2011
Tongue River Hydrologic Summary Report
Tongue River Information Program

Prepared for:
Montana Board of Oil & Gas Conservation
Montana Department of Natural Resources and Conservation

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EXECUTIVE SUMMARY

Tongue River Hydrology Report
Tongue River Information Program
September 2011

The Tongue River valley of Wyoming and Montana has over 71,000 acres of irrigated land that has supported cattle ranching and farming operations for more than 120 years. The Tongue River runs through the coal-rich Powder River geologic basin, which has experienced growth in coal bed natural gas (CBNG) development since 1999, along with surface coal mining since the early 1970's. The Tongue River Information Program (TRIP) has been funded by the Montana Board of Oil and Gas Conservation (MBOGC) since 2006 in response to concerns by irrigators, environmental regulators, and policy makers that the discharge of produced water from CBNG production in the upper Tongue River basin may be affecting the water quality of the river and, in turn, the soil properties and crop production. TRIP includes an agronomic and soils monitoring program called the Agronomic Monitoring and Protection Program (AMPP) and a hydrologic component, which is summarized in this Tongue River Hydrology Report. All TRIP reports may be accessed on-line at: http://bogc.dnrc.mt.gov/CoalBedMeth.asp.

Approximately 2,744 CBNG wells were active in the Tongue River basin at the end of 2010, 70% of which were in Wyoming (Figure 24) (Wyoming Oil & Gas Conservation Commission 2011). Production of CBNG requires pumping of water to depressurize coal aquifers and release the adsorbed gas. The quantity of CBNG-produced water within the basin averaged about 2.97 gallons per minute (gpm) per CBNG well during 2010, for a total of 18.2 cubic feet per second (cfs) of produced water, roughly 3.9% of the median flow of the Tongue River at the State Line, 454.1 cfs. For the second consecutive year in a row since CBNG production began in the Tongue River basin, the number of producing wells declined relative to the previous year. There was a 10.1% decrease in production in Wyoming and 7.9% decrease in Montana. Total gas production in the basin declined by 14.5% while produced water volume declined by 11.9%.

This study, along with other recent studies (Clark and Mason 2007; U.S. Environmental Protection Agency 2007), have documented that the salinity and sodicity of the Tongue River, as measured by specific conductance (SC), or electrical conductivity (EC), and sodium adsorption ratio (SAR) are inversely related to the rate of flow; that is, the river typically has higher SC and SAR at lower flows and vice versa. The years from 2001 to 2006 included the lowest average annual flows of the Tongue River since records at the State Line station began in 1961. The median salinity of the river was higher during those dry years, but has since declined in response to normal and above normal river flows. Charts of SC and SAR versus streamflow presented in this report indicate comparable readings before and after the onset of CBNG development at all USGS monitoring stations on the Tongue River.

Charts of pre-2000 (before CBNG development) and 2010 Water Year data are presented showing the statistical trends of down-river increases in salinity and SAR. Median SC and SAR in Water Year 2010 were somewhat higher at the State line station, but generally close to or

less than the pre-2000 historic trends at all other stations. Tongue River water quality for Water Year 2010 met Montana irrigation season SC standards at all stations upstream of the T&Y gauging station. The SC monthly average standard was exceeded during a portion of March (data were not collected the entire month), and April at the T&Y and Miles City gauges. This occured before snowmelt runoff began, when groundwater base flow and runoff from low-elevation areas contributes proportionally greater salts and sediment. No stations had maximum SC readings above the Montana Maximum SC Standards during the 2010 Water Year. The SAR average and maximum standards were met at all Tongue River USGS gauging stations in Water Year 2010, including the Miles City station, based on the daily data as well as the periodic water quality sampling conducted by the USGS (2011)..

There were eight active permits resulting in direct discharge of CBNG-produced water to the Tongue River or to on-channel reservoirs in 2010; two in Montana and six in Wyoming. However, one of the Montana permits, MT0030457, was revoked effective November 1, 2010 due to a court decision regarding Montana discharge standards conflicting with EPA guidance. These direct discharge permits authorized the discharge of untreated CBNG water at a rate ranging from 173 to 2,500 gpm (0.39 to 5.57 cfs) and the discharge of 4,438 gpm (9.9 cfs) of treated CBNG water. Actual CBNG discharges have been less than the permitted discharge limits. The discharge rates and/or water quality authorized by permits are seasonally adjustable in order to meet irrigation water standards set by the State of Montana. During the April-September 2010 irrigation season, total CBNG discharges comprised from 0.26% to 5.63% of the flow released from the Tongue River dam, with untreated discharge ranging from 0.21% to 4.59%. About 22.4% of all produced water was discharged to the Tongue River without treatment, and 7.6% with treatment. About 70% of all produced water in the basin was discharged to permitted off-channel impoundments, beneficially used in managed irrigation, injected underground, or treated and discharged under a MPDES permit.

The 2010 Montana Department of Environmental Quality's 303 (d) List of impaired water bodies indicates that four of the seven segments of the Tongue River basin are rated as "Partially Supporting" or "Not Supporting" of some beneficial water uses and will require a Total Maximum Daily Load (TMDL) (Montana Department of Environmental Quality 2010). The most common causes of impairments were streamflow modification from dams and diversions, irrigated crop production, stream bank and riparian zone deterioration, and natural sources. The 2010 Wyoming 303 (d) List indicates that the Tongue River below Goose Creek, much of Big and Little Goose Creeks, all of Prairie Dog Creek, and other smaller tributaries are impaired for beneficial uses (Wyoming Department of Environmental Quality 2010). The most common causes of impairments were flow alterations from dams and diversions, irrigation, sources of fecal bacteria, storm water discharges and high water temperatures. CBNG was not listed as a cause of impairment in Montana nor Wyoming. The EPA approved a TMDL for Goose Creek in September 2010 and the WYDEQ approved and published the Prairie Dog Creek Watershed Plan in January 2011. Further studies to support future TMDLs for the Tongue River in both states are still underway.

In summary, this study indicates that the water quality of the Tongue River varies directly with the quantity of streamflow. The salinity and sodium levels have been comparable to pre-development levels since the beginning of CBNG development in 1999. CBNG discharges are one of a number of point and non-point discharges and natural sources that affect the water quality of the Tongue River. Concerns over irrigation water quantity and quality in relation to energy development in the Tongue River basin are likely to continue. Improved and temporally consistent accounting of basin-wide stream characteristics in addition to that of point and non-point sources of salinity and sodium loading is warranted.

Foreword

The Tongue River Hydrology Report is a companion report to the Agricultural Monitoring and Protection Program (AMPP) Report, produced under the auspices of the Tongue River Information Program (TRIP). The MBOGC, a division of the Montana Department of Natural Resources and Conservation, has funded this program since 2006. The AMPP program was originally launched in 2003 by Fidelity Exploration & Production Company, a subsidiary of MDU Resources Group, Inc., in response to concerns by Tongue River irrigators over whether crop yields, soils, and/or water quality were being affected by discharges from the coal bed methane industry.

Through its Administrator, Tom Richmond, the MBOGC specified that the TRIP project include a scientific summary of the available hydrology and water quality information on the Tongue River, to place the AMPP findings in context. This report provides that summary. The 2010-2011 TRIP contract was administered by HydroSolutions Inc, a Montana based hydrology and engineering firm. The principal author of this report is Tom Osborne, P.H., the owner and principal hydrologist with HydroSolutions Inc, Billings, Montana. Technical assistance and reviews were provided by other HydroSolutions staff including Stephanie Anderson, GIS Analyst/Environmental Scientist, Alison Mantz, Research Associate, Jeannie Riddle, Contract Officer, and Shane Bofto, Senior Environmental Engineer. The interpretations provided herein are solely those of the authors.

The Tongue River Information Program (TRIP)

The Tongue River is a principal tributary of the Yellowstone River. Its headwaters are in the Bighorn Mountains of northern Wyoming and its confluence is with the Yellowstone River in southeastern Montana. The Tongue River valley, which is developed extensively for irrigated agricultural production, flows through the coal-rich Powder River geologic basin. Large scale coal strip mining began in the Tongue River valley the early 1970's. Coal bed natural gas (CBNG) development began in 1999. The Tongue River Information Program (TRIP) is an expansion of the Agronomic Monitoring and Protection Program (AMPP) which preceded it from 2003 to 2006. The AMPP program, which was originally privately funded, was developed in response to concerns by Tongue River irrigators that the discharge of produced water from CBNG development in the upper Tongue River basin could impact the water quality of the river and, in turn, the soil quality and ultimately the crop production.

The Montana Board of Oil and Gas Conservation (MBOGC) began sponsoring this program in 2006 due to its significance to the energy production activities under its jurisdiction, along with the need to protect water resources of the State of Montana. The project includes scientific evaluations in the areas of agronomy, soil science, hydrology and water quality; and public information and education related to project results. This report is a summary of the hydrology of the Tongue River watershed in Montana and Wyoming. It is a companion report to the AMPP report which presents the results of the crops and soils monitoring at the study fields in the Tongue River valley. The agronomic and soils studies developed by the AMPP portion of TRIP are designed to detect changes in soil salinity, sodium content, and crop yields related to changes in irrigation water quality from the Tongue River. All TRIP reports may be accessed on-line at: http://bogc.dnrc.mt.gov/CoalBedMeth.asp.

Tongue River Hydrology and Water Quality Trends

The hydrology portion of TRIP is a focused effort to assemble existing sources of flow, salinity, and sodicity data on the Tongue River and to evaluate the temporal and spatial trends along the Tongue River from Wyoming through Montana. Salinity refers to the dissolved mineral content of the water and sodicity to the dissolved sodium content. This assessment integrates existing sources of streamflow data and of point sources and non-point sources of salinity and sodium loading to the Tongue River.

The specific tasks for the Hydrology Report include the following:

1. Obtain streamflow and water quality monitoring results for all U.S. Geological Survey (USGS) stations and any other publicly-available monitoring on the Tongue River and its tributaries in Wyoming and Montana for the 2010 Water Year (October 1, 2009 – September 30, 2010);

2. Obtain information from state agencies and irrigation companies regarding rates, volumes, and quality of discharges into the Tongue River basin. Another task is to obtain the withdrawals information from the basin for industrial and agricultural uses during the previous year, including the quantities of produced water from oil and gas operations in the Tongue River basin to the extent that they are available;

3. Analyze temporal and spatial trends in stream discharge and water quality throughout the Tongue River basin; and

4. Prepare a scientifically valid synopsis of the most recent Water Year's discharge, salinity, and sodium characteristics along the river and place it in context with the available historical record.

1.0 Trends in Tongue River Flow and Water Quality

1.1 The Tongue River Watershed

The Tongue River watershed encompasses approximately 5,399 square miles in the states of Wyoming and Montana (Figure 1). The headwaters originate in the Bighorn Mountains of north-central Wyoming and flow generally to the northeast into southeastern Montana. Approximately 70% of the watershed (3,781 square miles) lies in Montana, while 30% (1,618 square miles) lies in Wyoming. Major tributaries include: Goose Creek, Prairie Dog Creek, Hanging Woman Creek, Otter Creek, and Pumpkin Creek. The Tongue River Dam and Reservoir are located approximately 10 miles downstream of the Wyoming-Montana state line. The reservoir has a storage capacity of 79,071 acre-feet.

Three trans-basin water diversions, originally built in the 1880's, transfer water for irrigation from the North Fork and South Fork of Piney Creek into Jenks Creek, a tributary of Prairie Dog Creek. The transfers amount to approximately 60 cubic feet per second (cfs) over an average 153-day irrigation season per year (EnTech Inc. 2001). Piney Creek is a tributary of Clear Creek and eventually the Powder River.

1.2 Relation of Streamflow to Precipitation

In the plains region of the basin, elevations range from 3,000 to 6,000 feet above mean sea level with level with annual average precipitation ranging from 14.72 inches at Sheridan, WY in the Upper Tongue River Basin, to 13.49 inches at Miles City, MT in the Lower Tongue River Basin (National Oceanic and Atmospheric Administration's National Weather Service 2011). Rainfall is the dominant form of precipitation (Lidner-Lunsford, et al. 1992). In the 2010 Water Year, the total annual precipitation for the Tongue River basin was 14.33 inches at Sheridan, WY and 17.84 inches at Miles City, MT. Typically, average monthly precipitation is greatest from April through September, with maximum temperatures in July and minimum values in January (Tetra Tech, Inc. 2003). About 75% of the year's precipitation falls as rain during the April-September growing season. May and June are usually the wettest months of the year.

Streamflow is driven by precipitation, although the relationship is complex in reality. Variations in the pattern and timing of precipitation over the basin and lag time between snowfall and snowmelt are some of the complicating factors. A general correlation between the precipitation at the Sheridan Field weather station and streamflow in the Tongue River at the State Line gauging station is displayed in Figure 2.

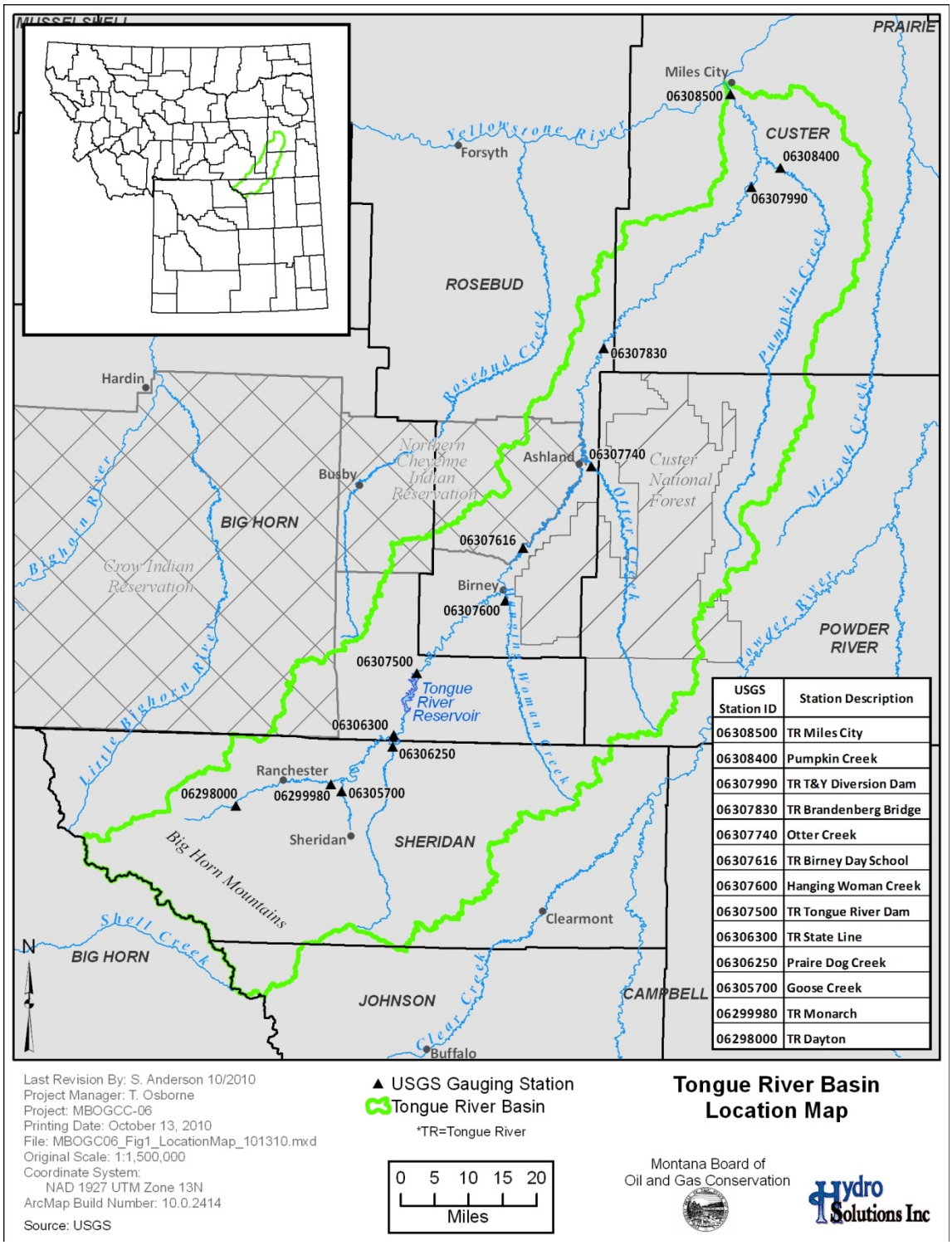


Figure 1 Tongue River Basin Location Map

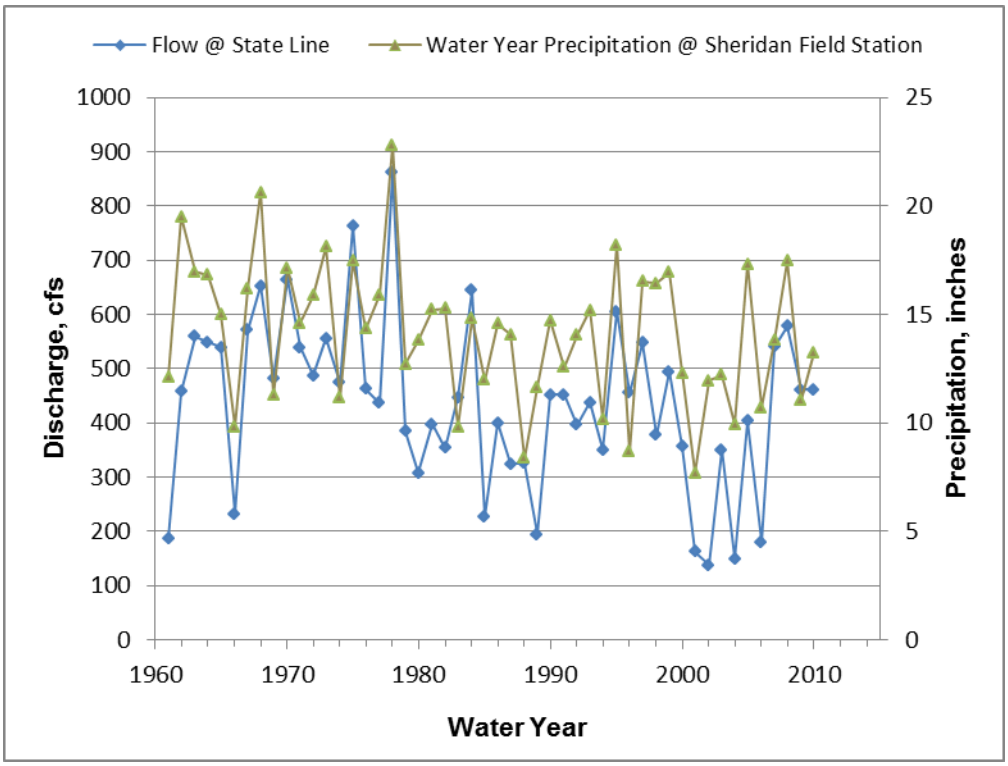


Figure 2 Precipitation at the Sheridan Field Weather Station and Average Annual Discharge of Tongue River at State Line Gauging Station

(Water Years 1961 through 2010).
(U.S. Geological Survey 2011; Western Regional Climate Center 2011)

Correlation of precipitation with river discharge becomes less well defined at gauging stations lower in the basin because of the increase in the variability of the factors mentioned above and an increasing number of human sources of diversions, discharges, and impoundments throughout the basin, particularly the Tongue River Reservoir. The USGS stream gauging stations in the basin are shown on Figure 1.

1.3 Long Term Flow Trends, Upper & Lower Basin

The average annual discharge for the Tongue River at Miles City for Water Years 1961 through 2010 is approximately 415.1 cfs (Figure 3). The average annual discharge at the State Line gauging station (Figure 4) for the same period is 436.8 cfs. Long-term low flows were realized in 1961, 2001, 2002, 2004, and 2006. Long term high flows were seen in1947, 1968, 1970, 1971, 1975, and 1978. May 19-20, 1978 saw the largest flood on record, with 17,500 cfs measured at the State Line station and 10,800 cfs measured at the Tongue River Dam station.

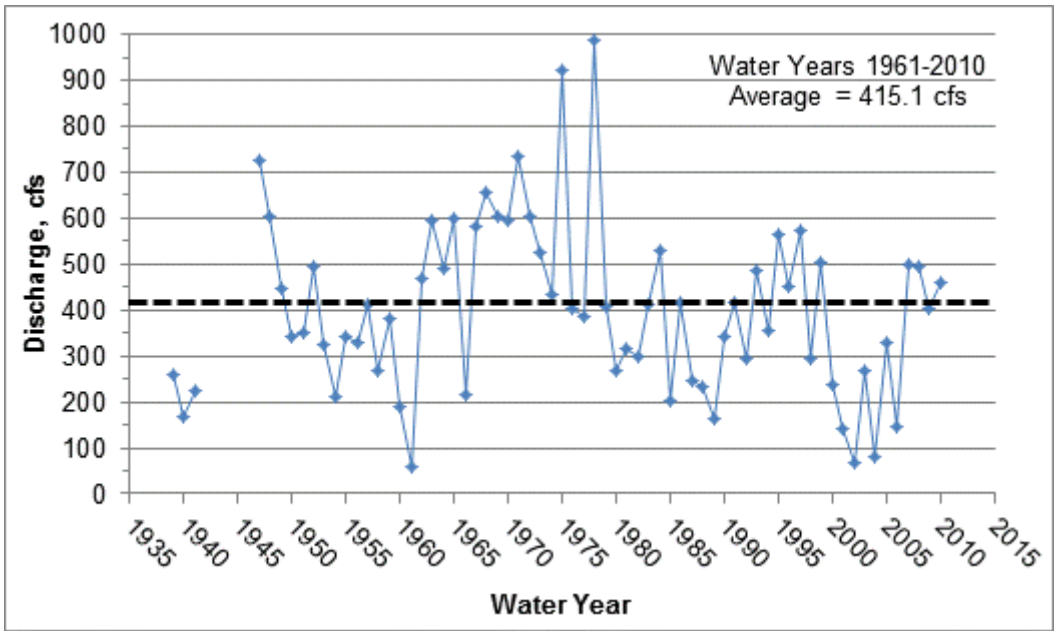


Figure 3 Annual Discharge of the Tongue River at Miles City, MT through Water Year 2010

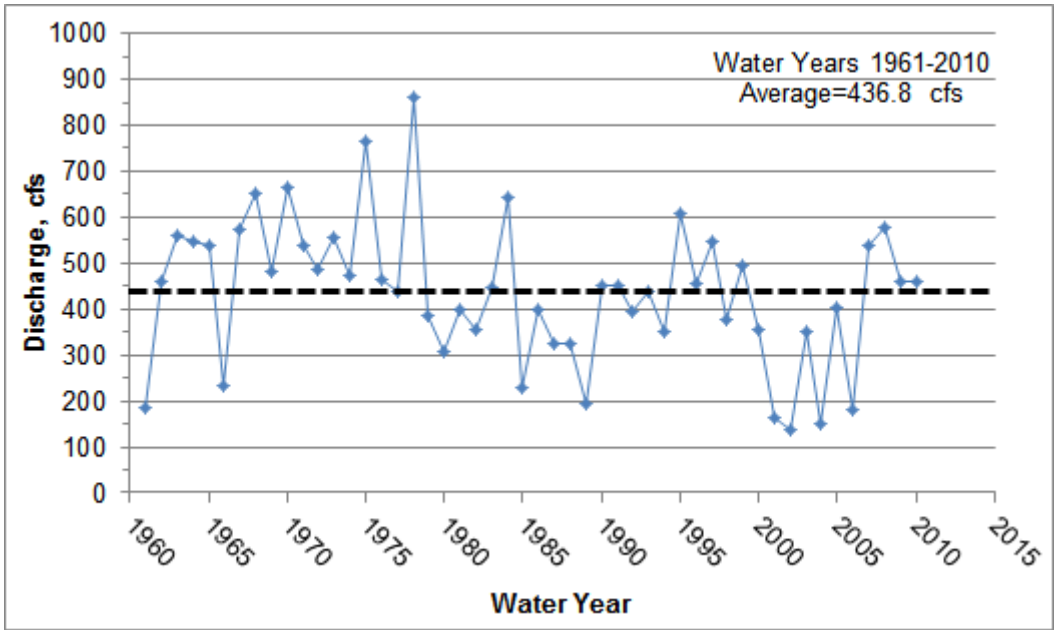


Figure 4 Annual Discharge of the Tongue River at the State Line through Water Year 2010

Over the ten Water Years from 2001 through 2010, the average annual discharge at the State Line and Miles City gauging stations exceeded the respective long term average discharge during Water Years 2007 through 2010. The seven consecutive years of below normal flows from 2000 to 2006 is the longest such series in the monitoring records for the State Line station and the second longest for the Miles City Station. Table 1 summarizes the rank order of annual

discharges from the lowest to the respective median flows over the periods of records for the two stations.

Table 1 Low Annual Average Flows for the Tongue River in Ascending Rank Order

Tongue River at State Line		Tongue River at Miles City	
Year by Rank	**Annual Discharge (cfs)**	**Year by Rank**	**Annual Discharge (cfs)**
2002	137.9	1961	57.2
2004	149.6	2002	67.9
2001	163	2004	79.5
2006	180	2001	143
1961	187.2	2006	147.1
1989	194.4	1989	165.5
1985	227.5	1940	166.5
1966	231.8	1960	187.6
1980	307.7	1985	204.7
1987	324.3	1954	212.2
1988	325.6	1966	215.2
1994	350.8	1941	224.8
2003	350.8	1988	235.1
1982	354.4	2000	237.7
2000	356.3	1987	244.8
1998	378	1939	257.7
1979	385.2	1980	266
1992	396.1	2003	266.2
1981	397.5	1958	268.5
1986	399.8	1998	293.5
2005	404	1992	296.1
1977	436.6	1982	297.2
1993	437.9	1981	318
1983	447.7	1953	324.3
1991	452	2005	329.7
		1956	330.2
		1990	340.6
		1950	340.7
		1955	343.2
		1951	351.8
		1994	354.6
		1959	382.2
		1977	384.1
		1976	401.7

Source: U.S. Geological Survey 2011

Principal statistics of annual discharge at USGS gauging stations from Dayton, Wyoming to Miles City, Montana are provided in Figure 5, including the median, mean, 25th percentile, 75th percentiles, maximum flows, and minimum flows. The stations are plotted according to their river mile distance upstream from the mouth of the Tongue River near Miles City. The historic discharge data available at each station prior to, and through, Water Year 1999 (in key as Pre-2000) are shown with the various shades of gray representing the statistics shown in the key. For this study, pre-2000 data are regarded as the baseline period prior to CBNG development in the basin. The period and frequency of records varies among the stations. The same statistics

calculated for the daily 2010 Water Year data are plotted on Figure 5 as colored points for each of the USGS Tongue River stations having both historic and current data.

Figure 5 indicates that Water Year 2010 discharges were above the pre-2000 minimums at all stations and near or below the pre-2000 25th percentiles, means, medians, and 75th percentiles. The station at Birney Day School was the only site where daily maximum flows exceeded pre-2000 maximums.

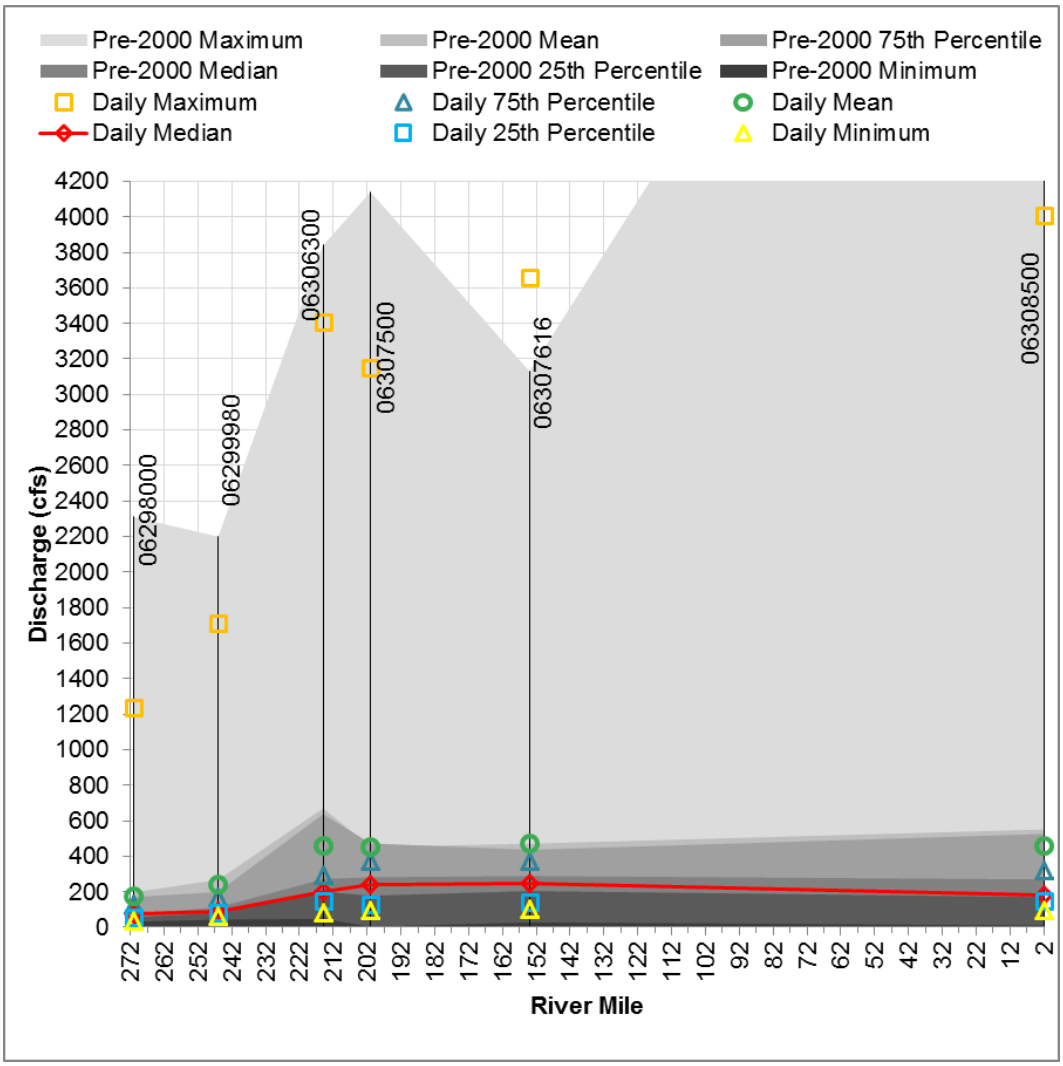


Figure 5 Statistics of Annual Discharge for Tongue River stations at Dayton, Monarch, State Line, TR-Dam, Birney, and Miles City, Montana.

Statistics for all historic data through Water Year 1999 are shown in shades of gray. Some maximum historic values plot above the discharge scale shown. Daily statistics for the 2010 Water Year are shown as colored points. Refer to Figure 1 for station locations.

A comparison of average annual discharge of the Tongue River at gauging stations between the State Line and Miles City indicates that in some years there are net increases in flow, while in others there are net decreases. Evaporation from the river and wet areas, riparian zone

transpiration, and crop irrigation tend to deplete streamflow except in years where surface runoff and groundwater contributions from the lower basin are sufficient to offset these losses.

A summary of average annual discharges at the USGS gauging stations at State Line, Tongue River Dam and Miles City for Water Years 1961 through 2010 is provided in Table 2. Gray-shaded entries designate values which are less than that of the upstream gauging station, indicating years when net decreases in average flow occurred between the stations.

Table 2 Trends in Down River Average Annual Discharge of the Tongue River Water Years 1961-2010

Water Year	State Line (cfs)	TR Dam (cfs)	Miles City (cfs)
1961	187.2	153.6	57.2
1962	458.1	487.1	467.5
1963	559.4	581.9	595.6
1964	549.1	565	489.9
1965	539.2	542.3	601.5
1966	231.8	270.1	215.2
1967	571.4	567.1	581.6
1968	652.5	628.2	658.3
1969	482.6	512.2	603.7
1970	664.3	662.4	593.2
1971	539.5	554.2	735
1972	487.1	485.4	604.1
1973	555.5	564.5	526
1974	474	484.5	432
1975	763.5	782.2	923.7
1976	463	414.5	401.7
1977	436.6	436.6	384.1
1978	861.6	853.4	986.2
1979	385.2	376.6	406.7
1980	307.7	319.3	266
1981	397.5	373.9	318
1982	354.4	325.7	297.2
1983	447.7	445.9	413.4
1984	644.8	610.7	529.6
1985	227.5	249.8	204.7
1986	399.8	406	417.3
1987	324.3	295.8	244.8
1988	325.6	340.3	235.1
1989	194.4	206.4	165.5
1990	452.4	425.7	340.6
1991	452	422.3	417.3
1992	396.1	374.3	296.1
1993	437.9	445.7	484.9
1994	350.8	348.4	354.6
1995	606.1	637.8	562.9
1996	455.5	480.5	449.8
1997	548	572.2	573.6
1998	378	388.2	293.5
1999	494.7	468	502.9
2000	356.3	349.7	237.7
2001	163	174	143
2002	137.9	133.3	67.9

Water Year	State Line (cfs)	TR Dam (cfs)	Miles City (cfs)
2003	350.8	309.1	266.2
2004	149.6	162.3	79.5
2005	404	366.2	329.7
2006	180	175.8	147.1
2007	540.5	526.1	497.4
2008	578.8	578.3	492.9
2009	461.4	447.7	403.4
2010	461.4	454.7	461

Note: Gray shading indicates stations having net streamflow loss with respect to the up-stream gauging station.
Source: U.S. Geological Survey 2011

The data for the Tongue River Dam station indicates that over the 50 years of record, 23 years show gains and 27 years show losses compared to the State Line station, with an average loss of 2 cfs. The Miles City gauging station had 16 years of average streamflow gains, with 34 years of losses when compared to the gauging station at Tongue River Dam, with an average loss of 20 cfs.

1.4 Relation of Flow to Quality

Many authoritative sources have established that the water quality of the Tongue River and that of many streams in the region are directly related to the quantity of flow. A 2007 report by the U.S. Geological Survey, in cooperation with the Wyoming Department of Environmental Quality and Clark and Mason 2007 studied the trends in water quality at 22 sampling sites in the Tongue, Powder, Cheyenne and Belle Fourche River systems in Wyoming. They specifically examined the relation of streamflows to SC and SAR, as illustrated by the following excerpts from their report:

- "Water-quality constituents frequently are correlated with streamflow."

- "Specific conductance and streamflow for Water Years 2001–05 were negatively correlated at all 22 sampling sites; however, the strengths of the relations were variable. For most streams, the largest specific-conductance values tended to occur during low-flow conditions, when ground water composes a large part of the streamflow. Correspondingly, the smallest values tended to occur during high streamflows associated with precipitation runoff."

- "SAR and streamflow were negatively correlated at 21 of the 22 sites. Similar to specific conductance, the largest SAR values tended to occur during low-flow conditions, when ground water composes a large part of the streamflow."

In their summary, the authors concluded:

- "An analysis of specific conductance and sodium-adsorption ratios indicated both constituents generally had inverse relations with streamflow; thus, the largest concentrations tended to occur during low flows when ground water composes a large part of the streamflow." *(Clark and Mason 2007).*

The U.S. Environmental Protection Agency (EPA) conducted an assessment of water quality in the Tongue River, Tongue River Reservoir, and all the principal tributaries in Montana (U.S. Environmental Protection Agency, Tetra Tech, Inc 2007). The EPA report included charts similar to Figures 6 through 13 below, and concluded that:

- "SC in the Tongue River increases with decreasing flow. The relationship between SC and flow is strongest upstream of the Tongue River Reservoir Dam, as exemplified at the Dayton, Monarch, and Stateline stations in Figure 3-3. Downstream of the Tongue River Reservoir Dam, the relationship weakens, with the weakest relationship (R^2 = 0.3821) occurring at the Miles City gage."

EPA found a similar relationship between flow and SAR, stating:

- "As evidenced by Figure 3-13, SAR tends to increase with decreasing flow. The relationship between SAR and flow is strongest at the Stateline gauge (R^2 of 0.8044)"

Weaker relationships at down-stream stations are due to the higher mineral content of runoff derived from the more abundant shale and siltstone terrain found in the lower portion of the basin. The relationship between salinity and streamflow may be made by comparing the SC of the water with the rate of flow at each Tongue River gauging station. Figures 6 through 9 provide charts displaying this relationship for the main USGS gauging stations along the Tongue River, from upstream to downstream. Similar streamflow-water quality relationships can be seen for SAR in Figures 10 through 13. Each point represents one concurrent measurement of discharge and water quality. Note that in each chart, green circle symbols represent the period of record through Water Year 1999, blue square symbols represent the period from Water Years 2000 through 2009, and the triangles are data for Water Year 2010. The earliest CBNG production in the basin began in 1999 in both Wyoming and Montana. River discharge is portrayed on a logarithmic scale. If there were trends of increasing SC and/or SAR since 2000, the data since 2000 would be evident on these graphs as a shift of those data points above the range of the pre-2000 data, at any given rate of flow.

The charts reveal that SC and SAR for comparable flows at all of the gauging stations remain relatively consistent. The graphs indicate that many of the data points in the 2000-2009 category are shifted slightly to the left, which is indicative of the lower flows primarily in the period of 2000 - 2006. If the SC and SAR had increased, it would be denoted on the graphs by an upward shift of the data points. The range in distribution of the data points since 2000 is generally within that of the pre- 2000 data points.

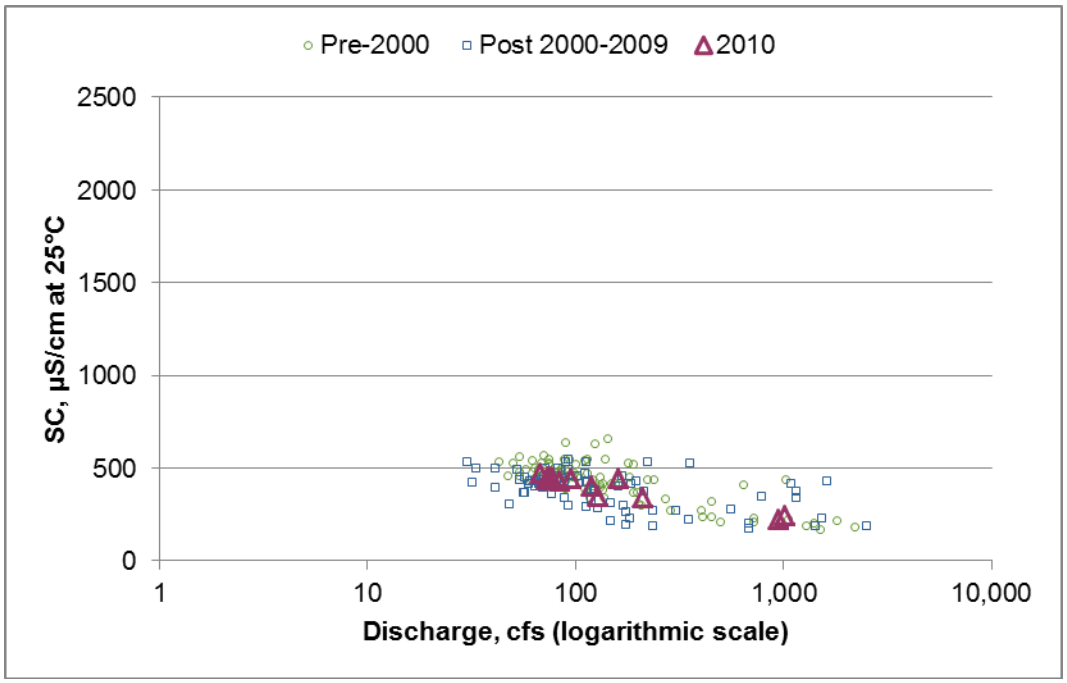


Figure 6 SC versus Discharge for the Tongue River at Monarch, WY

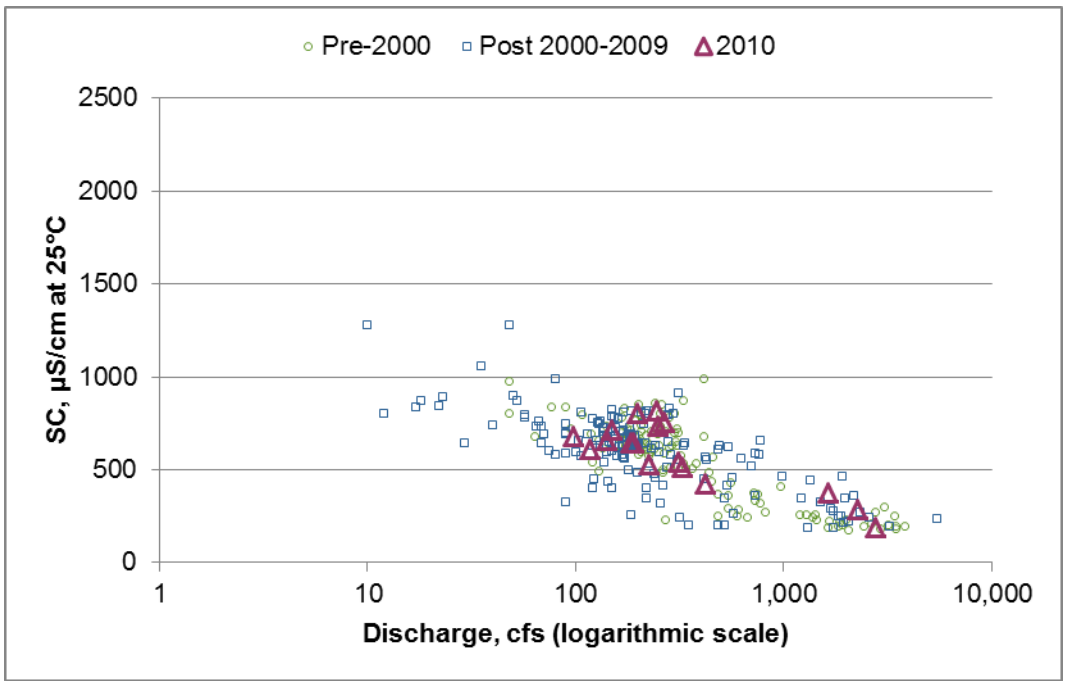


Figure 7 SC versus Discharge for the Tongue River at the State Line

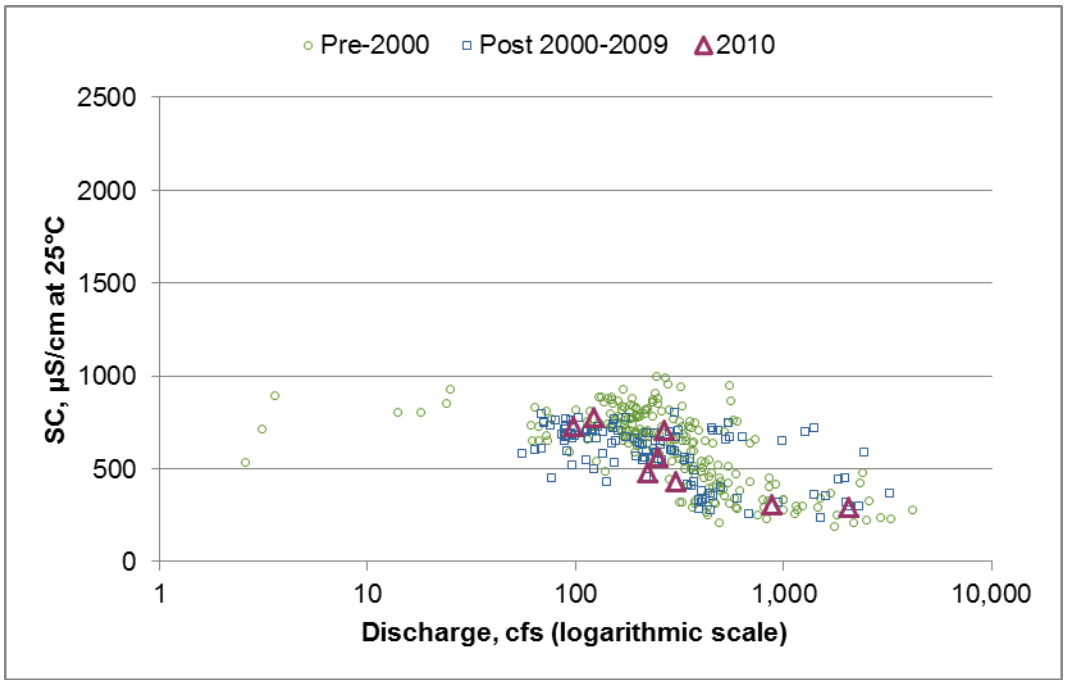


Figure 8 SC versus Discharge for the Tongue River at Tongue River Dam

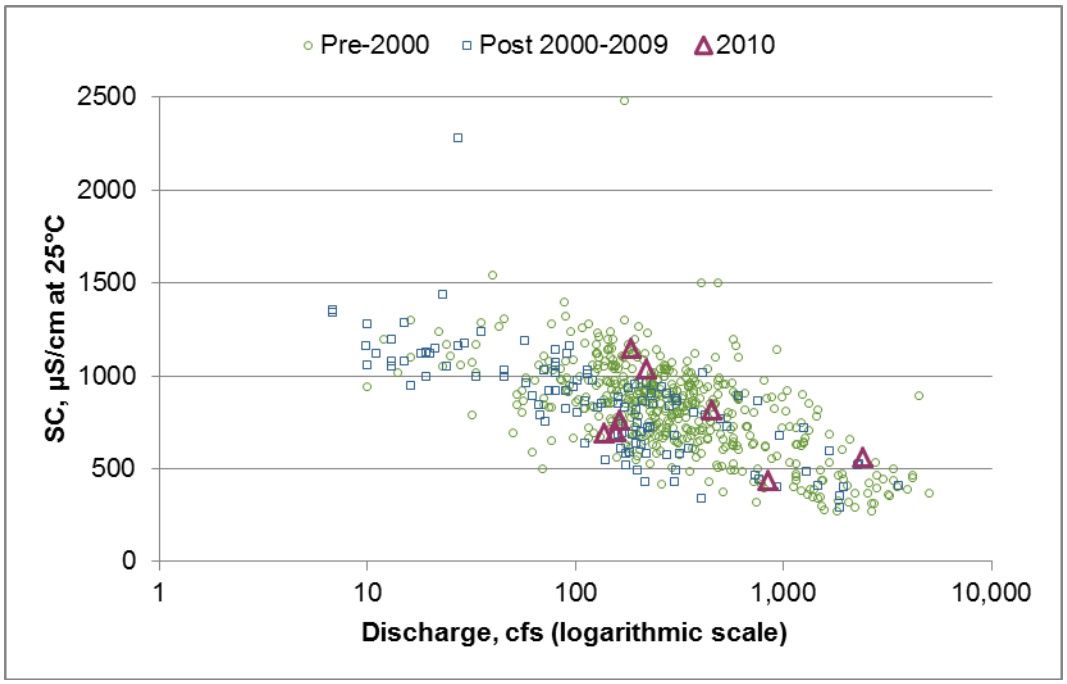


Figure 9 SC versus Discharge for the Tongue River at Miles City, MT

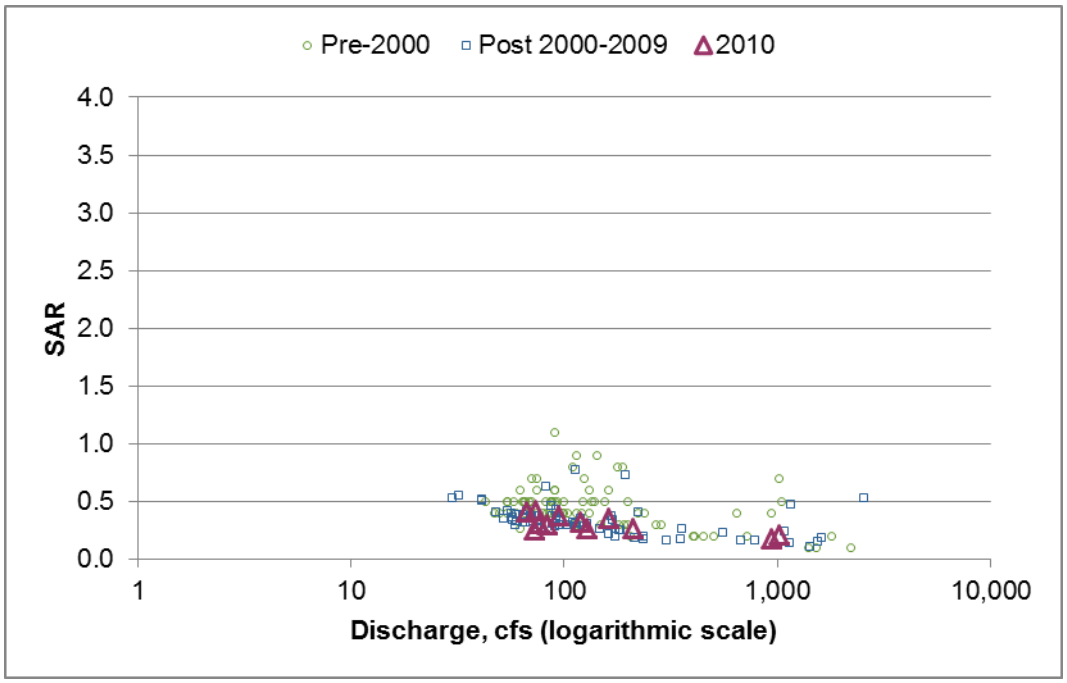


Figure 10 SAR versus Discharge for the Tongue River at Monarch, WY

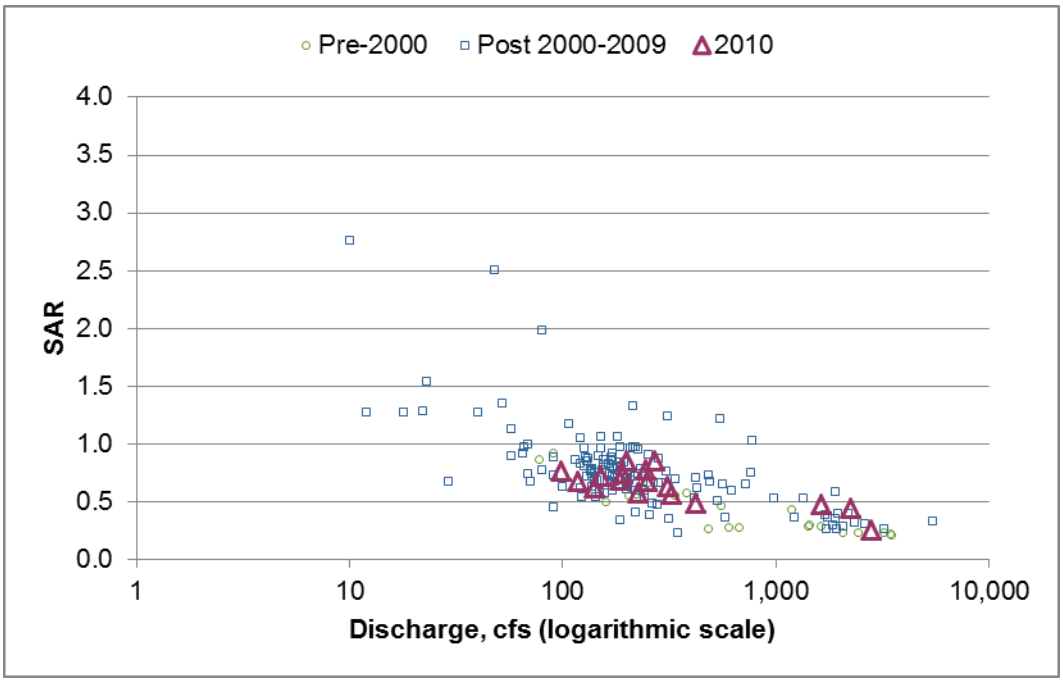


Figure 11 SAR versus Discharge for the Tongue River at the State Line

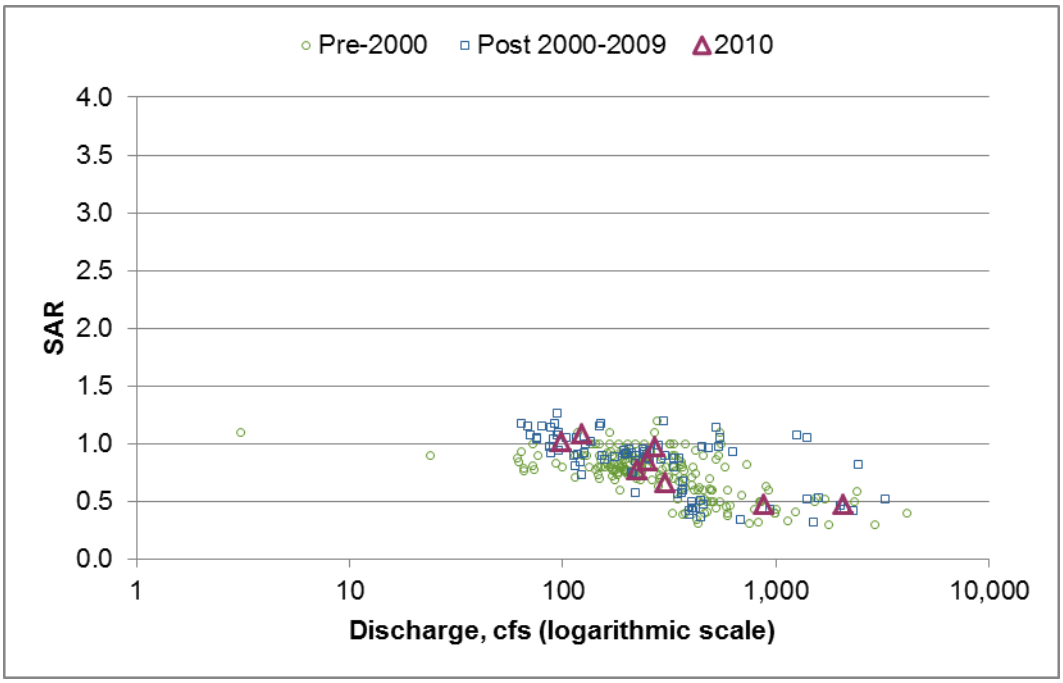


Figure 12 SAR versus Discharge for the Tongue River at Tongue River Dam

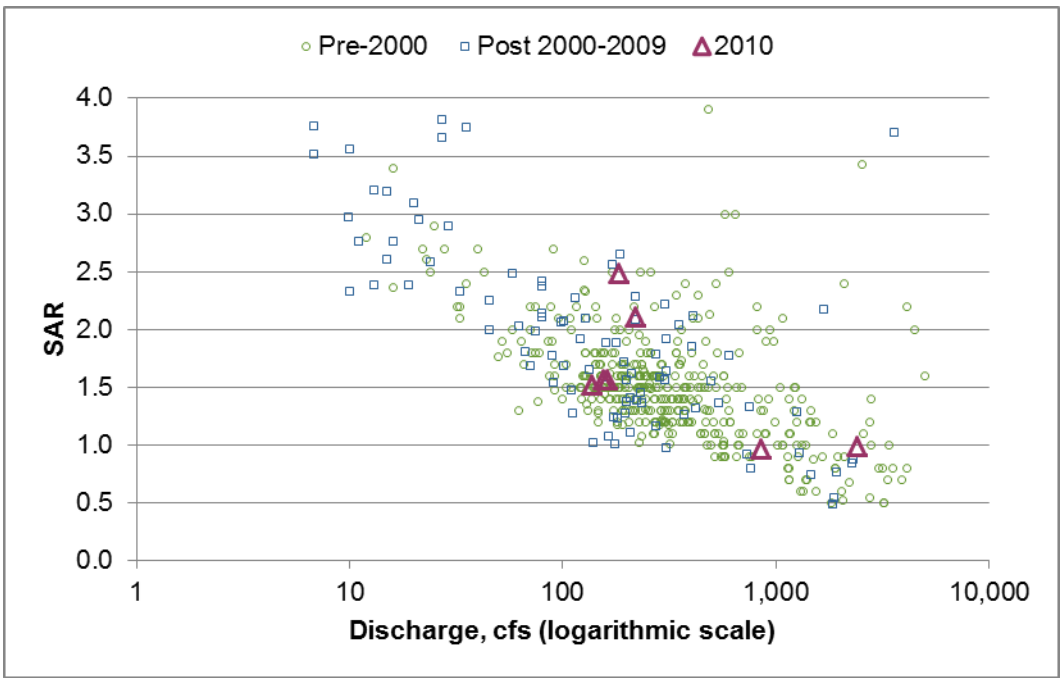


Figure 13 SAR versus Discharge for the Tongue River at Miles City, MT

Detailed statistical tests of water quality trends were not performed in this study. However, the USGS study by Clark and Mason (2007) conducted statistical analyses of SC at two Tongue River basin stations. This report characterized the water quality at 22 sampling sites in the Tongue, Powder, Cheyenne, and Belle Fourche River drainage basins. Data for general

hydrology, field measurements, major-ion chemistry, and selected trace elements were summarized, and specific conductance and SAR were evaluated for relations with streamflow and seasonal variability. Trend analysis for Water Years 1991–2005 was conducted for selected sites and constituents to assess change through time. The authors made the following finding in the Abstract of the paper:

> *Eight sites in the Tongue, Powder, and Belle Fourche River drainage basins having sufficient long-term data were evaluated for trends in SC during Water Years 1991–2005. Trends in SC were found to be not significant (p-values greater than 0.10) at the eight sites when values were flow-adjusted for streamflow variability*.

Thus, the USGS did not find any trend up or down in the SC data from the stations they evaluated. Their analysis included the USGS stations on the Tongue River at the State Line and Goose Creek below Sheridan.

1.5 Seasonal Trends in SC and SAR

The SC and SAR of the Tongue River have natural seasonal variations. These seasonal patterns reflect changes in the flow regime of the river, notably a period of the higher flows in April through June when mountain snowmelt occurs. The average daily SC and SAR of the principal USGS gauging stations along the river for Water Year 2010 are displayed in Figures 14 and 15.

Montana has numeric water quality standards for SC and SAR (Montana Secretary of State 2007) while the State of Wyoming has narrative standards. The Montana standards have monthly average and maximum value limits which vary according to source water and season. These standards are summarized in Table 3.

Table 3 Montana's Numeric Salinity (SC*) and SAR Standards for the Tongue River, Tongue River Tributaries and Tongue River Reservoir

Waterbody	Season	Monthly Average SC (µS/cm)	Maximum SC (µS/cm)
Tongue River	Nov 1 – Mar 1	1,500	2,500
	Mar 2 – Oct 31	1,000	1,600
Tributaries	Nov 1 – Mar 1	500	500
	Mar 2 – Oct 31	500	500
Tongue River Reservoir	Nov 1 – Mar 1	1,000	1,500
	Mar 2 – Oct 31	1,000	1,500
		Monthly Average SAR (µS/cm)	**Maximum SAR (µS/cm)**
Tongue River	Nov 1 – Mar 1	5.0	7.5
	Mar 2 – Oct 31	3.0	4.5
Tributaries	Nov 1 – Mar 1	5.0	7.5
	Mar 2 – Oct 31	3.0	4.5
Tongue River Reservoir	Nov 1 – Mar 1	3.0	4.5
	Mar 2 – Oct 31	3.0	4.5

**Montana's standards refer to EC or electrical conductivity, which is equivalent to SC or specific conductance as applied.*
Source: (Montana Secretary of State 2007)

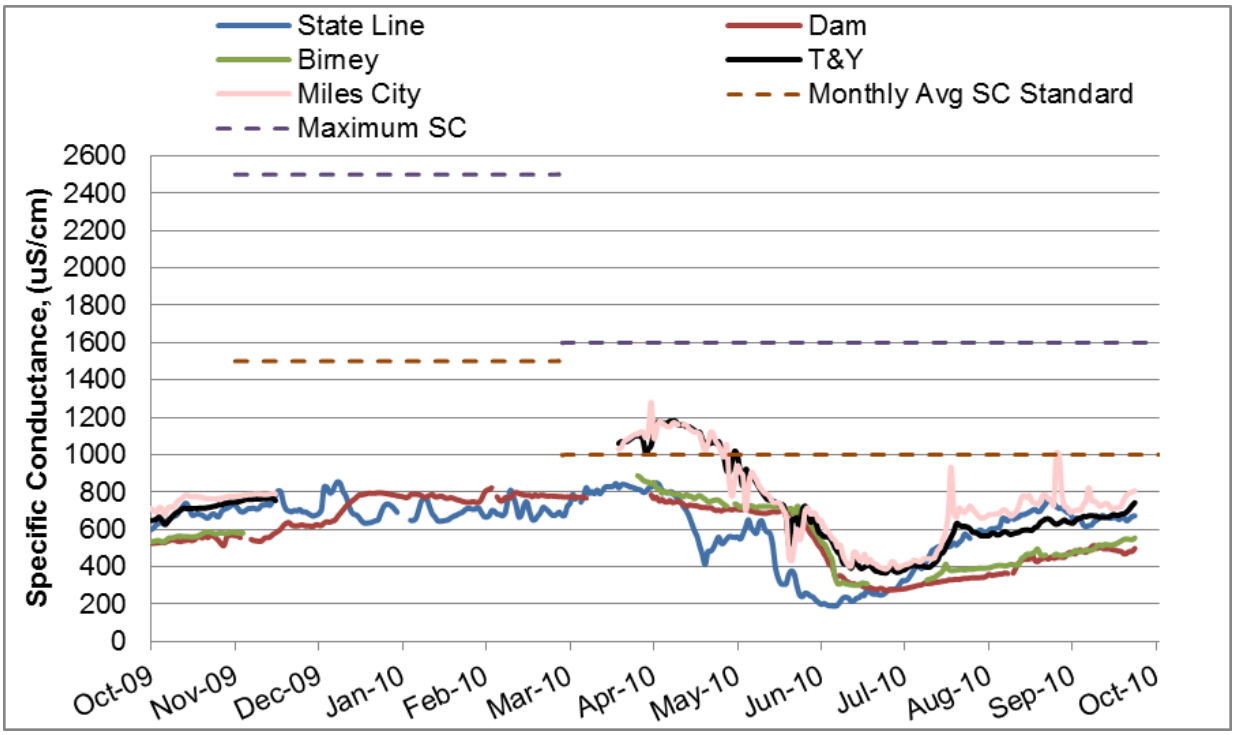


Figure 14 Daily SC at Five Tongue River Stations, Water Year 2010

Source: U.S. Geological Survey 2011

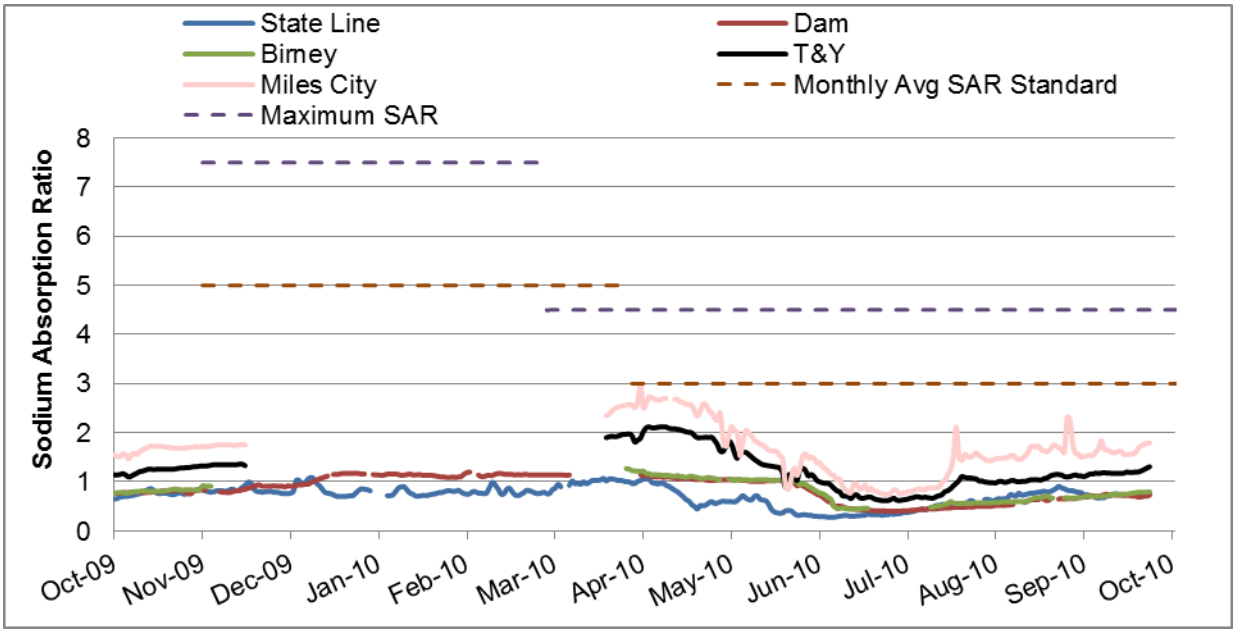


Figure 15 Daily SAR at Five Tongue River Stations, Water Year 2010

Source: U.S. Geological Survey 2011

The highest SC values were seen at the Miles City and T&Y gauges in the spring, with the average monthly concentration values exceeding the Montana Average SC standard during a portion of March (data collection began March 23), and April. None of the upstream monitoring

sites had monthly average SC above the Montana Average SC Standards during the 2010 Water Year. No sites had maximum SC readings above the Montana Maximum SC Standards during the 2010 Water Year. High SC values are typically seen in spring just before the onset of mountain snowmelt, when groundwater base flow and runoff from low-elevation areas contributes salts and sediment.

The salinity declines dramatically throughout the basin during the period of spring runoff, dropping from annual highs ranging around 1,000 to 2,000 µS/cm in April to annual lows ranging around 200 to 400 µS/cm in June. Salinity gradually climbs at all stations throughout summer, when high temperatures and lower flows result in a higher concentration of salts from evaporation and transpiration by riparian vegetation. The point sources and non-point sources of salinity along the river (discussed in section 4.0) have a larger effect on river SC as stream flow declines throughout the summer. Salinity stabilizes or declines with the onset of cooler weather in September and October.

The Tongue River Reservoir stores mountain runoff and releases it later in the irrigation season, producing a delay in the downstream seasonal low SC compared to that above the reservoir. The seasonal trend of SAR generally follows that of SC, though with slightly less dramatic fluctuations. There were no sites whose average monthly SAR exceeded the Montana Average SAR standard during the 2010 Water Year, nor did any of the monitored sites have SAR results above the Montana Maximum SAR Standard.

The USGS report by Clark and Mason (2007) studied the statistical evaluation of seasonality in SC and SAR. Seasonal variability of these parameters was statistically significant for streams that have headwaters in mountainous areas such as the Tongue River and Goose Creek. Seasonal variability in SC generally was not statistically significant for streams that have headwaters in the plains. However, seasonal variability generally was observed for sodium-adsorption ratios at these sites.

Most CBNG discharges, which have a greater proportion of sodium than other sources, lie above the state line station, and all lie above the TR-Dam Station. Figure 15 indicates that sources of sodium, other than CBNG discharges, are causing the increased SAR at the T& Y and Miles City gauges. The SAR at all stations was less than the State of Montana monthly average and maximum SAR Standard.

1.6 Down-River Trends in SC and SAR

The Tongue River accumulates more salinity and sodium in its downstream travel which follows a trend that is common to many streams in the western United States. Principal statistics of SC at USGS gauging stations from Dayton, Wyoming to Miles City, Montana are provided in Figure 16. The stations are plotted according to their river mile distance upstream from the mouth of the Tongue River near Miles City. The historic SC data available at each station prior to, and through water year 1999 (in key as Pre-2000) are shown with the various shades of gray representing the statistics shown in the key. The period and frequency of records varies among the stations. The same statistics calculated from daily records for the 2010 water year are

plotted on Figure 16 as colored points. Note that there are no pre-2000 historic data from the station just above the T&Y irrigation diversion dam south of Miles City (06307990), which was established in 2006. Historic data were available for the Tongue River at Dayton, Wyoming (0629800), but water quality data collection ended in August 2002 (USGS 2011).

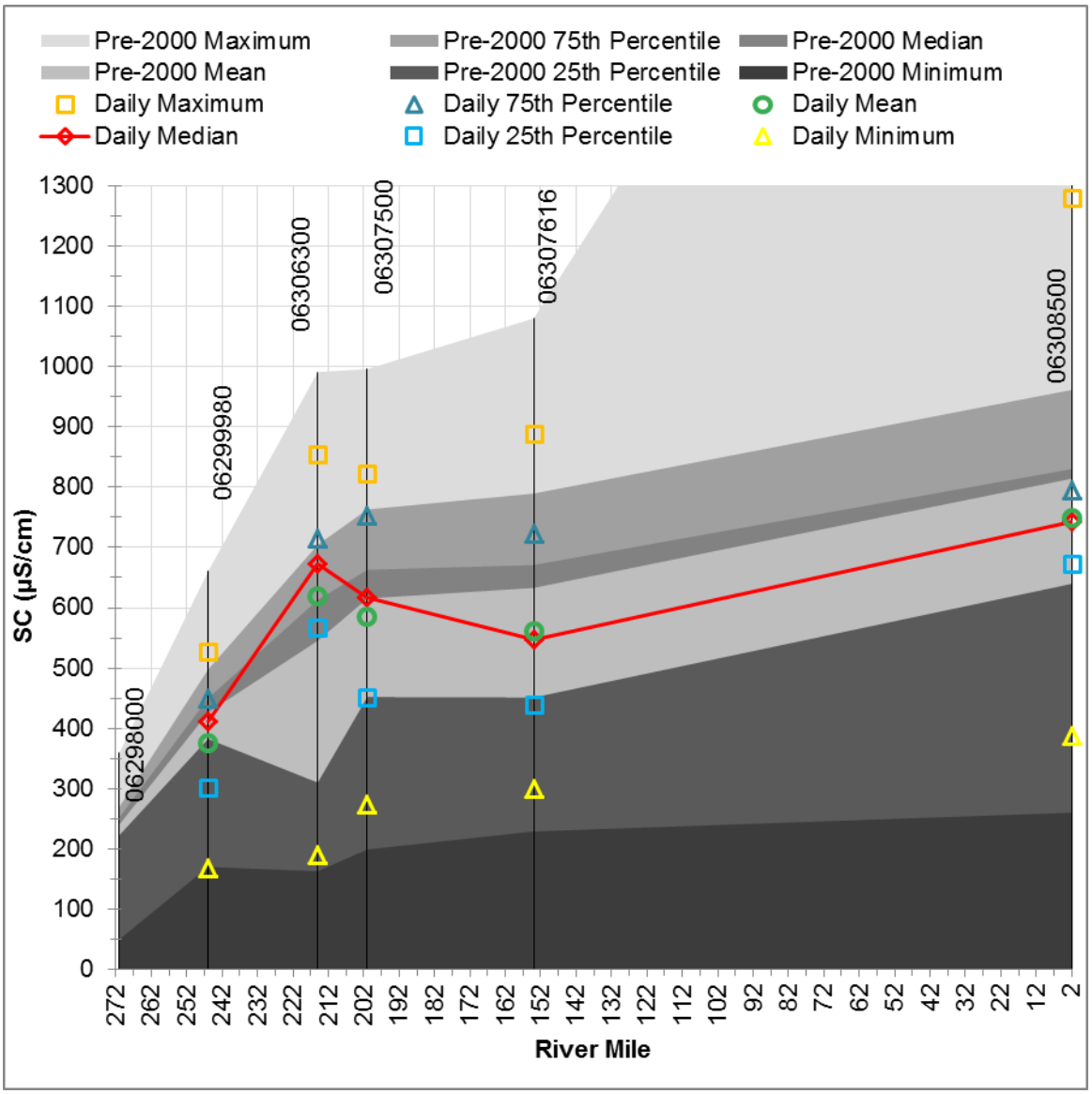


Figure 16 Statistical Trends in SC for Tongue River stations at Dayton, Monarch, State Line, TR-Dam, Birney Day, T&Y, and Miles City.

Statistics for all historic data through Water Year 1999 are shown in shades of gray. 2010 Water Year statistics shown as colored points. Maximum historic values may plot above the scale shown. Refer to Figure 1 for station locations.
Source: U.S. Geological Survey 2011

The largest increase in SC historically occurred between Dayton, Wyoming and the State Line stations where the Tongue River leaves the Big Horn Mountains and enters the prairie. Naturally occurring salts from the Fort Union formation in this reach are more abundant in the soils, and

the soils are more erodible than those of the mountains. Irrigation diversions and return flows begin to alter the natural flow and water quality of the river in this reach. Salinity is contributed by Goose Creek, which averages 50% to 60% higher salt concentration than does the Tongue River at the Monarch station just two miles upstream from their confluence (U.S. Geological Survey 2010). Goose Creek drains the city of Sheridan and a large irrigated area. Salinity is also contributed by Prairie Dog Creek, which is a plains stream having naturally higher SC and SAR than mountain-fed streams. Flow and water quality in Prairie Dog Creek are also affected by three transbasin water diversions into the creek from North Piney Creek and South Piney Creek, irrigation diversions, and return flows. Although no USGS water quality data exist for the Prairie Dog Creek site prior to 2000, SC data since then average approximately 1,445 µS/cm @25ºC (USGS 2011).

A small historical SC increase occurs between the State Line and Tongue River Dam stations. Historical salinity factors in this reach include the salt-concentrating effect of lake evaporation, shoreline erosion, and permitted discharges from pit dewatering from the Decker Coal Company.

SC has historically been stable between the Tongue River Dam and Birney, Montana stations. Limited irrigation occurs in this reach. Moderate increases in SC typically occur between the stations at Birney and Miles City, Montana. Contributing factors include irrigation diversions and return flows as well as salt inputs from Otter Creek and other ephemeral tributaries.

Figure 16 indicates that historically, the SC increases by 150 to 190 µS/cm between the Birney and Miles City stations, with the exception of maximum values, which increased more steeply at times. Historic maximum values at these stations have exceeded the Montana numeric salinity criteria at times in the past. Between Brandenburg and Miles City, the surficial geology of the basin transitions from the Tongue River member of the Fort Union Formation to the Lebo Shale and the Tullock members, which are erodible and contain more natural salinity and sodium. Pumpkin Creek contributes salinity and sodium to the Tongue River via surface and sub-surface flow, with most measurements exceeding the applicable Montana SC and SAR standards (Bobst 2008). In addition, irrigation diversions decrease the dilution capacity of the river, and irrigation return flows, which follow surface and subsurface pathways, contain higher salinity and sodium concentrations than the river. During low flow periods, the water quality that is monitored at the Miles City station is more representative of irrigation return flows and groundwater base flow than of typical Tongue River flow, because most of the water in the Tongue is diverted for irrigation during low flows (Bobst 2006).

Figure 16 indicates that for sites where daily data were available for the 2010 Water Year, daily maximum and 75th percentile SC values during Water Year 2010 were close to or less than the corresponding pre-2000 levels at all stations. Median and average SC were less than pre-2000 values at all gauging stations, with the exception of State Line, where these daily statistics trended higher than historic. As discussed above in connection with Figure 5, the average discharge at the State Line was also less than the pre-2000 average. Minimum SC values were close to or greater than pre-2000 levels at all stations.

Since 1999, outfalls of CBNG discharges have occurred upstream and downstream from the State Line station under Fidelity Exploration & Production Company's MPDES permits for untreated produced water (MT0030457) and treated water (MT0030724) (see Section 4.0 for more discussion). In 2010, untreated CBNG discharges have ranged from 0.006 to 3.6666 cfs with SC ranging from 1,515 to 2,693 µS/cm @ 25ºC. Treated CBNG discharge rates have ranged from 1.5 to 2.6 cfs with an SC of about 1,395 µS/cm @25ºC. One CBNG discharge, outfall 016A under Fidelity's MPDES permit MT0030457, occurs between the State Line station and the Tongue River reservoir.

Principal statistics of SAR at USGS gauging stations from Dayton, Wyoming to Miles City, Montana are provided in Figure 17. The historical pre-CBNG trend in SAR shows an increasing trend in the down-stream direction similar to that of SC. However, the pattern of increase in SAR above the Tongue River reservoir differed from that of SC, with the higher historic rate of increase in SAR occuring between the State Line and Dam stations and the higher historic rates of increase in SC occuring between Monarch and the State Line. Historically increases in SAR below the reservoir were relatively greater than that of SC, which is also true for the 2010 Water Year. Many of the factors contributing to SC increases also lead to increases in SAR, but in somewhat different proportions. As noted above, below Brandenburg, the lower members of the Fort Union formation, which tend to contain more sodium-bearing shale, are exposed at the surface.

Soils and groundwater monitoring under the TRIP program at Sites DA and YAA found elevated sodium which appears to be associated with soils derived from ephemeral drainages carved into lower Fort Union deposits (Schafer, Fehringer and Osborne 2011). During the 2010 water year, shallow groundwater beneath irrigated fields at Sites DA and YAA had SAR values of 16 and 11. Dissolved sodium concentrations were 3,466 and 1,961 mg/l, respectively, which is greater than that found in CBNG produced water discharges. SAR and sodium levels at other TRIP field locations were low to moderate.

Figure 17 indicates that for sites where daily data were available for the 2010 Water Year, daily minimum SAR values were greater than pre-2000 levels at all stations. All other daily statistics for the Monarch station were below historic levels. The 2010 water year shows the 25th percentile, median, mean, 75th percentile, and maximums at the State Line, TR Dam, and Birney Day stations were slightly above or within historic ranges. All indicators at the Miles City station were above their respective pre-2000 historic ranges.

In 2010, untreated CBNG discharges had an SAR ranging from 39.5 to 71.5, with sodium concentrations typically between 333 to 767 mg/l. All CBNG discharges, except one outfall of untreated water, occurred upstream of the USGS State Line station.

It is notable that while down-river increases in salinity and SAR have occurred both before and since CBNG development began in 1999, the Tongue River meets Montana irrigation seasonal SC and SAR standards everywhere except during some periods at the Miles City and T&Y gauging stations. The SAR standards were met at the Miles City station throughout Water Year

2010, and SC standards were met for 10 months based on the daily data as well as the periodic water quality sampling conducted by the USGS (2011).

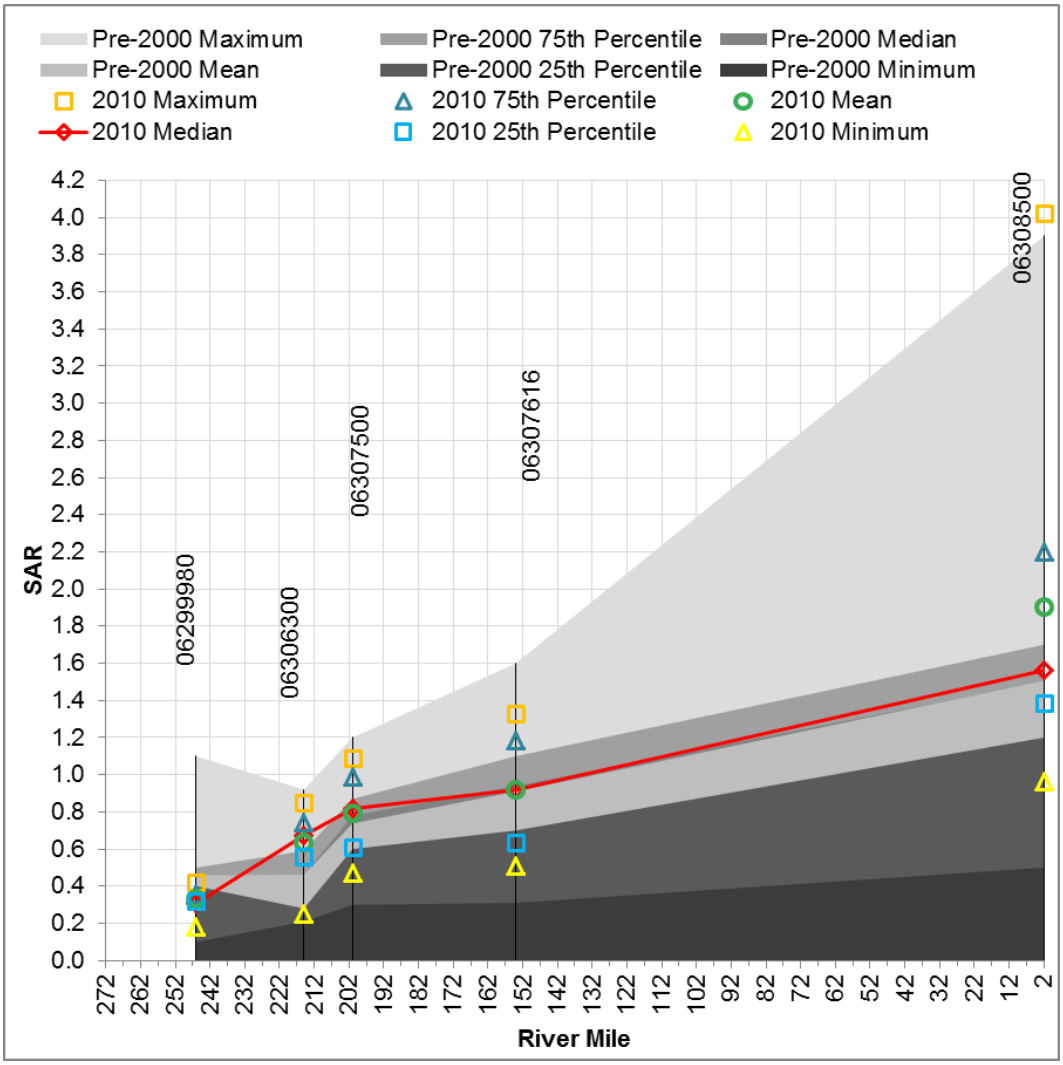


Figure 17 Statistical Trends in SAR for Tongue River stations at Monarch, State Line, TR-Dam, Birney Day and Miles City.

Statistics for All historic data through Water Year 1999 are shown in shades of gray. 2010 Water Year statistics shown as colored points. Maximum historic values may plot above the scale shown. Refer to Figure 1 for station locations.
Source: *U.S. Geological Survey 2011*

The major tributary streams to the Tongue River usually have significantly higher SC and SAR than the Tongue River at their respective confluences. Principal statistics of SC and SAR at USGS gauging stations near the mouths of Prairie Dog Creek, Hanging Woman Creek, Otter Creek, and Pumpkin Creek are provided in Figures 18 and 19, respectively. The stations are plotted according to the river mile distance of the mouth upstream from the mouth of the Tongue River near Miles City. The historic data available at each station prior to, and through Water Year 1999 (in key as Pre-2000) are shown with the various shades of gray representing the statistics shown in the key, with the exception of Prairie Dog Creek which has no data recorded

before 2000. The period and frequency of records varies among the stations. The same statistics for the 2010 Water Year are plotted as colored lines.

Note that water quality sampling of the Tongue River tributary stations has declined since Water Year 2008. Daily SC and SAR are now only available for the Prairie Dog Creek and Hanging Woman Creek sites. The USGS continues to sample Otter Creek and Pumpkin Creek periodically, each of these stations was sampled twelve times in Water Year 2010 (USGS 2011). Water quality monitoring of the Goose Creek station was wholly discontinued in August 2008. Sampling frequency and timing can be a significant factor affecting interpretation of trends.

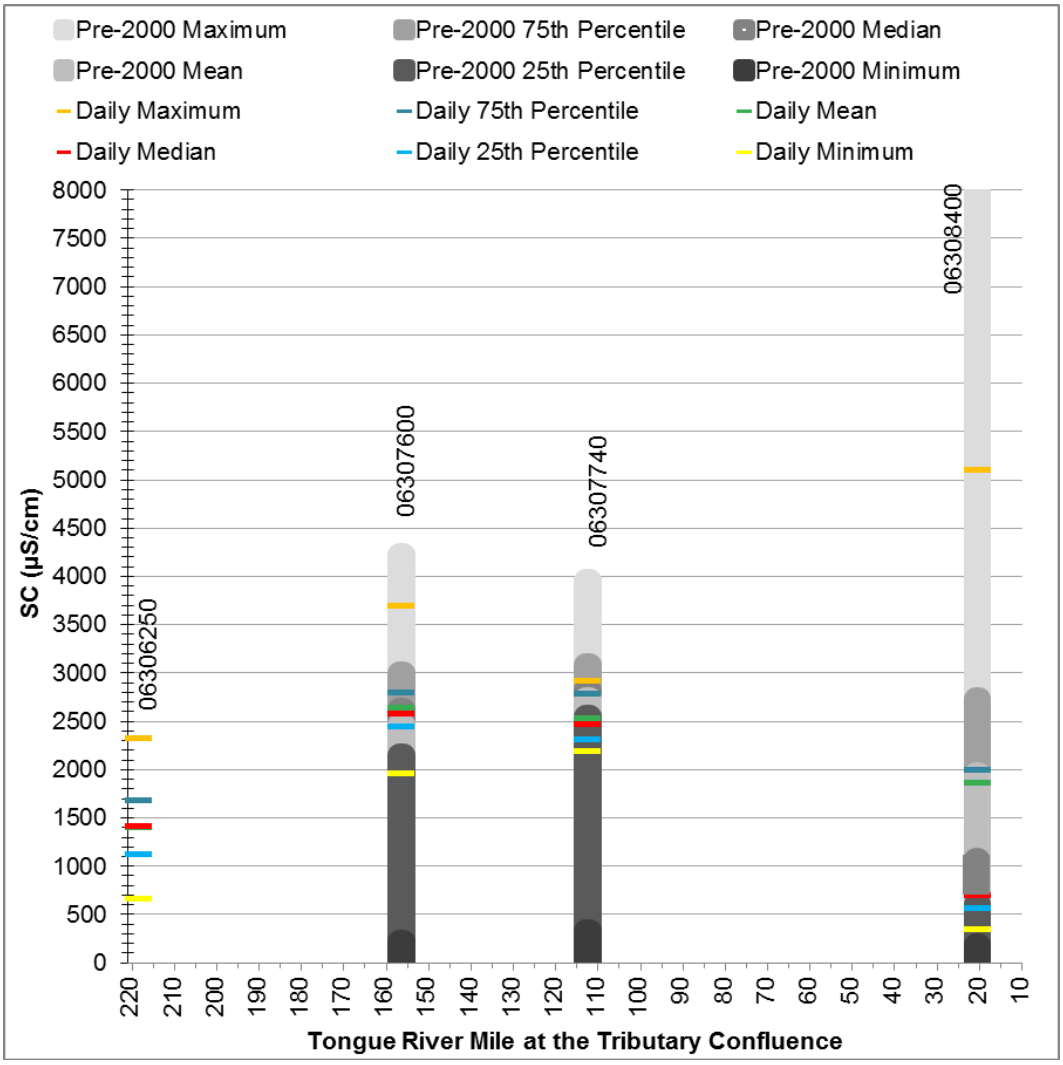


Figure 18 Statistical Trends in SC for Tongue River Tributaries Stations at Prairie Dog Creek, Hanging Woman Creek, Otter Creek and Pumpkin Creek

Statistics for all historic data through Water Year 1999 are shown in shades of gray. 2010 Water Year statistics are shown as colored points and are representative of best available data for each site. Maximum historic values may plot above the scale shown. Refer to Figure 1 for station locations.
Source: U.S. Geological Survey 2011

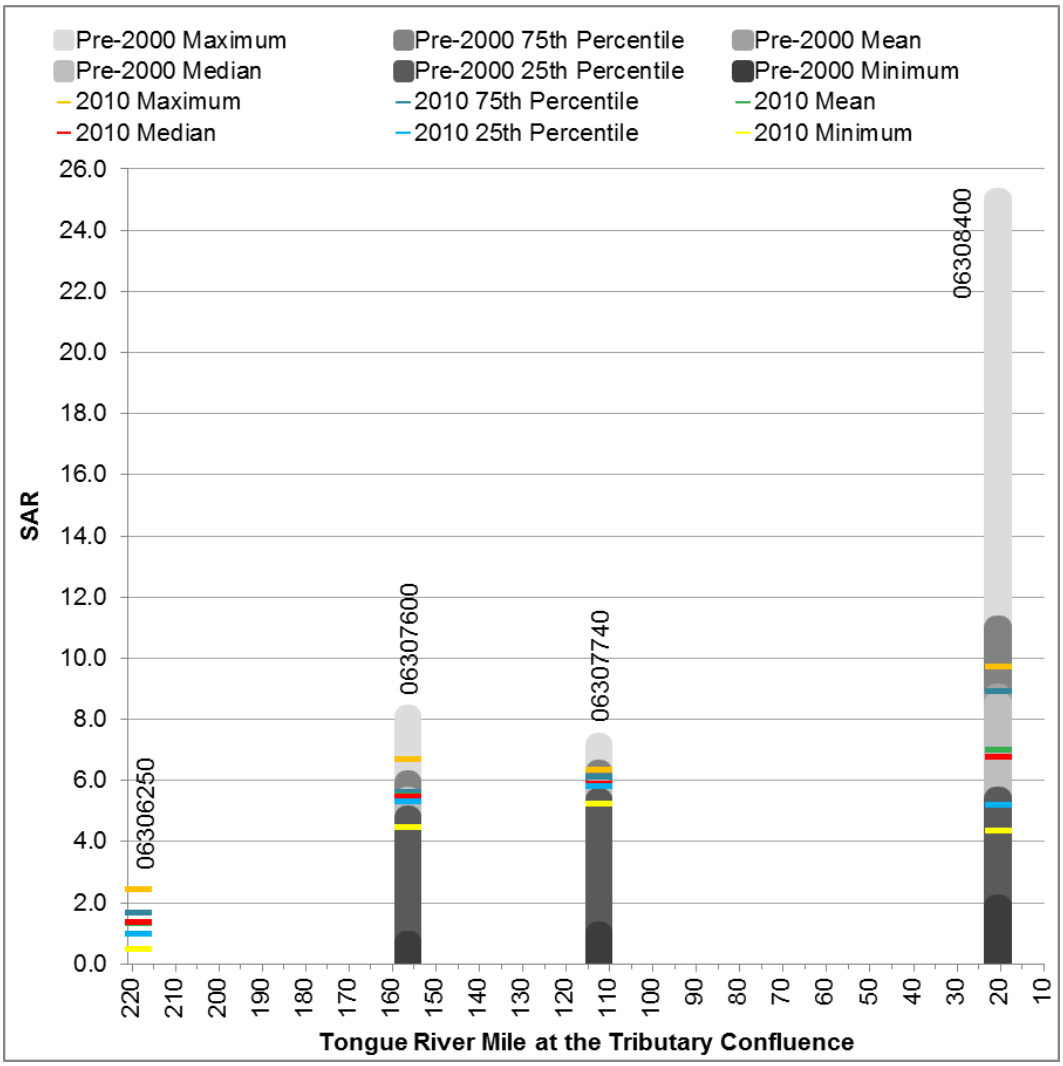


Figure 19 Statistical Trends in SAR for Tongue River Tributary Stations at Prairie Dog Creek, Hanging Woman Creek, Otter Creek and Pumpkin Creek.

Statistics for all historic data through Water Year 1999 are shown in shades of gray. 2010 Water Year statistics are shown as colored points and are representative of best available data for each site. Maximum historic values may plot above the scale shown. Refer to Figure 1 for station locations.
Source: U.S. Geological Survey 2011

The 2010 Water Year average SC of Hanging Woman Creek was higher than pre-2000 levels, but the median and maximum were near or just below historic levels. The 2010 Water Year statistics for Otter Creek showed little variation between sampling events, with all statistics trending below the pre-2000 range, except the minimum and the 25th percentile which were near or higher than historic ranges. 2010 Water Year statistics for Pumpkin Creek are based on twelve laboratory analyses with the median, 75th percentile and maximum statistics being below pre-2000 levels. While the 2010 statistics reflect some values lower and some greater than pre-2000 levels, maximum statistics values did not surpass historic values at any of the tributaries.

The 2010 Water Year SAR 25th percentile, mean, median, and 75th percentile of Hanging Woman Creek were within about 0.5 units of pre-2000 levels. The maximum was within the

range of historic levels and the minimum was greater than historic levels. The 2010 Water Year SAR statistics for Otter Creek all clustered between values of about 5.2 to 6.4, generally or close to within pre-2000 levels, except for the minimum SAR, which was greater than historic. The 2010 Water Year mean, median, 75th percentile, and maximum SAR for Pumpkin Creek fell below pre-2000 levels while the minimum and 25th percentile were higher or within 0.2 units of their respective pre-2000 levels.

In his reports on surface water quality in the Tongue River basin, Bobst (2007; 2008) found that the water quality at tributary stations typically exceeded the Montana Department of Environmental Quality (MDEQ) surface water standards for SC and SAR, and that elevated SC and SAR occurred even in watersheds where little or no CBNG development has occurred. The U.S. Environmental Protection Agency's water quality assessment of the Tongue River (2007) included detailed evaluations of the trends and sources of salinity and sodicity in Hanging Woman Creek, Otter Creek and Pumpkin Creek. A synopsis of the findings of that report follows.

Hanging Woman Creek: Based on all available data, the monthly average standard (<500 µS/cm) is exceeded 100% of the time during both the growing season and non-growing season (where data were available). The instantaneous maximum salinity standard (<500 µS/cm) has been exceeded 99% of the time (2,318 out of 2,331 samples). The monthly average SAR standard (<3.0 in growing season and <5.0 in non-growing season) is exceeded between 98% and 100% during the growing season and 94% during non-growing season. The instantaneous maximum SAR standard (<4.5 in growing season and <7.5 in non-growing season) has been exceeded 70% of the time during the growing season, and 6% of the time during the non-growing season. Extensive CBNG development has occurred in the headwaters region of Hanging Woman Creek in Wyoming, with a total of 341 completed wells and 4 permitted to drill (Wyoming Oil & Gas Conservation Commission 2011). Produced water is managed by discharge to off-channel and on-channel impoundments, managed irrigation and injection. There are no direct discharges of CBNG water to Hanging Woman Creek or its tributaries (Wyoming Department of Environmental Quality 2010). The EPA study reported that, based on their modeling results, the observed exceedances of Montana's SC and SAR standards for Hanging Woman Creek are due to natural causes.

Otter Creek: Based on all available data, the monthly average standard (<500 µS/cm) is exceeded 100% of the time during both the growing season and non-growing season (where data were available). In the main stem of Otter Creek, the instantaneous maximum salinity standard has been exceeded almost 100% of the time during both the growing and non-growing seasons. From 1974 to 2006, the monthly average SAR standard (<3.0 in growing season and <5.0 in non-growing season) is exceeded between 98% and 100% during the growing season and 100% during non-growing season. The instantaneous maximum SAR standard (<4.5 in growing season and <7.5 in non-growing season) has been exceeded 96% of the time during the growing season, and 4.8% of the time during the non-growing season. The EPA study reported that modeling results suggest the exceedances of Montana's SC and SAR standards in

Otter Creek are due largely to natural causes. There is no CBNG development anywhere in the Otter Creek basin.

Pumpkin Creek: Based on all available data (1974 – 2006) the monthly average standard (<500 µS/cm) is exceeded 100% of the time during the growing season. No data are available for the non-growing season. The instantaneous maximum salinity standard (<500 µS/cm) has been exceeded 89% of the time during the growing season and from 86 to 100% of the time during the non-growing season. From 1974 to 2006, the monthly average SAR standard (<3.0 in growing season and <5.0 in non-growing season) is exceeded between 98% and 100% during the growing season and 83% during the non-growing season. The instantaneous maximum SAR standard (<4.5 in growing season and <7.5 in non-growing season) has been exceeded from 67% to 82% of the time during the growing season, and 33% to 55% of the time during the non-growing season. The EPA study reported that modeling results suggest the exceedances of Montana's SC standard in Pumpkin Creek are due largely to natural causes. SAR was not modeled in the EPA study due to insufficient data (U.S. Environmental Protection Agency, Tetra Tech, Inc 2007). There is no CBNG development anywhere in the Pumpkin Creek basin.

2.0 Trends in Water Use, Montana and Wyoming

2.1 Population

The total population for the watershed is not directly available, but may be inferred from the 2010 U.S. Census data. A population analysis found that approximately 32,119 people reside within the Tongue River watershed. The watershed population totals by county are given in Table 4. The Wyoming portion of the Tongue River watershed is home to 27,700 people, which represents 86.2% of the total watershed population. The Montana portion of the watershed contains 44,419 persons, or 13.8% of the total.

Cities and towns account for 19,056 people (59.3%) in the basin, all in Wyoming. Two census designated places in Montana account for an additional population of 961 inhabitants. The remaining 12,102 residents (37.7%) occupy rural areas of the basin. Sheridan, Wyoming is the only urban population center, with 17,444 inhabitants or 54.3%t of the entire population within the watershed. The second largest total county population is found in Custer County, Montana, with 2,555 people (77.9% of the total watershed population). The largest community in the Montana portion of the watershed is the town of Ashland with a population of 824.

Table 4 Population Distribution within the Tongue River Basin

County	Total Watershed Population	Percent of Total Population
Sheridan, WY	27,688	86.2
Custer, MT	2,555	8.0
Rosebud, MT	1,401	4.4
Powder River, MT	383	1.2
Big Horn, MT	80	0.2
Johnson, WY	12	0.0
Total	**32,119**	**100**

Source: U.S. 2010 Census and GIS analysis.

2.2 Principal Water Uses

In the Montana counties that are part of the Tongue River watershed, agriculture accounts for 94.22% of all water used. Of the remaining 5.78% of water use documented for the Montana counties in the Tongue River watershed, industrial uses (including thermoelectric power generation and mining) account for 87.53%, public water supplies for 10.18%, self-supplied domestic sources for 2.25% and Aquaculture for 0.5%. Water use data for the Montana portion of the Tongue River watershed are provided in Figure 20 and show withdrawals by the category for which they were reported.

The Tongue River basin in Wyoming lies primarily in Sheridan County. While there is a small portion of the basin in Johnson County, the water well evaluation did not return water wells in the intersecting area, therefore water use data evaluated here and

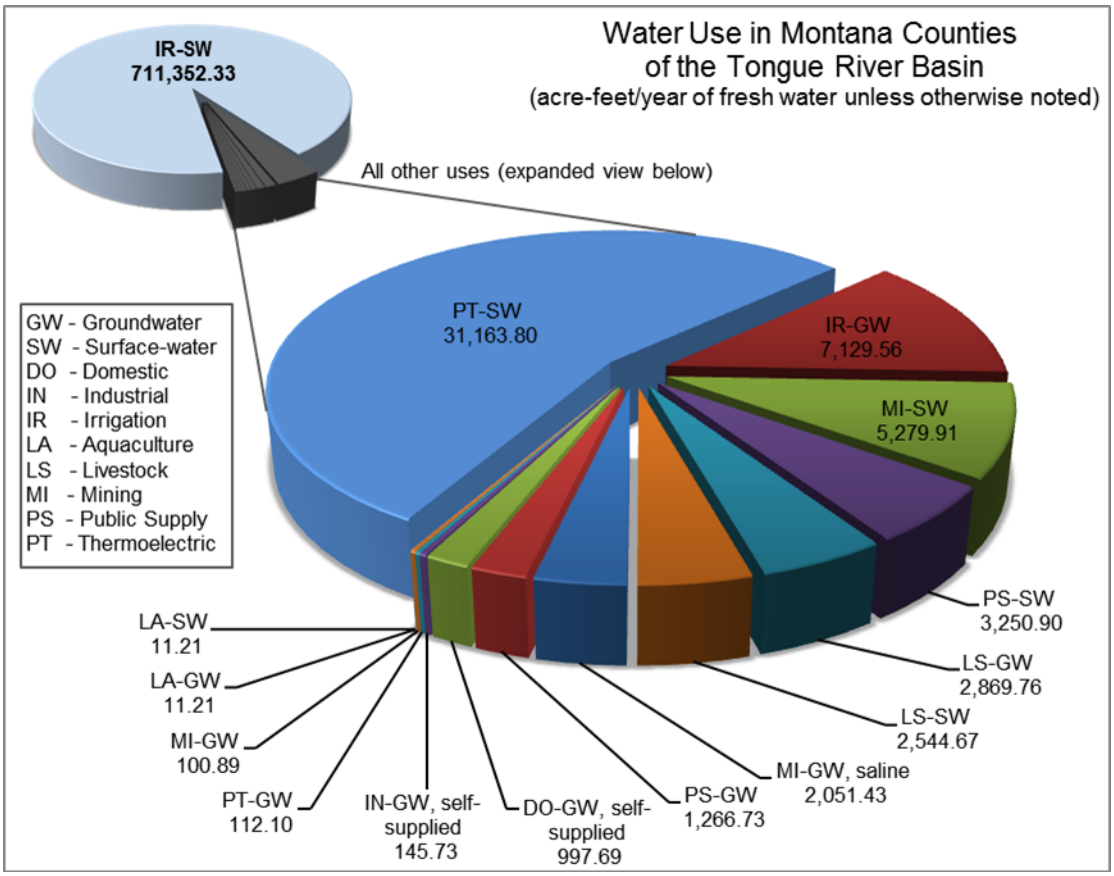


Figure 20 Water Use in Montana portion of the Tongue River Basin
(USGS 2005)

provided in Figure 21 are for Sheridan County. Within Sheridan County, irrigation accounts for 97.34% of all water used. Of the remaining 2.66%, public water supplies account for 85.94%, self-supplied domestic accounts for 9.15%, and industrial uses 4.91%.

The estimated area of irrigated lands obtained from various public sources was significantly different. The time frame, methodology, and resolution behind the data sources all contributed to the variability. In addition, the actual area of irrigated land fluctuates from year to year as the availability of irrigation water changes.

According to the most recent authoritative source, the 2007 Census of Agriculture (U.S Department of Agriculture National Agricultural Statistics Service 2007), irrigated land accounted for 59,570 acres in the Tongue River Basin out of 222,262 acres identified as total cropland, or approximately 27%.

The best visual representation of irrigated lands from the most current land cover datasets publicly available are depicted in Figure 22 (HKM Engineering, Inc.; Lord Consulting, LLC, Watts and Associates, Inc. 2002; Montana Department of Revenue 2010). The irrigated acreage estimates derived from these datasets include Montana areas identified as irrigated and Wyoming areas identified as lands with full and/or partial service irrigation. Other land classification categories that indicated lower intensity irrigation or subirrigation were excluded

from this analysis. The spatial analysis produced an irrigated acreage estimate of 20,686 acres in Montana and 50,478 acres in Wyoming for a total estimate of 71,164 acres for the Tongue River Basin.

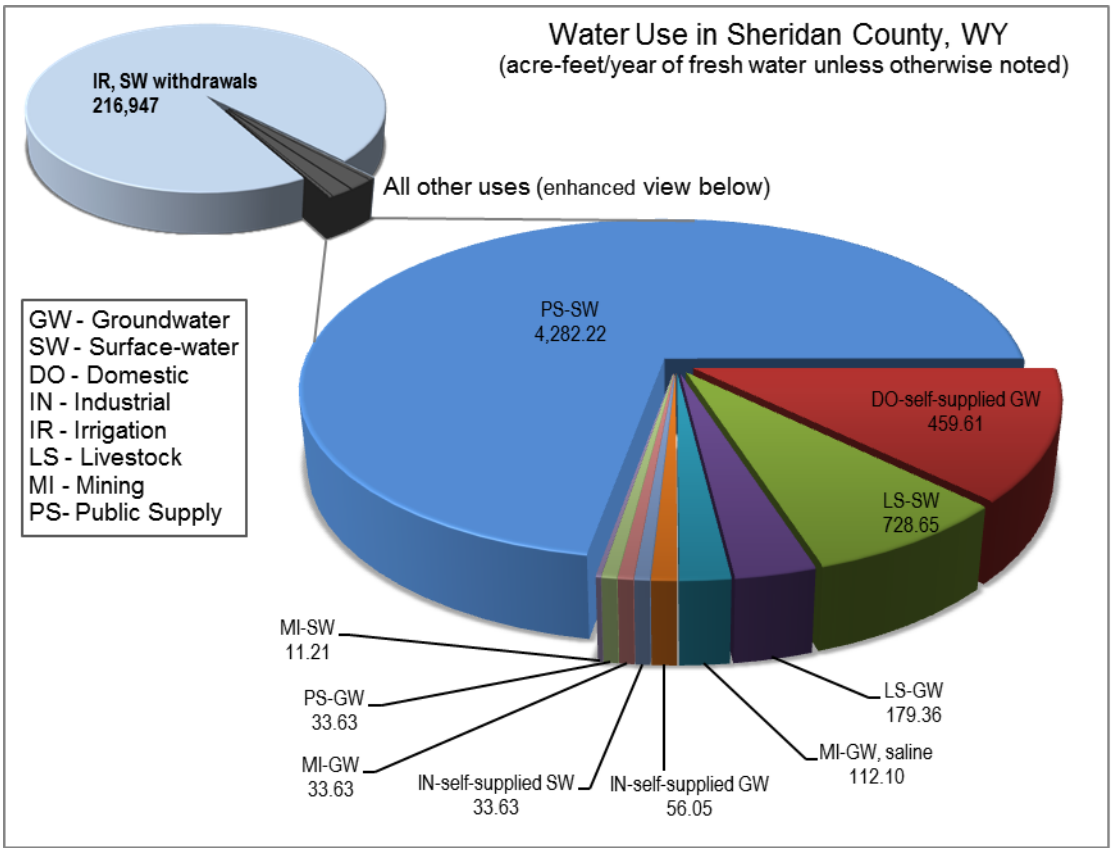


Figure 21 Water Use in Sheridan County, Wyoming
(USGS 2005)

The Tongue River Dam and Reservoir is located about 10 miles north of the Montana-Wyoming state line. The dam was planned and completed by the Montana Water Conservation Board in 1938. Reservoir storage surface area is about 3,200 acres following an enlargement in 1999 that added 20,000 acre-feet to provide for the Northern Cheyenne Tribe's negotiated federal reserved water rights. Current storage capacity is 79,071 acre-feet. The project provides water for the irrigation of 15,000 acres of land between the dam and Miles City. Water use under contract includes 39,300 acre-feet for irrigation and 7,500 acre-feet dedicated for use by the Northern Cheyenne Tribe. Additional water is contracted for the fish hatchery near Miles City and the St. Labre Mission in Ashland. Total contracted water is 40,000 acre-feet. The Tongue River Water Users Association manages the dam.

In early 2002, the MDEQ and the Tongue River Water Users (TRWU) sent surveys to landowners in the watershed to obtain better information on irrigation practices. Some of the key findings of the surveys were summarized by the MDEQ in the TMDL Status Report (Tetra Tech, Inc. 2003). Responding landowners indicated that close to 90% irrigate from the Tongue River or its tributaries. Most irrigate less than 50 acres of land, but some irrigate as many as 9,400

acres. The average land area irrigated per farm is 163 acres. Flood irrigation is the most common form of applying the water, but sprinkler and spreader dikes are also employed. Almost 40% of the landowners that responded to the surveys reported that they have experienced crop yield problems due to existing water quality. Slightly more than half of the respondents reported having soil salinity problems.

The NRCS (Natural Resources Conservation Service) conducted a “rapid aerial assessment” of stream corridor reaches along the Montana portion of the Tongue River in 2001 (U.S Department of Agriculture 2001). Approximately 105 river miles were inventoried in Big Horn and Custer Counties. Rosebud County did not participate. The NRCS identified and mapped a total of 263 individual point and linear features. Irrigation pump sites (63 each) were by far the most prevalent type. Most of the pump sites appeared to serve full season irrigation systems.

The NRCS reported two direct diversions located on the Tongue River (U.S. Department of Agriculture 2002). The Tongue River Diversion Dam is located on the Tongue River near the confluence of Pumpkin Creek and approximately 12 miles upstream of Miles City. It diverts a large portion of the Tongue River during the irrigation season (April to October) to the T&Y Ditch, which in turn supplies water to fields throughout the lower Tongue River watershed and irrigated areas in the Yellowstone River basin east of Miles City. Flows in the T&Y Ditch are approximately 200 cfs during the irrigation season when the ditch is full.

On the tributaries, water spreading systems are by far the more common method of water application compared to sprinkler or contour irrigation. In this method, water is periodically diverted or stored in ponds when available from the stream into a feeder canal or directly into a basin contained by earthen dikes. The NRCS report (2002) identified 20 surface irrigation return flows to the Tongue River (which omitted Rosebud County).

2.3 Water Rights Information

Water rights records are another source of information for water appropriation and beneficial use in the Tongue River watershed. The Montana Water Court issued a Preliminary Decree in February 2008 for water rights in both the Upper Tongue River basin (42B, the portion of the basin above and including Hanging Woman Creek) and the Lower Tongue River Basin (42C, below Hanging Woman Creek). Adjudication is not yet completed. However, the Montana General Adjudication Basin Status update reports 1,347 decreed claims in basin 42B and 4,712 decreed claims in basin 42C. The largest private surface water right is 42C 40137 00, held by Tongue and Yellowstone River Irrigation Company for 187.5 cfs (priority date of 1886).

Water rights information acquired from the Montana Department of Natural Resources and Conservation (DNRC) showed approximately 1,291,727 acre-feet of water per year in the Montana portion of the Tongue River watershed in preliminarily decreed surface water rights (Montana Department of Natural Resources & Conservation 2011), accounting for approximately 38% of water rights in the basin. The remaining 62% are stock water rights, which the DNRC does not standardly decree numeric flow or volume limits to, but rather restricts by historic beneficial use at an estimated volume of 30 gallons per day per animal unit.

The estimated volume of preliminarily decreed surface water rights on the Tongue River in Montana is 758,147 acre-feet per year. 80% of Tongue River water right decrees reported a maximum flowrate or maximum volume. The remaining 20% are stock water rights.

The average amount of total water available annually from the Tongue River is approximately 316,500 acre-feet, based on the average annual flow at State Line (USGS 2011). While the allocated water right volume estimates made here are far in excess of the total available water in the basin, the water right system is intricate and there are varying requirements for actual allocation, including historic beneficial use and senior versus junior water rights. It may also be noted that the allocation estimates are reflective of the maximum rates allowed and do not reflect the actual rate nor duration of use.

2.4 Water Well and Spring Information

The private water wells installed into shallow aquifers of the Tongue River basin are an important source of water for rural households, farms, ranches, and livestock. Irrigation from shallow groundwater is typically limited to household lawns and gardens, not agricultural fields, due to relatively low well yields. Most private wells range in depth from several tens to several hundred feet. Wyoming State Engineer’s records show that 93% of private water wells with reported total depths are 400 feet deep or less. Montana water well records (Montana's Groundwater Information Center 2010) indicate that 90% of private water wells with reported total depths are 400 feet deep or less. Approximately 67% of private water wells in Montana and 71% in Wyoming are 200 feet deep or less. The principal aquifers providing groundwater to wells include alluvium along stream valleys, along with coals and sandstones of the Fort Union and Wasatch Formations.

The number of private water wells registered in public records in the Wyoming and Montana portions of the Tongue River basin are summarized in Table 5 and displayed on Figure 23. For this report, the water well classification for Montana based on records in the Montana Groundwater Information Center (GWIC) database are as follows:

- Industrial Well was defined as any well with the following well use attributes from GWIC: Commercial, Industrial, Injection,

- Domestic Well was defined as any well with the following well use attributes from GWIC: Domestic,

- Agricultural Well was defined as any well with the following well use attributes from GWIC: Irrigation, Stockwater; and

- Wells with any use not mentioned above, or of the following GWIC defined site types were omitted from the calculations for this report: Spring, Coal Bed Methane Well, Petwell.

The water well classification for Wyoming, based on the records at the State Engineer's Office (Wyoming State Engineers Office 2009) was defined as follows:

- Industrial Well was defined as any well with the following well use attributes from SEO: IND_GW;IND_GW; IRR_GW; MIS;IND_GW; MISMIS,

- Domestic Well was defined as any well with the following well use attributes from SEO: DOM_GW;DOM_GW; IRR_GW;DOM_GW; IRR_GW; MIS;DOM_GW; IRR_GW; STK;DOM_GW; MIS;DOM_GW; MIS; STK;DOM_GW; STK;DOM_GW;STK;MIS; MUN_GW;MUN_GW;STK; DOM_GWGW,

- Agricultural Well was defined as any well with the following well use attributes from SEO: IRR_GW;IRR_GW; MIS; MIS; MIS;IRR_GW; MIS; STK;IRR_GW; STK;MIS; STK;STK;STK; MIS;STK; MIS; MIS.

Springs are not differentiated from wells in the current SEO data retrieval system and are therefore not explicitly omitted from the counts provided.

Table 5 Private Water Wells of Record in the Tongue River Basin, 2009

County	Industrial Wells	Domestic Wells	Agricultural Wells	Totals
Big Horn, MT	17	78	141	**236**
Rosebud, MT	2	147	240	**389**
Powder River, MT	1	239	758	**998**
Custer, MT	4	219	474	**697**
Sheridan, WY	10	2,769	746	**3,525**
Totals	**34**	**3,452**	**2,359**	**5,845**

Sources: Montana's Groundwater Information Center 2010 and Wyoming State Engineers Office 2009 (as defined above)

CBNG produced from coal beds of the Fort Union Formation in the Tongue River basin in both Wyoming and Montana entails pumping groundwater to reduce water pressure in the coal seams, facilitating the release of natural gas. Pumping occurs from coal beds, which may also serve as aquifers for private wells. Private water wells completed in gas-producing coal beds within approximately three miles of active CBNG fields could experience drawdown of water levels, reduced yield, or gas migration into the well bore. However, most CBNG wells are deeper than private water wells. Wyoming Oil and Gas Conservation Commission (WOGCC) records (2009) indicate that 91% of CBNG wells in the Wyoming portion of the Tongue River basin are deeper than 400 feet. MBOGC (2009) records indicate that 83% of CBNG wells in the Montana portion of the basin are greater than 400 feet deep.

Gas producers in Montana are required to offer Water Source Mitigation Agreements to nearby well owners. Wyoming producers are not required to do so, but it is a common practice. Coal beds in the Powder River Basin are generally separated from other aquifers by shale units that act as confining beds or aquitards. Due to these confining shale units, significant water-level drawdown in response to CBNG production is expected to be limited to the coal aquifers and is

not expected to migrate vertically to impact overlying or underlying aquifers in most areas (Wheaton, et al. 2006).

Springs are also important water sources for livestock and some domestic uses in the Tongue River basin. Original homesteads and ranches were sometimes located near historic springs. Springs typically issue from clinker beds, coal beds, and sandstones near their contacts with underlying mudstone or shale units (Donato and Wheaton 2004). Between 2001 and 2003, the Montana Bureau of Mines and Geology (MBMG) inventoried a total of 279 springs in the Montana portion of the Tongue River and Powder River basins (Donato and Wheaton 2004). Of these, 164 were found to have a measurable discharge, which ranged from 0.01 gallons per minute (gpm) to 82 gpm. A total of 55 springs were found to have a discharge rate of 1 gpm or greater. The SC of inventoried springs ranged from 123 to 8,540 µS/cm at 25°C. No spring inventory is publicly available in the Wyoming portion of the Tongue River basin.

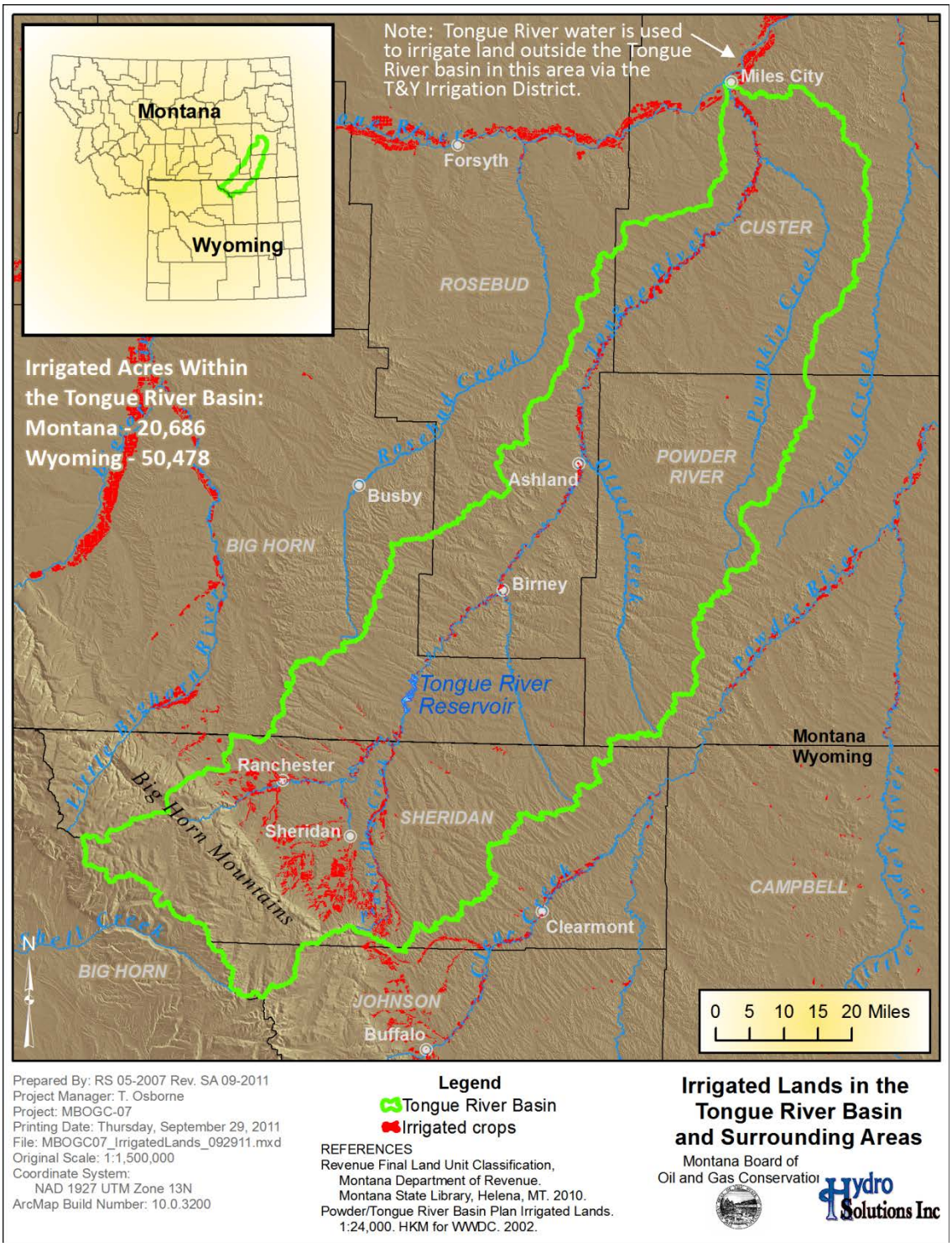
The MBMG spring inventory identified springs as discharging from regional or local groundwater flow systems. It found that most springs are fed by local groundwater systems, which are unlikely to be hydraulically connected to coal bed aquifers that are targeted for CBNG production. In its Draft Supplemental Environmental Impact Statement (U.S. Department of the Interior Bureau of Land Management 2007), the U.S. Bureau of Land Management (BLM) stated that the fact that a coal seam produces CBNG strongly suggests that it is isolated from a surface unit and therefore is unlikely to impact springs.

3.0 Oil and Gas Wells in the Tongue River Basin

The distribution of oil and gas wells in the Tongue River basin is shown on Figure 24. One oil field (Ash Creek) and six gas fields (Castle Rock, Coal Creek, CX, Dietz, Wildcat, Big Horn, and Waddle Creek) lie within the Tongue River basin in Montana. Of these, the Coal Creek, CX, Waddle Creek, and Dietz fields have been recently active (J. Halvorson, pers. comm.). The CX field is a CBNG producing area in southern Big Horn County that is operated by Fidelity Exploration & Production Company. In 2010, the CX field produced 8,717,200 thousand cubic feet (MCF) of natural gas and 28,187,361 barrels of water (J. Halvorson, pers. comm.). Pinnacle Gas Resources produces the Coal Creek and Dietz fields. The Coal Creek field produced 183,912 MCF of natural gas and 22,554,361 barrels of water. The Dietz field produced 537,271 MCF of gas and 1,795,829 barrels of water (J. Halvorson, pers. comm.). The sixth gas field, Waddle Creek, is operated by Quaneco, LLC in the upper Hanging Woman basin. It produced 38,516 MCF of natural gas and 146,481barrels of water. Total 2010 CBNG production in Montana (all in the Tongue River basin) was 9,476,899 MCF of gas and 32,684,032 barrels of water from 813 active wells (J. Halvorson, pers. comm.). Compared to 2009, Montana CBNG operators produced 20.7% less gas and 55.5% less water in 2010.

The history of CBNG wells permitted and wells completed as recorded by the MBOGC is provided in Figure 25. Nearly all of these permits and wells lie in the Tongue River basin. CBNG wells that access federally owned minerals or surface must be approved by both the MBOGC and the BLM. The permits and wells shown in these maps and figures are based on MBOGC records. The number of CBNG well permits issued in 2010 hit its lowest number (3) since CBNG production began in 1999. The number of new CBNG well completions in 2010 (2) was the lowest since 2002 (J. Halvorson, pers. comm.).

The number of CBNG wells and the average rate of water production per well for the Tongue River basin is shown in Figure 26. The historical trends in production of natural gas, water and well counts for CBNG production in the Montana portion of the Tongue River basin are shown in Table 6.



Prepared By: RS 05-2007 Rev. SA 09-2011
Project Manager: T. Osborne
Project: MBOGC-07
Printing Date: Thursday, September 29, 2011
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Original Scale: 1:1,500,000
Coordinate System:
NAD 1927 UTM Zone 13N
ArcMap Build Number: 10.0.3200

Legend
Tongue River Basin
Irrigated crops

REFERENCES
Revenue Final Land Unit Classification, Montana Department of Revenue. Montana State Library, Helena, MT. 2010.
Powder/Tongue River Basin Plan Irrigated Lands. 1:24,000. HKM for WWDC. 2002.

Irrigated Lands in the Tongue River Basin and Surrounding Areas

Montana Board of Oil and Gas Conservatio

Hydro Solutions Inc

Figure 22 Irrigated Lands in the Tongue River Basin

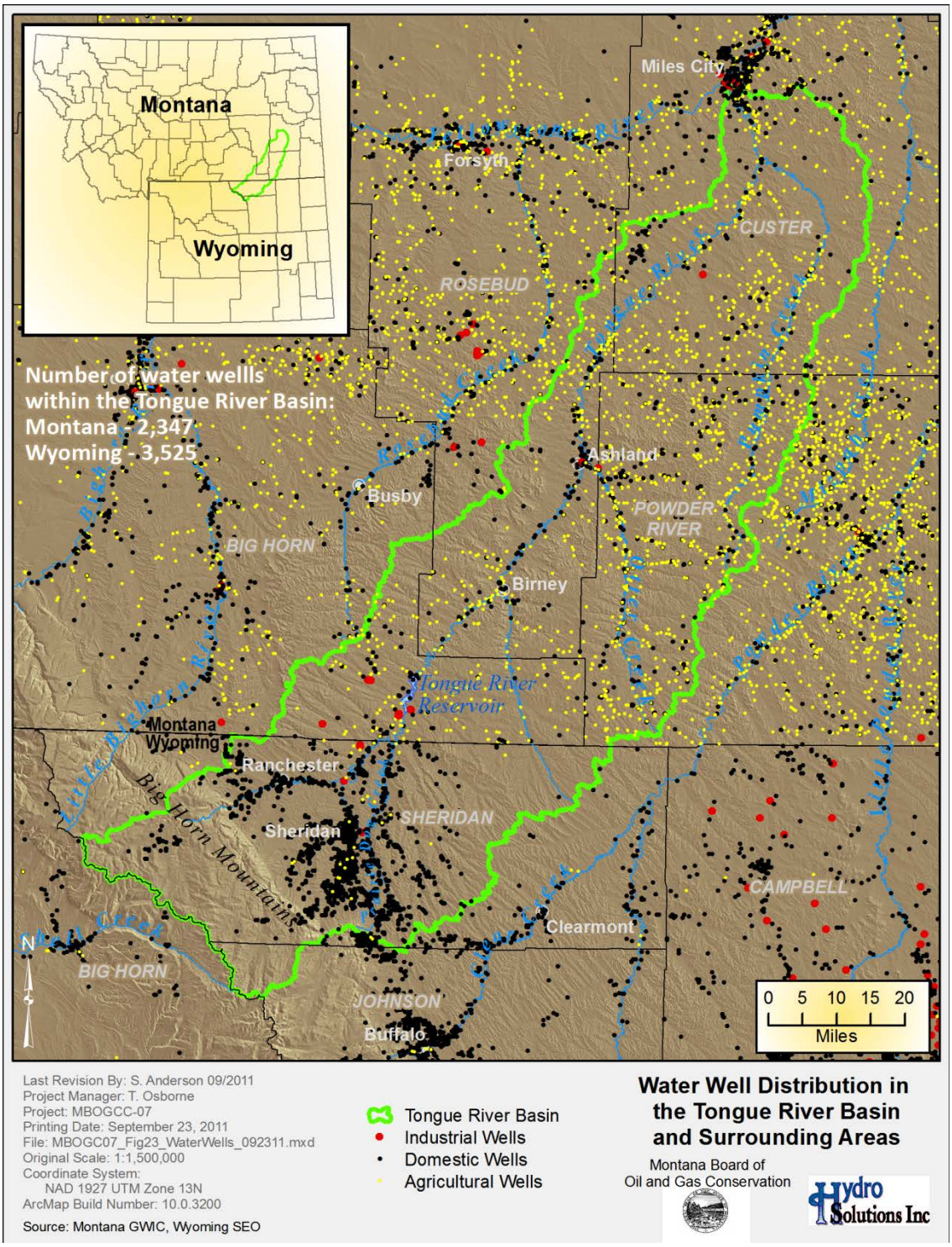

Figure 23 Water Well Distribution in the Tongue River Basin and Surrounding Areas, 2010

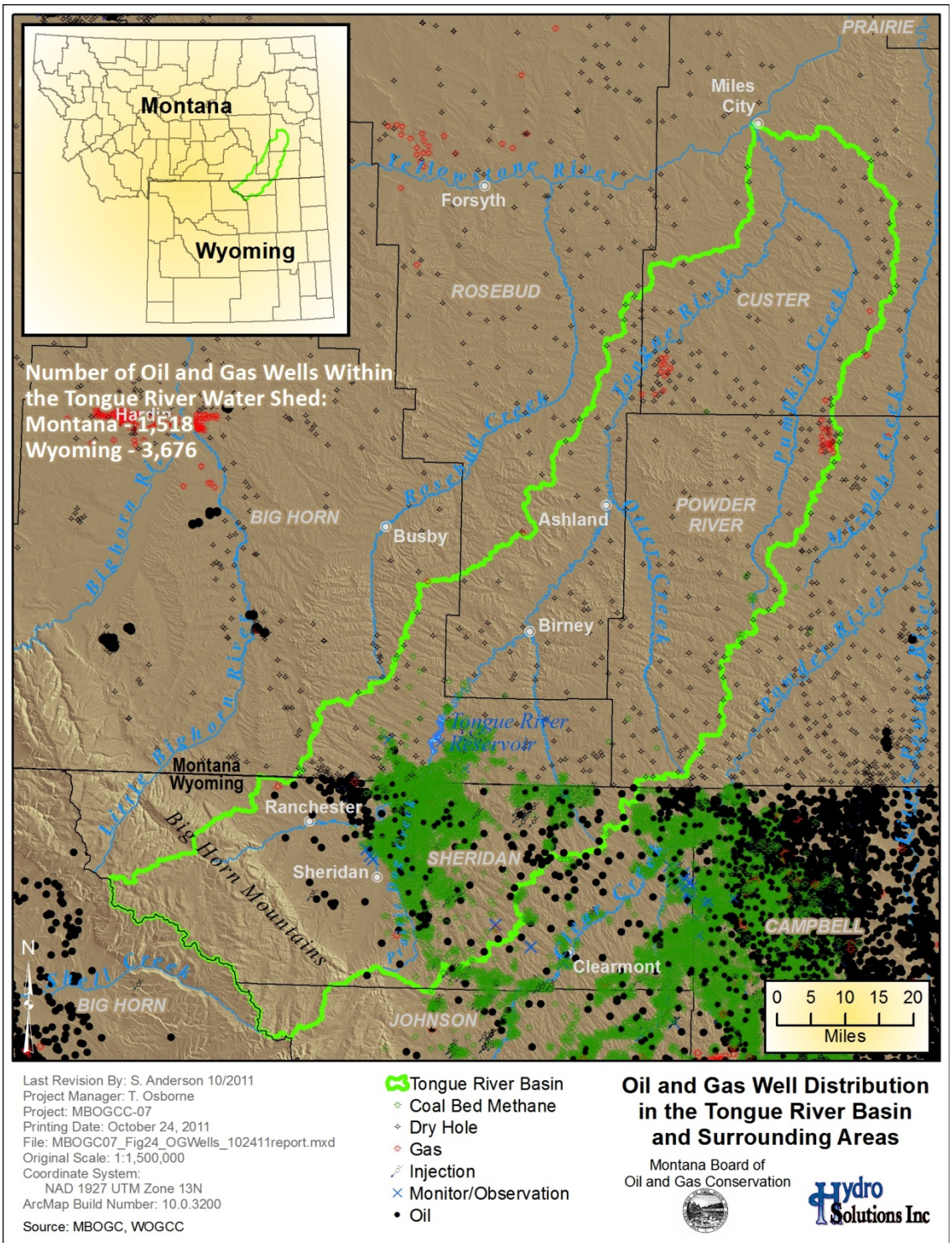

Figure 24 Oil and Gas Well Distribution in the Tongue River Basin and Surrounding Areas, 2010

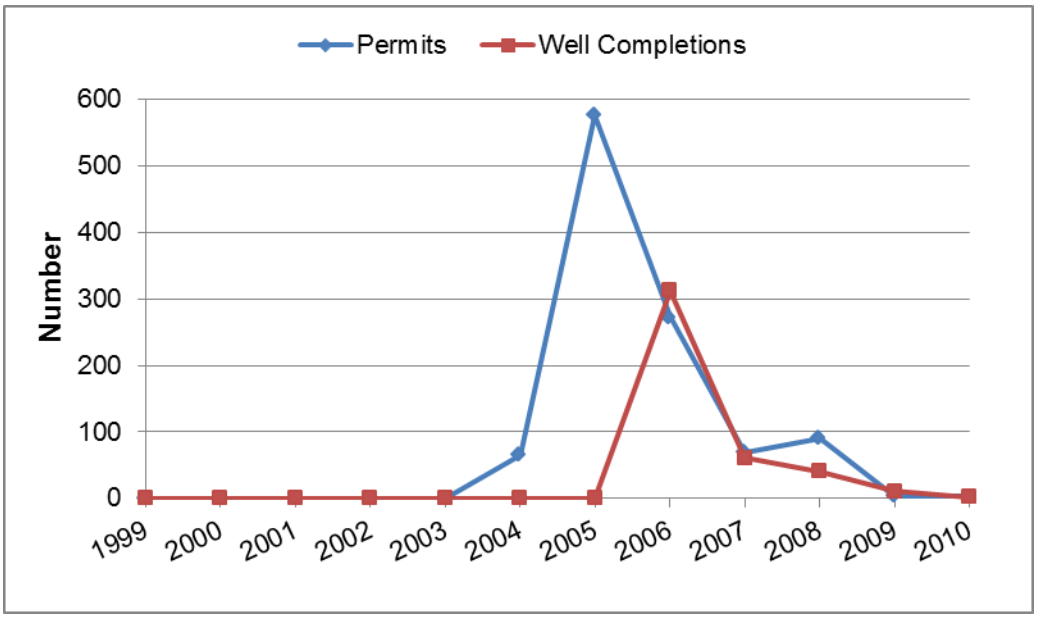

Figure 25 Numbers of CBNG Well Permits and Well Completions in Montana

Source: MBOGC Montana Board of Oil & Gas Conservation 2011

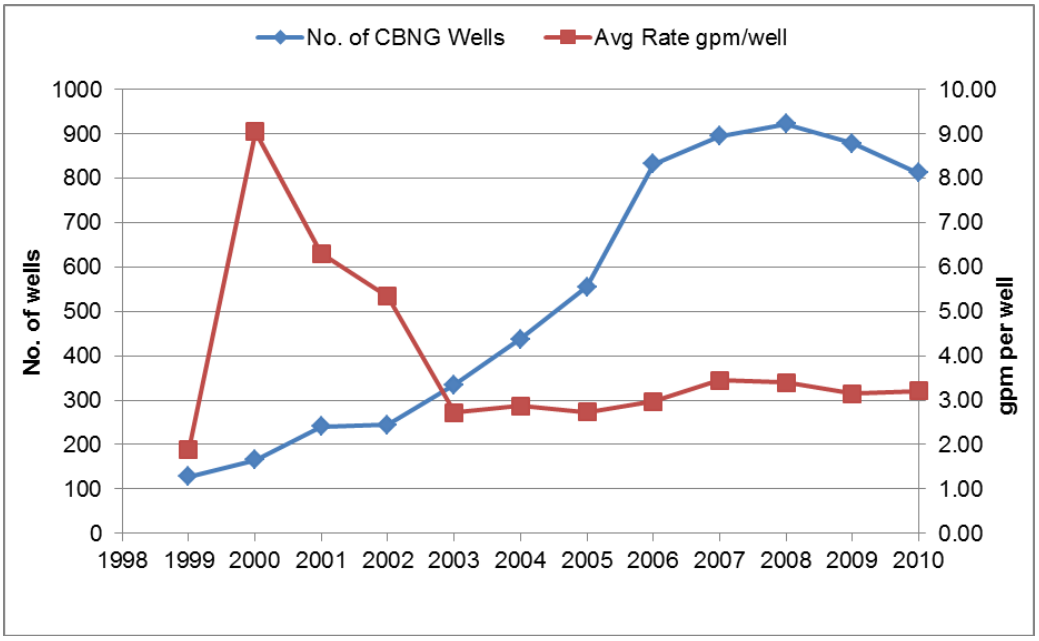

Figure 26 Number of CBNG Wells and Average Rate of Water Production Per Well in the Tongue River Basin of Montana

Source: Montana Board of Oil & Gas Conservation 2011

Table 6 Number of CBNG Wells and Water Produced from Montana Portion of the Tongue River Basin

Year	Well Count	Volume (bbls)	Volume (ac-ft)	Avg Rate (gpm/well)	Combined flow rate (cfs)
1999	128	3,015,039	389	1.88	0.54
2000	166	18,815,397	2,425	9.06	3.35
2001	241	19,017,873	2,451	6.31	3.39
2002	244	16,298,716	2,101	5.34	2.90
2003	335	11,410,961	1,471	2.72	2.03
2004	437	15,679,211	2,021	2.87	2.79
2005	556	18,980,523	2,447	2.73	3.38
2006	832	30,931,774	3,987	2.97	5.51
2007	895	38,654,241	4,983	3.45	6.88
2008	923	39,374,106	5,075	3.40	6.99
2009	879	34,581,502	4,458	3.14	6.16
2010	813	32,684,032	4,213	3.20	5.80
Total		279,443,375	36,021		
Average	537.416667	23,286,948	3,002	3.92	4.14

Key: bbl= 42 gallon barrel; ac-ft= acre feet; gpm= gallons per minute; cfs= cubic feet per second.
Source: (Montana Board of Oil & Gas Conservation 2011)

Initial water production from CBNG wells in the Wyoming portion of the Tongue River basin began in May 1999, with initial gas production beginning in February 2000. The historic trends in numbers of CBNG well permits and well completions are shown in Figure 27. As of December 2010, approximately 1865 CBNG wells were in production in the Tongue River basin area of Wyoming and another 1,017 were shut in (WOGCC 2011). Trends in the number of producing CBNG wells and average rate of water production per well are shown in Figure 28. The WOGCC reports that of the 8,058 CBNG well permits issued to date, 2,621 wells had been completed and 4,582 had expired, indicating that these wells were not drilled. The remaining wells had been or were in the process of being plugged and abandoned, in a preliminary stage, or dormant. The historical trends in production of natural gas, water and well counts for CBNG production in the Wyoming portion of the Tongue River basin are shown in Table 7. Total 2010 CBNG production in the Wyoming portion of the Tongue River basin was 69,730,726 barrels (bbls) of water (Wyoming Oil & Gas Conservation Commission 2011).

The combined history of CBNG well completions in the Tongue River basin is summarized in Figure 29. A total of 2,744 wells were active in the basin in 2010, marking the second consequtive year of decline in CBNG well counts. Since the peak of development in 2008, the number of producing wells in the basin has declined by approximatey 18.5%. Total gas production in the basin has declined by 21%t in Wyoming and 32% in Montana. Produced water volume declined by 32% in Wyoming and 17% in Montana.

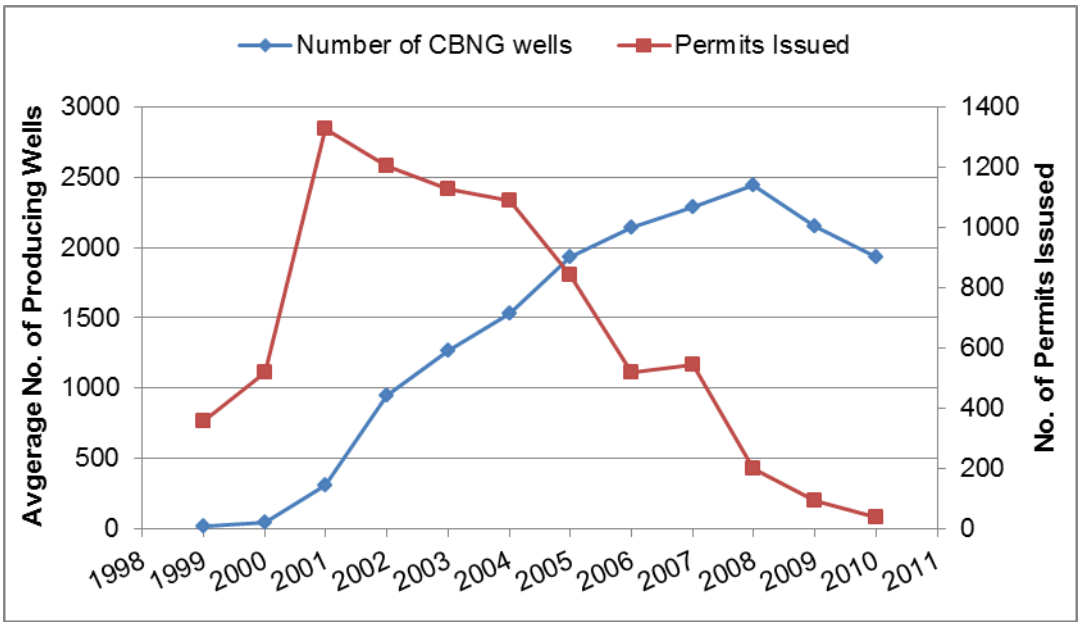

Figure 27 Numbers of CBNG Well Permits Issued and Well Completions in Wyoming
(average number of producing wells in each year)
Source: Wyoming Oil & Gas Conservation Commission 2011

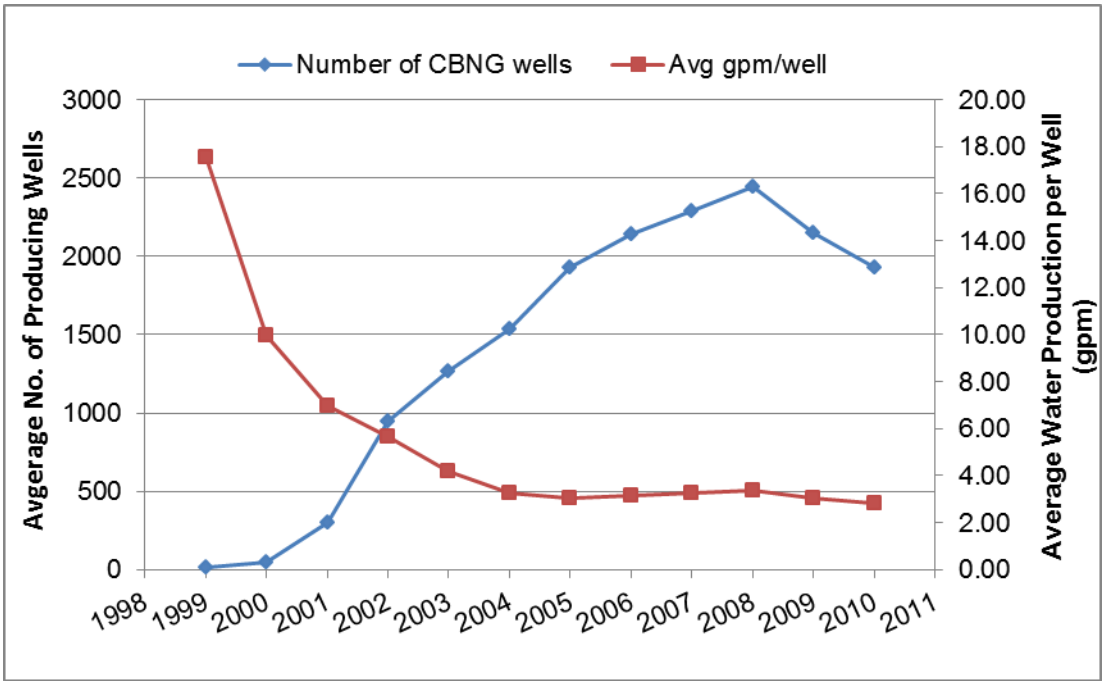

Figure 28 Number of CBNG Wells and Average Rate of Water Production Per Well in the Tongue River Basin of Wyoming
Source: Wyoming Oil & Gas Conservation Commission 2011

Table 7 Number of Wells and Water Produced from Wyoming Portion of the Tongue River Basin

Year	Well Count	Volume (bbls)	Volume (ac-ft)	Avg Rate (gpm/well)	Combined flow rate (cfs)
1999	11	2,489,402	321	17.55	0.4
2000	45	5,654,563	729	9.97	1
2001	305	26,590,602	3,428	6.97	4.7
2002	950	67,312,635	8,677	5.66	12
2003	1265	66,526,676	8,575	4.20	11.8
2004	1533	62,094,845	8,004	3.24	11.1
2005	1931	73,196,121	9,435	3.03	13
2006	2141	84,080,757	10,838	3.14	15
2007	2286	93,245,953	12,020	3.26	17
2008	2444	102,956,097	13,271	3.37	18
2009	2148	81,651,901	10,525	3.04	14.5
2010	1931	69,730,726	8,988	2.82	12.1
Totals		735,530,278	94,811		
Average	1,416	61,294,190	7,901	6	11

Key: bbl= 42 gallon barrel; ac-ft= acre feet; gpm= gallons per minute; cfs= cubic feet per second.
Source: Wyoming Oil & Gas Conservation Commission 2011

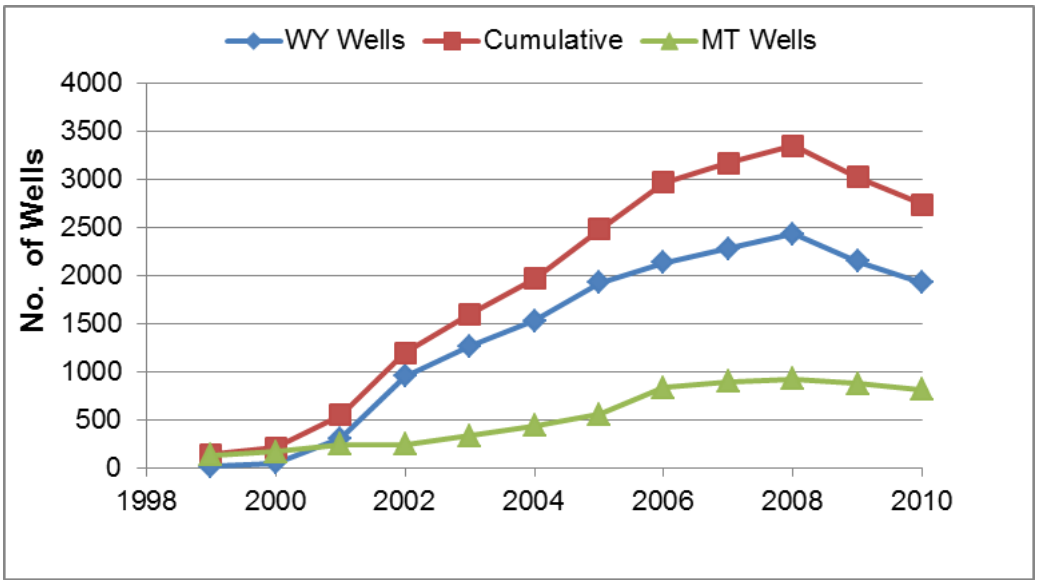

Figure 29 Combined History of CBNG Production Wells in the Tongue River Basin
(Average number of producing wells in each year)
Sources: Montana Board of Oil & Gas Conservation 2011; Wyoming Oil & Gas Conservation Commission 2011

4.0 Discharges to the Tongue River

The growth of public awareness and concern for controlling water pollution led to the enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the Clean Water Act. The Clean Water Act established the basic structure for regulating discharges of pollutants into the waters of the United States (U.S. Environmental Protection Agency, Tetra Tech, Inc 2007). It gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry. The Clean Water Act requires that water quality standards be set for all contaminants in surface waters. The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. Permits are issued under the "National Pollution Discharge Elimination System" (NPDES). The EPA has delegated the administration of the Clean Water Act of the Tongue River to the States of Montana and Wyoming, both of which do so through their respective Departments of Environmental Quality (DEQ).

NPDES permits are only issued for "point sources" of pollution; those with specific outfalls. According to MDEQ (2010), non-point source pollution is the state's single largest source of water quality impairment. The MDEQ states that point source pollution in Montana was a source of impairment for 10% of Montana's streams and 20% of its lakes (Montana Department of Environmental Quality 2011), with the remainder of impairments due to non-point sources of pollution. The Non-point Source Pollution Program is designed to encourage voluntary pollution control activities, provide guidance, and match local funding.

4.1 Point Sources

In Montana, permitting is administered by the MDEQ under the Montana Pollutant Discharge Elimination System (MPDES). The average discharge rate per month and total quantity of discharge were obtained from Discharge Monitoring Reports (DMRs) on file at the Montana Department of Environmental Quality. These reports provide average and maximum discharge rates for each month. The average annual rates given in Table 8 are based on the average of all months reported. Data for the Miles City fish hatchery were obtained from the EPA database Integrated Compliance Information System (EPA 2011). Available records for 2010 indicate that five MPDES permits reported direct discharges into the Tongue River. Permits may have multiple outfalls, or discharge locations. Locations of outfalls from available records are mapped on Figure 30.

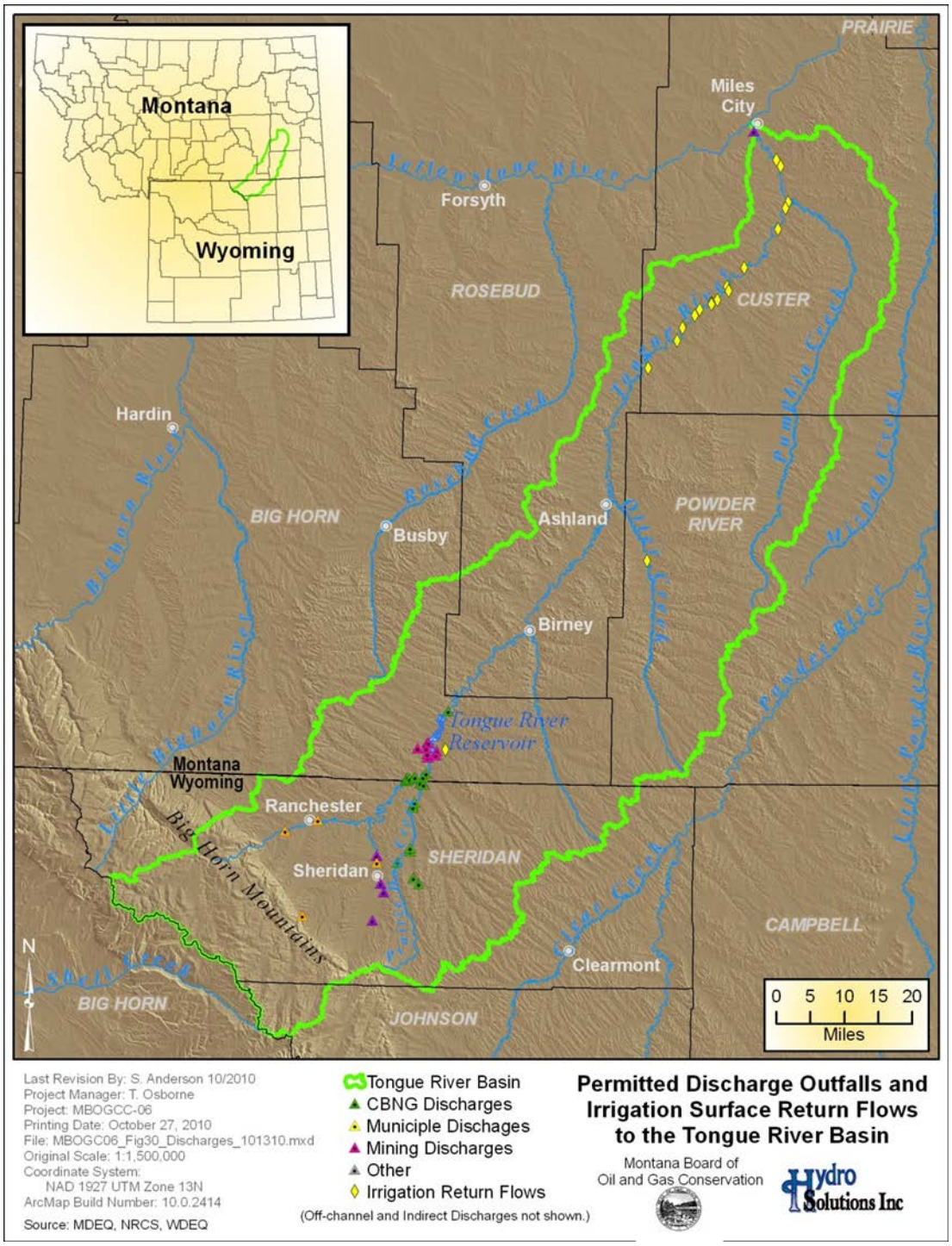

Figure 30 Permitted Discharge Outfalls and Irrigation Surface Return Flows to the Tongue River Basin

Table 8 Summary of MPDES Direct Discharge Permits to the Tongue River in Montana

MPDES# No. of Outfalls	Permit Holder	Facility Description	Receiving Water	Permit Status Description	Average CY 2010 Rate of Discharge (cfs)
MTG130015 Outfalls: 1	MT DFWP - MILES CITY HATCHERY	Fish Hatchery Effluent	Tongue River	Effective	5.13
*MT0030457 Outfalls:15	FIDELITY EXPLORATION & PRODUCTION CO	Coal Bed Methane Produced Water	Tongue River	Effective	3.62
MT0030660 Outfalls: 1	PINNACLE GAS RESOURCES INC	Coal Bed Methane Produced Water (treated)	Tongue River	Did not discharge in 2010	No discharge
MT0030724 Outfalls: 3	FIDELITY EXPLORATION & PRODUCTION CO	Coal Bed Methane Produced Water (treated)	Tongue River	Effective	1.49
MT0000892 Outfalls: 5	DECKER COAL CO (WEST MINE)	Surface Coal Mine Effluent	Tongue River Reservoir	Effective	6.70
MT0024210 Outfalls:1	DECKER COAL CO (EAST MINE)	Surface Coal Mine Effluent	Tongue River Reservoir	Effective	2.21

Sources: L.Tucker, pers. comm., 09/20/2011
**Permit Terminated effective 11/01/2011*

Two CBNG MPDES permits were active for approximately 10 months in 2010. Fidelity's permit MT0030457, originally issued in 1999, was renewed with modifications on April 1, 2006. It allowed for the discharge of 1,600 to 2,500 gpm (3.57 to 5.57 cfs) of untreated water, year round, with the rate varying by season (Montana Department of Environmental Quality 2011). The actual average discharge rate under this permit in 2010 was approximately 1,622.61 gpm (3.62 cfs) for a total volume of 2,619.6 acre-feet (L. Tucker, pers. comm.). This is approximately 21% less than was discharged under this permit in 2009. Fidelity's permit MT0030724 for treated discharge into the Tongue River also became active April 1, 2006. This permit allowed for the discharge of 1,700 gpm (3.79 cfs) year round; however, the quality of the water allowed to be discharged varied by season. In 2010, the average discharge rate under this permit was 666.6 gpm (1.49 cfs) for a total volume of 1076.2 acre-feet. This is 0.97% more than the amount discharged under this permit in 2009.

Fidelity operations discharged effluent for two months less under permit MT0030457 than the previous year, which is partially responsible for the drop in discharge rates. Discharge from this outfall ceased effective November 2010. The permit was voided by the Supreme Court of the State of Montana in decision DA 09-0131, Northern Cheyenne Tribe, Tongue River Water Users' Association, and Northern Plains Resource Council, Inc., versus the Montana DEQ and Fidelity Exploration & Production Company. The Court concluded the MPDES permit program's allowance of water to be discharged without a pre-discharge treatment as long as the amount of water being expelled did not alter the water quality of the receiving waters, was in conflict with the Clean Water Act and the EPA's National Pollutant Discharge Elimination System (NPDES) permit. The NPDES permit imposes pre-discharge treatment standards on all polluted waters. Since Montana has adopted this EPA regulation, which supersedes the MPDES permit

regulation, the courts ruled the DEQ violated the superseding regulations by allowing Fidelity to release untreated produced waters (Montana Legislature 2011).

Pinnacle Gas Resources' permit MT0030660 allowed a maximum instantaneous discharge rate of 1,122 gpm of treated water. There was no discharge under this permit in 2010. The MPDES Authorization to Discharge record states the authorization expired at midnight, December 31, 2010 and there was no record of renewal (Montana Department of Environmental Quality 2011).

The East and West Decker mines combined to discharge a total average rate of 8.91 cfs to the Tongue River Reservoir. The State of Montana fish hatchery near Miles City reported an average discharge of 5.13 cfs based on the highest month in each semi-annual reporting period (EPA 2011).

In Wyoming, permitting is administered by the Wyoming Department of Environmental Quality (WDEQ) under the Wyoming Pollutant Discharge Elimination System (WYPDES). Available records indicated there were 54 active WYPDES permits in the Tongue River basin of Wyoming in 2010 (J. Fruhwirth, pers. comm.). The permit discharge categories include:

- Five municipal wastewater treatment plants; including Sheridan, Ranchester, and Dayton;
- One drinking water treatment plant;
- 45 CBNG-related permits, all but nine of which were for off-channel, non-direct discharge impoundments; and
- Three Industrial permits.

Specific WYPDES permit information was obtained from the WDEQ and the US EPA on all permitted direct discharges to the Tongue River basin, as summarized in Table 9.

Table 9 Summary of WYPDES Direct Discharge Permits to the Tongue River in Wyoming

Permit Holder	Permit (# of Outfalls)	Description	Receiving Water	Discharge Rate (cfs, 2010 CY monthly average)
ConocoPhillips Company	WY0030481 (1)	Industrial-Gas and Petroleum Storage Terminal Run-off	Ephemeral Tributary to Meade Creek to Prairie Dog Creek to Tongue River	0.009
Dayton, Town of	WY0020435 (2)	Municipal - Sewage System	Tongue River	0.701
Fidelity Exploration and Production Company	WY0038628 (7)	CBNG	On-channel Reservoirs tributary to Goose Creek	0.009
	*WY0038636 (2)	CBNG	Mid-year change From Ephemeral Tributary of Tongue River to On-channel Reservoir	0.019

Permit Holder	Permit (# of Outfalls)	Description	Receiving Water	Discharge Rate (cfs, 2010 CY monthly average)
JM Huber Corporation	*WY0040568 (12)	CBNG	On-channel reservoirs to ephemeral tributaries to Prairie Dog Creek	0.079
	WY0050571 (1)	Pod B CBM Water Treatment Facility	Tongue River via Prairie Dog Creek via direct discharge from treatment unit	No Discharge
Mullinax Concrete Service Company	WY0094366 (1)	Industrial - Construction Sand and Gravel	Goose Creek	0.005
Pennaco Energy, Inc.	*WY0051489 (3)	CBNG	On-channel reservoirs	0.021
	*WY0051497 (5)	CBNG	On-channel reservoirs	0.031
	*WY0051705 (4)	CBNG	On-channel reservoirs	0.030
	*WY0054364 (2)	CBM Treatment Facility	Tongue River via Prairie Dog Crk via Wildcat Crk via direct discharge from treatment facility	No Discharge
Powder Horn Ranch, LLC	WY0036251 (1)	Industrial - Sewage System	Treatment Pond, overflow to Little Goose Creek	0.047
Ranchester, Town of	WY0022161 (4)	Wastewater Treatment Drainage	Tongue River	0.310
Sheridan Big Horn Mountain KOA	WY0026441 (1)	Wastewater Treatment Drainage	Goose Creek	0.002
Sheridan County School District #1	WY0056308 (1)	Wastewater Treatment Drainage	Jackson Creek	0.009
Sheridan, City of	WY0020010 (1)	Wastewater Treatment Drainage	Goose Creek	4.075
	WY0035661 (2)	Municipal Water Intake	Big Goose Creek	2.279
USFS - Big Horn	WY0020931 (2)	Wastewater Treatment Drainage	Unnamed Drainage to North Fork Tongue River	0.063

** Note: Discharge from these facilities occurs to on-channel reservoirs, which only discharge to the drainage during runoff events which cause overtopping.*

Sources: J. Fruhwirth, pers. comm., 8/25/2011

Three of the eight CBNG permits in Table 9 allow direct discharge to the Tongue River or tributaries. These permits include some of the outfalls of WY0038628 (Fidelity), one of the outfalls of WY0054364 (Pennaco), and WY0050571 (Huber). However, no discharge actually

occurred in 2010 from the latter two facilities, which are CBNG water treatment plants (J. Fruhwirth, pers. comm.). Seven of the permits in Table 9, including some of the outfalls of permit WY0038628 (Fidelity) and one of the outfalls of permit WY0054364 (Pennaco), allow discharge of CBNG produced water to on-channel impoundments that are required to contain all produced water within the reservoir during “dry” operating conditions. These permits prohibit discharge of effluent from the reservoir except during periods of time in which natural precipitation causes the reservoir to overtop and spill. Intentional or draw-down type releases from the reservoir constitute a violation of this permit. Discharge from the reservoir is limited by the permit to natural overtopping and shall not extend beyond a 48 hour period following commencement of natural overtopping. The discharge rates shown in Table 9 for these seven facilities are the average rates of discharge to the reservoirs associated with each of the permits, not directly to the Tongue River or tributaries. The actual amount and timing of any overtopping and flow into the Tongue River or tributaries is not known from the WYPDES reporting data. In response to this limitation, it was assumed, for purposes of accounting for CBNG discharges shown in Figure 31, that the monthly discharges to the off-channel reservoirs accrued to the Tongue River or tributaries in the month reported. This results in a small overstating of the untreated and total direct CBNG discharge in most or all months.

There are three CBNG discharge permit options in Wyoming:

- Option 1A – Discharge is contained within an off-channel pit (class 4C) capable of containing all effluent plus up to a 50-year / 24-hour storm event. For existing permits only, Option 1A also applies to discharges that are contained within a headwater reservoir situated within a class 4 channel and capable of containing all effluent plus up to a 50-year/24-hour storm event, provided that the discharge was permitted for 50-year/24-hour containment prior to June 24th, 2008. Option

- 1B – Discharge is contained within a natural closed basin or playa lake (class 3A). For existing permits only, Option 1B also applies to discharges that are contained within a headwater reservoir situated within a class 3 channel and capable of containing all effluent plus up to a 50-year/24-hour storm event, provided that the discharge was permitted for 50-year/24 hour storm containment prior to June 24th, 2008. Option 1B headwater reservoirs shall not be located within alluvial deposits or the floodplain of any perennial, intermittent or ephemeral stream. Option 1B headwater reservoirs less than 50 acre feet in capacity shall not be located within 500 feet of such features; reservoirs greater than 50 acre feet in capacity shall not be located within ¼ mile (1320 feet) of such features.

- Option 2 – This option includes any on-channel discharge (including discharge into an on-channel reservoir) that does not meet the impoundment requirements specified in options 1A or 1B above. (Wyoming Department of Environmental Quality 2008).

The majority of the WYPDES discharge permits were for Option 1A and 1B. Permits for Option 2 were less common and, as discussed above, contained additional directives to ensure the

dilution of any released CBNG water sufficiently to meet Montana's irrigation water quality standards for the Tongue River. Discharges from six permits from this class of impoundments were known to occur in the Tongue River basin in 2010 (J. Fruhwirth, pers. comm.)

The monthly totals of all CBNG direct discharges to the Tongue River and tributaries in Montana and Wyoming are compared to the average monthly flow of the Tongue River below the Tongue River Dam in Figure 31. Both untreated and the total of untreated and treated CBNG discharges is shown. It can be seen that total CBNG discharges comprised a maximum of 5.63% of the river flow in April 2010. In the same month, untreated discharge reached a maximum of 4.59% of river flow. During the April-September irrigation season, total CBNG discharges comprised from 0.26% to 5.63% of river flow, with untreated discharge ranging from 0.21% to 4.59%. As explained above, a small fraction of the percentages shown actually reach the Tongue River during precipitation events that cause the receiving reservoir to overtop (i.e., during high river flow), rather than in the month the discharge is actually reported to occur to the reservoir. However, this approximation would not significantly change the overall interpretation.

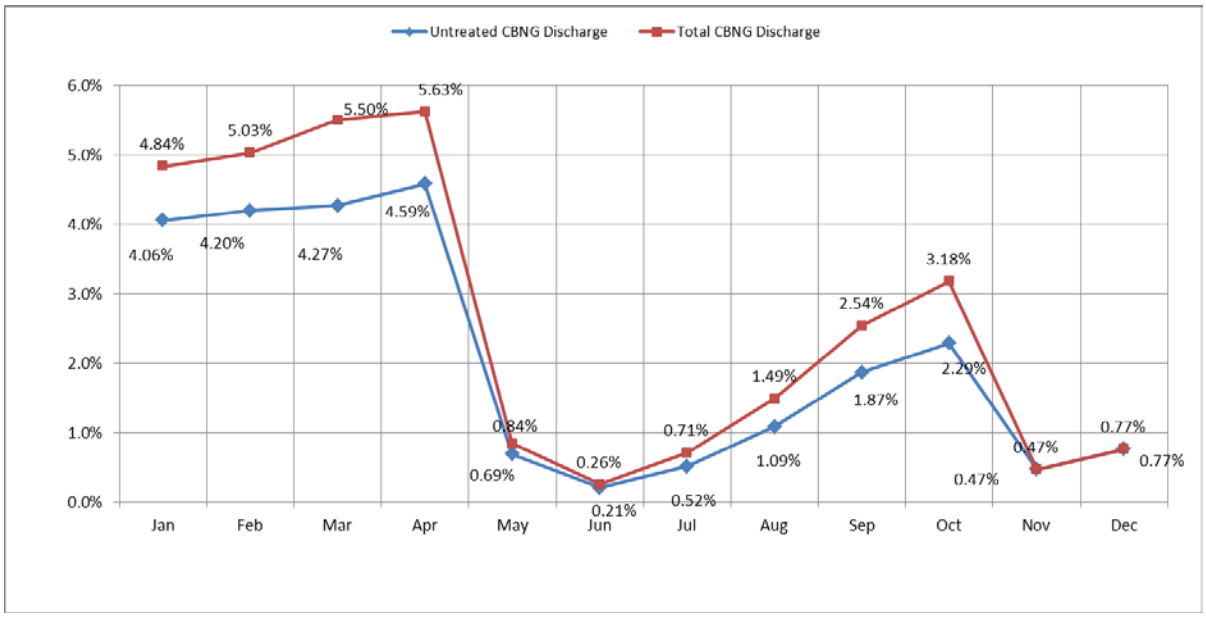

Figure 31 2010 CBNG Direct Discharges to the Tongue River in Montana and Wyoming as a Percent of Flow in the Tongue River below Tongue River Dam

Sources: L. Tucker, MDEQ pers. comm. on 2011, J. Fruhwirth, pers. comm., 2011, and USGS 2011

The average rate of direct point discharges to the Tongue River basin in Montana and Wyoming for 2010 can be summarized as follows:

- Total CBNG discharges: 5.5 cfs; (4.01 cfs untreated and 1.49 cfs treated)
- Total of coal mine discharges: 8.91 cfs
- Total of municipal and domestic wastewater: 7.44 cfs

- Total Other Industrial: 0.061 cfs

The U.S. Environmental Protection Agency (EPA) conducted an assessment of water quality in the Tongue River, Tongue River Reservoir and all the principal tributaries in Montana (U.S. Environmental Protection Agency, Tetra Tech, Inc 2007). This study included a water quality modeling component to evaluate the sources of salinity within the Tongue River basin (U.S. Environmental Protection Agency, Tetra Tech, Inc 2007, Appendix J). They found that the river salinity of the "natural scenario" in which the various human sources of salinity were removed was significantly less than the existing scenario, with the difference in mean SC being 176 µS/cm and 200 µS/cm at the State Line and Miles City gauging stations, respectively. CBNG sources were found to represent from 4% to 5% and irrigation sources from 20% to 21% of existing salinity.

4.2 Non-Point Sources

Non-point sources of contaminants are not covered by the NPDES permit system. Potentially significant human and natural causes of non-point sources of contaminants to the Tongue River basin include the following:

- Irrigation return flows: surface and subsurface;
- Sediment, bacteria, nutrients and salinity from agricultural sources;
- Septic system effluent discharge to groundwater in communication with the river;
- Municipal and industrial storm water runoff;
- Natural sources including runoff from wild lands and groundwater discharge;
- Evaporation from the river and Tongue River Reservoir; and
- Salinity concentration via transpiration from riparian vegetation.

Non-point sources have traditionally been addressed, to a limited extent, by a combination of federal, state and local agencies, including the EPA, NRCS, DEQs, DNRC, and county Conservation Districts. In September 2000, the Sheridan County Conservation District (SCCD), in cooperation with the NRCS and the Tongue River Watershed Steering Committee (TRWSC), worked with local landowners to publish a local watershed plan for the Upper Tongue River Watershed (Sheridan County Conservation District 2007). After 9 years, numerous new projects have been implemented to increase the water quality in the Tongue River Basin. In 2005, interim monitoring continued to identify unacceptable bacteria levels and excessive sediment in streams. As a result, the TRWSC updated the plan and a revised version was completed in 2007 and again in 2009 (Sheridan County Conservation District 2007; Sheridan County Conservation District 2009).

Non-point source control efforts in the Wyoming portion of the Tongue River basin undertaken by the SCCD (Sheridan County Conservation District 2009) include:

- Completion of seven animal feeding operation improvement projects and one project in progress;
- Eleven stream bank/riparian improvement projects with two under construction;
- Five septic system projects;
- Educational programs on animal feeding operation;
- Pathogen workshops;
- Development and maintenance of a progress register map;
- General Natural Resource Public Education;
- A series of educational brochures and newsletters published and distributed to 1300 residents in the Upper Tongue River Watershed;
- A video describing a septic system replacement and design considerations.

Other non-point source improvement projects were reported for the Goose Creek watershed (Sheridan County Conservation District 2009). These projects included:

- Implementation of one stream restoration, two water conservation, and one riparian/wildlife improvement projects;
- Twelve livestock improvement projects;
- Ten septic improvement projects;
- 2010 Goose Creek Watershed TMDL/Plan Update;
- Interim Monitoring;
- Watershed information and educational workshops, tours, and publications.

The SCCD report acknowledged that the voluntary nature of the program makes it difficult to determine specifically what types of improvement projects and/or assistance will be requested by landowners.

In Montana, Conservation Districts in Big Horn, Rosebud, and Custer Counties undertake educational efforts and sponsor grants to support voluntary reductions of nonpoint source

contaminants. In 2004, the Rosebud County Conservation District formally adopted Land Use Ordinance #1, which is intended to regulate management of CBNG produced water and to require additional bonding of CBNG water management facilities (Rosebud Conservation District 2007).

In the Tongue River TMDL Status Report (Tetra Tech, Inc. 2003), the MDEQ acknowledged that it is difficult to determine the effects of all agricultural sources on the Tongue River because of the large watershed size and multiple contributions from different sources. Agricultural land and rangelands comprise approximately 72% of the Tongue River basin (U.S. Department of Agriculture 2002). Since irrigation is the largest water use in the Tongue River basin, irrigation return flows are a potential source of contaminants. Unfortunately, there is little data available (Tetra Tech, Inc. 2003). The NRCS Phase 1 Rapid Aerial Assessment identified 20 visible irrigation return flows (Figure 30) along the Tongue River in Montana, exclusive of Rosebud County. Most irrigation return flows occur via the subsurface as part of groundwater discharge to streams. No comprehensive inventory or estimate of surface or subsurface irrigation return flows is known to exist in either Montana or Wyoming.

The 2010 Montana “303 (d) List” (Montana Department of Environmental Quality 2010) of impaired water bodies indicates that four of the seven segments of the Tongue River basin in Montana are rated as “Partially Supporting” or “Not Supporting” of some beneficial water uses and will require a TMDL. The two segments not needing TMDLs are from the Tongue River Dam to Prairie Dog Creek (in Montana) and from Prairie Dog Creek to Hanging Woman Creek. The most frequently listed “Probably Sources” of impairment are listed as:

- Impacts from hydrostructure flow regulation/modification;
- Irrigated crop production;
- Streambank modifications/destabilization; and
- Natural sources.

Most hydrostructures are diversion structures for irrigation. The MDEQ indicates that TMDLs for the Tongue River basin are pending completion of additional studies.

The 2010 Wyoming 303 (d) List (Wyoming Department of Environmental Quality 2010) indicates that the Tongue River below Goose Creek, much of Big and Little Goose Creeks, all of Prairie Dog Creek, and other smaller tributaries are impaired for beneficial uses. The most common causes of impairments were flow alterations from dams and diversions, irrigation, sources of fecal bacteria, storm water discharges and high water temperatures.

Water quality improvement projects in the Tongue River and Goose Creek basins have been implemented by the SSCD including animal feeding operation projects, riparian buffer development, stream bank stabilization, and grazing management.

Natural processes can increase or decrease salinity, sodium, and other contaminants, but the water quality effect of these processes in the Tongue River basin is not well understood. Transpiration of groundwater by riparian vegetation along the Powder River, for example, has been shown through USGS studies to cause an average decrease in flow of approximately 0.3 cfs per river mile from Arvada, Wyoming to Locate, Montana (Lenfest and LW 1987; Ringen and Daddow 1990). Evaporation from the Tongue River, in particular the Tongue River Reservoir, also reduces the volume of water and increases the salinity of the water released. The evaporative loss from the Tongue River Reservoir is equivalent to an average of 9.7 cfs on an annual basis. This is about 2.2% of the median discharge of the Tongue River at the State Line gauging station. Since water evaporates leaving the salts, the salinity theoretically increases by an equivalent percent, or about 14 µS/cm, based on a median SC of 640 µS/cm (HydroSolutions Inc 2009). Such withdrawals from the river remove water, leaving the salts and increasing the salinity of the surface water-groundwater system.

4.3 Summary of Discharges

In summary, during 2010, there were two active CBNG direct discharge permits in Montana and six in Wyoming. Three permits, MT0030724, WY0050571, and WY0054364 were for discharging treated water. However the two Wyoming permits had no discharge in 2010. The remaining active permits discharged untreated water. The untreated water discharge permit, MT0030457, was revoked by a court decision and discharge ceased on November 1, 2010.The total discharges averaged 5.067 cfs, compared to an average river flow of 444.8 cfs at the Tongue River Dam station. On a monthly basis, total CBNG discharge to the Tongue River in 2010 amounted to from 0.26% to 5.63% of the flow released from the Tongue River dam, with untreated discharge ranging from 0.21% to 4.59%. Point source discharges from other municipal, mining, and industrial facilities in Montana and Wyoming totaled to an annual average of 16.41 cfs. The EPA-sponsored Water Quality Assessment for the Tongue River Watershed, Montana (2007) conducted analysis of some non-point sources of discharge to the Tongue River in Montana. The EPA's water quality modeling study of salinity in the river found that existing salinity is significantly higher than "natural" conditions in which human sources of salinity were removed. The study reported that the estimated salinity contribution from irrigation ranges from 20% to 21% of the existing salinity levels, while the estimated contribution from CBNG ranged from 4% to 5%. (Wyoming Department of Environmental Quality 2008, U.S. Environmental Protection Agency, Tetra Tech, Inc 2007)

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(TO BE INCLUDED IN SUBMITTED DOCUMENT IMMEDIATELY BEFORE THE APPENDICES/ATTACHMENTS)

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