AQUIFER TESTS IN THE UPPER JEFFERSON VALLEY



Andrew L. Bobst and Ali Gebril

Montana Bureau of Mines and Geology Ground Water Investigations Program



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May 2020

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Montana Bureau of Mines and Geology Open-File Report 727



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1 INTRODUCTION

The Upper Jefferson Groundwater Investigation was conducted to evaluate how changes in irrigation management activities and increased residential development may affect water availability in the Upper Jefferson Valley. Five aquifer tests were conducted during this investigation. These tests were conducted in the Upper Jefferson Valley, southwestern Montana, between Silver Star and Cardwell (fig. 1-1). These tests were conducted to provide site-specific aquifer property estimates (e.g., transmissivity and storativity) of the tested aquifers, and to evaluate potential boundary effects. These results were then used in developing groundwater budgets for the model areas



Figure 1-1. Five aquifer tests were conducted for the Upper Jefferson Groundwater Investigation. Four of these tests were in the Tertiary Renova Formation, and one (Hunt) was in the Quaternary alluvium.

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near Waterloo and Whitehall, and the values were used to evaluate the reasonableness of aquifer properties used in the calibrated groundwater models (Gebril and Bobst, in preparation, a and b). The results were also used in interpreting the overall hydrologic conditions within the Upper Jefferson Valley (Bobst and Gebril, in preparation).

The Upper Jefferson Valley is an intermontane basin, with the Highland Mountains to the west, and the Tobacco Root Mountains to the east. The valley is filled with sediment transported from both sides and from the overall Jefferson River drainage area to the south. Tertiary and Quaternary pediment gravels occur at the bases of the mountains. Quaternary alluvium underlies the modern floodplain, and is underlain by the relatively fine-grained Tertiary Renova Formation (Vuke and others, 2004). The Renova Formation is characterized by fine-grained strata (>70% fine sand and finer; Kuenzi and Fields, 1971; Vuke, 2004), with channels of immature sandstone (Vuke, 2004). Estimates of the thickness of unconsolidated Tertiary and Quaternary basin-fill material over bedrock in the vallev bottom range from about 2,000 to 10,000 ft (Vuke and others, 2004). Four aquifer tests were conducted in the Renova Formation, and one was in the alluvium (table 1-1). The data collected during each test can be accessed from GWIC (http://mbmggwic.mtech. edu/) by using the GWIC ID numbers for the pumping wells.

The local nature of the aquifer and boundaries at each site were evaluated based on drawdown observations and evaluation of derivative plots (Renard and others, 2009). The two tests of the Renova Formation in the floodplain (HCC Floodplain and LTP Floodplain; fig. 1-1) showed a leaky-confined response. This shows that the tested aquifers were hydrologically connected with shallower zones, but that there was some degree of confinement. One of the tests from the Renova Formation on the bench (HCC Bench) showed an unconfined response, and the other Renova Formation bench test (LTP Bench) showed a confined response. The Hunt aquifer test in the Quaternary alluvium showed an unconfined response and the influence of a nearby recharge boundary. Aquifer test solutions for each test were selected based on the hydrogeologic setting and derivative plots, taking into account the degree to which the assumptions inherent in each solution were violated (Fetter, 1994). Sediment types in the completion zones ranged from silty sand to gravel. The results from the aquifer tests reflect these differences in sediment types, with the lowest permeability and storativity occurring in the finest sediments and the highest values occurring in the coarsest grained.

2 HCC FLOODPLAIN TESTS

2.1 Background

2.1.1 Purpose of Test

This test was designed to estimate the transmissivity (T) and storativity (S) of the Tertiary Renova Formation. The test was also conducted to evaluate interconnections among the Renova Formation, the overlying surficial Quaternary alluvium, and the nearby Jefferson River. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

2.1.2 Test Location

Four wells were installed in the Jefferson River floodplain (T. 2 S., R. 5 W., sec. 5; figs. 2-1 and 2-2, table 2-1; appendix 2A) 1.5 mi northeast of Silver Star. The site is located within a flood-irrigated hay field, and is 0.8 mi from the nearest residence. The Jefferson River is 0.3 mi northwest of the site.

Table 1-1. Aquife	er test results.				
Toot Nomo	Pumping Well GWIC	Aquifor	Transmissivity	Storativity	Solution Type
	U	Aquiler	(1, 11-/0)	(S, unitiess)	Solution Type
Floodplain	277403	Renova	74–77	1.5 x 10 ⁻⁷ to 1.6 x 10 ⁻⁵	Leaky-confined
HCC Bench	280980	Renova	255	0.20	Unconfined
Hunt	279259	Alluvium	41,000– 44,500	0.14	Unconfined
LTP Floodplain	279262	Renova	310– 440	8 x 10 ⁻⁴ to 2 x 10 ⁻³	Leaky-confined
LTP Bench	280978	Renova	5,800	5.2 x 10⁻⁵	Confined

2.1.3 Test Type

A step-test, a 10-h aquifer test (truncated due to equipment failure), and a 72-h aquifer test were performed. The step-test was performed on 2/4/2015, the 10-h test was conducted on 2/9/2015, and the 72-h test ran from 2/10/2015 to 2/13/2015. Water-level

recovery was monitored until 2/18/2015. During the 10-h test the time-weighted average pumping rate was 15.7 gpm, and during the 72-h test the time-weighted average pumping rate was 13.6 gpm. Drawdown and recovery were monitored in the pumping well and in three observation wells.



Figure 2-1. The HCC Floodplain aquifer test site is located in the Jefferson River floodplain approximately 1.5 mi northeast of the town of Silver Star, Montana.



Figure 2-2. The HCC Floodplain aquifer test site had a pumping well completed in the Renova Formation (OW1), two observation wells in the Renova Formation (OW2 and PW), and one observation well in the overlying alluvium (OW3). Water was discharged approximately 300 ft northwest of the pumping well.

2.1.4 Hydrogeologic Setting

The stratigraphy is topsoil and silt from 0 to 5 ft, gravel with some silt from 5 to 30 ft, silty clay from 30 to 75 ft, and fine to medium silty sand from 75 to 100 ft. The upper 30 ft is Quaternary alluvium, while the deeper silty clay and silty sand are the Renova Formation (appendix 2A; Vuke and others, 2004).

During longer-term monitoring, from February 2014 to May 2015, groundwater levels fluctuated from about 1.5 to 5.5 ft below ground surface (bgs). The timing of groundwater fluctuations was similar to that of the Jefferson River stage. Groundwater elevation was typically higher in the alluvium than in the Renova Formation; however, this reverses in the late summer when the river stage is low (fig. 2-3).

Table 2-1. Well designations, locations, and completion information, HCC Floodplain Aquifer test site.

GWIC ID	Name	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (ft-amsl)	Total Depth (ft-bgs)	Screened Interval (ft-amsl)	Distance from OW1 (ft)	Maximum Drawdown (ft)	Aquifer	Type of Well
277403	OW1	45.695992	-112.254563	4497.2	94	4403– 4423	_	43.0	Renova	Pumping
277404	OW2	45.696123	-112.254643	4497.1	103	4394– 4416	51.9	5.7	Renova	Observation
277405	PW	45.696076	-112.254497	4497.3	100	4397– 4418	34.9	10.6	Renova	Observation
277406	OW3	45.696028	-112.254535	4497.3	30	4467– 4478	14.7	0.0	Alluvium	Shallow Observation

Note. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface. All locations and elevations determined by survey. Horizontal Datum, NAD83; Vertical Datum, NAVD88.



Figure 2-3. Long-term monitoring at the HCC Floodplain site shows that the shallow and deep aquifers both respond to changes in river stage.

2.1.5 Hydrologic Features

The Jefferson River is a significant hydrologic feature in the area, and several secondary channels near the test site flow during high river stages (figs. 2-1 and 2-2). The "Secondary Channel" noted in fig. 2-2 is likely an ancestral channel of the Jefferson River. During the aquifer tests, the secondary channels contained standing water.

2.2 Field Procedure

A step-test was conducted on 2/4/2015 to determine a sustainable pumping rate for the constant-rate test. Well OW1 was used as the pumping well because a crooked casing precluded the installation of the pump in well PW (table 2-1). From the step-test data it was determined that 16 gpm would be a reasonable pumping rate for the 72-h constant-rate test.

During the first attempt at the 72-h constant-rate aquifer test, equipment failure led to the test being terminated after 10 h. A second test started 17 h later, after water levels had recovered and stabilized. The second constant-rate test extended a full 72 h after the restart.

2.3 Data Collection

A vented pressure transducer with data logger was installed in each well on 2/3/2015 and removed on 2/18/2015 (5 days after the end of pumping). Each transducer was programmed to record water levels at a 1-min interval. An e-tape was used to measure water levels in all wells prior to installing transducers, throughout the test, and prior to transducer removal (figs. 2-4 to 2-7). These measurements were used to calibrate transducer response, and to provide a backup in case of transducer malfunction.

Pumping rates were monitored using a bucket and stopwatch and a totalizing flow meter. During the first 4 hs of the 72-h test we measured flow on average every 9 mins. The maximum interval between discharge measurements was 244 min.

All water-level data and pumping rates are available from GWIC by using the wells' GWIC ID numbers (table 2-1) and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmgg-wic.mtech.edu/).



Figure 2-4. Depth to water in the pumping well (OW1) during the aquifer test.

2.4 Results

Data collected before and after the aquifer test show that there were no groundwater level trends during the test period. (figs. 2-4 to 2-7). For example, the depth to water in OW1 was 7.95 ft before the step-test on February 4th, and 7.98 ft at the end of recovery on February 18th. Therefore, no correction was made for antecedent trends.

2.4.1 Water-Level Response

The maximum drawdown in the pumping well (OW1) during the 72-h test was 43.0 ft (table 2-1; fig. 2-4). Drawdown in well OW1 showed a rapid initial decline followed by a gradual leveling out. Drawdown was increasing slightly at the end of the pumping portion of the test. The water level in well OW1 responded rapidly to the cessation of pumping, reaching 90 percent recovery in about 12 min.

Drawdown in the deep observation wells (OW2 and PW) differed from the pumping well in that the drawdowns toward the end of the test were slightly decreasing (figs. 2-5 and 2-6). The maximum drawdown in PW, 10.6 ft, was nearly twice that in OW2, 5.7 ft. The shallow observation well (OW3) showed no measurable response to pumping (fig. 2-7).

2.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was a leaky-confined response to the test (appendix 2B). Therefore, aquifer properties were determined using observations from the two deep observation wells (PW and OW2), and a leaky-confined solution (Hantush and Jacob, 1955). AQTESOLV was used to analyze the aquifer test data. These results indicated transmissivity values between 74 and 77 ft²/d, and storativity values between 1.5 x 10⁻⁷ and 1.6 x 10⁻⁵.

2.4.3 Aquifer Boundaries

A leaky-confined solution was needed to replicate observations; however, the simulated leakage was relatively small. Long-term monitoring shows that water levels in the deeper aquifer changed in response to short-term variations in river stage. Therefore, even though no drawdown was observed in the shallow observation well on site, the deep aquifer appears to be connected to the shallow aquifer system, and to the Jefferson River. The absence of response in the shallow aquifer during the test is attributed to the slight leakage needed, and the fact that unconfined aquifers have much higher storativity than confined aquifers (specific yield is much larger than specific storage).



Figure 2-5. Depth to water in observation well OW2 during the aquifer test.



Figure 2-6. Depth to water in observation well PW during the aquifer test.



Figure 2-7. Depth to water in observation well OW3 during the aquifer test. Note that this hydrograph is at a different scale than those for the other observation wells.

2.5 Summary

The silty sand of the Renova Formation at this site had a transmissivity of about 75 ft²/d and an average storativity of about 8 x 10⁻⁶. Our interpretation indicates that this portion of the Renova Formation is a leaky-confined aquifer, and appears to be connected to the shallow Quaternary alluvium, and to the Jefferson River.

3 HCC BENCH TESTS

3.1 Background

3.1.1 Purpose of Test

This test was designed to estimate the transmissivity (T) and storativity (S) of the Tertiary Renova Formation. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

3.1.2 Test Location

Two wells were installed on the bench on the east side of the Jefferson Valley, in T. 2 S., R. 5 W., sec. 9 (figs. 3-1 and 3-2; table 3-1; appendix 3A). This site is 2.7 mi east of Silver Star, and 0.7 mi from the nearest residence.

3.1.3 Test Type

We performed a step-test and a 50-h constant-rate aquifer test. The step-test was performed on 2/16/2015 and the 50-h test ran from 2/17/2015 to 2/19/2015. Water-level recovery data were monitored until 2/23/2015. During the 50-h test the time-weighted average pumping rate was 11 gpm. Drawdown and recovery were monitored in the pumping well and one observation well.

3.1.4 Hydrogeologic Setting

The stratigraphy is interlayered silty sand and silty gravel from 0 to 105 ft, silty clay from 105 to 115 ft, gravel and sandy silt from 115 to 135 ft, and silty gravel with some sand from 135 to 220 ft (appendix 3A). The pumping and observation wells were installed to total depths 220 and 222 ft bgs, respectively, and were constructed with 10-ft screen (table 3-1). These wells are completed within the Renova Formation.

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Figure 3-1. The HCC bench aquifer test site is located on the bench east of the Jefferson River approximately 2.7 mi east of the town of Silver Star, Montana.

3.1.5 Hydrologic Features

This site is on a bench above the floodplain, upgradient of all irrigation canals. There are several centerpivot irrigated fields adjacent to this site (fig. 3-2). The test was conducted in February, when there is little potential for influence from irrigation.

3.2 Field Procedure

A step-test was conducted on 2/16/2015 to determine a sustainable pumping rate for the constant-rate test. From the step-test data it was determined that 11 gpm would be a reasonable pumping rate. The constant-rate aquifer test was scheduled to run for 72 h but was terminated after 50 h due to equipment failure.







Figure 3-3. The hydrograph for PW showed a slight downward antecedent trend. Time-weighted corrections were applied to remove these effects.

			Ground			Distance			
			Surface	Total	Screened	from	Maximum		
SWIC L	atitude	Longitude	Elevation	Depth	Interval	PW	Drawdown	Aquifer	
ID Name (d	legrees)	(degrees)	(ft-amsl)	(ft-bgs)	(ft-amsl)	(ft)	(ft)		Well Type
80980 PW 45	.684520	-112.226762	4644.5	222	4423-4433	I	32.9	Renova	Pumping
80979 OW 45	.684633	-112.226694	4643.3	220	4423-4433	44.8	2.4	Renova	Observation

3.3 Data Collection

A vented pressure transducer was installed in each well. The observation well (OW) transducer was installed on 2/11/2015, and the pumping well (PW) transducer was installed along with the pump on 2/16/2015. Each transducer recorded water levels at 1-min intervals. An e-tape was used to collect depth to water (DTW) readings prior to installation of the transducers, throughout the tests, and during the recovery period. These measurements were used to calibrate transducer response, and to provide a backup in case of transducer malfunction.

Pumping rates were monitored using a bucket and stopwatch and a totalizing flow meter. During the first 4 h of the 72-h test, we measured flow on average every 10 min. The maximum interval between discharge measurements was 230 min (~4 h).

Water-level data and pumping rates are available from GWIC using the wells' GWIC ID numbers (table 3-1), and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmggwic.mtech. edu).

3.4 Results

A downward antecedent trend in groundwater levels was noted during the constant-rate test. Timeweighted corrections were applied to results to correct for this trend. Trend-corrected data are shown in figures 3-3 and 3-4.

3.4.1 Water-Level Response

The maximum recorded drawdown in the pumping well (PW) was 32.9 ft (table 3-1; fig. 3-3). Drawdown in PW showed a rapid initial decline followed by gradually declining water levels. The rate of drawdown decreased throughout the test. Well PW exhibited a rapid response to the cessation of pumping, reaching 90% recovery in about 4 min (fig. 3-3).

Drawdown in OW reached a maximum of 2.3 ft. The shape of the hydrograph was similar to that of PW (fig. 3-4).

3.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was an unconfined response to the test (appendix 3B). Therefore, aquifer properties were determined using observations from OW and an unconfined solution



Figure 3-4. The hydrograph for OW showed a slight downward antecedent trend during the 50-h test. Timeweighted correction was used to remove trend.

(Neuman, 1974). AQTESOLV was used to analyze the aquifer test data. These results indicated a transmissivity value of 255 ft^2/d , and a storativity of 0.2.

3.5 Summary

The tested portion of the Renova Formation (silty gravel with some sand) has a transmissivity of about $255 \text{ ft}^2/\text{d}$, and a storativity of about 0.2. The aquifer test showed an unconfined response, and did not reveal any boundary effects.

4 HUNT TESTS

4.1 Background

4.1.1 Purpose of Test

This test was designed estimate the transmissivity (T) and storativity (S) of the Quaternary alluvial aquifer. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

4.1.2 Test Location

Three wells were installed in the floodplain east of

the Jefferson River, near Waterloo, in T. 1 S., R. 5 W., sec. 24 (figs. 4-1 and 4-2; table 4-1), and 1.6 mi southeast of Parson's Bridge. The site is used as a pasture (fig. 4-2) and is 0.3 mi from the nearest residence.

4.1.3 Test Type

We performed a step-test and a 55-h constantrate aquifer test. The step-test was performed on 2/23/2015, and the 55-h test ran from 2/24/2015 to 2/26/2015. Water-level recovery was monitored until 3/6/2015. During the 55-h test the time-weighted average pumping rate was 433 gpm. Drawdown and recovery were monitored in the pumping well and two observation wells (table 4-1).

4.1.4 Hydrogeologic Setting

The stratigraphy is silty sand from 0 to 12 ft, clay from 12 to 18 ft, silty sand and gravel from 18 to 20 ft, and gravel with little sand from 20 to 60 ft (appendix 4A). These unconsolidated materials are Quaternary alluvium (Vuke and others, 2004). The pumping and observation wells were installed in the deepest gravel (table 4-1), and the static water level was approximately 7 ft below ground surface. Wells were completed



Figure 4-1. The Hunt aquifer test site was located in the floodplain east of the Jefferson River. This site is 1.6 mi southeast of Parson's Bridge.

using steel casing with open bottoms, and perforations (table 4-1; appendix 4A).

4.1.5 Hydrologic Features

This site is a pasture located in the floodplain of the Jefferson River. It is downgradient from the Parrot Canal, and adjacent to irrigated fields. Two groundwater-fed streams (WET, written commun., 2006), Parson's Slough and Willow Springs Creek, are located 1.1 and 0.5 mi from the site. The Jefferson River is approximately 1.8 mi west of the site (fig. 4-1). The



Figure 4-2. At the Hunt aquifer test site one pumping well and two observation wells were completed in the unconsolidated alluvium (table 3-1). During the tests, produced water was discharged approximately 300 ft northeast of the pumping well.

wells were installed adjacent to a wetland area (figs. 4-1 and 4-2).

4.2 Field Procedure

A step-test was conducted on 2/23/2015 to determine a sustainable pumping rate for a constant-rate test. From the step-test data it was determined that a pumping rate of 450 gpm would be appropriate.

Although scheduled for 72 h, the constant-rate aquifer test was terminated after 55 h due to equipment failure. During the constant-rate test, the timeweighted mean pumping rate was 433 gpm. Considerable variation in pumping rates occurred near the end of the test due to pump failure.

4.3 Data Collection

A vented pressure transducer was installed in each well. The observation well transducers were installed on 2/18/2015, and the pumping well transducer was installed along with the pump on 2/23/2015. Each

transducer was programmed to record water levels at 1-min intervals. Manual water-level measurements were made using an e-tape prior to placing transducers, during the test, and during recovery. These measurements were used to calibrate transducer response, and to provide a backup in case of transducer malfunction.

Pumping rates were monitored using a totalizing flow meter. Discharge measurements were made more frequently at the start of the test, and near the end when the pump began to fail. The maximum interval between discharge measurements was 273 min (~4.6 h).

All water-level data and pumping rates are available from GWIC by using the wells' GWIC ID numbers (table 4-1) and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmgg-wic.mtech.edu/).

				Ground						
				Surface	Total	Perforated	Distance	Maximum		
GWIC ID	Name	Latitude	Longitude	Elevation	Depth	Interval	from PW	Drawdown	Aquifer	Well Type
		(degrees)	(degrees)	(ft-amsl)	(ft-bgs)	(ft-amsl)	(ft)	(ft)		
279259	ΡW	45.728924	-112.171926	4457.0	60	4397-4417	1	15.2	Alluvium	Pumping
279258	0W1	45.728987	-112.171934	4457.1	60	4397-4417	22.8	1.2	Alluvium	Observation
279260	OW2	45.728930	-112.172012	4457.2	60	4397-4407	22.0	1.2	Alluvium	Observation
Vote. ft-ams	sl, feet abo	ve mean sea le	vel; ft-bgs, feet b	elow ground	surface. All	locations and e	evations de	etermined by s	urvey. Horizo	ntal

Datum, NAD83; Vertical Datum, NAVD88.

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4.4 Results

Although this test was conducted in February to avoid interference from irrigation practices, static groundwater levels changed slightly during the constant-rate test. Therefore, time-weighted corrections were applied to measurements (figs. 4-3 to 4-6).

4.4.1 Water-Level Response

During the constant-rate test the maximum drawdown in the pumping well (PW) was 15.2 ft (fig. 4-3). Drawdown in PW showed a rapid initial decline followed by gradually declining water levels. Fluctuating water levels observed near the end of the test are attributed to variation in the pumping rate as the pump failed. PW exhibited a rapid recovery after the cessation of pumping, reaching 90% recovery in less than 1 min (fig. 4-3).

The maximum drawdowns in both observation wells were 1.2 ft. These hydrographs were similar to that of PW (figs. 4-5 and 4-6).

4.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was an unconfined response to the test, with a nearby recharge source (appendix 4B). Aquifer properties were determined using observations from the two observation wells (OW1 and OW2), an unconfined solution (Hantush and Jacob, 1955), and a constant head boundary set at the edge of the wetland (100 ft to the north). AQTESOLV was used to analyze the aquifer test data. These results indicated transmissivity values between 41,000 and 44,500 ft²/d, and a storativity value of about 0.14.

4.5 Summary

The transmissivity of the gravel at this site ranges from 41,000 to 44,500 ft²/d, and has a storativity of about 0.14. An unconfined solution with a nearby constant-head boundary replicates observations, indicating that the clay overlying the gravel aquifer is not laterally continuous, and this aquifer is hydraulically connected to the wetlands.



Figure 4-3. The hydrograph for PW shows an antecedent trend in water levels, so a time-weighted correction was applied to remove this effect. This is shown in greater detail in figure 3-4. The maximum drawdown during the constant-rate test (after correction) was 15.2 ft.



Figure 4-4. The hydrograph for PW shows an antecedent trend in water levels during the aquifer tests. This chart shows the groundwater levels at a higher resolution to illustrate the antecedent trend. For a full scale hydrograph see figure 3-3.



Figure 4-5. This hydrograph shows changes in water levels in OW1 during the aquifer tests. There was a slight downward trend during the test, so a time-weighted correction was applied to remove the effect of this antecedent trend. The maximum drawdown (after correction) during the constant-rate test was 1.2 ft.



Figure 4-6. This hydrograph shows changes in water levels in OW2 during the aquifer tests. There was a slight downward trend during the test, so a time-weighted correction was applied to remove the effect of this antecedent trend. The maximum drawdown (after correction) during the constant-rate test was 1.2 ft.

5 LAZY TP FLOODPLAIN TESTS

5.1 Background

5.1.1 Purpose of Test

This test was designed to estimate the transmissivity (T) and storativity (S) of the Renova Formation. Potential hydrologic connection to the overlying alluvial aquifer was also evaluated. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

5.1.2 Test Location

Three wells were installed in the floodplain between the Jefferson River and Slaughterhouse Slough (fig. 5-1; table 5-1; appendix 5A). The wells are located in T. 1 N., R. 4 W., sec. 11, 2 mi southeast of Whitehall. The site is located next to an inactive flooded gravel pit and an irrigated field (fig. 5-2). It is 0.7 mi from the nearest residence.

5.1.3 Test Type

We performed a step-test and a 72-h constant-rate aquifer test. The step-test was conducted on 3/6/2015, and the 72-h test ran from 3/16/2015 to 3/19/2015. Water-level recovery was monitored until 3/30/2015. During the 72-h test, the time-weighted average pumping rate was 21.3 gpm. Drawdown and recovery were recorded in the pumping well and two observation wells (table 5-1).

5.1.4 Hydrogeologic Setting

The stratigraphy includes gravel and sand from 0 to 20 ft, clay and gravel from 20 to 25 ft, and interbedded sand and mudstone from 25 to 60 ft (appendix 5A). The wells were installed in a sand-dominated portion of the interbedded sand and mudstone zone (table 5-1), and the static water level was approximately 7 ft below ground surface. The wells are completed in the Tertiary Renova Formation (Vuke and others, 2004). The overlying shallow sand and gravel (0–20 ft) is Quaternary alluvium.

5.1.5 Hydrologic Features

This site is in the floodplain of the Jefferson River, approximately 0.4 mi north of the river. The Slaughterhouse Slough (an ancestral channel of the Jefferson River) is located approximately 0.2 mi north of the site (fig. 5-1). Water produced during the aquifer test was

Well Type	Pumping Observation Observation
Aquifer	Renova Renova Renova
Maximum Drawdown (ft)	21.8 2.7 4.2
Distance from PW (ft)	— 34.6 27.4
Screened Interval (ft-amsl)	4274–4294 4274–4284 4274–4294
Total Depth (ft-bgs)	60 60
Ground Surface Elevation (ft-amsl)	4334.0 4333.8 4334.2
Longitude (degrees)	-112.068528 -112.068593 -112.068626
Latitude (degrees)	45.848671 45.848588 45.848703
Name	PW OW1 OW2
SWIC ID	279262 279261 279263

Table 5-1. Well designations, locations, and completion information, Lazy TP Floodplain aquifer test

Note. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface. All locations and elevations determined by survey. Horizontal Datum, NAD83; Vertical Datum, NAVD88



Figure 5-1. The Lazy TP Floodplain test site is located between the Jefferson River and Slaughterhouse Slough. This site is approximately 2 mi southeast of Whitehall.

discharged to the flooded gravel pit, approximately 200 ft north of the site (fig. 5-2).

5.2 Field Procedure

A step-test was conducted to determine a sustain-

able pumping rate for the constant-rate test. From the step-test data a pumping rate of 22 gpm was selected for the constant-rate test. The constant-rate test ran for 72 h, from 3/16/2015 to 3/19/2015.



Figure 5-2. The Lazy TP Floodplain test site had a pumping well (PW) and two observation wells installed in the Renova Formation. During the tests, water was discharged into the unused flooded gravel pit approximately 225 ft north of the pumping well.

5.3 Data Collection

Manual depth to water measurements were taken at this site using an e-tape from September 2014 to May 2015. A non-vented transducer was installed in OW1 in October 2014 and ran until May 2015 (fig. 5-3). The readings from the non-vented transducer were corrected for barometric pressure variations based on data from a barometric logger located near Cardwell.

A vented pressure transducer was installed in each well prior to the start of the tests. On 2/3/2015 the transducer for OW2 and the pump for PW were installed. The transducers for PW and OW1 were installed before the start of the step-test on 3/6/2015, and at that time all vented transducers were programed to record at 1-min intervals. Manual depth to water readings were made prior to placing the transducers throughout the tests, and during recovery (figs. 5-4 to 5-7). These manual measurements were used to calibrate transducer response and served as a backup in case of transducer malfunction.

Pumping rates were monitored using a totalizing flow meter and bucket and stopwatch. Discharge measurements were made more frequently at the start of the test; during the first 4 h discharge measurements were made on average every 15 min. The maximum interval between discharge measurements was 363 min (~6 h).

All water-level data and pumping rates are available from GWIC by using the wells' GWIC ID numbers (table 5-1) and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmgg-wic.mtech.edu/).

5.4 Results

Static groundwater levels changed noticeably during the constant-rate test, coincident with increases in the stage of the Jefferson River. As such, time-



Figure 5-3. Transducer data were collected in OW1 from October 2014 to May 2015. Changes in water levels appear to correlate with changes in stage in the Jefferson River, which are partly due to ice jams in the winter.



Figure 5-4. The hydrograph for PW during the constant-rate test shows changes in water levels during the aquifer tests; however, at a scale that shows all of the drawdown, the effect of antecedent trends cannot be clearly seen. Figure 5-5 shows the antecedent trend at a higher resolution. Maximum detrended drawdown during the constant rate test was 21.8 ft.



Figure 5-5. The hydrograph for PW shows changes in water levels during the constant-rate aquifer test. This chart shows the groundwater levels at a higher resolution to more clearly illustrate the antecedent trend. For a full scale hydrograph see figure 5-4.



Figure 5-6. This hydrograph shows changes in water levels in OW1 during the constant-rate aquifer test. Maximum detrended drawdown was 2.7 ft.



Figure 5-7. This hydrograph shows changes in water levels in OW2 during the constant-rate aquifer test. Maximum detrended drawdown was 4.2 ft.

weighted corrections were applied to account for the antecedent trends (figs. 5-4 to 5-7).

5.4.1 Water-Level Response

The maximum drawdown in the pumping well (PW) was 21.8 ft. Water levels in this well declined rapidly at the start of pumping, followed by gradually increasing water levels (fig. 5-4). This upward trend reflected the overall rise in groundwater levels during the test. Corrections applied to the depth to water measurements removed most of this trend. After pumping ceased, the water level reached 90% recovery in 14 min (figs. 5-4 and 5-5).

The observation well hydrograph shapes are similar to that of PW (figs. 5-6 and 5-7). OW2 showed more drawdown than OW1 (4.2 vs. 2.7 ft).

5.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was a leaky-confined response to the test (appendix 5B). Aquifer properties were determined using observations from the two observation wells (OW1 and OW2) and a leaky-confined solution (Hantush and Jacob, 1955).

AQTESOLV was used to analyze the aquifer test data. These results indicated transmissivity values between 310 and 440 ft²/d, and storativity values between 8 x 10^{-4} and 2 x 10^{-3} . The test results support the interpretation of a sand aquifer within the interbedded sand and mudstone of the Renova Formation.

5.5 Summary

The sand aquifer in the Renova Formation had transmissivity values between 310 and 440 ft²/d. Storativity values ranged from 8 x 10^{-4} to 2 x 10^{-3} . A leaky-confined solution was needed to replicate observations, showing that the Renova Formation and the overlying alluvial aquifer are hydraulically connected. Long-term monitoring also showed that groundwater levels in this aquifer respond to changes in river stage (fig. 5-3).

6 LAZY TP BENCH TESTS

6.1 Background

6.1.1 Purpose of Test

This test was designed to estimate the transmissivity (T) and storativity (S) of the Renova Formation. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

6.1.2 Test Location

Two wells were installed on the Parrot Bench, south of the Jefferson River floodplain, in T. 1 N., R. 4 W., sec. 13, 3.5 mi southeast of Whitehall (fig. 6-1; table 6-1). The site is located next to the Parrot Canal, and between two irrigated fields (fig. 6-2). The nearest residence was under construction during the test, and is about 400 ft to the south.

6.1.3 Test Type

We performed a step-test and a 72-h constantrate aquifer test. The step-test was conducted on 3/20/2015, and the 72-h test ran from 3/23/2015 to 3/26/2015. Water-level recovery was monitored until 3/30/2015. During the 72-h test, the time-weighted average pumping rate was 25.2 gpm. Drawdown and recovery were monitored in the pumping well and one observation well (table 6-1).

6.1.4 Hydrogeologic Setting

The stratigraphy is silt and sand with some gravel from 0 to 105 ft, semi-lithified mudstone from 105 to 145 ft, and medium to fine sand from 145 to 183 ft (appendix 6A). The wells were both installed in the deep sand zone, and the static water level was approximately 100 ft bgs. This material is the Tertiary Renova Formation (Vuke and others, 2004).

6.1.5 Hydrologic Features

This site is approximately 100 ft north of the Parrot Canal, and is located between two center pivots (fig. 6-2). The canal was shut off in October, and the test was conducted in March to minimize the effects of canal leakage. However, long-term monitoring shows that groundwater levels decrease continually while the canal is not on, and rise when it is turned on (fig. 6-3). Monitoring for this test showed that water levels were following a downward antecedent trend for the duration of the test (figs. 6-4 and 6-5). Water levels continued to decrease through late April, and rose when the canal was turned on.

6.2 Field Procedure

A step-test was performed on 3/20/2015 to determine a sustainable pumping rate for the constant-rate

GWIC	Name	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (ft-amsl)	Total Depth (ft-bgs)	Screened Interval (ft-amsl)	Distance from PW (ft)	Maximum Drawdown (ft)	Aquifer	Well Type
280978	ΡW	45.834252	-112.047069	4441	160	4281–4291	I	12.0	Renova	Pumping
280977	ΟW	48.834419	-112.047125	4439	183*	4281–4291	62.4	0.9	Renova	Observation
<i>Note.</i> ft-al NAD83; V	nsl, feet at 'ertical Dat	bove mean sea tum, NAVD88.	a level; ft-bgs, feet	t below ground	d surface. A	Il locations and e	elevations det	ermined by sur	vey. Horizoni	tal Datum,

Table 6-1. Well designations, locations, and completion information, Lazy TP Bench aquifer test

*OW was backfilled to 160 ft bgs before completion



Figure 6-1. The Lazy TP bench test site is located on the Parrot Bench south of the Jefferson River, and approximately 3.5 mi southeast of Whitehall, Montana.

test. From the step-test data we determined that a pumping rate of about 25 gpm would be appropriate for the constant-rate test. The constant-rate test ran for 72-h, from 3/23/2015 to 3/26/2015.

6.3 Data Collection

Vented pressure transducers were used to record water levels at 1-min intervals in the pumping well (PW) and the observation well (OW). The vented transducers were installed with the pump on 3/17/2015, and were removed on 3/30/2015. Manual



Figure 6-2. The Lazy TP bench test site had a pumping well and an observation well completed in the Renova Formation. During the tests, water was discharged approximately 200 ft north, and downhill from the pumping well.



Figure 6-3. Monitoring of PW from 2015 to 2018 shows that each year water levels rise as the Parrot canal is turned on, and then fall after it is shut off. This suggests that the canal and associated irrigation affect the groundwater levels in the well despite the local confinement caused by the overlying mudstone.



Figure 6-4. The hydrograph for PW during the constant-rate test shows a slight downward trend, so a timeweighted correction factor was applied. The maximum detrended drawdown during the test was 12.0 ft.



Figure 6-5. The hydrograph for OW during the constant-rate test shows a slight downward trend, so a timeweighted correction factor was applied. The maximum detrended drawdown during the test was 0.9 ft.

Bobst and Gebril, 2020

readings of water levels were made for all wells using an e-tape prior to placing transducers, during the test, and during recovery. These measurements were used to calibrate transducer response, and provided backup in case of transducer malfunction (figs. 6-4 and 6-5).

Pumping rates were monitored using a totalizing flow meter and bucket and stopwatch. Discharge measurements were made more frequently at the start of the test, with the average interval during the first 4 h being 10 min. The maximum interval between discharge measurements during this test was 246 min (\sim 4 h).

All water-level data and pumping rates are available from GWIC by using the wells' GWIC ID numbers (table 6-1) and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmgg-wic.mtech.edu/).

6.4 Results

During the constant-rate test there was a slight downward antecedent trend. As such, a time-weighted correction was applied to the data so that static water levels before and after the test were equal (figs. 6-4 and 6-5).

6.4.1 Water-Level Response

The maximum drawdown in PW was 12.3 ft. Drawdown in this well showed a rapid initial decline followed by gradually decreasing water levels (fig. 6-4). After pumping ceased, PW reached 90% recovery in less than 2 min (fig. 6-4). Drawdown and recovery in the observation well were more gradual, and the maximum drawdown was 0.9 ft (fig. 6-5).

6.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was a confined response to the test (appendix 6B). Aquifer properties were determined using observations from OW and a confined solution (Theis, 1935). AQTE-SOLV was used to analyze the aquifer test data. These results indicated a transmissivity value of $5,800 \text{ ft}^2/\text{d}$ and a storativity value of 5.2×10^{-5} .

6.4 Summary

The sand aquifer in the Renova Formation at this site has a transmissivity of about $5,800 \text{ ft}^2/\text{d}$, and a storativity of about 5.2×10^{-5} . The test results suggest

that the aquifer is confined at this location, but longterm monitoring at this site indicates that this aquifer responds to changes in canal operations, indicating that the confining layer is not laterally continuous.

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Appendix 2A—HCC Floodplain Well Logs

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report. Other Options

Return to menu. Plot this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site View field visits for this site View scanned well log (6/9/2014 8:43:59 AM)

Site Name: HCC * MBMG OW-1 GWIC Id: 277403

Section 1: Well Owner(s)

1) HOYT, MARK (MAIL) 41 JUDD LANE SILVER STAR MT 59751 [02/14/2014]

Section 2: Location

Section 2. Local	lion			
Township	Range	Section	Quarter Se	ctions
02S	05W	5	SE¼ SW¼ NV	V14 NW14
	County		Geocod	le
MADISON				
Latitude		Longitude	Geomethod	D atum
45.69599244	3 11	12.254562866	SUR-GPS	NAD83
Ground St	ırface Altitu de	Method	Datum	Date
4497.24		SUR-GPS	NAVD88	1/12/2015
Measuring I	Point Altitude	Method	Datum	Date Applies

SUR-GPS

Block

NAVD88

2/14/2014

Lot

Section 3: Proposed Use of Water MONITORING (1) STOCKWATER (2)

4499.96

Section 4: Type of Work

Drilling Method: Status: NEW WELL

Addition

Section 5: Well Completion Date Date well completed: Friday, February 14, 2014

Section 6: Well Construction Details

Borenole dimensions										
From	From To Diameter									
0	0 94 8									
Casin	Casing									
	Т		Wa	ill –		Pres	sure			
From	<u>ا</u> ل	o Diameto	er Thi	ickı	iess	Rati	ng	Joint	Туре	
0	30) 8						WELDED	STEEL	
0	74	14						THREADED	PVC	
Comp	Completion (Perf/Screen)									
			# of		Size	e of				
From	То	Diameter	Openi	ngs	Ope	enings	Descr	iption		
74	94	4			.040	1	SCREEN-CONTINUOUS-			
Annular Space (Seal/Grout/Packer)										
				C	Cont.					
From	То	Descripti	on	_ F	ed?					
3	73	SMOOTH	GROU	IΤ						
73	94	10/20 GR	AVEL	Т						

Section 8: Remarks

Section 7: Well Test Data Total Depth: 94 Static Water Level: 7 Water Temperature:

Section 9: Well Log

Geologic Source 120SDMS - SEDIMENTS (TERTIARY)

include the reservoir of the well casing.

From	To	D es criptio n
0	1	TOPSOIL
1	5	GREY SILT / CLAY
5	10	COARSE GRAVEL WITH SOME SILT
10	15	MEDIUM GRAVEL WITH SOME SILT
15	30	MEDIUM GRAVEL WITH LITTLE SILT
30	75	REDDISH BROWN SILTY CLAY
75	90	TAN FINE TO MEDIUM SAND WITH LITTLE CLAY
90	100	TAN MEDIUM SAND TO FINE GRAVEL WITH LITTLE SILT

* During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: DAN OKEEFE
Company: OKEEFE DRILLING CO
License No: MWC-43
Date Completed: 2/14/2014

81 SMOOTH GROUT 103 10/20 GRAVEL

81

		MONTANA	WELL LOG	REPORT					Other Options
This well log rep within the boreh electronically fro Acquiring water	oorts the activ ole and casir om the conter rights is the	vities of a licensed Mo ng, and describes the nts of the Ground Wa well owner's respons	ontana well dri amount of wa ter Information ibility and is N	ller, serves as t ter encounteren n Center (GWIC OT accomplishe	he officia d. This re) databas d by the	l reco port i se for filing	ord o is co r this r of t	f work done mpiled s site. his report.	Return to menu Plot this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site View scanned well log (6/9/2014 8:42:28 AM)
Site Name: HCC GWIC Id: 27740	2 * MBMG O 4	W-2			Sectio	n 7: ۱	Well	Test Data	
Section 1: Well 1) HOYT, MARK 41 JUDD LANE	Owner(s) (MAIL)	(17/2014)			Total E Static \ Water)epth /Vatei Temp	: 10: r Lev pera	3 vel: 6.8 ture:	
SILVER STAR IV	11 08/01[02	117/2014]			* Durin	g the	wei	I test the disc	harge rate shall be as uniform as possible. This rate
Section 2: Loca	tion				include	may the	rese	be the sustail rvoir of the w	nable yield of the well. Sustainable yield does not ell casing
Township 02S	Range 05W County	Section 5	Quarter Se SE¼ SW¼ NV Geocor	ctions V¼ NW¼ Ie	Sectio	n 8: I	Rem	arks	en edonig.
MADISON					Sectio	n 9· 1	الم ۱۸۲	100	
Latitude	-	Longitude	Geomethod	Datum	Geolo	nic S	aur	ce de la cela cela cela cela cela cela cela	
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Ground S	urface Altitud	e Method		Uate 1/12/0015	Erom	Бо	·	Description	
44 Moseuring	97.00 Point Altitude	SUR-GFS Method	Datum	Date Annlies			6	GREY SILTY	SAND
449	99.86	SUR-GPS	NAVD88	2/17/2014		8	10	FINE GRAVEL	_ WITH SAND
Addition	00.00	Block	1111000	Lot	1		16	COARSE GRA	AVEL WITH SAND
					1		22	CLEAN COAR	SE GRAVEL, GOOD WATER
					2	2	- 30	SILTY GRAVE	EL WITH SAND
Section 3: Prop	osed Use of	Water			3		75	MOIST BROW	/N SILTY CLAY, STICKY, NO WATER PRODUCTION
MONITORING (1)					7:	5	80	MEDIUM GRA	WEL WITH SAND, SOME CLAY / SILT, GOOD WATER
STOCKWATER (2))				8		94	SOFT BROW	N CLAY, SOME WATER
Contion 4: Tuno	of M orde				9.	4	96	STRINGER O	F WEAKLY CEMENTED CLAY
Drilling Method:	OI WORK				9	8	100	SOFT BROW	N CLAY, SOME WATER
Status: NEW WELI	L					-			
	-					+			
Section 5: Well	Completion	Date				+			
Date well complete	ed: Monday, Fe	ebruary 17 , 2014				+			
					Driller	Cart	ifica	l	
Section 6: Well Borobolo dimonoi	Constructio	n Detalis			Allwor	k ner	form	ed and renor	ted in this well log is in compliance with the
Ecom To Diamet	an				Montar	na we	ell co	instruction sta	andards. This report is true to the best of my
0103	8				knowle	dge.			
Casing	0						N	ame: DAN OKE	EFE
	Wall	Pressure		٦		С	omp	any: OKEEFE	DRILLING CO
From To Diame	ter Thickne	ss Rating Joint	Туре			Lic	ense	e No: MWC-43	
0 30 8		WELD	ED STEEL		Da	te Co	mple	eted: 2/17/2014	
D 81 4		THRE	ADED PVC						
Completion (Perf/	/Screen)			-					
	∀of	Size of							
FromTo Diamet	er Openings	Openings Description		-					
<u>B1 1034</u>		.U4U SCREEN-CO	NIINUOUS-P	rC					
Annular Space (S	eal/Grout/Pac	cker)							
From To Descrip	ption Fe	ed?							

	MONTAN	A WELL LOG REPORT	Other Options	
This well log reports the a within the borehole and c electronically from the co Acquiring water rights is t	activities of a licensed M asing, and describes the ntents of the Ground Wa he well owner's respons	ontana well driller, serves a e amount of water encounte ater Information Center (GV sibility and is NOT accompli-	s the official record of work done red. This report is compiled AC) database for this site. shed by the filing of this report.	
Site Name: HCC * MBMG GWIC Id: 277405	F PW		Section 7: Well Test Data	
Section 1: Well Owner(s) 1) HOYT, MARK (MAIL) 41 JUDD LANE			Total Depth: 100 Static Water Level: 6.9 Water Temperature:	
SILVER STAR MT 59751 Section 2: Location	[U2/18/2U14]		* During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casino.	
Township Range 02S 05W County	s Section 5	Quarter Sections SE¼ SW¼ NW¼ NW¼ Geocode	Section 8: Remarks	
MADISON Section 9: Well Log Latitude Longitude Geomethod Datum Section 9: Well Log 45.696076144 112.254496537 SUR-GPS NAD83 Geologic Source				
4497.28 Measuring Point Altit	Ground Surface Altitude Method 4497.28 SUR-GPS Measuring Point Altitude Method		5 From To Description 6 0 5 BROWN SILTY SAND	
4499.79 Addition	SUR-GPS Block	NAVD88 2/18/2014 Lot	5 10]GREY TO BLACK SILT AND GRAVEL 10 17]GREY SILTY GRAVEL 11 20 TANK OF EAN SAND AND CONVEL	
Section 3: Proposed Use MONITORING (1) STOCKWATER (2)	e of Water		17 20 TAY CLEAN SAND AND GRAVEL 20 30 [CLEAN GRAVEL 30 50 REDDISH BROWN SILTY CLAY 50 55 FINE TO MEDIUM SAND WITH SOME CLAY 55 60 SAND WITH SOME GRAVEL AND LITTLE CLAY	
Section 4: Type of Work Drilling Method: Status: NEW WELL			60 63 FINE TO MEDIUM SAND WITH SOME CLAY 63 65 REDDISH BROWN SILTY CLAY 65 68 FINE TO MEDIUM SAND WITH SOME CLAY 68 FINE FOLISH BROWN SILTY CLAY	
Section 5: Well Complet Date well completed: Tuesda	ion Date y, February 18, 2014		85 90 FINE TO MEDIUM SAND WITH SOME CLAY 90 100 REDDISH BROWN SILTY CLAY	
Section 6: Well Construct Borehole dimensions From To Diameter	tion Details		Driller Certification All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.	
Casing From To Diameter Thick 0 30 8 0 78 4	Pressure kness Rating Joint WELD THRE	Type DED STEEL FADED PVC	Name: DAN OKEEFE Company: OKEEFE DRILLING CO License No: MWC-43 Date Completed: 2/18/2014	
Completion (Perf/Screen) From To Diameter Openin 79 100 4 Annular Space (Seal/Grout/	Size of gs Openings Description 040 SCREEN-CO Packer)	DNTINUOUS-PVC		
	Cont			

٢

To Description

100TH GROUT /20 GRAVEL

Fed?

33

		MONTANA	WELL LOG	REPORT	Other Options
This well log reports the within the borehole an electronically from the Acquiring water rights	e activities of d casing, and contents of th is the well ow	a licensed Mo describes the e Ground Wa ner's responsi	ontana well dri amount of wa ter Informatior bility and is No	ller, serves as t iter encounteren n Center (GWIC OT accomplishe	he official record of work done d. This report is compiled :) database for this site. ed by the filing of this report. He this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site View scanned well log (6/9/2014 8:39:38 AM)
Site Name: HCC * MB GWIC Id: 277406	MG OW-3				Section 7: Well Test Data
Section 1: Well Owne 1) HOYT, MARK (MAIL 41 JUDD LANE SILVER STAR MT 597	r(s) .) 51 [02/20/201	4]			Total Depth: 30 Static Water Level: 6.3 Water Temperature:
Section 2: Location					may or may not be the sustainable yield of the well. Sustainable yield does not
Township Ra	nae Sect	ion	Quarter Se	ctions	include the reservoir of the well casing.
02S 05	iw 5		SE¼ SW¼ NV Gencor	 V¼ NW¼ le	Section 8: Remarks
MADISON					
L atitude 45.696027873	Longi 112.254	tude 535351	Geomethod SUR-GPS	Datum NAD83	Section 9: Well Log Geologic Source
Ground Surface	Altitude	Method	Datum	D ate	Unassigned
4497.33		SUR-GPS	NAVD88	1/12/2015	From To Description
Measuring Point #	Altitude	Method	Datum	Date Applies	U 5 GREY SILT WITH LITTLE FINE SAND
4499.55 Addition		SUR-GPS	NAVDOO	2/20/2014	10 17 EINE TO MEDIUM GRAVEL WITH LITTLE SILT
		DIOOR		LUX	17 23 CLEAN FINE TO MEDIUM GRAVEL
MONITORING (1) STOCKWATER (2) Section 4: Type of W of Drilling Method: Status: NEW WELL Section 5: Well Comp Date well completed: Thu	ork Ietion Date Isday, February	20,2014			
P P	,				
Section 6: Well Const Borehole dimensions From To Diameter	ruction Detai	ls			Driller Certification All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.
Casing					Name: DAN OKEEFE
W L	all Pre	ssure	_	1	Company: OKEEFE DRILLING CO
From To Diameter T	nickness Rat	ing Joint Wei De	D STEEL	4	License No: MWU-43 Date Completed: 2/0/2014
0 18 4		THREA	DED PVC	4	Date Completed. 2/20/2014
Completion (Perf/Screer # of From To Diameter Oper 19 30 4 Annular Space (Seal/Gro	n) Size of Nings Openings 040 Dut/Packer)	Description SCREEN-COM	NTINUOUS-PV		
From To Description 3 19 SMOOTH GRO 19 30 10/20 GRAVEL	Cont. Fed?				



Appendix 2B—HCC Floodplain Aquifer Test Analysis

The derivative plot for observation well PW (gray symbols) indicates a leaky confined aquifer, or a nearby recharge boundary (Renard and others, 2009). Testing combinations of confined and leaky-confined solutions with and without nearby recharge boundaries showed that a leaky-confined solution with no constant head boundary was the best fit with observations. Therefore, the Hantush model was used to simulate this test.



Client: <u>BWIPUJ</u> Project: <u>Upper Jefferson</u> Location: <u>HCCA</u> Test Well: <u>OW1</u> Test Date: <u>2/4/15</u>			
	AQUIFER DATA		
Saturated Thickness: <u>40.</u> ft Aquitard Thickness (b'): <u>80.</u> ft	Anisotropy Ratio (Kz Aquitard Thickness (/Kr): <u>1.</u> b''): <u>80.</u> ft	
	WELL DATA		
Pumping Wells	Obs	ervation Wells	
Well Name X (ft)	Y (ft) Well Name	X (ft)	Y (ft)
OW1 (pumping) 0	0 △ OW2	-18.8	48.2
	SOLUTION		
Aquifer Model: Leaky	Solution Method: Ha	antush	
$T = 74.13 \text{ ft}^2/\text{day}$	S = 1.494E-7		
$1/B' = 5.439E-7 \text{ ft}^{-1}$	$B'/r = 2.879E-7 \text{ ft}^{-1}$		
$1/B'' = 0.008724 \text{ ft}^{-1}$	$(S''/r) = 0.281 \text{ ft}^{-1}$		

The derivative plot for observation well OW2 (gray symbols) indicates a leaky-confined aquifer, or a nearby recharge boundary (Renard and others, 2009). Testing combinations of confined and leaky-confined solutions with and without nearby recharge boundaries showed that a leaky-confined solution with no constant head boundary provided the best fit with observations. Therefore, the Hantush model was used to simulate this test.

Appendix 3A—HCC Bench Well Logs

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Quarter Sections

NE¼ NE¼ NW¼

Datum

NAD83

Date

1/12/2015

Date Applies

11/21/2014

Lot

Gencode

Geomethod

SUR-GPS

Datum

NAVD88

Datum

NAVD88

Return to menu Plot this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site

Other Options

View field visits for this site View water quality for this site

Section 7: Well Test Data

Total Depth: 222 Static Water Level: 160 Water Temperature:

Air Test *

7_gpm with drill stem set at <u>218</u>_feet for <u>1</u> hours Time of recovery <u>1</u> hours. Recovery water level <u>160</u> feet. Pumping water level _ feet.

* During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.

Section 8: Remarks

Section 9: Well Log

Geologic Source 120SDMS - SEDIMENTS (TERTIARY)

From	То	D es criptio n
0	10	SILT WITH SOME GRAVEL
10	15	GRAVEL
15	25	SILTY GRAVEL
25	40	SILTY GRAVEL AND SAND
40	45	SILT Y SAND
45	60	SILT Y GRAVEL
60	65	SILT Y SAND
65	90	SILTY GRAVEL WITH SOME SAND
90	130	SILT AND FINE SAND WITH SOME GRAVEL
130	135	SILTY SAND WITH SOME GRAVEL
135	220	SILTY GRAVEL WITH SOME SAND

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my

knowledge.

Name: RTAN LINDSAT
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 11/21/2014

Section 3: Proposed Use of Water STOCKWATER (1)

> Section 4: Type of Work Drilling Method: ROTARY

Status: NEW WELL

Site Name: MBMG-HCCB-PW

Section 1: Well Owner(s)

1) MBMG-HCCB-PW (MAIL) 1300 WEST PARK

BUTTE MONTANA N/A [11/21/2014]

County

Ground Surface Altitude

4644.53

Measuring Point Altitude

4646.11

Range

05W

Section

9

Method

SUR-GPS

Method

SUR-GPS

Block

Longitude

112.226762198

GWIC Id: 280980

Section 2: Location

Township

02S

45.684519804

MADISON Latitude

Addition

Section 5: Well Completion Date

Date well completed: Friday, November 21, 2014

Section 6: Well Construction Details

Boreh	ole	dimension	S			
From	To	Diameter				
0	140	10				
140	222	8				
Casin	g					
			Wall	Pressure	e	
From	Τo	Diameter	Thicknes	sRating	Joint	Туре
-2	205	8	0.25		WELDED	A53B STEEL
-2	222	4			SPLINE	PVC-SCHED 160
Comp	letio	in (Perf/Sc	reen)			
			∜ of	Size of		
From	То	Diameter	Openings	Openings	Descriptio	n
212	222	4			SCREEN-C	ONTINUOUS-PVC
Annul	lar S	pace (Sea	l/Grout/Pa	cker)		
	LT		Cont.			

Fo Descriptio

50 GROUT

This welling reports the activations of a licensed Montana well onliker, serves as the official record rownk dome with the benchais and casing, and describes the amount of water normative of this report is completed by the fing of this report. Edition is that Licensed Water information Center (CWC) database for this site. Acquiring Water information and and describes the amount of water normative in reports. Edition is that Licensed Water information Center (CWC) database for this site. Acquiring Water information Center (CWC) database for this site. Acquiring Water information Center (CWC) database for this site. Acquiring Water information Center (CWC) database for this site. Acquiring Water information is the clearange in the information is possible. This is the information is possible information informati			MONTAN	A WELL LOC	REPORT				Other Options
Site Kame: MBMG-HCCB-OW GWIC Id: 200679 Section 7: Well Test Data Section 1: Well Owner(s) 1) MEMO-HCCB-CWI (MALL) 300 WEST PARK BUTTE MONTANA NA [11/21/2014] Total Depth: 220 State: Vater Level: 100 Water Temperature: Section 2: Location Township Range Section OLS 05W 9 County Geocode Ouarter Sections 0 Geocode Air Test * Township Range Section OLS 05W 9 County Geocode Ouarter Sections 0 Geocode The of recovery 1_ hours. The of recovery 1_ hours. ADJSIN Latitude Longitude Geocode Geomethod Datum Date A454325 Datum Date Datum Date A454325 Datum Date Datum Date A45432 Datum Date Datum Date A45432 Section 8: Remarks Section 3: Proposed Use of Water MontTorRine (I) Section 9: Well Conglecton Data Block Datum Date Datum Date Applies Section 9: Well Log Geologic Source Unassigned Section 3: Proposed Use of Water MontTorRine (I) Section 9: Well Conglecton Data Bate well completed: Friday, Novemeter 21, 2014 Section 9: Well Conglecton Data Bate well completed: Friday, Novemeter 21, 2014 Section 9: Well Conglecton Data Bate well completed: Friday, Novemeter 21, 2014 Section 9: Section 9: Site of Data Bate well completed: Friday, Novemeter 21, 2014 Section 9: Stan Diameter Tem Ton Diameter Data Section S: Well Conglecton Data Bate well completed: Friday, Novemeter 21, 2014 Section 9: Stan Diameter Data Section S: Well Conglecton Data Bate well of Site of Data Section Sis Construction Data Bate well of Site of Data Section Si	This well log report within the borehole electronically from water rights is the v	s the activities and casing, a the contents o vell owner's re	s of a licensed Mo ind describes the if the Ground Wat esponsibility and is	ntana well dri amount of wa er Informatior s NOT accom	ler, serves as t ter encountere Center (GVMC olished by the f	he official n d. This repo) database iling of this	ecord ort is c for thi report	of work done ompiled is site. Acquiring 	<u>Return to menu</u> Plot this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site
Static 1: Weil Conver(s) Total Depth: 220 Section 1: Weil Conver(s) Static Water Level: 180 Static Water Level: 100 Static Water Level: 180 Water Temperature: Air Test * Tormship Range Section 025 DSW 9 NEX NEX NWW Courry Geocode MADISON Longitude Geomethod Datum 45 6846308 112226694266 SUR-GPS NADBB 6432 26 SUR-GPS NADBB Total Depth: 20 MADISON Longitude Method Datum Date Applie: 45 6846308 112226694266 SUR-GPS NADBB 6 4342 26 SUR-GPS NADBB Total Depth: 20 6 444224 SUR-GPS NADBB Total Construction Date 5 Section 3: Proposed Use of Water Monito Rone (The Weil Congletion Date Section 9: Weil Log 5 Section 6: Weil Congletion Date Section 9: Weil Construction Datails Section 9: Weil Construction Datails 5 Section 6: Weil Construction Datails Section 9: Weil Construction Construction Construction Section Proceeding Construction Section Proceeding Construction Secon Proceeding Section 6: Weill	Site Name: MBMG	HCCB-OW				Section	7:We	ll Test Data	
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Section 2: Location 1	BUTTE MONTANA	INA [TD2D20	114]			_			
UCS DBW 9 NEX NEX NVA Pumping water level _ fest. County Geocode * During the well test the discharge rate shall be as uniform as possible. This rai may or may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing. * During the well test the discharge rate shall be as uniform as possible. This rai may or may or may or the well casing. 4643.26 SUR-GPS NADB8 11/2/2015 Measuring Point Altitude Method Datum Date Applies 4644.24 SUR-GPS NADB8 11/2/2015 Section 3: Proposed Use of Water Section 4: Type of Work Section 5: Well Cog Geologic Source Dilling Method. ROTARY Status: NEW WELL Section 6: Generation Galance Section 6: Well Construction Details 30 32 SILTY GRAVEL WITH SOME GRAVEL 10 30 32 SILTY SAND WITH SOME GRAVEL 10 10 10 114 20 Scetton 6: Well Construction Details 30 30 30 31 20 Size of Fuller From To Discrition Struction standards. This report is true to the best of my knowled. 113 113 114 125 130 136 131 135	Section 2: Location Township	n Range	Section	Quarter	Sections	<u>/</u> gpm v Time of r Recovery	vith dr 'ecove / wate	ill stem set at <u>218</u> ry <u>1</u> hours. r level <u>160</u> feet.	feet for <u>1</u> hours.
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Date well completed: Friday, November 21, 2014 Section 5: Well Construction Details Borehole dimensions From To Diameter 0140 8 140 220 6 Tom To Diameter Thickness Rating Joint Type 2 205 6 D.25 WELDED A53B STEEL 2 202 FLUSH THREAD PVC-SCHED 80 Completion (Per/Screen) From To Diameter Openings Description 210 220 2 SCREEN-CONTINUOUS-PVC Annular Space (Seal/Grout/Packer) From To Description Details Bandwards This report is true to the best of my knowledge. Name: RYAN LINDSAY Completed: 11/21/2014 B0 70 SAND AND GRAVEL 70 80 SILTY GRAVEL WITH SOME CLAY AND LITTLE GRAVEL 90 105 SILTY SAND WITH LITTLE GRAVEL 105 115 SILTY CLAY WITH LITTLE GRAVEL 105 115 SILTY CLAY WITH SOME GRAVEL 120 125 ANDY SILT WITH SOME GRAVEL 121 125 ANDY SILT AND GRAVEL 122 130 GRAVEL 123 130 GRAVEL 124 130 GRAVEL 130 I 35 SANDY SILT AND GRAVEL 131 I 35 SANDY SILT AND GRAVEL 132 I 30 GRAVEL 133 I 35 SANDY SILT AND GRAVEL 134 GRAVEL 135 I 30 GRAVEL 136 GRAVEL 137 I 30 GRAVEL 137 I 30 GRAVEL 138 GRAVEL 139 I 35 SANDY SILT AND GRAVEL 139 I 35 SANDY SILT AND GRAVEL 130 I 35 SANDY SILT AND GRAVEL 121 I 30 GRAVEL 122 I 30 GRAVEL 122 I 30 GRAVEL 122 I 30 GRAVEL 123 I 30 GRAVEL 124 I 30 GRAVEL 125 I 30 GRAVEL 125 I 30 GRAVEL 125 I 30 GRAVEL 125 I 30 GRAVEL 126 I 30 GRAVEL 127 I 30 GRAVEL 128 I 30 GRAVEL 129 I 30 GRAVEL 129 I 30 GRAVEL 120 I 30 GRAVEL 120 I 30 GRAVEL	Section 5: Well Co	mpletion Dat	e			55	6	O SILTY SAND WITH	SOME GRAVEL
Section 6: Well Construction Details Borehole dimensions From To Diameter 0 140 80 140 20 6 0140 140 20 70 Borgslitt Y SAND WITH SOME SAND 140 20 6 0140 140 20 70 Borgslitt Y SAND WITH SOME CLAY AND LITTLE GRAVEL 15 SILTY SAND WITH SOME CLAY AND LITTLE GRAVEL 15 SILTY GRAVEL 165 115 170 Diameter Thickness Rating 170 Diameter Thickness Rating 170 Diameter Openings 2 205 0 0.25 Well DED A53B STEEL 2 202 2 Flugst THREAD PVC-SCHED 80 Completion (Perf/Screen) Size of Openings Openings Description 210 220 2 Screen-continuous-pvc Annualar Space (Seal/Grout/Packer) Screen-continuous-pvc Cont Cont From To Description 210	Date well completed: F	⁼ riday, Novemb	er 21, 2014			60	7	0 SAND AND GRAVE	
Section 6: Well Construction Details Borehole dimensions From To Diameter O 140 0 140 0 140 0 140 0 140 0 140 0 140 0 14 0 15 SILTY SAND WITH LITTLE GRAVEL 90 105 SILTY SAND WITH SOME CLAY AND LITTLE GRAVEL 90 105 SILTY SAND WITH SOME CLAY AND LITTLE GRAVEL 90 105 SILTY SAND WITH SOME CLAY AND LITTLE GRAVEL 115 120 SILTY GRAVEL 120 125 ANDY SILT WITH SOME GRAVEL 120 125 ANDY SILT WITH SOME GRAVEL 120 125 130 GRAVEL 130 130 135 SANDY SILT AND GRAVEL 130 130 135 SANDY SILT AND GRAVEL 130 130 135 SANDY SILT WITH SOME GRAVEL 130 130 135 SANDY SILT AND GRAVEL 130 130 135 SANDY SIT AND GRAVEL 14 130 130 135 SANDY SIT AND GRAVE 14 130 130 135 SANDY SI						/0	8	U SILI Y GRAVEL WI	TH SOME SAND
Borehole dimensions 90 105/SILTY SAND WITH SOME CLAY AND LITTLE GRAVEL Into 10 0 140 20 6 140 20 6 105 115 SILTY SAND WITH SOME CLAY AND LITTLE GRAVEL Casing Into 10 130 SILTY GRAVEL 120 125 ANDY SILT WITH SOME GRAVEL Casing Value Pressure 120 125 ANDY SILT WITH SOME GRAVEL 2 205 D.2.5 WELDED A53B STEEL 130 GRAVEL 2 202 FLUSH THREAD PVC-SCHED 80 All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge. From To Diameter Openings Description 210 220 SCREEN-CONTINUOUS-PVC Annular Space (Seal/Grout/Packer) SCREEN-CONTINUOUS-PVC Annular Space (Seal/Grout/Packer) Cont.	Section 6: Well Co	nstruction De	etails			80	9	U SILLY SAND WITH	LITTLE GRAVEL
From To Diameter 140 20 Casing From To Prom To Diameter Thickness Rating Joint 120 2125 2 205 D.25 Wall Pressure From To Diameter Thickness Rating Joint 120 125 130 2 205 D.25 Wall Pressure From To Diameter Openings Optimings Description 210 220 220 SCREEN-CONTINUOUS-PVC Annular Space (Seal/Grout/Packer) SCREEN-CONTINUOUS-PVC From To Cont. From To Cont.	Borehole dimensions	3				90	10	5 SILLY SAND WITH	SOME CLAY AND LITTLE GRAVEL
0 140 20 6 140 220 6 Casing From To Diameter Thickness Rating Joint Type 120 130 GRAVEL 130 GRAVEL 120 205 D.25 WELDED A53B STEEL 130 135 SANDY SILT WITH SOME GRAVEL 120 220 FLUSH THREAD PVC-SCHED 80 A53B STEEL 130 135 SANDY SILT AND GRAVEL 220 Image: Ryan Linds well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge. Name: RYAN LINDSAY 210 220 SCREEN-CONTINUOUS-PVC Amular Space (Seal/Grout/Packer) Completed: 11/21/2014	From to Diameter					105	11	5 SILLY CLAY WITH	LITTLE SAND
14dip220 6 Casing Casing From To Diameter Thickness Rating Joint Type -2 205 6 D.25 WELDED A53B STEEL -2 202 2 FLUSH THREAD PVC-SCHED 80 Completion (Per/Screen) FLUSH THREAD PVC-SCHED 80 Prom To Diameter Openings Description 210 220 2 SCREEN-CONTINUOUS-PVC Annular Space (Seal/Grout/Packer) SCREEN-CONTINUOUS-PVC Completed: 11/21/2014 Completed: 11/21/2014	0140 8					115	12	U SILI Y GRAVEL	
Casing 120 130 <t< td=""><td>140220 6</td><td></td><td></td><td></td><td></td><td>120</td><td>12</td><td>SANDY SILL WITH S</td><td>SUME GRAVEL</td></t<>	140220 6					120	12	SANDY SILL WITH S	SUME GRAVEL
Wail Pressure Town To Diameter Diameter Flockness Rating Joint Type 2 205 0.5 WELDED A53B STEEL 2 202 FLUSH THREAD PVC-SCHED 80 Completion (Perf/Screen) # of Size of 7 mm To Diameter Openings Description 210 220 SCREEN-CONTINUOUS-PVC Annular Space (Seal/Grout/Packer) SCREEN-CONTINUOUS-PVC Completed: Cont.	Casing			_	_	125	13	U GRAVEL	
From To Diameter Processing of the point Type Annular Space (Seal/Grout/Packer) Cont. Completed: 11/21/2014		vali Pres	sure	T		130	1.5	SANDY SILLAND	GRAVEL
12 205 p 0.25 MMELDED PASB STEEL 12 2012 FLUSH THREAD PVC-SCHED 80 12 2012 FLUSH THREAD PVC-SCHED 80 12 2012 FLUSH THREAD PVC-SCHED 80 12 10 10 12 10 10 12 10 10 12 10 10 12 10 2012 12 10 2012 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10 12 10 10		nickness Rau		Type		Driller C	ertific	ation	and the second second
Variation Problem Provention Completion Perform From To Diameter Openings Description 210 220 220 SCREEN-CONTINUOUS-PVC Name: RYAN LINDSAY Completion Completion SCREEN-CONTINUOUS-PVC License No: WWC-607 Completed: 11/21/2014 Date Completed: 11/21/2014	From to Diameter	.23	VVELDED	ASSESTED	L.	All Work	perrorr	med and reported in	n this well log is in compliance with the
Completion (Peri/Schem) Noncodes From To Diameter Openings Openings 210 220 SCREEN-CONTINUOUS-PVC Annular Space (Seal/Grout/Packer) SCREEN-CONTINUOUS-PVC Cont. Cont. From ToO Description Date Completed: 11/21/2014	-2 2056			AD PVC-SUND	.U 6U	International	wen u 1e	unstruction stanual	us. This report is true to the best of my
From To Diameter Openings Openings Description 210 220 2 SCREEN-CONTINUOUS-PVC Company: LINDSAY DRILLING CO INC Annular Space (Seal/Grout/Packer) Cont. Cont. From ToD Description Date Completed: 11/21/2014	-2 205 6	:00p)	FLUSHTHRE			K U DZ90PU U			
Company: LINDSAY DRILLING COUNC 210 220 Annular Space (Seal/Gout/Packer) Cont. From To D escription Fed?	-2 205 6	reen)			_	Knowledy	<u>y</u> u. N		v
License No: WWC-607 Annular Space (Seal/Grout/Packer) Cont. FromToDescription[Fed?]	Prom To Diameter 2056 2020 2002 Completion (Perf/Scr From To Diameter	een) # of Size	e of			Knowled	<u>10.</u> N	ame: RYAN LINDSA	Y
FromToD escription Fed?	From To Diameter -2 205 5 5 -2 220 2 2 Completion (Perf/Sci 6 From To Diameter 210 220 2 2	reen) # of Sizo Openings Ope	e of enings Description		N/C	Knowled	Com	lame: RYAN LINDSA pany: LINDSAY DRIL	Y LING CO INC
From To Description Fed?	From To Diameter -2 205 6 -2 220 2 Completion (Perf/Scr From To Diameter 210 220 2	reen) # of Size Openings Ope	e of enings Description SCREEN-C	n ONTINUOUS-F	v∨c		Com Com Licens	Name: RYAN LINDSA pany: LINDSAY DRIL se No: WWC-607	Y LING CO INC
	From To Drameter -2 2205 2 -2 2202 2 Completion (Perf/Scr 1 From To Diameter 210 220 Annular Space (Seal	reen) # of Siz(Openings Op (Grout/Packer)	e of enings Description SCREEN-C	n Ontinuous-f	VC	Date	Com Licens Comp	lame: RYAN LINDSA pany: LINDSAY DRIL e No: WWC-607 leted: 11/21/2014	Y LING CO INC

Site Name: GWIC Id: 28 Additional I	MBMG-HCCI 0979 .ithology Re	3-OW cords
From	To	Description
135	140	GRAVEL
140	180	SILTY GRAVEL WITH SOME SAND
180	220	SILTY GRAVEL WITH SOME SAND AND FEW COBBLES

	10. _E	
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it (ft)		
men	0.1	
olace	0.1	
Disp	_	
	-	
	0.01	
	E	
	0.001	
	0.001 -	10. 100. 1000. 1.0E+4
		Time (min)
		HCC BENCH AQUIFER TEST
Data Set:	M:\\HCC	B CR NeumanUC.aqt
Date: 11/1	2/19	Time: <u>10:16:28</u>
		PROJECT INFORMATION
Company: Client: BW	MBMG (IPUJ	
Project: Up	oper Jeffer	son
Test Well:	HCCB-PV	
Test Date:	2/17/15	
Saturated 1	Thickness:	<u>105.</u> ft
	_	WELL DATA
Well Name	P	Imping Wells Observation Wells X (ft) Y (ft) Well Name X (ft) Y (ft)
PW		0 0 0 44.79
		SOLUTION
Aquifer Mo	del: <u>Unco</u>	nfined Solution Method: Neuman
T = $\frac{255}{2}$	5. ft ² /day	S = 0.0001 Kz/Kr = 1
<u> </u>		

Appendix 3B—HCC Bench Aquifer Test Analysis

The derivative plot for observation well OW (gray symbols) indicates an unconfined aquifer (Renard and others, 2009). We used the Neuman solution to simulate this test.

Appendix 4A—Hunt Well Logs Montana's Ground-Water Information Center (GWIC) | Site Report | V.11.2015

Page 1 of 1

		MONTAN	A WELL LOO	REPORT				Other Options	
This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.							<u>Return to menu</u> <u>Plot this site in State Library Digital Atlas</u> <u>Plot this site in Google Maps</u> <u>View hydrograph for this site</u>		
Site Name: MB	MG-HA-OW1				Section	7: Wel	Test Data	,	
Section 1: Well Owner(s) 1) MBMG-HA-OWL (MAIL) 1300 WEST PARK BUTTE M ONTTANA 59701 [07/23/2014]				Total Depth: 60 Static Water Level: 6 Water Temperature: Air Test *					
Section 2: Loca Township	Section 2: Location Township Range Section Quarter Sections			<u>200</u> gpm with drill stern set at <u>58</u> feet for <u>1</u> hours. Time of recovery <u>1</u> hours. Recovery water level <u>6</u> feet.					
010	County	24	Geocod	e	Pumpin	ı water	level_feet.		
MADISON Latitude 45.72898659 Ground S 4. Measuring	97 1 urface Altitude 457.06 Point Altitude	Longitude 12.171933642 • Method SUR-GPS Method	Geomethod SUR-GPS Datum NAVD88 Datum	Datum NAD83 Date 1/12/2015 Date Applies	 * During the well test the discharge rate shall be as uniform as possible. 7 may or may not be the sustainable yield of the well. Sustainable yield doe include the reservoir of the well casing. Section 8: Remarks 			e rate shall be as uniform as possible. This rate y yield of the well. Sustainable yield does not sing.	
44 Addition	58.49	Block	NAVD88	7/23/2014 Lot	Section	9: Wel	Log		
					Geologi	c Sour	ce		
Section 3: Prop	osed Use of	Water			Unassig From	ned To	D es criptio n		
STUCKWATER (I)				0	2	TOPSOIL		
Section 4: Type	of W ork				12	12	SILI Y SAND CLAY		
Drilling Method: R0 Status: NEW WEI	JTARY				18	20	SILTY SAND AND	GRAVEL	
Dialdo, NEW WEE	-				20	60	GRAVEL WITH LIT	TLE SAND	
Section 5: Well	Completion I	Date							
Date well complete	ed: VVednesday,	July 23, 2014							
Section 6: Well	Construction	Details							
Borehole dimens	ions								
From To Diamete	6								
Casing	-								
	Wall	Pressure	-	7					
-2 60.6	er Thickness	Rating Joint WELDED	A53B STEEL	-	Driller (ortific	tion		
Completion (Perf.	Completion (Perf/Screen)					perforn	ned and reported in	this well log is in compliance with the	
# of Size of					Montana	well c	onstruction standar	ds. This report is true to the best of my	
From Follomete	100 3/	HOLTE PERFO	DRATOR SLOT	S	Knowled	ge. N		v	
Annular Space (S	Annular Space (Seal/Grout/Packer)					Name: RYAN LINUSAY Company: LINDSAY DRILLING CO INC			
	Cont.				License No: WWC-607				
From To Descrip	tion Fed?				Date Completed: 7/23/2014				

		MONTAN	A WELL LOO	REPORT	Other Options			
This well log reports the activities of a licensed Montana well driller, serves as the within the borehole and casing, and describes the amount of water encountered electronically from the contents of the Ground Water Information Center (GWIC) water rights is the well owner's responsibility and is NOT accomplished by the fit					he official record of work done d. This report is compiled) database for this site. Acquiring iling of this report. Return to menu Plot this site in State Library Digital Atlas Plot this site in Gocale Maps View hydrograph for this site			
Site Name: MBMG-F	HA-OW2				Section 7: Well Test Data			
Section 1: Well Owner(s) 1) MBMG-HA-OW2 (MAIL) 1300 WEST PARK BUITTE MONTANA N/A I/7/28/20141					Total Depth: 60 Static Water Level: 6 Water Temperature: Air Test *			
Section 2: Location Township 01S Cou	Section 2: Location Township Range Section Quarter Sections 01S 05W 24 County Geocode			Sections le	<u>200</u> gpm with drill stem set at <u>58</u> feet for <u>1</u> hours. Time of recovery <u>1</u> hours. Recovery water level <u>6</u> feet. Pumping water level _ feet.			
Latitude 45.728929629 Ground Surfac 4457.1 Measuring Poin	Lo 112.1 ce Altitu de 9 t Altitu de	ngitude 172011919 Method SUR-GPS Method	Geomethod SUR-GPS Datum NAVD88 Datum	Datum NAD83 Date 1/12/2015 Date Applies	[*] During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing. Section 8: Remarks			
4458.37 Addition		Block	NAVD88	7/28/2014 Lot	Section 9: Well Log Geologic Source			
Section 3: Proposed STOCKWATER (1) Section 4: Type of V	d Use of Wa Vork	ter			From To Description 0 2 TOPSOIL 2 12 SILTY SAND 12			
Drilling Method: Status: NEW WELL					18 20 SILTY SAND AND GRAVEL 20 SOIGRAVEL WITH LITLE SAND			
Section 5: Well Con Date well completed: M	n pletion Dat onday, July 28	e 3, 2014						
Section 6: Well Con Borehole dimensions From To Diameter O 60 6 Casing From To Diameter 2 60 5 Completion (Perf/Scree # 0 From To Diameter Op 50 60 6 100 Annular Space (Seal/ From To Description 0 60 GROUT	Mall P Fhickness R 0.25 sen) of Size of enings Openi 0 3/8 Grout/Packer) Cont, Fed? V	etails ressure ating Joint WELDED of ings Description HOLTE PERFC	Type A53B STEEL		Driller Certification All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge. Name: RYAN LINDSAY Company: LINDSAY DRILLING CO INC License No: WWC-607 Date Completed: 7/28/2014			

This well log reports t within the borehole a								
water rights is the we	nd casing, a e contents o ell owner's re	s of a licensed Mo and describes the of the Ground Wat esponsibility and is	ntana well dril amount of wa er Informatior s NOT accom	ller, serves as t ter encountered o Center (GVIC plished by the f	he official record of work done d. This report is compiled .) database for this site. Acquiring liling of this report. 			
Site Name: MBMG-H	A-PW				Section 7: Well Test Data			
Section 1: Well Own	er(s)				Total Depth: 60 Static Water Level: 6			
1) MBMG-HA-PW (MA 1300 WEST PARK	AIL)	1.41			vvater Temperature:			
30TTE MONTANA N	/A [U//24/20	114]						
Section 2: Location Township 01S	Range 05W	Section 24	Quarter	Sections	<u>400</u> gpm with drill stem set at <u>58</u> feet for <u>1</u> hours. Time of recovery <u>1</u> hours. Recovery water level <u>6</u> feet.			
Cour	nty		Geocod	le	Fumping water level _ leet.			
Latitude 45.72892428 Ground Surface	Lon 112.13 e Altitude	ngitude 71926249 Method	Geomethod SUR-GPS Datum	Datum NAD83 Date	* During the well test the discharge rate shall be as uniform as possible. This r may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.			
4400.90 Measuring Point 4458.6	Altitude	Method SUR-GPS		Date Applies	Section 8: Remarks			
Addition		Block	10/17/2000	Lot	Section 9: Well Log			
Section 3: Proposed	Use of Wa	ter			From To Description			
STOCKWATER (1)					0 2 TOPSOIL			
Section 4: Type of W	ork				2 12 SILT Y SAND			
Drilling Method: ROTAR	γ							
Status: NEW WELL					20 60 GRAVEL WITH LITTLE SAND			
Section 5: Well Com	nletion Dat	·e						
Date well completed: The	ursday, July 1	24, 2014						
Section 6: Well Cons Barabala dimensions	struction D	etails						
From To Diameter								
0 60 10								
Casing				_				
	fall P bioknopp D	ressure						
2 60 10 n	25	weinen	A53B STEEL	-	Driller Certification			
Completion (Perf/Scree	en)		100001000		All work performed and reported in this well log is in compliance with the			
# of	Size o	of		7	Montana well construction standards. This report is true to the best of my			
From To Diameter Ope	enings Open	ings Description			knowledge.			
40 60 10 150 Annulas Snaca (Saal/C	3/6 rout/Decker)	HOLTE PERF	DRATOR SLOT	8	Name: RYAN LINDSAY			
annular space (seal/G	iouvPacker) Cont.				Lompany: LINDSAY DRILLING CO INC			
From To Description F	ed?				License No: WWC-607			
D BOGROUT Y	,				Date Completed. / /24/2014			



Appendix 4B—Hunt Aquifer Test Analysis

The derivative plot for observation well OW1 (gray symbols) indicates an unconfined aquifer, with a nearby recharge boundary (Renard and others, 2009). The Neuman unconfined solution was used along with a constant head boundary 100 ft to the west, representing the wetland near the site.



The derivative plot for observation well OW2 (gray symbols) indicates an unconfined aquifer, with a nearby recharge boundary (Renard and others, 2009). The Neuman unconfined solution was used along with a constant head boundary 100 ft to the west, representing the wetland near the site.

Appendix 5A—LTP Floodplain Well Logs

		MONTAN	A WELL LO	3 REPORT				Other Options
This well log reports the activities of a licensed Montana well driller, serves as th within the borehole and casing, and describes the amount of water encountered electronically from the contents of the Ground Water Information Center (GWIC) water rights is the well owner's responsibility and is NOT accomplished by the fil					re official record of work done I. This report is compiled) database for this site. Acquiring ling of this report. Plot this site in State Library Digital A Plot this site in Google M View hy drograph for this			<u>Return to menu</u> Plot this site in State Library Digital Atlas Plot this site in Google Maps <u>View hydrograph for this site</u>
Site Name: MBMG-T GWIC Id: 279261	PA-OW1				Section	7:Wel	Test Data	
Section 1: Well Owner(s) 1) MBMG-TPA-OW1 (MAIL) 1300 WEST PARK BUITTE MONTANA IVA IN8/05/20141				Total Depth: 60 Static Water Level: 7 Water Temperature: Air Test *				
	-	-			30. anm	with d	ill stem set at 59	feet for 1 hours
Section 2: Location Township 01N Cou	Section 2: Location Township Range Section Quarter Sections 01N 04W 11 SW4 NE1/4 SW4 County Geocode			Time of recovery 1, hours. Recovery water level <u>7</u> feet. Pumping water level _feet.				
MADISON Latitude 45.848587583 Ground Surfac 43336 Measuring Point 4335 36	L or 112.0 e Altitude : Altitude	ngitude 68593201 SUR-GPS Method SUR-GPS	Geomethod SUR-GPS Datum NAVD88 Datum NAVD88	Datum NAD83 Date 1/12/2015 Date Applies 8/5/2014	 * During the well test the discharge rate shall be as uniform as possible. This may or may not be the sustainable yield of the well. Sustainable yield does include the reservoir of the well casing. Section 8: Remarks 			
Addition		Block		Lot	Section Geologi	9:Well cSour	Log ce	
Section 3: Proposed MONITORING (1)	Use of Wat	ter			Unassigr From 0	ned To 4	Description TOPSOIL	
Section 4: Type of W Drilling Method: ROTAR Status: NEW WELL	/ ork Y				4 20 25	20 25 60	GRAVEL AND SA CLAY AND GRAV MUDSTONE WITH	ND EL I SAND SEAMS
Section 5: Well Com Date well completed: Tu	pletion Date esday, August	e t 05,2014						
Section 6: Well Con Borehole dimensions From To Diameter 0 60 6 Casing	struction De	ure		-				
From To Diameter Thickness Rating Joint Type 2 40 0.25 WELDED A538 STEEL 2 60 2 FLUSH THREAD PVC-SCHED 80 Completion (Perf/Screen) From To Diameter Openings Description 60 60 2 SCREEN-CONTINUOUS-PVC					Driller C All work Montana knowled	ertific a perform well co ge. N Comp	tion ed and reported instruction standa ame: RYAN LINDS, any: LINDSAY DR	in this well log is in compliance with the ards. This report is true to the best of my AY ILLING CO INC
Annular Space (Seal/G	rout/Packer) Cont. Fed?				Date	Licens Compl	e No: WWC-607 eted: 8/5/2014	
45 60 GRAVEL PAC	K I							

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Site Name: MBMG-TPA-PW GWIC Id: 279262

Section 1: Well Owner(s)

1) MBMG-TPA-PW (MAIL) 1300 WEST PARK BUTTE MONTANA N/A [08/05/2014]

Section 2: Location

	•		
Township	Range	Section	Quarter Sections
01N	04W	11	SW14 NE14 SW14
(County		Geocode
MADISON			

Latitude	Longitu	de	Geomethod	D atum
45.84867114	112.06852	2844	SUR-GPS	NAD83
Ground Surface Al	titu de	Method	Datum	D ate
4333.95		SUR-GPS	NAVD88	1/12/2015
Measuring Point Alt	itude	Method	Datum	Date Applies
4335.22		SUR-GPS	NAVD88	8/5/2014
Addition		Block		Lot

Section 3: Proposed Use of Water STOCKWATER (1)

Section 4: Type of Work Drilling Method: ROTARY Status: NEW WELL

Section 5: Well Completion Date Date well completed: Tuesday, August 05, 2014

Section 6: Well Construction Details

Boreh	ole	dimensio	ns				
From	To	Diameter					
0	60	8					
Casin	g						
			Wall	Pressur	e		
From	Τo	Diameter	Thickness	Rating	þ	oint	Туре
-2	35	8	0.25		M	/ELDED	A53B STEEL
-2	60	4			F	LUSH THREAD	PVC-SCHED 80
Comp	leti	on (Perf/S	creen)				
			# of	Size of			
From	То	Diameter	Openings	Openin	igs	Description	
40	60	4				SCREEN-CON	TINUOUS-PVC
Annul	ar S	Space (Se	al/Grout/Pa	icker)			
				Cont.			
From	Τo	Descripti	on	Fed?			
0	35	GROUT		Y			
33	38	BENTONI	TE CHIPS				
38	60	GRAVEL I	PACK				

Other Options

Return to menu Plot this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site View field visits for this site View water quality for this site

Total Depth: 60 Static Water Level: 7 Water Temperature:

Section 7: Well Test Data

Air Test *

<u>30</u> gpm with drill stem set at <u>58</u> feet for <u>1</u> hours. Time of recovery <u>1</u> hours. Recovery water level <u>7</u> feet. Pumping water level <u>_</u>feet.

* During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.

Section 8: Remarks

Section 9: Well Log

Geologic Source

120SDMS - SEDIMENTS (TERTIARY)

From	To	D es criptio n
0	4	TOPSOIL
4	20	GRAVEL AND SAND
20	25	CLAY AND GRAVEL
25	60	MUDSTONE WITH SAND SEAMS

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: RYAN LINDSAY Company: LINDSAY DRILLING CO INC License No: WWC-607 Date Completed: 8:5/2014

MONTANA WELL LOG REPORT

B STEE C-SCHED 80

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Site Name: MBMG-TPA-OW2 GWIC Id: 279263

Section 1: Well Owner(s)

1) MBMG-TPA-OW2 (MAIL) 1300 WEST PARK BUTTE MONTANA N/A [08/05/2014]

Section 2: Location

Range	Section	Quarter S	Sections
04W	11	SW¼ NE¼ SW¼	
unty		Geocod	e
L	ongitude	Geomethod	Datum
112.	068625817	SUR-GPS NAD	
ce Altitu de	Metho d	Datum	Date
21	SUR-GPS	NAVD88	1/12/2015
nt Altitude	Method	Datum	Date Applies
6	SUR-GPS	NAVD88	8/5/2014
	Block		Lot
	Range 04W L 112. ce Altitude 21 th Altitude 6	Range Section 04W 11 unty Longitude 112.068625817 ce Altitude Method 21 SUR-GPS at Altitude Method 6 SUR-GPS Block	Range Section Quarter S 04W 11 SW% NE unty Geocod Longitude Geomethod 112.068625817 SUR-GPS ce Altitude Method Datum 21 SUR-GPS NAVD88 at Altitude Method Datum 6 SUR-GPS NAVD88 Block Block Block

Section 3: Proposed Use of Water MONITORING (1)

Section 4: Type of Work Drilling Method: ROTARY

Status: NEW WELL

Section 5: Well Completion Date Date well completed: Tuesday, August 05, 2014

Section 6: Well Construction Details

Boreh	Borehole dimensions									
From	From To Diameter									
0	0 60 6									
Casin	Casing									
			Wall	Pressure						
From	To	Diameter	Thickness	Rating	Joint					
-2	35	6	0.25		WELDED					
-2	60	2			FLUSH THRE					
Comp	Completion (Perf/Screen)									

			# of	Size of				
From	То	Diameter	Openings	Openings	Description			
40	60	2			SCREEN-CONTINUOUS-PVC			
Annular Space (Seal/Grout/Backer)								

Cont.

To Description Fed? 30 GROUT

Section 7: Well Test Data

Total Depth: 60 Static Water Level: 7 Water Temperature:

Air Test *

<u>30</u> gpm with drill stem set at <u>58</u> feet for <u>1</u> hours. Time of recovery <u>1</u> hours. Recovery water level <u>7</u> feet. Pumping water level <u>_</u> feet.

* During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.

Section 8: Remarks

Section 9: Well Log

Geologic Source

Unassig	Inassigned						
From	To	D es criptio n					
0	4	TOPSOIL					
4	20	GRAVEL AND SAND					
20	25	CLAY AND GRAVEL					
25	60	MUDSTONE WITH SEAMS OF SAND					

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607

Date Completed: 8/5/2014

Other Options

Return to menu Plot this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site



Appendix 5B—LTP Floodplain Aquifer Test Analysis

The derivative plot for observation well OW1 (gray symbols) indicates a leaky-confined aquifer (Renard and others, 2009). We used the Hantush-Jacob leaky-confined solution, without aquitard storage, to simulate this test.



The derivative plot for observation well OW1 (gray symbols) indicates a leaky-confined aquifer (Renard and others, 2009). We used the Hantush-Jacob leaky-confined solution, without aquitard storage, to simulate this test.

Appendix 6A—LTP Bench Well Logs

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Site Name: MBMG-LTPB-OW1 GWIC Id: 280977

Section 1: Well Owner(s)

1) MBMG (MAIL) 1300 WEST PARK BUTTE MONTANA N/A [10/22/2014]

Section 2: Location

Township	Range	Section	Quarter	Sections
01N	04W	13	SE¼ N	E1/4 SW1/4
C	County		Geoco	de
MADISON				
Latitude	Longitud	e	Geomethod	Datum
45.834444	112.04694	4	NAV-GPS	NAD27
Ground Su	ırface Altitude	Metho	d Datum	Date
4	439	DEM	NAVD88	8/21/2015
Measuring F	Point Altitude	Method	Datum	Date Applies
44	40.5	MAP	NAVD88	10/22/2014
Addition		Block		Lot

Section 3: Proposed Use of Water MONITORING (1)

Section 4: Type of Work

Drilling Method: ROTARY Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Wednesday, October 22, 2014

Section 6: Well Construction Details Borehole dimensions From To Diameter 8

Casin	Casing					
			Wall	Pressure		
From	Τo	Diameter	Thickness	Rating	Joint	Туре
-2	183	6	0.25		WELDED	A53B STEEL
-2	160	2			FLUSH THREAD	PVC-SCHED 80
Comp	letio	n (Perf/So	reen)			
			# of	Size of		
From	Т٥	Diam eter	Openings	Openings	Description	
150	160	6	50	3/8	HOLTE PERFO	RATOR SLOTS
150	160	2			SCREEN-CONT	INUOUS-PVC
Annul	Annular Space (Seal/Grout/Packer)					
	П		Cont.			
From	Тон	Descriptio	n Fed?			

From	Тο	Description	Fed?
0	50	GROUT	Y

Other Options

Return to menu Plot this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site

Section 7: Well Test Data

Total Depth: 183 Static Water Level: 92 Water Temperature:

Air Test *

40 gpm with drill stem set at 160 feet for 1 hours Time of recovery 1 hours. Recovery water level 72 feet. Pumping water level _ feet.

* During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing

Section 8: Remarks

Section 9: Well Log

Geologic Source

Jnassigned						
From	Тο	Description				
0	2	TOPSOIL				
2	15	LIGHT TAN SILT AND FINE SAND WITH LITTLE GRAVEL				
15	20	FINE TO MEDIUM GRAVEL				
20	30	LIGHT TAN SILT AND FINE SAND WITH SOME GRAVEL				
30	65	LIGHT TAN SILT WITH SOME FINE SAND				
65	70	LIGHT TAN SILT WITH SOME FINE SAND AND LITTLE GRAVEL				
70	80	LIGHT TAN SILT WITH SOME FINE SAND				
80	90	LIGHT TAN SILT WITH SOME FINE SAND AND SOME GRAVEL				
90	98	FINE TO MEDIUM GRAVEL				
98	105	MDIUM SAND WITH LITTLE SILT				
105	120	SEMI-LITHOFIED MUDSTONE WITH LITTLE SAND				
120	130	SEMI-LITHOFIED MUDSTONE WITH TRACE SAND				
130	135	SEMI-LITHOFIED MUDSTONE WITH SOME SAND				
135	145	SEMI-LITHOFIED MUDSTONE WITH TRACE SAND				
145	183	FINE TO MEDIUM SAND				

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: RYAN LINDSAY	
Company: LINDSAY DRILLING CO INC	
License No: WWC-607	
Date Completed: 10/22/2014	
	_

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Site Name: MBMG-LTPB-PW GWIC Id: 280978

Section 1: Well Owner(s)

1) MBMG-LTPB-PW (MAIL) 1300 WEST PARK BUTTE MONTANA N/A [10/22/2014]

Section 2: Location

Section 2. Loca				
Township	Range	Section	Quarter	Sections
01N	04VV	13	SW1/4 N	E¼ SW¼
с	ounty		Geoco	de
MADISON				
Latitude	Longitud	e	Geomethod	Datum
45.834444	112.04694	4	NAV-GPS	NAD27
Ground Su	face Altitude	Metho	d Datum	Date
4.	44 1	DEM	NAVD88	8/21/2015
Measuring P	oint Altitude	Method	Datum	Date Applies
444	2.5	MAP	NAVD88	10/22/2014
Addition		Block		Lot

Section 3: Proposed Use of Water

STOCKWATER (1)

Section 4: Type of Work

Drilling Method: ROTARY Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Wednesday, October 22, 2014

Section 6: Well Construction Details

Borehole dimensions					
From	То	Diameter			
0	100	10			
100	158	8			

	_	<u>.</u>				
Casin	g					
			Wall	Pressure		
From	Тο	Diameter	Thicknes	s Rating	Joint	Туре
-2	100	18	0.25		WELDED	A53B STEEL
-2	158	34			SPLINE	PVC-SCHED 160
Comp	leti	on (Perf/Sc	reen)			
			# of	Size of		
From	Тο	Diameter	Openings	Openings	Description	n
148	158	84			SCREEN-C	ONTINUOUS-PVC
Annul	ar S	Space (Sea	l/Grout/Pa	cker)		
			Cont.			
From	Т٥	Description	n Fed?			
0	50	GROUT	Υ			

Other Options

Retum to menu Plot this site in State Library Digital Atlas Plot this site in Google Maps View hydrograph for this site View field visits for this site View water quality for this site

Section 7: Well Test Data

Total Depth: 158 Static Water Level: 72 Water Temperature:

Air Test *

<u>40</u> gpm with drill stem set at <u>156</u> feet for <u>1</u> hours. Time of recovery <u>1</u> hours. Recovery water level <u>72</u> feet. Pumping water level <u>_</u> feet.

* During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.

Section 8: Remarks

Section 9: Well Log

Geologic Source 120SDMS - SEDIMENTS (TERTIARY)

From	То	Description
0	2	TOPSOIL
2	20	SILT WITH SOME MEDIUM GRAVEL
20	35	TAN FINE SAND AND SILT WITH SOME MEDIUM GRAVEL
35	45	FINE SAND WITH SOME SILT AND CLAY
45	70	SILT AND CLAY WITH SOME SAND AND GRAVEL
70	90	SILT AND SAND WITH SOME MEDIUM GRAVEL
90	95	SAND AND GRAVEL
95	105	GRAVEL WITH SOME SAND
105	120	SEMI-LITHOFIED MUDSTONE WITH SOME MEDIUM SAND
120	125	SEMI-LITHOFIED MUDSTONE WITH SOME SAND AND GRAVEL
125	140	SEMI-LITHOFIED MUDSTONE
140	145	MEDIUM TO COARSE SAND WITH LITTLE MUDSTONE
145	160	FINE TO MEDIUM SAND

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: RYAN LINDSAY Company: LINDSAY DRILLING CO INC License No: WWC-607 Date Completed: 10/22/2014



Appendix 6B—LTP Bench Aquifer Test Analysis

The derivative plot for the observation well OW (gray symbols) indicates a confined aquifer (Renard and others, 2009). We used the Theis solution to simulate this test.