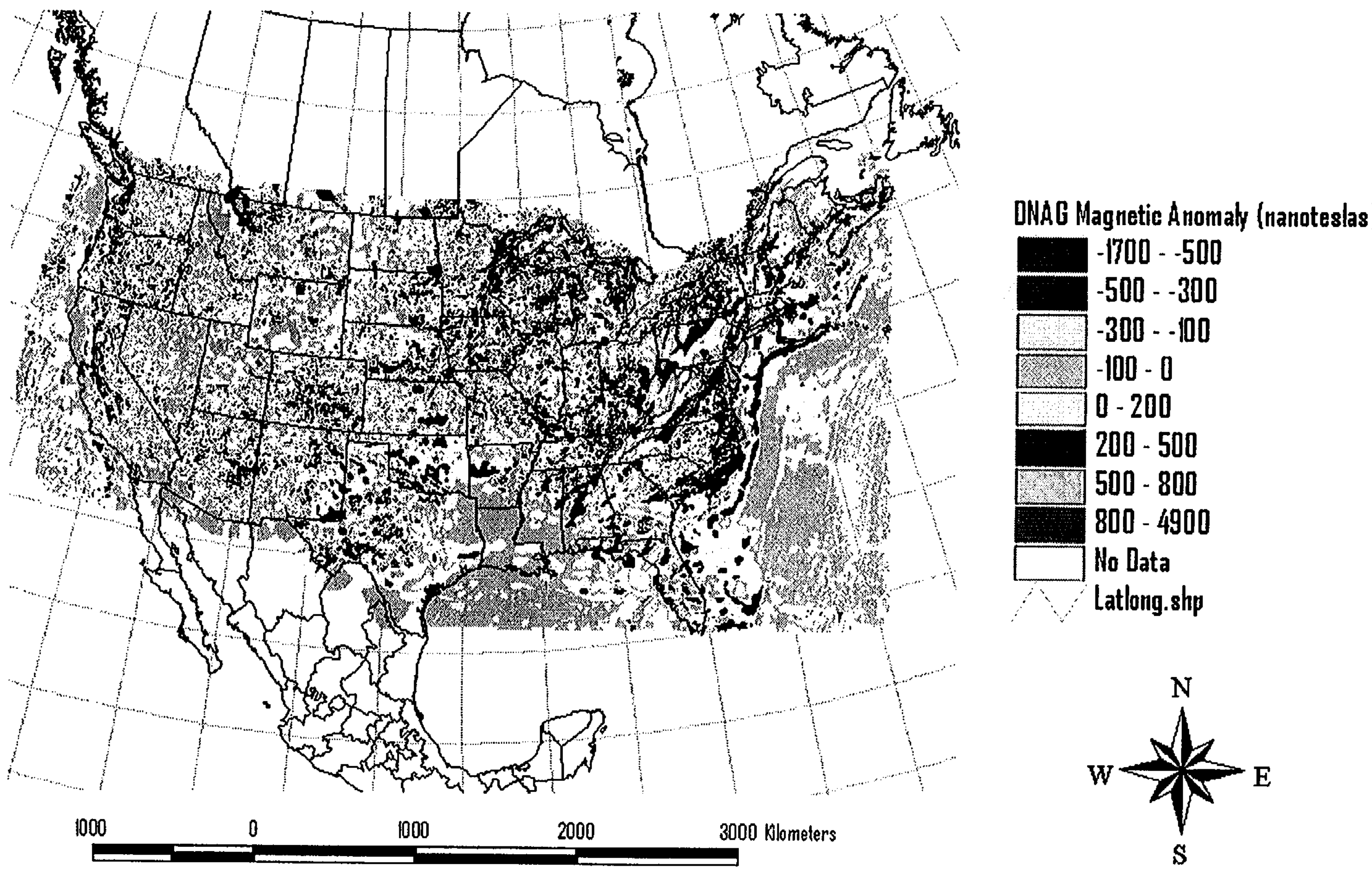

Figure 18(c). This layout view shows the magnetic anomaly grid theme from the Geophysics of North America view. The surface interpolation was created using the Spatial Analyst 1.0 extension to ArcView and data compiled during the Decade of North American Geology (DNAG) project. Initially, the data were decimated to 4 km grid spacing from the original 2 km spacing. The IDW method of interpolation was applied with the following parameters: a) cell size = 4000 m; b) Nearest Neighbors = 12; c) Power = 3; d) No Barriers. The theme is displayed using the Albers Equal Area Conic projection.

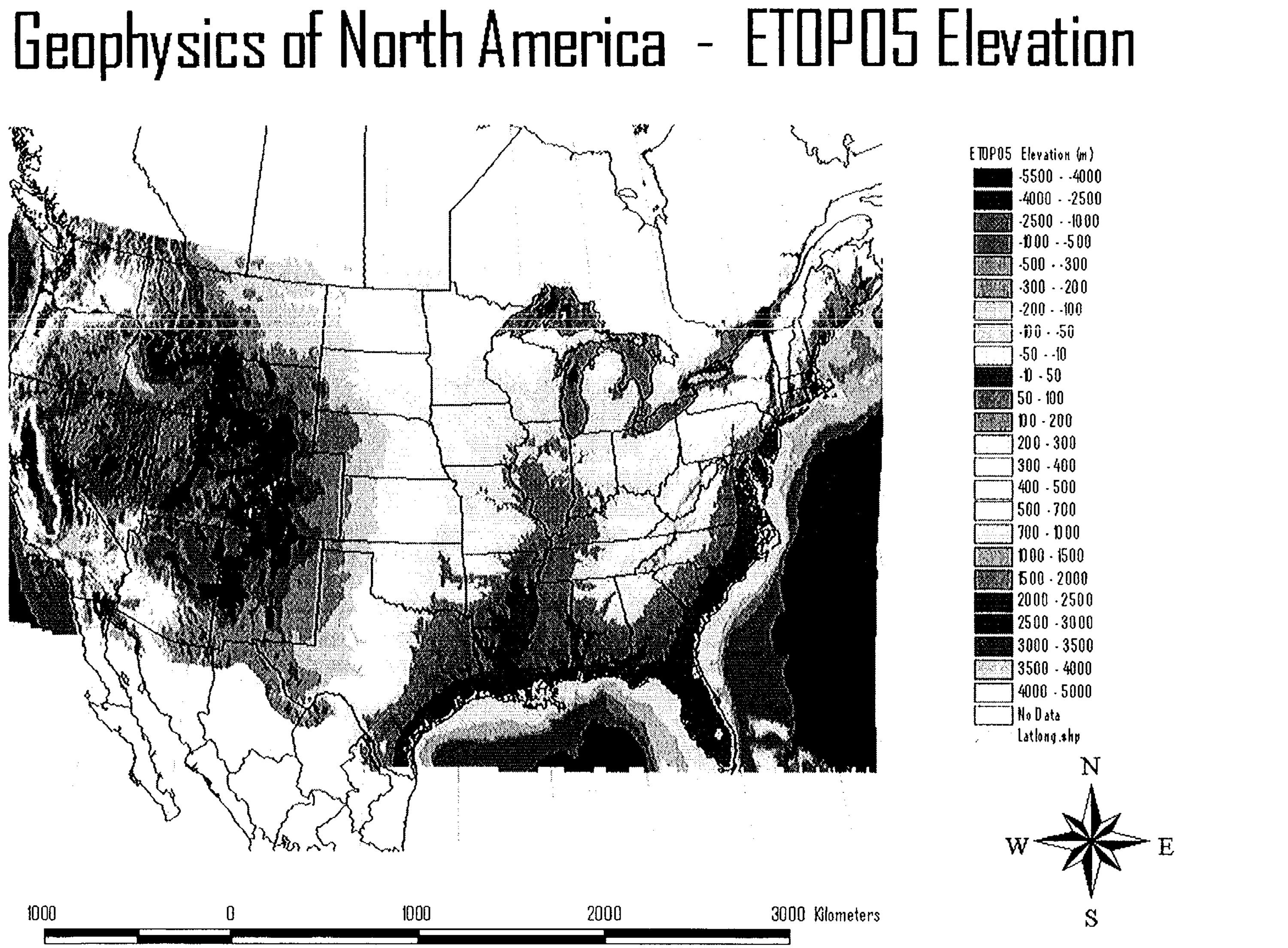

Figure 18(d). Surface grid of ETOPO5 elevation in meters with grid spacing of 5-minute intervals, from the Geophysics of North America view. The grid theme was created with Spatial Analyst 1.0 extension to ArcView and using the IDW method of interpolation with the following parameters: a) cell size = 6000 m; b) Nearest Neighbors = 12; c) Power = 3; d) No Barriers. A mask grid was used to clip the outer regions with no data. The theme is displayed with the Albers Equal Area Conic projection.

Geophysics of North America - Elevation and Contours

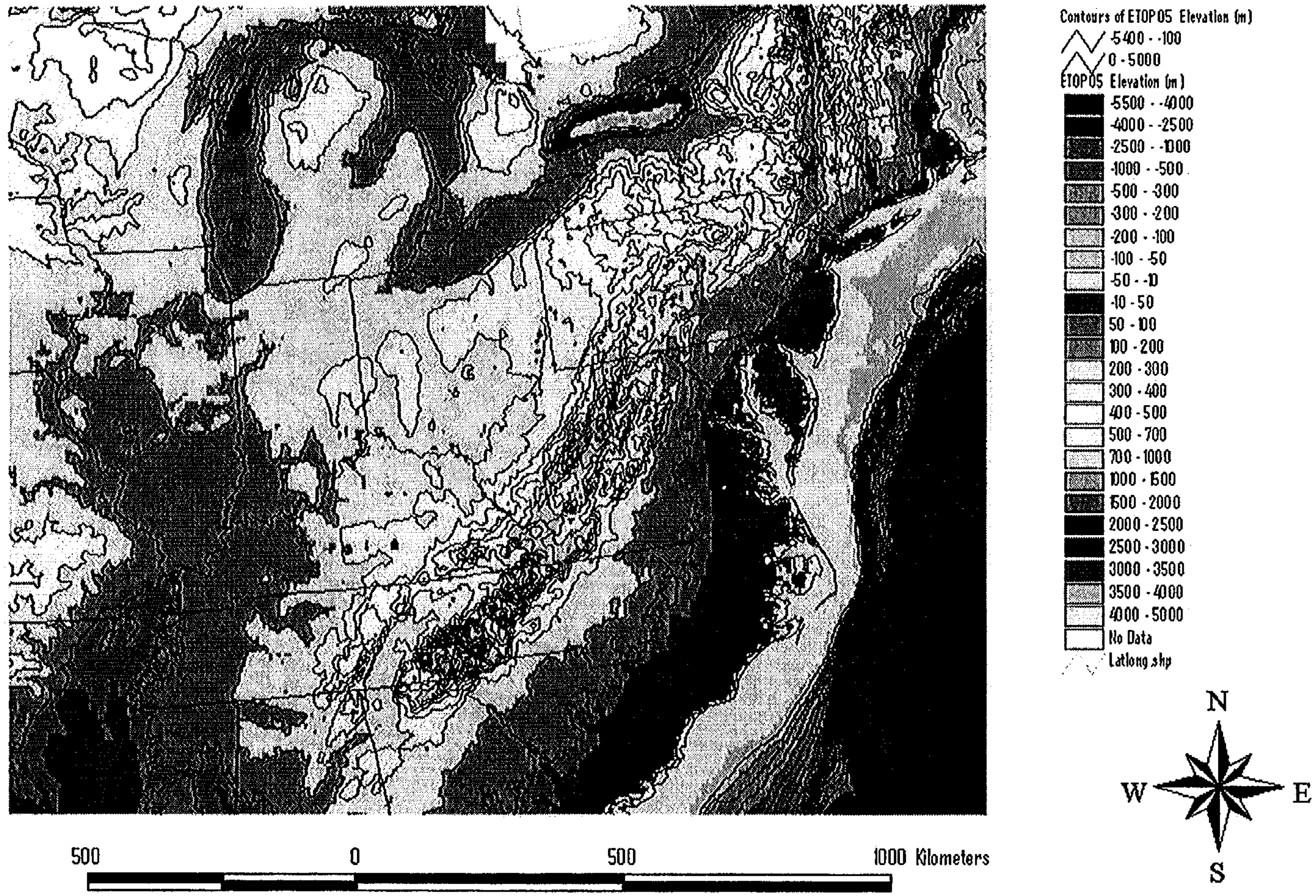

Figure 18(e). Layout view of ETOPO5 elevation theme with contour theme overlay, which shows a portion of eastern U.S. Contours were generated with the Spatial Analyst 1.0 extension to ArcView and using the elevation grid theme as input. Contour interval is 100 m.

/local3/arc/sdaes_gis/gis/gna

consists of a subset of the original data and was used as input to the surface interpolation. A mask grid was created to clip areas outside of the data coverage. The Inverse Distance Weighting (IDW) method of interpolation with the following parameters was used: a) cell size = 6000m; b) Nearest Neighbors = 12; c) Power of 3; d) No Barriers. Additional documentation can be found in the User's Manual and file "etopo5.doc" in

/local3/arc/sdaes_gis/gis/gna.

The legend file "etopo5.avl" contains the symbolized table of contents shown in the view.

All four grid themes discussed above were generated using the Albers Equal-Area Conic view projection, with the parameters shown below. Note that changing the View Projection will result in misalignment of objects from other themes when overlaid.

Projection:	Albers Equal-Area Conic
Spheroid:	Clarke 1866
Central Meridian:	-96.0
Reference Latitude:	37.5
Standard Parallel 1:	29.5
Standard Parallel 2:	45.5
False Northing:	0.0
False Easting:	0.0
Map Units:	meters

Useful software tools which supplement the GNA CDROM can be found at the following FTP site:

ftp://ftp.ngdc.noaa.gov/Access_Tools/gna

References:

Hittelman, A. M., J. O. Kinsfather and H. Meyers (1994). Geophysics of North America CD-ROM Users Manual, National Oceanic and Atmospheric Administration, United States Department of Commerce.

3.2.27 Peak and Spectral Acceleration (from USGS Geohazards)

Seismic hazards maps from the USGS Earthquake Hazards Program – National Seismic Hazard Mapping Project are displayed for the Eastern and Central U.S., including the seismicity rate, peak acceleration, and spectral acceleration. Files were downloaded from the USGS anonymous FTP site http://ghtftp.cr.usgs.gov either as gridded ASCII values (Seismicity Rate) or ARC/INFO export files (Peak and Spectral Acceleration).

The Seismicity Rate map is derived by generating surface contours using the Spatial Analyst extension to ArcView from the original gridded values at 0.2 degree intervals. The seismicity rate values represent the incremental seismicity rate per year per cell (i.e., the value of 10***a*) where the lat, lon grid points are centers of cells. See USGS Open File Report OFR-96-532 for additional details. The IDW (Inverse Distance Weighting) method of interpolation was used to produce the contours from the input file "seisrate_grid.txt" in the geohazards directory.

The Peak Acceleration map provides estimates of earthquake ground acceleration (as a percentage of gravity, %g) having a 10 percent probability of being exceeded in 50 years.

Peak Acceleration (%g) with 10% Probability of Exceedance in 50 Years

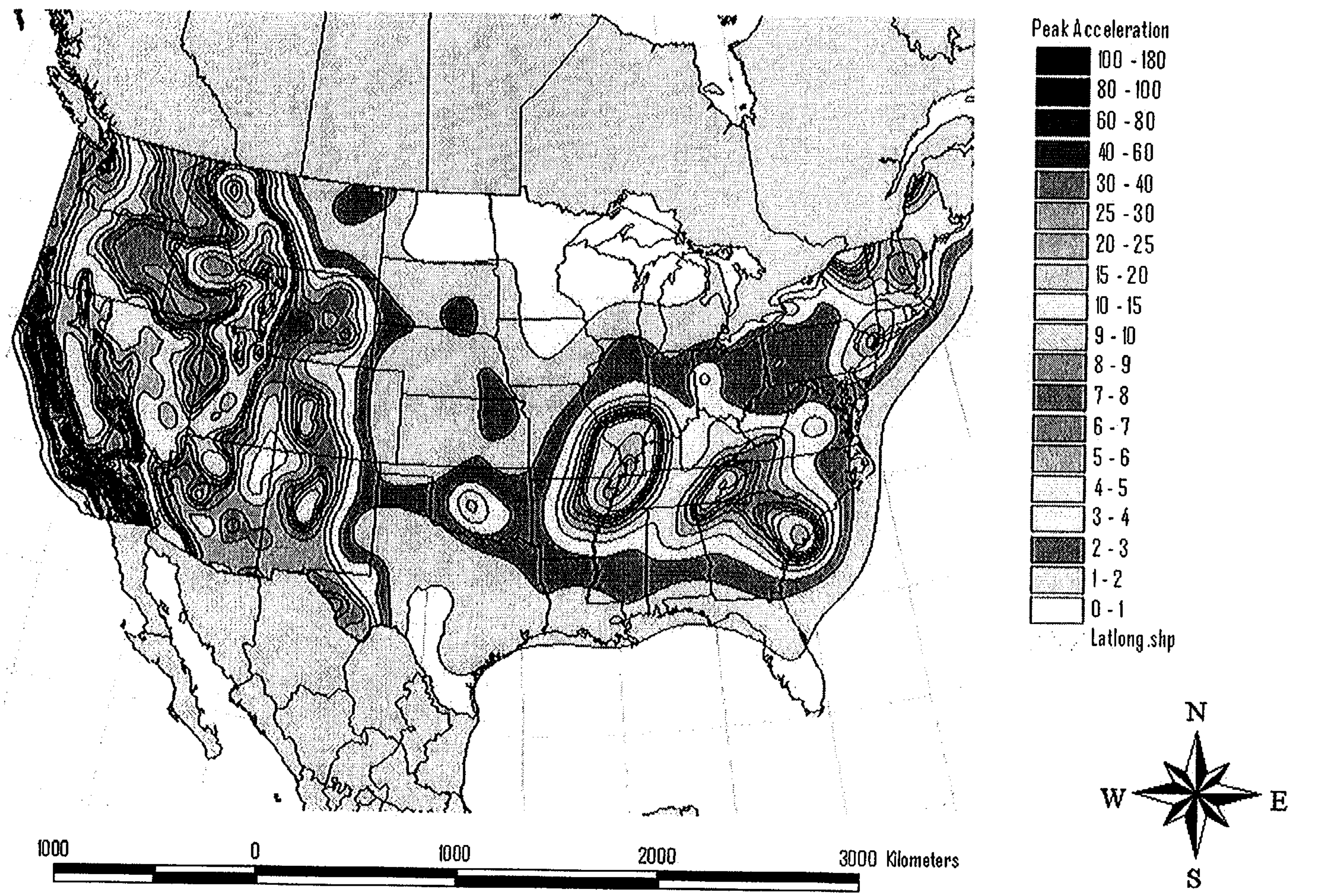

Figure 18(f). Peak acceleration as a percentage of gravity (%g) with a 10% probability of being exceeded in 50 years illustrates the earthquake hazard in the U.S. This theme was provided by the USGS Geohazards web site http://geohazards.cr.usgs.gov/eq. Other available themes include Spectral Acceleration for 1, 3, and 5 Hz frequencies.

Spectral Acceleration for frequencies of 1 Hz, 3 Hz, and 5 Hz are also shown with values expressed as a percentage of gravity (%g) having a 10 percent probability of being exceeded in 50 years.

View projection parameters:

Projection:	Albers Equal Area Conic
Spheroid:	Clarke 1866
Central Meridian:	-96.0
Reference Latitude:	37.5
Parallel 1:	29.5
Parallel 2:	45.5
False Easting:	0.0
False Northing:	0.0

Map Units: meters

Web sites:

http://geohazards.cr.usgs.gov/eq/index.shtml (USGS Earthquake Hazards Program)
http://geohazards.cr.usgs.gov/eq/hazmapsdoc/junecover.shtml (USGS OFR 96-532)

FTP site:

ftp://ghtftp.cr.usgs.gov/pub/hazmaps

Reference:

Frankel, A., Mueller, C. Barnhard, T., Perkins, D. Leyendecker, E.V., Dickman, N., Hanson, S., Hopper, M., 1996. National Seismic Hazard Maps, June 1996 Documentation, U.S. Geological Survey Open File Report OFR 96-532 (http;//geohazards.cr.usgs.gov/eq/hazmapsdoc/junecover.shtml).

3.3 ArcView v3.2 Software and Environment Requirements

As of May 2001, ArcView 3.2 has been installed at NRC on the Unix workstation *res11*. The installation currently resides in directory "/local3/multimax/arcview32/arcview3", and the executable binary application "arcview" is in the "bin" subdirectory. The program is invoked by typing the full path to the executable, i.e.,

"/local3/multimax/arcview32/arcview3/bin/arcview"

or more conveniently, either by placing the full name of the directory in the user's path in the ".cshrc" (or ".cshrcUSER") file located in the home directory or by using an alias.

Certain environment variables must also be placed in the user's ".cshrc" (or ".cshrcUSER") file. The following two lines set the AVHOME and AVDATA variables:

```
setenv AVHOME /local3/multimax/arcview32/arcview3
setenv AVDATA /local3/multimax/av3data
```

Next, add $AVHOME/lib path to the LD_LIBRARY_PATH variable. Separate the library paths with a colon ":", e.g.,

```
setenv LD_LIBRARY_PATH /usr/lib:$AVHOME/lib
```

The user's path should also contain the "arcview bin" directory, e.g.,

```
setenv PATH /usr/local/bin:$AVHOME/bin
```

If an alias is used instead, add a line to the ".cshrc" (or ".cshrcUSER") file, e.g., alias arcview '$AVHOME/bin/arcview &'

ArcView v3.2 requires proper setup of the license manager before startup on the installed workstation *res11*. Files that control the license manager may be found in the subdirectory $AVHOME/sysgen. The license file "license.dat" contains the information provided by ESRI that is specific to the machine *res11*. If, for any reason, ArcView must be reinstalled on another machine, the current license file will not work, and this reinstallation will require contacting ESRI to obtain a new license file. See ArcView GIS v3.2 documentation for further details.

The ArcView software extensions Spatial Analyst 1.1 and 3D Analyst have been installed in the directories /local3/multimax/spatial_analyst and /local3/multimax/3d_analyst, respectively. These extensions are automatically loaded from ArcView v3.2 when the latter is started, provided these two options are checked in the "Extensions" submenu under "File" in the project window.

The Unix version of ArcView v3.x apparently fails to read uppercase characters in the directory and filename structure of a given ArcView project. For this reason, the entire "sdaes.apr" ArcView project, i.e., all directories and files under /local3/arc/sdaes_gis, have been given lowercase names only.

3.4 Directory and Filename Structure of SDAES ArcVIEW GIS Project

The ArcView GIS project file named "sdaes.apr" is located on the Unix workstation *res11* in the directory "/local3/arc", and this file may be opened as an existing project after starting the ArcView application. Project files store vital information used by ArcView to control how windows are displayed and where data files are located. Every time a project is saved, ArcView updates the project file. The "sdaes.apr" project file references over 1.5 Gigabytes of data stored in the subdirectory "sdaes_gis". This section will provide a detailed description of the directory and filename structure for the SDAES ArcView project.

The general top level directory tree structure for the SDAES ArcView GIS project looks as follows:

```
local3
  \
  arc
   \
   sdaes_gis
    /   |   \
  gis work plots
```

Most data files are stored under the directory "gis" in a total of 21 subdirectories. The "work" directory is usually used as a temporary work space to store ArcView results before saving them permanently. The "plots" directory contains PostScript or JPEG plots exported from ArcView, but the plots themselvesare not used by the project otherwise.

The text file "sacdata.txt" in "/local3/arc/sdaes_gis" consists of 9559 lines, each of which describes a SAC waveform file stored under the "/local3/SAT/Events/archive" directory on *res11*. These SAC files comprise the waveform data collected for the SDAES contract between the years 1995 to 1999, both from the VSAT satellite connection and other data centers such as USGS and IRIS. The "sacdata.txt" file has been loaded into the "sdaes.apr" project in the Tables section of the project window. The "sacdata.txt" attributes include the first three fields which define the path to the SAC waveform, i.e, the year, month, and "Epoch" time, and the fourth field contains the SAC filename. The "Epoch" time is a 10-character numeric string used as a unique event identifier, and defined as the number of seconds since January 1, 1970 to the origin time of the event. This is a standard time designation used by the Center for Monitoring Research in

Arlington, Virginia and it was also adopted by the International Data Center for the seismic data used in monitoring the Comprehensive Test Ban Treaty.

A useful approach to using the "sacdata.txt" table in ArcView is to link attributes to other tables, such as SDAES Events or Seismic Stations. In this manner, events or stations may be selected, directly or by query, a process that also selects common records in the "sacdata.txt" table. Refer to ArcView 3.2 documentation about links for more detail.

As stated earlier, 21 subdirectories under "/local3/arc/sdaes_gis/gis" contain nearly all the data required by the "sdaes.apr" project. A detailed description of each View has been presented in Section 3.2. We have retained some data files not required by ArcView, such as text files used to generate grids with Spatial Analyst. For example, the text file "heatflow.txt" in directory "/local3/arc/sdaes_gis/gis/sedmap" consists of longitude, latitude, and heatflow values which were originally used by ArcView to generate the interpolated grid theme named "heatflow". Input data files such as "heatflow.txt" may be used for future surface interpolations using Spatial Analyst 1.1 with different input parameters. A brief description of each data directory follows:

```
(1) centus -- contains ARC/INFO coverages for several themes in the View
              titled "Central U.S. - Seismic Hazard".  The sdaes.apr
              project uses the files in the "revised" directory.

(2) crust5 -- contains interpolated grids in ARC/INFO format for themes
              in the View named "CRUST 5.1 Model and Elastic Parameters"
              The "analysis" subdirectory has derived contours of
              crustal thickness in shapefile format.  CRUST 5.1 is
              based on a 7-layer global crustal model.  Files include:
       crthick   -- crustal thickness
       rho3soft  -- density rho, soft sediment layer 3
       rho4hard  -- density rho, hard sediment layer 4
       rho5upcr  -- density rho, upper crust, layer 5
       rho6midcr -- density rho, middle crust, layer 6
       rho7lowcr -- density rho, lower crust, layer 7
       rho8moho  -- density rho, Moho
       sed       -- sediment thickness
       topo      -- topography, surface elevation
       vp3soft   -- P velocity, soft sediment, layer 3
       vp4hard   -- P velocity, hard sediment, layer 4
       vp5upcr   -- P velocity, upper crust, layer 5
       vp6midcr  -- P velocity, middle crust, layer 6
       vp7lowcr  -- P velocity, lower crust, layer 7
       vp8moho   -- P velocity, Moho
       vs3soft   -- S velocity, soft sediment, layer 3
       vs4hard   -- S velocity, hard sediment, layer 4
       vs5upcr   -- S velocity, upper crust, layer 5
       vs6midcr  -- S velocity, middle crust, layer 6
       vs7lowcr  -- S velocity, lower crust, layer 7
       vs8moho   -- S velocity, Moho

(3) dcw    -- ARC/INFO coverages displayed in the View titled
              "Digital Chart of the World" for 29 states with nuclear
              power plant sites in eastern and central U.S.  The
              "lookup" directory contains dbase files with detailed
              attribute definitions for joining or linking tables.
              Other files of interest are:
       us15a468m.tif -- TIFF image of color shaded relief map used
                        as background theme
```

```
us15a468m.tfw -- tiff world file used to align TIFF image
color_map.txt -- text documentation for color shaded relief map
dcwdoc.pdf    -- PDF documentation file for DCW
```

(4) dem -- Digital elevation models (DEM) in ARC/INFO format for 60 nuclear power plant sites. The "sdaes.apr" project displays the DEM's in six different themes with titles starting with "DEM/DLG, UTM Projection, Zone ...". Also TINs for Arkansas (arktin) and Three Mile Island (t_miletin) were derived. The "analysis" directory contains ARC/INFO themes created with Spatial Analyst such as hillshading and contours. The file "sdts2dem.exe" is a Windows PC application which was used to convert the DEMs from SDTS format to DEM format before loading into ArcView.

(5) dlg -- Digital line graphs (DLG) for 36 nuclear power plant sites are displayed together with DEMs on six views with titles starting "DEM/DLG, UTM Projection, Zone...". Themes are organized by feature type, such as roads or hydrography, and stored as shapefiles. Two "lookup" directories (lookup and lookup2) contain dbase tables of attribute definitions which can be used to join or link with feature tables. DLG shapefiles were produced by converting from SDTS format using the following Windows PC software files and Avenue scripts:

    attr2dat.exe
    dlgbld.exe
    dosxmsf.exe
    sdts2dlg.exe
    dlg20a.ave

The files below were extracted from the compressed archive file "00MasterDD_LRG_SDTS_tar.zip" which was downloaded as instructed from the USGS ftp site "edcftp.cr.usgs.gov". These are "Master DDF" files in SDTS format:

    dlg3.ver
    dlg3mdef.ddf
    dlg3mdir.ddf
    dlg3mdom.ddf
    dlg3mide.ddf
    dlg3mqcg.ddf
    dlg3mqhl.ddf

Documentation about the conversion procedure is given in these text files (and other web sites).

    sdts2dlg.txt
    sdts_av.txt

(6) doq -- JPEG images of Digital Orthophoto Quads for 34 nuclear power plant sites are displayed on the View titled "JPEG Aerial Photos (from Digital Orthophoto Quads)". GIF images are also available.

(7) drg -- Digital raster graphics (DRG) files of topographic maps as TIFF images are available for 65 nuclear power plant sites. Seven views in the ArcView project are used to display the topo maps, with the five Pennsylvania plants

```
                in one View named "DRG Topographic Maps, Pennsylvania,
                Albers Equal Area Projection".  The other 60 plants are
                displayed in six UTM projection views from Zone 14 to 19,
                with titles starting "DRG Topographic Maps, UTM
                Projection, Zone...".

(8) dted   -- Digital Terrain Elevation Data (Level 0) from the
              National Imagery and Mapping Agency (NIMA) are stored
              as ARC/INFO coverages under the name of the nuclear
              power plant.  The "analysis" subdirectory contains
              derived themes using Spatial Analyst 1.1 such as
              contours and hillshading.  The title of the View is
              "DTED - Digital Terrain Elevation Data  1:250K".

(9) general -- General information related to nuclear power plants,
               SDAES event and station lists, as well as themes like
               crustal thickness, NEIC seismicity, and Pn velocity
               are displayed on the View titled "SDAES General View".
               Themes are formatted as shapefiles.  File contents are:
    crust.shp      -- crustal thickness of U.S. (line theme)
    events277.shp  -- 277 SDAES events with waveform data (point)
    neic.shp       -- NEIC historical seismicity 1973-1998 (point)
    npp_saf.shp    -- 69 nuclear power plants in eastern and central
                      U.S. with soil amplification factors derived
                      from H/Z contour (point theme)
    pbarvel.shp    -- average seismic velocity Pbar of crust (line)
    pnveloc.shp    -- Pn velocity of North American crust (line)
    sta240.shp     -- 240 seismic stations with waveform data and which
                      recorded SDAES events (point theme)

(10) geohazards -- Shapefiles of five themes from the USGS Geohazards
                   web site "geohazards.cr.usgs.gov/eq/index.shtml",
                   including seismicity rate, peak acceleration, and
                   spectral acceleration for 1, 3, and 5 Hz frequencies.
                   Legend files for each have ".avl" suffix.  Displayed
                   in View titled "Peak and Spectral Acceleration (from
                   USGS Geohazards)".  Filenames are defined as follows:
     seisrate.shp -- Seismicity Rate shapefile derived by generating
                     surface contours with Spatial Analyst from the
                     original values in text file "seisrate_grid.txt"
                     using Spatial Analyst.
     seisrate_grid.txt -- Text file of longitude, latitude, and
                     Seismicity Rate used as input to Spatial
                     Analyst to derive surface contours.  Seismicity
                     Rate values represent the incremental seismicity
                     rate per year per cell (10**a value).
     us1hz050.shp -- Spectral acceleration at 1 Hz with a 10 percent
                     probability of being exceeded in 50 years.
     us3hz050.shp -- Spectral acceleration at 3 Hz with a 10 percent
                     probability of being exceeded in 50 years.
     us5hz050.shp -- Spectral acceleration at 5 Hz with a 10 percent
                     probability of being exceeded in 50 years.
     uspga050.shp -- Peak acceleration (as a percentage of gravity)
                     with a 10 percent probability of being exceeded
                     in 50 years.
```

```
(11) geolmap -- Geologic Map of U.S. based on King and Beikman (1974) is
                shown in View titled "U.S. Geologic Map".  Directories
                are ARC/INFO coverages.  Two ArcView legend files are
                available: "geolmap.avl" provides detailed geologic
                symbols for the geologic map ("kbge") table of contents,
                and "kbfault.avl" provides symbols for the faults map
                ("kbf").  Available ARC/INFO coverages include:
       kbge    -- Geologic map (King and Beikman)
       kbf     -- Faults map (King and Beikman)
       grid    -- Lat/Lon grid overlay
       kbgl    -- Glacial map boundaries
       states  -- U.S. state boundaries map

(12) gna     -- Used for View titled "Geophysics of North America".
                Consists of four interpolated grids: DNAG gravity, DNAG
                magnetic, SEG gravity, and ETOPO5 elevation, and
                contours.  Contents include:
       dnaggrav     -- ARC/INFO grid of DNAG gravity
       dnaggrav.txt -- input text file used to create grid in Spatial
                       Analyst.  Contains fields of longitude, latitude,
                       and gravity (mgals) with grid spacing of 6 km.
       dnaggrav.avl -- Legend file used to symbolize table of contents
                       for DNAG Gravity theme in ArcView.
       dnaggrav.doc -- Documentation (text) of DNAG Gravity
       seggrav      -- ARC/INFO grid of SEG gravity
       seggrav.txt  -- input text file used to create grid in Spatial
                       Analyst.  Contains fields of longitude, latitude,
                       and SEG gravity (mgals) with grid spacing of 8 km
                       after decimating from the original 4 km spacing.
       seggrav.avl  -- Legend file used to symbolize table of contents
                       for SEG Gravity theme in ArcView
       seggrav.doc  -- Documentation (text) of SEG Gravity
       dnagmag      -- ARC/INFO grid of DNAG magnetic anomaly
       dnagmag.txt  -- input text file used to create grid in Spatial
                       Analyst.  Contains fields of longitude, latitude,
                       and magnetic anomaly (gammas) with grid spacing
                       of 4 km after decimating from the original 2 km
                       spacing
       dnagmag.avl  -- Legend file used to symbolize table of contents
                       for DNAG Magnetic Anomaly theme in ArcView
       dnagmag.doc  -- Documentation (text) of DNAG Magnetic Anomaly
       etopo5       -- ARC/INFO grid of ETOPO5 elevation for U.S.
       etopo5.txt   -- input text file used to create grid in Spatial
                       Analyst.  Contains fields of longitude, latitude,
                       and elevation (m) with grid spacing of 5 minutes
       etopo5.avl   -- Legend file used to symbolize table of contents
                       for ETOPO5 elevation theme in ArcView
       etopo5.doc   -- Documentation (text) of ETOPO5 elevation
       ctour_dnaggrav.shp -- Contours of DNAG Gravity (shapefile)
       ctour_seggrav.shp -- Contours of SEG Gravity (shapefile)
       ctour_etopo5.shp -- Contours of ETOPO5 Elevation (shapefile)

(13) hzcontours -- Mean horizontal/vertical (H/Z) station terms based
                   on bandpass filtered Lg amplitudes for seven
                   frequency bands from 1.25 to 7 Hz for U.S. events
                   recorded at LRSM stations.  Themes are displayed
                   in "Frequency Dependent H/Z Contours (from EPRI)"
```

```
                View.  Legend files have ".avl" suffix.  Files in
                this directory include:
   hzgrid[1-7]         -- ARC/INFO grids of H/Z (Lg) for 1.25 to 7 Hz
   hz_sta[2-7]hzd.txt  -- Text file of LRSM station lat/lon locations
                          and H/Z (Lg) values for given frequency.
                          Used as input for Spatial Analyst to create
                          grids, and to mark LRSM sites in ArcView
   hzsta125hz.shp      -- Shapefile of LRSM stations used in ArcView
                          to overlay 1.25 Hz grid
   ctour[1-7]hz.shp    -- Shapefile of contours of H/Z (Lg) station
                          terms which overlay grids for 1.25 to 7 Hz

(14) lakesup     -- Used in "Lake Superior Geologic Map" View.  Includes
                    three shapefile themes for the geologic map, faults,
                    and mines.  Shapefiles are stored in data directory.
                    Legend files (.avl) are found in "other" directory.
                    Documentation is placed in the "doc" directory.
                    The "project" directory containing "supgeol.apr"
                    is redundant, and not used.  Useful files are:
   geology.shp  -- Shapefile of Lake Superior geologic map
   faults.shp   -- Shapefile of Lake Superior region faults map
   mrds.shp     -- Shapefile of MRDS mineral resource (mines) map

(15) legend      -- This directory has nine legend files (.avl) used
                    to symbolize the table of contents for the same
                    number of themes in various views.  Note that most
                    legend files are stored in the same directory as
                    the data files used for a given theme.  Legend files
                    included are defined below:
   crust.avl      -- Crustal Thickness (km) used in View titled
                     "CRUST 5.1 Model and Elastic Parameters"
   heatflow.avl   -- Heatflow (mW/m^2) used in View titled
                     "Heat Flow and Sediment Thickness"
   neic.avl       -- NEIC Eqks (1973-1998) used in View titled
                     "SDAES General View"
   npp.avl        -- Nuclear Power Plants used in many views
   sdaesmag.avl   -- SDAES Events in ascending magnitude order
                     displayed in many views
   sed5x5.avl     -- Sediment Thickness (km) used in view titled
                     "CRUST 5.1 Model and Elastic Parameters"
   sedmap.avl     -- Sediment Thickness (km) used in view titled
                     "Heat Flow and Sediment Thickness"
   sedthickc.avl  -- Sediment Thickness (m) used in view titled
                     "Heat Flow and Sediment Thickness"
   sedthick.avl   -- not used

(16) nebraska    -- Sample Nebraska maps with four themes including
                    geologic bedrock, gravity, magnetic, and depth
                    to Precambrian layer maps. Displayed on view titled
                    "Nebraska Sample Maps".  The ARC/INFO coverages
                    (not used in ArcView) were converted to decimal
                    degrees with "Projector!" extension as shapefiles.

(17) newmad      -- ARC/INFO coverages of themes displayed in view
                    "New Madrid Region Seismotectonic Map" from the
                    USGS Open File Report 95-0574.  Uses coverages in
                    the "revised" directory:
```

```
axgrav       -- Axial gravity anomaly
basehyd      -- Hydrography selected on the basis of significant
                ground shaking or liquefaction potential
enrgcen      -- Locations of probable subsurface ruptures of the
                1811-1812 earthquakes, as defined by sandblow
                distribution (Obermeier 1989).  Obermeier uses the
                description "energy centers" of those earthquakes
                rather than the spatially limited term "epicenter"
faults       -- Locations of faults
gravstr      -- Structures identified from gravity field data
hrvpshal     -- P velocity contours for depths of 0-5 km
hrvpdeep     -- P velocity contours for depths of 5-14 km
magdep       -- Depth to magnetic basement (km)
misspoly     -- Polygon coverage of the Mississippi River
pzcon        -- Depth to Paleozoic Surface contours
```

```
(18) sedmap   -- Displayed on "Heat Flow and Sediment Thickness" View.
                 Consists of ARC/INFO grids created with Spatial
                 Analyst including heatflow, sediment thickness, and
                 seismic velocity, density rho, and layer thickness.
                 Also includes shapefiles of contours of heatflow and
                 and sediment thickness.  The following is available:
     heatflow    -- ARC/INFO grid of heatflow (mW/m^2) derived from
                    input file "heatflow.txt"
     sedthickc   -- Sediment thickness of U.S. (meters) based on
                    a 1x1 degree grid (Laske and Masters 1997) with
                    interpolated values in file "sedthickc.txt" used
                    as input to Spatial Analyst
     sedthick2   -- Sediment thickness of U.S. (km) also based on
                    1x1 degree grid but using observed values from
                    input file "sedmapus.txt" as input
     velocityp1  -- P velocity of upper sediment layer
     velocityp2  -- P velocity of middle sediment layer
     velocityp3  -- P velocity of lower sediment layer
     velocitys1  -- S velocity of upper sediment layer
     velocitys2  -- S velocity of middle sediment layer
     velocitys3  -- S velocity of lower sediment layer
     rho1        -- Density (rho) of upper sediment layer
     rho2        -- Density (rho) of middle sediment layer
     rho3        -- Density (rho) of lower sediment layer
     thickness1  -- Thickness (km) of upper sediment layer
     thickness2  -- Thickness (km) of middle sediment layer
     thickness3  -- Thickness (km) of lower sediment layer
     vp[1-3].txt -- Text files used as input to Spatial Analyst for
                    P velocity grids
     vs[1-3].txt -- Text files used as input to Spatial Analyst for
                    S velocity grids
     rho[1-3].txt -- Text files used as input to Spatial Analyst for
                     density (rho) grids
     thk[1-3].txt -- Text files used as input to Spatial Analyst for
                     layer thickness grids
     ctour_heatflow.shp -- Shapefile of contours of heatflow
     ctour_sedthickc.shp -- Shapefile of contours of sediment
                           thickness used to overlay on "sedthickc" grid
     ctoursedth.shp -- Shapefile of contours of sediment thickness
                       used to overlay on "sedthick2" grid
```

(19) statsgo -- Displayed on "Soils Maps (STATSGO) scale=1:250,000" View. The 29 state soils maps with nuclear power plant sites are found in the directories with two letter state abbreviations under "spatial". Subdirectories "header" and "metadata" contain projection and metadata documentation, respectively. The "spatial" directory contains a shapefile of the soils map, and several dbase files (dbf) with detailed attributes derived from the Map Unit Interpretation Database (MUIR). Refer to the documentation directory for more information. Attribute files (in "dbase" format) include:

- comp.dbf -- map unit components table
- compyld.dbf -- component crop yields table
- forest.dbf -- woodland native plants table
- interp.dbf -- use interpretations table
- layer.dbf -- soil profile layers table
- mapunit.dbf -- soil survey unit table
- plantcom.dbf -- rangeland native plants table
- plantnm.dbf -- plant name table
- rsprod.dbf -- range site productivity table
- taxclass.dbf -- lookup table contains the soil classification
- windbrk.dbf -- wind break species table
- wlhabit.dbf -- wildlife habitat table
- woodland.dbf -- common indicator trees table
- woodmgt.dbf -- woodland management table
- yldunits.dbf -- units of measure for crops table

(20) wabash -- Displayed on the View "Wabash Region Seismotectonic Map". These are ARC/INFO coverages derived from USGS Open File Report 97-681, "Seismotectonic Maps in the vicinity of the Lower Wabash Valley, IL, IN, and KY". A brief description is given of the data files used in the ArcView project "sdaes.apr":

- bfaults --- basement faults
- ibcflt --- faults from the Illinois Basin Consortium
- kyflt --- faults from the Geologic Map of Kentucky, 1988, Kentucky Geologic Survey
- padflt --- faults from Paducah Quad
- bcontours_all -- depth to basement contours in units of thousands of feet below sea level
- magdep --- depth to magnetic basement

(21) wsm -- Displayed on View titled "World Stress Map (1997)". The dbase file "wsm_usa.dbf" is shown as an overlay of the U.S.

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