

# EARTHQUAKE-INDUCED WATER-LEVEL FLUCTUATIONS AT YUCCA MOUNTAIN, NEVADA, APRIL, 1992

by Grady M. O'Brien

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## CONVERSION FACTORS

<i>Multiply</i>	<i>By</i>	<i>To obtain</i>
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)

**Earthquake-Induced Water-level Fluctuations at  
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**ABSTRACT**

This report presents earthquake-induced water-level and fluid-pressure data for well USW H-5 during April 1992. Well USW H-5 is located in the Yucca Mountain area, Nevada. On April 22, 1992 a 6.2-magnitude earthquake occurred in southern California which caused a maximum fluid-pressure change of approximately 50 centimeters in well USW H-5. Within 18 hours on April 25-26, 1992, three major earthquakes occurred in northern California. The water-level responses to these earthquakes were detected in well USW H-5. The maximum water-level fluctuation from the northern California earthquakes was in excess of 52.5 cm.

**INTRODUCTION**

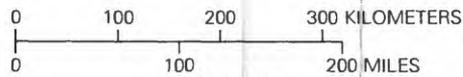
The Yucca Mountain area in southern Nevada is being studied by the U.S. Department of Energy as a potential site for an underground high-level nuclear-waste repository (U.S. Department of Energy, 1988). As part of that study, the U.S. Geological Survey monitors water levels in about 25 wells to define the potentiometric surface, determine long-term and seasonal water-level changes, and estimate hydraulic properties using short-term water-level fluctuations. Frequency of monitoring ranges from quarterly to continuous with most measurements being done either monthly or hourly. Monthly measurements are sufficient to detect long-term and seasonal changes, whereas hourly measurements are required to detect changes induced by barometric-pressure fluctuations and earth tides. Only continuous measurements are capable of detecting seismically induced water-level fluctuations.

During late April 1992, the water-level response to earthquakes in California was detected at well USW H-5 on the crest of Yucca Mountain just west of the Nevada Test Site (fig. 1) (lat 36°51'22"N., long 116°27'55"W.). Water-level and fluid-pressure data collected from well USW H-5 during the period of the earthquakes are presented in this report.

Hydroseisms, or water-level fluctuations in response to earthquakes, are relatively common phenomena observed in wells penetrating confined aquifers (Todd, 1980, p. 250-252). For example, the Anchorage, Alaska earthquake of 1964, the largest North American earthquake thus far in the 20th century, caused water-level fluctuations throughout the world; the largest peak-to-trough range was about 7.0 m (meters) in a well in South Dakota (Vorhis, 1967, p. 32). Hydroseisms are more commonly in the centimeters-to-meter range and typically are observed for minutes to tens of minutes. Hydroseisms roughly resemble damped oscillation curves but are



Base from U.S. Geological Survey 1:7,500,000, 1979



**EXPLANATION**

- ▲ EARTHQUAKE EPICENTER
- USW H-5 ● WELL AND NUMBER

**Figure 1.--Geographic locations of earthquake epicenters.**

somewhat more complicated because several different types of seismic waves participate in the phenomena. Relatively small dilatational (P) and shear (S) body waves are followed by long-period surface waves. Distant earthquakes generating long-period surface waves can produce water-level fluctuations somewhat larger than aquifer-pressure changes. However, short-period body waves probably predominate during local seismic events and produce aquifer-pressure changes much larger than water-level fluctuations. Rayleigh surface waves from earthquakes, with depths less than 15 km (kilometers), produce the largest water-level fluctuations in wells several degrees from the earthquake epicenter (Eaton and Takasaki, 1959, p. 227-229).

## **DESCRIPTION AND INSTRUMENTATION OF WELL USW H-5**

Well USW H-5 was drilled to a depth of 1,219 m and cased to a depth of 788 m. The well penetrates various volcanic units of Tertiary age. Approximate depth to water is 703 m, and the water-level altitude in this well is approximately 775 m. The well contains two intervals separated by a packer located at a depth of 1,091 m. The upper interval is a free water surface and is used to monitor the water level in the Bullfrog and Tram Members of the Crater Flat Tuff and a lower lava flow. The lower interval of the well is used to monitor the fluid pressure in an unnamed lava flow beneath the Crater Flat Tuff (Robison and others, 1988). The lower interval access tube is equipped with an air-inflatable small-diameter packer so that fluid pressure (rather than free water surface) is measured. The packer configuration in the lower interval eliminates well storage as well as viscosity and inertia effects that retard the movement of water as it flows to and from the well. Fluid-pressure measurements in the lower interval detect rapidly changing aquifer pressure induced by short-period earthquake waves. Due to the time required for water to move into and out of the well a free water surface can not respond efficiently to short-period earthquake waves (Leggette and Taylor, 1935).

To detect seismically induced water-level fluctuations, continuous monitoring of wells is required. Well USW H-5 has been equipped to monitor seismic events since March 17, 1992. The data-collection system in the upper and lower intervals of the well consists of gauge pressure transducers with 5 pounds per square inch pressure ranges. The pressure transducers are continuously powered, and the output is recorded on an analog chart recorder. The chart recorder prints the transducer output and grid simultaneously so that no signal distortion or chart drift occurs. Chart speed is set to 1 millimeter per minute, and the full-scale range for each interval is 50 millivolts. The chart scale was chosen so that local small-magnitude earthquakes, underground nuclear explosions (UNE), and distant earthquakes could be detected.

## **EARTHQUAKE-INDUCED WATER-LEVEL FLUCTUATIONS**

Four earthquakes in California during late April, 1992 produced measurable water-level and fluid-pressure fluctuations in well USW H-5. Sections of the analog chart that recorded the effects of the four earthquakes in well USW H-5 are shown

in figures 2-5. Earthquake information was obtained from the U.S. Geological Survey National Earthquake Information Center Quick Epicenter Determination system.

The water-level and fluid-pressure response to a southern California earthquake near Palm Springs (fig. 1), at 4:50:23 Universal Time (UTC), April 23, 1992 (8:50:23 pm PST, April 22) is shown in figure 2. The 6.2-magnitude earthquake occurred at lat 34°2'2" N., long 116°26'13" W. The earthquake was reportedly felt in the Las Vegas area. The distance from epicenter to well USW H-5 was approximately 311 km, and the first water-level response was detected at 04:51 UTC. Standard continental crust P-wave velocity of 8 km per second and Rayleigh wave (18-20 second period) velocity of 3 km per second provide good correlation in well USW H-5 between expected seismic wave arrival time and water-level response. Water-level fluctuations caused by the arrival of P-waves and Rayleigh waves are difficult to distinguish in figure 2, probably due to the relatively short distance from earthquake epicenter to well USW H-5 and the compressed time scale. Well USW H-5 water-level response to the P-wave is smaller in magnitude and precedes the Rayleigh wave which produces the maximum water-level fluctuations (fig. 3-5). The peak water-level rise and fall in the upper interval were approximately 14.6 cm (centimeters) and -11.5 cm. The fluctuations damped to 1 cm in about 19 minutes. The peak fluid-pressure rise in the lower interval was off scale and, thus, exceeded 23.4 cm; the peak fluid-pressure fall was -26.5 cm of water. The fluctuations damped to 1 cm in about 26 minutes.

Three major earthquakes occurred within 18 hours on April 25-26, 1992 in northern California (fig. 1). Significant damage and injuries were reported in the Eureka, California area. The water-level and fluid-pressure response to the northern California earthquake at 18:06:04 UTC, April 25, 1992 is shown in figure 3. The 7.0-magnitude earthquake occurred at lat 40°20'24" N., long 124°2'28" W. The distance from epicenter to well USW H-5 was approximately 767 km, and the first water-level response was detected at 18:08 UTC. The initial, small-magnitude, water-level fluctuations were caused by P-wave arrivals; the maximum water-level fluctuations were caused by Rayleigh waves (fig. 3). The peak water-level rise and fall in the upper interval of the well were off scale and, thus, exceeded 33.1 cm and -19.4 cm. The fluctuations damped to 1 cm in about 76 minutes. The peak fluid-pressure rise in the lower interval was off scale and, thus, exceeded 23.0 cm; the peak fluid-pressure fall was -26.1 cm of water. The fluctuations damped to 1 cm in about 97 minutes.

The water-level and fluid-pressure response to the northern California earthquake at 07:41:40 UTC, April 26, 1992, is shown in figure 4. The 6.5-magnitude earthquake occurred at lat 40°25'19" N., long 124°16'48" W. The distance from epicenter to well USW H-5 was approximately 789 km, and the first water-level response was detected at 07:44 UTC. The peak water-level rise and fall in the upper interval of the well were 11.0 cm and -10.2 cm. The fluctuations damped to 1 cm in about 12 minutes. The peak fluid-pressure rise and fall in the lower interval were 12.4 cm and -13.7 cm of water. The fluctuations damped to 1 cm in about 18 minutes.

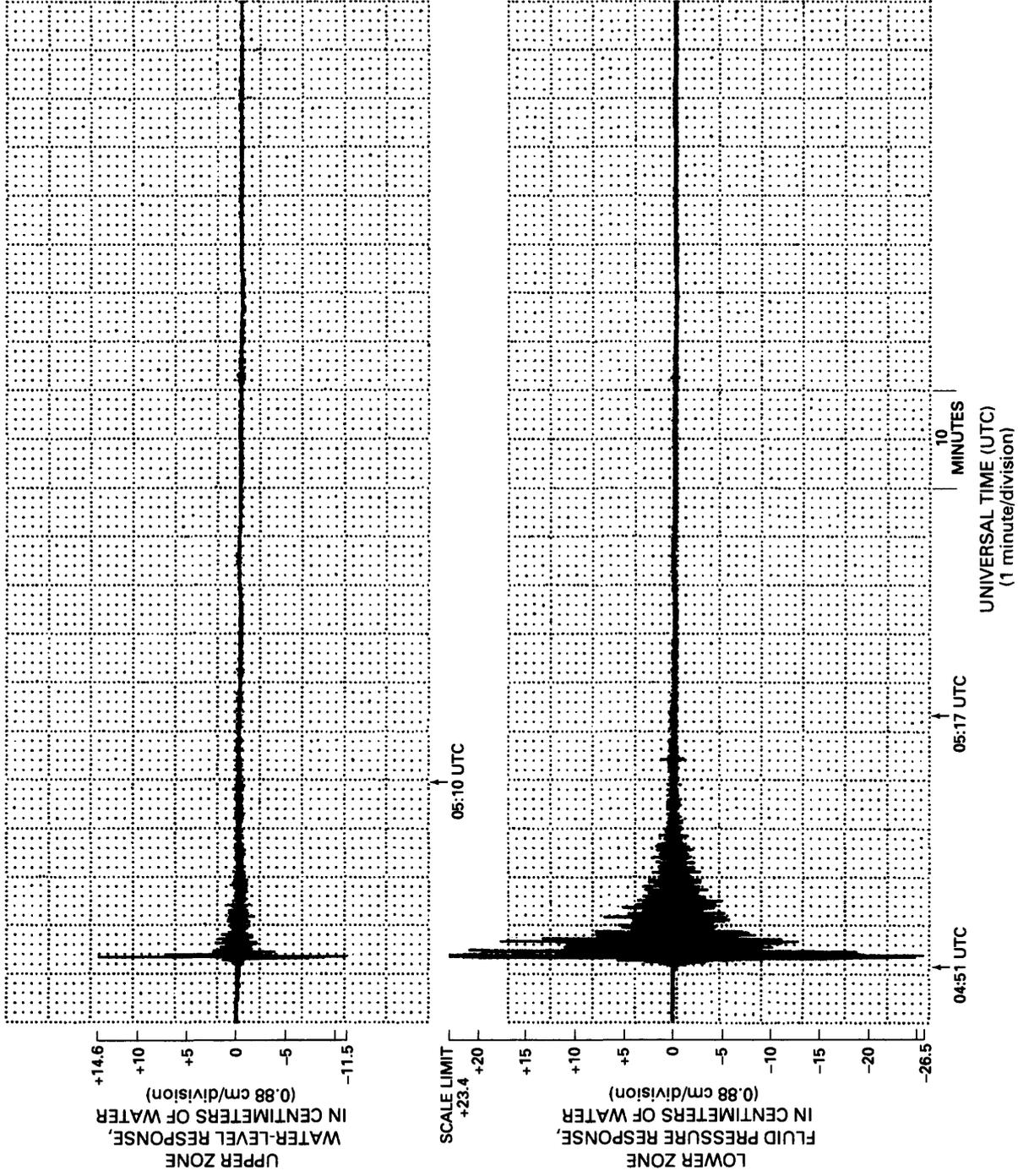


Figure 2.—Well USW H-5 response to earthquake near Palm Springs, California, occurring at 04:50 UTC, April 23, 1992.

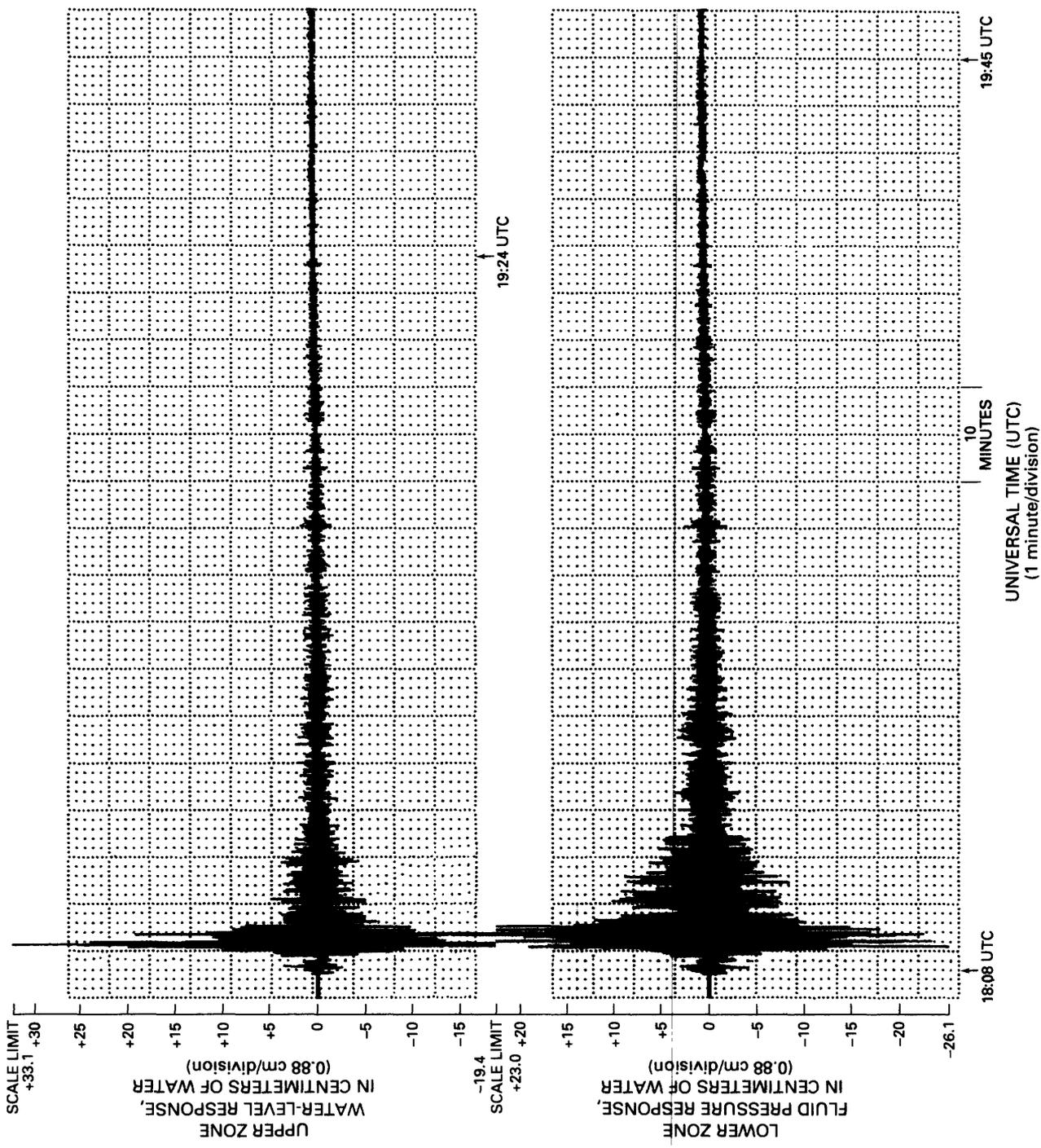


Figure 3.—Well USW H-5 response to earthquake near Eureka, California, occurring at 18:06 UTC, April 25, 1992.

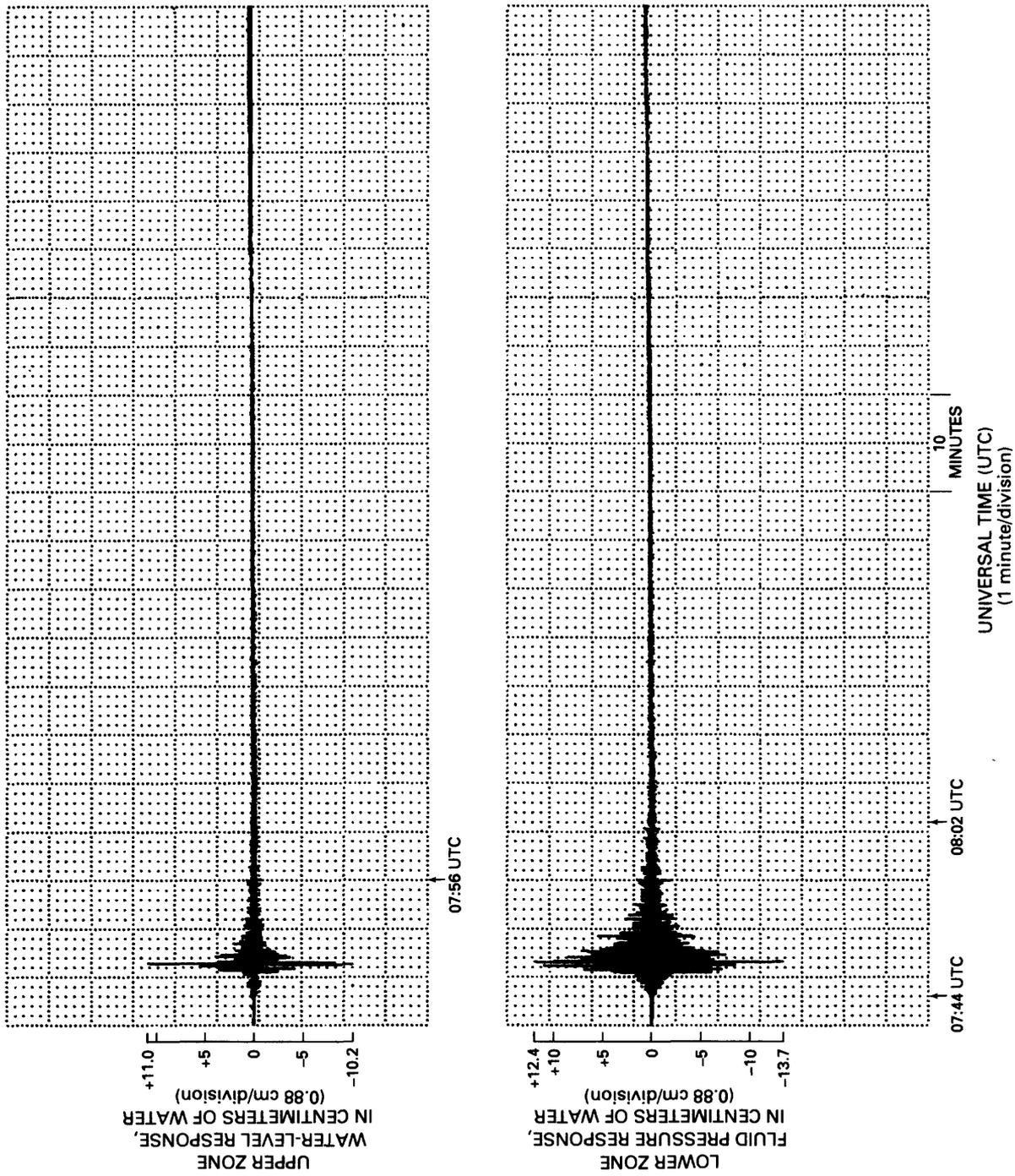


Figure 4.--Well USW H-5 response to earthquake near Eureka, California, occurring at 07:41 UTC, April 26, 1992.

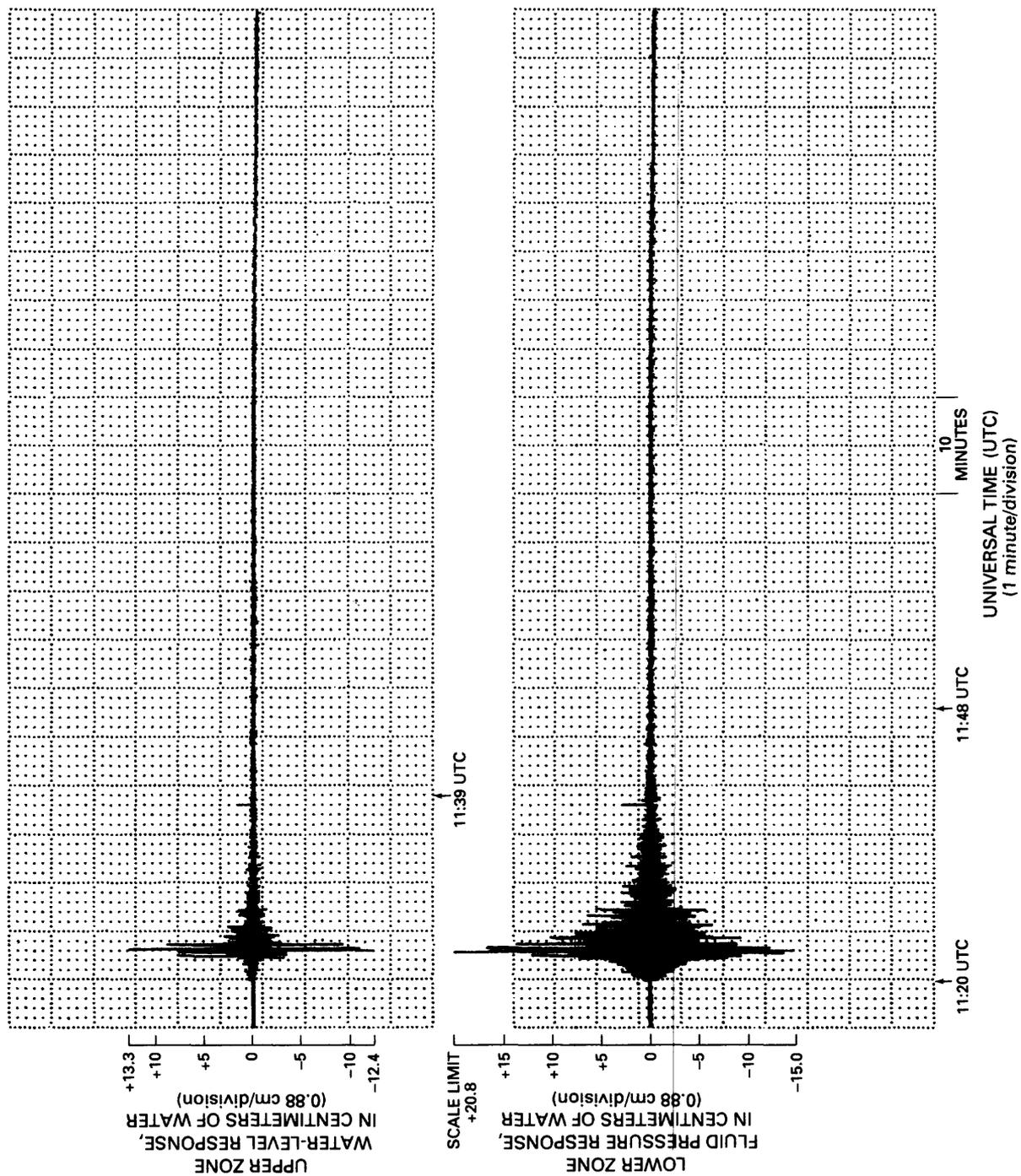


Figure 5.—Well USW H-5 response to earthquake near Eureka, California, occurring at 11:18 UTC, April 26, 1992.

The water-level and fluid-pressure response to the northern California earthquake at 11:18:26 UTC, April 26, 1992, is shown in figure 5. The 6.6-magnitude earthquake occurred at lat 40°23'53" N., long 124°18'14" W. The distance from epicenter to well USW H-5 was approximately 789 km, and the first water-level response was detected at 11:20 UTC. The peak water-level rise and fall in the upper interval were 13.3 cm and -12.4 cm. The fluctuations damped to 1 cm in about 19 minutes. The peak fluid-pressure rise in the lower interval was off scale and, thus, exceeded 20.8 cm; the fall remained on scale and was -15.0 cm of water. The fluctuations damped to 1 cm in about 28 minutes.

Water levels in well USW H-5 returned to pre-earthquake altitude following each of the April, 1992 earthquakes. No response to the earthquakes was detected in wells that were monitored monthly or hourly.

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