

**Water Year 2005
Overview of Surface Water
Monitoring Data for SC, SAR and Flow
in the Tongue River Watershed**



This cover photo shows the Tongue River near its junction with Hanging Woman Creek, near Birney, MT

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Introduction.....	3
Data Review.....	9
Main Stem Sites	9
Tongue River at Monarch, WY	9
Tongue River at State Line, near Decker, MT.....	12
Tongue River below Tongue River Dam, near Decker MT	12
Tongue River at Birney Day School Bridge, near Birney, MT	13
Tongue River below Brandenburg Bridge, near Ashland, MT.....	13
Tongue River above TY Diversion.....	14
Tongue River at Miles City, MT.....	14
Tributary Sites.....	16
Goose Creek near Acme, WY.....	16
Prairie Dog Creek near Acme, WY	16
Hanging Woman Creek near Birney, MT.....	17
Otter Creek at Ashland, MT.....	17
Pumpkin Creek near Miles City, MT.....	18
Conclusions.....	19
References.....	20
Reviewers.....	20
Figures.....	21

Introduction

When Coal Bed Natural Gas (CBNG) is developed it is necessary to cause the methane to desorb from the coal, and flow to production wells. This is typically achieved by pumping groundwater from the coal bed aquifer being developed, since this reduces the hydrostatic pressure within the coal seam (allowing the methane to desorb) and creates a pressure gradient within the aquifer that causes methane to flow towards the pumping wells. The water contained within the coal seams is a sodium-bicarbonate type water. This coal seam water in the Montana portion of the Powder River Basin is typically moderately saline, having a Specific Conductance (SC; which is proportional to salinity) on the order of 2,000 microSiemens per centimeter ($\mu\text{S}/\text{cm}$). High salinity irrigation water may result in decreased crop yields depending on the crop being grown (See Fig. 1). In this report, in order to allow for comparison to the Electrical Conductance (EC) standards, it is assumed that SC is comparable to EC. SC measurements are EC measurements which have been corrected to reflect the EC that would be recorded if the water were at 25°C (Stednick, 1991). CBNG water in Montana is a sodium-bicarbonate (Na-HCO₃) type water, while surface waters are typically relatively balanced (see Fig. 2). This dominance of sodium cations cause this water to have a high Sodium Adsorption Ratio (SAR; which is a complex ratio of Na to Ca+Mg); typically between 30 and 60. High SAR values may cause impacts to soil structure, and impair the ability for clay rich soils to infiltrate water (see Fig. 3). There is also little sulfate in the water in productive coal seams (VanVoast, 2003). Much of the produced water is managed through treated or untreated discharge to surface waters under National Pollutant Discharge Elimination System (NPDES) permits.

In Montana, NPDES permitting is conducted by the Montana Department of Environmental Quality (MDEQ) under the Montana Pollutant Discharge Elimination System (MPDES) permit program. During Water Year 2005, two CBNG MPDES permits were in use. One permit (Fidelity's MT0030457) allowed for up to 1,600 gallons per minute (gpm) (3.57 cubic feet per second (cfs)) of untreated discharge. This permit has been in use since September 1999. According to the Discharge Monitoring Reports (DMRs) submitted to MDEQ, this permit discharged an average of 1,067 gpm during water year 2005, with the water having a median EC of 2,136 $\mu\text{S}/\text{cm}$, and a median SAR of 57. Table 1 provides a summary of the data from the DMRs submitted for this permit. When evaluating the data in Table 1 it is important to note that Prairie Dog Creek and Badger Creek enter the Tongue River between the upstream and downstream monitoring locations. The other permit (Pinnacle Gas Resources' (PGR) MT0030660) allows for the discharge of up to 1,122 gpm (2.5 cfs) of treated CBNG water, with SAR < 3 and EC < 1000 $\mu\text{S}/\text{cm}$. During water year 2005, PGR discharged under this permit from April to September. PGR's average discharge rate was 200 gpm, with the water having a median EC of 255 $\mu\text{S}/\text{cm}$, and a median SAR of 2.9 (See Table 2 for details). Note that the data in Table 2 are not synoptic, and so the upstream to downstream comparison is not intended to be direct.

In Wyoming, NPDES discharge permitting is conducted by the Wyoming Department of Environmental Quality (WDEQ) under the Wyoming Pollutant Discharge Elimination System (WYPDES). Within Wyoming, two permits were originally issued in 1999

TABLE 1-Summary of DMR data for Fidelity’s MPDES Permit MT0030457

	Average Monthly Flow at State Line (cfs)	Tongue River Upstream of Discharge Points		Weighted Average Discharges (001-016)			Tongue River Downstream of Discharge Points		
		EC (uS/cm)	SAR	Discharge		EC (uS/cm)	SAR	EC (uS/cm)	SAR
				(gpm)	(cfs)				
31-Oct-04	157	560	0.6	1022	2.28	2137	55	682	0.9
30-Nov-04	139	571	0.5	1017	2.27	2207	61	697	0.8
31-Dec-04	115	643	0.6	1217	2.71	2111	58	758	0.9
31-Jan-05	94	649	0.6	835	1.86	2199	57	850	1.2
28-Feb-05	86	589	0.5	979	2.18	2097	56	657	0.8
31-Mar-05	124	579	0.5	960	2.14	2141	56	766	1.0
30-Apr-05	158	576	0.5	1070	2.38	2232	56	723	1.0
31-May-05	1703	508	0.5	1153	2.57	2136	58	649	0.9
30-Jun-05	1527	166	0.2	1248	2.78	2113	58	188	0.3
31-Jul-05	384	475	0.5	1190	2.65	2144	57	543	0.8
31-Aug-05	180	505	0.5	1124	2.50	2130	58	658	0.9
30-Sep-05	162	517	0.6	988	2.20	2096	57	662	1.0
AVERAGE	402	528	0.5	1067	2.38	2145	57	653	0.9
MEDIAN	158	566	0.5	1046	2.33	2136	57	672	0.9

TABLE 2-Summary of DMR data for PGR's MPDES Permit MT0030660

	Upstream USGS Data (06307500) (mean monthly)			Discharge (001) (mean monthly)				Tongue River Downstream of Discharge (mean monthly)	
	Flow (cfs)	SC (uS/cm)	SAR	Discharge		SC	SAR	SC (uS/cm)	SAR
				(gpm)	(cfs)	(uS/cm)			
30-Apr-05	83	748	1.1	184	0.41	300	2.3	810	1.0
31-May-05	1136	584	1.0	171	0.38	280	2.8	770	1.0
30-Jun-05	1496	323	0.5	214	0.48	220	2.0	340	0.5
31-Jul-05	511	294	0.4	192	0.43	220	3.0	340	0.4
31-Aug-05	399	373	0.5	219	0.49	240	2.9	318	0.5
30-Sep-05	292	447	0.6	222	0.49	270	2.9	400	0.6
AVERAGE	653	462	0.7	200	0.45	255	2.7	496	0.7
MEDIAN	455	410	0.5	203	0.45	255	2.9	370	0.6

allowing for the direct discharge of untreated CBNG water to surface waters in the Tongue River watershed. Both permits were renewed in April, 2004. Currently, these permits authorize the discharge of 0.3 cfs from 11 discharge points to Goose Creek, and 0.09 cfs from three discharge points to the Tongue River. More recently, the "Brinkerhoff" permits were issued in the Prairie Dog Creek watershed for discharge of untreated water into impoundments. A permit for the discharge of treated water into Prairie Dog Creek has also been approved by the WDEQ. This permit, establishes a dissolved sodium effluent limit of 50 mg/l and an EC effluent limit of 1000 μ S/cm (Zygmunt, pers. com., 2006). Within the Wyoming portion of Hanging Woman Creek there is a WYPDES permit for the discharge of untreated CBNG water to 13 off-channel impoundments (WY0053023), and a WPDES permit for the discharge of untreated CBNG water to one on-channel impoundment (WY0052407).

Several other factors have noticeable impacts on the Tongue River system. The Decker Coal mines near Decker, MT, discharge excess water from pit dewatering into the Tongue River Reservoir under MPDES permits. The Tongue River Reservoir reduces the variability in flow and water quality downstream of it. Irrigation withdrawals and return flows occur along the entire length of the river. The TY diversion dam near Miles City diverts a significant portion of the water in the river during low flow periods.

In response to the potential for CBNG development in this area, the MDEQ and Northern Cheyenne Tribe have developed surface water quality standards for EC and SAR in the Tongue River watershed. These standards provide criteria against which to compare the monitoring data. These standards are summarized in Table 3 below. It should be noted that the MDEQ standards have been reviewed and approved by the United States Environmental Protection Agency (EPA), and therefore have Clean Water Act standing; however, the Northern Cheyenne Tribe has not been granted "Treatment as a State" (TAS) status by the EPA, therefore, the Northern Cheyenne standards do not have Clean Water Act standing. Also, note that irrigation season standards are different from the non-irrigation season, and the MDEQ and Northern Cheyenne have defined the irrigation season differently. The irrigation season standards developed by the MDEQ are applicable year-round to the Tongue River above the Tongue River Dam. MDEQ standards are applicable at the Wyoming-Montana state line; however they are not applicable in Wyoming.

The Montana Board of Environmental Review (BER) has modified the standards which apply to CBNG in Montana; however this report only considers those standards which were in place in water year 2005. The most substantial change adopted by the BER was to designate EC and SAR "harmful" parameters.

For fiscal year 2005 the United States Congress appropriated funding for the USGS to conduct surface-water-quality monitoring in the Tongue River watershed to collect and disseminate data to stakeholders and the general public, as well as to State and Federal agencies tasked with managing and regulating CBNG development. Since this congressional funding was not sufficient to fully fund this network, the US Bureau of

TABLE 3: MDEQ and Northern Cheyenne Surface Water Standards Applicable for Water Year 2005 for EC and SAR in the Tongue River Watershed (from MDEQ, 2003a and Greystone and ALL, 2003)

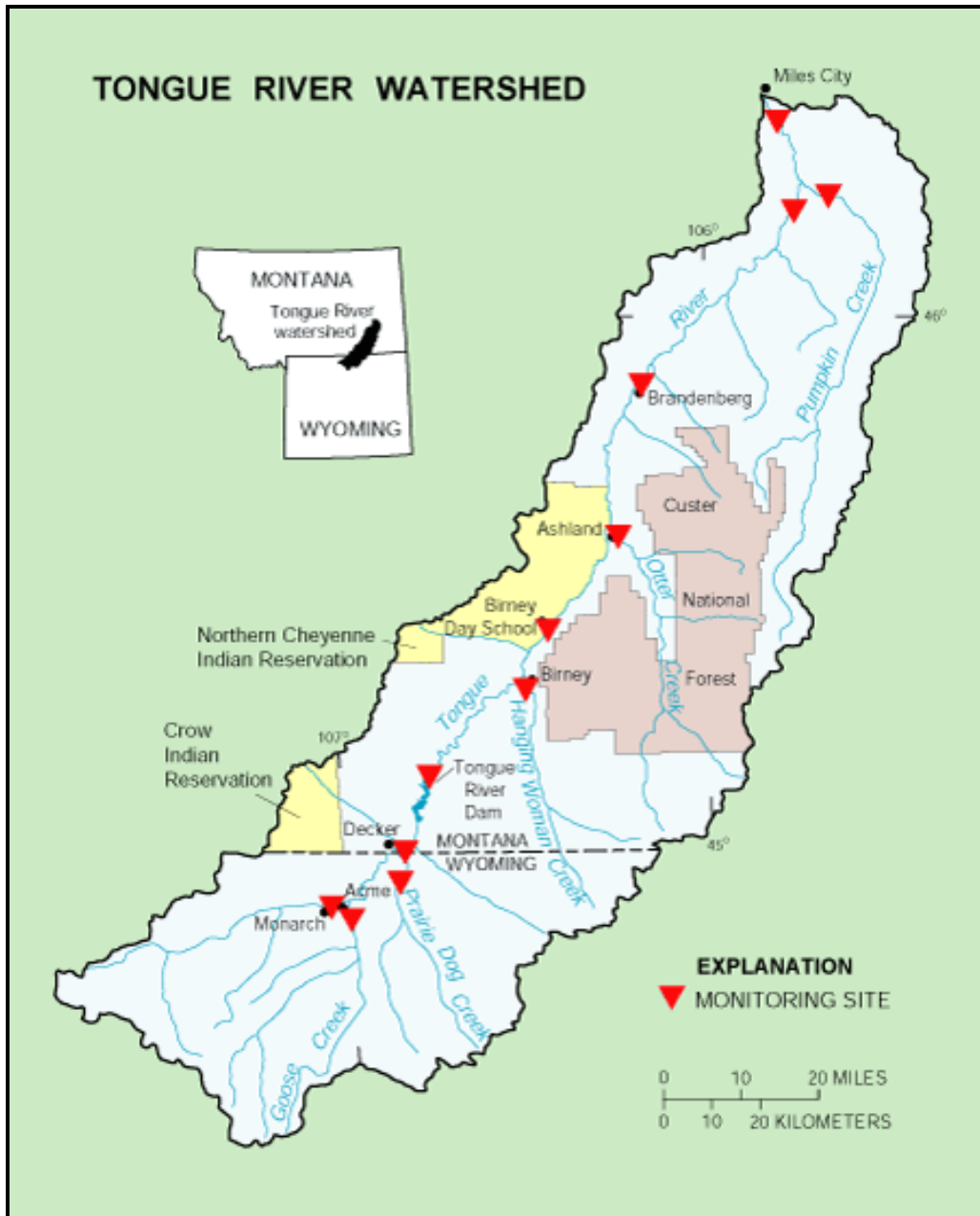
Irrigation Season¹						
	MDEQ			Northern Cheyenne		
	Tongue River	Tributaries	Tongue River Reservoir	Tongue River Southern Boundary	Tongue River Northern Boundary	Tributaries
EC (µS/cm)						
Monthly Average	1000	500	1000	1000	1500	1500
Not to Exceed	1500	500	1500	2000	2000	2000
SAR						
Monthly Average	3.0	3.0	3.0	---	---	---
Not to Exceed	4.5	4.5	4.5	2.0	3.0	3.0

Non-Irrigation Season¹						
	MDEQ			Northern Cheyenne		
	Tongue River	Tributaries	Tongue River Reservoir	Tongue River Southern Boundary	Tongue River Northern Boundary	Tributaries
EC (µS/cm)						
Monthly Average	1500	500	1000	---	---	---
Not to Exceed	2500	500	1500	2000	2000	2000
SAR						
Monthly Average	5.0	5.0	3.0	---	---	---
Not to Exceed	7.5	7.5	4.5	2.0	3.0	3.0

1: The Irrigation Season specified by the MDEQ is from March 1st to October 31st while the Irrigation Season specified by the Northern Cheyenne is from April 1st to November 15th.

Land Management (BLM), MDEQ, WDEQ, Wyoming State Engineer's Office (WSEO), Montana Department of Natural Resource Conservation (MDNRC), T & Y Irrigation District, and the Northern Cheyenne Tribe also provided funding for this network. This network has also been funded, with minor modifications, for fiscal year 2006 (Davis, pers. com, Nov05). The stations included in this network are shown on Map 1.

During water year 2005 (October 2004 – September 2005) Specific Conductance (SC) monitoring and SAR estimation in the Tongue River watershed was conducted by the U.S. Geological Survey. In this report the mean daily values for SC and mean daily estimated SAR values are used. These data are considered provisional by the USGS because they were retrieved from the USGS web site prior to final USGS approval; final values, which became available in April 2006 may be slightly different due to revisions made during final quality-assurance and review. SAR was estimated at some stations from the relationship between SC and SAR. The estimation procedure is discussed in



Map 1 shows the Tongue River Watershed as it extends from Wyoming into Montana. Also shown are major streams, and major land-ownership patterns (USFS, Northern Cheyenne Reservation, and Crow Reservation). The locations of the 12 surface water monitoring sites (3 in Wyoming, 9 in Montana), which are the subject of this report, are also shown.

detail at <http://tonguerivermonitoring.cr.usgs.gov/projects/index.htm>. The SC-SAR equations used to estimate the SAR data reviewed in this report were developed from 2004 data, and in some cases, from 1999-2003 and 1990-1996 data as well. At some sites the relationship between SC and SAR was not sufficiently robust to provide a reliable estimation of SAR, and so SAR was not estimated.

Surface water-quality samples are also obtained under this program. Although these samples were analyzed by the USGS for many parameters, this report will focus on SC, SAR, and flow. SC and SAR are considered to be the parameters most likely to be affected by CBNG development (MDEQ, 2003b), and SC and SAR in the natural system fluctuate significantly with flow. An expanded set of analytical data, and additional information about this network are available from the USGS project website at <http://tonguerivermonitoring.cr.usgs.gov/index.htm>.

Data Review

For all sites, please see the figures section for graphical display of the data. Tabulated summary statistics for the sites are provided on Tables 4A and 4B below. Complete data sets can be obtained at <http://tonguerivermonitoring.cr.usgs.gov/index.htm>.

For each station a summary of the mean daily flow, SC, and SAR data collected during water year 2005 is presented. Analytical SC and SAR data is also presented. Comparisons are made to the MDEQ and Northern Cheyenne surface water standards for EC and SAR (including mean monthly standards) where they are applicable. For comparison to the mean monthly EC and SAR standards the mean monthly values are calculated as the simple average of all the mean daily and analytical measurements recorded during each calendar month. Note that within the figures section the daily mean and analytical data are combined when discussing the range of values recorded. SC vs. Flow, SAR vs. Flow, and SC vs. SAR with historical data are presented in graphical form to allow evaluation of 2005 data in context.

Since SC and SAR are dependent on flow, it is important to recognize up front that water year 2005 was substantially wetter than 2004, with flows near long-term averages. If comparison is made between water quality data from different years, it is important to also take flow into account.

Main Stem Sites

Tongue River at Monarch, WY

Flow and SC were measured continuously at this site. SAR was estimated from the SC data. Water-quality samples were also collected. There are no CBNG discharges upstream of this station. Some irrigation diversion/return flow occurs upstream of this station.

TABLE 4A: Summary of USGS Monitoring Data of Mainstem Sites in the Tongue River Watershed for Water Year 2005

	Mean Daily Values			Water Quality Samples		Mean Monthly ⁺		
	Flow (cfs)	SC (uS/cm)	Estimated SAR	SC (uS/cm)	SAR	SC (uS/cm)	SAR	
Main Stem Sites								
Tongue River at Monarch, WY*	n	365	230	213	14	14	11	11
	min	44	156	0.1	193	0.2	200	0.2
	max	2660	445	0.4	495	0.5	495	0.4
	mean	214	346	0.3	363	0.3	375	0.3
	median	73	387	0.3	390	0.3	415	0.3
Tongue River at State Line, MT	n	365	336	336	18	18	12	12
	min	65	192	0.4	186	0.3	250	0.4
	max	4740	869	1.2	792	1.0	773	1.0
	mean	404	647	0.8	592	0.7	633	0.8
	median	150	689	0.9	647	0.8	651	0.8
Tongue River below Dam, MT	n	365	281	---	18	18	12	11
	min	68	279	---	282	0.4	294	0.4
	max	2740	782	---	753	1.1	753	1.1
	mean	366	557	---	563	0.8	596	0.9
	median	94	685	---	687	1.0	690	1.0
Tongue River at Birney Day School, MT	n	365	230	---	19	18	11	11
	min	70	301	---	319	0.4	323	0.4
	max	2640	792	---	807	1.3	807	1.3
	mean	357	536	---	592	0.9	612	0.9
	median	95	495	---	692	0.9	694	1.2
Tongue River at Brandenburg Bridge, MT	n	365	228	225	19	18	11	11
	min	40	331	0.5	337	0.5	391	0.6
	max	2190	993	1.7	926	1.8	930	1.6
	mean	347	617	1.0	663	1.2	700	1.2
	median	107	526	0.9	744	1.3	768	1.4
Tongue River above TY Diversion, MT	n	365	149	---	19	19	11	11
	min	40	331	---	351	0.5	347	0.6
	max	2100	990	---	1000	2.1	1000	2.1
	mean	348	655	---	727	1.4	747	1.4
	median	100	536	---	744	1.3	768	1.4
Tongue River at Miles City, MT	n	365	229	229	18	18	11	11
	min	12	379	0.7	354	0.5	464	0.9
	max	2880	1260	2.9	1070	3.7	1070	2.3
	mean	330	727	1.6	764	1.8	806	1.8
	median	109	651	1.4	777	2.0	829	2.0

Indicates exceedance of Irrigation Season Standards.

* = MDEQ Standards do not apply.

+ = Mean Monthly Values are calculated by taking the simple mean of all daily mean and analytical samples collected during each calendar month.

Note that SC and EC measurements are assumed to be comparable for this analysis.

TABLE 4B: Summary of USGS Monitoring Data of Tributary Sites in the Tongue River Watershed for Water Year 2005

	Mean Daily Values			Water Quality Samples		Mean Monthly ⁺		
	Flow (cfs)	SC (uS/cm)	Estimated SAR	SC (uS/cm)	SAR	SC (uS/cm)	SAR	
Tributary Sites								
Goose Creek near Acme, WY*	n	365	223	206	12	12	10	10
	min	21	136	0.2	130	0.2	193	0.3
	max	2000	826	0.8	772	1.2	771	0.7
	mean	167	562	0.6	575	0.6	603	0.6
	median	59	657	0.6	644	0.6	670	0.6
Prairie Dog Creek near Acme, WY*	n	365	231	214	13	13	11	11
	min	1.0	754	0.6	807	0.8	861	0.7
	max	354	2170	2.2	1790	1.7	1720	1.6
	mean	27	1159	1.0	1351	1.2	1267	1.1
	median	19	1050	0.9	1400	1.4	1340	1.1
Hanging Woman Creek near Birney, MT	n	365	140	101	11	11	8	8
	min	0.0	1520	4.0	1660	3.1	1558	3.1
	max	2.2	2710	5.2	2320	4.8	2348	4.7
	mean	0.1	2131	4.5	2095	4.2	2113	4.1
	median	0.1	2195	4.6	2170	4.4	2206	4.1
Otter Creek near Ashland, MT	n	365	164	164	13	12	10	10
	min	0.1	1900	4.8	2260	5.3	2293	5.4
	max	12	3160	6.8	3180	6.9	2950	6.4
	mean	1.9	2623	6.0	2709	6.0	2577	5.8
	median	1.7	2625	6.0	2810	6.1	2641	6.0
Pumpkin Creek near Miles City, MT	n	365	105	---	10	10	6	5
	min	0.0	275	---	442	5.1	526	5.9
	max	692	1260	---	2460	15	944	13
	mean	12	736	---	901	10	727	9.2
	median	0.0	748	---	742	10.3	692	9.6

Indicates exceedance of Irrigation Season Standards.

* = MDEQ Standards do not apply.

+ = Mean Monthly Values are calculated by taking the simple mean of all daily mean and analytical samples collected during each calendar month.

Note that SC and EC measurements are assumed to be comparable for this analysis.

Mean daily flow values ranged from 44 to 2660 cfs, with the mean being 214 cfs. Peak flows occurred from May to mid July. Historical flow data are not available for this station (see Fig. 4).

Mean daily SC data collected at this station ranged from 156 to 445 $\mu\text{S}/\text{cm}$, with a mean value of 346 $\mu\text{S}/\text{cm}$. Mean daily estimated SAR at this station ranged from 0.1 to 0.4, with a mean value of 0.3 (see Fig. 5). Analytical SC values at this site ranged from 193 to 495 $\mu\text{S}/\text{cm}$, with the mean being 363 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.2 to 0.5 with the mean being 0.3 (see Figs. 5-8). Mean monthly SC values ranged from 200 to 495 $\mu\text{S}/\text{cm}$, with a mean of 375 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.2 to 0.4, with a mean of 0.3 (see Fig. 5).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 6-8).

Tongue River at State Line, near Decker, MT

Flow and SC were measured continuously at this site. SAR was estimated from the SC data. Water-quality samples were also collected. Wyoming CBNG discharges, and some of Fidelity's CBNG discharges in Montana, and irrigation diversions/return flows occur upstream from this station.

Mean daily flow values ranged from 65 to 4740 cfs, with the mean being 404 cfs. Peak flows occurred from May to mid July. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 157 to 1962 cfs with the mean being 436 cfs (see Fig. 9). The flows observed here are substantially greater than those seen at Monarch due to the addition of Goose and Prairie Dog Creeks (See Map 1).

Mean daily SC data collected at this station ranged from 192 to 869 $\mu\text{S}/\text{cm}$, with a mean value of 647 $\mu\text{S}/\text{cm}$. Mean daily estimated SAR at this station ranged from 0.4 to 1.2, with a mean value of 0.8 (see Fig. 10). Analytical SC values at this site ranged from 186 to 792 $\mu\text{S}/\text{cm}$, with the mean being 592 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.3 to 1.0 with the mean being 0.7 (see Figs. 10-13). Mean monthly SC values ranged from 250 to 773 $\mu\text{S}/\text{cm}$, with a mean of 633 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.4 to 1.0, with a mean of 0.8 (see Fig. 10). All recorded SC and SAR values collected at this station were below the applicable MDEQ Standards (see Fig. 10). Note that irrigation season standards apply year-round upstream of the reservoir.

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 11-13).

Tongue River below Tongue River Dam, near Decker MT

Flow and SC were measured continuously at this site. Water-quality samples were also collected. Wyoming CBNG discharges, Fidelity's CBNG discharges, irrigation diversions/return flows, the Tongue River Reservoir, and the Decker Coal Mines occur upstream from this station. The PGR's discharge is located just downstream from this location.

Mean daily flow values ranged from 68 to 2740 cfs, with the mean being 366 cfs. Peak flows occurred from May to mid July. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 167 to 1526 cfs with the mean being 430 cfs (see Fig. 14). Flows at this station are strongly regulated by Tongue River Dam operations (See Map 1).

Mean daily SC data collected at this station ranged from 279 to 782 $\mu\text{S}/\text{cm}$, with a mean value of 557 $\mu\text{S}/\text{cm}$. Mean daily SAR was not estimated at this station (see Fig. 15). Analytical SC values at this site ranged from 282 to 753 $\mu\text{S}/\text{cm}$, with the mean being 563

$\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.4 to 1.1 with the mean being 0.8 (see Figs. 15-18). Mean monthly SC values ranged from 294 to 753 $\mu\text{S}/\text{cm}$, with a mean of 596 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.4 to 1.1, with a mean of 0.9 (see Fig. 15). All recorded SC and SAR values collected at this station were below the applicable MDEQ Standards (see Fig. 15).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 16-18).

Tongue River at Birney Day School Bridge, near Birney, MT

Flow and SC were measured continuously at this site. Water-quality samples were also collected. Wyoming CBNG discharges, Fidelity's CBNG discharges, the Decker Coal Mines, the Tongue River Dam, PGR's CBNG discharges, and irrigation diversions/return flows occur upstream from this station.

Mean daily flows ranged from 70 to 2,640 cfs, with the mean being 357 cfs. Peak flows occurred from May to mid July. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 156 to 1,220 cfs with the mean being 369 cfs (see Fig. 19). Flows at this station are strongly regulated by Tongue River Dam operations.

Mean daily SC data collected at this station ranged from 301 to 792 $\mu\text{S}/\text{cm}$, with a mean value of 536 $\mu\text{S}/\text{cm}$. Mean daily SAR was not estimated at this station (see Fig. 20). Analytical SC values at this site ranged from 319 to 807 $\mu\text{S}/\text{cm}$, with the mean being 612 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.4 to 1.3 with the mean being 0.9 (see Figs. 20-23). Mean monthly SC values ranged from 323 to 807 $\mu\text{S}/\text{cm}$, with a mean of 612 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.4 to 1.3, with a mean of 0.9 (see Fig. 20). All recorded SC and SAR values were below the applicable MDEQ and Northern Cheyenne Standards for this site (see Fig. 20).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 21-23).

Tongue River below Brandenburg Bridge, near Ashland, MT

Flow and SC were measured continuously at this site. SAR was estimated from the SC data. Water-quality samples were also collected. Wyoming CBNG discharges, Fidelity's CBNG discharges, the Decker Coal Mines, the Tongue River Dam, PGR' CBNG discharges, and irrigation diversions/return flows occur upstream from this station.

Mean daily flows during Water Year 2005 ranged from 40 to 2190 cfs, with the mean being 347 cfs. Peak flows occurred from May to mid July. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 164 to 1416 cfs with the mean being 422 cfs (see Fig. 24). The substantial decrease in flow observed at this station during low flows (min flow of 40 vs. 70 cfs at Birney Day

School) are believed to be mainly attributable to irrigation diversions. Flows at this station are strongly regulated by Tongue River Dam operations.

Mean daily SC data collected at this station ranged from 331 to 993 $\mu\text{S}/\text{cm}$, with a mean value of 617 $\mu\text{S}/\text{cm}$. Mean daily estimated SAR at this station ranged from 0.5 to 1.7, with a mean value of 1.0 (see Fig. 25). Analytical SC values at this site ranged from 337 to 926 $\mu\text{S}/\text{cm}$, with the mean being 663 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.5 to 1.8 with the mean being 1.2 (see Figs. 25-28). Mean monthly SC values ranged from 391 to 930 $\mu\text{S}/\text{cm}$, with a mean of 700 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.6 to 1.6, with a mean of 1.2 (see Fig. 25). All recorded EC and SAR values are below the applicable MDEQ and Northern Cheyenne Standards for this site (see Fig. 25).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 26-28).

Tongue River above TY Diversion

Flow and SC were measured continuously at this site. Water-quality samples were also collected. Wyoming CBNG discharges, Fidelity's CBNG discharges, the Decker Coal Mines, the Tongue River Dam, PGR' CBNG discharges, and irrigation diversions/return flows occur upstream from this station. This station was began operation on 10/1/2004.

Mean daily flows ranged from 40 to 2100 cfs, with the mean being 348 cfs. Peak flows occurred from May to mid July (see Fig. 29). Historical data are not available for this station. Flows at this station are strongly regulated by Tongue River Dam operations.

Mean daily SC data collected at this station ranged from 331 to 990 $\mu\text{S}/\text{cm}$, with a mean value of 655 $\mu\text{S}/\text{cm}$. Mean daily SAR was not estimated at this station (see Fig. 30). Analytical SC values at this site ranged from 351 to 1000 $\mu\text{S}/\text{cm}$, with the mean being 727 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.5 to 2.1 with the mean being 1.4 (see Figs. 30-33). Mean monthly SC values ranged from 347 to 1000 $\mu\text{S}/\text{cm}$, with a mean of 747 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.6 to 2.1, with a mean of 1.4 (see Fig. 30). All recorded SC and SAR values are below the applicable MDEQ Standards for this site (see Fig. 30).

The SC vs. Flow, SAR vs. Flow, and SC vs. SAR relationships for this site seem to be well defined (see Figs. 31-33). There is no historical data available for this station.

Tongue River at Miles City, MT

Flow and SC were measured continuously at this site. SAR was estimated from the SC data. Water-quality samples were also collected. Wyoming CBNG discharges Fidelity's CBNG discharges, the Decker Coal Mines, the Tongue River Dam, PGR' CBNG

discharges, irrigation diversions/return flows, and the TY Diversion dam occur upstream from this station.

The portion of the Tongue River immediately upstream from this station (from the TY diversion dam just above Pumpkin Creek to the mouth) is listed as impaired on the MDEQ's current (2004) 303(d) list, with the probable cause of impairment being identified as flow alteration, and the source being hydromodification. Once water is diverted at the TY diversion dam the majority is either consumed, flows to the Yellowstone River as irrigation return flow, or returns to the Tongue River as irrigation return flow. As such, during low flows, the water flowing through this lower portion of the Tongue River, and monitored at the Miles City station, is more representative of irrigation return flows than the Tongue River, since most of the water in the Tongue is diverted for irrigation during low flows.

Mean daily flows ranged from 12 to 2880 cfs, with the mean being 330 cfs. Peak flows occurred from May to mid July. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 152 to 1494 cfs with the mean being 405 cfs (see Fig. 34). Flows at this station are strongly regulated by Tongue River Dam operations and the operation of the TY diversion dam.

Mean daily SC data collected at this station ranged from 379 to 1260 $\mu\text{S}/\text{cm}$, with a mean value of 727 $\mu\text{S}/\text{cm}$. Mean daily estimated SAR at this station ranged from 0.7 to 2.9, with a mean value of 1.6 (see Fig. 35). Analytical SC values at this site ranged from 354 to 1070 $\mu\text{S}/\text{cm}$, with the mean being 764 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.5 to 3.7 with the mean being 1.8 (see Figs. 35-38). The highest SAR value was collected on June 9th when there was significant precipitation in the immediate vicinity of Miles City. It appears that this area produces high sodium runoff. During this time (6/7/05) the SAR at the TY station was 0.67. The difference in flow between the two stations on June 9th was 1460 cfs. The fact that this high SAR sample was collected during high flows seems counterintuitive; however it appears to result from intense local precipitation in the Miles City area and little precipitation in the remainder of the watershed. Mean monthly SC values ranged from 464 to 1070 $\mu\text{S}/\text{cm}$, with a mean of 806 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.9 to 2.3, with a mean of 1.8 (see Fig. 35). The mean monthly SC value recorded for March was slightly greater than the mean monthly irrigation season standard (1000.3 vs. 1000 $\mu\text{S}/\text{cm}$). The mean monthly SC value recorded in April was only slightly less than the mean monthly irrigation season standard (999.4 vs. 1000 $\mu\text{S}/\text{cm}$). All other SC and SAR values are below the applicable MDEQ for this site (see Fig. 35). Note that the highest mean monthly SC value (1070 $\mu\text{S}/\text{cm}$) was recorded in March, and does not exceed the non-irrigation season standard.

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 36-38).

Tributary Sites

Goose Creek near Acme, WY

Flow and SC data were collected continuously at this station. SAR was estimated from the SC data. Water-quality samples were also collected. The 1999 WYPDES permits allow for the direct discharge of approximately 0.3 cfs (135 gpm) of untreated CBNG water to Goose Creek from 11 discharge points upstream from this station (Zygmunt, pers. com., 2006). Irrigation diversions/return flows are also occurring upstream from this station.

Mean daily flows ranged from 21 to 2000 cfs, with the mean being 167 cfs. Peak flows occurred from May to mid July. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 48 to 693 cfs with the mean being 152 cfs (see Fig. 39).

Mean daily SC data collected at this station ranged from 136 to 826 $\mu\text{S}/\text{cm}$, with a mean value of 562 $\mu\text{S}/\text{cm}$. Mean daily estimated SAR at this station ranged from 0.2 to 0.8, with a mean value of 0.6 (see Fig. 40). Analytical SC values at this site ranged from 130 to 772 $\mu\text{S}/\text{cm}$, with the mean being 575 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.2 to 1.2 with the mean being 0.6 (see Figs. 40-43). Mean monthly SC values ranged from 193 to 771 $\mu\text{S}/\text{cm}$, with a mean of 603 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.3 to 0.7, with a mean of 0.6 (see Fig. 40).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 41-43).

Prairie Dog Creek near Acme, WY

Flow and SC data were collected continuously at this station. SAR was estimated from the SC data. Water-quality samples were also collected. The "Brinkerhoff" permits allow for the discharge of untreated water into impoundments within the Prairie Dog Creek watershed. A permit for the discharge of treated water into Prairie Dog Creek has also approved by WDEQ which allows for the discharge of treated CBNG water with dissolved sodium less than 50 mg/l and $\text{EC} < 1000 \mu\text{S}/\text{cm}$ (Zygmunt, pers. com., 2006). Irrigation diversions/return flows are also occurring upstream from this station.

Mean daily flows during Water Year 2005 ranged from 1.0 to 354 cfs, with the mean being 27 cfs. Peak flows occurred from May to mid July. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 13 to 276 cfs with the mean being 38 cfs (see Fig. 44).

Mean daily SC data collected at this station ranged from 754 to 2170 $\mu\text{S}/\text{cm}$, with a mean value of 1159 $\mu\text{S}/\text{cm}$. Mean daily estimated SAR at this station ranged from 0.6 to 2.2, with a mean value of 1.0 (see Fig. 45). Analytical SC values at this site ranged from 807 to 1790 $\mu\text{S}/\text{cm}$, with the mean being 1351 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site

ranged from 0.8 to 1.7 with the mean being 1.2 (see Figs. 45-48). Mean monthly SC values ranged from 861 to 1720 $\mu\text{S}/\text{cm}$, with a mean of 1267 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 0.8 to 1.6, with a mean of 1.1 (see Fig. 45).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 46-48).

Hanging Woman Creek near Birney, MT

Flow and SC data were collected continuously at this station. SAR was estimated from the SC data. Water-quality samples were also collected. Nance Petroleum Corporation has permits for the discharge of untreated water into impoundments within the Wyoming portion of the Hanging Woman Creek watershed. Irrigation diversions/return flows are also occurring upstream from this station.

Mean daily flows during Water Year 2005 ranged from 0 to 2.2 cfs, with the mean being 0.1 cfs. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 0.38 to 82 cfs with the mean being 3 cfs (see Fig. 49).

Mean daily SC data collected at this station ranged from 1520 to 2710 $\mu\text{S}/\text{cm}$, with a mean value of 2131 $\mu\text{S}/\text{cm}$. Mean daily estimated SAR at this station ranged from 4.0 to 5.2, with a mean value of 4.5 (see Fig. 50). Analytical SC values at this site ranged from 1660 to 2320 $\mu\text{S}/\text{cm}$, with the mean being 2095 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 3.1 to 4.8 with the mean being 4.2 (see Figs. 50-53). Mean monthly SC values ranged from 1558 to 2348 $\mu\text{S}/\text{cm}$, with a mean of 2113 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 3.1 to 4.7, with a mean of 4.1 (see Fig. 50). All recorded SC values were far in excess of the MDEQ's EC standard. Many of the recorded SAR values were in excess of the MDEQ's SAR standards (see Fig. 50).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 51-53).

Otter Creek at Ashland, MT

Flow and SC were measured continuously at this site. SAR was estimated from the SC data. Water-quality samples were also collected. No CBNG discharge is occurring upstream of this station. Irrigation diversions/return flows are occurring upstream from this station.

Mean daily flows ranged from 0.1 to 12 cfs, with the mean being 1.9 cfs. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 0.55 to 32 cfs with the mean being 4 cfs (see Fig. 54).

Mean daily SC data collected at this station ranged from 1900 to 3160 $\mu\text{S}/\text{cm}$, with a mean value of 2623 $\mu\text{S}/\text{cm}$. Mean daily estimated SAR at this station ranged from 4.8 to

6.7, with a mean value of 6.0 (see Fig. 55). Analytical SC values at this site ranged from 2260 to 3180 $\mu\text{S}/\text{cm}$, with the mean being 2709 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 5.3 to 6.9 with the mean being 6.0 (see Figs. 55-58). Mean monthly SC values ranged from 2293 to 2950 $\mu\text{S}/\text{cm}$, with a mean of 2577 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 5.4 to 6.4, with a mean of 5.8 (see Fig. 55). All recorded SC values were far in excess of the MDEQ's EC standards. Most of the recorded SAR values were in excess of the MDEQ's SAR standards (see Fig. 55).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 56-58).

Pumpkin Creek near Miles City, MT

Flow and SC were measured continuously at this site. Water-quality samples were also collected. CBNG discharge is not occurring upstream of this station. Irrigation diversions/return flows are occurring upstream from this station.

Mean daily flows ranged from 0 to 692 cfs, with the mean being 12 cfs. The historical mean daily flow record for this site indicates that flow at this station in an "average" year ranges from 0.01 to 151 cfs with the mean being 14 cfs (see Fig. 59).

Mean daily SC data collected at this station ranged from 275 to 1260 $\mu\text{S}/\text{cm}$, with a mean value of 736 $\mu\text{S}/\text{cm}$. Mean daily SAR was not estimated at this station (see Fig. 60). Analytical SC values at this site ranged from 442 to 2460 $\mu\text{S}/\text{cm}$, with the mean being 901 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 5.1 to 15 with the mean being 10 (see Figs. 60-63). Mean monthly SC values ranged from 526 to 944 $\mu\text{S}/\text{cm}$, with a mean of 727 $\mu\text{S}/\text{cm}$. Mean monthly SAR values ranged from 5.9 to 13, with a mean of 9.2 (see Fig. 60). Most recorded SC values were in excess of the MDEQ's EC standards. All of the recorded SAR values were in excess of the MDEQ's SAR standards (see Fig. 60).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 61-63).

Conclusions

During Water Year 2005 (October 2004-September 2005) flows within the Tongue River watershed were lower than historical averages until the end of April 2005 and comparable to historical averages from May to September 2005. EC and SAR can be correlated with flow so an evaluation of EC and SAR must also take flow into account.

The main stem stations showed that the MDEQ and Northern Cheyenne surface water standards for EC and SAR are not exceeded, except at the Miles City station. The mean monthly EC values at Miles City were slightly greater than the mean monthly irrigation season EC standard during March (1000.3 vs. 1000 $\mu\text{S}/\text{cm}$).

The tributary stations showed that the MDEQ surface water standards for EC were typically exceeded by existing conditions. In many cases the existing conditions resulted in water quality values that were always in excess of the EC standards. The MDEQ standards for SAR were often exceeded at the Hanging Woman and Otter Creek stations, and were always exceeded at the Pumpkin Creek station. These exceedances in watersheds where little or no development has occurred indicate that natural conditions are responsible for these exceedances.

A statistical trend analysis was not conducted for this data; however based upon evaluation of the 2005 data vs. historical data (SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts) it appears that overall there has not been a noticeable change in surface water quality. An interpretive report is scheduled to be completed in 2007 which will include data through Water Year 2006.

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Figures

Figure 1: Comparison of Crop Yield to SC (Salinity) and Recorded 2005 SC Values in the Tongue River Watershed

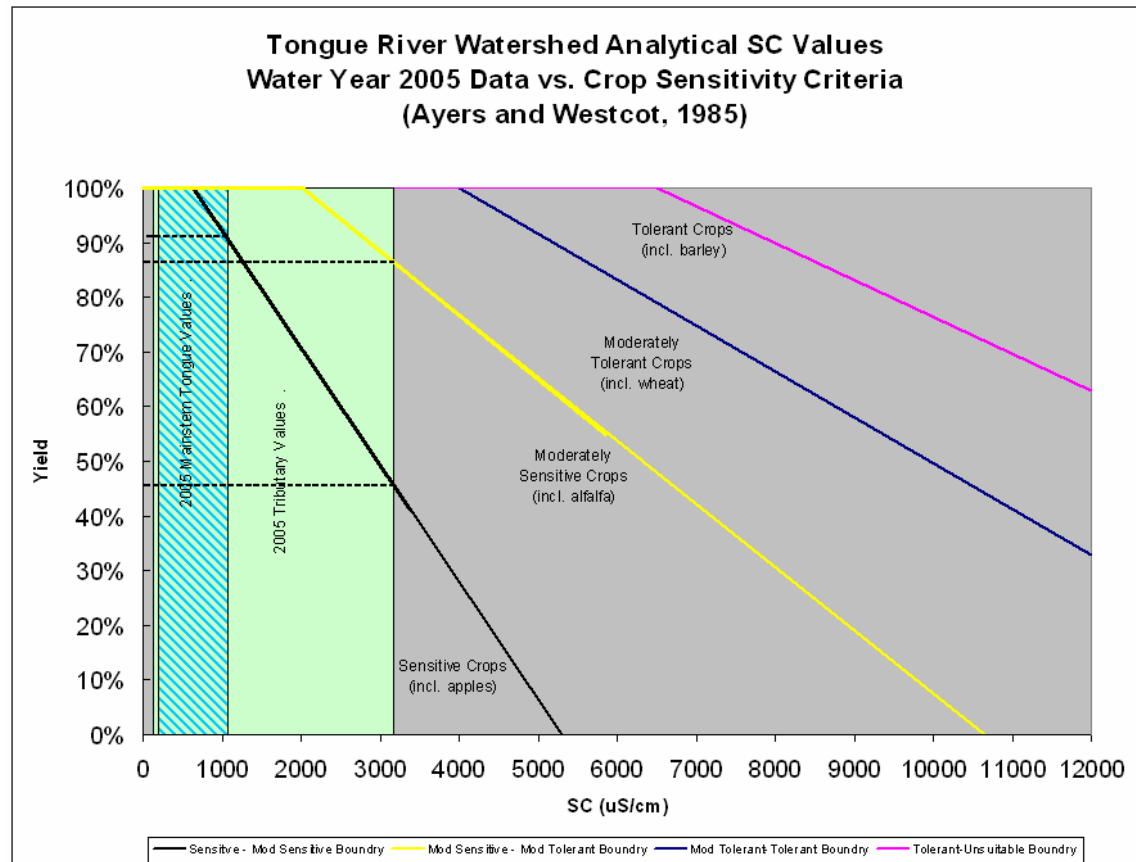


Figure 1 shows the range of SC values recorded during water year 2005 compared to yield vs. salinity curves for representative crops. Note that yield comparisons are made to that which would be attained using low salinity irrigation water, and assumes that all other factors are equal. Mainstem values ranged from 156 to 1260 $\mu\text{S/cm}$. The high end of these values would be expected to cause approximately an 8% drop in the yield of sensitive crops. Tributary values ranged from 130 to 3180 $\mu\text{S/cm}$. The high end of these values would be expected to cause approximately a 13% drop in the yield of moderately sensitive crops, and approximately a 55% drop in the yield of sensitive crops.

Figure 2: Comparison of Stiff Plots for CBNG and Surface Waters

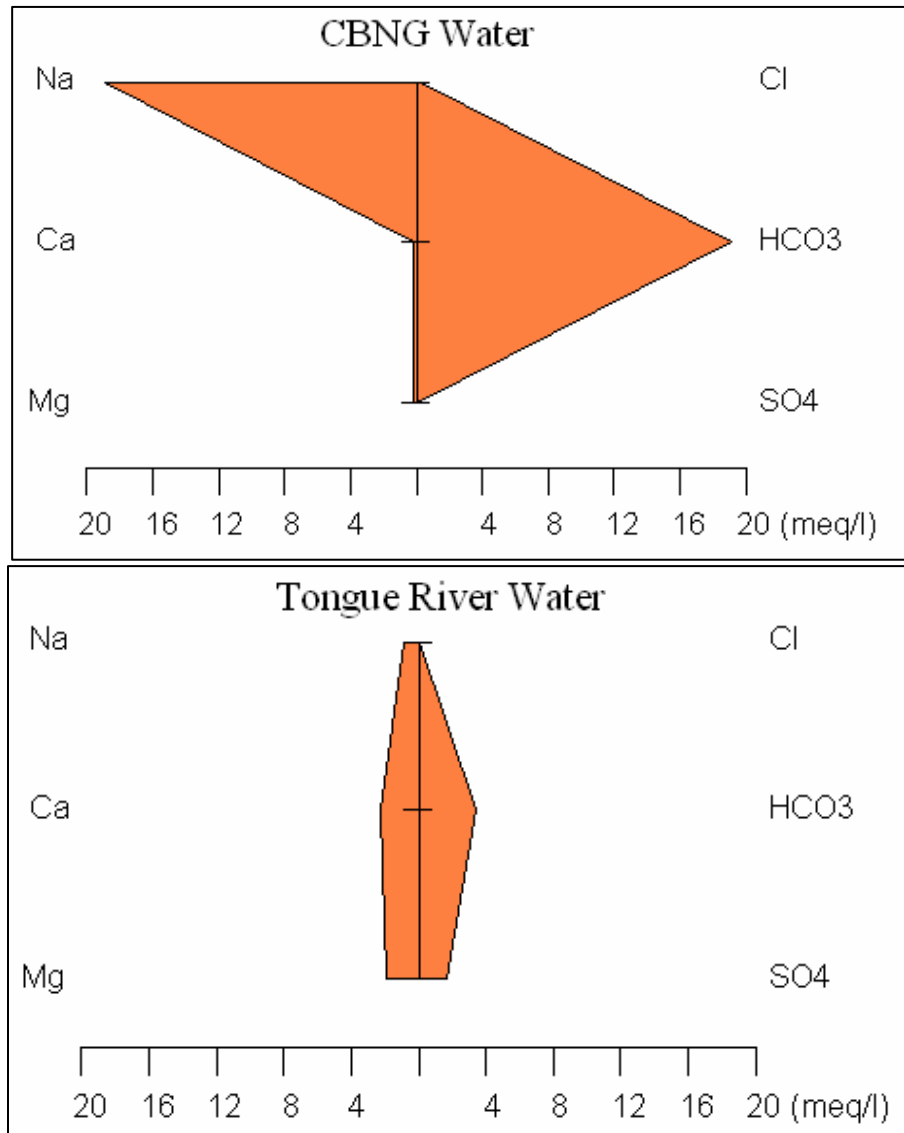


Figure 2 shows a comparison of the major ions in a representative sample of CBNG water from a well near Decker, MT, and from the Tongue River at the State Line USGS station. The CBNG water is dominated by Na and HCO₃ while the surface water sample is relatively balanced with Ca>Mg>Na and HCO₃>SO₄.

Figure 3: Comparison of Infiltration Criteria and Recorded 2005 SC and SAR Values in the Tongue River Watershed

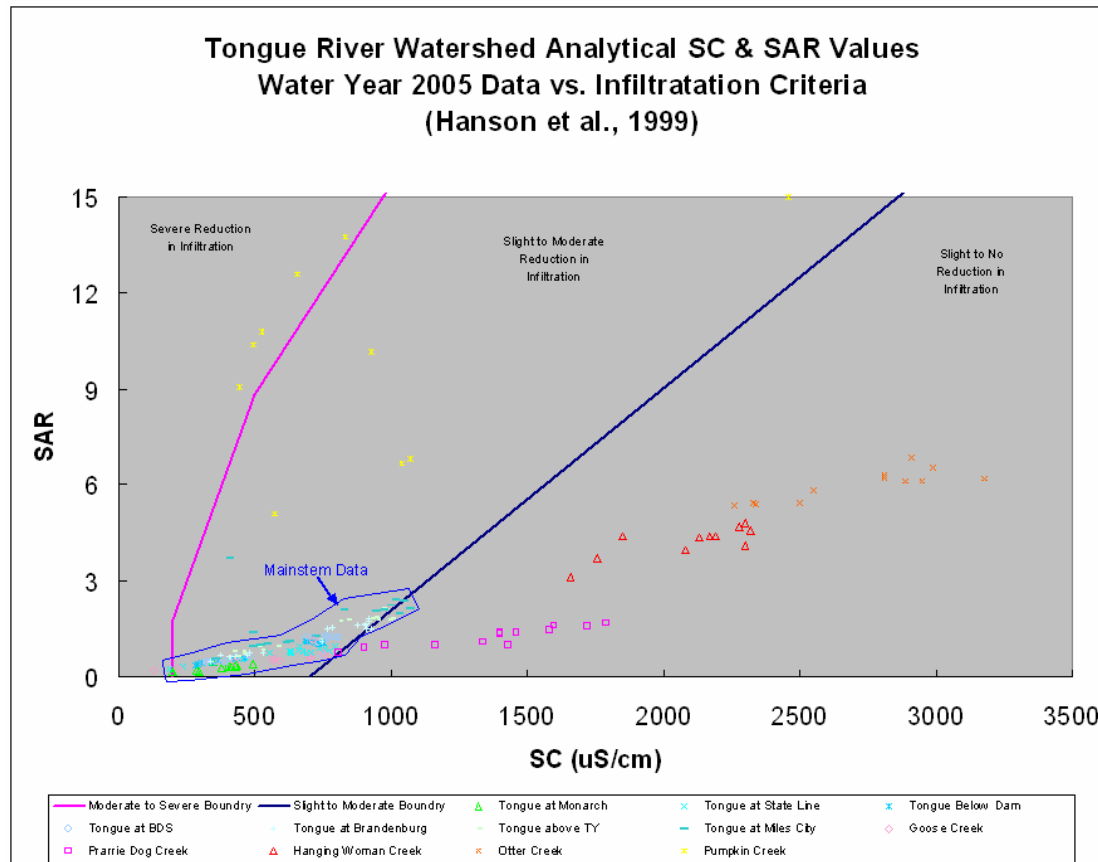


Figure 3 shows water quality data from water year 2005 in the Tongue River Watershed compared to the infiltration criteria developed by Hanson et al. (1999). Mainstem and Goose Creek values fall within the Slight to Moderate reduction in infiltration field due to their relatively low SC values. Pumpkin Creek Values fall within the Severe and Slight to Moderate reduction in infiltration fields due to its having relatively high SAR values relative to SC. Other tributaries mainly fall within the Slight to No reduction in infiltration field.

Figure 4: Tongue River at Monarch, WY

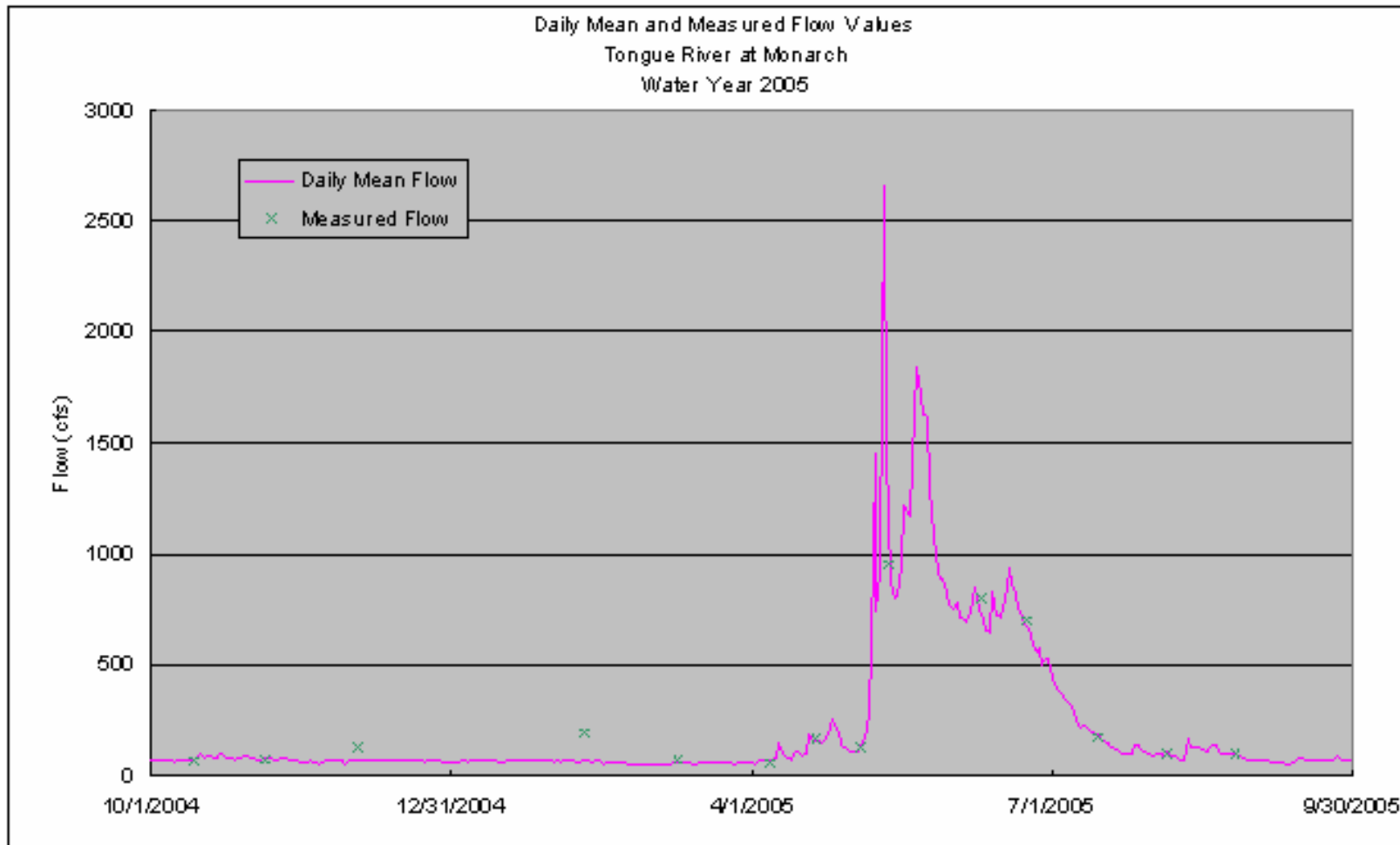


Figure 4 shows mean daily and field measurements of flow in a time series plot for water year 2005 for the Tongue River at Monarch. Flow values ranged from 44 to 2660 cfs. Historical mean daily flow values were not available for this station since daily streamflow has only been active since 5/1/04.

Figure 5: Tongue River at Monarch, WY

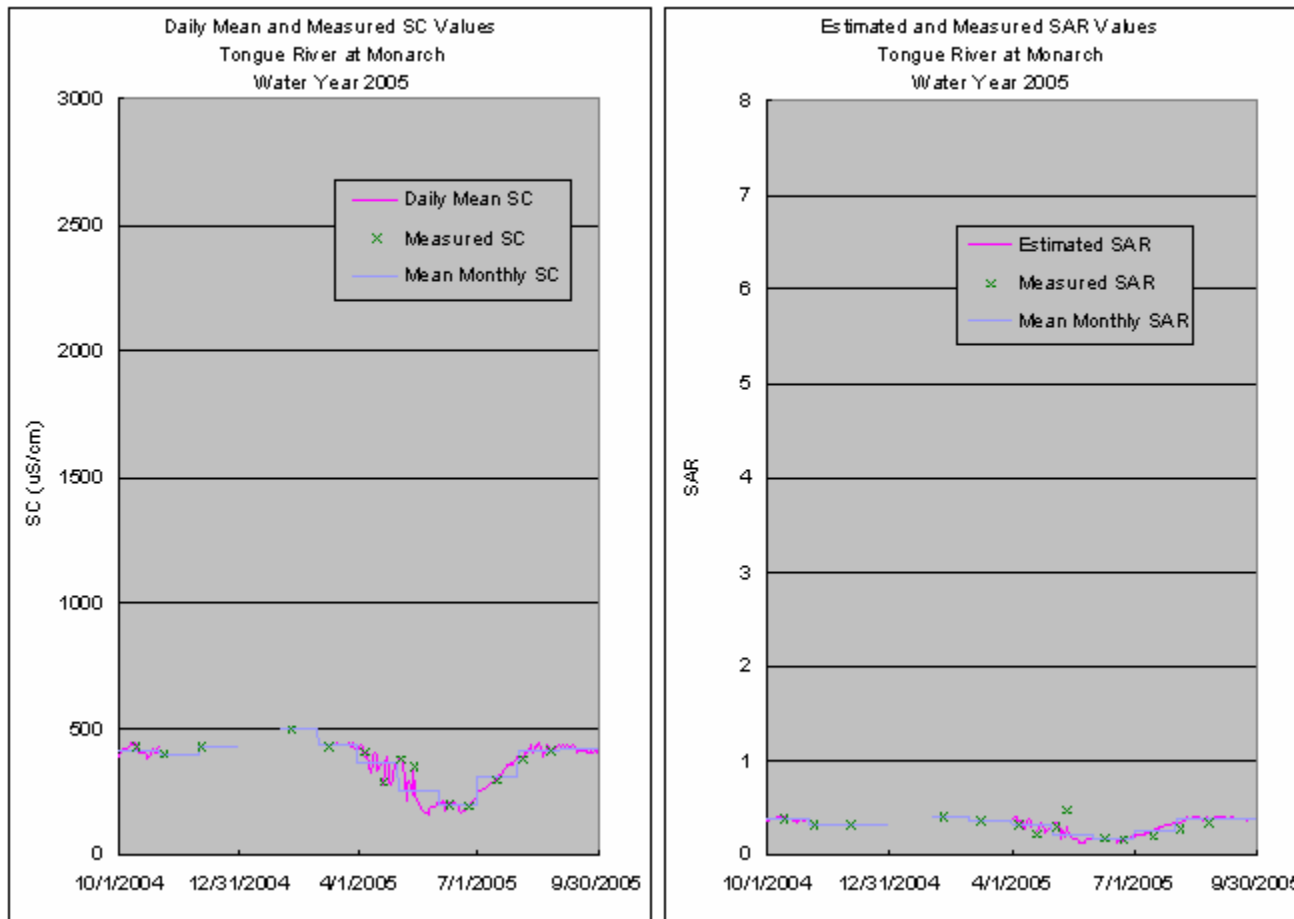


Figure 5 shows analytical and mean daily SC values (A) and analytical and mean daily estimated SAR values (B) in time series plots for water year 2005 for the Tongue River at Monarch. Mean Monthly SC and SAR values are also shown. SC values ranged from 156 uS/cm to 495 uS/cm. SAR values ranged from 0.1 to 0.5.

Figure 6: Tongue River at Monarch, WY

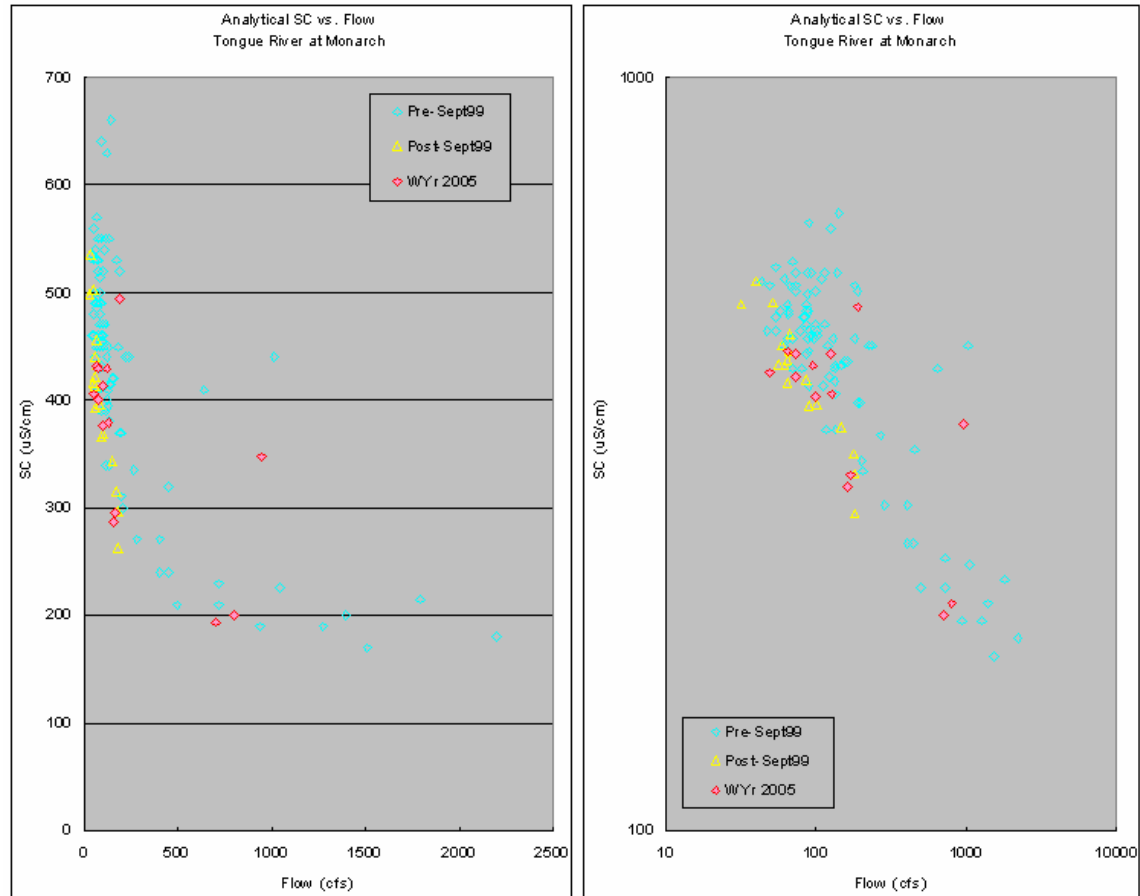


Figure 6 shows analytical SC vs. Flow data for water year 2005 for the Tongue River at Monarch. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 7: Tongue River at Monarch, WY

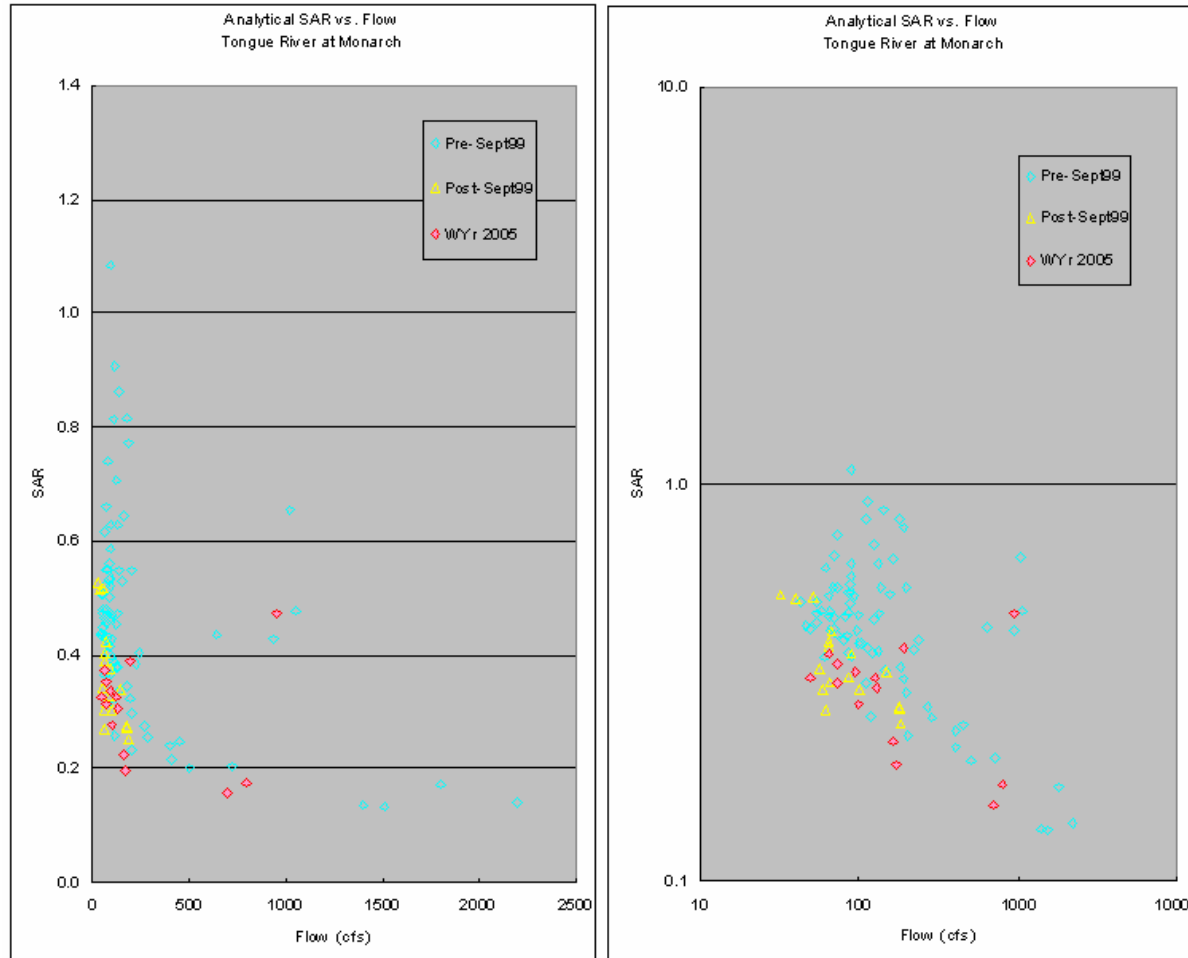


Figure 7 shows analytical SAR vs. Flow data for water year 2005 for the Tongue River at Monarch. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 8: Tongue River at Monarch, WY

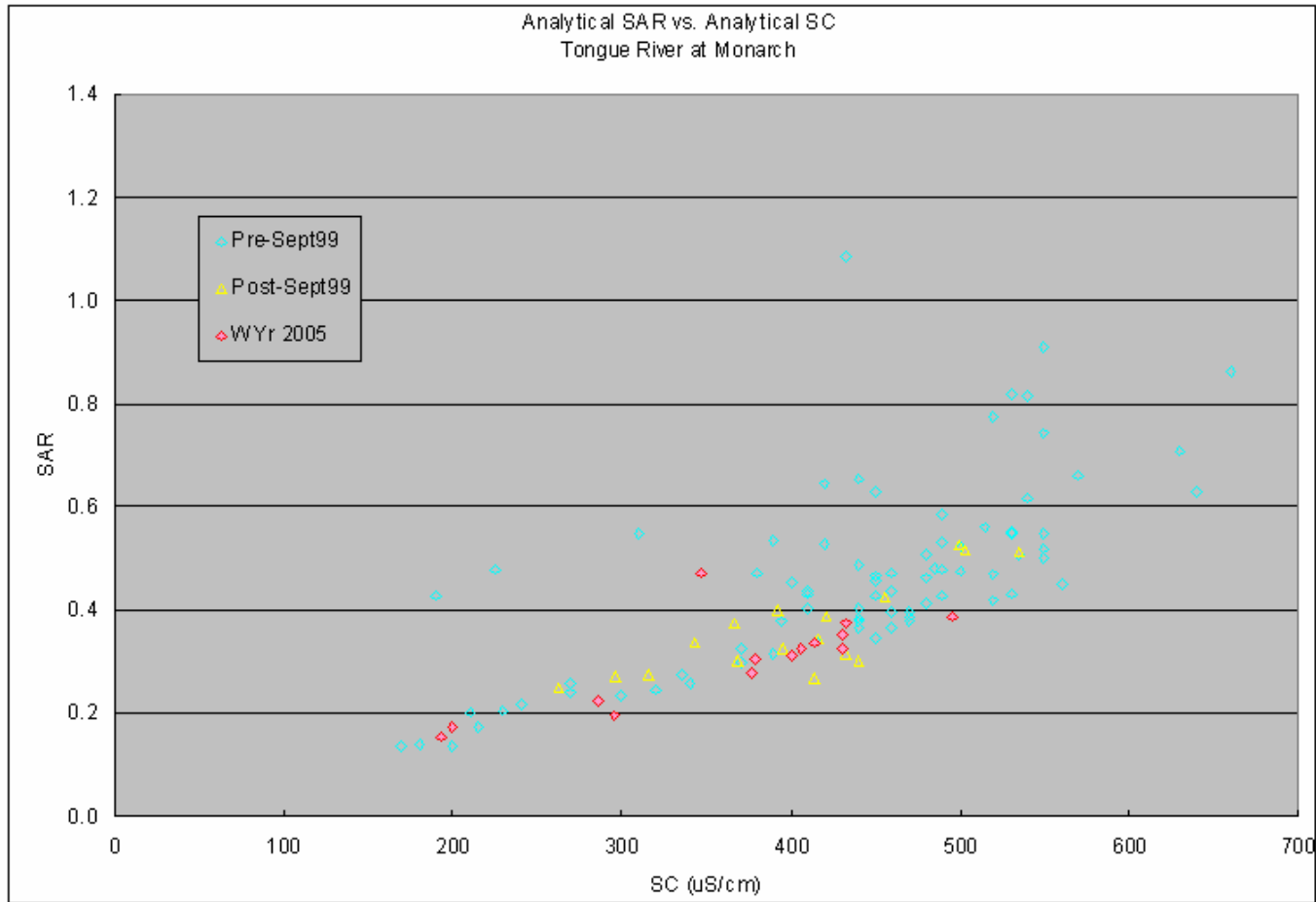


Figure 8 shows analytical SAR vs. analytical SC data for water year 2005 for the Tongue River at Monarch. Historical SAR vs. SC data are also shown to place the data in context.

Figure 9: Tongue River at State Line, near Decker, MT

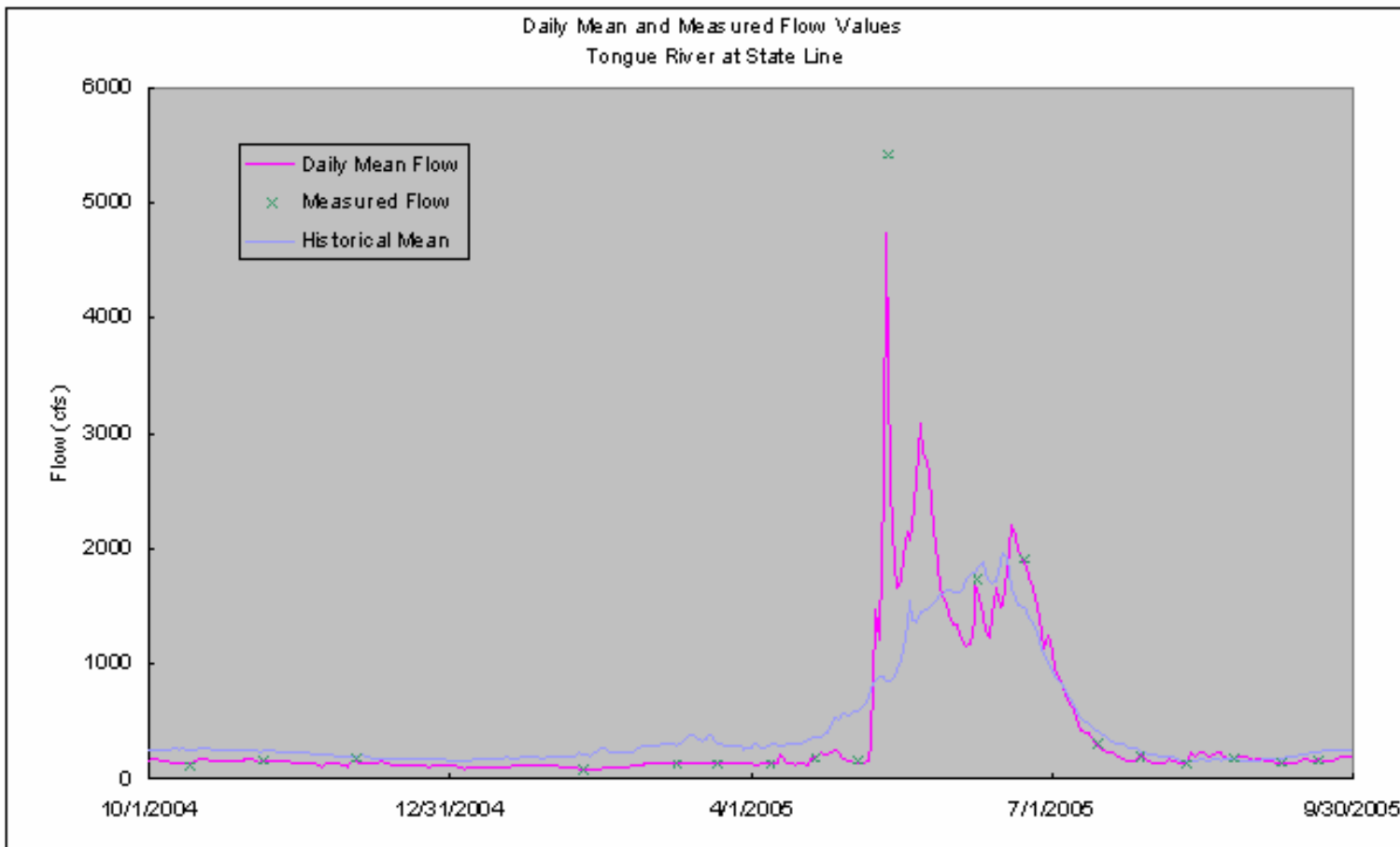


Figure 9 shows mean daily and field measurements of flow in a time series plot for water year 2005 for the Tongue River at the State Line. The historical average mean daily flow values are also shown. Mean daily flow values ranged from 65 to 4740 cfs. Flows were less than average through April, then from May to September flows were comparable to average.

Figure 10: Tongue River at State Line, near Decker, MT

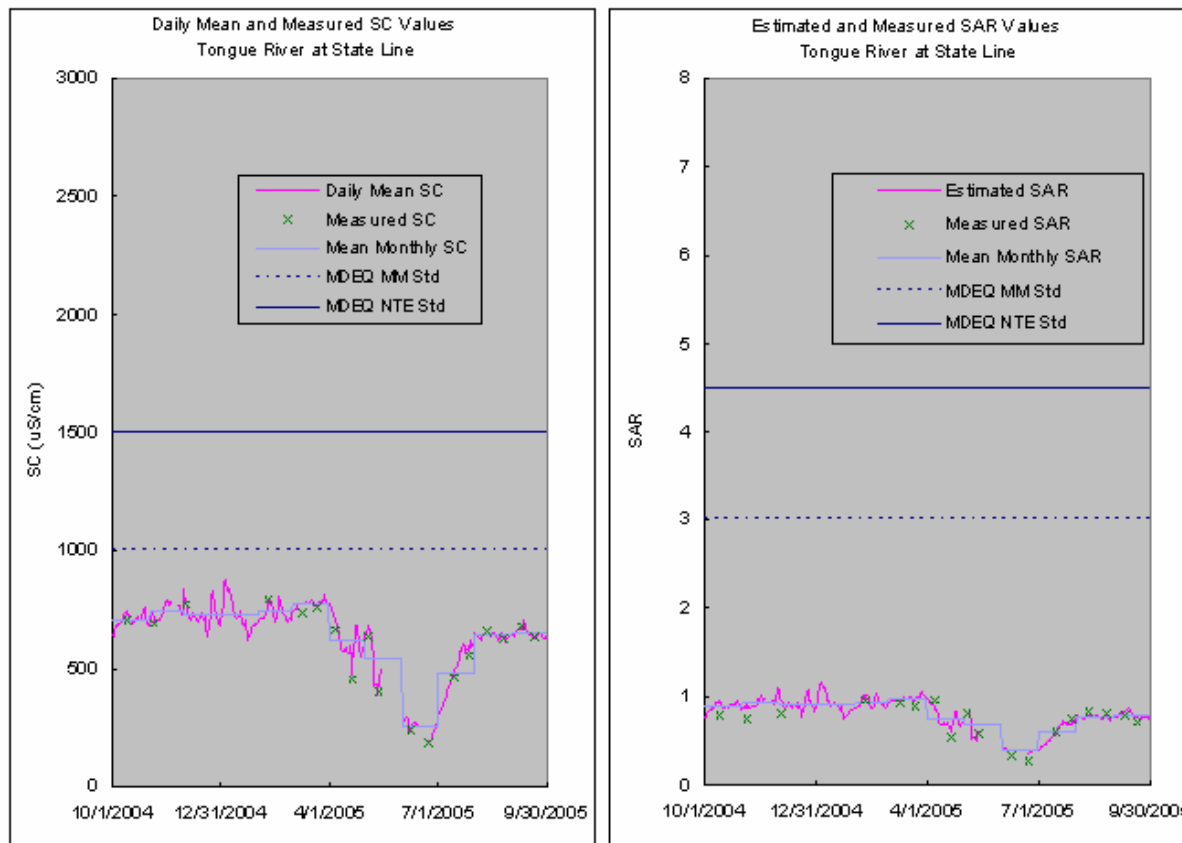


Figure 10 shows analytical and mean daily SC values (A) and analytical and mean daily estimated SAR values (B) values in time series plots for water year 2005 for the Tongue River at the State Line. Mean Monthly SC and SAR values are also shown. SC values ranged from 186 to 869 uS/cm. SAR values ranged from 0.3 to 1.2. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. Recorded values are below these standards for the entire year. Note that the irrigation season standards apply year-round upstream of the reservoir.

Figure 11: Tongue River at State Line, near Decker, MT

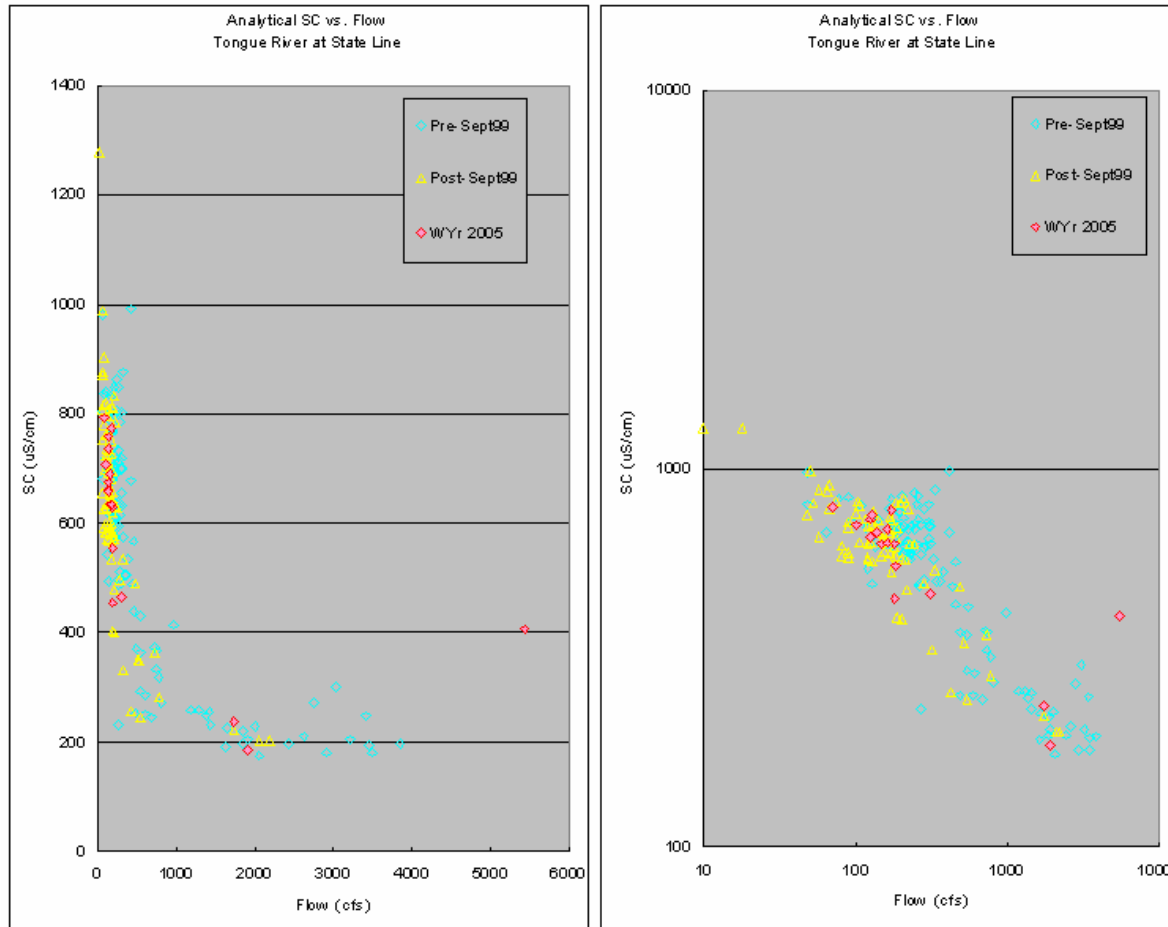


Figure 11 shows analytical SC vs. Flow data for water year 2005 for the Tongue River at the State Line. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 12: Tongue River at State Line, near Decker, MT

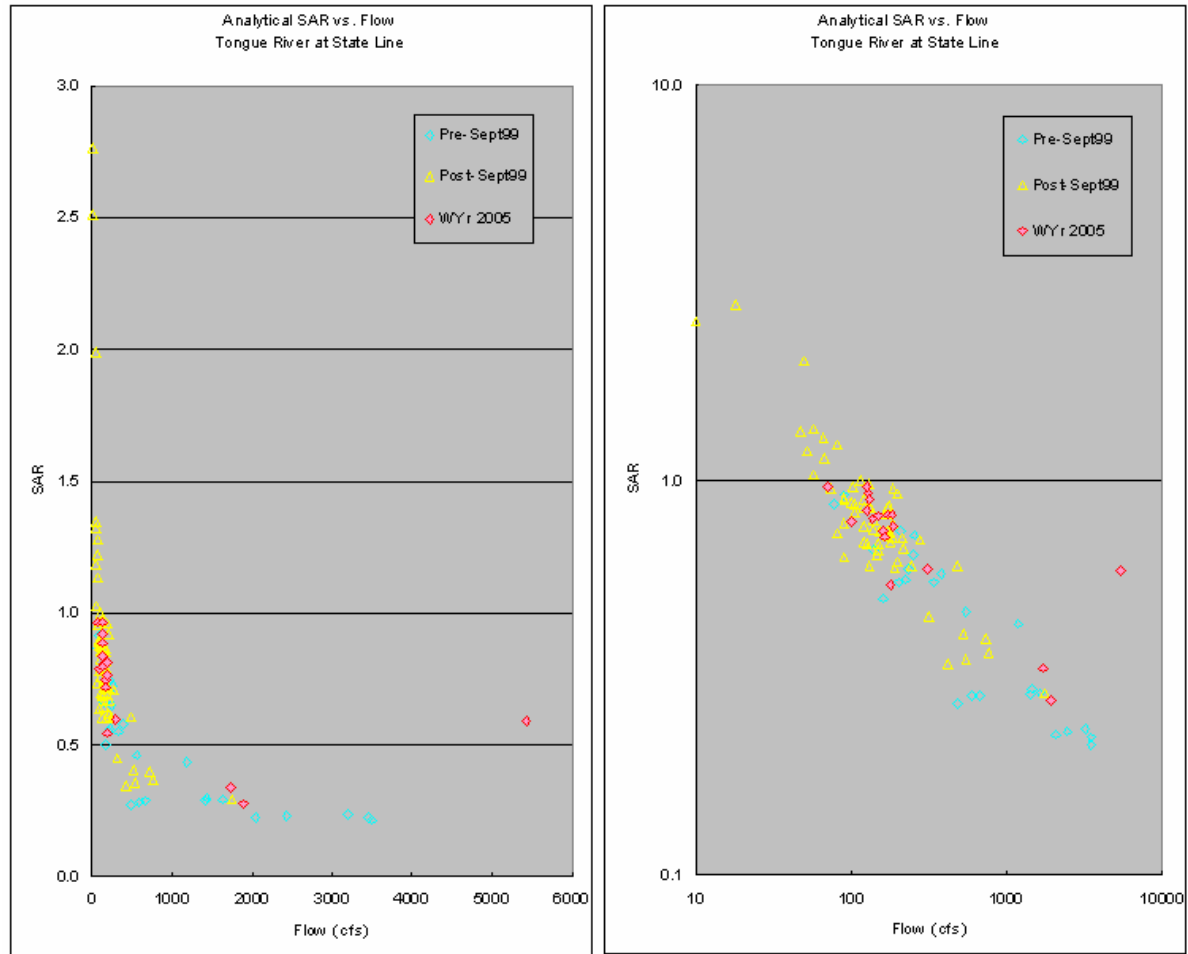


Figure 12 shows analytical SAR vs. Flow data for water year 2005 for the Tongue River at the State Line. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 13: Tongue River at State Line, near Decker, MT

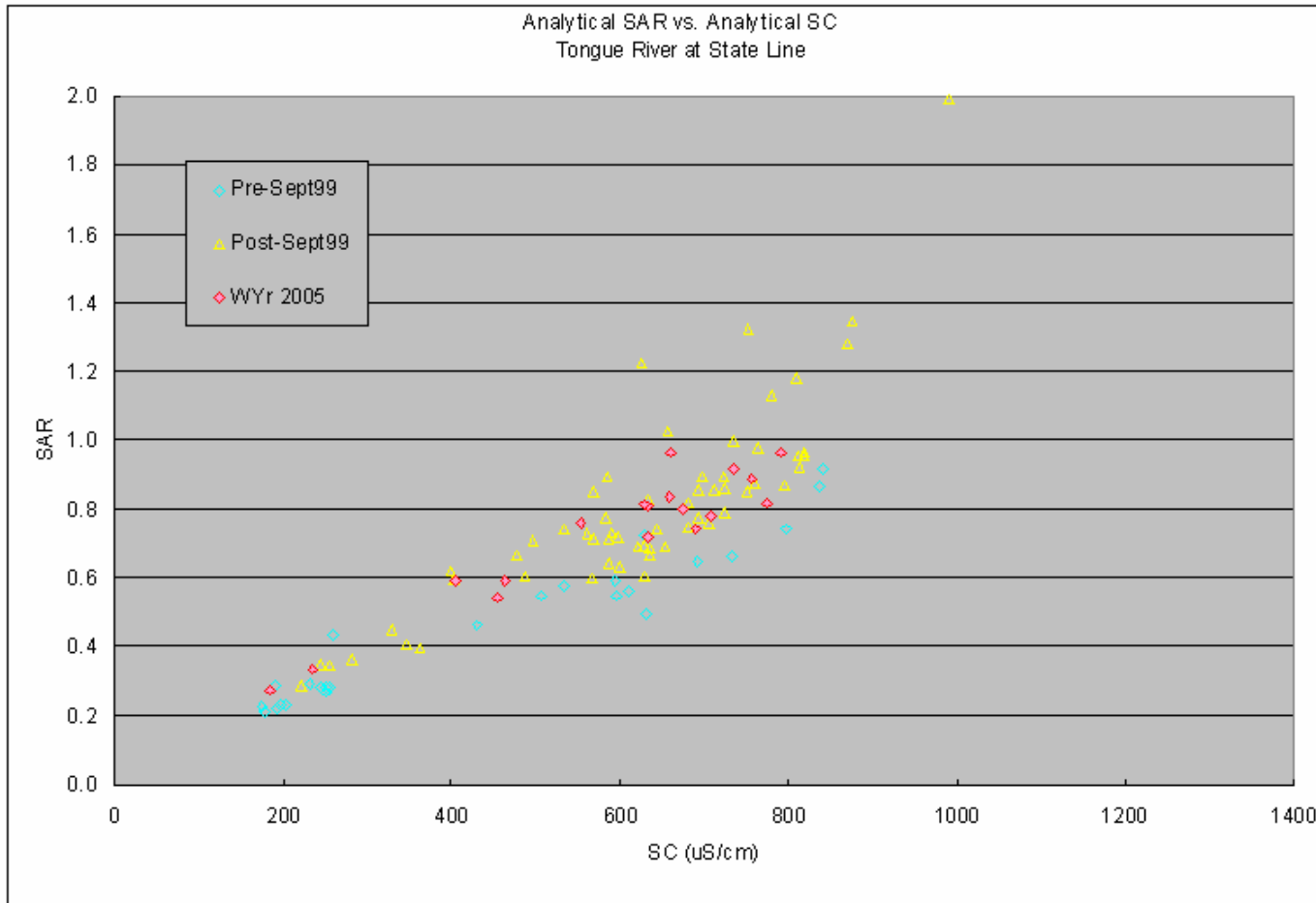


Figure 13 shows analytical SAR vs. analytical SC data for water year 2005 for the Tongue River at the State Line. Historical SAR vs. SC data are also shown to place the data in context.

Figure 14: Tongue River at Tongue River Dam, near Decker, MT

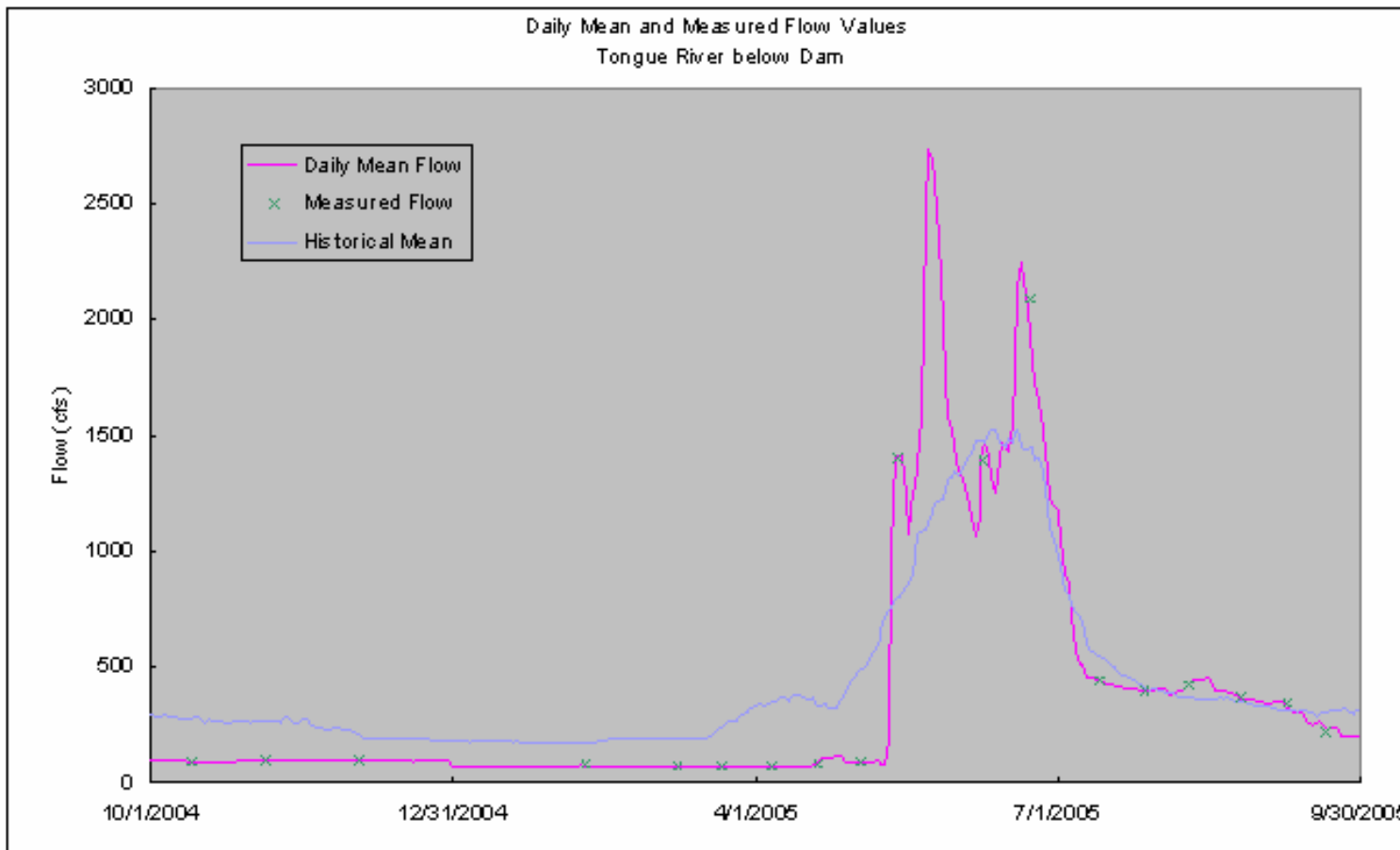


Figure 14 shows mean daily and field measurements of flow in a time series plot for water year 2005 for the Tongue River at Tongue River Dam, near Decker. The historical average mean daily flow values are also shown. Flow values ranged from 68 to 2740 cfs. Flows were less than average through April, then from May to September flows were comparable to average. The noticeable decrease in peak flow at this station vs. the state line station (2740 vs. 4740 cfs) is due to the presence of the reservoir.

Figure 15: Tongue River at Tongue River Dam, near Decker, MT

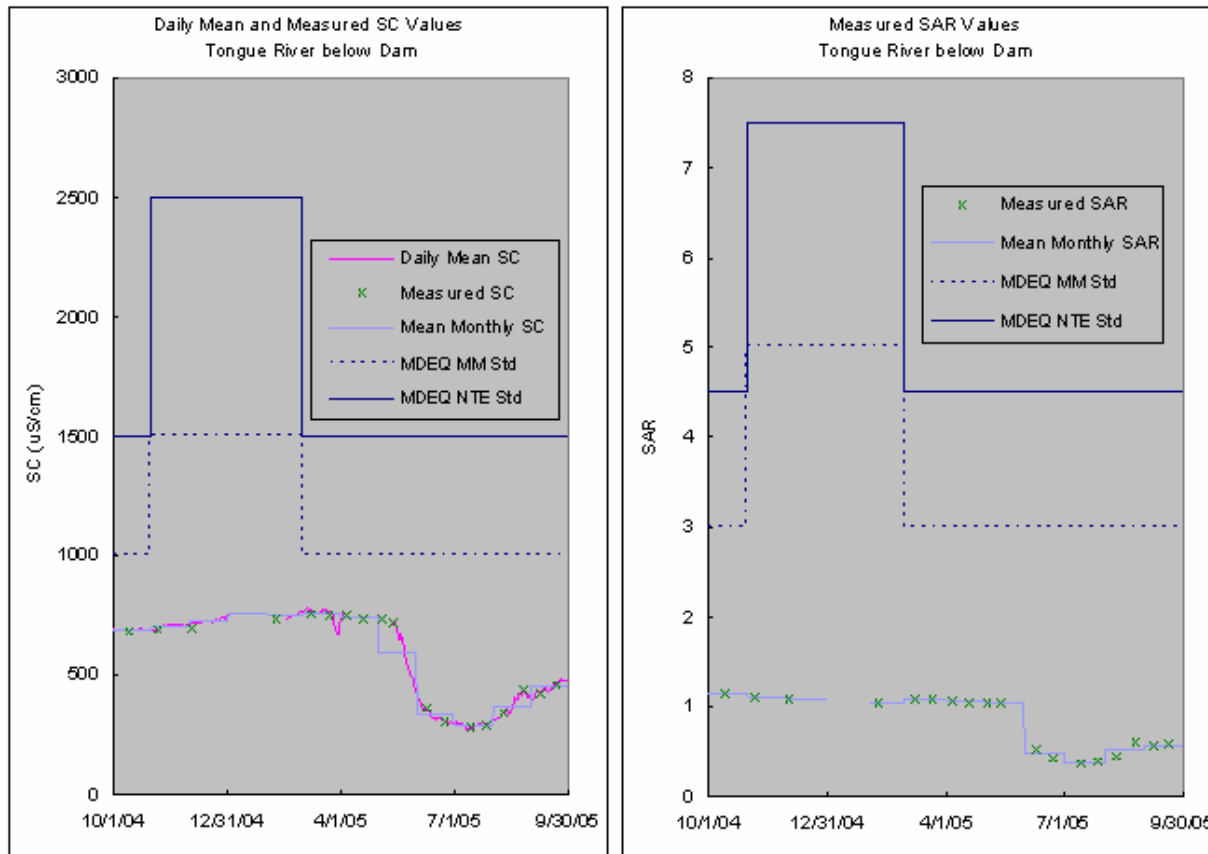


Figure 15 shows analytical and mean daily SC values (A) and analytical SAR values (B) values in time series plots for water year 2005 for the Tongue River at Tongue River Dam, near Decker. SAR values were not estimated. Mean Monthly SC and SAR values are also shown. SC values ranged from 279 to 782 uS/cm. SAR values ranged from 0.4 to 1.1. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. Recorded values are below these standards for the entire year.

Figure 16: Tongue River at Tongue River Dam, near Decker, MT

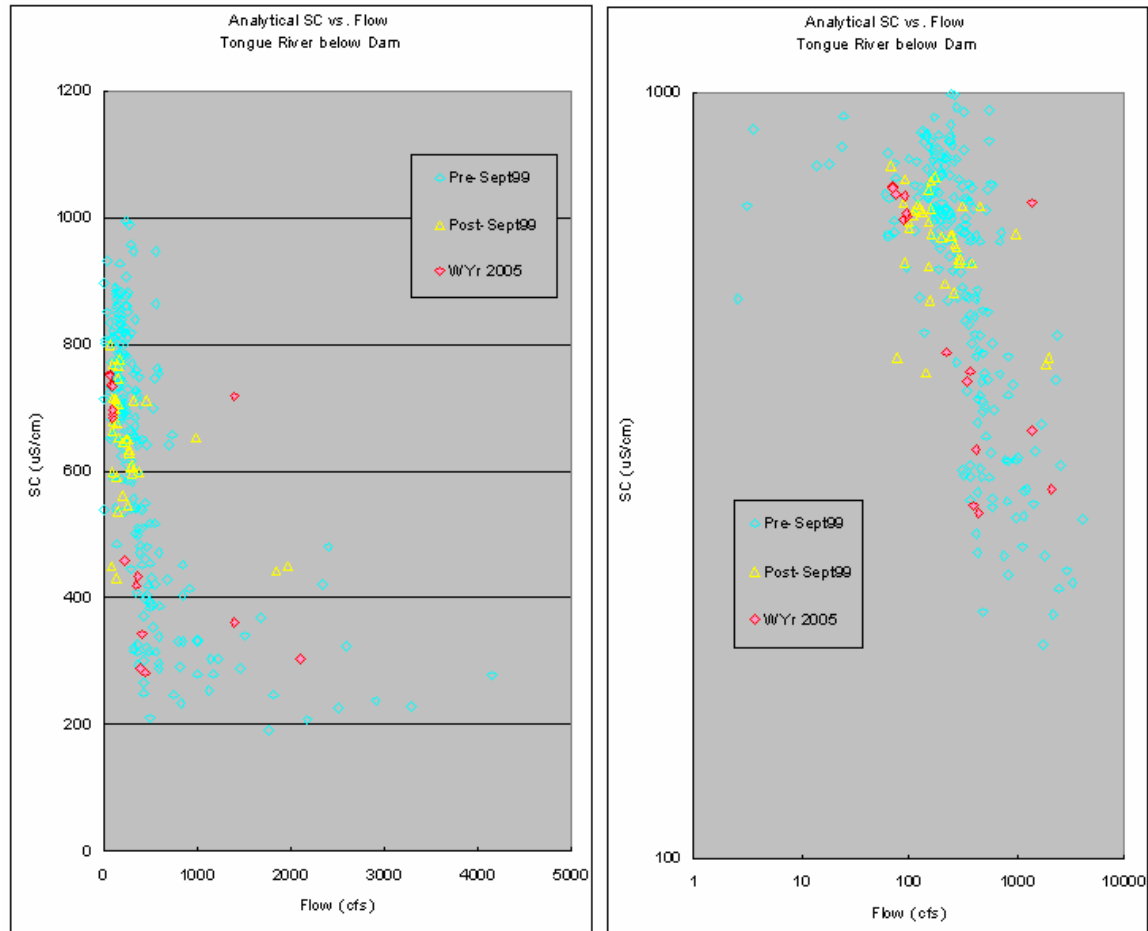


Figure 16 shows analytical SC vs. Flow data for water year 2005 for the Tongue River at Tongue River Dam, near Decker. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 17: Tongue River at Tongue River Dam, near Decker, MT

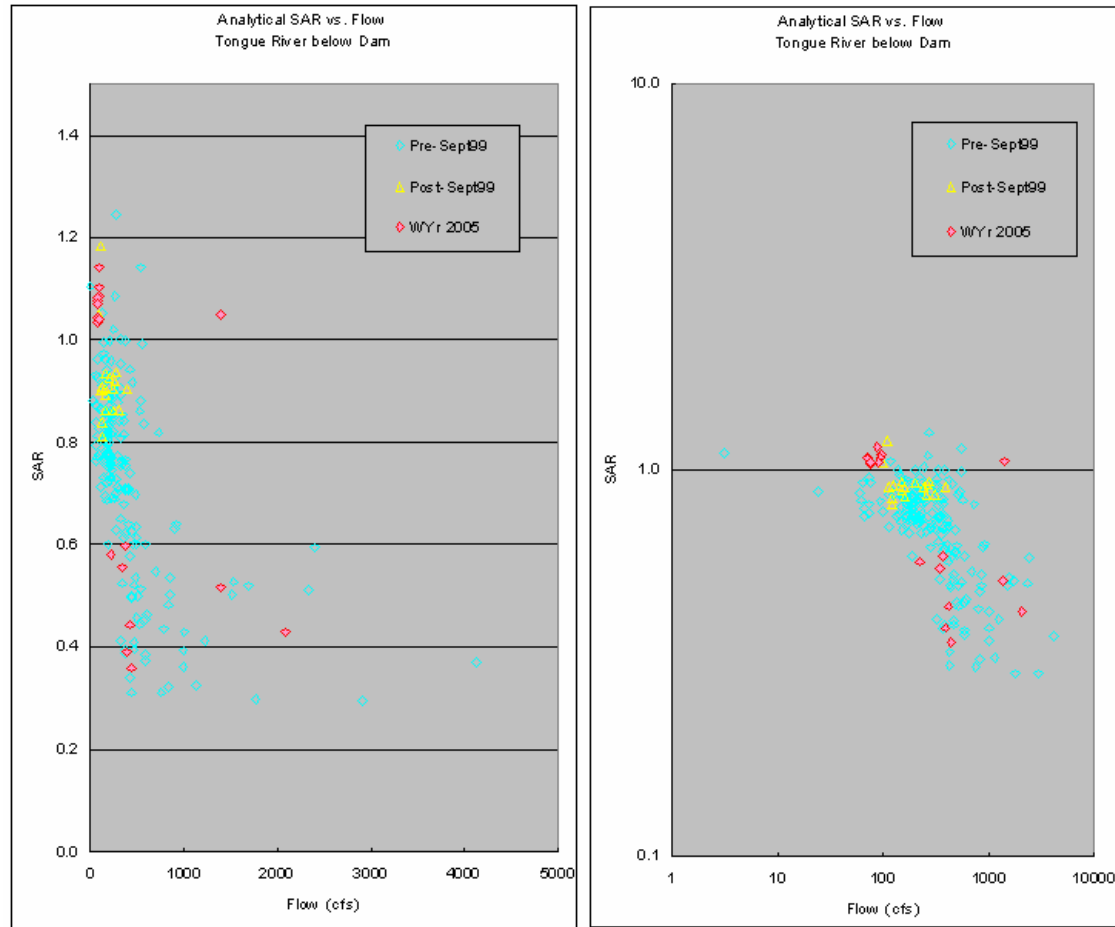


Figure 17 shows analytical SAR vs. Flow data for water year 2005 for the Tongue River at Tongue River Dam, near Decker. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 18: Tongue River at Tongue River Dam, near Decker, MT

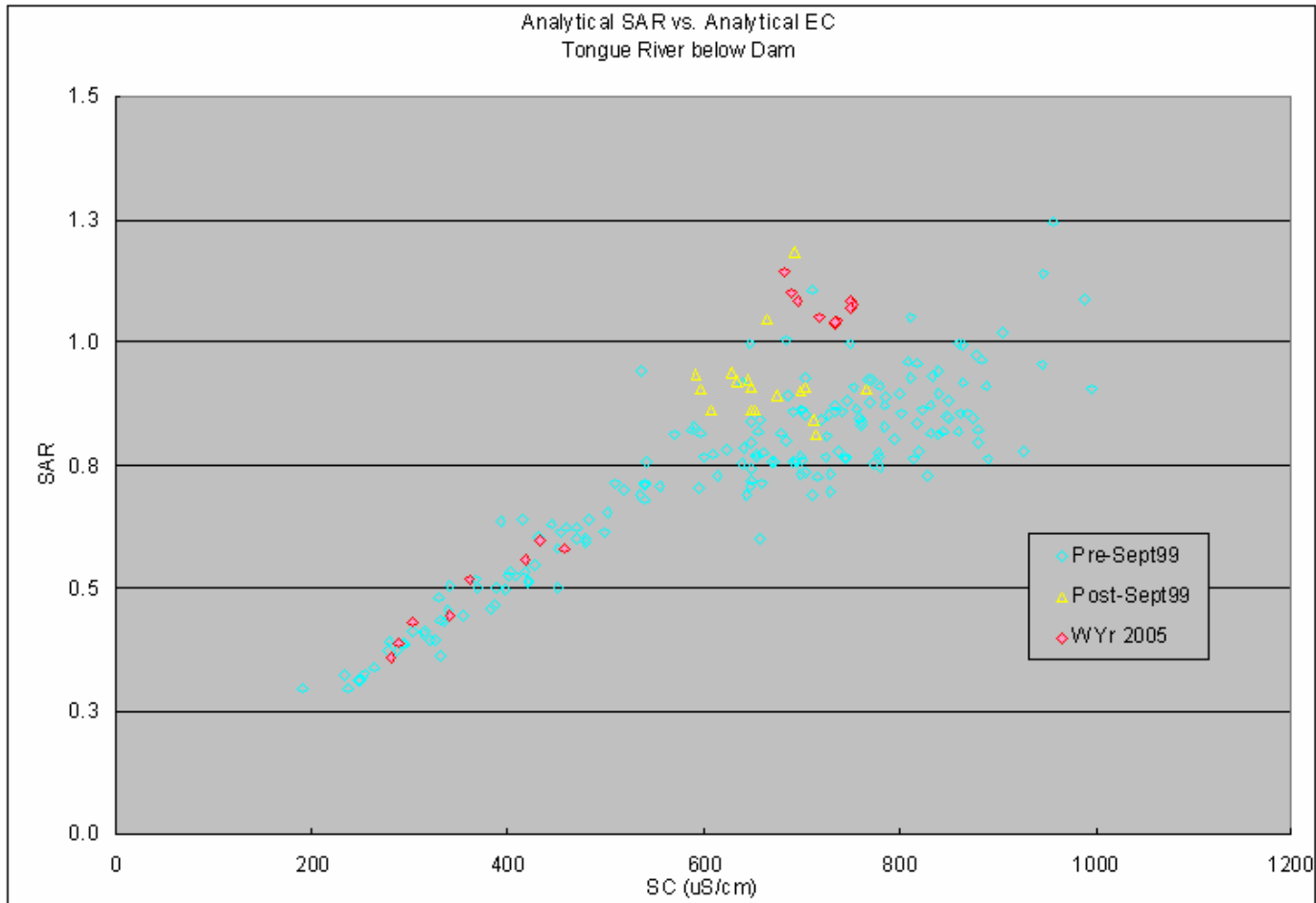


Figure 18 shows analytical SAR vs. analytical SC data for water year 2005 for the Tongue River at Tongue River Dam, near Decker. Historical SAR vs. SC data are also shown to place the data in context.

Figure 19: Tongue River at Birney Day School Bridge, near Birney, MT

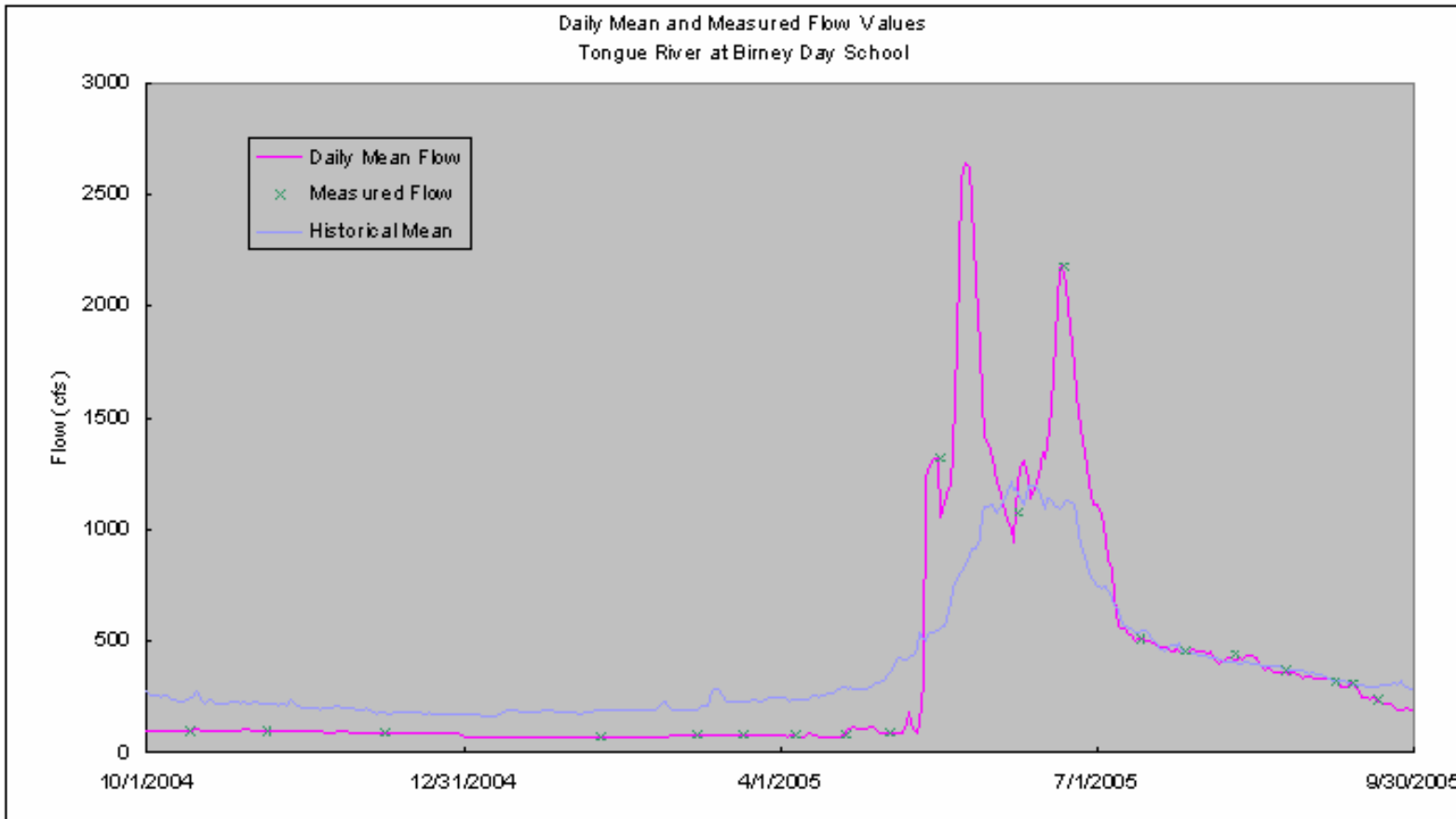


Figure 19 shows mean daily and field measurements of flow in a time series plot for water year 2005 for the Tongue River at Birney Day School Bridge, near Birney. The historical average mean daily flow values are also shown. Flow values ranged from 70 to 2640 cfs. Mean daily flows were less than average through April, then from May to September flows were comparable to or somewhat greater than average.

Figure 20: Tongue River at Birney Day School Bridge, near Birney, MT

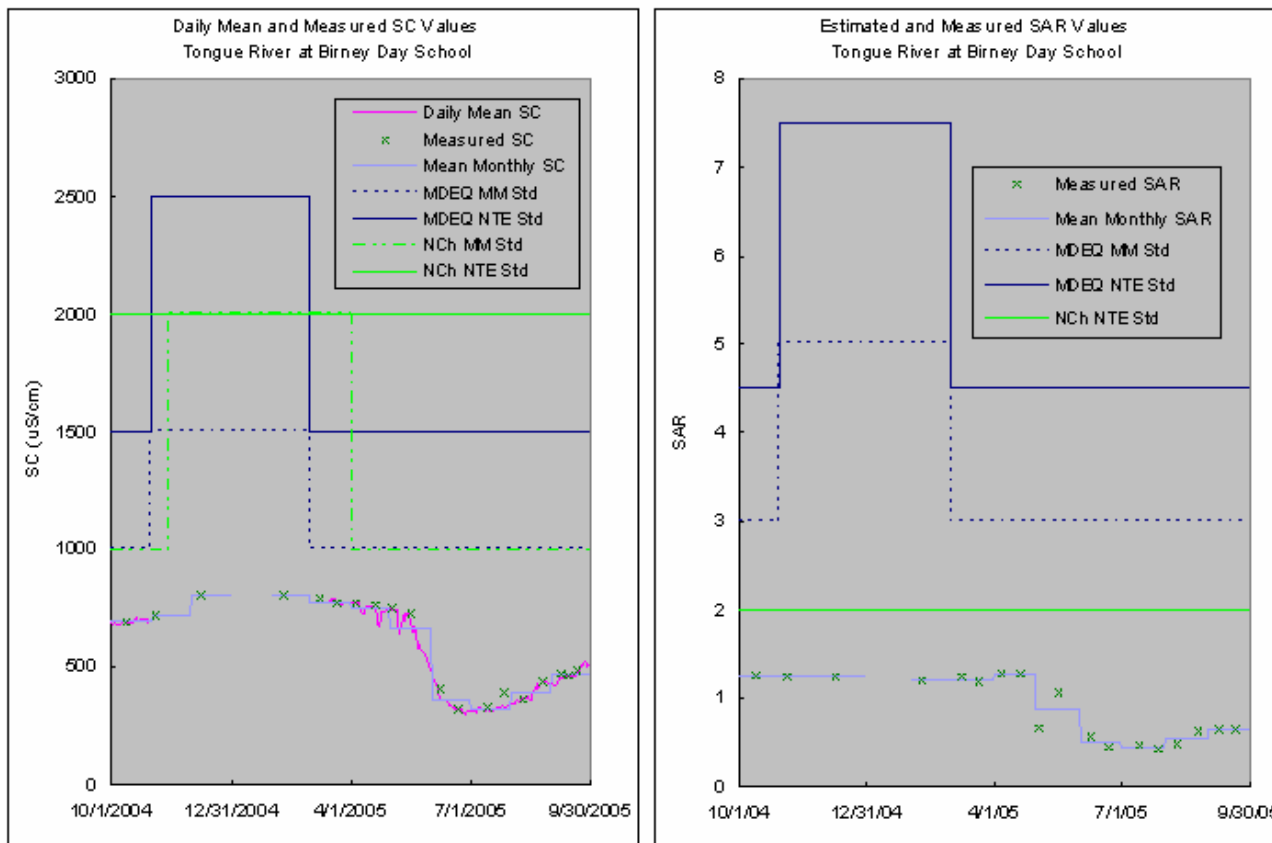


Figure 20 shows analytical and mean daily SC values (A) and analytical SAR values (B) values in time series plots for water year 2005 for the Tongue River at Birney Day School Bridge, near Birney. SAR values were not estimated. Mean Monthly SC and SAR values are also shown. SC values ranged from 301 to 807 $\mu\text{S/cm}$. SAR values ranged from 0.4 to 1.3. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ and the Northern Cheyenne Tribe. Recorded values are below these standards for the entire year.

Figure 21: Tongue River at Birney Day School Bridge, near Birney, MT

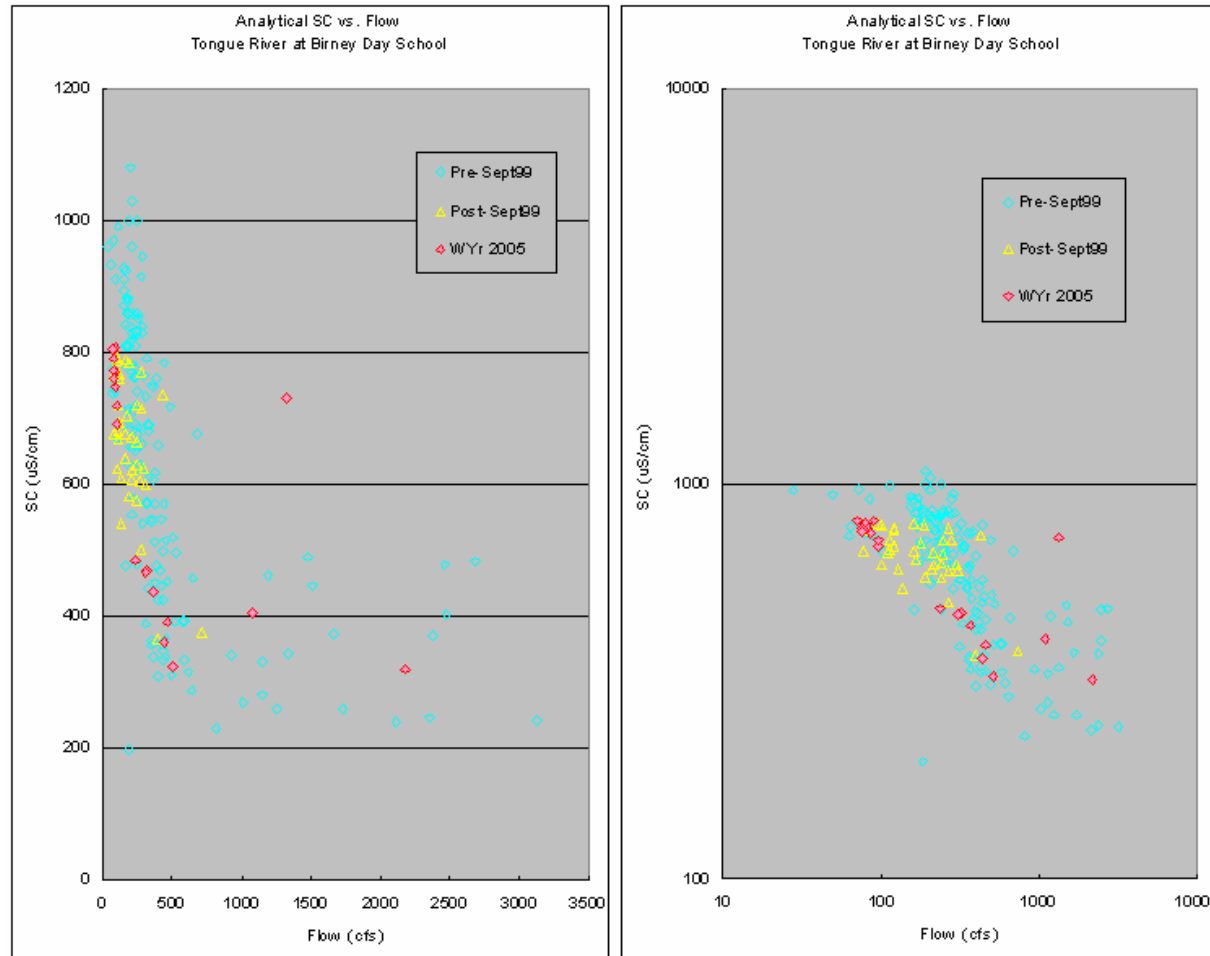


Figure 21 shows analytical SC vs. Flow data for water year 2005 for the Tongue River at Birney Day School Bridge, near Birney. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 22: Tongue River at Birney Day School Bridge, near Birney, MT

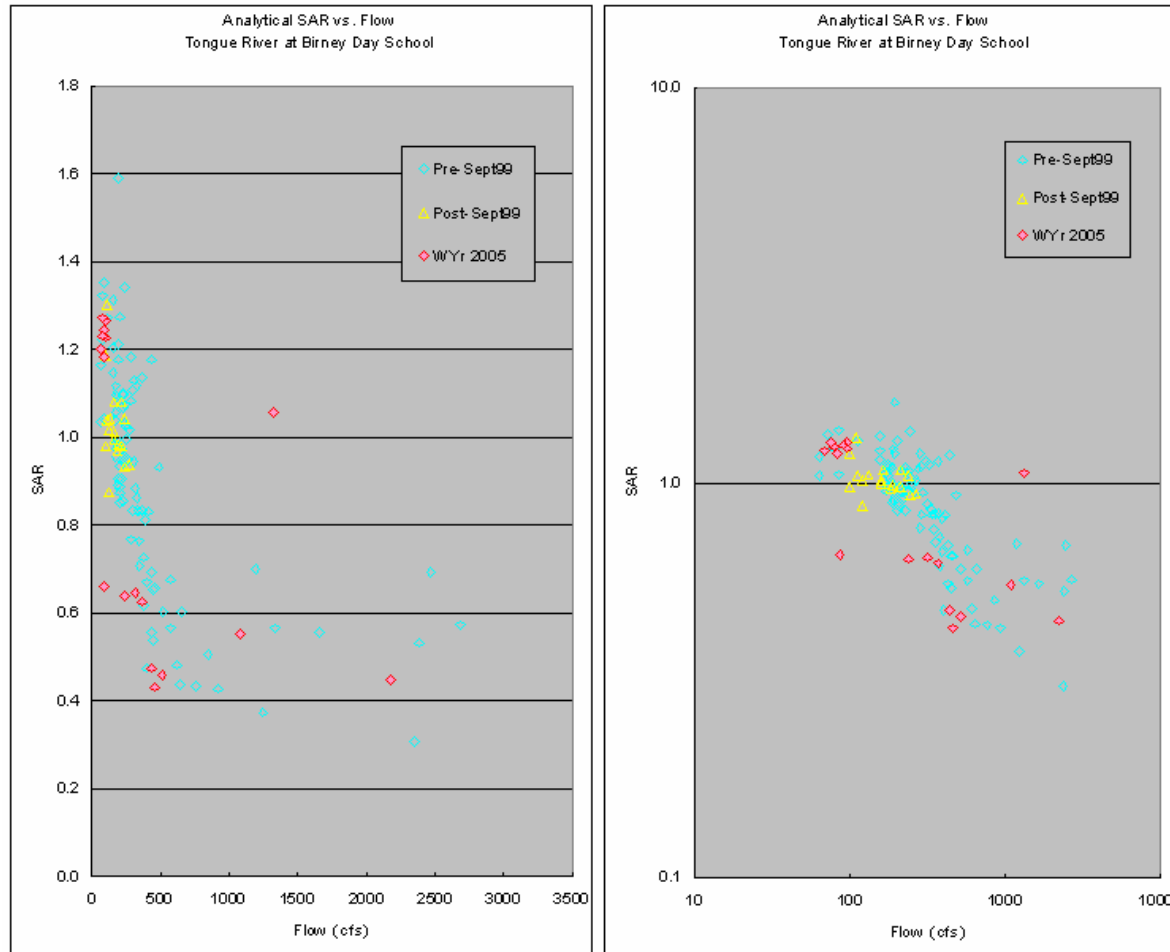


Figure 22 shows analytical SAR vs. Flow data for water year 2005 for the Tongue River at Birney Day School Bridge, near Birney, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 23: Tongue River at Birney Day School Bridge, near Birney, MT

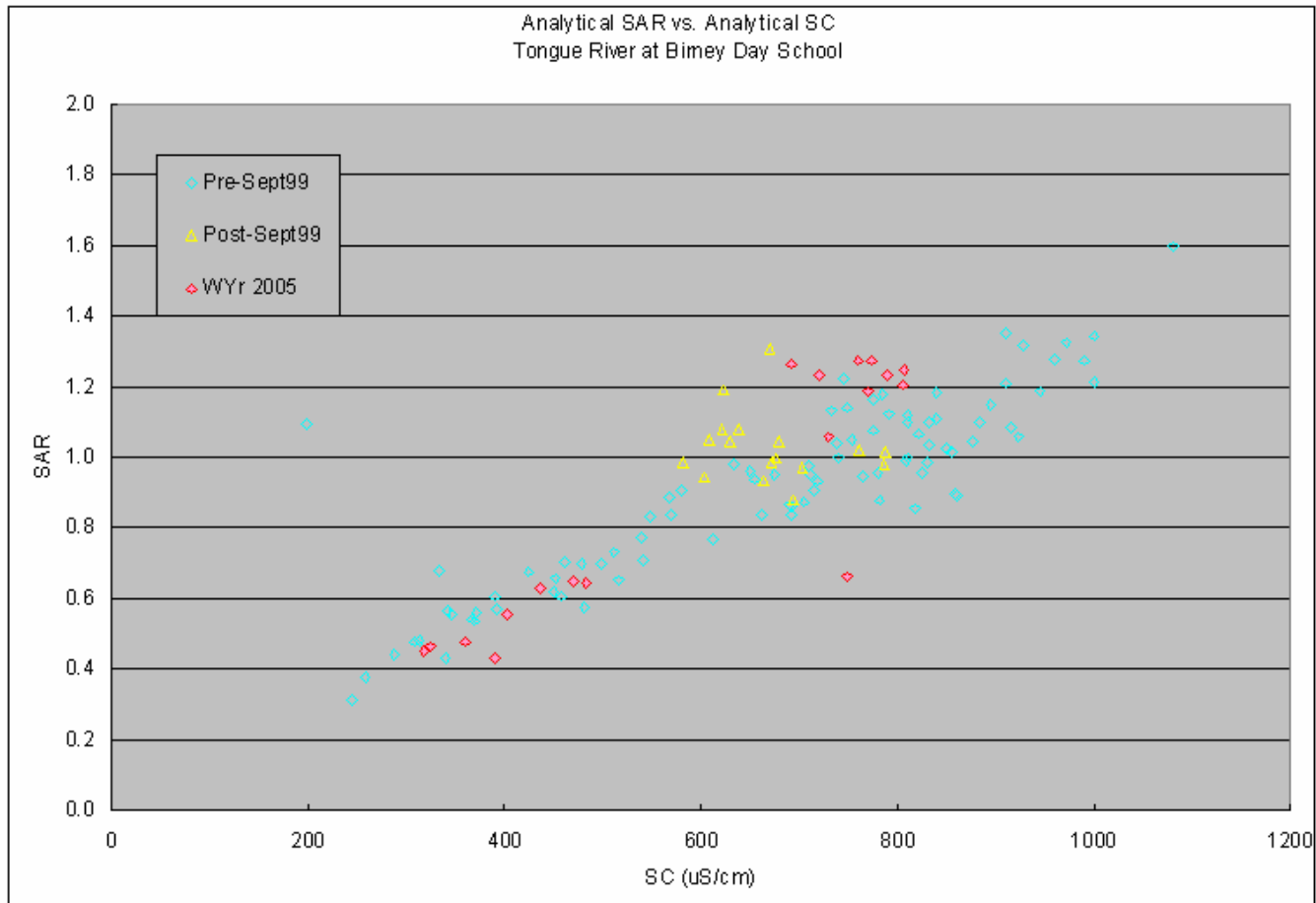


Figure 23 shows analytical SAR vs. analytical SC data for water year 2005 for the Tongue River at Birney Day School. Historical SAR vs. SC data are also shown to place the data in context.

Figure 24: Tongue River below Brandenburg Bridge, near Ashland, MT

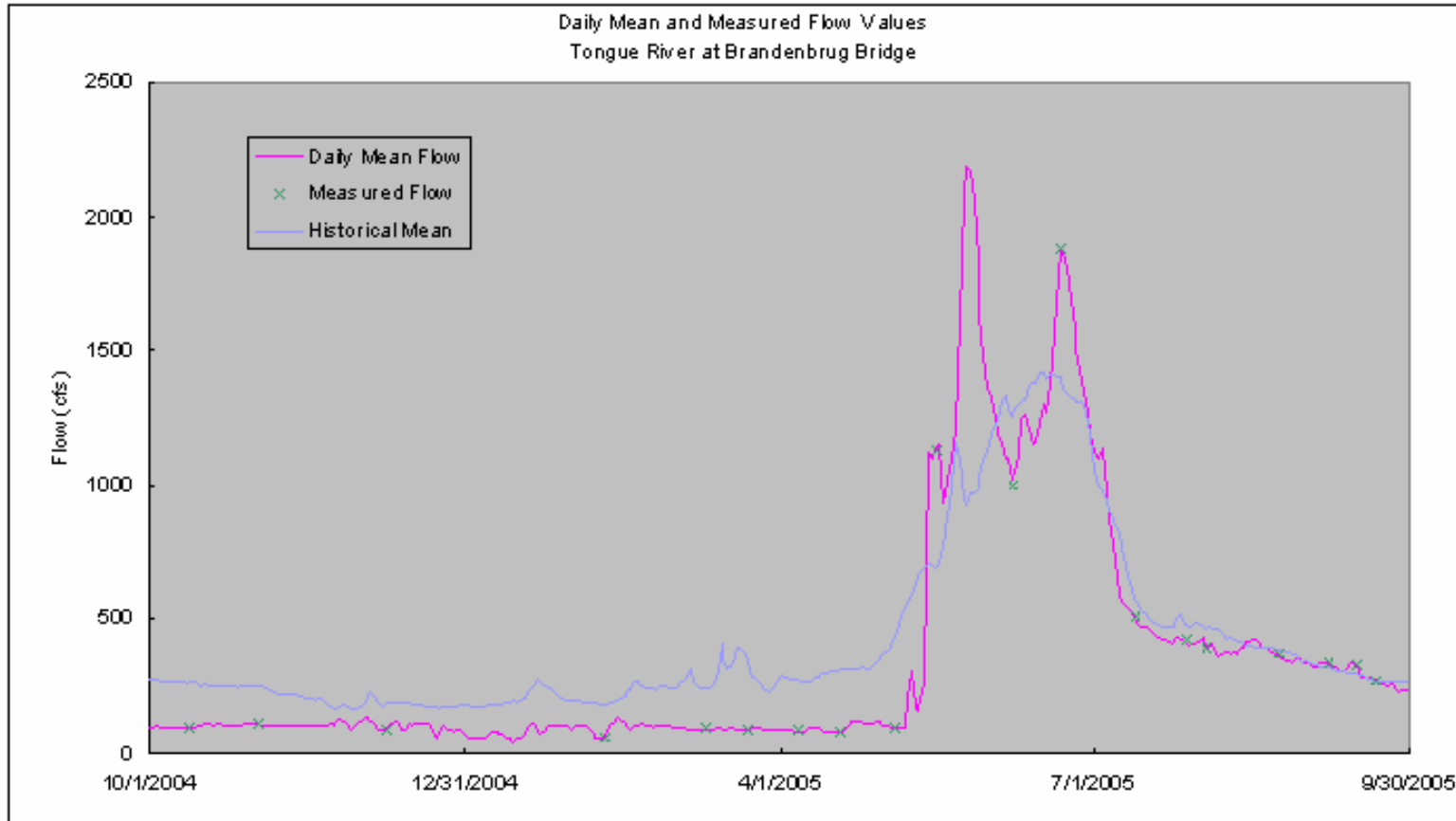


Figure 24 shows mean daily and field measurements of flow in a time series plot for water year 2005 for the Tongue River below Brandenburg Bridge. The historical average mean daily flow values are also shown. Flow values during 2005 ranged from 40 to 2190 cfs. Mean daily flows were less than average through April, then from May to September flows were comparable to average.

Figure 25: Tongue River below Brandenburg Bridge, near Ashland, MT

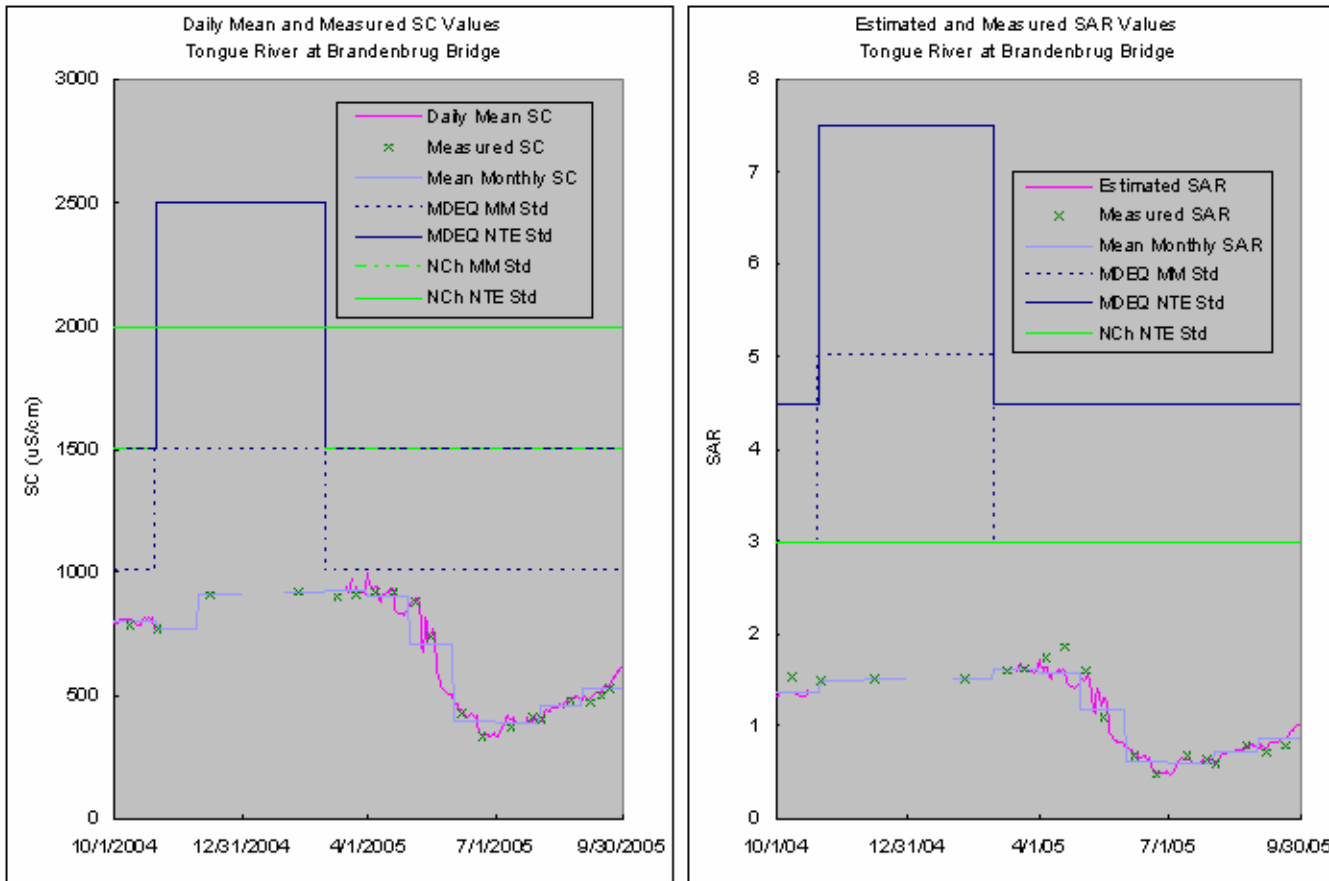


Figure 25 shows analytical and mean daily SC values (A) and analytical and mean daily estimated SAR values (B) in time series plots for water year 2005 for the Tongue River below Brandenburg Bridge, near Ashland, MT. Mean Monthly SC and SAR values are also shown. SC values ranged from 331 to 993 uS/cm. SAR values ranged from 0.5 to 1.8. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ and the Northern Cheyenne Tribe. Recorded values are below these standards for the entire year.

Figure 26: Tongue River below Brandenburg Bridge, near Ashland, MT

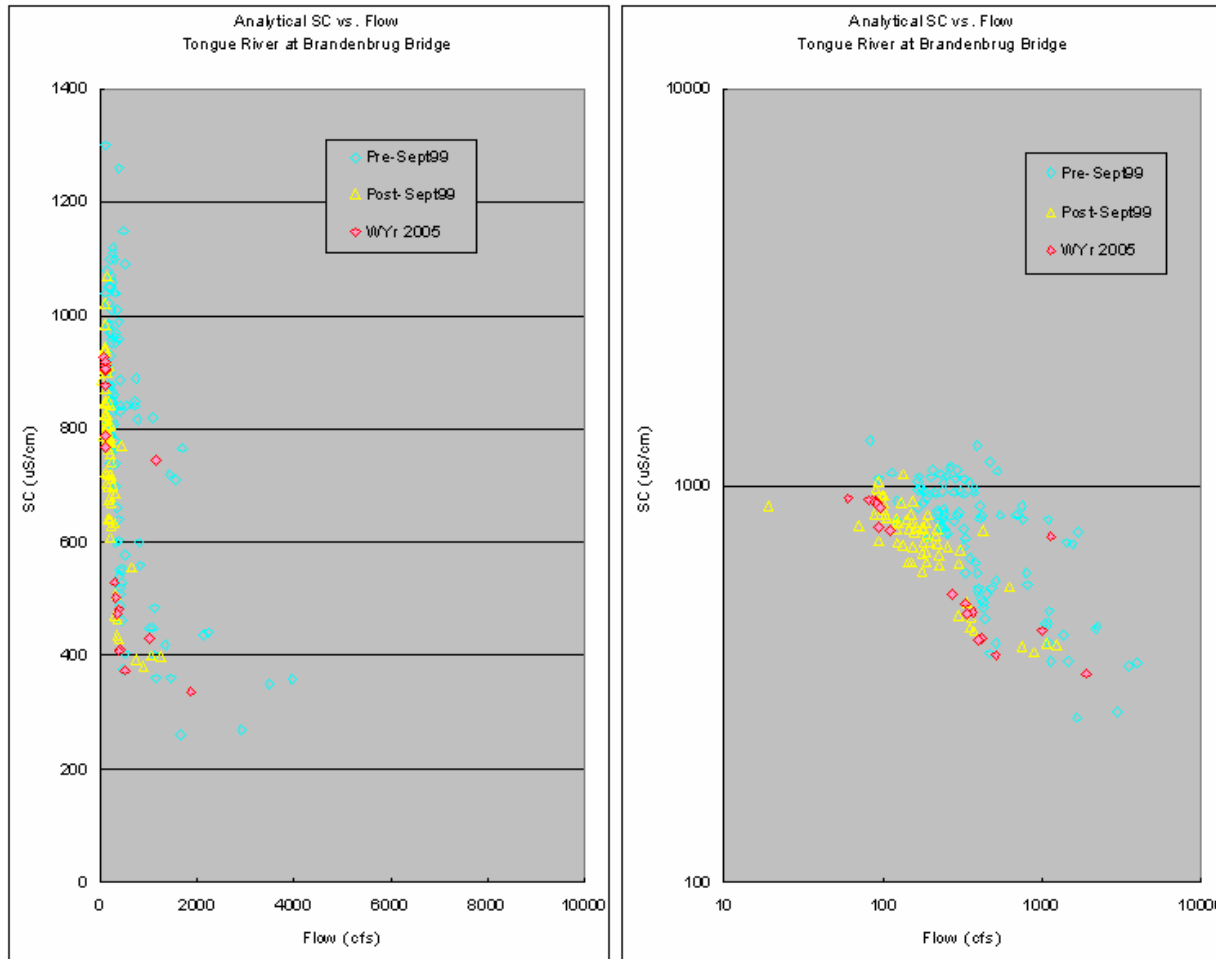


Figure 26 shows analytical SC vs. Flow data for water year 2005 for the Tongue River below Brandenburg Bridge, near Ashland, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 27: Tongue River below Brandenburg Bridge, near Ashland, MT

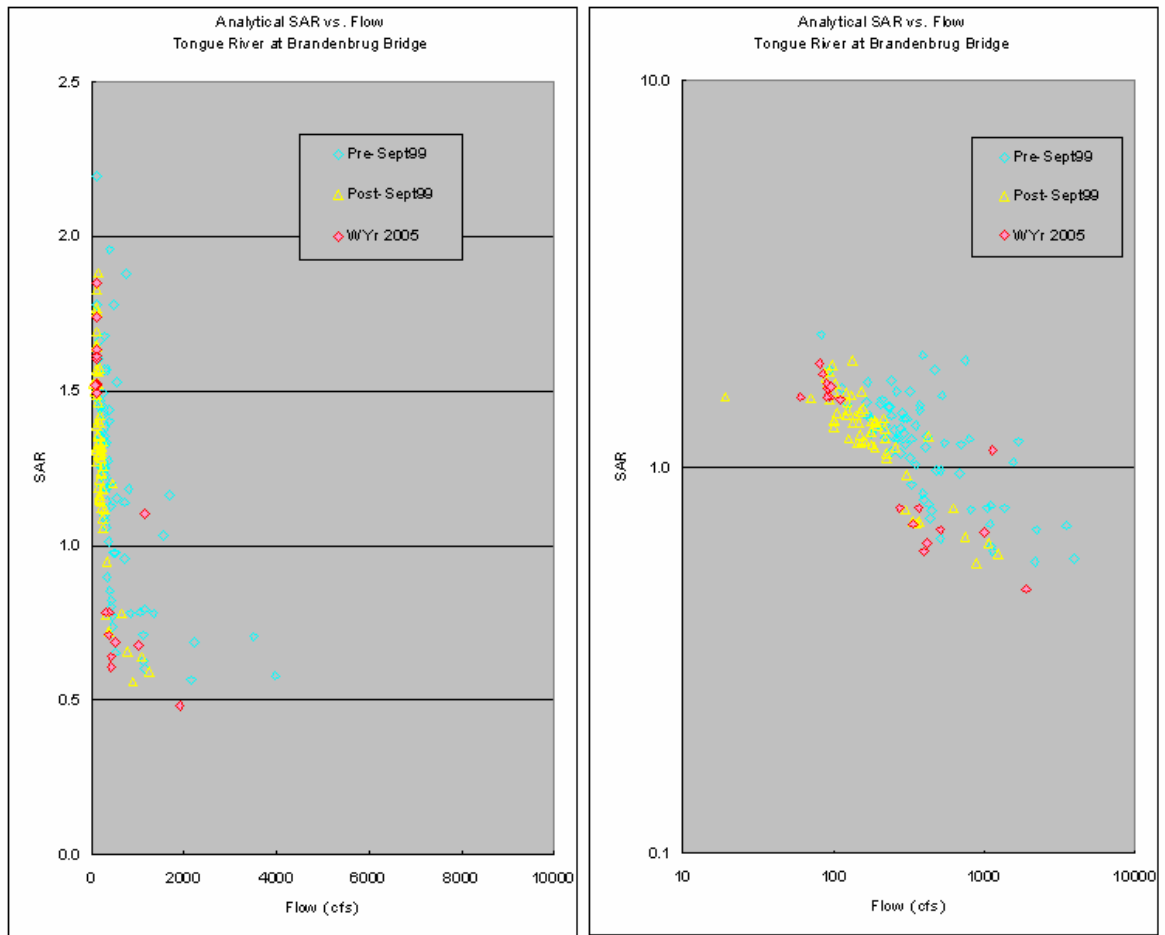


Figure 27 shows analytical SAR vs. Flow data for water year 2005 for the Tongue River below Brandenburg Bridge, near Ashland, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 28: Tongue River below Brandenburg Bridge, near Ashland, MT

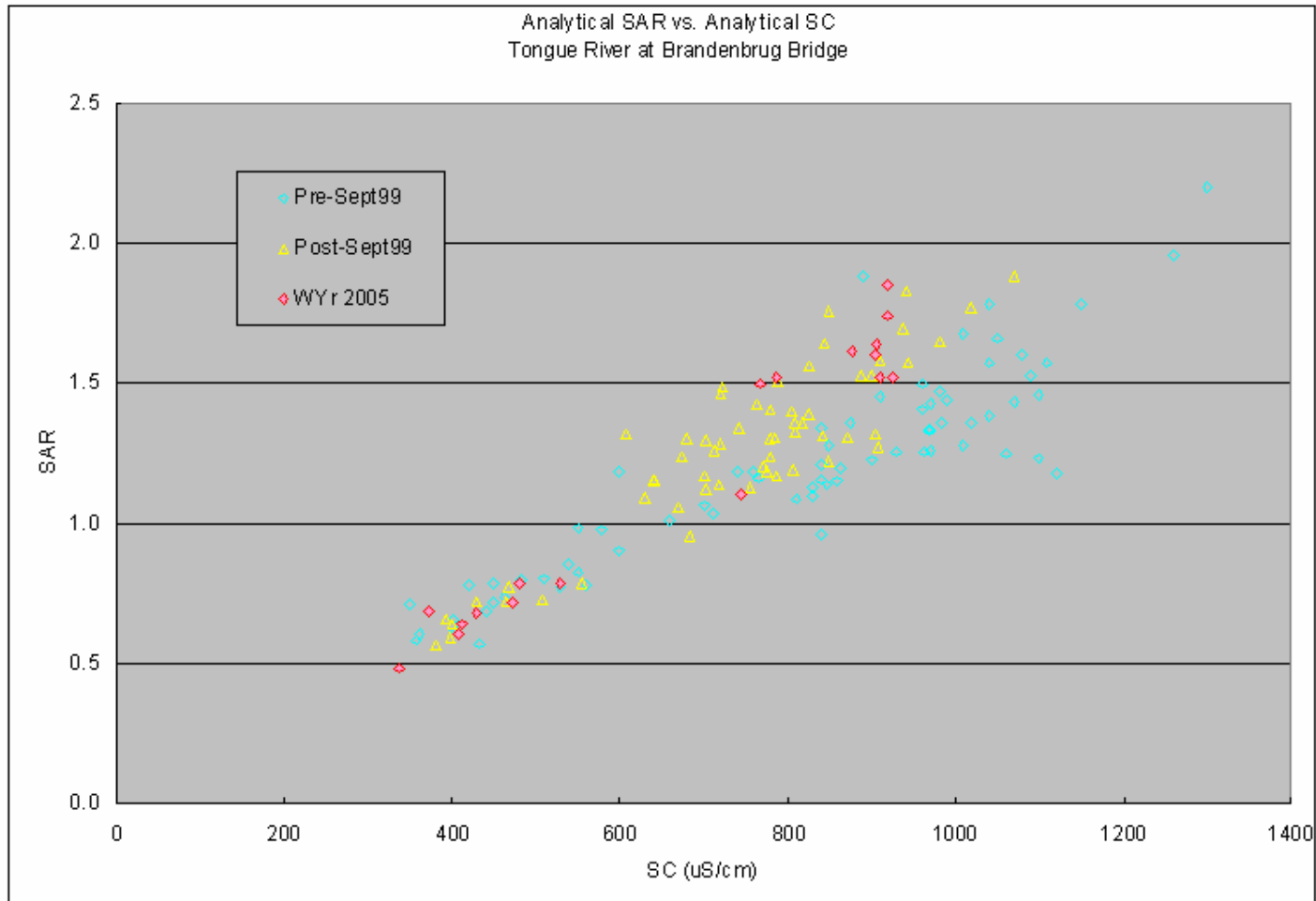


Figure 28 shows analytical SAR vs. analytical SC data for water year 2005 for the Tongue River below Brandenburg Bridge. Historical SAR vs. SC data are also shown to place the data in context.

Figure 29: Tongue River above TY Diversion

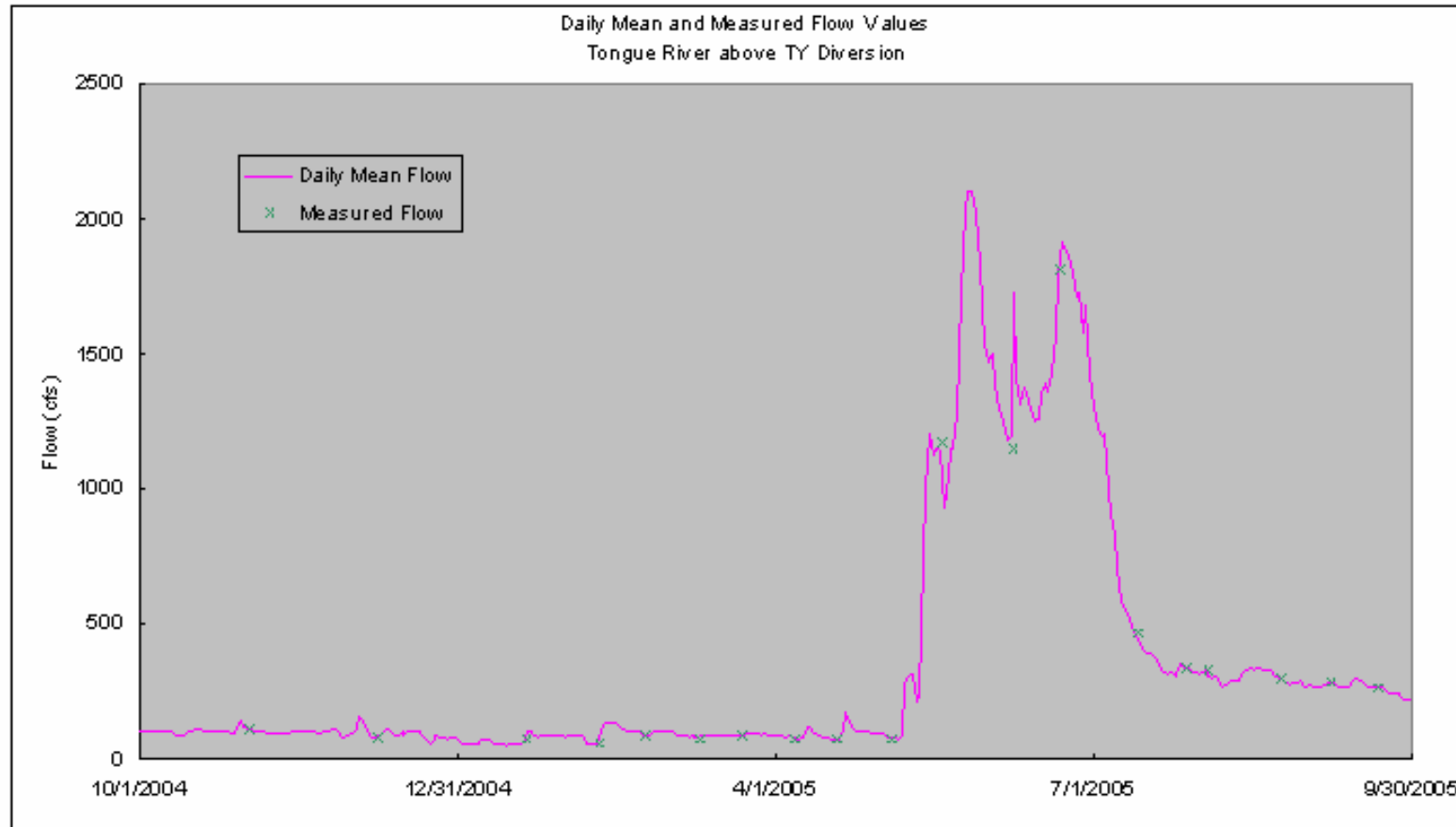


Figure 29 shows mean daily and field measurements of flow in a time series plot for water year 2005 for the Tongue River above the TY Diversion. Flow values ranged from 40 to 2100 cfs. Historical mean daily flow data is not available for this station.

Figure 30: Tongue River above TY Diversion

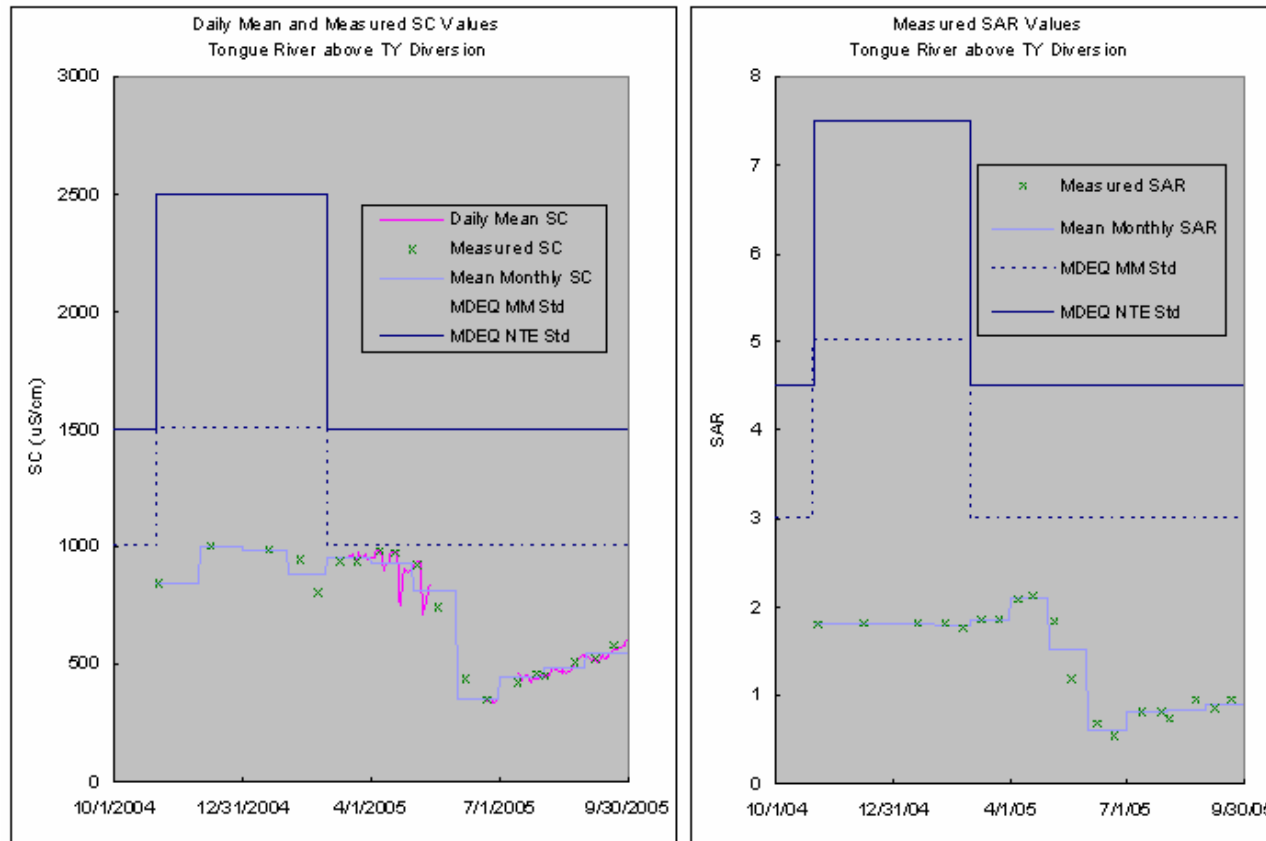


Figure 30 shows analytical and mean daily SC values (A) and analytical SAR values (B) in time series plots for water year 2005 for the Tongue River above the TY Diversion, near Miles City, MT. Mean Monthly SC and SAR values are also shown. SC values ranged from 331 to 1000 uS/cm. SAR values ranged from 0.5 to 2.1. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. Recorded values are below these standards for the entire year.

Figure 31: Tongue River above TY Diversion

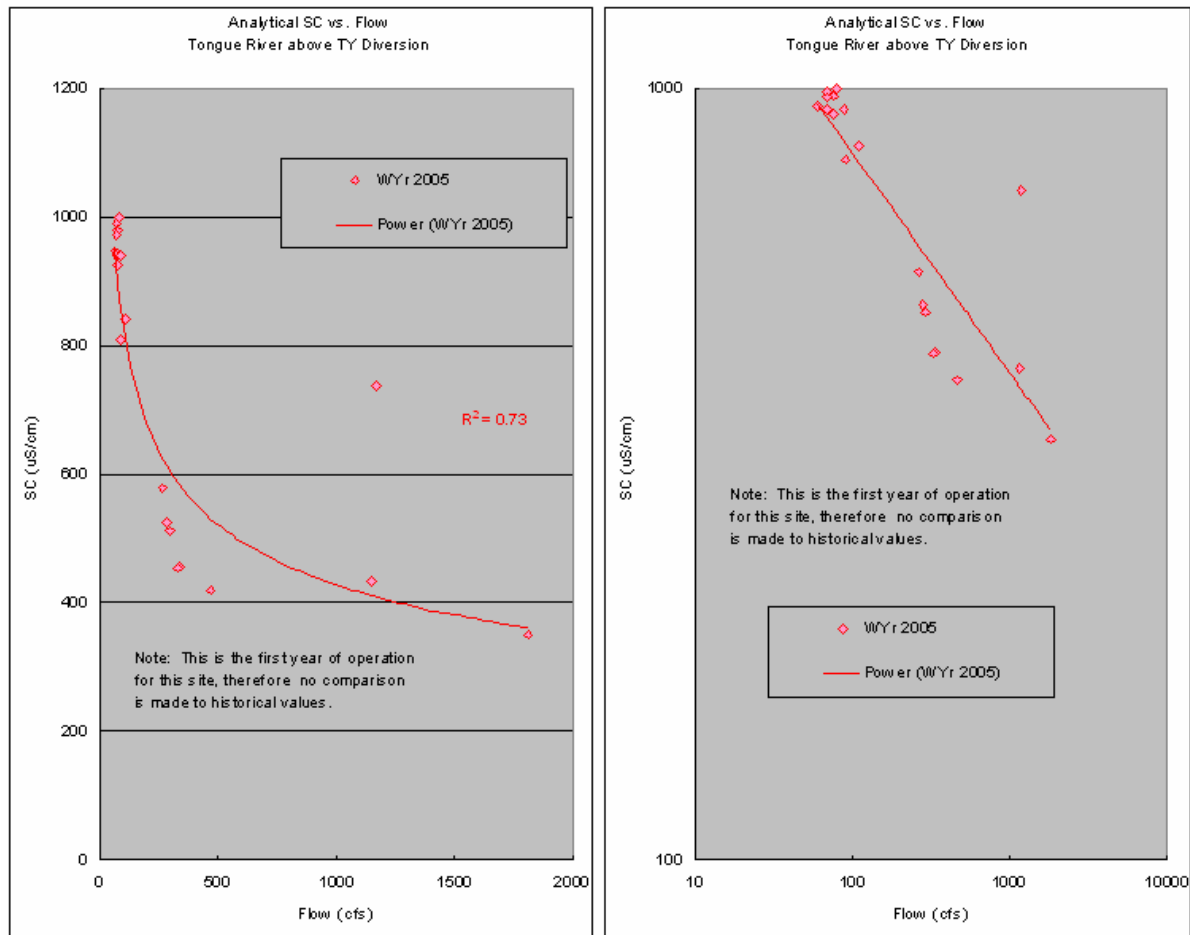


Figure 31 shows analytical SC vs. Flow data for water year 2005 for the Tongue River above the TY Diversion Dam, near Miles City, MT. These data are charted on both linear (A) and logarithmic (B) scales. Water Year 2005 SC data show a fair power relationship between SC and Flow ($r^2=0.73$). Historical data is not available for this station.

Figure 32: Tongue River above TY Diversion

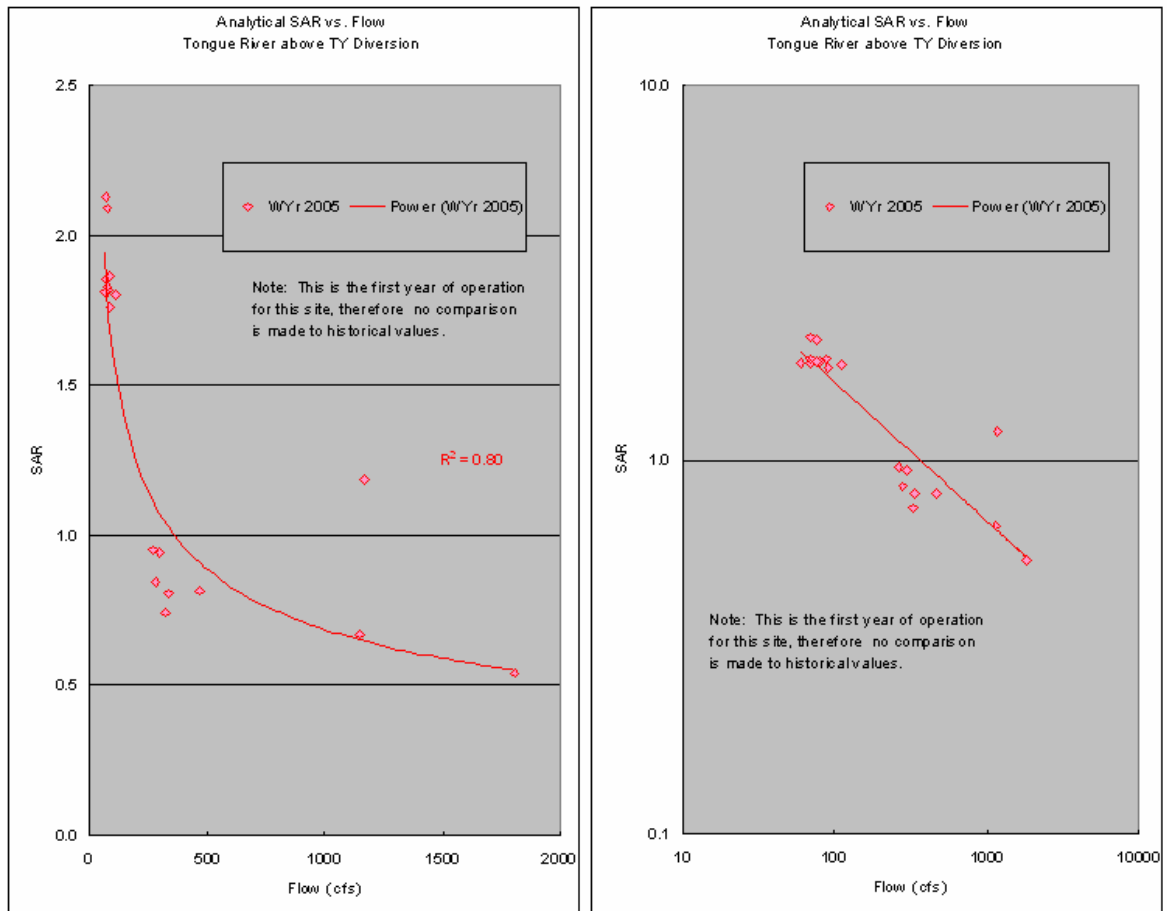


Figure 32 shows analytical SAR vs. Flow data for water year 2005 for the Tongue River above the TY Diversion Dam, near Miles City, MT. These data are charted on both linear (A) and logarithmic (B) scales. 2005 data show a good power relationship between SAR and Flow ($r^2=0.80$). Historical data is not available for this station.

Figure 33: Tongue River above TY Diversion

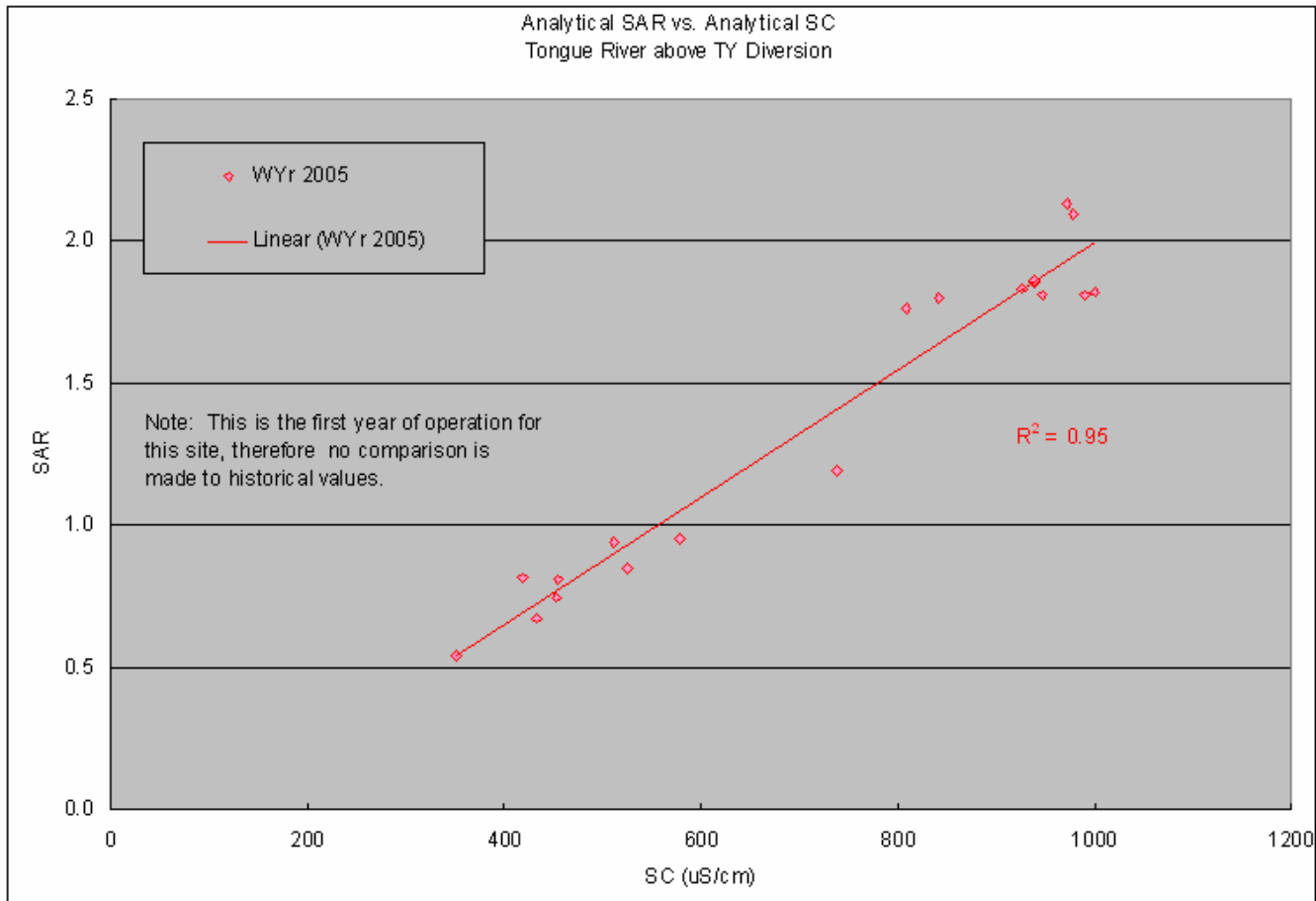


Figure 33 shows analytical SAR vs. analytical SC data for water year 2005 for the Tongue River above the TY Diversion Dam, near Miles City, MT. This relationship was a well defined linear relationship at this station during water year 2005 ($r^2=0.95$). Historical data is not available for this station.

Figure 34: Tongue River at Miles City, MT

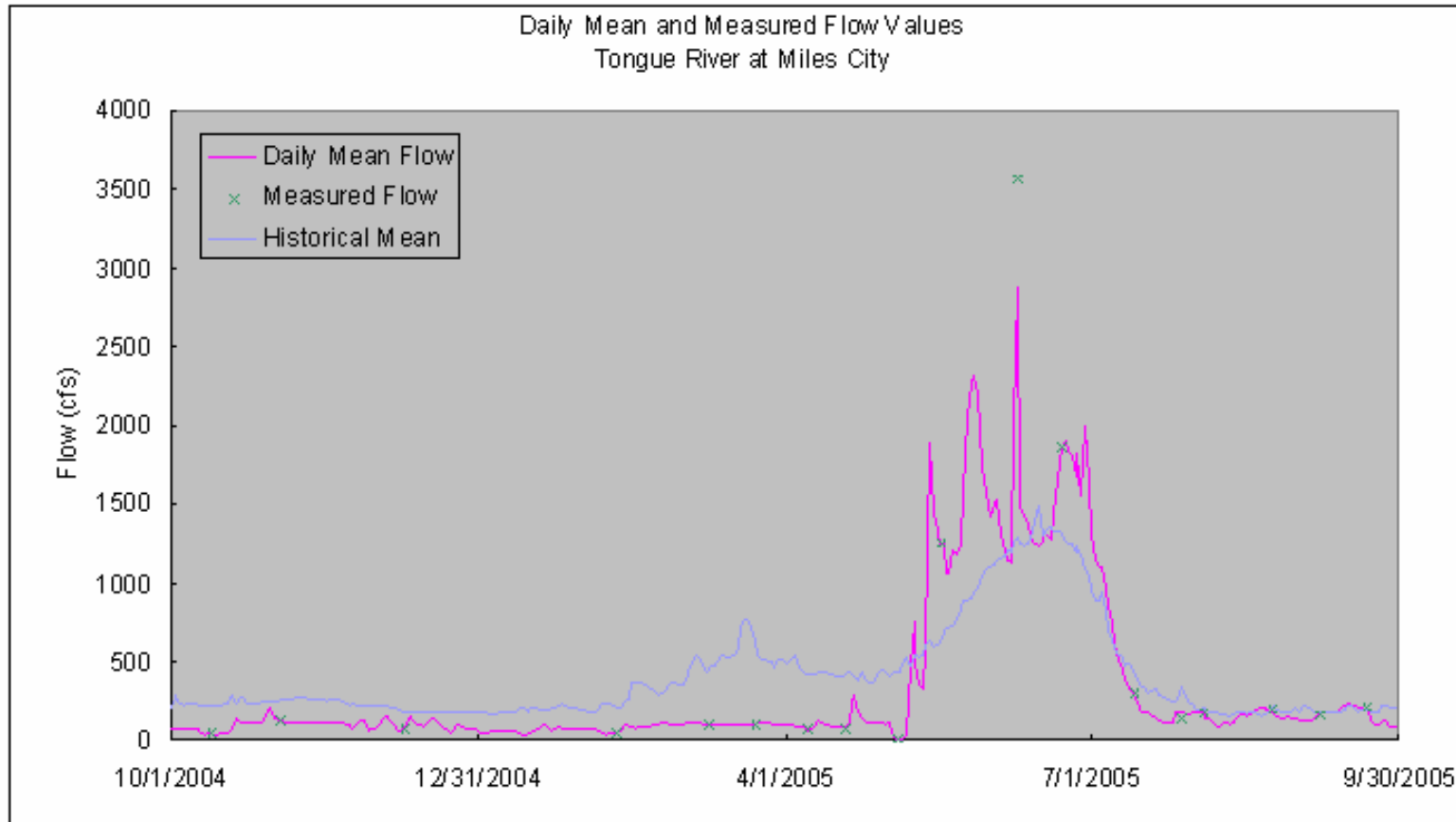


Figure 34 shows mean daily and field measurements of flow in a time series plot for water year 2005 for the Tongue River at Miles City, MT. The historical average mean daily flow values are also shown. Flow values ranged from 12 to 2880 cfs. Flows were less than average through April, then from May to September flows were comparable to average.

Figure 35: Tongue River at Miles City, MT

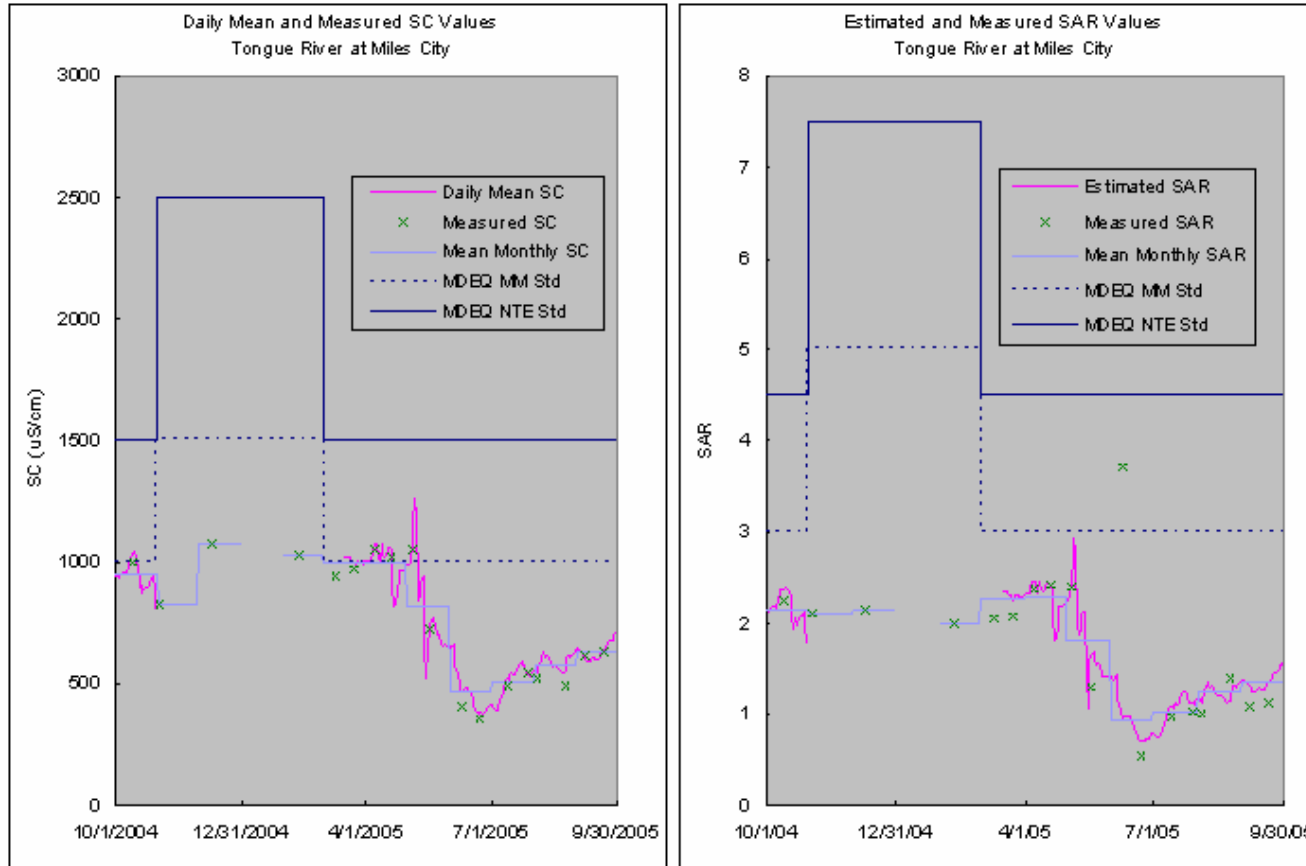


Figure 35 shows analytical and mean daily SC values (A) and analytical and mean daily estimated SAR values (B) in time series plots for water year 2005 for the Tongue River at Miles City, MT. Mean Monthly SC and SAR values are also shown. SC values ranged from 354 to 1260 uS/cm. SAR values ranged from 0.5 to 3.7. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. The mean monthly SC value during March was slightly above the MDEQ mean monthly standard for EC (1000.3 vs, 1000 uS/cm). During April the mean monthly SC value was slightly below the MDEQ mean monthly standard for EC (999.4 uS/cm vs, 1000 uS/cm). All other values were below the standards.

Figure 36: Tongue River at Miles City, MT

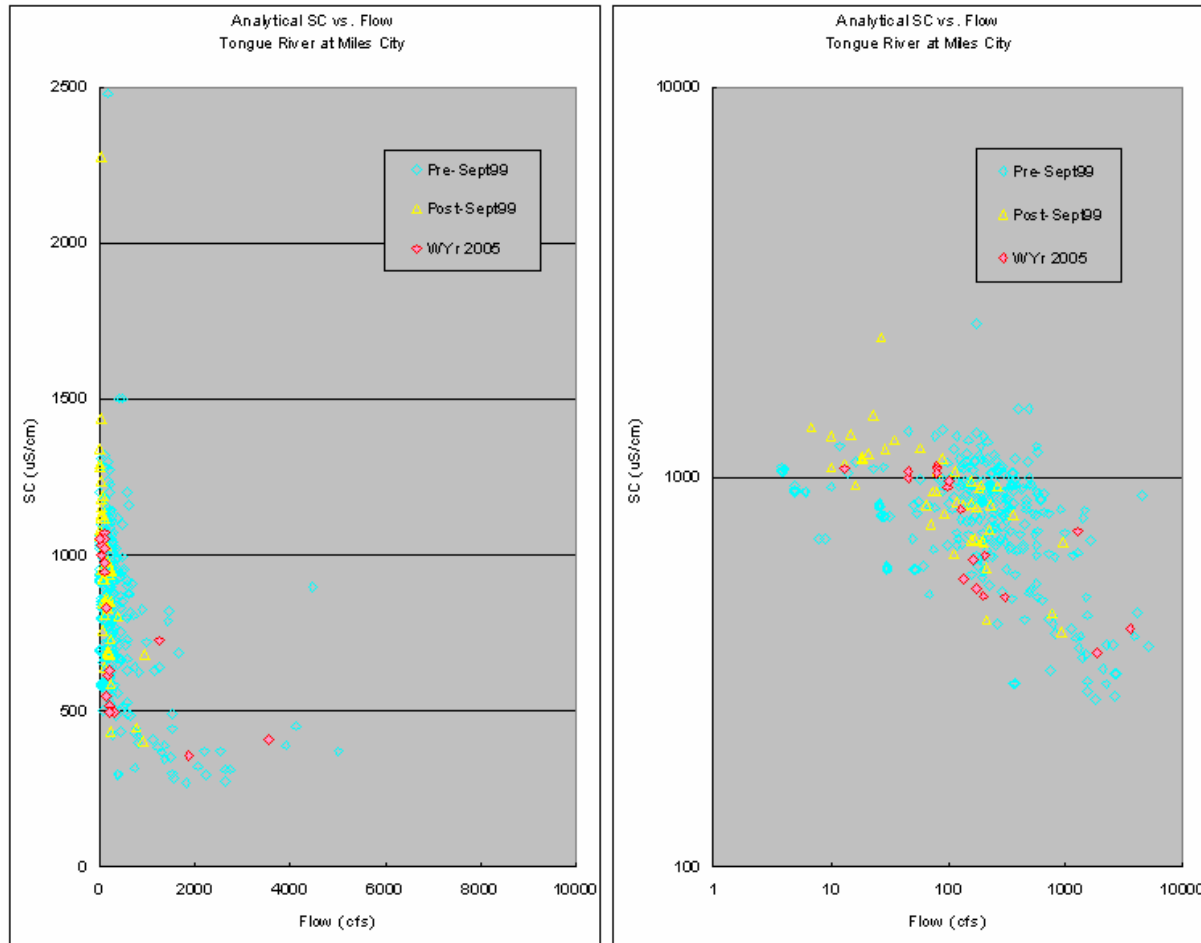


Figure 36 shows analytical SC vs. Flow data for water year 2005 for the Tongue River at Miles City, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 37: Tongue River at Miles City, MT

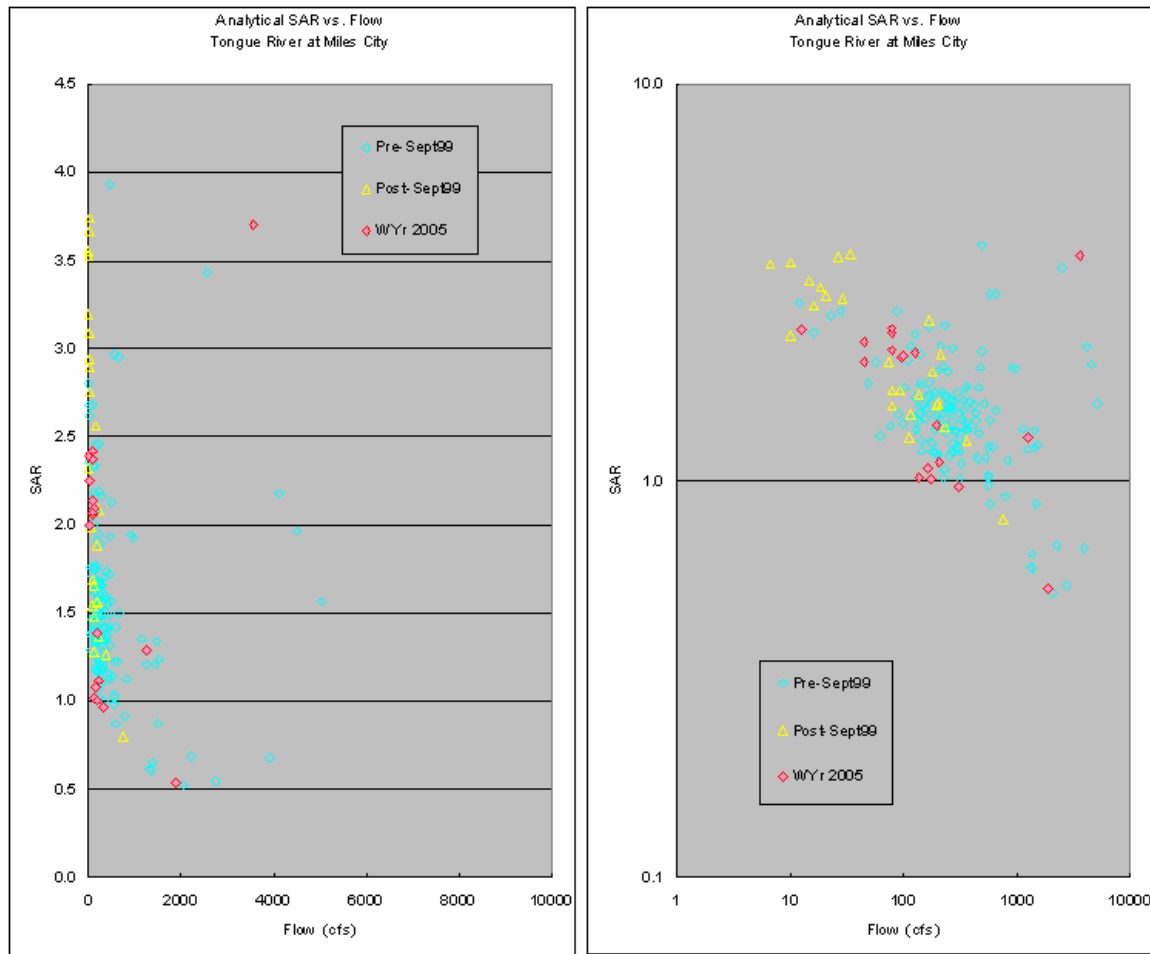


Figure 37 shows analytical SAR vs. Flow data for water year 2005 for the Tongue River at Miles City, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 38: Tongue River at Miles City, MT

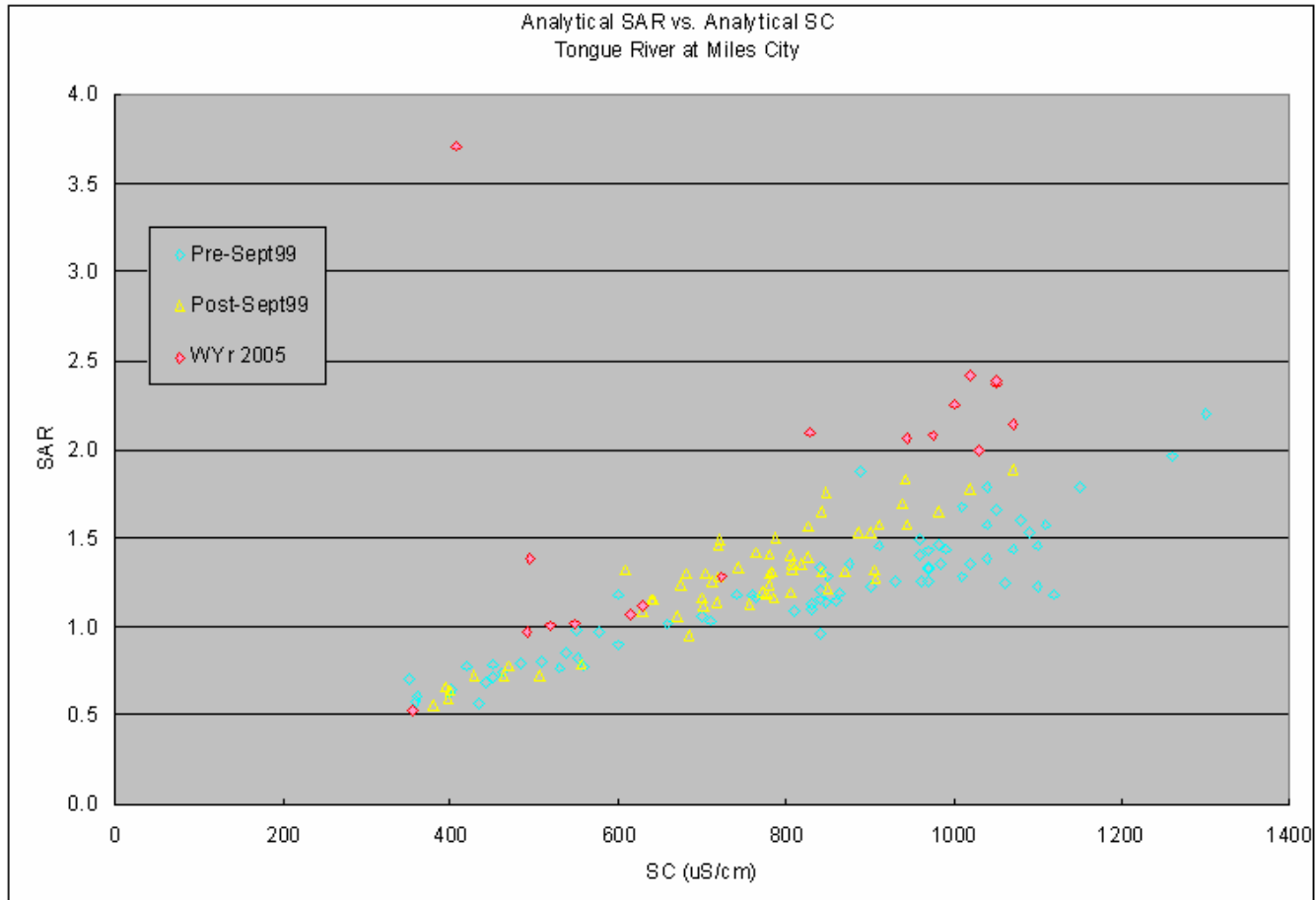


Figure 38 shows analytical SAR vs. analytical SC data for water year 2005 for the Tongue River at Miles City. Historical SAR vs. SC data are also shown to place the data in context.

Figure 39: Goose Creek near Acme, WY

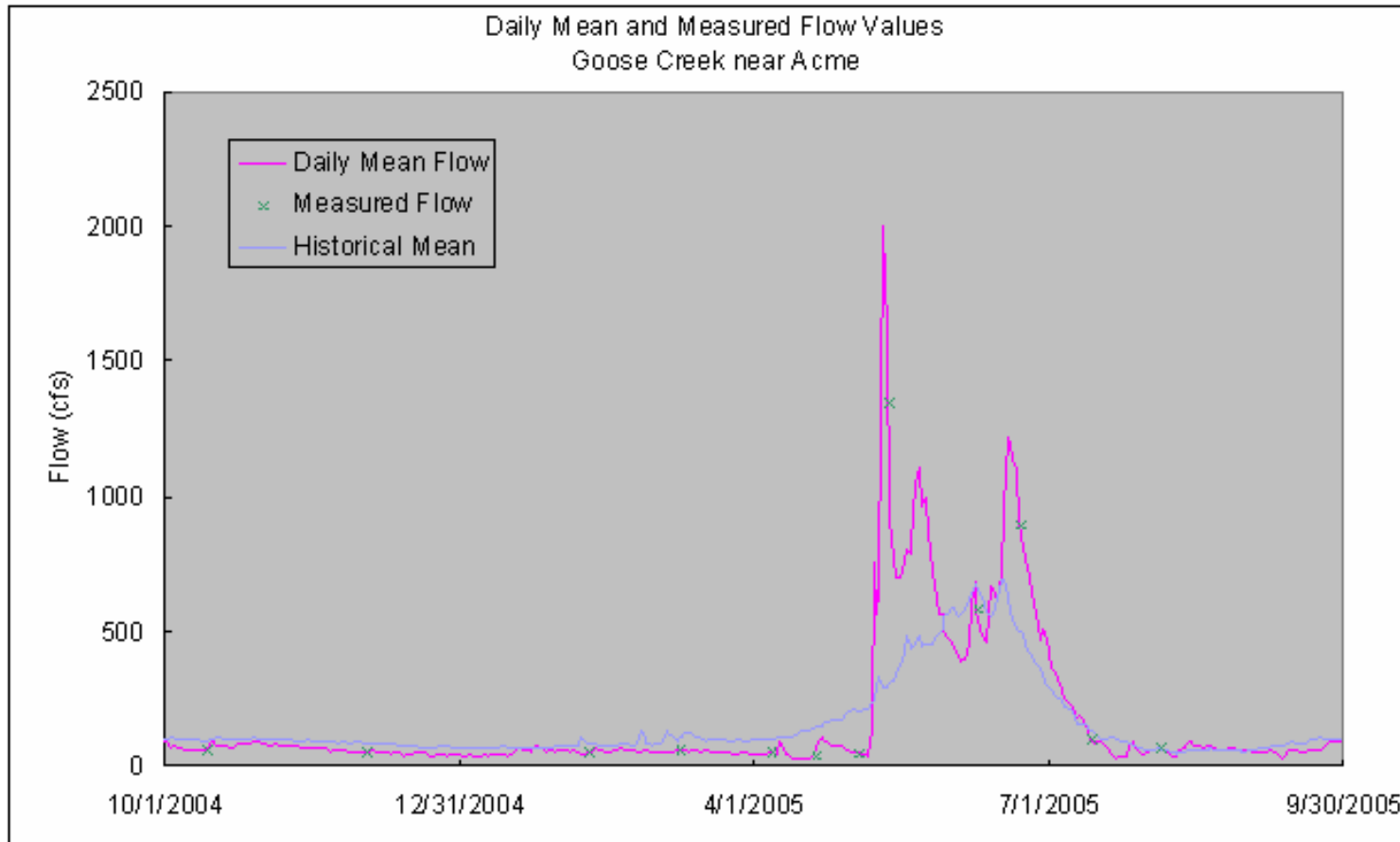


Figure 39 shows mean daily and field measurements of flow in a time series plot for water year 2005 for Goose Creek near Acme. The historical average mean daily flow values are also shown. Flow values ranged from 21 to 2000 cfs. Flows were less than average through April; from May to September flows were comparable to average.

Figure 40: Goose Creek near Acme, WY

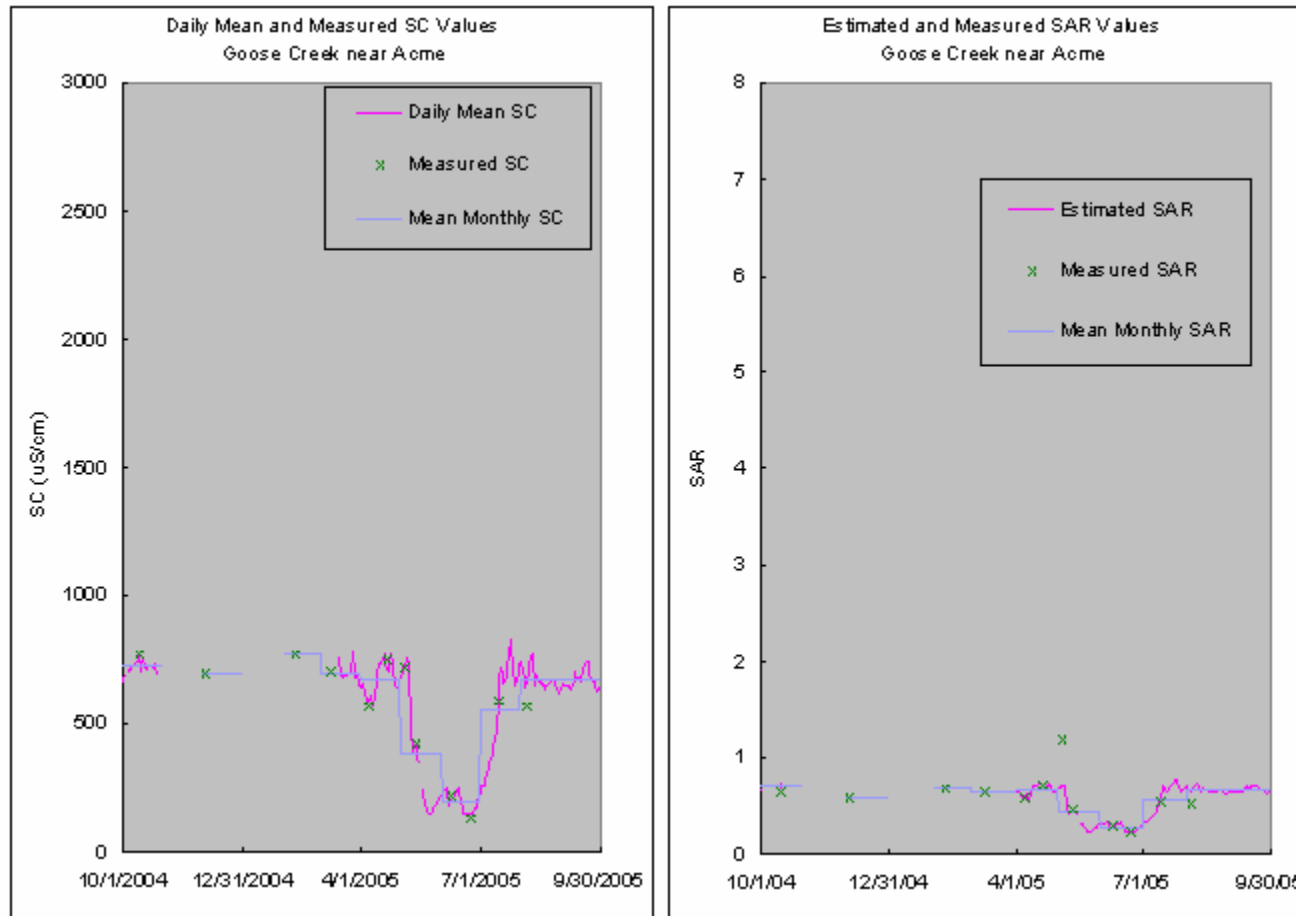


Figure 40 shows analytical and mean daily SC values (A) and analytical and mean daily estimated SAR values (B) in time series plots for water year 2005 for Goose Creek near Acme, WY. Mean Monthly EC and SAR values are also shown. SC values ranged from 130 to 826 uS/cm. SAR values ranged from 0.2 to 1.2.

Figure 41: Goose Creek near Acme, WY

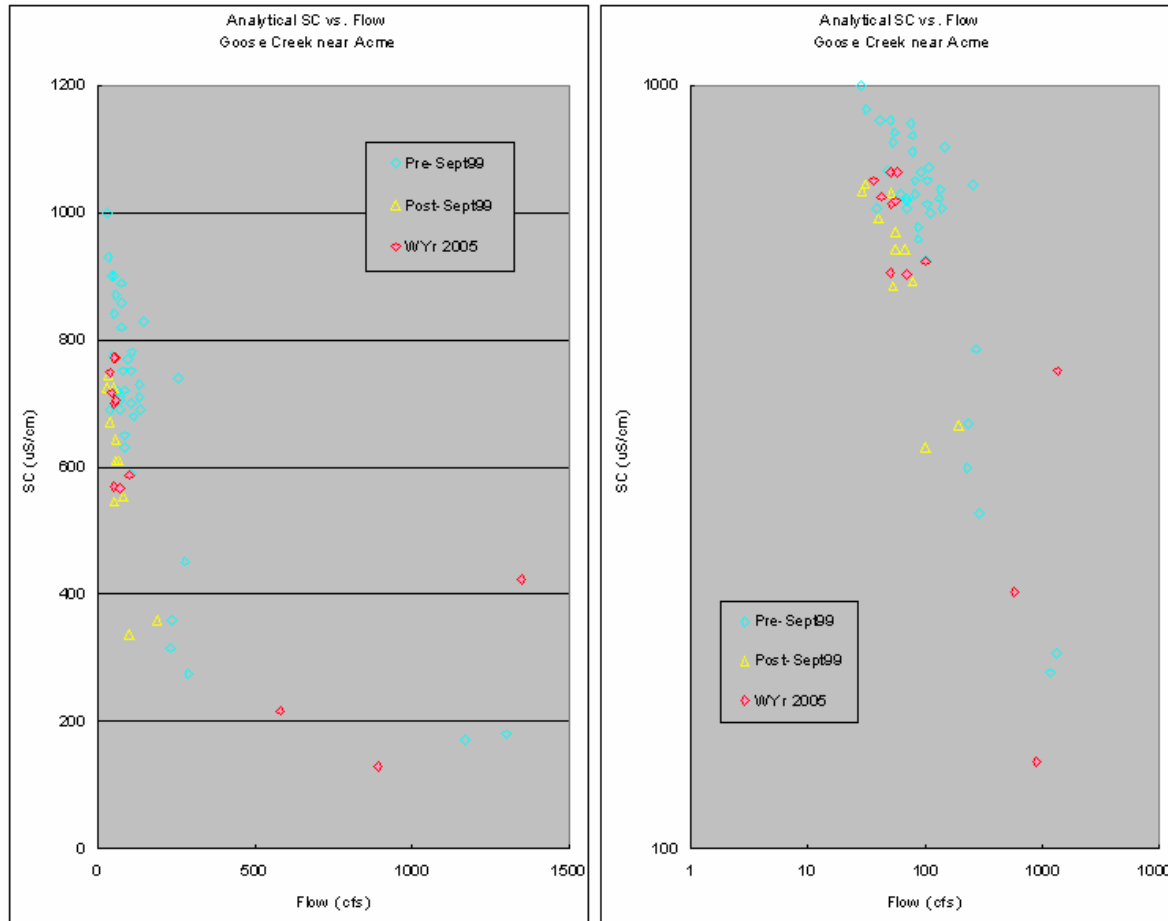


Figure 41 shows analytical SC vs. Flow data for water year 2005 for Goose Creek near Acme, WY. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 42: Goose Creek near Acme, WY

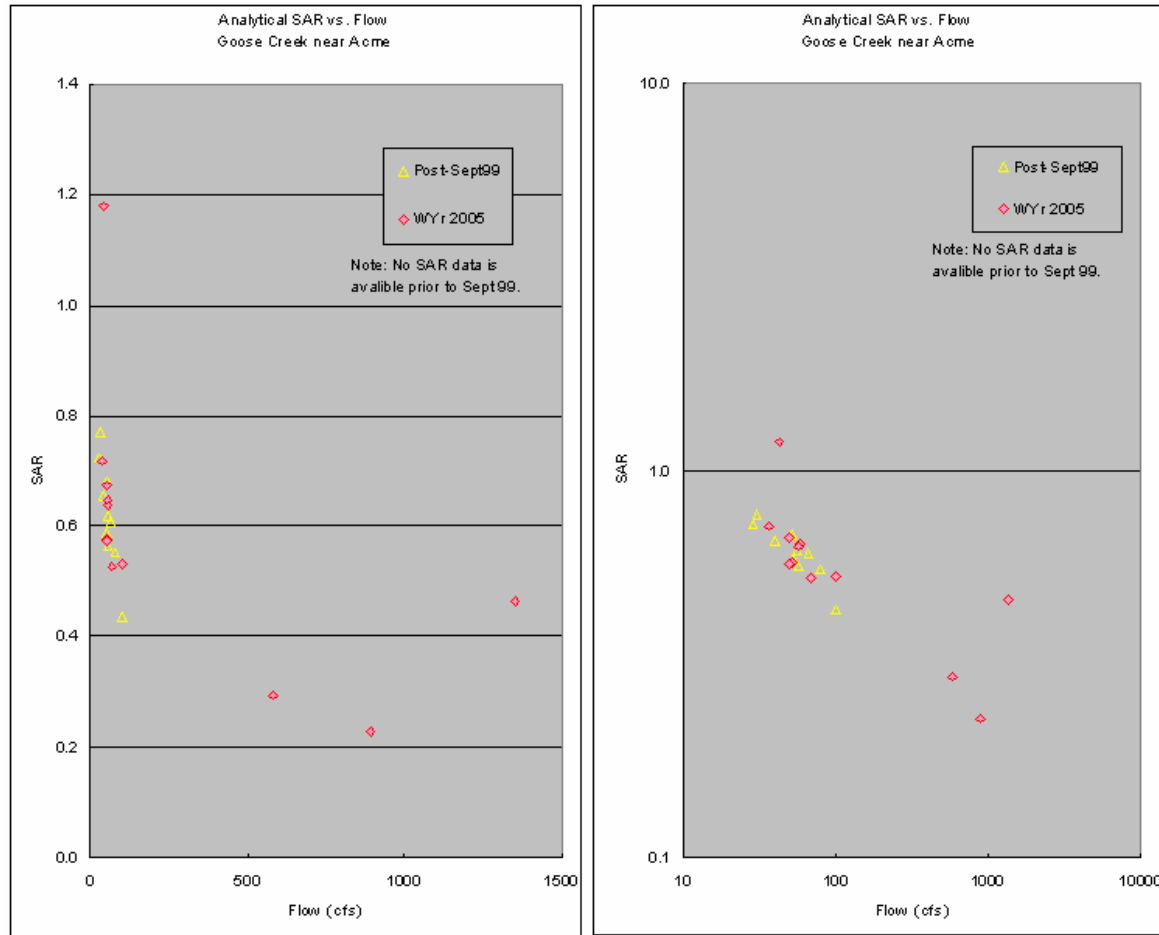


Figure 42 shows analytical SAR vs. Flow data for water year 2005 for Goose Creek near Acme, WY. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 43: Goose Creek near Acme, WY

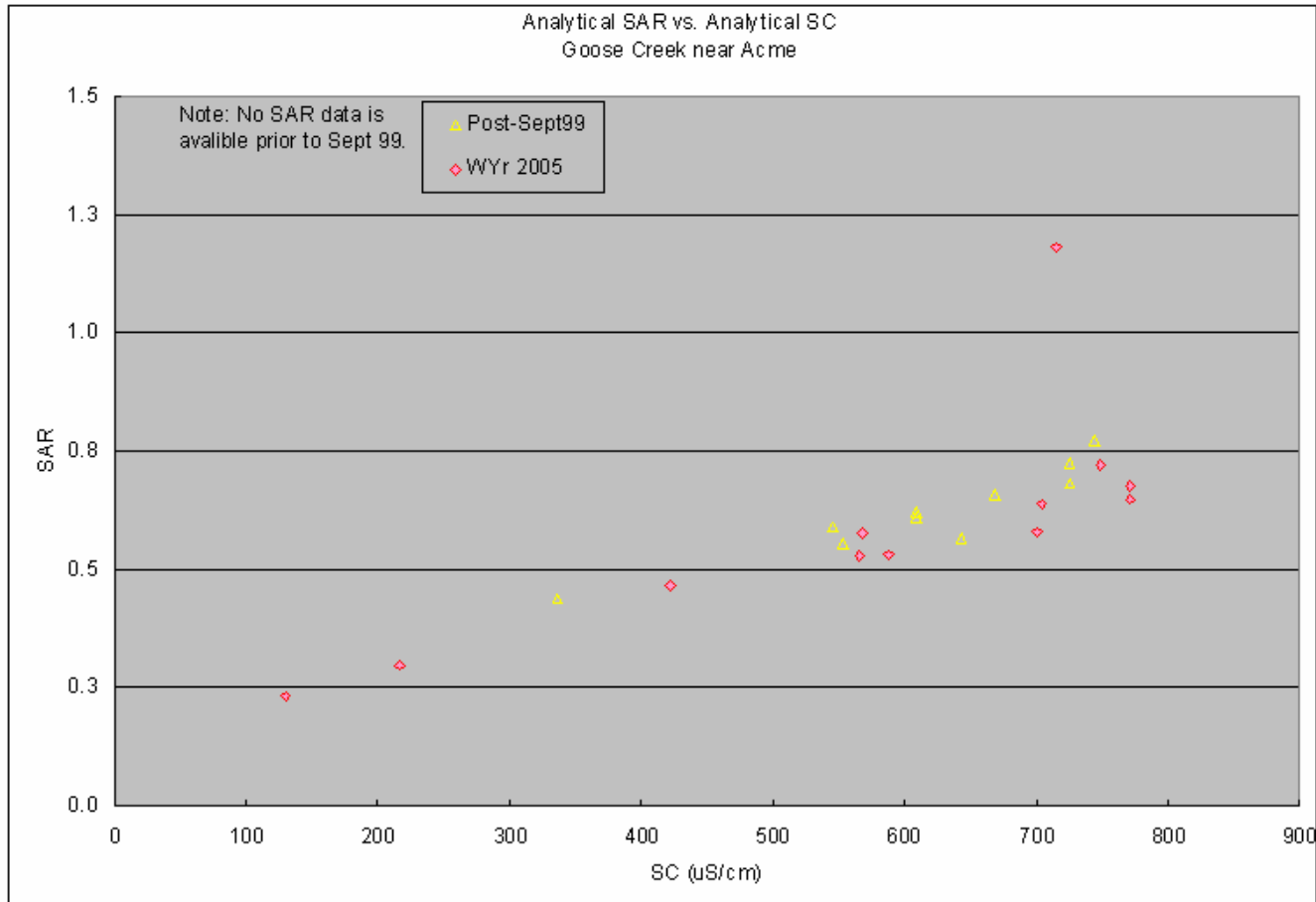


Figure 43 shows analytical SAR vs. analytical SC data for water year 2005 for Goose Creek near Acme, WY. Historical SAR vs. SC data are also shown to place the data in context.

Figure 44: Prairie Dog Creek near Acme, WY

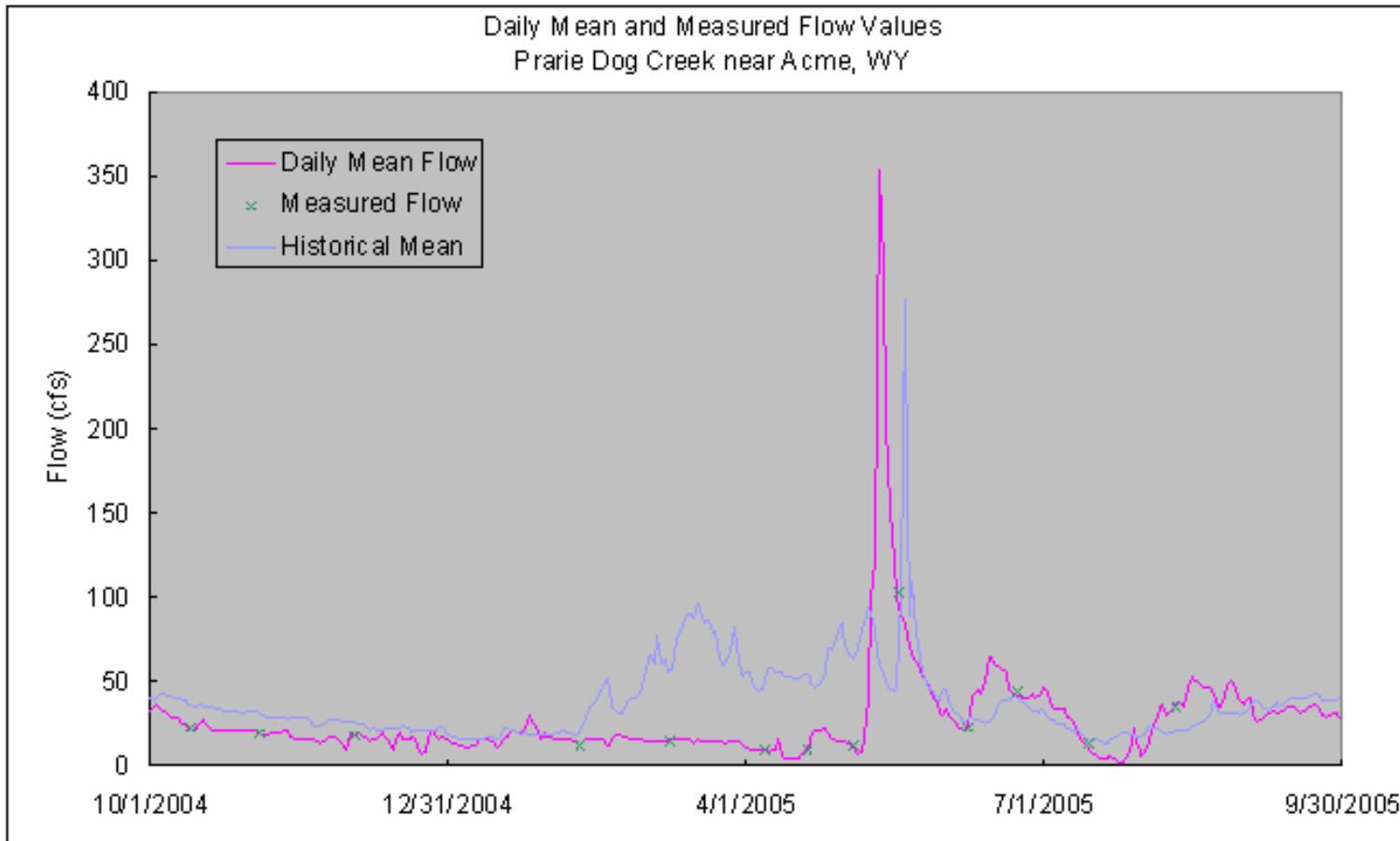


Figure 44 shows mean daily and field measurements of flow in a time series plot for water year 2005 for Prairie Dog Creek near Acme. The historical average mean daily flow values are also shown. Flow values ranged from 1 to 354 cfs. Flows were less than average through April; from May to September flows were comparable to average.

Figure 45: Prairie Dog Creek near Acme, WY

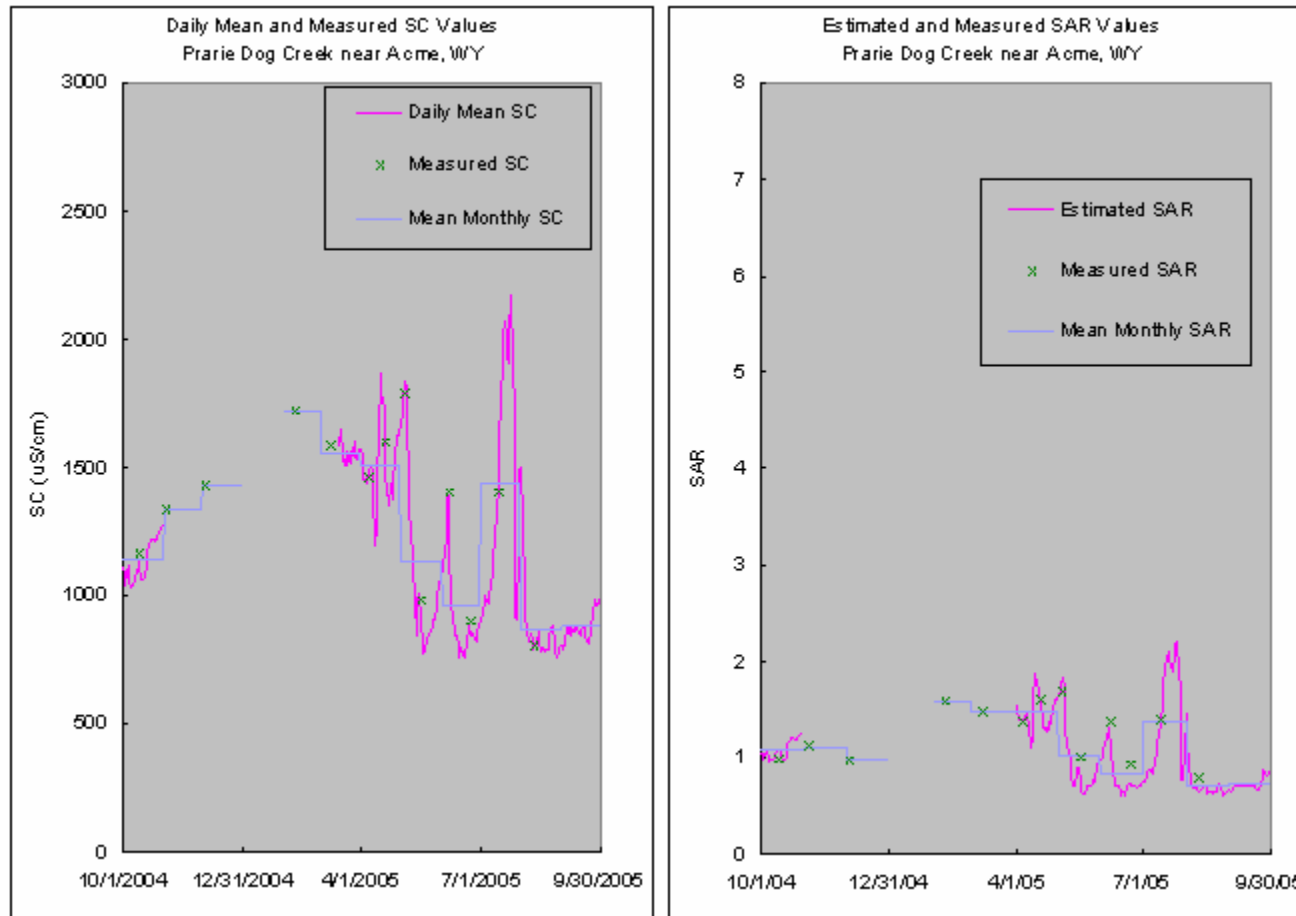


Figure 45 shows analytical and mean daily SC values (A) and analytical and mean daily estimated SAR values (B) in time series plots for water year 2005 for Prairie Dog Creek near Acme, WY. Mean Monthly SC and SAR values are also shown. SC values ranged from 754 to 2170 uS/cm. SAR values ranged from 0.6 to 2.2.

Figure 46: Prairie Dog Creek near Acme, WY

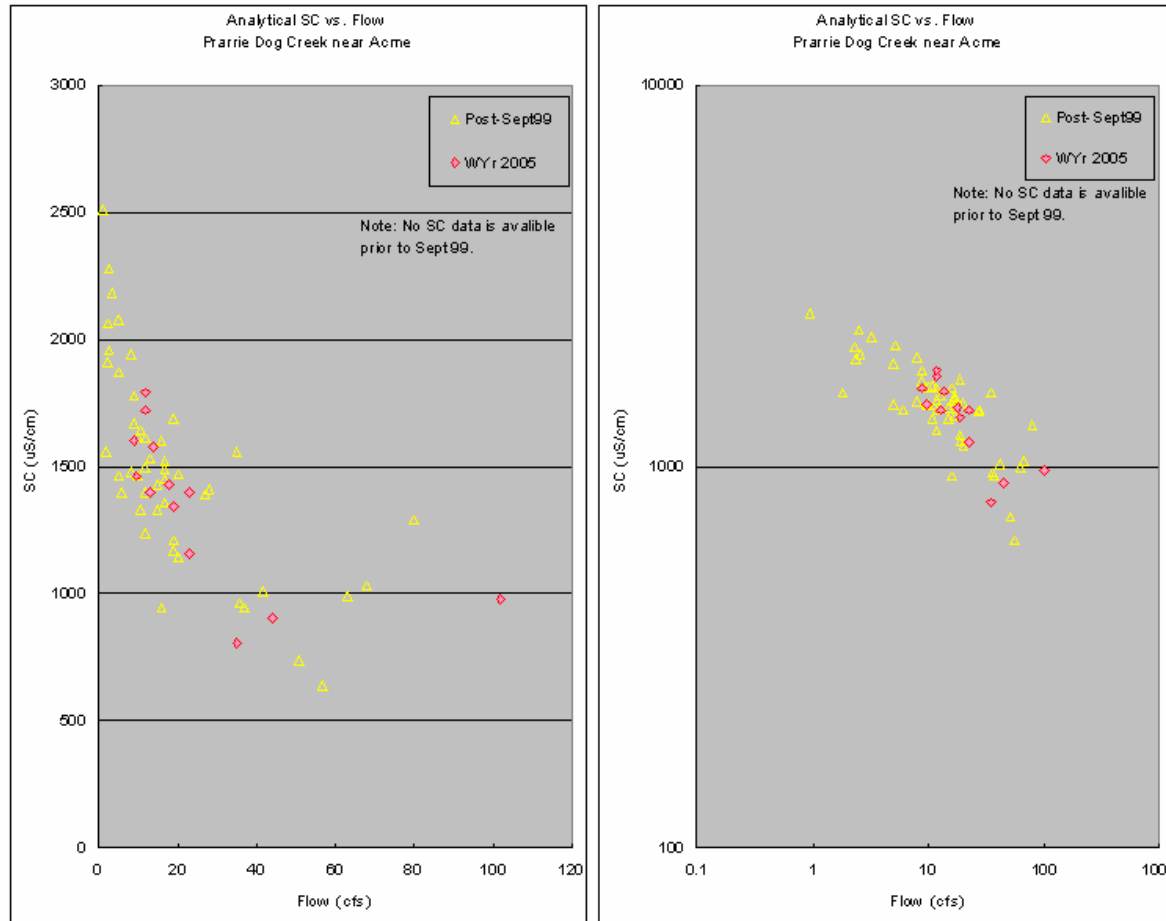


Figure 46 shows analytical SC vs. Flow data for water year 2005 for Prairie Dog Creek near Acme, WY. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 47: Prairie Dog Creek near Acme, WY

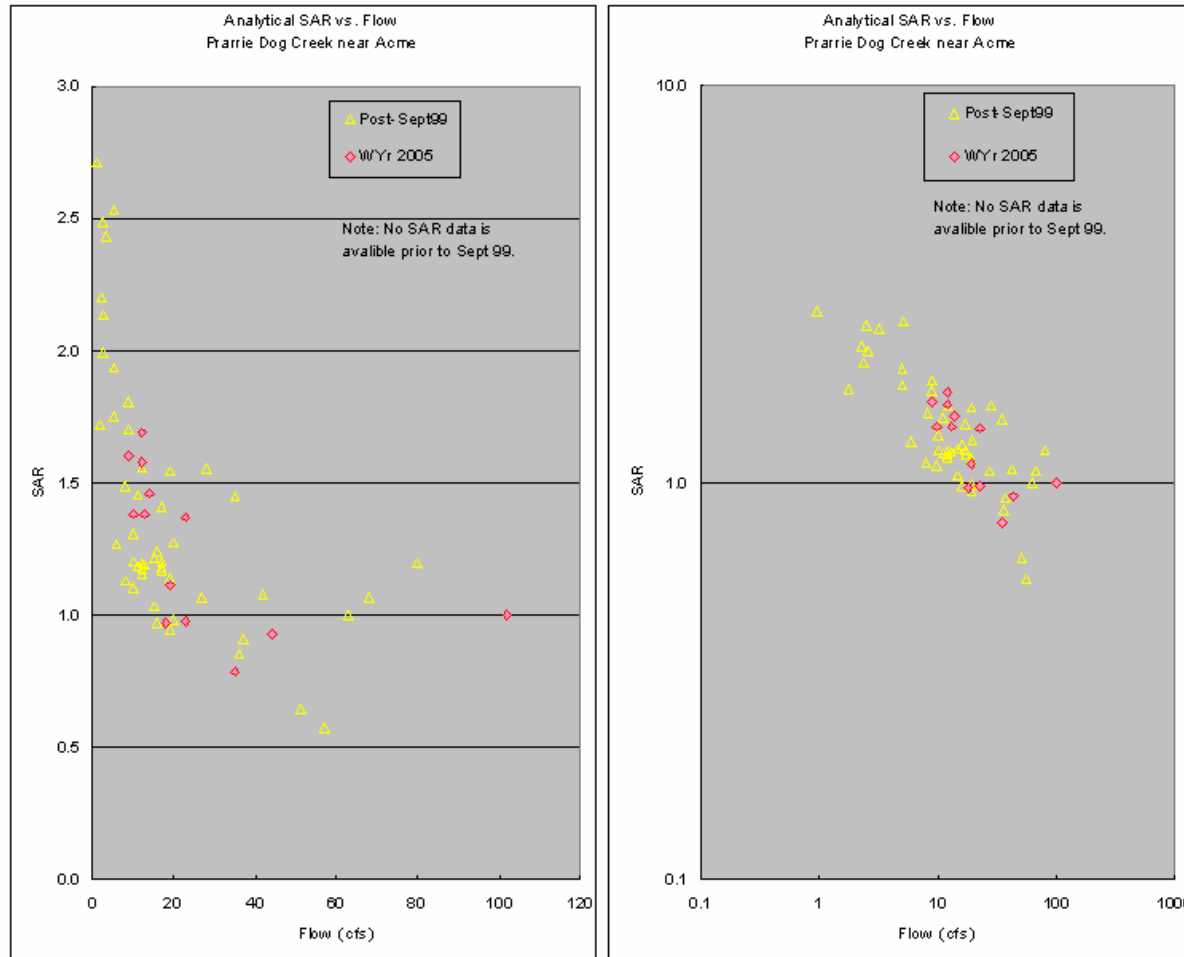


Figure 47 shows analytical SAR vs. Flow data for water year 2005 for Prairie Dog Creek near Acme, WY. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 48: Prairie Dog Creek near Acme, WY

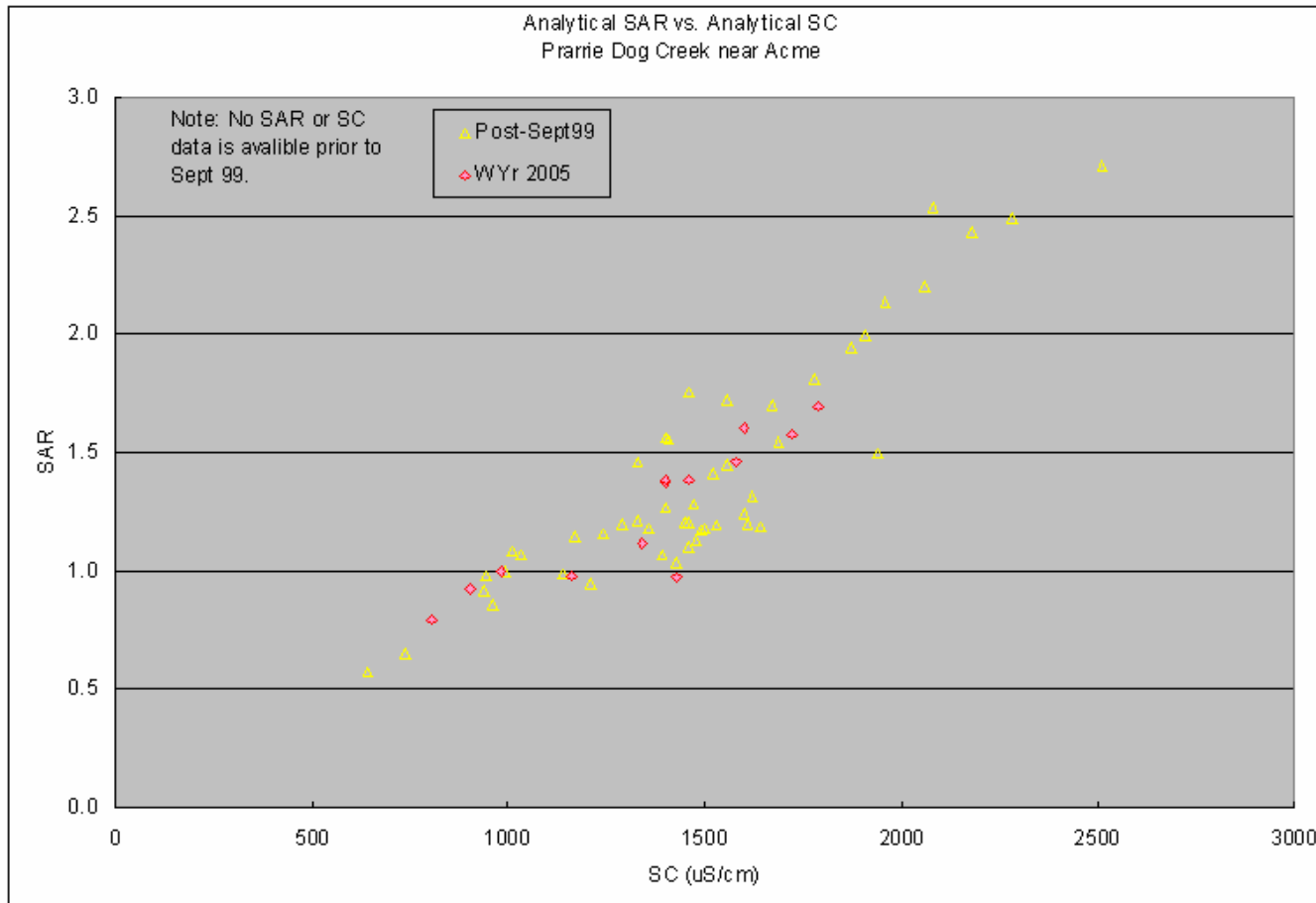


Figure 48 shows analytical SAR vs. analytical SC data for water year 2005 for Prairie Dog Creek near Acme, WY. Historical SAR vs. SC data are also shown to place the data in context.

Figure 49: Hanging Woman Creek near Birney, MT

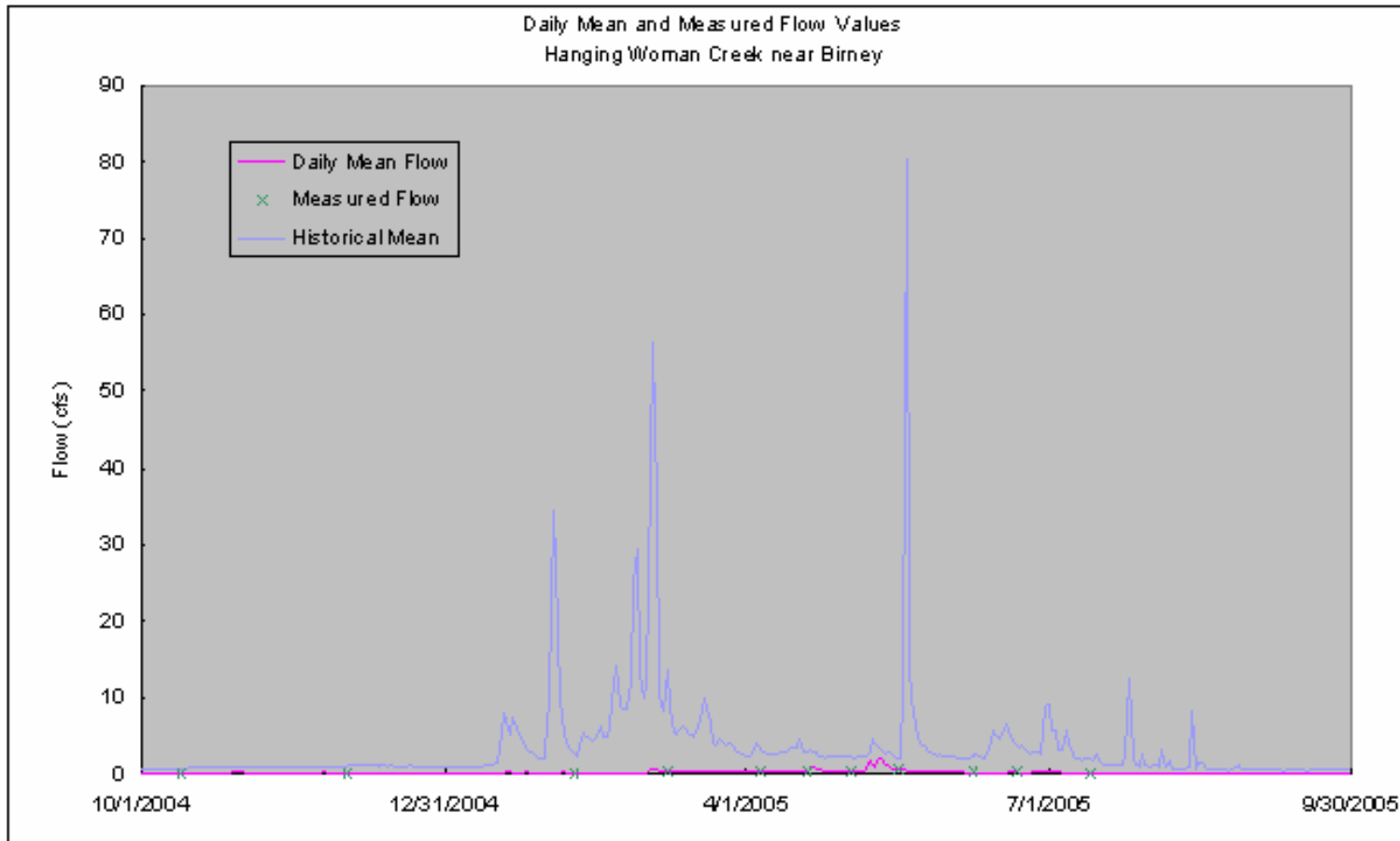


Figure 49 shows mean daily and field measurements of flow in a time series plot for water year 2005 for Hanging Woman Creek near Birney, MT. The historical average mean daily flow values are also shown. Flow values ranged from 0 to 2.2 cfs. Flow throughout the entire year was substantially less than average.

Figure 50: Hanging Woman Creek near Birney, MT

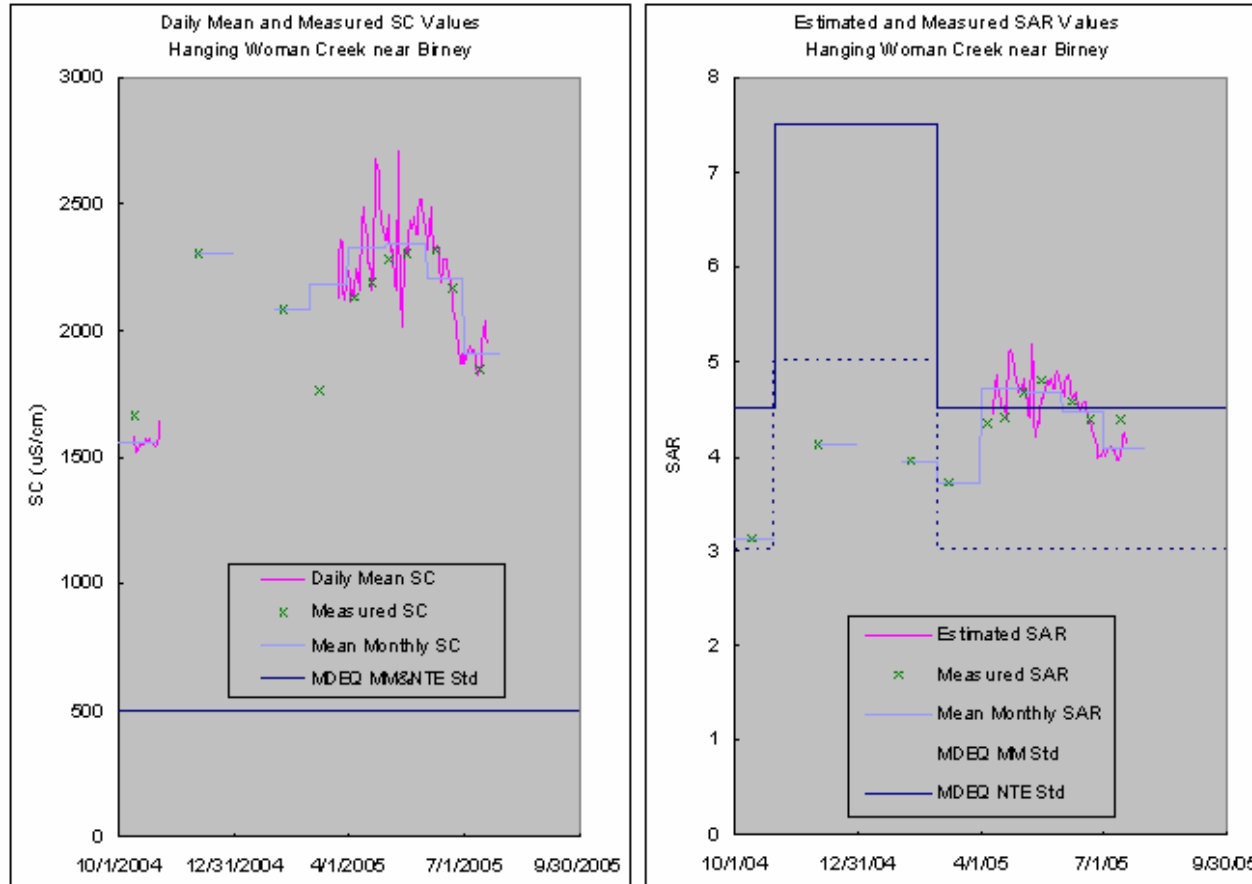


Figure 50 shows analytical and mean daily SC values (A) and analytical and mean daily estimated SAR values (B) in time series plots for water year 2005 for Hanging Woman Creek near Birney, MT. Mean Monthly SC and SAR values are also shown. SC values ranged from 1520 to 2710 uS/cm. SAR values ranged from 3.1 to 5.2. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. SC values were in excess of the EC standards for the entire year. SAR values were often above the standards.

Figure 51: Hanging Woman Creek near Birney, MT

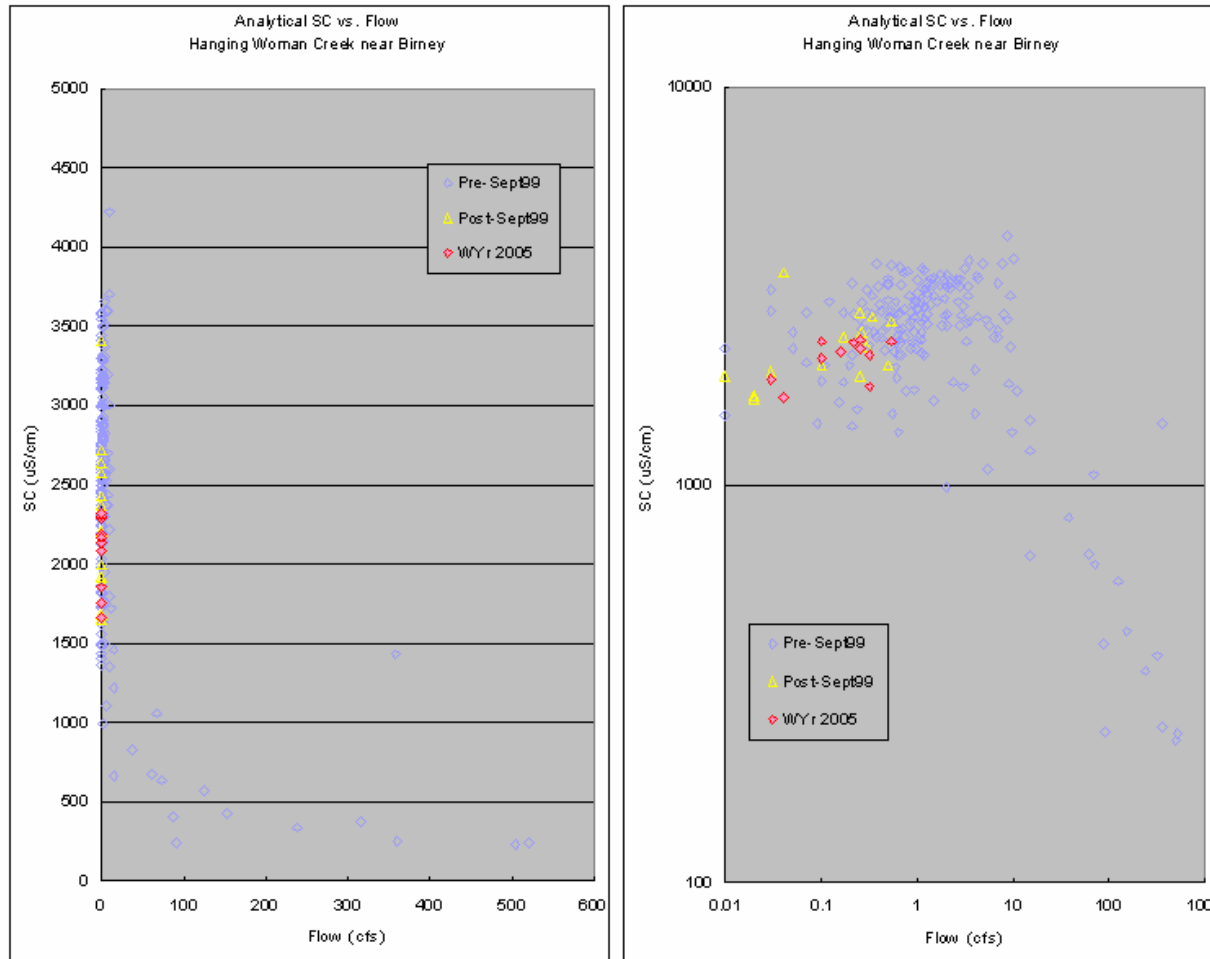


Figure 51 shows analytical SC vs. Flow data for water year 2005 for Hanging Woman Creek near Birney, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 52: Hanging Woman Creek near Birney, MT

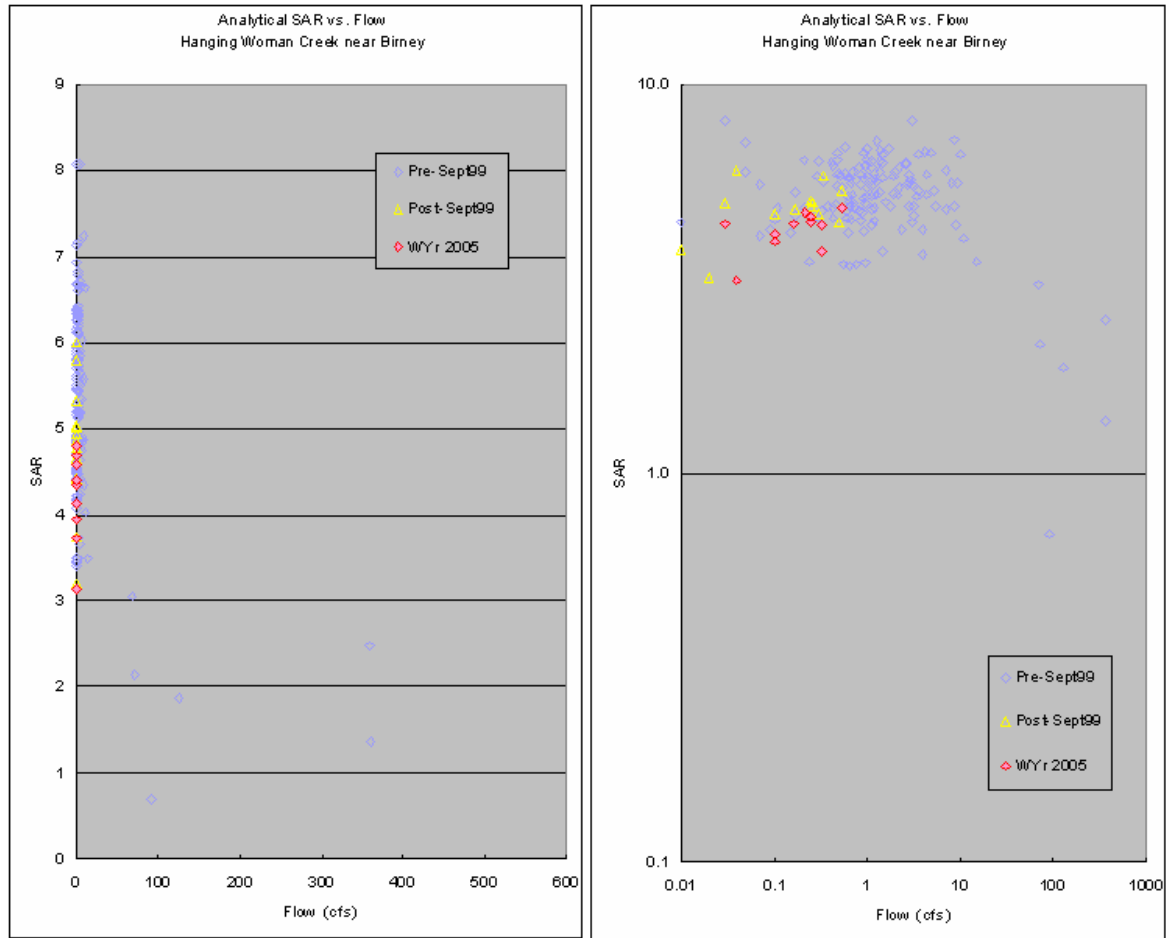


Figure 52 shows analytical SAR vs. Flow data for water year 2005 for Hanging Woman Creek near Birney, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 53: Hanging Woman Creek near Birney, MT

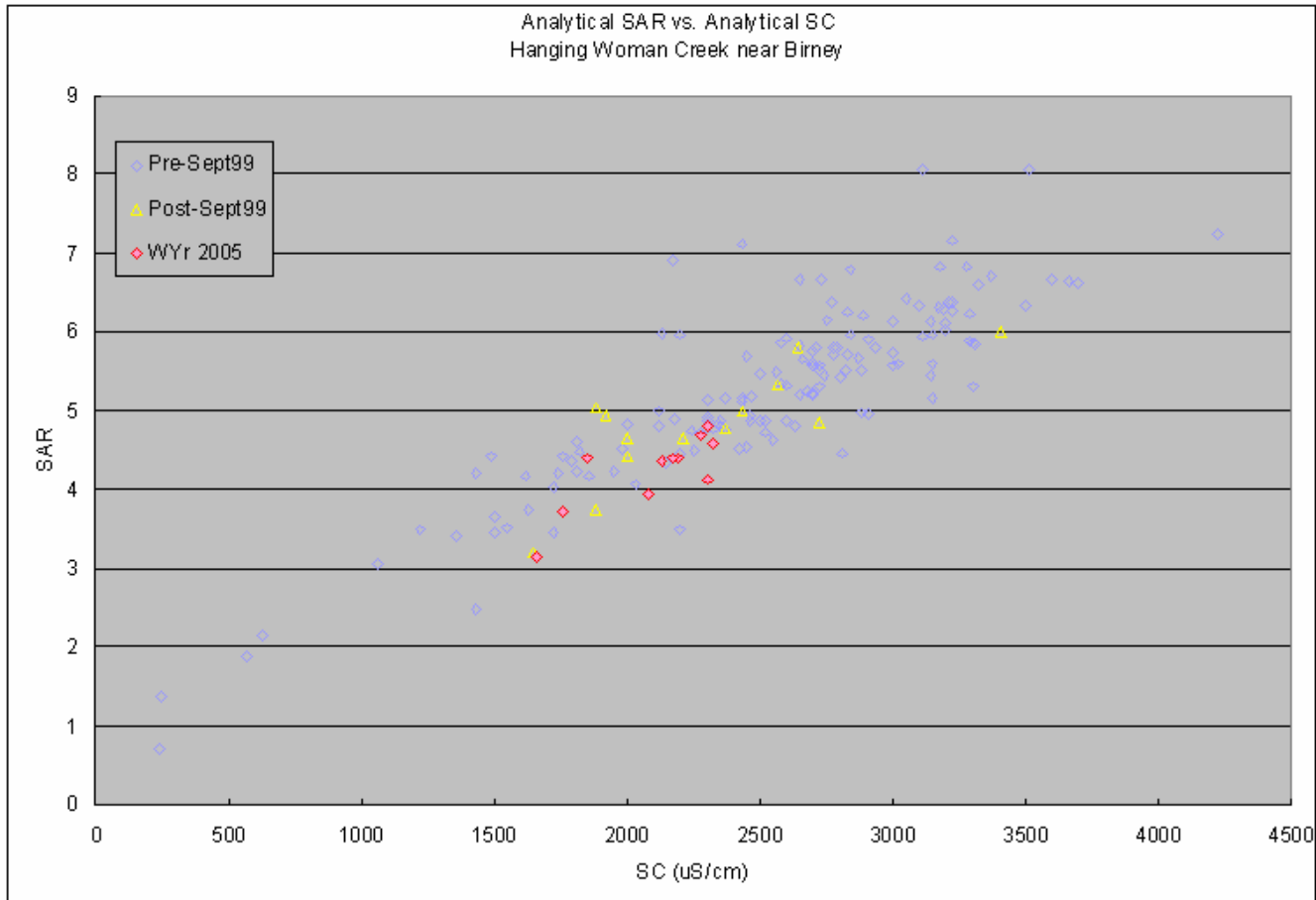


Figure 53 shows analytical SAR vs. analytical SC data for water year 2005 for Hanging Woman Creek near Birney, MT. Historical SAR vs. SC data are also shown to place the data in context.

Figure 54: Otter Creek at Ashland, MT

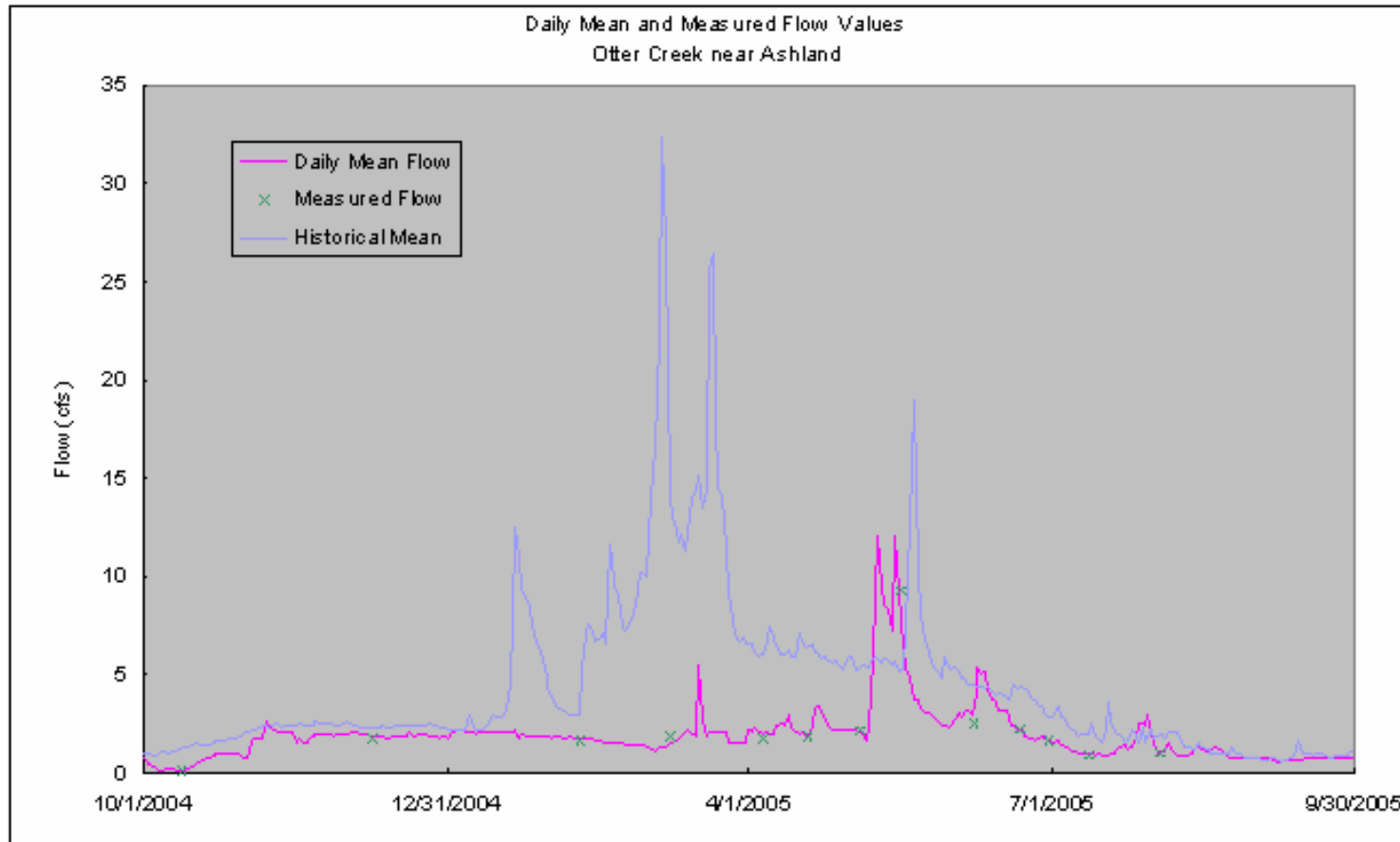


Figure 54 shows mean daily and field measurements of flow in a time series plot for water year 2005 for Otter Creek near Ashland, MT. The historical average mean daily flow values are also shown. Flow values ranged from 0.1 to 12 cfs. Flows during 2005 were less than average.

Figure 55: Otter Creek at Ashland, MT

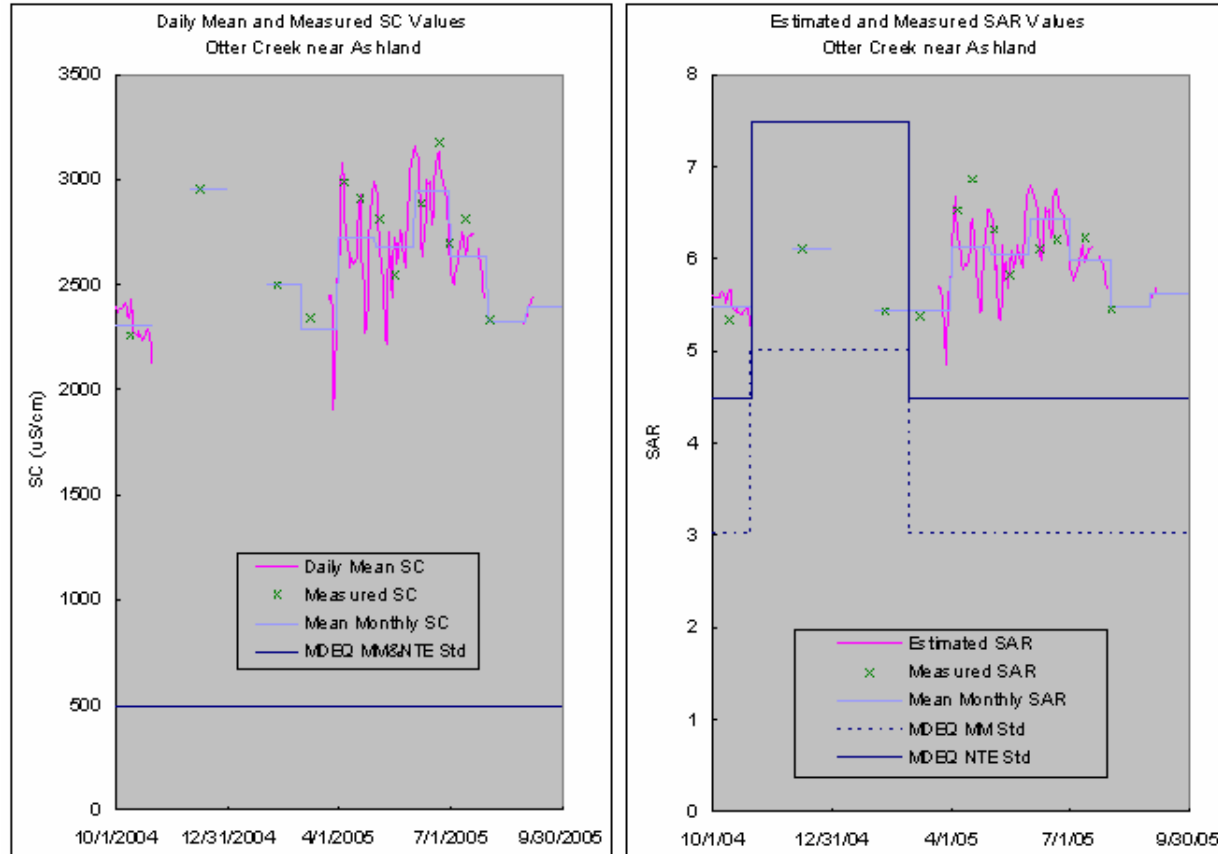


Figure 55 shows analytical and mean daily SC (A) and analytical and mean daily estimated SAR (B) values in time series plots for water year 2005 for Otter Creek at Ashland, MT. Mean Monthly SC and SAR values are also shown. SC values ranged from 1900 to 3180 uS/cm. SAR values ranged from 4.8 to 6.9. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. SC values were in excess of the EC standards for the entire year. Recorded SAR values were always above the mean monthly standard, and always above the irrigation season instantaneous maximum standard.

Figure 56: Otter Creek at Ashland, MT

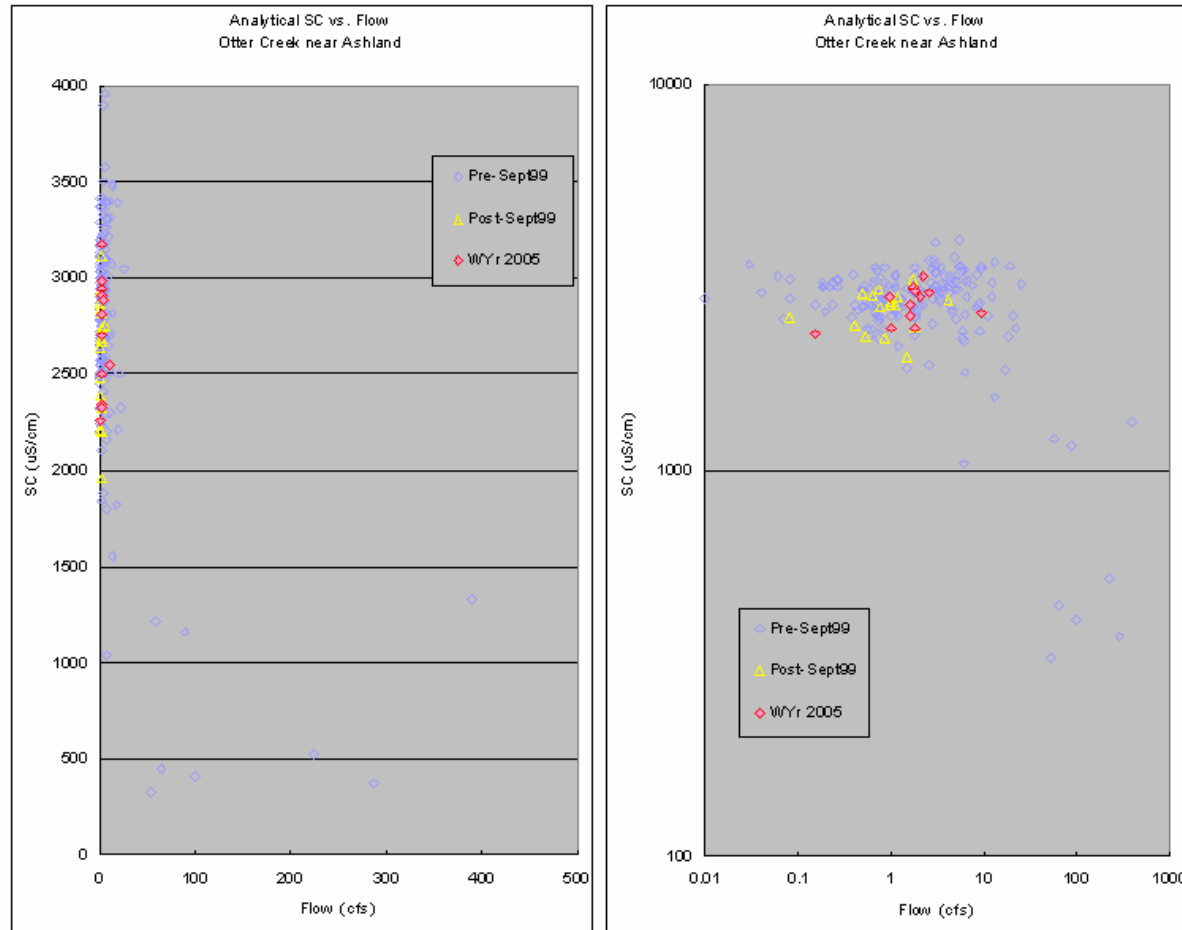


Figure 56 shows analytical SC vs. Flow data for water year 2005 for Otter Creek at Ashland, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 57: Otter Creek at Ashland, MT

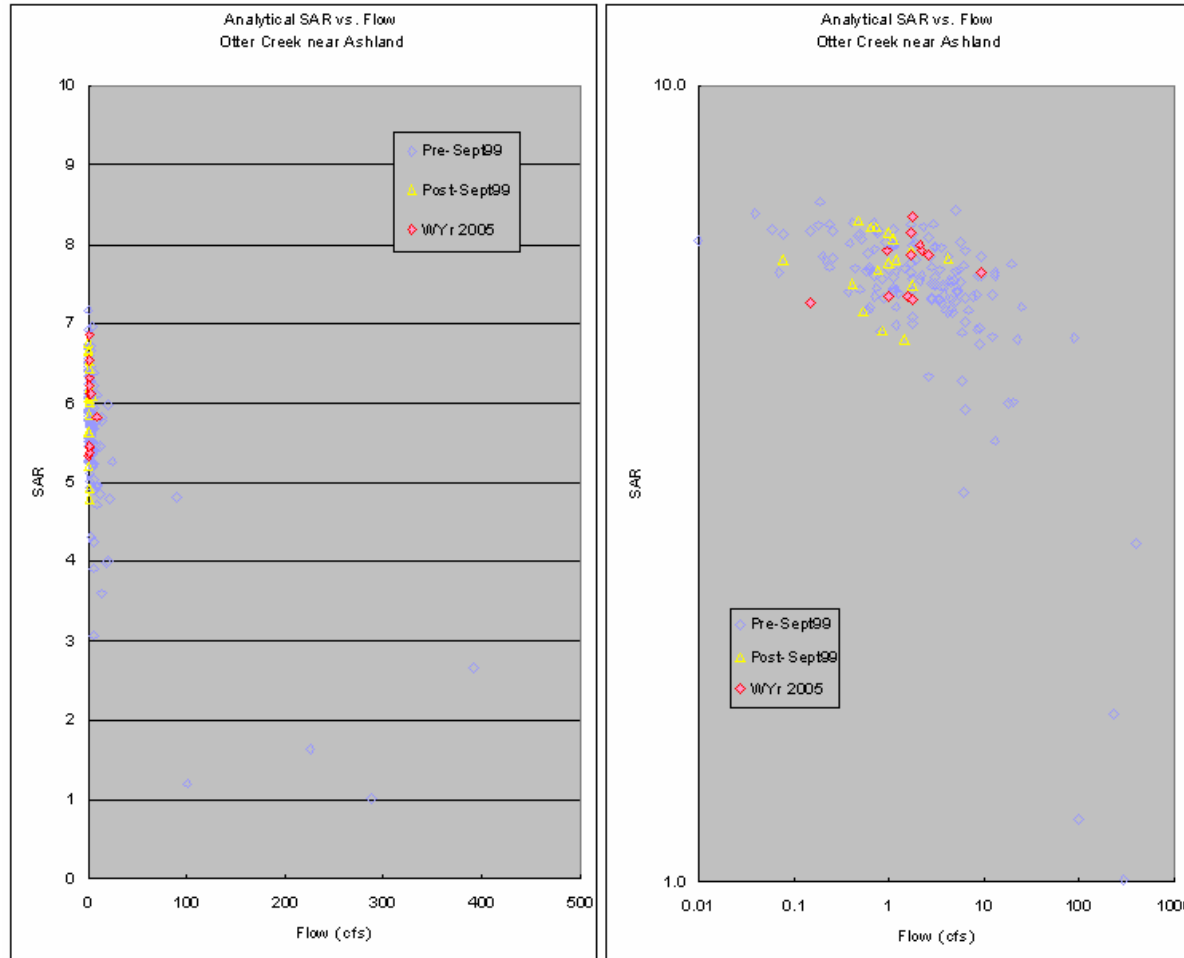


Figure 57 shows analytical SAR vs. Flow data for water year 2005 for Otter Creek at Ashland, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 58: Otter Creek at Ashland, MT

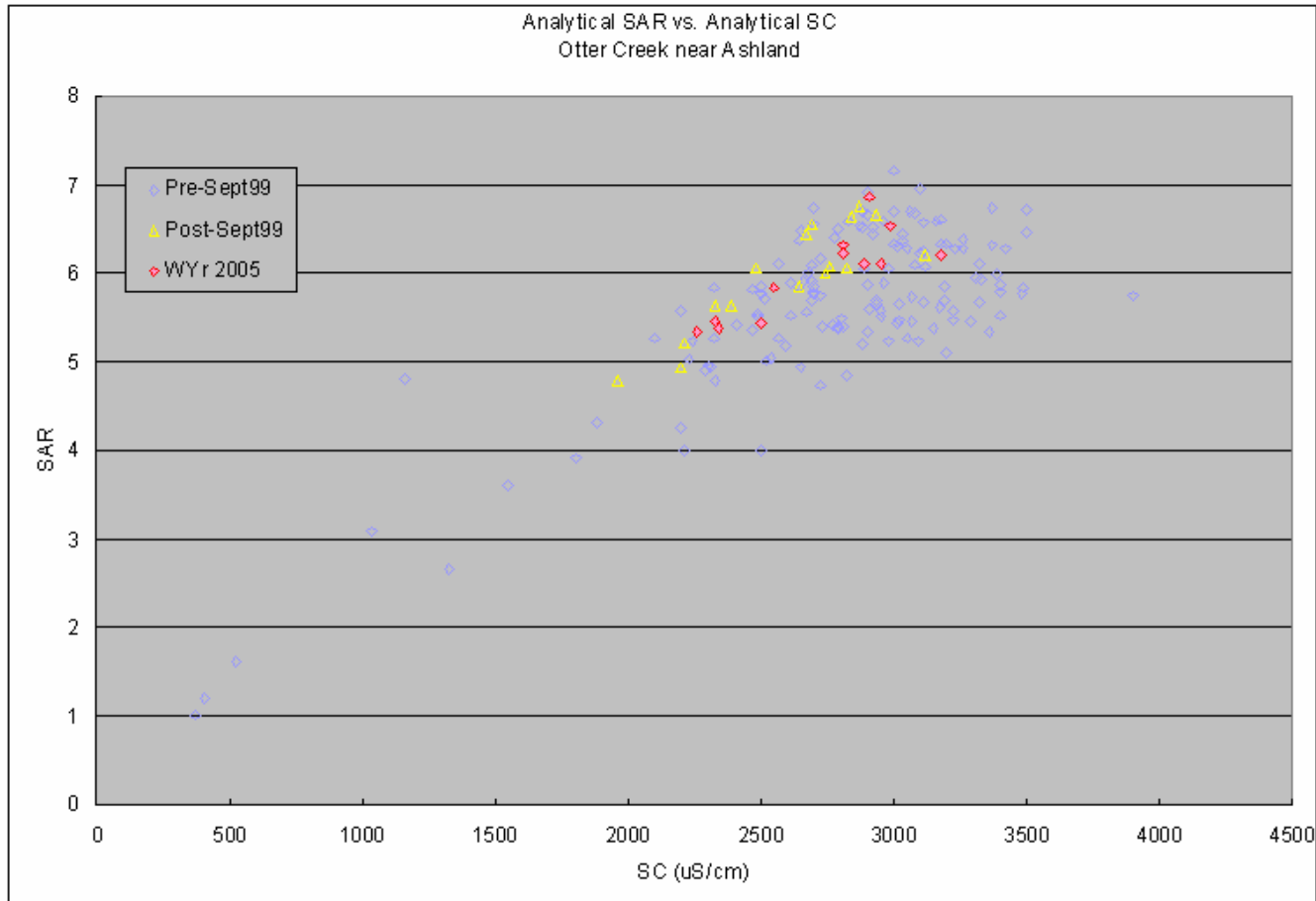


Figure 58 shows analytical SAR vs. analytical SC data for water year 2005 for Otter Creek near Ashland, MT. Historical SAR vs. SC data are also shown to place the data in context.

Figure 59: Pumpkin Creek near Miles City, MT

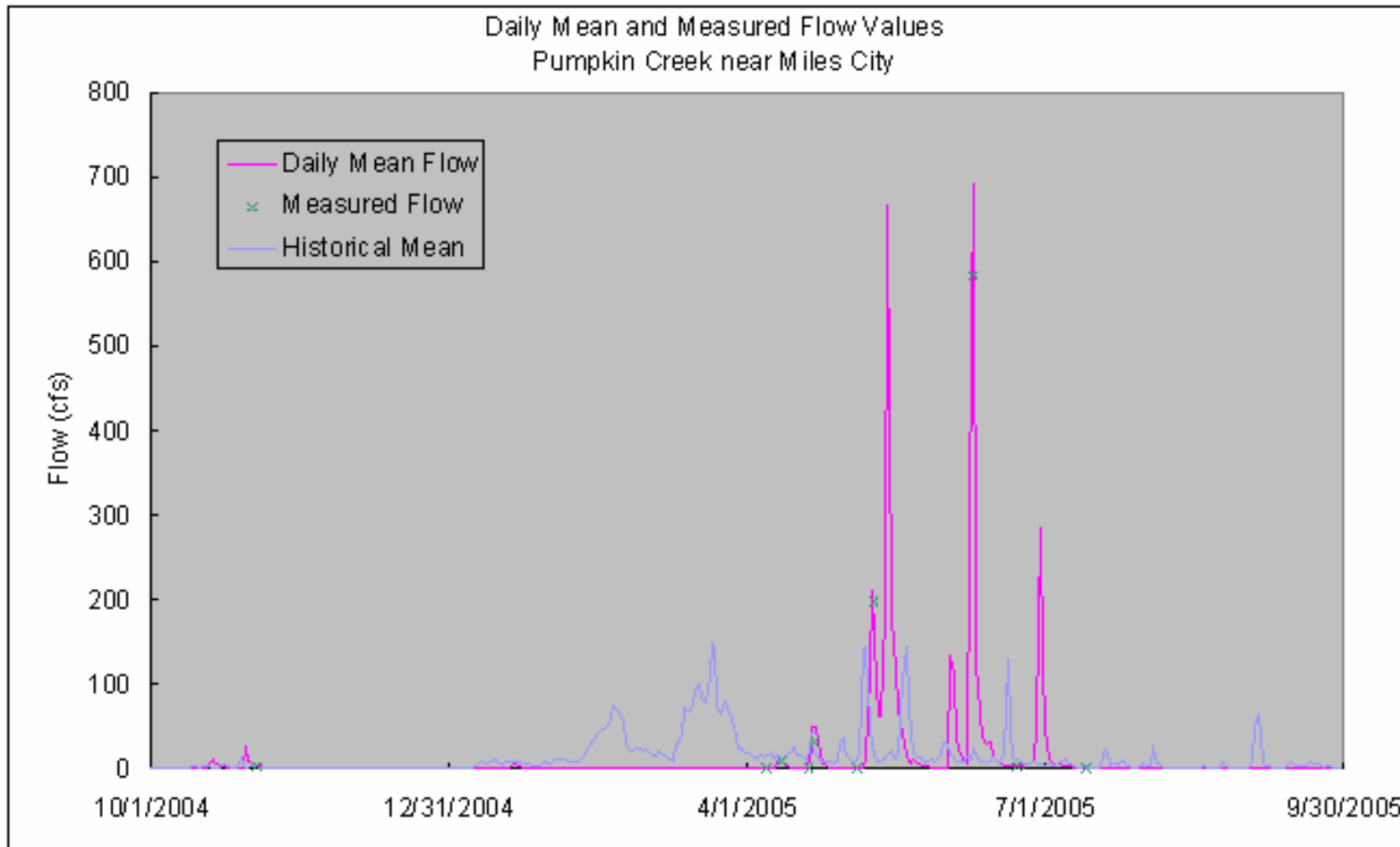


Figure 59 shows mean daily and field measurements of flow in a time series plot for water year 2005 for Pumpkin Creek near Miles City, MT. The historical average mean daily flow values are also shown. Flow values ranged from 0 to 692 cfs. Flows during 2005 were somewhat less than average except for during the spring (May-June).

Figure 60: Pumpkin Creek near Miles City, MT

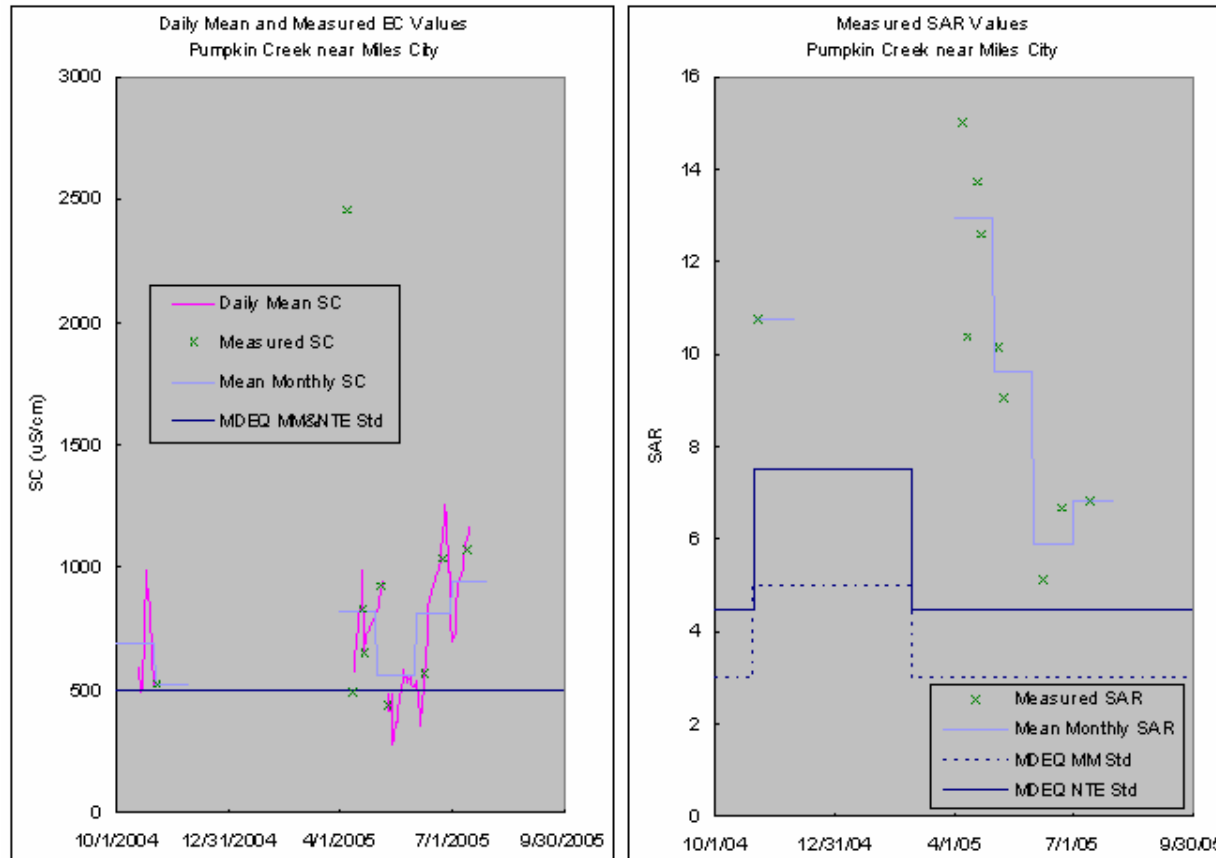


Figure 60 shows analytical and mean daily SC (A) and analytical SAR (B) values in time series plots for water year 2005 for Pumpkin Creek near Miles City, MT. Mean Monthly SC and SAR values are also shown. SC values ranged from 275 to 2460 uS/cm. SAR values ranged from 5.1 to 15. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. SC values were above the EC standard for most of the year. SAR values were always above both the mean monthly and instantaneous maximum standards.

Figure 61: Pumpkin Creek near Miles City, MT

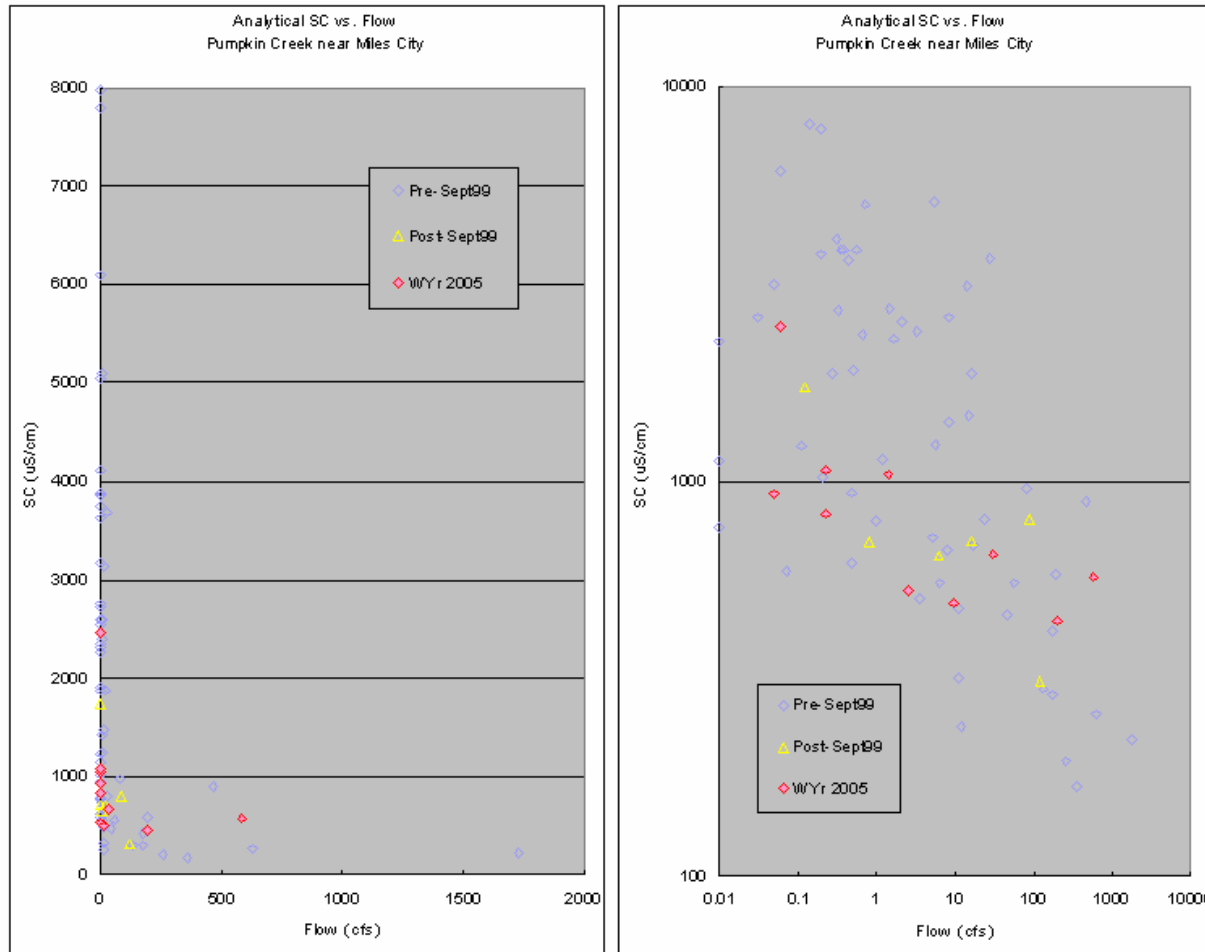


Figure 61 shows analytical SC vs. Flow data for water year 2005 for Pumpkin Creek near Miles City, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 62: Pumpkin Creek near Miles City, MT

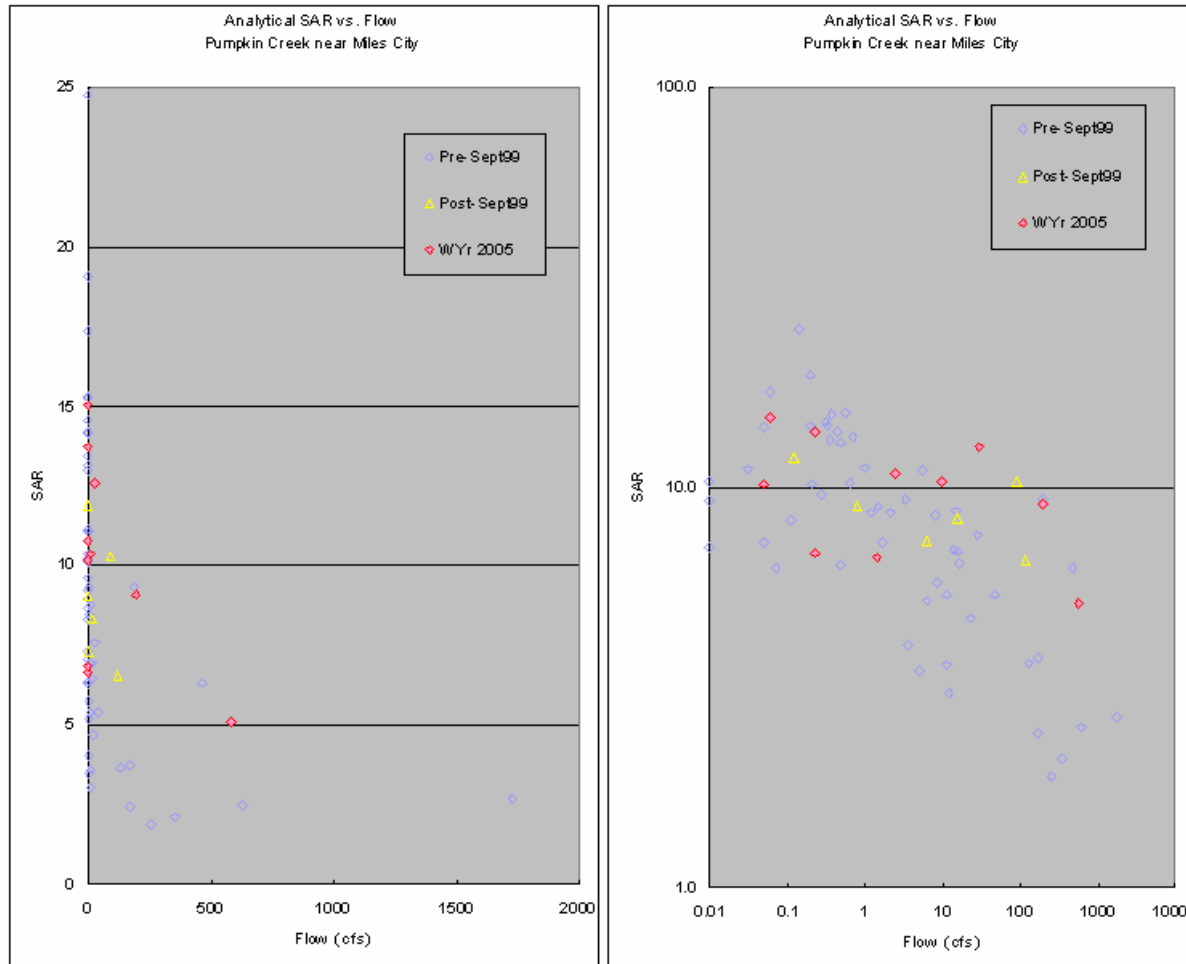


Figure 62 shows analytical SAR vs. Flow data for water year 2005 for Pumpkin Creek near Miles City, MT. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 63: Pumpkin Creek near Miles City, MT

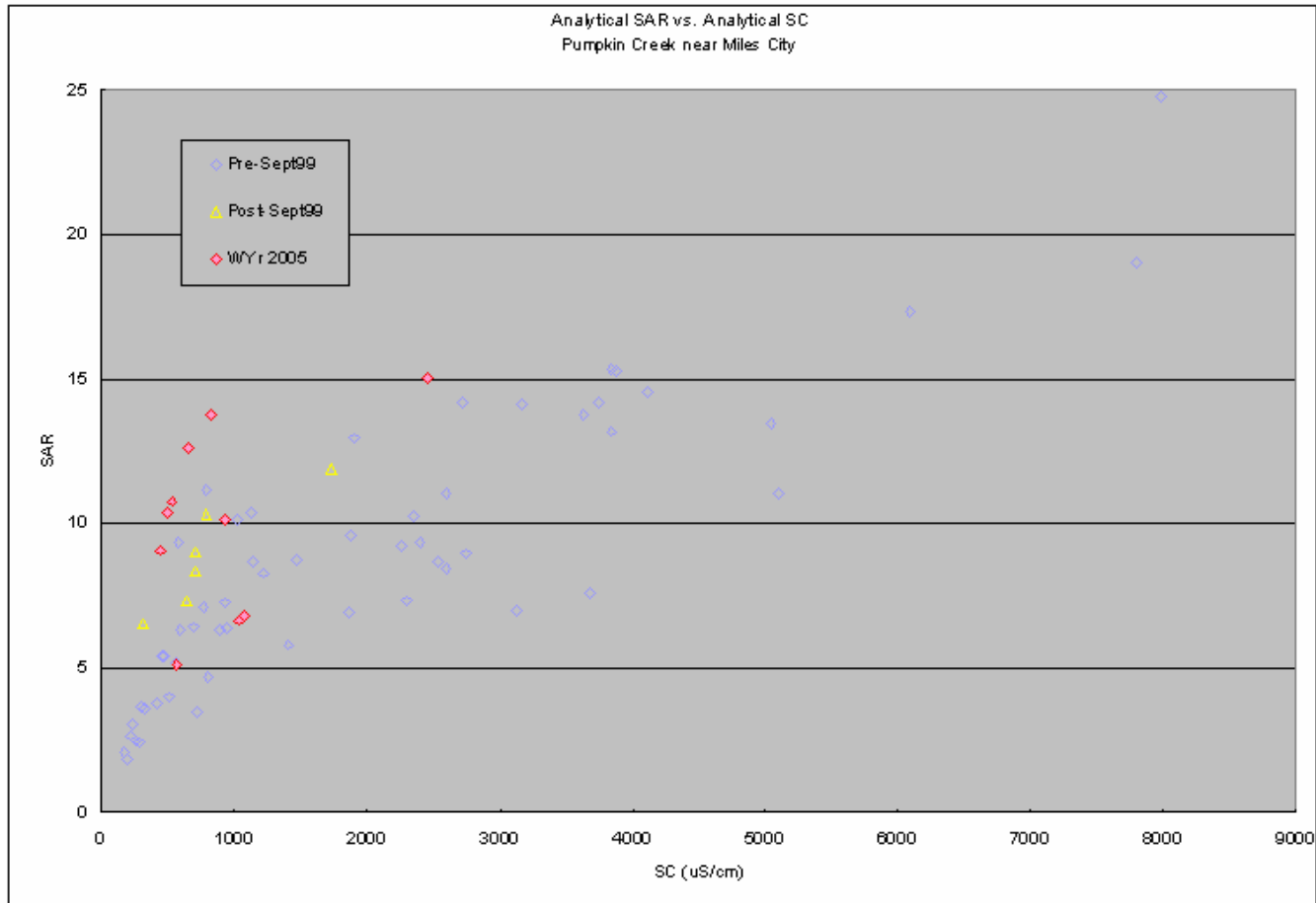


Figure 63 shows analytical SAR vs. analytical SC data for water year 2005 for Pumpkin Creek near Miles City. Historical SAR vs. EC data are also shown to place the data in context.