TECHNICAL REPORT 95-2

SEISMIC ACTIVITY NEAR THE V.C. SUMMER NUCLEAR STATION

FOR THE PERIOD

APRIL-JUNE, 1995

BY

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CONTRACT NO. N622702

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INTRODUCTION

Analysis of the seismic activity near the V.C. Summer Nuclear Station in South Carolina between April 1 and June 30, 1995 is presented in this report. During this period, forty-nine events were recorded in the vicinity of the Monticello Reservoir. All forty-nine events were located and ranged in magnitude from -0.6 to 2.5.

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 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 HYPO71 output is given in Appendix IV. The event magnitude was determined from the signal duration at JSC using the following relation:

$$M_L = -1.83 + 2.04 \text{ Log } D,$$

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):

$$\text{Log}_{10} E = 11.8 + 1.5 M_L$$

OBSERVED SEISMICITY DURING APRIL-JUNE, 1995

Seismicity around Monticello Reservoir was moderate during the second quarter of 1995. Forty-nine events were recorded and located (Figure 1). All events for the quarter were shallow and varied in depth between 0.09 and 3.64 km. The largest event occurred on April 18, 1995 at 14:36:46 UTC and had a duration magnitude of 2.5 (Appendix V). A total of forty events occurred in April, 1995 with thirteen in a 21 hour burst on April 18, 1995 (Appendix V). Six events occurred in the month of May and three occurred in June (Appendix V). By the end of the quarter the burst of activity had subsided. The majority of the events were located in the central area of the reservoir between stations MR07 and MR10. The remaining events occurred in two groups, one between stations MR01 and MR10, the other west of station MR10 (Figure 1). One event located in the center of the reservoir with a 0.3 magnitude was an A quality location (Appendix V). Twenty event locations were of good quality (B) with the remaining twenty-eight of fair quality (C) (Appendix V).

The long term decline in seismicity observed at Monticello Reservoir is continuing (Figure 2) and the cumulative seismicity has shown relative flattening since 1985-86 (Figure 3).

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 4. 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 second quarter of 1995 was moderate and occurred generally in the central section of the reservoir, with the exception of the seven events west of station MR10. No systematic correlation was observed between the reservoir level fluctuations and the seismicity.

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.

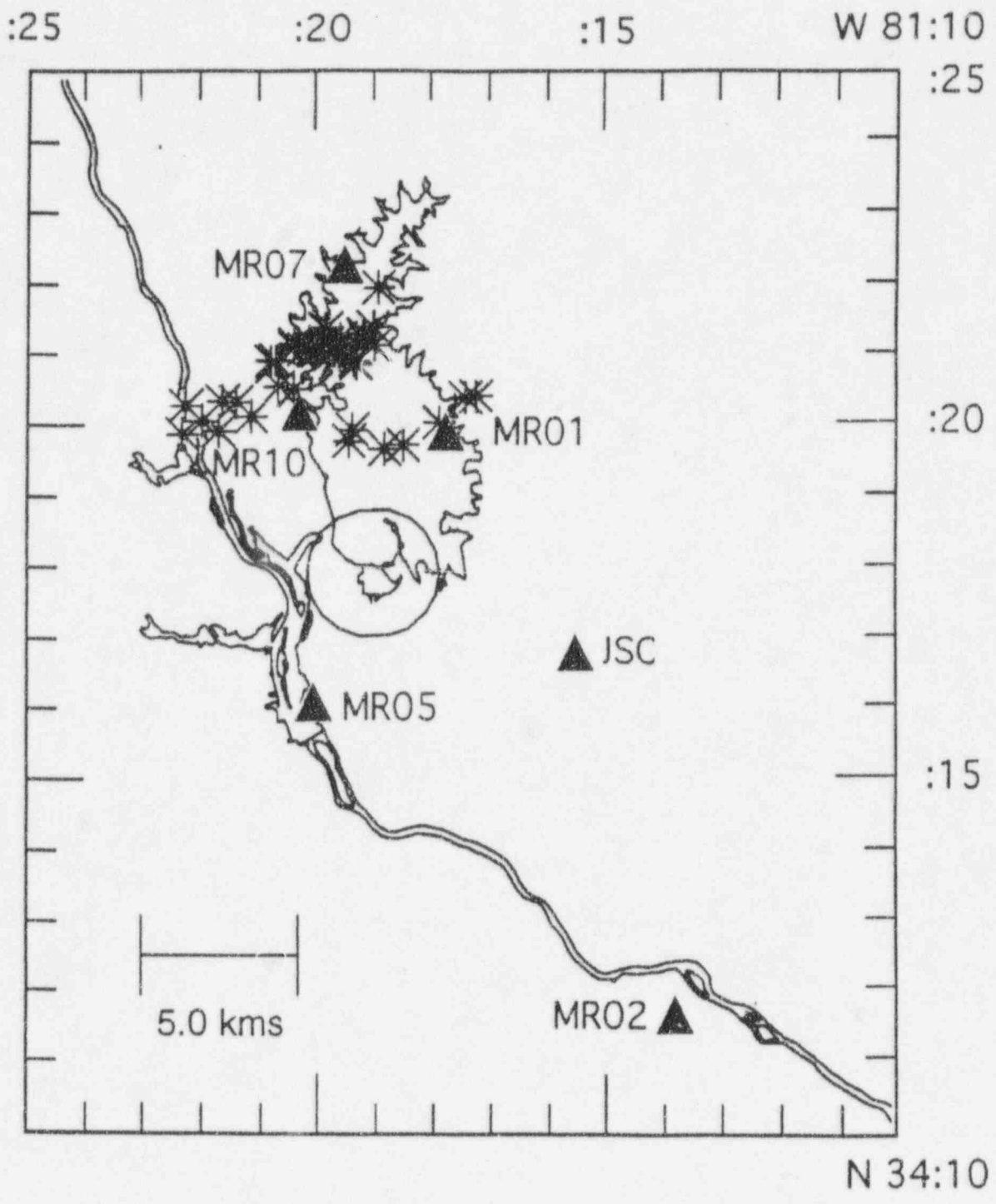

Figure 1. Station locations of the Monticello Reservoir sub-network. Earthquakes located near Monticello Reservoir during the period April - June, 1995 (stars).

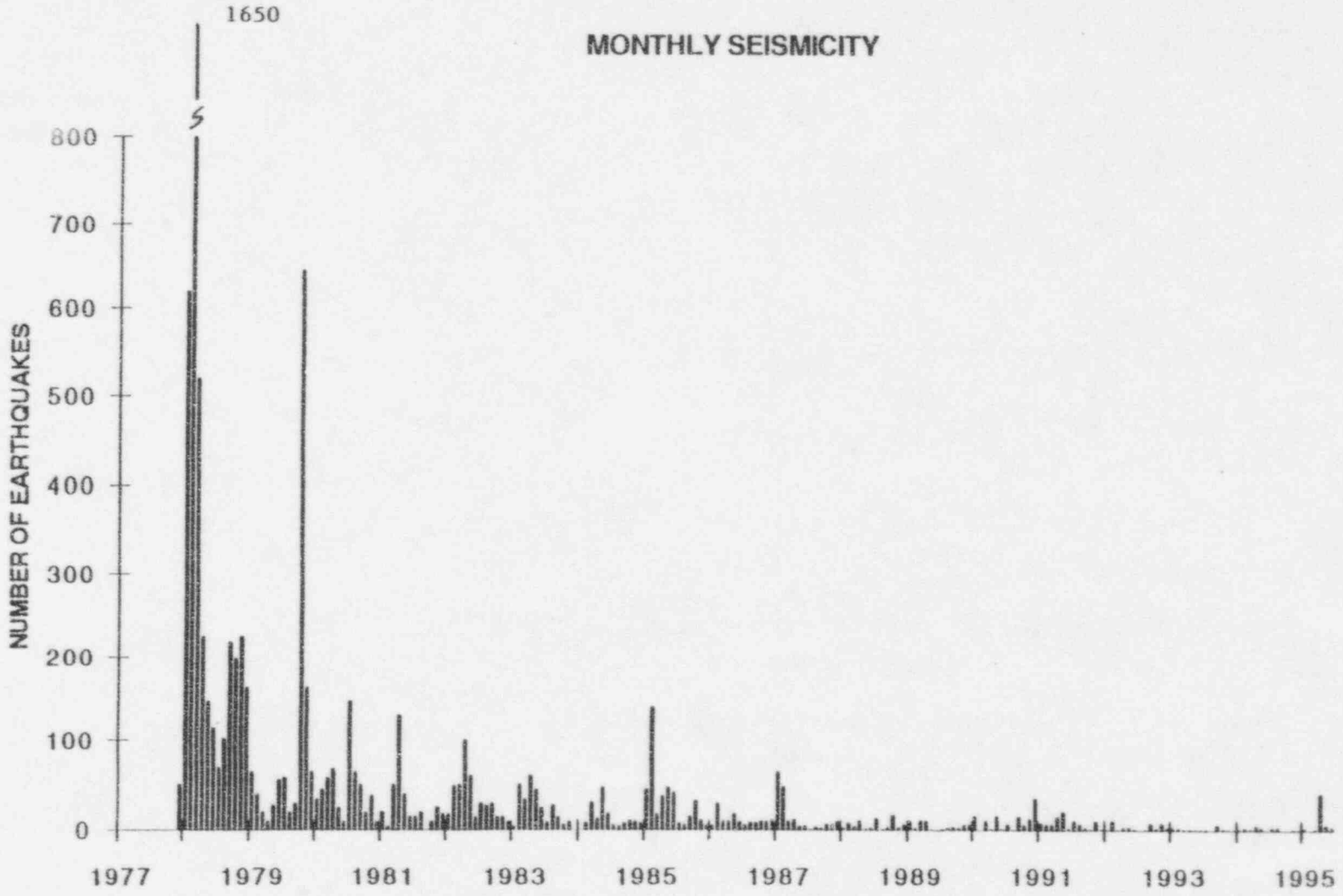

Figure 2. Earthquakes between impoundment and June, 1995.

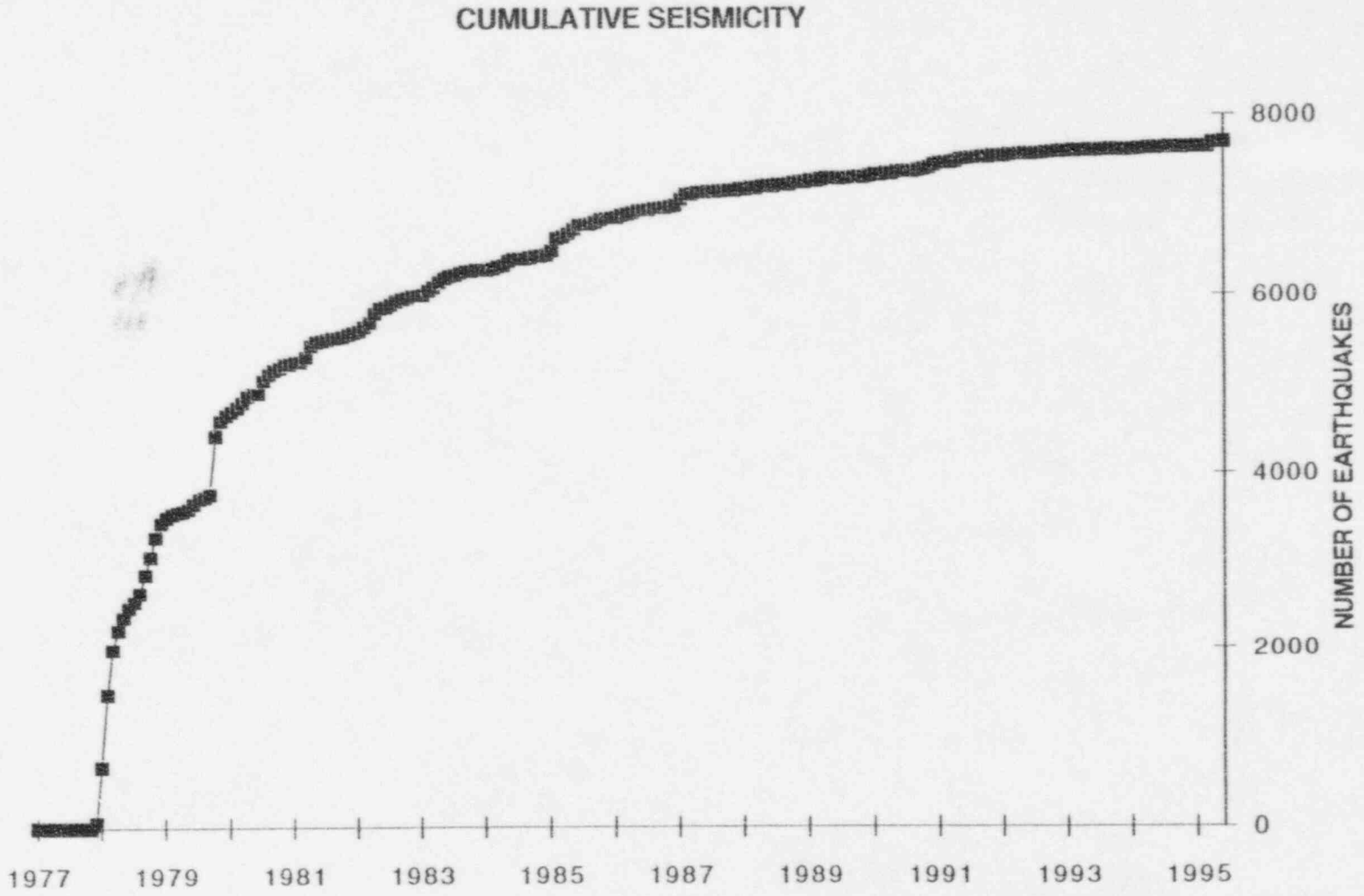

Figure 3. Cumulative seismicity near Monticello Reservoir since impoundment.

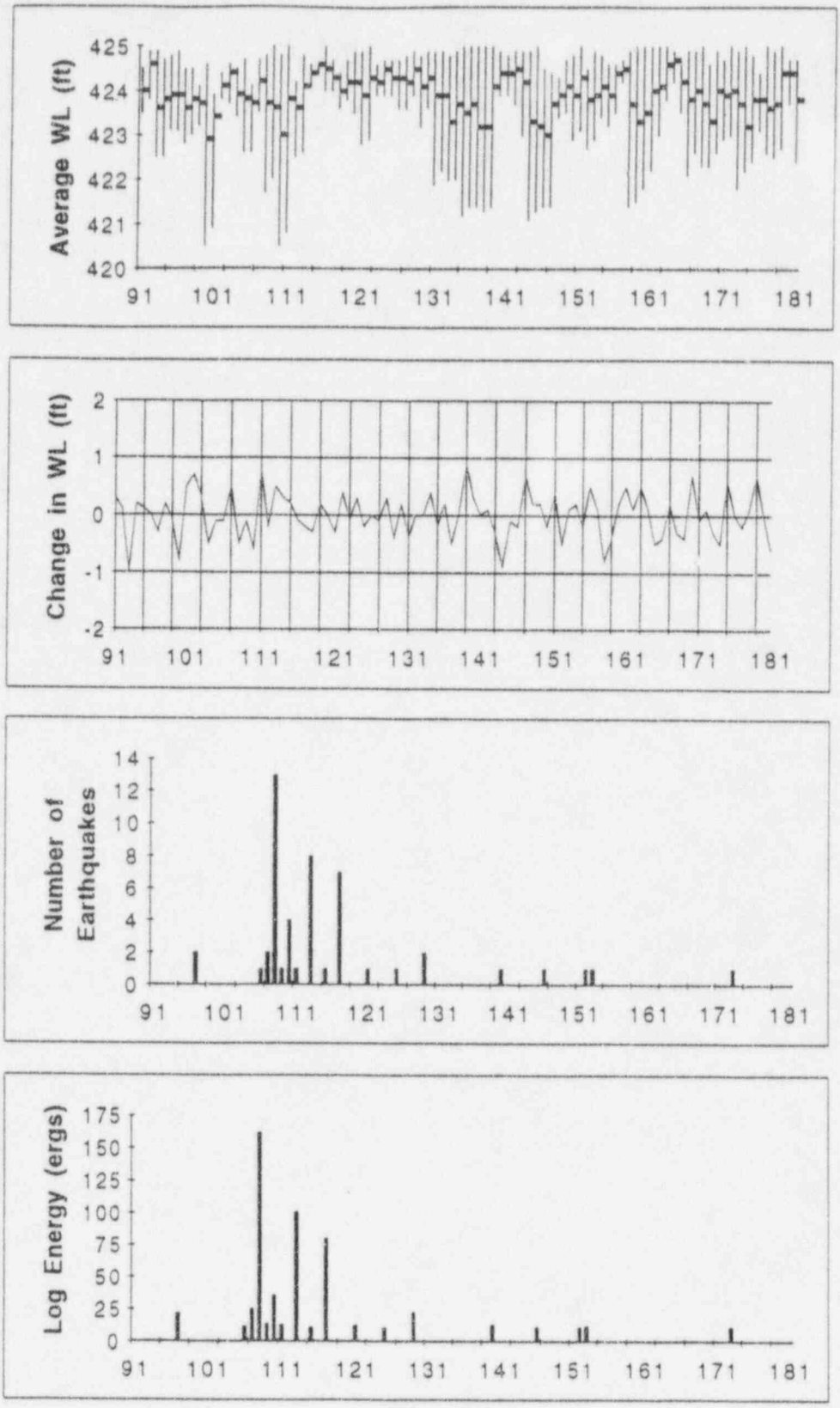

Figure 4. Comparison of daily lake level, changes in lake level, number of earthquakes and the log of energy release in ergs per day at Monticello Reservoir. Error bars in the top panel indicate daily fluctuations in water level.

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

APRIL 1 - JUNE 30, 1995

STATION	PERCENT DOWNTIME
MR01	0.0
MR02	0.0
MR05	0.0
MR07	2.2
MR10	6.6
JSC	0.0

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.

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* 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
APRIL - JUNE, 1995

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	M
950407	1754 22.19	34-21.29	81-19.17	1.02	-0.60	6	163	1.8	0.02	0.2	0.9	B	1
950407	1940 11.81	34-21.15	81-20.35	2.89	-0.60	6	218	1.8	0.03	0.4	0.3	C	1
950416	0207 59.13	34-19.65	81-18.79	2.95	0.12	6	157	2.4	0.04	0.6	0.9	B	1
950417	0512 42.29	34-21.08	81-20.00	0.19	0.91	10	187	1.7	0.05	0.3	0.6	C	1
950417	1804 44.28	34-21.07	81-20.02	1.27	0.37	6	189	1.7	0.04	0.6	0.8	C	1
950418	0257 20.87	34-21.05	81-19.67	0.42	0.37	6	158	1.8	0.01	1.3	2.5	C	1
950418	0458 22.94	34-21.36	81-19.82	2.04	1.88	9	180	1.7	0.04	0.4	0.5	C	1
950418	0802 43.83	34-21.05	81-19.51	0.45	0.21	6	145	2.0	0.04	0.3	1.4	B	1
950418	1101 00.57	34-21.12	81-18.96	0.42	0.87	12	162	2.2	0.09	0.6	2.0	B	1
950418	1436 46.59	34-21.31	81-19.57	1.47	2.48	12	157	1.7	0.07	0.4	0.7	B	1
950418	1439 26.09	34-21.07	81-19.45	0.28	-0.24	7	141	2.1	0.04	0.4	1.2	B	1
950418	1753 39.66	34-21.07	81-20.04	1.61	0.01	8	190	1.7	0.04	0.4	0.5	C	1
950418	1826 33.49	34-21.37	81-19.80	2.71	1.24	12	178	1.7	0.06	0.4	0.4	B	1
950418	1944 30.68	34-21.07	81-20.19	1.33	1.24	8	203	1.7	0.03	0.3	0.4	C	1
950418	1944 48.98	34-21.05	81-19.77	0.65	0.01	6	166	1.8	0.01	0.2	0.4	B	1
950418	1947 21.91	34-21.03	81-19.76	0.59	-0.86	6	164	1.7	0.01	0.1	0.3	B	1
950418	2122 23.33	34-21.09	81-20.35	3.00	-0.86	6	217	1.7	0.10	1.6	1.3	C	1
950418	2301 34.59	34-20.98	81-19.58	0.09	0.01	8	148	1.8	0.05	0.2	0.8	B	1
950419	0053 15.82	34-21.05	81-19.93	0.71	1.44	9	180	1.7	0.04	0.5	0.8	B	1
950420	1234 04.92	34-21.22	81-19.14	0.68	-0.40	6	163	1.9	0.01	1.1	3.0	C	1
950420	1303 10.32	34-21.04	81-19.65	0.26	0.44	9	156	1.8	0.02	0.3	0.6	B	1
950420	1306 03.83	34-20.90	81-19.32	0.22	-0.11	8	134	2.0	0.07	0.2	0.7	B	1
950420	2247 09.86	34-21.22	81-19.56	1.95	0.01	6	154	1.9	0.00	0.1	0.1	B	1
950421	0124 32.39	34-20.38	81-17.21	0.82	0.82	8	205	4.7	0.03	0.2	0.9	C	1
950423	0154 52.35	34-20.28	81-21.67	3.64	1.02	6	278	2.2	0.08	1.4	1.0	C	1
950423	0216 19.40	34-20.53	81-20.63	0.91	0.82	6	251	0.9	0.01	0.1	0.1	C	1
950423	0230 42.34	34-20.91	81-20.69	3.00	0.99	12	223	1.5	0.10	0.7	0.6	C	1
950423	0236 44.19	34-20.49	81-20.35	1.07	-0.11	6	217	0.6	0.05	0.8	0.6	C	1
950423	0355 07.67	34-20.28	81-21.42	2.23	0.12	6	273	1.8	0.05	0.9	0.7	C	1
950423	0950 31.50	34-20.90	81-20.77	3.00	0.95	6	249	1.5	0.07	1.1	0.8	C	1
950423	1845 59.47	34-21.05	81-20.01	1.36	-0.40	6	186	1.6	0.04	0.5	0.7	C	1
950423	1951 04.07	34-21.08	81-19.99	1.71	1.09	6	186	1.7	0.01	0.2	0.2	C	1
950425	0936 37.43	34-21.19	81-20.08	1.68	-0.40	4	197	1.9	0.00			C	1
950427	0810 45.65	34-19.87	81-22.27	3.17	-0.11	6	285	3.2	0.05	1.1	1.0	C	1
950427	1740 14.55	34-20.02	81-21.96	3.56	0.82	6	281	2.6	0.06	1.1	0.8	C	1
950427	2015 55.75	34-21.15	81-19.66	1.89	-0.24	6	161	2.0	0.02	0.3	0.4	B	1
950427	2202 36.14	34-20.03	81-21.25	1.33	0.95	8	227	1.6	0.06	0.5	0.6	C	1
950427	2211 32.92	34-21.39	81-18.99	0.28	-1.83	4	284	3.0	0.01			C	1
950427	2211 34.30	34-21.95	81-18.90	0.53	-0.86	4	302	3.9	0.05			C	1
950427	2213 14.12	34-20.28	81-22.28	2.41	-0.24	6	288	3.1	0.08	1.3	1.5	C	1
950501	2206 38.22	34-21.15	81-19.78	0.30	0.68	12	170	1.9	0.04	0.4	0.8	B	1
950505	1708 22.22	34-20.01	81-17.84	0.99	-0.60	4	350	0.2	0.05			C	1
950509	0101 47.87	34-20.36	81-17.38	0.55	-0.24	8	201	1.0	0.02	0.2	0.3	C	1
950509	0811 38.33	34-19.77	81-19.40	3.00	-0.40	6	167	1.5	0.06	0.8	0.9	B	1
950520	2300 28.39	34-21.12	81-19.84	0.51	0.91	12	174	1.9	0.05	0.3	0.8	B	1
950526	2146 02.26	34-21.07	81-19.77	0.92	-0.24	6	167	1.8	0.01	0.2	0.5	B	1
950601	1349 44.13	34-19.90	81-19.32	1.95	-0.24	8	155	1.5	0.03	0.2	0.3	B	1
950602	1823 13.90	34-19.70	81-18.46	2.27	0.29	10	89	1.2	0.08	0.4	0.6	A	1
950622	1727 41.88	34-19.91	81-21.66	0.58	-0.11	6	276	2.2	0.02	0.3	0.7	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 April 1 - June 30, 1995. Dates are given in Julian Calendar.

J.DATE	WL (max)	WL (min)	WL (avg)	WL (ch)	# of eqs	Energy
91	424.5	423.5	424	0.3	0	0
92	424.9	423.8	424.6	0.1	0	0
93	424.9	422.5	423.6	-1	0	0
94	424.7	422.5	423.8	0.2	0	0
95	424.8	423.1	423.9	0.1	0	0
96	424.9	423.1	423.9	0	0	0
97	424.5	422.8	423.6	-0.3	2	21.8
98	424.5	423	423.8	0.2	0	0
99	424.1	423.2	423.7	-0.1	0	0
100	424.6	420.5	422.9	-0.8	0	0
101	423.9	420.9	423.4	0.5	0	0
102	424.4	423.8	424.1	0.7	0	0
103	424.6	423.7	424.4	0.3	0	0
104	424.5	423.4	423.9	-0.5	0	0
105	424.7	422.6	423.8	-0.1	0	0
106	424.1	422.6	423.7	-0.1	1	11.97
107	424.7	423.5	424.2	0.5	2	25.52
108	424.8	421.7	423.7	-0.5	13	161.94
109	425	422	423.6	-0.1	1	13.96
110	424.8	420.5	423	-0.6	4	35.92
111	425	420.8	423.8	0.8	1	13.04
112	424.2	422.5	423.6	-0.2	0	0
113	424.8	422.6	424.1	0.5	8	101.1
114	424.6	424.1	424.4	0.3	0	0
115	424.6	424.4	424.6	0.2	1	11.19
116	425	424	424.5	-0.1	0	0
117	424.7	424	424.3	-0.2	7	80.34
118	424.4	423.6	424	-0.3	0	0
119	424.7	423.8	424.2	0.2	0	0
120	424.9	423.5	424.2	0	0	0
121	424.9	422.8	423.9	-0.3	1	12.82
122	425	422.9	424.3	0.4	0	0
123	424.6	423.9	424.2	-0.1	0	0
124	424.7	423.9	424.5	0.3	0	0
125	424.7	423.9	424.3	-0.2	1	10.9
126	424.7	423.6	424.3	0	0	0
127	424.8	423.6	424.2	-0.1	0	0
128	424.9	423.9	424.5	0.3	0	0
129	424.8	423.2	424.1	-0.4	2	22.63
130	424.9	423.6	424.3	0.2	0	0
131	424.9	421.9	423.9	-0.4	0	0
132	424.9	422.2	423.9	0	0	0
133	424.8	422	423.3	0	0	0
134	424.9	422	423.7	0.4	0	0
135	425	421.2	423.5	-0.2	0	0
136	425	421.4	423.7	0.2	0	0

APPENDIX VI (continued)

J.DATE	WL (max)	WL (min)	WL (ave)	WL (ch)	# of eqs	Energy
137	425	421.4	423.2	-0.5	0	0
138	425	421.3	423.2	0	0	0
139	425	421.4	424.1	0.9	0	0
140	424.9	423.9	424.4	0.3	1	13.16
141	424.8	423.9	424.4	0	0	0
142	424.9	423.7	424.5	0.1	0	0
143	424.9	423	424.2	-0.3	0	0
144	424.9	421.1	423.3	-0.9	0	0
145	425	421.3	423.2	-0.1	0	0
146	424.5	421.4	423	-0.2	1	11.64
147	424.4	421.4	423.7	0.7	0	0
148	424.3	423.4	423.9	0.2	0	0
149	424.7	423.5	424.1	0.2	0	0
150	424.8	422.9	423.9	-0.2	0	0
151	425	423.1	424.3	0.4	0	0
152	424.5	422.7	423.8	-0.5	1	11.64
153	424.9	422.9	423.9	0.1	1	12.24
154	424.8	423.4	424.1	0.2	0	0
155	424.6	423.2	423.9	-0.2	0	0
156	424.6	423.5	424.4	0.5	0	0
157	424.7	424.2	424.5	0.1	0	0
158	424.9	421.4	423.7	-0.8	0	0
159	425	421.5	423.3	-0.4	0	0
160	425	421.8	423.5	0.2	0	0
161	425	422.2	424	0.5	0	0
162	425	423	424.1	0.1	0	0
163	425	423.8	424.6	0.5	0	0
164	424.9	424.2	424.7	0.1	0	0
165	424.6	423.5	424.2	-0.5	0	0
166	424.9	422.1	423.8	-0.4	0	0
167	424.9	422.6	424	0.2	0	0
168	425	422.3	423.7	-0.3	0	0
169	424.6	422.3	423.3	-0.4	0	0
170	424.9	422.6	424	0.7	0	0
171	424.7	422.9	423.9	-0.1	0	0
172	425	423	424	0.1	0	0
173	424.9	421.8	423.7	-0.3	1	11.64
174	425	422.2	423.2	-0.5	0	0
175	424.8	422.4	423.8	0.6	0	0
176	424.4	423.1	423.8	0	0	0
177	425	422.6	423.6	-0.2	0	0
178	424.9	422.5	423.7	0.1	0	0
179	425	422.7	424.4	0.7	0	0
180	424.7	423.7	424.4	0	0	0
181	424.7	422.4	423.8	-0.6	0	0