APPENDIX A

OTTER CREEK MINE BASELINE REPORT 304E
MONITORING WELL LOGS
**Well Construction**

- **Bentonite Chips**
- **8" steel**
- **0.025-inch Slot Screen**
- **10/20 Silica Sand**
- **End cap**
- **Bottom of Hole**

**Geological Description**

- **0.0 - 2.0' Silt and clay**
  - Slightly moist, moderate brown, loose, soft, non-plastic, roots
- **2.0 - 8.0' Silt, clay and sand**
  - [Alluvium]
  - Slightly moist to very moist, dark yellow brown, non-plastic, loose
- **5.0 - 15.0' Gravel**
  - [Alluvium]
  - Wet, medium reddish brown, clinker origin, sub-angular, to sub-rounded, some sand, sizes up to 1.5"
- **15.0 - 20.0' Thermally altered sandstone**
  - [Clinker]
  - Wet, very hard, mostly medium reddish brown, some light brown (5YR 6/4), angular fragments (clinker), making a lot of water

Remarks:
Hole sloughed from 17'-20' bgs. Yield approximately 15 gpm. Water quality after development; SC=3000 µmhos/cm, pH=8.14, Temp=14.8°C.
### WELL CONSTRUCTION

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Bentonite Chips</td>
</tr>
<tr>
<td>2.0</td>
<td>8&quot; steel</td>
</tr>
<tr>
<td>57.0</td>
<td>0.025-inch Slot Screen</td>
</tr>
<tr>
<td>65.0</td>
<td>10/20 Silica Sand</td>
</tr>
<tr>
<td>77.0</td>
<td>end cap, centralizer</td>
</tr>
<tr>
<td>80.0</td>
<td>hole collapsed</td>
</tr>
</tbody>
</table>

### GEOLOGICAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 10.0</td>
<td>Clayey silt [Alluvium]</td>
</tr>
<tr>
<td>10.0 - 15.0</td>
<td>Silt [Alluvium]</td>
</tr>
<tr>
<td>15.0 - 20.0</td>
<td>Clayey silt [Alluvium]</td>
</tr>
<tr>
<td>20.0 - 25.0</td>
<td>Silty very fine sand</td>
</tr>
<tr>
<td>25.0 - 27.0</td>
<td>Sand, fine</td>
</tr>
<tr>
<td>27.0 - 33.0</td>
<td>Gravelly sand</td>
</tr>
<tr>
<td>33.0 - 35.0</td>
<td>Clayey sand</td>
</tr>
<tr>
<td>35.0 - 41.0</td>
<td>Clayey sand</td>
</tr>
<tr>
<td>41.0 - 45.0</td>
<td>Gravelly sand</td>
</tr>
<tr>
<td>45.0 - 50.0</td>
<td>Gravels</td>
</tr>
<tr>
<td>50.0 - 55.0</td>
<td>Gravelly sand</td>
</tr>
<tr>
<td>55.0 - 65.0</td>
<td>Silty gravels</td>
</tr>
<tr>
<td>65.0 - 75.0</td>
<td>Gravels [Alluvium]</td>
</tr>
<tr>
<td>75.0 - 79.0</td>
<td>Sand [Bedrock - weathered]</td>
</tr>
<tr>
<td>79.0 - 80.0</td>
<td>Claystone [Bedrock]</td>
</tr>
</tbody>
</table>

- 0.0 - 10.0': Clayey silt (Alluvium). Dry, loose, roots, medium olive brown (5Y 4/4), color change at 3'.
- 10.0 - 15.0': Silt (Alluvium). Dry, soft, minor very fine sand, medium olive brown (5Y 4/4).
- 20.0 - 25.0': Silty very fine sand. Dry, loose.
- 27.0 - 33.0': Gravelly sand. Moist, fine cinder gravels (red-orange). Clinker gravels up to 2", sub-rounded, minor clay, medium brown (5YR 4/4) at 30-33'.
- 33.0 - 35.0': Clayey sand. Moderate brown (5YR 4/4), no gravels.
- 35.0 - 41.0': Clayey sand. Moderate brown (5YR 4/4), fine sand, gravel comprised of cinder present.
- 41.0 - 45.0': Gravelly sand. Very moist, moderate brown (5YR 4/4), red-orange cinder gravels.
- 45.0 - 50.0': Gravels. Clinker gravels increase in size and occurrence, angular, flaggy, clayey.
- 55.0 - 65.0': Silty gravels. Wet, poorly sorted gravels up to 3" diameter (clinker), sub-rounded, minor fine sand, moderate brown (5YR 3/4).
- 65.0 - 75.0': Gravels [Alluvium]. Wet, multicolored, angular, poorly sorted, moderate brown, becomes clayey at 66', cobbles up to 4", sub-rounded, color change to grayish brown (5YR 3/2).
- 75.0 - 79.0': Sand [Bedrock - weathered]. Wet, yellowish brown, fine, poorly cemented.
- 79.0 - 80.0': Claystone [Bedrock]. Firm, greasy texture, greenish gray (SGY 6/1), streaks of carbonaceous material.
Bentonite Chips
0.025-inch Slot Screen

Bottom of Hole:
0.0 - 5.0'

Sandy silt
Dry, firm, minor fine gravels, moderate brown (5YR 4/4), becomes moist at 3', becomes wet at 4'; adding water at 4'-5'

5.0 - 8.0'
Sandy gravel
[Alluvium] Wet; with silt; loose gravels, angular, medium, (moderate reddish brown (10R 4/6) clinker); matrix is dark yellowish brown (10YR 4/2)

8.0 - 25.0'
Sand
[Alluvium] Medium, dark yellowish brown (10YR 4/2), few fine to medium slightly rounded flaggy gravels 10%, gravels increasing in size and occurrence, some coal gravels, sub-rounded, weathered

25.0 - 40.0'
Gravel
[Alluvium] Poorly sorted; multi-colors (moderate brown, dark yellowish brown, dark yellowish orange), black to red (clinker and sandstone) cobbles up to 5", rounded to angular; making water, sandstone gravels increase with depth; some sand 10-15%

40.0 - 57.0'
Gravel
[Alluvium] Multi-colors (moderate brown, dark yellowish brown, dark yellowish orange); making water; sand <5%, poorly sorted, up to 4" diameter, rounded to angular

57.0 - 59.0'
Siltstone
[Bedrock] Moist, weak, dark yellowish brown (10YR 4/2) to light olive gray; very fine bedding

Remarks: Drove 8" steel 60'; air lift for 20 minutes; SC=3430 µmhos/cm. Hole collapsed 5'-49'. Centralizer placed at 59' bgs.
Bentonite Chips
0.025-inch Slot Screen
Bottom of Hole
0.0 - 10.0'
Silty clay
[Alluvium/Colluvium]Moist to wet at 4'; pale yellowish brown and light olive gray (5Y 5/2), mild plasticity, roots, moderately loose; color to light olive gray and greenish gray (5GY 6/1) at 6'; start injecting water at 6'
10.0 - 14.0'
Sand, moderately fine, clayey/silty
Wet, pale yellowish brown and light olive gray (5Y 5/2), very loose
14.0 - 19.0'
Silty, sandy, clay
Wet, pale yellowish brown, dense, moderately plastic, rolls to 1/8"19.0 - 22.0'
Gravel
[Alluvium]Wet, medium reddish brown, clinker, burned siltstone, hard, loose, flaggy, sub-round to sub-angular22.0 - 26.0'
Clay and gravel
Wet, clay is light olive gray and pale yellowish brown, pea size gravels, clinker, medium reddish brown, loose26.0 - 28.0'
Gravel
Wet, mostly pea gravel, sub-angular to sub-round, clinker origin and trace sandstone28.0 - 31.0'
Very sandy gravel, poorly sorted, sand to 50%
Wet, medium yellowish brown sand, clinker (burned sandstone/shale) gravels, hard, coarse gravels to 1"31.0 - 50.0'
Gravel and sand, poorly sorted
Wet, multi-colored: dark yellowish orange, medium yellowish brown, medium reddish brown, light brown (5YR6/6); clinker and sandstone origin, increasing sandstone gravel with depth, increasing gravel size with depth, gravels to 3", sand to 30% at 32'-39' then sand decreases to 10% at 40'
39'-40' - clay stringer, silty, light olive gray to dark olive gray, soft, moderately plastic50.0 - 55.0'
Sandy clay
Wet, dark greenish gray (5GY 4/1), loose, soft, moderately plastic55.0 - 68.5'
Gravel, some sand (2%)
[Alluvium]Wet, multi-colored: light gray, light brown, medium reddish brown, pale yellowish brown, and light olive gray, clinker and sandstone origin, hard, gravels to 5"68.5 - 69.0'
Claystone
[Bedrock]Medium gray, soft, very thinly bedded69.0 - 70.0'
Coal
[Bedrock]Black, cleated multiple planes, stiff
Hole Name: A5

Date Hole Started: 8/18/11  Date Hole Finished: 8/18/11

WELL COMPLETION  Y/N  DESCRIPTION  INTERVAL
Well Installed?  Y  8" steel open bottom  +2-25
Surface Casing Used?  N  8" steel  +2-25
Screen/Perforations?  N
Sand Pack?  N
Annular Seal?  Y  Bentonite Chips  annulus - drill/drive
Surface Seal?  N

DEVELOPMENT/SAMPLING
Well Developed?  Y  Rig Air
Water Samples Taken?  N
Boring Samples Taken?  N

Static Water Level Below MP:  8.45
Surface Casing Height (ft):  2.07
Riser Height (ft):
Ground Surface Elevation (ft):  3134.77
MP Elevation (ft):  3136.84

Remarks: Injecting water at 5', open hole with 9 7/8" bit to 20'. Drive 28' 8-inch steel, silica sand and bentonite poured in annulus. Developed with rig air; SC=4800 µmhos/cm, pH= 8.00, temp= 11.1°C, open hole yield=~50 gpm.

GEOLOGICAL DESCRIPTION

0.0 - 12.0'  Silty clay
Dry to wet with depth, pale yellowish brown to dark yellowish brown, w moisture at depth; some fine sand at 2'-5', becomes wet at 5'; medium to high plasticity, mostly soft and loose; trace gravel at 6'-1', becomes sandy at 8'; increasing gravel at 10'-12'

12.0 - 26.0'  Sand and gravel
Wet, moderate yellowish brown sand with light brown and moderate reddish brown clinker gravels, some sandstone gravels, light olive gray and yellowish brown, gravels to 2", mostly flat to moderate sphericity, sub-angular to sub-rounded, size increases to 3" at 20', increasing with depth

26.0 - 28.0'  Claystone, silty  [Bedrock]
Light olive gray to greenish gray, moderate dense but soft, low to medium plasticity, calcareous
Well Construction:

- **Bentonite Chips**
- **8" steel +3-5**
- **0.025-inch Slot Screen**
- **15.0**
- **25.0**

Geological Description:

- **0.0 - 5.0'** Silty clay [Topsoil/Colluvium]
  - Dry, moderate to dark yellowish brown, loose to moderate cohesive, non-plastic, roots, trace very coarse sand and fine gravel at depth

- **5.0 - 10.0'** Clayey sandy gravel [Alluvium]
  - Light brown and moderate reddish brown clinker gravels, moderate yellowish brown sand fine to medium gravel, loose, roots in top 1'

- **10.0 - 20.0'** Sand and gravel (50/50) [Alluvium]
  - Wet, moderate yellowish brown sand, light brown and grayish orange clinker gravels; gravel size increases with depth to 3" gravels

- **20.0 - 23.0'** Gravel, clean moderately poorly sorted up to 1" [Alluvium]
  - Wet, color from black to very pale orange, moderately loose to dense, sub-round, low to high sphericity; coal and clinker origin

- **23.0 - 25.0'** Siltstone [Bedrock]
  - Dry, pale to dark yellowish orange with light olive gray, soft, non-plastic; some very thin dark colored laminations

Remarks: Start injecting water at ground surface, 11 7/8" bit to 20', drive 25" of 8" steel to bedrock. Developed with rig air, stopped after 10 minutes to avoid flooding field or discharging to creek. SC=5700 µmhos/cm, pH=8.15, temp= 10.9° C, yield=50 gpm after development.
Hole Name: A7

Well Installed? Y 4.5” Sch 40, PVC
Surface Casing Used? Y 8” steel
Screen/Perforations? Y 0.025-inch slot, Sch 40 PVC
Sand Pack? Y 10/20 silica sand
Annular Seal? Y Bentonite Chips
Surface Seal? N

DEVELOPMENT/SAMPLING
Well Developed? Y Rig Air
Water Samples Taken? N
Boring Samples Taken? N

Notching: 459251.91  Easting: 2825659.93
Static Water Level Below MP: 8’ 7”  Surface Casing Height (ft): 1.95
Date: 7/19/2011  Riser Height (ft): 1.61
MP Description: Top PVC  Ground Surface Elevation (ft): 3079.33
MP Height Above or Below Ground (ft): 1.61  MP Elevation (ft): 3080.94

Remarks: SC at start of air lift = 3000 µmhos/cm; SC at completion = 3970 µmhos/cm, stable. SWL = 8’7”. Hole collapsed 12’-23’.

WELL CONSTRUCTION

* 8” steel
* 10/20 Silica Sand
* Bentonite Chips
* 0.025-inch Slot Screen
* 41.0 - 43.5” Clay [Alluvium]
  Stiff, plastic, medium gray (NS), minor fine sand, finely laminated
* 43.5 - 44.0” Sandstone [Bedrock]
  Very hard, medium grained, well-sorted, well cemented, medium light gray (N6)

GRAPHICS

GEOLICAL DESCRIPTION

* 0.0 - 5.0” Silt
  Dry to 2” then moist, adding water at 4”; minor very fine sand, soft, roots, moderate yellowish brown (10YR 5/4)
* 5.0 - 14.0” Silty clay [Alluvium]
  Stiff, moderate yellowish brown (10YR 5/4); some fine sand, orange oxidation at 10’-12’
* 14.0 - 23.0” Silty gravels [Alluvium]
  Multi-color clinker, flaggy, sub-rounded, very sandy below 20’
* 23.0 - 26.0” Clay
  Stiff, moderate olive brown (5Y 4/4)
* 26.0 - 41.0” Gravels [Alluvium]
  Multi-colored clinker; making water, very little sand at 26’, increases with depth to ~15%; coal pieces in gravels at 34’
### Geological Description

<table>
<thead>
<tr>
<th>Interval</th>
<th>Description</th>
</tr>
</thead>
</table>
| 0.0 - 5.0' | Clayey sand - Loam (Topsoil)  
Wet; olive gray; loose; fine to very fine grain; high plasticity, cohesive |
| 3' below ground level - first groundwater (driller) | |
| 5.0 - 10.0' | Clayey sand - Alluvium  
Wet; increase in clay; saturated black organics (charcoal) inclusions |
| 10.0 - 15.0' | Clinker gravel, sandy with clay - Alluvium  
Angular pieces; flat <1" |
| 15.0 - 20.0' | Clinker gravel, sandy with clay - Alluvium  
Olive gray with red, brown, dark gray; clinker pieces; increase in size to 2" |
| 20.0 - 21.0' | Clinker gravel, sandy with clay - Alluvium  
Small pieces to <1/2 -1/4", sub-angular to angular |
| 21.0 - 25.0' | Clay - sandy  
Olive green; stiff; cohesive; high plasticity |
| 25.0 - 26.0' | Clay - sandy  
Olive green; stiff; cohesive; high plasticity |
| 26.0 - 30.0' | Clinker gravel, sandy with clay - Alluvium  
Includes coal chips; large; sub-angular and sub-rounded <2" |
| 30.0 - 35.0' | Clinker gravel, sandy with clay - Alluvium  
Varies between sub-angular and sub-rounded; increase in sand |
| 35.0 - 40.0' | Clinker gravel, sandy with clay - Alluvium  
Decrease in sand; clean clinker; no clay; no bedrock; clinker sub-rounded |
| 40.0 - 45.0' | Clinker gravel, sandy with clay - Alluvium  
Decrease in sand; clean clinker; no clay; no bedrock; clinker sub-rounded |
| 45.0 - 50.0' | Clinker gravel, sandy with clay - Alluvium  
Decrease in sand; slight increase in clay; clean clinker; no clay; no bedrock; clinker sub-rounded |
| 50.0 - 55.0' | As above, Clinker gravel, sandy with clay - Alluvium  
Slight increase in clay percent; large cobbles to 6''; no bedrock material; increase in coal chips in Alluvium |
| 55.0 - 63.0' | Weathered silty clay (shale) - Bedrock  
Damp; greenish gray, moderately stiff; non plastic; no cohesioness |

### Well Construction

- **0.08" steel (0.25" thick wall) +4.10' to 26'**
- **23.0** Bentonite Chips
- **26.0** 0.025-inch Slot Screen
- **64.0** Bottom of Hole
- **64.0** 10/20 Silica Sand
- **End cap; centralizer**
Remarks: Drove steel to 40' then pulled back to 18'; flow ~20 gpm. Poured sand on outside of 8" steel to 10' below ground surface (bgs); poured bentonite on outside of 8" steel from 0'-10' bgs. Started injecting water at 20' (water from Askin's shop). After 15 minutes of developing pH 7.99, SC=3355 µmhos/cm, temp=15.3°C. After 30 minutes of developing pH 7.88, SC=3271 µmhos/cm, temp=13.5°C
Well Installed? Y
Surface Casing Used? Y
Screen/Perforations? N
Sand Pack? N
Annular Seal? Y
Surface Seal? N

8" steel open bottom
+2-32
8" steel +2-32

Well Developed? Y
Rig Air

8" steel
Bentonite Chips

Y
N
N

Wet, moderate yellowish brown, loose, roots in top 1'
Moist, moderate yellowish brown, very loose, poorly sorted, trace coarse sand, < 2%
Moist, moderate yellowish brown to dark yellowish brown, very soft, rolls from 1/8" to 1/16", plasticity increases with depth, poorly sorted, fines with depth in this interval, calcareous, reacts with HNO₃, wet at 10'
Wet, pale yellowish brown, high plasticity, rolls to 1/16", soft
Wet yellowish brown, with very thin dark yellowish brown beds, calcareous (reacts with acid)

Clayey silt
Silty clayey sand
Silty clay, some sand
Gravel and sand, poorly sorted
Clay

Alluvium
Alluvium
Alluvium
Alluvium
Bedrock

0.0 - 3.0'
3.0 - 5.0'
5.0 - 15.0'
15.0 - 32.5'
32.5 - 33.0'

Dry, moderate yellowish brown, loose, roots in top 1'
Moist, moderate yellowish brown, very loose, poorly sorted, trace coarse sand, < 2%
Moist, moderate yellowish brown to dark yellowish brown, very soft, rolls from 1/8" to 1/16", plasticity increases with depth, poorly sorted, fines with depth in this interval, calcareous, reacts with HNO₃, wet at 10'
Wet, pale yellowish brown, high plasticity, rolls to 1/16", soft
Wet yellowish brown, with very thin dark yellowish brown beds, calcareous (reacts with acid)
**GEOLOGICAL DESCRIPTION**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
</table>
| 0.0 - 3.0' | Clayey silt [Alluvium]  
Dry, moderate yellowish brown, loose, roots in top 1' |
| 3.0 - 5.0' | Silty clayey sand [Alluvium]  
Moist, moderate yellowish brown, very loose, poorly sorted, trace coarse sand, < 2% |
| 5.0 - 15.0' | Silty clay, some sand [Alluvium]  
Moist, moderate yellowish brown to dark yellowish brown, very soft, rolls from 1/8" to 1/16", plasticity increases with depth, fines with depth, calcareous, wet at 10' |
| 15.0 - 25.0' | Gravel and sand, poorly sorted [Alluvium]  
Wet, gravels to 1.5", low sphericity, sub-rounded, sand to 50% less with depth to 10%, gravel to 2", gravel, clinker, coal, bedrock origin |
| 25.0 - 26.0' | Woody debris |
| 26.0 - 32.0' | Gravel and sand |

**WELL CONSTRUCTION**

- **8" steel**  
- **10/20 Silica Sand**  
- **end cap; centralizer**  
- **Bottom of Hole**  
- **hole sloughed 14-19'**  
- **0.025-inch Slot Screen**  
- **Bentonite Chips**

**REMARKS**

- Drove 8" steel to 30', pulled out, replaced with 5 ft steel, slough from 14-19' bgs; SC=1776 µhos/cm, pH=7.99, temp=10.8°C after development.
**WELL CONSTRUCTION**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 5.0’ Silty clay**
  - Dry to wet at 5’, pale yellowish brown to medium yellowish brown with moisture and depth. Roots to 3’, non-plastic to medium plastic with depth and moisture. Some fine sand at 5’, very loose and soft

- **5.0 - 16.0’ Clayey sand**
  - Wet, dark yellowish brown. Very soft, loose, flowing. Trace gravel of clinker origin at 15’

- **16.0 - 33.0’ Gravel**
  - Some sand, wet, light brown, reddish brown, pale yellowish orange. Clinker and sandstone origin. Loose, hard, flat, sub-rounded size to 2”. Trace coal/shale gravel at 29’. Shale gravels more angular than clinker and sandstone

- **33.0 - 38.0’ Claystone [Bedrock]**
  - Pale yellowish brown, soft to medium firm, medium plasticity, rolls to 1/8”, possibly tagged coal at 38’
**Well Construction**

<table>
<thead>
<tr>
<th>Depth Interval</th>
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</tr>
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<tbody>
<tr>
<td>0.0 - 1.0'</td>
<td>Silty clay</td>
</tr>
<tr>
<td></td>
<td>Slightly moist, grayish orange pink, loose, roots, some weakly cemented</td>
</tr>
<tr>
<td>1.0 - 7.0'</td>
<td>Silty sand</td>
</tr>
<tr>
<td></td>
<td>Moist, moderate yellowish brown, loose, soft</td>
</tr>
<tr>
<td>7.0 - 10.0'</td>
<td>Sandy clay</td>
</tr>
<tr>
<td></td>
<td>Wet, dark yellowish brown, moderate plasticity, rolls to 1/8&quot;</td>
</tr>
<tr>
<td>10.0 - 11.0'</td>
<td>Clay</td>
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<tr>
<td></td>
<td>Wet, dark yellowish brown and olive gray (5Y 3/2), very plastic rolls to 1/16&quot;</td>
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<td>11.0 - 12.0'</td>
<td>Gravel sand</td>
</tr>
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<tr>
<td>21.0 - 21.5'</td>
<td>Coal/carbonaceous shale</td>
</tr>
<tr>
<td></td>
<td>Wet, medium dark gray to black, soft, weathered, making ~15 gpm, SC=3220 µmhos/cm</td>
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<tr>
<td>21.5 - 22.0'</td>
<td>Siltstone, some fine sand</td>
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**WELL CONSTRUCTION**

- **2.0 ft**: 8" steel
- **6.0 ft**: 10/20 Silica Sand
- **31.0 ft**: Bentonite Chips, end cap

**GEOLOGICAL DESCRIPTION**

- **0.0 - 4.0'**: Silty clay [Alluvium]
  - Slightly moist, moderate yellowish brown, loose, roots, debris in top 1'
- **4.0 - 11.0'**: Sandy clay [Alluvium]
  - Wet, moderate to dark yellowish brown, non-plastic, calcareous
- **11.0 - 20.0'**: Gravel, silty sandy, poorly sorted [Alluvium]
  - Wet, fines are moderate yellowish brown, gravels multicolored, clinker origin, size up to 1", sub-round, medium sphericity, coarsens with depth to 3.5", sand to 10%, no silt
- **20.0 - 30.0'**: Poorly sorted sand and gravel
  - Wet, multi-color, sand to 50%, flat, sub-angular to sub-rounded gravels of clinker and sandstone origin, medium sphericity
- **30.0 - 31.0'**: Sandstone, silty clayey [Bedrock]
  - Wet from above, medium gray, soft

Remarks: Bottom of hole sloughed 2'. Too loose and sandy for open bottom completion. Blew on hole at total depth to clean out, complete with 6" PVC. SC=3110 µmhos/cm, pH=7.84, temp=9.2°C, yield~100 gpm
**WELL CONSTRUCTION**

- **2.5 ft**
  - **8" steel**
- **10.20 Silica Sand**
- **0.025-inch Slot Screen**
- **17.0 ft**
  - **Bentonite Chips**
- **1.0 ft**
  - **Slough**
- **6.0 ft**
  - **Ground Surface Elevation (ft): 3003.14**
- **2.43 ft**
  - **Static Water Level Below MP:** 3.54
- **2.22 ft**
  - **MP Elevation (ft): 3005.36**
- **32.0 ft**
  - **end cap; centralizer**
  - **Bottom of Hole**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 4.0'**
  - **Silty clay** [Alluvium]
  - Slightly moist, moderate yellowish brown, loose, roots, debris in top 1'
- **4.0 - 11.0'**
  - **Sandy clay** [Alluvium]
  - Wet, moderate to dark yellowish brown, non-plastic, calcareous
- **11.0 - 20.0'**
  - **Sand and gravel poorly sorted**
  - Wet, multi-colors, moderate reddish brown to dark yellowish brown or dark gray, cinder and sandstone, thin mostly flat, sub-angular to sub-rounded to 3"; sand 30-50% and grayish brown (5YR 3/2)
- **20.0 - 20.5'**
  - **Clay**
  - Moist, medium light gray, gravel from above embedded in surface, streaks of moderate olive brown, calcareous, non-plastic
- **20.5 - 28.0'**
  - **Gravel** [Alluvium]
  - Wet, clean, sand less than 2%, gravel multi-colored clinkers and sandstone
- **28.0 - 30.0'**
  - **Gravel, sandy** [Alluvium]
  - Wet, multi-colored clinkers and sandstone gravels; moderate yellowish brown (10YR 5/4) sand up to 50%
- **30.0 - 32.0'**
  - **Siltstone** [Bedrock/ Fort Union]
  - Dry, light olive gray (5Y 5/2), moderately firm, some very thin dark brown interlayers, calcareous
### WELL CONSTRUCTION

- **Well Diameter (in):** 7 7/8"
- **Total Depth Drilled (ft):** 35
- **Static Water Level Below MP:** 5.33
- **Date:** 7/15/2011
- **MP Description:** Top PVC
- **MP Height Above or Below Ground (ft):** 1.80
- **Riser Height (ft):** 1.80
- **Ground Surface Elevation (ft):** 3005.30
- **MP Elevation (ft):** 3007.09
- **Remarks:** Drive 8” steel casing to 32’, drilled with 7 7/8” drag bit, all steel and replace with 5’ monument. SC=4620 µmhos/cm, pH=2.93, temp=10.1°C; hole sloughed from 34’-35’

### GEOLOGICAL DESCRIPTION

- **0.0 - 2.0’** Silty clay [Alluvium/Topsoil]
  - Dry to slightly moist, moderate yellowish brown, loose, roots to 3’
- **2.0 - 13.0’** Silty clay with sand [Alluvium]
  - Moist to wet with depth, moderate to dark yellowish brown, moderate plasticity, rolls to 1/8”, calcareous
- **13.0 - 35.0’** Gravel, sandy [Alluvium]
  - Clayey at 24.5’; wet, clay=non-plastic, calcareous
  - Sandy again at 24.5’-35’, sand=dark yellowish brown, gravels to 3’
  - Total depth, tagged bedrock at 35’, no bedrock cuttings logged

### WELL COMPLETION

- **Well Installed:** Y
- **Surface Casing Used:** Y
- **Screen/Perforations:** Y
- **Sand Pack:** Y
- **Annular Seal:** Y
- **Surface Seal:** N

### DEVELOPMENT/SAMPLING

- **Well Developed:** Y
- **Water Samples Taken:** N
- **Boring Samples Taken:** N

### LEGAL DESCRIPTION

- **T3S, R45E, Sec. 32; N485192.4, E 2814623.06**

### PROJECT INFORMATION

- **Client:** Arch Coal
- **Project:** Otter Creek Mine Permit (10068)
- **County:** Powder River
- **State:** Montana
- **Legal Description:** T3S, R45E, Sec. 32; N485192.4, E 2814623.06
- **Location Description:** AVF2 south of cemetery near south edge of Trusler meadow
- **Recorded By:** RJL
- **Drilling Company:** Askin Drilling
- **Driller:** Ron Askin
- **Drilling Method:** Air Rotary
- **Drilling Fluids Used:** None
- **Purpose of Hole:** Install Monitor Well
- **Target Aquifer:** Otter Creek Alluvium
- **Hole Diameter (in):** 7 7/8"
- **Total Depth Drilled (ft):** 35

### MONITOR WELL LOG

- **Well Name:** AVF2-3
- **Date Hole Started:** 1/28/2011
- **Date Hole Finished:** 1/28/2011
- **Easting:** 2814623.06
- **Northing:** 485192.4
- **Static Water Level Below MP:** 5.33
- **Surface Casing Height (ft):** 2.22
- **Riser Height (ft):** 1.80
- **Ground Surface Elevation (ft):** 3005.30
- **MP Elevation (ft):** 3007.09
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River State: Montana
Property Owner: J. Trusler
Legal Description: T3S, R45E, Sec. 32; N 485129.2 E 2813441.03
Location Description: AVF2 south of cemetery near south edge of Trusler meadow
Recorded By: RJL
Drilling Company: Askim Drilling
Driller: Ron Askim
Drilling Method: Air Rotary
Drilling Fluids Used: None
Purpose of Hole: Install Monitor Well
Target Aquifer: Otter Creek Alluvium
Hole Diameter (in): 8"
Total Depth Drilled (ft): 32

WELL CONSTRUCTION

8" steel

Bentonite Chips

10/20 Silica Sand

22.0

0.025-inch Slot Screen

2.5

9.0

2.5 - 2.5 8" steel

22.0 - 32.0 Bentonite Chips

17.0 - 22.0 10/20 Silica Sand

32.0 - 32.0 Bottom of Hole

GEOLOGICAL DESCRIPTION

0.0 - 5.0' Silty clay [Alluvium]
Dry, moderate yellowish brown, roots, non-plastic

5.0 - 17.0' Sandy silty clay
Wet, pale to moderate yellowish brown, very soft

17.0 - 29.0' Gravel and sand poorly sorted
Wet, multi-colored gravel, clinker and sandstone sub-round, moderate sphericity, sand dark yellowish brown, changes to moderate yellowish brown at 25'

29.0 - 30.0' Coal [Bedrock]
Black, cleated multiple planes, moderately weathered, moderately firm

30.0 - 32.0' Claystone [Bedrock]
Medium light gray, soft, non-plastic, mild calcareous

Remarks: Drive 8" steel casing 32', pull casing out 5', drill in casing with 7 7/8" bit. SC=5000 µmhos/cm, pH=7.78, temp=11.8° C, yield = 10-15 gpm. Hole sloughed from 9-17'

Hydrometrics, Inc. Consulting Scientists and Engineers
Billings, Montana

Date Hole Started: 1/28/2011 Date Hole Finished: 1/28/2011

Well Name: AVF2-4

Static Water Level Below MP: 8.96
Surface Casing Height (ft): 2.60
Date: 1/28/2011
Riser Height (ft): 2.29
MP Description: Top PVC
Ground Surface Elevation (ft): 3006.85
MP Height Above or Below Ground (ft): 2.29
Well Developed? Y
Water Samples Taken? N
Boring Samples Taken? N

Well Developed? Y
Water Samples Taken? N
Drilled to 19' with 7 7/8” bit, hole collapsed to 17.5’, 4.5” casing pushed through sloughed material to total cased depth of 17.5’, fines getting through screen, bottom cap broken, casing pulled, re-drilled to 20' inside 8” casing. SC=4400 µmhos/cm, pH=8.10, temp=14.3° C, yield= 2-4 gpm after development, still some fines through screen.
Hydrometrics, Inc.
Consulting Scientists and Engineers
Billings, Montana

Hole Name: AVF2-6
Date Hole Started: 2/11/2011  Date Hole Finished: 2/11/2011

Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River  State: Montana
Property Owner: J. Trusler
Legal Description: T3S, R45E, Sec. 33; N 485180.63, E 2815413.49
Location Description: AVF2 - south of cemetery
Recorded By: RJL
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Method: Air Rotary
Drilling Fluids Used: None
Purpose of Hole: Install Monitor Well
Target Aquifer: Otter Creek Alluvium
Hole Diameter (in): 8"
Total Depth Drilled (ft): 47

Remarks: Drill and drive 8" steel casing to 44', 7 7/8" drag bit. SC=2000 µmhos/cm, pH=8.13, temp=10.2°C, open hole yields ~150 gpm

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**WELL CONSTRUCTION**

3.0
Bentonite Chips (7/8") poured during drill/drive

---

**GEOLOGICAL DESCRIPTION**

3.0 - 3.0'  Silt  [Colluvium]
Dry, pale yellowish brown, moderately loose to weakly cemented, roots

3.0 - 5.0'  Silty clay  [Alluvium/Colluvium]
Moist, medium gray and brownish gray with light brown (SYR 5/6) mottles, non-plastic, moderately dense

5.0 - 16.0'  Silty, sandy, clay  [Colluvium/Alluvium]
Very moist to wet at 7', very plastic (rolls to 1/16") to moderately plastic with depth, becomes very sandy at 10', moderate yellowish brown with some light brown (SYR 5/6) and medium gray (N4) streaks

16.0 - 24.0'  Gravel, sandy, clayey, poorly sorted  [Alluvium]
Wet, moderate to dark yellowish brown fines, clinker gravels with gravels to 1" at 16-24', very loose

24.0 - 47.0'  Gravel, sandy
Less sand (~5%) with depth, gravels to 3" at 24' - gravels = clinker, coal, sandstone; sub-rounded, low to moderate sphericity.
Very sandy again at 36'-41', dark yellowish brown sand
No sand at 40'-46', gravels to 6', hole stays open
Bedrock at 46', claystone?; no sample returns, total depth at 47'

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GRAPHICS

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STANDARD_REV13_OTTER_CREEK_WELL_LOGS.GPJ  HYDHLN2.GDT  10/6/14
WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

0.0 - 3.0' Silt, clayey [Topsoil]
Dry to moist, moderate yellowish brown (10YR 5/4), calcareous, non-cohesive, few roots

3.0 - 7.0' Clay, silty [Colluvium]
Very moist, moderate yellowish brown (10YR 5/4), weakly cohesive, calcareous, very soft, no roots, rolls 1/8" thread

7.0 - 15.5' Clay, some silt (5-10%) [Colluvium]
Very moist to wet, dark yellowish brown (10YR 4/2), cohesive, rolls thread to 1/16", calcareous

15.5 - 27.0' Sandy, silty gravel [Colluvium]
Wet, variable colors, majority of gravel is angular to sub-rounded clikers, some coal fragments, very gravelly, very poorly sorted, more sandy at 22', back to gravel at 27'

27.0 - 40.0' Sandy, silty gravel [Alluvium]
Wet, variable colors, rock fragments, sandstone, siltstone, and cliker, very poorly sorted, angular to well rounded

40.0 - 60.0' Sandy, silty gravel [Alluvium]
Wet, variable colors, 5% coal fragments, silt and clay increases at 47'-49', coal 10% up to 3" in length at 60', more angular cuttings

60.0 - 65.0' Gravel mostly comprised of coal - 90%

65.0 - 85.0' Sand, loose, silty [Alluvium]
Flowing sand, very loose, liquefiable?, dark yellowish brown (10YR 4/2) cuttings contain 50% fine quartz sand and 50% coal flakes, quartz grain sub-angular to sub-rounded suggesting sandstone source

85.0 - 97.0' Coal
Cleated 3x, very soft, fragments to 3", may be in place, some sand

97.0 - 100.0' Clay
Olive black (5Y 2/1), fat, cohesive, very soft

100.0 - 101.0' Claystone
Greenish gray (5GY 6/1), soft, non-calcareous, well blowing 600gpm at 100-101

Remarks: Drill to 10', drive 8" steel, advance 40', drilled out; add more steel drive to 59' bgs then to 79' then to 98'. Very high sediment load in cuttings, strong H2S odor; SC=2910 µmhos/cm, pH=8.56. Plug back pull casing to 60'. 30-40 gpm after completion
**Well Construction**

- **.client**: Arch Coal
- **Project**: Otter Creek Mine Permit (10068)
- **County**: Powder River
- **State**: Montana
- **Property Owner**: Great Northern Properties
- **Legal Description**: T45S, R45E, Sec. 15; N470043.96, E 2823459.65
- **Location Description**: 55 yards East of Otter Creek, 10' East of well AVF3-1
- **Recorded By**: AJH
- **Drilling Company**: Askin Drilling
- **Driller**: Ron Askin
- **Drilling Method**: Air Rotary
- **Drilling Fluids Used**:
- **Purpose of Hole**: Install Monitor Well
- **Target Aquifer**: Alluvium
- **Hole Diameter (in)**: 8"
- **Total Depth Drilled (ft)**: 59

**Well Completion**

<table>
<thead>
<tr>
<th>WELL COMPLETION</th>
<th>Y/N</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Installed?</td>
<td>Y</td>
<td>4.5&quot; Sch 40, PVC</td>
</tr>
<tr>
<td>Surface Casing Used?</td>
<td>Y</td>
<td>8&quot; steel</td>
</tr>
<tr>
<td>Screen/Perforations?</td>
<td>Y</td>
<td>0.025-inch slot, Sch 40 PVC</td>
</tr>
<tr>
<td>Sand Pack?</td>
<td>Y</td>
<td>10/20 silica sand</td>
</tr>
<tr>
<td>Annular Seal?</td>
<td>Y</td>
<td>Bentonite Chips</td>
</tr>
<tr>
<td>Surface Seal?</td>
<td>Y</td>
<td>Concrete Pad</td>
</tr>
</tbody>
</table>

**Geological Description**

- **0.0 - 3.0'**: Silt (Topsoil)
  - Dry to very moist, moderate yellowish brown (10YR 5/4), calcareous, non-cohesive, few roots

- **3.0 - 15.0'**: Silty clay to clay (Colluvium)
  - Very moist to wet at 8-9', moderate yellowish brown (10YR 5/4), cohesive, rolls 1/16" thread

- **15.0 - 48.0'**: Sandy, silty gravel
  - Wet, color variable, fines pale yellowish brown (10YR 6/2), lots of clinker, sandstone, siltstone, some clay intervals but thin, calcareous, very poorly sorted, angular to rounded, rock fragments to 3" coal fragments increase below 40'

- **48.0 - 54.0'**: Sand with gravel (Alluvium)
  - Wet, very soft, trace coal

- **54.0 - 55.0'**: Sandy clay
  - Blue gray with black flakes, some clinker gravel, soft

- **55.0 - 58.0'**: Sandy gravel
  - Variable color, very poorly sorted, rounded to angular, most rock fragments are flat

**Remarks**: Air lift develop 15 minutes, clear, SC stable at 4800 µmhos/cm, pH 8.02, temp 9.3°C. Advanced steel to 60' by driving with casing hammer, drill out cuttings, install well, pull back steel.
### WELL CONSTRUCTION

- **0.0 - 8.0'**: 8" steel +2-5
- **8.0'**: Bentonite Chips +2-5
- **10/20 Silica Sand 25.0'**
- **55.0'**
- **65.0'**

### GEOLOGICAL DESCRIPTION

- **0.0 - 1.0'**: Silty clay [Topsoil]
  - Moist, moderate yellowish brown, loose to moderately cohesive, roots of grass and shrubs

- **1.0 - 10.0'**: Silty clay [Colluvium]
  - Dry, grayish orange, loose, non-plastic

- **10.0 - 15.0'**: Silty clay
  - Slightly moist, pale to moderate yellowish brown, non-plastic

- **15.0 - 23.0'**: Clay, silty [Colluvium]
  - Very moist, moderate yellowish brown, moderate to high plasticity with moisture increase, moisture increases with depth; wet at 18', trace of sand at 10', injecting water at 20'

- **23.0 - 25.0'**: Sand [Alluvium]
  - Fine to medium grained, wet, pale to moderate yellowish brown, very loose

- **25.0 - 51.0'**: Sand and gravel [Alluvium]
  - Poorly sorted (50/50), wet, pale to moderate yellowish brown sand with light brown and moderate orange pink gravel; gravel is clinker origin, fist, sub-angular to sub-round, hard

- **51.0 - 52.0'**: Gravel (sand 20%) [Alluvium]
  - Wet, pale to dark yellowish brown and grayish orange sandstone gravels, light brown clinker gravel up to 3", cleaner than above

- **52.0 - 64.0'**: Sand, fine to medium, some silty clay [Alluvium]
  - Moderate to pale yellowish brown, very loose, soft; coarse sand and gravels (up to 2') of sandstone origin at bedrock contact

- **64.0 - 65.0'**: Coal [Bedrock]
  - Wet, black, hard, very cleated (Upper Knobloch?)

**Remarks:** Drill to 30' with 7 7/8" bit, ream out with 12" bit, drive 8" steel to 58', drill out with 4" bit to 60', drive 8" steel to 65', bentonite poured with steel. Hole sloughed when steel pulled back from 18'-25' bgs, developed with rig air. After development SC=4290 µmhos/cm, pH=8.03, temp=9.9° C.
**WELL COMPLETION**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2-46</td>
<td>Well Installed? Y, 4.5&quot; Sch 40, PVC</td>
</tr>
<tr>
<td>+2-4</td>
<td>Surface Casing Used? Y, 8&quot; steel</td>
</tr>
<tr>
<td>26-46</td>
<td>Screen/Perforations? Y, 0.025-inch slot, Sch 40 PVC</td>
</tr>
<tr>
<td>10.5-18</td>
<td>Sand Pack? Y, 10/20 Silica Sand</td>
</tr>
<tr>
<td>+1-10.5</td>
<td>Annular Seal? Y, Bentonite Chips</td>
</tr>
<tr>
<td>N</td>
<td>Surface Seal? N</td>
</tr>
</tbody>
</table>

**DEVELOPMENT/SAMPLING**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Well Developed? Y, Rig Air</td>
</tr>
<tr>
<td>N</td>
<td>Water Samples Taken? N</td>
</tr>
<tr>
<td>N</td>
<td>Boring Samples Taken? N</td>
</tr>
</tbody>
</table>

**WELL CONSTRUCTION**

- **8" steel**
- **10/20 Silica Sand**
- **Bentonite Chips**
- **0.025-inch Slot Screen**
- **end cap, centralizer**
- **Bottom of Hole**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 10.0' Silty clay** (Colluvium)
  - Moist to wet, pale to moderate yellowish brown, loose to dense, plastic, roots; injecting water at 5' bgs

- **10.0 - 19.0' Clay, silty/sandy, some gravels**
  - Wet, moderate yellowish brown, plastic, very loose

- **19.0 - 33.0' Sand and gravel**
  - Wet, moderate yellowish brown fines with multi-colored (e.g. light brown, moderate reddish brown) clinker gravels and sandstone gravels (poorly sorted 50/50), very loose; gravels to 2" at 19', increase to 4" at 30', some clay from 19'-25'

- **33.0 - 50.0' Thermally altered shale** (Clinker)
  - Wet, moderate red and moderate reddish brown, some pale yellowish orange (10YR 8/6), in place very hard, cobbles size to 6", sub-angular to angular. At 46'-56' very hard shale, light bluish gray, light brownish gray, and grayish purple

- **50.0 - 56.0' Coal** (Top of Knobloch Coal)
  - Wet, black (N1), hard, cleated

Remarks: Drilled to 18' with 10 7/8" drag bit, set 51' of 8" steel. Drilled out with 7 7/8" bit to 56'. Pulled steel to complete well in alluvium. Hole sloughed from 46'-56' bgs below casing; and hole sloughed from 18'-46' around casing. Blow with rig air to develop; after development SC= 4800 µmhos/cm, pH= 8.05, temp= 12.3°C.
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River  State: Montana
Property Owner: Great Northern Properties
Legal Description: T4S, R45E, Sec. 15, NW1/4; N 470024.461, E 2823417.91
Location Description:
Recorded By:  R JL
Drilling Company:  Hydrometrics, Inc
Driller:  Larry Johnson and Carl Lanz
Drilling Method:  Direct Push
Drilling Fluids Used:  None
Purpose of Hole:  Install Monitor Well
Target Aquifer:  Root Zone Ground Water
Hole Diameter (in):  2 1/8"
Total Depth Drilled (ft):  12

Remarks:  Direct Pushed pilot hole to 14’. Tripped out and backfilled pilot hole with 3/8” bentonite chips. Moved ~ 5’ and direct pushed to 12’. Used 10/20 silica sand to fill in around the 3/4 inch pre-pack screen. Interval for 10/20 sand pack is 3’-12’.

Hydrometrics, Inc.
Consulting Scientists and Engineers
Billings, Montana

Well Developed?  Y
Water Samples Taken?  N
Boring Samples Taken?  N

Well Installed?  Y
Surface Casing Used?  Y
Screen/Perforations?  Y
Sand Pack?  Y
Annular Seal?  Y
Surface Seal?  Y

Well Developed?  Y  Peristaltic Pump
Water Samples Taken?  N
Boring Samples Taken?  N

Notching:  470024.461  Easting:  2823417.908
Static Water Level Below MP:  10.95  Surface Casing Height (ft):  2.82
Date:  8/28/2013  Riser Height (ft):  1.62
MP Description:  Top PVC  Ground Surface Elevation (ft):  3050.069
MP Height Above or Below Ground (ft):  1.62  MP Elevation (ft):  3051.69

Depositional/Sampling

WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

0.0 - 4.0’  Clay
Dry, pale yellowish brown; moderately loose; trace sand; roots

4.0 - 13.0’  Silty Sandy Clay
Dry to very moist; moderate yellowish brown; loose; very sandy from 12'-13'

13.0 - 14.0’  Sandy Gravel
Wet; light brown to moderate yellowish brown; cinder gravel up to 3/4” in size
**Well Construction**

- **0.0 - 0.5 ft:** 3/8" Bentonite Chips
- **0.5 - 4.0 ft:** Concrete Pad
- **4.0 - 7.0 ft:** 1" x 2" 0.020 Slot Field Pack Screen
- **7.0 - 12.0 ft:** Sandy Clay
- **12.0 ft:** End Cap

**Geological Description**

- **0.0 - 2.0 ft:** Sandy Clay
  - Dry to moist; light yellowish brown; loose roots
- **2.0 - 4.0 ft:** Clayey Sand
  - Very moist to wet; moderate yellowish brown; very loose
- **4.0 - 12.0 ft:** Clayey Sand
  - Wet; moderate yellowish brown; very loose
### WELL CONSTRUCTION

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.6</td>
<td>end cap</td>
</tr>
<tr>
<td>8.0</td>
<td>Bottom of well 8.6</td>
</tr>
<tr>
<td>6.6</td>
<td>Bottom of Hole</td>
</tr>
<tr>
<td>3.6</td>
<td>1'' x 2'' 0.020 slot field pack screen</td>
</tr>
<tr>
<td>3.0</td>
<td>10/20 Silica Sand</td>
</tr>
<tr>
<td>0.5</td>
<td>3/8'' Bentonite Chips</td>
</tr>
</tbody>
</table>

### GEOLOGICAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0 - 8.6</td>
<td>No Core Logged</td>
</tr>
<tr>
<td>4.0 - 8.0</td>
<td>Clayey Sand</td>
</tr>
<tr>
<td>0.0 - 4.0</td>
<td>Sandy Clayey Silt</td>
</tr>
</tbody>
</table>

**Remarks:** Direct Pushed pilot hole to 8'. Tripped out and backfilled pilot hole with 3/8" bentonite chips. Moved ~ 3' and augered to 8'. Well pushed in and completed at 8.6' below ground surface due to soft clay.

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**Table: WELL COMPLETION**

<table>
<thead>
<tr>
<th>Completion</th>
<th>Description</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1-inch, flush threaded, Sch 40, PVC</td>
<td>+1.79-8.6</td>
</tr>
<tr>
<td>Yes</td>
<td>4'' steel</td>
<td>+1.79-3.21</td>
</tr>
<tr>
<td>Yes</td>
<td>0.020-inch slot, 1'' x 2'' field pack</td>
<td>3.6-8.6</td>
</tr>
<tr>
<td>Yes</td>
<td>10/20 Silica Sand</td>
<td>3-8</td>
</tr>
<tr>
<td>Yes</td>
<td>3/8'' Bentonite Chips</td>
<td>+1-3</td>
</tr>
<tr>
<td>Yes</td>
<td>Concrete Pad</td>
<td></td>
</tr>
</tbody>
</table>

**Table: DEVELOPMENT/SAMPLING**

<table>
<thead>
<tr>
<th>Development</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Peristaltic Pump</td>
</tr>
<tr>
<td>Yes</td>
<td>N</td>
</tr>
</tbody>
</table>

**Static Water Level Below MP:** 7.29
**Date:** 8/28/2013
**MP Description:** Top PVC
**MP Height Above or Below Ground (ft):** 1.36
**Ground Surface Elevation (ft):** 3043.64
**MP Elevation (ft):** 3044.99

**Remarks:** Direct Pushed pilot hole to 8'. Tripped out and backfilled pilot hole with 3/8" bentonite chips. Moved ~ 3' and augered to 8'. Well pushed in and completed at 8.6' below ground surface due to soft clay.

---

**Technical Details:**

- **Client:** Arch Coal
- **Project:** Otter Creek Mine Permit (10068)
- **County:** Powder River
- **State:** Montana
- **Property Owner:** Great Northern Properties
- **Legal Description:** T4S, R45E, Sec. 15, NW1/4; N 470379.922, E2822669.47
- **Date Hole Started:** 8/15/13
- **Date Hole Finished:** 8/15/13
- **Northing:** 470379.922
- **Easting:** 2822669.476
- **Total Depth Drilled:** 8 ft
- **Hole Diameter:** 6 1/4''
- **Driller:** Larry Johnson and Carl Lanz
- **Drilling Method:** Auger/ Direct Push
- **Purpose of Hole:** Install Monitor Well
- **Target Aquifer:** Root Zone Ground Water
- **Remarks:** Direct Pushed pilot hole to 8'. Tripped out and backfilled pilot hole with 3/8" bentonite chips. Moved ~ 3' and augered to 8'. Well pushed in and completed at 8.6' below ground surface due to soft clay.
Bentonite Chips

0.025-inch Slot Screen

Bottom of Hole

0.0 - 17.0'

Silty clay

<5% fine sand (orange red); soft; dry to moist at 4', adding water; dark yellowish brown (10YR 4/2), silty layer at 10'-12', pale yellowish brown (10YR 6/2)

17.0 - 33.0'

Gravels [Alluvium]

Multi-color; flaggy angular to sub-rounded, matrix is dark yellowish brown (10YR 4/2); clinker gravels and sandstone, rounded cobbles

33.0 - 34.0'

Weathered coal [Bedrock]

Black, dusky brown, oxidized

34.0 - 35.0'

Coal [Bedrock]

Hard, black cleated, glossy fracture planes

Remarks: Hole collapsed at 9'-20'. Start air lift at 3:30 p.m., SC= 5350 µmhos/cm at 3:32 p.m.; SC= 5430 µmhos/cm at 3:40 p.m., slightly cloudy. Yield est. at 15-20 gpm.
Bentonite Chips

hole collapsed

Bottom of Hole: 0.0 - 18.0'
Clayey silt
Dry to 5', moist below, adding water; soft, moderate yellowish brown (10YR 5/4), orange oxidation staining at 5'-10'

18.0 - 26.0'
Silty clay
[Alluvium]
Slightly stiff, fine sand <10%, moderate yellowish brown (10YR 5/4) with medium gray layers

hole collapsed

26.0 - 40.0'
Clayey gravels
[Alluvium]
Some coarse sand (~10%); cinder gravels red orange, multi-color, poorly sorted; flaggy angular coal chunks in gravels at 35' to 40'

40.0 - 55.0'
Gravel with sand (10-15%)
[Alluvium]
Multi-color (moderate reddish orange/dusky yellow/moderate brown), poorly sorted, flaggy, sub-rounded; cinder gravels, cobbles to 8” diameter, producing water

55.0 - 55.5'
Coal
[Bedrock]
Hard, black, cleated

Remarks: Hole collapsed at 26'-43'. Gravels heaved to 49’. Start airlift at 6:00 p.m., SC=4250 µmhos/cm at 6:15p.m., stable.
### WELL CONSTRUCTION

- **8" steel**
- **Bentonite Chips**
- **10/20 Silica Sand**
- **Gravels**
- **Coal**

### GEOLOGICAL DESCRIPTION

- **0.0 - 4.0' Silty clay**
  - Dry at surface to moist at 3', very moist at 4'; moderate yellowish brown (10YR 5/4), roots, minor very fine sand

- **4.0 - 15.0' Clayey silt [Alluvium]**
  - Very moist, some very fine sand, moderate yellowish brown, adding water at 5'

- **15.0 - 18.0' Silty sand [Alluvium]**
  - Coarse with very fine clinker gravels

- **18.0 - 21.0' Sandy gravels [Alluvium]**
  - Multi-color (blacks to reds); poorly sorted; flaggy, angular, up to 4" diameter; sand 15%+

- **21.0 - 23.0' Clay [Alluvium]**
  - Stiff, moderate olive brown (5Y 4/4)

- **23.0 - 31.0' Gravels [Alluvium]**
  - Multi-color, overall color dark reddish brown (10R 3/4); average 1/2", sorted; little sand <5%; flaggy, sub-rounded

- **31.0 - 32.0' Coal [Bedrock]**
  - Black, cleated, glossy

### WELL COMPLETION

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>DESCRIPTION</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.025-inch slot</td>
<td>Bentonite Chips</td>
<td>Y</td>
</tr>
<tr>
<td>0.025-inch slot</td>
<td>10/20 silica sand</td>
<td>Y</td>
</tr>
<tr>
<td>2.0 - 32</td>
<td>Well Installed?</td>
<td>Y</td>
</tr>
<tr>
<td>Surface Casing Used?</td>
<td>8&quot; steel</td>
<td>Y</td>
</tr>
<tr>
<td>Screen/Perforations?</td>
<td>0.025-inch slot, Sch 40 PVC</td>
<td>Y</td>
</tr>
<tr>
<td>Sand Pack?</td>
<td>10/20 silica sand</td>
<td>Y</td>
</tr>
<tr>
<td>Annular Seal?</td>
<td>Bentonite Chips</td>
<td>Y</td>
</tr>
<tr>
<td>Surface Seal?</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

### DEFORMATION/SAMPLING

- **Well Developed?** Y
- **Rig Air**
- **Water Samples Taken?** N
- **Boring Samples Taken?** N

### DEVELOPMENT/SAMPLING

- **Nothing:** 461198.56
- **East:** 2824564.14

### STATIC WATER LEVEL BELOW MP:

- **8.6 ft**

### DATE:

- **7/19/2011**

### MP DESCRIPTION:

- **Top PVC**

### MP HEIGHT ABOVE OR BELOW GROUND:

- **1.87 ft**

### HOLE COLLAPSED:

- **10'-17'**

### REMARKS:

- Hole collapsed at 10'-17'. Start airlift at 10:10 a.m., SC=4260 µmhos/cm at 10:20 a.m., stable.
Remarks: Lithology based on well AVF4-1. After 10 minutes of development SC=6340 µmhos/cm, pH= 7.7, temp= 12.2°C. Hole collapsed at 8'-17'.

**WELL CONSTRUCTION**

- **Bentonite Chips**
- **8" steel**
- **0.025-inch Slot Screen**
- **Bottom of Hole**
- **Weathered Coal**
- **10/20 Silica Sand end cap at 34'**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 17.0' Silty Clay**
  - <5% fine sand (orange red); soft; dry to moist at 4', adding water; dark yellowish brown (10YR 4/2), silty layer at 10'-12', pale yellowish brown (10YR 6/2)

- **17.0 - 33.0' Gravels [Alluvium]**
  - Multi-color; flaggy angular to sub-rounded, matrix is dark yellowish brown (10YR 4/2); clinker gravels and sandstone, rounded cobbles

- **33.0 - 34.0' Weathered Coal [Bedrock]**
  - Black, dusky brown, oxidized

- **Surface Seal?** N
- **Screen/Perforations?** Y
- **Sand Pack?** Y
- **Annular Seal?** Y
- **Surface Casing Used?** Y
- **Well Installed?** Y
- **Target Aquifer: Alluvium**
**WELL CONSTRUCTION**

- **4" Steel Concrete Pad**
- **3/4" Bentonite Chips**
- **10/20 Silica Sand**
- **3/4" 0.010 Slot Pre-Pack Screen**
- **Bottom of Hole**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 4.0' Silty Clay**
  - dry, moderate yellowish brown to pale yellowish brown; roots
- **4.0 - 16.0' Silty Clay**
  - moist to wet, moderate yellowish brown; trace sand (minor)

Remarks:
- Direct Pushed to 16’. Installed 3/4” well to 16’. Used 10/20 silica sand to fill in around the 3/4 inch pre-pack screen. Interval for 10/20 sand pack is 5’-16’.

**Well Installed?** Y
**Surface Casing Used?** Y
**Screen/Perforations?** Y
**Sand Pack?** Y
**Annular Seal?** Y
**Surface Seal?** Y

**DEVELOPMENT/SAMPLING**

- **Well Developed?** Y
- **Water Samples Taken?** N
- **Boring Samples Taken?** N

**WELL COMPLETION**

- **Well Installed?** Y
- **Surface Casing Used?** Y
- **Screen/Perforations?** Y
- **Sand Pack?** Y
- **Annular Seal?** Y
- **Surface Seal?** Y

**INTERVAL**

- **+3.13-16**
- **+3.13-1.87**
- **11-16**
- **5-16**
- **+1-5**
- **+1-16**

**Static Water Level Below MP:** 12.75
**Date:** 8/28/2013
**MP Description:** Top PVC
**MP Height Above or Below Ground (ft):** 2.87
**Riser Height (ft):** 2.87
**Ground Surface Elevation (ft):** 3074.143
**MP Elevation (ft):** 3077.01
**Well Construction**

- **0.0 - 0.5 ft**: 3/8" Bentonite Chips
- **0.5 - 3.5 ft**: 4" Steel Concrete Pad
- **3.5 - 4.0 ft**: 10/20 Silica Sand
- **4.0 - 9.0 ft**: 1" x 2" 0.020 Slot Field Pack Screen
- **9.0 ft**: Bottom of Hole

**Geological Description**

- **0.0 - 12.0 ft**: Silty Clay
  - dry to wet; moderate yellowish brown; some sand; loose; roots in upper interval; tagged sand and gravel at 12'; poorly sorted fine gravels to coarse sands

**Well Construction**

- **Well Installed**: Y
- **Surface Casing Used**: Y
- **Screen/Perforations**: Y
- **Sand Pack**: Y
- **Surface Seal**: Y

**Well Completion**

- **Well Developed**: Y
- **Water Samples Taken**: N
- **Boring Samples Taken**: N

**Development/Sampling**

- **Well Name**: AVF4-P2
- **Date Hole Started**: 8/16/13
- **Date Hole Finished**: 8/16/13

**Client**: Arch Coal
**Project**: Otter Creek Mine Permit (10068)
**County**: Powder River
**State**: Montana
**Property Owner**: Great Northern Properties

**Legal Description**: T4S, R45E, Sec. 27, NE1/4; N 461288.85, E 2825354.32
**Location Description**: Near AVF4-1

**Drilled By**: RJL
**Drilling Company**: Hydrometrics, Inc
**Driller**: Larry Johnson and Carl Lanz

**Purpose of Hole**: Install Monitor Well
**Target Aquifer**: Root Zone Ground Water

**Hole Diameter (in)**: 6 1/4"
**Total Depth Drilled (ft)**: 9

**Remarks**: Direct Pushed pilot hole to 12'. Tripped out and backfilled pilot hole with 3/8" bentonite chips. Moved ~ 5' and augered to 9'. Completed well at 9'.
WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

- **Well Installed?**: Y
- **Surface Casing Used?**: Y
- **Screen/Perforations?**: Y
- **Sand Pack?**: Y
- **Annular Seal?**: Y
- **Surface Seal?**: Y

**DESCRIPTION**

- **Well Installed**: 3/4"-inch, flush threaded, Sch 40, PVC
- **Surface Casing**: 4" steel
- **Screen/Perforations**: 0.010-inch slot, 3/4" pre-pack
- **Sand Pack**: 20/30 Silica Sand
- **Annular Seal**: 3/8 Bentonite Chips
- **Surface Seal**: Concrete Pad

**INTERVAL**

- 0.0 - 13.0' Silty Clay
dry to wet, moderate yellowish brown

Remarks: Direct Pushed to 13'. Installed 3/4" well to 13'. Used 10/20 silica sand to fill in around the 3/4 inch pre-pack screen. Interval for 10/20 sand pack is 5'-13'.
**WELL CONSTRUCTION**

- **8" steel +2 - 4**
- **10/20 Silica Sand**
- **Bentonite Chips**

**DEVELOPMENT/SAMPLING**

- **Well Developed?** Y
- **Rig Air**
- **Surface Casing Used?** Y
- **Screen/Perforations?** Y
- **Sand Pack?** Y
- **Annular Seal?** Y
- **Surface Seal?** N

**INTERVAL**

- **0.0 - 10.0'**
  - **Silty clay and sand**
  - Dry to moist with depth, pale yellowish brown to moderate brown (5YR 3/4) with depth (color change at 4'); trace gravel at 5', increasing with depth, roots to 5', loose, trace white calcareous precipitates throughout

- **10.0 - 15.0'**
  - **Clayey, sandy, gravel**
  - Moist, fines are moderate brown (5YR 3/4), gravels multicolored: pale yellowish orange (10YR 5/6), dark yellowish orange (10YR 6/6), moderate orange pink (10R 7/9). Gravels cinder origin, hard to very hard, flat to spherical, sub-angular to sub-round, (50% gravel/50% sandy clay), wet making water at 12.5'

- **15.0 - 20.0'**
  - **Clayey, sandy, gravel**
  - As above, much less gravel, very loose/soft, possibly flowing

- **20.0 - 22.0'**
  - **Sand and gravel poorly sorted**
  - Wet, clinker gravels in moderate brown sand (55% sand) multicolored/hard

- **22.0 - 24.0'**
  - **Clay**
  - Wet, very plastic, very dense, trace small gravels and some very large cobbles at bottom of clay, some calcareous (one 7" cobble ejected from hole), mottled light gray (N7), light brown (5YR 6/4)

- **24.0 - 33.5'**
  - **Sand and gravel poorly sorted**
  - Wet, moderate brown sand (25% sand) with clinker gravels; gravels hard, multicolored: moderate reddish brown (10R 4/6), grayish brown (5YR 3/2), grayish orange (10YR 7/4), light brown (5YR 5/8). Baked shale and baked sandstone origin

- **33.5 - 34.0'**
  - **Siltstone [Bedrock]**
  - Dry, light olive gray (5Y 6/1), pale yellowish brown and dark yellowish orange with thin dark interbeds, laminated, non calcareous, soft to moderately firm, tagged coal, hard, black, in place at 34'
### WELL CONSTRUCTION

- **3.0** 8" steel +2 - 3
- **10/20 Silica Sand**
- **18.0** Native material
- **6" 100-slot screen**
- **31.0**
- **71.0** Bottom of Hole
- **71.0** End cap

### GEOLOGICAL DESCRIPTION

#### 0.0 - 9.0' Silty clay [Alluvium]
- Dry to slightly moist, moderate yellowish brown and pale yellowish brown, soft, loose
- **INTERVAL**

#### 9.0 - 14.0' Sand [Alluvium]
- Slightly moist, very fine to fine with depth, trace clinker gravels, moderate yellowish brown to moderate brown, loose
- **INTERVAL**

#### 15.0 - 19.0' Sand and gravel [Alluvium]
- Moist to very moist, sand loose, moderate brown, gravel to 25%, clinker origin, multicolored, hard, light brown, dark yellowish brown, flat, sub-angular
- **INTERVAL**

#### 19.0 - 69.0' Sand and gravel (50/50) [Alluvium]
- Very moist to wet, moderate brown (SYR 4/4) sand, loose, light brown (SYR 5/6) clinker gravel, flat, sub-angular to sub-rounded, size up to 1.5", baked sandstone and baked shale origin, colors more diverse with depth, some yellowish gray.
- At 28' gravel fraction to 30%
- At 30' sand fraction to 10%
- At 35' more sand again (50%), gravel size increases to 3", colors more diverse with depth, some dark gray, some grayish red (SR 4/2).
- At 55' gravels to 5", sand fraction to ~2%, then grinding on large boulder at 57', some coal gravel at 65'-66'
- **INTERVAL**

#### 69.0 - 70.0' Carbonaceous shale/junk coal
- Dry, medium gray to dark gray, moderately firm, non-plastic, non-reactive with HCl
- **INTERVAL**

#### 70.0 - 71.0' Claystone [Bedrock]
- Dry, light olive gray to greenish gray, firm to stiff, moderately calcareous
- **INTERVAL**
Bentonite Chips

0.0 - 9.0' Silty clay [Alluvium]
Dry to slightly moist, moderate yellowish brown and pale yellowish brown, soft, loose

9.0 - 14.0' Sand [Alluvium]
Slightly moist, very fine to fine with depth, trace clinker gravels, moderate yellowish brown to moderate brown, loose

14.0 - 19.0' Sand and gravel [Alluvium]
Moist to very moist, sand loose, moderate brown, gravel to 25%, clinker origin, multicolored, hard, light brown, dark yellowish brown, flat, sub-angular; fine to medium grained sand with 10% flat clinker pebbles to 1/2" at 19'

19.0 - 50.0' Gravel, very coarse [Alluvium]
Very moist to wet, moderate brown (5YR 4/4) sand, loose, light brown (5YR 5/6) clinker gravel, flat, sub-angular to sub-round, size up to 1.5", baked sandstone and baked shale origin, some rounded boulders to 4"
### WELL CONSTRUCTION

- **8” steel** +2-5
- **10/20 Silica Sand**
- **hole sloughed**
- **10/20 Silica Sand end cap**
- **Bottom of Hole** 74.0
- **0.025-inch Slot Screen**
- **centralizer**
- **Bentonite Chips**
- **72.0**
- **71.0 - 74.0’ Shale [Bedrock]**
- **64.0**
- **54.0**
- **45.0 - 45.0’ Gravel, some sand 20% to 2% with depth, sand from fine to coarse with depth [Alluvium]**
- **Wet, carbonaceous olive gray and olive black to non-carbonaceous medium light gray then light olive gray at Total Depth, firm**
- **45.0 - 71.0’ Gravel, some sand 10% to 20% with depth, sand from fine to coarse with depth [Alluvium]**
- **Wet, carbonaceous olive gray and olive black to non-carbonaceous medium light gray then light olive gray at Total Depth, firm**
- **25.0 - 45.0’ Sand and gravel, poorly sorted, sand 50% to 20% with depth**
- **Wet, pale yellowish brown sand (fine to medium) with multi-colored clinker gravels, sub-round, up to 3”**
- **25.0**
- **10/20 Silica Sand**
- **30.0**
- **hole sloughed**
- **10.0 - 10.0’ Silty clay**
- **Dry to wet with depth, pale yellowish brown, plasticity none to slight with moisture and depth**

### GEOLOGICAL DESCRIPTION

- **0.0 - 10.0’ Silty clay**
  - Dry to wet with depth, pale yellowish brown, plasticity none to slight with moisture and depth
- **10.0 - 25.0’ Sand, clayey, trace gravel with depth**
  - Wet, pale yellowish brown, moderately dense to dense
- **25.0 - 45.0’ Sand and gravel, poorly sorted, sand 50% to 20% with depth**
  - Wet, pale yellowish brown sand (fine to medium) with multi-colored clinker gravels, sub-round, up to 3”
- **45.0 - 71.0’ Gravel, some sand 20% to 2% with depth, sand from fine to coarse with depth [Alluvium]**
  - Wet, carbonaceous olive gray and olive black to non-carbonaceous medium light gray then light olive gray at Total Depth, firm

### WELL COMPLETION

- **Well Installed?** Y
- **Surface Casing Used?** Y
- **Screen/Perforations?** Y
- **Annular Seal?** Y
- **Sand Pack?** Y
- **Surface Seal?** N

### INTERVAL

- **+2-5**
- **+2-74**
- **54-74**
- **25-30, 72-74**
- **+1-25**

### COMMENTS

- **Remarks:** Hole sloughed 30'-72' when steel pulled back, clean gravel. Developed with rig air, yield ~100 gpm.

---

**Hydrometrics, Inc.**
Consulting Scientists and Engineers
Billings, Montana

**Hole Name:** AVF5-4
**Date Hole Started:** 3/26/2011  **Date Hole Finished:** 3/26/2011

**Client:** Arch Coal
**Project:** Otter Creek Mine Permit (10068)
**County:** Powder River  **State:** Montana
**Property Owner:** J. Trusler

**Legal Description:** T3, R45, Sec. 28; N 489376.30, E 2819988.69
**Location Description:** AVF battery near Trusler's dike
**Recorded By:** RJL

**Drilling Company:** Askin Drilling  **Driller:** Ron Askin  **Drilling Method:** Air Rotary  **Drilling Fluids Used:** Water

**Purpose of Hole:** Install Monitor Well  **Target Aquifer:** Home Creek Alluvium  **Hole Diameter (in):** 8”  **Total Depth Drilled (ft):** 74
**WELL CONSTRUCTION**

- **0.0 - 0.5**' Bentonite Chips

**GEOLOGICAL DESCRIPTION**

- **0.0 - 2.0**' Silt and Sand
  - [Alluvium]
  - dry, yellow brown

- **2.0 - 16.0**' Clay with Silt
  - [Alluvium]
  - moist, light brown, cuttings returned in balls

- **16.0 - 22.0**' Sand and Silt
  - [Alluvium]
  - (50/50), damp

- **22.0 - 28.0**' Silty Sand
  - [Alluvium]
  - wet

- **Sand and Gravel (10%)**
  - [Alluvium]
  - red brown cinder chips to 1", total depth before plugging and abandoning

**REMARKS**

Lost 20' of 8" steel down hole; rig slid off of jacks. ABANDONED HOLE, filled with 18 bags of 3/8" bentonite chips.
Bentonite Chips 0.0 - 25.0' Clayey silt with fine grained sand [Alluvium/Colluvium]

8.0 steel (+2' - 3')

10/20 Silica Sand 25.0 - 38.5' Sand

Wet, medium grained, well sorted, first water at 25'

38.5 - 40.0' Sand and gravel

Medium grained sand (20%); rusty red, sub-angular, flat chips of shale gravel (60-80%)

40.0 - 44.5' Gravel

Sub-angular to sub-rounded cleft cobbles to 4' (>5%), medium grained sand (>10%) and flat rusty red shale chips (70%)

44.5 - 46.0' Mudstone [Bedrock]

Light gray, soft

Remarks: Set 5’ screen (41’-46’), sand pack to 35’, pull casing, sand settled to 38’, add sand pack to 21’, bentonite to 2’.
Hole Name: AVF6-1

Date Hole Started: 8/18/11  Date Hole Finished: 8/18/11

Well Developed? Y  Water Samples Taken? N
Boring Samples Taken? N

GEOLOGICAL DESCRIPTION

-2.0  8" steel

Well Installed? Y  8" steel open bottom
Surface Casing Used? Y  8" steel
Screen/Perforations? N
Sand Pack? N
Annular Seal? N
Surface Seal? N

DEVELOPMENT/SAMPLING

Well Developed? Y  Rig Air

Nothing: 477256.84  Easting: 2822637.93
Static Water Level Below MP: 14.1  Surface Casing Height (ft):
Date: 8/18/2011  Riser Height (ft): 2.05
MP Description: Top of Steel  Ground Surface Elevation (ft): 3038.31
MP Height Above or Below Ground (ft): 2.05  MP Elevation (ft): 3040.36

Remarks: Drove 8" steel to 48', drilled to 36' with 4" bit. Drove 8" steel to 47', drilled out with 7 7/8" bit to 50'. Pulled steel back to 40' bgs. Developed with rig air at 20' bgs; SC=4000 μhos/cm, pH= 8.27, temp= 11.1°C, open hole yield= 100+ gpm. Blew on open hole at AVF6-2 approximately 10' away (~300 gpm), SWL dropped 0.4' - H_o = 14.1 and H_a = 14.5
**Client:** Arch Coal  
**Project:** Otter Creek Mine Permit (10068)  
**County:** Powder River  
**State:** Montana  

**WELL COMPLETION**  
Y/N DESCRIPTION INTERVAL
---
Well Installed? Y 4.5" Sch 40, PVC +2-40
Surface Casing Used? Y 8" steel +2-3
Screen/Perforations? Y 0.025-inch slot, Sch 40 PVC 20-40
Annular Seal? Y Bentonite Chips +1-10
Surface Seal? N  

**DEVELOPMENT/SAMPLING**

**WELL CONSTRUCTION**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 3.0' Silt [Alluvium/Colluvium]**  
  Dry, moderate yellowish brown, loose, roots, Topsoil

- **3.0 - 10.5' Sand [Alluvium]**  
  Moist to very moist, moderate to dark yellowish brown and moderate brown at depth; silty/clayey from 3'-6'; soft loose, fine-grained; trace gravel present at 10'

- **10.5 - 30.0' Sandy gravel [Alluvium]**  
  Very moist to wet with depth; moderate yellowish brown sand with light brown and reddish brown clinker gravels; poorly sorted (~50/50), gravels up to 2" at 10.5'-20' and up to 4" at 20'-30'; mostly flat, sub-angular, some spherical and/or sub-round; trace petrified bone t 25'

- **30.0 - 40.0' Clinker gravel [Alluvium/Clinker]**  
  Wet, very angular blocky, dark reddish brown, makes 100 gpm; trace sandstone gravel (mixture) at 30'; size up to 6"; then grades to very angular clinker in place at 35'-42'; thermally altered shale

---

**Remarks:** Lithology based on AFV6-1, cuttings verified in field. Open hole to 20' with 9 7/8" bit. Drive 8" steel to 40' bgs. Set 40' of 4.5" PVC (20' screen), pour sand (3 bags) around bottom of screen and pull 8" steel. Developed with rig air, SC= 2520 µmhos/cm, pH= 8.25, temp= 13.2°C; SC rose to 3170 µmhos/cm after 20 minutes blowing at 20' bgs.
Bentonite Chip

0.050-inch, 6" slot screen

Bottom of Hole
0.0 - 5.0'
Silty clay
[Colluvium/Alluvium]
Dry, pale yellowish brown (10YR 6/2), loose, soft, some roots

5.0 - 9.0'
Sand, trace gravel
[Alluvium]
Moist, moderate yellowish brown (10YR 5/4), loose, fine-grained

9.0 - 30.0'
Sand and gravel, poorly sorted (70% sand and 30% gravel)
Moist, moderate yellowish brown (10YR 5/4), loose, fine-grained; grades 20% sand and 90% gravel at 15', gravels to 2", clinker and sandstone origin; sub-round, flat to medium sphericity, gravel to 6" at 20'

30.0 - 64.0'
Gravel/clinker and sandstone origin
[Alluvium]
Wet, pale yellowish brown (10YR 6/2), light brown, moderate reddish brown (10R 4/6) with light brownish gray (5YR 5/1) and grayish red purple (5RP 4/2) shale (altered shale); increasing sandstone gravel at 35', sub-angular to sub-rounded, loose, flat to spherical

64.0 - 66.0'
Silty claystone
[Bedrock]
Pale yellowish brown (10YR 6/2) grades to light olive gray (5Y 6/1) and very light gray (N8), moderately firm, moderate plasticity, rolls to 1/8", calcareous

Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River
State: Montana
Property Owner: Ark Land Company
Legal Description: T4S, R45E, Sec. 10; N 477471.58, E 2822620.04
Location Description: AVF6 on old Gratwohl property on Three Mile Creek
Recorded By: RJL
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Method: Air Rotary
Drilling Fluids Used: Water
Purpose of Hole: Install Monitor Well
Target Aquifer: Three Mile Creek Alluvium
Hole Diameter (in): 8"
Total Depth Drilled (ft): 66

WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

0.0 - 5.0' Silty clay
[Colluvium/Alluvium]
Dry, pale yellowish brown (10YR 6/2), loose, soft, some roots

5.0 - 9.0' Sand, trace gravel
[Alluvium]
Moist, moderate yellowish brown (10YR 5/4), loose, fine-grained

9.0 - 30.0' Sand and gravel, poorly sorted (70% sand and 30% gravel)
Moist, moderate yellowish brown (10YR 5/4) and moderate brown sand with light brown, dark yellowish orange (10YR 6/6) and moderate reddish orange (10R 6/6) gravel, loose, hard, cliner origin; grades 20% sand and 90% gravel at 15', gravels to 2", clinker and sandstone origin; sub-round, flat to medium sphericity, gravel to 6" at 20'

30.0 - 64.0' Gravel/clinker and sandstone origin
[Alluvium]
Wet, pale yellowish brown (10YR 6/2), light brown, moderate reddish brown (10R 4/6) with light brownish gray (5YR 5/1) and grayish red purple (5RP 4/2) shale (altered shale); increasing sandstone gravel at 35', sub-angular to sub-rounded, loose, flat to spherical

64.0 - 66.0' Silty claystone
[Bedrock]
Pale yellowish brown (10YR 6/2) grades to light olive gray (5Y 6/1) and very light gray (N8), moderately firm, moderate plasticity, rolls to 1/8", calcareous

Request: Pulled 8" steel that was set during drilling; hole sloughed to 8' when pulled; set 6" PVC. Blew rig air to develop; SC= 3790 µmhos/cm, pH= 8.2, temp= 11.3°C, yield estimate ~100+ gpm.
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River State: Montana
Property Owner: Ark Land Company
Legal Description: T4S, R45E, Sec. 3; N 477789.43, E 2822602.67
Location Description: AVF6 on Three Mile Creek
Recorded By: RJL
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Method: Air Rotary
Drilling Fluids Used: Water
Purpose of Hole: Install Monitor Well
Target Aquifer: Three Mile Creek Alluvium
Hole Diameter (in): 8"
Total Depth Drilled (ft): 71
Remarks: Drill to 20' with 7 7/8" bit, drove 8" steel to 70', drill pilot with 3 7/8" bit. Ream out with 7 7/8" bit; 10/20 silica sand poured while driving 8" steel. Hole sloughed from 23'-71'. Developed with rig air; after development SC= 3770 µmhos/cm, pH= 8.18, temp= 13°C.

WELL CONSTRUCTION

GEOSYNTETIC

GRAPHICS

WELL COMPLETION

Y/N  DESCRIPTION  INTERVAL
Well Installed?  Y  4.5" Sch 40, PVC  +2-71
Surface Casing Used?  Y  8" steel  +2-3
Screen/Perforations?  Y  0.025-inch slot, Sch 40 PVC  31-71
Annular Seal?  Y  Bentonite Chips  +1-15
Surface Seal?  N  

DEVELOPMENT/SAMPLING

Well Developed?  Y  Rig Air
Water Samples Taken?  N
Boring Samples Taken?  N

Noth:  477789.43  Easting:  2822602.67
Static Water Level Below MP:  23.00  Surface Casing Height (ft):  2.06
Date:  8/22/2011  Riser Height (ft):  1.81
MP Description: Top PVC  Ground Surface Elevation (ft):  3046.46
MP Height Above or Below Ground (ft):  1.81  MP Elevation (ft):  3048.27

Well Developed?  Water Samples Taken?  Boring Samples Taken?  No

LEGEND

- Bentonite Chips
- 0.025-inch Slot Screen
- centralizer
- Bottom of Hole
- end cap
- 8" steel
- 10/20 Silica Sand
- hole sloughed (native)
- Static Water Level
- Surface Casing
- Screen/Perforations
- Sand Pack
- Annular Seal
- Surface Seal
- 4.5" Sch 40, PVC
- 8" steel
- 0.025-inch slot, Sch 40 PVC
- 10/20 Silica Sand
- Bentonite Chips
- Silty clay
- Silt, trace clay and very fine sand
- Sandy clay
- Silty sandy clay, very fine gravel sand
- Clayey sand and gravel, poorly sorted
- Sand and gravel, poorly sorted
- Siltystone/claystone

GEOLOGICAL DESCRIPTION

0.0 - 5.0'  Silty clay [Colluvium/Topsoil]
Dry, pale to moderate yellowish brown, roots, loose to moderately cohesive

5.0 - 10.0'  Silt, trace clay and very fine sand  [Alluvium/Colluvium]
Slightly moist, moderate yellowish brown, white precipitates, loose

10.0 - 15.0'  Sandy clay  [Alluvium/Colluvium]
Moist, dark yellowish brown, plastic, rolls to 1/16", white precipitates, loose

15.0 - 20.0'  Silty sandy clay, very fine gravel sand  [Alluvium/Colluvium]
Moist, moderate yellowish brown to moderate brown, loose, moderate plasticity

20.0 - 21.0'  Clayey sand and gravel, poorly sorted
Wet, moderate yellowish brown fines, with light brown cinder gravels (80% fines 20% gravel), very fine-grain sand; injecting water at 20'

21.0 - 66.0'  Sand and gravel, poorly sorted  [Alluvium]
Wet, pale to medium yellowish brown sand with cinder and sandstone gravels (70% gravel 30% sand), gravels light brown, moderate reddish brown, and pale yellowish brown to dark gray, sub-angular to sub-rounded, medium sphericity to flat, gravels up to 6" (cobbles); sand decreases with depth <10%; clay stringer at 30'

66.0 - 70.0'  Siltystone/claystone  [Bedrock]
Dry, pale yellowish brown and light olive gray, dense, moderate firm to stiff, slightly plastic, calcareous
**WELL CONSTRUCTION**

- **Hole Name**: AVF6-5
- **Date Started**: 8/23/11
- **Date Finished**: 8/23/11

### WELL CONSTRUCTION GRAPHICS

- **8" steel**
- **10/20 Silica Sand**
- **0.025-inch Slot Screen**
- **Bottom of Hole**
- **End cap at 30'**

### GEOREGICAL DESCRIPTION

#### 0.0 - 5.0' Silty clay [Colluvium/Alluvium]
- Dry, pale yellowish brown (10YR 6/2), loose, soft, some roots

#### 5.0 - 9.0' Sand, trace gravel [Alluvium]
- Moist, moderate yellowish brown (10YR 5/4), loose, fine-grained

#### 9.0 - 30.0' Sand and gravel, poorly sorted (70% sand and 30% gravel)
- Moist, moderate yellowish brown (10YR 5/4) and moderate brown sand with light brown, dark yellowish brown (10YR 6/6) and moderate reddish orange (10R 6/6) gravel, loose, hard, clinker origin; grades 20% sand and 90% gravel at 15', gravels to 2", clinker and sandstone origin; sub-round, flat to medium sphericity, gravel to 8" at 20'

**Remarks**: Lithology based on well AFV6-3, cuttings verified in field. Drill to 18' with 10 7/8" drag bit, set 30' of 8" steel casing. Drill out with 7 7/8" drag bit. Hole sloughed around casing at 13'-25'. Blew with rig air once completed; after development SC= 3600 µmhos/cm, pH= 8.1, temp= 15.0°C.
**WELL CONSTRUCTION**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>Bentonite Chips</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 10.0'</td>
<td>Y</td>
</tr>
<tr>
<td>10.0 - 25.0'</td>
<td>N</td>
</tr>
<tr>
<td>25.0 - 40.0'</td>
<td>N</td>
</tr>
<tr>
<td>40.0 - 45.0'</td>
<td>N</td>
</tr>
</tbody>
</table>

**GEOLOGICAL DESCRIPTION**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>Bentonite Chips</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 10.0'</td>
<td>Y</td>
</tr>
<tr>
<td>10.0 - 19.0'</td>
<td>N</td>
</tr>
<tr>
<td>19.0 - 25.0'</td>
<td>N</td>
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<tr>
<td>25.0 - 40.0'</td>
<td>N</td>
</tr>
<tr>
<td>40.0 - 45.0'</td>
<td>N</td>
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</table>

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>Bentonite Chips</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 10.0'</td>
<td>Y</td>
</tr>
<tr>
<td>10.0 - 19.0'</td>
<td>N</td>
</tr>
<tr>
<td>19.0 - 25.0'</td>
<td>N</td>
</tr>
<tr>
<td>25.0 - 40.0'</td>
<td>N</td>
</tr>
<tr>
<td>40.0 - 45.0'</td>
<td>N</td>
</tr>
</tbody>
</table>

**Bentonite Chips**
- **Bottom of Hole**: 0.0 - 10.0'
- Silty clay
  - [Colluvium]
  - Dry to moist at 3', pale yellowish brown to grayish orange, moderate plasticity, rolls to 1/8", loose to trace cemented, roots; trace white precipitates at 5'-10', becomes sandy at 10', very fine-grain

**Sand, silty clayey**
- [Colluvium]
  - Moist, moderate yellowish brown, trace coarse sand or fine gravel size clinker fragments; loose, sand is fine-grain

**Sand and gravel, poorly sorted**
- Moist, moderate yellowish brown to moderate brown fines, with light brown and moderate reddish brown clinker gravels, flat, sub-angular to sub-rounded (80 % fines, 20% gravel at 19')

**Gravel, some sand <10%**
- [Alluvium]
  - Wet, multi-colored: pale yellowish brown, dark gray, light brown, cobble size up to 8", clinker and sandstone origin; sub-angular, moderate sphericity

**Siltstone, clayey**
- [Bedrock]
  - Dry, pale yellowish brown to light olive gray, dense, moderately firm to stiff, non-plastic to mild plasticity with depth, calcareous; trace sand at 41'-45'. No SC from open hole, blew with rig air at 20', very muddy

**Remarks:** Open hole with 10 7/8" bit to 18', drive 8" steel to 45', pulled steel, plugged hole with 3/8" bentonite chips.
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River State: Montana
Property Owner: Ark Land Company
Legal Description: T4S, R45E, Sec. 9, NE1/4; N 476126.85, E 2819323.30
Location Description:
Recorded By: RJL
Drilling Company: Hydrometrics, Inc
Driller: Larry Johnson and Carl Lanz
Drilling Method: Auger/ Direct Push
Drilling Fluids Used: None
Purpose of Hole: Install Monitor Well
Target Aquifer: Root Zone Ground Water
Hole Diameter (in): 6 1/4"
Total Depth Drilled (ft): 14

WELL COMPLETION

<table>
<thead>
<tr>
<th>WELL COMPLETION</th>
<th>Y/N</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Installed?</td>
<td>Y</td>
<td>1-inch, flush threaded, Sch 40, PVC</td>
</tr>
<tr>
<td>Surface Casing Used?</td>
<td>Y</td>
<td>4&quot; steel</td>
</tr>
<tr>
<td>Screen/Perforations?</td>
<td>Y</td>
<td>0.020-inch slot, 1&quot;x 2&quot; field pack</td>
</tr>
<tr>
<td>Sand Pack?</td>
<td>Y</td>
<td>10/20 Silica Sand</td>
</tr>
<tr>
<td>Annular Seal?</td>
<td>Y</td>
<td>3/8 Bentonite Chips</td>
</tr>
<tr>
<td>Surface Seal?</td>
<td>Y</td>
<td>Concrete Pad</td>
</tr>
</tbody>
</table>

INTERVAL

2.09-14
2.34-2.66
9-14
7-14
+2-7

DEVELOPMENT/SAMPLING

Well Developed? Y Peristaltic Pump
Water Samples Taken? N
Boring Samples Taken? N

Graphics

GEOLOGICAL DESCRIPTION

0.0 - 11.0' Silty Clay
dry to moist at 7'; moderate yellowish brown; non plastic to moderately plastic w/ depth trace sand at 9'

11.0 - 14.0' Sand with Silt and Clay
wet; moderate yellowish brown; loose

14.0 - 18.0' Sand
as above, less fines with depth

18.0 - 19.0' Sand and Gravel
loose; moderate yellowish brown to light brown; gravel is clinker in origin and up to 1/4" in size.

Remarks: Wet at 11' bgs. Direct Push to 19' no gravel. Tripped out and moved rig ~2'. 2 1/4" Direct Push hole collapsed to 9' when tools were pulled. Piezometer was pushed to 14' through sloughed soils.
### WELL CONSTRUCTION

- **0.0** - **3.0** ft: **Concrete Pad**
- **3.0** - **6.0** ft: **3/8 Bentonite Chips**
- **6.0** - **10.0** ft: **10/20 Silica Sand**
- **10.0** - **16.0** ft: **Slough**
- **16.0** ft: **Bottom of Hole**

### GEOLOGICAL DESCRIPTION

- **0.0** - **10.0** ft: **Silty Clay**
  - Dry to moist with depth; moderate yellowish brown to moderate brown; roots to 5' ; some sand at depth

- **10.0** - **16.0** ft: **Silt, Sand, and Clay**
  - Moist to wet; moderate yellowish brown; loose; some coarse sand from 12' - 16'
**WELL CONSTRUCTION**

- **Well**
  - 4" Steel
  - Concrete Pad

- **Slotted Screen**
  - 0.020-inch slot, 1"x 2" field pack

- **Sand Pack**
  - 10/20 Silica Sand

- **Peristaltic Pump**

**GEOLOGICAL DESCRIPTION**

- **Silty Clay**
  - 0.0 - 4.0'
  - Dry to moist with depth; very fine sand with depth; loose soft (roots)

- **Silty Sand**
  - 4.0 - 5.0'
  - Slightly moist; moderate yellowish brown

- **Sand**
  - 5.0 - 12.0'
  - Wet; moderate yellowish brown; loose to very loose; poorly sorted very fine to medium sand, some silt and clay to lots of fines at depth

**DEVELOPMENT/SAMPLING**

- **Well Developed?** Y
- **Water Samples Taken?** N
- **Boring Samples Taken?** N

**MONITOR WELL LOG**

- **Well Name:** AVF7-P3
- **Date Hole Started:** 8/14/13
- **Date Hole Finished:** 8/14/13

**LEGAL DESCRIPTION**

- **T4S, R45E, Sec. 9, NE1/4; N 476190.12, E 2819849.76**
- **County:** Powder River
- **State:** Montana
- **Location:** County: Powder River Property Owner: Ark Land Company
- **Remarks:** Direct Pushed pilot hole to 12'. Tripped out and backfilled pilot hole with 3/8" bentonite chips. Moved ~ 3' and augered to 11'.

**WELL COMPLETION**

- **Well Installed?** Y
- **Surface Casing Used?** Y
- **Screen/Perforations?** Y
- **Annular Seal?** Y
- **Surface Seal?** Y

**INTERVAL**

- **Well Installed:** 1-inch, flush threaded, Sch 40, PVC
- **Surface Casing Used:** 4" steel
- **Screen/Perforations:** 0.020-inch slot, 1"x 2" field pack
- **Annular Seal:** 3/8 Bentonite Chips
- **Surface Seal:** Concrete Pad

**HYDROGEOLOGICAL DATA**

- **Static Water Level Below MP:** 5.91
- **Surface Casing Height (ft):** 1.78
- **Riser Height (ft):** 1.45
- **Ground Surface Elevation (ft):** 3029.089
- **MP Elevation (ft):** 3030.54
- **MP Height Above or Below Ground:** 1.45
### WELL CONSTRUCTION

- **4" Steel Concrete Pad**: 0.0
- **1" x 2" 0.020 Slot Field Pack Screen**: 4.0
- **10/20 Silica Sand**: 3.5
- **3/8 Bentonite Chips**: 0.5
- **Bottom of Hole**: 9.0

### GEOLOGICAL DESCRIPTION

- **0.0 - 4.0' Silt**:
  - dry; pale yellowish brown; trace clay and fine sand; loose, roots

- **4.0 - 6.0' Sandy Clay**: to clayey sand; dry to very moist at 5'; moderate yellowish brown; very soft;

- **6.0 - 12.0' Sandy Clay**: as above; wet

- **12.0 - 16.0' Sandy Gravel**: wet; moderate yellowish brown sand to light brown cinder gravel; sub-angular up to 3/4"
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River State: Montana
Property Owner: Great Northern Properties
Legal Description: T4S, R45E, Sec. 22, NW1/4; N 464455.85, E 2823411.65
Location Description:
Recorded By: RJL
Drilling Company: Hydrometrics, Inc
Driller: Larry Johnson and Carl Lanz
Drilling Method: Direct Push
Drilling Fluids Used: None
Purpose of Hole: Install Monitor Well
Target Aquifer: Root Zone Ground Water
Hole Diameter (in): 2 1/2"
Total Depth Drilled (ft): 16

Remarks: Direct Pushed to 16’. Completed 3/4” well inside of 2 1/8” rods. Used 2 1/2” outside diameter steel knock off plug at bottom. Used 10/20 silica sand to fill in around the 3/4 inch pre-pack screen. Interval for 10/20 sand pack is 8.5’-16’.

---

**Well Construction**

0.0 - 4.0’ Silt w/ Fine Sand
dry; pale yellowish brown; soft loose roots

4.0 - 8.0’ Silt, Sand Gravel
dry; pale yellowish brown; w/ multicolored (brown to reddish brown) sub-angular to sub-rounded clinker gravels about 15% gravels up to 3/4” in size

8.0 - 12.0’ Sand and Gravel
dry to slightly moist; medium yellowish brown; clinker and shale gravels, shale gravels at 10’, gravels up to +1’ in size

12.0 - 15.0’ Gravel
dry; multicolored; clinker and sandstone in origin; large up to cobble sized; sub-angular to angular

15.0 - 16.0’ Clay
moist; weathered claystone

---

**Geological Description**

Well Installed? Y 3/4”-inch, flush threaded, Sch 40, PVC +1.59-16
Surface Casing Used? Y 4” steel +2.28-2.72
Screen/Perforations? Y 0.010-inch slot, 3/4” pre-pack 11-16
Sand Pack? Y 20/30 Silica Sand 8.5-16
Annular Seal? Y 3/8 Bentonite Sand +1-8.5
Surface Seal? Y Concrete Pad

---

**Graphical Representation**

---
Well Developed? Y
Water Samples Taken? N
Boring Samples Taken? N

Static Water Level Below MP:   Dry at 17.84'
Date:   8/28/2013
MP Description:   Top PVC
MP Height Above or Below Ground (ft):  3073.524

Remarks:   Direct Pushed pilot hole to 16', didn't tag gravel, installed 3/4" well to 16' in pilot hole.  Used 10/20 silica sand to fill in around the 3/4 inch pre-pack screen. Interval for 10/20 sand pack is 6'-16'.

---

**WELL CONSTRUCTION**

0.0 - 4.0' Silt and Clay
very dry; pale yellow to moderate yellowish brown; very dense; white salt precipitate; roots throughout

4.0 - 8.0' Silty Clay
as above; more coarse w/ depth

8.0 - 12.0' Silty Sand
dry to slightly moist; trace gravel <5%

12.0 - 16.0' Sandy Clay
slightly moist; moderate yellowish to moderate yellowish brown [10YR 4/4]
**Well Construction**

- **4" Steel Concrete Pad**
- **1" x 2" 0.020 Slot Field Pack Screen**
- **Bottom of Hole 0.0 - 4.0' Silt** dry; pale yellowish brown [10YR 5/4]; soft; moderately loose, roots
- **4.0 - 10.0' Silt to Clayey Sand** dry to very moist; moderate yellowish brown; more clayey sand with depth
- **10.0 - 11.8' Sandy Clay to Clayey Sand** wet; moderate yellowish brown
- **11.8 - 12.0' Gravel** 1/4" clinker and sand poorly sorted

**Geological Description**

- **Well Installed?** Y 1-inch, flush threaded, Sch 40, PVC +1.90-11.8
- **Surface Casing Used?** Y 4" steel +1.90-3.10
- **Screen/Perforations?** Y 0.020-inch slot, 1" x 2" field pack 6-11
- **Sand Pack?** Y 10/20 Silica Sand 4.11
- **Annular Seal?** Y 3/8 Bentonite Chips +1-4
- **Surface Seal?** Y Concrete Pad

**Development/Sampling**

- **Well Developed?** Y Peristaltic Pump
- **Water Samples Taken?** N
- **Boring Samples Taken?** N

**Water Log**

- **Well Name:** AVF8-P3
- **Date Hole Started:** 8/15/13
- **Date Hole Finished:** 8/15/13
- **Static Water Level Below MP:** 8.61
- **Surface Casing Height (ft):** 1.90
- **Riser Height (ft):** 1.58
- **Ground Surface Elevation (ft):** 3060.35
- **MP Elevation (ft):** 3061.92
- **Remarks:** Direct Pushed pilot hole to 12'. Tripped out and backfilled pilot hole with 3/8" bentonite chips. Moved ~ 3' and augered to 11'.
4’ Steel Concrete Pad

1” x 2” 0.020 Slot Field Pack Screen

Bottom of well 12’

WELL COMPLETION | Y/N | DESCRIPTION | INTERVAL
--- | --- | --- | ---
Well Installed? | Y | 1-inch, flush threaded, Sch 40, PVC | +1.60-12
Surface Casing Used? | Y | 4” steel | +1.88-3.22
Screen/Perforations? | Y | 0.020-inch slot, 1” x 2” field pack | 7-12
Sand Pack? | Y | 10/20 Silica Sand | 5-11
Annular Seal? | Y | 3/8 Bentonite Chips | +1.5
Surface Seal? | Y | Concrete Pad |

DEVELOPMENT/SAMPLING

Well Developed? Y Peristaltic Pump
Water Samples Taken? N
Boring Samples Taken? N

No. | 0.5 | 3/8” Bentonite Chips
5.0 | 1/2” Bentonite Chips

GEOLOGICAL DESCRIPTION

0.0 - 4.0’ Silt, Sand and Clay
dry to slightly moist; pale to moderate yellowish brown; loose, roots

4.0 - 7.0’ Sand and Gravel
dry to slightly moist; pale reddish brown to moderate yellowish brown; multicolored gravels sub-angular to 3/4”

7.0 - 11.0’ Sandy Clay to Clayey Sand
very moist to wet; very soft, loose; less clay to no clay at 10’ - 12’ and fine to moderately fine

11.0 - 12.0’ No Core Logged
well advanced passed the drilled depth into soft clay

Remarks: Direct Pushed pilot hole to 11’. Tripped out and augered to 11’. Well pushed in and completed at 12’ below ground surface due to soft clay.
### WELL CONSTRUCTION

<table>
<thead>
<tr>
<th>Layer</th>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.0</td>
<td>Bentonite Chips</td>
</tr>
<tr>
<td>3.0</td>
<td>3.0</td>
<td>Slough</td>
</tr>
<tr>
<td>4&quot; Steel</td>
<td>3.0</td>
<td>Concrete Pad</td>
</tr>
</tbody>
</table>

### GEOLOGICAL DESCRIPTION

<table>
<thead>
<tr>
<th>Interval</th>
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</tr>
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<tbody>
<tr>
<td>0.0 - 3.0'</td>
<td>Silty Clay; dry to slightly moist, moderate to dark yellowish brown; loose, roots</td>
</tr>
<tr>
<td>3.0 - 9.0'</td>
<td>Silty Sandy Clay; slightly moist, moderate yellowish brown; moderate plasticity; loose</td>
</tr>
<tr>
<td>9.0 - 16.0'</td>
<td>Clayey Sand and Sandy Clay; slightly moist to very moist with depth, soft, loose</td>
</tr>
</tbody>
</table>

### WELL COMPLETION

<table>
<thead>
<tr>
<th>Completion</th>
<th>Description</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Installed?</td>
<td>Y 3/4&quot;-inch, flush threaded, Sch 40, PVC</td>
<td>+2.36-14</td>
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<tr>
<td>Surface Casing Used?</td>
<td>Y 4&quot; steel</td>
<td>+2.36-2.64</td>
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<tr>
<td>Screen/Perforations?</td>
<td>Y 0.010-inch slot, 3/4&quot; pre-pack</td>
<td>9-14</td>
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<tr>
<td>Sand Pack?</td>
<td>Y 20/30 Silica Sand</td>
<td>9-14</td>
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<tr>
<td>Annular Seal?</td>
<td>Y 3/8 Bentonite Chips</td>
<td>+1-3</td>
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<tr>
<td>Surface Seal?</td>
<td>Y Concrete Pad</td>
<td></td>
</tr>
</tbody>
</table>

### DEVELOPMENT/SAMPLING

- Well Developed? Y
- Water Samples Taken? N
- Boring Samples Taken? N
- Peristaltic Pump

### OTHER

- Project: Otter Creek Mine Permit (10068)
- Client: Arch Coal
- Location: Powder River, Montana
- Date Hole Started: 8/16/13
- Date Hole Finished: 8/16/13
- Legal Description: T4S, R45E, Sec. 22, NE1/4; N 465061.70, E 2825528.65
- Remarks: Direct Pushed pilot hole to 16’. Tripped out and augered hole for steel casing to 3’ with 6 1/4" auger. Directed pushed well hole to 14’. Installed 3/4" well at 14’. Used 10/20 silica sand to fill in around the 3/4 inch pre-pack screen. Interval for 10/20 pre-pack is 9-14’, hole sloughed from 3-9’.
**WELL CONSTRUCTION**

- **8" steel +2 - 18**
- **1.0**
- **Bentonite Chips**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 3.0' Silty clay** [Colluvium]
  - Slightly moist (frost), moderate to dark yellowish brown, moderately cohesive, non-plastic, roots
- **5.0 - 4.0' Silty clay, trace sand with depth** [Colluvium]
  - Dry, moderate yellowish brown, loose to dense, roots
- **4.0 - 5.0' Sand, some gravel (2%)** [Colluvium]
  - Dry, moderate yellowish brown, loose
- **5.0 - 8.0' Clay, sandy, silty** [Colluvium]
  - Dry, moderate yellowish brown, soft, white calcareous nodules/precipitates
- **8.0 - 15.0' Clayey sand (clay & sand)** [Alluvium/Colluvium]
  - Dry, moderate yellowish brown, loose to moderately dense, thinly interlayered, trace gravel (1-2%), cinder flat, light brown, major sand layers at 8'-11' and at 14'-15'
- **15.0 - 30.0' Claystone, very silty, interbedded siltstone** [Bedrock]
  - Dry to very moist with depth, multicolored pale and moderate yellowish brown, light olive gray and grayish orange (10YR 7/4), mild reaction to HCl (calcareous), most very hard, some soft with moderate plasticity, rolls to 1/8" when wet
- **30.0 - 33.5' Coal**
  - Wet, makes ~5 gpm, injecting water; black (N1), moderately weathered, cleated on multiple planes, moderately firm
- **33.5 - 36.0' Carbonaceous shale**
  - Dry, brownish gray (5YR 4/1) to olive gray (5Y 4/1), firm to stiff
- **36.0 - 40.0' Shale**
  - Dry, light brownish gray (5YR 6/1) and light olive gray (5Y 6/1) to brownish black (5YR 2/1), carbonaceous, firm
- **40.0 - 66.5' Coal** [Knobloch]
  - Wet, black, hard, cleated multiple times, no visible impurities
- **66.5 - 69.0' Shale**
  - Olive gray (5Y 4/1), firm, non-plastic
- **69.0 - 76.5' Coal** [Middle Knobloch]
  - Black, hard, cleated multiple times, no visible impurities
- **76.5 - 79.5' Shale**
  - Light olive gray (5Y 5/2), moderate plasticity, soft to moderately firm
- **79.5 - 80.0' Coal**
  - Black, thin stringer, cleated multiple times, hard
- **80.0 - 97.0' Siltstone**
  - Dry, light olive gray (5Y 5/2) to medium light gray (N6), mostly moderate firm with intercalcated, hard, yellowish gray (5Y 7/2), mildly calcareous, some fine sandstone at 80'-82'
- **97.0 - 119.0' Sandstone**
  - Medium light gray, light olive gray, soft to stiff at 97'-110', then very soft. Moderately fine grained interbedded shale, yellowish gray (5Y 7/2), hard calcareous layers at (97'-103'), and (115'-116'). Blew with rig air - yield =~5 gpm
119.0 - 136.0' Claystone/siltstone
  Light olive gray (5Y 6/1), soft to moderately firm; moderately fine grained interbedded shale, yellowish gray (5Y 7/2), hard

136.0 - 146.5' Coal [Lower Knobloch]
  Wet, making water, black, cleated on multiple planes, hard

146.5 - 147.0' Siltstone [Bedrock]
  Medium light gray, firm to moderately stiff
Remarks: Lithology based on well B10-U, checked cuttings for verification. Drill to 20' with a 7 7/8" drag bit, drive 8" steel to 20', injecting water at 35°. Yield is 1.2 gpm, removed ~48 gallons total. Upon well completion very turbid, dark brown color, SC=4930 µmhos/cm, pH=7.75, temp=11.1°C.
**WELL CONSTRUCTION**

- **8" steel +2 - 18**
- **10/20 Silica Sand 28.0**
- **Bentonite Chips 35.0**
- **0.025-inch Slot Screen 30.0**
- **Bottom of Hole 35.0**
- **end cap 35.0**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 3.0' Silty clay** [Colluvium]
  Slightly moist (frost), moderate to dark yellowish brown, moderately cohesive, non-plastic, roots

- **3.0 - 4.0' Silty clay, trace sand with depth** [Colluvium]
  Dry, moderate yellowish brown, loose to dense, roots

- **4.0 - 5.0' Sand, some gravel (2%)** [Colluvium]
  Dry, moderate yellowish brown, loose

- **5.0 - 8.0' Clay, sandy, silty** [Colluvium]
  Dry, moderate yellowish brown, soft, white calcareous nodules/precipitates

- **8.0 - 15.0' Clayey sand (clay & sand)** [Alluvium/Colluvium]
  Dry, moderate yellowish brown, loose to moderately dense, thickly interlayered, trace gravel (1-2%), clinker flat, light brown, major sand layers at 8'-11' and at 14'-15'

- **15.0 - 30.0' Claystone, very silty, interbedded siltstone** [Bedrock]
  Dry to very moist with depth, multicolored pale and moderate yellowish brown, light olive gray and grayish orange (10YR 7/4), mild reaction to HCl (calcereous), most very hard, some soft with moderate plasticity, rolls to 1/8" when wet

- **30.0 - 33.5' Coal**
  Wet, makes ~5 gpm, injecting water; black (N1), moderately weathered, cleated on multiple planes, moderately firm

- **33.5 - 35.0' Carbonaceous shale**
  Dry, brownish gray (5YR 4/1) to olive gray (5Y 4/1), firm to stiff
### WELL CONSTRUCTION

<table>
<thead>
<tr>
<th>DEPTH</th>
<th>MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Bentonite Chips</td>
</tr>
<tr>
<td>2.0</td>
<td>8&quot; steel +2 - 3'</td>
</tr>
<tr>
<td>3.0</td>
<td>8&quot; steel 10'-30'</td>
</tr>
</tbody>
</table>

### GEOLOGICAL DESCRIPTION

- **0.0 - 3.0'**: Silty clay
  - [Colluvium]
  - Slightly moist (frost), moderate to dark yellowish brown, moderately cohesive, non-plastic, roots
- **3.0 - 4.0'**: Silty clay, trace sand with depth
  - [Colluvium]
  - Dry, moderate yellowish brown, loose to dense, roots
- **4.0 - 5.0'**: Sand, some gravel (2%)
  - [Colluvium]
  - Dry, moderate yellowish brown, loose
- **5.0 - 8.0'**: Clay, sandy, silty
  - [Colluvium]
  - Dry, moderate yellowish brown, soft, white calcareous nodules/precipitates
- **8.0 - 15.0'**: Clayey sand (clay & sand)
  - [Alluvium/Colluvium]
  - Dry, moderate yellowish brown, loose to moderately dense, thickly interlayed, trace gravel (1-2%), clinker flat, light brown, major sand layers at 8'-11' and at 14'-15'
- **15.0 - 30.0'**: Claystone, very silty, interbedded siltstone
  - [Bedrock]
  - Dry to very moist with depth, multicolored pale and moderate yellowish brown, light olive gray and grayish orange (10YR 7/4), mild reaction to HCl (calcareous), most very hard, some soft with moderate plasticity, rolls to 1/8" when wet
- **30.0 - 33.5'**: Coal
  - Wet, makes ~5 gpm, injecting water; black (N1), moderately weathered, cleated on multiple planes, moderately firm
- **33.5 - 36.0'**: Carbonaceous shale
  - Dry, brownish gray (5YR 4/1) to olive gray (5Y 4/1), firm to stiff
- **36.0 - 40.0'**: Shale
  - Dry, light brownish gray (5YR 6/1) and light olive gray (5Y 6/1) to brownish black (5Y 2/1), carbonaceous, firm
- **40.0 - 66.5'**: Coal
  - [Knobloch]
  - Wet, black, hard, cleated multiple times, no visible impurities
- **66.5 - 69.0'**: Shale
  - [Middle Knobloch]
  - Dry, thin stringer, cleated multiple times, hard
- **69.0 - 76.0'**: Coal
  - [Middle Knobloch]
  - Black, hard, cleated multiple times, no visible impurities
- **76.0 - 79.5'**: Shale
  - Light olive gray (5Y 5/2), moderate plasticity, soft to moderately firm
- **79.5 - 80.0'**: Coal
  - Black, thin stringer, cleated multiple times, hard
- **80.0 - 97.0'**: Siltstone
  - Dry, light olive gray (5Y 5/2) to medium light gray (N6), mostly moderate firm with intercalated, hard, yellowish gray (5Y 7/2), mildly calcareous, some fine sandstone at 80'-82'
- **97.0 - 119.0'**: Sandstone
  - Medium light gray, light olive gray, soft to stiff at 97'-110', then very soft. Moderately fine grained interbedded shale, yellowish gray (5Y 7/2), hard calcareous layers at (97'-103') and (115'-118')
- **119.0 - 123.0'**: Claystone
  - Light olive gray (5Y 6/1), soft to moderately firm
- **123.0 - 124.0'**: Shale
  - Moderately fine grained interbedded shale, yellowish gray (5Y 7/2), hard

Remarks: Drill to 20' with 7 7/8" bit, ream with 10' bit, drive 20' steel casing (8'). Lost 20' steel down open hole, backfilled with bentonite seal. Static water level in casing lower than open hole, seal ok. Removed approximately 1170 gallons with rig air; upon well completion slightly turbid, SC=1437 µhos/cm, pH=8.70, temp=15.3°C.
## WELL CONSTRUCTION

<table>
<thead>
<tr>
<th>Depth</th>
<th>Formation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>124.0</td>
<td>Siltstone</td>
<td>Light olive gray (5Y 6/1), moderately firm</td>
</tr>
<tr>
<td>135.0</td>
<td>Coal [Lower Knobloch]</td>
<td>Wet, making water, black, cleated on multiple planes, hard</td>
</tr>
<tr>
<td>146.0</td>
<td>Fine sandstone/siltstone</td>
<td>Medium light gray, firm to moderately stiff</td>
</tr>
<tr>
<td>153.0</td>
<td>Sandstone [Bedrock]</td>
<td>Medium light gray, hard, rig chattering at 153'</td>
</tr>
<tr>
<td>154.0</td>
<td>Siltstone/shale</td>
<td>Dry, interbedded fine sandstone, very stiff to hard at 175'-177', Colors from medium light gray to medium dark gray with depth, shale becomes carbonaceous with depth, firm to stiff</td>
</tr>
<tr>
<td>188.0</td>
<td>Sandstone</td>
<td>Very hard, rig chattering, slow to advance</td>
</tr>
<tr>
<td>197.0</td>
<td>Siltstone/interbedded sandstone</td>
<td>Greenish gray to medium light gray, soft to moderately firm</td>
</tr>
<tr>
<td>204.0</td>
<td>Sandstone</td>
<td>Medium light gray, very soft to moderately firm, moderately fine grained</td>
</tr>
<tr>
<td>207.0</td>
<td>Coal</td>
<td>Black, hard cuttings ground, appears cleated</td>
</tr>
<tr>
<td>214.0</td>
<td>Siltstone, sandy</td>
<td>Olive gray (5Y 4/1), moderately firm</td>
</tr>
<tr>
<td>221.5</td>
<td>Siltstone</td>
<td>Light gray to light olive gray (5Y 6/1)</td>
</tr>
<tr>
<td>240'</td>
<td>very thin coal stringer</td>
<td></td>
</tr>
<tr>
<td>250'-253'</td>
<td>very hard cemented interval, rig chattering/slow to advance, medium light gray to light gray, calcareous</td>
<td></td>
</tr>
<tr>
<td>280'-281.5'</td>
<td>carbonaceous shale, medium dark gray</td>
<td></td>
</tr>
<tr>
<td>281.5'</td>
<td>very thin coal stringer</td>
<td></td>
</tr>
<tr>
<td>285'-290'</td>
<td>soft, advanced very quickly</td>
<td></td>
</tr>
<tr>
<td>296'</td>
<td>sandstone stringer</td>
<td></td>
</tr>
<tr>
<td>305'</td>
<td>coal stringer</td>
<td></td>
</tr>
<tr>
<td>310'</td>
<td>very sandy from 310'-315'</td>
<td></td>
</tr>
<tr>
<td>320.0</td>
<td>Coal</td>
<td>Black, cleated on multiple planes</td>
</tr>
<tr>
<td>324.0</td>
<td>Siltstone/shale</td>
<td>Light gray to light olive gray, some yellowish gray (5Y 7/2) shale, intercalculated, mildly calcareous, hard, otherwise only firm.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth</th>
<th>Formation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>326'</td>
<td>Sandstone</td>
<td>Very hard cemented layer, thin</td>
</tr>
</tbody>
</table>

---

**GEOLOGICAL DESCRIPTION**

- 124.0 - 135.0' Siltstone: Light olive gray (5Y 6/1), moderately firm.
- 135.0 - 146.0' Coal [Lower Knobloch]: Wet, making water, black, cleated on multiple planes, hard.
- 146.0 - 153.0' Fine sandstone/siltstone [Bedrock]: Medium light gray, firm to moderately stiff.
- 153.0 - 154.0' Sandstone [Bedrock]: Medium light gray, hard, rig chattering at 153'.
- 154.0 - 188.0' Siltstone/shale: Dry, interbedded fine sandstone, very stiff to hard at 175'-177'. Colors from medium light gray to medium dark gray with depth, shale becomes carbonaceous with depth, firm to stiff.
- 188.0 - 197.0' Sandstone: Very hard, rig chattering, slow to advance.
- 197.0 - 204.0' Siltstone/interbedded sandstone: Greenish gray to medium light gray, soft to moderately firm.
- 204.0 - 207.0' Coal: Black, hard cuttings ground, appears cleated.
- 207.0 - 214.0' Siltstone, sandy: Olive gray (5Y 4/1), moderately firm.
- 214.0 - 221.5' Coal: Black, hard cuttings ground.
- 221.5 - 320.0' Siltstone: Light gray to light olive gray (5Y 6/1).
- 240' very thin coal stringer.
- 250'-253' very hard cemented interval, rig chattering/slow to advance, medium light gray to light gray, calcareous.
- 280'-281.5' carbonaceous shale, medium dark gray.
- 281.5' very thin coal stringer.
- 285'-290' soft, advanced very quickly.
- 296' sandstone stringer.
- 305' coal stringer.
- 310' very sandy from 310'-315'.

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**Continued Next Page**
### WELL CONSTRUCTION

- 360.0' - 370.0' Shale
  - Olive gray to olive black, mildly carbonaceous, firm

- 370.0' - 460.0' Sandstone
  - Medium light gray, very soft, gravels coarser with depth, fine to moderately fine grain; making ~20 gpm

- 10/20 Silica Sand

### GEOLOGICAL DESCRIPTION

- 0.025-inch Slot Screen
- Centralizer
- End cap

**Date Hole Started:** 2/28/2011  
**Date Hole Finished:** 2/28/2011

**Hole Name:** B10-U

**Billings, Montana**

**Hydrometrics, Inc.**
Consulting Scientists and Engineers

**STANDARD_REV3  OTTER CREEK WELL LOGS.GPJ  HYDHLN2.GDT  10/6/14**
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River State: Montana
Property Owner: Great Northern Properties
Legal Description: T4S, R45E, Sec. 23; N467914.49, E 2829529.76
Location Description: B11 Battery East Center

Proposed Mine Area
Recorded By: ajh
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Method: Air Rotary
Drilling Fluids Used:
Purpose of Hole: Install Monitor Well
Target Aquifer: Knobloch Coal
Hole Diameter (in): 7 7/8"
Total Depth Drilled (ft): 313

Well Developed? Y
Water Samples Taken? N
Boring Samples Taken? N

Nothing: 467914.49
East: 2829529.76
Static Water Level Below MP: 190.77
Date: 11/8/2010
Surface Casing Height (ft): 1.70
MP Description: Top PVC
Ground Surface Elevation (ft): 3250.18
MP Height Above or Below Ground (ft): 0.99
MP Elevation (ft): 3251.17

Remarks: Open hole 20-25gpm (est.); SC 1,382 µmhos/cm & 1,442 µmhos/cm. Blew hole with rig air 135-147.5' test for addtl water; makes 1-2gpm including 36' interval which was making 1/4gpm, this interval sealed off but completed as B11-O in different bore hole.

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**WELL CONSTRUCTION**

- **0.0 - 1.0'** Clayey Silt (Topsoil)
  - Dry, grayish orange (10YR 7/4), non-cohesive, calcareous

- **1.0 - 2.0'** Silt, Clayey, grading to shale
  - Dry, grayish orange (10YR 7/4), non-cohesive, calcareous

- **2.0 - 5.0'** Shale [Fort Union Formation]
  - Slightly moist to dry, moderate brown (5YR 3/4), grades to carbonaceous shale

- **5.0 - 7.0'** Coal
  - Dry, dusky brown (5YR 2/2), very soft, weathered, trace pyrite, sulfur

- **7.0 - 13.0'** Claystone
  - Moist, grayish orange (7YR 7/4), mottled gray, calcareous, shell fragments

- **13.0 - 15.5'** Siltstone, Clayey [Fort Union Formation]
  - Moist, greenish gray (5Y 6/1), soft, calcareous, laminated

- **15.5 - 23.0'** Clayey grading to shale
  - Moist, dark yellowish orange (10YR 6/6), calcareous, soft, iron oxide mottled at 17'

- **23.0 - 24.5'** Siltstone
  - Moist, medium dark gray (N4), soft, weakly calcareous; carbonaceous shale at 24.5-25'

- **24.5 - 25.0'** Carbonaceous Shale
  - Brownish gray (5YR 4/1), soft

- **25.0 - 27.0'** Shale
  - Dry, medium light gray (N6), calcareous cemented at base, soft to moderately hard

- **27.0 - 30.0'** Siltstone
  - Moist, light olive gray (5Y 6/1), calcareous, soft, appears massive

- **30.0 - 66.0'** Shale
  - Dry but wet zone (1-2' only) on top of CaCO3 cemented zone (hard) that exists 36.5 - 37', light brown gray to medium gray (N5), makes 1/4 to 1/2gpm with rig air. Note: no springs observed around perimeter of hill. Carbonaceous shale (non

- **66.0 - 67.0'** Silty Sandstone
  - Moist, light olive gray, soft, non-calcaceous

- **67.0 - 70.5'** Shale, carbonaceous
  - Dry, brownish gray (5YR 4/1), soft

- **70.5 - 72.0'** Sandstone, silty, very fine
  - Moist, non-calcaceous, soft

- **72.0 - 102.0'** Shale, carbonaceous to regular
  - Brownish gray to gray, contains silty stringer, calcareous hard stringer at 86.5', becomes fissile at 95'

  Hard CaCO3 cemented shale at 87.5-87.8+-; hard zone at 100 to 100.5'
102.0 - 106.0' Coal
Dry to moist at bottom, cleated 2x, brownish black (5YR 2/1), soft

106.0 - 110.5' Shale
Dry, medium dark gray (N4)

110.5 - 116.0' Shale, carbonaceous
Dry, brownish gray (5YR 4/1) to gray, soft

116.0 - 123.0' Shale, carbonaceous, but silty
Dry, brownish gray (5YR 4/1) to gray, soft

123.0 - 127.0' Coal
Dry, black, cleated 3x

127.0 - 135.0' Shale
Dry, brownish gray (5YR 4/1), carbonaceous shale at top; less at base

135.0 - 147.5' Siltstone, clayey
Moist, light olive gray (5Y 6/1), soft, calcareous, very moist at 140' but no free water at connection, interval yields 0.5 to 1.5 gpm with rig air

147.5 - 179.5' Shale
Dry, brownish gray (5YR 4/1), soft, hard calcareous cemented layer at 147.5-148' and 152-152.5', coal flakes at 159', carbonaceous shale streaks at 169', coal stringer at 176-176.5
Hard, cemented shale, CaCO3 at 147.5-148'
Siltstone at 177-178'

179.5 - 181.0' Coal
Black (N1), soft

181.0 - 187.5' Shale
Dark gray (N3), soft, carbonaceous

187.5 - 189.0' Siltstone grading to silty fine sandstone
Olive gray, non calcareous, soft

189.0 - 201.0' Shale
Brownish gray (5YR 4/1), carbonaceous

201.0 - 206.0' Shale with minimal siltstone

206.0 - 238.0' Shale
Light brownish gray (5YR 6/1), soft, more carbonaceous at 215', CaCO3 cemented at 216.5-217', harder also at 223-223.24', hard at 231', carbonaceous at 233'

238.0 - 312.0' Coal [Knobloch Coal]
Black (N1), cleated 3x, dense, making 10gpm +/- at 300' with rig air, claystone 1 cm to 1 ft at 292-293', no pyrite observed but sulphur odor
Centralizer

313.0 - 313.2' Claystone, silty
Light olive gray, very soft, non-calcareous
WELL CONSTRUCTION

- 1.5" steel +1.5' to -3'
- Bentonite Chips

GEOLOGICAL DESCRIPTION

- 0.0 - 1.0" Clayey Silt [Topsoil]
  - Dry, grayish orange (10YR 7/4), non-cohesive, calcareous
- 1.0 - 2.0" Silt, Clayey, grading to shale
  - Dry, grayish orange (10YR 7/4), non-cohesive, calcareous
- 2.0 - 5.0" Shale [Fort Union Formation]
  - Slightly moist to dry, moderate brown (5YR 3/4), grades to carbonaceous shale
- 5.0 - 7.0" Coal
  - Dry, dusky brown (5YR 2/2), very soft, weathered, trace pyrite, sulfur
- 7.0 - 13.0" Claystone
  - Moist, grayish orange (10YR 7/4), mottled gray, calcareous, shell fragments
- 13.0 - 15.5" Siltstone, Clayey [Fort Union Formation]
  - Moist, greenish gray (5Y 3/1), soft, calcareous, laminated
- 15.5 - 23.0" Claystone
  - Moist to very moist, dark yellowish orange (10YR 5/6), calcareous, soft, balls on bit
- 23.0 - 25.0" Siltstone
  - Moist, medium dark gray (N4), soft, weakly calcareous; carbonaceous shale at 24.5-25'
- 25.0 - 26.0" Carbonaceous Shale
  - Brownish gray (5YR 4/1), soft
- 25.0 - 27.0" Shale
  - Dry, medium light gray (N6), calcareous cemented at base, soft to moderately hard
- 27.0 - 30.0" Siltstone
  - Moist, light olive gray (5Y 6/1), calcareous, soft, appears massive
- 30.0 - 66.0" Shale
  - Hard CaCO₃ layer at 37-37.5', makes less than 1/4gpm, injection at 40'. Hard CaCO₃ layer at 43'; CaCO₃ cemented siltstone at 55-61' numerous calcite crystals
- 66.0 - 68.0" Silty Sandstone
  - Moist, light olive gray, soft, non-calcareous
- 68.0 - 71.0" Carbonaceous shale
  - Dry, brownish gray (5YR 4/1), soft; no siltstone layer
- 71.0 - 72.0" Sandstone, silty, very fine
  - Moist, non-calcareous, soft
- 72.0 - 103.0" Shale, carbonaceous to regular
  - Brownish gray to gray, contains silt stringer, calcareous hard stringer at 86.5', becomes fissile at 95'; hard layers at 88' and 87'

Remarks: Set 20' steel through upper weathered deposits (-18.5'). Developed with bailer, bailed dry, yield at 1 minute intervals +/- 1/2gpm; SC of last bail 7500 µmos/cm, pH=8.26, temp 11.7°C, water level 142 and rising BMP
WELL CONSTRUCTION

103.0 - 107.0' Coal
Dry to moist at bottom, cleated 2x, brownish black (5YR 2/1), soft

107.0 - 110.5' Shale
Dry, medium dark gray (NA)

110.5 - 116.0' Shale, carbonaceous
Dry, brownish gray (5YR 4/1) to gray, soft

116.0 - 124.0' Shale, carbonaceous, but silty
Dry, brownish gray (5YR 4/1) to gray, soft

124.0 - 129.0' Coal
Dry, black, cleated, clay stringer at 127-127.5'

129.0 - 138.0' Shale
Dry, brownish gray (5YR 4/1), carbonaceous shale at top, less at base

138.0 - 141.0' Siltstone, clayey
Moist, light olive gray (5Y 6/1), soft, calcareous, very moist at 140' but no free water at connection

141.0 - 151.0' Siltstone
Medium light gray (N4), hard layer at 148-151', CaCO₃, makes little water 1gpm

GEOLOGICAL DESCRIPTION

10/20 Silica Sand
0.025-inch Slot; centralizer 141'

Bottom of Hole: 151.0'

End cap
**GEOLOGICAL DESCRIPTION**

**WELL COMPLETION**

**DESCRIPTION**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0'</td>
<td>Silt, Clayey [Topsoil] Dry, grayish orange (10YR 7/4), non-cohesive, calcareous</td>
</tr>
<tr>
<td>1.0 - 2.0'</td>
<td>Silt, Clayey, grading to shale Dry, grayish orange (10YR 7/4), non-cohesive, calcareous</td>
</tr>
<tr>
<td>2.0 - 4.0'</td>
<td>Shale [Fort Union Formation] Slightly moist to dry, moderate brown (SYR 3/4), grades to carbonaceous shale at base of interval</td>
</tr>
<tr>
<td>4.0 - 6.0'</td>
<td>Coal Dry, dusky brown (SYR 2/2), very soft, weathered, trace pyrite, sulfur</td>
</tr>
<tr>
<td>6.0 - 12.0'</td>
<td>Claystone Moist, grayish orange (10YR 7/4), mottled gray, calcareous, contains shell fragments</td>
</tr>
<tr>
<td>12.0 - 14.5'</td>
<td>Siltstone, Clayey [Fort Union Formation] Moist, greenish gray (5Y 6/1), soft, calcareous, laminated</td>
</tr>
<tr>
<td>14.5 - 22.0'</td>
<td>Claystone grading to shale Moist, dark yellowish orange (10YR 6/6), calcareous, soft</td>
</tr>
<tr>
<td>22.0 - 24.0'</td>
<td>Siltstone Moist, medium dark gray (N4), soft, weakly calcareous</td>
</tr>
<tr>
<td>24.0 - 24.5'</td>
<td>Shale, carbonaceous Brownish gray (SYR 4/1), soft</td>
</tr>
<tr>
<td>24.5 - 26.0'</td>
<td>Shale Dry, medium light gray (N6), calcareous cemented at base, soft to moderately hard</td>
</tr>
<tr>
<td>26.0 - 29.0'</td>
<td>Siltstone Moist, light olive gray (SYR 6/1), calcareous, soft, appears massive</td>
</tr>
<tr>
<td>29.0 - 66.0'</td>
<td>Shale Dry but wet zone (1’-2” only) on top of CaCO₃ cemented zone (hard) that exists 35 - 36.5’, light brown gray to medium gray (N5), makes 1/4 to 1/2 gpm with rig air. Note: no springs observed around perimeter of hill. Carbonaceous shale (non-calc) 55.0 - 66.0' Silty Sandstone Moist, light olive gray, soft, non-calcareous</td>
</tr>
<tr>
<td>66.0 - 69.5'</td>
<td>Shale, carbonaceous Dry, brownish gray (SYR 4/1), soft</td>
</tr>
<tr>
<td>69.5 - 71.0'</td>
<td>Sandstone, silty, very fine Moist, non-calcareous, soft</td>
</tr>
<tr>
<td>71.0 - 101.0'</td>
<td>Shale, carbonaceous to regular Brownish gray to gray, contains silty stringer, calcareous hard stringer at 86.5’, becomes fissile at 96’</td>
</tr>
<tr>
<td>101.0 - 105.0'</td>
<td>Coal Dry to moist at bottom, cleated 2x, brownish black (SYR 2/1), soft</td>
</tr>
<tr>
<td>105.0 - 109.5'</td>
<td>Shale Dry, medium dark gray (N4)</td>
</tr>
<tr>
<td>109.5 - 115.0'</td>
<td>Shale, carbonaceous Dry, brownish gray (SYR 4/1) to gray, soft</td>
</tr>
<tr>
<td>115.0 - 122.0'</td>
<td>Shale, carbonaceous, but silty Dry, brownish gray (SYR 4/1) to gray, soft</td>
</tr>
</tbody>
</table>

**Remarks:** Inject at 36'; pull steel, set thru upper perched water zone. TDS exceeds 5000ppm, 8”steel to 38.5’bgs. Total est. vol. from open hole ~20gpm during develop, SC combined 1180µmhos/cm, well yield est. +/- 6gpm at 370’ water level with bailer in completed well.
### Well Construction

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>360.0</td>
<td>Bottom of Hole</td>
</tr>
<tr>
<td>380.0</td>
<td>End cap</td>
</tr>
<tr>
<td>370.0</td>
<td>Centralizer</td>
</tr>
<tr>
<td>10/20 Silica Sand; centralizer 358'</td>
<td></td>
</tr>
</tbody>
</table>

### Geological Description

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>122.0 - 127.0'</td>
<td>Coal</td>
</tr>
<tr>
<td>127.0 - 134.0'</td>
<td>Shale</td>
</tr>
<tr>
<td>134.0 - 143.0'</td>
<td>Silty Shale, clayey</td>
</tr>
<tr>
<td>143.0 - 146.0'</td>
<td>Silty Shale with coal stringer, stratified non-calcareous</td>
</tr>
<tr>
<td>146.0 - 176.5'</td>
<td>Shale</td>
</tr>
<tr>
<td>178.5 - 180.0'</td>
<td>Coal</td>
</tr>
<tr>
<td>180.0 - 186.5'</td>
<td>Shale</td>
</tr>
<tr>
<td>186.5 - 188.0'</td>
<td>Silty Shale grading to silty fine sandstone</td>
</tr>
<tr>
<td>188.0 - 203.0'</td>
<td>Shale with minor siltstone</td>
</tr>
<tr>
<td>200.0 - 205.0'</td>
<td>Shale with minor siltstone</td>
</tr>
<tr>
<td>205.0 - 237.0'</td>
<td>Shale</td>
</tr>
<tr>
<td>311.0 - 324.0'</td>
<td>Claystone, silty</td>
</tr>
<tr>
<td>324.0 - 335.0'</td>
<td>Shale</td>
</tr>
<tr>
<td>335.0 - 340.0'</td>
<td>Silty Shale</td>
</tr>
<tr>
<td>340.0 - 343.0'</td>
<td>Fine Sandstone</td>
</tr>
<tr>
<td>343.0 - 350.0'</td>
<td>Silty Shale</td>
</tr>
<tr>
<td>350.0 - 352.0'</td>
<td>Sandstone fine to medium, silty</td>
</tr>
<tr>
<td>352.0 - 354.0'</td>
<td>Silty Shale</td>
</tr>
<tr>
<td>354.0 - 357.0'</td>
<td>Coal</td>
</tr>
<tr>
<td>357.0 - 360.0'</td>
<td>Sandstone</td>
</tr>
<tr>
<td>360.0 - 380.0'</td>
<td>Shale</td>
</tr>
<tr>
<td>380.0 - 380.5'</td>
<td>Shale</td>
</tr>
</tbody>
</table>

**Notes:**
- Dry, black, cleated 3x, coal stringer at 290', making 10gpm +/- at 300' with rig air.
- Light brown gray (5YR 6/1), moderate hard, carboniferous, becomes medium sandstone and better sorted with depth, less coal with depth, approximately 6 gpm yield, appears to have picked up more water.
- Yellowish gray (5Y 8/1), moderately hard, carboniferous.
**Well Construction**

- **0.0 - 20.0'**: Silty clayey sand loam (Colluvium)
  - Dry to slightly moist; reddish gray - reddish brown; mixed sand, clay, silt, clinker chips to <3/4"; sub-angular, flat, loose, soft, no plasticity/no cohesiveness; coarse grain to very coarse grain; at 20' increase in moisture - damp

- **25.0**: 10/20 Silica Sand

- **40.0**: 0.025-inch Slot Screen

**Geological Description**

- **0.0 - 20.0'**: Silty clayey sand loam (Colluvium)
  - Damp; reddish gray - reddish brown; mixed sand, clay, silt, clinker chips to <3/4"; sub-angular, flat; loose, soft, no plasticity/no cohesiveness; coarse grain to very coarse grain
  - 33' first groundwater (driller)

- **30.0 - 40.0'**: Silty clayey sand loam (Colluvium)
  - Wet - saturated at 33'; reddish gray - reddish brown; mixed sand, clay, silt, clinker chips to <3/4"; sub-angular to flat; loose, soft, no plasticity/no cohesiveness; coarse grain to very coarse grain
  - No pea gravels/no alluvium as was present in B12-U

**Well Data**

- **Well Name**: B12-CO
- **Date Hole Started**: 6/4/14
- **Date Hole Finished**: 6/5/14

**Well Completion**

- **Well Installed?**: Y
- **Surface Casing Used?**: Y
- **Screen/Perforations?**: Y
- **Sand Pack?**: Y
- **Annular Seal?** Y
- **Surface Seal?**: Y

**Well Developed?**: Y

**Water Samples Taken?**: N

**Boring Samples Taken?**: N

**Static Water Level Below MP**: 29.47

**Date**: 6/10/2014

**MP Description**: BMP (TOPVC)

**MP Height Above or Below Ground (ft)**

- **0'-25'**: 2.00
- **25'-40'**: 1.37
- **40'+2'**: 1.37

**Remarks**: Approximately 2.0 to 2.5 gpm; 39 bails/30 minutes; SC= 5,340 µmhos/cm.
**Hole Name: B12-LK**

**Date Hole Started:** 6/3/14  
**Date Hole Finished:** 6/3/14

---

**Well Construction**

- **Steel:** 8" (0.25" thickwall) + 2.00' - 38'
- **Bentonite Chips:** 0.1

---

**Geological Description**

- **0.0 - 26.0' Clinker gravel [Alluvium & Colluvium]**
  - Pale red; mix of clinker, clay-silt loam, sand; angular sub-round pieces to 1.25" and less.
  - Moisture increases with depth

- **26.0 - 32.0' Sandstone, large blocks (1"x8" max)**
  - Red-orange-tan clinker gravel with high clay-sand percentage
  - 3' first groundwater (driller)

- **32.0 - 38.0' Sandstone [Colluvium]**
  - Wet, saturated; no large sandstone blocks

- **38.0 - 45.0' Weathered bedrock [Bedrock]**
  - Gray silt; slightly sandy; damp

- **45.0 - 66.0' Coal [Upper Knobloch (2)]**
  - Bluish-gray, fissile, soft to medium hard to soft; minor brittleness; non-plastic, non-cohesive; medium density

- **66.0 - 80.0' Clay shale**
  - Bluish-gray; becoming more silty about 75'

- **80.0 - 95.0' Shale**
  - Bluish-gray; minor cohesion; moderately dense; brittle; silty; at 90' seems to be softer less dense with depth

- **95.0 - 96.5' Coal**
  - Greenish-gray, fissile, soft to medium hard to soft; minor brittleness; non-plastic, non-cohesive; medium density

- **96.5 - 108.0' Shale**
  - Greenish-gray, siltstone-mudstone

- **108.0 - 110.0' Hard silty sandstone**
  - Olive brown; very fine grain

- **110.0 - 128.0' Shale**
  - Brownish, greenish-gray to bluish-gray

- **128.0 - 136.0' Siltstone-mudstone**
  - Dark yellowish-brown; no bedding; fractured into flakes 3/8"

- **136.0 - 137.0' Coal**

- **137.0 - 140.0' Silty shale**
  - Gritty minor sand content

- **140.0 - 152.0' Coal [Upper Knobloch (1)]**

- **152.0 - 160.0' Shale**
  - Greenish-gray, sandy-silt to 155-160'; very fine grain; silty, gritty feel; stiff; minor fissility; dense

- **160.0 - 163.0' Silty sandy shale**
### Geological Description

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.025 - 240.0</td>
<td><strong>Sandstone</strong>&lt;br&gt;Bluish-gray; silty; very fine grain; dense; becoming less dense (less stiff) with depth; increase in shale content below 178'; sandstone, very weak, silty, very fine grain; salt and pepper texture, light bluish-gray; becoming loose sand with depth</td>
</tr>
<tr>
<td>203.0 - 205.0</td>
<td><strong>Mudstone</strong>&lt;br&gt;Grayish-yellow; very hard</td>
</tr>
<tr>
<td>205.0 - 207.0</td>
<td><strong>Sandstone with calcite (yellow) Healed Fracture (?)</strong>&lt;br&gt;Frac-face; large crystals encrusted onto bluish-gray sandstone; hard</td>
</tr>
<tr>
<td>207.0 - 208.0</td>
<td><strong>Mudstone/Sandstone</strong>&lt;br&gt;Mixed brown chert, yellowish-gray mudstone; bluish-gray sandstone; hard</td>
</tr>
<tr>
<td>208.0 - 220.0</td>
<td><strong>Silty sandstone</strong>&lt;br&gt;Bluish-gray with minor coal</td>
</tr>
<tr>
<td>220.0 - 223.0</td>
<td><strong>Carbonaceous shale</strong>&lt;br&gt;Brownish-black; moderately dense; non-plastic-no cohesion; stiff</td>
</tr>
<tr>
<td>223.0 - 239.0</td>
<td><strong>Coal [Lower Knobloch]</strong>&lt;br&gt;Black</td>
</tr>
<tr>
<td>239.0 - 240.0</td>
<td><strong>Shale</strong>&lt;br&gt;Bluish-gray; moderately dense - soft; low cohesiveness</td>
</tr>
</tbody>
</table>
**GEOLOGICAL DESCRIPTION**

- **0.0 - 2.0’** Clayey silt
  - Moderately brown; moist; minor sand

- **2.0 - 6.0’** Silty sand, Very fine to fine
  - Moderately brown; moist; non-cohesive; non-plastic

- **6.0 - 10.0’** Sedimentary clinker gravel
  - Orange platy clinker to 1”; silty sand; no rounded gravels; sub-round clinker and medium grain sandstone blocks to 3”

- **10.0 - 13.0’** As above with sandstone blocks to 1” x 6”
  - Grayish-yellow; medium grain; cohesive; consolidated

- **13.0 - 25.0’** Silty sand, clayey
  - Yellowish-gray; slightly moist; clinker chips to 1”; platy; minor consolidated; sandstone (<1” x 2”)

- **25.0 - 30.0’** Silty sand, clayey
  - Wet; clay silt with clinker gravel and light gray silty sandstone; plastic

- **30.0 - 35.0’** Clinker and bedrock (sandstone) gravel
  - Wet; sub-round - round; unconsolidated; fragments to <1”; non-plastic, non-cohesive; pea size gravel

- **35.0 - 40.0’** Silty clay [Weathered Bedrock]
  - Bluish-green; slightly moist; cohesive; fine grained; soft; minor plasticity and minor cohesion, weathered

- **40.0 - 45.0’** Silty clay
  - Bluish-green; slightly moist; cohesive; fine grained; soft; minor plasticity and minor cohesion

- **45.0 - 50.0’** Coal [Upper Knobloch (2)]
  - Wet; black with orange stain on frac face; fractured with cleats to 1”; hole making water, began rig injection (potable water)

- **50.0 - 66.0’** Coal [Upper Knobloch (2)]
  - Wet; black without orange stain; fine fractures <1/4”; hole making 4 to 5 gpm; conductivity 2,870 µmhos (maximum)

- **66.0 - 67.0’** Clay
  - Bluish-gray - slight greenish; fissile; cohesive; moderately stiff - minor plastic (low)

- **67.0 - 70.0’** Shale
  - Bluish-gray; cohesive; fissile; stiff; non-plastic; cuttings to 1” typical

- **70.0 - 85.0’** Siltstone
  - Light bluish-gray; very fine grained; brittle; silty-sandy

- **85.0 - 95.0’** Shale
  - Bluish-gray; light cohesion, non-plastic; becoming silty with depth

**Remarks:** At 10:38 a.m. began drilling with kelly rod. Well development: seven (7) gallons/bail x 42 bails = 294 gallons, 30 minutes bailing. Water level at start of development (100.74’ BTOSC), end of development water level at 214’ BTOSC, rising 6’ per minute, TDS = 966 ppm
95.0 - 96.0' Coal
96.0 - 113.0' Shale
Greenish-gray; fissile; non-plastic; brittle; silty sand streak at 106' - 107'

113.0 - 115.0' Shale
Brownish-gray; hard

115.0 - 130.0' Shale
Greenish-gray; fissile; brittle; non-plastic; non-cohesive; stiff

130.0 - 135.0' Mudstone
Pale yellowish-brown; hard; brittle

135.0 - 136.0' Shale
Greenish-gray; fissile; brittle; non-plastic; non-cohesive; stiff

136.0 - 136.5' Coal
Black; brittle

136.5 - 140.5' Silty sand
Pale yellowish-brown; fissile; hard; brittle

140.5 - 153.0' Coal [Upper Knobloch (1)]
Black; brittle

153.0 - 157.0' Shale
Greenish-gray

157.0 - 157.5' Sandstone
Yellowish-gray; fine grain to medium grain; hard

157.5 - 160.0' Shale
Bluish-gray; fissile; non-plastic; non-cohesive; stiff

160.0 - 180.0' Shale, silty
Bluish-gray; fissile; non-plastic; non-cohesive; stiff; at 167' slight increase in sandy content

180.0 - 215.0' Sand
Bluish-gray; very fine grain to medium grain; loose; silty; at 270' and 290' hard mudstone; at 205' petrified tree material

215.0 - 220.0' Sand
Moderate yellowish brown; thin streaks of hard mudstone; calcareous

220.0 - 238.0' Coal [Lower Knobloch]
Black

238.0 - 257.0' Shale
Light bluish-gray; platy; fissile; non-cohesive, non-plastic; soft
**GEOLOGICAL DESCRIPTION**

- **250.0 - 256.0'** Coal
  - Wet; dark yellowish-brown; medium grain; loose; not consolidated

- **257.0 - 258.0'** Sand
  - Wet; dark yellowish-brown; medium grain; loose; not consolidated

- **275.0 - 278.0'** Mixed sand and coal
  - Wet; dark yellowish-brown; medium grain; loose; not consolidated

- **285.0 - 300.0'** Silty sandstone
  - Moderately stiff

- **285.0 - 300.0'** Silty shale
  - Bluish-gray; silty; stiff; increase in silty toward 300'; at 285' to 300' mixed coal and shale
### WELL CONSTRUCTION

- **8" steel (0.25" thick wall) +2.00'-41'**
- **10/20 Silica Sand**
- **Bentonite Chips**

### GEOLOGICAL DESCRIPTION

#### 0.0 - 2.0'
- **Sandy silty loam**
- Pale red - grayish red; dry; fragments <1/4 to ~1" diameter; angular to sub-angular

#### 2.0 - 20.0'
- **Clinker, clay, silt, sand**
  - Pale red - grayish red; dry; fragments <1/4 to ~1" diameter; angular to sub-angular
- **Clinker gravel (1/4 to 3/4")**
- Wet - nearly saturated; grayish red; clayey silty
- **30' first groundwater (driller)**

#### 20.0 - 35.0'
- **Silty shale**
  - Bluish-gray; not saturated - damp

#### 35.0 - 44.0'
- **Coal**
  - [Upper Knobloch (2)]

#### 44.0 - 65.0'
- **Shale**
  - Yellowish-bluish-gray; dry; stiff; fissile; non-plastic, non-cohesive

#### 65.0 - 75.0'
- **Shale**
  - Light to dark olive gray; fissile; medium dense; non-plastic, no cohesion; becoming bluish-gray with depth
  - **Silty shale**
  - Bluish-gray; becoming more silty; gritty feel

#### 75.0 - 80.0'
- **Shale**
  - Yellowish-bluish-gray; dry; stiff; fissile; non-plastic, non-cohesive

#### 80.0 - 94.0'
- **Coal**
  - [Upper Knobloch (2)]

#### 94.0 - 95.0'
- **Shale**
  - Bluish-gray to greenish-gray; more sand/silt with depth
  - **Sandstone**
  - Olive gray; very hard; stiff; very fine grain
  - **Shale, slightly silty**
  - Olive gray to greenish-gray; dry; medium dense; brittle; fissile; no plasticity, no cohesion; At 130' an increase in silt (fine sand?)

#### 104.0 - 105.0'
- **Sandstone**

#### 105.0 - 135.0'
- **Shale**
  - Bluish-gray to greenish-gray; dry; medium dense; brittle; fissile; no plasticity, no cohesion; At 130' an increase in silt (fine sand?)

#### 135.0 - 136.0'
- **Coal**
  - [Upper Knobloch]
  - **Siltstone, shaley**
  - Greenish-gray; dry; medium dense; becoming yellowish-brown

#### 136.0 - 150.5'
- **Coal**
  - [Upper Knobloch]

#### 150.5 - 151.0'
- **Silty shale**
  - Greenish-gray; medium dense; fissile; no plasticity, no-cohesion

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Remarks: Bailed 37 minutes, ~32 bails estimate 156 gallons; water level at start of development 59.5' BTOSC; water level immediately after development 137.5' BTOSC; water quality at 4,664 μmhos/cm; well making ~3 gpm; surface casing pilot hole 11" diameter to 19' below ground level (bgl) - 14 bags Hole Plug in annulus
**Client:** Arch Coal  
**Project:** Otter Creek Mine Permit (10068)  
**County:** Powder River  
**State:** Montana  
**Legal Description:** T4S, R46E, S31 NESENE  
**Location Description:** B12 Battery near Coal Creek  
**Recorded By:** JS  
**Drilling Company:** Askin Drilling  
**Driller:** Doug Askin  
**Drilling Method:** Air Rotary  
**Drilling Fluids Used:** Potable Water  
**Purpose of Hole:** Install Monitor Well  
**Target Aquifer:** Upper Knobloch 2 Coal  
**Hole Diameter (in):** 7 7/8"  
**Total Depth Drilled (ft):** 65

**WELL COMPLETION Y/N DESCRIPTION INTERVAL**  
- Well Installed? Y 4.5" Sch 40, PVC  +1.05'AGL - 65'  
- Surface Casing Used? Y 8" steel 0.250" wall  +1.65'AGL - 38'  
- Screen/Perforations? Y 0.025-inch slot, Sch 40 PVC  43'-65'  
- Sand Pack? Y 10/20 Silica Sand  42'-65'  
- Annular Seal? Y Bentonite Chips  0'-42'  
- Surface Seal? Y Bentonite around steel csg

**DEVELOPMENT/SAMPLING**  
- Well Developed? Y Bailed  
- Water Samples Taken? N  
- Boring Samples Taken? N

**WELL CONSTRUCTION**  
- 0.0 - 2.0' Sandy, silty loam  
- 2.0 - 42.0' Mixture of clay, sand, silt, clinker [Colluvium]  
- Reddish-brown - grayish-red; dry to moist; clinker chips to 1/2"; chips flat; sub-angular; loose materials; soft; very coarse grain; no plasticity, no cohesion; moisture increases with depth - damp, clay begins to agglomerate (bond). Large sandstone blocks below 25', sub-angular to sub-round, no gravels like in B12-U.  
- 30' first groundwater (driller)

**GEOLOGICAL DESCRIPTION**  
- 42.0 - 43.0' Coal [Upper Knobloch (2)]  
- Black, orange mottling stain on frac face; no stain below 46'

**Remarks:** Bailed for 30 minutes, 17 bails, <1/2 gallon per minute; centralizers installed; however not recorded. Water level prior to development 54.3' BTOSC on June 4, 2014 at 1:30 p.m.; water level at 44.30' BTOSC on June 5, 2014 at 8:35 a.m.
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River  State: Montana
Property Owner: Ark Land Company
Legal Description: T3S R45E Sec 27 NENW; N 492160.74, E 2822873.31
Location Description: 15’ North of B1U, just West of Stevens corrals
Recorded By: HJK
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Method: Air Rotary
Drilling Fluids Used: None
Purpose of Hole: Install Monitor Well
Target Aquifer: Knobloch Coal
Hole Diameter (in): 7 7/8”
Total Depth Drilled (ft): 37.5

Well Installed? Y 4.5” Sch 40, PVC
Surface Casing Used? Y 8” steel
Screen/Perforations? Y 0.025-inch slot, Sch 40 PVC
Sand Pack? Y 10/20 Silica Sand
Annular Seal? Y Bentonite Chips
Surface Seal? N

Well Developed? Y Air Lift for 20 Minutes
Water Samples Taken? N
Boring Samples Taken? N

Nothing: 492160.74  Easting: 2822873.31
Static Water Level Below MP: Dry  Surface Casing Height (ft): 2.28
Date:  Riser Height (ft): 1.83
MP Description: Ground Surface Elevation (ft): 3077.39
MP Height Above or Below Ground (ft): 1.83  MP Elevation (ft): 3079.23

Remarks: Well completed 15:45 pm; bailed for water - dry at 1600 hours 12/28/2010.  Dry on 12/29/10

GEOLOGICAL DESCRIPTION

0.0 - 6.0’ Clayey silt
Slightly moist, fine gravels; moderate brown (5YR 4/4), roots, becomes sandy with depth, soft, slightly calcareous

6.0 - 7.0’ Sand
Slightly moist, medium grained, light olive gray (5Y 5/2)

7.0 - 9.0’ Sand and gravel [Alluvium/Colluvium]
Clinker gravels, moderate reddish brown (10R 4/6), dry

9.0 - 19.0’ Shale-baked [Bedrock:Clinker]
Dry, moderate orange pink (10R 7/4) and grayish pink (10R 8/2), hard/brittle

19.0 - 29.0’ Shale-baked [Clinker]
Dry, light olive gray (5Y 6/1) with black streaks, angular, brittle, moist at 25’

29.0 - 34.0’ Clay (Ash)
Wet, pale gray pink, clays and some fine sandstone

34.0 - 37.5’ Claystone
Light olive gray (5Y 6/1), firm, greasy

WELL CONSTRUCTION

- Bentonite Chips
- 0.025-inch Slot Screen
- 0.0 - 6.0’ Clayey silt
- 6.0 - 7.0’ Sand
- 7.0 - 9.0’ Sand and gravel [Alluvium/Colluvium]
- 9.0 - 19.0’ Shale-baked [Bedrock:Clinker]
- 19.0 - 29.0’ Shale-baked [Clinker]
- 29.0 - 34.0’ Clay (Ash)
- 34.0 - 37.5’ Claystone
- 37.0’ end cap
WELL COMPLETION  Y/N  DESCRIPTION  INTERVAL
Well Installed?  Y  4.5" Sch 40, PVC  +2-90
Surface Casing Used?  Y  8" steel  +2-38
Screen/Perforations?  Y  0.025-inch slot, Sch 40 PVC  60-90
Sand Pack?  Y  10/20 Silica Sand  49-90
Annular Seal?  Y  Bentonite Chips  0-49
Surface Seal?  N

GEOLOGICAL DESCRIPTION

0.0 - 6.0' Clayey silt
Slightly moist, fine gravels; moderate brown (5YR 4/4), roots, becomes sandy with depth, soft, slightly calcareous

2.0  8" steel

8" .33 wall

4.0 - 7.0' Sand
Medium grain, slightly moist, light olive gray (5Y 5/2)

7.0 - 9.0' Sand and gravel [Alluvium/Colluvium]
Clinker gravels, moderate reddish brown (10R 4/6), dry

9.0 - 19.0' Shale-baked [Bedrock/Clinker]
Dry, moderate orange pink (10R 7/4) and grayish orange pink (10R 8/2), hard/brittle

19.0 - 29.0' Shale-baked [Clinker]
Light olive gray (5Y 6/1) with black streaks, angular, brittle and dry, moist at 25'

29.0 - 34.0' Clay (Ash)
Moist, pale pink, soft, pale yellowish orange (10YR 8/6)

34.0 - 35.0' Sandstone, altered [Clinker]
Dark reddish brown and dusky brown, moderately hard

35.0 - 36.0' Clay/silt (Ash)
Moist, soft, pale pink

36.0 - 40.0' Mudstone [Bedrock]
Wet, moist, soft, greenish gray (5G 6/1), black carbonaceous streaks

40.0 - 44.0' Siltstone [Bedrock]
Slightly moist, soft, carbonaceous (plant remains visible), pale yellowish brown (10YR 6/2), dry at 43'

44.0 - 45.0' Siltstone
Slightly moist, soft, carbonaceous (plant remains visible), stained to dark yellowish orange (10YR 6/6)

45.0 - 46.0' Siltstone
Slightly moist, soft, carbonaceous (plant remains visible), back to gray

46.0 - 47.0' Fine sand/silt
Moist, soft, light gray

47.0 - 60.0' Fine sand
Wet, light olive gray (5Y 5/2), poorly cemented, arenite, black/salt-pepper, (adding 18 gpm drilling from 50-60'), making about 7-10 gpm at 60'

60.0 - 70.0' Fine sand
Light olive gray (5Y 5/2) to yellowish olive gray, micaeous, slightly better cemented at 75-80', some medium/coarse fragments

70.0 - 80.0' Fine sand
Light olive gray (5Y 5/2) to yellowish olive gray, micaeous, flaggy sandstone fragments (making 50 gpm)

80.0 - 83.0' Claystone
Firm, olive gray (5Y 4/1), minor black organic inclusions

83.0 - 90.0' Bentonite Chips

90.0 - End cap

0.025-inch Slot Screen

Centralizer

Bottom of Hole

CLAYEN COMPANY
Billings, Montana

Hydrometrics, Inc.
Consulting Scientists and Engineers

Sheet 1 of 1
## WELL CONSTRUCTION

- **8" steel**
- **Bentonite Chips**

## GEOLOGICAL DESCRIPTION

- **0.0 - 1.0' Silt with shale bedrock fragments**
  - Topsoil
  - Dry, dark yellowish orange, soft, loose, roots, debris

- **1.0 - 5.0' Shale**
  - Fort Union Formation/Bedrock
  - Dry, light brown (5YR 5/6) to moderate yellowish brown (10YR 5/4), soft to firm

- **5.0 - 6.5' Coal shale**
  - Dry, brownish gray to dark yellowish brown, soft to firm

- **6.5 - 10.0' Coal**
  - Dry, dusky yellowish brown (10YR 2/2) to black, stiff, brittle, well fractured/cleated

- **10.0 - 25.0' Siltstone, some very fine sandstone**
  - Dry, very soft, many colors: pale yellowish brown to light olive gray at 10-12'; light brown (5YR 5/6) at 12-13'; light gray at 13-14'; moderate yellowish brown at 14-14.5'; light gray at 15-25'; carbonaceous shale at 14.5-15'

- **25.0 - 34.0' Shale**
  - Dry, medium gray to brownish gray, firm to stiff, carbonaceous from 25-30' (dark brown)

- **34.0 - 41.0' Siltstone, some very fine sandstone**
  - Dry to slightly moist, medium light gray, soft to firm, some very thin dark beds

- **41.0 - 43.0' Coal**
  - Dry, dusky yellowish brown and moderate brown, impurities, pyrite

- **43.0 - 54.5' Shale**
  - Dry, medium gray color to moderate olive brown, firm, carbonaceous at 43-44' and at 54', some calcareous at 51-51.5' gray cemented zone, very hard

- **54.5 - 57.0' Sandstone**
  - Moist, medium gray, soft; not making water

- **57.0 - 65.0' Shale**
  - Dry, medium gray, firm, carbonaceous stringer at 59'. Medium light gray, very hard cemented zone, calcareous at 63-64'

- **65.0 - 75.0' Siltstone, interbedded sandstone**
  - Dry to slightly moist, medium light gray, soft

- **75.0 - 126.5' Silty fine sandstone**
  - Medium light gray, soft, very moist at 81', cemented zone at 85', intercalcated shale at 85-93', less shale, sandstone hardness to some firm at 93'

- **126.5 - 128.5' Coal**
  - Black, cleated, blochy, stiff

- **128.5 - 160.0' Shale**
  - Medium dark gray, stiff, carbonaceous at 128.5-130', becomes silty at 145', mild color change to medium gray

- **160.0 - 165.0' Fine to very fine sandstone**
  - Dry, medium light gray to light olive gray (5Y 6/1)

- **165.0 - 190.0' Siltstone, some very fine sandstone in top 5'**
  - Dry, medium gray, firm, cemented zone at 184'

Remarks: Drill with 7 7/8" bit to 20', ream with 11 3/4". Stopped at 220' to check sandstone, blew with rig air, SC= injection water. Start development with bailer at 3:00p.m. bailed at 7 gal/35s. Removed ~240 gallons
WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

190.0 - 195.0' Sandstone
Dry, medium gray, firm

195.0 - 217.0' Siltstone, some very fine sandstone in top 5'
Dry, medium gray, firm, very thinly bedded coal stringer at 195.5' (trace), thin cemented light brown shale at 202'

217.0 - 222.0' Sandstone, fine grain, silty
Medium gray, soft to firm, blew with rig air, not making water

222.0 - 242.0' Shale, inter calcitated sandstone
Dry, medium gray, traces very hard light brown shale (non-calcareous), carbonaceous at 222', very thin coal stringer, black, hard.
Less to no sand at 236-242'

242.0 - 303.5' Coal [Kroblach]
Black, no visible impurities, possibly cleated on multiple planes

303.5 - 304.0' Sandstone, silty, fine grain [Bedrock]
Medium light gray, firm to stiff

Date Hole Started: 1/26/2011
Date Hole Finished: 1/26/2011
Billings, Montana
**WELL CONSTRUCTION**

- **WELL COMPLETION**
  - Well Installed? Y
  - Surface Casing Used? Y
  - Screen/Perforations? Y
  - Sand Pack? Y
  - Annular Seal? Y
  - Surface Seal? N

- **INTERVAL**
  - 0-130
  - +2-18
  - 80-130
  - 66-130
  - +1-66

- **DESCRIPTION**
  - Bentonite Chips
  - 0.025-inch slot, Sch 40 PVC
  - 10/20 Silica Sand
  - Sand Pack
  - Annular Seal

- **DEVELOPMENT/SAMPLING**
  - Well Developed? Y
  - Water Samples Taken? N
  - Boring Samples Taken? N

- **Static Water Level Below MP:** Dry
- **Surface Casing Height (ft):** 2.01
- **Riser Height (ft):** 1.64
- **Ground Surface Elevation (ft):** 3269.76
- **MP Elevation (ft):** 3271.4

**HYDROGEOLOGICAL DESCRIPTION**

- **8" steel**
- **10/20 Silica Sand**
- **centralizer**
- **end cap**

- **0.0 - 1.0' Silt with shale bedrock fragments**
  - [Topsoil]
  - Dry, dark yellowish orange, soft, loose, roots, debris
- **1.0 - 5.0' Shale [Fort Union Formation/Bedrock]**
  - Dry, light brown (5YR 5/6) to moderate yellowish brown (10YR 5/4), soft to firm
- **5.0 - 6.5' Coal shale**
  - Dry, brownish gray to dark yellowish brown, soft to firm
- **6.5 - 10.0' Coal**
  - Dry, dusty yellowish brown (10YR 2/2) to black, stiff, brittle, well fractured/cleated
- **10.0 - 25.0' Siltstone, some very fine sandstone**
  - Dry, very soft, many colors: pale yellowish brown to light olive gray at 10-12'; light brown (5YR 5/6) at 12-13'; light gray at 13-14'; moderate yellowish brown at 14-14.5'; light gray at 15-25';
  - Carbonaceous shale at 14.5-15'
- **25.0 - 34.0' Shale**
  - Dry, medium gray to brownish gray, firm to stiff, carbonaceous from 25-30' (dark brown)
- **34.0 - 41.0' Siltstone, some very fine sandstone**
  - Dry to slightly moist, medium light gray, soft to firm, some very thin dark beds
- **41.0 - 43.0' Coal**
  - Dry, dusty yellowish brown and moderate brown, impurities, pyrite
- **43.0 - 54.5' Shale**
  - Dry, medium gray color to moderate olive brown, firm, carbonaceous at 43-44', some calcareous at 54', light gray cemented zone at 51-51.5', very hard, calcareous, reacts with acid
- **54.3 - 57.0' Sandstone**
  - Moist, medium gray, soft
- **57.0 - 65.0' Shale**
  - Dry, medium gray, firm, carbonaceous stringer at 59'. Medium light gray, very hard cemented zone, calcareous at 63-64'
- **65.0 - 75.0' Siltstone, interbedded fine sandstone**
  - Dry to slightly moist, medium light gray, soft
- **75.0 - 126.5' Sandstone at 75' (less silt than above)**
  - Medium light gray, thin cemented shale stringer, calcareous at 80', very moist at 81', injecting water, cemented zone at 85', intercalculated shale at 85-93', less shale but sandstone hardness to some firm.
  - Very hard grayish orange shale at 108-109'

- **126.5 - 130.0' Coal**
  - Black, cleated, blochy, stiff
- **128.5 - 130.0' Shale**
  - Medium dark gray, stiff, carbonaceous at 128.5-130', becomes silty at 145', mild color change to medium gray

### WELL CONSTRUCTION

- **Below PVC**
  - Bentonite Chips
  - Silt with shale bedrock fragments

- **6.5 - 10.0'**
  - Coal

- **10.0 - 25.0'**
  - Siltstone, some very fine sandstone

- **25.0 - 34.0'**
  - Shale

- **34.0 - 41.0'**
  - Siltstone, some very fine sandstone

- **41.0 - 43.0'**
  - Coal

- **43.0 - 54.5'**
  - Shale

- **54.0 - 57.0'**
  - Sandstone

- **57.0 - 65.0'**
  - Shale

- **65.0 - 75.0'**
  - Siltstone, interbedded fine sandstone

- **75.0 - 126.5'**
  - Sandstone at 75' (less silt than above)

- **126.5 - 128.5'**
  - Coal

- **128.5 - 160.0'**
  - Shale

- **160.0 - 165.0'**
  - Fine to very fine sandstone

- **165.0 - 190.0'**
  - Siltstone, some very fine sandstone in top 5'

### GEOLOGICAL DESCRIPTION

- **Deeper Below PVC**
  - Coal

- **126.5 - 128.5'**
  - Coal

- **128.5 - 160.0'**
  - Shale

- **160.0 - 165.0'**
  - Fine to very fine sandstone

- **165.0 - 190.0'**
  - Siltstone, some very fine sandstone in top 5'

### WELL COMPLETION

- **Surface Casing Used?** Y
- **Screen/Perforations?** Y
- **Sand Pack?** Y
- **Annular Seal?** Y
- **Surface Seal?** N

### DEVELOPMENT/SAMPLING

- **Well Developed?** Y
- **Water Samples Taken?** N
- **Boring Samples Taken?** N

### LEGAL DESCRIPTION

- **T3S, R44E, Sec. 36; N483993.19, E 2804357.02**

### WELL DATA

- **Monitor Well Log**
- **Well Name:** B2-U
- **Date Hole Started:** 1/25/11
- **Date Hole Finished:** 1/26/11
- **Well Developed?** Y
- **Water Samples Taken?** N
- **Boring Samples Taken?** N
- **Purpose of Hole:** Underburden
- **Target Aquifer:** Underburden
- **Total Depth Drilled (ft):** 420
- **Static Water Level Below MP:** 281.66
- **Surface Casing Height (ft):** 2.20
- **Riser Height (ft):** 1.51
- **Ground Surface Elevation (ft):** 3269.55
- **MP Elevation (ft):** 3271.06
- **Nothing:** 483993.19
- **Eastling:** 2804357.02
- **Static Water Level Below MP:** 281.66
- **Surface Casing Height (ft):** 2.20
- **Date:** 1/26/2011
- **Date Hole Started:** 1/25/11
- **Date Hole Finished:** 1/26/11

### OTHER DATA

- **Remarks:** PVC well SWL=235.91 BPVC (existing State well). At start of development SC=4700-4990 µhos/cm, pH=7.77, temp=14.2°C. Final SC=3110 µhos/cm, pH=8.18, temp=14.6°C. Developed with bailer, start 10:00a.m. 7 gal/50s, end 10:53a.m. 5 gpm.
Date Hole Started: 1/25/11     Date Hole Finished: 1/26/11
Billings, Montana

**WELL CONSTRUCTION**

**GEOLOGICAL DESCRIPTION**

- **190.0 - 195.0'**
  - Sandstone
  - Dry, medium gray, firm

- **195.0 - 217.0'**
  - Siltstone, some very fine sandstone in top 5'
  - Dry, medium gray, firm, very thinly bedded coal stringer at 195.5' (trace), thin cemented light brown shale at 202'

- **217.0 - 222.0'**
  - Sandstone
  - Medium gray, soft to firm

- **222.0 - 242.0'**
  - Shale, inter calcated sandstone
  - Dry, medium gray, traces very hard light brown shale (non-calcareous), carbonaceous at 222', very thin coal stringer, black, hard.
  - Very thin coal stringer at 235-236', predominately fine graded shale at 236-242'

- **242.0 - 303.5'**
  - Coal (Knobloch)
  - Black, no visible impurities, possibly cleated on multiple planes

- **303.5 - 315.0'**
  - Sandstone, silty, fine grain
  - Medium light gray, firm to stiff, some very thin iron streaks (pyrite), coal stringer at 315-316'

- **315.0 - 330.5'**
  - Shale/siltstone
  - Medium light gray to medium gray with depth, stiff to very hard at 328-330.5', rig chattering 2'/8 minutes

- **330.5 - 355.0'**
  - Intercalated sandstone/shale
  - Medium gray, stiff, trace coal at 331', trace carbonaceous medium brown shale at 345', non-calcareous

- **355.0 - 357.0'**
  - Coal
  - Black, cleated

- **357.0 - 410.0'**
  - Sandstone
  - Medium gray, wet, making water, soft to moderately firm upper, becomes very soft with depth to 404', cemented, hard then moderately firm with medium light gray and black grains at 404-405'

- **410.0 - 415.0'**
  - Coal
  - Black, wet, making water, soft to moderately firm upper, becomes very soft with depth to 404', cemented, hard then moderately firm with medium light gray and black grains at 404-405'

- **415.0 - 420.0'**
  - Shale
  - Medium light gray, firm

---

**STANDARD_REV13 OTTER CREEK WELL LOGS.GPJ  HYDHLN2.GDT  10/6/14**
GEOLOGICAL DESCRIPTION

0.0 - 1.0' Silty clay [Topsoil/Coluvium]
Dry crust then slightly moist to moist, moderate yellowish brown to light brown, moderately loose, some plasticity, roots

1.0 - 6.0' Claystone [Weathered Bedrock]
Slightly moist, moderate yellowish brown and light brown, moderately dense to soft, trace of gypsum crystals

6.0 - 12.0' Carbonaceous shale [Bedrock]
Slightly moist to dry, brownish gray and some olive gray, moderately firm; brownish black at 8'-9' and 10'-11'

12.0 - 22.0' Shale with thinly interbedded siltstone [Bedrock]
Slightly moist, multicolored: pale yellowish brown, dark yellowish orange; moderately firm, trace of iron streaks; calcareous and non-calcereous

22.0 - 30.0' Shale
Slightly moist, medium gray to brownish gray, possibly mildly carbonaceous, moderately firm, non-plastic

30.0 - 61.0' Siltstone
Slightly moist to dry, pale yellowish brown and moderate yellowish brown; soft - loose to moderately firm, calcereous; very hard cemented zone at 32'-34', interbedded fine sand at 40'-43', interbedded fine sand 45'-51', cemented zone light brown siltstone at 51'-52' and 58'-59'; interbedded fine sand at 55'-60'

61.0 - 67.0' Sandstone
Dry, pale yellowish brown, soft, very fine to fine grain

67.0 - 70.0' Siltstone
Dry, grayish orange to dark yellowish orange, soft to moderately firm, calcereous

70.0 - 78.0' Carbonaceous shale
Dry, brownish gray (SYR 4/1) and yellowish brown (SYR 3/2), moderately firm, most only mildly carbonaceous, very carbonaceous/coal at 76'-77'

78.0 - 89.0' Shale/siltstone
Dry, light olive gray to yellowish brown with depth, moderately dense to very soft with depth; color change to yellowish gray at 87'

89.0 - 120.0' Sandstone, very fine [Clinker]
Dry, yellowish gray (SYR 8/1), cuttings ground, soft; thin light brown siltstone stringer at 98'; color change to grayish orange pink (SYR 7/2) and light brown (SYR 8/4) at 117' [Thermally Altered Bedrock]

120.0 - 166.0' Siltstone, some very fine sandstone [Clinker]
Dry, very pale orange and pale yellowish brown, soft, to very soft in some intervals, calcereous, poor circulation; color change to dark yellowish orange at 130.5, pale yellowish orange at 141'; very hard cemented zone at 142'-146', cemented zone calcereous, yellowish gray and very pale orange; moderately firm from 146'-166'; color change to brownish gray (SYR 6/1) at 160'; color change to light olive gray at 163' [Thermally Altered Bedrock]
**WELL CONSTRUCTION**

- 163.0: 10/20 Silica Sand
- 175.0: centralizer
- 205.0: 0.025-inch Slot Screen
- 210.0: end cap

**GEOLOGICAL DESCRIPTION**

166.0 - 208.0': **Coal** [Knobloch]
- Dry, black to greenish/grayish black, soft and weak, becomes more blochy, cleated, harder at 198', moist at 195', injecting water

208.0 - 210.0': **Siltstone/claystone** [Bedrock]
- Light olive gray to light gray, moderately firm to soft
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River  State: Montana
Property Owner: Ark Land Company
Legal Description: N 45.53069 E 106.17119
(Location Description: B3 battery on Ark Land property)
Recorded By: RJL
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Method: Air Rotary
Drilling Fluids Used: None
Purpose of Hole: Install Monitor Well
Target Aquifer: NA
Hole Diameter (in): 8"
Total Depth Drilled (ft): 100

**WELL COMPLETION**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>DESCRIPTION</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
</tr>
</tbody>
</table>

**DESCRIPTION**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Bentonite Chips</td>
</tr>
<tr>
<td>0.0 - 2.0'</td>
<td>Dry at surface to very moist, moderate yellowish brown, clay cracked at surface, trace coarse sand/gravel clinkers, roots, moderately plastic, rolls to 1/8&quot;</td>
</tr>
<tr>
<td>2.0 - 5.0'</td>
<td>Shale [Bedrock]</td>
</tr>
<tr>
<td>5.0 - 10.0'</td>
<td>Siltstone</td>
</tr>
<tr>
<td>10.0 - 17.0'</td>
<td>Siltstone, light brown</td>
</tr>
<tr>
<td>17.0 - 43.0'</td>
<td>Siltstone</td>
</tr>
<tr>
<td>43.0 - 45.0'</td>
<td>Sandstone</td>
</tr>
<tr>
<td>45.0 - 51.0'</td>
<td>Siltstone, some interbedded fine sand</td>
</tr>
<tr>
<td>51.0 - 54.0'</td>
<td>Sandstone, fine</td>
</tr>
<tr>
<td>54.0 - 63.0'</td>
<td>Siltstone</td>
</tr>
<tr>
<td>63.0 - 65.0'</td>
<td>Sandstone</td>
</tr>
<tr>
<td>65.0 - 78.0'</td>
<td>Siltstone/shale</td>
</tr>
<tr>
<td>78.0 - 100.0'</td>
<td>Sandstone</td>
</tr>
</tbody>
</table>

Remarks: Drill to 100', hole collapsing due to burned sediments, plugged hole 3/8" bentonite chips (68 bags); move locations.
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River State: Montana
Property Owner: Ark Land Company
Legal Description: T3S, R45E, Sec. 34; N 484871.99, E 2821619.97
Location Description: B3 battery on Ark Land property
Recorded By: RJL & HJK
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Fluids Used: Water
Purpose of Hole: Install Monitor Well
Target Aquifer: Knobloch Coal
Hole Diameter (in): 8"
Total Depth Drilled (ft): 325

Remarks: Drill to 160' with 7 7/8" drag bit, ream out with 10" bit. Poor circulation, set 160' of 8" steel. Drilling with water at 200' and below. Developed with air lifting - estimate 5 gpm. Initial SC=2100 µmhos/cm, final SC=1830 µmhos/cm.
WELL CONSTRUCTION

10/20 Silica Sand

end cap

Bottom of Hole 325.0

0.025-inch Slot Screen

centralizer

169.0 - 170.0' Baked claystone [Clinker]
Dry, very weak, light brown/orange
170.0 - 185.0' Coal
Dry, brownish black, very weak
185.0 - 192.0' Coal
Dry, becoming slightly cleated
192.0 - 195.0' Coal
Slightly moist, moderately hard to weak
195.0 - 200.0' Coal
Moist, cleated, few glossy surfaces, moderately hard to weak
200.0 - 208.0' Coal
Moist, cleated, black, wet at 203', start adding water to hole
208.0 - 220.0' Siltstone
Gray, weak, laminated
220.0 - 238.0' Silty sandstone
Gray, weak, with fine sand
238.0 - 239.0' Claystone
Gray, weak
239.0 - 242.0' Coal, finely interbedded with claystone
Gray and black, laminated
242.0 - 246.0' Claystone
Gray, moderately hard
246.0 - 249.0' Shale
Gray, hard
249.0 - 261.0' Claystone
Gray, moderately hard, thinly laminated with black organics
261.0 - 264.0' Coal stringer
Black, cleated
264.0 - 267.0' Sandstone
Tan, hard, very fine grained
267.0 - 270.0' Sandstone
Gray/tan, moderately hard, fine grained
270.0 - 276.0' Claystone
Gray, firm, slightly sandy (very fine)
276.0 - 278.0' Shale
Medium gray, very hard, difficult drilling
278.0 - 283.0' Siltstone
Medium gray, very firm
283.0 - 293.0' Claystone
Medium gray, greasy, thinly laminated
293.0 - 296.0' Sandstone, very fine
Light gray, hard
296.0 - 297.0' Coal
Black, cleated
297.0 - 315.0' Sandstone
Gray/brown, firm, fine to medium grained; black carbonaceous shale stringer at 314', reddish brown, weak
315.0 - 324.0' Coal
Black, cleated, making water, estimated at 5 gpm
324.0 - 325.0' Claystone
Blue/gray, firm, finely laminated
**GEOLOGICAL DESCRIPTION**

**WELL CONSTRUCTION**

**Well Completion**
- **Well Installed?** Y
- **Surface Casing Used?** Y
- **Screen/Perforations?** Y
- **Sand Pack?** Y
- **Annular Seal?** Y
- **Surface Seal?** N

**Interval**
- 0.0 - 2.46' Bentonite Grout & Chips
- 2.46' - 7.5' Silt
- 7.5' - 11.5' Sandstone
- 11.5' - 24.5' Siltstone
- 24.5' - 36.5' Shale
- 36.5' - 43.5' Shale
- 43.5' - 51.5' Siltstone
- 51.5' - 60.5' Carbonaceous Shale
- 60.5' - 80.5' Carbonaceous Shale
- 80.5' - 105.5' Siltstone
- 105.5' - 132.5' Sandstone
- 132.5' - 135.5' Carbonaceous Shale
- 135.5' - 145.5' Sandstone
- 145.5' - 148.5' Siltstone and Shale

**Well Construction**
- **8" steel**
- **2.0' Bentonite Grout & Chips**

**Geological Description**
- 0.0 - 2.0' Silt (Weathered Bedrock/Colluvium): Some clay, dry, pale yellowish brown, loose
- 2.0 - 8.0' Sandstone (Bedrock): Very fine, slightly moist, pale yellowbrown to light olive gray; soft
- 6.0 - 11.0' Siltstone: Dry, dark yellowish orange
- 11.0 - 12.0' Shale: Slightly moist, dark yellowish brown, moderately firm, low plasticity, mildly carbonaceous
- 12.0 - 14.0' Shale: Dry, light olivegray to moderatelygray, moderatelycarbonaceous, moderatelyfirm
- 14.0 - 27.0' Siltstone: Dry, light olivegray, gypsum crystals from 16'-19'; color to dark yellowish orange at 17'. Mild carbonaceous shale stringer at 19'-20'; medium dark gray. Color change to medium dark gray at 22'; and dark yellowish orange at 27'
- 27.0 - 28.0' Carbonaceous shale: Dry, medium gray and dark greenish gray
- 28.0 - 36.0' Siltstone: Dry, light gray, center very hard, then dark greenishgray and medium gray at 29'. Hardness is dense to medium firm
- 36.0 - 39.0' Carbonaceous shale: Junk coal, dry, brownish gray and medium dark gray; moderately stiff
- 39.0 - 105.0' Siltstone: Light gray, dry, firmto stiff, medium very hard cemented at 45'-47' and 51'-52'. Minor trace very fine sandstone at 50'-53'. Color change to grayish brown at 63'-67'. Color change to back light gray at 67'. Trace interbedded very fine sandand hardness to soft; cemented stringer 0.5' thick at 75'. Color change to light olivegray at 75'
- 105.0 - 132.0' Sandstone: Slightly moist to moist, medium light gray to medium gray, stiff, cuttings ground, grain size from very fine to fine with depth. Siltstone, dry, medium gray and grayish blue, interbedded from 116'-120'. Siltstone interbedded at 125'. Moist to very moist at 130', injected water, possibly making water. Very thin coal stringer at 132'
- 132.0 - 145.0' Shale/siltstone: Medium gray, firm to very hard cemented zone at 133'-137'; very hard shale. Color change to medium light gray at 140'
- 145.0 - 151.0' Sandstone: Medium light gray, medium firm to stiff; bloomed with rig air; open hole possibly making little water
- 151.0 - 180.0' Siltstone and Shale: Medium gray to medium light gray; moderately firm to stiff; thin cemented zone at 165'
WELL CONSTRUCTION

175.0  10/20 Silica Sand centralizer
181.0  
196.0  centralizer
206.0  centralizer
216.0  centralizer
226.0  centralizer
236.0  centralizer
246.0  end cap
246.0  0.025-inch Slot Screen
182.4  180.0 - 246.0' Coal [Knobloch]
Black, hard, dense, cleated 3x

GEOLOGICAL DESCRIPTION

Date Hole Started: 7/26/11  Date Hole Finished: 7/27/11
**Monitor Well Log**

**Hole Name: B4-O**

---

**WELL CONSTRUCTION**

- **8" steel**
- **10/20 Silica Sand**
- **120.0**
- **122.0**
- **0.025-inch Slot Screen**
- **Bottom of Hole**

---

**GEOLOGICAL DESCRIPTION**

- **2.0 - 2.0' Silt**
  - Weathered Bedrock/Colluvium
  - Dry, yellowish orange

- **2.0 - 8.0' Sandstone**
  - Bedrock
  - Very fine, slightly moist, pale yellow brown to light olive gray; soft

- **6.0 - 11.0' Siltstone**
  - Dry, dark yellowish orange

- **11.0 - 12.0' Shale**
  - Very fine, dry, pale yellowish brown to light olive gray; loose

- **12.0 - 14.0' Shale**
  - Dry, light olive gray to moderately gray, moderately carbonaceous, moderately firm

- **14.0 - 27.0' Siltstone**
  - Dry, light olive gray, gypsum crystals from 16'-19'; color to dark yellowish orange at 17'. Mild carbonaceous shale stringer at 19'-20'; medium dark gray. Color change to medium dark gray at 22', and dark yellowish orange at 27'

- **27.0 - 28.0' Carbonaceous shale**
  - Dry, medium gray and dark greenish gray

- **28.0 - 36.0' Siltstone**
  - Dry, light gray, center very hard, then dark greenish gray and medium gray at 29'. Hardness is dense to medium firm

- **36.0 - 39.0' Carbonaceous shale**
  - Junk coal, dry, brownish gray and medium dark gray; moderately stiff

- **39.0 - 105.0' Siltstone**
  - Light gray, dry, firm to stiff, medium very hard cemented at 45'-47' and 51'-52'. Minor trace very fine sandstone at 50'-53'. Color change to grayish brown at 63'-67'. Color change back to light gray at 67'. Trace interbedded very fine sand and hardness to soft; cemented stringer 0.5' thick at 75'. Color change to light olive gray at 75'

- **105.0 - 132.0' Sandstone**
  - Slightly moist to moist; medium light gray to medium gray, stff, cuttings ground, grain size from very fine to fine with depth. Siltstone, dry, medium gray and grayish blue, interbedded from 116'-120'. Siltstone interbedded at 125'. Moist to very moist at 130', injected water, possibly making water. Very thin coal stringer at 132'

---

**Remarks:** Lithology based on well B4-U. Bailed ~5 gallons, yield ~30 ounces per bail; SC= 3200 µmhos/cm.
**WELL CONSTRUCTION**

- **2.0 8” steel**
- **1.0 Bentonite Grout**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 2.0’ Silt (Weathered Bedrock/Colluvium)**
  - Some clay, dry, pale yellowish brown, loose

- **2.0 - 8.0’ Sandstone (Bedrock)**
  - Very fine, slightly moist, pale yellow brown to light olive gray; soft

- **6.0 - 11.0’ Siltstone**
  - Dry, dark yellowish orange

- **11.0 - 12.0’ Shale**
  - Slightly moist, dark yellowish brown, moderately firm, low plasticity, mildly carbonaceous

- **12.0 - 14.0’ Shale**
  - Dry, light olive gray to moderately gray, moderately carbonaceous, moderately firm

- **14.0 - 27.0’ Siltstone**
  - Dry, light olive gray, gypsum crystals from 16’-19’; color to dark yellowish orange at 17’. Mildly carbonaceous shale stringer at 19’-20’; medium dark gray. Color change to medium dark gray at 22’, and dark yellowish orange at 27’

- **27.0 - 28.0’ Carbonaceous shale**
  - Dry, medium gray and dark greenish gray

- **28.0 - 36.0’ Siltstone**
  - Dry, light gray, center very hard, then dark greenish gray and medium gray at 29’. Hardness is dense to medium firm

- **36.0 - 39.0’ Carbonaceous shale**
  - Junk coal, dry, brownish gray and medium dark gray; moderately stiff

- **39.0 - 105.0’ Siltstone**
  - Light gray, dry, firm to stiff, medium hard cemented at 45’-47’ and 51’-52’. Minor trace very fine sandstone at 50’-53’. Color change to grayish brown at 63’-67’. Color change back to light gray at 67’. Trace interbedded very fine sand and hardiness to soft; cemented stringer 0.5” thick at 75’. Color change to light olive gray at 75’

- **105.0 - 132.0’ Sandstone**
  - Slightly moist to moist; medium light gray to medium gray, stiff, cuttings ground, grain size from very fine to fine with depth. Siltstone, dry; medium grey and grayish blue; interbedded from 116’-120’. Siltstone interbedded at 125’. Moist to very moist at 130’, injected water, possibly making water. Very thin coal stringer at 132’

- **132.0 - 145.0’ Shale/siltstone**
  - Medium gray, firm to very hard cemented zone at 133’-137’; very hard shale. Color change to medium light gray at 140’

- **145.0 - 151.0’ Sandstone**
  - Medium light gray, medium firm to soft; blew with rig air; open hole possibly making little water

**REMARKS**

Sealed annular space with 15 bags of 3/8” bentonite chips from 285’-295’ bgs prior to developing with rig bailer. Bailed with rig bailer, seal sealing, finished grouting with Hi-solids bentonite grout to seal. Bailed with rig bailer after sealed; yields approx. 1-1.5 gpm. After development water quality: SC=4000 µmhos/cm, pH=8.16, temp= 16.3° C.
WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

151.0 - 180.0' Siltstone and shale
Medium gray to medium light gray; moderately firm to stiff; thin cemented zone at 165'

180.0 - 245.0' Coal [Knobloch]
Black, hard, dense, cleated 3x

245.0 - 250.0' Shale
Grayish brown, mildly carbonaceous, firm to stiff

250.0 - 300.0' Siltstone/interbedded fine sandstone
Medium gray to light olive gray. Firm, less sand; mostly all siltstone at 260'. Thin coal stringer at 260'. Stiff, thin cemented zone at 265'. Hard cemented zone at 274'-276'. Then general hardness increase to stiff or very hard, hardness decrease to firm at 285'. Trace interbedded sandstone at 285'-290'. Thin coal stringer at 295'. also trace very hard shale, grayish orange pink. Some intercalated sandstone at 295'-300'

295.0 311.0
Bentonite Chips

311.0
centralizer

301.0 321.0
4.5" SDR-17
0.025-inch slot

321.0 331.0
centralizer

331.0
centralizer

341.0
Bottom of Hole

341.0
end cap

300.0 - 341.0' Sandstone
Medium gray, soft to medium hard with depth. Very hard cemented zone at 313'-315'; intercalated shale at 317'-320'. Inconsitent texture sand/shale/siltstone from 320'-340' intercalated. Blew with rig air, difficult to determine yield, approximately less than 2 gpm. Tagged shale, medium dark gray, medium firm at 341'
WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

0.0 - 3.0' Silty clay/grades to siltstone
Moist, soft, weathered, roots to 3', calcareous, trace grayish white precipitates; trace cinder gravel from 0'-1'

3.0 - 6.0' Sandstone, fine
Slightly moist, light olive gray to medium light gray, soft

6.0 - 7.0' Siltstone
Dry, pale yellowish brown to light olive gray, moderately firm to stiff, calcareous

7.0 - 9.0' Coal
Dry, brownish gray and black with medium gray shale, firm to stiff, junk

9.0 - 10.0' Carbonaceous shale
Dry, moderate brown and grayish red, moderately firm, moderately carbonaceous, trace micaceous material

10.0 - 13.0' Coal
Dry, brownish gray black, firm to stiff, junk

13.0 - 34.0' Siltstone
Dry to slight moist, light olive gray and very pale orange (10YR 8/2), soft to very soft, most cuttings gravel to rock flow

34.0 - 35.0' Coal
Color change to olive grown at 24'

35.0 - 42.0' Carbonaceous shale to non carbonaceous shale at 36'
Dry, olive gray (5Y 4/1) moderately firm; medium dark gray to medium light gray and greenish gray with change from carbonaceous shale to non-carbonaceous shale

42.0 - 44.0' Siltstone
Dry, medium light gray, soft

44.0 - 45.0' Coal
Dry, brownish gray black (5YR 2/1), stiff, ground cuttings, multiple cleats?, junk

45.0 - 76.0' Shale
Dry, colors medium light gray, olive gray, moderately firm to stiff with hard cemented zones as follows: Cemented zone, light gray shale at 48'; Moderately carbonaceous at 51'-52'; Cemented zone, light gray shale at 53'; Cemented zone, light gray shale at 67'; Cemented zone, light gray shale at 69'; Moderately carbonaceous at 72'-74'

76.0 - 80.0' Siltstone and interbedded fine sandstone
Dry, medium to medium light gray, soft to moderately firm, non-calcareous

80.0 - 99.0' Shale
Dry, medium light gray and light olive gray, firm, non-carbonaceous, non-calcareous; Interbedded siltstone at 81'-82' and at 84'-86'
Carbonaceous stringer at 95.5', dark yellowish gray and brownish black

99.0 - 102.0' Siltstone and interbedded fine sandstone
Slightly moist, light gray, soft to firm
# Geological Description

102.0 - 140.0' **Siltstone/shale**
- Dry, light olive gray and medium gray, calcareous, firm, stiff stringer at 120'
- Grades to no shale, all siltstone at 121';125'
- Silty at 130'-135'
- Cemented, light gray shale, non-calcareous at 139'

140.0 - 155.5' **Siltstone and fine sandstone interbedded**
- Slightly moist to moist, greenish gray (5GY 6/1) and medium light gray, soft to moderately firm cemented at 143'-144'
- Hard; very thin carbonaceous (coal) interbed at 150', very sandy with mild increase in moisture
- Very hard cemented, dry, light gray siltstone at 155.5', mildly calcareous

155.5 - 185.0' **Siltstone and shale**
- Dry, light olive gray (5Y 5/2) and pale yellowish brown, moderately firm to stiff
- Color change to light greenish gray at 179'
- Moderately carbonaceous stringer at 182', brownish gray

185.0 - 255.0' **Coal**
- Dry, brownish gray and brownish black, stiff, brittle ground cuttings appear cleated, junk
- Grades to black cleated, well developed/dense coal at 205'-210', wet at 210', injecting water at 215', [Knobloch Coal]

255.0 - 260.0' **Fine sandstone**
- Wet, medium light gray, moderately firm (open hole yields 20 gpm)
Well Name: B5-O

WELL COMPLETION

<table>
<thead>
<tr>
<th>WELL COMPLETION</th>
<th>Y/N</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Installed?</td>
<td>Y</td>
<td>4.5&quot; Sch 40, PVC</td>
</tr>
<tr>
<td>Surface Casing Used?</td>
<td>Y</td>
<td>8&quot; steel</td>
</tr>
<tr>
<td>Screen/Perforations?</td>
<td>Y</td>
<td>0.025-inch slot, Sch 40 PVC</td>
</tr>
<tr>
<td>Sand Pack?</td>
<td>Y</td>
<td>10/20 silica sand</td>
</tr>
<tr>
<td>Annular Seal?</td>
<td>Y</td>
<td>Bentonite Chips</td>
</tr>
<tr>
<td>Surface Seal?</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

INTERVAL

+2-156
+2-18
141-156
136-156
+1-136

GEOLOGICAL DESCRIPTION

0.0 - 3.0' Silty clay/grades to siltstone
Moist, soft, weathered, roots to 3', calcareous, trace grayish white precipitates; trace clinker gravel from 0-1'

0.0 - 6.0' Sandstone, fine
[Bedrock]
Slightly moist, light olive gray to medium light gray, soft

6.0 - 7.0' Siltstone
Dry, pale yellowish brown to light olive gray, moderately firm to stiff, calcareous

7.0 - 9.0' Coal
Dry, brownish gray and black with medium gray shale, firm to stiff, junk

9.0 - 10.0' Carbonaceous shale
Dry, moderate brown and grayish red, moderately firm, moderately carbonaceous, trace micaceous material

10.0 - 13.0' Coal
Dry, brownish gray black, firm to stiff, junk

13.0 - 34.0' Siltstone
Dry to slight moist, light olive gray and very pale orange (10YR 8/2), soft to very soft, most cuttings gravel to rock flow

Color change to medium gray at 20', calcareous
Mist at 22', interbedded very fine sandstone starting at 22'

Color change to olive grown at 24'

34.0 - 35.0' Coal
Dry, brownish black, stiff to hard

35.0 - 42.0' Carbonaceous shale to non carbonaceous shale at 36'
Dry, olive gray (5Y 4/1) moderately firm; medium dark gray to medium light gray and greenish gray with change from carbonaceous shale to non-carbonaceous shale

42.0 - 44.0' Siltstone
Dry, medium light gray, soft

44.0 - 45.0' Coal
Dry, brownish black (5YR 2/1), stiff, ground cuttings, multiple cleats?, junk

45.0 - 76.0' Shale
Dry, colors medium light gray, olive gray, moderately firm to stiff with hard cemented zones as follows: Cemented zone, light gray shale at 48', Moderately carbonaceous at 51'-52', Cemented zone, light gray shale at 53', Cemented zone, light gray shale at 67', Cemented zone, light gray shale at 69', Moderately carbonaceous at 72'-74'

76.0 - 80.0' Siltstone and interbedded fine sandstone
Dry, medium to medium light gray, soft to moderately firm, non-calcareous

80.0 - 95.0' Shale
Dry, medium light gray and light olive gray, firm, non-calcareous, non-calcareous; Interbedded siltstone at 81'-82' and at 84'-86'
Carbonaceous stringer at 95.5', dark yellowish gray and brownish black
99.0 - 102.0’ Siltstone and interbedded fine sandstone
Slightly moist, light gray, soft to firm

102.0 - 140.0’ Siltstone/shale
Dry, light olive gray and medium gray, calcareous, firm, stiff stringer at 120’
Grades to no shale, all siltstone at 121’ - 125’
Silty at 130’ - 135’
Cemented, light gray shale, non-calcareous at 139’

140.0 - 156.0’ Siltstone and fine sandstone interbedded
Slightly moist to moist, greenish gray (5GY 6/1) and medium light gray, soft to moderately firm;
cemented at 143’ - 144’; hard, very thin carbonaceous (coal) interbed at 150’, very sandy, mild
increase in moisture; very hard cemented, dry, light gray siltstone at 155.5’, mildly calcareous
WELL COMPLETION | Y/N | DESCRIPTION | INTERVAL
--- | --- | --- | ---
Well Installed? | N | Y/N | NA
Surface Casing Used? | N | Y/N | NA
Screen/Perforations? | N | Y/N | NA
Sand Pack? | N | Y/N | NA
Annular Seal? | N | Y/N | NA
Surface Seal? | Y | Bentonite Chips | 0-100

DEVELOPMENT/SAMPLING
Well Developed? | N | Y/N | NA
Water Samples Taken? | N | Y/N | NA
Boring Samples Taken? | N | Y/N | NA

INTENDED USE: Well installed.

Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River State: Montana
Property Owner: Ark Land Company
Legal Description: T4S, R45E, Sec. 10; N45.50291, E-106.1569 (NAD83)
Location Description: near weather station

Recorded By: RJL
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Method: Air Rotary
Drilling Fluids Used: None
Purpose of Hole: Install Monitor Well
Target Aquifer: NA
Hole Diameter (in): 8"
Total Depth Drilled (ft): 105

Remarks: Lost circulation in burn, plugged hole with 3/8” bentonite chips (68 bags).

Well Construction
---

0.0 Bentonite Chips

Geological Description
---

0.0 - 1.0’ Silty clay [Colluvium/Topsoil]
Moist, moderate brown, soft, moderately dense

1.0 - 8.0’ Siltstone [Bedrock]
Dry to slightly moist, very pale orange to pale yellowish orange, very soft, highly weathered to 6’, then hardens to moderately firm and less weathered at 6’-8’, colors change to pale yellowish brown and olive gray

8.0 - 10.0’ Shale, very silty
Dry, dark yellowish brown to pale yellowish brown with depth, moderately carbonaceous to non-carbonaceous with depth, soft to moderately firm

10.0 - 15.0’ Siltstone/shale, interbedded
Dry, pale yellowish brown and olive gray to medium light gray, moderately firm to firm, all non-calcareous

15.0 - 18.0’ Siltstone [Bedrock]
Dry, multi-colored from pale yellowish brown, pale yellowish orange to dark yellowish brown, soft, non-calcareous

18.0 - 48.0’ Shale/siltstone, interbedded
Dry, medium light gray to medium gray, moderately firm to firm, all non-calcareous; slight carbonaceous at 18’-26’, some thin laminations and oxidized beds: brownish gray at 21’-22’, light brown (5YR 5/6) at 25’-26’, pale reddish brown at 33’-34’; then color changes from grays to orange/red; highly oxidized; colors variable from grayish orange, light brown (5YR 5/6), and moderate red (5R 5/4)

Hardness to stiff from 43’-44’
Hard from 47’-48’

48.0 - 66.0’ Siltstone/some very fine sandstone
Dry, dark yellowish orange, (10YR 6/6) and light brown to grayish orange pink, soft; very hard cemented zone at 65.5’-66’, burned sandstone

66.0 - 75.5’ Fine sandstone
Dry, very pale orange and grayish orange pink, soft to very soft; burned cemented zone at 72’-73’, hard

75.5 - 79.0’ Oxidized shale (burned)
Dry, light brown (5YR 6/4) and grayish orange, very hard, rig chattering

79.0 - 84.0’ Sandstone, very fine
Dry, grayish orange to grayish orange pink with depth, soft with some intercalated very hard shale, stinger of very hard burned shale at 83’

84.0 - 100.0’ Siltstone
Dry, light brown (5YR 6/4 and 5YR 5/6), hard to very hard, cuttings ground, some interbedded fine sandstone at 87’-88’; oxidized, sandy at 92’-94’

100.0 - 105.0’ Oxidized shale [Clinker]
Dry, moderate orange pink to light brown, very hard/cemented

Bottom of Hole 105.0
**GEological Description**

- **8.0 - 10.0' Carbonaceous Shale**
  - Dry, brown, gray and black with medium gray shale, firm to stiff, moderately carbonaceous, trace micaceous material

- **10.0 - 13.0' Coal**
  - Dry, brownish gray black, firm to stiff, junk

- **13.0 - 34.0' Siltstone**
  - Dry, dry, brownish gray black, firm to stiff, junk

- **34.0 - 35.0' Coal**
  - Dry, brownish black, stiff to hard

- **35.0 - 42.0' Carbonaceous Shale to Non Carbonaceous Shale at 36'**
  - Dry, olive gray (5YR 4/1) moderately firm, medium dark gray to medium light gray and greenish gray with change from Carbonaceous Shale to Non-Carbonaceous Shale

- **42.0 - 44.0' Siltstone**
  - Dry, medium light gray, soft

- **44.0 - 45.0' Coal**
  - Dry, brownish black (5YR 2/1), stiff, cuttings ground, multiple cleats?, junk

- **45.0 - 76.0' Shale**
  - Dry, colors medium light gray, olive gray, moderately firm to stiff with hard cemented zones as follows: Cemented Zone, light gray shale at 48', Moderately Carbonaceous at 51'-52', Cemented Zone, light gray shale at 52', Cemented Zone, light gray shale at 57', Cemented Zone, light gray shale at 67', Moderately Carbonaceous at 72'-74'

- **76.0 - 80.0' Siltstone and Interbedded Fine Sandstone**
  - Dry, medium to medium light gray, soft, to moderately firm, non-carbonaceous

- **80.0 - 99.0' Shale**
  - Dry, medium light gray and light olive gray, firm, non-carbonaceous, non-non-carbonaceous; Interbedded siltstone at 81'-82' and at 84'-86'

- **99.0 - 102.0' Siltstone and Interbedded Fine Sandstone**

**Well Completed?**
- Yes

**Water Samples Taken?**
- No

**Boring Samples Taken?**
- No

**Remarks:** Sand pack interval estimated based on 2" per bag, measuring string broke off in well. Cuttings verified in field. Injecting water at 225', developed with rig air at 280' bgs 5 minutes, at 320' bgs 20 minutes ~500 gallons removed; SC=1096 μmhos/cm after development.
102.0 - 140.0' Siltstone/shale
Slightly moist, light gray, soft to firm
Dry, light olive gray and medium gray, calcareous, firm, stiff stringer at 120'
Grades to no shale, all siltstone at 121'-125'
Silty at 130-135'
Cemented, light gray shale, non-calcareous at 139'

140.0 - 155.5' Siltstone and fine sandstone interbedded
Slightly moist to moist, greenish gray (5GY 6/1) and medium light gray, soft to moderately firm;
cemented at 143'-144', hard, very thin carbonaceous (coal) interbed at 150', interbed very sandy;
slight moisture increase; very hard cemented, dry, light gray siltstone at 155.5', mildly calcareous

155.5 - 185.0' Siltstone and shale
Dry, light olive gray (5Y 5/2) and pale yellowish brown, moderately firm to stiff
Color change to light greenish gray at 179'
Moderately carbonaceous stringer at 182', brownish gray

185.0 - 255.0' Coal
Dry, brownish gray and brownish black, stiff, brittle ground cuttings appear cleated, junk
Grades to black cleated, well developed coal at 205'-210', wet at 210', injecting water at 215',
dense [Knobloch Coal]

255.0 - 266.0' Sandstone
Wet, medium light gray, moderately firm to very hard at 261', rig chattering/slow to advance;
hardness returning to moderately firm at 265'
**GEOLOGICAL DESCRIPTION**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>266.0 - 275.0'</td>
<td>Siltstone Medium light gray, moderately firm to firm, thin coal stringer at 270'</td>
</tr>
<tr>
<td>275.0 - 280.0'</td>
<td>Sandstone Medium light gray, soft to moderately firm, very hard cemented zone at 283' - 284.5', very pale orange; then sandstone/intercalated shale 284.5' - 292'</td>
</tr>
<tr>
<td>290.0 - 292.0'</td>
<td>Siltstone/claystone Medium light gray to light olive gray, firm, calcareous</td>
</tr>
<tr>
<td>292.0 - 295.0'</td>
<td>Coal/interbedded carbonaceous shale Medium gray to light brownish gray shale, black coal, moderately firm to firm</td>
</tr>
<tr>
<td>295.0 - 299.0'</td>
<td>Sandstone with coal stringers throughout Light brownish gray sandstone, black coal, firm</td>
</tr>
<tr>
<td>299.0 - 308.0'</td>
<td>Fine sandstone, some silt Light gray to medium light gray, firm, siltstone calcareous, very hard sandstone stringer cemented 305' - 306'</td>
</tr>
<tr>
<td>308.0 - 317.0'</td>
<td>Siltstone/shale Medium light gray, moderately firm to very stiff, calcareous/reacts strongly with HCl</td>
</tr>
<tr>
<td>317.0 - 321.0'</td>
<td>Coal Black, cleated multiple places, moderately dense but very dirty, has intercalated light brownish gray sandstone and shale throughout</td>
</tr>
<tr>
<td>321.0 - 335.0'</td>
<td>Siltstone and interbedded sandstone Medium light gray, moderately firm, calcareous</td>
</tr>
<tr>
<td>335.0 - 380.0'</td>
<td>Sandstone Medium light gray and light olive gray; coal stringer at 344' - 345'; intercalated coal, very dirty at 353' - 362'. Stop at 360', blow on hole and make multiple checks of TDS. No change in TDS from water in coal interval. Very hard fine sandstone interval at 362', rig slow, chattering Hardness to stiff at 370' Interbedded coal/carbonaceous shale interval at 375' - 380'; shale also calcareous; light brownish gray. Stop at 380', blow on hole and make multiple TDS checks, not making water</td>
</tr>
<tr>
<td>380.0 - 399.0'</td>
<td>Shale/siltstone Light olive gray and medium light gray, non-calcereous Very hard shale at 383' - 384.5' Coal stringer at 385'-386' Becomes sandy at 389'; some interbedded sandstone from 389'-399'</td>
</tr>
<tr>
<td>399.0 - 404.0'</td>
<td>Sandstone Medium light gray to light brownish gray, firm to very hard, not making water</td>
</tr>
<tr>
<td>404.0 - 440.0'</td>
<td>Siltstone and interbedded shale Medium light gray to brownish gray, moderately firm to hard; carbonaceous to non-carbonaceous Predominately siltstone at 412', moderate firm Coal stringer at 429' Color changes to brownish gray and light brownish gray at 429' Coal stringer at 430'</td>
</tr>
</tbody>
</table>

**Continued Next Page**
**WELL CONSTRUCTION**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
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<tbody>
<tr>
<td>0.0</td>
<td>10/20 Silica Sand</td>
</tr>
<tr>
<td>46.0</td>
<td>4.5&quot; Perf SDR -17</td>
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<tr>
<td>47.0</td>
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<tr>
<td>48.0</td>
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<tr>
<td>49.0</td>
<td>Centralizer</td>
</tr>
<tr>
<td>50.0</td>
<td>End Cap</td>
</tr>
<tr>
<td>500.0</td>
<td>Bottom of Hole</td>
</tr>
</tbody>
</table>

**GEOLOGICAL DESCRIPTION**

- **440.0 - 500.0'** Fine sandstone
- Interbedded siltstone/claystone, wet, brownish gray to light olive gray to medium light gray with depth; texture to all sandstone at 450', moderately firm to very soft with depth, fine to moderately fine grain with depth
**Monitor Well Log**

**Hole Name: B6-K**

**Date Hole Started: 8/16/11**
**Date Hole Finished: 8/16/11**

**WELL CONSTRUCTION**

<table>
<thead>
<tr>
<th>Depth Interval</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 7.0’</td>
<td>Silt [Colluvium]</td>
</tr>
<tr>
<td>7.0 - 39.0’</td>
<td>Siltstone [Bedrock]</td>
</tr>
<tr>
<td>39.0 - 41.0’</td>
<td>Coal/carbonaceous shale</td>
</tr>
<tr>
<td>41.0 - 80.0’</td>
<td>Siltstone/shale</td>
</tr>
<tr>
<td>80.0 - 100.0’</td>
<td>Sandstone [Bedrock]</td>
</tr>
<tr>
<td>100.0 - 145.0’</td>
<td>Siltstone, sandy/clayey</td>
</tr>
<tr>
<td>145.0 - 155.0’</td>
<td>Sandstone</td>
</tr>
</tbody>
</table>

**GEOLOGICAL DESCRIPTION**

- **0.0 - 7.0’ Silt [Colluvium]**
  - Dry to slightly moist, pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), roots and debris in top 1’

- **7.0 - 39.0’ Siltstone [Bedrock]**
  - Dry to slightly moist, dark yellowish orange (10YR 6/6) to light olive gray at 10’, moderately firm, calcareous. Very hard cemented shale stringer 13’-14’, light olive gray to light brownish gray (5Y 6/1), also calcareous. Very hard cemented shale, calcareous, medium light gray (N6) and greenish gray (5G 6/1) at 21’-22’. Color change to light olive gray at 24’. Color change to dark yellowish orange (10YR 6/6) at 26’. Color change to light olive gray at 31’. Becomes soft at 35’ and color changes to moderate yellowish brown (10YR 5/4) and grayish orange (10YR 7/4)

- **39.0 - 41.0’ Coal/carbonaceous shale**
  - Dry, dark brownish black (5YR 2/1), stiff

- **41.0 - 80.0’ Siltstone/shale**
  - Dry, medium gray (N5) and medium light gray (N6), firm to stiff. Very hard cemented zone at 56’. Metal shavings from drill bit in cuttings. Non-calcareous at 41’-57’, calcareous from 57’-80’

- **80.0 - 100.0’ Sandstone [Bedrock]**
  - Dry, medium light gray (N6) and greenish gray (5GY 6/1), soft to moderately firm, some siltstone from 80’-87’. Very hard, cemented, very fine grained sandstone from 87’-90.5’. Color change to medium dark gray (N4), moisture to moist at 91’, hardness to soft; sandstone becomes clayey at 99’

- **100.0 - 145.0’ Siltstone, sandy/clayey**
  - Slightly moist, moderately firm, medium dark gray (N4), non-calcareous, soft to firm, texturally complex. Calcareous cemented zone at 111’, medium light gray (N6); becomes very sandy at 137’, moisture to moist; very clayey, mildly plastic at 142’, then grades to very sandy at 145’, injecting water at 145’

- **145.0 - 155.0’ Sandstone**
  - Wet, light olive gray to medium gray (NS). Thin interbedded siltstone stringer at 150’, silty again at 154’-155’. Sandstone is fine to very fine and silty at 155’. Blew on open hole at 155’, makes some water

*Remarks: Drilled to 20’ with 11” bit, set 8” steel casing. Developed with submersible pump at 20 gpm. Pump hung at 206’ BMP. Recovered 11” when pumped turned off temporarily for 7 minutes. WL=152.23’ BMP after 50 minutes at 20 gpm. SC= 2200 µmhos/cm, pH= 8.27, temp= 18.2°C.*
155.0 - 180.0' **Siltstone**
Dark gray (N3), some sand/some clay, moderately firm. Hard cemented, intercalated shale, light brownish gray (5YR 6/1) at 158'. Very thin coal stringer at 163', texture grades to no sand below coal stringer, becomes shaley, non-plastic

180.0 - 246.0' **Coal** [Knobloch]
Hard, loose, black (N1), cleated

246.0 - 247.0' **Shale** [Underburden]
Dry, light olive gray (5Y 5/2), stiff
**Bentonite Chips**

0.025-inch Slot Screen

**Bottom of Hole**

0.0 - 7.0' Silt

[Colluvium] Dry to slightly moist, pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), roots and debris in top 1'

7.0 - 39.0' Siltstone

[Bedrock] Dry to slightly moist, dark yellowish orange (10YR 6/6) to light olive gray at 10', moderately firm, calcareous. Very hard cemented shale stringer 13'-14', olive gray to light brownish gray (5Y 6/1), also calcareous. Very hard cemented shale, calcareous, medium light gray (N6) and greenish gray (5G 6/1) at 21'-22'. Color change to light olive gray at 24'. Color change to dark yellowish orange (10YR 6/6) at 26'. Metal shavings from drill bit in cuttings. Non-calcareous at 41'-57', calcareous from 57'-80'; very hard cemented zone at 64'-66' and at 75'-76'.

39.0 - 41.0' Coal/carbonaceous shale

Dry, dark brownish black (5YR 2/1), stiff

41.0 - 82.0' Siltstone/shale

Dry, medium gray (N5) and medium light gray (N6), firm to stiff. Metal shavings from drill bit in cuttings. Non-calcareous at 41'-57', calcareous from 57'-80'; very hard cemented zone at 64'-66' and at 70'-76'.

82.0 - 100.0' Sandstone

[Bedrock] Dry, medium light gray (N8) and greenish gray (5GY 6/1), soft to moderately firm, some siltstone from 80'-82'. Sandy texture at 82'-83.5', very hard, cemented, thin siltstone very fine grained sandstone from 83.5'-90.5'. Color change to medium dark gray (N4), moisture to moist at 91', hardness to soft; sandstone becomes clayey at 99'

100.0 - 137.0' Siltstone, sandy/clayey

Slightly moist, moderately firm, medium dark gray (N4), non-calcareous, soft to firm, texturally complex. Calcareous cemented zone at 111', medium light gray (N6); becomes very sandy at 137', moisture to moist; very clayey, mildly plastic at 142', then grades to very sandy at 145', injecting water at 149'

137.0 - 155.0' Sandstone

Wet, light olive gray to medium gray (N5), clayey at 142' and 155', fine-grained sand, TD=155', tagged siltstone at 155'
Bentonite Chips

Hi Solids grout 0.0 - 7.0’

Silt

[Colluvium] Dry to slightly moist, pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), roots and debris in top 1’

7.0 - 39.0’

Siltstone

[Bedrock] Dry to slightly moist, dark yellowish orange (10YR 6/6) to light olive gray at 10’, moderately firm, calcareous. Very hard cemented shale stringer 13’-14’, light olive gray to light brownish gray (5Y 6/1), also calcareous. Very hard cemented shale, calcareous, medium light grey (N6) and greenish gray (5G 6/1) at 21’-22’. Color change to light olive gray at 24’. Color change to dark yellowish orange (10YR 6/6) at 26’. Color change to light olive gray at 31’; becomes soft at 35’ and color changes to moderate yellowish brown (10YR 5/4) and grayish orange (10YR 7/4)

39.0 - 41.0’

Coal/carbonaceous shale

Dry, dark brownish black (5YR 2/1), stiff

41.0 - 80.0’

Siltstone/shale

Dry, medium gray (N5) and medium light gray (N6), firm to stiff. Very hard cemented zone at 56’; metal shavings from drill bit in cuttings. Non-calcareous at 41’-57’, calcareous from 57’-80’

80.0 - 100.0’

Sandstone

[Bedrock] Dry, medium light gray (N6) and greenish gray (5G 6/1), soft to moderately firm, some siltstone from 80’-87’. Very hard, cemented, very fine grained sandstone from 87’-90.5’. Color change to medium dark gray (N4), moisture to moist at 91’, hardness to soft; sandstone becomes clayey at 99’

100.0 - 145.0’

Siltstone, sandy/clayey

Slightly moist, moderately firm, medium dark gray (N4), non-calcareous, soft to firm, texturally complex. Calcareous cemented zone at 111’, medium light gray (N6); becomes very sandy at 137’, moisture to moist; very clayey, mildly plastic at 142’, then grades to very sandy at 145’, injecting water at 140’

145.0 - 155.0’

Sandstone

Wet, light olive gray to medium gray (N5). Thin interbedded siltstone stringer at 150’, silty again at 154’-155’. Sandstone is fine to very fine and silt at 155’. Blow on open hole at 155’, makes some water

155.0 - 181.0’

Siltstone

Dark grey (N3), some sand/some clay, moderately firm. Hard cemented, intercalated shale, light brownish gray [5YR 6/1] at 158’. Very thin coal stringer at 163’, texture grades to no sand below coal stringer, becomes shaley, non-plastic

181.0 - 248.5' Coal [Knobloch]
Hard, loose, black (N1), cleated

248.5 - 260.0' Shale/siltstone [Underburden]
Light olive gray, stiff, non-calcareous; trace sand at 250', increases with depth to 260'

260.0 - 288.0' Sandstone [Underburden]
Medium light gray (N6), stiff to soft from 260'-265', very soft from 265'-273', hard from 273'-276'; grain sizes poorly sorted, very fine to moderately fine

288.0 - 331.0' Silty shale to siltstone
Medium to medium light gray (N6), firm, non-plastic, calcareous; interbedded sands at 290'-300', sand absent at 300', ... Some interbedded sand at 325'-327'; then very hard cemented sandy siltstone at 327'-331'; rig chattering, slow to advance

331.0 - 338.0' Sandstone, fine to very fine
Very hard to hard, medium gray (N5); very thin coal stringer at 335'

338.0 - 352.0' Siltstone and interbedded fine sandstone
Medium gray (N5), firm, calcareous, with thin carbonaceous shale and coal stringer at 338', no sandstone 350'-352'

352.0 - 360.0' Coal [Flowers-Goodale]
Black (N1), moderately dense, hard, cleated, mild sulfur odor

360.0 - 364.0' Siltstone
Light olive gray, firm, non-calcareous
WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

0.0 - 5.0' Siltstone [Bedrock]
Slightly moist to dry, pale yellowish brown and grayish orange, soft to moderately firm, weathered "soil top 3'

5.0 - 18.0' Siltstone/shale
Dry, colors from dark yellowish orange at 5' to medium gray at 18', hard to moderately firm, all moderately carbonaceous (reacts with HCl)

18.0 - 19.0' Carbonaceous shale stringer
Dry, medium dark gray, moderately firm

19.0 - 20.0' Carbonaceous shale/coal
Dry, brownish black, hard, not cleated

20.0 - 37.0' Siltstone
Dry, medium light gray to olive gray, firm, non-carbonaceous

37.0 - 47.0' Sandstone
Dry to slightly moist, medium gray, moderately firm to soft with depth; cemented layer at 40'-41', very light gray sandstone; cemented very hard layer at 44'-47'; bluish white to medium light gray, rig chattering, slow to advance, moderately calcareous

47.0 - 52.0' Silty sandstone
Moist, medium light gray, soft

52.0 - 60.0' Siltstone
Dry, medium light gray, color change at 56' to brownish gray (5YR 4/1)

60.0 - 62.0' Siltstone, some very fine sand
Moist, light olive gray to medium gray, soft, non-calcareous

62.0 - 65.0' Carbonaceous shale
Dry, olive gray (5Y 3/2), moderately firm, stringer cemented siltstone at 63', very light gray, non-calcareous

65.0 - 67.0' Sandstone
Slight moist, medium light gray, very soft, non-calcareous, medium fine grained

67.0 - 70.0' Shale
Dry, grayish brown, mildly carbonaceous, moderately firm

70.0 - 71.0' Sandstone
Moist, medium light gray, fine grained

71.0 - 77.0' Siltstone
Dry to slightly moist, medium gray, soft, carbonaceous shale stringer at 71', dry, brownish gray

77.0 - 104.0' Shale, interbedded siltstone
Dry, medium light gray and greenish gray, firm, mildly calcareous, reacts to HCl

104.0 - 108.0' Interbedded sandstone/siltstone
Very fine, soft, medium dark gray

108.0 - 119.0' Shale
Dry, medium light gray, moderately firm, non-calcareous

119.0 - 122.5' Coal
Dry, brownish black, cleated

122.5 - 140.0' Siltstone
Dry, very light gray to light gray, calcareous, soft to moderately firm, interbedded sandstone at 125'-130', hard cemented stringer at 130'

140.0 - 152.0' **Shale**
Dry, very thin dark interbeds, medium light gray, firm, non-calcareous, moderately carbonaceous at 140' - 145', very hard cemented layer at 151'

152.0 - 155.5' **Sandstone**
Slightly moist to dry, light olive gray, soft to very soft

155.5 - 179.0' **Coal**
Dry, grayish and brownish black to black, cleated multiple planes, junk

179.0 - 190.0' **Siltstone**
Dry, light gray and yellowish gray, stiff, non-calcareous

190.0 - 228.0' **Sandstone, medium fine grained**
Moist to very moist with depth, light medium gray, silty to 207', very soft to firm at 210', interbedded claystone at 207' - 209', then no fines at 210' - 228'

228.0 - 233.0' **Coal**
Wet, black, hard, cleated multiple planes

233.0 - 239.0' **Carbonaceous shale/non-carbonaceous shale**
Dry, medium gray and olive gray, soft, non-plastic; cemented zone at 236' - 239', non-carbonaceous, medium light gray shale, very hard, rig chattering

239.0 - 241.5' **Coal**
Wet, black, hard, cleated multiple planes

241.5 - 248.0' **Sandstone**
Very moist, light olive gray (5Y 6/1)

248.0 - 259.0' **Coal** [Upper Knobloch]
Black, hard, cleated 3x

259.0 - 265.0' **Fine sandstone/interbedded claystone**
Moist, light gray and light olive gray, soft

265.0 - 295.0' **Claystone, some trace intercalcated sandstone**
Moist, soft

295.0 - 320.0' **Sandstone, medium fine grained**
Very moist to wet, some interbedded claystone, light olive gray, very soft

320.0 - 339.0' **Coal** [Lower Knobloch]
Black, hard, cleated 3x

339.0 - 340.0' **Claystone, silty**
Dry, light gray, moderately firm, non-calcareous, non-plastic

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**WELL CONSTRUCTION**

- 10/20 Silica Sand
- 0.025-inch Slot Screen
- Centralizer
- End Cap
- Bottom of Hole
WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

0.0 - 5.0' Siltstone (Bedrock)
- Slightly moist to dry, pale yellowish brown and grayish orange, soft to moderately firm, weathered topsoil to 3'
5.0 - 18.0' Siltstone/shale
- Dry, colors from dark yellowish orange at 5' to medium gray at 18', hard to moderately firm, all moderately carbonaceous (reacts with HCl)
18.0 - 19.0' Carbonaceous shale stringer
- Dry, medium dark gray, moderately firm
19.0 - 20.0' Carbonaceous shale/coal
- Dry, brownish black, hard, not cleated
20.0 - 37.0' Siltstone
- Dry, medium light gray to olive gray, firm, non-carbonaceous
37.0 - 47.0' Sandstone
- Dry to slightly moist, medium gray, moderately firm to soft with depth; cemented layer at 40' - 41'; very light gray sandstone, cemented very hard layer at 44' - 47'; bluish white to medium light gray, rig chattering, slow to advance, moderately calcareous
47.0 - 52.0' Silty sandstone
- Moist, medium light gray, soft
52.0 - 60.0' Siltstone
- Dry, medium light gray, color change at 56' to brownish gray (5YR 4/1)
60.0 - 62.0' Silty sandstone, some very fine sand
- Moist, light olive gray to medium gray, soft, non-calcareous
62.0 - 65.0' Carbonaceous shale
- Dry, olive gray (5Y 3/2), moderately firm, stringer cemented siltstone at 63', very light gray, non-calcareous
65.0 - 67.0' Sandstone
- Slightly moist, medium light gray, very soft, non-calcareous, medium fine grained
67.0 - 70.0' Shale
- Dry, grayish brown, mildly carbonaceous, moderately firm
70.0 - 71.0' Sandstone
- Moist, medium light gray, fine grained
71.0 - 77.0' Siltstone
- Dry to slightly moist, medium gray, soft; carbonaceous shale stringer at 71', dry, brownish gray
77.0 - 104.0' Shale, interbedded siltstone
- Dry, medium light gray and greenish gray, firm, mildly calcareous, reacts to HCl
104.0 - 108.0' Interbedded sandstone/siltstone
- Very fine, soft, medium dark gray
108.0 - 119.0' Shale
- Dry, medium light gray, moderately firm, non-calcareous
119.0 - 122.5' Coal
- Dry, brownish black, cleated
122.5 - 140.0' Siltstone
- Dry, very light gray to light gray, calcareous, soft to moderately firm, interbedded sandstone at 125' - 130', hard cemented stringer at 130'
WELL CONSTRUCTION

GRAPHICS

GEOLOGICAL DESCRIPTION

140.0 - 152.0’ Shale
Dry, very thin dark interbeds, medium light gray, firm, non-calcareous, moderately carbonaceous at 140'-145', very hard cemented layer at 151'

152.0 - 155.0’ Sandstone
Slightly moist to dry, light olive gray, soft to very soft

155.5 - 179.0’ Coal
Dry, grayish and brownish black to black, cleated multiple planes, junk

179.0 - 190.0’ Siltstone
Dry, light gray and yellowish gray, stiff, non-calcareous

190.0 - 228.0’ Sandstone, moderately fine grained
Moist to very moist with depth, light medium gray, silty to 207’, very soft to firm at 210’,
Interbedded claystone at 207'-209’, then no fines at 210'-228’

Wet; inject water at 210’

228.0 - 233.0’ Coal
Wet, black, hard, cleated multiple planes

233.0 - 239.0’ Carbonaceous shale/non-carbonaceous shale
Dry, medium gray and olive gray, soft, non-plastic; cemented zone at 236'-239’,
Non-carbonaceous, medium light gray shale, very hard, rig chattering

239.0 - 241.5’ Coal
Wet, black, hard, cleated multiple times

241.5 - 250.0’ Siltstone
Wet, light olive gray, soft

250.0 - 260.0’ Coal [Upper Knobloch]
Black, hard, cleated, tagged shale at 260’
**WELL CONSTRUCTION**

- 2.0" steel +2-18
- Bentonite Chips 1.0

**GEOLOGICAL DESCRIPTION**

- **0.0 - 5.0' Siltstone [Bedrock]**
  - Slightly moist to dry, pale yellowish brown and grayish orange, soft to moderately firm, weathered topsoil top 3'

- **5.0 - 18.0' Siltstone/shale**
  - Dry, colors from dark yellowish orange at 5' to medium gray at 18', hard to moderately firm, all moderately carbonaceous (reacts with HCl)

- **18.0 - 19.0' Carbonaceous shale stringer**
  - Dry, medium dark gray, moderately firm

- **19.0 - 20.0' Carbonaceous shale/coal**
  - Dry, brownish black, hard, not cleated

- **20.0 - 37.0' Siltstone**
  - Dry, medium light gray to olive gray, firm, non-calcareous

- **37.0 - 47.0' Sandstone**
  - Dry to slightly moist, medium gray, moderately firm to soft with depth; cemented layer at 40'-41', very light gray sandstone; cemented very hard layer at 44'-47'; bluish white to medium light gray, rig chattering, slow to advance, moderately carbonaceous

- **47.0 - 52.0' Silty sandstone**
  - Moist, medium light gray, soft

- **52.0 - 60.0' Siltstone**
  - Dry, medium light gray, color change at 56' to brownish gray (5YR 4/1)

- **60.0 - 62.0' Siltstone, some very fine sand**
  - Moist, light olive gray to medium gray, soft, non-calcareous

- **62.0 - 65.0' Carbonaceous shale**
  - Dry, olive gray (5Y 3/2), moderately firm, stringer cemented siltstone at 63', very light gray, non-calcareous

- **65.0 - 67.0' Sandstone**
  - Slightly moist, medium light gray, very soft, non-calcareous, medium fine grained

- **67.0 - 70.0' Shale**
  - Dry, grayish brown, mildly carbonaceous, moderately firm

- **70.0 - 71.0' Sandstone**
  - Moist, medium light gray, fine grained

- **71.0 - 77.0' Siltstone**
  - Dry to slightly moist, medium gray, soft; carbonaceous shale stringer at 71', dry, brownish gray

- **77.0 - 104.0' Shale, interbedded siltstone**
  - Dry, medium light gray and greenish gray, firm, mildly calcareous, reacts to HCl

- **104.0 - 106.0' Interbedded sandstone/siltstone**
  - Very fine, soft, medium dark gray

- **108.0 - 119.0' Shale**
  - Dry, medium light gray, moderately firm, non-calcareous

- **119.0 - 122.5' Coal**
  - Dry, brownish black, cleated

- **122.5 - 140.0' Siltstone**
  - Dry, very light gray to light gray, calcareous, soft to moderately firm, interbedded sandstone at 125'-130', hard/cemented stringer at 130'
140.0 - 152.0' **Shale**
Dry, very thin dark interbeds, medium light gray, firm, non-calcareous, moderately carbonaceous at 140'-145', very hard cemented layer at 151'

152.0 - 155.5' **Sandstone**
Slightly moist to dry, light olive gray, soft to very soft

155.5 - 179.0' **Coal**
Dry, grayish and brownish black to black, cleated multiple planes, junk

179.0 - 190.0' **Siltstone**
Dry, light gray and yellowish gray, stiff, non-calcareous

190.0 - 228.0' **Sandstone, moderately fine grained**
Moist to very moist with depth, light medium gray, silty to 207', very soft to firm at 210', interbedded claystone at 207'-209', then no fines at 210'-228' wet; inject water at 220'

228.0 - 233.0' **Coal**
Wet, black, hard, cleated multiple planes
**GEOLOGICAL DESCRIPTION**

**WELL CONSTRUCTION**
122.5 - 140.0' Siltstone  
Dry, very light gray to light gray, calcareous, soft to moderately firm, interbedded sandstone at 125'-130', hard/cemented stringer at 130'

140.0 - 152.0' Shale  
Dry, very thin dark interbeds, medium light gray, firm, non-calcareous, moderately carbonaceous at 140'-145', very hard cemented layer at 151'

152.0 - 155.5' Sandstone  
Slightly moist to dry, light olive gray, soft to very soft

155.5 - 179.0' Coal  
Dry, grayish and brownish black to black, cleated multiple planes, junk

179.0 - 190.0' Siltstone  
Dry, light gray and yellowish gray, stiff, non-calcareous

190.0 - 228.0' Sandstone, moderately fine grained  
Moist to very moist with depth, light medium gray, silky to 207', very soft to firm at 210', wet; inject water at 200'

228.0 - 229.0' Coal  
Wet, black, hard, cleated multiple planes

229.0 - 233.0' Carbonaceous shale/non-carbonaceous shale  
Dry, medium gray and olive gray, soft, non-plastic; cemented zone at 236'-239', non-carbonaceous, medium light gray shale, very hard, rig chattering

239.0 - 241.5' Coal  
Wet, black, hard, cleated multiple times

241.5 - 248.0' Sandstone  
Very moist, light olive gray (5Y 6/1)

248.0 - 259.0' Coal [Upper Knobloch]  
Black, hard, cleated 3x

259.0 - 265.0' Fine sandstone/interbedded claystone  
Moist, light gray and light olive gray, soft

265.0 - 295.0' Claystone, some trace intercalcated sandstone  
Moist, soft

295.0 - 320.0' Sandstone, medium fine grained  
Very moist to wet, some interbedded claystone, light olive gray, very soft

320.0 - 339.0' Coal [Lower Knobloch]  
Black, hard, cleated 3x
Date Hole Started: 3/21/11  
Date Hole Finished: 3/22/11  

**WELL CONSTRUCTION**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
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<td>100.0</td>
<td>10/20 Silica Sand</td>
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<tr>
<td>120.0</td>
<td>centralizer</td>
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<tr>
<td>140.0</td>
<td>centralizer</td>
</tr>
<tr>
<td>150.0</td>
<td>end cap</td>
</tr>
<tr>
<td><strong>410.0</strong></td>
<td>0.025-inch Slot, SDR 17 Screen</td>
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**GEOLOGICAL DESCRIPTION**

<table>
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<tr>
<th>Depth</th>
<th>Description</th>
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</table>
| 339.0 - 340.0' | Claystone, silty  
Dry, light gray, moderately firm, non-calcareous, non-plastic |
| 340.0 - 341.0' | Hard, dense shale (6")  
Light yellowish gray |
| 341.0 - 350.0' | Claystone  
Medium gray, greasy, some silt, firm |
| 350.0 - 355.0' | Siltstone  
Medium gray, weak |
| 355.0 - 360.0' | Sandstone/claystone  
Sandstone 1-2" thick, claystone brownish gray |
| 360.0 - 368.0' | Siltstone  
Medium gray, weak |
| 368.0 - 371.0' | Fine sandstone, hard ledge  
Medium gray, well cemented |
| 371.0 - 374.0' | Sandstone, fine  
Medium gray, firm |
| 374.0 - 380.0' | Silty sandstone  
Medium gray, weak |
| 380.0 - 390.0' | Silty sandstone  
Medium gray, very weak, very few chunks in cuttings |
| 390.0 - 391.0' | Coal  
Black, hard, cleated |
| 391.0 - 398.0' | Sandstone  
Weak |
| 398.0 - 400.0' | Claystone  
Medium brown |
| 400.0 - 401.0' | Siltstone  
Light gray, greasy claystone |
| 401.0 - 405.0' | Fine sandstone, silty  
Siltstone medium gray |
| 405.0 - 420.0' | Some very fine sand  
Very weak |
| 420.0 - 423.0' | Some very fine sand  
Very weak |
| 423.0 - 430.0' | Sandstone  
Medium gray, becomes harder and coarser than above; becomes fine grained at 430', micaeous, medium to light gray |
| 430.0 - 440.0' | Sandstone  
Becomes clayey, color change to brownish gray |
| 440.0 - 443.0' | Coal  
Black, cleated |
| 443.0 - 444.0' | Sandstone  
Light gray, hard, dense |
| 444.0 - 446.0' | Claystone  
Light gray, firm |
Remarks: Inject water at 60'. Annular seal with Hi-Solids (20% solid) bentonite grout and 3/8" bentonite chips. Pump test at 8 gpm, yield at full draw down +/- 12.5. SC=2090 µmhos/cm after 300 gallon purge, pH=8.18; SWL 7-11-2011 174.17 Top PVC. Developed 65 minutes - 700 to 750 gallons pumped.
3/8" bentonite chips
0.025-inch Slot Screen
Bottom of Hole

165.0 - 191.0' Siltstone
Dry, brownish gray to light olive gray, moderately firm, calcareous, very hard cemented at 168'-170.5', firm again at 171'; trace sand at 188'

191.0 - 239.0' Coal [KU - Upper Knobloch]
Black, hard, cleated on multiple planes, dense

239.0 - 255.0' Siltstone/shale
Dry, medium light gray, moderately stiff, non-calcareous, non-carbonaceous; very hard cemented zone at 246'-249' and 250'-250.5'

255.0 - 265.0' Carbonaceous shale
Becomes carbonaceous at 255'; color change to dark gray and brownish gray, stiff

265.0 - 281.0' Coal [KL - Lower Knobloch]
Black, dense, cleated on multiple planes

281.0 - 282.0' Siltstone
Very light gray, moderately firm, non-calcareous, non-carbonaceous, TD = 282'
### WELL CONSTRUCTION

<table>
<thead>
<tr>
<th>Depth Range (ft)</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 10.0'</td>
<td>Silt and clay</td>
<td>Slightly moist, moderate yellowish brown (10YR 5/4), loose, roots, non-plastic</td>
</tr>
<tr>
<td>10.0 - 10.5'</td>
<td>Shale</td>
<td>Dry, dark yellowish brown (10YR 4/2), hard, cemented</td>
</tr>
<tr>
<td>10.5 - 22.0'</td>
<td>Siltstone</td>
<td>Dry, pale yellowish brown (10YR 6/2) and medium yellowish brown (10YR 5/4), very soft, calcareous, some interbedded fine sand at 15'-20'</td>
</tr>
<tr>
<td>22.0 - 80.0'</td>
<td>Sandstone, fine to very fine</td>
<td>Dry, grayish orange (10YR 7/4), soft, calcareous, streaks of light brown throughout (5YR 5/6); cemented fine sandstone stringer, yellowish gray (5Y 8'1) at 22' and 28'; grain size increases with depth from 41'-51', to fine and medium fine grained; color change to very light gray (N8) at 41', color change to light brown (5YR 6/4) and moderate yellowish brown (10YR 5/4) at 51'; becomes moist at 55', wet, begin injecting water at 60'. Cemented siltstone stringer at 65', light brown (5TR 5/6); yield ~2 gpm open hole, TDS = 4,300 ppm</td>
</tr>
<tr>
<td>80.0 - 100.0'</td>
<td>Siltstone</td>
<td>Moderate yellowish brown (10YR 5/4), soft to moderately firm, some fine sandstone interbedded</td>
</tr>
<tr>
<td>100.0 - 105.5'</td>
<td>Siltstone</td>
<td>Dry, light olive gray (5Y 6/1), moderately firm, calcareous, trace coal, very minimal trace at 102'</td>
</tr>
<tr>
<td>105.5 - 160.0'</td>
<td>Sandstone</td>
<td>Medium light gray (N6) to medium gray (N5), hard, cemented, rig chattering; becomes silty, hardness decreases to firm at 111'; no silt, hard again at 115'-116'; soft to moderately firm from 116'-120', wet, making water at 130', yield estimated at 5-7 gpm; trace coal at 160'-162'</td>
</tr>
</tbody>
</table>

### GEOLOGICAL DESCRIPTION

Remarks: Lithology based on well B8-KL. Injection at 60'; three hours for development and completion. Developed with 4 inch submersable pump; pumped at 19 gpm.
165.0 - 191.0' **Siltstone**
Dry, brownish gray (5YR 4/1) to light olive gray (5Y 6/1), moderately firm, calcareous, very hard cemented at 168'-170.5', firm again at 171'; trace sand at 188'

191.0 - 239.0' **Coal** [KU - Upper Knobloch]
Black, hard, cleated on multiple planes, dense, estimated yield 19 gpm

239.0 - 255.0' **Siltstone/shale**
Dry, medium light gray (N6), moderately stiff, non-calcareous, non-carbonaceous; very hard cemented zone at 246'-249' and 250'-250.5'
Bentonite Chips

0.025-inch Slot Screen

Bottom of Hole

0.0 - 10.0' Silt and clay

[Topsoil/Colluvium] Slightly moist, moderate yellowish brown (10YR 5/4), loose, roots, non-plastic

10.0 - 10.5' Shale

[Bedrock] Dry, dark yellowish brown (10YR 4/2), hard, cemented

10.5 - 22.0' Siltstone

[Bedrock] Dry, pale yellowish brown (10YR 6/2) and medium yellowish brown (10YR 5/4), very soft, calcareous, some interbedded fine sand at 15'-20'

22.0 - 80.0' Sandstone, fine to very fine

Dry, grayish orange (10YR 7/4), soft, calcareous, streaks of light brown throughout (5YR 5/6); cemented fine sandstone stringer, yellowish gray (5Y 8/1) at 22 and 26'. Grain size increases with depth from 41'-51', to fine and medium fine grained. Color change to very light gray at 41', color change to light brown (5YR 5/6) and moderate yellowish brown (10YR 5/4) at 51'; becomes moist at 55', wet, begin injecting water at 60'. Cemented siltstone stringer at 65', light brown (5YR 5/6); yield ~2 gpm open hole, TDS = 4,300 ppm

80.0 - 100.0' Siltstone

Moderate yellowish brown (10YR 5/4), soft to moderately firm, some fine sandstone interbedded

100.0 - 104.5' Siltstone

Dry, light olive gray (5Y 6/1), moderately firm, calcareous, trace coal, very minimal trace at 102'

104.5 - 110.0' Shale

[Dark gray (N3)]

110.0 - 116.0' Sandstone

Medium light gray (N6) to medium gray (N5), hard, cemented, rig chattering; becomes silty, hardness decreases to firm at 111'; no silt, hard again at 115-116'; soft to moderately firm from 116'-120', wet, making water at 130', yield estimated at 5-7 gpm; trace coal at 160'

163.0 - 165.0' Clayey siltstone

[Fort Union Formation] Olive gray (5Y 4/1), weakly calcareous, weakly laminated (mm)

Remarks: Lithology based on well B8-KL. Drilled through sandstone, deepest water at 130'-165' interval, screened this interval; trace water at 70' maybe 1-2 gpm at 80'. Yield estimated at 5-7 gpm during air-lift development.
**Well Construction**

- **2.0" steel**
- Hi-solids (20%) EZSeal grout

**Geological Description**

- **0.0 - 10.0' Silt and clay**
  - Topsoil/Colluvium
  - Slightly moist, moderate yellowish brown, loose, roots, non-plastic

- **10.0 - 10.5' Shale**
  - Bedrock
  - Dry, dark yellowish brown, hard, cemented

- **10.5 - 22.0' Siltstone**
  - Bedrock
  - Dry, pale yellowish brown and medium yellowish brown, very soft, calcareous, some interbedded fine sand at 15'-20'

- **22.0 - 80.0' Sandstone, fine to very fine**
  - Dry, grayish orange, soft, calcareous, streaks of light brown throughout (5YR 5/6); cemented fine sandstone stringer, yellowish gray at 22' and 26'. Grain size increases with depth from 41'-51', to fine and medium fine grained. Color change to very light gray at 47'; color change to light brown and moderate yellowish brown at 51'; becomes moist at 55', inject water at 60'. Cemented siltstone stringer at 65'; light brown; yield ~2 gpm open hole, TDS = 4,300 ppm

- **80.0 - 100.0' Siltstone**
  - Moderate yellowish brown, soft to moderately firm, some fine sandstone interbedded

- **100.0 - 105.5' Siltstone**
  - Dry, light olive gray, moderately firm, calcareous, trace coal, very minimal trace at 102'

- **105.5 - 165.0' Sandstone**
  - Medium light gray to medium gray, hard, cemented, rig chattering; becomes silty, hardness decreases to firm at 111'; no silt, hard again at 115'-116'; soft to moderately firm from 116'-120', wet, making water at 130', yield ~30 gpm, TDS=1,800 ppm; trace coal at 160'-162'

- **165.0 - 191.0' Siltstone**
  - Dry, brownish gray to light olive gray, moderately firm, calcareous, very hard cemented at 168'-170.5', firm again at 171'; trace sand at 186
WELL CONSTRUCTION

GEOLOGICAL DESCRIPTION

191.0 - 239.0' **Coal** [KU - Upper Knobloch]
Black, hard, cleated on multiple planes, dense

239.0 - 255.0' **Siltstone/shale**
Dry, medium light gray, moderately stiff, non-calcareous, non-carbonaceous; very hard cemented zone at 246'-249' and 250'-256.5'

255.0 - 265.0' **Carbonaceous shale**
Becomes carbonaceous at 255'; color change to dark gray and brownish gray, stiff

265.0 - 281.0' **Coal** [KL - Lower Knobloch]
Black, dense, cleated on multiple planes

281.0 - 290.0' **Siltstone/sandstone**
Very light gray, moderately firm, non-calcareous, non-carbonaceous; grades to nearly all finesandstone from 282'-285'; siltier again at 288'; color change to medium light gray

290.0 - 292.0' **Coal stringer**
Black, dense

292.0 - 300.0' **Claystone/siltstone**
Dry, medium light gray to brownish gray, moderately carbonaceous; coal stringer at 297'-298', thin, black, dense

300.0 - 310.0' **Sandstone**
Light gray, stiff to hard, very cemented at 310' then hardness decreases to stiff

310.0 - 370.0' **Shale/siltstone**
Medium light gray with some brownish gray; carbonaceous shale/coal stringer at 316' and 320'; non-carbonaceous from 321'-335', moderately calcareous; very hard cemented zone at 350'-352', shale, rig chattering, slow to advance; hardness remains at very stiff from 352'-361'; very hard cemented stringer at 361'; carbonaceous shale stringer at 361.5

370.0 - 375.0' **Coal**
Black, dense, cleated on multiple planes

375.0 - 410.0' **Siltstone/shale**
Dry, medium light gray, mildly carbonaceous to non-carbonaceous, non-calcareous, firm, carbonaceous shale from 400'-410'

410.0 - 420.0' **Sandstone, silty**
Medium gray to medium light gray, firm to stiff, medium fine grained

420.0 - 440.0' **Shale, moderately carbonaceous**
Medium gray to light brownish gray, stiff, silty with some intercalated sandstone, sandstone increases with depth, becomes less carbonaceous to non-carbonaceous with depth

440.0 - 478.0' **Sandstone, fine grained**
Medium gray, moderately firm to soft with depth

478.0 - 480.0' **Shale, moderate carbonaceous**
Brownish gray, moderately stiff to firm, TD = 480'
Client: Arch Coal
Project: Otter Creek Mine Permit (10068)
County: Powder River State: Montana
Property Owner: State of Montana
Legal Description: T4S, R45E, Sec. 16, N 471769.36, E 2817516.92
Location Description: North edge State Section 16
Recorded By: AJH
Drilling Company: Askin Drilling
Driller: Ron Askin
Drilling Method: Air Rotary
Drilling Fluids Used:
Purpose of Hole: Install Monitor Well
Target Aquifer: Knobloch Coal
Hole Diameter (in): 7 7/8"
Total Depth Drilled (ft): 185

WELL COMPLETION
Y/N DESCRIPTION INTERVAL
Well Installed? Y 4.5" Sch 40, PVC +1.27-185
Surface Casing Used? Y 8" steel +1.6-18.5
Screen/Perforations? Y 4.5" 0.025-inch slot 116-185
Sand Pack? Y 10/20 silica sand 185-109
Annular Seal? Y Bentonite Chips 109-0
Surface Seal? N

DEVELOPMENT/SAMPLING
Well Developed? Y Air Lift
Water Samples Taken? N
Boring Samples Taken? N

Nothing: 471769.36
Easting: 2817516.92

Static Water Level Below MP: 99.26
Surface Casing Høt: 1.65
Surface Casing Height (ft): 1.65
Riser Height (ft): 1.32
Ground Surface Elevation (ft): 3135.00
MP Elevation (ft): 3136.32

Remarks: Lithology based on well B9-U. Tested 40 ft. zone extensively and found to be very moist with no free water. Top of the Knobloch at 115.5' bgs, and bottom of the Knobloch at 185' bgs.
Well Installed? Y
Surface Casing Used? Y
Screen/Perforations? Y
Sand Pack? Y
Annular Seal? Y
Surface Seal? N

Well Developed? Y
Water Samples Taken? N
Boring Samples Taken? N

Static Water Level Below MP: 104.57
Surface Casing Height (ft): 1.88
Riser Height (ft): 1.54
Ground Surface Elevation (ft): 3134.60
MP Elevation (ft): 3136.14

Hydrometrics, Inc.
Consulting Scientists and Engineers
Billings, Montana

Date Hole Started: 7/13/11
Hole Name: B9-U
Date Hole Finished: 7/13/11

Remarks:

- Tested Knobloch for yield at base of coal, 5-8 gpm. Tested for water at 241'-251' and there was apparently no water, SC=1698 µmhos/cm, pH=8.44, may be trace water due to SC change. Cased coal may be Flowers-Goodale seam. Yield est. at 1.5 gpm.

- Tested for yield at base of coal, 5-8 gpm. Tested for water at 241'-251' and there was apparently no water, SC=1698 µmhos/cm, pH=8.44, may be trace water due to SC change. Cased coal may be Flowers-Goodale seam. Yield est. at 1.5 gpm.
Date Hole Started: 7/13/11  Date Hole Finished: 7/13/11

WELL CONSTRUCTION

GRAPHICS

GEOLOGICAL DESCRIPTION

182.0 - 195.0'  Silty claystone
Dry, light olive gray (5Y 6/1), laminated, soft, grades to shale at 190'

195.0 - 199.0'  Siltstone
Olive gray (5Y 4/1), calcareous, carbonaceous laminae, weakly laminated, 1/2 coal stringer at base

199.0 - 204.0'  Silty shale
Light olive gray (5Y 6/1), calcareous, soft

204.0 - 215.0'  Shale, calcareous
Dry, light olive gray (5Y 6/1), hard calcareous layer at 208'-209.5'

215.0 - 220.0'  Clayey siltstone
Light olive gray (5Y 6/1), calcareous, soft, coal stringer at 219'-219.5'

220.0 - 230.0'  Siltstone, grading to fine silty sandstone
Light olive gray (5Y 6/1), calcareous

230.0 - 238.0'  Siltstone
Light olive gray (5Y 6/1), calcareous, hard at 238'

238.0 - 240.0'  Sandstone, fine, silty
Light olive gray (5Y 6/1), soft, calcareous, poorly sorted, sub-rounded

240.0 - 241.0'  Shale
Light olive gray (5Y 6/1), soft

241.0 - 251.0'  Fine sandstone to very fine silty sandstone
75% quartz; sub-rounded, poorly sorted, calcareous. Tested for water, did not appear to have any gain over Knobloch water

251.0 - 261.0'  Shale
Dark greenish gray (5Y 4/1), coal stringer at 256'-258'

261.0 - 273.0'  Sandy siltstone, siltstone and shale
Light olive gray (5Y 6/1), intercalated, hard at 266'-266.5'

273.0 - 275.0'  Silty shale
Olive gray (5Y 6/1), calcareous, soft

275.0 - 282.0'  Fine silty sandstone
Light olive gray (5Y 6/1), calcareous, soft

282.0 - 293.0'  Coal
Black, cleated in 3 directions, firm, appears to make water

293.0 - 295.0'  Clayey siltstone
Olive gray (5Y 4/1), soft
### WELL CONSTRUCTION

- **Client:** Arch Coal
- **Project:** Otter Creek Mine Permit (10068)
- **County:** Powder River
- **State:** Montana
- **Property Owner:** Ark Land Company
- **Legal Description:**
  - **Location Description:** Just west of Stevens road to house
  - **Recorded By:** HJK
  - **Drilling Company:** Askin Drilling
  - **Driller:** Ron Askin
  - **Drilling Method:** Air Rotary
  - **Drilling Fluids Used:** None
  - **Purpose of Hole:** Install Monitor Well
- **Target Aquifer:** Knobloch Coal
- **Hole Diameter (in):** 4.5"
- **Total Depth Drilled (ft):** 19

### GEOLOGICAL DESCRIPTION

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0'</td>
<td>Silty sand</td>
</tr>
<tr>
<td>1.0 - 19.0'</td>
<td>Clinker</td>
</tr>
</tbody>
</table>

- **Dry, light brown, roots**
- **Dry, light reddish brown to moderate red (5R 4/6), dusky red (5R 3/4), altered shales and fine-grained sandstone, hard**

### WELL COMPLETION

- **Well Installed?** N
- **Surface Casing Used?** N
- **Screen/Perforations?** N
- **Sand Pack?** N
- **Annular Seal?** N
- **Surface Seal?** Y, Bentonite Chips

### DEVELOPMENT/SAMPLING

- **Well Developed?** N
- **Water Samples Taken?** N
- **Boring Samples Taken?** N

### Remarks:

Hole abandoned, backfilled with bentonite chips - moved to South to avoid thick clinker.
**GEOLOGICAL DESCRIPTION**

0.0 - 1.0’ Silt with clinker gravel  
(Colluvium/Weathered Bedrock Clinker)  
Slightly moist, dark reddish brown (10R 3/4) to moderate brown (5YR 3/4)

1.0 - 3.0’ Thermally altered sandstone  
(Clinker)  
Dry, moderate reddish orange to moderate reddish brown, hard, cuttings ejected as gravel/cobble size fragments. Very sandy, cuttings were ground at 10’, color change to all moderate reddish brown; less sand again at 20’. Color change to moderate orange pink (10R 7/4 and 5YR 8/4) at 22’; color change to grayish red (10R 4/2) at 33’

3.0 - 10.0’ Thermally altered sandstone/siltstone  
(Clinker)  
Dry, very hard, cuttings ejected as gravel/cobble size fragments. Very sandy, cuttings were ground at 10’, color change to all moderate reddish brown; less sand again at 20’. Color change to moderate orange pink (10R 7/4 and 5YR 8/4) at 22’; color change to grayish red (10R 4/2) at 33’

35.0 - 55.0’ Thermally altered shale  
(Clinker)  
Dry, pale red and pale brown, some light brown (5YR 6/4), very hard. Color change to grayish orange pink (5YR 7/2) and light brown (5YR 6/4) at 40’

55.0 - 90.0’ Thermally altered siltstone/sandstone  
Dry, sandstone texture fine to very fine, pale red (5R 6/2) and 10R 6/2), hard to very hard. Trace calcareous, very pale orange baked siltstone at 55’. Color change to pale reddish brown at 85’

90.0 - 105.0’ Thermally altered shale  
Dry, pale red to very dusky purple to very dusky red purple, very hard, rig slow to advance. Medium light gray to light bluish gray color at 99-101’. Color returns to pale red to very dusky purple to very dusky red purple with traces medium light gray to light bluish gray at 101’. Switch from drag bit to 7 7/8” Tricone roller bit at 102’, drove steel to 120’, injected some water at 105’

105.0 - 110.0’ Burned siltstone/sandstone interbedded  
Dry, pale red, some hard to very hard, ejected as cobbles, other cuttings ground; some medium light gray shale interbeds

110.0 - 134.0’ Burned sandstone  
(Clinker)  
Dry, pale red to grayish orange and grayish orange pink with depth; softer than above but still hard, cuttings ground mostly to sand size particles, some cohesive gravel size fragments. Color change to very pale orange at 125’, poor returns on cuttings/poor circulation

134.0 - 145.0’ Burned shale  
(Clinker)  
Dry, very light gray and yellowish gray, very hard; colors include pale reddish brown and pale red purple at 137’

145.0 - 150.0’ Burned sandstone/ash  
(Clinker/Bedrock)  
Slightly moist, trace other vitrified sediments, grayish orange and very pale orange, some hard, some loose, cuttings ground

148.0 - 150.0’ Baked shale/carbonaceous  
(Bedrock)  
Very moist to wet from 145-147’, medium dark gray, very hard to firm with depth, injecting water at 148’; harder at top due to proximity to burn
**GEOLOGICAL DESCRIPTION**

**0.0 - 14.0' Silty clay** [Colluvium]
Dry to moist, moderate yellowish brown and moderate brown, loose, trace white calcareous precipitates; trace clinker gravel at 9', becomes sandy at 11' and color change to pale reddish brown (10R 5/4).

**14.0 - 21.0' Sandstone, thermally altered** [Clinker]
Dry, grayish orange pink to pale red, very hard to soft, medium fine grain, color change to pale reddish brown at 21'.

**21.0 - 33.0' Baked siltstone/sandstone (50/50)** [Clinker]
Dry, pale reddish brown, sandstone soft, cuttings ground; siltstone hard ejected as cobble-sized fragments; becomes mostly sandstone from 29'-33'.

**33.0 - 45.0' Baked sandstone** [Clinker]
Dry, pale red (10R 6/2), hard, cuttings ground; moisture to very moist at 43'.

**45.0 - 55.0' Baked shale** [Clinker]
Wet, light brown to moderate reddish brown, very hard, gravel to cobble size cuttings ejected, color change to light olive gray at 53'-55'; trace ash - very little to no ash.

**55.0 - 63.0' Coal** [Knobloch]
Wet, black, cleated, very hard, refusal of 8" steel.

**Remarks:** Drill with 7 7/8" drag bit to 40' ream with 10" drag bit; drive 61' of 8" steel, steel pulled back to expose perforations; developed with rig air and 2 gpm pump, color from dark brown to clear during development. Hole sloughed from 40'-43' bgs when steel pulled back. SC=3450 µmhos/cm, pH=8.03, temp=18.5° C; after development.
**GEOLOGICAL DESCRIPTION**

0.0 - 10.0' 
- **Clinker, burned sandstone**
  - Dry, pale reddish brown (0'-1') then moderate reddish orange, hard, cuttings ground by bit, moderately to severely brecciated at ground surface

10.0' - 19.0' 
- **Clinker, baked shale**
  - Hard, very hard, moderate reddish orange (10R 6/6) to light brown (5YR 5/6), very thin, soft, pale yellowish orange interbed (precipitated salts) at 15', calcareous

19.0' - 55.0' 
- **Clinker, baked siltstone/some sandstone, thickly interbedded**
  - Dry, moderate red (5R 4/6); increasing sand texture to 30', color change to pale red/grayish pink at 30' then decreasing sand texture to 40', color change to moderate reddish orange at 40'
  - Color change to pale reddish brown at 45', sandy
  - Color change to moderate red (5R 4/6) at 50', silty

55.0' - 124.0' 
- **Clinker, baked sandstone, fine to medium fine grain**
  - Dry, moderate reddish brown (10R 4/6) and moderate reddish orange (10R 6/6), stiff to moderately hard, cuttings ground
  - Becomes very hard at 81'-83', rig slow to advance, color change to grayish orange pink then color back to moderate reddish brown, hardness to stiff
  - Some interbedded baked siltstone at 70', then multiple color changes:
    - Dusty red at 71'-73'
    - Moderate orange pink (10R 7/4) at 73'-74', hardness change to soft, drills fast
    - Moderate orange pink (5YR 8/4) and light red (5R 6/6) at 74'-75'
    - Moderate orange pink (10R 7/4) at 75-76'
    - Dusty red (5R 3/4) at 76'-77'
    - Moderate reddish orange (10R 6/6) at 77'-80'
    - Moderate reddish brown (10R 6/4) to moderate red (5R 5/4) at 80-87'
    - Colors from moderate reddish orange to pale reddish brown at 87'-100'
    - Moisture increase to slightly moist at 90', increase to moderately moist at 93', very moist at 100', wet at 105' makes water, cuttings returned in clumps, try to inject water at 115'
    - Hardness to very hard at 121'-124'

- Bottom of Hole: 140.0' 

- **Clinker, baked sandstone, fine to medium fine grain**
  - As above, some sandstone with interbedded baked shale, color to pale yellowish orange (10YR 6/6)

- **Clinker, baked shale**
  - Wet, very dark red (5R 2/6) and dusty red (5R 3/4), very hard

- **Clinker, baked sandstone**
  - Color change to moderate reddish brown at 131'
  - Color change to dark reddish brown and dusty brown/black at 133-135' then multi-colored with light to dark grays and grayish reds from 135-140', laminated black streaks and iron (orange) streaks

Remarks: Drill and drive 8" steel to 62' bgs (refusal), drill to 120', lost circulation/poor returns. Attempted to use Drilling Foam to increase circulation on 4-7-2011. Returned to borehole on 4-13-2011; drive 6" steel to 138', drill to 140' bgs. Hole sloughed to 138' bgs, completed open hole. Well developed with rig air, yield approximately 100 gpm, SC=3700 µmhos/cm after development.
**GEOLOGICAL DESCRIPTION**

- **0.0 - 3.0' Silty Clay**
  - Dry, moderate yellowish brown (10YR 5/4), weakly calcareous, few roots, poor topsoil/colluvium

- **3.0 - 7.0' Clay [Colluvium]**
  - Moist, moderate brown (5YR 3/4), cohesive, may be plastic, very soft, calcareous, rolls 1/8"

- **7.0 - 10.0' Clay, silt and siltstone inclusions [Colluvium]**
  - Moist, grayish orange (10YR 7/4), to moderate brown (5YR 4/4), weakly calcareous but harder

- **10.0 - 12.0' Claystone [Bedrock]**
  - Moist, grayish orange (10YR 7/4) to moderate brown (5YR 4/4), weakly calcareous

- **12.0 - 15.0' Claystone**
  - Moist, grayish orange (10YR 7/4) to moderate brown (5YR 4/4), weakly calcareous but harder

- **15.0 - 17.0' Shale**
  - Slightly moist, dark yellowish brown (10YR 6/6), weakly calcareous, very soft

- **17.0 - 18.0' Shale**
  - Slightly moist, dusky yellowish brown (10YR 2/2), weakly calcareous, very soft

- **18.0 - 20.0' Clayey Siltstone**
  - Slightly moist, dark yellowish orange (10YR 6/6), calcareous, soft

- **20.0 - 25.0' Claystone, silt**
  - Slightly moist to dry at top, dark yellowish orange (10YR 6/6), calcareous, CaCO₃ cemented, hard at 20-20.5'

- **25.0 - 27.0' Siltstone**
  - Slightly moist, dark yellowish orange (10YR 6/6), calcareous, red streak at 26'

- **27.0 - 30.0' Siltstone**
  - Dry, light brown (5YR 4/4), calcareous

- **30.0 - 43.0' Siltstone**
  - Dry, light brown (5YR 4/4), calcareous but stratified (1mm), dark red streak at 36', grades to thermally altered sediments

- **43.0 - 60.0' Baked siltstone and shale [Clinker]**
  - Dry at top

- **60.0 - 80.0' Silty sandstone, baked [Clinker]**
  - Moist to wet at 73', moderate reddish brown (10R 4/6) to dusky red (5R 3/4), non calcareous, hard calcareous layer at 73', tan color, poor circulation, high yield of H₂O but difficult to determine due to lost circulation. Borehole making 30

- **80.0 - 100.0' Sandstone and siltstone [Clinker]**
  - Moderate red (5R 4/6) to dark yellowish orange (10YR 6/6), rock fragments to 3', very angular

- **100.0 - 110.0' Sandstone and siltstone [Clinker]**
  - Moderate red (5R 4/6) to dark yellowish orange (10YR 6/6), rock fragments to 3', very angular

- **110.0 - 120.0' Sandstone and siltstone [Clinker]**
  - Very soft, may have been coal but no coal detected in cuttings, no circulation below pipe
Hydrometrics, Inc.
Billing, Montana

**Stock Well Log**

**Hole Name: Chromo-2**
Date Hole Started: 4/12/11  Date Hole Finished: 4/13/11

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**WELL CONSTRUCTION**

- **8" STEEL +2-98**
- **4.5" SDR-17 Certa-Lok**

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**GEOLOGICAL DESCRIPTION**

- **0.0 - 2.0** Silty clay, some sand [Colluvium]
  - Slightly moist, moderate yellowish brown, loose, non-plastic

- **2.0 - 5.0** Silty clay, trace of sand [Colluvium]
  - Dry, pale orange, loose, non-plastic

- **5.0 - 30.5** Silty fine sand [Colluvium/Alluvium]
  - Dry to slightly moist with depth, loose to moderately dense with depth, grain size increases to medium fine and medium from 22'-30.5'
  - Wet at 35', gravel increases to >50%, gravels 3", gravels sub-angular to sub-rounded, low to medium sphericity, mostly flat, some moderately spherical
  - Becomes increasingly angular at 45', gravels to 5" at 55', sand fraction to 5% at 65'

- **30.5 - 78.0** Sand and gravel, poorly sored gravel to (10-20%) [Alluvium]
  - Slightly moist, moderate yellowish brown sand with multicolored clinker gravels, some sandstone gravels, clinker, light brown (5YR 5/6), moderate reddish brown, dark yellowish orange
  - Wet at 35', gravel increases to >50%, gravels 3", gravels sub-angular to sub-rounded, low to medium sphericity, mostly flat, some moderately spherical

- **78.0 - 111.0** Sandstone, medium fine grain [Bedrock]
  - Wet, light olive gray (5Y 6/1) to olive gray, soft to very soft, dense tight (very soft) from 90'-100', trace coal at 100', moderately siliceous, increasing silica at 105'

- **111.0 - 115.0** Siltstone, sandy
  - Dry, medium bluish gray (SB 9/1), moderately firm, non-calcareous, fétid odor

- **115.0 - 135.0** Sandstone
  - Wet, makes ~7 gpm, SC=2,140 µmhos/cm, open hole, medium bluish gray to medium gray, moderately firm to very stiff, rig grinding, fétid odor at top 115'-116'

- **135.0 - 141.0** Coal
  - Wet, black, dense, cleated multiple planes, making water, open hole, yield ~10 + gpm

- **147.0 - 148.5** Carbonaceous shale
  - Brownish gray (5Y 4/1) and olive gray (5Y 3/2), stiff, moderately plastic

- **148.5 - 150.0** Coal
  - Wet, black, dense, cleated multiple planes, open hole, SC=1,800 µmhos/cm

- **150.0 - 175.0** Shale/siltstone
  - Apparently dry, medium light gray and greenish gray, firm to stiff, non-plastic, non-calcareous, thin very hard moderate yellowish brown stringer at 168'

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Remarks:
Drilled to 30' with 7 7/8" bit, ream out with 12" bit, drive 40' of 8" steel casing. Poured 20 bags bentonite around steel while driving. Added 60' more of 8" steel through gravel (100' total). Inject water at 100'. Developed with rig air at 25 gpm; SC=1095 µmhos/cm (20 minutes, 500 gallons); ~625 gallons total removed. High Solids Bentonite EZ-Plug Grout - 20% solid.
175.0 - 205.0'  Sandstone  
Wet?, medium light gray and greenish gray, firm to soft with depth, thin coal stringer at 203'

205.0 - 308.0'  Siltstone/shale  
Medium light gray to medium gray, stiff to very hard at 206'-211', rig chattering, non-calcareous at 205'-206', then nearly all at least moderately calcareous to 308' 
Very thin dark brown laminations at 205'-206' 
Moderately carbonaceous thin coal stringer at 212'-214', hardens to moderately firm at 214' 
Coal stringer at 217'-218' 
Interbedded siltstone at 225'-230' and at 241'-242' 
Coal stringer/carbonaceous shale stringer at 242' 
Color change to olive gray (SY 4/1) at 246' 
Coal stringer at 250'-252' 
Color change to greenish gray (SGY 6/1) and medium light gray at 255' 
Very hard yellowish gray shale stringer at 270' 
Some interbedded sandstone at 275' 
Coal/carbonaceous shale stringer, grayish brown, soft at 290'-293'

308.0 - 313.0'  Sandstone, fine grain  
Medium light gray, very hard, cemented, rig chattering/slow to advance, trace calcareous precipitates at bottom of cemented interval/siltstone contact

313.0 - 335.0'  Siltstone/shale  
Dry, medium light gray and greenish gray, firm to stiff; carbonaceous shale stringer, grayish brown, soft at 320'; hardness decreases to moderately firm or firm at 321'; becomes very sandy at 330'-335'

335.0 - 445.0'  Sandstone, medium fine grain  
Wet, moderately firm to soft, medium light gray 
More cohesive, stiff interval at 350'-355' 
Moderate yellowish brown interbeds (sandstone) and some intercalated shale at 410'-412' 
Yield open hole ~100 gpm

445.0 - 450.0'  Siltstone/sandstone  
[Bedrock] Medium light gray, moderately firm, more cohesive
**WELL CONSTRUCTION**

- **2.0" steel**
- **Hi Solids Grout (20% solids)**

**GEOLOGICAL DESCRIPTION**

- **0.0 - 20.0'** **Silt with some clay and fine sand** [Colluvium]
  - Pale (10YR 6/2) to moderate (10YR 5/4) yellowish brown, loose, soft, trace clinker gravel fragments

- **20.0 - 35.0'** **Sand** [Colluvium to Bedrock]
  - Slightly moist, pale (10YR 6/2) to moderate (10YR 5/4) yellowish brown, very fine grain, soft, loose, very clayey at 20'-21', trace clinker gravel fragments

- **35.0 - 77.0'** **Sandstone** [Bedrock]
  - Slightly moist, pale yellowish brown (10YR 6/2), soft, with light olive gray interbeds, some moderately cohesive. Dark yellowish orange (10YR 6/6) from 43'-44'. Dark yellowish orange (10YR 6/6) stringer at 47'. Moist at 57°, color change to moderate yellowish brown (10YR 5/4), injecting water at 60°, TDS=2,700 ppm. Dark gray (N3) particles in sand from 60°-77°; yield 3 gpm open-hole

- **77.0 - 82.0'** **Siltstone/sandstone**
  - Brownish gray (5YR 4/1), moderately firm, non-plastic, non-calcareous, grades to all siltstone at 80'

- **82.0 - 115.0'** **Coal** [Knobloch]
  - Black (N1), hard, dense, cleated

- **115.0 - 120.0'** **Silty sandstone** [Bedrock]
  - Brownish gray (5YR 4/1) to light brownish gray (5YR 6/1), moderately firm. TDS=2,600 ppm, yield=15 gpm open hole

- **120.0 - 133.0'** **Coal** [Knobloch]
  - Black (N1), hard, dense, cleated

- **133.0 - 137.0'** **Shale**
  - Medium dark gray (N4) and brownish gray (5YR 4/1), stiff to very hard, moderately carbonaceous, non-calcareous

- **137.0 - 139.0'** **Sandstone**
  - Medium light gray (N6), medium fine grained, hard, rig chatters, slow to advance

- **139.0 - 155.5'** **Siltstone/shale**
  - Medium dark gray (N4) and brownish gray (5YR 4/1), stiff to firm with depth, non-plastic, non-calcareous, softer at 145°, thin dusky brown (5YR 2/2) carbonaceous shale at 155°

- **155.5 - 174.0'** **Coal** [Lower Knobloch]
  - Dark brownish gray to black (N1) with depth, firm to dense, some cleats, very stong reduced sulfur odor
### Geological Description

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>174.0 - 180.0'</td>
<td>Sandstone, Medium light gray (N6) and light olive gray, soft, blew on open hole at 180', TDS=1,500 ppm, open hole=35 gpm</td>
</tr>
<tr>
<td>190.0 - 196.0'</td>
<td>Siltstone, Medium light gray (N6), soft, non-plastic, non-calcareous, thin coal stringer at 190'</td>
</tr>
<tr>
<td>196.0 - 205.0'</td>
<td>Sandstone, Medium gray (N5), soft to firm</td>
</tr>
<tr>
<td>205.0 - 215.0'</td>
<td>Siltstone, some interbedded sand, Medium light gray (N6) and light olive gray, firm, mildly calcareous coal/Carbonaceous shale stringer at 210'</td>
</tr>
<tr>
<td>215.0 - 223.0'</td>
<td>Sandstone, fine grained, some silt, Medium light gray (N6) to medium gray (N5), soft</td>
</tr>
<tr>
<td>223.0 - 225.0'</td>
<td>Coal, Black (N1), hard, local deposits</td>
</tr>
<tr>
<td>225.0 - 241.0'</td>
<td>Shale/siltstone, Brownish gray (5YR 4/1) to medium dark gray (N4), non-plastic, moderately firm; very hard at 237°-240°, rig chatters, slow to advance, cuttings angular</td>
</tr>
<tr>
<td>241.0 - 251.0'</td>
<td>Sandstone, Medium light gray (N6), soft, fine grained, very hard crusted zone at 250'-251°, ~3&quot; thick</td>
</tr>
<tr>
<td>251.0 - 265.0'</td>
<td>Shale, Grayish brown (5YR 3/2) and dark yellowish brown (10YR 4/2), moderately firm</td>
</tr>
<tr>
<td>265.0 - 268.0'</td>
<td>Coal, Local coal deposits</td>
</tr>
<tr>
<td>268.0 - 310.0'</td>
<td>Shale, Grayish brown (5YR 3/2) and dark yellowish brown (10YR 4/2), moderately firm. Color change to medium light gray (N6) at 273°; cemented from 270°-271°; Carbonaceous shale/coal at 290°-297°</td>
</tr>
<tr>
<td>310.0 - 315.0'</td>
<td>Sandstone, Medium gray (N5) to brownish gray (5YR 4/1), soft</td>
</tr>
<tr>
<td>315.0 - 337.0'</td>
<td>Claystone/shale/siltstone, Moderately firm, mild to moderate plasticity, medium gray (N5), non-calcareous</td>
</tr>
<tr>
<td>337.0 - 390.0'</td>
<td>Sandstone, Fine to medium fine grained, Medium light gray (N6) to medium gray (N5), soft; silty clayey at 365°-375°. Very clayey, moderate plasticity from 375°-380°, clayey from 385°-390°, still predominantly sandstone; borehole making noticeably more water</td>
</tr>
<tr>
<td>390.0 - 400.0'</td>
<td>Siltstone/interbedded claystone, Medium gray (N5), soft, mild plasticity, non-calcareous</td>
</tr>
</tbody>
</table>
Bentonite Chips

Silty clay [Colluvium/Topsoil]
Dry, pale yellowish brown (10YR 6/2), loose, roots, becomes sandy at 5'

Sand and gravel poorly sorted [Alluvium]
Slightly moist, fines are moderate yellowish brown (10YR 5/4) (sand is fine to medium fine); multi-colored clinker gravels (e.g., light brown, moderate reddish brown 10R 4/6); gravels flat to moderately spherical, sizes up to 4", mostly sub-angular, few sub-rounded, loose to moderately dense; sand to 10% at 15'

Thermally altered siltstone/shale [Clinker]
Dry, multi-colored (e.g., light browns, reds and reddish browns with light gray N7 and greenish gray 5G 6/1); hard, thin, hard pale orange and pale yellowish orange (10YR 8/6) bed at 30', interbedded with softer clay and ash?

Shale, silty [Bedrock]
Dry, medium light gray (N6), moderately firm, calcareous, trace sandstone intervals at 80'-85' and 85'-90'; rock very hard, cemented at 119'-124', rig chattering, drilling slowly. Very thin coal/carbonaceous shale stringer at 125'

Sandstone
Light olive gray, soft, fine medium-grained

Coal
Black (N1), hard, moderately dense, cleated

Silty claystone [Bedrock]
Medium gray (N5), to greenish gray, non-plastic, moderately firm, non-calcareous; very hard, cemented at 62'-65'

Siltstone
Medium light gray (N6), moderately firm, calcareous, trace sandstone intervals at 80'-85' and 85'-90'

Coal [Local]
Black (N1), hard, dense, cleated multiple planes

Siltstone
Medium light gray (N6), moderately firm, calcareous, trace sandstone intervals at 102'-105', no sand at 110'; rock very hard, cemented at 119'-124', rig chattering, drilling slowly. Very thin coal/carbonaceous shale stringer at 125'

Remarks: Drilled to 15' with 10 7/8" bit; drilled from 15' to 380' with 7 7/8" bit; injecting water at 35' bgs; yield ~20 gpm. Bentonite 3/8" chips poured continuously while setting 8" steel.
### WELL CONSTRUCTION

**10/20 Silica Sand**

**Silica Centralizers**

**Centralizer**

**Bottom of Hole**

**End Cap**

### GEOLOGICAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
</table>
| 173.0 - 182.0' | Sandstone, fine to very fine grain  
Medium light gray (N6), soft |
| 182.0 - 200.0' | Siltstone  
Medium light gray (N6), moderately firm to moderately stiff, non-plastic, calcareous; very very hard cemented shale at 182'-190' (light olive gray), then general increase in hardness stiff to moderately hard but brittle at 190'-195'. At 195' clayey, soft, very slight plasticity, non-calcareous |
| 200.0 - 215.0' | Sandstone, fine  
Medium light gray (N6) to greenish gray, very soft to soft, cemented firm stringer at 210' |
| 215.0 - 235.0' | Interbedded siltstone/sandstone  
Medium gray (N5) to medium light gray (N6), moderately firm, non-calcareous, yield ~30 gpm open hole |
| 235.0 - 242.0' | Coal [Local]  
Black (N1), hard |
| 242.0 - 295.0' | Shale  
Medium light gray (N6), firm, clayey, non-plastic, mostly non-carbonaceous, non-calcareous; moderately carbonate stringer, brownish gray (5YR 4/1) at 250'. Very silty at 260'-265'; thin coal stringer at 265'-265'; carbonaceous shale stringer at 270'. Color change to olive gray (5Y 3/2) at 270'-280', carbonate stringer at 280', very thin sandstone stringer at 290', light olive gray (5Y 6/1), hard cemented light olive gray shale, rig chattering at 292'-297' |
| 295.0 - 322.0' | Shale/siltstone  
Some interbedded fine sandstone at 295'-300', light olive gray and light brownish gray (5YR 6/1), soft to firm, non-calcareous; clayey, sandstone absent at 300' |
| 322.0 - 375.0' | Sandstone  
Medium light gray (N5) to medium gray (N5), soft, fine grained to medium fine grained at 350' |
| 375.0 - 380.0' | Siltstone [Bedrock]  
Medium bluish gray (5B 5/1), moderately stiff |
### WELL CONSTRUCTION

- **10/20 Silica Sand**
- **0.025-inch Slot Screen; centralizer**
- **110' centralizer**
- **0.025-inch slot, Sch 40 PVC**
- **10/20 Silica Sand**

### GEOLOGICAL DESCRIPTION

- **0.0 - 9.0' Clay, silty [Topsoil & Colluvium]**
  - Dry to slightly moist, grayish orange, cohesive when wet, calcareous, few roots

- **9.0 - 11.0' Clay, silty [Colluvium]**
  - Dry to slightly moist, light brown (5YR 5/6), cohesive when wet, calcareous, few roots

- **11.0 - 15.0' Clay, silt [Colluvium]**
  - Slightly moist, pale yellowish brown (10YR 6/2), cohesive, non-calcareous

- **15.0 - 17.0' Siltstone [Bedrock]**
  - Slightly moist, dark yellowish orange (10YR 6/6), very soft

- **17.0 - 21.0' Claystone [Bedrock]**
  - Slightly moist, dark yellowish orange (10YR 6/6), very soft, calcareous

- **21.0 - 22.0' Claystone**
  - Slightly moist, light brown (5YR 6/4), very soft, non-calcareous

- **22.0 - 30.0' Very fine silty sandstone**
  - Dry to slightly moist, yellowish gray (10YR 5/1), soft, hard layer at 29'

- **30.0 - 31.0' Very fine silty sandstone**
  - Dry to slightly moist, slightly cohesive, yellowish gray (5YR 5/1), soft, calcareous

- **31.0 - 37.0' Siltstone**
  - Slightly moist, yellowish gray, calcareous

- **37.0 - 39.0' Siltstone**
  - Slightly moist, dark yellowish orange (10YR 6/6), very soft

- **39.0 - 41.0' Shale**
  - Dry, medium gray (N6), soft

- **41.0 - 42.0' Clay and baked shale**
  - Dry to slightly moist, moderate yellowish brown (10YR 5/4)

- **42.0 - 43.0' Siltstone, clayey**
  - Dry to slightly moist, moderate yellowish brown (10YR 5/4)

- **43.0 - 44.0' Claystone**
  - Dry, moderate yellowish brown (10YR 5/4), soft

- **44.0 - 45.0' Claystone**
  - Dry, more orange staining, iron

- **45.0 - 48.0' Silty claystone**
  - Slightly moist, dark yellowish orange (10YR 6/6), very soft, weakly calcareous

- **48.0 - 52.0' Claystone**
  - Slightly moist, dark yellowish orange (10YR 6/6), very soft, weakly calcareous

- **52.0 - 55.0' Shale**
  - Dry, medium gray (N5)

- **55.0 - 61.0' Shale**
  - Dry, light olive gray (5Y 5/2), soft. At 56-59' cemented shale/claystone, dry, calcareous, hard

- **61.0 - 68.0' Siltstone with claystone inclusions**
  - Moist, medium gray (N6), soft, non-calcareous

- **68.0 - 70.0' Shale**
  - Slightly moist, brownish gray (5YR 4/1), soft, non-calcareous

---

Remarks: Open hole SC 2,180 µmhos/cm, pH 8.66, temp 13.2°C, yield open hole with rig air 30gpm +. First bail 2,790 µmhos/cm, last bail 2,180 µmhos/cm pH 8.44.
70.0 - 74.0' Sandy siltstone
  Moist, medium gray (N5), soft, non-calcareous

74.0 - 75.0' Silty shale
  Slightly moist, light olive gray (5Y 6/1), soft

75.0 - 79.0' Siltstone
  Moist to very moist, medium dark gray (N4), non-calcareous, soft

79.0 - 83.0' Silty shale
  Wet at top, more water in cuttings, light olive gray (5Y 6/1), hard at bottom of interval, trace water on top of hard layer

83.0 - 102.0' Shale
  Dry, dark gray (N3), soft, coal stringer at 93'

102.0 - 174.0' Knobloch
  Wet, black (N1), dense, cleated 3x, trace gypsum, no pyrite observed, partly laminated brownish gray siltstone from 151 to 152', coal unit making combined 30gpm+ open hole, more water apparently below siltstone parting

174.0 - 175.0' Silty shale
  Dry, light gray (N7)
### GEOLOGICAL DESCRIPTION

**0.0 - 24.0'** Silty, fine sandstone [Fort Union Formation]
- Moderate yellowish brown, dry to slightly moist, very soft, calcareous, some soft calcareous cemented zones

**24.0 - 27.0'** Silty shale
- Gray with orange fines, dry, soft

**27.0 - 29.0'** Very fine silty sandstone, trace claystone
- Tan, moist, very soft, calcareous

**29.0 - 32.0'** Siltstone
- Light gray with orange streaks, moist, laminated

**32.0 - 34.0'** Claystone
- Orange, dry

**34.0 - 37.0'** Claystone
- More orange, dry

**37.0 - 71.0'** Sandstone, very fine
- Coarsening with depth to medium, poorly sorted at top to well sorted near base, moist to wet at 65', calcareous; iron stained at 40', moist at 50'. Possibly wet at 65' but no water from open hole, thin carbonaceous shale at 62-62.3'; sandstone coarser below 65'

**71.0 - 73.0'** Siltstone
- Dark yellowish orange, dry, laminated

**73.0 - 104.0'** Fine medium sandstone
- Gray, wet, poor to moderately sorted; cemented 73-90', uncemented or poorly cemented at 90-104', approximately 3-5 gpm estimated at base of sandstone

**104.0 - 148.0'** Knobloch Coal
- Black, dealed 3x, note that no shale or siltstone observed, abrupt contact with overlying sandstone, note also that sandstone from upper hole and siltstone from upper hole sloughing during drilling, strong sulphur odor in upper coal

**148.0 - 186.0'** Shale
- Dark olive gray, firm interburden, woven tight, very hard CaCO₃ cemented layers at 166', 167-168', and 178-179', carbonaceous shale at 165-166', field odor at 178-179'

**186.0 - 190.0'** Sandstone
- Sub lithic arenite, gray, non-calcareous, poorly sorted, weakly cemented

**190.0 - 200.0'** Coal
- Black, dealed, dense, very faint sulphur odor

**208.0 - 209.0'** Siltstone
- Estimate 30% clay, laminated, medium gray
**Well Construction**

- **8" steel**
- **Bentonite Chips**

**Geological Description**

- **0.0 - 1.0' Silt and fine sand** (Topsoil)
  - Slightly moist, moderate brown (5YR 3/4), roots, loose, soft

- **1.0 - 30.0' Silty fine to very fine sandstone** (Fort Union Formation/ Bedrock)
  - Dry, moderate yellowish brown (10YR 5/4), soft to very soft, some thin cemented beds from 27-30'

- **30.0 - 30.5' Shale** (Bedrock)
  - Dry, gray with orange fines, very hard

- **30.5 - 61.0' Coal** (Upper Knobloch)
  - Dry, dusky brown to black, firm to stiff, mild sulfur odor, slightly moist at 61', becomes hard at 52'

- **61.0 - 61.5' Silty shale**
  - Dry, pale yellowish brown to brownish gray, firm, moderately calcareous, reacts with acid

**Remarks:** Inject water at total depth to stimulate flow, developed with bailer for 20 minutes, yield ~2.5 - 3 gpm, SC=2140 µmhos/cm, pH=7.46, temp=11.6°C
### GEOLOGICAL DESCRIPTION

<table>
<thead>
<tr>
<th>Interval</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0'</td>
<td>Silt to fine sand [Topsoil] - Slightly moist, moderate brown (5YR 3/4), roots, loose, soft</td>
</tr>
<tr>
<td>1.0 - 30.0'</td>
<td>Silty very fine sandstone [Fort Union Formation/Bedrock] - Dry, moderate yellowish brown (10YR 5/4), soft to very soft, minor cemented zone from 27-30'</td>
</tr>
<tr>
<td>30.0 - 30.5'</td>
<td>Shale - Dry, gray with orange fines, very hard</td>
</tr>
<tr>
<td>30.5 - 61.0'</td>
<td>Coal [Upper Knobloch] - Dry, dusky brown to black, very dusky at surface, firm to stiff, mild cleats possibly 1x, mild sulfur odor, becomes hard at 52', slightly moist at 61'</td>
</tr>
<tr>
<td>61.0 - 61.5'</td>
<td>Silty shale - Dry, pale yellowish brown to brownish gray, firm, moderately calcareous interburden, reaction to acid</td>
</tr>
<tr>
<td>61.5 - 75.0'</td>
<td>Coal - Dry, dusky brown to black, very dusky at surface, firm to stiff, mild cleats possibly 1x, mild sulfur odor, wet at 67', SC=2300 µmhos/cm, yield=3-5 gpm</td>
</tr>
<tr>
<td>75.0 - 95.0'</td>
<td>Shale intercalcated and strong - Moist (from above) to dry, medium light gray to medium gray, cemented, very hard sandstone at 84-85' and 91-92'</td>
</tr>
<tr>
<td>95.0 - 130.0'</td>
<td>Sandstone, minor shale intercalcated - Very soft to firm, medium gray with thinly bedded dark yellowish brown streaks</td>
</tr>
<tr>
<td>130.0 - 147.5'</td>
<td>Coal [Lower Knobloch] - Stiff, black, cleating not distinct</td>
</tr>
<tr>
<td>147.5 - 150.0'</td>
<td>Silty shale - Soft, medium light gray</td>
</tr>
</tbody>
</table>

### WELL CONSTRUCTION

- **Well Diameter (in):** 7 7/8" to 40' then 11 3/4" Total Depth Drilled (ft): 150
- **8" steel:** Bentonite Chips, centralizer, end cap
- **10/20 Silica Sand centralizer:** Bottom of Hole
- **0.025-inch slot, Sch 40 PVC:** Screen/Perforations
- **Bentonite Chips:** Annular Seal
- **8" steel:** Surface Seal

### Remarks

Drive 40' of 8" steel casing, bentonite in annulus, injecting water at 75', developed with bailer 20 minutes. Yield ~4.5 gpm, SC=1873 µmhos/cm, pH=8.64, temp=12.7°C
**GEOLOGICAL DESCRIPTION**

- **0.0 - 2.5'** Shale [Bedrock]
  - Dry, olive gray changing to dark yellowish orange (10YR 6/6), soft, non-calcareous

- **2.5 - 5.0'** Cemented shale
  - Dry, light gray (N8), calcareous cement, hard

- **5.0 - 20.0'** Claystone
  - Slightly moist, dark yellowish orange (10YR 6/6), very soft, non-calcareous

- **20.0 - 20.5'** Shale, cemented with CaCO₃
  - Dry, hard

- **20.5 - 25.0'** Claystone
  - Slightly moist, dark yellowish orange (10YR 6/6), calcareous, soft

- **25.0 - 33.0'** Siltstone with interbedded shale
  - Slightly moist, dark yellowish orange (10YR 6/6) to moderate yellowish brown (10YR 5/4), calcareous, soft

- **33.0 - 74.0'** Shale
  - Dry, medium gray (N5) to dark yellowish orange (10YR 6/6), non-calcareous, very soft, trace silt-rich zones, siltstone layer at 43-43.5', 57-57.5', and 65.5 to 66'

- **74.0 - 76.0'** Shale, CaCO₃ cemented
  - Dry, light gray (N7), hard

- **76.0 - 82.0'** Siltstone
  - Dry to moist, dark yellowish orange (10YR 6/6), clay vari-colored, calcareous, stratified 1mm, soft

- **82.0 - 83.0'** Shale
  - Dry, various colors, gray to dark yellowish orange (10YR 6/6), hard CaCO₃ cemented zone at 83'

- **83.0 - 85.5'** Shale, CaCO₃ cemented
  - Dry, light gray (N6), hard, marker bed

- **95.5 - 97.0'** Sandy siltstone
  - Moist, dark yellowish orange (10YR 6/6), weakly calcareous, soft

- **97.0 - 99.0'** Siltstone
  - Moist, dark yellowish orange (10YR 6/6), weakly calcareous, soft

- **99.0 - 107.0'** Shale becoming silty at 100'
  - Slightly moist, medium gray (N5), soft, weakly calcareous

- **107.0 - 114.5'** Shale
  - Dry, grayish brown (5YR 3/2) (top foot) to dark yellowish brown (10YR 4/2), soft, carbonaceous shale

**WELL CONSTRUCTION**

- **1.0** Bentonite Chips

- **1.5'** steel

- **8" steel** 0.250" wall 0.025-inch slot, Sch 40 PVC
WELL CONSTRUCTION

126.0  0.025-inch Slot Screen
136.0  centralizer
146.0  centralizer
156.0  centralizer
166.0  centralizer
186.0  end cap

GEOLOGICAL DESCRIPTION

114.5 - 186.0’ Coal [Knobloch]
Dry at top, wet at 134’, dusky yellowish brown (10YR 2/2), cleated, no pyrite observed, making 5-7gpm (estimate) at 160’ open hole, very few impurities, trace silt which appears to be white precipitate, but very minor.

Silty shale, light gray (N7), sof
**WELL COMPLETION**

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>DESCRIPTION</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-149</td>
<td>Well Installed?</td>
<td>Y</td>
</tr>
<tr>
<td>0-38</td>
<td>Surface Casing Used?</td>
<td>Y</td>
</tr>
<tr>
<td>10/20 Silica Sand</td>
<td>Bentonite Chips</td>
<td>Y</td>
</tr>
<tr>
<td>0.025-inch slot, Sch 40 PVC</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>97-149</td>
<td>Sand Pack?</td>
<td>Y</td>
</tr>
<tr>
<td>0-97</td>
<td>Screen/Perforations?</td>
<td>Y</td>
</tr>
<tr>
<td>0-97</td>
<td>Annular Seal?</td>
<td>Y</td>
</tr>
<tr>
<td>0-97</td>
<td>Screen Seal?</td>
<td>Y</td>
</tr>
</tbody>
</table>

**DEVELOPMENT/SAMPLING**

- Well Developed? | Y
- Water Samples Taken? | N
- Boring Samples Taken? | N

**GEOLOGICAL DESCRIPTION**

- **0.0 - 24.0'** Silty, fine sandstone [Fort Union Formation]
  - Moderate yellowish brown, dry to slightly moist, very soft, calcareous, some soft calcareous cemented zones

- **24.0 - 27.0'** Silty shale
  - Gray with orange fines, dry, soft

- **27.0 - 29.0'** Very fine silty sandstone, trace claystone
  - Tan, moist, very soft, calcareous

- **29.0 - 32.0'** Siltstone
  - Light gray with orange streaks, moist, laminated
  - Orange, dry

- **32.0 - 34.0'** Claystone
  - More orange, dry

- **34.0 - 37.0'** Siltstone, very fine
  - Coarsening with depth to medium, poorly sorted at top to well sorted near base, moist to wet at ~65', calcareous; iron stained at 43' and shale at 43-43.5', carbonaceous shale at 64-64.5'

- **37.0 - 73.5'** Siltstone
  - Dark yellowish orange, dry, laminated

- **73.5 - 75.0'** Sandstone
  - Shale stringer at 77-77.5'

- **75.0 - 79.0'** Fine medium sandstone
  - Gray, wet, poor to moderately sorted; cemented 73-90', uncemented or poorly cemented at 90-104', approximately 3-5 gpm estimated at base of sandstone; intercalated shale/sandstone at 79-80', cemented sandstone at 81-94'; less concentration below 89-89.5'

- **79.0 - 104.0'** Coal
  - Weak sulphur odor, cleated in up to 3 directions, but not distinct, approximately 10-15 gpm open hole

**Remarks:**
- Set 8” steel to 38’, upper portion of hole sloughing 11 3/4” pilot, water injected at 63’. Well making +/- 5 gpm during development, rod at 100', 3 min. SC=3070 µmhos/cm, turbidity med.-high, pH 8.02, 30 min. SC=3270 µmhos/cm, turbidity med., pH 8.28.