Great West Engineering, Inc.

Judith Basin Monitoring Stations Annual Report, Sep. 2016 - Sep. 2017

Central Montana Regional Water Authority

October 2017

Western Groundwater Services, LLC
6595 Bear Claw Lane
Bozeman, MT 59715
(406) 585-5947
www.westerngroundwaterservices.com

WESTERN GROUNDWATER SERVICES

Table of Contents

List of Tables

List of Figures

List of Appendices

1. INTRODUCTION

The Central Montana Regional Water Authority (CMRWA) is developing the U Bet Wellfield near Garneill for the Musselshell Judith Regional Water System (MJRWS) (see also http://www.centralmontanawater.com). A single well has been installed at the wellfield (CMRWA #2) and was used to verify the source capacity and to obtain water right permits (**Figure 1**). CMRWA #2 and future wells will produce groundwater from the Madison aquifer.

Further investigation and monitoring of water resources in Judith Basin (Basin) has been undertaken by the CMRWA pursuant to a Water Resources Monitoring Plan (Plan) prepared in 2014.[1] This Plan detailed several activities to gather and assess water resources data in relation to the U Bet Wellfield and for the Basin in general. In 2015, the CMRWA obtained a grant from the State of Montana[2] to fund the implementation of several monitoring activities from the Plan. Grant funds provide for set up of the monitoring stations and three years of monitoring (9/2016 to 9/2019).[3]

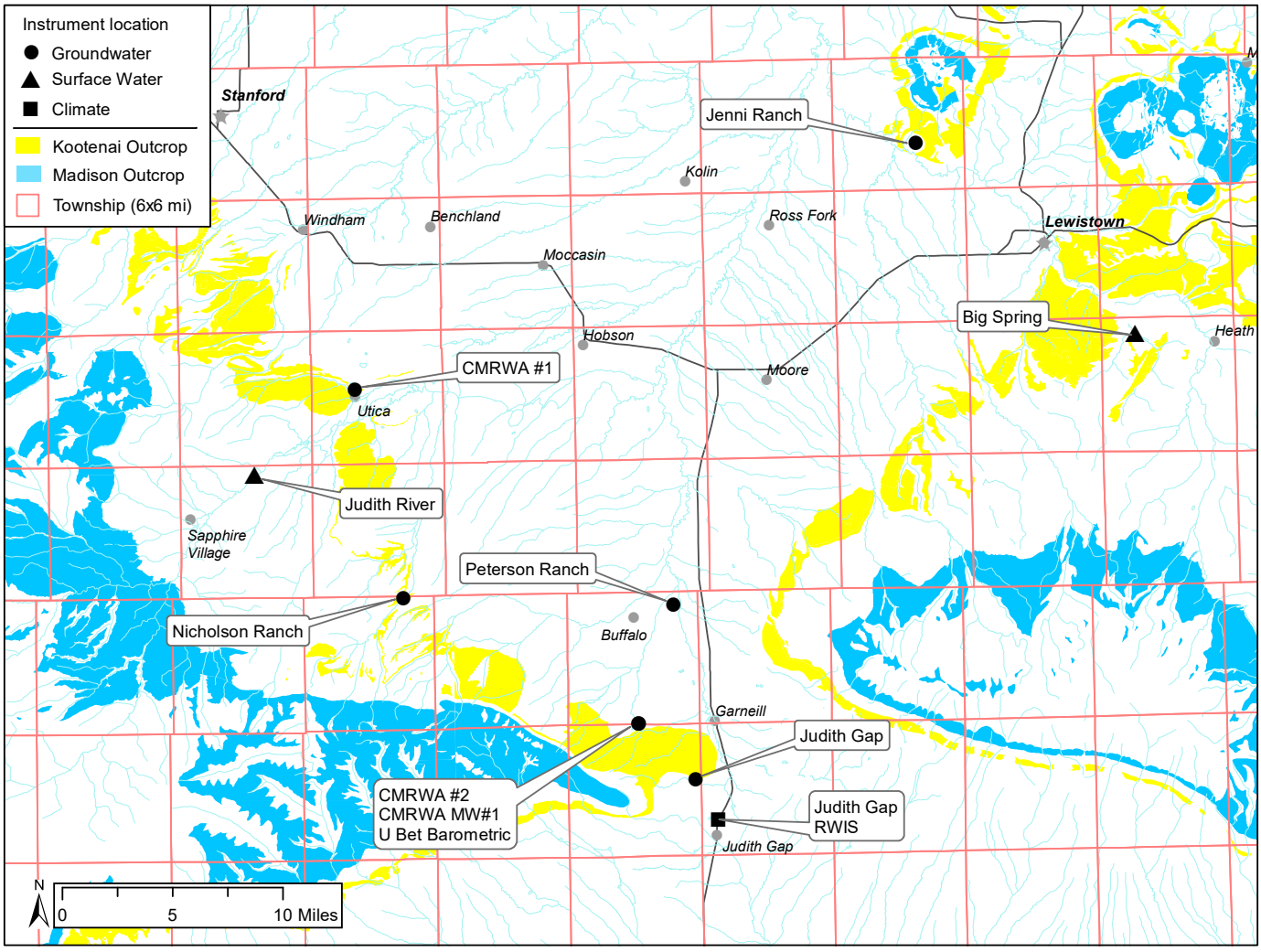


Figure 1. Location Map

1 Western Groundwater Services, LLC (2014) Water Resources Monitoring Plan, Central Montana Regional Water Authority, report to Great West Engineering, Inc., Helena, MT.

2 Grant funds are being administrated through the Department of Natural Resources and Conservation.

3 The Judith River gage was not funded from the grant. It was installed and will be maintained by the U.S. Geological Survey.

This report is documenting the basic information for the monitoring stations and presenting current data for the first year. It has been prepared by Western Groundwater Services, LLC working as a subconsultant to Great West Engineering, Inc. Great West Engineering, Inc. is the lead consulting engineer for CMRWA on the MJRWS project.

1.1 Hydrogeology Summary

The primary bedrock aquifer in Judith Basin is the basal sandstone of the Kootenai formation, also known as the Third Cat Creek sand.[4] The Kootenai aquifer is developed by numerous domestic and agricultural wells. In the basin interior, many of these wells are flowing artesian and used without pumps. The Madison aquifer also occurs in Judith Basin, but at present has seen limited use, most likely because it is much deeper than the Kootenai aquifer.[5] The Madison aquifer was 1,500 feet deeper than the Kootenai aquifer at the U Bet Wellfield and 3,000 feet deeper at Utica.

The U Bet Wellfield will produce groundwater from the Madison aquifer. There appear to be no more than three existing wells into this aquifer in Judith Basin, two of which are owned by CMRWA. The first Madison well in Judith Basin was the Hanover Well, now owned and operated by the Jenni Ranch for power generation. This well was drilled to 750 feet in 1921 and reportedly flowed at 4,500 gpm[6], but now is estimated to yield about 1,100 gpm. The next well into the Madison was not drilled until 2005, when the CMRWA constructed their CMRWA #1 well to 3,700 feet at Utica. The third Madison well is the CMRWA #2 well constructed to 2,250 feet at the U Bet Wellfield in 2012. For economic reasons, the CMRWA is focusing on the U Bet Wellfield as the primary source to the MJRWS.

There are also several major springs in Judith Basin that discharge from the Madison aquifer. These include Big Spring (100 cubic feet per second (cfs)) and Warm Spring (150 cfs). There are at least two other Madison springs in the vicinity of Big Spring with lower but still strong flows. These include the Hatchery Spring and Lehman Spring.

2. MONITORING LOCATIONS AND SENSORS

Monitoring locations are shown on **Figure 1**. Additional information on sensors at these locations is provided in Table 1 and described in this section.

2.1 Well Sensors

As-built construction logs for the wells that are being monitored are provided in Appendix A. Wells are equipped with computer logging pressure transducers with the pressure ratings shown. These sensors are programmed to record water levels every 15-minutes. The sensors use vented cables, thereby reading gauge pressure, except for the barometric pressure sensor which uses a non-vented cable, and reads absolute pressure.

Wells that have a subsurface static water level (CMRWA #1, CMRWA #2, Nicholson Ranch) have the sensor set down the well in a 1-inch diameter PVC deployment tube. These tubes are set to the top of the pumping equipment. The setting depths are: 1) CMRWA #1 – 697 ft bgs; 2) CMRWA #2 – 372 ft bgs; and 3) Nicholson Ranch – 92 ft bgs. A barometric sensor is also located at the CMRWA #2 wellhead. This sensor measures

4 There are also many wells and springs that discharge from alluvial aquifers.

5 The depth from the Kootenai to the Madison can be less on the basin margin near to the mountain ranges.

6 Feltis, R. D. (1973) Geology and Water Resources of the Eastern Part of Judith Basin, Montana, Bureau of Mines and Geology Bulletin 87, Butte, MT.

atmospheric pressure for the purpose of determining the relation between the water level in CMRWA #2 and changes in atmospheric pressure.[7]

The Kootenai monitoring well at the U Bet Wellfield (CMRWA MW#1) has a static water level at ground surface, and is equipped with a packer set at approximately 6 ft bgs to provide frost protection of the wellhead. The sensor for this well is also set in a PVC tube to the top of the pump at a depth of 287 ft bgs. The sensor cable passes through the packer using a cable seal.

In order to access the instrument in the CMRWA MW#1 monitoring well, the mechanical packer (Well Buster ™) must be removed by loosening a 1-1/2" nut using a socket ratchet tool with 6-inch extension. Once loose, the packer can be lifted from the well (15 lbs) and the sensor can be retrieved. In resetting the packer, care must be exercised to ensure that none of the pump or sensor wires move between the packer gland and the casing, as this condition will result in leaking of water past the packer—the well would not be frost free (these wires are taped to the pump column below the packer in order to ensure a proper setting of the packer). After the packer is set, it is necessary to remove water from above the packer. This can be done by air-lifting or bailing, or (preferred method) by running the well pump, in which case the water drains down through the packer in the well (drainage occurs to about 1-inch above the packer—the packer is not exposed). The 1-1/2 hp submersible pump in the well can be run using a 3.5 kW generator (1P, 240 VAC) with discharge through the hydrant adjacent to the wellhead.[8] The pump wire has sufficient excess and is terminated with 20A/240 VAC plug for direct connection to a generator.

Sensors set onto flowing artesian wells are mounted onto fittings in the well piping at land surface.[9] These include the sensors for Judith Gap, Peterson Ranch, and Jenni Ranch. The Judith Gap sensor is mounted onto piping that allows for discharge from the well casing. When this pump runs, drawdown occurs into the casing for some depth. This drawdown is not measured; valid readings only occur when the pump is off and the static water level has risen to elevations above the sensor. The sensor at the Peterson Ranch is mounted onto the discharge piping from the well. This well is not pumped and flows naturally for the water use by the ranch. The Jenni Ranch well is also used without a pump, and the sensor is mounted onto the outside of the well casing, about 1.5 ft bgs. This sensor was removed from the well in September 2017 for the winter in order to prevent frost damage to the instrument. It is intended that this sensor location will be winterized in 2018.

2.2 Judith River

The Judith River gauge (No. 06110020) was newly constructed by the U.S. Geological Survey (USGS) in 2014, and started producing data on 10/1 of that year. This gauge is located at a bridge upstream from the confluence with Carr Creek. The gauge is also maintained by the USGS and the data are directly available from the USGS stream gauging database.[10]

7 Confined aquifers will to varying degrees exhibit a rising water level in a well when atmospheric pressure declines, and vice versa.

8 Western Groundwater Services, LLC (2017) Kootenai Monitoring Well CMRWA MW#1 Construction Report, report to Great West Engineering, Inc., Helena, MT.

9 Flowing artesian wells flow naturally and hold pressure at the surface when shut-in.

10 This website is most easily access by browsing for "USGS Stream Gauge 06110020", but can also be accessed from this URL: https://waterdata.usgs.gov/mt/nwis/uv?site_no=06110020.

2.3 Big Spring

Big Spring requires multiple instruments to measure discharge. The spring discharge is directed to three locations: 1) the City of Lewistown; 2) the FWP Fish Hatchery; and 3) Big Spring Creek. Additionally, Hansen Creek discharges into Big Spring Creek immediately above the spring. In order to measure the spring flow rate, the Hansen Creek flow must be subtracted from the other discharges.

FWP measures Big Spring Creek by traditional stream gauging methods and has developed a stage-discharge relationship. The Hatchery and Hansen Creek are measured with FWP flow meters. The City measures withdrawals from the spring also with flow meters. The instrument readings are processed by computer in the City's control building located at Big Spring. The integration of the monitoring system, which included both hardware and software improvements, was funded from the CMRWA grant. The grant is also paying for operation of the monitoring system for the three year monitoring period ending 9/2019.

2.4 Climate

Climate data for the elevation of the U Bet Wellfield and the Kootenai outcrop area in Judith Basin are being measured at the Montana Department of Transportation (MDT) Remote Weather Information Station (RWIS) at Judith Gap. This station was equipped with a new precipitation sensor from the CMRWA grant and operated and maintained by MDT. The data are accessed by direct request to MDT through their website.[11] Data from this site will be integrated into the water balance analysis for the Kootenai aquifer.[12]

3. DATA PLOTS FOR 2017

Data plots for the first year of monitoring from September 2016 through September 2017 are provided in Appendix B. A summary discussion for each of the plots is provided below.

3.1 CMRWA #1 (Madison)

There is a definitive seasonal pattern in the well water level with an apparent amplitude of about 35 feet (plot B-1). The water temperature is approximately constant at just under 48°F. A seasonal trend of this magnitude and the cold water temperature are unusual for a deep confined aquifer.

3.2 CMRWA #2 (Madison)

The initial data shown (plot B-2) are reflecting the pumping test conducted during fall 2016. During this testing, the well was pumped at 575 gpm with about 35 ft of drawdown. The water temperature increased by about 15°F due to heating from the 125 hp submersible pump motor. After the pumping test, water level data exhibit a definitive seasonal pattern and the water temperature is slightly greater than 49°F. The seasonal amplitude is about seven feet. The peak during 2017 is almost 10-ft lower than the apparent peak of 2016.

11 By requesting atmospheric data in converted units for the Judith Gap RWIS, within specified dates. The public information request web page can be accessed at URL: http://www.mdt.mt.gov/mdt/information_request.shtml.

12 Water balance analysis is also incorporating the PRISM data developed by Oregon State University (http://prism.oregonstate.edu/) and NRCS SNOTEL data local to the area.

Table 1. Monitoring System

Location ID	Source	Latitude Longitude	Sensor Rating	Model	Mfg.
CMRWA #1	Madison	46.973135 -110.092816	300 psig	Level Troll 500	In-Situ, Inc.
CMRWA #2	Madison	46.751668 -109.825567	100 psig		
CMRWA Baro	Atmospheric		30 psia	Level TROLL 400	
CMRW MW #1	Kootenai	46.751664 -109.825252	300 psig	Level TROLL 500	
Judith Gap	Kootenai	46.714447 -109.771655	100 psig		
Peterson Ranch	Kootenai	46.829638 -109.790520	300 psig		
Nicholson Ranch	Kootenai	46.836131 -110.048608	100 psig		
Jenni Ranch	Madison	47.129547 -109.550441	100 psig		
Judith River 06110020	Judith River	46.900548 -110.233129	NA	NA	USGS
Big Spring	Madison	47.001867 -109.343260	NA	NA	NA
Judith Gap RWIS	Climate	46.687538 -109.750838	NA	PWD12 (precipitation)	Vaisala

3.3 CMRWA Baro (Atmospheric)

Changes in well water level in relation to barometric pressure was assessed for the CMRWA #2 well for the month of March 2017 (arbitrarily selected, plot B-3). These data illustrate the inverse relation between well water level and atmospheric pressure. A rise in atmospheric pressure corresponds to depression of well water level, and vice versa.

These data have been processed by linear regression analysis to remove trends, and subtraction of the resulting mean to establish a common datum of zero.[13] The data pairs were then plotted (plot B-4) to determine a linear relation between changes in well water level and changes in atmospheric pressure. The slope of this regression curve is referred to as the barometric efficiency (BE) for the well, and was determined to be -0.455, or 46%. The BE value is used to apply corrections to well water levels in order to remove effects of barometric pressure when necessary.

3.4 CMRWA MW#1 (Kootenai)

The early data for fall 2016 are reflecting operation of the submersible pump that is set in this well (plot B-5). The pump is used for sampling of the groundwater, and otherwise will not be in regular use. After this time, the water level data exhibit a very slight possible seasonal fluctuation with an amplitude of one to two feet.

13 Because de-trending was imperfect, the resulting data values did not have a mean of zero. A second step to remove the mean was then completed.

The deflection occurring in July 2017 is most likely a response to aquifer pumping in private wells. Water temperature in the Kootenai aquifer is about 48.5°F.

3.5 Judith Gap (Kootenai)

The Town of Judith Gap Mauws Well is artesian but must be pumped to produce at sufficient capacity for the water system (plot B-6). The sensor is mounted at the wellhead and cannot read water level when this level drops below ground during a pump cycle. The thick band of data with a level of about 4635 ft reflects the normal static condition. The other points occurring mostly above but also below the band occur in relation to when the pump is shut off. They appear to document oscillation of the well water level of several tens of feet occurring over a period of at least 15- to 30-minutes at the end of each run cycle. The higher density of points above the band during summer 2017 is probably reflecting a greater number of pump run cycles due to higher water demand. The dip in the band that occurs in June 2017 is probably caused by incomplete recovery of the well between pump cycles.

3.6 Peterson Ranch (Kootenai)

The Peterson Ranch well is a flowing artesian well operated without pumping equipment (plot B-7). The water level data for this well are dominated by usage of the well. The recovery levels, shown by the highest points on any given date, generally to not achieve a static water level because of the high frequency of use. The highest level observed corresponds to a pressure of 122 psig.

3.7 Nicholson Ranch (Kootenai)

The Nicholson Ranch well has established pumping and recovery water levels through the monitoring period (plot B-8). This well is producing groundwater with about one to two feet of total drawdown. The static water level exhibits a seasonal pattern with a peak in May. The aquifer water temperature is about 45°F. The higher temperatures shown on the plot are a result of the pump motor heating the water.

3.8 Jenni Ranch (Madison)

The Jenni Ranch owns and operates the Hanover Well for power generation (plot B-9). This well is estimated to flow at approximately 1,100 gpm. A pressure sensor was set onto the well casing about 1.5-ft below ground surface in April 2017 and was removed at the end of September for winter. It is planned to winterize the sensor in 2018. Work on the power generation system results in the stepwise changes in the pressure data. The well level appears to exhibit a seasonal trend from May to early September 2017, although more data are needed to better define this trend.

3.9 Big Spring (Madison)

Discharge data for Big Spring (plot B-10) are presented as daily totals, and show a rate of about 90 to 100 cfs. There is some possibility that measurement error is contributing to the fluctuations. Additional data for the spring will better establish discharge rate and associated trends.

3.10 Judith River Gauge

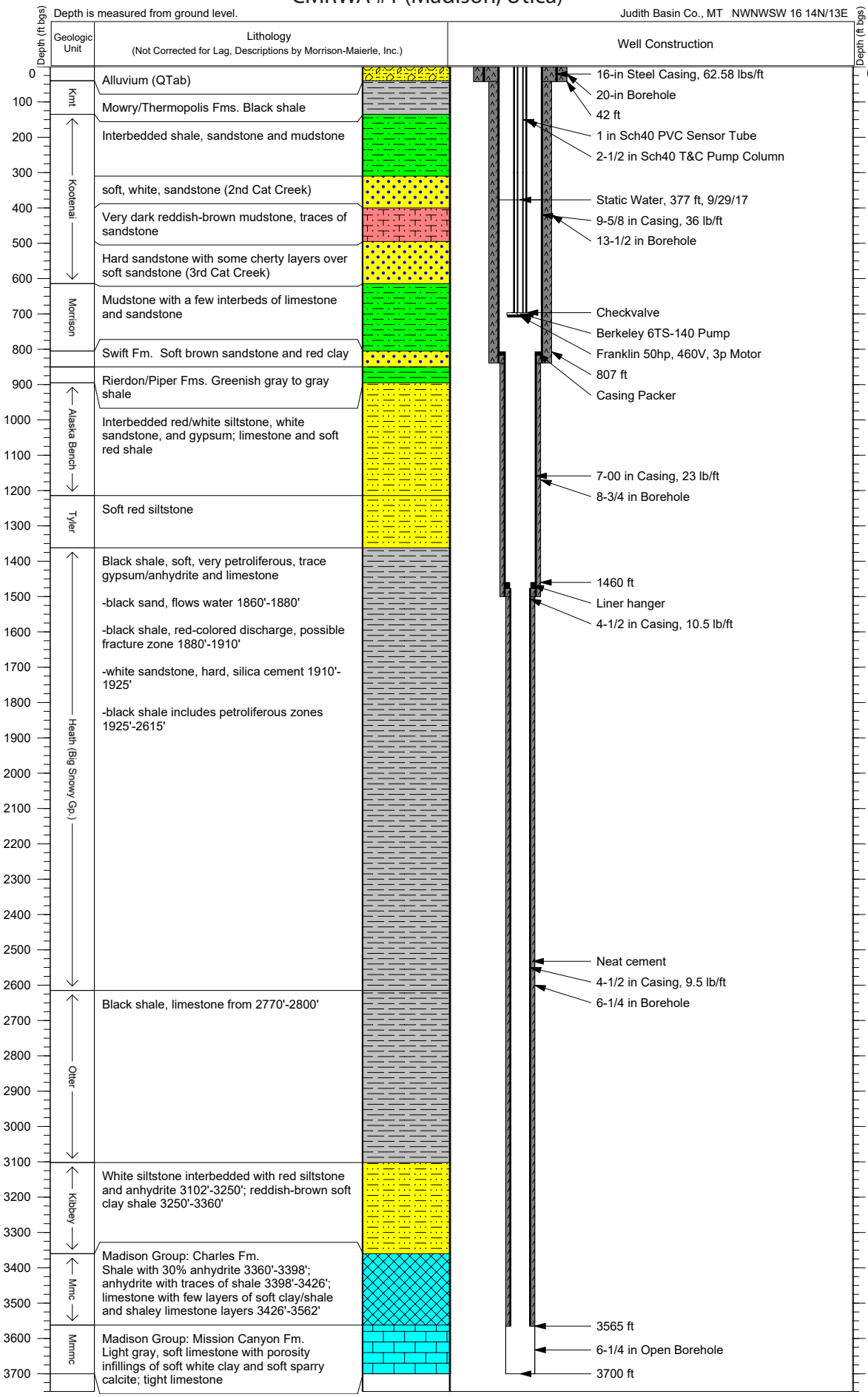
This gauge measures flow in the Judith River a short distance upstream from the confluence with Carr Creek (plot B-11). Peak flow during runoff ranged from 232 to 542 cfs. The baseflow occurring in late winter and early spring declines to rates less than 5 cfs. These low rates are outside the irrigation season and represent the natural base flow from groundwater.

3.11 Judith Gap RWIS

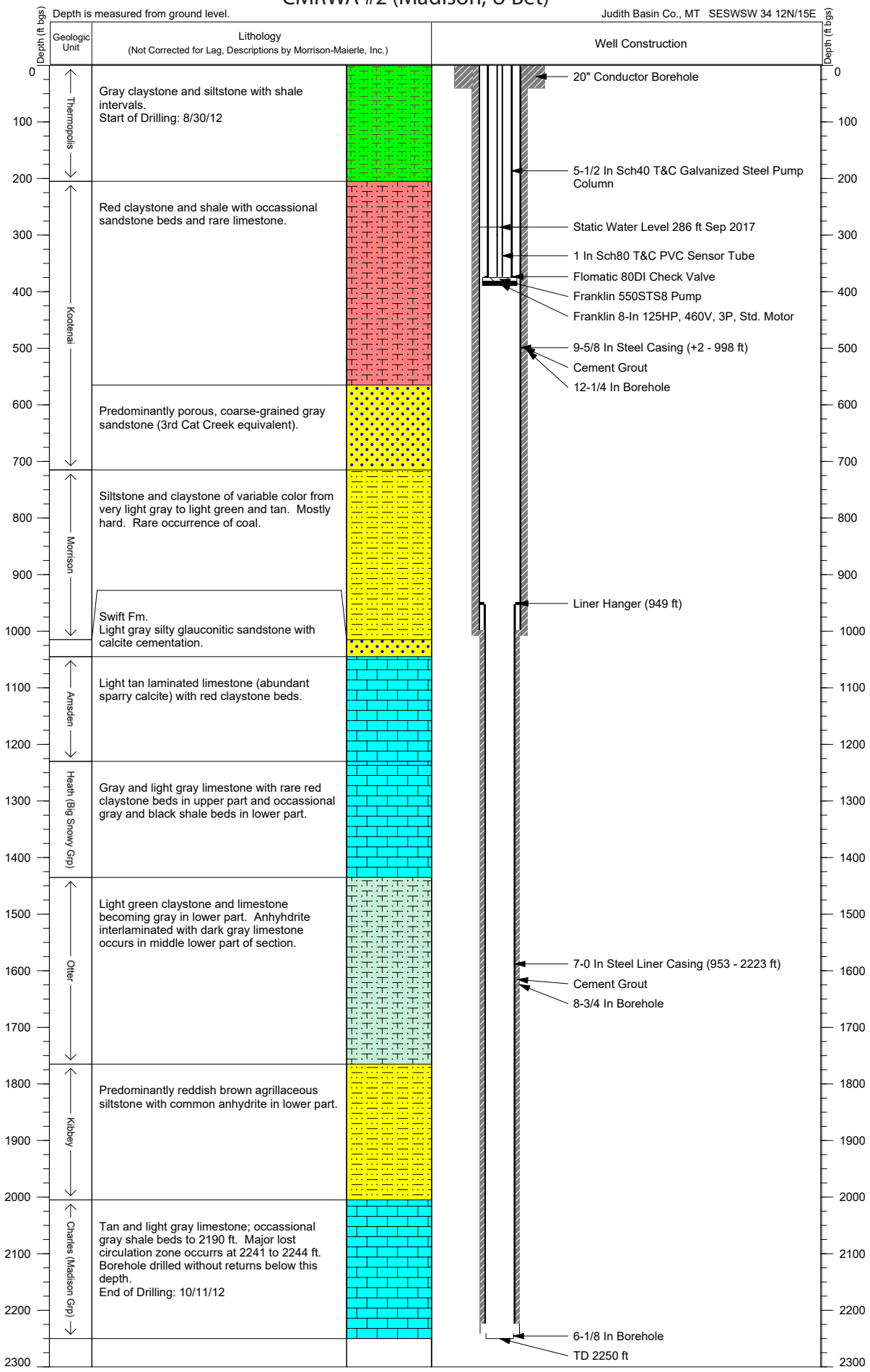
Climate data for the weather station at Judith Gap provide direct measurements that will be incorporated into water balance analysis. The new precipitation sensor installed at this station was activated on February 3, 2017. This plot is showing daily totals for the precipitation and daily mean air temperature (plot B-12).

APPENDIX A – WELL LOGS

CMRWA #1 (Madison, Utica)



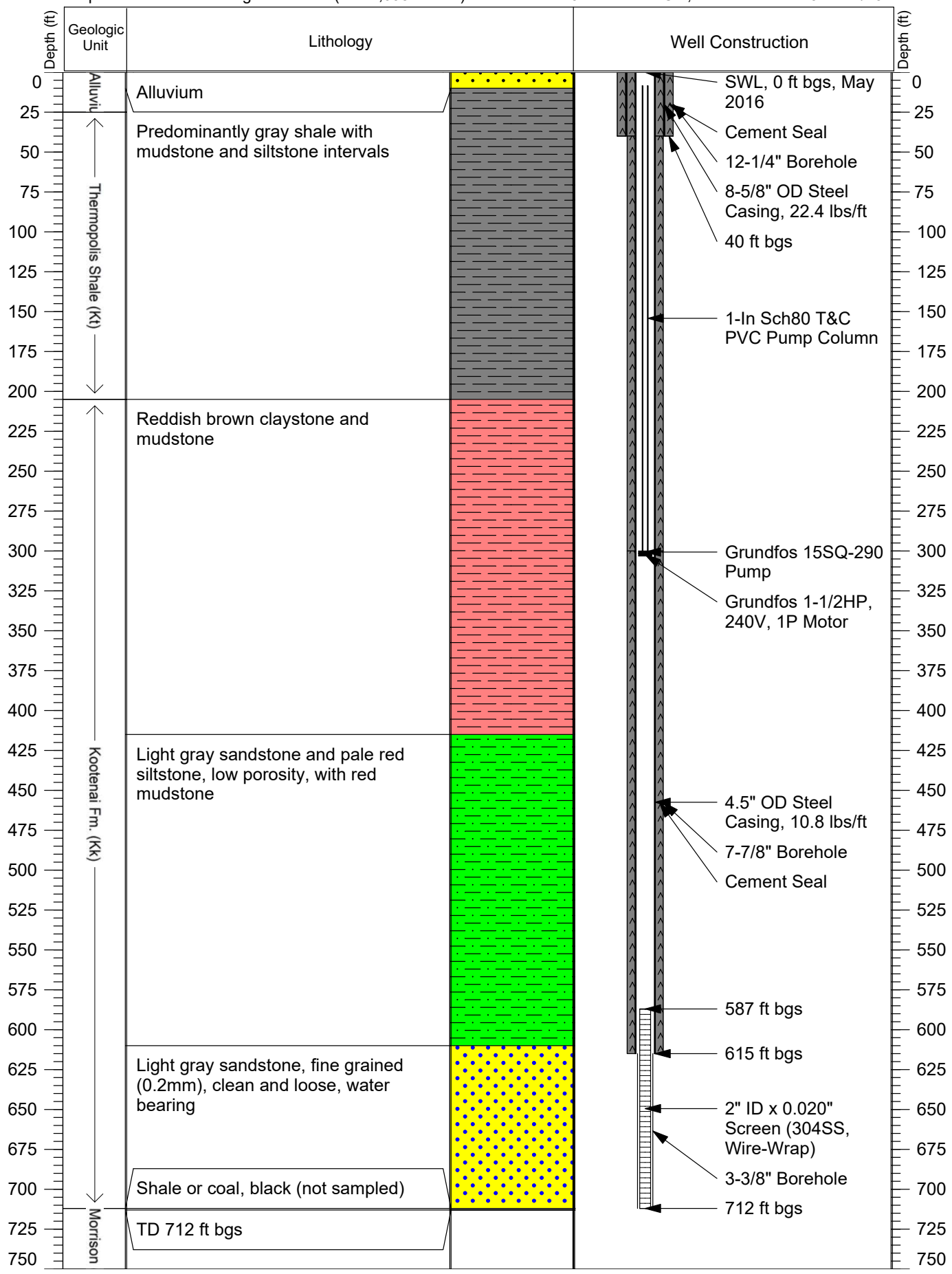
CMRWA #2 (Madison, U Bet)



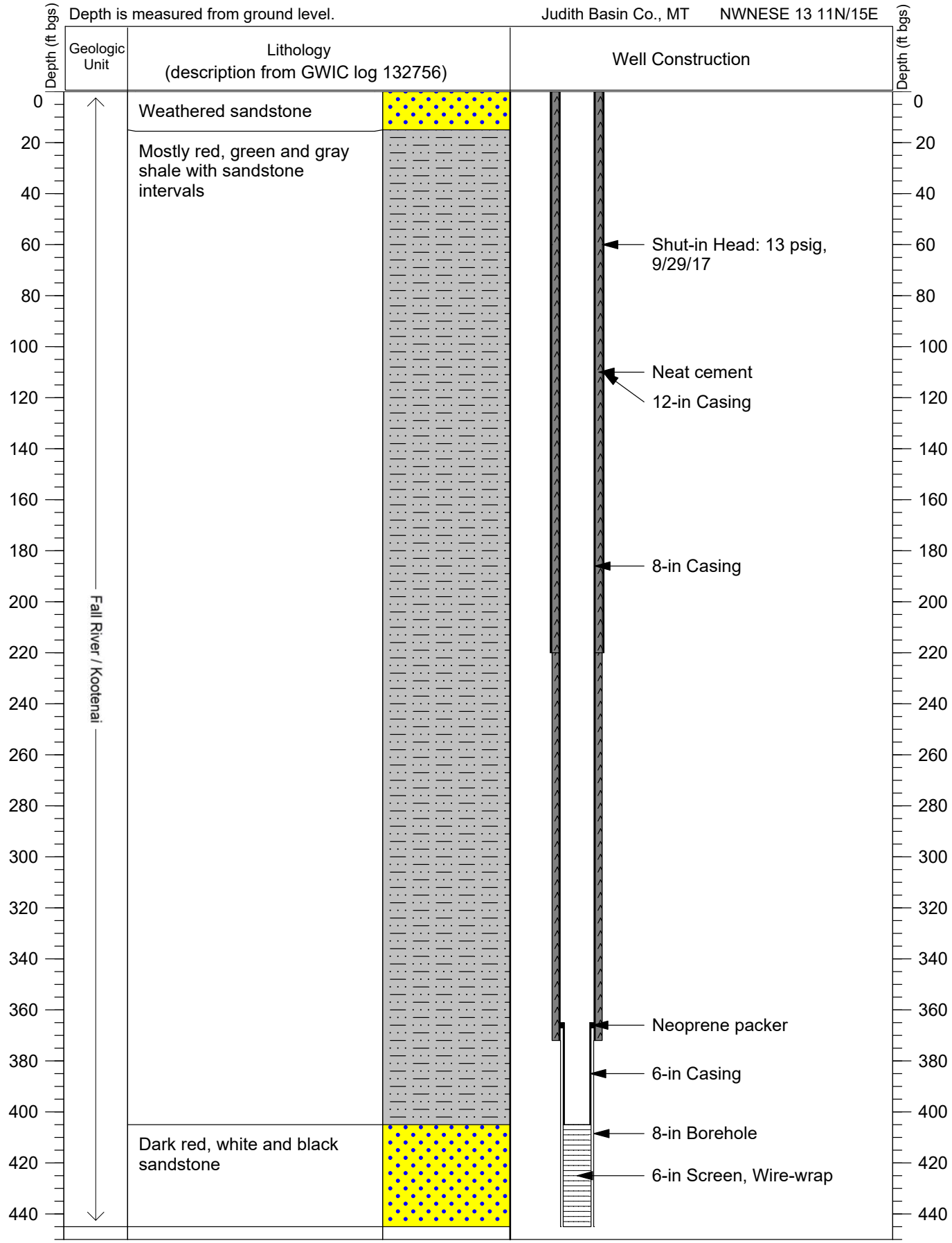
CMRWA MW#1 (Kootenai, U Bet)

Depth is measured from ground level (est. 4,698 ft MSL)

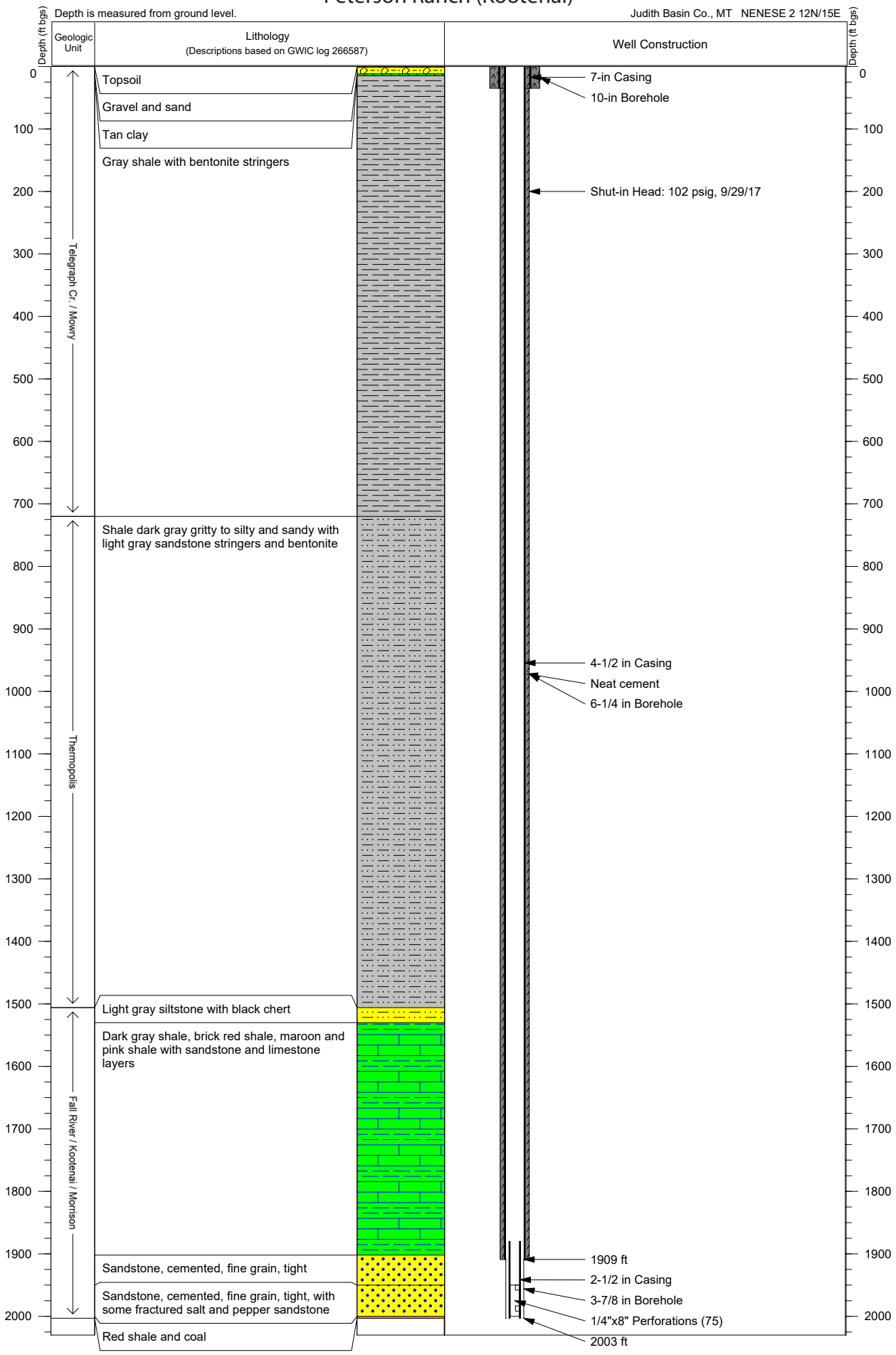
Judith Basin Co., MT SESWSW 34 12N/15E



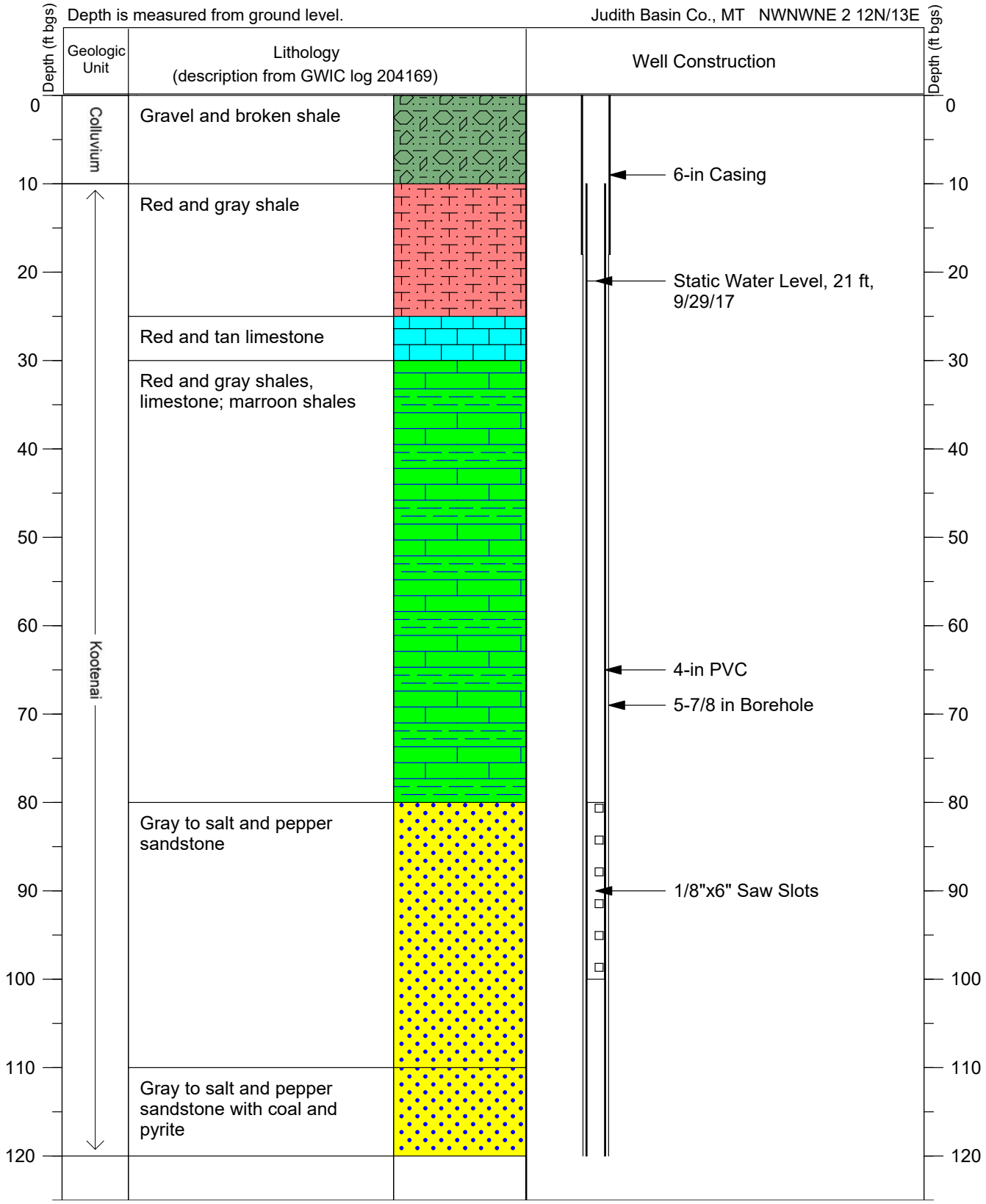
Judith Gap Mauws Well (Kootenai)



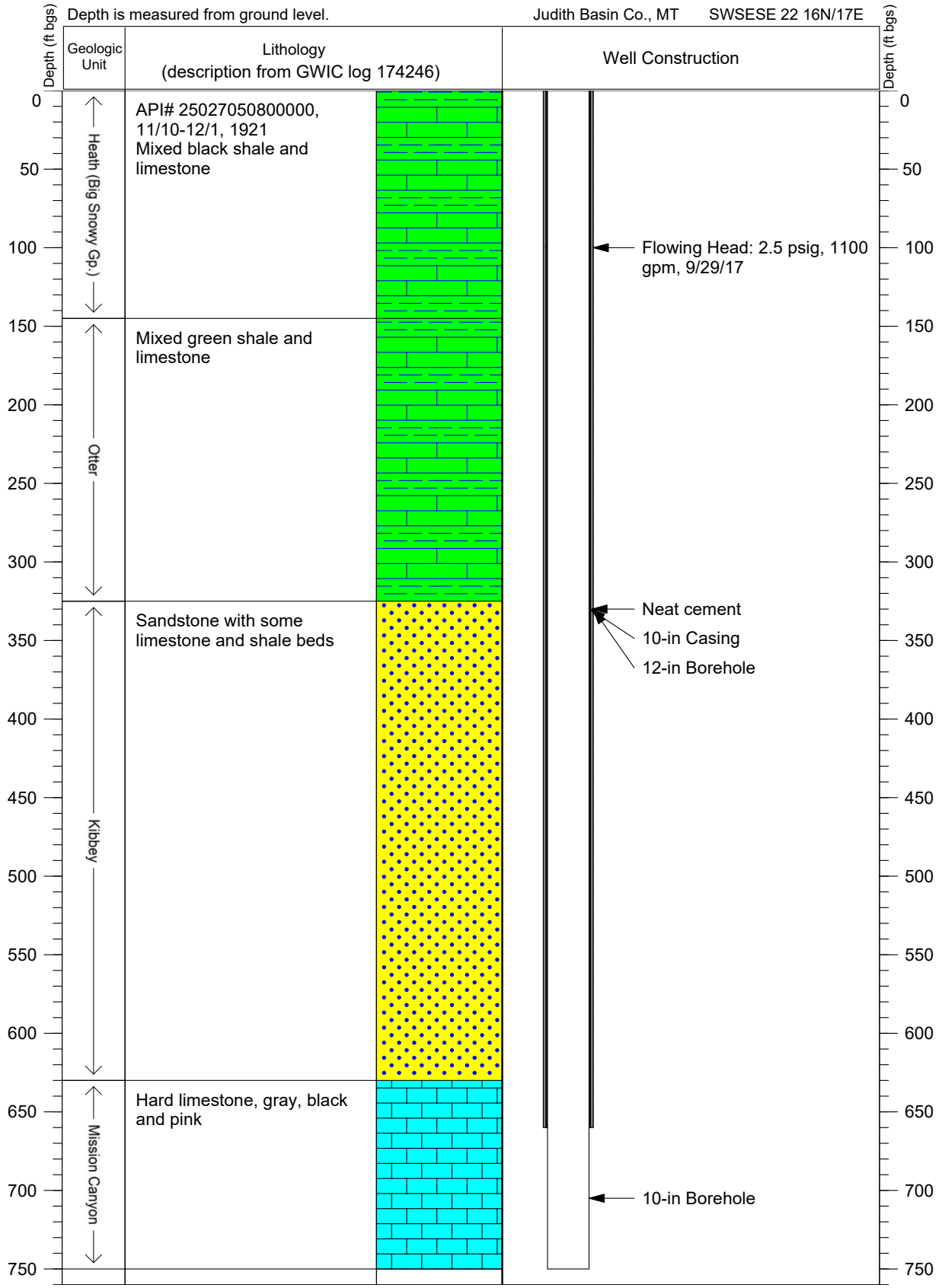
Peterson Ranch (Kootenai)



Nicholson Ranch (Kootenai)

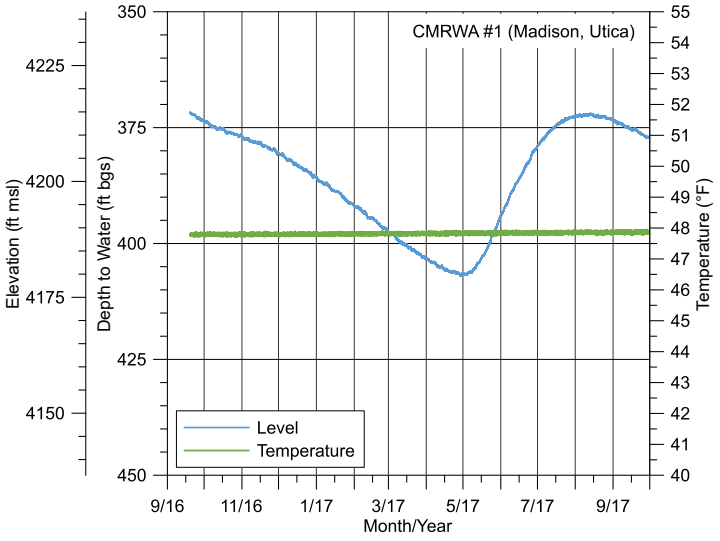


Jenni Ranch (Madison)

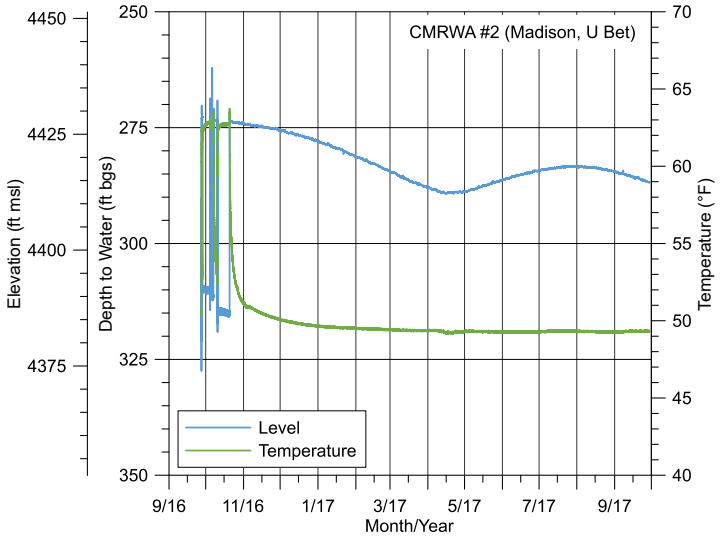


APPENDIX B – DATA PLOTS

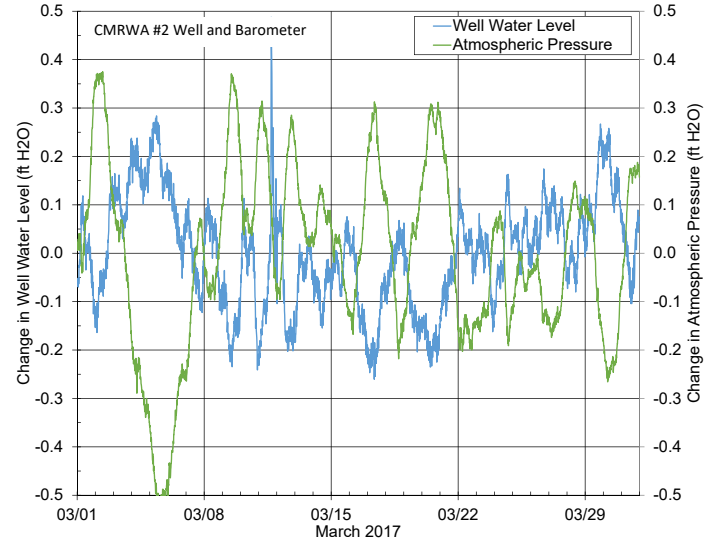
B-1



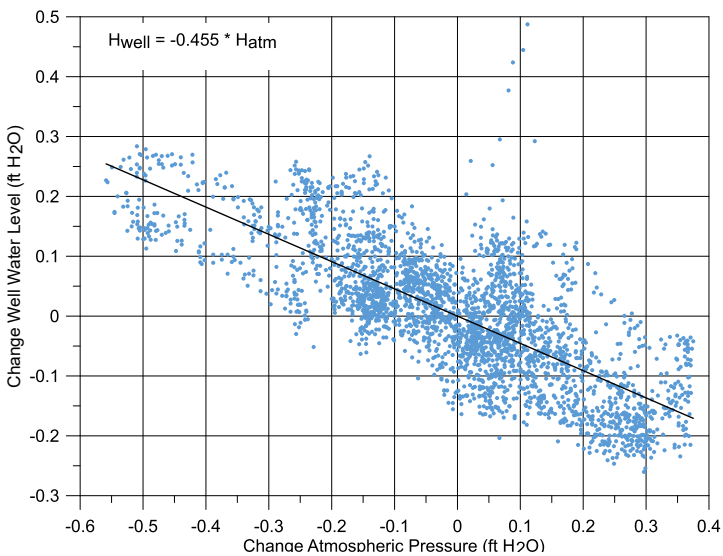
B-2



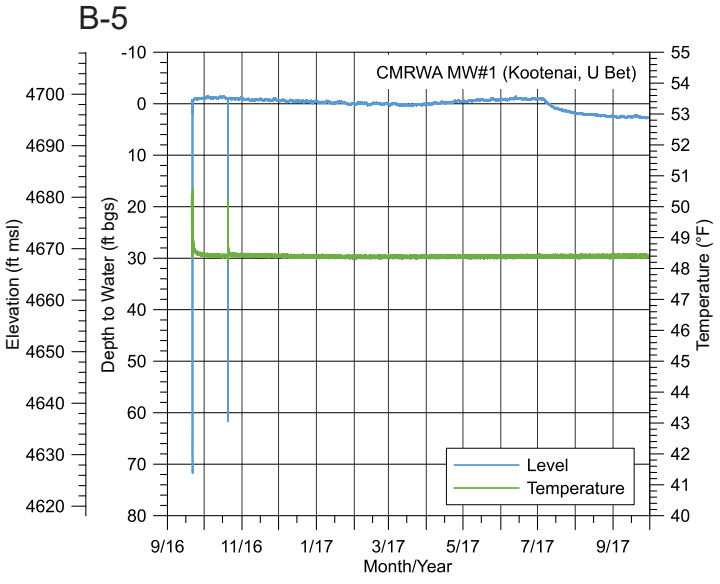
B-3



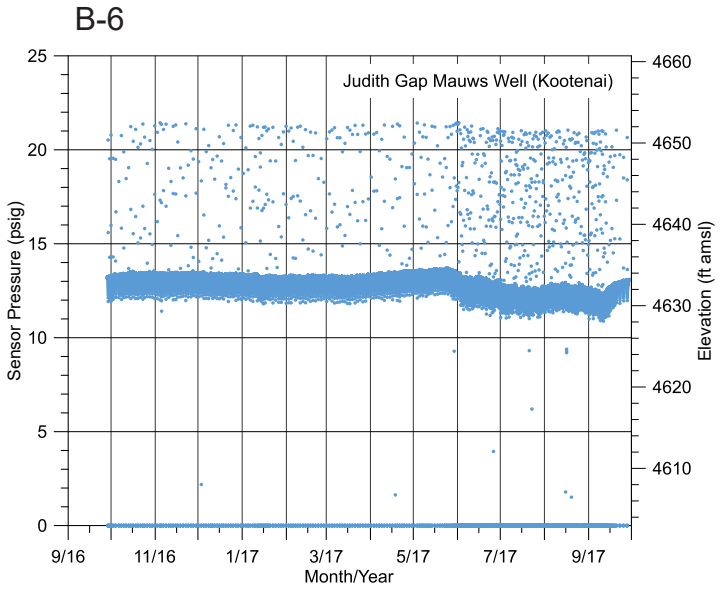
B-4



B-5

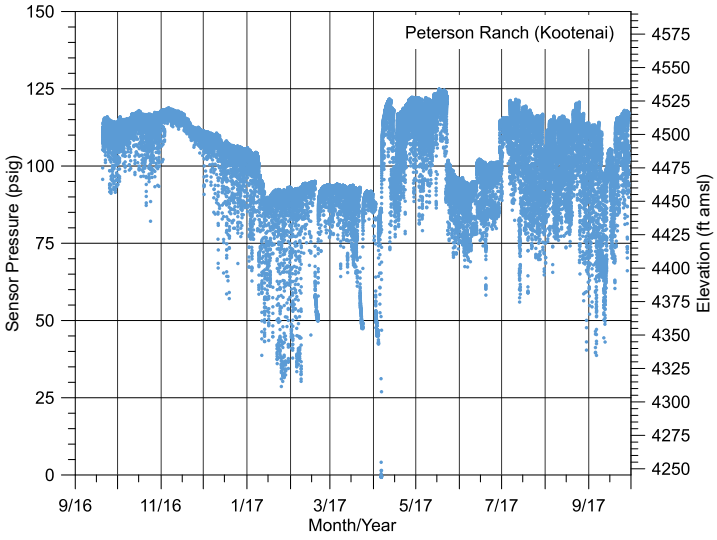


B-6

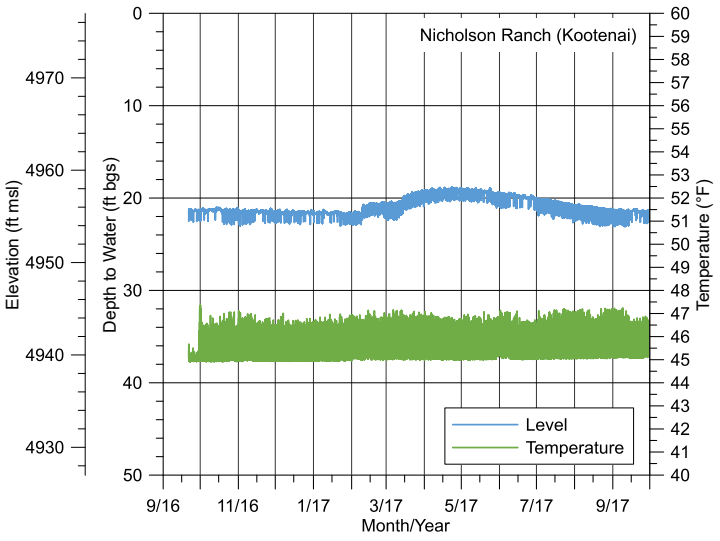


Time scale of all plots is in units of days.

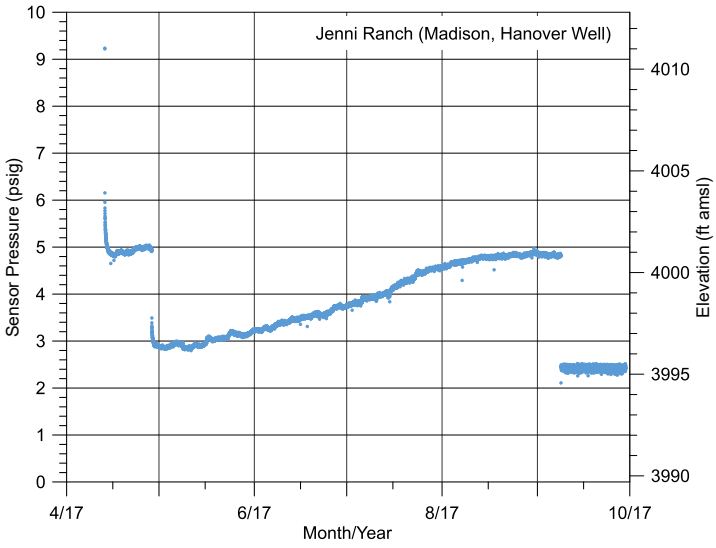
B-7



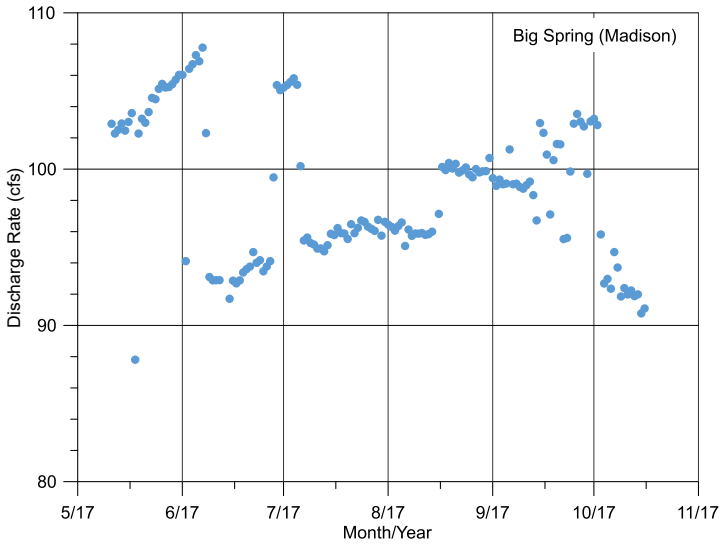
B-8



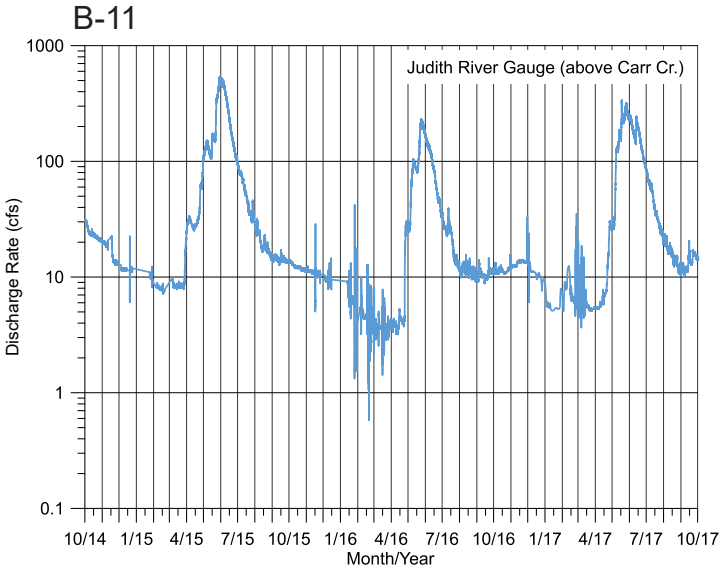
B-9



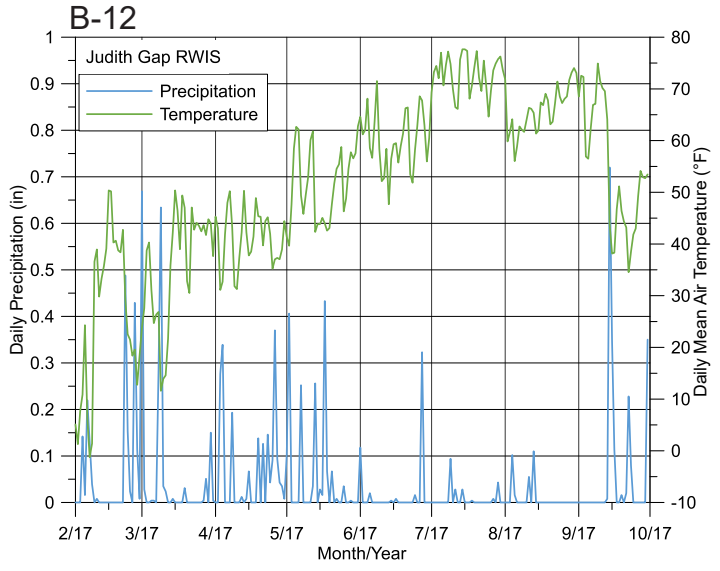
B-10



B-11



B-12



Time scale of all plots is in units of days.