

TECHNICAL REPORT 92-4

SEISMIC ACTIVITY NEAR THE
V.C. SUMMER NUCLEAR STATION

FOR THE PERIOD
OCTOBER - DECEMBER 1992

BY

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Principal Investigator

DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA, SOUTH CAROLINA 29208

CONTRACT NO. N574984

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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, 1992 is presented in this report. During this period, 15 events were recorded in the vicinity of Monticello Reservoir, 5 of which were located. There were three events of magnitude $M_L \geq 1.1$.

A review of seismic activity during the year 1992 is also presented in this report. The level of activity and its spatial distribution are discussed. A performance report of various stations of the network during the past year is also presented in this report.

SEISMIC NETWORK

Earthquakes during this period were recorded on stations of Monticello Reservoir and South Carolina Seismic Network. The configuration of stations utilized to locate Monticello 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 the computer program HYPO71 (Lee and Lahr, 1972). The velocity model used in the earthquake locations is given in Appendix III. The format of the 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, 1992

There was no unusual seismic activity around Monticello Reservoir during the last quarter of 1992. A total of 15 events were recorded, of which five were located (Appendix V; Figure 2). The located events were of poor quality (C or D). The largest event in the quarter occurred on October 05 (19:59:01.06 UTC) and it had a magnitude $M_L = 1.18$. This event occurred to the northwest of the lake. The other located events occurred in the middle and around the west side of the lake.

Eight of the 15 events of this quarter occurred during the month of November. These occurred within an epicentral distance of < 9 km from JSC. The earthquakes that could not be located were of short duration and were generally recorded on only one station (Appendix VI)

The long term decline in seismicity observed at Monticello Reservoir is continuing (Figure 3). The cumulative seismicity at Monticello Reservoir shows a 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 Appendices V and VI. The average water level, daily changes in water level, number of earthquakes and energy release are given in Appendix VII. No systematic correlation was observed between the seismicity and reservoir level fluctuations.

CONCLUSIONS

There was no unusual seismic activity during the fourth quarter of 1992. The largest recorded magnitude was $M_L=1.18$. The seismicity was scattered, both temporally and spatially. No systematic correlation was observed between the reservoir level fluctuations and the seismicity.

MONTICELLO NETWORK AND SEISMICITY DURING 1992

Station Operational Status

The operational status of the Monticello Network during 1992 is presented in Figure 6. Most of the stations of the network were fully operational during the year. Only station MR05 was down for significant periods during the third quarter of the year.

Seismicity

A total of 47 events were recorded around the Monticello Reservoir area during 1992, of which 14 were located (Appendix VIII; Figure 7). Six of the located events occurred in the center of the lake at shallow focal depth (< 2.0 km). Scattered activity was observed in the northern and north western parts of the lake. Most of the located

earthquakes occurred at shallow depths, with maximum activity occurring at depths ≤ 1.5 km (Fig. 8). The temporal distribution of seismicity is shown in Figure 9.

The unlocatable events were generally of short duration and not recorded on more than one or two stations. The magnitude range of the located and unlocatable events are shown in Figure 10. Most of the unlocatable events were of magnitude < 0.0 . Most of the locatable events during 1992 were in the magnitude range of 0-1.0. The higher detection and location capabilities are attributed to the improved operation of the network, particularly the digital recording on the Puffin computer.

In conclusion, the activity during 1992 was not particularly different from the past several years and remained at a relatively low level. There were 7 events of magnitude $M_L \geq 1.0$ during 1992, with the largest event of magnitude $M_L = 1.18$ occurring on October 5, 1992. The long term decline in the activity is continuing. Only in the middle of the lake was there any repeated activity. A larger percent of smaller events have been located, with improved operation of the stations.

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 Seismic Network

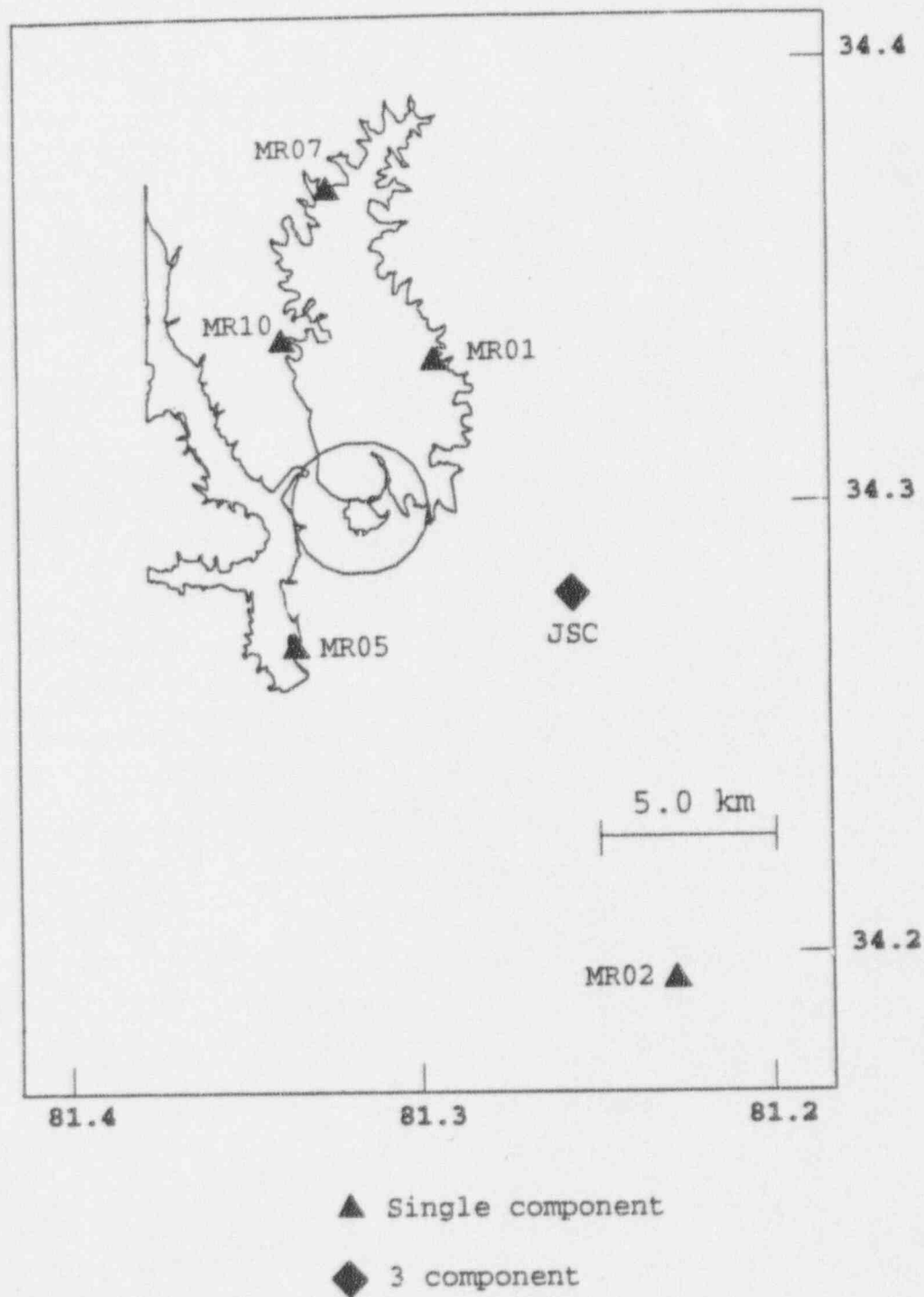


Figure 1. Monticello Reservoir area showing locations of seismic stations used to locate seismicity.

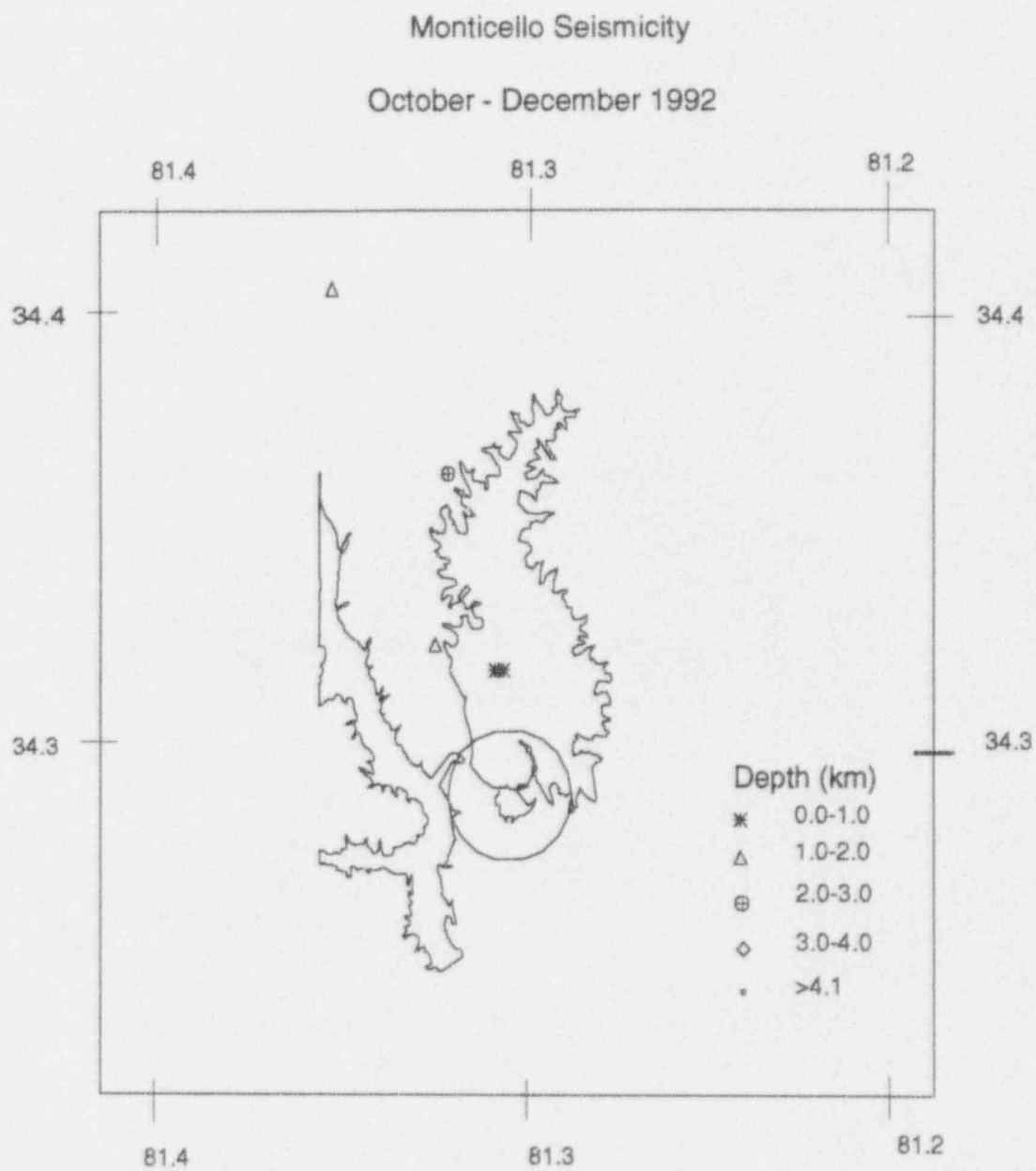


Figure 2. Earthquakes located near Monticello Reservoir during the period October 1 - December 31, 1992

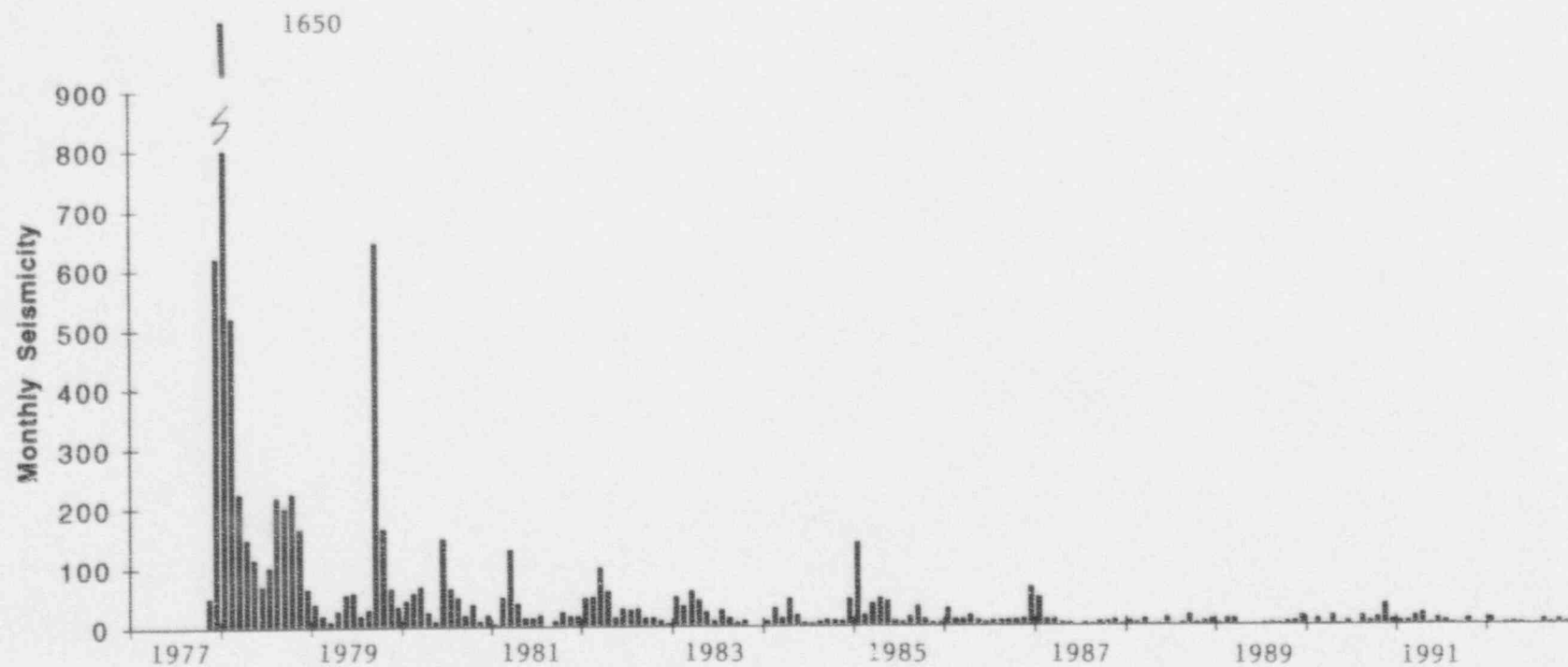


Figure 3. Earthquakes between impoundment and December 1992.

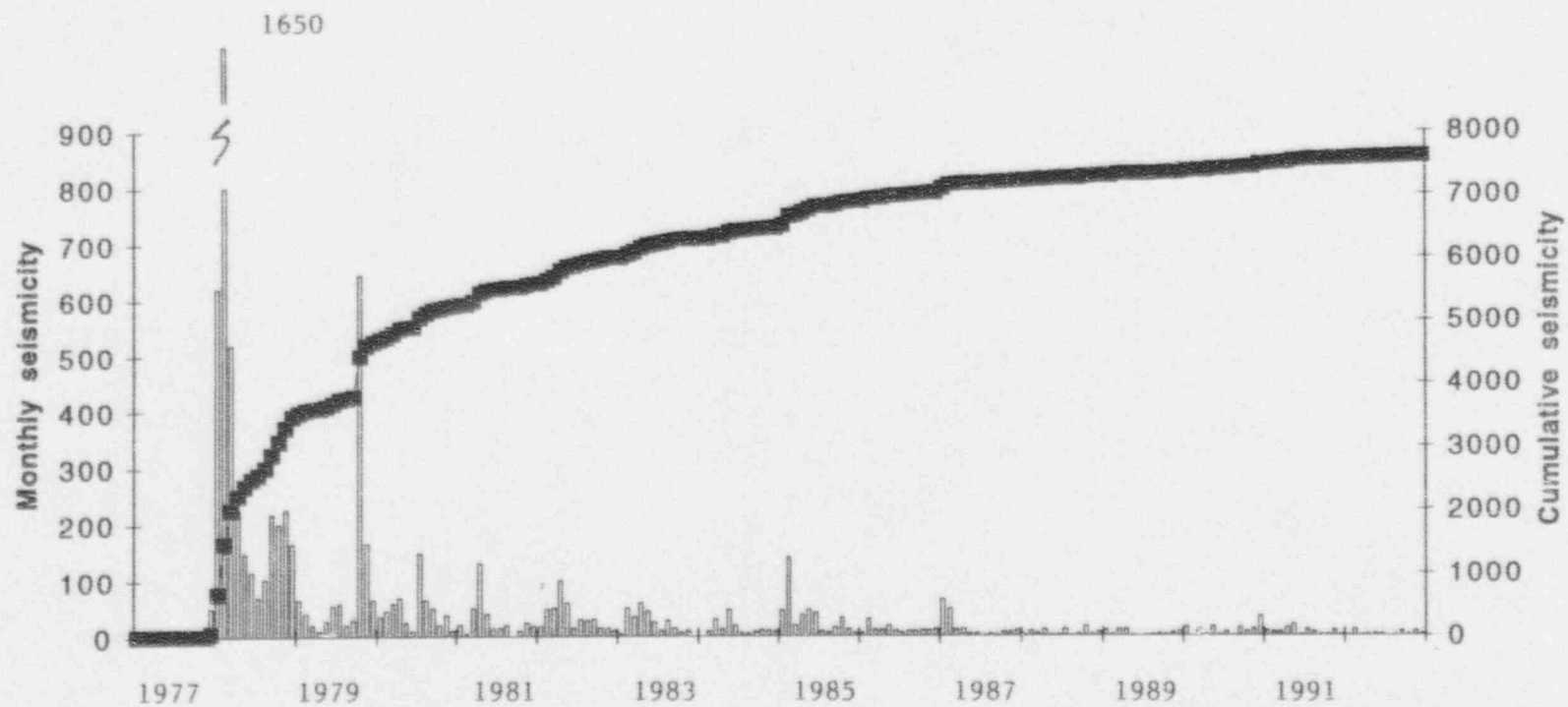


Figure 4. Monthly seismicity (bars) and cumulative seismicity (line) near Monticello Reservoir since impoundment

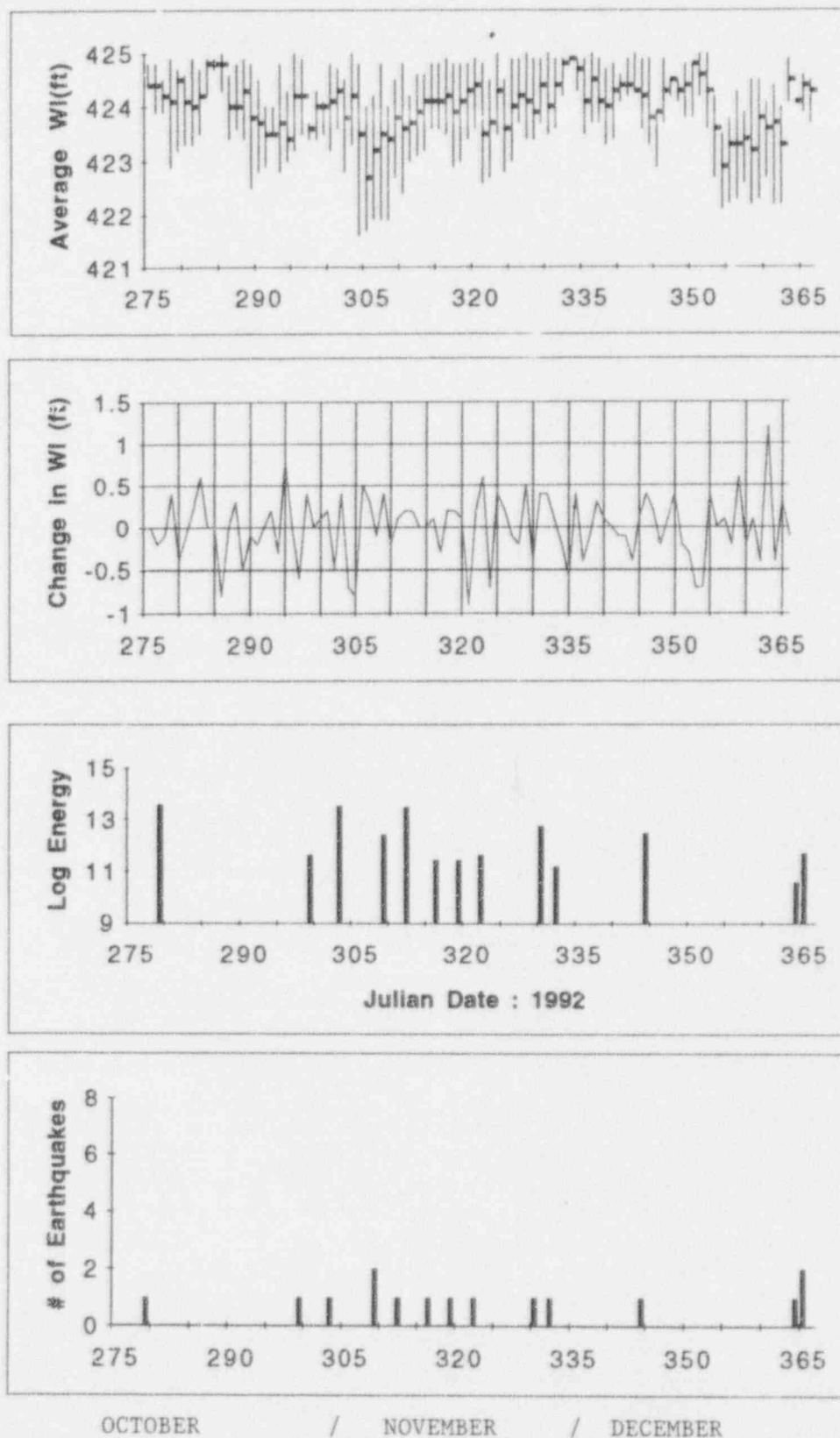


Figure 5. Comparison of daily lake level, changes in lake level, number of earthquakes and log of energy release in ergs per day at Monticello Reservoir. Error bars in the top panel indicate daily fluctuations in water level.

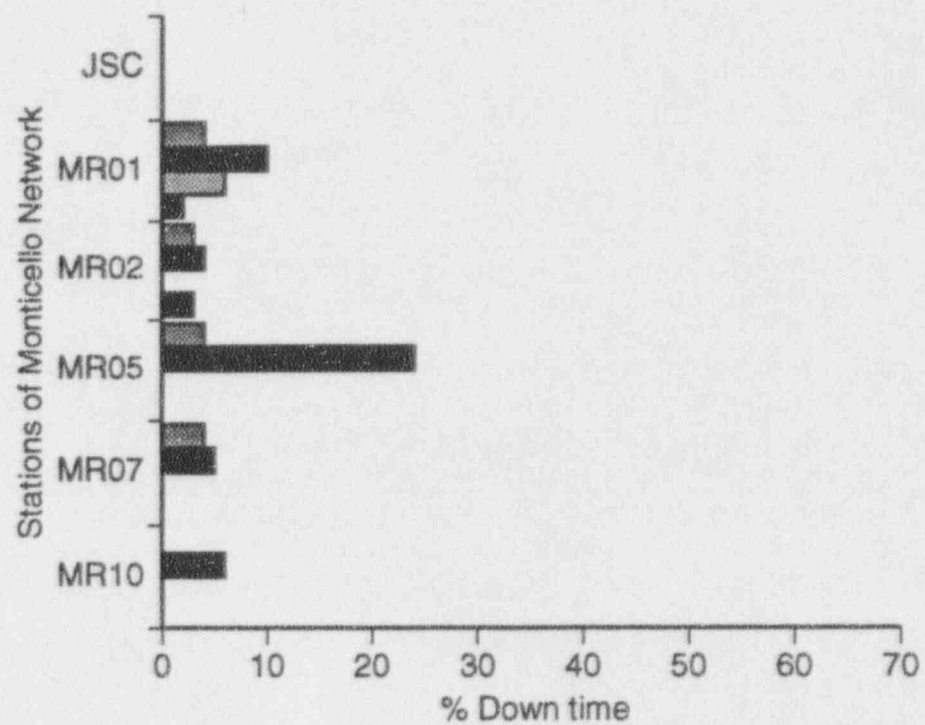


Figure 6. Operational status of Monticello Network during 1992. Four bars from bottom to top correspond to the four quarters.

Monticello Seismicity :1992

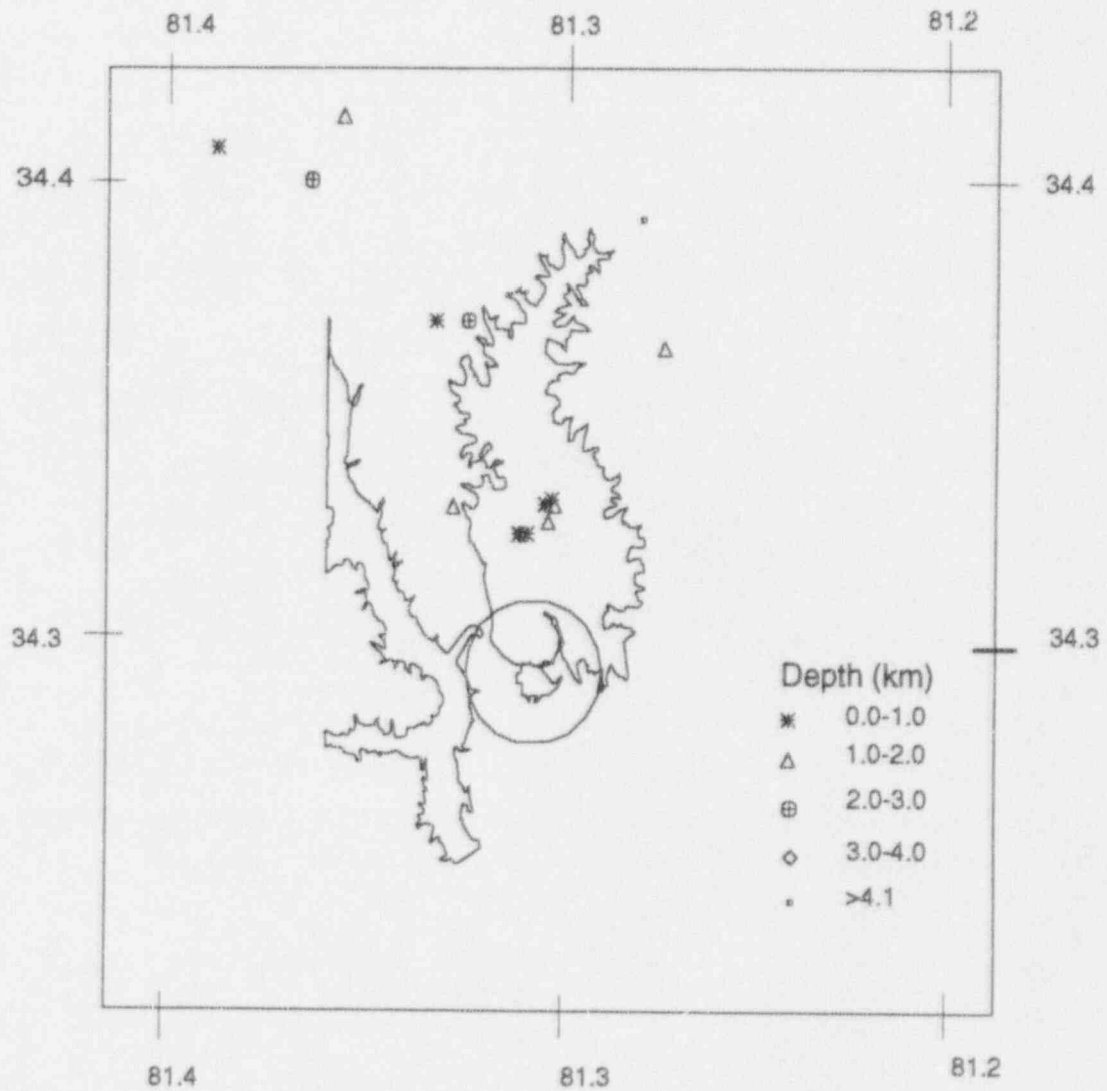


Figure 7. Earthquakes located near Monticello Reservoir during January - December, 1992.

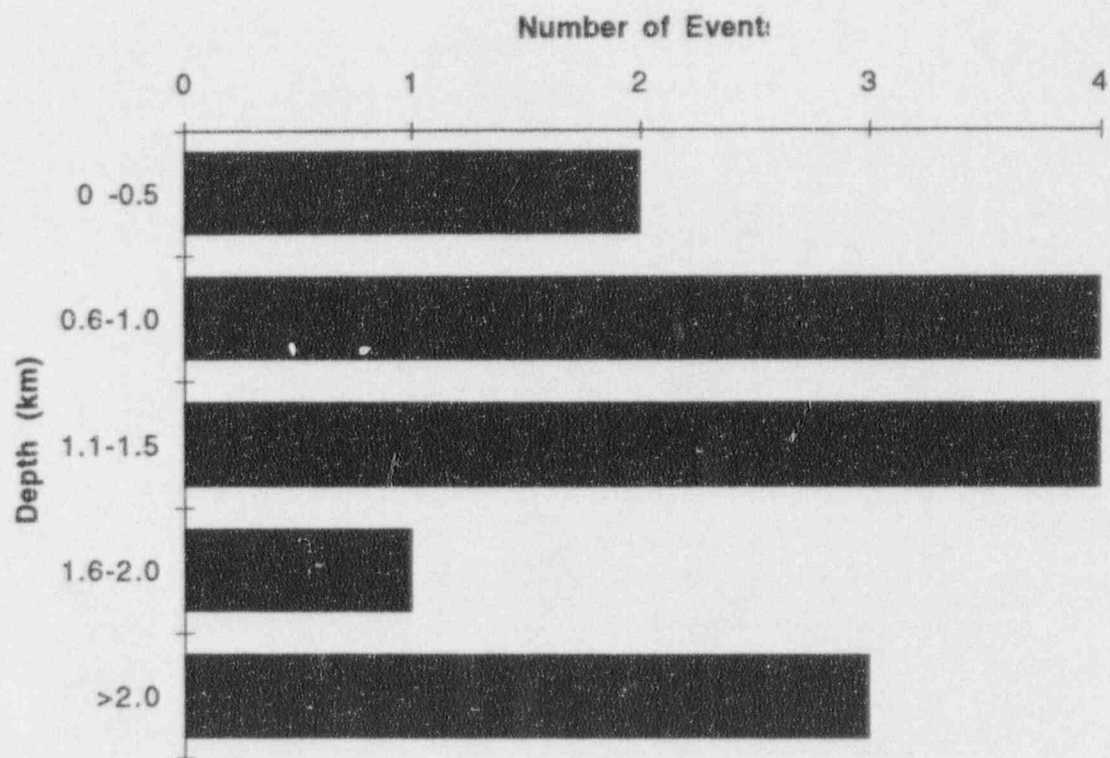


Figure 8. Depth distribution of seismicity at Monticello Reservoir during January 1 -December 31, 1992.

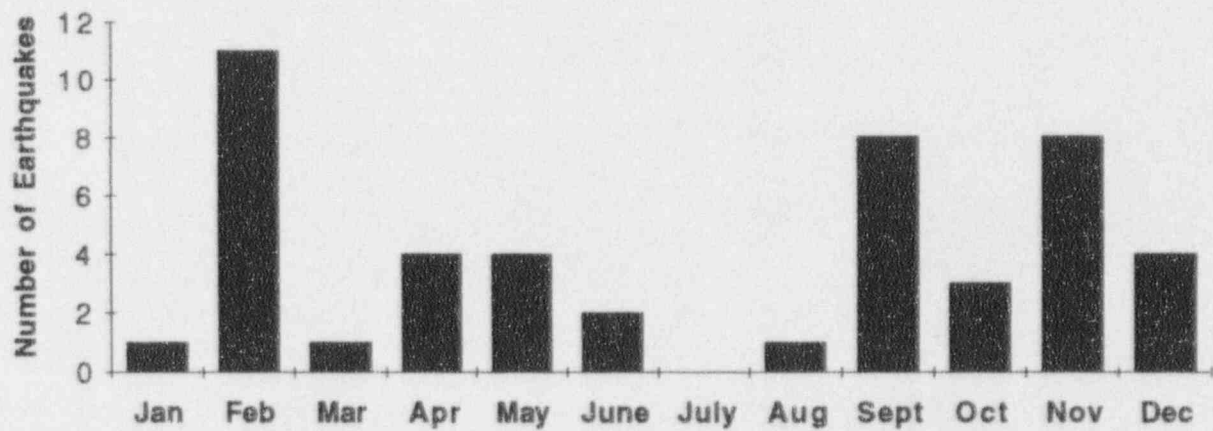


Figure 9. Distribution of earthquakes at Monticello Reservoir during January 1 - December 31, 1992.

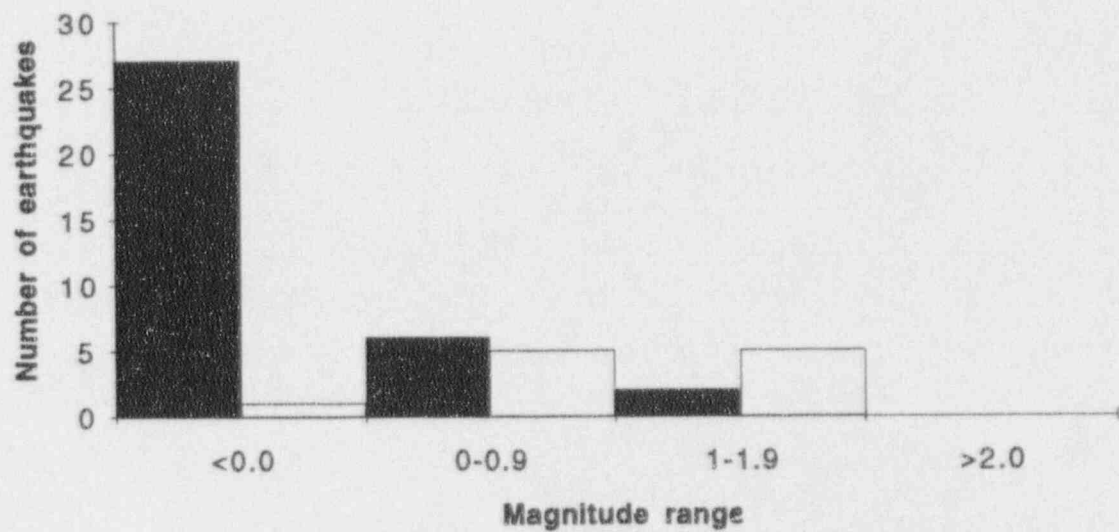


Figure 10. Magnitude ranges of earthquakes at Monticello Reservoir during January 1 - December 31, 1992. Solid and open bars indicate unlocated and located events respectively.

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, 1992

STATION	% DOWNTIME
MR01	4
MR02	3
MR05	4
MR07	4
MR10	0
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. $RMS = R_i^2 / N_o$, 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 1 - DECEMBER 31, 1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6	339	6.5	0.01	0.2	1.0 C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6	170	1.9	0.08	7.6	11.8 D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8	147	2.0	0.12	1.2	2.6 C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8	278	1.0	0.09	1.0	0.7 C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8	230	0.4	0.10	1.2	0.8 C1

APPENDIX VI

List of earthquakes with (S-P) \leq 2.5 seconds recorded around
Monticello Reservoir during October 1 - December 31, 1992.

Sl.No.	Date	Station	P-arrival	(S-P) Sec	Ep.Dist (S-P)x8.5	Dur Sec	Mag
1	92 11 04	JSC	19 34 09.00	0.6	5.1	10	0.2
2	92 11 04	JSC	19 37 11.00	0.6	5.1	8	0
3	92 11 11	JSC	17 09 03.80	0.5	4.3	6	-0.2
4	92 11 14	JSC	16 14 43.50	0.9	7.7	6	-0.2
5	92 11 17	JSC	21 12 29.00	1	8.5	7	-0.1
6	92 11 25	JSC	17 09 33.60	1	8.5	15	0.6
7	92 11 27	JSC	10 59 19.00	0.5	4.3	5	-0.4
8	92 12 29	JSC	23 12 52.00	0.2	1.7	3	-0.9
9	92 12 30	MR10	14 54 29.20	*		3.5	-0.6
10	92 12 30	MR10	14 54 54.1	*		5.5	
	*	JSC	14 54 55.4	1.1	9.4		-0.2

* Event too close to the station

APPENDIX VII

Maximum and minimum water levels, changes in water level, number of earthquakes and energy release in ergs at Monticello Reservoir during October 1 - December 31, 1992. Dates are given in Julian Calender.

Day	Wl(Min)	Wl(Max)	Wl(Avg)	Change	# of Eqs	Log E
275	424.4	424.8	424.4	0	0	0
276	423.9	424.8	424.4	0	0	0
277	423.9	424.5	424.2	-0.2	0	0
278	422.9	424.9	424.1	-0.1	0	0
279	423.2	424.7	424.5	0.4	1	13.57
280	423.3	424.6	424.1	-0.4	0	0
281	423.3	424.9	424	-0.1	0	0
282	423.5	424.7	424.2	0.2	0	0
283	424.2	424.9	424.8	0.6	0	0
284	424.7	424.9	424.8	0	0	0
285	424.3	425	424.8	0	0	0
286	423.4	424.6	424	-0.8	0	0
287	423.6	424.8	424	0	0	0
288	423.4	424.9	424.3	0.3	0	0
289	422.5	424.8	423.8	-0.5	0	0
290	422.8	424.5	423.7	-0.1	0	0
291	422.9	424	423.5	-0.2	0	0
292	423.5	424	423.5	0	0	0
293	422.8	424.8	423.7	0.2	0	0
294	423	424.3	423.4	-0.3	0	0
295	423.2	425	424.2	0.8	0	0
296	423.5	424.9	424.2	0	0	0
297	423.4	423.7	423.6	-0.6	0	0
298	423.4	424.3	424	0.4	0	0
299	423.5	424.1	424	0	1	11.64
300	423.2	424.8	424.1	0.1	0	0
301	423.6	424.7	424.3	0.2	0	0
302	422.8	424.5	423.8	-0.5	0	0
303	423.3	425	424.2	0.4	1	13.53
304	421.6	424.8	423.5	-0.7	0	0
305	421.7	424	422.7	-0.8	0	0
306	421.9	424.2	423.2	0.5	0	0
307	421.9	424.8	423.5	0.3	0	0
308	421.9	424	423.4	-0.1	0	0
309	422.7	424.5	423.8	0.4	2	12.41
310	422.4	424.8	423.6	-0.2	0	0
311	423	424.2	423.7	0.1	0	0
312	423.1	424.6	423.9	0.2	1	13.48
313	423.2	424.6	424.1	0.2	0	0
314	423.6	424.8	424.1	0	0	0
315	423.6	424.8	424.1	0	0	0
316	423.5	424.9	424.2	0.1	1	11.44
317	422.9	424.8	423.9	-0.3	0	0

Appendix VII cont'd.....

Day	WI(Min)	WI(Max)	WI(Avg)	Change	# of Eqs	Log E
318	423	424.8	424.1	0.2	0	0
319	423.4	424.8	424.3	0.2	1	11.44
320	423.6	424.9	424.4	0.1	0	0
321	422.6	424.8	423.5	-0.9	0	0
322	422.7	424.5	423.7	0.2	1	11.64
323	423.5	425	424.3	0.6	0	0
324	422.8	424.5	423.6	-0.7	0	0
325	423	424.9	424	0.4	0	0
326	423.7	424.9	424.2	0.2	0	0
327	423.4	425	424.1	-0.1	0	0
328	423.4	424.9	423.9	-0.2	0	0
329	423.7	424.9	424.4	0.5	0	0
330	423.5	425	424	-0.4	1	12.74
331	423.6	424.9	424.4	0.4	0	0
332	424.2	424.9	424.8	0.4	1	11.19
333	424.9	424.9	424.9	0.1	0	0
334	424.9	424.3	424.7	-0.2	0	0
335	423.5	424.9	424.1	-0.6	0	0
336	423.7	425	424.5	0.4	0	0
337	423.7	424.9	424.1	-0.4	0	0
338	423.3	424.7	424	-0.1	0	0
339	423.4	424.8	424.3	0.3	0	0
340	424.1	424.6	424.4	0.1	0	0
341	424.2	424.9	424.4	0	0	0
342	424.3	425	424.3	-0.1	0	0
343	423.6	424.9	424.2	-0.1	0	0
344	423.3	424.9	423.8	-0.4	1	12.46
345	423.5	422.9	423.0	0.1	0	0
346	423.7	424.9	424.3	0.4	0	0
347	424.2	424.5	424.5	0.2	0	0
348	424.1	424.5	424.3	-0.2	0	0
349	423.8	424.8	424.4	0.1	0	0
350	423.8	424.5	424.8	0.4	0	0
351	424.2	425	424.6	-0.2	0	0
352	423.6	425	424.3	-0.3	0	0
353	422.7	424.2	423.6	-0.7	0	0
354	422.1	423.5	422.9	-0.7	0	0
355	422.2	423.8	423.3	0.4	0	0
356	422.3	424.3	423.3	0	0	0
357	422.6	423.9	423.4	0.1	0	0
358	422.2	424.5	423.2	-0.2	0	0
359	422.3	424.5	423.8	0.6	0	0
360	422.7	424.1	423.6	-0.2	0	0
361	422.2	424.4	423.7	0.1	0	0
362	422.2	424	423.3	-0.4	0	0
363	424.1	424.9	424.5	1.2	0	0
364	424.1	424.1	424.1	-0.4	1	10.57
365	423.9	424.6	424.4	0.3	2	11.7
366	423.7	424.5	424.3	-0.1	0	0

APPENDIX VIII

MONTICELLO RESERVOIR EARTHQUAKES JANUARY 1 - DECEMBER 31,1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
920225	1337	42.78	34-20.00	81-18.64	1.18	1.02	10	159	2.5	0.08	0.5	1.9 B1
920226	1010	10.46	34-19.79	81-18.74	1.31	0.21	10	153	2.4	0.10	0.4	1.3 B1
920315	8 0	47.48	34-20.07	81-18.68	0.97	0.82	10	159	2.4	0.06	0.3	1.7 B1
920402	1714	29.62	34-22.33	81-20.66	1.00	1.02	7	281	1.8	0.15	2.9	4.5 D1
920429	1810	2.98	34-23.60	81-17.18	4.90	0.82	7	292	4.4	0.15	3.6	2.7 D1
920521	1431	33.09	34-20.01	81-18.79	0.42	0.21	7	111	1.6	0.08	0.8	2.1 B1
920529	1654	44.12	34-24.09	81-22.80	2.79	1.02	8	333	6.1	0.07	1.2	1.6 C1
920825	17 4	57.66	34-24.50	81-24.40	0.69	1.02	7	333	8.6	0.23		5.4 D1
920908	1755	43.74	34-21.98	81-16.80	2.00	0.82	6	253	4.2	0.08	1.2	3.6 D1
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6	339	6.5	0.01	0.2	1.0 C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6	170	1.9	0.03	7.6	11.8 D1
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The long term decline in seismicity observed at Monticello Reservoir is continuing (Figure 3). The cumulative seismicity at Monticello Reservoir shows a 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 Appendices V and VI. The average water level, daily changes in water level, number of earthquakes and energy release are given in Appendix VII. No systematic correlation was observed between the seismicity and reservoir level fluctuations.

CONCLUSIONS

There was no unusual seismic activity during the fourth quarter of 1992. The largest recorded magnitude was $M_L=1.18$. The seismicity was scattered, both temporally and spatially. No systematic correlation was observed between the reservoir level fluctuations and the seismicity.

MONTICELLO NETWORK AND SEISMICITY DURING 1992

Station Operational Status

The operational status of the Monticello Network during 1992 is presented in Figure 6. Most of the stations of the network were fully operational during the year. Only station MR05 was down for significant periods during the third quarter of the year.

Seismicity

A total of 47 events were recorded around the Monticello Reservoir area during 1992, of which 14 were located (Appendix VIII; Figure 7). Six of the located events occurred in the center of the lake at shallow focal depth (< 2.0 km). Scattered activity was observed in the northern and north western parts of the lake. Most of the located

earthquakes occurred at shallow depths, with maximum activity occurring at depths ≤ 1.5 km (Fig. 8). The temporal distribution of seismicity is shown in Figure 9.

The unlocatable events were generally of short duration and not recorded on more than one or two stations. The magnitude range of the located and unlocatable events are shown in Figure 10. Most of the unlocatable events were of magnitude < 0.0 . Most of the locatable events during 1992 were in the magnitude range of 0-1.0. The higher detection and location capabilities are attributed to the improved operation of the network, particularly the digital recording on the Puffin computer.

In conclusion, the activity during 1992 was not particularly different from the past several years and remained at a relatively low level. There were 7 events of magnitude $M_L \geq 1.0$ during 1992, with the largest event of magnitude $M_L = 1.18$ occurring on October 5, 1992. The long term decline in the activity is continuing. Only in the middle of the lake was there any repeated activity. A larger percent of smaller events have been located, with improved operation of the stations.

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 Seismic Network

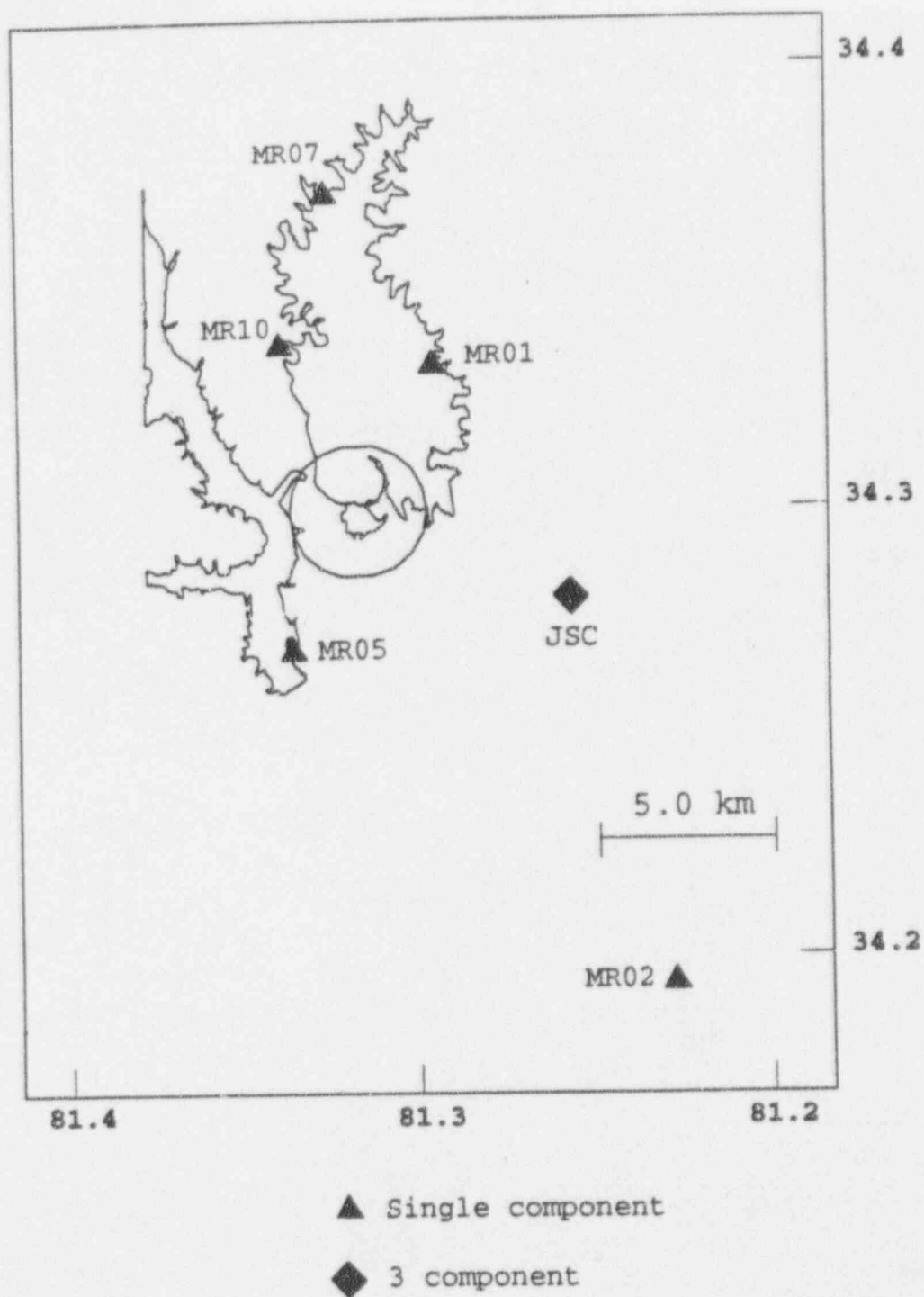


Figure 1. Monticello Reservoir area showing locations of seismic stations used to locate seismicity.

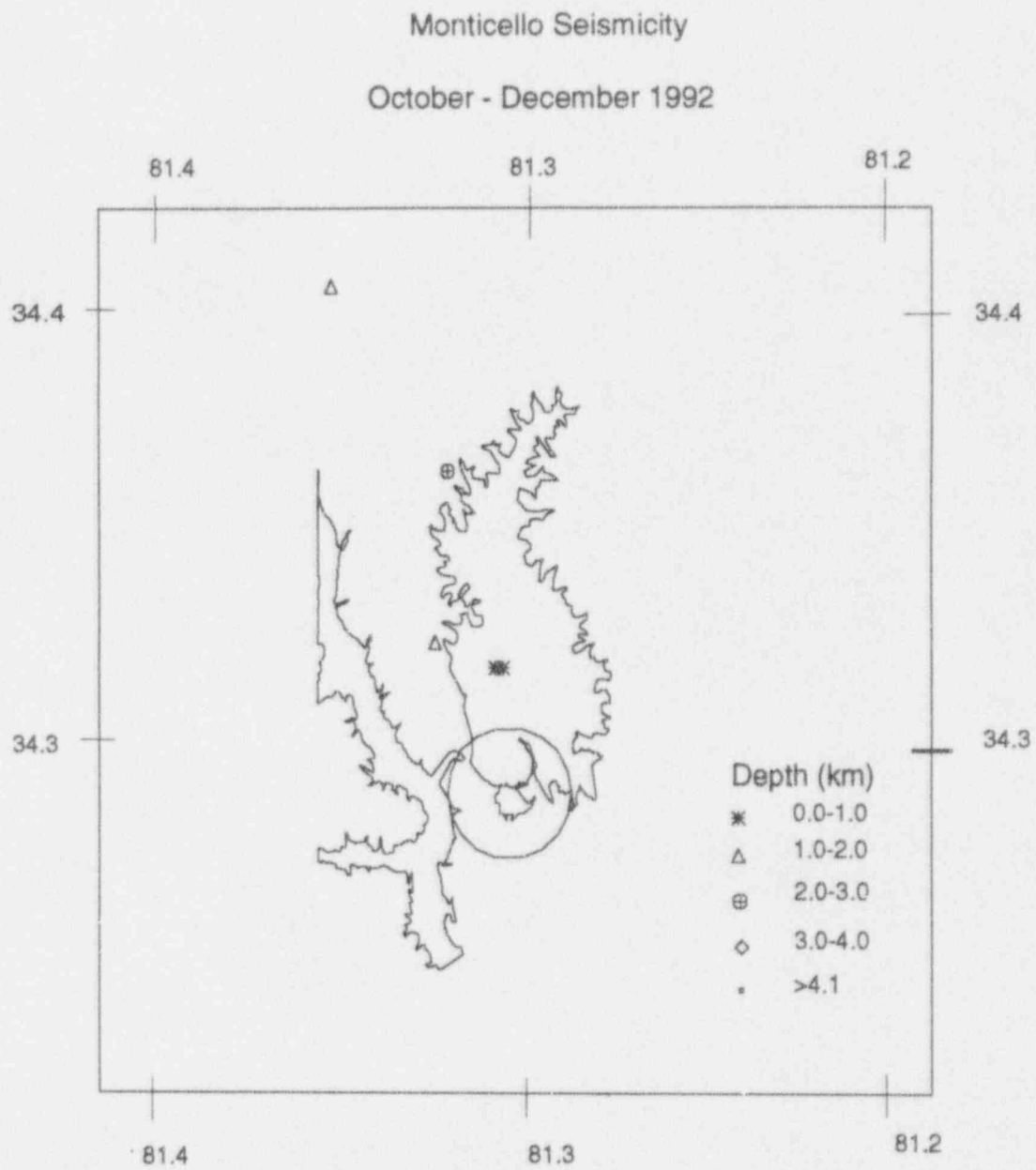


Figure 2. Earthquakes located near Monticello Reservoir during the period October 1 - December 31, 1992

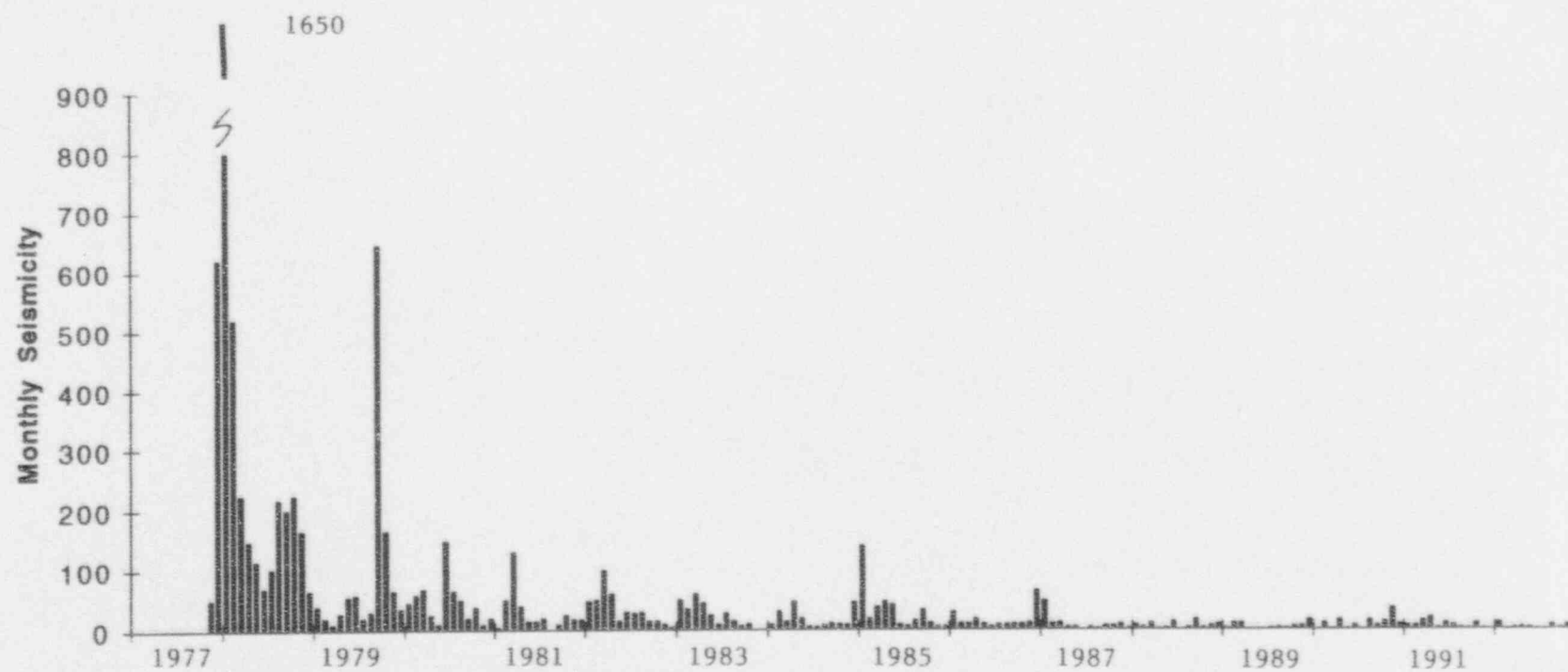


Figure 3. Earthquakes between impoundment and December 1992.

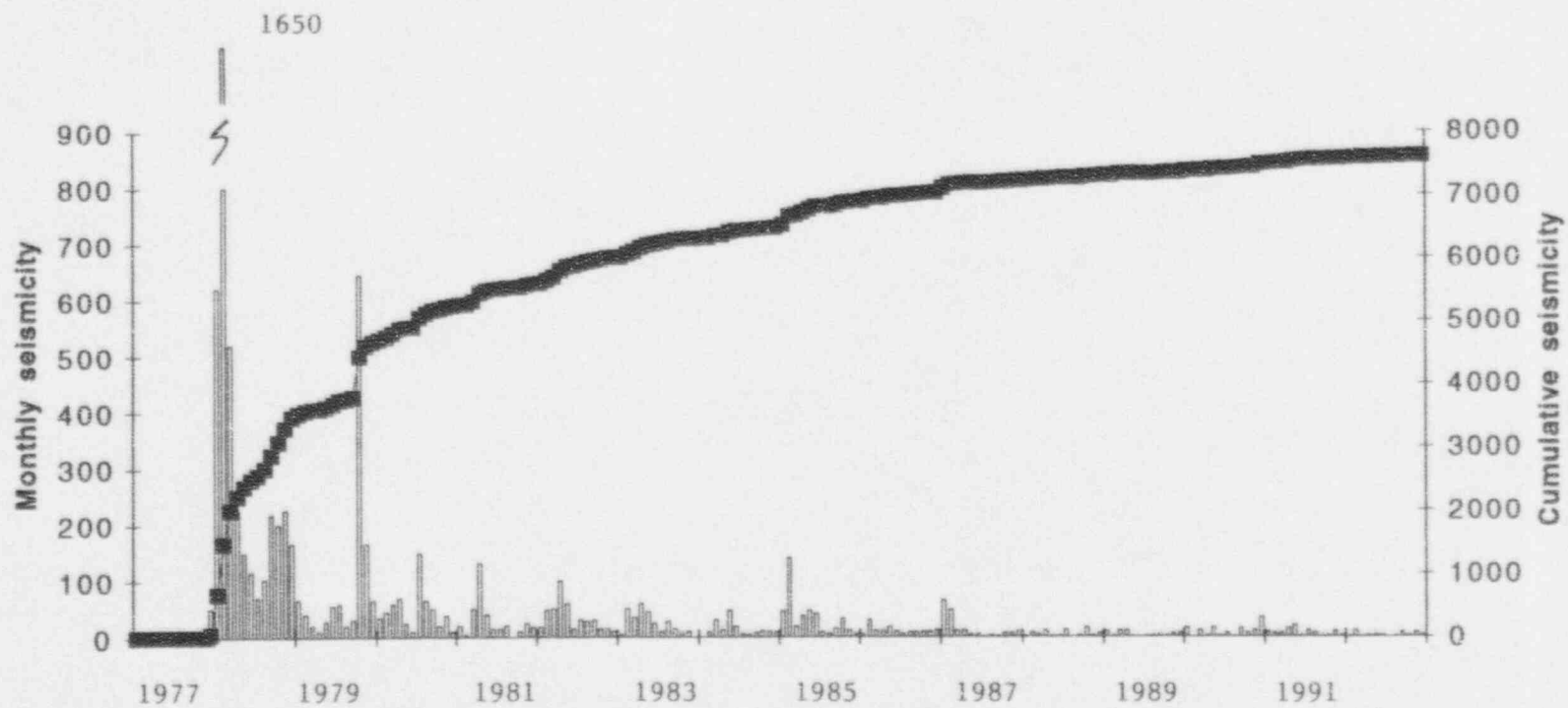


Figure 4. Monthly seismicity (bars) and cumulative seismicity (line) near Monticello Reservoir since impoundment

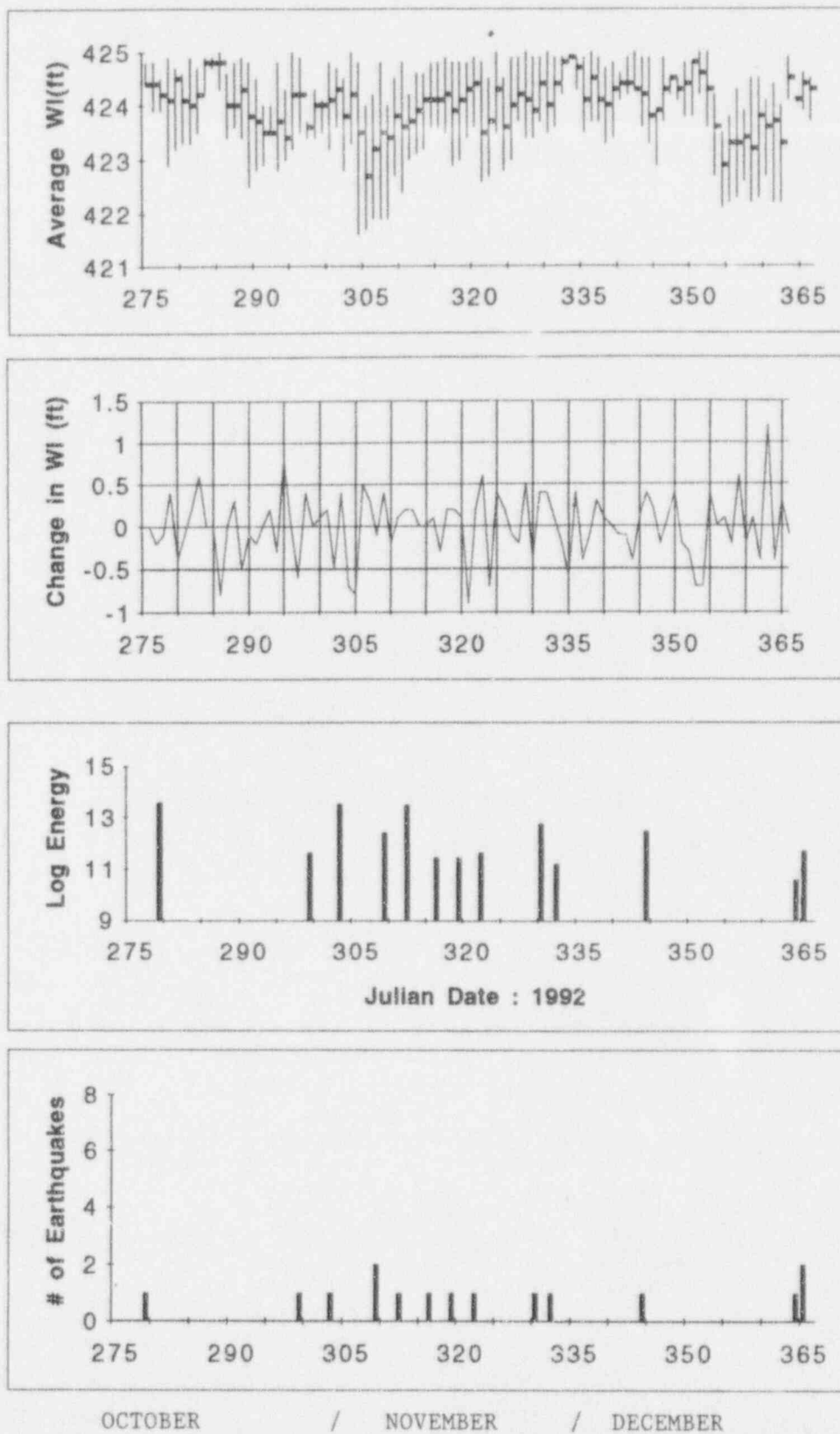


Figure 5. Comparison of daily lake level, changes in lake level, number of earthquakes and log of energy release in ergs per day at Monticello Reservoir. Error bars in the top panel indicate daily fluctuations in water level.

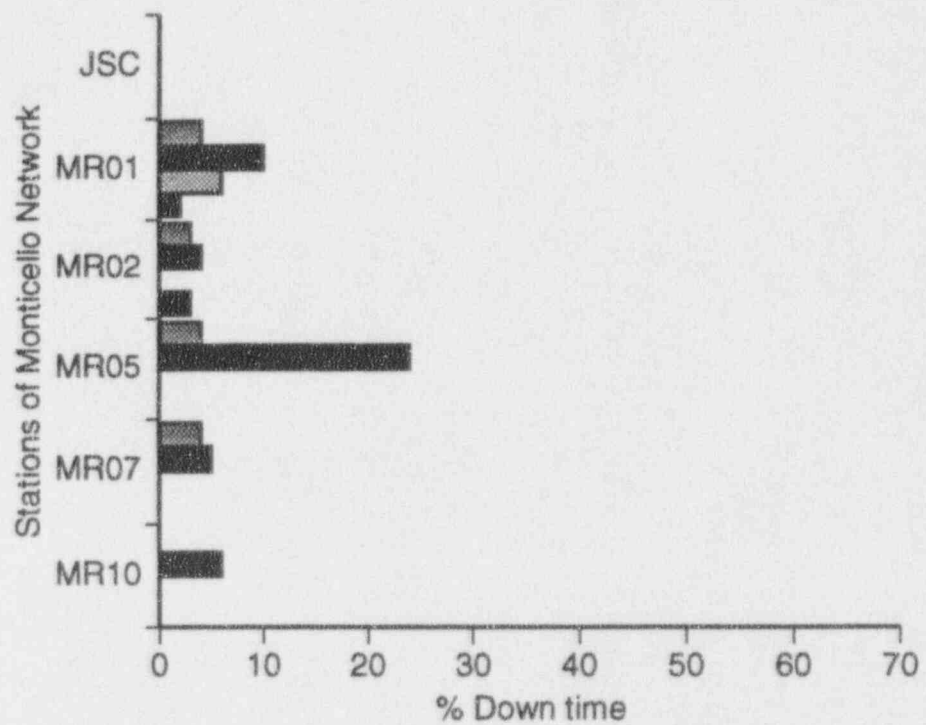


Figure 6. Operational status of Monticello Network during 1992. Four bars from bottom to top correspond to the four quarters.

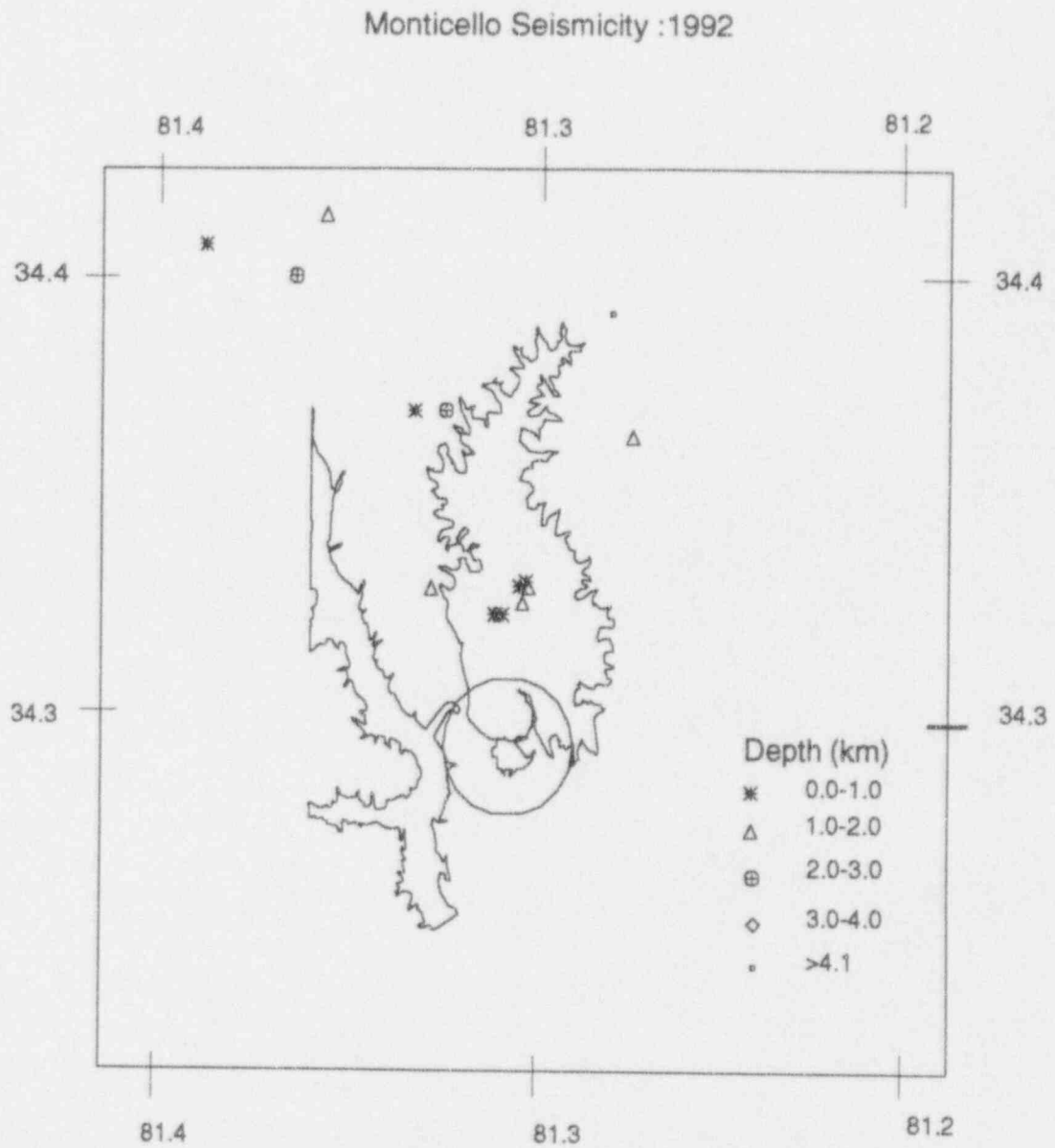


Figure 7. Earthquakes located near Monticello Reservoir during January - December, 1992.

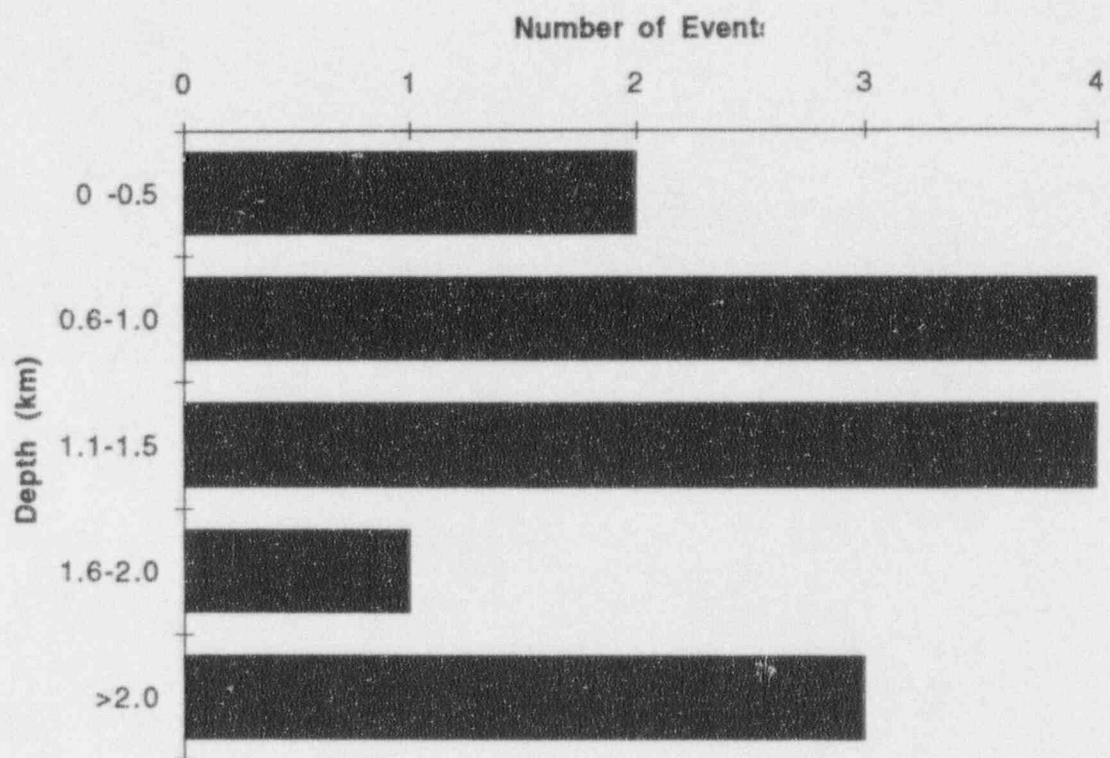


Figure 8. Depth distribution of seismicity at Monticello Reservoir during January 1 -December 31, 1992.

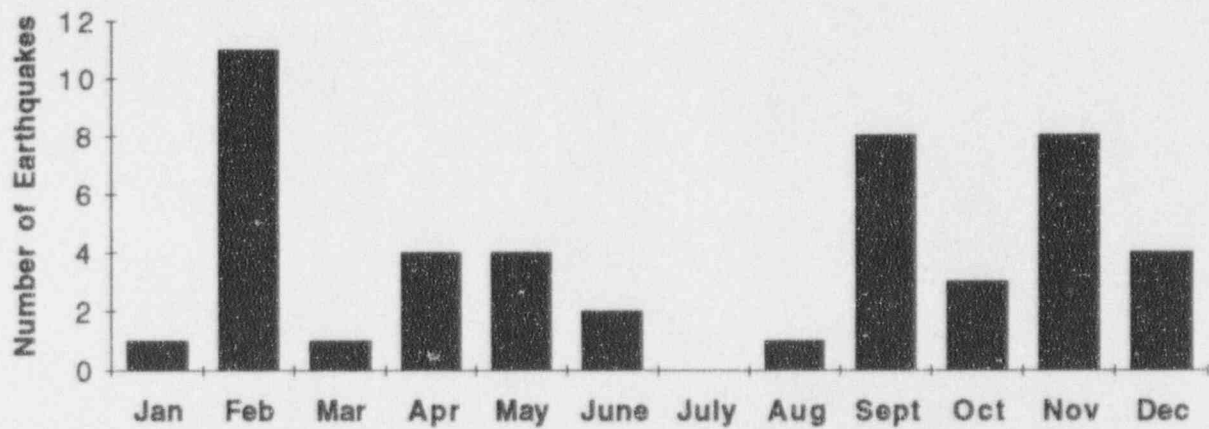


Figure 9. Distribution of earthquakes at Monticello Reservoir during January 1 - December 31, 1992.

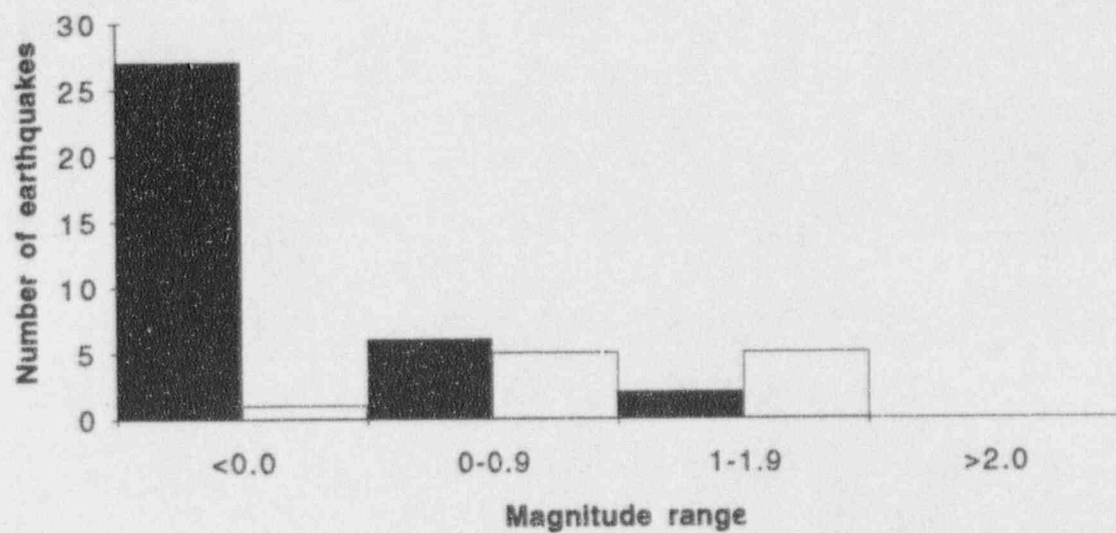


Figure 10. Magnitude ranges of earthquakes at Monticello Reservoir during January 1 - December 31, 1992. Solid and open bars indicate unlocated and located events respectively.

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, 1992

STATION	% DOWNTIME
MR01	4
MR02	3
MR05	4
MR07	4
MR10	0
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 1 - DECEMBER 31, 1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM	
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6	339	6.5	0.01	0.2	1.0	C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6	170	1.9	0.08	7.6	11.8	D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8	147	2.0	0.12	1.2	2.6	C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8	278	1.0	0.09	1.0	0.7	C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8	230	0.4	0.10	1.2	0.8	C1

APPENDIX VI

List of earthquakes with (S-P) \leq 2.5 seconds recorded around
Monticello Reservoir during October 1 - December 31, 1992.

Sl.No.	Date	Station	P-arrival	(S-P) Sec	Ep.Dist (S-P)x8.5	Dur Sec	Mag
1	92 11 04	JSC	19 34 09.00	0.6	5.1	10	0.2
2	92 11 04	JSC	19 37 11.00	0.6	5.1	8	0
3	92 11 11	JSC	17 09 03.80	0.5	4.3	6	-0.2
4	92 11 14	JSC	16 14 43.50	0.9	7.7	6	-0.2
5	92 11 17	JSC	21 12 29.00	1	8.5	7	-0.1
6	92 11 25	JSC	17 09 33.60	1	8.5	15	0.6
7	92 11 27	JSC	10 59 19.00	0.5	4.3	5	-0.4
8	92 12 29	JSC	23 12 52.00	0.2	1.7	3	-0.9
9	92 12 30	MR10	14 54 29.20	*		3.5	-0.6
10	92 12 30	MR10	14 54 54.1	*		5.5	
	"	JSC	14 54 55.4	1.1	9.4		-0.2

* Event too close to the station

APPENDIX VII

Maximum and minimum water levels, changes in water level, number of earthquakes and energy release in ergs at Monticello Reservoir during October 1 - December 31, 1992. Dates are given in Julian Calender.

Day	Wl(Min)	Wl(Max)	Wl(Avg)	Change	# of Eqs	Log E
275	424.4	424.8	424.4	0	0	0
276	423.9	424.8	424.4	0	0	0
277	423.9	424.5	424.2	-0.2	0	0
278	422.9	424.9	424.1	-0.1	0	0
279	423.2	424.7	424.5	0.4	1	13.57
280	423.3	424.6	424.1	-0.4	0	0
281	423.3	424.9	424	-0.1	0	0
282	423.5	424.7	424.2	0.2	0	0
283	424.2	424.9	424.8	0.6	0	0
284	424.7	424.9	424.8	0	0	0
285	424.3	425	424.8	0	0	0
286	423.4	424.6	424	-0.8	0	0
287	423.6	424.8	424	0	0	0
288	423.4	424.9	424.3	0.3	0	0
289	422.5	424.8	423.8	-0.5	0	0
290	422.8	424.5	423.7	-0.1	0	0
291	422.9	424	423.5	-0.2	0	0
292	423.5	424	423.5	0	0	0
293	422.8	424.8	423.7	0.2	0	0
294	423	424.3	423.4	-0.3	0	0
295	423.2	425	424.2	0.8	0	0
296	423.5	424.9	424.2	0	0	0
297	423.4	423.7	423.6	-0.6	0	0
298	423.4	424.3	424	0.4	0	0
299	423.5	424.1	424	0	1	11.64
300	423.2	424.8	424.1	0.1	0	0
301	423.6	424.7	424.3	0.2	0	0
302	422.8	424.5	423.8	-0.5	0	0
303	423.3	425	424.2	0.4	1	13.53
304	421.6	424.8	423.5	-0.7	0	0
305	421.7	424	422.7	-0.8	0	0
306	421.9	424.2	423.2	0.5	0	0
307	421.9	424.8	423.5	0.3	0	0
308	421.9	424	423.4	-0.1	0	0
309	422.7	424.5	423.8	0.4	2	12.41
310	422.4	424.8	423.6	-0.2	0	0
311	423	424.2	423.7	0.1	0	0
312	423.1	424.6	423.9	0.2	1	13.48
313	423.2	424.6	424.1	0.2	0	0
314	423.6	424.8	424.1	0	0	0
315	423.6	424.8	424.1	0	0	0
316	423.5	424.9	424.2	0.1	1	11.44
317	422.9	424.8	423.9	-0.3	0	0

Appendix VII cont'd.....

Day	WI(Min)	WI(Max)	WI(Avg)	Change	# of Eqs	Log E
318	423	424.8	424.1	0.2	0	0
319	423.4	424.8	424.3	0.2	1	11.44
320	423.6	424.9	424.4	0.1	0	0
321	422.6	424.8	423.5	-0.9	0	0
322	422.7	424.5	423.7	0.2	1	11.64
323	423.5	425	424.3	0.6	0	0
324	422.8	424.5	423.6	-0.7	0	0
325	423	424.9	424	0.4	0	0
326	423.7	424.9	424.2	0.2	0	0
327	423.4	425	424.1	-0.1	0	0
328	423.4	424.9	423.9	-0.2	0	0
329	423.7	424.9	424.4	0.5	0	0
330	423.5	425	424	-0.4	1	12.74
331	423.6	424.9	424.4	0.4	0	0
332	424.2	424.9	424.8	0.4	1	11.19
333	424.9	424.9	424.9	0.1	0	0
334	424.9	424.3	424.7	-0.2	0	0
335	423.5	424.9	424.1	-0.6	0	0
336	423.7	425	424.5	0.4	0	0
337	423.7	424.9	424.1	-0.4	0	0
338	423.3	424.7	424	-0.1	0	0
339	423.4	424.8	424.3	0.3	0	0
340	424.1	424.6	424.4	0.1	0	0
341	424.2	424.9	424.4	0	0	0
342	424.3	425	424.3	-0.1	0	0
343	423.6	424.9	424.2	-0.1	0	0
344	423.3	424.9	423.8	-0.4	1	12.46
345	423.5	422.9	423.9	0.1	0	0
346	423.7	424.9	424.3	0.4	0	0
347	424.2	424.5	424.5	0.2	0	0
348	424.1	424.5	424.3	-0.2	0	0
349	423.8	424.8	424.4	0.1	0	0
350	423.8	424.5	424.8	0.4	0	0
351	424.2	425	424.6	-0.2	0	0
352	423.6	425	424.3	-0.3	0	0
353	422.7	424.2	423.6	-0.7	0	0
354	422.1	423.5	422.9	-0.7	0	0
355	422.2	423.8	423.3	0.4	0	0
356	422.3	424.3	423.3	0	0	0
357	422.6	423.9	423.4	0.1	0	0
358	422.2	424.5	423.2	-0.2	0	0
359	422.3	424.5	423.8	0.6	0	0
360	422.7	424.1	423.6	-0.2	0	0
361	422.2	424.4	423.7	0.1	0	0
362	422.2	424	423.3	-0.4	0	0
363	424.1	424.9	424.5	1.2	0	0
364	424.1	424.1	424.1	-0.4	1	10.57
365	423.9	424.6	424.4	0.3	2	11.7
366	423.7	424.5	424.3	-0.1	0	0

APPENDIX VIII

MONTICELLO RESERVOIR EARTHQUAKES JANUARY 1 - DECEMBER 31,1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
920225	1337	42.78	34-20.00	81-18.64	1.18	1.02	10 159	2.5	0.08	0.5	1.9	B1
920226	1010	10.46	34-19.79	81-18.74	1.31	0.21	10 153	2.4	0.10	0.4	1.3	B1
920315	8 0	47.48	34-20.07	81-18.68	0.97	0.82	10 159	2.4	0.06	0.3	1.7	B1
920402	1714	29.62	34-22.33	81-20.66	1.00	1.02	7 281	1.8	0.15	2.9	4.5	D1
920429	1810	2.98	34-23.60	81-17.18	4.90	0.82	7 292	4.4	0.15	3.6	2.7	D1
920521	1431	33.09	34-20.01	81-18.79	0.42	0.21	7 111	1.6	0.08	0.8	2.1	B1
920529	1654	44.12	34-24.09	81-22.80	2.79	1.02	8 333	6.1	0.07	1.2	1.6	C1
920825	17 4	57.66	34-24.50	81-24.40	0.69	1.02	7 333	8.6	0.23		5.4	D1
920908	1755	43.74	34-21.98	81-16.80	2.00	0.82	6 253	4.2	0.08	1.2	3.6	D1
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6 339	6.5	0.01	0.2	1.0	C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6 170	1.9	0.03	7.6	11.8	D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8 147	2.0	0.12	1.2	2.6	C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8 278	1.0	0.09	1.0	0.7	C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8 230	0.4	0.10	1.2	0.8	C1

TECHNICAL REPORT 92-4

SEISMIC ACTIVITY NEAR THE
V.C. SUMMER NUCLEAR STATION

FOR THE PERIOD
OCTOBER - DECEMBER 1992

BY

PRADEEP TALWANI
Principal Investigator

DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA, SOUTH CAROLINA 29208

CONTRACT NO. N574984

TECHNICAL REPORT 92-4

**SEISMIC ACTIVITY NEAR THE
V.C. SUMMER NUCLEAR STATION**

FOR THE PERIOD

October - December 1992

BY

PRADEEP TALWANI
Principal Investigator

Kusala Rajendran

and

Katherine Ulmer

**DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA, SOUTH CAROLINA 29208**

CONTRACT NO. N574984

INTRODUCTION

Analysis of the seismic activity near the V.C. Summer Nuclear Station in South Carolina between October 1 and December 31, 1992 is presented in this report. During this period, 15 events were recorded in the vicinity of Monticello Reservoir, 5 of which were located. There were three events of magnitude $M_L \geq 1.1$.

A review of seismic activity during the year 1992 is also presented in this report. The level of activity and its spatial distribution are discussed. A performance report of various stations of the network during the past year is also presented in this report.

SEISMIC NETWORK

Earthquakes during this period were recorded on stations of Monticello Reservoir and South Carolina Seismic Network. The configuration of stations utilized to locate Monticello 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 the computer program HYPO71 (Lee and Lahr, 1972). The velocity model used in the earthquake locations is given in Appendix III. The format of the 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, 1992

There was no unusual seismic activity around Monticello Reservoir during the last quarter of 1992. A total of 15 events were recorded, of which five were located (Appendix V; Figure 2). The located events were of poor quality (C or D). The largest event in the quarter occurred on October 05 (19:59:01.06 UTC) and it had a magnitude $M_L = 1.18$. This event occurred to the northwest of the lake. The other located events occurred in the middle and around the west side of the lake.

Eight of the 15 events of this quarter occurred during the month of November. These occurred within an epicentral distance of < 9 km from JSC. The earthquakes that could not be located were of short duration and were generally recorded on only one station (Appendix VI)

The long term decline in seismicity observed at Monticello Reservoir is continuing (Figure 3). The cumulative seismicity at Monticello Reservoir shows a 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 Appendices V and VI. The average water level, daily changes in water level, number of earthquakes and energy release are given in Appendix VII. No systematic correlation was observed between the seismicity and reservoir level fluctuations.

CONCLUSIONS

There was no unusual seismic activity during the fourth quarter of 1992. The largest recorded magnitude was $M_L=1.18$. The seismicity was scattered, both temporally and spatially. No systematic correlation was observed between the reservoir level fluctuations and the seismicity.

MONTICELLO NETWORK AND SEISMICITY DURING 1992

Station Operational Status

The operational status of the Monticello Network during 1992 is presented in Figure 6. Most of the stations of the network were fully operational during the year. Only station MR05 was down for significant periods during the third quarter of the year.

Seismicity

A total of 47 events were recorded around the Monticello Reservoir area during 1992, of which 14 were located (Appendix VIII; Figure 7). Six of the located events occurred in the center of the lake at shallow focal depth (< 2.0 km). Scattered activity was observed in the northern and north western parts of the lake. Most of the located

earthquakes occurred at shallow depths, with maximum activity occurring at depths ≤ 1.5 km (Fig. 8). The temporal distribution of seismicity is shown in Figure 9.

The unlocatable events were generally of short duration and not recorded on more than one or two stations. The magnitude range of the located and unlocatable events are shown in Figure 10. Most of the unlocatable events were of magnitude < 0.0 . Most of the locatable events during 1992 were in the magnitude range of 0-1.0. The higher detection and location capabilities are attributed to the improved operation of the network, particularly the digital recording on the Puffin computer.

In conclusion, the activity during 1992 was not particularly different from the past several years and remained at a relatively low level. There were 7 events of magnitude $M_L \geq 1.0$ during 1992, with the largest event of magnitude $M_L = 1.18$ occurring on October 5, 1992. The long term decline in the activity is continuing. Only in the middle of the lake was there any repeated activity. A larger percent of smaller events have been located, with improved operation of the stations.

REFERENCES

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Monticello Reservoir Seismic Network

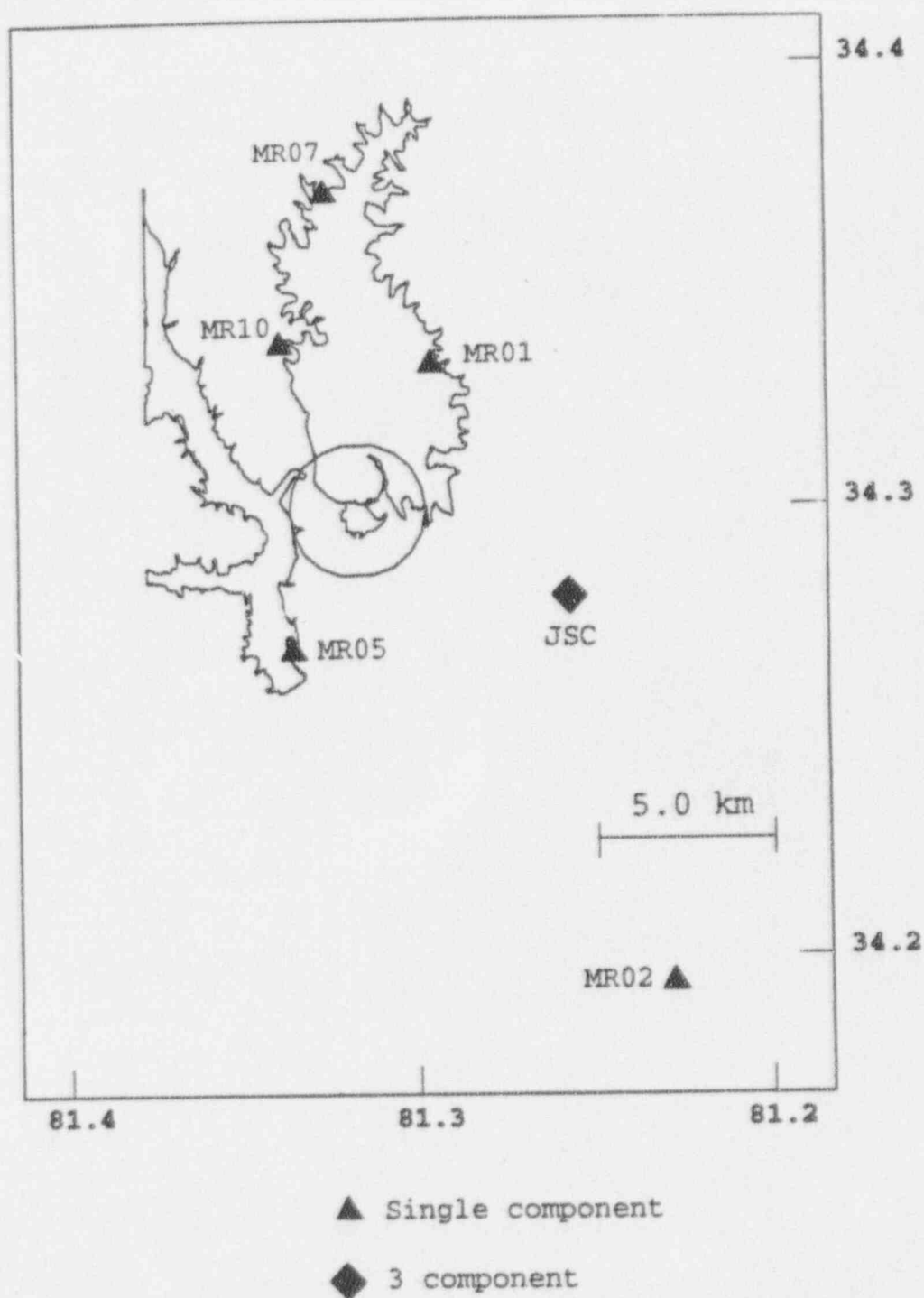


Figure 1. Monticello Reservoir area showing locations of seismic stations used to locate seismicity.

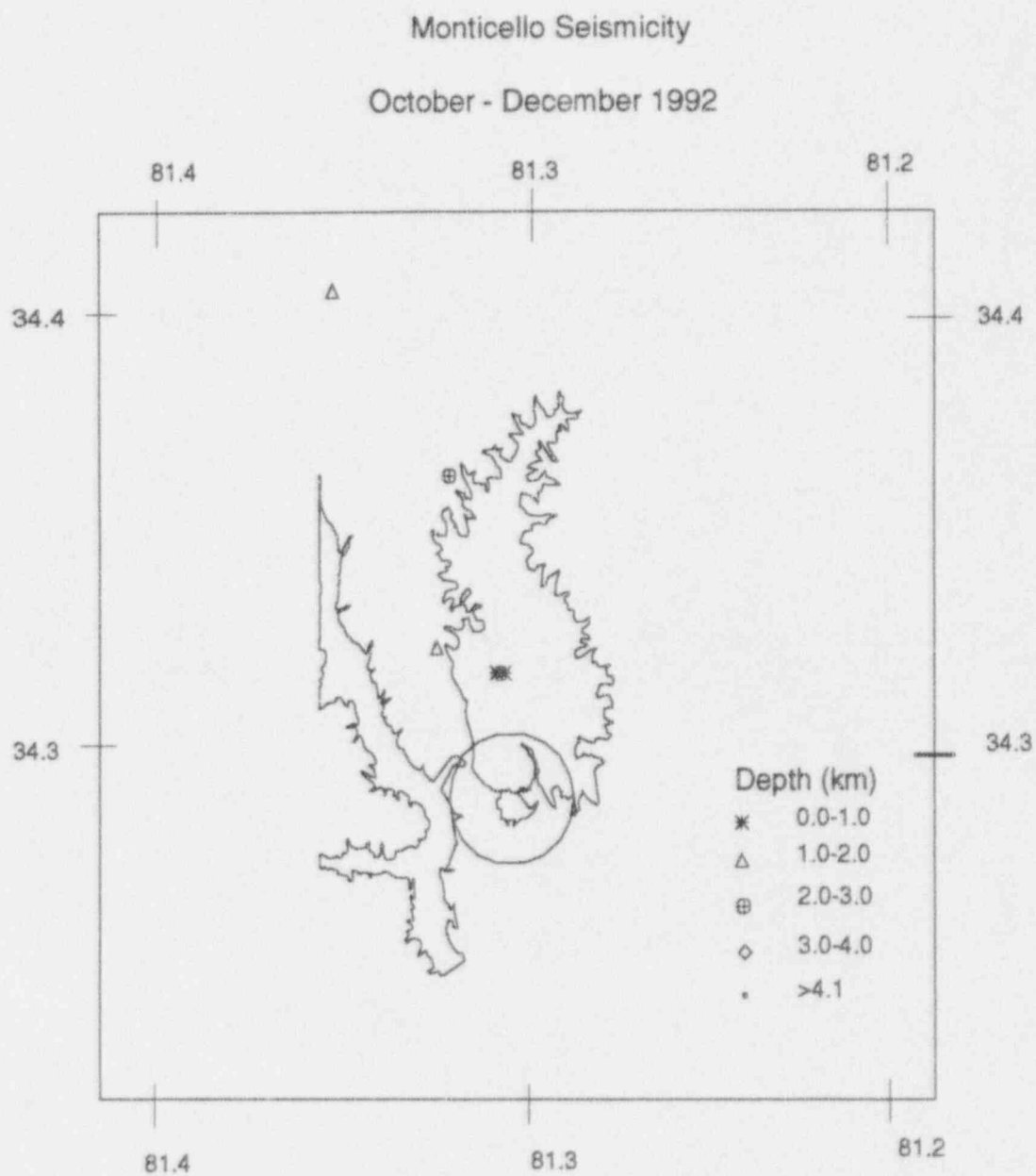


Figure 2. Earthquakes located near Monticello Reservoir during the period October 1 - December 31, 1992

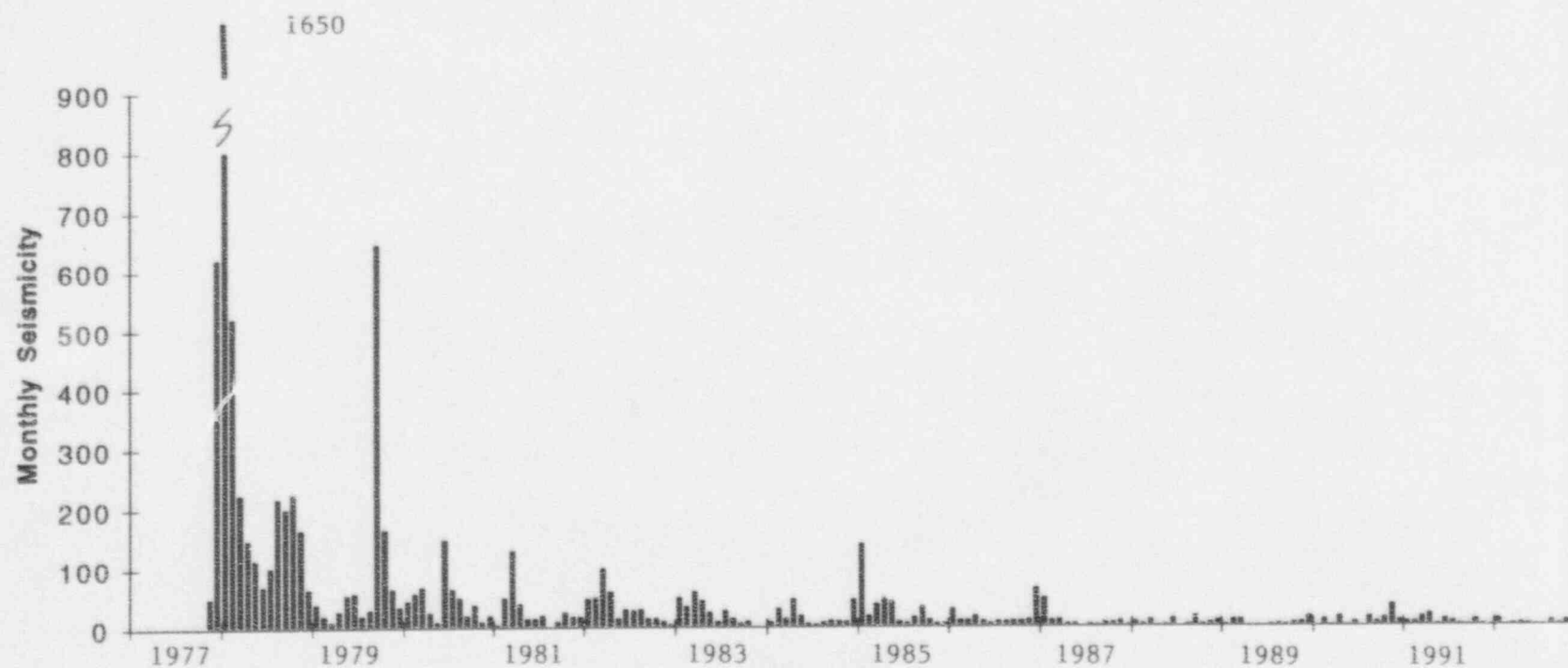


Figure 3. Earthquakes between impoundment and December 1992.

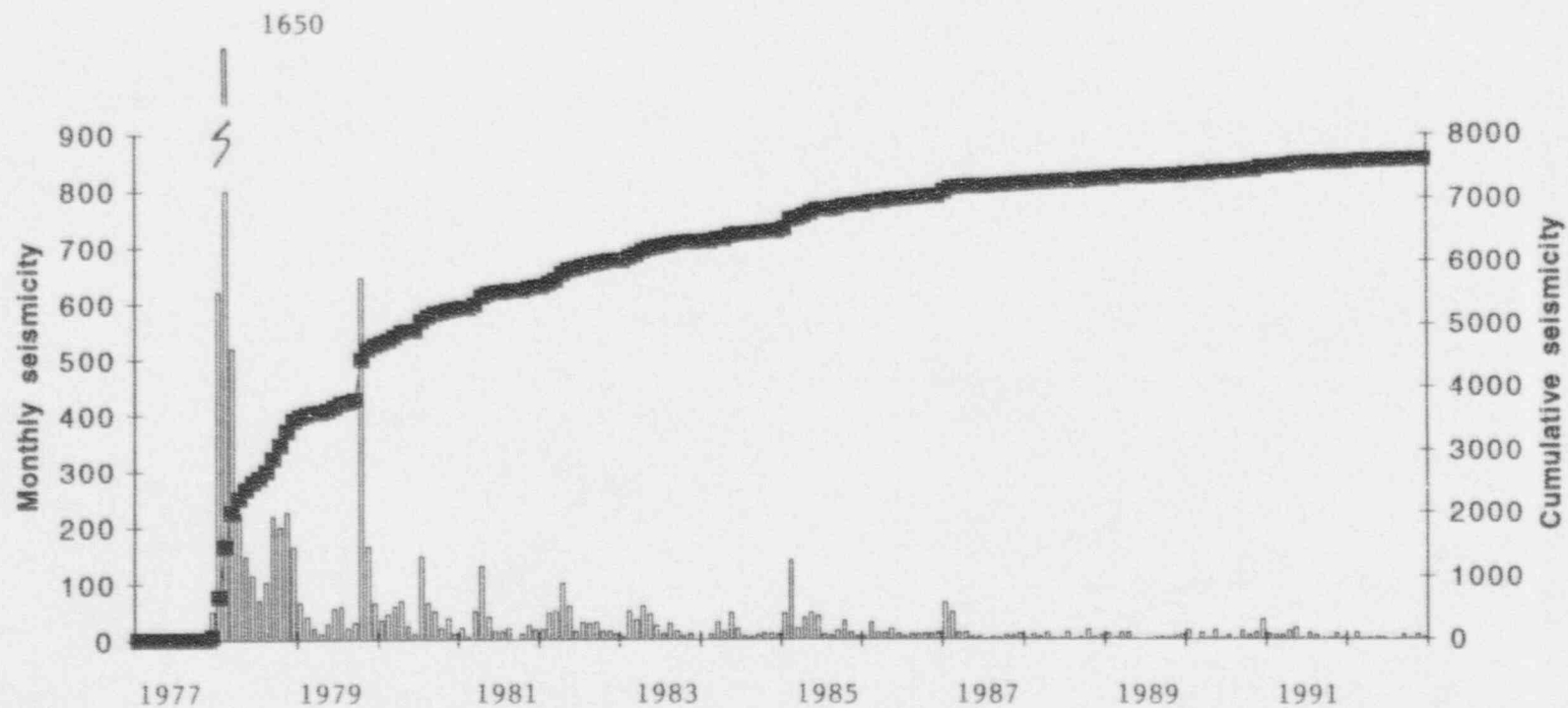


Figure 4. Monthly seismicity (bars) and cumulative seismicity (line) near Monticello Reservoir since impoundment

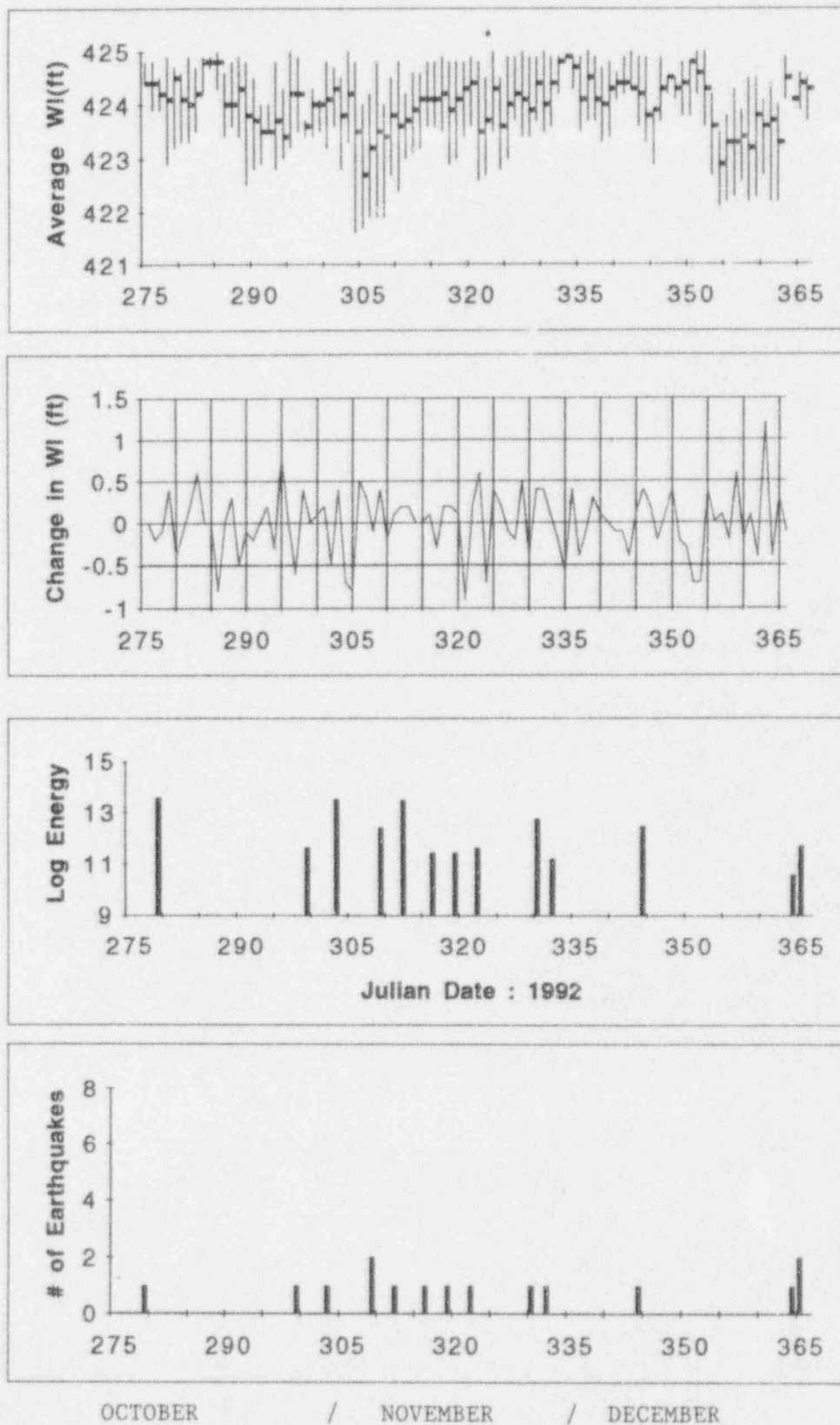


Figure 5. Comparison of daily lake level, changes in lake level, number of earthquakes and log of energy release in ergs per day at Monticello Reservoir. Error bars in the top panel indicate daily fluctuations in water level.

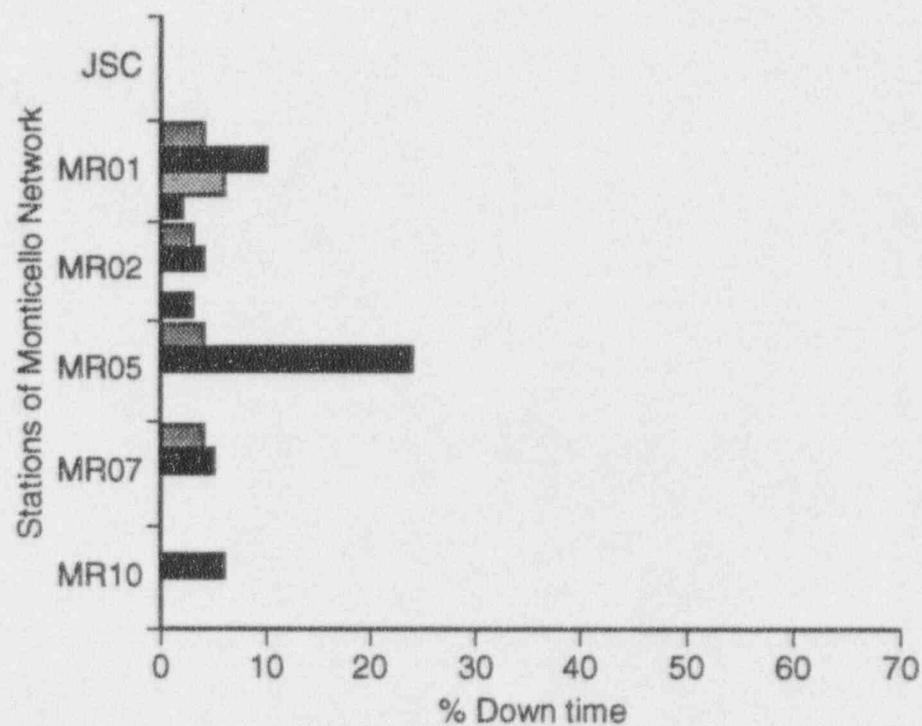


Figure 6. Operational status of Monticello Network during 1992. Four bars from bottom to top correspond to the four quarters.

Monticello Seismicity :1992

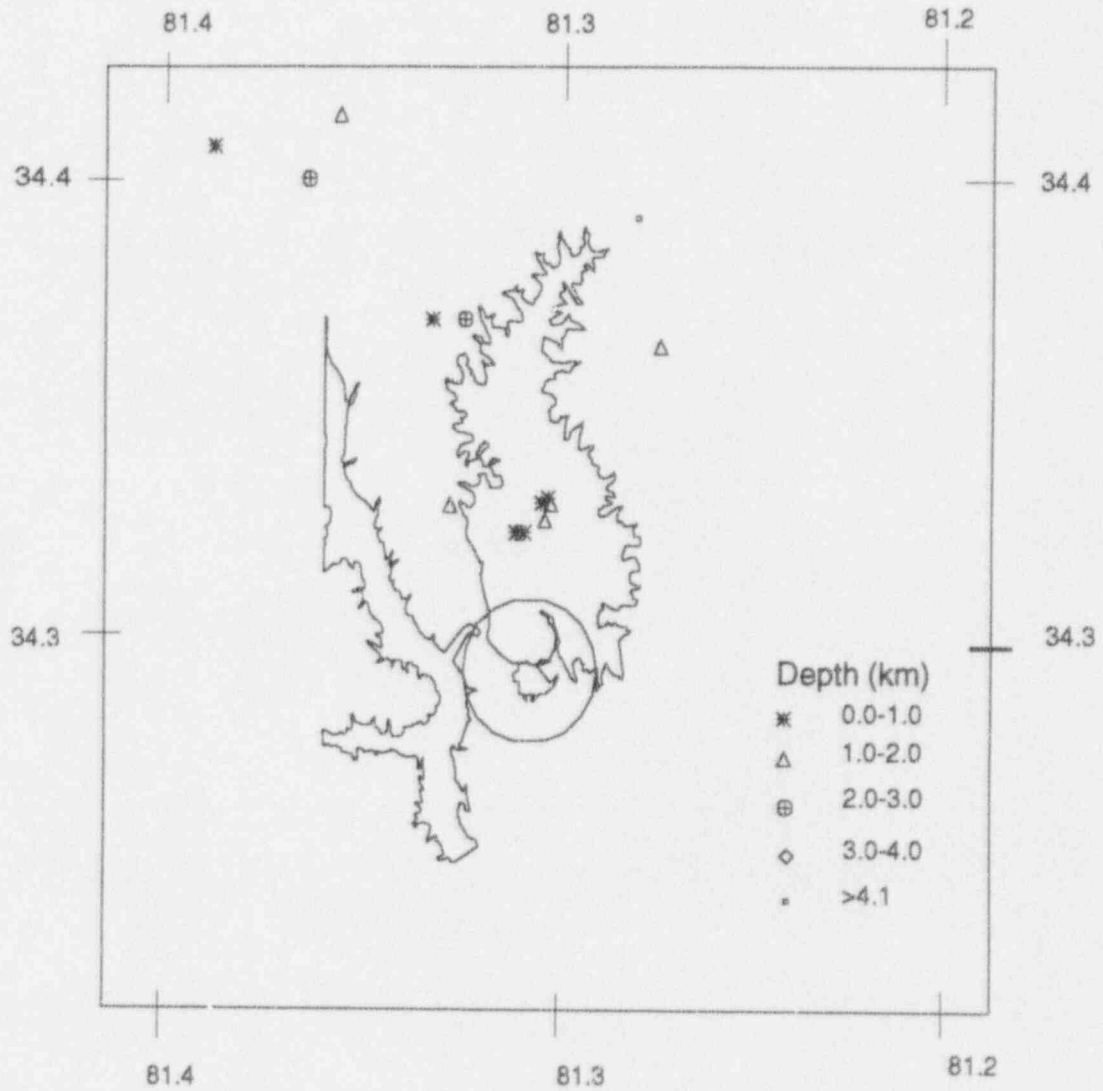


Figure 7. Earthquakes located near Monticello Reservoir during January - December, 1992.

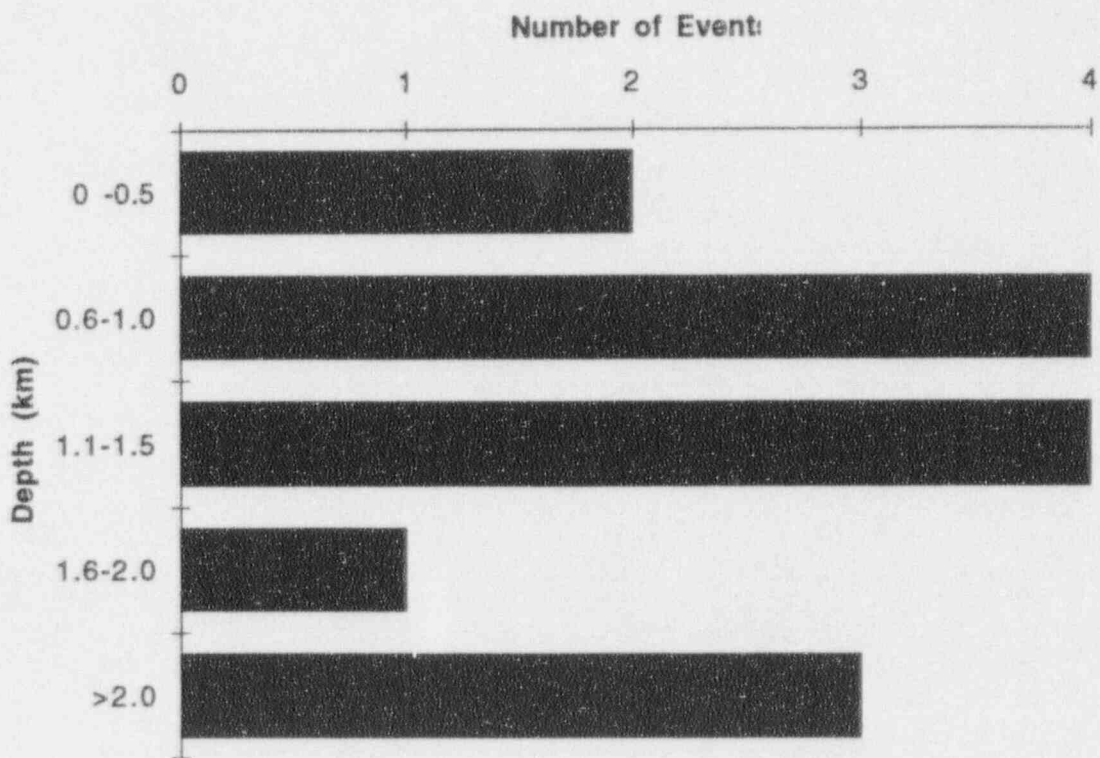


Figure 8. Depth distribution of seismicity at Monticello Reservoir during January 1 -December 31, 1992.

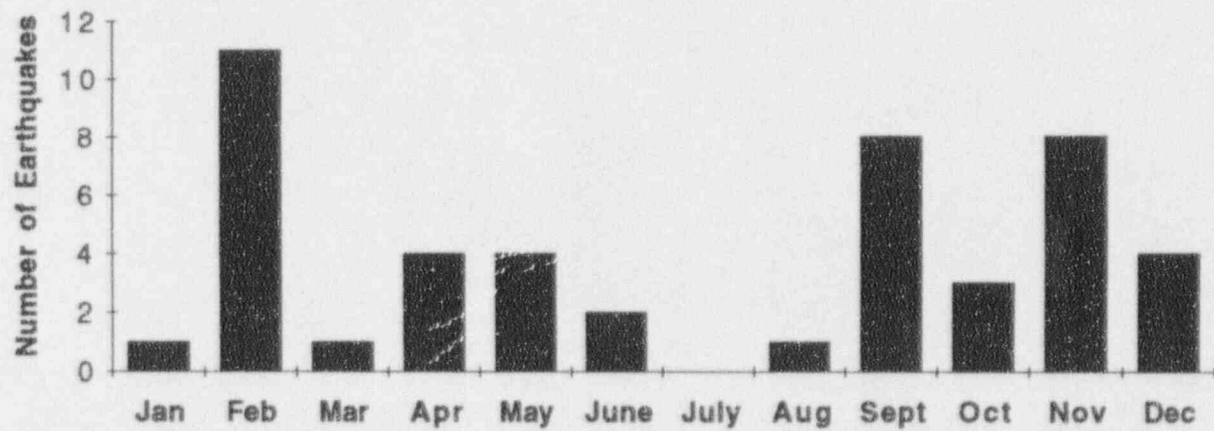


Figure 9. Distribution of earthquakes at Monticello Reservoir during January 1 - December 31, 1992.

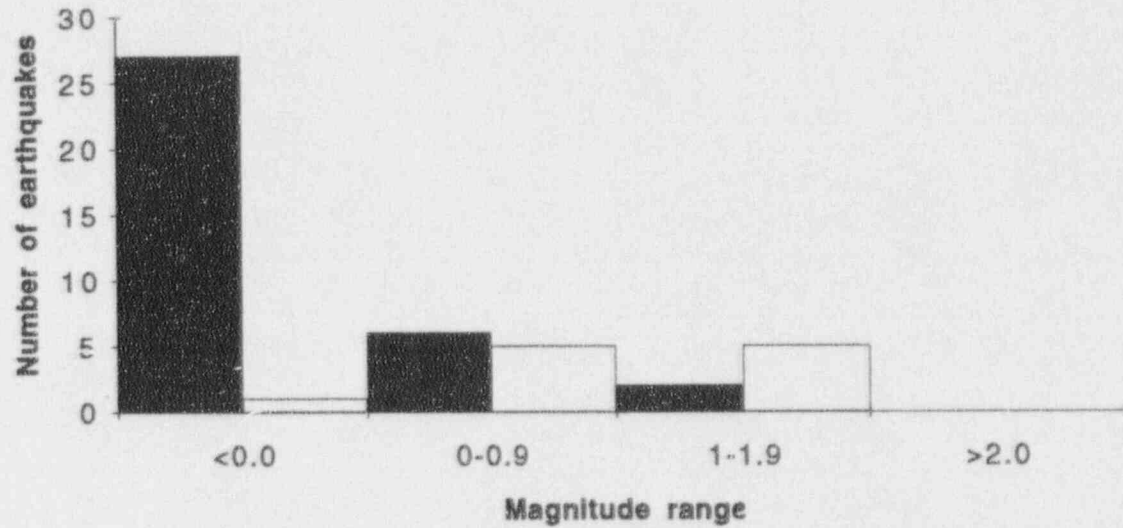


Figure 10. Magnitude ranges of earthquakes at Monticello Reservoir during January 1 - December 31, 1992. Solid and open bars indicate unlocated and located events respectively.

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, 1992

STATION	% DOWNTIME
MR01	4
MR02	3
MR05	4
MR07	4
MR10	0
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 1 - DECEMBER 31, 1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6 339	6.5	0.01	0.2	1.0	C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6 170	1.9	0.08	7.6	11.8	D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8 147	2.0	0.12	1.2	2.6	C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8 278	1.0	0.09	1.0	0.7	C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8 230	0.4	0.10	1.2	0.8	C1

APPENDIX VI

List of earthquakes with (S-P) \leq 2.5 seconds recorded around
Monticello Reservoir during October 1 - December 31, 1992.

Sl.No.	Date	Station	P-arrival	(S-P) Sec	Ep.Dist (S-P)x8.5	Dur Sec	Mag
1	92 11 04	JSC	19 34 09.00	0.6	5.1	10	0.2
2	92 11 04	JSC	19 37 11.00	0.6	5.1	8	0
3	92 11 11	JSC	17 09 03.80	0.5	4.3	6	-0.2
4	92 11 14	JSC	16 14 43.50	0.9	7.7	6	-0.2
5	92 11 17	JSC	21 12 29.00	1	8.5	7	-0.1
6	92 11 25	JSC	17 09 33.60	1	8.5	15	0.6
7	92 11 27	JSC	10 59 19.00	0.5	4.3	5	-0.4
8	92 12 29	JSC	23 12 52.00	0.2	1.7	3	-0.9
9	92 12 30	MR10	14 54 29.20	*		3.5	-0.6
10	92 12 30	MR10	14 54 54.1	*		5.5	
	"	JSC	14 54 55.4	1.1	9.4		-0.2

* Event too close to the station

APPENDIX VII

Maximum and minimum water levels, changes in water level, number of earthquakes and energy release in ergs at Monticello Reservoir during October 1 - December 31, 1992. Dates are given in Julian Calendar.

Day	WI(Min)	WI(Max)	WI(Avg)	Change	# of Eqs	Log E
275	424.4	424.8	424.4	0	0	0
276	423.9	424.8	424.4	0	0	0
277	423.9	424.5	424.2	-0.2	0	0
278	422.9	424.9	424.1	-0.1	0	0
279	423.2	424.7	424.5	0.4	1	13.57
280	423.3	424.6	424.1	-0.4	0	0
281	423.3	424.9	424	-0.1	0	0
282	423.5	424.7	424.2	0.2	0	0
283	424.2	424.9	424.8	0.6	0	0
284	424.7	424.9	424.8	0	0	0
285	424.3	425	424.8	0	0	0
286	423.4	424.6	424	-0.8	0	0
287	423.6	424.8	424	0	0	0
288	423.4	424.9	424.3	0.3	0	0
289	422.5	424.8	423.8	-0.5	0	0
290	422.8	424.5	423.7	-0.1	0	0
291	422.9	424	423.5	-0.2	0	0
292	423.5	424	423.5	0	0	0
293	422.8	424.8	423.7	0.2	0	0
294	423	424.3	423.4	-0.3	0	0
295	423.2	425	424.2	0.8	0	0
296	423.5	424.9	424.2	0	0	0
297	423.4	423.7	423.6	-0.6	0	0
298	423.4	424.3	424	0.4	0	0
299	423.5	424.1	424	0	1	11.64
300	423.2	424.8	424.1	0.1	0	0
301	423.6	424.7	424.3	0.2	0	0
302	422.8	424.5	423.8	-0.5	0	0
303	423.3	425	424.2	0.4	1	13.53
304	421.6	424.8	423.5	-0.7	0	0
305	421.7	424	422.7	-0.8	0	0
306	421.9	424.2	423.2	0.5	0	0
307	421.9	424.8	423.5	0.3	0	0
308	421.9	424	423.4	-0.1	0	0
309	422.7	424.5	423.8	0.4	2	12.41
310	422.4	424.8	423.6	-0.2	0	0
311	423	424.2	423.7	0.1	0	0
312	423.1	424.6	423.9	0.2	1	13.48
313	423.2	424.6	424.1	0.2	0	0
314	423.6	424.8	424.1	0	0	0
315	423.6	424.8	424.1	0	0	0
316	423.5	424.9	424.2	0.1	1	11.44
317	422.9	424.8	423.9	-0.3	0	0

Appendix VII cont'd.....

Day	Wl(Min)	Wl(Max)	Wl(Avg)	Change	# of Eqs	Log E
318	423	424.8	424.1	0.2	0	0
319	423.4	424.8	424.3	0.2	1	11.44
320	423.6	424.9	424.4	0.1	0	0
321	422.6	424.8	423.5	-0.9	0	0
322	422.7	424.5	423.7	0.2	1	11.64
323	423.5	425	424.3	0.6	0	0
324	422.8	424.5	423.6	-0.7	0	0
325	423	424.9	424	0.4	0	0
326	423.7	424.9	424.2	0.2	0	0
327	423.4	425	424.1	-0.1	0	0
328	423.4	424.9	423.9	-0.2	0	0
329	423.7	424.9	424.4	0.5	0	0
330	423.5	425	424	-0.4	1	12.74
331	423.6	424.9	424.4	0.4	0	0
332	424.2	424.9	424.8	0.4	1	11.19
333	424.9	424.9	424.9	0.1	0	0
334	424.9	424.3	424.7	-0.2	0	0
335	423.5	424.9	424.1	-0.6	0	0
336	423.7	425	424.5	0.4	0	0
337	423.7	424.9	424.1	-0.4	0	0
338	423.3	424.7	424	-0.1	0	0
339	423.4	424.8	424.3	0.3	0	0
340	424.1	424.6	424.4	0.1	0	0
341	424.2	424.9	424.4	0	0	0
342	424.3	425	424.3	-0.1	0	0
343	423.6	424.9	424.2	-0.1	0	0
344	423.3	424.9	423.8	-0.4	1	12.46
345	423.5	422.9	423.9	0.1	0	0
346	423.7	424.9	424.3	0.4	0	0
347	424.2	424.5	424.5	0.2	0	0
348	424.1	424.5	424.3	-0.2	0	0
349	423.8	424.8	424.4	0.1	0	0
350	423.8	424.5	424.8	0.4	0	0
351	424.2	425	424.6	-0.2	0	0
352	423.6	425	424.3	-0.3	0	0
353	422.7	424.2	423.6	-0.7	0	0
354	422.1	423.5	422.9	-0.7	0	0
355	422.2	423.8	423.3	0.4	0	0
356	422.3	424.3	423.3	0	0	0
357	422.6	423.9	423.4	0.1	0	0
358	422.2	424.5	423.2	-0.2	0	0
359	422.3	424.5	423.8	0.6	0	0
360	422.7	424.1	423.6	-0.2	0	0
361	422.2	424.4	423.7	0.1	0	0
362	422.2	424	423.3	-0.4	0	0
363	424.1	424.9	424.5	1.2	0	0
364	424.1	424.1	424.1	-0.4	1	10.57
365	423.9	424.6	424.4	0.3	2	11.7
366	423.7	424.5	424.3	-0.1	0	0

APPENDIX VIII

MONTICELLO RESERVOIR EARTHQUAKES JANUARY 1 - DECEMBER 31,1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
920225	1337	42.78	34-20.00	81-18.64	1.18	1.02	10 159	2.5	0.08	0.5	1.9	B1
920226	1010	10.46	34-19.79	81-18.74	1.31	0.21	10 153	2.4	0.10	0.4	1.3	B1
920315	8 0	47.48	34-20.07	81-18.68	0.97	0.82	10 159	2.4	0.06	0.3	1.7	B1
920402	1714	29.62	34-22.33	81-20.66	1.00	1.02	7 281	1.8	0.15	2.9	4.5	D1
920429	1810	2.98	34-23.60	81-17.18	4.90	0.82	7 292	4.4	0.15	3.6	2.7	D1
920521	1431	33.09	34-20.01	81-18.79	0.42	0.21	7 111	1.6	0.08	0.8	2.1	B1
920529	1654	44.12	34-24.09	81-22.80	2.79	1.02	8 333	6.1	0.07	1.2	1.6	C1
920825	17 4	57.66	34-24.50	81-24.40	0.69	1.02	7 333	8.6	0.23		5.4	D1
920908	1755	43.74	34-21.98	81-16.80	2.00	0.82	6 253	4.2	0.08	1.2	3.6	D1
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6 339	6.5	0.01	0.2	1.0	C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6 170	1.9	0.03	7.6	11.8	D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8 147	2.0	0.12	1.2	2.6	C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8 178	1.0	0.09	1.0	0.7	C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8 230	0.4	0.10	1.2	0.8	C1

TECHNICAL REPORT 92-4

SEISMIC ACTIVITY NEAR THE
V.C. SUMMER NUCLEAR STATION

FOR THE PERIOD
OCTOBER - DECEMBER 1992

BY

PRADEEP TALWANI
Principal Investigator

DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA, SOUTH CAROLINA 29208

CONTRACT NO. N574984

TECHNICAL REPORT 92-4

**SEISMIC ACTIVITY NEAR THE
V.C. SUMMER NUCLEAR STATION**

FOR THE PERIOD

October - December 1992

BY

PRADEEP TALWANI
Principal Investigator

Kusala Rajendran

and

Katherine Ulmer

**DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA, SOUTH CAROLINA 29208**

CONTRACT NO. N574984

INTRODUCTION

Analysis of the seismic activity near the V.C. Summer Nuclear Station in South Carolina between October 1 and December 31, 1992 is presented in this report. During this period, 15 events were recorded in the vicinity of Monticello Reservoir, 5 of which were located. There were three events of magnitude $M_L \geq 1.1$.

A review of seismic activity during the year 1992 is also presented in this report. The level of activity and its spatial distribution are discussed. A performance report of various stations of the network during the past year is also presented in this report.

SEISMIC NETWORK

Earthquakes during this period were recorded on stations of Monticello Reservoir and South Carolina Seismic Network. The configuration of stations utilized to locate Monticello 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 the computer program HYPO71 (Lee and Lahr, 1972). The velocity model used in the earthquake locations is given in Appendix III. The format of the 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, 1992

There was no unusual seismic activity around Monticello Reservoir during the last quarter of 1992. A total of 15 events were recorded, of which five were located (Appendix V; Figure 2). The located events were of poor quality (C or D). The largest event in the quarter occurred on October 05 (19:59:01.06 UTC) and it had a magnitude $M_L = 1.18$. This event occurred to the northwest of the lake. The other located events occurred in the middle and around the west side of the lake.

Eight of the 15 events of this quarter occurred during the month of November. These occurred within an epicentral distance of < 9 km from JSC. The earthquakes that could not be located were of short duration and were generally recorded on only one station (Appendix VI)

The long term decline in seismicity observed at Monticello Reservoir is continuing (Figure 3). The cumulative seismicity at Monticello Reservoir shows a 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 Appendices V and VI. The average water level, daily changes in water level, number of earthquakes and energy release are given in Appendix VII. No systematic correlation was observed between the seismicity and reservoir level fluctuations.

CONCLUSIONS

There was no unusual seismic activity during the fourth quarter of 1992. The largest recorded magnitude was $M_L=1.18$. The seismicity was scattered, both temporally and spatially. No systematic correlation was observed between the reservoir level fluctuations and the seismicity.

MONTICELLO NETWORK AND SEISMICITY DURING 1992

Station Operational Status

The operational status of the Monticello Network during 1992 is presented in Figure 6. Most of the stations of the network were fully operational during the year. Only station MR05 was down for significant periods during the third quarter of the year.

Seismicity

A total of 47 events were recorded around the Monticello Reservoir area during 1992, of which 14 were located (Appendix VIII; Figure 7). Six of the located events occurred in the center of the lake at shallow focal depth (< 2.0 km). Scattered activity was observed in the northern and north western parts of the lake. Most of the located

earthquakes occurred at shallow depths, with maximum activity occurring at depths ≤ 1.5 km (Fig. 8). The temporal distribution of seismicity is shown in Figure 9.

The unlocatable events were generally of short duration and not recorded on more than one or two stations. The magnitude range of the located and unlocatable events are shown in Figure 10. Most of the unlocatable events were of magnitude < 0.0 . Most of the locatable events during 1992 were in the magnitude range of 0-1.0. The higher detection and location capabilities are attributed to the improved operation of the network, particularly the digital recording on the Puffin computer.

In conclusion, the activity during 1992 was not particularly different from the past several years and remained at a relatively low level. There were 7 events of magnitude $M_L \geq 1.0$ during 1992, with the largest event of magnitude $M_L = 1.18$ occurring on October 5, 1992. The long term decline in the activity is continuing. Only in the middle of the lake was there any repeated activity. A larger percent of smaller events have been located, with improved operation of the stations.

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 Seismic Network

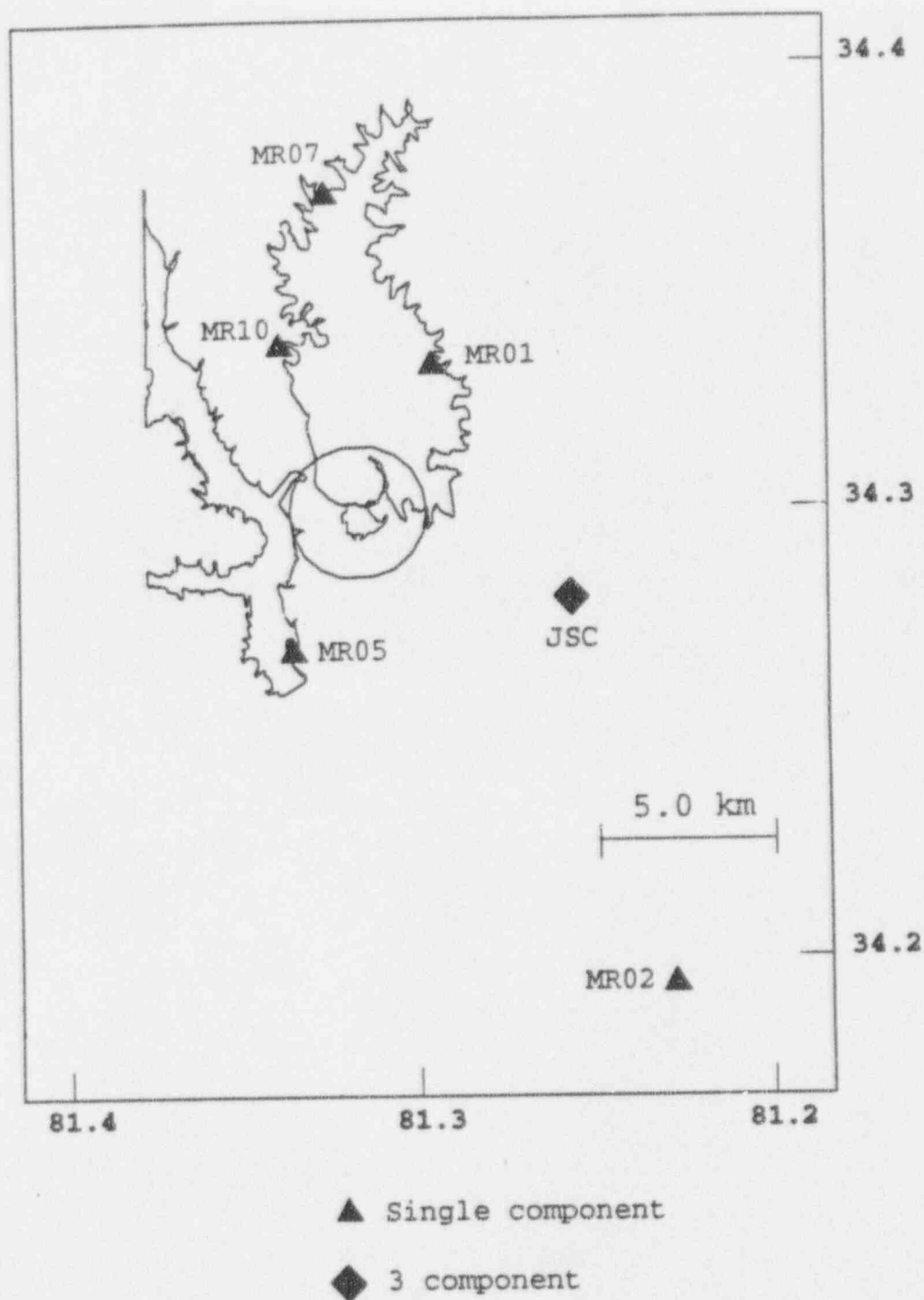


Figure 1. Monticello Reservoir area showing locations of seismic stations used to locate seismicity.

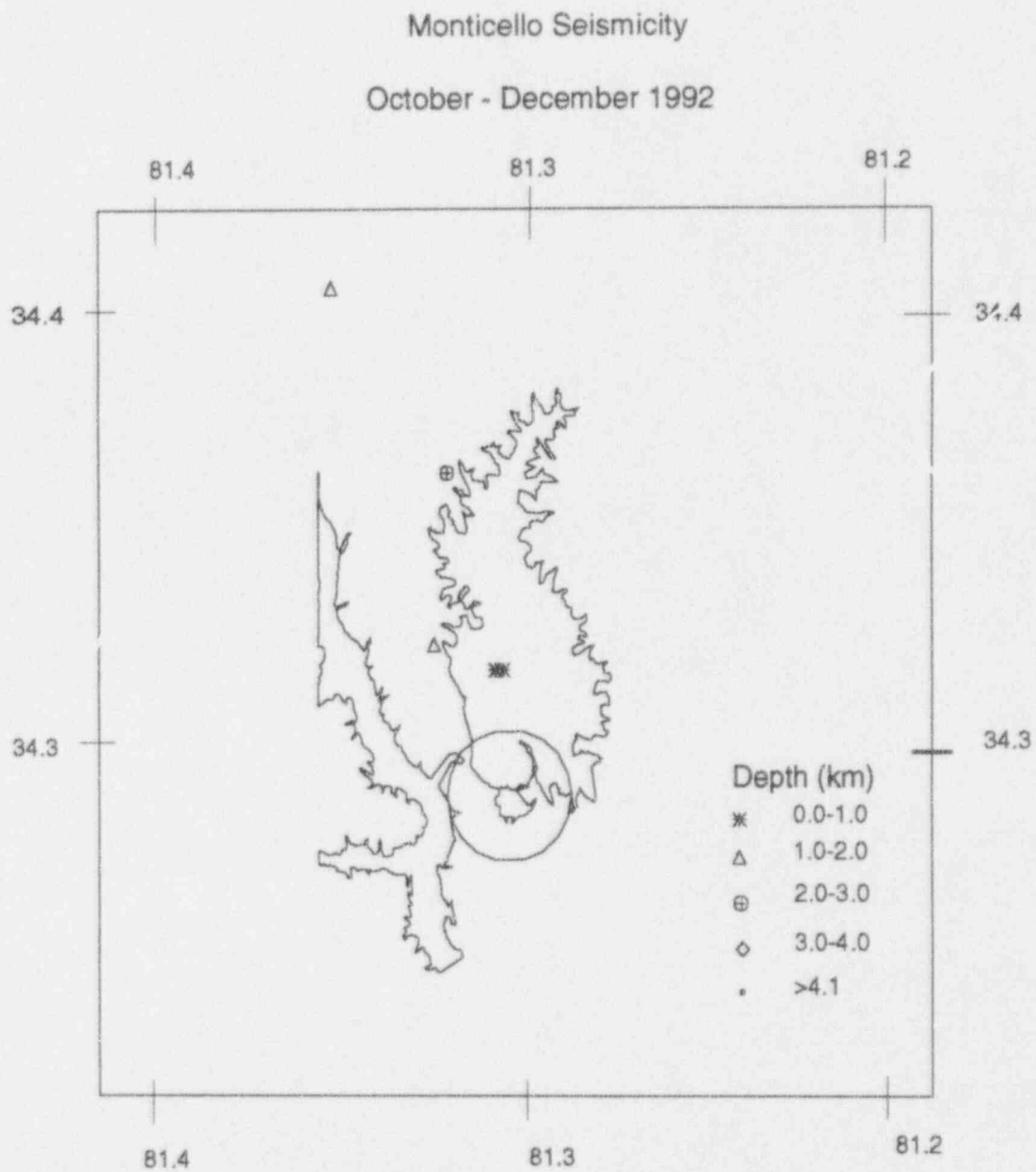


Figure 2. Earthquakes located near Monticello Reservoir during the period October 1 - December 31, 1992

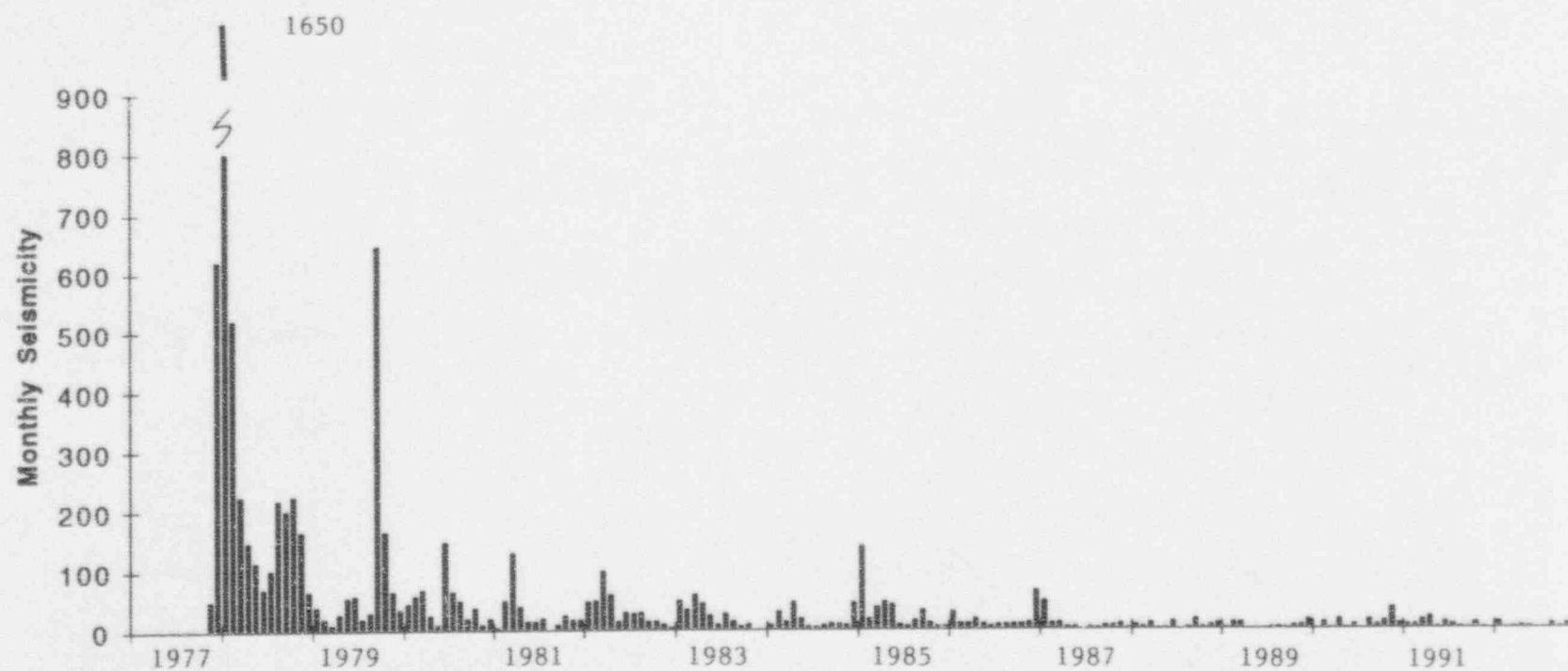


Figure 3. Earthquakes between impoundment and December 1992.

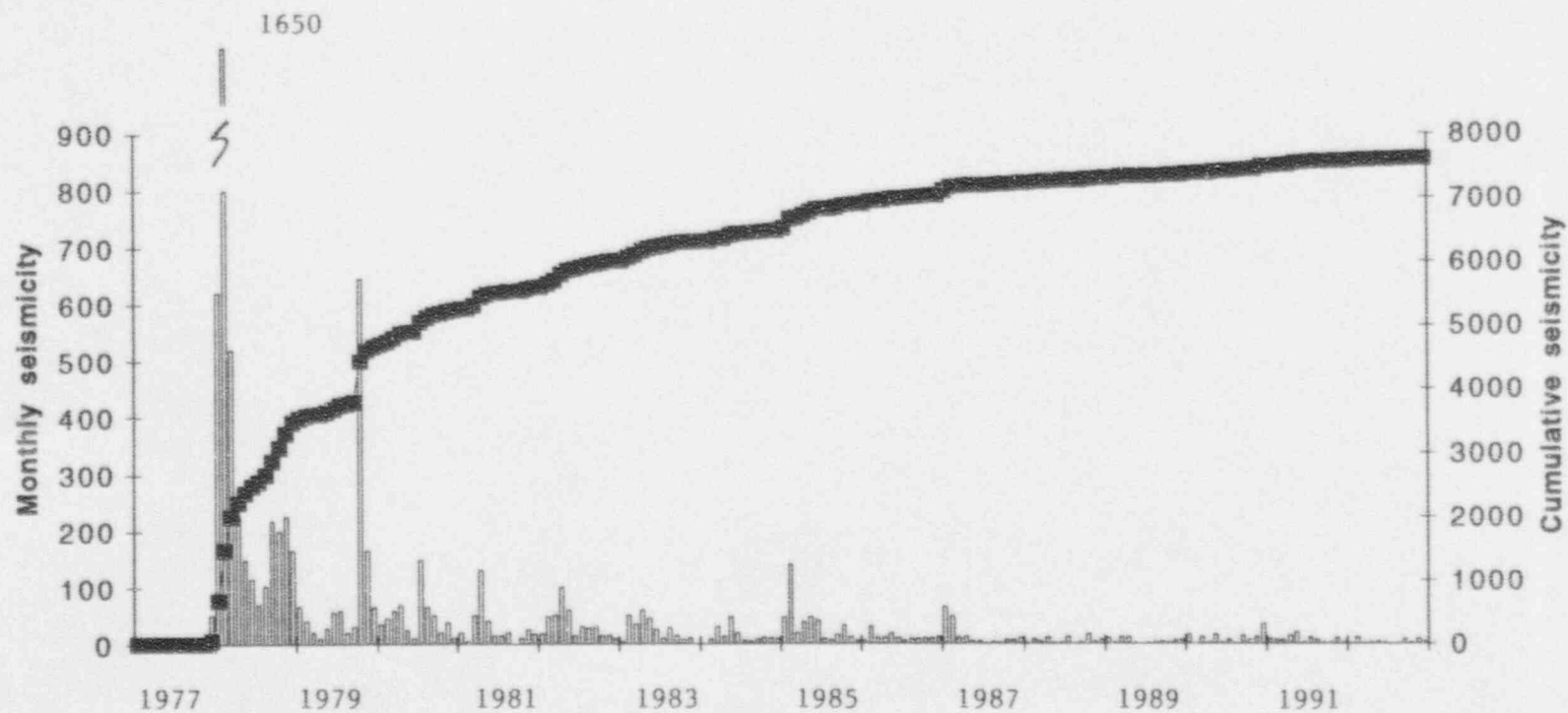


Figure 4. Monthly seismicity (bars) and cumulative seismicity (line) near Monticello Reservoir since impoundment

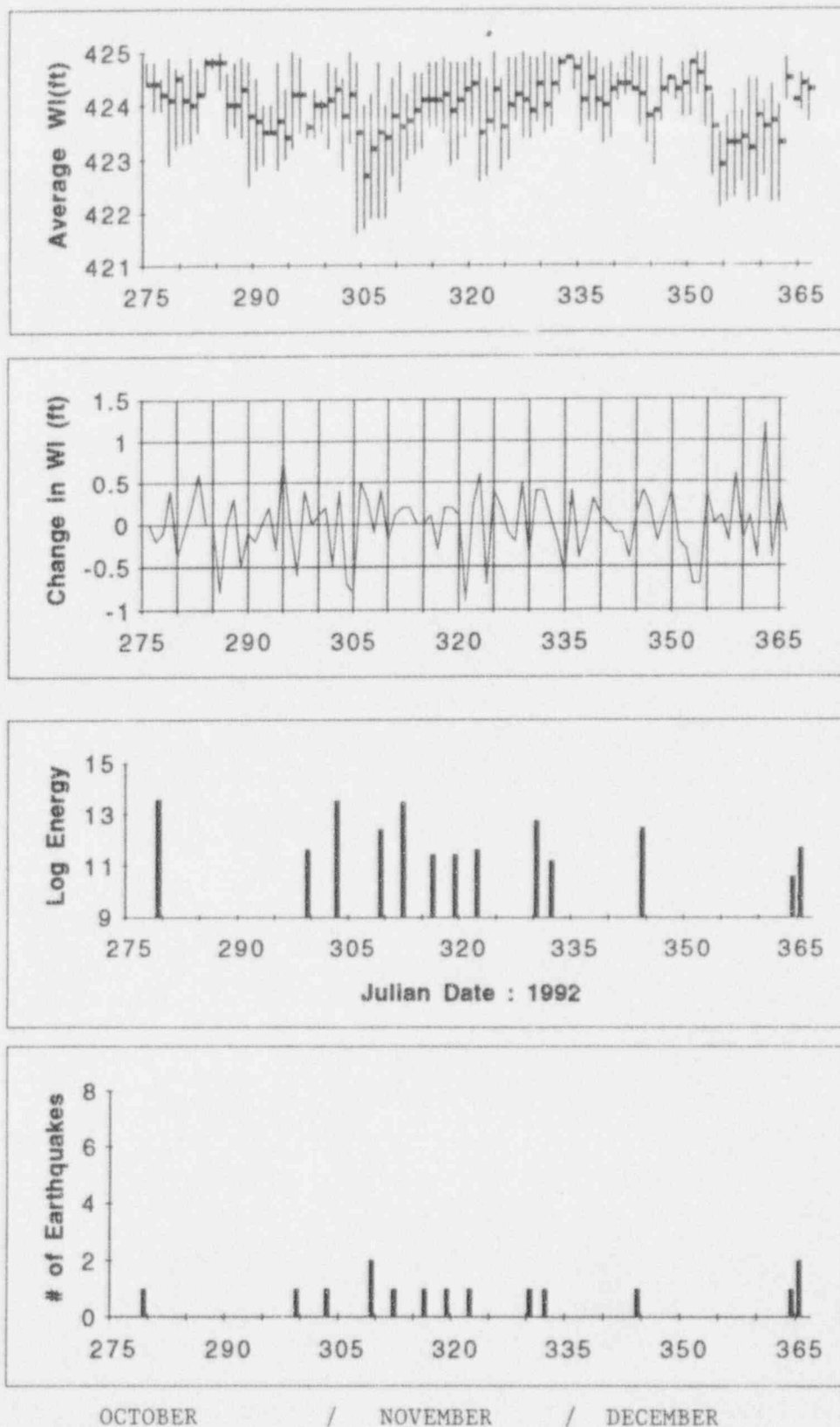


Figure 5. Comparison of daily lake level, changes in lake level, number of earthquakes and log of energy release in ergs per day at Monticello Reservoir. Error bars in the top panel indicate daily fluctuations in water level.

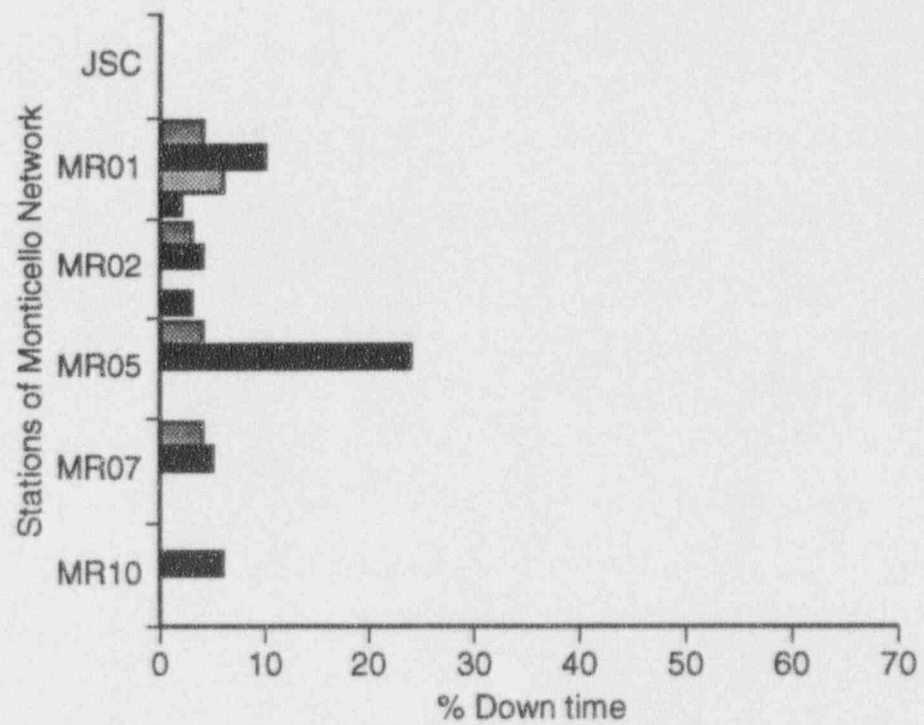


Figure 6. Operational status of Monticello Network during 1992. Four bars from bottom to top correspond to the four quarters.

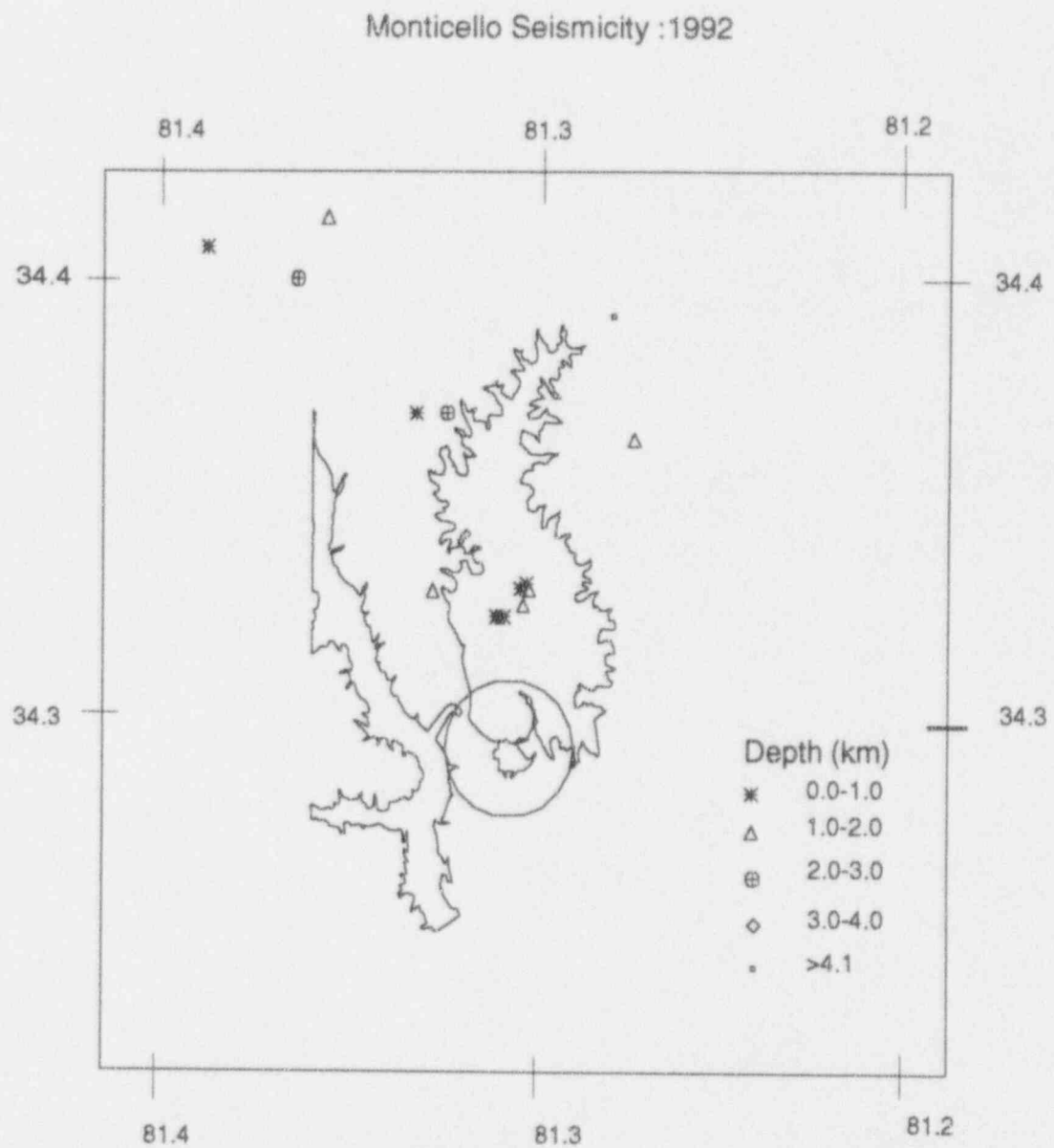


Figure 7. Earthquakes located near Monticello Reservoir during January - December, 1992.

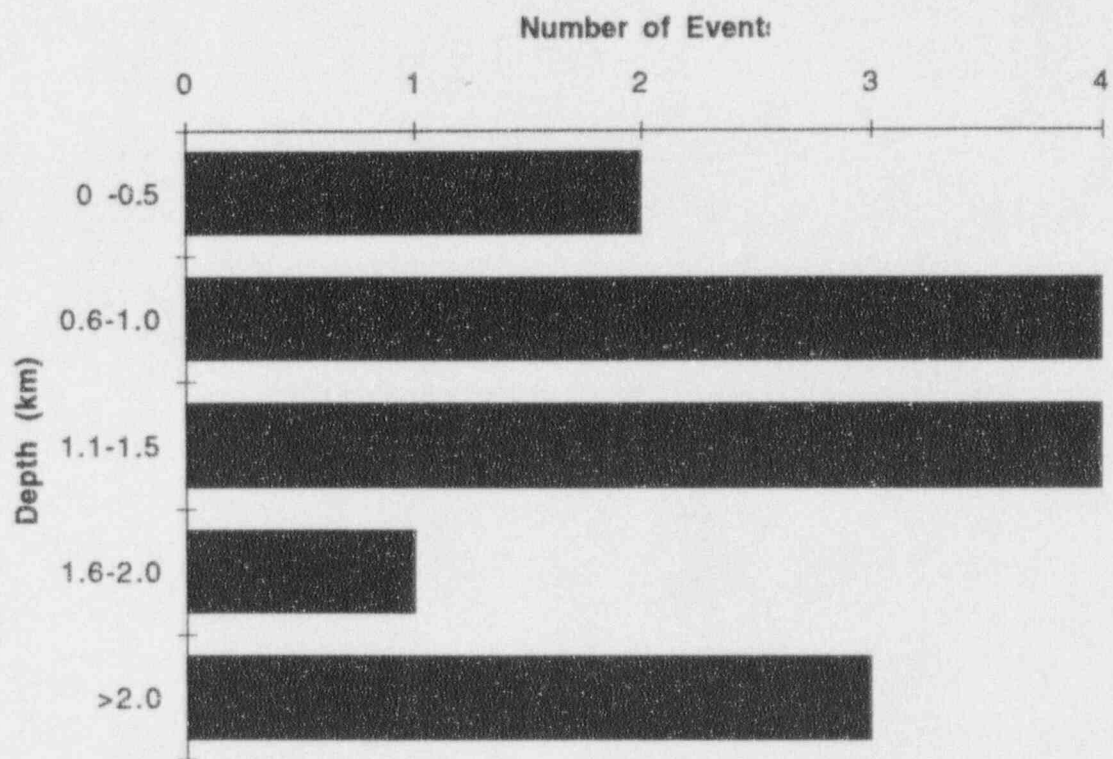


Figure 8. Depth distribution of seismicity at Monticello Reservoir during January 1 -December 31, 1992.

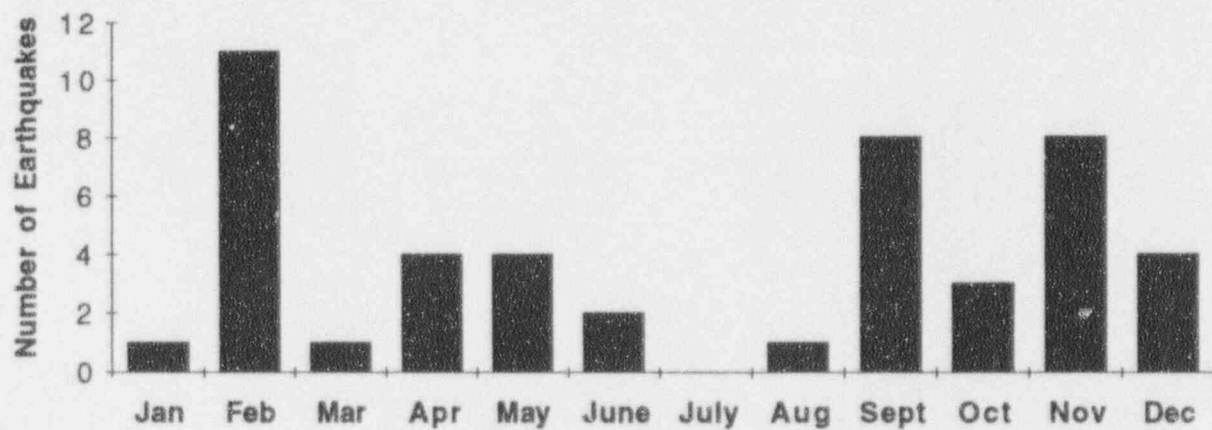


Figure 9. Distribution of earthquakes at Monticello Reservoir during January 1 - December 31, 1992.

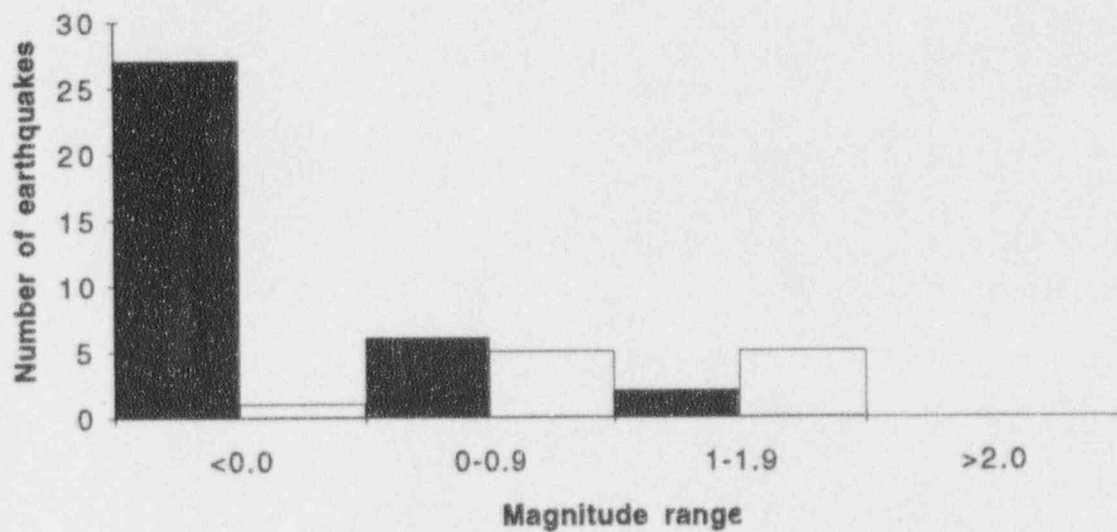


Figure 10. Magnitude ranges of earthquakes at Monticello Reservoir during January 1 - December 31, 1992. Solid and open bars indicate unlocated and located events respectively.

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, 1992

STATION	% DOWNTIME
MR01	4
MR02	3
MR05	4
MR07	4
MR10	0
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 1 - DECEMBER 31, 1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6 339	6.5	0.01	0.2	1.0	C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6 170	1.9	0.08	7.6	11.8	D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8 147	2.0	0.12	1.2	2.6	C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8 278	1.0	0.09	1.0	0.7	C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8 230	0.4	0.10	1.2	0.8	C1

APPENDIX VI

List of earthquakes with (S-P) \leq 2.5 seconds recorded around
Monticello Reservoir during October 1 - December 31, 1992.

Sl.No.	Date	Station	P-arrival	(S-P) Sec	Ep.Dist (S-P)x8.5	Dur Sec	Mag
1	92 11 04	JSC	19 34 09.00	0.6	5.1	10	0.2
2	92 11 04	JSC	19 37 11.00	0.6	5.1	8	0
3	92 11 11	JSC	17 09 03.80	0.5	4.3	6	-0.2
4	92 11 14	JSC	16 14 43.50	0.9	7.7	6	-0.2
5	92 11 17	JSC	21 12 29.00	1	8.5	7	-0.1
6	92 11 25	JSC	17 09 33.60	1	8.5	15	0.6
7	92 11 27	JSC	10 59 19.00	0.5	4.3	5	-0.4
8	92 12 29	JSC	23 12 52.00	0.2	1.7	3	-0.9
9	92 12 30	MR10	14 54 29.20	*		3.5	-0.6
10	92 12 30	MR10	14 54 54.1	*		5.5	
	"	JSC	14 54 55.4	1.1	9.4		-0.2

* Event too close to the station

APPENDIX VII

Maximum and minimum water levels, changes in water level, number of earthquakes and energy release in ergs at Monticello Reservoir during October 1 - December 31, 1992. Dates are given in Julian Calendar.

Day	Wl(Min)	Wl(Max)	Wl(Avg)	Change	# of Eqs	Log E
275	424.4	424.8	424.4	0	0	0
276	423.9	424.8	424.4	0	0	0
277	423.9	424.5	424.2	-0.2	0	0
278	422.9	424.9	424.1	-0.1	0	0
279	423.2	424.7	424.5	0.4	1	13.57
280	423.3	424.6	424.1	-0.4	0	0
281	423.3	424.9	424	-0.1	0	0
282	423.5	424.7	424.2	0.2	0	0
283	424.2	424.9	424.8	0.6	0	0
284	424.7	424.9	424.8	0	0	0
285	424.3	425	424.8	0	0	0
286	423.4	424.6	424	-0.8	0	0
287	423.6	424.8	424	0	0	0
288	423.4	424.9	424.3	0.3	0	0
289	422.5	424.8	423.8	-0.5	0	0
290	422.8	424.5	423.7	-0.1	0	0
291	422.9	424	423.5	-0.2	0	0
292	423.5	424	423.5	0	0	0
293	422.8	424.8	423.7	0.2	0	0
294	423	424.3	423.4	-0.3	0	0
295	423.2	425	424.2	0.8	0	0
296	423.5	424.9	424.2	0	0	0
297	423.4	423.7	423.6	-0.6	0	0
298	423.4	424.3	424	0.4	0	0
299	423.5	424.1	424	0	1	11.64
300	423.2	424.8	424.1	0.1	0	0
301	423.6	424.7	424.3	0.2	0	0
302	422.8	424.5	423.8	-0.5	0	0
303	423.3	425	424.2	0.4	1	13.53
304	421.6	424.8	423.5	-0.7	0	0
305	421.7	424	422.7	-0.8	0	0
306	421.9	424.2	423.2	0.5	0	0
307	421.9	424.8	423.5	0.3	0	0
308	421.9	424	423.4	-0.1	0	0
309	422.7	424.5	423.8	0.4	2	12.41
310	422.4	424.8	423.6	-0.2	0	0
311	423	424.2	423.7	0.1	0	0
312	423.1	424.6	423.9	0.2	1	13.48
313	423.2	424.6	424.1	0.2	0	0
314	423.6	424.8	424.1	0	0	0
315	423.6	424.8	424.1	0	0	0
316	423.5	424.9	424.2	0.1	1	11.44
317	422.9	424.8	423.9	-0.3	0	0

Appendix VII cont'd.....

Day	Wl(Min)	Wl(Max)	Wl(Avg)	Change	# of Eqs	Log E
318	423	424.8	424.1	0.2	0	0
319	423.4	424.8	424.3	0.2	1	11.44
320	423.6	424.9	424.4	0.1	0	0
321	422.6	424.8	423.5	-0.9	0	0
322	422.7	424.5	423.7	0.2	1	11.64
323	423.5	425	424.3	0.6	0	0
324	422.8	424.5	423.6	-0.7	0	0
325	423	424.9	424	0.4	0	0
326	423.7	424.9	424.2	0.2	0	0
327	423.4	425	424.1	-0.1	0	0
328	423.4	424.9	423.9	-0.2	0	0
329	423.7	424.9	424.4	0.5	0	0
330	423.5	425	424	-0.4	1	12.74
331	423.6	424.9	424.4	0.4	0	0
332	424.2	424.9	424.8	0.4	1	11.19
333	424.9	424.9	424.9	0.1	0	0
334	424.9	424.3	424.7	-0.2	0	0
335	423.5	424.9	424.1	-0.6	0	0
336	423.7	425	424.5	0.4	0	0
337	423.7	424.9	424.1	-0.4	0	0
338	423.3	424.7	424	-0.1	0	0
339	423.4	424.8	424.3	0.3	0	0
340	424.1	424.6	424.4	0.1	0	0
341	424.2	424.9	424.4	0	0	0
342	424.3	425	424.3	-0.1	0	0
343	423.6	424.9	424.2	-0.1	0	0
344	423.3	424.9	423.8	-0.4	1	12.46
345	423.5	422.9	423.9	0.1	0	0
346	423.7	424.9	424.3	0.4	0	0
347	424.2	424.5	424.5	0.2	0	0
348	424.1	424.5	424.3	-0.2	0	0
349	423.8	424.8	424.4	0.1	0	0
350	423.8	424.5	424.8	0.4	0	0
351	424.2	425	424.6	-0.2	0	0
352	423.6	425	424.3	-0.3	0	0
353	422.7	424.2	423.6	-0.7	0	0
354	422.1	423.5	422.9	-0.7	0	0
355	422.2	423.8	423.3	0.4	0	0
356	422.3	424.3	423.3	0	0	0
357	422.6	423.9	423.4	0.1	0	0
358	422.2	424.5	423.2	-0.2	0	0
359	422.3	424.5	423.8	0.6	0	0
360	422.7	424.1	423.6	-0.2	0	0
361	422.2	424.4	423.7	0.1	0	0
362	422.2	424	423.3	-0.4	0	0
363	424.1	424.9	424.5	1.2	0	0
364	424.1	424.1	424.1	-0.4	1	10.57
365	423.9	424.6	424.4	0.3	2	11.7
366	423.7	424.5	424.3	-0.1	0	0

APPENDIX VIII

MONTICELLO RESERVOIR EARTHQUAKES JANUARY 1 - DECEMBER 31, 1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
920225	1337	42.78	34-20.00	81-18.64	1.18	1.02	10 159	2.5	0.08	0.5	1.9	B1
920226	1010	10.46	34-19.79	81-18.74	1.31	0.21	10 153	2.4	0.10	0.4	1.3	B1
920315	8 0	47.48	34-20.07	81-18.68	0.97	0.82	10 159	2.4	0.06	0.3	1.7	B1
920402	1714	29.62	34-22.33	81-20.66	1.00	1.02	7 281	1.8	0.15	2.9	4.5	D1
920429	1810	2.98	34-23.60	81-17.18	4.90	0.82	7 292	4.4	0.15	3.6	2.7	D1
920521	1431	33.09	34-20.01	81-18.79	0.42	0.21	7 111	1.6	0.08	0.8	2.1	B1
920529	1654	44.12	34-24.09	81-22.80	2.79	1.02	8 333	6.1	0.07	1.2	1.6	C1
920825	17 4	57.66	34-24.50	81-24.40	0.69	1.02	7 333	8.6	0.23		5.4	D1
920908	1755	43.74	34-21.98	81-16.80	2.00	0.82	6 253	4.2	0.08	1.2	3.6	D1
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6 339	6.5	0.01	0.2	1.0	C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6 170	1.9	0.03	7.6	11.8	D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8 147	2.0	0.12	1.2	2.6	C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8 178	1.0	0.09	1.0	0.7	C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8 230	0.4	0.10	1.2	0.8	C1

TECHNICAL REPORT 92-4

SEISMIC ACTIVITY NEAR THE
V.C. SUMMER NUCLEAR STATION

FOR THE PERIOD
OCTOBER - DECEMBER 1992

BY

PRADEEP TALWANI
Principal Investigator

DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA, SOUTH CAROLINA 29208

CONTRACT NO. N574984

TECHNICAL REPORT 92-4

**SEISMIC ACTIVITY NEAR THE
V.C. SUMMER NUCLEAR STATION**

**FOR THE PERIOD
October - December 1992**

BY

PRADEEP TALWANI
Principal Investigator

Kusala Rajendran

and

Katherine Ulmer

**DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA, SOUTH CAROLINA 29208**

CONTRACT NO. N574984

INTRODUCTION

Analysis of the seismic activity near the V.C. Summer Nuclear Station in South Carolina between October 1 and December 31, 1992 is presented in this report. During this period, 15 events were recorded in the vicinity of Monticello Reservoir, 5 of which were located. There were three events of magnitude $M_L \geq 1.1$.

A review of seismic activity during the year 1992 is also presented in this report. The level of activity and its spatial distribution are discussed. A performance report of various stations of the network during the past year is also presented in this report.

SEISMIC NETWORK

Earthquakes during this period were recorded on stations of Monticello Reservoir and South Carolina Seismic Network. The configuration of stations utilized to locate Monticello 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 the computer program HYPO71 (Lee and Lahr, 1972). The velocity model used in the earthquake locations is given in Appendix III. The format of the 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, 1992

There was no unusual seismic activity around Monticello Reservoir during the last quarter of 1992. A total of 15 events were recorded, of which five were located (Appendix V; Figure 2). The located events were of poor quality (C or D). The largest event in the quarter occurred on October 05 (19:59:01.06 UTC) and it had a magnitude $M_L = 1.18$. This event occurred to the northwest of the lake. The other located events occurred in the middle and around the west side of the lake.

Eight of the 15 events of this quarter occurred during the month of November. These occurred within an epicentral distance of < 9 km from JSC. The earthquakes that could not be located were of short duration and were generally recorded on only one station (Appendix VI)

The long term decline in seismicity observed at Monticello Reservoir is continuing (Figure 3). The cumulative seismicity at Monticello Reservoir shows a 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 Appendices V and VI. The average water level, daily changes in water level, number of earthquakes and energy release are given in Appendix VII. No systematic correlation was observed between the seismicity and reservoir level fluctuations.

CONCLUSIONS

There was no unusual seismic activity during the fourth quarter of 1992. The largest recorded magnitude was $M_L=1.18$. The seismicity was scattered, both temporally and spatially. No systematic correlation was observed between the reservoir level fluctuations and the seismicity.

MONTICELLO NETWORK AND SEISMICITY DURING 1992

Station Operational Status

The operational status of the Monticello Network during 1992 is presented in Figure 6. Most of the stations of the network were fully operational during the year. Only station MR05 was down for significant periods during the third quarter of the year.

Seismicity

A total of 47 events were recorded around the Monticello Reservoir area during 1992, of which 14 were located (Appendix VIII; Figure 7). Six of the located events occurred in the center of the lake at shallow focal depth (< 2.0 km). Scattered activity was observed in the northern and north western parts of the lake. Most of the located

earthquakes occurred at shallow depths, with maximum activity occurring at depths ≤ 1.5 km (Fig. 8). The temporal distribution of seismicity is shown in Figure 9.

The unlocatable events were generally of short duration and not recorded on more than one or two stations. The magnitude range of the located and unlocatable events are shown in Figure 10. Most of the unlocatable events were of magnitude < 0.0 . Most of the locatable events during 1992 were in the magnitude range of 0-1.0. The higher detection and location capabilities are attributed to the improved operation of the network, particularly the digital recording on the Puffin computer.

In conclusion, the activity during 1992 was not particularly different from the past several years and remained at a relatively low level. There were 7 events of magnitude $M_L \geq 1.0$ during 1992, with the largest event of magnitude $M_L = 1.18$ occurring on October 5, 1992. The long term decline in the activity is continuing. Only in the middle of the lake was there any repeated activity. A larger percent of smaller events have been located, with improved operation of the stations.

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 Seismic Network

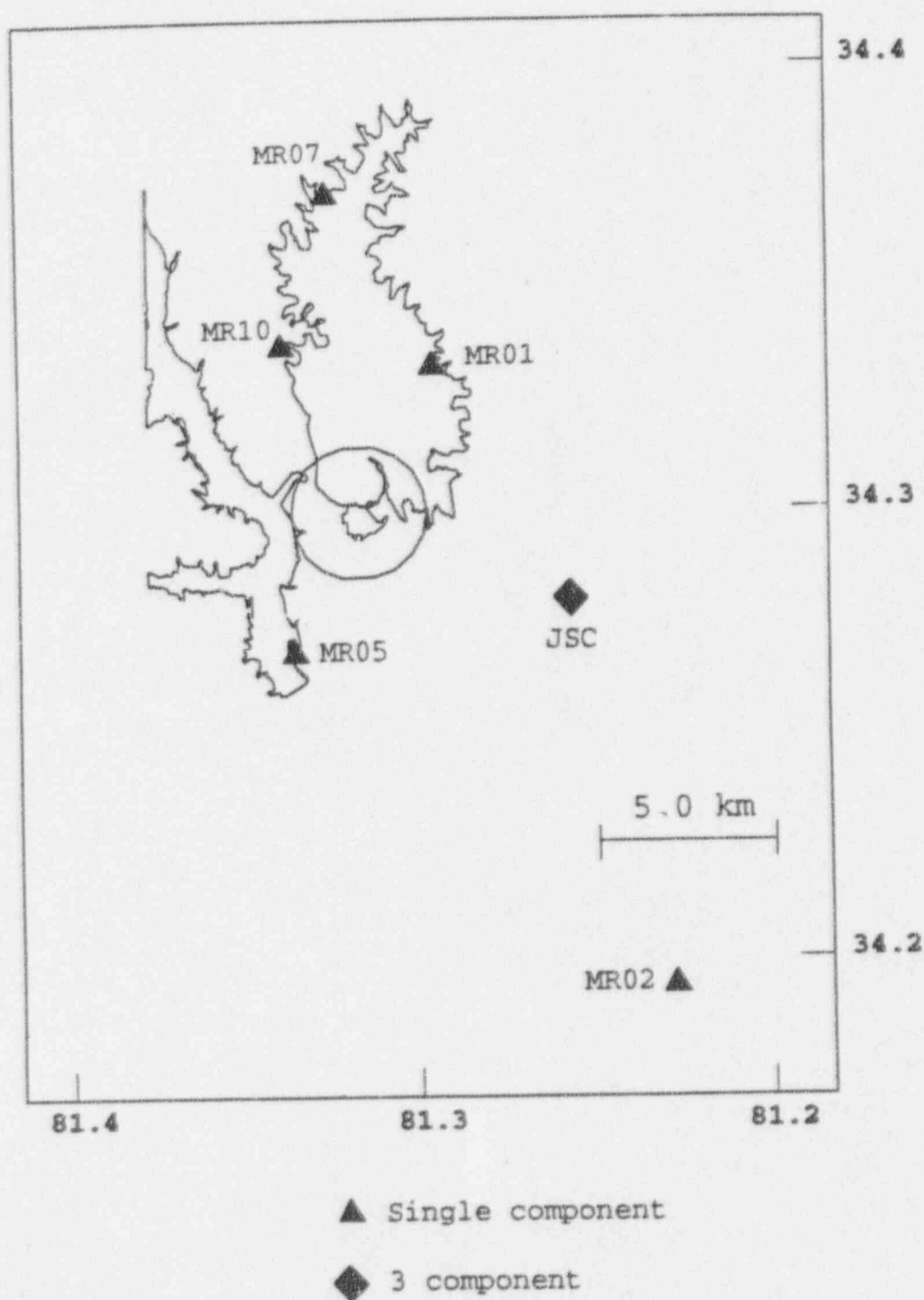


Figure 1. Monticello Reservoir area showing locations of seismic stations used to locate seismicity.

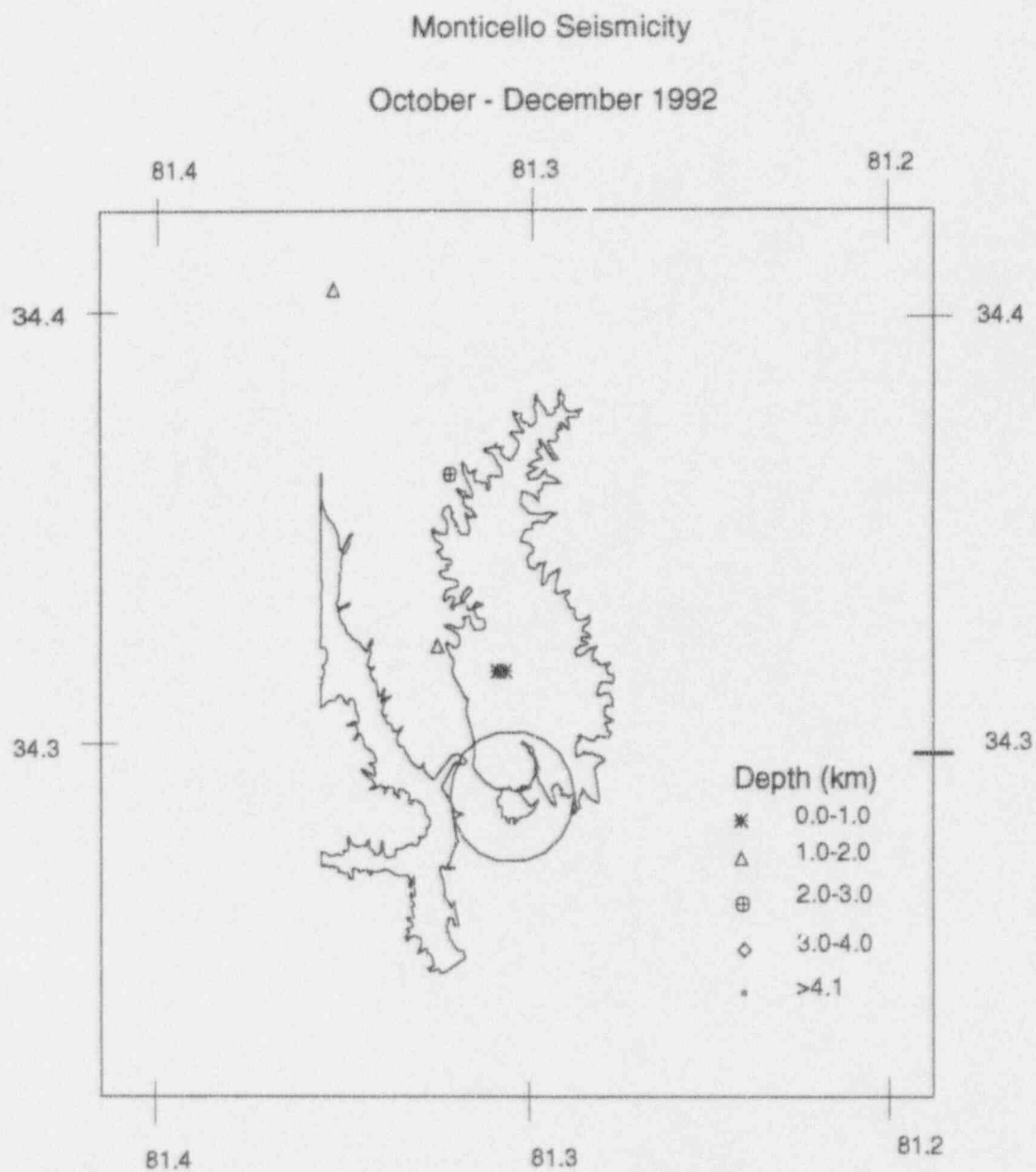


Figure 2. Earthquakes located near Monticello Reservoir during the period October 1 - December 31, 1992

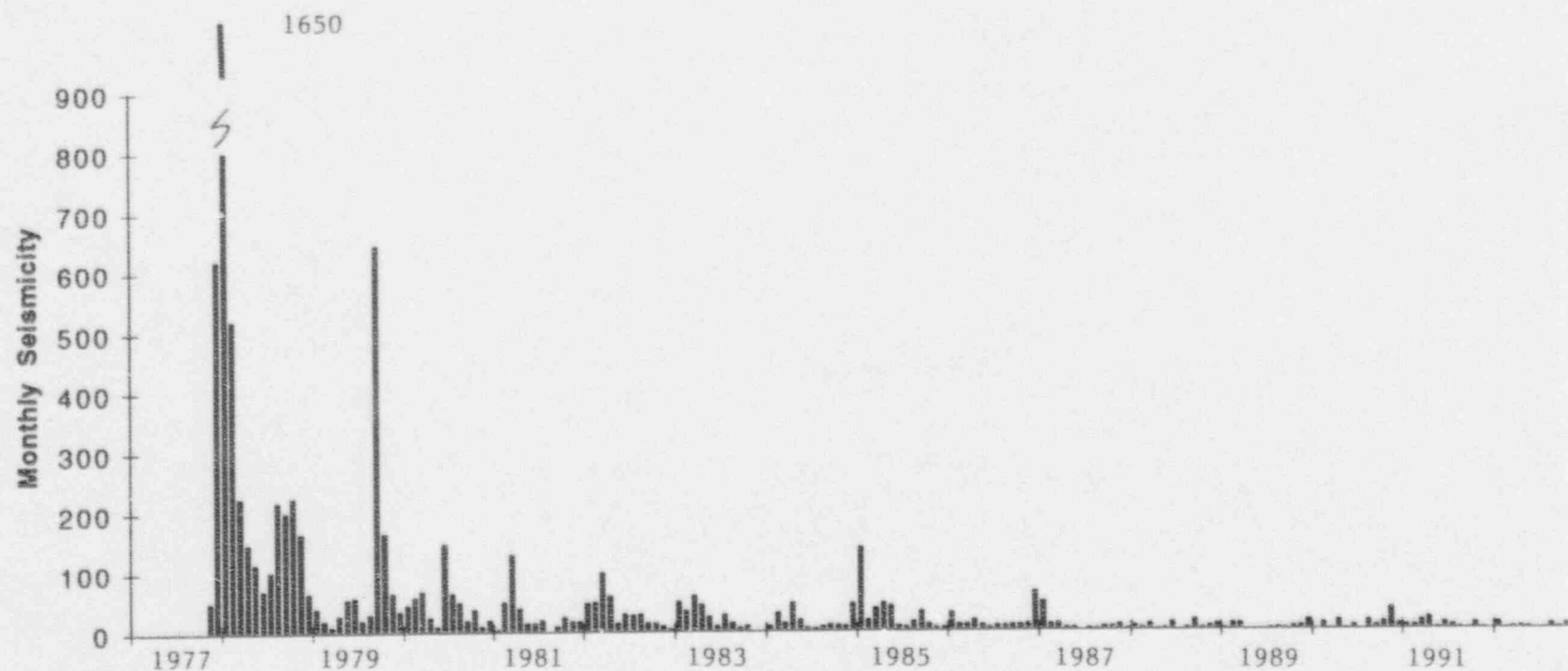


Figure 3. Earthquakes between impoundment and December 1992.

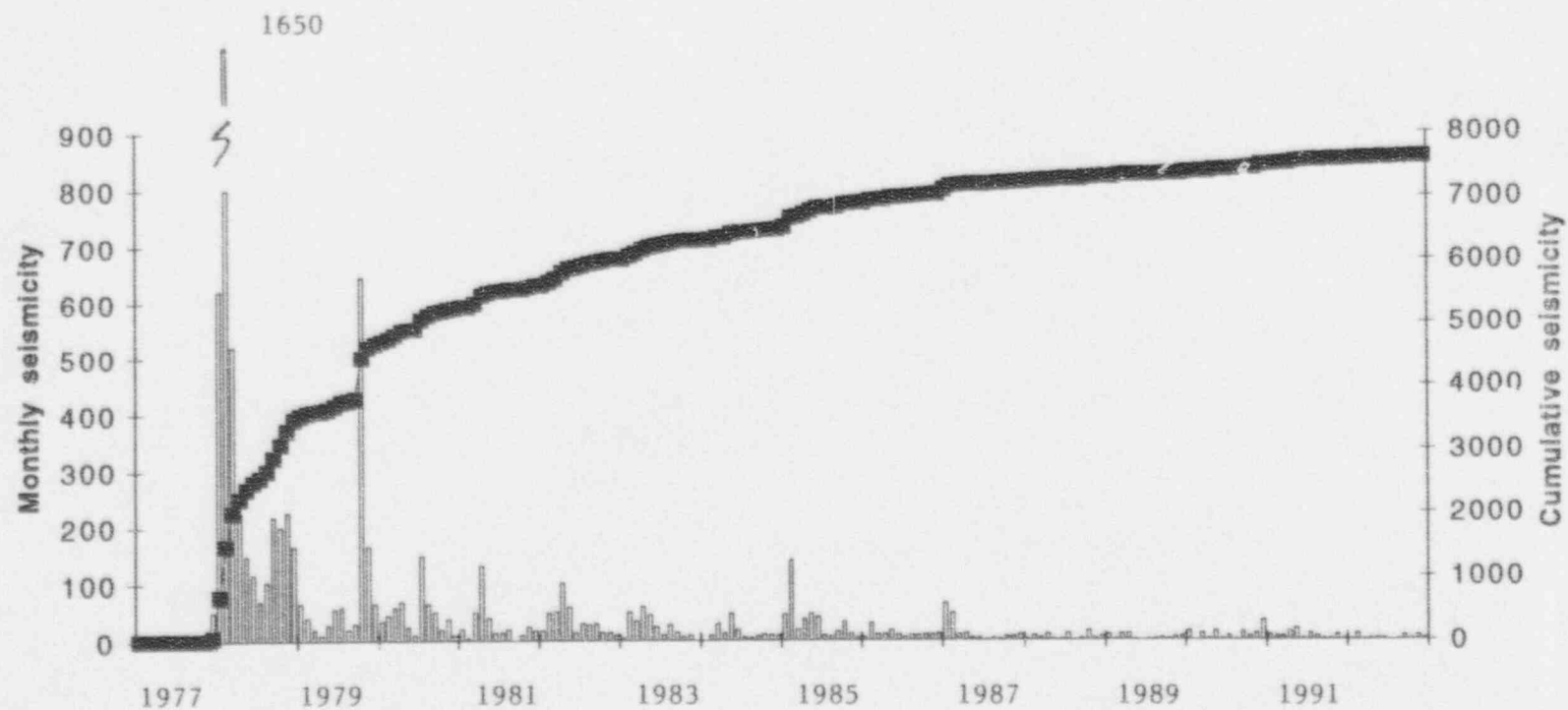


Figure 4. Monthly seismicity (bars) and cumulative seismicity (line) near Monticello Reservoir since impoundment

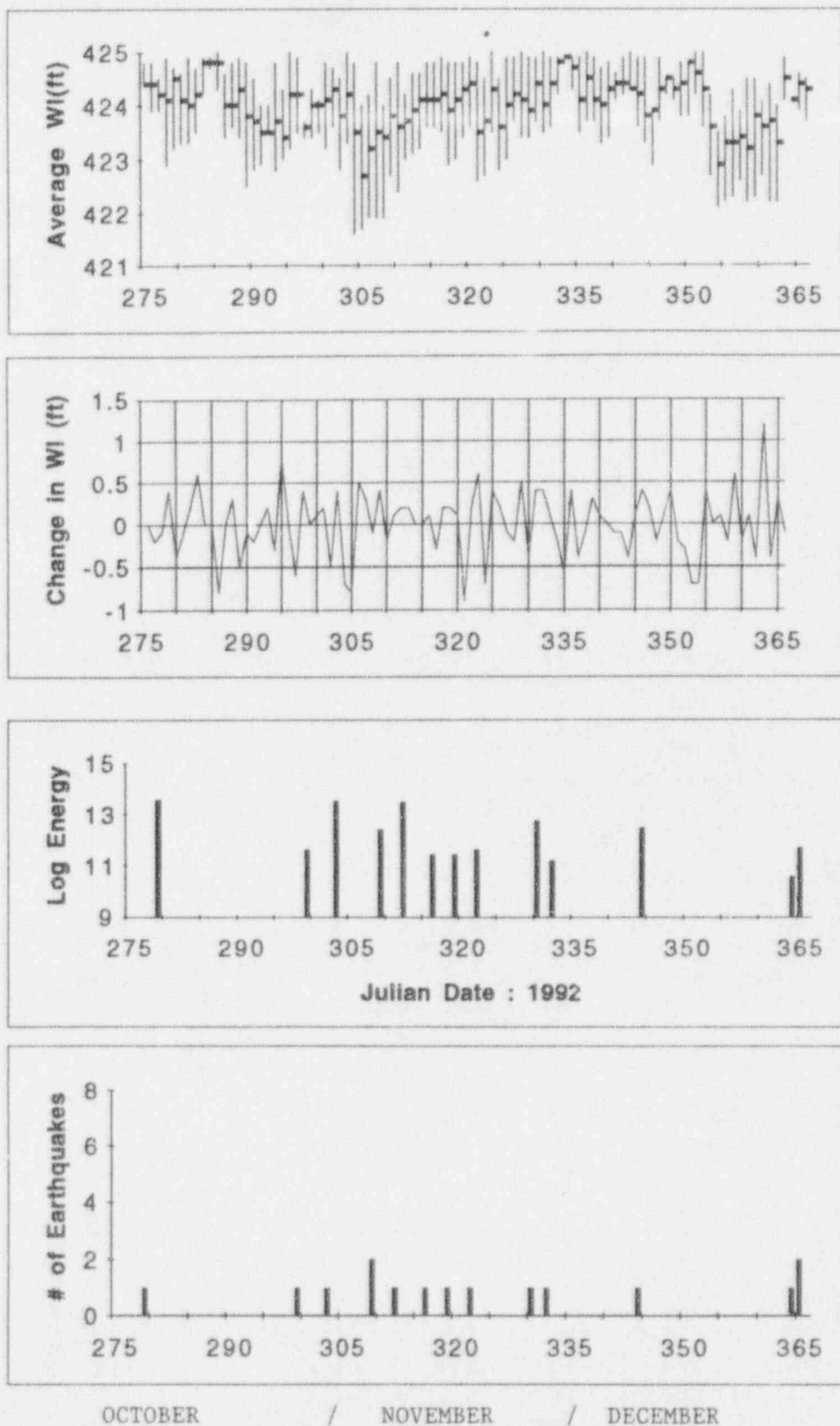


Figure 5. Comparison of daily lake level, changes in lake level, number of earthquakes and log of energy release in ergs per day at Monticello Reservoir. Error bars in the top panel indicate daily fluctuations in water level.

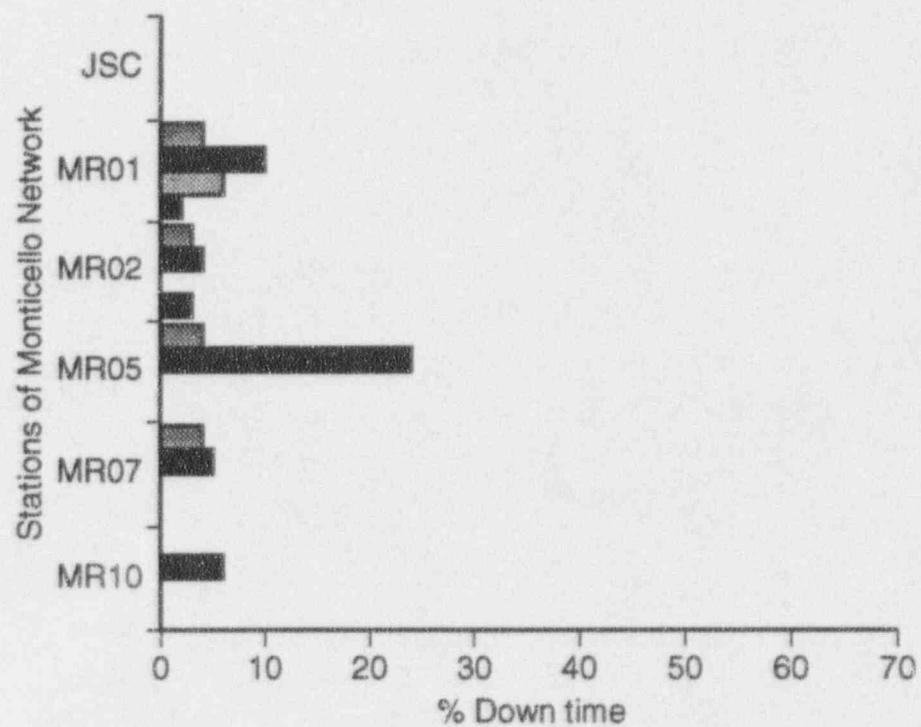


Figure 6. Operational status of Monticello Network during 1992. Four bars from bottom to top correspond to the four quarters.

Monticello Seismicity :1992

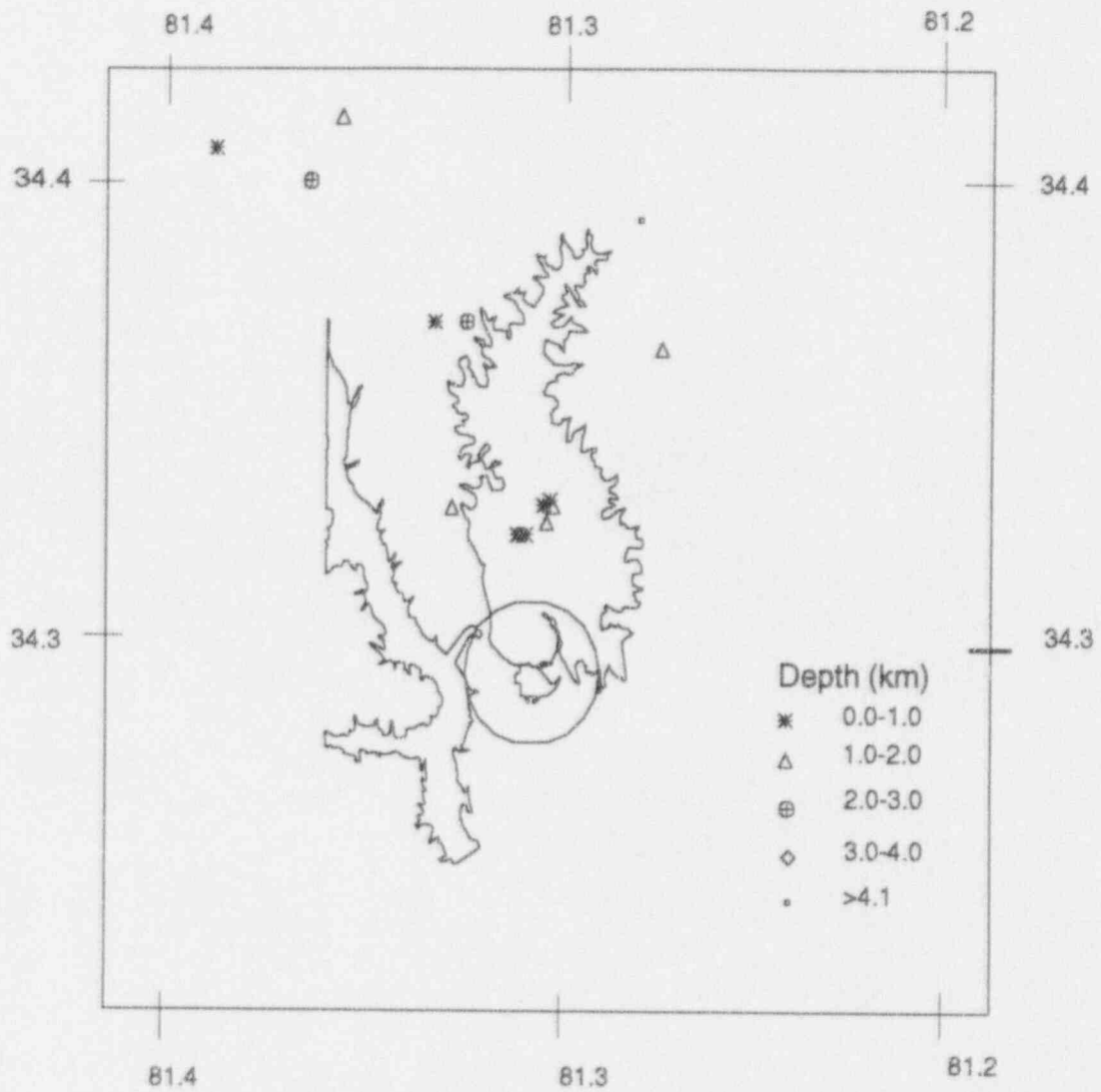


Figure 7. Earthquakes located near Monticello Reservoir during January - December, 1992.

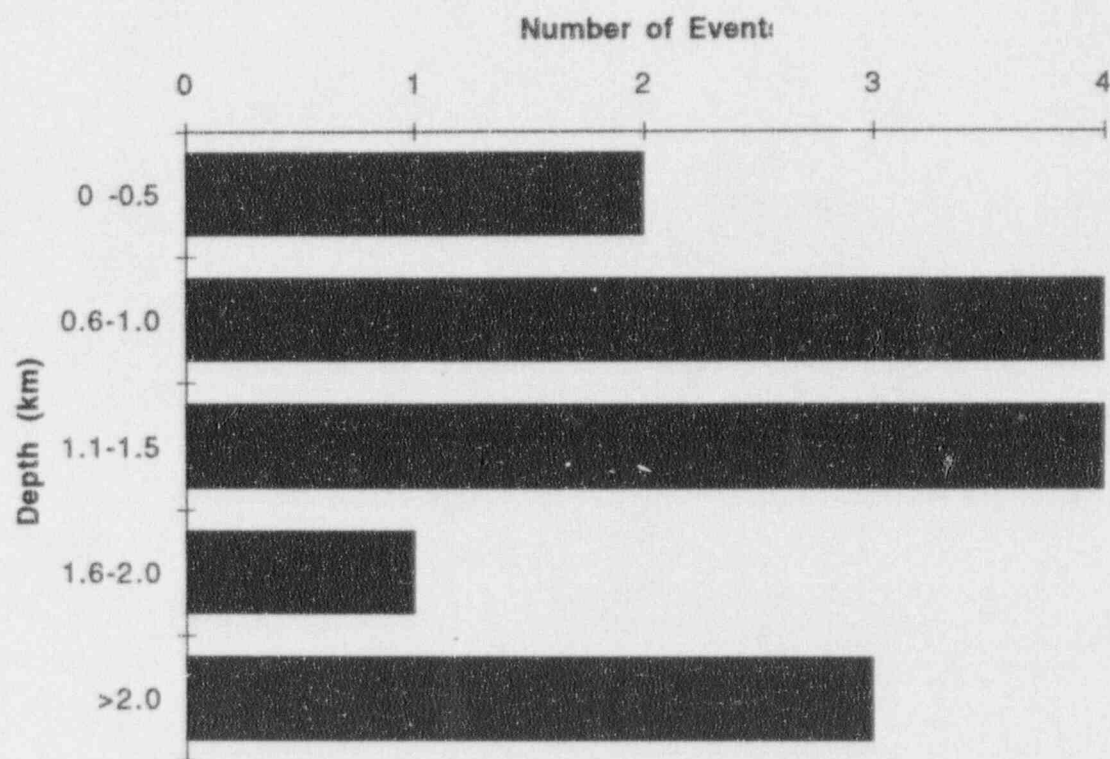


Figure 8. Depth distribution of seismicity at Monticello Reservoir during January 1 -December 31, 1992.

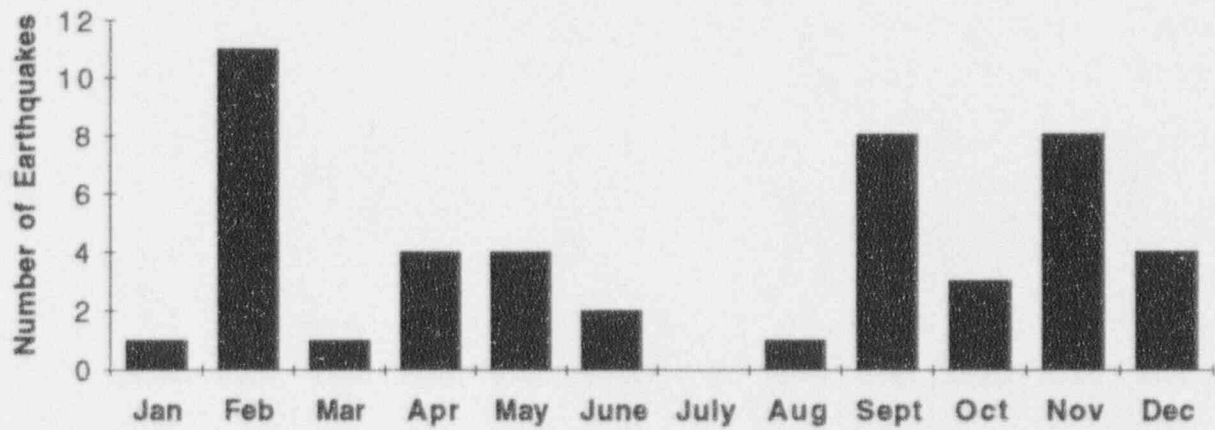


Figure 9. Distribution of earthquakes at Monticello Reservoir during January 1 - December 31, 1992.

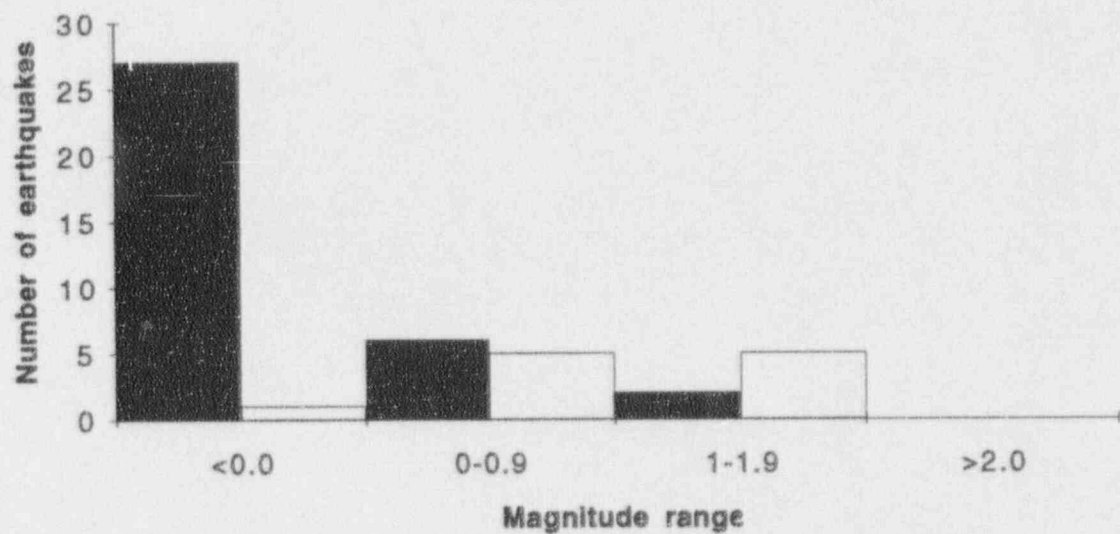


Figure 10. Magnitude ranges of earthquakes at Monticello Reservoir during January 1 - December 31, 1992. Solid and open bars indicate unlocated and located events respectively.

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, 1992

STATION	% DOWNTIME
MR01	4
MR02	3
MR05	4
MR07	4
MR10	0
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 / N_o , 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 1 - DECEMBER 31, 1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6	339	6.5	0.01	0.2	1.0 C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6	170	1.9	0.08	7.6	11.8 D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8	147	2.0	0.12	1.2	2.6 C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8	278	1.0	0.09	1.0	0.7 C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8	230	0.4	0.10	1.2	0.8 C1

APPENDIX VI

List of earthquakes with (S-P) \leq 2.5 seconds recorded around
Monticello Reservoir during October 1 - December 31, 1992.

Sl.No.	Date	Station	P-arrival	(S-P) Sec	Ep.Dist (S-P)x8.5	Dur Sec	Mag
1	92 11 04	JSC	19 34 09.00	0.6	5.1	10	0.2
2	92 11 04	JSC	19 37 11.00	0.6	5.1	8	0
3	92 11 11	JSC	17 09 03.80	0.5	4.3	6	-0.2
4	92 11 14	JSC	16 14 43.50	0.9	7.7	6	-0.2
5	92 11 17	JSC	21 12 29.00	1	8.5	7	-0.1
6	92 11 25	JSC	17 09 33.60	1	8.5	15	0.6
7	92 11 27	JSC	10 59 19.00	0.5	4.3	5	-0.4
8	92 12 29	JSC	23 12 52.00	0.2	1.7	3	-0.9
9	92 12 30	MR10	14 54 29.20	*		3.5	-0.6
10	92 12 30	MR10	14 54 54.1	*		5.5	
	"	JSC	14 54 55.4	1.1	9.4		-0.2

* Event too close to the station

APPENDIX VII

Maximum and minimum water levels, changes in water level, number of earthquakes and energy release in ergs at Monticello Reservoir during October 1 - December 31, 1992. Dates are given in Julian Calendar.

Day	WI(Min)	WI(Max)	WI(Avg)	Change	# of Eqs	Log E
275	424.4	424.8	424.4	0	0	0
276	423.9	424.8	424.4	0	0	0
277	423.9	424.5	424.2	-0.2	0	0
278	422.9	424.9	424.1	-0.1	0	0
279	423.2	424.7	424.5	0.4	1	13.57
280	423.3	424.6	424.1	-0.4	0	0
281	423.3	424.9	424	-0.1	0	0
282	423.5	424.7	424.2	0.2	0	0
283	424.2	424.9	424.8	0.6	0	0
284	424.7	424.9	424.8	0	0	0
285	424.3	425	424.8	0	0	0
286	423.4	424.6	424	-0.8	0	0
287	423.6	424.8	424	0	0	0
288	423.4	424.9	424.3	0.3	0	0
289	422.5	424.8	423.8	-0.5	0	0
290	422.8	424.5	423.7	-0.1	0	0
291	422.9	424	423.5	-0.2	0	0
292	423.5	424	423.5	0	0	0
293	422.8	424.8	423.7	0.2	0	0
294	423	424.3	423.4	-0.3	0	0
295	423.2	425	424.2	0.8	0	0
296	423.5	424.9	424.2	0	0	0
297	423.4	423.7	423.6	-0.6	0	0
298	423.4	424.3	424	0.4	0	0
299	423.5	424.1	424	0	1	11.64
300	423.2	424.8	424.1	0.1	0	0
301	423.6	424.7	424.3	0.2	0	0
302	422.8	424.5	423.8	-0.5	0	0
303	423.3	425	424.2	0.4	1	13.53
304	421.6	424.8	423.5	-0.7	0	0
305	421.7	424	422.7	-0.8	0	0
306	421.9	424.2	423.2	0.5	0	0
307	421.9	424.8	423.5	0.3	0	0
308	421.9	424	423.4	-0.1	0	0
309	422.7	424.5	423.8	0.4	2	12.41
310	422.4	424.8	423.6	-0.2	0	0
311	423	424.2	423.7	0.1	0	0
312	423.1	424.6	423.9	0.2	1	13.48
313	423.2	424.6	424.1	0.2	0	0
314	423.6	424.8	424.1	0	0	0
315	423.6	424.8	424.1	0	0	0
316	423.5	424.9	424.2	0.1	1	11.44
317	422.9	424.8	423.9	-0.3	0	0

Appendix VII cont'd.....

Day	WI(Min)	WI(Max)	WI(Avg)	Change	# of Eqs	Log E
318	423	424.8	424.1	0.2	0	0
319	423.4	424.8	424.3	0.2	1	11.44
320	423.6	424.9	424.4	0.1	0	0
321	422.6	424.8	423.5	-0.9	0	0
322	422.7	424.5	423.7	0.2	1	11.64
323	423.5	425	424.3	0.6	0	0
324	422.8	424.5	423.6	-0.7	0	0
325	423	424.9	424	0.4	0	0
326	423.7	424.9	424.2	0.2	0	0
327	423.4	425	424.1	-0.1	0	0
328	423.4	424.9	423.9	-0.2	0	0
329	423.7	424.9	424.4	0.5	0	0
330	423.5	425	424	-0.4	1	12.74
331	423.6	424.9	424.4	0.4	0	0
332	424.2	424.9	424.8	0.4	1	11.19
333	424.9	424.9	424.9	0.1	0	0
334	424.9	424.3	424.7	-0.2	0	0
335	423.5	424.9	424.1	-0.6	0	0
336	423.7	425	424.5	0.4	0	0
337	423.7	424.9	424.1	-0.4	0	0
338	423.3	424.7	424	-0.1	0	0
339	423.4	424.8	424.3	0.3	0	0
340	424.1	424.6	424.4	0.1	0	0
341	424.2	424.9	424.4	0	0	0
342	424.3	425	424.3	-0.1	0	0
343	423.6	424.9	424.2	-0.1	0	0
344	423.3	424.9	423.8	-0.4	1	12.46
345	423.5	422.9	423.9	0.1	0	0
346	423.7	424.9	424.3	0.4	0	0
347	424.2	424.5	424.5	0.2	0	0
348	424.1	424.5	424.3	-0.2	0	0
349	423.8	424.8	424.4	0.1	0	0
350	423.8	424.5	424.8	0.4	0	0
351	424.2	425	424.6	-0.2	0	0
352	423.6	425	424.3	-0.3	0	0
353	422.7	424.2	423.6	-0.7	0	0
354	422.1	423.5	422.9	-0.7	0	0
355	422.2	423.8	423.3	0.4	0	0
356	422.3	424.3	423.3	0	0	0
357	422.6	423.9	423.4	0.1	0	0
358	422.2	424.5	423.2	-0.2	0	0
359	422.3	424.5	423.8	0.6	0	0
360	422.7	424.1	423.6	-0.2	0	0
361	422.2	424.4	423.7	0.1	0	0
362	422.2	424	423.3	-0.4	0	0
363	424.1	424.9	424.5	1.2	0	0
364	424.1	424.1	424.1	-0.4	1	10.57
365	423.9	424.6	424.4	0.3	2	11.7
366	423.7	424.5	424.3	-0.1	0	0

APPENDIX VIII

MONTICELLO RESERVOIR EARTHQUAKES JANUARY 1 - DECEMBER 31, 1992

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
920225	1337	42.78	34-20.00	81-18.64	1.18	1.02	10 159	2.5	0.08	0.5	1.9	B1
920226	1010	10.46	34-19.79	81-18.74	1.31	0.21	10 153	2.4	0.10	0.4	1.3	B1
920315	8 0	47.48	34-20.07	81-18.68	0.97	0.82	10 159	2.4	0.06	0.3	1.7	B1
920402	1714	29.62	34-22.33	81-20.66	1.00	1.02	7 281	1.8	0.15	2.9	4.5	D1
920429	1810	2.98	34-23.60	81-17.18	4.90	0.82	7 292	4.4	0.15	3.6	2.7	D1
920521	1431	33.09	34-20.01	81-18.79	0.42	0.21	7 111	1.6	0.08	0.8	2.1	B1
920529	1654	44.12	34-24.09	81-22.80	2.79	1.02	8 333	6.1	0.07	1.2	1.6	C1
920825	17 4	57.66	34-24.50	81-24.40	0.69	1.02	7 333	8.6	0.23		5.4	D1
920908	1755	43.74	34-21.98	81-16.80	2.00	0.82	6 253	4.2	0.08	1.2	3.6	D1
921005	1959	1.06	34-24.89	81-22.27	1.32	1.18	6 339	6.5	0.01	0.2	1.0	C1
921025	1142	19.73	34-19.64	81-19.23	0.74	-0.11	6 170	1.9	0.03	7.6	11.8	D1
921029	524	54.20	34-19.64	81-19.08	0.42	1.15	8 147	2.0	0.12	1.2	2.6	C1
921107	321	40.11	34-22.33	81-20.11	2.46	1.12	8 278	1.0	0.09	1.0	0.7	C1
921209	2148	49.10	34-19.98	81-20.35	1.50	0.44	8 230	0.4	0.10	1.2	0.8	C1