Impacts of Blasting on Domestic Water Wells

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Workshop on Mountaintop Mining Effects on Groundwater
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Opening Statement:

I'm going to cover two areas of the impacts of blasting on domestic wells and associated aquifers. First, I will discuss my personal experiences with researching this problem. Second, I will review the studies of others on the subject. Then, I will summarize some thoughts and give some points for discussion.

I. My research. - I used to work at the U.S. Bureau of Mines researching ground and surface water problems related to surface and underground mining.

A. At the request of Mike Smith, District Mining Manager in the Hawk Run Office of the PADEP, I began looking at the blasting problem early in 1994. I shut the work down at the end of 1995 because of my departure from the Bureau. Many of you know that the Bureau was eliminated in 1996. During the short period of research, I did manage to instrument a few shots and conduct several aquifer tests, before, between, and after the blasts.

Incidentally, I have recently had discussions with the PADEP on the initiation of a new study on the impacts of blasting on ground water and wells.

My study site was in Clearfield Co. Pennsylvania (*Fig 1)*, a mountaintop job, similar topography to southern WV. Numerous well nests were completed across the site with 4 to 6 wells at each nest (*Fig 2)***.** Here are the well nests. The area that I will show data from is this nest here and the mining was initiated in this area.

B. Monitoring of Blasts was the first part of the study-

1. Wells were instrumented with pressure transducers wired to data loggers.

2. The wells initially instrumented included *(Fig 3)*

   a. One well was completed similar to domestic water wells, i.e. an open borehole drilled to the top of the seat rock of the mined coal seam with 20 feet of casing installed at the top. This represented the water-table aquifer.

   b. A second well was completed to the first coal seam below the one being mined (~60 feet). The well was cased all the way down with an open interval at the lower coal seam and the immediate roof rock. The remainder of the hole was properly grouted. This represented the first yielding unit below the water-table aquifer.

Figure 1

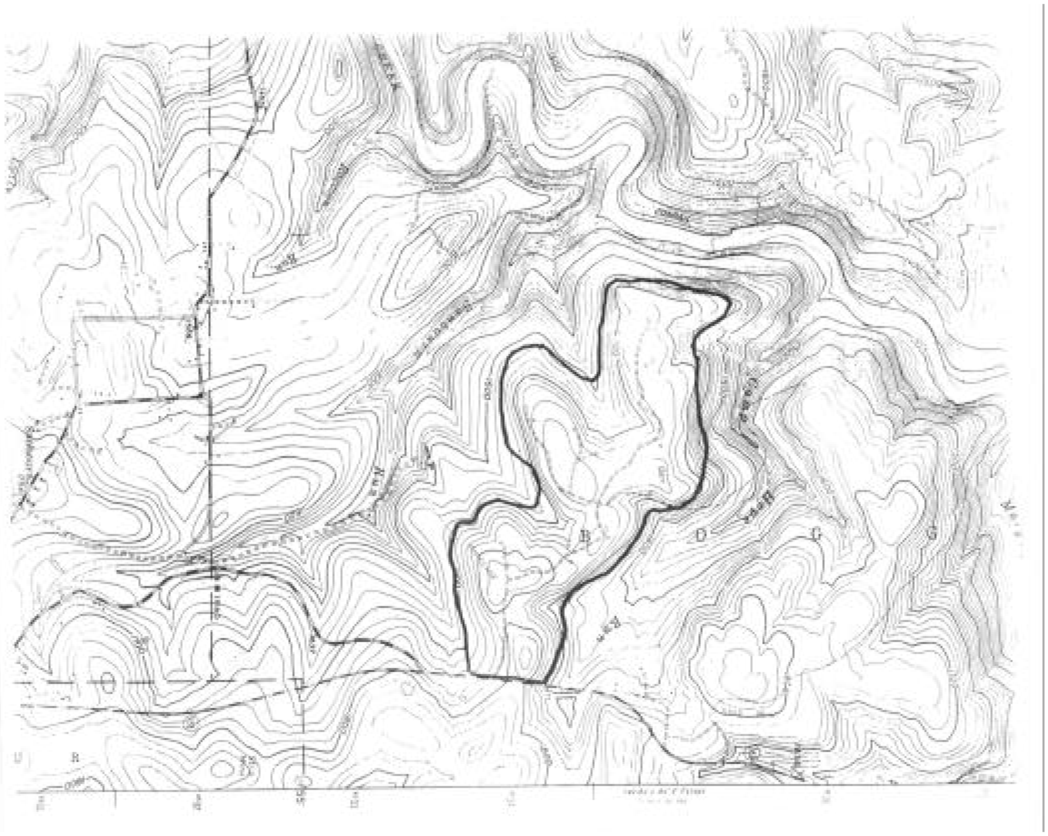
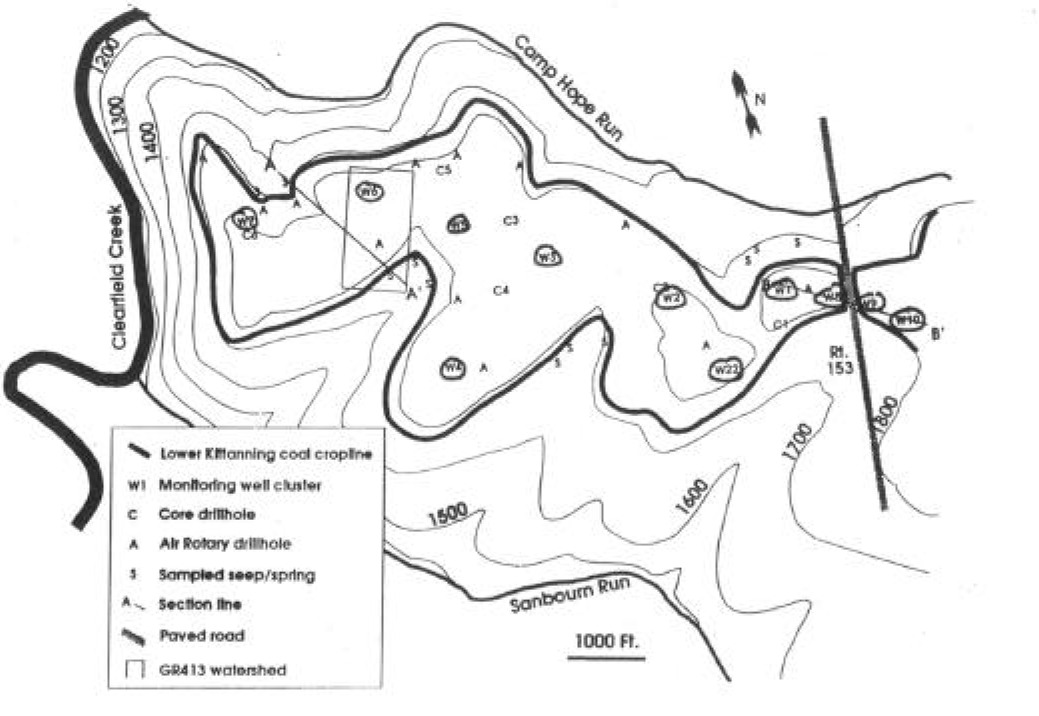


Figure 2



PEDA Kauffman Site Layout With Selected Borehole and Monitoring Well Locations.

3. The monitoring interval was every 15 seconds. Before, during, and for 15 to 20 minutes after the blast.

4. The shots ranged from 50 to 100 holes with approx. 60' of overburden.

5. The blasting was initially 900-1000 feet from the wells.

6. The graphs of the water level monitoring (figs. 4-6) show no noticeable ground-water level fluctuations that could be attributed to the blasting. The scale for observing changes was 1/100th of a foot. The blasting for the first 2 graphs occurred at about 15 minutes. The blasting occurred at about 5 to 7 minutes.

C. Aquifer testing was also conducted to determine impacts of blasts.

1. Types of tests: 1) Slug injection (falling-head test), 2) Slug withdraw, and Single well constant-discharge testing.

2. Conducted prior to the first shot, between shots, and after the shots. Some testing was performed after the pit was opened. But the well that was completed like a domestic well was eventually dewatered by the pumping at the open pit.

3. Results: No observable changes due to blasting were noted. However, expected seasonal variations are seen.

4. Other wells across the site and further away were also tested with similar results.

D. These results are very, very preliminary:

1. Blasting caused no noticeable water table fluctuations and the hydraulic conductivity was unchanged.

2. The pumping of the pit and encroachment of the highwall toward the wells dewatered the water table aquifer.

Results of Other Studies (published).

A. **D.A. Roberson (1988)** - Summarized two studies.

A study tested wells 150 feet from a blast. Scaled distance of 30 which is fairly high. Wells exhibited no quality or quantity impacts. Blast pressure surges ranged from 0.1 to 0.3 feet. (Montana). Not everything can be translated from this study to West Virginia, because the ground water hydrologic systems in Montana are radically different.

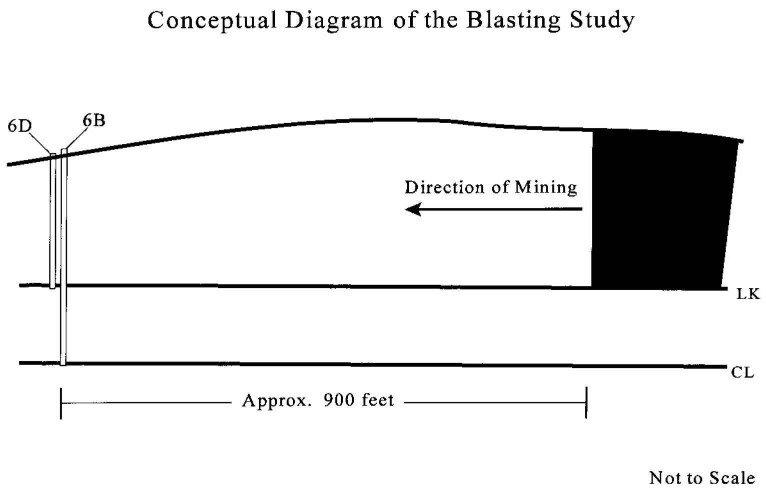


Figure 3

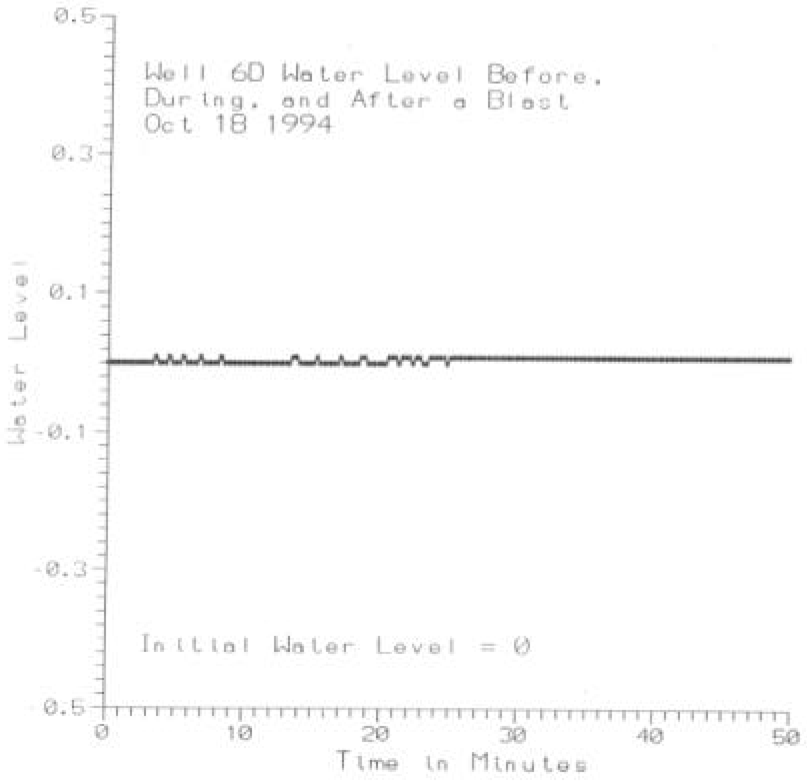


Figure 4

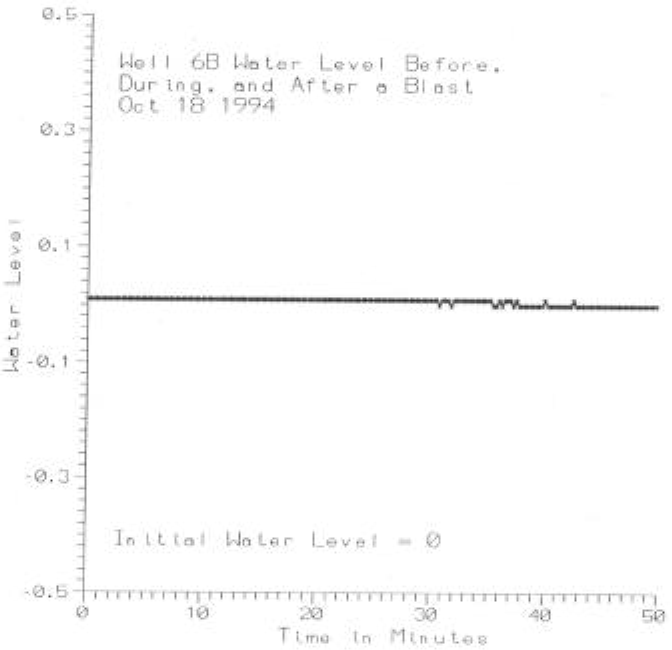


Figure 5

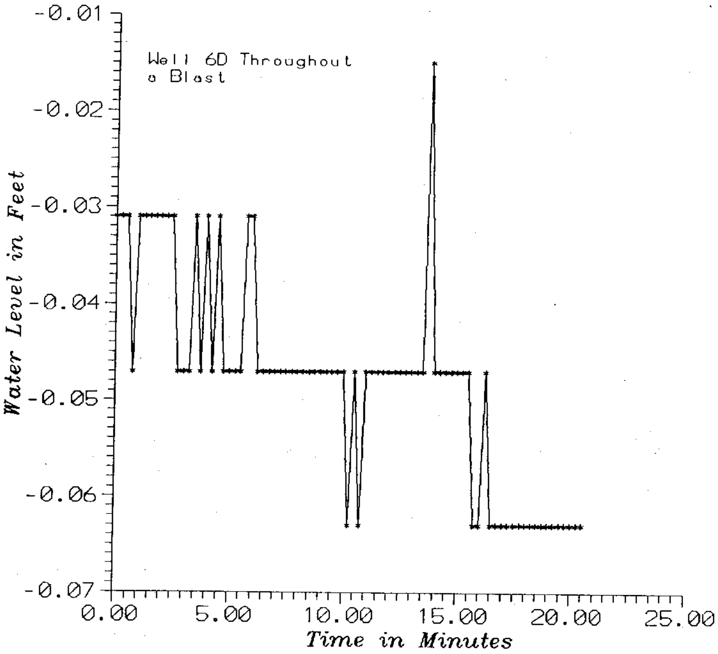


Figure 6

The other study (the Berger Study) observed ground-water impacts from manmade stress-release caused the rock mass removal during mining, but nothing from the blasting. The water quality and water levels were unaffected by the blasting. The “opening up” of the fractures lowered the ground-water levels by increasing the storage or porosity This work was conducted in West Virginia, Pennsylvania, and Ohio.

B. **D. E. Siskind and J. W. Kopp (1987)** - Based on the Berger work.

Looked at 36 case histories. Vibration levels up 2 in/s.

The well yield and aquifer storage improved as the mining neared the wells, because of the opening of the fractures from loss of lateral confinement, not blasting. This is similar to how stress-relief fractures form.

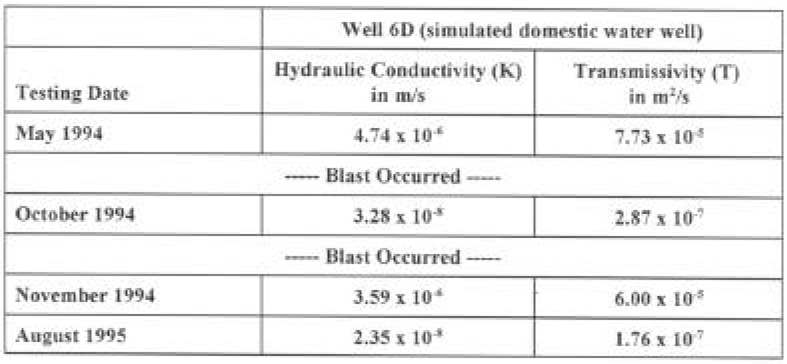
At one site the process was reversed after the mine was backfilled. They conjectured that the fractures closed back up or “fines” clogged the fractures. In my experience, it is doubtful the fractures clogged that quickly with fines. Ground water in the Appalachian Plateau moves very slowly and seldom carries anything but the finest suspended solids. It is more likely the fractures were recompressed.

They stated that blasting may cause some temporary (transient) turbidity similar to those events that cause turbidity without blasting.

Such as:

1. natural sloughing off inside of the well bore due to inherent rock instability. This can be accelerated by frequent over pumping. And is common to wells completed through considerable thickness of poorly consolidated and/or highly fractured claystones and shales.

2. significant rainfall events. The apertures of the shallow fractures that are intersected by a domestic well are commonly highly transmissive, thus will transmit substantial amounts of shallow flowing and rapidly recharging water. This water will commonly be turbid and can enter the well in high volumes. I have recorded water-level increases in the wells I was studying by over 50 feet in less than one hour from a large rainfall event. The lack of grouting of the near surface casing (~20 feet) commonly allows this to happen. Also, if the top of the well is not grouted properly surface water can enter along the side of the casing and flow down the annulus.



	Well 6D (simulated domestic water well)	
Testing Date	Hydraulic Conductivity (K) in m/s	Transmissivity (T) in m²/s
May 1994	4.74×10^{-6}	7.73×10^{-5}
----- Blast Occurred -----		
October 1994	3.28×10^{-8}	2.87×10^{-7}
----- Blast Occurred -----		
November 1994	3.59×10^{-6}	6.00×10^{-5}
August 1995	2.35×10^{-8}	1.76×10^{-7}

Table 1

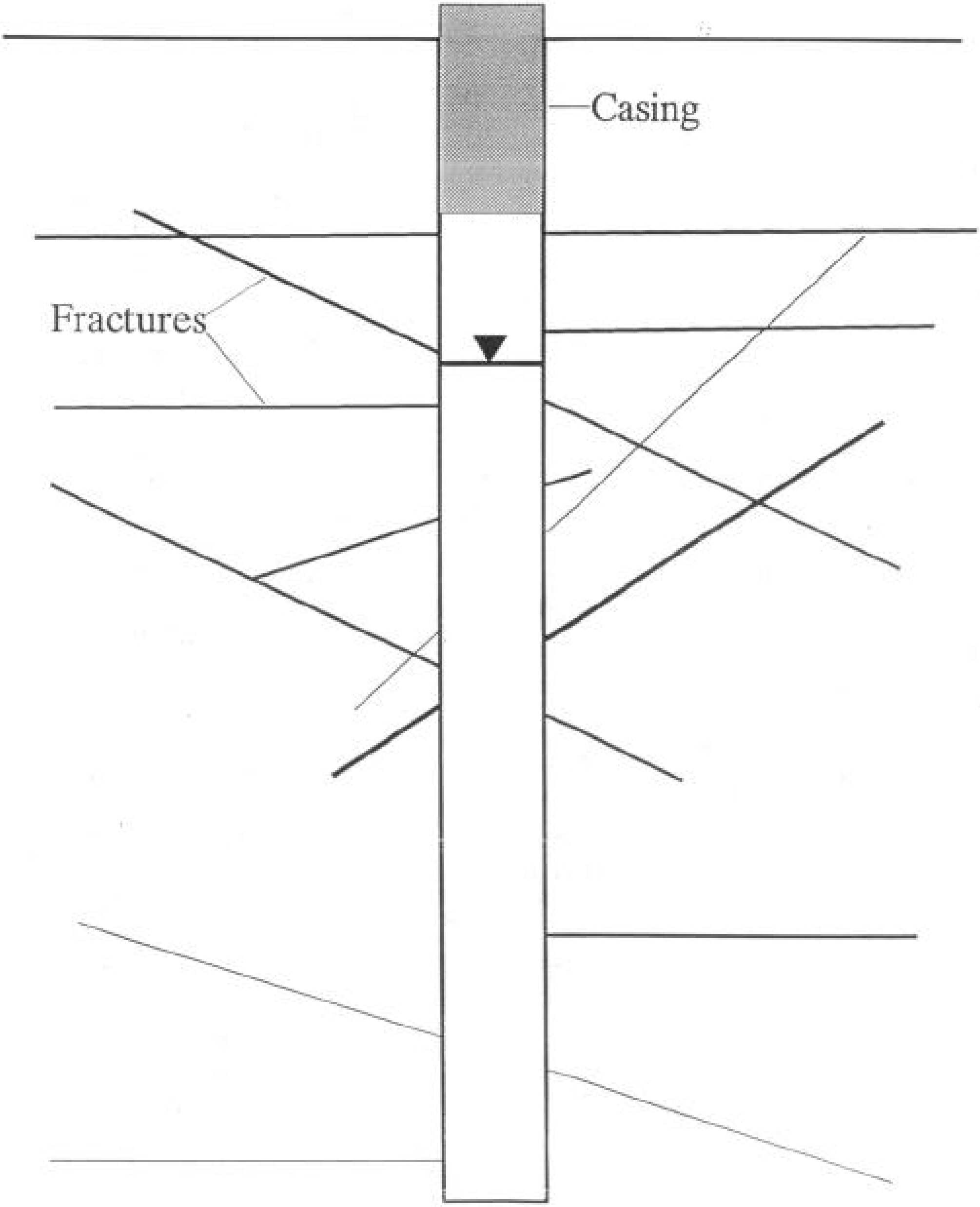


Figure 7

Siskind and Kopp (1987) recommended the use of well screens to prevent the sloughing of the well bore.

C. J.A. Kipp and J. S. Dinger (1991)

They recorded what they called “blasting shadows” in the shallow water table wells (70 and 71) and not in the deeper wells (80) accessing confined units *(fig 7*).

They said that “the shots were extremely strong”. They don’t say how close the blasting was to the wells.

Based on their graph the water level spikes ranged from about 0.2 feet to nearly 1.4 feet. Greater water level changes will be observed for the normal pumping of a domestic well or from infiltrating precipitation.

General Discussion:

1. Depending on the well construction, lithologic units encountered, and proximity to the blasting, I believe that some of the larger shots could act as a catalyst for some well sloughing or collapse**.** However, the well would have to be inherently weak to begin with. The small to moderate shots have not shown these to impact wells.

2. The minor water fluctuations attributed to blasting may cause a short term turbidity problem, but do not pose any long term problems. This fluctuation would not cause well collapse, as fluctuations from recharge and pumping occurs frequently.

3. Long term changes to the well yield are more likely due to the opening of fractures from loss of lateral confinement. Short term dewatering of wells is caused by the opening of the fractures creating additional storage. A longer term dewatering is caused by encroachment of the highwall and pumping of the pit water. The pit acts like a large pumping well.

4. I do not believe that long term water quality problems will be caused by blasting alone. With the possible exception of the introduction of residual nitrates, from the blasting materials, into the ground water system. The question arises what levels of nitrates are being seen in domestic wells hydrologically connected to a site? How long does it take before they are gone or return to baseline concentrations? I personally believe that natural attenuation will take care of most of the nitrites with in a short distance of the source over a short period of time.

5. Most of the long term impacts on water quality are due to the mining (the breakup of the rocks). The mechanisms of these changes (via pyrite oxidation) are well known. They increase the dissolved solids component especially sulfate, iron, manganese, aluminum, and sometimes sodium. Occasionally, other minor metals show up.

Where Do We Go From Here?

The nitrates question may need to be answered.
Perhaps pre-blast surveys of wells need to be conducted. This would include at least:

- Well testing. I recommend both a wet and dry season tests.
- Visual inspection with a borehole camera to determine the integrity of the well bore and the delivery system.

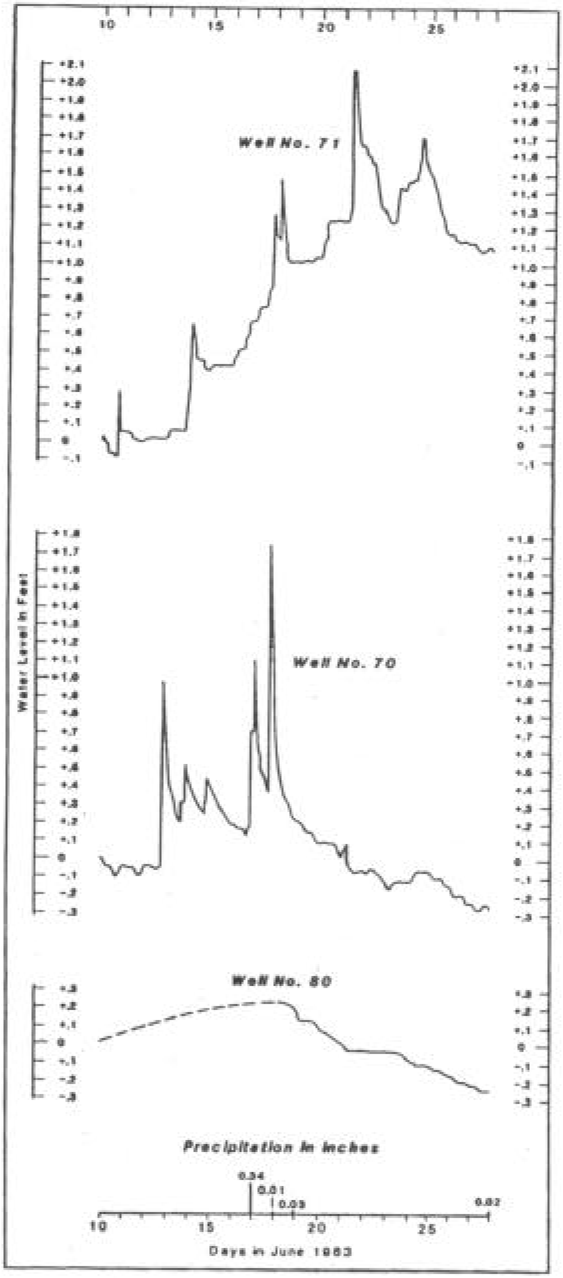
Water quality testing, 6 to 12 monthly samples. Both the wet and dry season need to be characterized.

Perhaps some maximum particle velocity or scaled distance needs to be established for well protection. For example, the Bureau of Mines stated particle velocities over 2.0 in/sec are likely to cause structure damage. Perhaps a scaled distance of 50 per shot delay, as suggested by the Bureau of Mines would work.

Restrict blasting on days with temperature inversions. The air blast tends to reflect off of the inversion and appear worse on these days.

Some earthquakes have been shown to impact shallow ground-water flow in the Appalachian Plateau. An earthquake of 5.2 (which is fairly large) occurred in 1998 near Jamestown Pennsylvania. It is believed that it may have increased the hydraulic conductivity of certain units and dewatered some ridge top wells. However, an earthquake of this magnitude is much much larger than any shot for MTM would be. A rough equivalency for a magnitude 1.0 earthquake is 200,000 pounds of explosive per delay. A magnitude 5.0 earth quake is roughly 10,000 times greater than a 1.0 earthquake.

Figure 8



Hydrographs of wells 70,71 and 80 showing the effects of blasting.

After Kipp and Dinger (1991)