

TECHNICAL REPORT 94-4

SEISMIC ACTIVITY NEAR THE
V.C. SUMMER NUCLEAR STATION

FOR THE PERIOD
OCTOBER-DECEMBER, 1994

BY

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Principal Investigator

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COLUMBIA, SOUTH CAROLINA 29208

CONTRACT NO. N622702

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INTRODUCTION

Analysis of the seismic activity near the V.C. Summer Nuclear Station in South Carolina between October 1 and December 31, 1994 is presented in this report. During this period, three events were recorded in the vicinity of the Monticello Reservoir, all of which were located. All of the events were of relatively low magnitude.

A compilation of the seismic activity and station performance for the year 1994 is also included at the end of this quarterly report.

SEISMIC NETWORK

Earthquakes during this period were recorded on stations of Monticello Reservoir and South Carolina Seismic Networks. The configuration of stations utilized to locate Monticello Reservoir events is shown in Figure 1 and station coordinates are listed in Appendix I. The operational status of the network is given in Appendix II.

DATA ANALYSIS

Hypocentral locations have been determined using a computer program HYPO71 (Lee and Lahr, 1972). The velocity model used for earthquake locations is given in Appendix III. The format of the HYPO71 output is given in Appendix IV. The event magnitude was determined from the signal duration at JSC using the following relation:

$$M_L = -1.83 + 2.04 \log D,$$

where D is the signal duration (seconds).

An estimate of daily energy release was determined using a simplified magnitude (M_L) - energy (E) relation by Gutenberg and Richter (1956):

$$\log_{10} E = 11.8 + 1.5 M_L$$

OBSERVED SEISMICITY DURING OCTOBER-DECEMBER, 1994

Seismicity around Monticello Reservoir was low during the fourth quarter of 1994. Three events were recorded and located (Figure 2). All events for the quarter were shallow and varied in depth between 1.25 and 1.95 km. The largest event occurred on November 29, 1994 at 22:54:28 UTC and had a duration magnitude of 0.6 (Appendix V). All events occurred in the central region of the Monticello Reservoir with two of the events located within the confines of the reservoir proper. All of the event locations were of fair quality (Appendix V).

The long term decline in seismicity observed at Monticello Reservoir is continuing (Figure 3) and the cumulative seismicity has shown relative flattening since 1985-86 (Figure 4).

CORRELATION OF WATER LEVEL WITH SEISMICITY

Monticello Reservoir is a pumped storage facility. Any decrease in the reservoir level associated with power generation is recovered when water is pumped back into the reservoir. There can be normal variations up to five feet per day between maximum and minimum water levels. The water level has been monitored to see if there is any correlation between the daily or seasonal changes in the reservoir level and the local seismicity. Water levels are compared with seismicity in Figure 5. The top panel shows the average water level; the error bars show the maximum and minimum water levels each day. The second panel shows the change in water level from day to day. The number of events per day and the log of energy released are shown in the lower histograms. These charts include all reported earthquakes listed in Appendix V. The average water level, daily changes in water level, number of earthquakes and energy release are given in Appendix VI. No systematic correlation was observed between the seismicity and reservoir level fluctuations.

CONCLUSIONS

Seismicity during the fourth quarter of 1994 was low and occurred in the central region of the reservoir with two of the events located within the confines of the reservoir proper. No systematic correlation was observed between the reservoir level fluctuations and the seismicity.

MONTICELLO NETWORK AND SEISMICITY DURING 1994

STATION OPERATION STATUS

The operational status of the Monticello Network during 1994 is presented in Figures 7 and 8. The generally high downtime for the Monticello Network during the fourth quarter (Figure 8) is due to a transmitter failure at Farr Tower which made the data relay for the network inoperative, accounting for 55% of the fourth quarter downtime. In addition, station MR05 was inoperative for 55% of the year (Figure 7) which is attributed to a loss of electricity at the site.

SEISMICITY

During 1994 twenty-four events were recorded (Appendix VII) around the Monticello Reservoir, all of which were located. The events were scattered throughout the area of the reservoir but generally can be separated into two groupings, one in the northwest and the other in the central region of the reservoir

(Figure 6). Every month but June, September and October had locatable events (Figure 9) with duration magnitudes ranging from $M_L = -1.2$ to $M_L = 2.2$ (Figure 10 and Appendix VII) and occurring at depths from 0.09 to 3.45 km (Figure 11 and Appendix VII). Twenty-two of the located events had magnitudes less than $M_L = 1.0$ while two of the events had magnitudes greater than $M_L = 1.0$ (Figure 10) and most were of good to fair quality (B or C) (Appendix VII).

Seismicity around the Monticello Reservoir in 1994 continued at the relatively low level that has been observed since 1987. Compared to the 1993 seismicity (Figure 12 and Appendix VIII) more activity was found in the central region of the reservoir while fewer events were found in the southern region (Figure 6). The greater percentage of good quality locations can be attributed to improved operation of the network and increased efforts to incorporate digital recording techniques.

REFERENCES

- Gutenberg, B. and Richter, C.F. (1956). Magnitude and energy of earthquakes, *Ann. Geof.* 9,1-15.
- Lee, W.H.K. and Lahr, J.C. (1972). A computer program for determining hypocenter, magnitude and first motion pattern of local earthquakes, revisions of HYPO71, U.S. Geological Survey, *Open-File Report*, 100 pp.

Monticello Reservoir Sub-Network

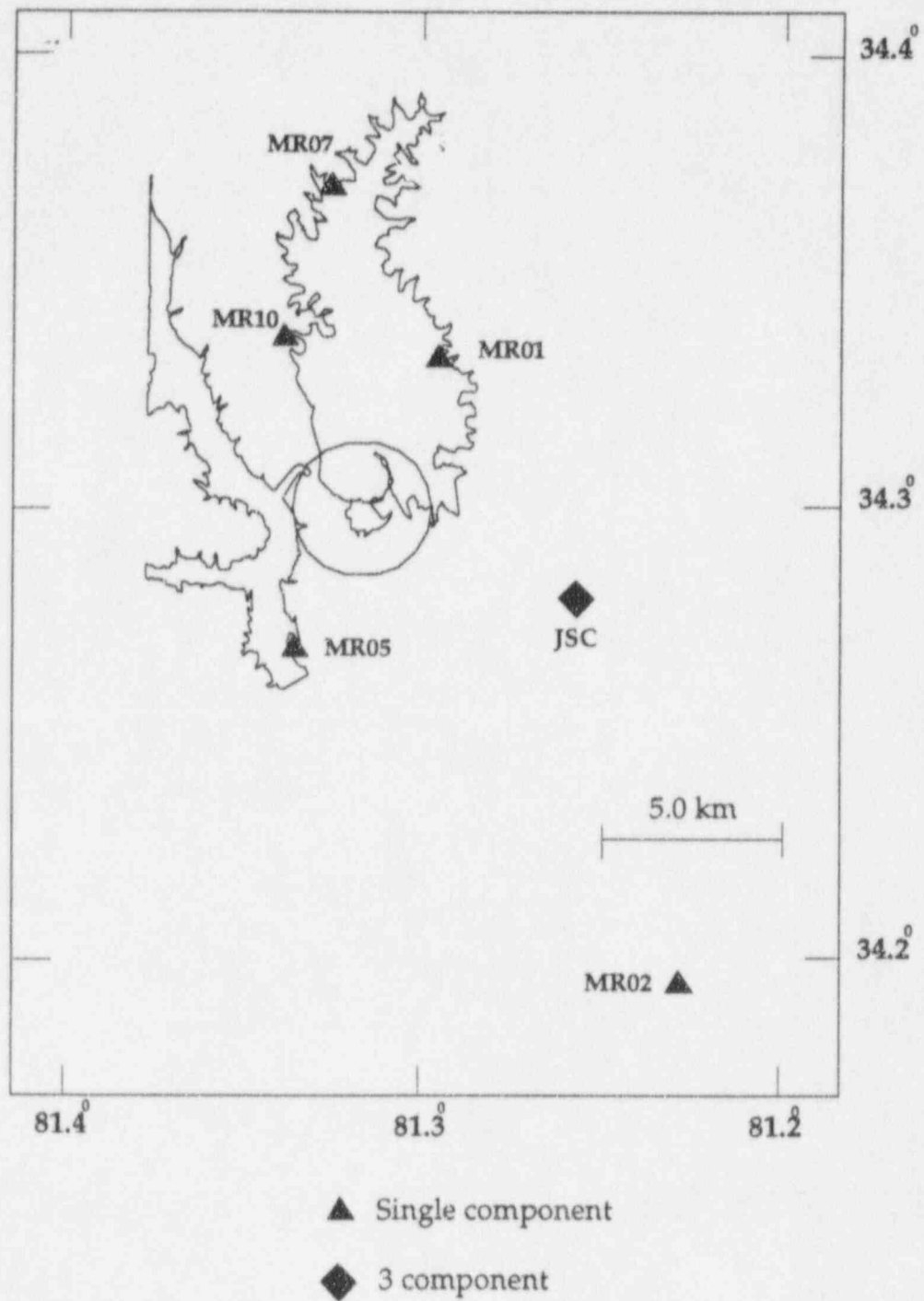


Figure 1. Location of the Monticello Reservoir sub-network stations

Monticello Reservoir Seismicity

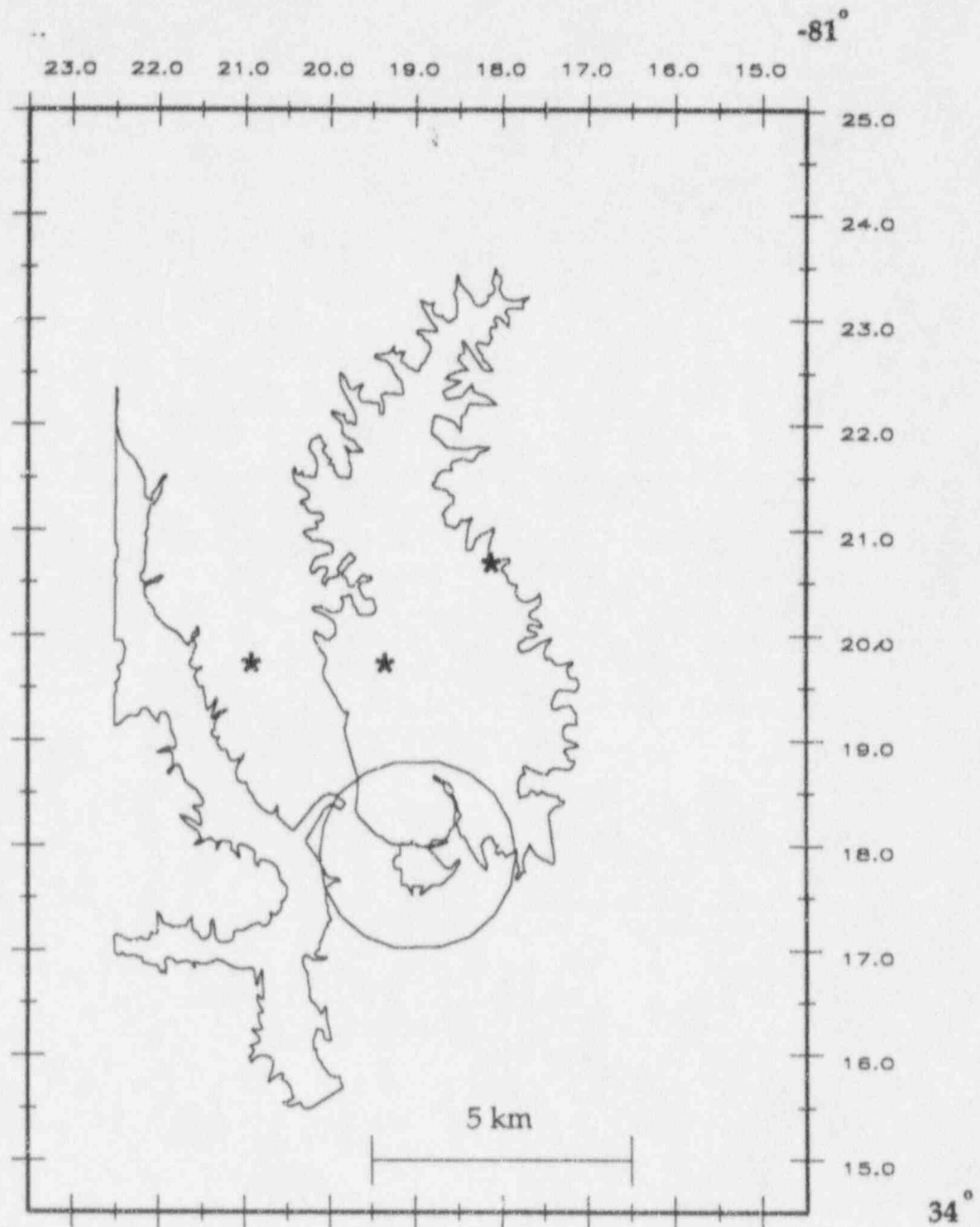


Figure 2. Events located near Monticello Reservoir during the period October - December, 1994 (stars).

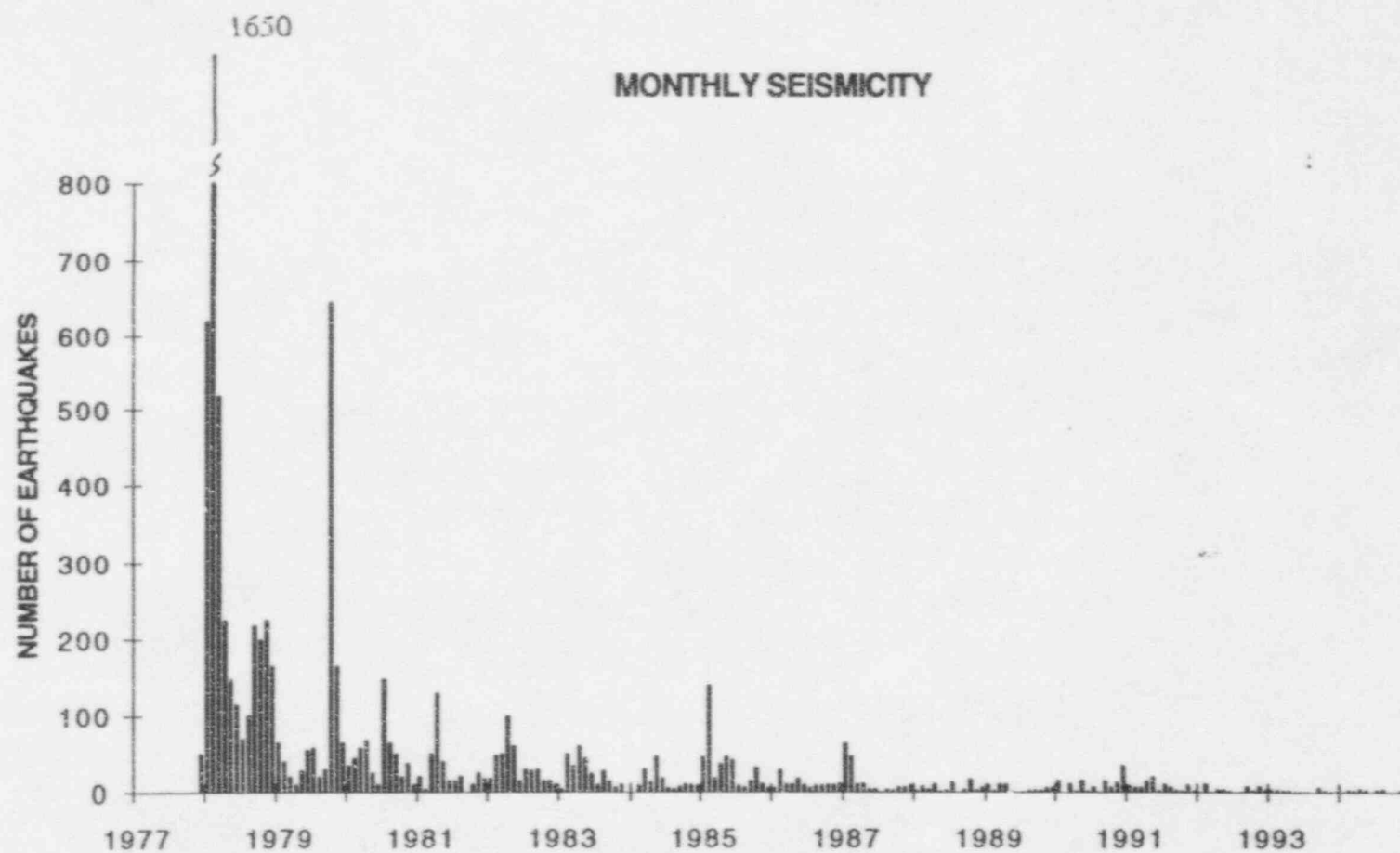


Figure 3. Earthquakes between impoundment and December, 1994.

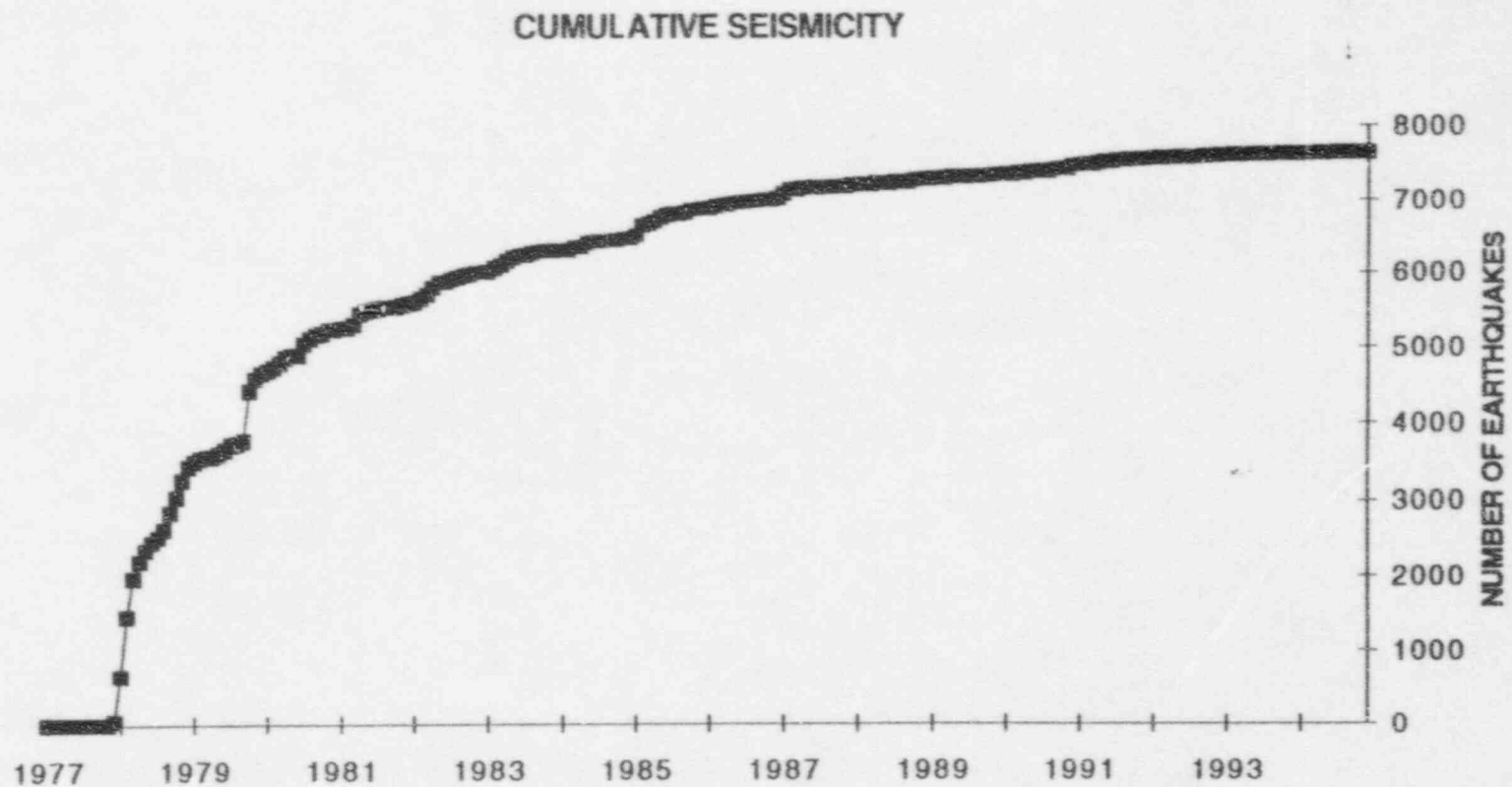


Figure 4. Cumulative seismicity near Monticello Reservoir since impoundment.

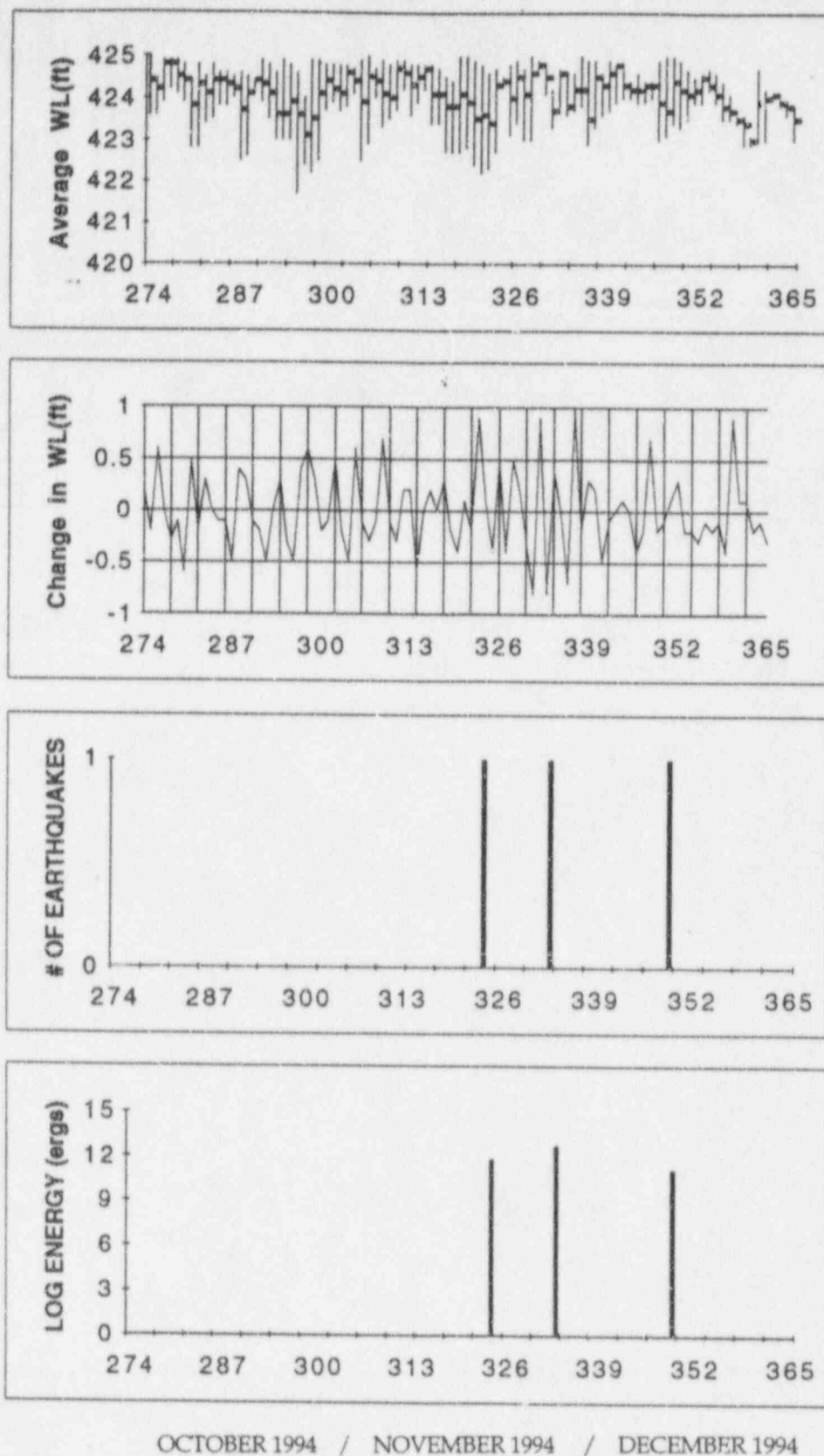


Figure 5. Comparison of daily lake level, changes in lake level, number of earthquakes and the log of energy release in ergs per day at Monticello Reservoir. Error bars in the top panel indicate daily fluctuations in water level.

Monticello Reservoir Seismicity

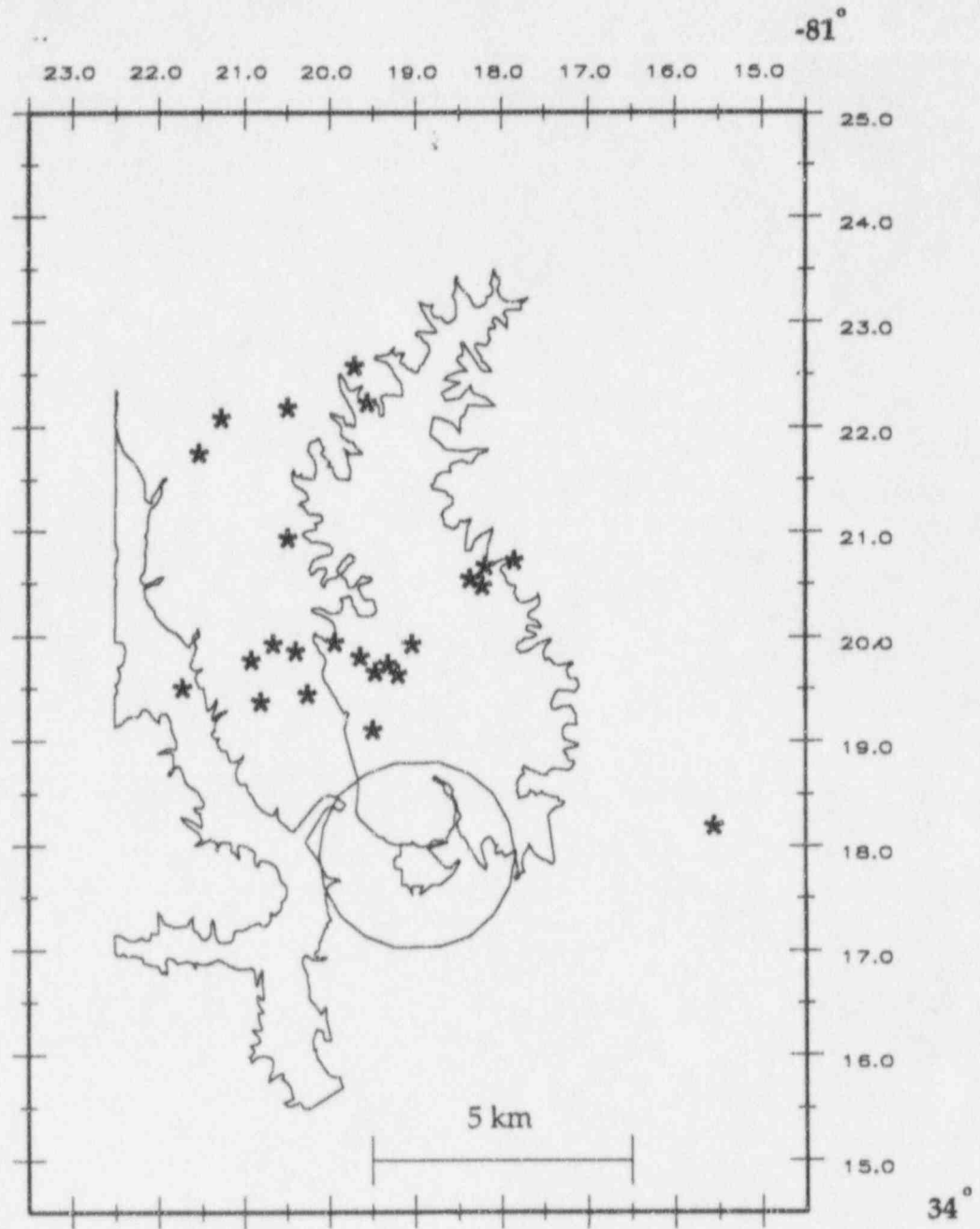


Figure 6. Events located near Monticello Reservoir during the year 1994 (stars)

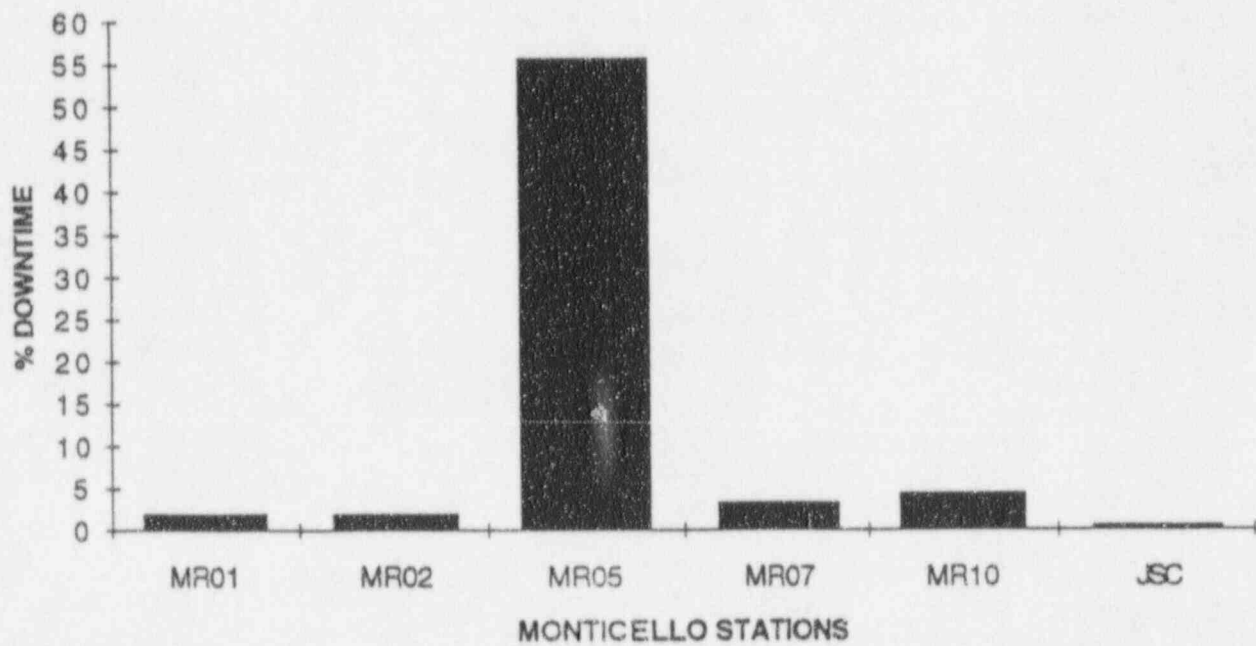


Figure 7. Operational status of Monticello Reservoir seismic sub-network stations for 1994.

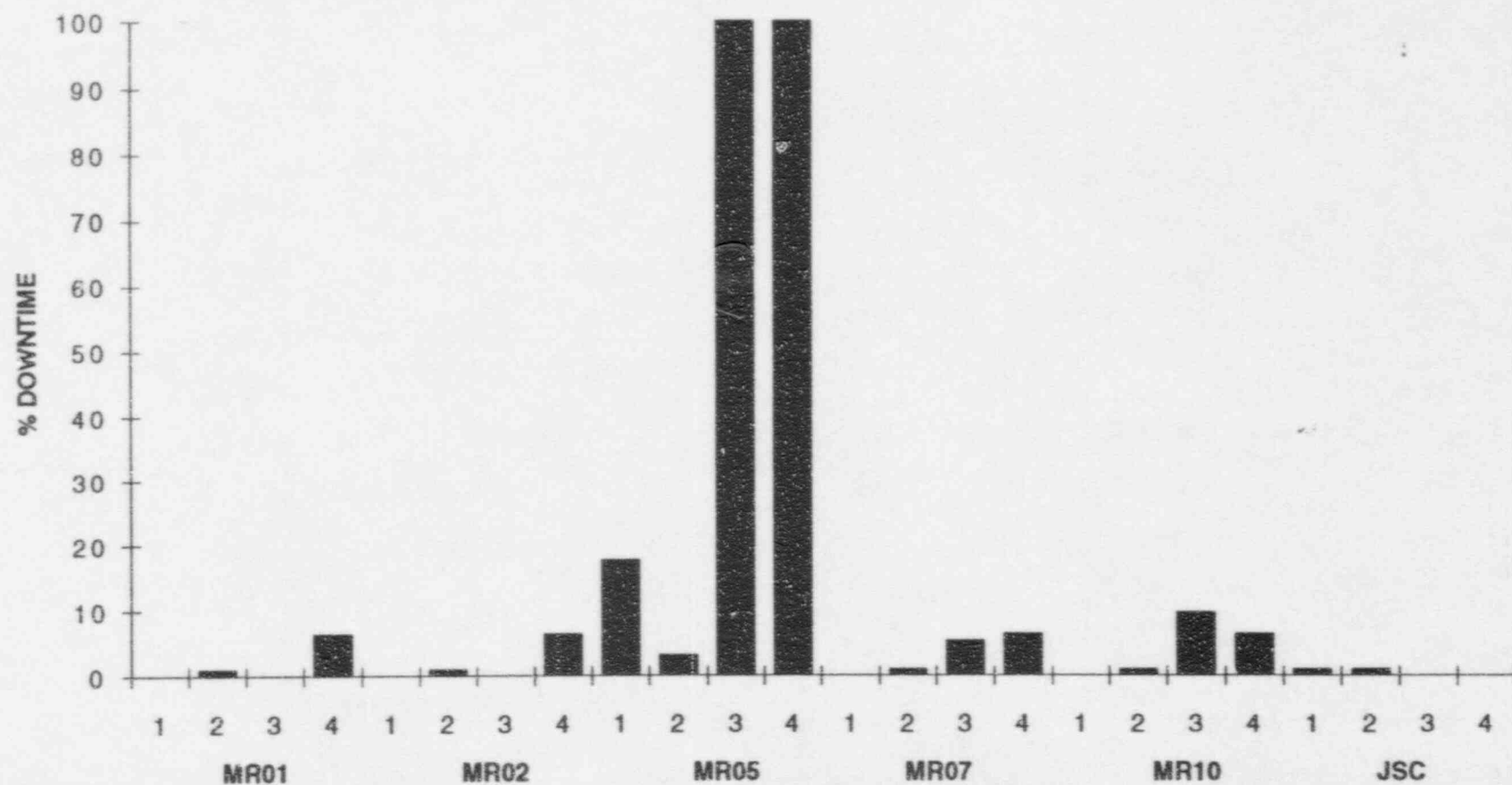


Figure 8. Operational status by quarter of Monticello Reservoir seismic sub-network stations during 1994. Quarters and stations designated.

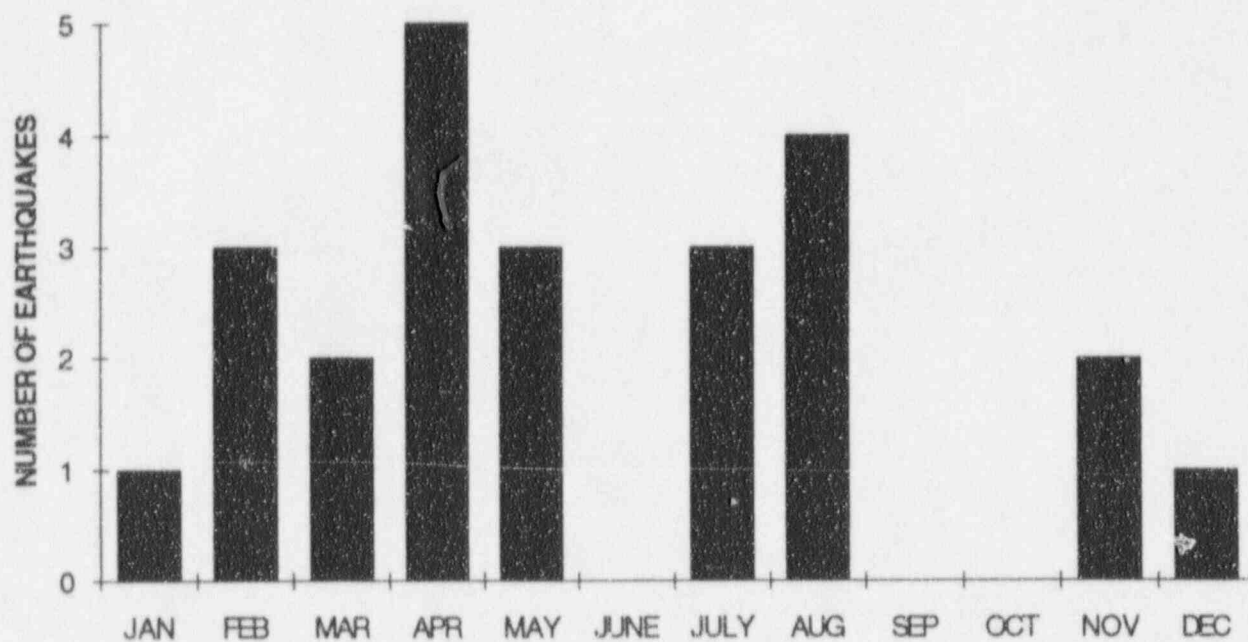


Figure 9. Monthly distribution of located earthquakes at Monticello Reservoir during 1994.

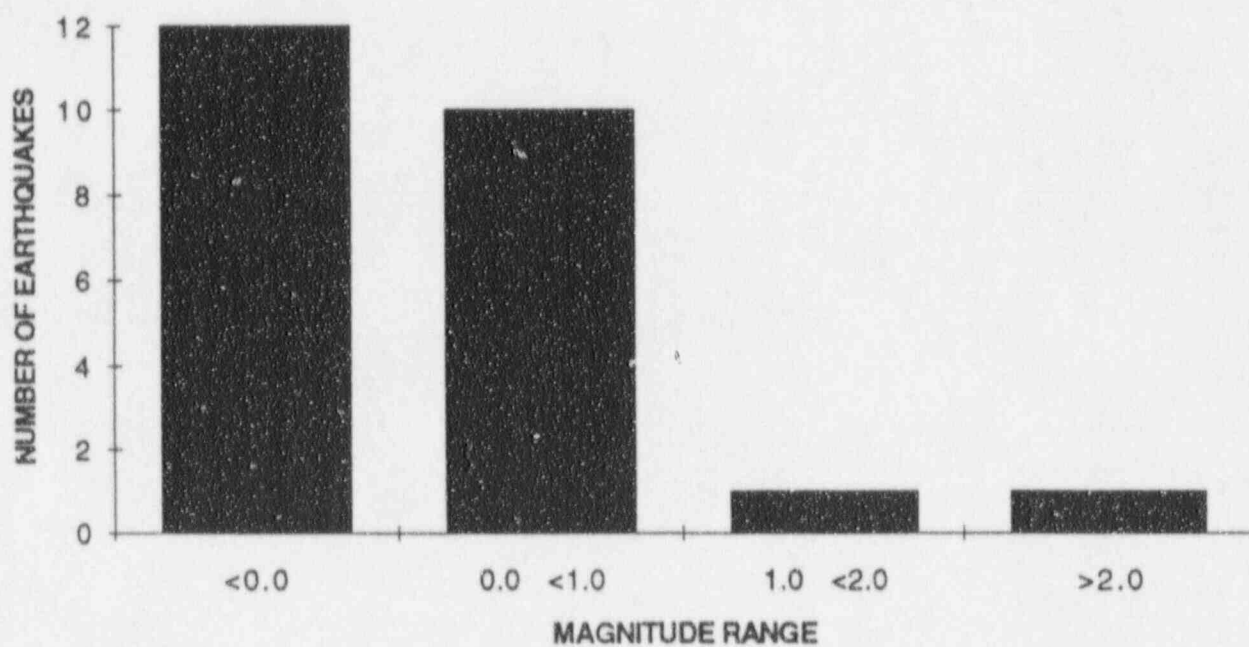


Figure 10. Magnitude ranges of located earthquakes at Monticello Reservoir during 1994.

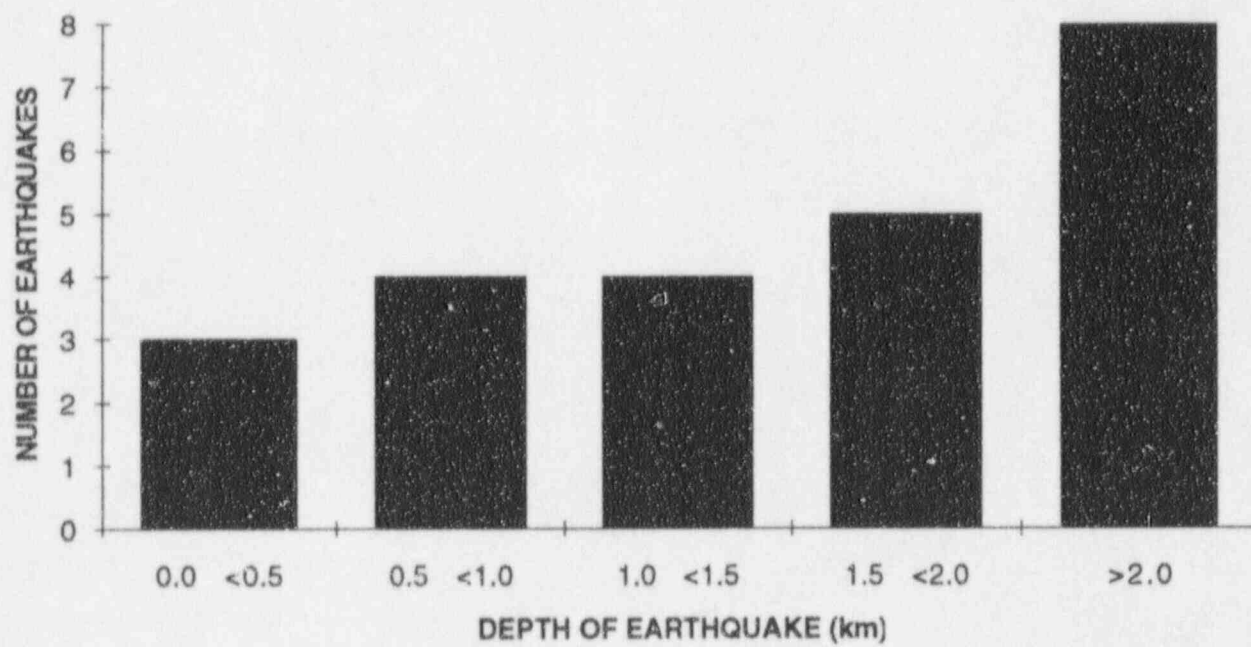


Figure 11. Depth distribution of located earthquakes at Monticello Reservoir during 1994.

Monticello Reservoir Seismicity

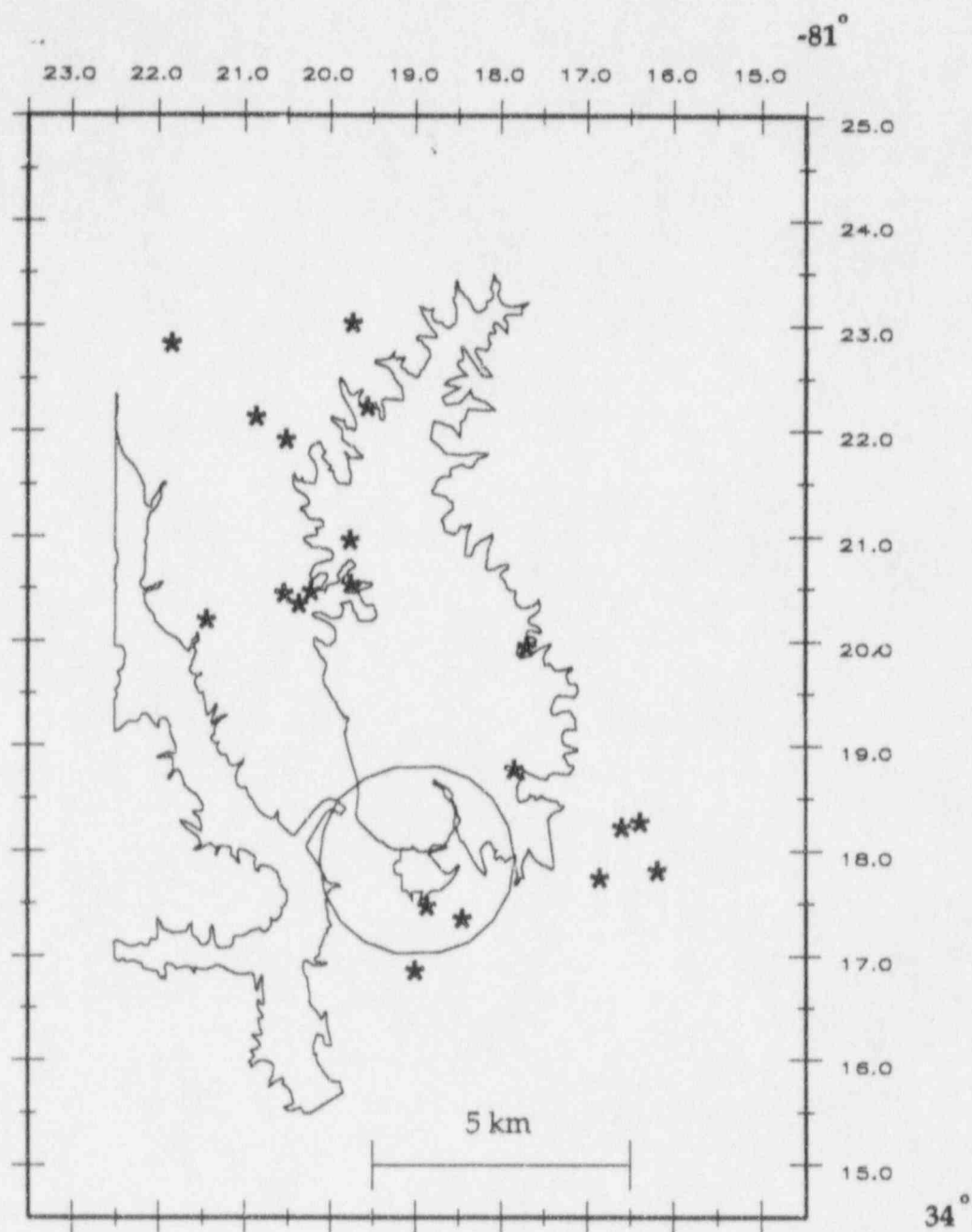


Figure 12. Events located near Monticello Reservoir during the year 1993 (stars).

APPENDIX I
STATION LOCATIONS

STATION	LAT° N	LONG° W
JSC	34°16.80'	81°15.60'
MR01	34°19.91'	81°17.74'
MR02	34°11.58'	81°13.81'
MR05	34°16.05'	81°20.05'
MR07	34°22.23'	81°19.50'
MR10	34°20.18'	81°20.25'

APPENDIX II

SEISMIC STATION OPERATIONAL STATUS

OCTOBER 1 - DECEMBER 31, 1994

STATION	PERCENT DOWNTIME
MR01	6.5
MR02	6.5
MR05	100
MR07	6.5
MR10	6.5
JSC	0

APPENDIX III
MONTICELLO RESERVOIR
VELOCITY MODEL

Velocity km/sec	Depth to top km
1.00	0.00
5.40	0.03
5.90	0.18
6.10	0.46
6.30	0.82
8.10	30.00

APPENDIX IV
MONTICELLO EARTHQUAKES
HYPO71 FORMAT

Column 1	Date
Column 2	Origin time (UTC) h.m.sec.
Column 3	Latitude (N) degrees, min.
Column 4	Longitude (W) degrees, min.
Column 5	Depth (km).
Column 6	Local duration magnitude.
Column 7	No. of station readings used to locate event. P and S arrivals from same stations are regarded as 2 readings.
Column 8	Largest azimuthal separation in degrees between stations.
Column 9	Epicentral distance in km to nearest station.
Column 10	Root mean square error of time residuals in sec. $RMS = R_i^2 / No$, where R_i is the time residual for the i^{th} station.
Column 11	Standard error of the epicenter in km*.
Column 12	Standard error of the focal depth in km*.
Column 13	Quality of the epicentral location.

* Statistical interpretation of standard errors involves assumptions which may not be met in earthquake locations. Therefore standard errors may not represent actual error limits.

Note: If ERH or ERZ is blank, this means that it cannot be computed, because of insufficient data.

APPENDIX V
MONTICELLO RESERVOIR EARTHQUAKES
OCTOBER- DECEMBER, 1994

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	M
941120	342 52.20	34-19.73	81-19.39	1.95	0.01	10	152	1.6	0.03	0.2	0.3	B	1
941129	2254 28.91	34-20.75	81-18.19	1.77	0.63	9	188	1.7	0.02	0.1	0.2	C	1
941215	634 33.31	34-19.75	81-20.88	1.25	-0.24	7	261	1.3	0.04	0.4	0.5	C	1

APPENDIX VI

Maximum and minimum water levels, change in water level, number of earthquakes and log of energy release per day at Monticello Reservoir during October 1 - December 31, 1994. Dates are given in Julian Calendar.

J.DATE	WL (max)	WL (min)	WL (avg)	WL (ch)	# of eqs	Energy
274	425	423.6	424.4	0.2	0	0
275	424.4	423.6	424.2	-0.2	0	0
276	424.9	423.9	424.8	0.6	0	0
277	424.9	424.2	424.8	0	0	0
278	424.9	424.1	424.5	-0.3	0	0
279	424.8	423.9	424.4	-0.1	0	0
280	424.4	422.8	423.8	-0.6	0	0
281	424.8	422.8	424.3	0.5	0	0
282	424.5	423.4	424.1	-0.2	0	0
283	424.8	423.5	424.4	0.3	0	0
284	424.6	423.8	424.4	0	0	0
285	424.6	423.8	424.3	-0.1	0	0
286	424.5	424	424.2	-0.1	0	0
287	424.6	422.5	423.7	-0.5	0	0
288	424.5	422.6	424.1	0.4	0	0
289	424.4	424.2	424.4	0.3	0	0
290	424.9	423.9	424.3	-0.1	0	0
291	424.8	423.5	424.1	-0.2	0	0
292	424.6	423	423.6	-0.5	0	0
293	424.9	423	423.6	0	0	0
294	424.8	423	423.9	0.3	0	0
295	424.6	421.7	423.6	-0.3	0	0
296	424	422.4	423.1	-0.5	0	0
297	424.9	422.2	423.5	0.4	0	0
298	424.9	422.5	424.1	0.6	0	0
299	424.8	423.7	424.4	0.3	0	0
300	424.8	423.9	424.2	-0.2	0	0
301	424.8	423.7	424.1	-0.1	0	0
302	424.8	423.8	424.6	0.5	0	0
303	424.7	424.1	424.4	-0.2	0	0
304	424.9	422.5	423.9	-0.5	0	0
305	425	422.9	424.5	0.6	0	0
306	424.7	424	424.4	-0.1	0	0
307	424.9	423.3	424.1	-0.3	0	0
308	424.8	423.5	424	-0.1	0	0
309	424.9	423.7	424.7	0.7	0	0
310	424.9	424.2	424.6	-0.1	0	0
311	424.8	423.6	424.3	-0.3	0	0
312	424.8	423.9	424.5	0.2	0	0
313	424.8	424.2	424.7	0.2	0	0
314	424.8	423.4	424.1	-0.6	0	0

APPENDIX VI (continued)

J.DATE	WL (max)	WL (min)	WL (avg)	WL (ch)	# of eqs	Energy
315	424.7	423.4	424.1	0	0	0
316	424.5	422.7	423.8	0.2	0	0
317	424.4	422.7	423.8	0	0	0
318	425	422.7	424.1	0.3	0	0
319	425	422.8	423.9	-0.2	0	0
320	424.9	422.4	423.5	-0.4	0	0
321	424.8	422.2	423.6	0.1	0	0
322	424.6	422.3	423.4	-0.2	0	0
323	424.7	422.7	424.3	0.9	0	0
324	424.5	424.4	424.4	0.1	1	11.82
325	424.8	423.1	424	-0.4	0	0
326	424.9	423.4	424.5	0.5	0	0
327	424.7	423	424.1	-0.4	0	0
328	425	423	424.6	0.5	0	0
329	424.9	424.7	424.8	0.2	0	0
330	424.7	424.1	424.5	-0.3	0	0
331	424.2	423.3	423.7	-0.8	0	0
332	424.7	423.8	424.6	0.9	0	0
333	424.6	423.6	423.8	-0.8	1	12.75
334	424.6	423.7	424.2	0.4	0	0
335	425	423.8	424.2	0	0	0
336	424.9	422.9	423.5	-0.7	0	0
337	424.9	423.3	424.5	1	0	0
338	424.6	423.6	424.3	-0.2	0	0
339	424.9	423.7	424.6	0.3	0	0
340	424.7	423.9	424.8	0.2	0	0
341	424.7	424	424.3	-0.5	0	0
342	424.4	424	424.2	-0.1	0	0
343	424.6	423.9	424.2	0	0	0
344	424.4	423.9	424.3	0.1	0	0
345	424.4	424	424.3	0	0	0
346	424.9	423	423.9	-0.4	0	0
347	425	423.1	423.7	-0.2	0	0
348	425	423.4	424.4	0.7	0	0
349	424.9	423.3	424.2	-0.2	1	11.14
350	424.7	423.5	424.1	-0.1	0	0
351	424.5	423.9	424.2	0.1	0	0
352	424.6	423.9	424.5	0.3	0	0
353	424.7	424.2	424.3	-0.2	0	0
354	424.6	423.9	424.1	-0.2	0	0
355	424.4	423.5	423.8	-0.3	0	0
356	424.1	423.5	423.7	0.1	0	0
357	423.6	423.4	423.5	-0.2	0	0
358	423.6	422.9	423.4	-0.1	0	0
359	423.1	422.9	423	-0.4	0	0
360	424.7	423	423.9	0.9	0	0
361	424.2	423	424	0.1	0	0
362	424.1	424	424.1	0.1	0	0
363	424	423.8	423.9	-0.2	0	0
364	423.9	423.6	423.8	-0.1	0	0
365	423.8	423	423.5	-0.3	0	0

APPENDIX VII
MONTICELLO RESERVOIR EARTHQUAKES
JANUARY - DECEMBER, 1994

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	M
940110	1746	0.43	34-19.38	81-20.76	0.81	0.73	10	210	1.7 0.02	0.2	0.2	C	1
940201	254	6.50	34-19.96	81-20.60	0.30	-0.40	10	236	0.7 0.04	0.3	0.3	C	1
940210	552	32.03	34-19.13	81-19.51	3.45	-0.11	6	212	5.7 0.02	1.1	1.3	C	1
940214	13 7	39.50	34-19.83	81-19.67	2.33	0.12	9	157	1.1 0.04	0.3	0.3	B	1
940318	1048	22.83	34-19.49	81-21.69	2.81	0.21	6	276	2.6 0.08	1.2	1.5	C	1
940330	2038	34.61	34-19.73	81-19.34	1.80	0.01	8	168	1.6 0.03	0.2	0.3	B	1
940409	1012	54.96	34-19.71	81-19.48	1.48	0.78	10	119	1.5 0.04	0.2	0.4	B	
940430	1341	13.83	34-20.64	81-18.37	2.17	-1.22	7	175	1.7 0.04	0.3	0.4	B	
940430	1341	17.47	34-20.49	81-18.27	1.82	-0.40	10	173	1.4 0.03	0.2	0.2	B	
940430	13 8	30.58	34-19.98	81-19.06	0.57	-0.40	8	103	1.9 0.10	0.5	1.5	B	
940430	1344	6.70	34-20.78	81-17.84	1.81	-0.40	6	198	1.6 0.08	0.6	0.9	C	
940510	1230	24.73	34-22.62	81-19.64	1.05	0.01	5	318	0.8 0.01	0.2	0.1	C	
940511	513	33.97	34-20.02	81-19.93	0.25	0.68	10	119	0.6 0.06	0.3	0.9	B	
940519	1011	19.15	34-20.99	81-20.43	0.81	-0.40	7	222	1.5 0.03	0.5	0.6	C	
940723	112	15.94	34-21.83	81-21.64	0.09	2.16	10	290	3.4 0.04	0.8	1.3	C	1
940725	1211	39.73	34-22.33	81-19.60	2.21	0.21	8	344	0.2 0.04	1.4	0.3	C	1
940728	16 4	31.50	34-18.29	81-15.70	2.68	1.54	6	213	2.8 0.03	2.2	0.8	C	1
940809	945	47.63	34-19.89	81-20.35	0.91	-0.86	4	248	0.6 0.03			C	1
940810	233	20.48	34-22.29	81-21.35	2.95	-0.60	6	332	4.3 0.06	2.2	1.8	C	1
940814	1258	19.27	34-19.45	81-20.21	1.12	-1.22	4	232	1.3 0.01			C	1
940830	1257	47.58	34-22.33	81-20.31	3.00	-0.86	4	314	1.2 0.03			C	1
941120	342	52.20	34-19.73	81-19.39	1.95	0.01	10	152	1.6 0.03	0.2	0.3	B	1
941129	2254	28.91	34-20.75	81-18.19	1.77	0.63	9	188	1.7 0.02	0.1	0.2	C	1
941215	634	33.31	34-19.75	81-20.88	1.25	-0.24	7	261	1.3 0.04	0.4	0.5	C	1

APPENDIX VIII

MONTICELLO RESERVOIR EARTHQUAKES
JANUARY-DECEMBER, 1993

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
930111	2227 43.49	34-16.90	81-19.03	3.64	0.82	7	120	2.3	0.04	0.3	0.5	B1
930112	043 25.39	34-17.52	81-18.93	0.24	-0.40	12	126	3.2	0.06	0.3	0.9	B1
930211	1736 46.55	34-22.33	81-19.60	1.94	-0.11	4	307	0.2	0.04			C1
930219	2051 47.72	34-22.33	81-20.95	0.82	1.02	6	282	2.2	0.08	9.8	8.1	D1
930219	2103 39.42	34-25.06	81-22.71	3.44	0.82	8	339	7.2	0.03	0.6	0.6	C1 *
930318	1753 15.06	34-25.25	81-22.72	6.55	0.57	8	341	7.4	0.08	1.6	0.8	C1 *
930322	1855 9.95	34-17.90	81-16.00	0.42	1.02	10	199	2.1	0.08	0.5	0.8	C1
930428	558 29.53	34-23.09	81-19.60	1.00	0.01	8	322	1.6	0.16	2.6	1.8	D1
930430	1615 12.49	34-22.09	81-20.72	0.6	0.21	4	274	1.9	0.01			C1
930524	1622 57.02	34-22.87	81-21.89	0.20	0.82	5	300	3.9	0.02	3.0	1.8	D1
930618	355 10.29	34-20.98	81-19.77	0.66	0.01	7	164	1.6	0.10	1.0	1.9	B1
930714	2006 13.27	34-20.01	81-17.71	2.31	0.16	10	185	0.2	0.05	0.3	0.3	C1
930906	1122 6.58	34-20.24	81-21.51	0.47	0.00	12	236	1.9	0.10	0.7	2.0	C1
930906	1246 37.07	34-20.50	81-19.85	0.05	0.00	7	144	0.8	0.07	0.4	0.9	B1
930906	1542 35.05	34-20.52	81-20.20	0.12	0.00	8	192	0.6	0.03	0.2	0.3	C1
930906	1659 37.11	34-20.49	81-20.43	0.48	0.00	8	229	0.6	0.05	0.5	0.5	C1
930906	1717 4.29	34-20.41	81-20.29	0.04	0.00	6	291	0.4	0.02	0.4	0.4	C1
930911	345 12.04	34-17.38	81-18.49	3.87	-0.27	10	121	3.4	0.25	1.2	2.5	B1
931001	1628 49.43	34-18.81	81-17.84	2.28	0.28	8	133	2.0	0.04	0.3	0.6	B1
931021	829 38.85	34-17.81	81-16.72	2.37	0.03	10	159	2.5	0.15	0.9	1.9	C1
931129	1729 20.70	34-18.35	81-16.21	0.63	0.15	12	197	3.0	0.03	0.2	0.3	C1
931211	2248 46.90	34-18.31	81-16.35	0.77	-0.68	8	191	3.0	0.03	0.2	0.3	C1

* Blair quarry blasts which are not plotted on figure 2