Figure 15 is a three-dimensional projection of the drift and deviation survey data compared to an imaginary plumb line representing a straight and plumb well.

The drift and deviation data on Figures 10 and 13 show that the departure of the well from straight and plumb in the 1000 to 1100-foot depth interval presents an area where pump column will rub against the casing. This conclusion was verified during test pumping of the well when PVC standpipes clamped to the pump column were deformed enough to make installation and removal of 0.75-inch diameter pressure transducers and their 0.25-inch cables difficult because the PVC pipes were compressed between the pump column and the well casing. The casing deviation in this area does not prevent the well from being used with submersible pumps; however, it indicates that only submersible pumps, not line shaft pumps, should be used in the well and the electrical motor cable to the submersible pump motor should be armored to prevent insulation from being rubbed off the wire in this part of the well.

4 DEVELOPMENT BY HYDRAULIC FRACTURING WITH ACID

A stepped rate pumping test of Test Well #2A conducted on October 21, 2012, resulted in nearly 540 feet of drawdown after three hours of pumping at 510 gpm and 21 minutes of pumping at 650 gpm. The results of this pumping test indicated the well yield was not adequate to provide the long-term design yield of 1400 gpm which was the target for this well. Accordingly, the decision was made to stimulate the well yield by hydraulically fracturing the Madison rock strata with concentrated hydrochloric acid; a process colloquially referred to as an "acid frac".

On 11/13/2012, Test Well #2A was hydraulically fractured with 15% hydrochloric acid to improve the hydraulic performance and, therefore, the yield of the well. The acid treatment to stimulate well production was provided by Basic Energy Services, using pumps and a control truck provided by Maverick Stimulation Company, LLC, of Fort Logan, CO. On 11/12/2012, an initial effort to stimulate the well was aborted when the packer failed to inflate, due to erroneous information about the inflation pressure required to seal the packer against the 10-3/4 steel casing. Because of that incident, an initial 383 bbl (16,086 gallons) of fresh water were injected into the Madison on the morning of 11/13/2012, prior to fracturing the well with acid, in order to test the packer and the acid-injection pumping equipment.

4.1 Acid-Fracturing Equipment

A Baski inflatable packer was set in the 10-3/4 inch well casing at a depth of 1951 feet. The packer was installed on 7-inch oilfield tubing with an allowable pressure rating of 1200 psi. The packer was inflated to 1500 psi with water applied with a small, high-pressure pump through stainless steel tubing (Photo 44), independent of the 7-inch tubing. In order to obtain the specified minimum injection rate and pressure of 2800 gpm (66.7 bbl/min) at 1200 psi, it was necessary to use five pumper trucks (Photo 45), each de-rated to operate at 2,000 hp for this project. Fresh water and chlorine water were stored in on-site frac tanks and connected to a mixing truck (Photo 46). The mixing truck was in turn connected to a manifold (Photos 47

through 50) which routed fluid to the pumping trucks and then into a common manifold discharging into the well downstream from the high-pressure pumps. Photos 52 and 53 show an overview of the well site with the high-pressure pumping equipment and acid trucks and the interior of the control truck from which all of the pumping equipment was operated and the fracturing operation coordinated between the pumpers, the mixing truck, and the crew that operated valves on the tanks and mixing truck, as directed by voice-activated radio headsets.

4.2 Hydraulic Fracturing with Acid

Figure 16 provides a summary of the 11/13/2012 acid treatment of Test Well #2A. An initial 44 bbl of clean water was used to load the tubing above the packer, then the pumping injection rate was gradually increased to 67 bbl/min (2814 gpm) with the surface treatment pressure hovering at 1000 psi plus or minus a few pounds of pressure (maximum pressure = 1006 psi) as a total of 350 bbl of water was pumped, including the initial 44 bbl. This provided a clear-water injection pressure of 1180 psi at the packer, assuming a static water level of 696 feet and tubing friction loss of 127.5 psi at 67 bpm. The total volume of clean water pumped, including injection as the pumping rate and pressure was decreased, was 383 bbl.

Photo 44: Stainless steel tubing for packer inflation.

Photo 45: Pumping truck with horizontal radiator, V-16 motor, driveline and pump.

Photo 46: Frac tanks connected to mixing truck, bulk acid trucks in background.

Photo 47: Mixing truck outlet hoses to manifold.

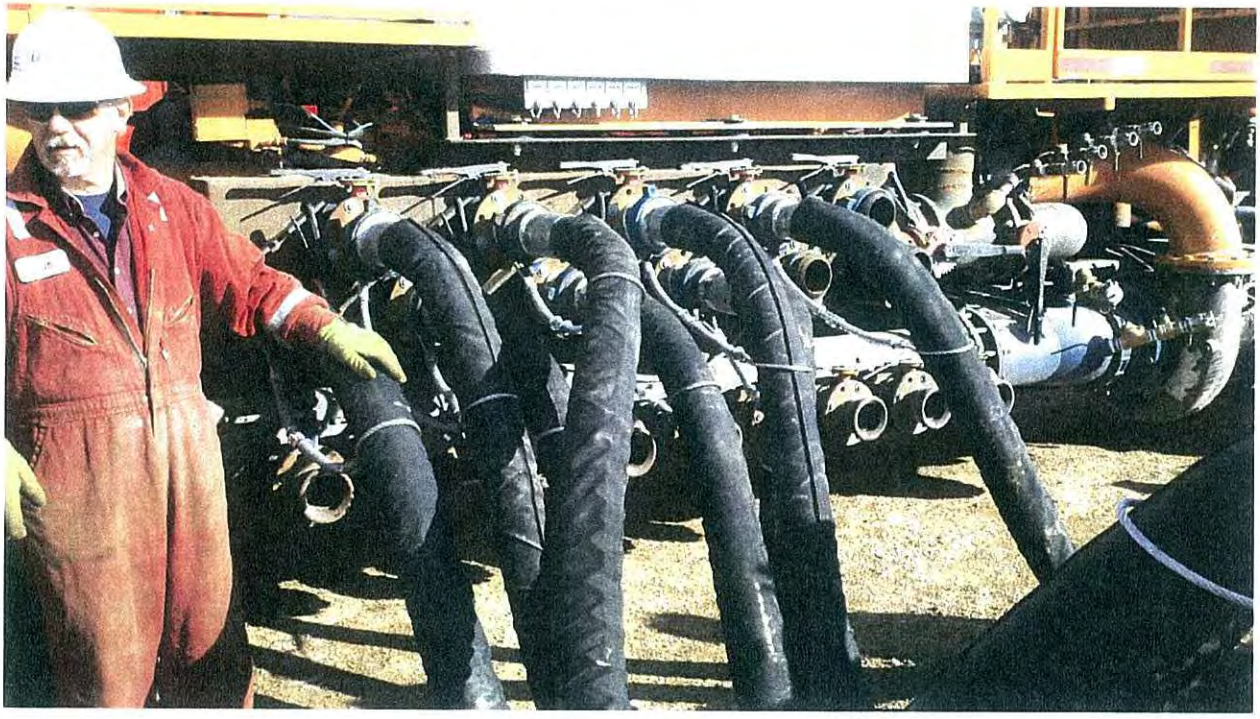


Photo 48: Manifold linking mixing truck to pumpers and pumpers to well.

Photo 49: Low-pressure inlet hoses and high-pressure steel lines to and from pumpers.

Photo 50: Two high-pressure steel lines to 7-inch tubing to packer in well.

Photo 51: Two pressure transducers used to record surface treatment pressure.

Photo 52: Overview of acid-frac equipment with control truck in foreground.

Photo 53: Interior of Maverick Stimulation Services pumping control truck.

After injecting clean water, the frac tanks and mixing truck hoses were moved to pump chlorine water followed by acid. The hoses available for pumping chlorine water limited the injection rate to 32 bbl/min (1344 pgm). The chlorine water was injected to react with the acid to form a strong disinfectant in the formation. As shown on Figure 16, injection of chlorine water began about 10:56 a.m.; however, after pumping 100 bbl of chlorine water into the formation injection was stopped in order to fix a leak at the connection to the 7-inch tubing for the packer. After a 1600-psi pressure test of the tightened fitting, chlorine water injection resumed and a total of 708 bbl (29,736 gal), including the initial 100 bbl, of 100-mg/L chlorine solution was injected at a rate of 31 to

32 bbl/min with the injection pressure (surface treatment pressure) at the land surface fluctuating five to six psi above a baseline pressure of 350 psi which is equivalent to a bottom hole pressure at the packer of essentially 618 psi with formation pressure equivalent to a static water level of 696 feet and tubing friction loss of 33.5 psi. The chlorine water was followed by 36.9 bbl of clear water to provide initial separation between the chlorine water and the acid to follow.

Acid injection followed the pad of clean water without interruption. Concentrated hydrochloric acid from the bulk trucks was mixed with clean water at the mixing truck to provide a concentration of 15 percent which was injected through the packer at a rate stabilizing at 67 - 68 bbl/min with surface treatment pressure fluctuating generally between 880 and 885 psi with peak pressure momentarily reaching 889 psi. Based on an initial acid surface treatment pressure of 880 psi at the tubing and a specific gravity of 1.0749, the approximate bottom hole pressure at the packer started at 1117 psi with tubing friction loss of 128 psi. As shown on Figure 17, acid surface treatment pressure began to decline almost immediately, even as the injection rate was held at 67 - 68 bbl/min. Half way through the acid injection, when the second frac tank of acid was injected; the injection rate changed to 63 - 64 bbl/min, as shown on Figure 17, and surface treatment pressure continued to decline to a minimum of 448 psi at 63 bbl/min after 604 bbl of 15% acid had been pumped. Shortly after this, the injection rate was ramped down in preparation for injection of a pad of clean water, starting at noon. A pad of 51.2 bbl of clean water was injected to provide separation between the acid and the chlorine water pumped after the acid.

After a total of 674 bbl of 15% acid had been injected, injection of clean water began at noon at an initial rate of approximately 33 bbl/min with a total of 51.2 bbl of clean water injected. The clean water and the following chlorine water were pumped at an average rate of 35 bbl/min (1470 gpm) with 6 psi of surface treatment pressure at the beginning of injecting clean water. The pressure declined to zero and began to pull a vacuum in about three minutes. When zero pressure followed by a vacuum occurred, the pumps were stopped and the well continued to take water at 30 bbl/min decreasing to 22 – 23 bbl/min with the vacuum (negative pressure) in the tubing to the packer fluctuating between negative 10 and negative 20 psi. Flow into the Madison aquifer stabilized at about 22 – 23 bbl/min and a negative surface treatment pressure of -14 to -15 psi after about 100 bbl of chlorine water flowed into the well following the initial 51.2 bbl of clean water. A total of 140 bbl of chlorine water was flowed into the well, followed by 54 bbl of clean water to flush the tubing, before the hydraulic fracture equipment was removed from the well.

Figure 19 shows the time-distribution of the total volume of fluid injected into the well during the stimulation treatment.

Figure 16: Summary plot of 11/13/2012 acid stimulation treatment of Test Well #2A.

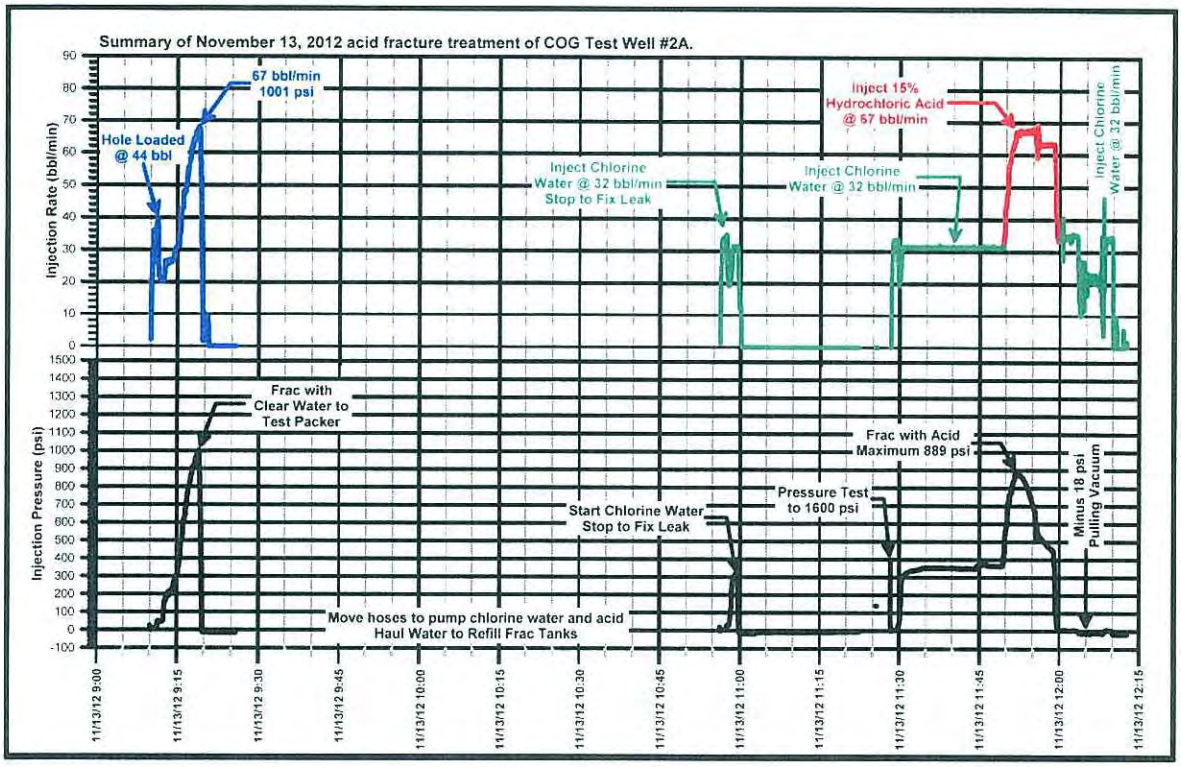


Figure 17: Expanded view of acid stimulation treatment of Test Well #2A.

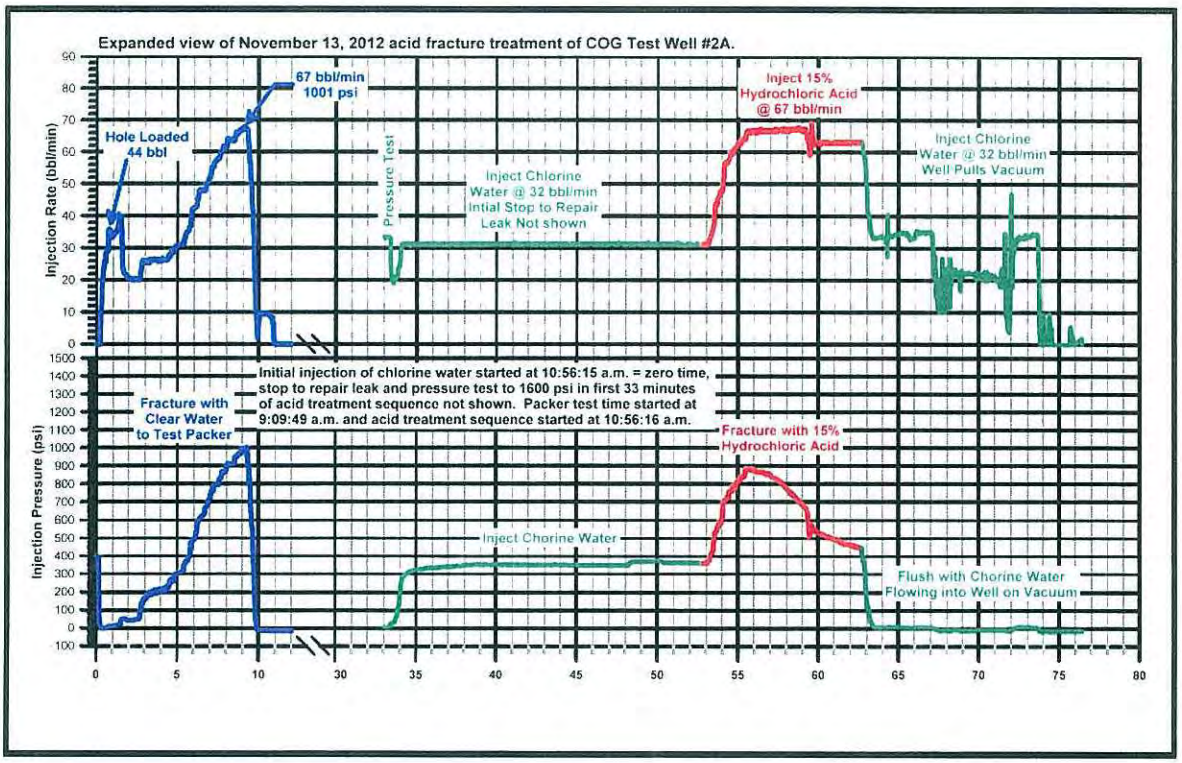
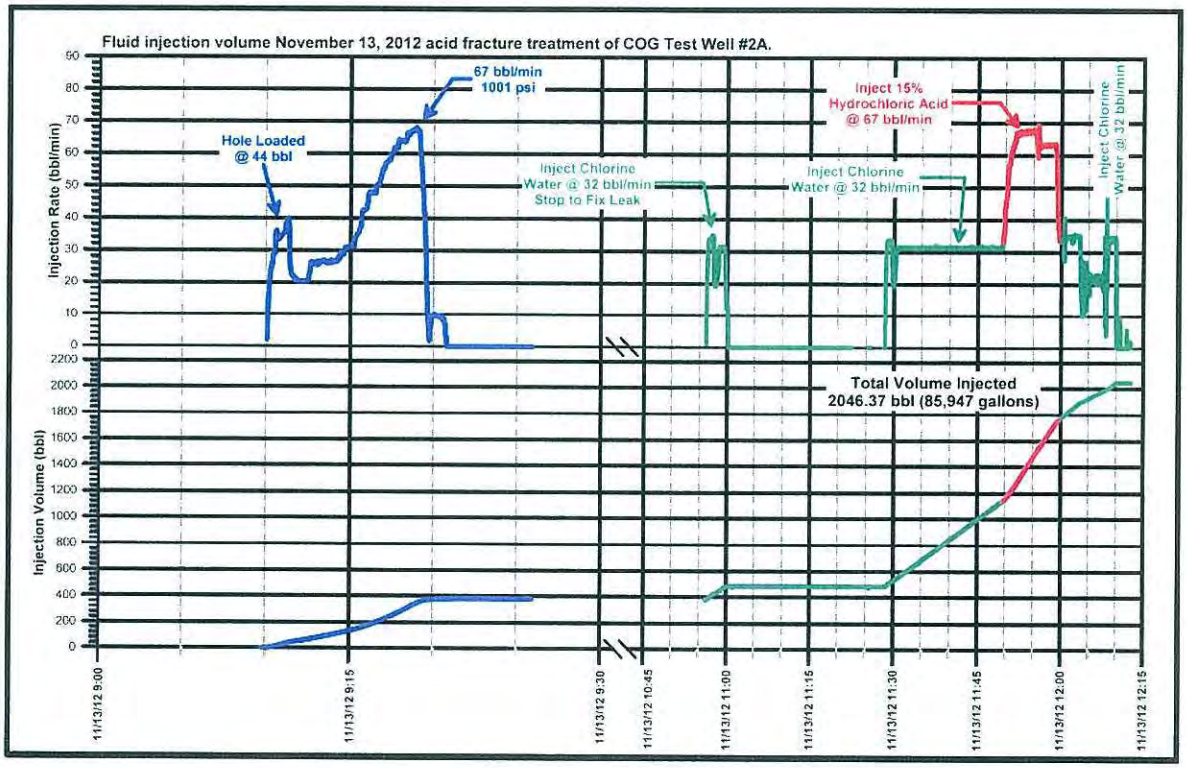


Figure 18: Acid simulation injection rates and volumes.



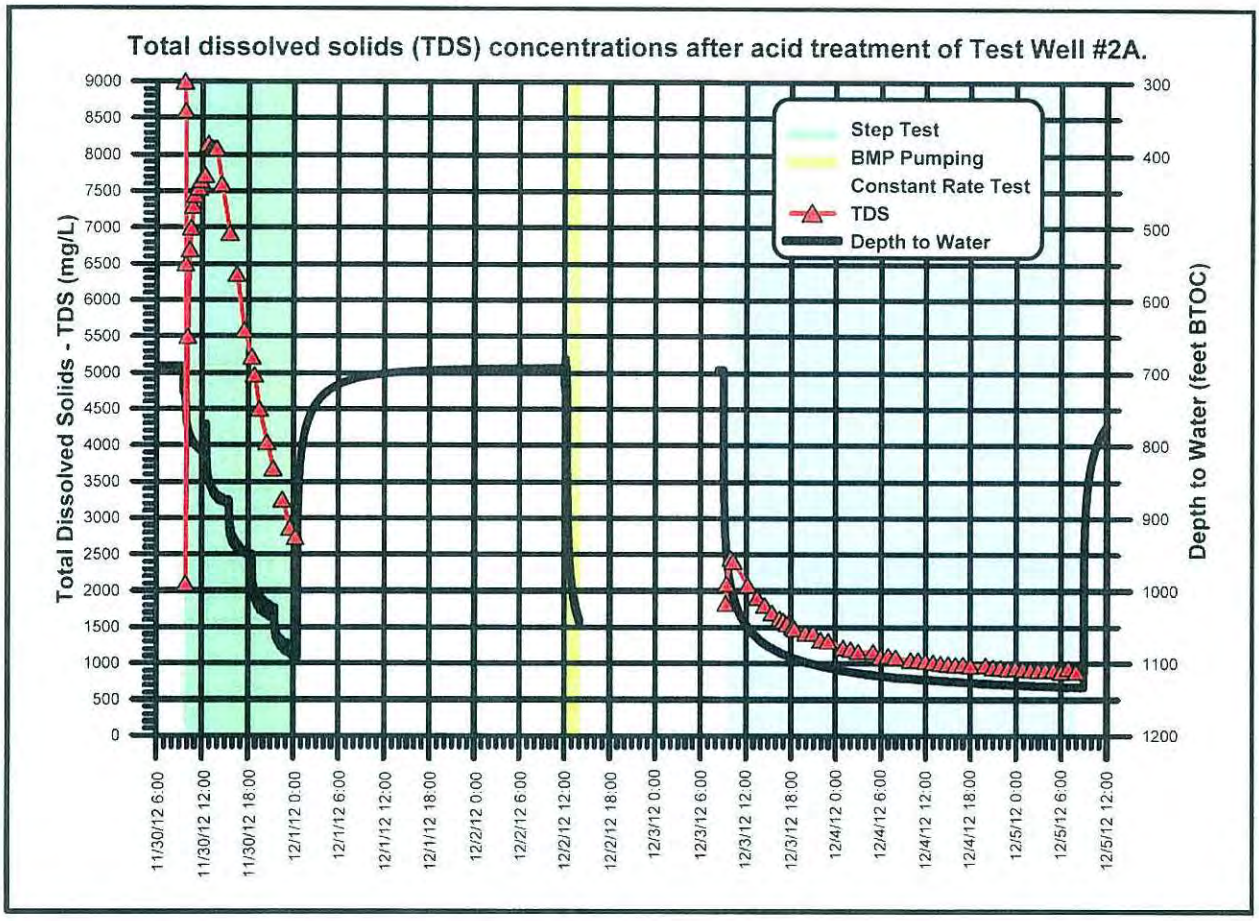
4.3 Post-Acid Treatment Water Quality

On 11/17/2012, installation of a small pump into the well was completed for checking the groundwater quality after the acid treatment of the well. Approximately 4800 BBL of water was pumped from the well on 11/17/2012 through 11/18/2012 at a rate of 240 gpm. The water pumped from the well was clear and exhibited a pH of 6.5 declining to a pH of 6.0 during the pumping period. A water sample collected at 4:00 p.m. on 11/18/2012 was submitted to a laboratory where it was found to contain a concentration of 10,900 mg/L total dissolved solids (TDS). The initial 16,000 gallons were pumped to a frac tank and hauled off site. After it was established that the pH was 6.5, the remaining water pumped through 11/18/2012 was discharged through the same dump line used for air rotary drilling and used for pumping test discharge.

The TDS concentrations of water pumped from the well were monitored with a TDS (EC) meter during the stepped rate and constant rate tests. Figure 19 shows the distribution of TDS by time compared to the depth to water hydrograph showing the pumping periods, included some pumping to test Best Management Practices (BMP) erosion control installed downstream from the pump discharge pipe between the date of the stepped rate and constant rate tests. The TDS values were not measured during the BMP pumping.

The final TDS concentration shown on Figure 19 is 891 mg/L at 8:00 a.m. on 12/5/2012. An additional sample was collected from the well at 12:30 p.m. on 12/13/2012 and analyzed in the laboratory which determined a TDS concentration of 760 mg/L.

Figure 19: TDS concentrations in water pumped after acid treatment of well.

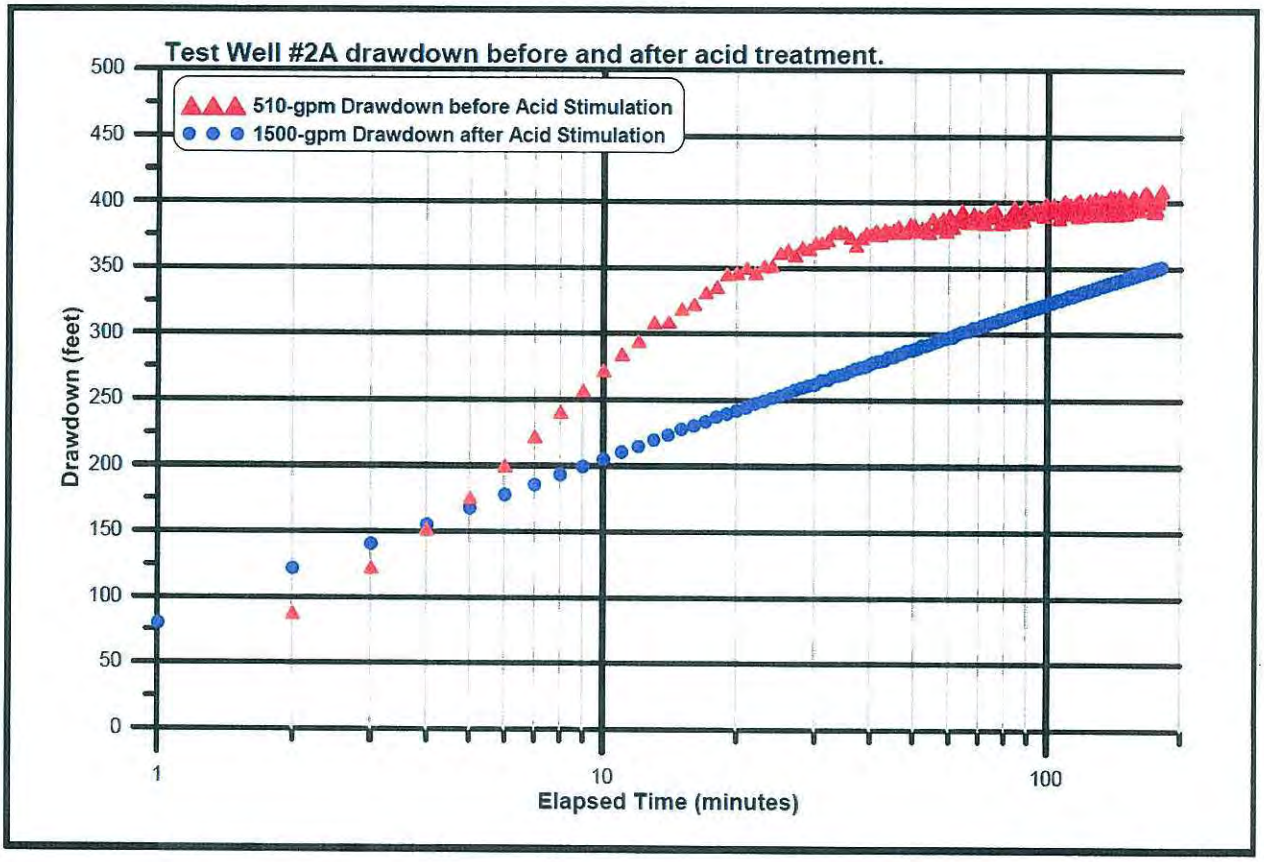


4.4 Result of Stimulation

The first indication of results from the stimulation is provided by the injection pressure and flow information on Figure 17. The initial pressure generated by injection of chlorine water into the well from 33 to 53 minutes into the stimulation was 350 psi at 31 - 32 bbl/min (1302 to 1344 gpm). The decrease in injection pressure as the acid was injected indicated the opening up of the formation and improvement of hydraulic performance, even as the acid was injected. After injection of the acid, the well was taking 35 bbl/min of chlorine water as the pressure rapidly declined from 6 psi to a vacuum. This indicates more than a 350-psi decrease in the pressure required to inject up to 1344 gpm into the Madison aquifer through the well, with the well taking approximately 1300 gpm with 350 psi before acid treatment and more than 1300 gpm with a vacuum after acid treatment.

Figure 20 compares the 510-gpm drawdown after three hours of pumping on 10/18/2012, prior to acid stimulation, to the 1500-gpm drawdown after three hours of pumping on 12/3/2012, after acid stimulation. The 510-gpm drawdown at 180 minutes, prior to hydraulic fracturing with acid is 409.5 feet. Following acid fracturing, the 1500-gpm drawdown after 180 minutes is 350.7 feet. This is an increase in specific capacity from 1.245 gpm per foot of drawdown to 4.277 gpm per foot of drawdown or a 343 percent increase in well hydraulic performance.

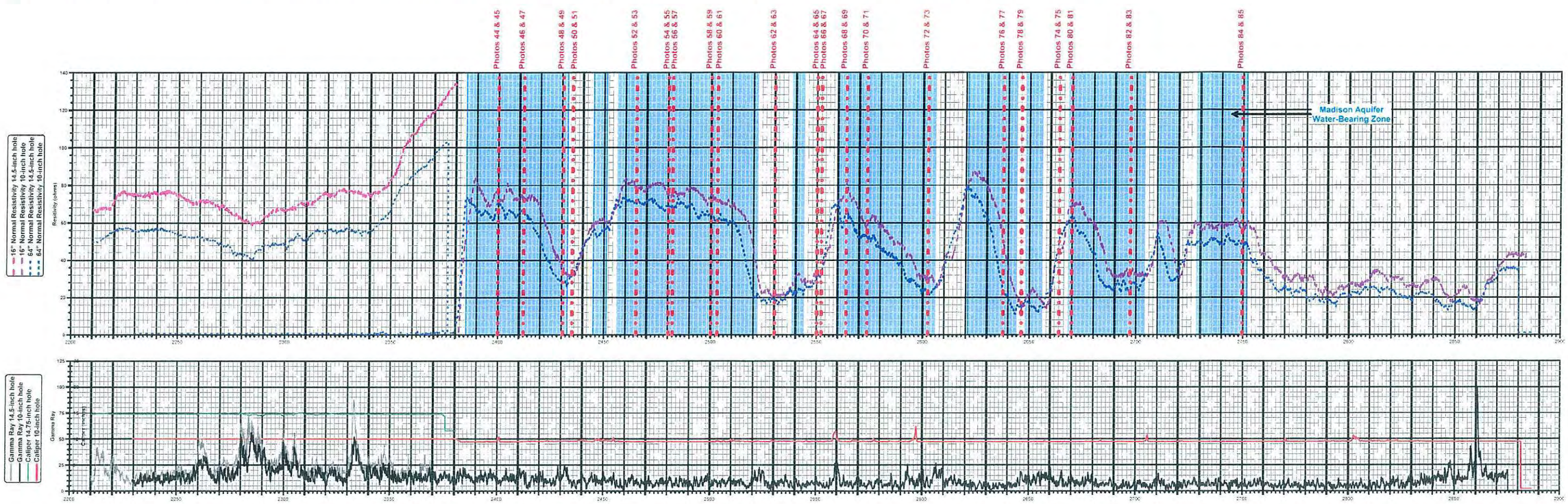
Figure 20: Comparison of drawdown before and after acid stimulation.



Photos 54 through 95 are sets of before and after pictures, copied from the video logs of the borehole, showing the borehole before and after the acid treatment.

Figure 21 shows the depths for the photos annotated on the resistivity logs made prior to the acid stimulation, showing the distribution of zones in the Madison aquifer interpreted on the basis of the logs to be water-bearing zones.

Figure 21: Downhole resistivity log annotated with depths of pictures showing before and after hydraulic fracturing with 15% hydrochloric acid.



Pre-Acid Treatment Photographs

Photo 54: 2400 feet, porous rock..

Photo 55: 2412 ft, porous rock.

Photo 56: 2430.5 ft, low porosity rock.

Post-Acid Treatment Photographs

Photo 57: Post frac 2400 feet.

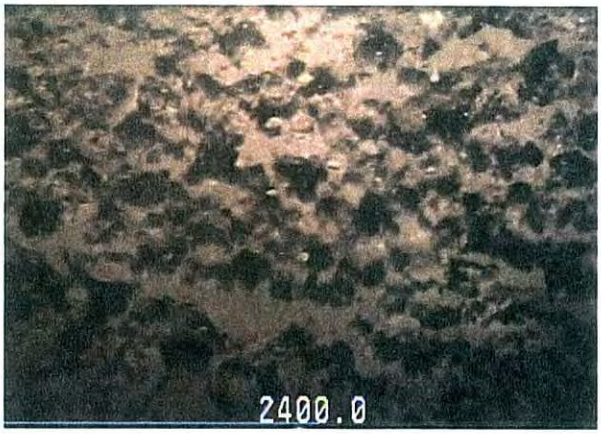


Photo 58: Post frac 2412 feet.

Photo 59: Post frac 2430.5 feet.

Pre-Acid Treatment Photographs

Photo 60: 2435 ft, low porosity rock.

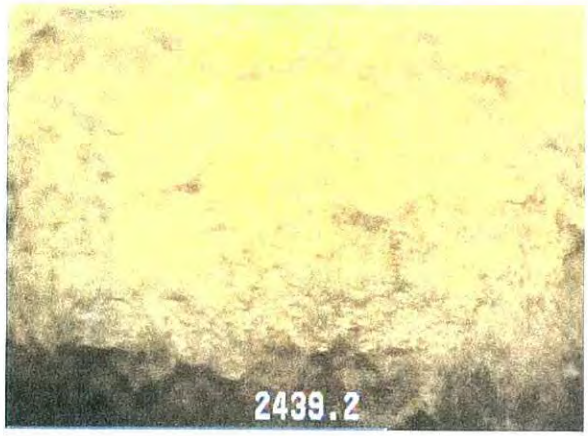


Photo 61: Pre-frac 2465, solid rock.

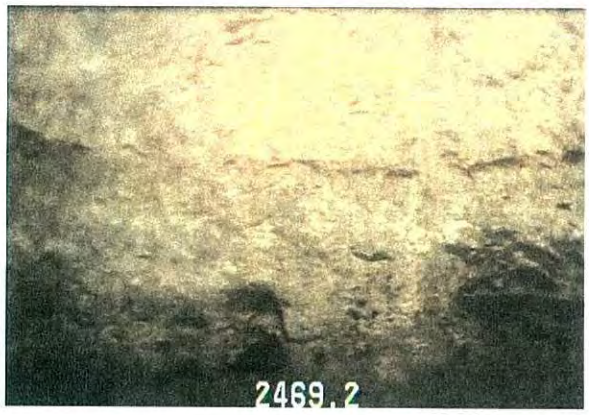


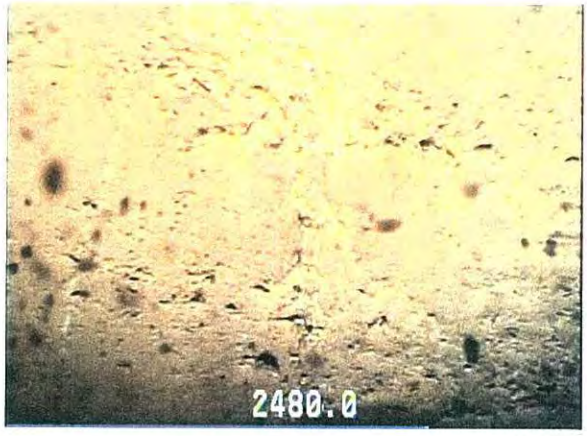
Photo 62: 2480 ft, low porosity rock.

Post-Acid Treatment Photographs

Photo 63: Post-frac 2435 feet.

Photo 64: Post-frac 2465.

Photo 65: Post-frac 2480 ft.



Pre-Acid Treatment Photographs

Photo 66: 2482 ft, solution cavity.

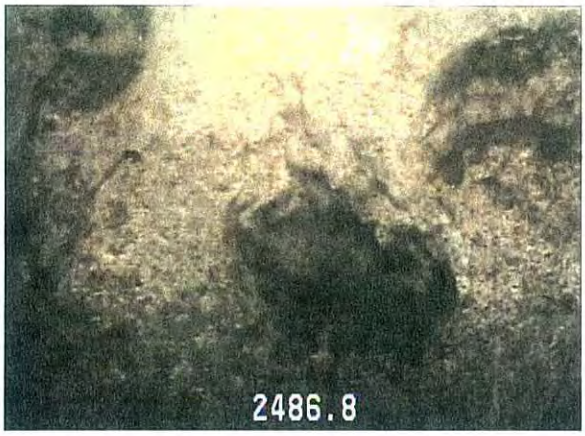
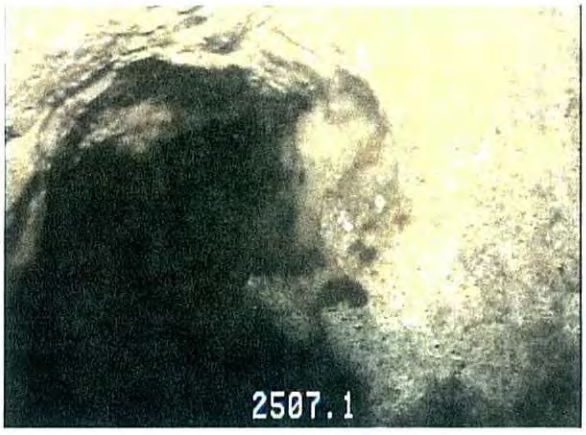


Photo 67: 2500, tight fracture in rock.

Photo 68: 2502.9 ft, large void.



Post-Acid Treatment Photographs

Photo 69: Post-frac 2482 ft.

Photo 70: Post-frac 2500 ft.

Photo 71: Post-frac, 2502.9 ft.

Pre-Acid Treatment Photographs

Photo 72: 2530 ft, tight fracture in rock.

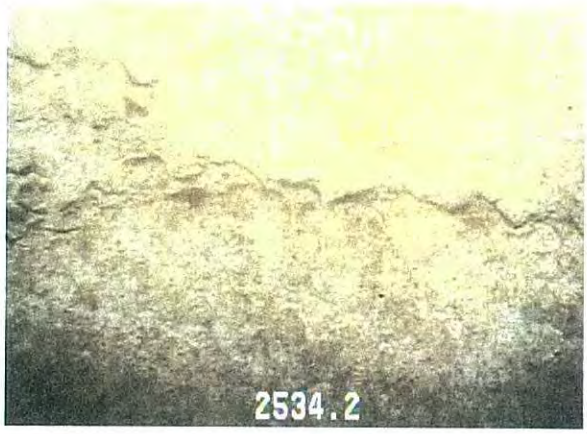


Photo 73: 2550 ft, porous rock.

Photo 74: 2552 ft, near open fracture.

Post-Acid Treatment Photographs

Photo 75: Post-frac 2530 ft.

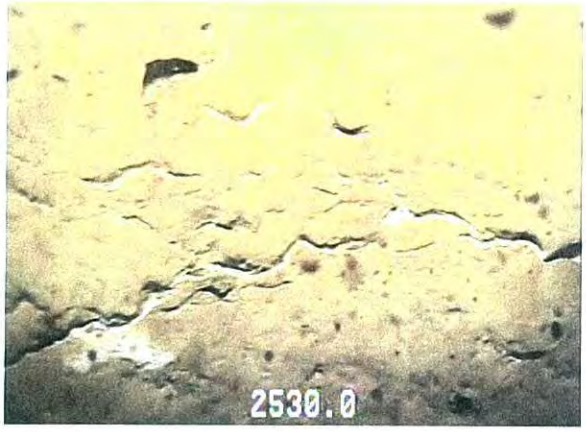
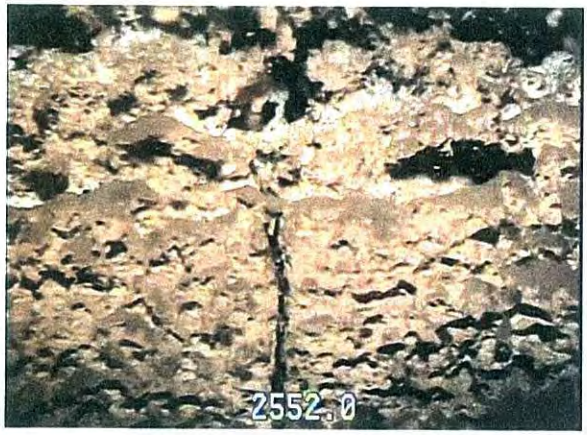


Photo 76: Post-frac 2550 ft.

Photo 77: 2552 ft, vertical fracture.



Pre-Acid Treatment Photographs

Photo 78: 2563.7 ft, large void.

Photo 79: 2573.7 ft, large void.

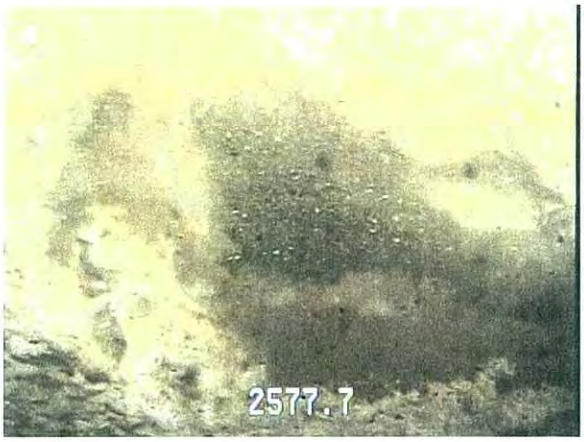


Photo 80: 2602.3 ft, large void.

Post-Acid Treatment Photographs

Photo 81: Post-frac 2563.7 ft.

Photo 82: Post-frac 2573.7 ft.

Photo 83: Post-frac 2602.3 ft.

Pre-Acid Treatment Photographs

Photo 84: 2624 ft, low porosity.

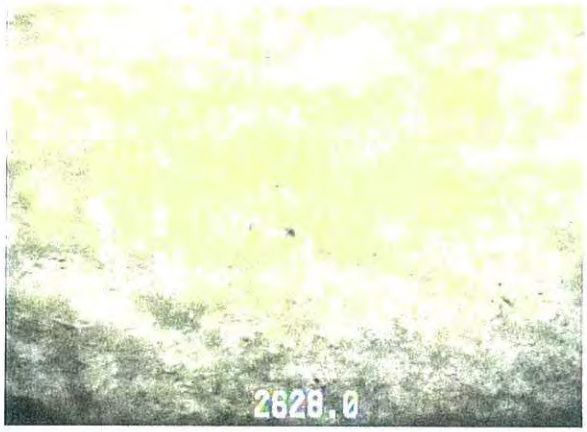
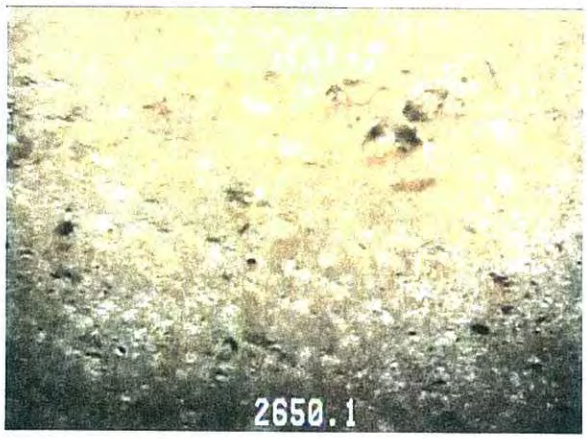


Photo 85: 2637.5 ft, fracture-tight rock.

Photo 86: 2646.1 ft, low porosity rock.



Post-Acid Treatment Photographs

Photo 87: Post-frac, 2624 ft.

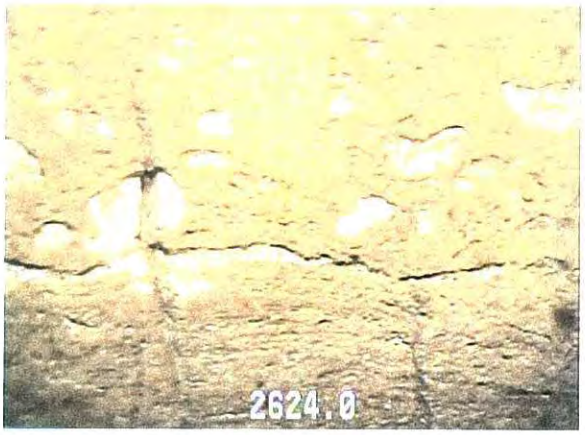


Photo 88: 2637.5 ft, fracture-tight rock.

Photo 89: Post-frac, 2646.1 ft.

Pre-Acid Treatment Photographs

Photo 90: 2669.7 ft, porous rock.

Photo 91: 2697.1 ft, porous rock.

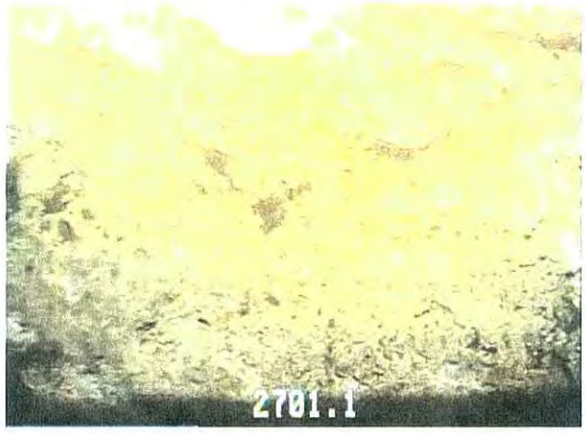


Photo 92: 2749.6 ft, vertical fractures.

Post-Acid Treatment Photographs

Photo 93: Post-frac 2669.7 ft.

Photo 94: Post-frac 2697.1 ft.

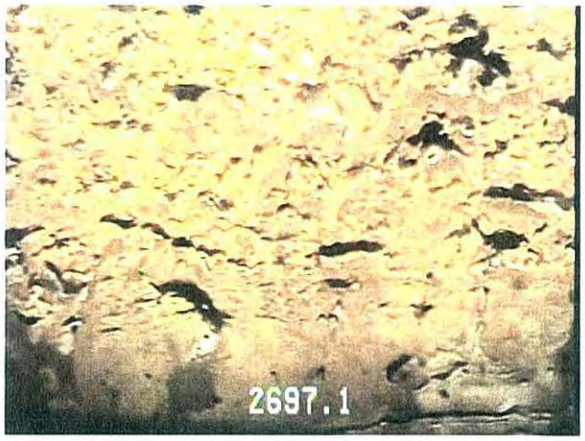


Photo 95: Post-frac 2752.7 ft.

In comparing the video logs and photos extracted from them, the bottom of the 10-3/4 inch casing at a depth of 2385 feet is used as the initial reference point. Other reference points used deeper in the well are a number of open voids that appear on both the pre-acid and post-acid video logs. By comparing the depth to those voids in each video, the difference in depth between the two video logs can be determined. The post-acid video log was reset to a depth of 2385 feet when the camera reached the bottom of the 10-3/4 inch casing, so all of the photographs for post-acid treatment conditions are considered to be the correct depth. The pre-acid treatment photos all show depths that are 4.0 to 4.2 feet deeper than the post-acid photos, based on comparison of common features in the two video logs. The post-acid photo depths are those shown on Figure 21.

Photos 54 through 95 provide very narrow snapshots of the openings evident in the video logs of the borehole. The field of view in the photographs depends on centering of the camera in the borehole, but in general, represent about 6-inches of the borehole from top to bottom. View of the continuous video footage is much more revealing than the individual photographs because the videos reveal the non-uniform distribution of porosity from both pores and fractures. The non-uniform conditions are not evident in the photos which show one condition or another.

The pre-acid and post-acid video logs show a dramatic cleaning and opening of pores, secondary solution openings and fractures in the carbonate rock of the Madison strata. The enlargement of openings and revelation of openings after acid treatment where only faint indications of the openings were visible prior to application of the acid is evident throughout the entire thickness of the Madison strata. However, the limited numbers of photos that can be included in a report of this nature do not and are not intended to show the distribution of porosity that is likely related to permeability. In general, there is some correlation between parts of the resistivity log showing relatively low porosity with less porous appearing rock in the videos; however, large lengths of borehole shown by the resistivity logs to offer the greatest porosity look like solid rock in the video logs; albeit with a number of larger individual solution openings evident in those parts of the borehole.

This indicates that some of the primary porosity of the predominantly dolomite rock offers favorable water-bearing zones, but perhaps the larger amount of the water-bearing zones are provided by less porous rock that is shot through with relatively large (compared to the pores), individual solution openings that have been dissolved into the rock and now provide flow conduits for relatively large yields of water. The smaller of these openings are not visible on the pre-acid video log but are evident on the post-acid log. In other cases, the video camera may have not scanned the same opening in one log or the other, so they cannot be compared. The larger openings are visible on both logs, but appear to have been cleaned up and had some secondary mineral cement removed in the post acid photographs. The resistivity logs show that most of the Madison strata are water-bearing. The principal water-bearing zones are identified in Table 4.

Table 4: Distribution of water-bearing zones in Madison strata penetrated by well.

Depth Interval (feet)	Thickness (feet)	Relative Porosity
2385 - 2433	48	High
2445 - 2451	6	High
2456 - 2522	66	High
2538 - 2544	6	High
2560 - 2606	46	High
2621 - 2644	23	High
2648 - 2656	8	High
2668 - 2704	36	High
2710 - 2720	10	High
2728 - 2752	24	High
	273	

The total thickness of Madison strata identified from a depth of 2370 to 2752 feet is 382 feet. The zones of relatively high porosity identified from the resistivity logs and summarized on Table 4 are interpreted to be the principal water-bearing zones in the Madison strata penetrated by this well and total 273 feet or 71.5 percent of the thickness of Madison strata penetrated. The distribution of the zones of high resistivity shown on Figure 21, which are interpreted to be the principal water-bearing zones in the Madison aquifer at this well, underscore the importance of fully penetrating the entire aquifer with the well to optimize well yield.

5 YIELD AND DRAWDOWN TESTS

Test Well #2A was initially tested in mid-October 2012. The static water level and barometric pressure were monitored from 10/13/2012 through 10/16/2012 prior to starting a stepped rate pumping test on 10/18/2012, after installation of a test pump on 10/16/2012 and 10/17/2012. The step test was terminated due to excessive vibration in the test pump, after one 510-gpm step of 181-minutes duration and 152 minutes at 650 gpm. The results of the brief step test indicated that the well performance was considerably less than required, and the well was stimulated with a high-pressure acid treatment described in the previous section of this report. After acid stimulation, the well was subjected to a second stepped rate test followed by a 48-hour constant rate test at 1500 gpm. The 1500-gpm constant rate test was limited by the capacity of the available test pump, not the well yield; however, it exceeded the design specifications for a 1400-gpm well.

5.1 Pre-Test Monitoring

Figure 22 shows the pre-test monitoring static water level and atmospheric pressure. It is evident that as the barometric pressure decreases, the static water level in the