Ground Water Quality Technical Report No. 30

# Well CM-1 Evaluation

# Craigmont, Idaho


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State Office
December 2007

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# Abstract

This report represents the findings of an evaluation of Craigmont well CM-1. This well, which was part of the public water supply system for the City of Craigmont, was removed from service in the past, reportedly because of water quality issues described as production of “red water.” The city removed the pump and the well has been unused for the past several years. Recently, the city expressed an interest in adding the well back onto the system but the well condition was unknown. Video and colloidal borescope surveys of the well were completed, and samples were collected for analysis of selected chemical and stable isotope parameters.

The video survey showed that a zone consisting of fractured basalt occurs from about 128 to 148 feet below land surface. The video survey also showed that the water within the casing was highly turbid, partly caused by running the video camera and colloidal borescope in the well. There is evidence of biological growth on some areas of the borehole sidewall. However, this material does not resemble an iron bacteria growth; it may be a byproduct of some of the more common soil bacteria.

A former sawmill facility is located approximately 500 feet to the west; this facility has not operated as a sawmill for at least 10 years. Analysis of water samples collected at sawmill facilities in northern Idaho has demonstrated the presence of elevated bacteria associated with log yard debris and water used to irrigate log decks. Runoff from these facilities can infiltrate to ground water if conditions are favorable, transporting sawmill contaminants.

The colloidal borescope survey was intended to demonstrate the site-specific ground water flow direction and flow velocity in zones identified during the video survey as being favorable for the presence of active ground water. This survey did not encounter areas of active ground water flow movement in the fractured rubble zones identified during the video survey. The high turbidity in the water column may have interfered with detection of colloids that identify active flow zones. Although the colloidal borescope survey did not determine a ground water flow direction, information from drillers’ logs in a study by the Idaho Water Resources Research Institute (Stevens and others, 2003) indicated that the general ground water flow direction in the area is to the northeast. If ground water flows to the northeast in the vicinity of well CM-1, the sawmill facility would be cross-gradient of the well.

Sample analysis results show that the nitrate concentration was 1.71 milligrams per liter (mg/L), the total dissolved solids concentration was 194 mg/L and the iron concentration was 8.91 mg/L. The latter concentration is considered to be very high; the Idaho Ground Water Rule lists a secondary standard for iron of 0.30 mg/L. Samples from two nearby wells contained less than 0.01 mg/L of iron, indicating that elevated iron is not widespread throughout the area. The water chemistry at well CM-1 can be compared to other wells in a monitoring network that has been established by DEQ. The water is a calcium bicarbonate type but contains slightly more sodium than wells in the sampling network.

Recommendations for well rehabilitation include treatment with a chlorine solution or other disinfectant followed by jetting and over-pumping to remove accumulated sediment from the well bore and aquifer adjacent to the well. The well should then be resampled for iron, bacteria, and nitrate after disinfection and before installation of a production pump to determine if elevated iron is still present in the well.

# Introduction

The city of Craigmont is located in Lewis County, approximately 30 miles north of Grangeville. The drinking water supply for the city (PWS # 2310001) currently is provided by two wells, CM-3 and CM-2. Well CM-3 is the primary supply well and well CM-2 provides additional water as needed. Figure 1 shows the location of these two wells, along with a third well, CM-1.

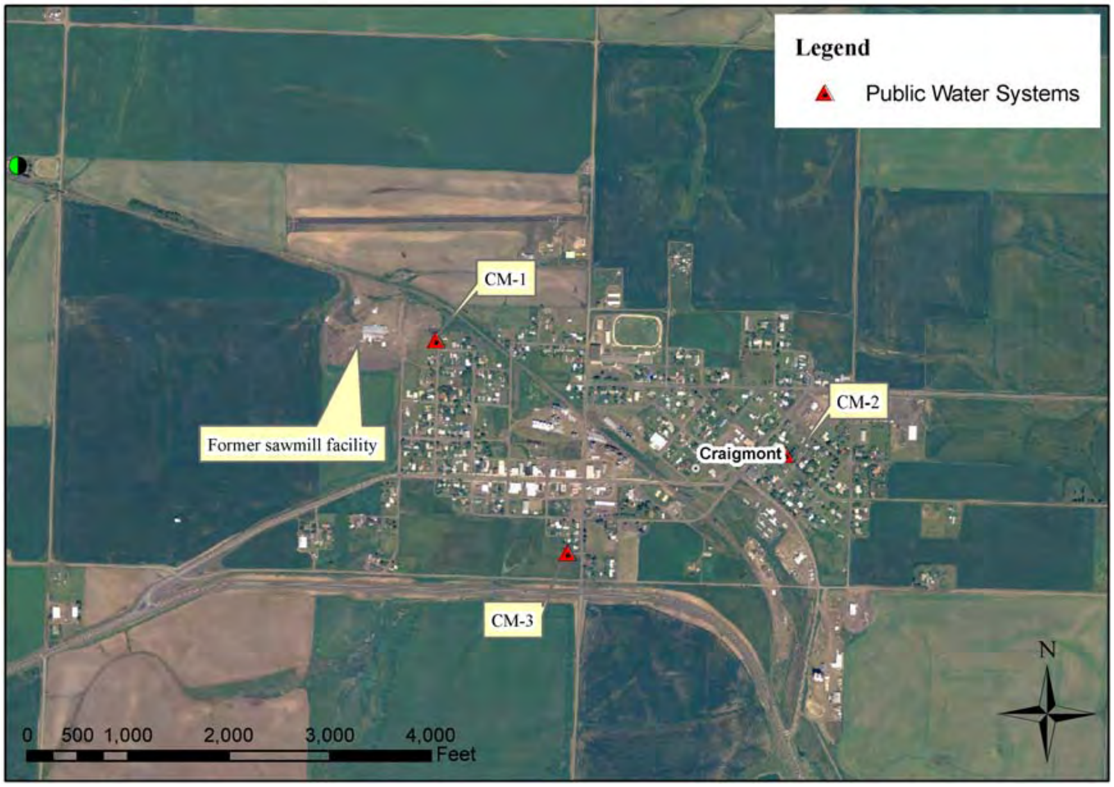


**Figure 1.** Air photo of Craigmont showing water supply wells CM-1, CM-2 and CM-3. Also shown is former sawmill facility.

Well CM-1 was taken off line several years ago, possibly due to water quality concerns. The only description of the problem was that the well was reported to have pumped ‘red’ water which may be an indication of iron bacteria growth (Stevens et al., 2003). Stevens et. al. (2003) reported the well depth at 168 feet and the approximate pumping capacity at 60 gallons per minute. Drawdown or pumping level information at this discharge rate is not available. The drinking water system has 330 service connections that serve approximately 550 people; the maximum daily production is listed as 792,000 gallons per day (gpd) and the average daily use is 73,000 gpd or about 50 gallons per minute (2004 numbers).

An industrial facility is located approximately 500 feet west of the well (Figure 1). In the past, the facility was an operational sawmill with log decks, irrigation of the logs, and generation of wood waste. Sampling from a sawmill site in northern Idaho demonstrated that there is the potential for runoff from sawmill facilities to negatively impact ground water. Potential contaminants could include bacteria, phenols, turpenes and other constituents associated with log decks and wood waste. Petroleum contamination in soils around hydraulic equipment at sawmill sites is common and pentachlorophenol may be present in site soils if wood treatment was conducted at the site. The facility currently is used as a storage and transfer location for finished dimension lumber and hasn't operated as a sawmill for at least 10 years, according to the Craigmont City clerk. This facility could pose a contaminant risk to well CM-1 if the sawmill is within the well's capture zone. The ground water flow direction in this area is not well known, but Stevens, et al. (2003) prepared a potentiometric map using water levels from drillers logs for wells in the area. This map indicates that ground water moves to the northeast. Based on this interpretation, well CM-1 would be cross-gradient of the sawmill, but still could be within the capture zone of the well.

Craigmont would like to return CM-1 to service to augment the water supply system during the summer period of high water demand. An investigation of the well was proposed, to evaluate the physical condition of the well and to review the water chemistry for the occurrence of iron bacteria or other parameters that may preclude use of the well. The investigation included:

- A video survey of the well to determine well completion details such as well total depth, casing depth and condition, and potential producing zones;
- A colloidal borescope survey of potential production zones in the well, based on the video survey, to evaluate ground water flow direction and velocity;
- Sample collection and analysis for field parameters (pH, specific conductance, dissolved oxygen, and temperature), major ions (calcium, magnesium, sodium, potassium, alkalinity, chloride, sulfate) total dissolved solids, the stable isotopes of oxygen ($^{18}O$) and hydrogen ($^{2}H$ or deuterium), and a depth to water measurement.

# Water Chemistry

For well CM-1, Table 1 shows the field parameters, Table 2 shows the major ions, and Table 3 shows nitrate as nitrogen, arsenic, iron, silica and laboratory parameters.

**Table 1. Field parameters for Craigmont well CM-1.**

| Field Parameters | | | | | | |
|---|---|---|---|---|---|---|
| Sample Date | Sample Time | pH units | Sp Cond uS/cm | DO mg/L | Temp deg C | Turbidity NTU |
| 9/18/2007 | 1130 | 6.7 | 270 | 6.19 | 10.5 | 108 |

Sp Cond = specific conductance, DO = dissolved oxygen, Temp = water temperature in degrees Celsius, µS/cm = microsiemens per centimeter, mg/L = milligrams per liter, Nephelometric Turbidity Units.

**Table 2. Major ions for Craigmont well CM-1.**

| Ca mg/L | Mg mg/L | Na mg/L | K mg/L | CO3 mg/L | HCO3 mg/L | Cl Mg/L | SO4 mg/L | TDS mg/L |
|---|---|---|---|---|---|---|---|---|
| 26.5 | 9.43 | 25.3 | 1.93 | 0 | 177 | 1.41 | 5.39 | 194 |

Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, CO3 = carbonate, HCO3 = bicarbonate, Cl = chloride, SO4 = sulfate and TDS = total dissolved solids.

**Table 3. Nitrate, metals, sufide, silica and laboratory parameters for Craigmont well CM-1.**

| NO3-N mg/L | As mg/L | Fe mg/L | Sulfide mg/L | SiO3 mg/L | Lab Turbidity NTU | Lab pH Units |
|---|---|---|---|---|---|---|
| 1.71 | **0.001** | 8.91 | 0.257 | 23.2 | 91.5 | 6.39 |

NO3-N = nitrate as nitrogen, As = total arsenic, Fe = total iron, SiO3 = silica. As concentration was less than the laboratory detection limit of 0.001 mg/L. The Idaho Drinking Water arsenic MCL is 0.10 mg/L.

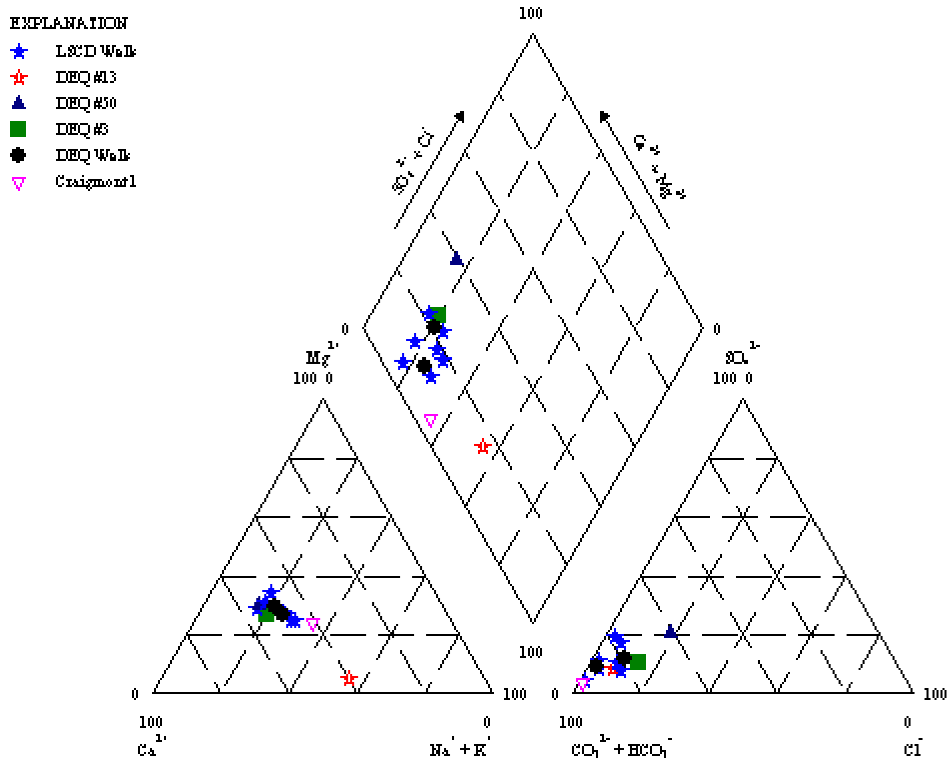


**Figure 2.** Piper diagram showing Craigmont well CM-1 water chemistry in comparison to other wells in the Clearwater Plateau area. **LSCD** is the Lewis Soil Conservation District. The District is cooperating with DEQ on a ground water sampling project on the Camas Prairie.

The water chemistry of well CM-1 is similar to wells in a DEQ sampling network on the Camas Prairie (Figure 2). All these wells have a calcium bicarbonate-type water. Well CM-1 has slightly more sodium and bicarbonate in proportion to other constituents than wells in the Camas Prairie sampling network. The nitrate at well CM-1 was 1.71 mg/L, well below the maximum contaminant level (MCL) of 10 mg/L for drinking water.

## Stable Isotopes

Table 4 shows results for the stable isotopes of oxygen ($^{18}O$) and hydrogen ($^{2}H$) for wells CM-1 and CM-3, and also, for comparison, isotope results from 23 wells sampled by DEQ in the Camas Prairie sampling network. Figure 3 shows a plot of $^{18}O$ versus $^{2}H$ for the wells listed in Table 4.

The stable isotope ratios of oxygen and deuterium in atmospheric water vapor are subject to changes that begin when water evaporates from the ocean. Oxygen and deuterium isotope ratios continue to evolve as the water vapor in an air mass moves inland and condenses to form precipitation. Oxygen and deuterium isotope ratios in precipitation can vary for different storm events in a particular area and for summer versus winter storm events for the same area. Isotope ratios can also vary for storm events that occur at different latitudes and at differing altitude and/or temperature conditions. Once precipitation infiltrates and enters the ground water system further changes in oxygen and deuterium ratios are limited because evaporative processes are no longer active. Seasonal isotopic variations in the recharged water become damped out once the water enters an aquifer. Oxygen and deuterium results can be compared to the Global Meteoric Water Line (GWML) which describes the world wide relationship between $^{18}O$ and $^{2}H$ in worldwide fresh surface waters. The equation describing a best fit line for these data is:

$$\delta^{2}H = 8\ \delta^{18}O + 10\ ‰\ SMOW\ (Craig,\ 1961b),$$

where SMOW is Standard Mean Ocean Water, used as a reference. VSMOW (Vienna Standard Mean Ocean Water) has since replaced SMOW as the accepted reference for the GWML.

**Table 4.** Oxygen ($^{18}O$) and hydrogen ( $^{2}H$) results for wells CM-1 and CM-3. Also shown for comparison are $^{18}O$ and $^{2}H$ results for 23 wells located on the Camas Prairie, sampled during August 2005.

| Well ID | δ18O (‰) | δ2H (‰) |
|---|---|---|
| CM-1 | -16.0 | -122 |
| CM-3 | -16.3 | -127 |
| DEQ 07 | -14.5 | -112 |
| DEQ 10 | -13.5 | -108 |
| DEQ 13 | -14.8 | -115 |
| DEQ 17 | -15.6 | -117 |
| DEQ 26 | -15.7 | -122 |
| DEQ 31 | -15.3 | -119 |
| DEQ 35 | -15.3 | -119 |
| DEQ 43 | -15.2 | -116 |
| DEQ 46 | -15.2 | -119 |
| DEQ 48 | -14.8 | -114 |
| DEQ 52 | -14.4 | -112 |
| DEQ 53 | -14.9 | -115 |
| LSCD 1 | -15.0 | -118 |
| LSCD 10A | -16.1 | -127 |
| LSCD 11 | -15.4 | -119 |
| LSCD 12 | -15.2 | -118 |
| LSCD 13 | -14.9 | -113 |
| LSCD 14 | -14.9 | -113 |
| LSCD 2 | -14.6 | -115 |
| LSCD 3 | -15.1 | -118 |
| LSCD 5 | -14.8 | -115 |
| LSCD 7 | -15.0 | -113 |
| LSCD 9 | -14.8 | -112 |

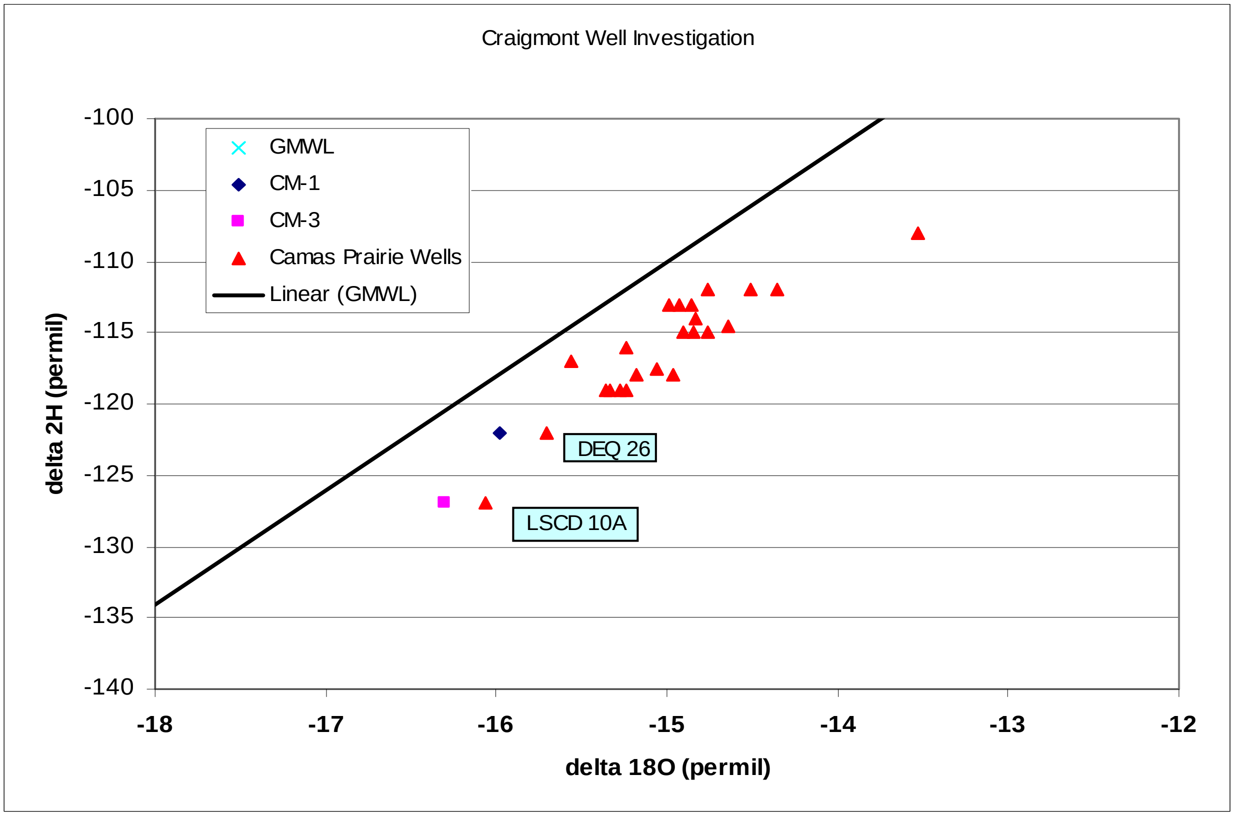


**Figure 3.** Plot of oxygen ($^{18}O$) versus deuterium ($^{2}H$) for Craigmont wells CM-1, CM-3, and wells currently being sampled by DEQ on the Camas Prairie.

Oxygen/deuterium results for ground water recharged at higher elevations or under colder temperatures plots in the lower left portion of an oxygen/deuterium plot while ground water recharged at lower elevations or under warmer temperatures tends to plot in the upper right portion of an oxygen/deuterium plot. Also, ground water that has undergone significant evaporation prior to recharge will plot in the upper right portion of an oxygen/deuterium plot.

Wells CM-3 and CM-1 plot in the lower left portion of Figure 4, indicating that these wells produce water from a deeper part of the aquifer than most other wells that have been sampled by DEQ. Well LSCD (Lewis Soil Conservation District) 10A is a flowing artesian well that also is believed to produce water from a deep portion of the aquifer; well DEQ 26 is screened from 115 to 136 feet below land surface and also appears to withdraw water from a deeper portion of the aquifer. The plotting position indicates that the water in wells CM-1, CM-3, DEQ 26, and LSCD 10A is older, i.e., the water has been in the flow system longer than at most other wells that have been sampled on the Camas Prairie.

## Iron Bacteria

According to the National Ground Water Association, although iron bacteria are commonly blamed for occurrences of slime in wells, only a small percentage of these problems actually are related to iron bacteria. This source indicated that most slime formation in wells is caused by naturally occurring soil bacteria. There are reports that well CM-1 produced "red" water, which could be an indication of the presence of iron bacteria.

There are several iron bacteria forms. A common form, *Galionella*, occurs in water that has elevated iron concentrations (up to 25 mg/L), has low dissolved oxygen (in the 0.1 to 1 mg/L range), a pH range of 6 to 7.6, and a temperature up to 15.6 $^{0}$C. As shown in Tables 1 and 3, the pH, temperature and iron parameters are favorable (pH = 6.7, temperature = 10.5 $^{0}$C and iron concentration = 8.91 mg/L) but the dissolved oxygen concentration of 6.1 mg/L indicates an unfavorable condition for this iron bacteria to form. The iron concentrations in two Idaho Department of Water Resopurces monitoring wells located near Craigmont and completed to similar depths were at or below the laboratory detection limit of 0.01 mg/L, which indicates that elevated iron concentrations are not found uniformly throughout the aquifer. The Idaho Ground Water Rule lists a secondary standard of 0.30 mg/L for iron, which is based on aesthetics. Iron bacteria can create masses of gel-like slime that can clog pump intakes and pipe systems. This type of deposit was not evident in the video survey and so even though iron concentrations were elevated in the ground water, the red color noted before the well was shut down may simply be due to the elevated iron concentration.

## Video and Colloidal Borescope Surveys

The well was evaluated with a video survey and a colloidal borescope survey, each of which is described in the following sections.

### Video Survey

A video survey of the well was conducted on September 18, 2007, using a camera with both downward and side view capability. The unit was lowered to the bottom of the well and a video image of the borehole was recorded as the camera was raised. A discrepancy was noted between the depth indicator on the camera system and the actual depth of the camera in the well. The camera indicated that the water table stood at 58.8 feet below the top of the casing (TOC) while a water level measurement with a steel tape indicated a depth to water of 66.54 feet below TOC, for a difference of about 7.7 feet (rounded to 8 feet). The camera depth measurements were adjusted by adding 8 feet to the video display readings. The bottom of the 8-inch casing is at 58 feet below TOC, based on the adjusted video survey. Table 5 lists descriptions of the borehole lithology for various depth intervals below the top of the casing.

**Table 5.** Description of well CM-1 lithology from video survey.

| Depth Below TOC[1] (feet) | Lithologic description (depths unadjusted) |
|---|---|
| 0 – 58 | 8 inch casing |
| 58 – 70 | Dense basalt, few vesicles, no fractures. Water table at 66.54 feet by steel tape (58.8 on video survey). |
| 70-91 | Basalt, large vesicles, non fractured. Large areas of side wall covered with 'mat' of precipitate. |

| Depth Below TOC[1] (feet) | Lithologic description (depths unadjusted) |
|---|---|
| 91-94 | Basalt, few vesicles, both large and small. |
| 94-100 | Dense basalt, small vesicles, scattered small fractures. |
| 100-104 | Dense basalt, few scattered vesicles, few fractures oriented at oblique angles. |
| 104-106 | Basalt, large horizontal fractures. |
| 106-116 | Basalt, large vesicles, few large oblique fractures. |
| 116-122 | Basalt, scattered horizontal and vertical fractures, few vesicles. |
| 122-124 | Basalt, large horizontal fractures, a few small vesicles. |
| 124-128 | Basalt, a few small vesicles, occasional small fractures. |
| 128-136 | Basalt, large vesicles, large fractures, and rubble zone. |
| 136-141 | Basalt, less vesicular than above, large vertical and horizontal fractures at 134, 136 and 139 feet. |
| 141-148 | Basalt, vesicular. |
| 148-151.5 | Water column highly turbid and lots of suspended material. Can't see sidewall details. |
| 151.5-158 | Video dark, camera probably bottomed out in sediment that has collected at bottom of well. |

1. Depth readings on video have been adjusted by adding 8 feet.

## Colloidal Borescope Survey

Colloids are naturally occurring particles that are transported with the ambient ground water flow field, so observing their movement provides information about ground water flow. An instrument called a colloidal borescope was deployed in the well to determine the ground water flow direction and flow velocity. This device consists of two CCD (charged-couple device) cameras, an internal compass, a 140X optical magnification lens, and an illumination source, all contained in a stainless steel housing. Signals are transmitted to the surface via a cable. Software provided with the instrument tracks the movement of colloids as they cross the camera's field of vision and records the direction of movement, the velocity and the number of these colloids (Kearl and Roemer, 1998). The number of colloids, recorded as a particle count by the software, can vary from one zone to another within a well, from well to well and from aquifer to aquifer.

The instrument is set at a particular depth where direction and velocity information are recorded and then is raised or lowered to another target zone where additional direction and velocity information are recorded. In a screened well, only the screened interval(s) can be surveyed. However, any favorable zone in an uncased borehole can be surveyed.

Target depths for the borescope surveys were selected based on lithologic information from the video survey. The main area of interest was the interval from 128 to 148 feet below land surface (actual depths), where several fractures, large vesicles and rubble zones were noted. Colloidal borescope surveys were run at 128 feet, 144 feet, 145 feet, 146 feet, and 147 feet. As noted above, mats, presumably of biological origin, coated some areas of the borehole walls and this material was dislodged as the video camera and colloidal borescope were run into the well. This resulted in elevated turbidity. The turbidity measured during sample collection was 108 NTU (Table 1); natural turbidity in ground water is usually less than 5 NTU (USGS, 2005). Since the borescope survey relies on visual detection of naturally occurring colloids traveling with ambient ground water flow, this high turbidity condition may have affected the outcome of the borescope survey.

Figures 4 and 5 show the results of colloidal borescope surveys at 145 and 128 feet below land surface. No distinct flow direction and flow velocity pattern was evident at either depth, and the same was true for all other depths investigated. For comparison, Figure 6 shows an example of results from a survey in a different well that produced a distinct flow direction and flow velocity. This survey was conducted at a screened monitoring well completed in saturated sand and gravel at Blackfoot, Idaho.

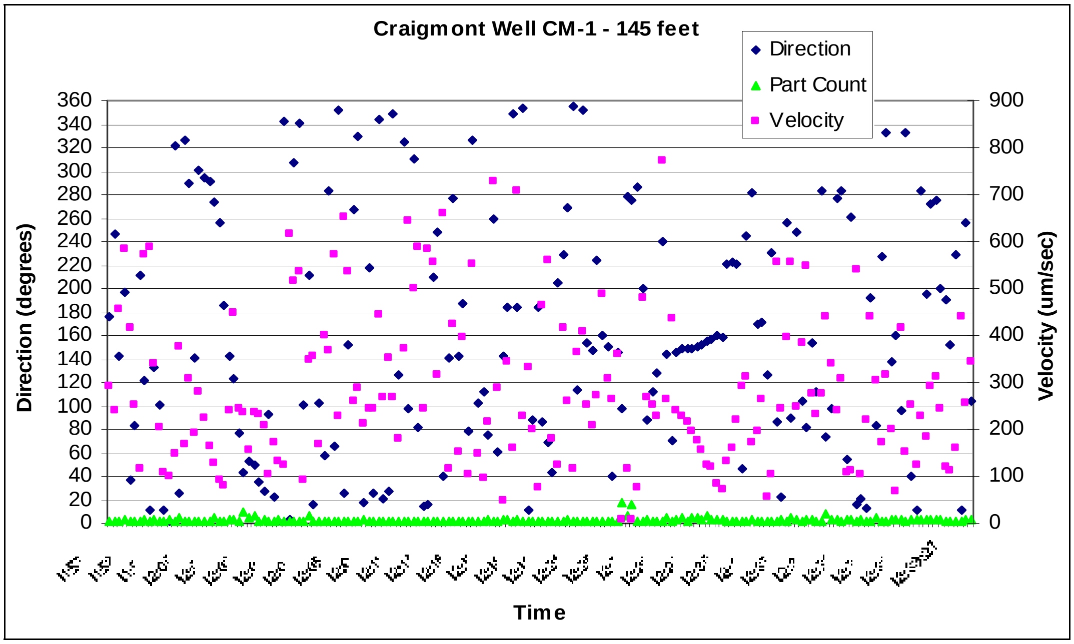


**Figure 4.** Colloidal borescope survey of Craigmont well CM-1, 145 feet below land surface.

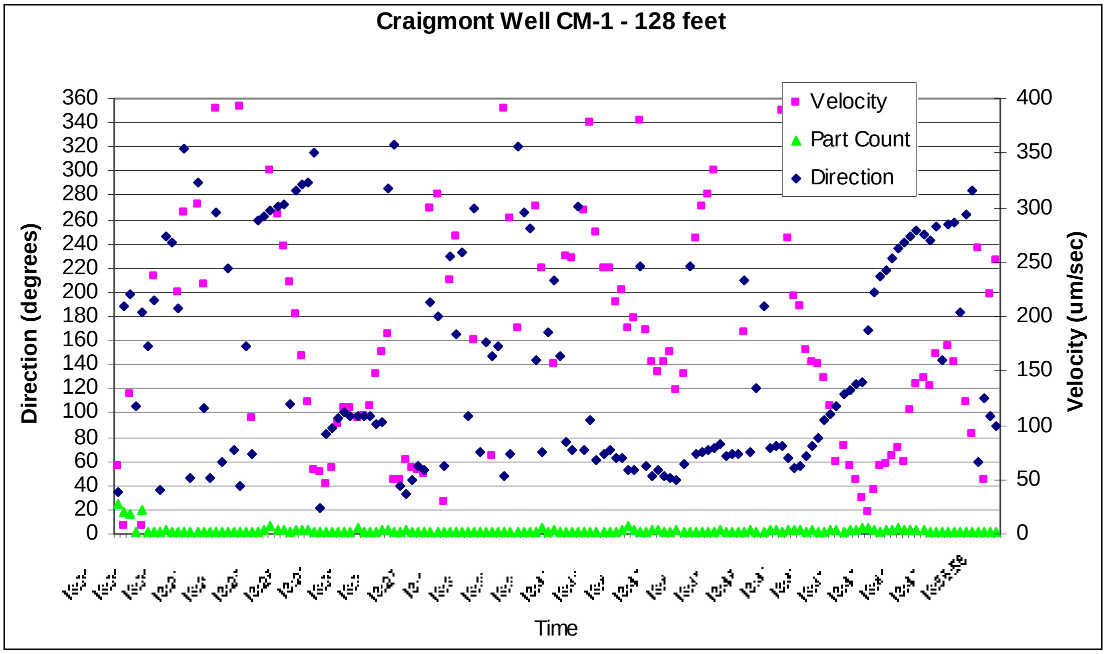


**Figure 5.** Colloidal borescope survey of Craigmont well CM-1, 128 feet below land surface.

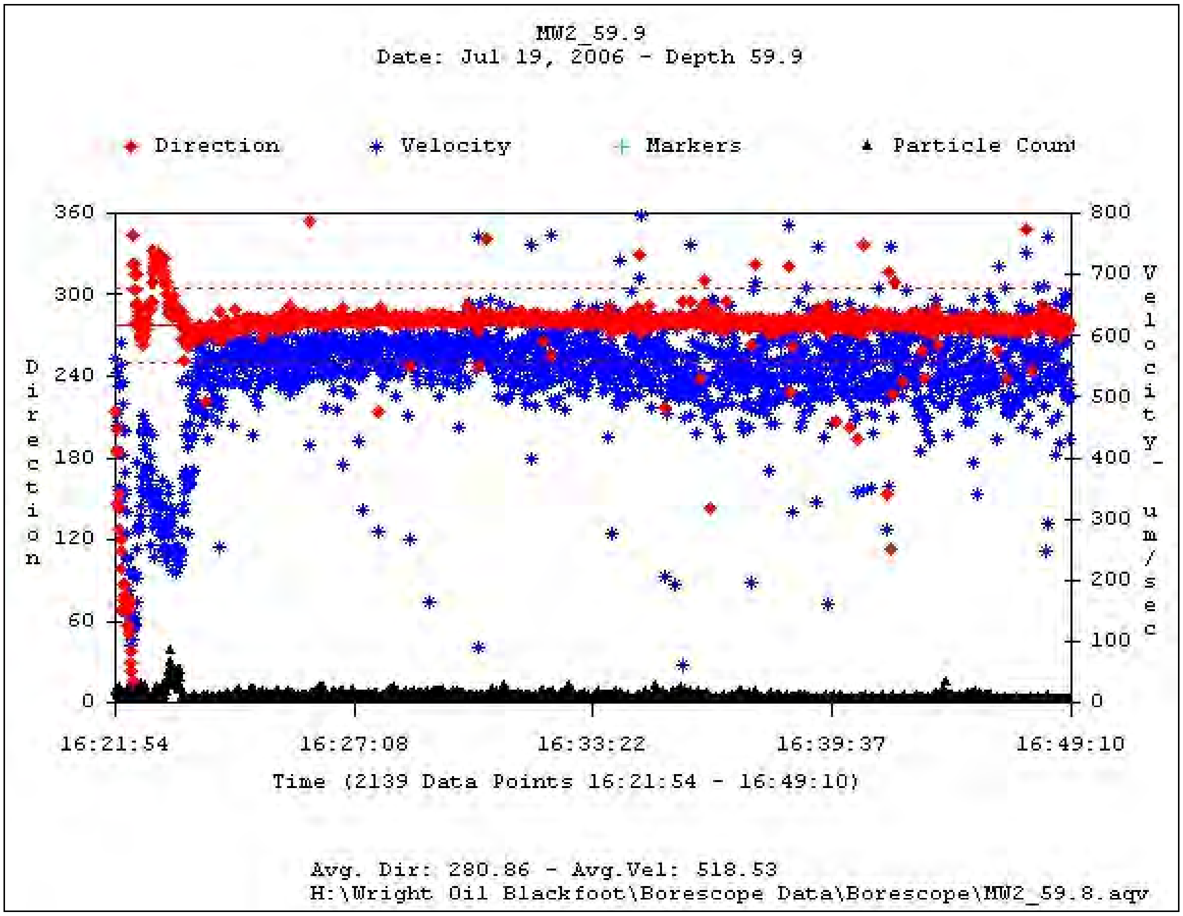


**Figure 6.** Example of colloidal borescope result from a monitoring well located at Blackfoot, Idaho. The average flow direction was 280 degrees and the average velocity was about 518 micrometers/second (147 feet per day).

The lack of distinct flow velocity and flow direction information from well CM-1 may indicate the potential yield from this well is low. There may be zones where ground water flow occurs that weren't evaluated during the borescope survey. Another possibility is that only limited ground water movement occurs in the fractured rubble zone identified with the video survey. This would mean that although water stands in the well bore, the well may have a limited production capacity. The well production capacity could be evaluated by test-pumping the well after rehabilitation operations recommended in this report are conducted.

# Conclusions

A video survey of Craigmont well CM-1 indicated that a zone of fractured basalt occurs from 128 to 148 feet below land surface. The well is cased to about 58 feet below land surface. A colloidal borescope survey was conducted at 5 locations in the well: 128 feet, 144 feet, 145 feet, 146 feet and 147 feet. The water column contained high turbidity due to disturbance to the sidewall from the video camera and colloidal borescope surveys. The high turbidity in the water column may have interfered with the colloidal borescope survey. None of the surveys produced data that indicated a ground water flow direction or flow velocity.

Although the iron concentration in the water sample was 8.91 mg/L, the video survey did not indicate that iron bacteria have become established in the well. A September 18, 2007, sample collected from the well had a nitrate concentration of 1.71 mg/L and a total dissolved solids (TDS) concentration of 194 mg/L. With the exception of the elevated iron, these data indicate the water quality in the well is very good.

There does appear to be a mat in some areas of the well that may be of bacterial origin. Since the well has not been used for an extended period, it could be rehabilitated by the following steps:

1. Dose the well with a chlorine solution and allow this solution to stand in the well overnight. Household bleach (5.25 percent sodium hypochlorite) can be added; however, approximately 35 gallons of bleach would be required for an 8-inch casing with an 83-foot water column (150 foot total depth – 67 feet to water) to achieve the recommended chlorine concentration of 1,000 mg/L. Other disinfection products may be more efficient.
2. Jet/pump the well the next day to remove accumulated sediment and clean the fracture zones. The drilling equipment should be cleaned prior to working on the well.
3. A sample should be collected after jetting and pumping, and analyzed for bacteria, iron, nitrate, chloride, sulfate, and TDS.

The well could be returned to service if the sample results are favorable and there is sufficient production during the jetting/pumping stage.

## References

Anderson, Chauncey M. 2005. National Field Manual for the Collection of Water-Quality Data, Chapter A6, Section7 – Turbidity. Techniques of Water-Resources Investigations, Book.

Kearl, Peter M., and Kirk Roemer. 1998. Evaluation of groundwater flow directions in a heterogeneous aquifer suing the colloidal borescope. Advances in Environmental Research, vol. 2, no. 1, 1998, pp 12-23.

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