Table 1: Depths to tops of formations penetrated by Test Well #1.

Formation Top Depths (feet)		Formations and Members Test Well #1
0		**Fall River Formation** – hole starts below formation top in mudstone unit
	40	Lower Fall River Formation siltstone unit
70		**Lakota Formation**
	70	Upper Lakota Fm.
	147	Basal sandstone unit Lakota Fm.
210		**Morrison Formation**
307		**Sundance Formation**
	307	Redwater Shale Member Sundance Fm.
	585	LAK Member Sundance Fm.
	640	Hulett Sandstone Member Sundance Fm.
	710	Stockade Beaver Shale Mbr. Sundance Fm.
770		**Spearfish Formation**
1410		**Minnekahta Limestone**
1430		**Opeche Shale**
1470		**Minnelusa Formation**
2315		**Madison Erosion Surface Deposit**
2350		**Madison Formation** (Pahasapa Limestone)
2690		**Whitewood Dolomite**
2791		**Winnipeg Formation**
2801		**Total depth** ending in Winnipeg Formation

The drill cuttings were examined microscopically and descriptions (lithologic descriptions) of the materials in each sample are provided in Appendix C for Test Well #1. Based on the lithology of the strata penetrated, individual geologic formations were identified and their names are included on each of the descriptions of the 10-foot interval drill cutting samples in Appendix C.

Formation tops in Test Well #1 (Table 1) were picked from Gamma Ray logs of the natural radiation emitted by the formation, used in conjunction with the drill cutting samples, to refine the depths selected for changes in the formation. Some refinement of the latter basis for selection of formation tops was made by continuously observing samples on the shale shaker as the borehole penetrated through the interval containing the top of the Madison strata and the top of the Winnipeg Formation.

3 CONSTRUCTION

The drilling equipment used for this project was Layne Christensen Company Rig No. 490 consisting of a Challenger 360 draw works and a Challenger 200 Derrick

mounted on a triple axel trailer with three 20,000-pound axels and a 4th pusher tag axel combination for a portable rotary drill rig combination. Photographs of the drilling rig and support equipment are shown in Appendix D.

3.1 Draw Works

The Challenger 360 draw works is equipped with a 10-foot elevated drill floor with a 200,000-pound floor capacity, 7 feet of under floor clearance and an IDECO 23-inch rotary table. On Test Well #1, the floor and rig was elevated one foot for flow line clearance to the mud pit in flooded reverse circulation configuration, providing an under floor clearance of 8-feet.

The Kelly drum and the hoisting drum on the double stacked drum rig were both 10-3/4" X 22-1/2 inch drums equipped with Wichita 24-inch, 3-plate clutches and a PARMAC hydromatic twin disc water brake. LeBus grooving with 7/8-inch line (1-inch swaged line) provided a single line pull of 36,000 pounds. A separate hydraulic wireline retrieval winch was equipped with 3000 feet of ¼-inch wireline for deviation measurements and other applications.

3.2 Derrick

The Challenger Model 200 derrick, with a top of crown height of 89 feet from ground level, was equipped with fluorescent derrick lighting and MD/TOTCO weight indicators. The working line was a Brewster 100-ton, 4-sheave traveling block and the drilling line was a McKissick 100-ton 4-sheave traveling block and hook combination with a rated hook load capacity of 200,000 pounds on 8 lines.

3.3 Power Unit

The power unit consisted of a Detroit Series 60, 540 horsepower diesel engine equipped with an Allison CLT5860 transmission with torque converter. The engine was housed in an enclosed engine compartment and equipped with a MAXIM silencer muffler and 100 gallons of on rig deck fuel storage.

3.4 Support Equipment

Support equipment included a 360-bbl portable mud pit plumbed for flooded reverse drilling. The mud pit was equipped with two shale shakers, fine mesh shale shaker screens for maximum solids removal, two de-sanders for solids removal, and a cyclone/gas buster. Two de-silters were added for Test Well #1 as well as a smaller portable mud pit to catch cuttings and fluid from the shale shakers.

The Challenger rig was equipped with an elevated, self-contained dog house; an 80-kW generator; a 300-amp welder; a 950-gallon diesel fuel storage tank with electric fueling pump; a hex Kelley and high-pressure swivel; a Bear automatic driller; a 15-horsepower Mission 2X3 mixing pump; a single-pen Geolograph for drilling rate; a 3 and 7 degree deviation survey tool and a Halliburton survey tool wire line. Other skid-mounted piston pumps and centrifugal pumps were added from time-to-time, as needed. The rig was

wired with explosion proof electrical connections and was PASON ready equipped, although PASON services were not used.

Additional support equipment included a duplex pump for shallow cementing, an 1170-cfm Ingersoll Rand compressor for reverse circulation drilling, a 225-kW Cat generator to run the shale shakers and mud pit pumps, a field office trailer with separate sample analysis room and living quarters, a Magnum 90-kW (single phase) generator for the field office power and a Cat 430E 4X4 backhoe with front-loader bucket and forks. A second 900-cfm air compressor was added during drilling of Test Well #1.

Two 400-bbl frac tanks were initially used for drilling operations and two more 400-bbl tanks were added later in drilling Test Wells #1 and #2A, to hold used drilling fluid until it was transported off-site for disposal. Various tractor-trailers and flatbed trailers were used to deliver equipment, casing, and drilling tools at various times. One Kenworth tractor was retained on site during drilling operations.

3.5 Air Package

The air package, used for direct air rotary drilling in the Madison aquifer strata, consisted of five compressors with a collective data-plate air capacity of 6,740 cfm and two 1600-psi boosters. The air compressor data-plate capacities were as follows:

Two	1350-CFM compressor	= 2700 CFM
One	1170-CFM compressor	= 1170 CFM
One	1070-CFM compressor	= 1070 CFM
Two	900-CFM compressors	= 1800 CFM
TOTAL RATED AIR VOLUME:		6740 CFM

The air compressors and boosters were connected through a common manifold that with valves to allow operation of individual compressors or combinations of compressors. Photo 1 shows the air compressors and boosters installed behind the drill rig.

Photo 2 shows a manifold used to direct compressed air from the five air compressors to the two boosters. Photo 3 shows the compressors and manifold with a light plant in the front, right foreground, blocking view of the connections to the two boosters out of sight to the right. Photo 4 shows the manifold used to connect high-pressure air from the boosters to the Kelly hose on the drill rig – two high-pressure steel lines coming in from the right from the 1600-psi boosters and a single high-pressure steel line going out left to the Kelly hose.

3.6 Drilling Methods

The portions of the test wells to be cased were drilled with conventional flooded reverse drilling methods. Open hole in the Madison limestone was drilled with direct air rotary methods.

3.6.1 Flooded Reverse Method

Static fluid level in the portable mud put adjacent to the well was maintained between ground level and the top of the surface conduit. The surface conduit, as shown in

Photo 1: Five air compressors and two boosters for air rotary drilling.

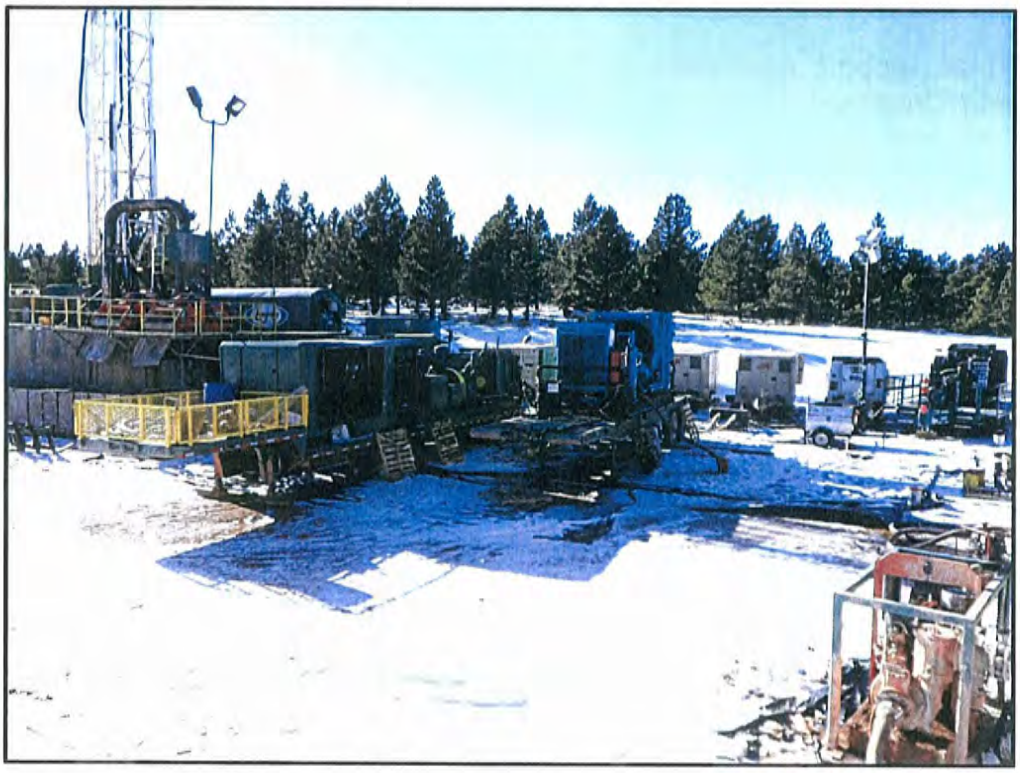


Photo 2: Manifold connecting compressors to boosters for air rotary drilling.

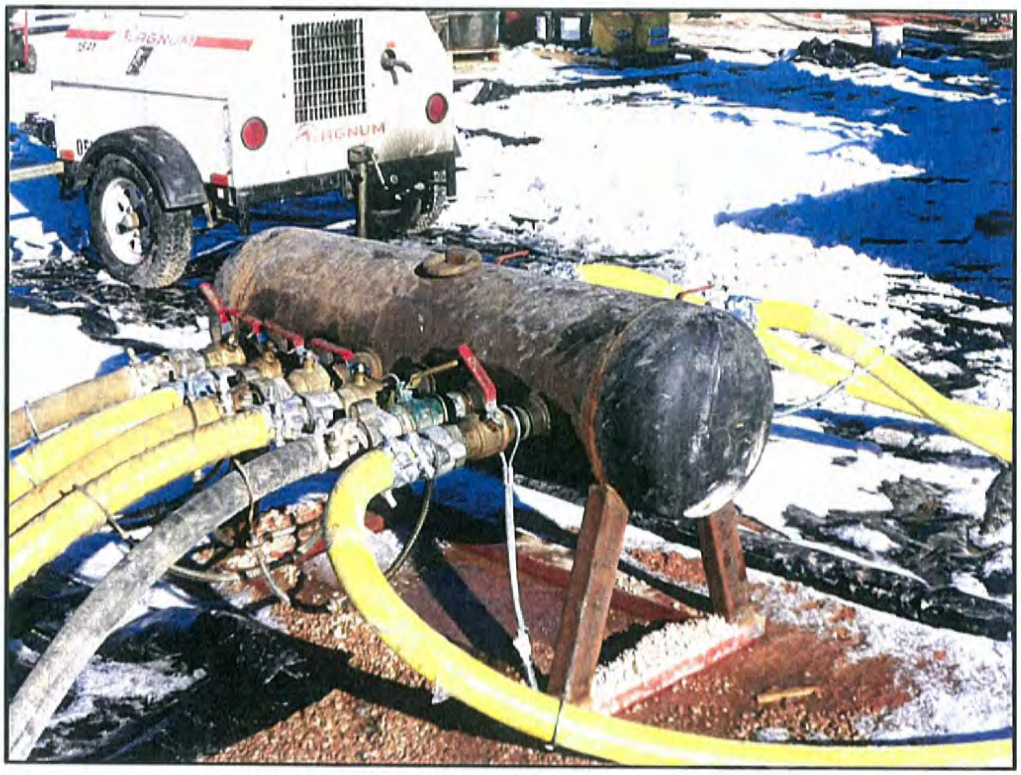


Photo 3: Compressors and manifold.

Photo 4: Manifold used to direct air from boosters to Kelly hose on drill rig.

Photo 5: View of surface conduit at Site #2 with mud pit line coming in from right and 24-inch casing hanging in hole.

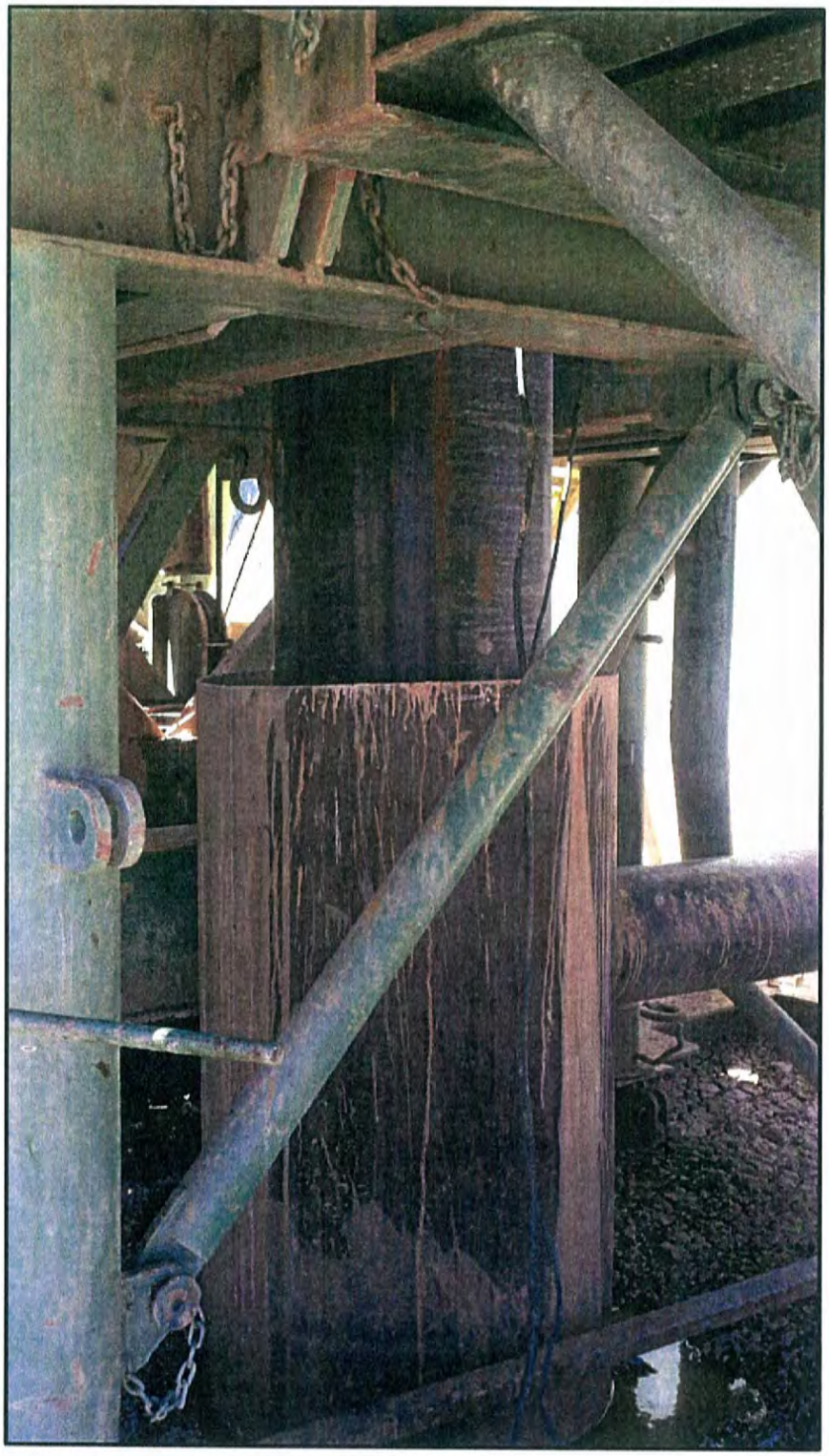


Photo 5 (Site #2A), extended high enough above the ground to allow a relatively full mud pit, but provide access to inspect drill bits and reamers above the surface conduit. Positive static pressure was maintained on the borehole with the drilling fluid level above the land surface. The static water level in the formation was subsequently determined to be 727 feet below land surface in the Madison aquifer and unknown for shallower water-bearing strata.

In flooded reverse drilling, the drilling fluid circulates from the mud pit, down the annulus between the drill pipe and the borehole wall. An airline is installed in the upper part of the drill pipe and compressed air is injected through the swivel on the Kelly to displace drilling fluid out of the upper part of the drill pipe. This causes the fluid level in the drill pipe to be lower than that in the annulus outside the drill pipe, so fluid circulates through the drill bit, up through the drill pipe, carrying drill cuttings up the drill pipe to where they are discharged to a cyclone separator.

The cyclone directs the cuttings and drilling fluid into shale shakers there the cuttings are separated from the fluid. The shaker screens dump the cuttings overboard onto the ground or into an auxiliary pit where they can be removed with a backhoe. The drilling fluid is directed back to the main mud pit after the cuttings are removed by the shale shaker screens. Continuous injection of air into the upper part of the drill pipe pumps the system and maintains circulation. Standard mill tooth and carbide insert button tri-cone drill bits are used; however, they usually have their skirts cut off to allow large cuttings to pass through the center of the bit body and into the drill pipe.

Photos 6 through 8 were taken at Test Well Site #2A and are provided to show the same equipment used at Site #1. Photo 6 shows the shale shakers dumping drill cuttings into a backhoe bucket. Photo 7 shows the shale shakers (orange equipment) mounted on the portable mud pit and dumping drill cuttings into an auxiliary mud pit. Photo 8 shows the auxiliary mud pit with the far end filling with drill cuttings from the shale shakers and the near end filling with saturated sand and silt in where it is discharged from the sand and silt separators that are used for solids control in the drilling fluid system. The auxiliary mud pit compartments shown in Photo 8 are cleaned periodically by means of a backhoe which moves the cuttings to a storage site on the drill pad. Photos 6, 7 and 8 were taken during drilling of Test Well #2A, and show the same equipment that was used in the same way for drilling Test Well #1.

3.6.2 Direct Air Rotary Method

The use of direct air rotary drilling for open hole in the Madison aquifer strata was selected for two reasons:

1. Discharge of formation water and drill cuttings from the hole during drilling would result in development of the production zones in the well while it was drilled. This would eliminate the need to develop the well after it was drilled with drilling mud.

Photo 6: Cyclone and shale shakers without auxiliary pit.

Photo 7: Shale shakers dumping samples into auxiliary pit.

Photo 8: Auxiliary mud pit with cuttings and sand and silt separator discharge.

2. Air rotary drilling would likely allow the borehole to penetrate the full thickness of the aquifer in conditions where mud rotary or flooded reverse rotary drilling would not be able to continue due to loss of circulation.

Reports of yield and drawdown tests of previously constructed Madison aquifer wells for the City of Gillette describe wells discharging large amounts of sediment and turbid water; even though they were developed with air lift pumping after they were drilled with direct rotary or flooded reverse rotary methods. The reports indicate that the air lift pumping rates used during development were not effective in cleaning up the productive formation around the wells. Therefore, a primary objective of direct air rotary drilling was to provide sufficient air lift capability to not only ensure that drill cuttings were removed from the advancing borehole during drilling, but that the rate of water pumped from the aquifer was sufficient to exceed potential pumping rates by test pumps after the well was completed. In order to meet these goals, the air package was designed with adequate pressure capability to air lift water from the bottom of the well, starting at static conditions.

The volume of compressed air required to accomplish the design goals was calculated with two different methods; volume based on minimum required up-hole flow velocity of 3000 ft/minute in 16-inch casing at the top of the well and volume based on kinetic energy requirements to lift drill cuttings and fluid out of the well. Both methods of calculating air requirements indicated that a minimum 6000 cfm flow of compressed air

was suitable for the anticipated drilling conditions. Estimates of probable static water levels in the Madison aquifer, based on the existing well field and the local geology, indicated a minimum air pressure of 1350 psi was required for the air package. Based on the foregoing requirements, the previously described air package with a data-plate capacity of 6740 cfm was provided, including two 1350-psi boosters. The use of two boosters was necessary to provide the required volume of 6000 cfm at the 1350-psi operating pressure.

Photos 9 and 10 show the rotating head attached to the top of the 16-inch well casing to provide a seal between the drill pipe and the casing while utilizing air rotary drilling methods. Photo 9 shows the connection to the horizontal 10-inch steel pipe that diverts water and air from the well casing to the cyclone or to a waste line. Photo 10 shows the large, high-pressure valve on the 10-inch discharge line (behind a green pipe) used to start and stop flow to the cyclone that is mounted over the shale shakers on the mud pit. When the hole is being unloaded after making up a joint or resuming drilling, this valve is closed and the air and water bypass the cyclone and mud pit and are discharged directly out the 10-inch steel dump line to the side of the drilling pad.

Photo 11 shows the rotating head and well casing, the valve on the line to the cyclone (background valve) and the valve on the 10-inch dump line (foreground valve). Photo 12 shows the dumpline valve (left) and a valve (right) on the outlet to auxiliary mud pit that is used during volumetric measurements of discharge in the mud pipe and

Photo 9: Rotating head.

Photo 10: Dump line and valve.

Photo 11: View of discharge valves to cyclone and dump line.

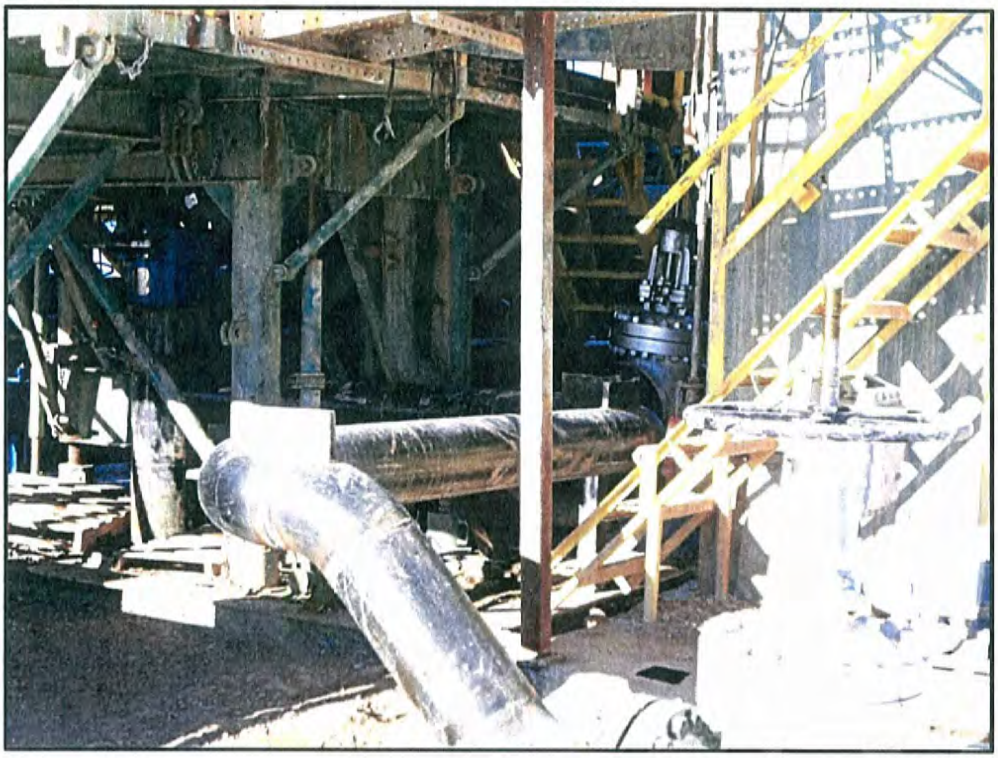
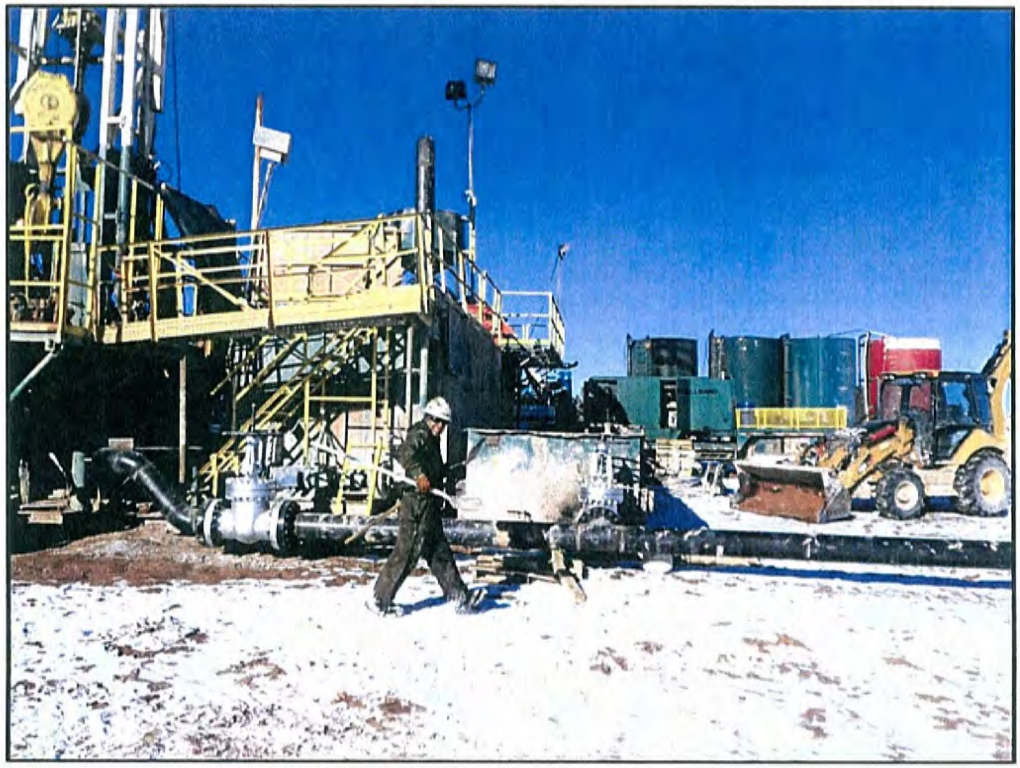


Photo 12: View of dump line valve and auxiliary pit outlet valve.



to prevent air and water from backing up into the auxiliary pit during unloading of the well. Isolation of the cyclone during unloading of the hole prevents water hammer and excess pressure in the cyclone during hole unloading. After constant airlift discharge is established, the valve to the cyclone (Photos 10 and 11) is opened and the valve to the dump line (Photos 11 and 12) is closed and the valve on the auxiliary mud pit outlet is manipulated to conduct volumetric measurements of airlift discharge during drilling. Photo 13 shows the dump line extending to the edge of the drilling pad with a pipe trailer loaded with a few drilling collars parked on the line.

Photo 13: View toward downstream end of dump line.

Photo 14 shows discharge at the end of the dump line with less than 250 gpm of production and airlift surging taking place. Photo 15 shows discharge while unloading the hole with substantial recovery in the hole while making a tool joint connection. An angle iron welded in the discharge elbow disperses the discharge water to prevent erosion. Photos 14 and 15 are copied from videos of the discharge.

Photo 14: Dump line bypass discharge with small yield of water and surging.

Photo 15: Dump line bypass discharge with large yield of water.

3.7 Drilling Fluids

Drilling fluids for flooded reverse drilling consisted of conventional gel/polymer water-based drilling fluid. The design parameters for the drilling fluid system were to maintain water loss at 12 mL/30 seconds for most of the formation and as low as 8 mL/30 sec for the soft shales in the uppermost 700 to 800 feet of the borehole. Associated design parameters were to maintain mud weight at generally less than 9.0 lb/gal and Marsh funnel fluid viscosity at 36 to 40 seconds per liter.

The Daily Driller's Reports, Disc 1 provided with this report, contain a record of the drilling fluid additives used during the project, including drilling gel, regular and low viscosity polymer and pH control with soda ash. The reports also indicate the drilling fluid Marsh funnel viscosity, weight and water loss at approximately four-hour intervals. The records reflect the influence of dissolving natural clays in the uppermost 800 feet of strata which tend to increase the viscosity and weight of the drilling fluid. Likewise the records reflect the influence of gypsum in the Spearfish Formation which required use of a large amount of soda ash combined with pumping off old mud and mixing new when calcium from the gypsum began to overwhelm sodium in the drilling fluid and modify the drilling fluid properties.

Control of drilling fluid properties during construction of Test Well #1 was given close attention with good results. A polymer designed for clay encapsulation was not applied in the drilling fluid in Test Well #1 and this fact is reflected in some measurements of fluid weights of 9.0 to 9.4 lb/gal and water loss exceeding 12 mL/30 sec while drilling the uppermost few hundred feet of borehole.

Addition of a low viscosity, clay inhibiting polymer brought the fluid properties closer to the desired parameters; however, penetration of calcium-rich gypsum and anhydrite intimately interbedded into the Spearfish strata resulted in considerable reaction between the drill cuttings and the drilling fluid below a depth of about 770 feet. In general, repeated pumping off of used mud to be replaced with new drilling fluid containing additional gel and polymer was necessary to keep fluid weight at about 9.2 lb/gal or less and water loss down to about 12 mL/30 sec with frequent excursions in the range of 12 to 15 mL/30 sec occurring before mud was pumped off and new mud mixed. As shown on the Daily Driller's Reports on Disc 1, large amounts of soda ash were required to condition the mud. Soda ash is regarded as a pH-control additive; however, its real importance is to provide enough sodium cations in the drilling fluid to ensure that cation-exchange sites on the drilling gel clay are occupied by sodium, rather than by calcium from the formation. If calcium dominates the cation exchange sites on the colloids in the drilling fluid, the fluid weight and viscosity become unmanageable and the mud must be replaced with new mud. Therefore, large amounts of soda ash were used in the drilling fluid for Test Well #1 to prevent calcium from the gypsum and anhydrite in the Spearfish Formation from overwhelming the fluid system and degrading the drilling mud properties. Even so, it was necessary to frequently pump off used mud and replace it with new product.

The drilling fluid for direct air rotary drilling was compressed air. Additives such as water or foam were not used with the compressed air because of the difficulty of attempting to inject fluid into the compressed air stream at high pressures.

3.8 Construction History

All depths recorded on Daily Drilling Reports, geological logs, geophysical logs, and construction logs for Test Well #1 are based on depth below ground level (BGL).

3.8.1 36-Inch Surface Conduit

On 10/29/2012, bucket auger drilling (Photo 16) of 44-inch diameter rat hole to 63 feet was accomplished by Rat Hole Drilling of Casper until bucket refusal on hard siltstone in the Fall River Formation at 63 feet. On 12/30/2012, a 24-inch bucket was used to advance pilot hole and 44-inch diameter hole followed to a depth of 72 feet. The auger rig broke down at that depth and Layne's site supervisor called the hole at 72 feet in hard rock. Samples at this depth (Appendix C) were caving from softer material above; however, the hole ended in very hard rock, which subsequent interpretation of geophysical logs revealed to be the uppermost sandstone of the Lakota Formation.

Surface casing consisting of 70 feet (not including stick up) of 0.375-inch wall, 36-inch casing was lowered into the hole (Photo 17) and centralized on 11/1/2012 and 10 cubic yards of 14.8-lb/gal, six gallons per sack, Portland cement grout were pumped through a tremmie pipe, displacing cement from the bottom of the annulus upward until the annulus was filled (Photos 18 and 19).

3.8.2 24-Inch Surface Casing

The 24-inch surface casing in Test Well #1 consists of 0.500-inch wall thickness casing installed to a depth of 1505 feet BGL.

Rigging up and waiting on surface conduit cement to harden ended 11/8/2012. Centralizing of a 14-3/4 inch diameter pilot hole began with installation of a tool string consisting of a 32-inch reamer (Photo 20) above a 14-3/4 inch lead bit. The bit plugged and the tool string was tripped out, cleared, and tripped back in to drill a centralized starter hole for the pilot hole. The tools were then tripped out and the reamer removed. The 14-3/4 pilot hole button bit was then tripped back into the hole and drilling of centered 14-3/4 inch pilot hole began at 7:30 A.M. on 11/9/2012. The button bit plugged with clay at 97 feet and was replaced with a long-tooth mill bit. Drilling of 14-3/4 inch pilot hole ended on 11/24/2012 at a total depth of 1543 feet.

Drilling through the gypsum-rich Spearfish Formation (770 to 1410 feet) required continuous addition of soda ash to the drilling fluid to suppress the flocculation of drilling gel and natural clay by calcium derived from the gypsum. Even so, a total of 525 barrels (BBL) of drilling fluid were pumped off and hauled off site for disposal in order to maintain proper drilling fluid properties. The 525 BBL hauled off site is equal to 164 percent of the 320-BBL true-hole size volume of 1515 feet of 14-3/4 inch borehole.

Photo 16: Bucket auger rig drilling 44-inch surface conduit hole.

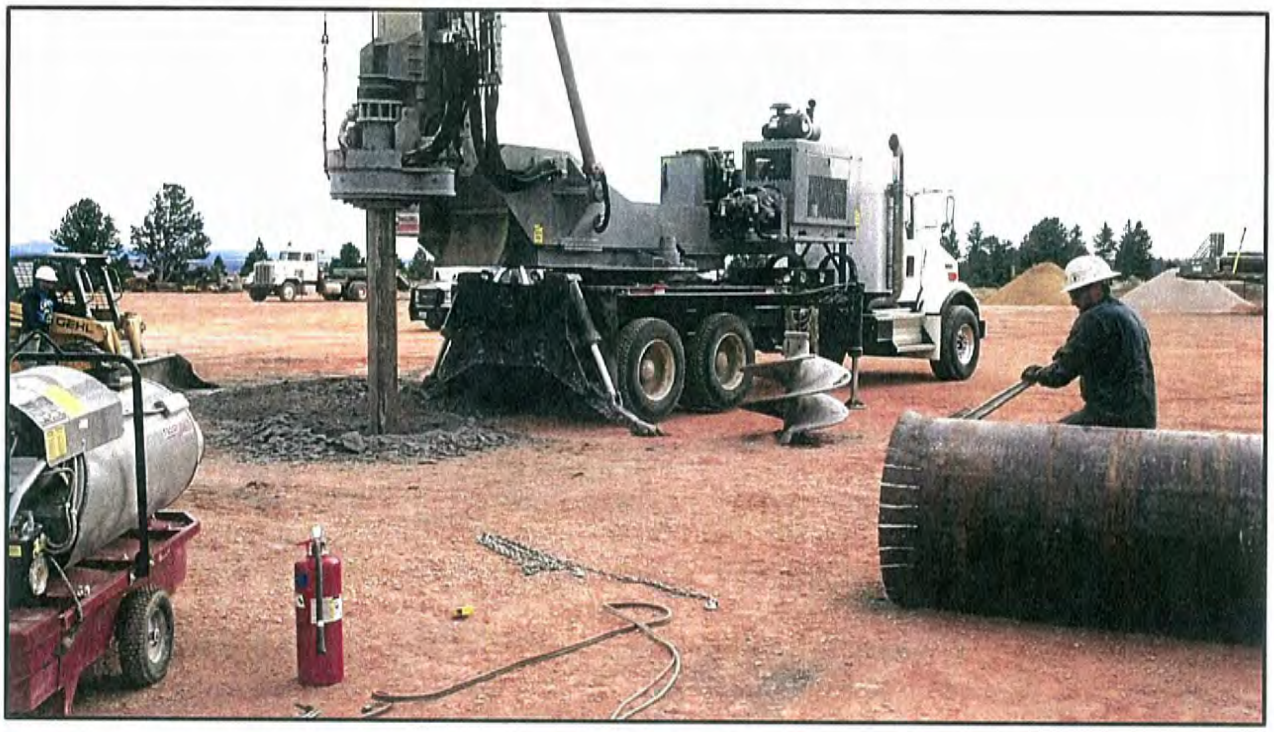


Photo 17: 36-inch surface conduit installation in 44-inch borehole.

Photo 18: Cementing Test Well #1 surface conduit.

Photo 19: Cement in annulus of surface conduit.

Photo 20: 32-inch reamer.

Table 2 summarizes the drilling fluid pumped off and hauled off site, as per the Daily Driller's Reports on Disc 1.

Table 2: Drilling fluid hauled off during drilling 14-3/4 inch pilot hole to 1515 feet.

Date	Mud Pumped Off (Barrels)	Depth Interval (feet)
11/14/2012	100	694- 767
11/15/2012	125	767- 821
11/17/2012	50	986-1032
11/21/2012	100	1291-1364
11/22/2012	50	1370-1435
11/23/2012	100	1435-1515
Total Mud Hauled Off:	**525**	

Table 3 summarizes deviation surveys conducted with a 3.5-degree, wire-line inclinometer using metal discs graduated for a 7-degree instrument. Accordingly, each 1-degree ring on the disc represents 0.5-degrees when used in the 3.5-degree tool.

Table 3: Deviation from vertical measured in 14-3/4 inch pilot hole from 70 to 1515 feet.

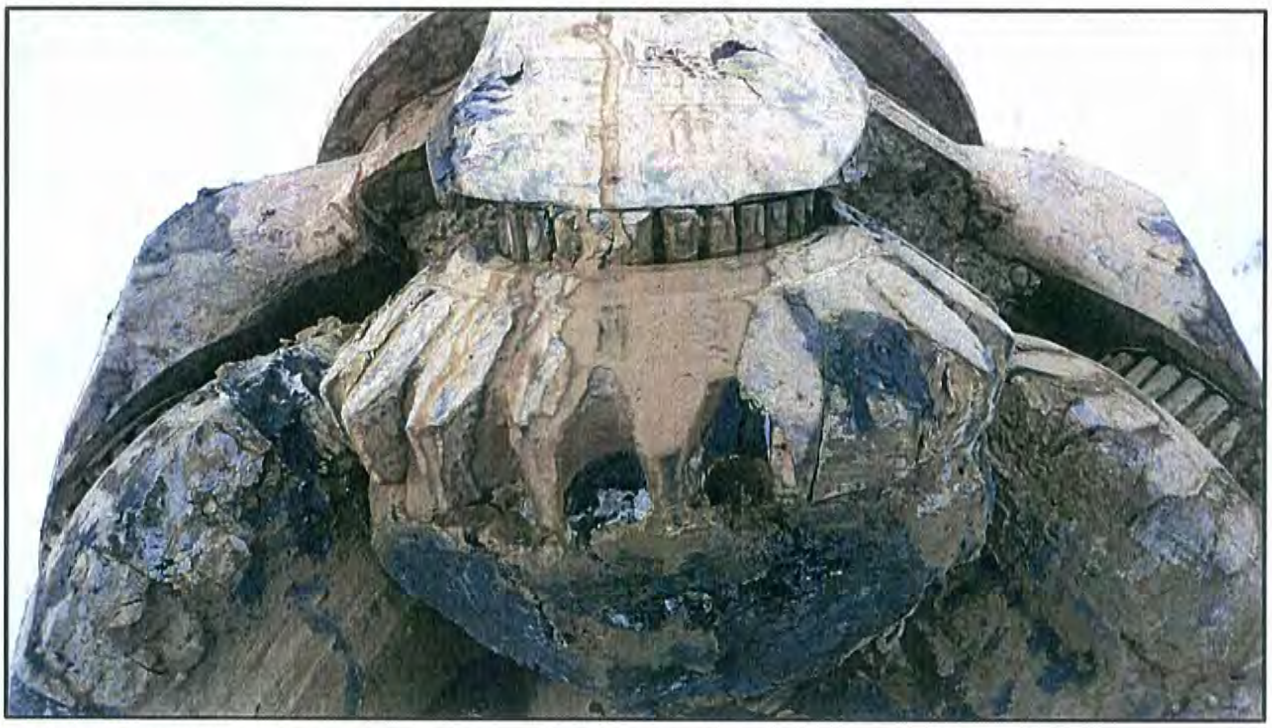
Depth (feet)	Deviation (degrees)
160	0.5
270	0.5
380	0.5
580	0.5
680	0.4
810	0.4
910	0.6
1020	0.25
1120	0.20
1235	0.40
1330	0.50

After completion of the pilot hole to 1515 feet, a 14-3/4 long-tooth lead bit and 32-inch button bit reamer were installed to begin reaming at 75 feet at 4:00 A.M. on 11/25/2012. The open-skirt, long-mill tooth lead bit was replaced with a similar 17-1/2 inch bit at 437 feet when the smaller lead bit balled up with clay. On 12/2/2012, at a reaming depth of 490 feet, it was determined that the bearings in the 32-inch reamer were set for deeper drilling and required more resistance for the reamer to turn than was available from this soft formation at relatively shallow depth. While replacement 32-inch reamers with bearings set specifically for this relatively shallow drilling were ordered, the 32-inch reamer was replaced with a 28-inch reamer that would turn in this soft formation.

At 952 feet, the 28-inch reamer was replaced with a 32-inch reamer and 22-inch lead bit and tripped to 489 feet where reaming resumed at midnight 12/9/2012. The bearings in the new 32-inch reamer failed at a reaming depth of 599 feet and a new 32-inch reamer was installed. At a reaming depth of 784 feet, the replacement 32-inch reamer bearings failed and the reamer was replaced with a 32-inch button bit reamer on 12/12/2012. The two failed reamers were found to have faulty bearings (Photo 21) from the manufacturer and were replaced for no cost, but still caused delay for tripping tools. Reaming with the replacement 32-inch reamer continued to 1238 feet, where the tools were tripped out to replace the lead bit. Tight spots were reamed out while tripping back in.

On 12/19/2012, helper Robert Russel was burned on his hand and forearm when he tried to tighten the leaking drain plug on a trash pump used to pump used mud to a frac tank. The pump was dead-headed against a frozen line to the frac tank and had gotten hot enough to generate steam which was leaking around the drain plug. When Russel attempted to tighten the plug with his gloved fingers to stop what he perceived to be a leak, the steam pressure blew the plug out and sprayed him with boiling mud.

Photo 21: Faulty bearings on 32-inch reamer.



On 12/20/2012, after replacing the 22-inch lead bit, more reaming was done in the under-gauge hole where the 32-inch reamer faulty bearings. After those intervals were reamed, the bit was tripped to 1238 feet by 4:00 A.M. on 12/21/2012, where it was found that the 22-inch lead bit would not turn in backfill consisting of loose reaming cuttings in bottom of hole. The lead bit and reamer were replaced with a single 20-inch bit to clean hole and ream the 14-3/4 inch diameter pilot hole. Reaming 14-3/4 inch pilot hole to 20-inch diameter to total depth of 1282 feet was accomplished by midnight 12/22/2012 and to 1316 feet at noon 12/23/2012.

At about 6:00 P.M. on 12/22/2012, driller Jim Coffer attempted to run a pig in the frozen 3-inch water line from the COG storage reservoir at the highway to clear ice from the line. When the pig reached a valve where Coffer was monitoring discharge out of the line, the line began violently whipping and ran over Coffer several times, breaking his leg at the top of his thigh bone an giving him other less serious bruises and cuts. He lost his cell phone that he was using to communicate with the man at the storage tank pump, but managed to crawl to his pickup truck and call for help on a different cell phone, even as the other man was coming up to his location to see why he was not talking on the cell phone. He was then hauled to the hospital in Gillette where he was hospitalized with his injuries and held for an operation to put his shattered leg back together.

Reaming of 14-3/4 inch pilot hole to 20-inch diameter was completed to 1538 feet by midnight on Christmas, 12/25/2012. The 20-inch mill tooth bit was replaced by an open

skirt 22-inch button lead bit and a 32-inch button reamer and reaming of the 20-inch hole to 32-inch borehole began at 1238 feet at 8:00 P.M. on 12/26/2012. Reaming continued until noon on 1/3/2013 with 32-inch hole reamed to a total depth of 1532 feet. Drilling and reaming the 32-inch borehole required drilling fluid to be pumped off and hauled off site with new fluid mixed to maintain the required drilling fluid properties. A total of 6070 barrels of mud, including the mud displaced out of the hole for cementing casing, were pumped off to frac tanks and hauled off site. The true-hole size volume of 1532 feet of 32-inch diameter borehole is 1524 BBL so the mud volume required to drill pilot hole, ream and case the 32-inch borehole was essentially four times the nominal borehole volume.

Geophysical logs were run and installation of 24-inch surface casing began by 7:30 A.M. on 1/4/2013. The 24-inch casing was landed at 1505 feet at 7:00 P.M. on 1/5/2013 and the 2-7/8 inch tubing for cementing was installed through a Bradenhead on the 24-inch casing to 1502 feet by midnight.

On 1/6/2013, Basic Energy Services cemented the annulus around the 24-inch surface casing with a lead cement consisting of a nominal 1400 sacks of 12-lb/gal light cement with a slurry yield of 2.64 cubic feet per sack at 15 gal/sack for 658 BBL of slurry displaced followed by tail cement consisting of a nominal 480 sacks of Type G 14.8-lb/gal oilfield cement with a slurry yield of 1.38 cubic feet per sack at 6 gal/sack for a recorded displacement of 118 BBL of slurry. The lead cement included 10% gel, 1/2-lb/gal flowcel, 3% calcium chloride and 2% sodium metasilicate. The tail cement included 2% gel and 2% calcium chloride. The tremmie pipe was displaced with 10 BBL of water after cement was pumped. No cement returned to the surface.

On 1/7/2013, the top of the cement in the annulus was tagged at 347 feet and Basic Energy Services returned at noon to displace additional Type G, 14.8-lb/gal cement from 347 feet to the surface followed by displacement of 2 BBL of fresh water. On 1/8/2013, cement was tagged inside the 24-inch casing at 1497 feet and drilled out to 1528 feet with new hole drilled to 1538 feet. On 1/9/2013, tubing was tripped out and a cement bond log (CBL) was run. Down-hole geophysical logs, including CBL are provided on Disc 2 in the pocket in the back of this report.

3.8.3 16-Inch Pumping Chamber

Test Well #1 was designed for installation of 16-inch casing in 22-inch borehole to a depth of 1850 feet to provide a chamber for a production pump. Drilling of 22-inch borehole began at 1538 feet at 6:00 A.M. on 1/10/2013 and was finished at a total depth of 1869 feet at 6:00 A.M. on 1/16/2013. Goodwell Inc. completed geophysical logging of the hole by 11:00 P.M. including Caliper/Gamma Ray, 16-inch and 64-inch normal resistivity and Spontaneous Potential.

The 0.500-inch wall, 16-inch diameter casing was landed at 1852.5 feet by noon on 1/18/2013. Photo 22 shows the cementing shoe welded into the bottom of the casing string (silver section of pipe). Photo 22 also shows the guide casing section below the cementing shoe with three sets of 4-inch cementing windows cut into the guide casing.

Photo 23 shows a cementing window. Photo 24 shows the 16-inch casing hanging on gussets cut into the 24-inch surface casing.

By 9:00 P.M. on 1/18/2013, 1838 feet of 4-1/2 XO drill pipe was stabbed into the cement shoe and circulation established through the drill pipe and up the outside of the 16-inch casing. On 1/19/2013, the 16-inch casing was cemented with 600 sacks of 14.8-lb/gal type G cement containing 2% gel, 3% calcium chloride and 1/2-pound flocel per gallon. At a slurry yield of 1.34 cubic feet per sack, 143 BBL of slurry was preceded by 10 BBL of clear water, and displaced by 26 BBL water, putting the top of the cement at 1300 ft.

3.8.4 10-3/4 Inch Intermediate Casing

A 10-3/4 inch, 0.375-inch wall thickness intermediate casing was installed in 14-3/4-inch borehole from 1800 to 2296 feet for the transition from the pumping chamber to the top of the Madison aquifer.

Tools were tripped into the hole beginning 12:30 P.M. on 1/21/2013 for drilling 14-3/4 inch borehole. The cement shoe and cement was reamed out with a 14-3/4 inch button bit to a depth of 1869 feet by 7:30 A.M. on 1/22/2013. Deviation from vertical measured with a 3.5-degree wireline inclinometer is shown in Table 4. Gypsum cement in the Minnelusa Formation reacted with the drilling mud requiring 170 BBL of mud to be pumped off and hauled out for disposal on 1/27/2013.

A cement bond log (CBL) of the 16-inch casing was completed by 2:00 P.M. and drilling with an open skirt 14-3/4 inch button bit began at 1:30 P.M. on 1/23/2013. The 14-3/4 inch diameter hole was completed at a depth of 2296 feet at 3:30 A.M. on 1/30/2013 and the open hole was geophysically logged by 6:00 P.M. when the crew began running 10-3/4 casing into the hole.

Table 4: Deviation from vertical in 14-3/4 inch hole for 10-3/4 casing.

Depth (feet)	Deviation (degrees)
1900	0.50
2011	0.25
2100	0.50
2220	0.50

Photo 22: Cementing shoe and casing guide with three sets of cementing windows.

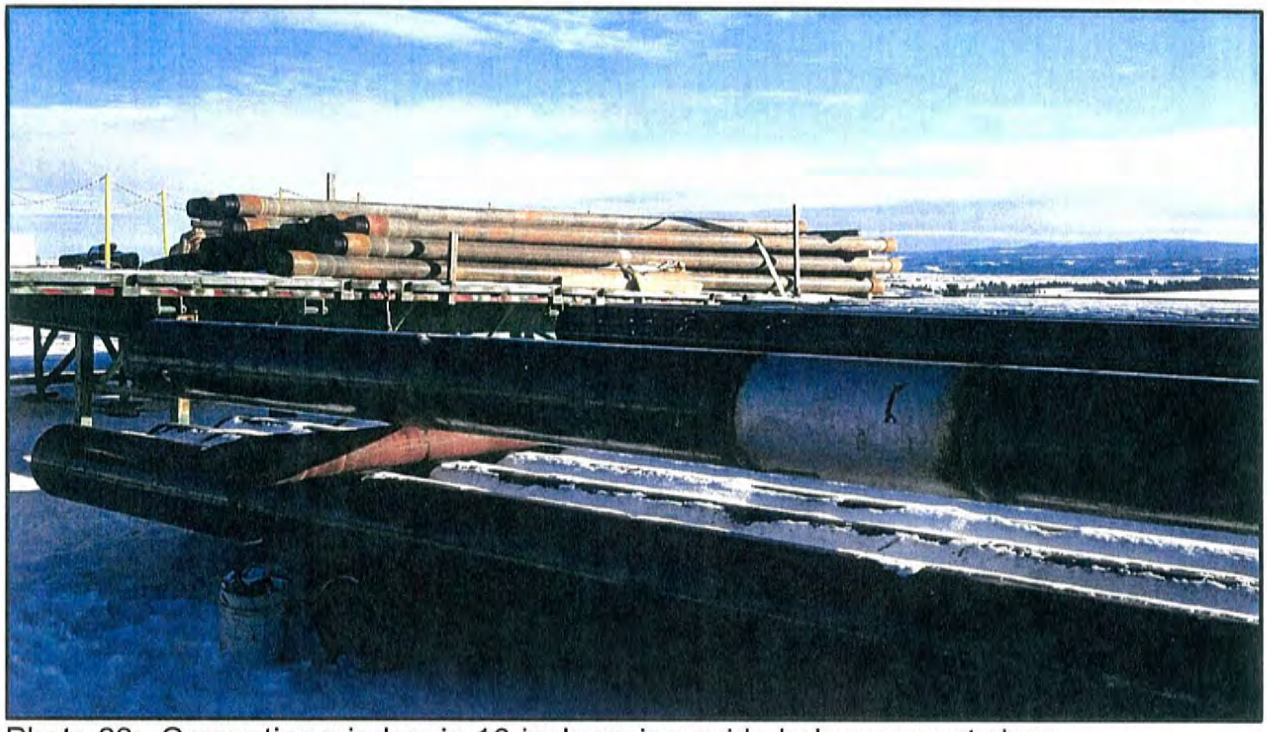


Photo 23: Cementing window in 16-inch casing guide below cement shoe.

Photo 24: 16-inch casing hanging on gussets cut into 24-inch surface casing.

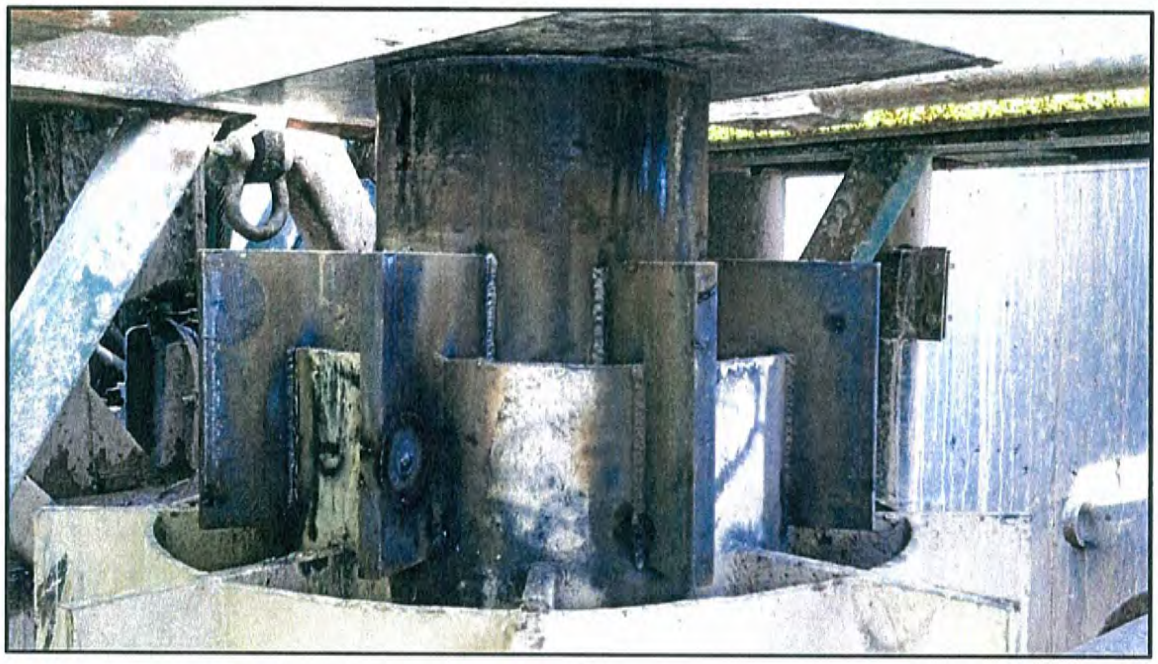


Photo 25: Cement pumper and bulk truck cementing 16-inch casing.

By 2:00 A.M. on 1/31/2013, the 10-3/4 inch casing was assembled and attached to the 7-inch drill pipe. The 7-drill pipe was used to lower the 10-3/4 casing and land it at 2296 feet, with its top at 1800 feet, by 1:30 P.M. after which the drill pipe was backed off of the left hand thread (LHT) adaptor on the casing.

After landing the casing, 4-1/2 inch X0 drill pipe was stabbed into the cementing shoe and circulation established by 2:00 A.M. 2/1/2013. The casing was then cemented with 275 sacks of Type G cement at 14.8-lb/gal with 2% calcium chloride, 2% gel and 1/2-pound flocel per gallon. The slurry yield of 1.34 lb/gal produced 66 BBL of slurry which was displaced with 32 BBL of water with cementing completed by 9:00 A.M. on 2/1/2013. The cementing shoe was drilled out by 8:00 P.M. on 2/4/2013 and the tools were tripped out for cement bond logging. The hole was logged 2/5/2013.

3.8.5 7-Inch Intermediate Casing

After cement bond logging of the 10-3/4 inch casing, rigging for air drilling began and was completed on 2/10/2013. On 2/10/2013 the hole was unloaded in stages as the drill pipe was tripped in. The bottom of the hole was tagged at 2298 feet at 4:30 A.M. on 2/10/2013 and air rotary drilling began with 9-7/8 hole advanced to 2410 feet by 8:00 P.M. on 2/10/2013. The interval from 2315 to 2350 feet was found to be unconsolidated sand and silt which had to be cased off to stabilize the borehole wall. Accordingly, drilling of 9-7/8 borehole was stopped at a depth of 2410 feet for installation of 7-inch casing.

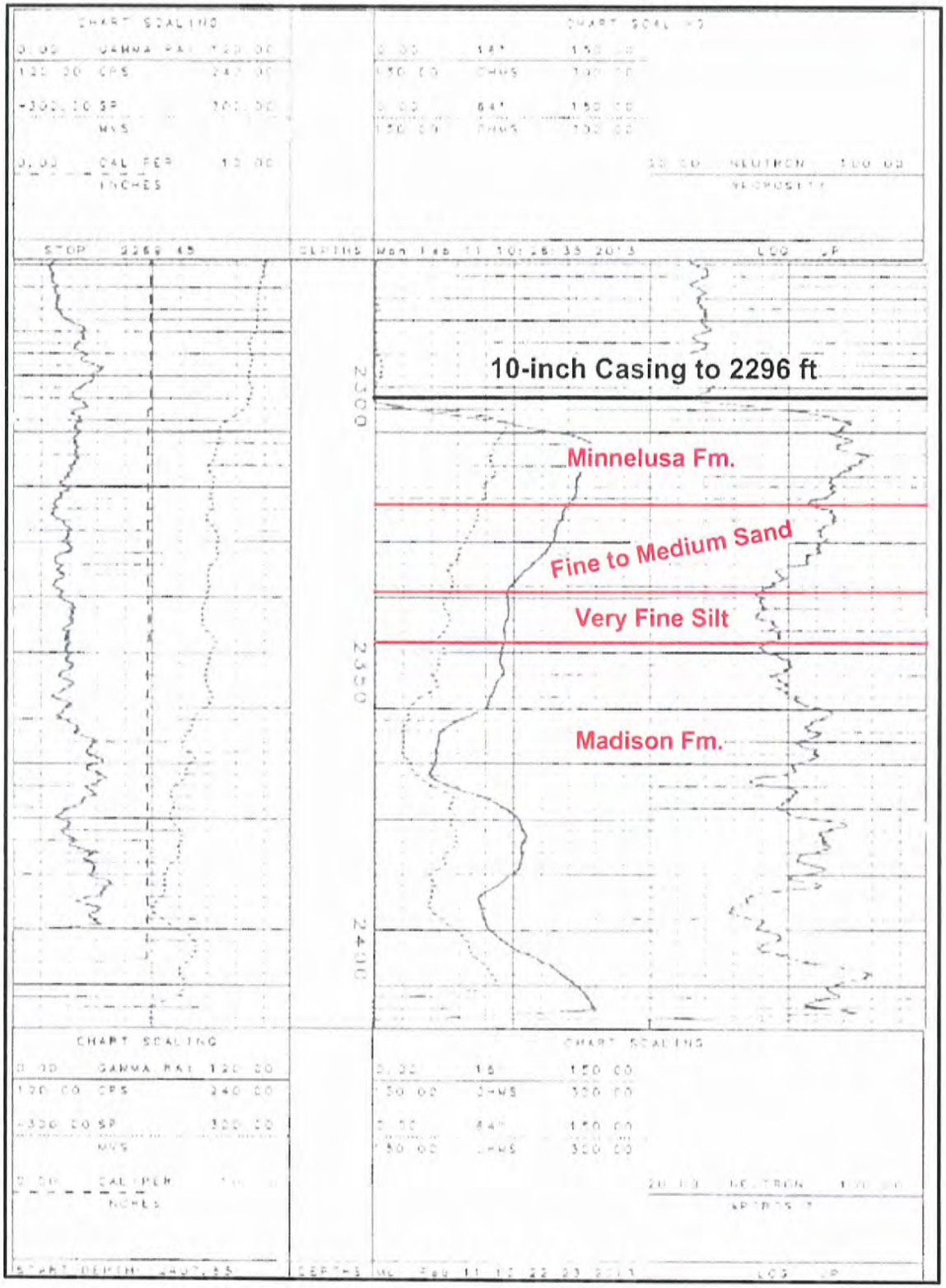
On February 11, 2013, geophysical logs of the open hole were obtained from 9:00 to 11:30 A.M. and interpreted to verify the exact interval of sand and silt and determine where to set the 7-inch casing. Figure 4 shows the interpretation of the geophysical log, based on the drilling breaks and the drill cutting samples. Depth is offset 2 feet.

Table 5: 7-inch casing tally.

Bottom of castellations to threaded collar	10.30 ft (7-inch pipe)
Threaded collar	0.80 ft
Float collar body	0.76 ft
7-inch casing	30.24 ft
7-inch casing	40.00 ft
7-inch casing	40.00 ft
7-inch casing	39.97 ft
7-inch casing	40.00 ft
Back-off shoe	2.25 ft
Total casing assembly:	204.32 feet

3-inch cementing windows at 1.40, 4.50 and 8.0 feet from bottom of casing.

Figure 4: Log of sediment interval from 2313 to 2348 feet.



After completion of geologic logging, a 7-inch intermediate casing design was completed for installation of casing from 2205 to 2410 feet. The tally of 7-inch casing actually installed in the well is shown on Table 5. The casing assembly included a float collar with its top 192.46 feet below the top of the back-off shoe at the top of the casing. The float collar length was 0.76 feet. On 2/17/2013, the 7-inch casing was landed at 5:00 P.M. with the top of the back-off shoe at 2205.7 feet and the bottom of the casing assembly at 2410 feet.

The 7-inch casing consisted of 0.272-inch wall steel casing with an I.D. of 6.456 inches. The casing was installed by lowering it into place with 7-inch drill pipe. The weight of the casing filled with 8.34-lb/gal water was 6810 pounds whereas cement column uplift on the casing was 6036 lbs, providing a net weight of 774 pounds over neutral buoyancy, not counting the weight of the stabbed-in drill pipe used for cementing. A cementing pipe consisting of 4-1/2 inch XO drill pipe was stabbed into the float collar, then the casing annulus was cemented by displacing cement through the drill pipe with a wiper plug intended to land on the float collar. The cement consisted of 45 sacks of Type G cement at 14.8 lb/gal, 2% gel, 2% calcium chloride, and 1/2-pound flocel per gallon for a slurry yield of 1.34 cubic feet per sack. Total slurry displaced was 10.5 BBL

Photo 26: 7-inch casing with cement window and castellated bottom.

Photo 27: Float shoe and collar in casing string.

displaced through drill pipe with 32.34 BBL of water behind the wiper plug. Basic Energy Services completed services on-site by 11:00 A.M. on 2/18/2013.

On 2/19/2013, tools were tripped into the hole and the top of a plug of soft material in the 10-3/4 inch casing was tagged at 2127 feet, showing that material was displaced out the top of the annulus between the 7-inch and 10-3/4 inch casing at a relatively high velocity. After tripping out tools and discussing presence of soft plug at 2127 feet, the tools were tripped back in with a 6-1/4 inch bit to drill out the plug, float collar and cement below the float collar. The plug was tagged at 3:30 A.M. on 2/20/2013 and the material drilled out was subsequently found to be about 12 feet of plug consisting primarily of flocel and loose cuttings that were washed up the hole from the annulus outside the 7-inch casing. This indicated that fluid was displaced out the top of the 7-inch annulus during cementing, as was expected.

After making a connection at 2187 feet and cleaning to about 2205 feet, the two 1350-psi boosters suddenly went to full boost at 1350-psi, blowing one booster hose off the booster manifold (Photo 28) and rupturing several compressor hoses (Photos 28 and 29) which also caught on fire and sprayed black soot on the snow-covered ground around the manifold (Photo 30). The pop-off valve body and four feet of 2-inch pipe on which the pop-off valve was mounted blew completely off the IR 920/350 compressor and was found out in the snow. Subsequent inspection of the equipment, after the event, indicated the oil separator on the IR 920/350 caught fire and began pumping oil into the air stream to the boosters. The oil in the boosters was the likely cause of the fire in the hoses and the subsequent overpressure.

The latter event occurred early in the morning of 2/20/2013. After high-pressure hoses were replaced and a replacement compressor located, drilling resumed with soft cement encountered in 7-inch casing at 2375 feet at 3:35 P.M., thus confirming that cement was displaced out the top of the 7-inch annulus, as expected, and fell back inside the annulus between the 7-inch casing and the cementing pipe. The float collar was tagged at the design depth and drilled out by 6:00 P.M., with the remainder of the guide casing drilled out and new hole into Madison formation made to a depth of 2412 feet.

3.8.6 6-1/4 inch Open-Hole Completion

After the float collar and cement were drilled out, the tools were tripped out and a tool string with 7-inch drill pipe combined with 4-3/4 inch diameter drill collar for drilling through 7-inch casing was assembled and tripped in. Drilling new 6-1/4 inch production hole in the Madison resumed at 10:30 P.M. 2/21/2013. Total depth of 2801 feet in the Winnipeg Formation was reached at 2:30 P.M. on 2/26/2013.

Figure 5 shows the air lift yield from the Madison strata as the 6-1/4 nominal diameter borehole was drilled. The data exhibit increasing scatter as depth increases. This is because the yield into the borehole increases with depth as well as the volume of water that must be unloaded from the hole each time a tool joint connection is made during drilling. The discharge rates shown on Figure 5 are based on volumetric measurements

Photo 28: Air manifold fittings after overpressure and ruptured lines.

Photo 29: Ruptured high-pressure air hose and soot on snow.

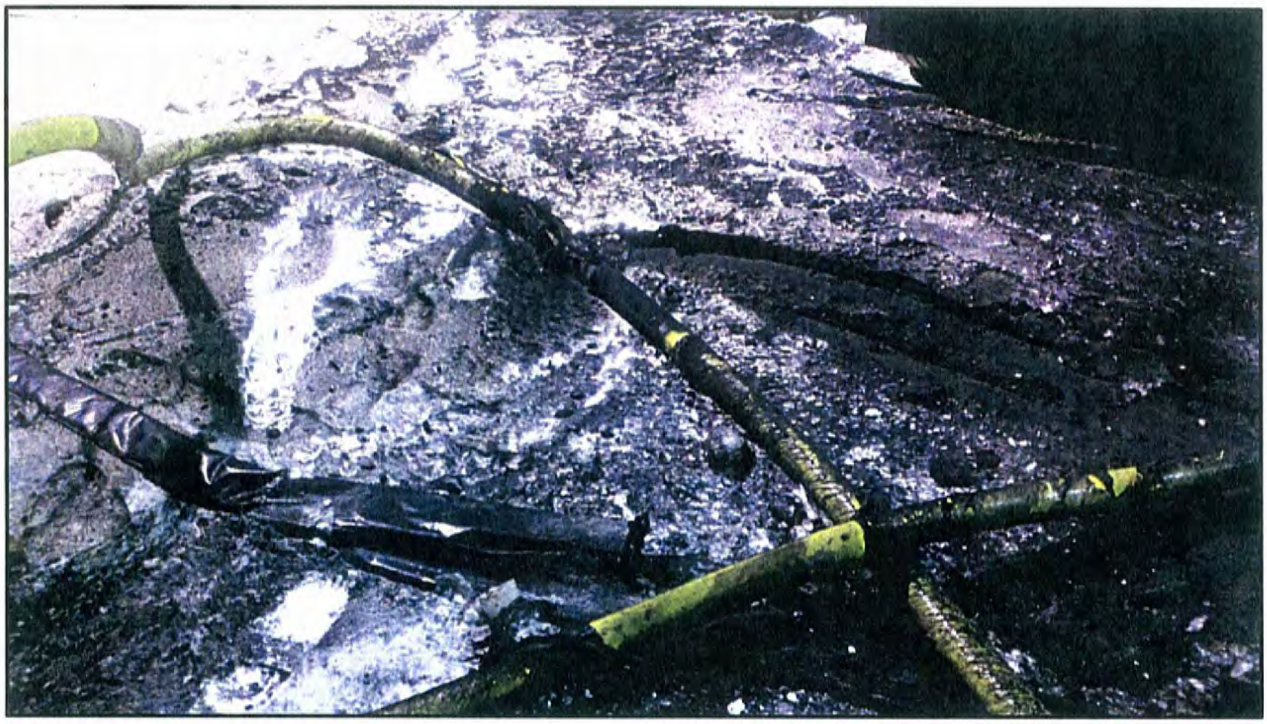


Photo 30: Soot-covered snow and manifold fitting missing blown-off air hose.

in the mud pits and some effects of unloading are evident as larger values of discharge. Similarly, the effects of drawdown are evident as the smallest rates of discharge after airlift pumping has gone on for a period of time after a tool joint connection. The scatter in these measurements is smoothed out somewhat with a 15-data point running average, as shown on Figure 5.

Airlift discharge from the Madison strata increased to about 325 gpm at a depth of about 2570 feet or as 170 feet of borehole was reached. The rate then increased to only about 350 gpm between 2570 and 2670 feet. At 2670 feet and on into the Whitewood Dolomite strata, the rate of airlift yield per foot of borehole drilled nearly doubled with the 15-point running average of the volumetric measurements equal to about 1075 gpm as the borehole depth reached 2800 feet. This was an increase of about 725 gpm from near the bottom of the Madison through the total thickness of the Whitewood Dolomite.

Figure 5 also shows the total dissolved solids concentrations in the groundwater discharged from the well as the borehole was advanced through the thickness of the Madison limestone and Whitewood Dolomite strata. The total dissolved solids concentrations were calculated by an electrical conductivity field tester, based on a coefficient to convert electrical conductivity (EC) to total dissolved solids (TDS). The conversion coefficient was based on laboratory analysis of water samples from City of Gillette Test Well #2A in this same area of the aquifer system.

Figure 5: Airlift discharge versus depth during drilling.

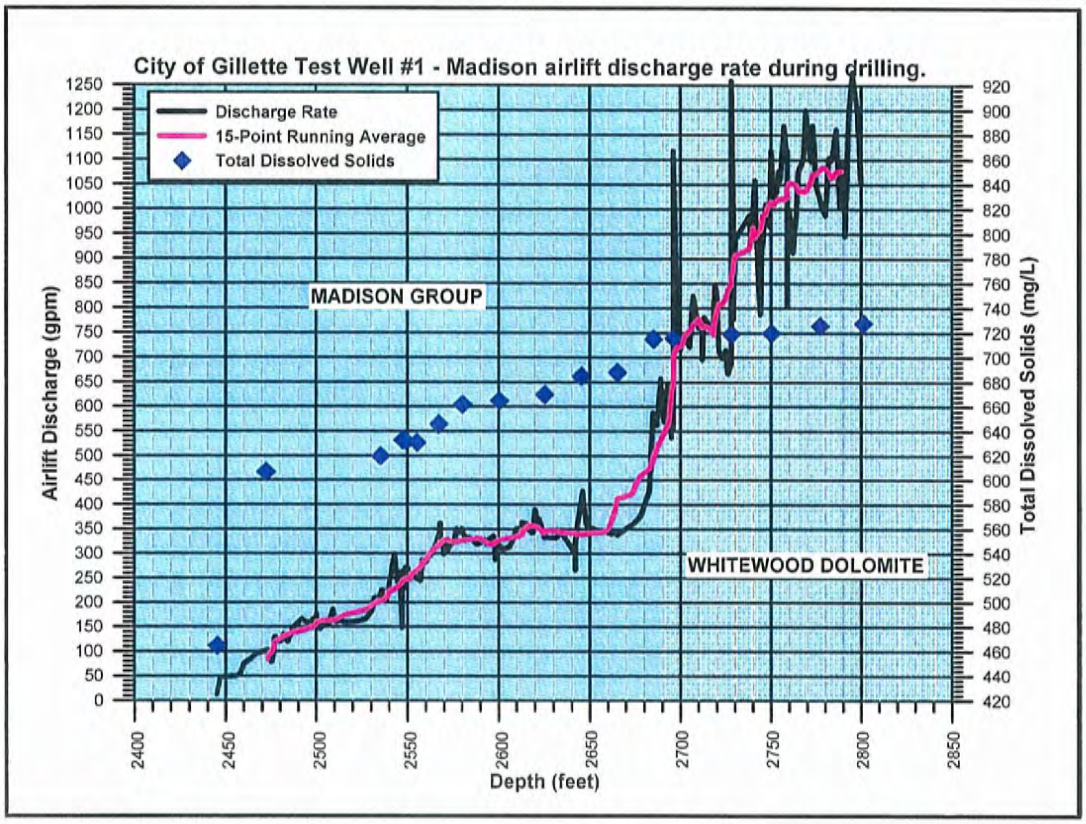


Photo 31: Volumetric measurement of airlift discharge during drilling.

After an initial increase from an improbably low initial value, the TDS concentrations increased relatively steadily with increasing depth. The last measurement taken at full borehole depth of 2801 feet indicated a concentration of 728 mg/L TDS.

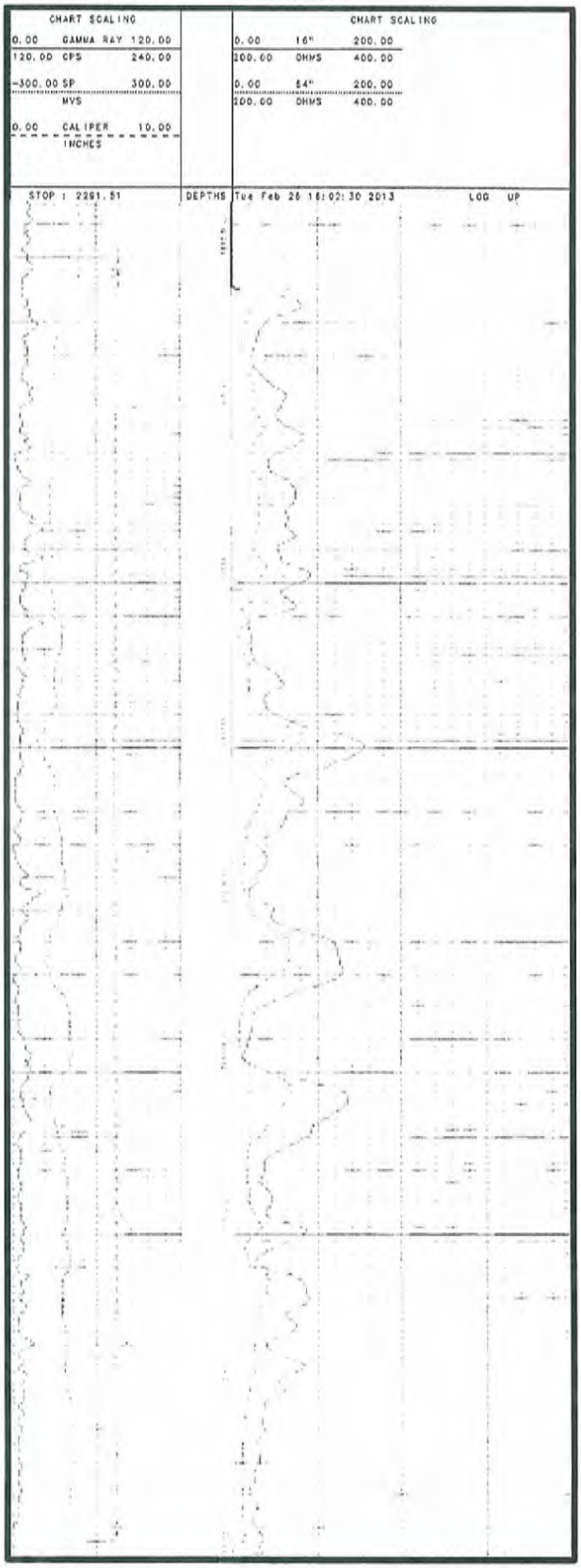
Figure 6 shows the short and long normal (16-inch and 64-inch) resistivity logs for the Madison and Whitewood strata. Interpretation of these logs is somewhat different than standard interpretation in mud-filled boreholes, where the tools detect the zones invaded by drilling fluid filtrate, thus indicating the presence of permeable rock in the borehole wall. Test Well #1 was drilled through the logged section with direct air rotary and discharged water from the well during the drilling. Therefore, there is no invaded zone and the resistivity tools respond to the natural electrolytes in the formation water, not to an induced filtrate.

Therefore, relatively large values of resistivity on Figure 6 generally indicate porous rock and, presumably, interconnection of porosity to provide permeability. In general, relatively smaller values of resistivity indicate less porous rock and, presumably, less permeability. Both of the foregoing interpretations are relative and subject to the effect of the water quality in the formation. Increasing TDS concentrations in the formation water cause relatively smaller values of resistivity on the logs. This results in a shift of both electric log curves to the left and, usually, a reduction in the separation between the short and long normal log values.

The separation between the short normal and long normal logs is also an important indication of permeability. A certain amount of damage is present at the borehole face and for a short distance into the rock such that the short normal tool consistently shows slightly higher resistivity than the long normal tool. Increasing separation between the short and long normal logs indicates increasing potential permeability of the strata in that interval. Based on the foregoing considerations, the logs on Figure 6 show good water-bearing material from the top of the log to about 2507 feet. Lower permeability persists from 2507 to 2524 feet where a relatively high-permeability zone begins and persists to about 2568 feet. Other high permeability zones are present from 2595 to 2620 feet and 2646 to 2658 feet. All of the latter zones include an increase in resistivity plus an increase in the separation between the short and long normal logs.

The Whitewood Dolomite shows increased resistivity and increased separation of the short and long normal logs from 2694 to 2740 feet. This is a zone of rapid increase in airlift discharge on Figure 5. Below 2740 feet, the resistivity values decrease (perhaps partly in response to increasing TDS concentrations) while relatively good separation of the two logs remains. This part of the log corresponds to a continuation in the rapid increase in airlift yield with increased penetration of the strata by the borehole, thus suggesting permeability provided largely by fractures, rather than by porous rock.

Figure 6: Electrical resistivity logs of principle Madison aquifer section.



The resistivity logs of the Madison and Whitewood sections indicate favorable conditions for stimulating well production with acid fracking. The logs suggest the main mechanism for increasing well yield will be high-pressure flooding the formation with acid to enlarge the existing porosity openings, including enlargement of interconnected pore space, enlargement of solution flow paths, and enlargement of existing fracture aperture. The key to increasing well yield will be use of a large volume of acid injected at a high rate of flow. A break-through pressure might be obtained; however, the highly porous nature of the rock indicated by the electric logs may frustrate actual hydraulic fracturing of the rock. Therefore, use of a large volume of acid injected at a high rate of injection will be important in order to maximize enlargement of existing permeability paths through the rock mass.

3.9 Borehole, Casing and Cement Summary

A summary of borehole, casing and cement used for completion of Test Well #1 is provided on Table 6.

3.10 Plumbness and Alignment

Drift and deviation of completed Test Well #1 was determined by a gyroscopic drift and deviation survey conducted on 5/2/2013. Companies offering drift and deviation services operate the equipment in either cased hole or inside drill pipe, but not in open hole where there is a risk of losing the equipment. Accordingly, the service company providing the survey, Gyrodata Incorporated, Casper, Wyoming, provided a survey limited to the cased portion of the well, with measurements in increments of 10 feet ending at a depth of 2400 feet.

Figure 7 is a polar view of the well drift and deviation. The polar view is a view directly down the theoretical vertical axis of a plumb and straight well. The polar view shows that the well pumping chamber down to 1800 feet drifts 11.26 feet at an azimuth of approximately 305 degrees from true north. Below 1800 feet depth, the well turns northwesterly at about 60 degrees, with the end of the 7-inch casing at 2400 feet 13.1 feet from plumb and straight on an azimuth of 330.3 degrees from the center of a plumb and straight imaginary well.

Figure 8 is a view of the drift and deviation projected onto a plane drawn through the center of the well at the land surface and the last point on the survey at 2400 feet depth. The maximum departure from vertical on this plane of projection, 13.1 feet, is shown as well as the departure from vertical on this plane for each 100 feet of the drift and deviation survey. Considering that the plot has a horizontal to vertical exaggeration factor of 90:1 (one inch on the vertical axis is equal to 90 times more feet than one inch on the horizontal axis), the plot reflects very little departure from vertical and a reasonably straight well in this plane.

Figures 9 and 10 show the drift and deviation in the east-to-west and north-to-south planes, respectively. The maximum departure from vertical in the east-to-west plane is

Table 6: Summary of borehole, casing and cement for Test Well #1.

Depth Interval (feet)	Nominal Borehole Diameter (inches)	Casing O.D. (inches)	Casing Wall Thickness (inches)	Cementing and Completion
0- 70	44	36	0.375	10 cubic yards 14.8-lb/gal, six gal/sack, Portland cement. .
72-1543 72-1532 0-1505	14-3/4 32 32	Pilot hole Borehole 24	 0.500	Install Bradenhead with 2-7/8 drill pipe to 1502 ft; pump 1400 sacks (658 BBL) 12.0 lb/gal lead cement; pump 480 sacks (118 BBL) 14.8-lb/gal tail cement.
1532-1869 0-1852.5	22 22	Borehole 16	 0.500	Bottom of 16-inch float shoe at 1839.5 ft with 4-1/2 inch x-hole drill pipe stabbed in; displaced 600 sacks (143 bbl) of 14.8-lb/gal cement into annulus.
1869-2296 1800-2296	14-3/4 14-3/4	Borehole 10-3/4	 0.375	Bottom of 10-inch float shoe at 2283 ft with 4-1/2 inch x-hole drill pipe stabbed in; pumped 25 bbl clean water, 275 sacks (66 bbl) of 14.8-lb/gal Type G followed by 32 bbl clear water
2296-2410 2205-2410	14-3/4 14-3/4	Borehole 7	 0.272	Top of float collar at 2397.46 feet with 4-1/2 XO drill pipe stabbed in; pumped 45 sacks (10.5 BBL) of 14.8-lb/gal Type G followed by 32.34 BBL clear water.
2410-2801	6-1/4	Open hole	No casing	Hydraulically fracture open hole section starting with 383 bbl clear water at up to 1600 psi, follow with 708 bbl chlorine water; 37 bbl clean water; 674 bbl 15% hydro-chloric acid at 67 bbl/min and up to 888 psi; 51 bbl clean water; and 140 bbl chorine water on vacuum, flush hoses with 54 bbl clean water on vacuum.

9.39 feet at 1870 and 1880 feet, and the well is exhibits a slight "S" curve. Recalling the vertical exaggeration of the graph, this is very little deviation. The maximum departure from vertical in the north-to-south plane is 6.53 feet at 1800 feet (the bottom of the pumping chamber) and 11.38 feet at the bottom of the 7-inch casing at 2400 feet depth.

Figure 7: Polar view of Test Well #1 drift and deviation.

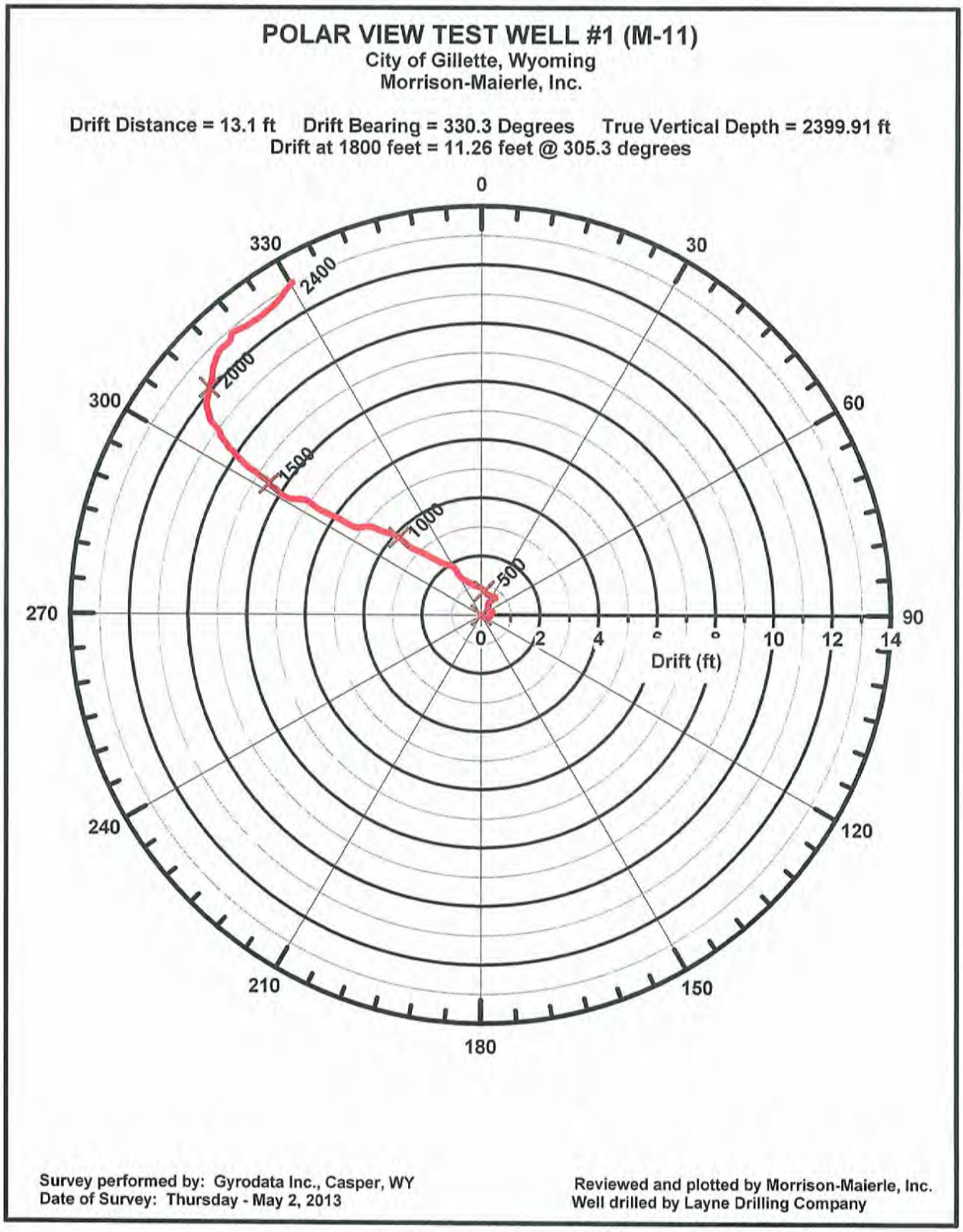


Figure 8: Drift and deviation in the plane of drift.

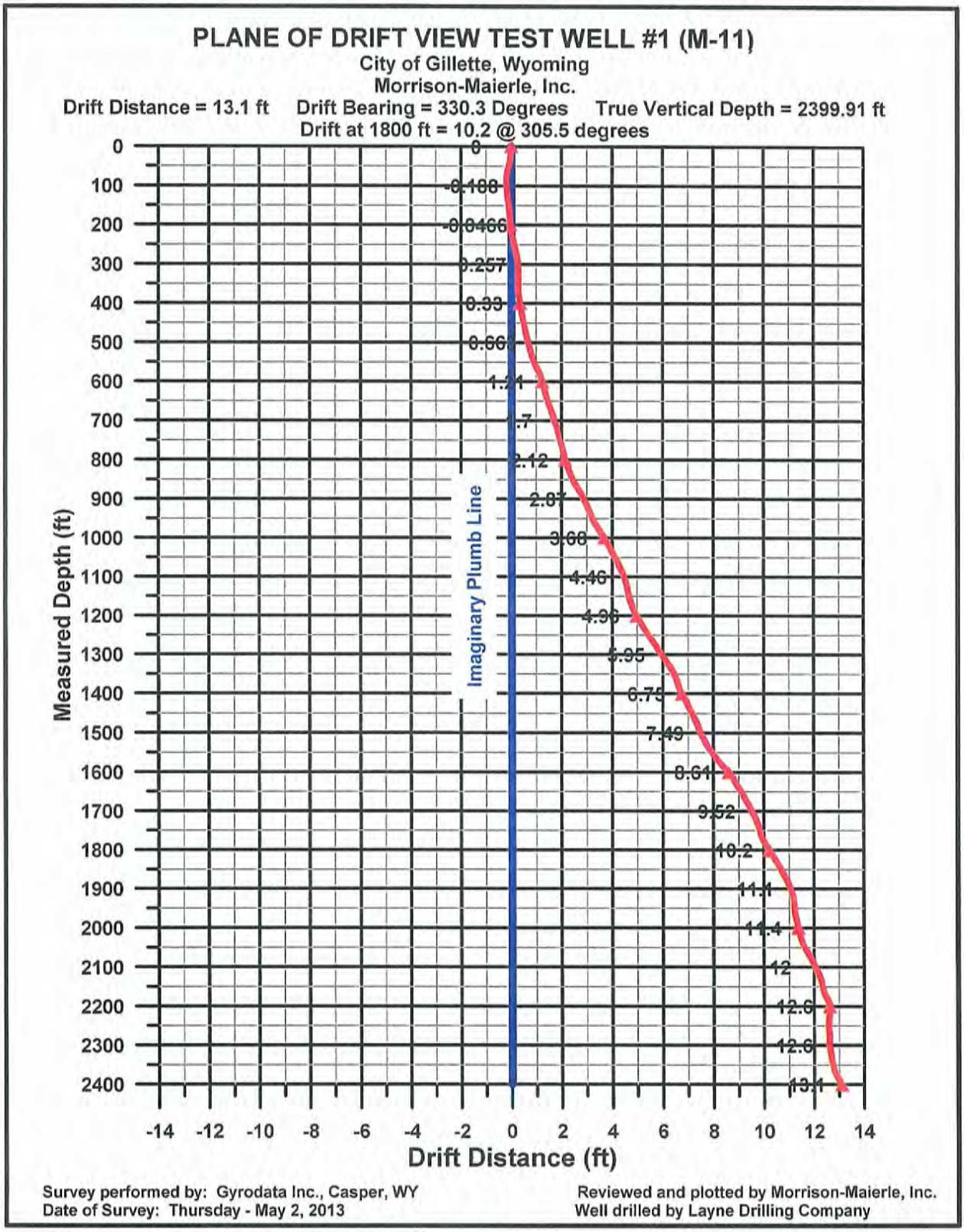


Figure 9: Drift and deviation in the east-west plane of view.

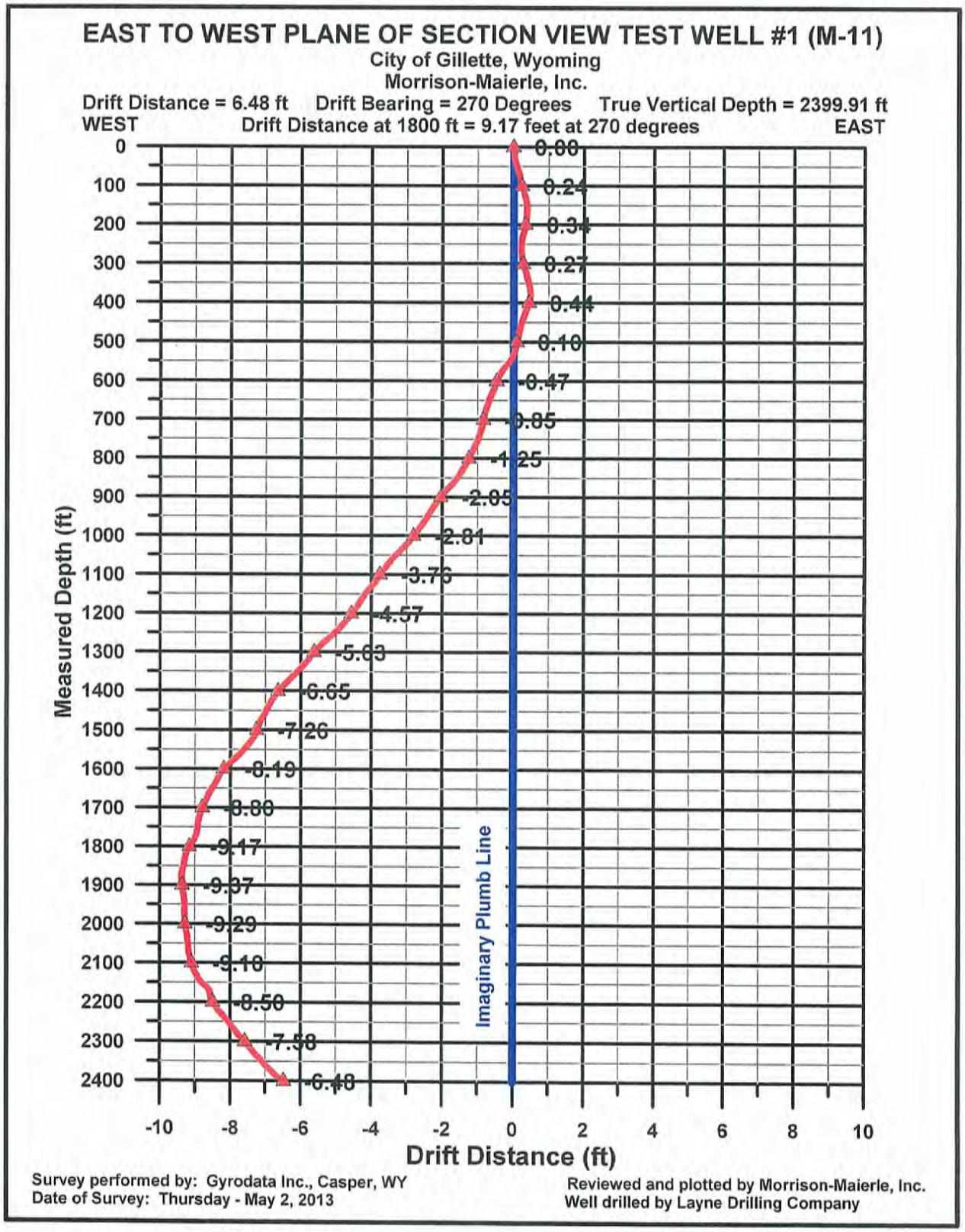


Figure 10: Drift and deviation in the north-south plane of view.

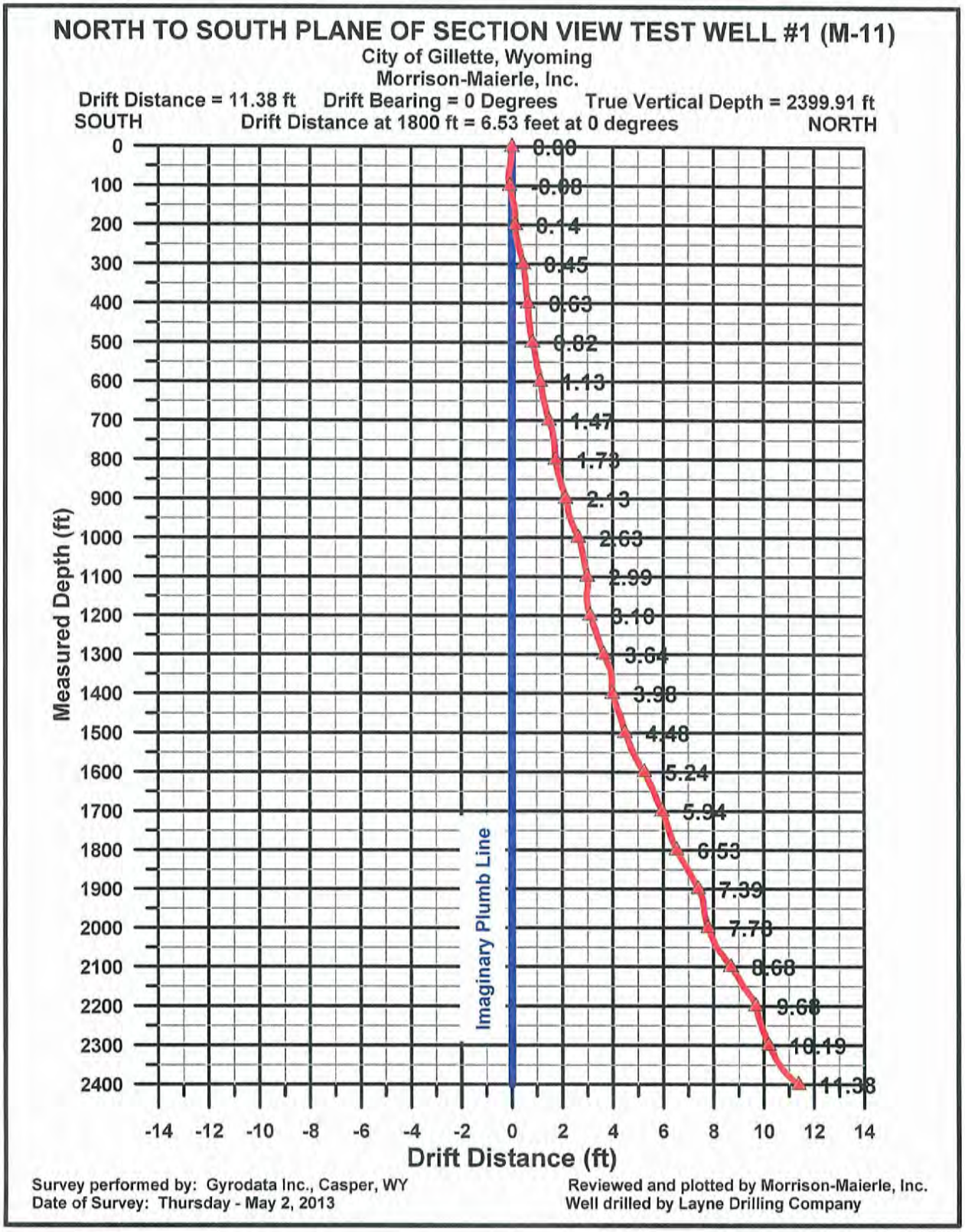


Figure 11: Drift and deviation compared to allowable 1-degree drift.

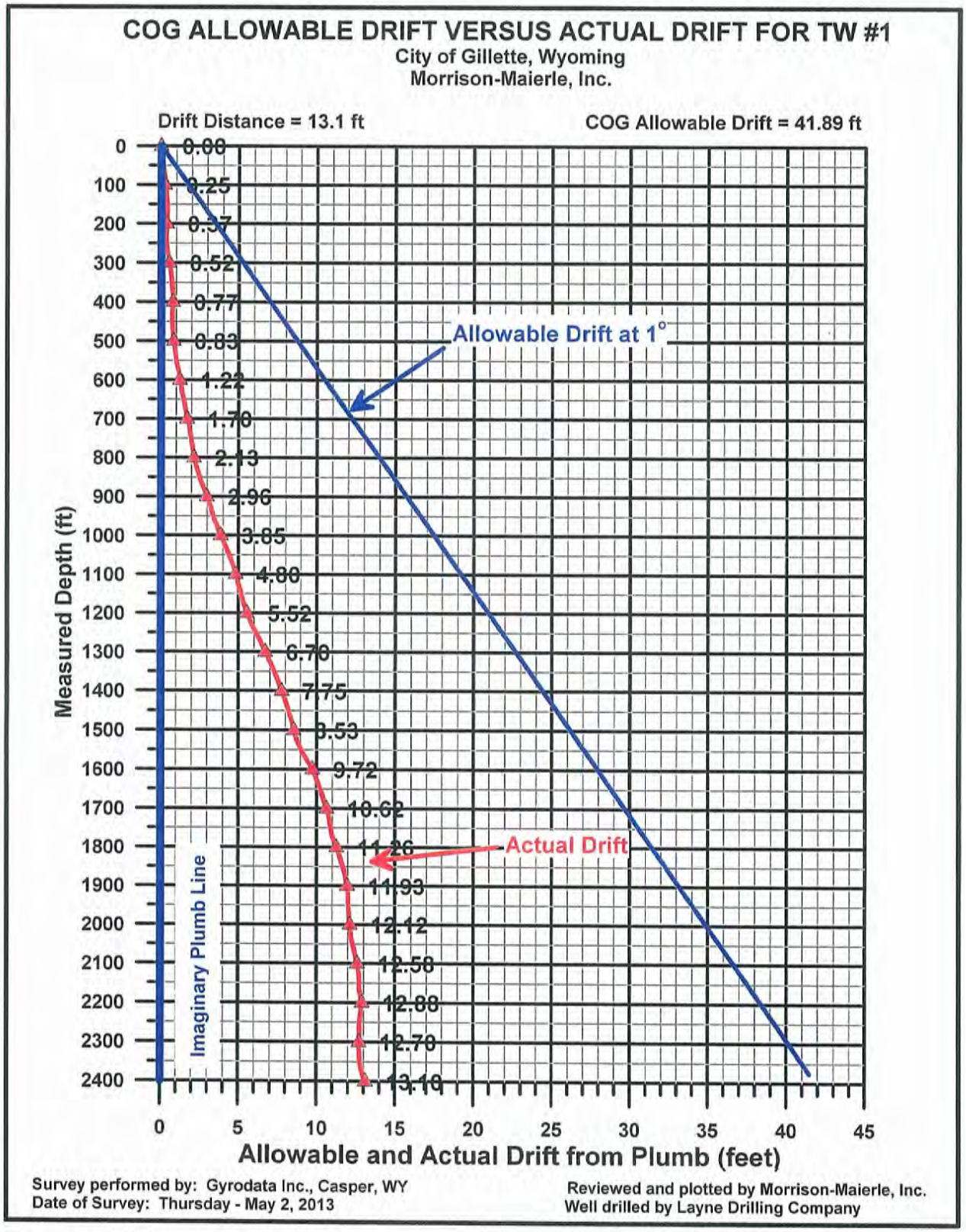


Figure 12: Three-dimensional projection view of drift and deviation.

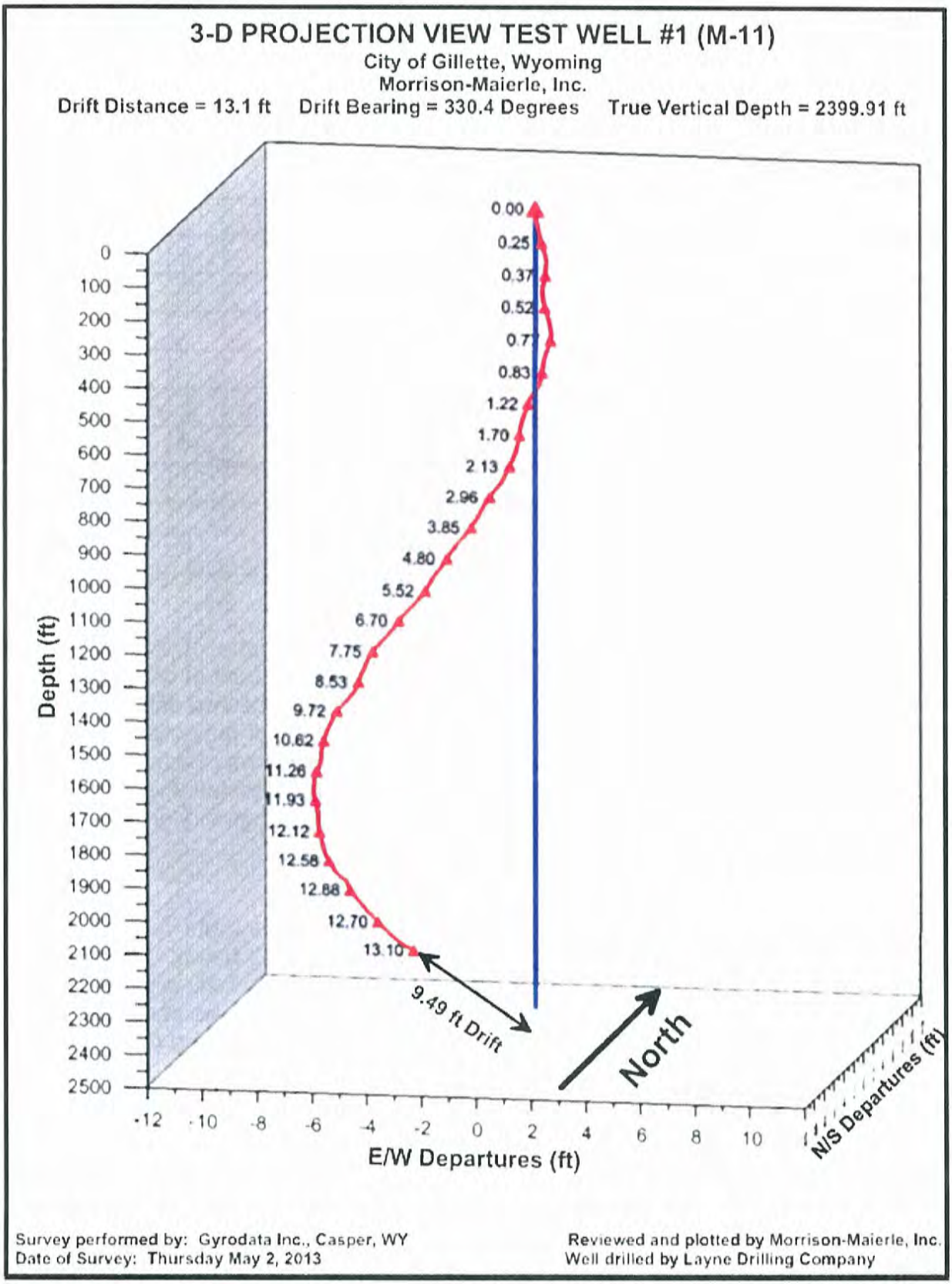


Figure 13: East-west deviation vs. north-south deviation.

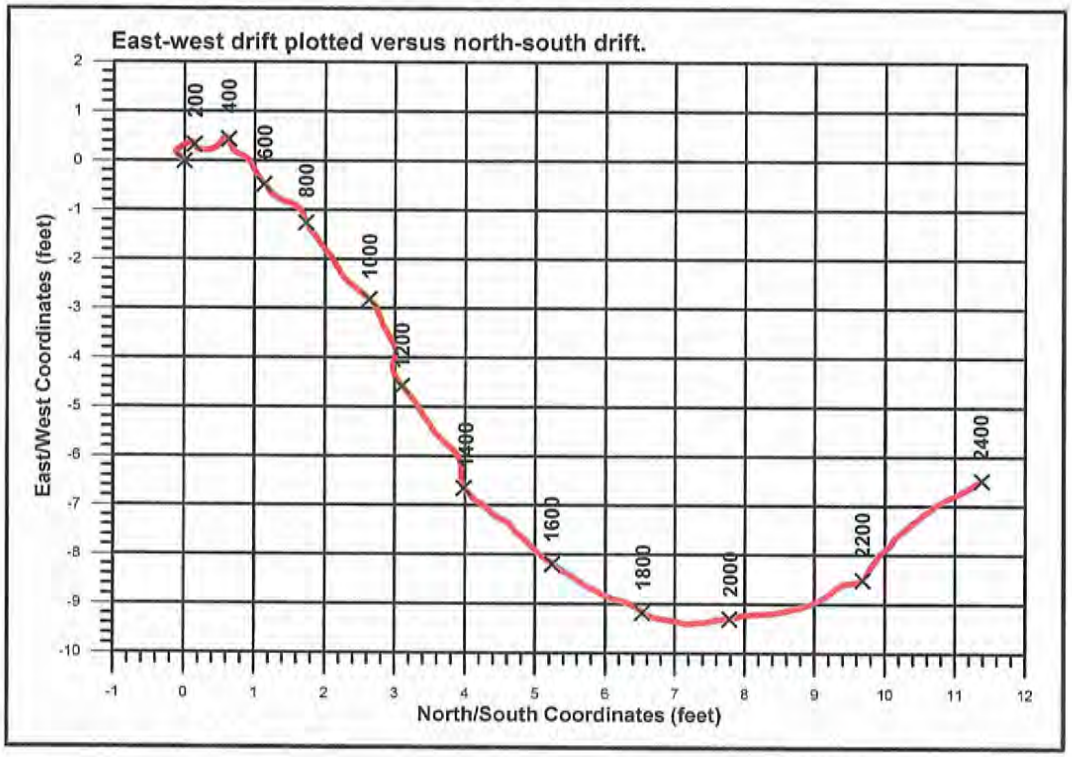


Figure 11 compares the departure from vertical in the plane of drift to a 1-degree constant departure from vertical, which is the limit of the amount of drift allowable in the specifications for the well. As shown on Figure 11, the measured drift is less than one third of the allowable drift. Figure 12 is a three-dimensional projection of the drift and deviation survey data compared to an imaginary plumb line representing a straight and plumb well. Figure 13 compares east-west drift to north-south drift and is another useful method of assessing the nature of the deviation of the well from straight and plumb.

4 ACID FRAC STIMULATION

Completed Test Well #1 was subjected to a 900-gpm constant rate yield and drawdown test beginning 3/11/2013 at 9:00 A.M. and continuing for 12 hours. The drawdown at the end of 12 hours of pumping at 900 gpm was 923.89 feet, providing a specific capacity of 0.97 gpm per foot of drawdown. The 12-hour test was considered sufficient to determine that the well required stimulation by hydraulic fracturing (fracking) with acid to achieve the target design yield of 1400 gpm.

Project specifications required hydraulic fracturing with a minimum bottom hole pressure of 1200 psi at a flow of 2800 gpm (66.7 BPM). On 3/26/2013, the well was treated with 714 BBL of 15% hydrochloric acid at bottom hole pressures in the range of 1300 to 1400 psi with flows of 50.1 to 64.3 BPM, as limited by the differential pressure rating of the packer.