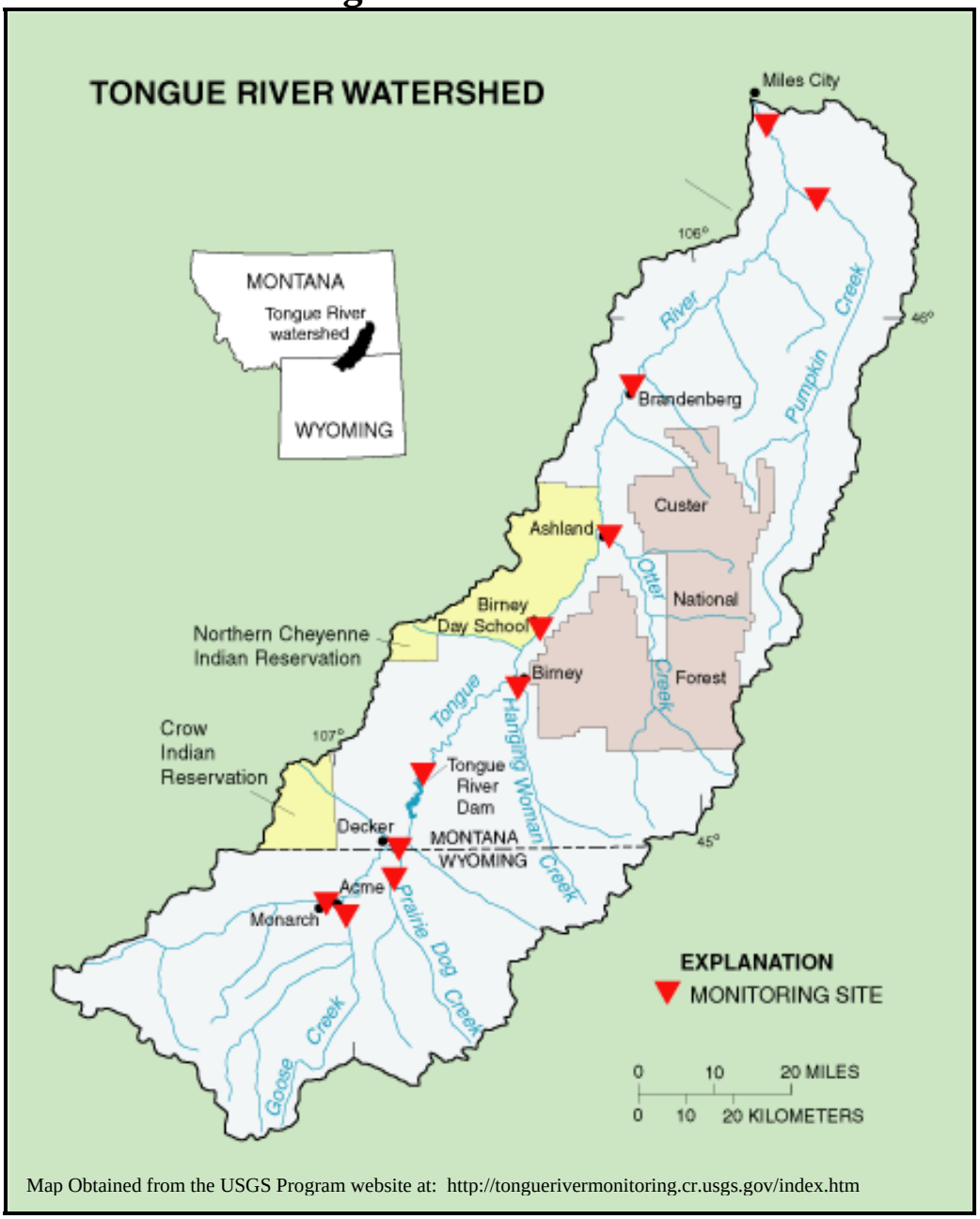
2004
Overview of Surface Water Monitoring Data for EC and SAR in the Tongue River Watershed



This cover map shows the Tongue River Watershed as it extends from Wyoming into Montana. Also shown are major streams, and major land patterns (USFS, Northern Cheyenne Reservation, and Crow Reservation). The locations of the 11 surface water monitoring sites (3 in Wyoming, 8 in Montana), which are the subject of this report, are also shown.

Prepared by: Andrew L. Bobst, Hydrologist, BLM-Miles City Field Office

March 11, 2005

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 waters contained within the coal seams have high sodium adsorption ratios (SAR (a complex ratio of Na to Ca+Mg) typically between 30 and 60), very little sulfate, and are moderately saline (EC on the order of 2,000 microseamens per centimeters (μS/cm)) (VanVoast, 2003).

One method which has been employed to manage this produced water is either treated or untreated discharge to surface waters under a National Pollutant Discharge Elimination System (NPDES) permit. In Montana discharge permitting is conducted by the Montana Department of Environmental Quality (MDEQ) under its Montana Pollutant Discharge Elimination System (MPDES) permit program. Currently, within the Tongue River watershed there are 2 existing CBNG MPDES permits, and one more permit has been applied for. One existing permit (Fidelity's MT0030457) is for up to 1,600 gallons per minute (gpm) (3.57 cubic feet per second (cfs))of untreated CBNG water and it has been in use since September 1999. This discharge water has an EC of approximately 1,987 μS/cm, and an SAR of approximately 53. The other existing permit (Powder River Gas' MT0030660) is for up to 1,122 gpm (2.5 cfs) of treated CBNG water, with SAR < 3 and EC < 1000; however no discharge occurred using this permit in 2004. The proposed permit (Fidelity's MT0030724) is anticipated to be for up to 1,700 gpm (3.79 cfs) of treated water with SAR < 3 and EC < 500 (BLM, 2005). In Wyoming discharge permitting is conducted by the Wyoming Department of Environmental Quality (WDEQ). Within Wyoming 2 permits were issued in 1999 which allow for direct discharge of untreated CBNG water to the Tongue River. These 1999 permits included 14 discharge points totaling approximately 0.3 cfs to Goose Creek, and 3 discharge points totaling approximately 0.2 cfs to the Tongue River (Hengel, pers. com., 2005). More recently the "Brickerhoaf" 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 approved which allows for the discharge of treated CBNG water with an SAR<3 and EC<1000 μS/cm (Parfitt, pers. com., 2005).

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 1 below. It should be noted that the MDEQ standards have been reviewed and approved by the 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 (also See Fig. 1).

Table 1: MDEQ and Northern Cheyenne Surface Water Standards for EC and SAR in the Tongue River Watershed (from MDEQ, 2003 and Greystone and ALL, 2003)

Irrigation Season[1]						
	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 Season[1]						
	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.

For fiscal year 2004 the United States Congress appropriated funding for the USGS to initiate a surface-water-quality monitoring program 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 Land Management (BLM), MDEQ, WDEQ, Wyoming State Engineer's Office (WSEO), Montana Department of Natural Resource Conservation (MDNRC), and the Northern Cheyenne Tribe joined together to fully fund this network. This network has also been funded, with minor modifications, for fiscal year 2005 (Nimick, pers. com., 2005).

In the spring of 2004 real time EC monitoring and SAR estimation in the Tongue River watershed began. SAR was estimated from the relationship between EC and SAR, and in some cases flow. This SAR estimation procedure is discussed in detail at http://tongueriver monitoring.cr.usgs.gov/projects/index.htm. The EC-SAR equations used to estimate the SAR data reviewed in this report were developed from pre-2004

data, and in some cases pre-1999 data. The USGS has indicated that preliminary review of the 2004 water-quality data indicates that revision of the EC-SAR equations is warranted at some sites (Nimick, pers. com., 2005).

Analytical surface water samples are also obtained under this program. Although analytical data was obtained for many parameters in this network, this report will focus on real time and analytical EC and SAR measurements. The 2004 data summarized in this report is USGS provisional data, which means they are preliminary, have not received final USGS approval, and may be revised during subsequent reviews. The final data will should be available in April, 2005 (Nimick, pers. com., 2005). For more information on this network see http://tonguerivermonitoring.cr.usgs.gov/index.htm.

It should be noted from the outset that flows within the Tongue River and its tributarys were extremely low during 2004, and the data collected must be viewed in this context (see Fig. 2).

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 Table 2 below. Complete tabulated data can be obtained at http://tonguerivermonitoring.cr.usgs.gov/index.htm. For comparison to the mean monthly EC and SAR standards the mean monthly values are typically calculated as the simple average of all the real time measurements recorded during each calendar month. In cases where no real time data were available for a station the monthly average of the analytical data was used.

Main Stem Sites:

Tongue River at Monarch, WY: Only flow data was collected in real time at this station. Recorded flow ranged from 23 to 244 cfs, with the mean being 96 cfs (see Fig. 3). Peak flows occurred from May to early July, with a marked decrease in flow after this time, presumably due to the end of snow melt. Historical flow data is not available for this station.

Analytical EC values at this site ranged from 263 to 535 µS/cm, with the mean being 406 µS/cm. Monthly mean EC values ranged from 290 to 517 µS/cm. Analytical SAR values at this site ranged from 0.25 to 0.53 with the mean being 0.36. Monthly mean SAR values ranged from 0.26 to 0.52. (see Fig. 4).

The recorded EC and SAR values were in line with, or slightly less than, historical values during comparable flows (see Figs. 5 and 6). The recorded EC and SAR values did not exceed the MDEQ's NTE or mean monthly standards (see Fig. 4).

Table 2: 2004 Summary Statistics from EC, SAR and Flow Monitoring in the Tongue River Watershed

		Flow	Realtime EC (µS/cm)			Analytical EC	Mean Monthly EC	Estimated	Analytical	Mean Monthly
		(cfs)	Daily Max	Daily Min	Daily Mean	(µS/cm)	(µS/cm)	SAR	SAR	SAR
Main Stem Sites										
Tongue River at Monarch	min	23	---	---	---	263	290	---	0.25	0.26
	max	244	---	---	---	535	517	---	0.53	0.52
	mean	96	---	---	---	406	409	---	0.36	0.36
Tongue River at State Line	min	47	402	384	393	400	463	0.49	0.60	0.57
	max	313	1310	883	971	876	795	1.12	1.35	0.93
	mean	147	702	658	679	639	665	0.81	0.83	0.79
Tongue River at Dam	min	73	602	483	597	593	608	0.73	0.81	0.75
	max	300	747	737	743	766	722	0.90	1.18	0.88
	mean	161	668	653	662	667	662	0.81	0.92	0.81
Tongue River at Birney Day School	min	80	569	548	561	581	583	0.77	0.87	0.80
	max	290	710	705	709	807	694	0.97	1.30	0.95
	mean	157	641	624	632	679	640	0.87	1.04	0.88
Tongue River below Brandenburg Bridge	min	97	644	602	631	641	665	1.06	1.06	1.12
	max	280	833	808	816	910	799	1.40	1.52	1.37
	mean	162	729	713	721	762	720	1.22	1.27	1.22
Tongue River at Miles City	min	7.6	743	508	651	585	930	1.28	1.47	2.07
	max	500	1340	1300	1320	1290	1108	3.19	3.56	2.58
	mean	83	1046	992	1019	983	1009	2.33	2.27	2.30
Tributary Sites										
Goose Creek near Acme	min	7.5	---	---	---	336	531	---	0.44	0.56
	max	176	---	---	---	772	772	---	0.77	0.77
	mean	57	---	---	---	636	655	---	0.62	0.63
Prairie Dog Creek near Acme	min	1.0	---	---	---	944	944	---	0.97	0.97
	max	43	---	---	---	2510	2090	---	2.71	2.27
	mean	16	---	---	---	1555	1472	---	1.65	1.51
Hanging Woman Creek near Birney	min	0	1410	1270	1330	1660	1789	3.46	4.42	3.98
	max	19	3070	2710	2760	3410	2435	4.66	6.00	4.62
	mean	---	2178	1995	2095	2318	2125	4.10	4.99	4.21
Otter Creek at Ashland	min	0	2130	2100	2120	1960	2310	5.19	4.79	5.44
	max	1.8	3010	2970	3000	2950	2810	6.33	6.75	6.09
	mean	---	2572	2523	2548	2606	2594	5.75	5.98	5.81
Pumpkin Creek near Miles City	min	0	---	---	498	311	717	---	6.55	6.55
	max	88	---	---	1230	1730	1113	---	11.88	11.88
	mean	---	---	---	801	774	853	---	8.90	8.80

Tongue River at State Line, near Decker, MT: Flow and EC were measured in real time at this site. SAR was estimated in real time from this data. Wyoming CBNG discharges, and Fidelity's CBNG discharges in Montana are occurring upstream from this station.

During 2004 recorded flow ranged from 47 to 313 cfs, with the mean being 147 cfs. Peak flows occurred from May to early July, with a marked decrease in flow after this time, presumably due to the end of snow melt. The historical mean flow record for this site (based on 44 years of data) indicates that flows at this station in an "average" year ranges from 158 to 2,004 cfs with the mean being 443 cfs. Low flows were only 30% of that seen in an average year while peak flows were only 16% of that seen in an average year. Thus flows during 2004 were much lower than the historical record, with a substantially reduced spring peak (see Fig. 7). This reduction vs. the historical record is believed to be mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, municipal, stock, or industrial use also could be affecting streamflow.

Daily mean EC data collected at this station ranged from 393 to 971 μS/cm, with a mean value of 679 μS/cm. Mean monthly EC values ranged from 463 to 795 μS/cm. Maximum EC values were as high as 1,310 μS/cm. Daily estimated SAR at this station ranged from 0.49 to 1.12, with a mean value of 0.81. Mean monthly SAR values ranged from 0.57 to 0.93 (see Fig. 8).

Analytical EC values at this site ranged from 400 to 876 μS/cm, with the mean being 639 μS/cm. Analytical SAR values at this site ranged from 0.60 to 1.35 with the mean being 0.83 (see Fig. 8).

The recorded EC values were in line with, or slightly less than, historical values during comparable flows (see Fig. 9). The recorded SAR values were in line with, or slightly more than, historical values during comparable flows (see Fig. 10). The recorded EC and SAR values did not exceed the MDEQ's NTE or mean monthly standards (see Fig. 8).

Tongue River at Tongue River Dam, near Decker MT: Flow and EC were measured in real time at this site. SAR was estimated in real time from this data. Wyoming CBNG discharges, and Fidelity's CBNG discharges in Montana are occurring upstream from this station.

During 2004 recorded flow ranged from 73 to 300 cfs, with the mean being 161 cfs. Peak flows occurred from May to mid-August, with a less marked decrease in flow in the late summer due to the presence of the Tongue River Reservoir. The historical mean flow record for this site (based on 65 years of data) indicates that flows at this station in an "average" year ranges from 168 to 1,545 cfs with the mean being 433 cfs. Low flows were 43% of that seen in an average year while peak flows were only 19% of that seen in an average year. Thus flows during 2004 were much lower than the historical record, with a substantially reduced spring peak (see Fig. 11). This reduction vs. the historical record is believed to be mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, municipal, stock, or industrial use also could be affecting streamflow.

Daily mean EC data collected at this station ranged from 597 to 743 µS/cm, with a mean value of 662 µS/cm. Mean monthly EC values ranged from 608 to 722 µS/cm. Maximum EC values were as high as 747 µS/cm. Daily estimated SAR at this station ranged from 0.73 to 0.90, with a mean value of 0.81. Mean monthly SAR values ranged from 0.75 to 0.88 (see Fig. 12).

Analytical EC values at this site ranged from 593 to 766 µS/cm, with the mean being 667 µS/cm. Analytical SAR values at this site ranged from 0.81 to 1.18 with the mean being 0.92 (see Fig. 12).

The recorded EC values were in line with, or slightly less than, historical values during comparable flows (see Fig. 13). The recorded SAR values were in line with, or slightly more than, historical values during comparable flows (see Fig. 14). The recorded EC and SAR values did not exceed the MDEQ's NTE or mean monthly standards (see Fig. 12).

Tongue River at Birney Day School Bridge, near Birney, MT: Flow and EC were measured in real time at this site. SAR was estimated in real time from this data. Wyoming CBNG discharges, and Fidelity's CBNG discharges in Montana are occurring upstream from this station.

During 2004 recorded flow ranged from 80 to 290 cfs, with the mean being 157 cfs. Peak flows occurred from May to mid-August. The historical mean flow record for this site (based on 24 years of data) indicates that flows at this station in an "average" year ranges from 159 to 1,264 cfs with the mean being 378 cfs. Low flows were 50% of that seen in an average year while peak flows were only 23% of that seen in an average year. Thus flows during 2004 were much lower than the historical record, with a substantially reduced spring peak (see Fig. 15). This reduction vs. the historical record is believed to be mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, municipal, stock, or industrial use also could be affecting streamflow.

Daily mean EC data collected at this station ranged from 561 to 709 µS/cm, with a mean value of 632 µS/cm. Mean monthly EC values ranged from 583 to 694 µS/cm. Maximum EC values were as high as 710 µS/cm. Daily estimated SAR at this station ranged from 0.77 to 0.97, with a mean value of 0.87. Mean monthly SAR values ranged from 0.80 to 0.95 (see Fig. 16).

Analytical EC values at this site ranged from 581 to 807 µS/cm, with the mean being 679 µS/cm. Analytical SAR values at this site ranged from 0.87 to 1.30 with the mean being 1.04 (see Fig. 16).

The recorded EC values were in line with, or slightly less than, historical values during comparable flows (see Fig. 17). The recorded SAR values were in line with historical values during comparable flows (see Fig. 18). The recorded EC and SAR values did not exceed the either the MDEQ's or the Northern Cheyenne NTE or mean monthly standards. (see Fig. 16).

Tongue River below Brandenburg Bridge, near Ashland, MT: Flow and EC were measured in real time at this site. SAR was estimated in real time from this data. Wyoming CBNG discharges, and Fidelity's CBNG discharges in Montana are occurring upstream from this station.

During 2004 recorded flow ranged from 97 to 280 cfs, with the mean being 162 cfs. Peak flows occurred from May to mid-August. The historical mean flow record for this site (based on 15 years of data) indicates that flows at this station in an "average" year ranges from 163 to 1,502 cfs with the mean being 440 cfs. Low flows were 60% of that seen in an average year while peak flows were only 19% of that seen in an average year. Thus flows during 2004 were much lower than the historical record, with a substantially reduced spring peak (see Fig. 19). This reduction vs. the historical record is believed to be mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, municipal, stock, or industrial use also could be affecting streamflow.

Daily mean EC data collected at this station ranged from 631 to 816 μS/cm, with a mean value of 721 μS/cm. Mean monthly EC values ranged from 665 to 799 μS/cm. Maximum EC values were as high as 833 μS/cm. Daily estimated SAR at this station ranged from 1.06 to 1.40, with a mean value of 1.22. Mean monthly SAR values ranged from 1.12 to 1.37 (see Fig. 20).

Analytical EC values at this site ranged from 641 to 910 μS/cm, with the mean being 762 μS/cm. Analytical SAR values at this site ranged from 1.06 to 1.52 with the mean being 1.27 (see Fig. 20).

The recorded EC values were in line with, or slightly less than, historical values during comparable flows (see Fig. 21). The recorded SAR values were in line with, or slightly less than historical values during comparable flows (see Fig. 22). The recorded EC and SAR values did not exceed the either the MDEQ's or the Northern Cheyenne NTE or mean monthly standards. (see Fig. 20).

Tongue River at Miles City, MT: Flow and EC were measured in real time at this site. SAR was estimated in real time from this data. Wyoming CBNG discharges, and Fidelity's CBNG discharges in Montana are occurring upstream from this station.

During 2004 recorded flow ranged from 7.6 to 500 cfs, with the mean being 83 cfs. Peak flows occurred from March to April. The historical mean flow record for this site (based on 63 years of data) indicates that flows at this station in an "average" year ranges from 154 to 1,516 cfs with the mean being 410 cfs. Thus flows during 2004 were much lower than the historical record. Low flows were only 5% of that seen in an average year while peak flows were only 33% of that seen in an average year (see Fig. 23). Much of this decrease in low flows is believed to be due to diversion for irrigation, since this level of reduction during low flows is not seen at the upstream stations. In particular the diversion dam for the TY ditch (12 mile diversion dam, just above Pumpkin Creek) is

known to divert a significant portion of the flow during low flows. The portion of the Tongue River below this diversion dam 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 sources being hydromodification. Once this water is diverted 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 very low flows, the water flowing through this lower portion of the Tongue River, and monitored at the Miles City station is likely to be more representative of irrigation return flows, and tributaries of the Tongue River (particularly Pumpkin Creek) than it is of the Tongue itself, since most of the water in the Tongue is diverted for irrigation. The lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region is also believed to contribute to these low flows. Other factors such as new or changed irrigation, municipal, stock, or industrial use also could be affecting streamflow.

Daily mean EC data collected at this station ranged from 651 to 1,320 μS/cm, with a mean value of 1019 μS/cm. Mean monthly EC values ranged from 930 to 1108 μS/cm. Maximum EC values were as high as 1,340 μS/cm. Daily estimated SAR at this station ranged from 1.28 to 3.19, with a mean value of 2.33. Mean monthly SAR values ranged from 2.07 to 2.58 (see Fig. 24).

Analytical EC values at this site ranged from 585 to 1290 μS/cm, with the mean being 983 μS/cm. Analytical SAR values at this site ranged from 1.47 to 3.56 with the mean being 2.27 (see Fig. 24).

The recorded EC values were in line with historical values during comparable flows (see Fig. 25). The recorded SAR values were in line with, or slightly more than historical values during comparable flows (see Fig. 26).

The EC and SAR values did not exceed the MDEQ's NTE standards. The mean monthly SAR values did not exceed the MDEQ's mean monthly standards. Mean monthly EC values did not exceed the non-irrigation season standards; however the irrigation season standard (1,000 μS/cm) was exceeded during July, August and September (1058, 1071, and 1108 μS/cm respectively). As discussed above, the high EC and SAR values observed are believed to be mainly due to the diversion of water from the Tongue River (i.e. the removal of the higher quality water from this down stream stretch, and a resulting lack of dilution of irrigation return flows and lower quality tributaries).

Tributary Sites:

Goose Creek near Acme, WY: Only flow data was collected in real time at this station. No direct discharges are occurring upstream from this station.

During 2004 recorded flow ranged from 7.5 to 176 cfs, with the mean being 57 cfs. The historical mean flow record for this site (based on 20 years of data) indicates that flows at this station in an "average" year ranges from 49 to 725 cfs with the mean being 157 cfs. Low flows were 15% of that seen in an average year while peak flows were 24% of that seen in an average year (see Fig. 27). This reduction vs. the historical record is believed

to be mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, municipal, stock, or industrial use also could be affecting streamflow.

Analytical EC values at this site ranged from 336 to 772 µS/cm, with the mean being 636 µS/cm. Monthly mean EC values ranged from 531 to 772 µS/cm. Analytical SAR values at this site ranged from 0.44 to 0.77 with the mean being 0.62. Monthly mean SAR values ranged from 0.56 to 0.77. (see Fig. 28).

The recorded EC values were in line with, or slightly less than, historical values during comparable flows (see Fig. 29). Historical SAR data was not available for comparison (see Fig. 30).

All but one of the recorded EC values were in excess of the tributary EC standard of 500 µS/cm. The recorded SAR values were well below the MDEQ's SAR standards (see Fig. 28). These water quality values result from a combination of natural conditions, and the current level of agricultural, forestry, or other land uses within the watershed.

Prairie Dog Creek near Acme, WY: Only flow data was collected in real time at this station. The Wyoming CBNG discharges in the Prairie Dog Creek watershed are occurring upstream from this station.

Recorded flow ranged from 1 to 43 cfs, with the mean being 16 cfs. The historical mean flow record for this site (based on 13 years of data) indicates that flows at this station in an "average" year ranges from 13 to 299 cfs with the mean being 40 cfs. Low flows were 8% of that seen in an average year while peak flows were 14% of that seen in an average year (see Fig. 31). This reduction vs. the historical record is believed to be mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, stock, or industrial use also could be affecting streamflow.

Analytical EC values at this site ranged from 944 to 2,510 µS/cm, with the mean being 1,555 µS/cm. Monthly mean EC values ranged from 944 to 2090 µS/cm. Analytical SAR values at this site ranged from 0.97 to 2.71 with the mean being 1.65. Monthly mean SAR values ranged from 0.97 to 2.27. (see Fig. 32).

The recorded EC and SAR values were in line with historical values during comparable flows (see Figs. 33 and 34).

All of the recorded EC values were in excess of the tributary EC standard of 500 µS/cm. The recorded SAR values were all below the MDEQ's SAR standards (see Fig. 32). These water quality values result from a combination of natural conditions, the current level of agricultural, forestry, or other land uses within the watershed, and the CBNG activity in this watershed.

Hanging Woman Creek near Birney, MT: Flow and EC were measured in real time at this site. SAR was estimated in real time from this data. Due to this site being dry on many days the data is not continuous. No CBNG discharge is occurring upstream of this station. Total containment impoundments are located within this watershed in Wyoming.

During 2004 recorded flow ranged from 0 to 19 cfs. The historical mean flow record for this site (based on 22 years of data) indicates that flows at this station in an "average" year ranges from 0.4 to 84 cfs with the mean being 3.5 cfs. Peak flows were 23% of that seen in an average year. Thus flows during 2004 were much lower than the historical record (see Fig. 35). This reduction vs. the historical record is believed to be mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, stock, or industrial use also could be affecting streamflow.

Daily mean EC data collected at this station ranged from 1,330 to 2,760 μS/cm, with a mean value of 2,095 μS/cm. Mean monthly EC values ranged from 1,789 to 2,435 μS/cm. Maximum EC values were as high as 3,070 μS/cm. Daily estimated SAR at this station ranged from 3.46 to 4.66, with a mean value of 4.10. Monthly mean SAR values ranged from 3.98 to 4.62 (see Fig. 36).

Analytical EC values at this site ranged from 1,660 to 3,410 μS/cm, with the mean being 2,318 μS/cm. Analytical SAR values at this site ranged from 4.42 to 6.00 with the mean being 4.99 (see Fig. 36).

The recorded EC and SAR values were in line with, or slightly less than, historical values during comparable flows (see Figs. 37 and 38).

The EC values were all far in excess of the tributary EC standard of 500 μS/cm. The estimated SAR values were greater than the MDEQ's irrigation season NTE standard of SAR < 4.5 on 11 days. The mean monthly SAR value for this site in June (4.62) was also in excess of the mean monthly tributary irrigation season SAR standard (4.5). These water quality values result from a combination of natural conditions, the current level of agricultural, forestry, or other land uses within the watershed, and the CBNG activity in this watershed.

Otter Creek at Ashland, MT: Flow and EC were measured in real time at this site. SAR was estimated in real time from this data. Due to this site being dry on many days the data is not continuous. Only a short flow record is available from this site, while the EC and SAR records are somewhat greater. No CBNG discharge is occurring upstream of this station.

During 2004 recorded flows ranged from 0 to 1.8 cfs. The historical mean flow record for this site (based on 22 years of data) indicates that flows at this station in an "average" year ranges from 0.6 to 35.3 cfs with the mean being 4.7 cfs. Peak flows were only 5% of that seen in an average year. Thus flows during 2004 were much lower than the historical record (see Fig. 39). This reduction vs. the historical record is believed to be

mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, stock, or industrial use also could be affecting streamflow.

Daily mean EC data collected at this station ranged from 2,120 to 3,000 μS/cm, with a mean value of 2,548 μS/cm. Mean monthly EC values ranged from 2,310 to 2810 μS/cm. Maximum EC values were as high as 3,010 μS/cm. Daily estimated SAR at this station ranged from 5.19 to 6.33, with a mean value of 5.75. Mean monthly SAR values ranged from 5.44 to 6.09 (see Fig. 40).

Analytical EC values at this site ranged from 1,960 to 2,950 μS/cm, with the mean being 2,606 μS/cm. Analytical SAR values at this site ranged from 4.79 to 6.75 with the mean being 5.98 (see Fig. 36).

The recorded EC and SAR values were in line with historical values at comparable flows (see Fig. 41 and 42).

The EC values were all far in excess of the tributary EC standard of 500 μS/cm. The estimated SAR values were all in excess of the MDEQ's irrigation season NTE standard (4.5). The mean monthly SAR values for this site were also all in excess of the mean monthly tributary irrigation season SAR standard (4.5). These water quality values result from a combination of natural conditions, and the current level of agricultural, forestry, or other land uses within the watershed.

Pumpkin Creek near Miles City, MT: Flow and EC were measured in real time at this site. The only historical water-quality data collected at this site were from 1975-85. Because land use and other factors that can affect water quality may have changed in the upstream watershed since 1985, any relation between EC and SAR developed using the 1975-85 data may not be appropriate for current conditions. Therefore, the USGS did not develop a relation for this site at this time. The USGS plans to examine the relationship between EC and SAR after water-quality data have been collected for 12 months (Nimick, pers. com. 2005). Due to this site being dry on many days the data is not continuous. No CBNG discharge is occurring upstream of this station.

During 2004 recorded flows ranged from 0 to 88 cfs. The historical mean flow record for this site (based on 14 years of data) indicates that flows at this station in an "average" year ranges from 0.01 to 156 cfs with the mean being 14.2 cfs. Peak flows were only 56% of that seen in an average year. Thus flows during 2004 were lower than the historical record (see Fig. 43). This reduction vs. the historical record is believed to be mainly attributable to the lack of snow pack during the winter of 2003-2004, and the continued drought throughout this region; however other factors such as new or changed irrigation, stock, or industrial use also could be affecting streamflow.

Daily mean EC data collected at this station ranged from 498 to 1,230 μS/cm, with a mean value of 801 μS/cm. Mean monthly EC values ranged from 717 to 1,113 μS/cm. SAR was not estimated in real time at this station (see Fig. 44).

Analytical EC values at this site ranged from 311 to 1,730 μS/cm, with the mean being 774 μS/cm. Analytical SAR values at this site ranged from 6.55 to 11.88 with the mean being 8.90. Mean monthly SAR values ranged from 6.55 to 11.88 (see Fig. 44).

The recorded EC values were in line with, or slightly less than, historical values during comparable flows (see Fig. 45). The recorded SAR values were in line with, or slightly greater than, historical values during comparable flows (see Fig. 46).

Most of the EC values (all but one) were greater than the MDEQ's tributary NTE irrigation standard of EC < 500 μS/cm. All of the SAR values were greater than the MDEQ's irrigation season tributary NTE standard of SAR < 4.5. These water quality values result from a combination of natural conditions, and the current level of agricultural, forestry, or other land uses within the watershed.

Conclusions:

During 2004 flows within the Tongue River watershed were substantially less than historical values. At the main stem stations peak flows ranged from 16% to 33% of "average" values. As EC and SAR are both closely correlated with flow, EC and SAR values were also elevated; however overall values were in line with that expected based upon historical relationships between EC and SAR vs. Flow. These low flows are believed to be mainly attributable to the small 2003-04 snow pack and continuing drought conditions; however other factors such as new or changed irrigation, municipal, stock, or industrial use could also be affecting streamflow.

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. At Miles City the EC NTE standards and the SAR standards were not exceeded. Mean monthly EC values at Miles City were in excess of the mean monthly irrigation season EC standard during July, August and September. These high values are believed to be mainly attributable to the diversion of the majority high quality water for irrigation during low flows, which results in less dilution of irrigation return flows and lower quality tributaries.

The tributaries for which data were collected 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 exceeded for a portion of the monitoring period at the Hanging Woman station, and were always exceeded at the Otter Creek and Pumpkin Creek stations.

References:

BLM, 2005, Tongue River - Coal Creek Environmental Assessment for Fidelity Exploration & Production Company, 150 pgs.

Greystone and ALL, 2003, Surface Water Quality Analysis Technical Report prepared in support of the MT and WY FEISs.

Hengle, Dan, 2005, WY-DEQ, Personal Communication, 2/16/05.

MDEQ, 2003, ARM Title 17, Chapter 30, Section 17.30.670.

Nimick, David, 2005, MT-USGS, Personal Communication, 2/14/05.

Parfitt, Todd, 2005, WY-DEQ, Personal Communication, 3/10/05.

USGS, 2005, Tongue River Surface-Water-Quality Monitoring Network, http://tongueriverm onitoring.cr.usgs.gov/index.htm.

VanVoast, W.A., 2003, Geochemical signature of formation waters associated with coalbed methane, AAPG Bulletin, v. 87, no. 4 (April 2003), pp. 667–676.

Reviewers:

Mike Philbin
Hydrology, Wetland, Riparian, and Air Program Lead — BLM, Billings, MT

David Nimick
Tongue River Project Chief — USGS, Helena MT

John Kilpatrick
Assistant District Chief — USGS, Helena, MT

Figures

Figure 1

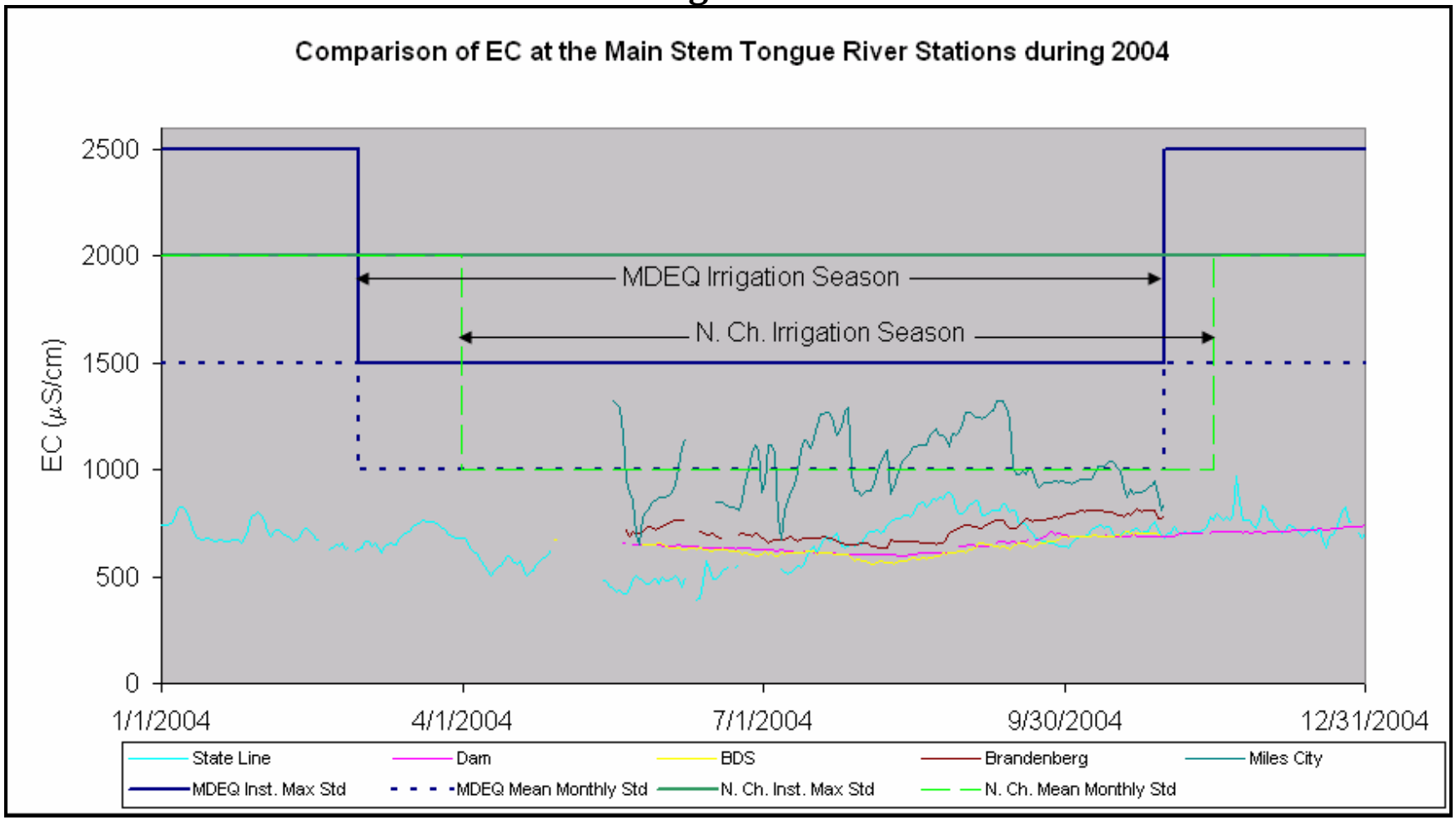


Figure 1 shows EC values in a time series plot for2004 for the main-stem Tongue sites (State Line, Below Dam, at Birney Day School, below Brandenburg Bridge, and at Miles City) compared to the MDEQ and Northern Cheyenne EC seasonal standards. The daily mean EC values at Miles City were greater than the mean monthly standards for periods during the irrigation season. All other stations are under all standards for the entire year.

Figure 2

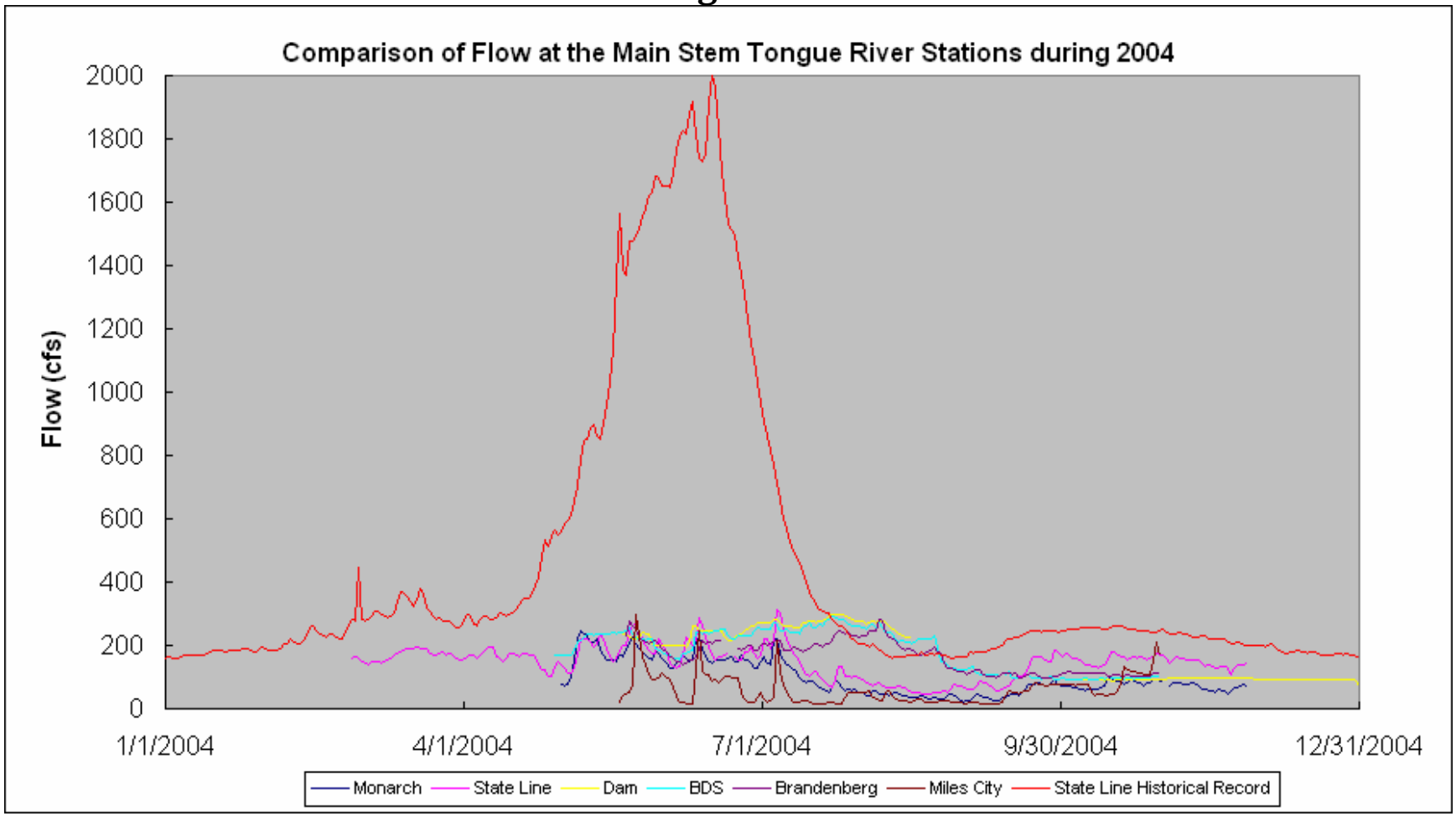


Figure 2 shows flows in a time series plot for2004 for the main-stem Tongue sites (Monarch, State Line, Below Dam, at Birney Day School, below Brandenburg Bridge, and at Miles City) compared to historical average values at the State Line Station. Flow values during 2004 showed much less of an increase in the spring, and much less flow over all, than is historically the case.

Figure 3: Tongue River at Monarch, WY

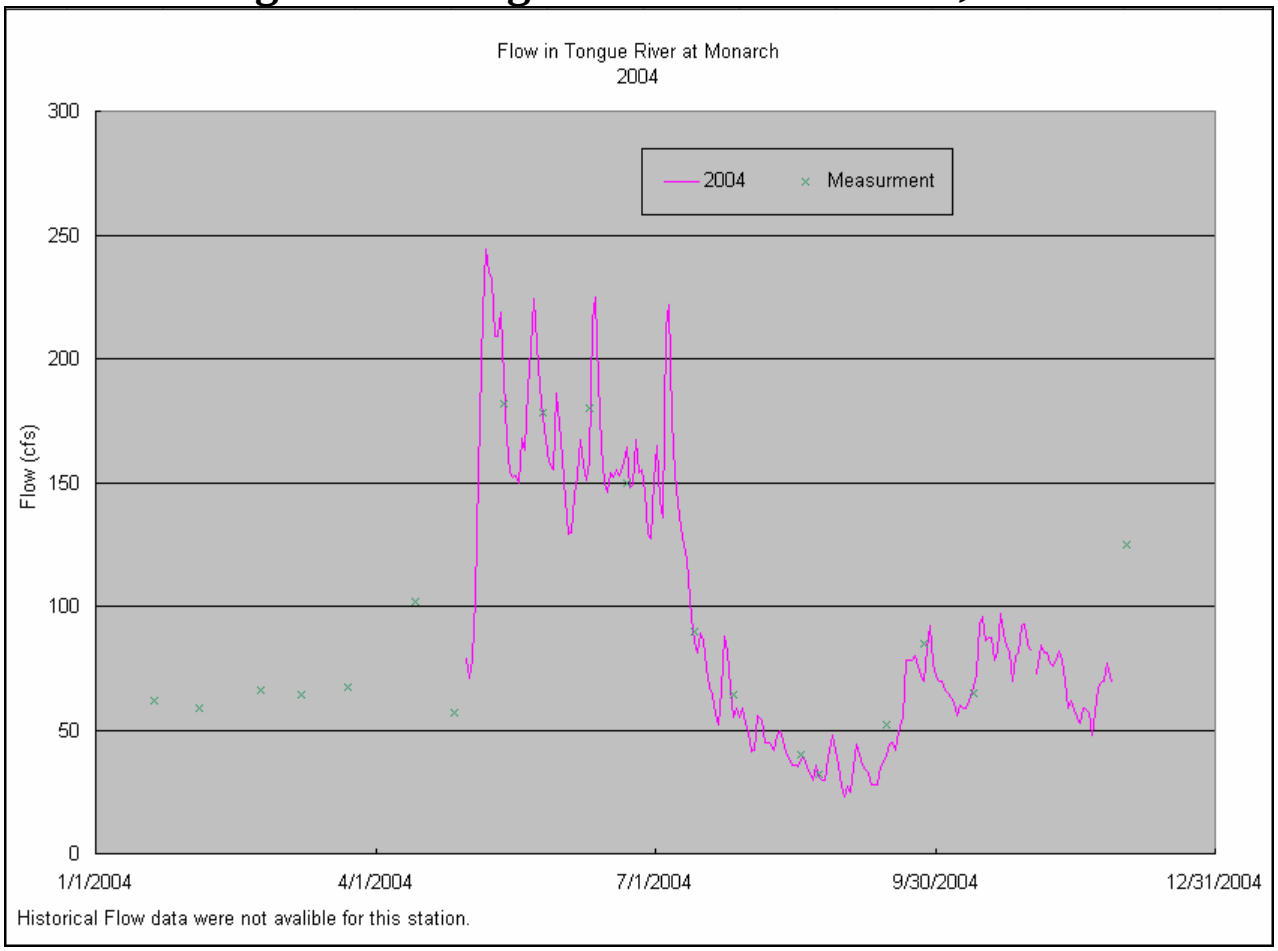
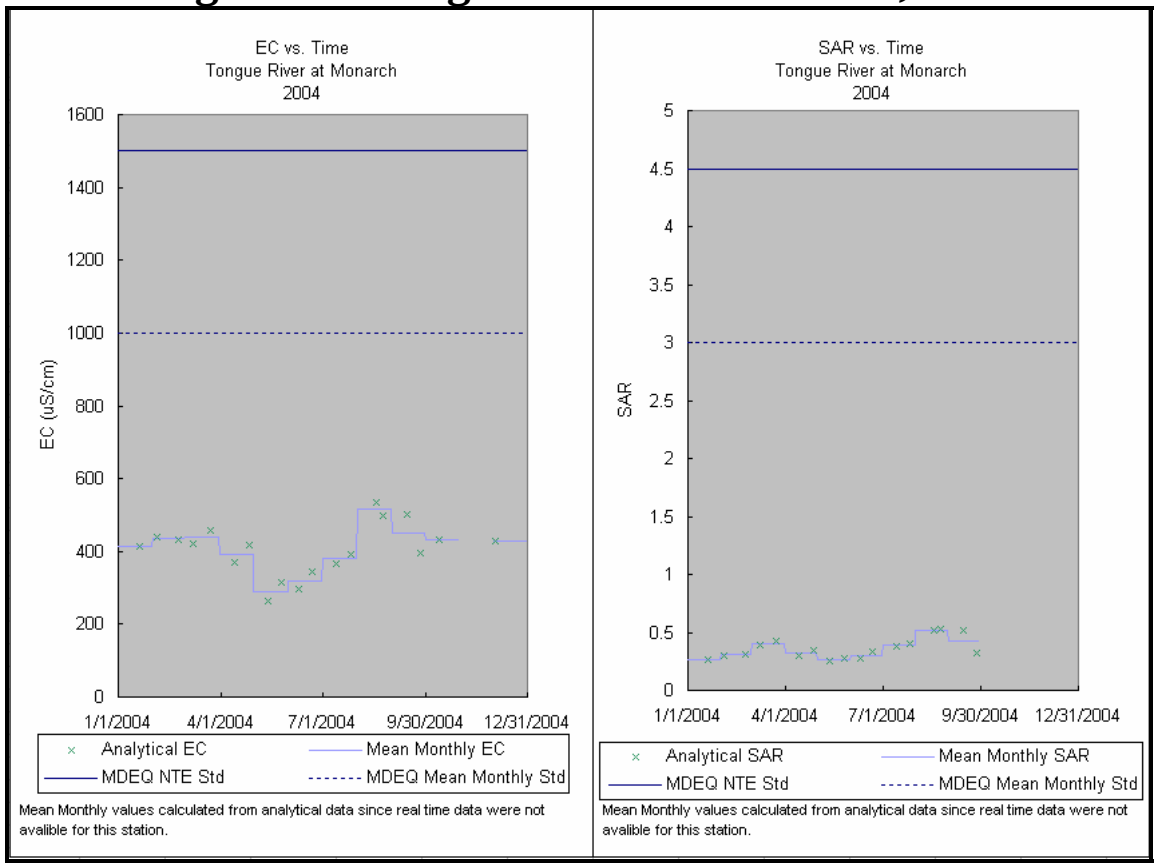


Figure 3 shows real time flow values in a time series plot for2004 for the Tongue River at Monarch, and field measurements of flow. Flow values during 2004 had a maximum of 244 cfs in May, and a minimum of 23 cfs in September. Historical mean flow values were not available for this station since daily streamflow has only been maintained since 5/1/04.

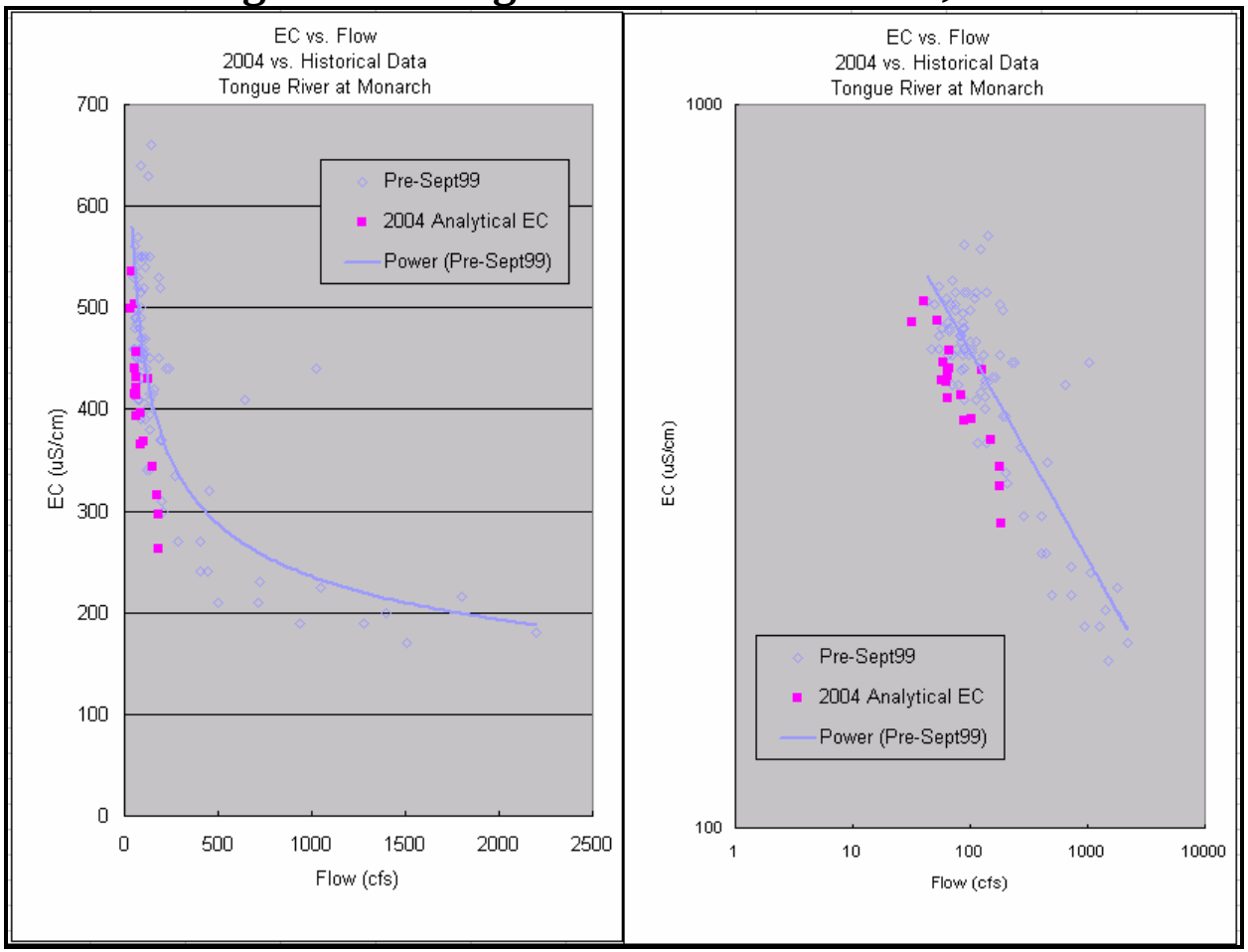
Figure 4: Tongue River at Monarch, WY



A **B**

Figure 4 shows analytical EC(A) and SAR (B) values in time series plots for2004 for the Tongue River at Monarch. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Analytical EC values during 2004 had a maximum of 535 uS/cm in August, and a minimum of 263 uS/cm in May. Analytical SAR values had a maximum of 0.53 in August, and a minimum of 0.25 in May. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. Recorded values were below these standards for the entire year. Realtime EC data were not collected for this station, and realtime SAR values were not estimated.

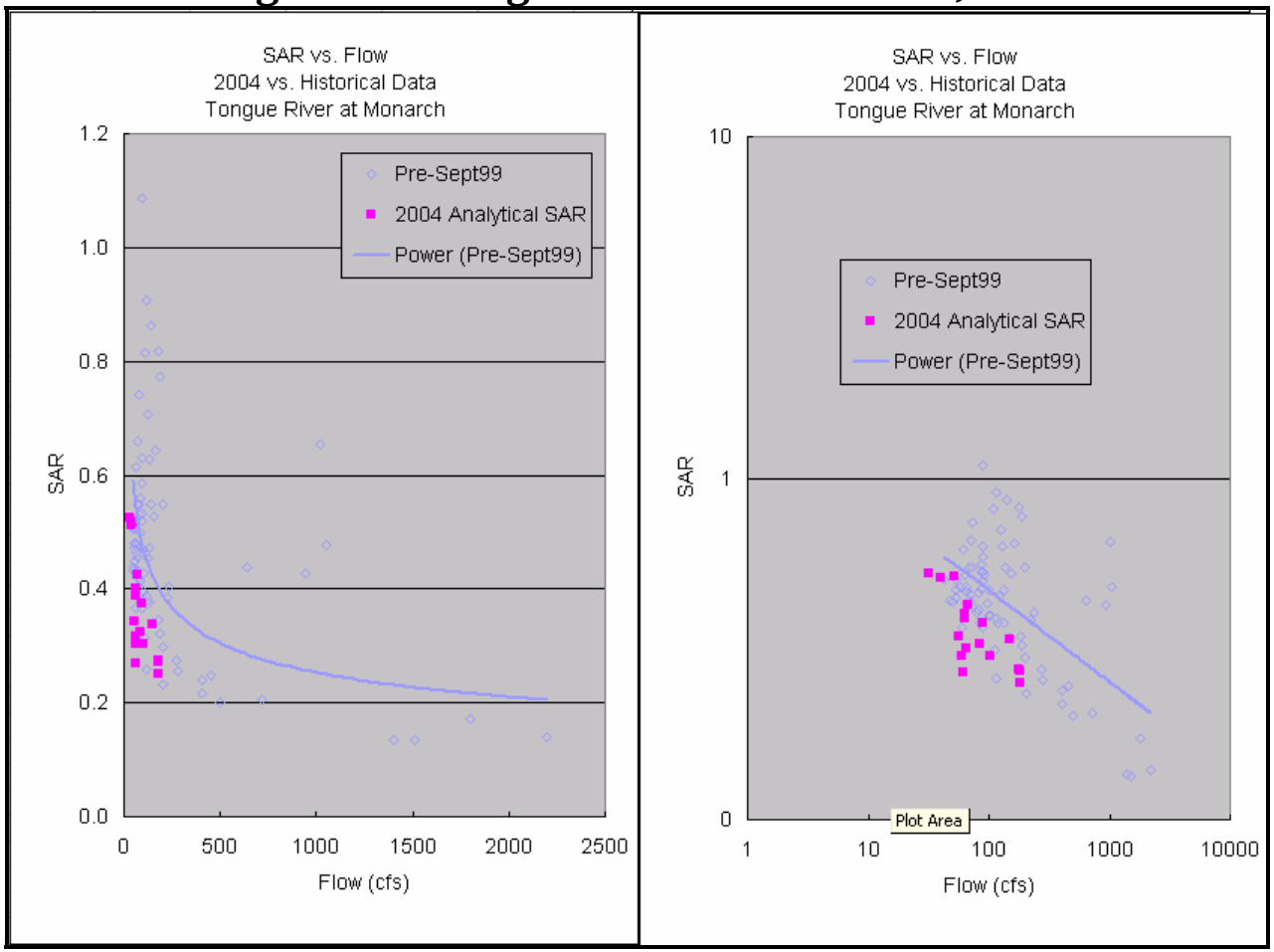
Figure 5: Tongue River at Monarch, WY



A **B**

Figure 5 shows analytical EC values charted vs. Flow for 2004 for the Tongue River at Monarch. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were in line with, or slightly less than, historical values during comparable flows.

Figure 6: Tongue River at Monarch, WY



A **B**

Figure 5 shows analytical SAR values charted vs. Flow for 2004 for the Tongue River at Monarch. These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values were in line with, or slightly less than, historical values during comparable flows.

Figure 7: Tongue River at State Line, near Decker, MT

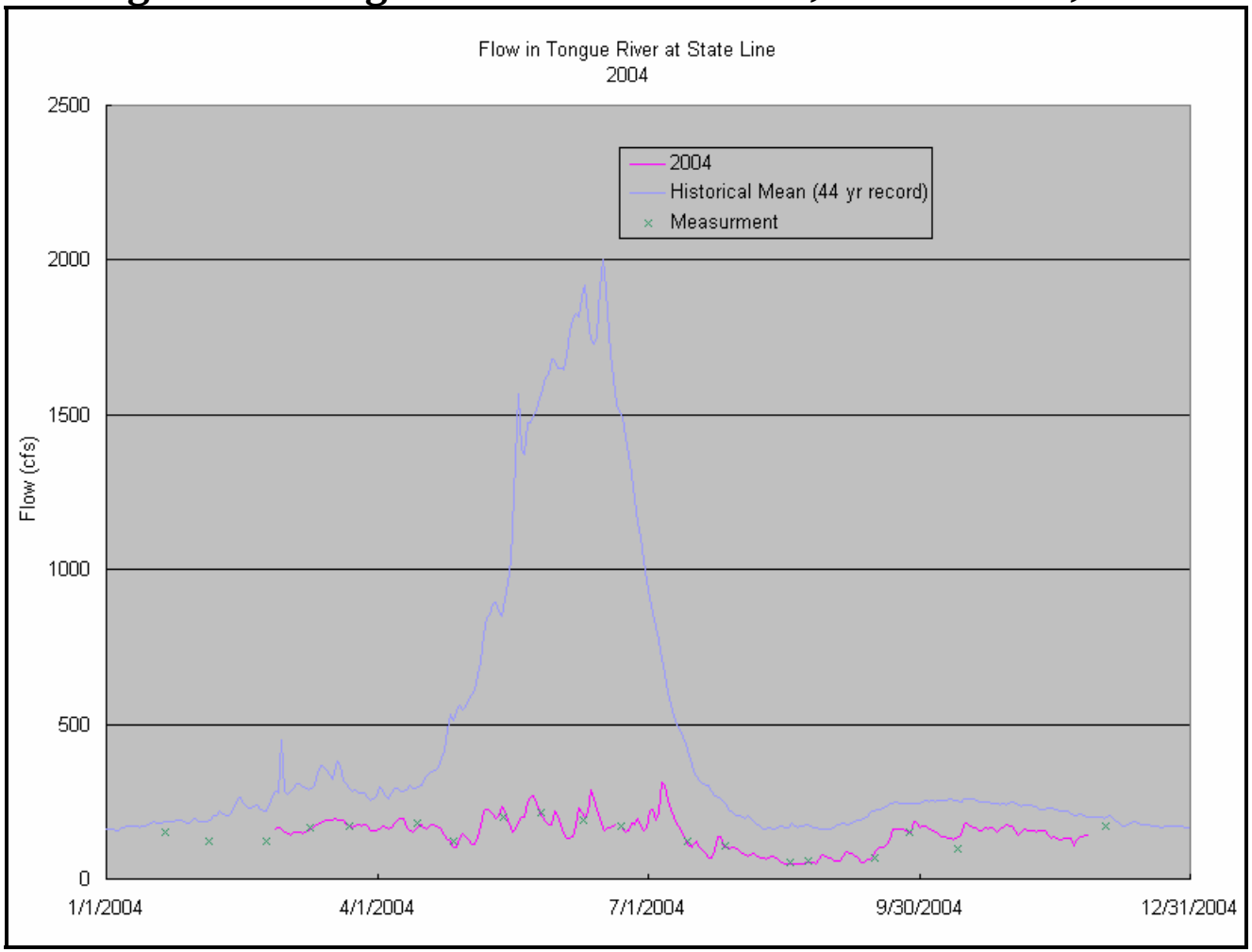
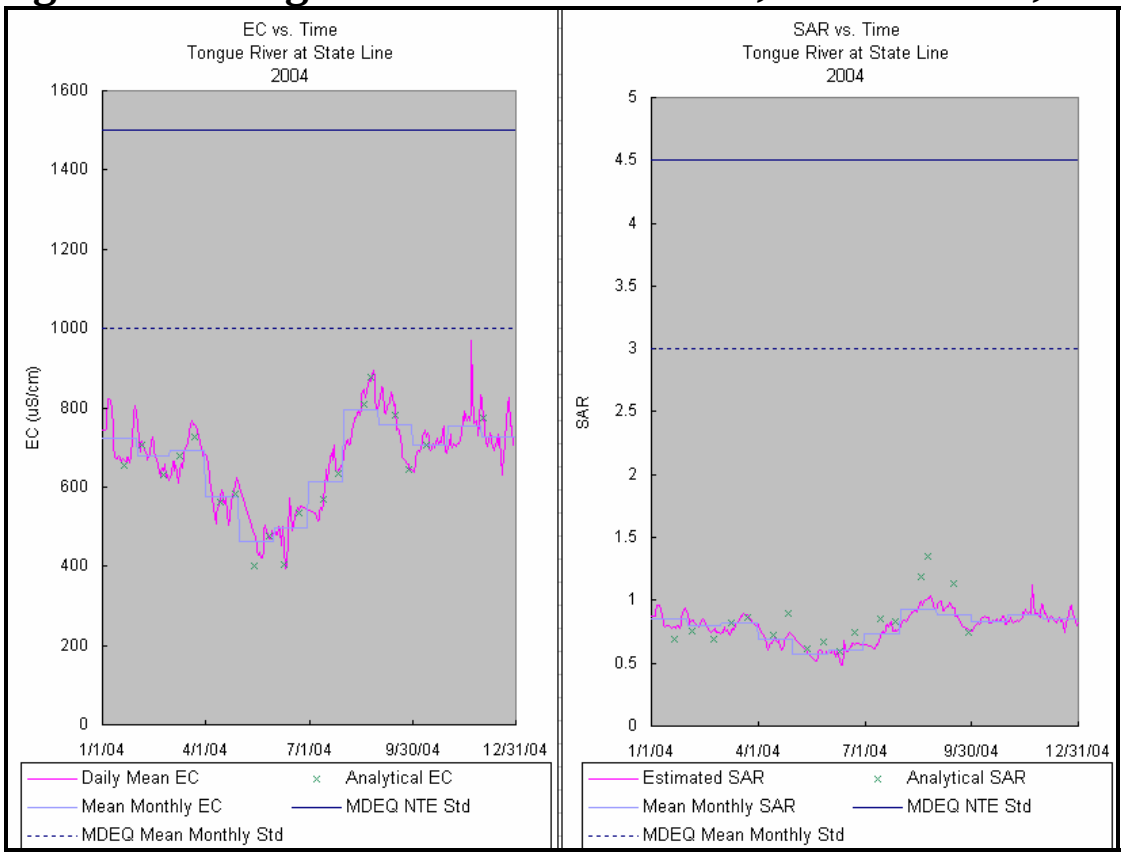


Figure 7 shows real time flow values in a time series plot for2004 for the Tongue River at the State Line, near Decker, and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 313 cfs in July, and a minimum of 47 cfs in August. The spring flow was substantially less then historical values, and flows were less than historical daily mean values for the entire year.

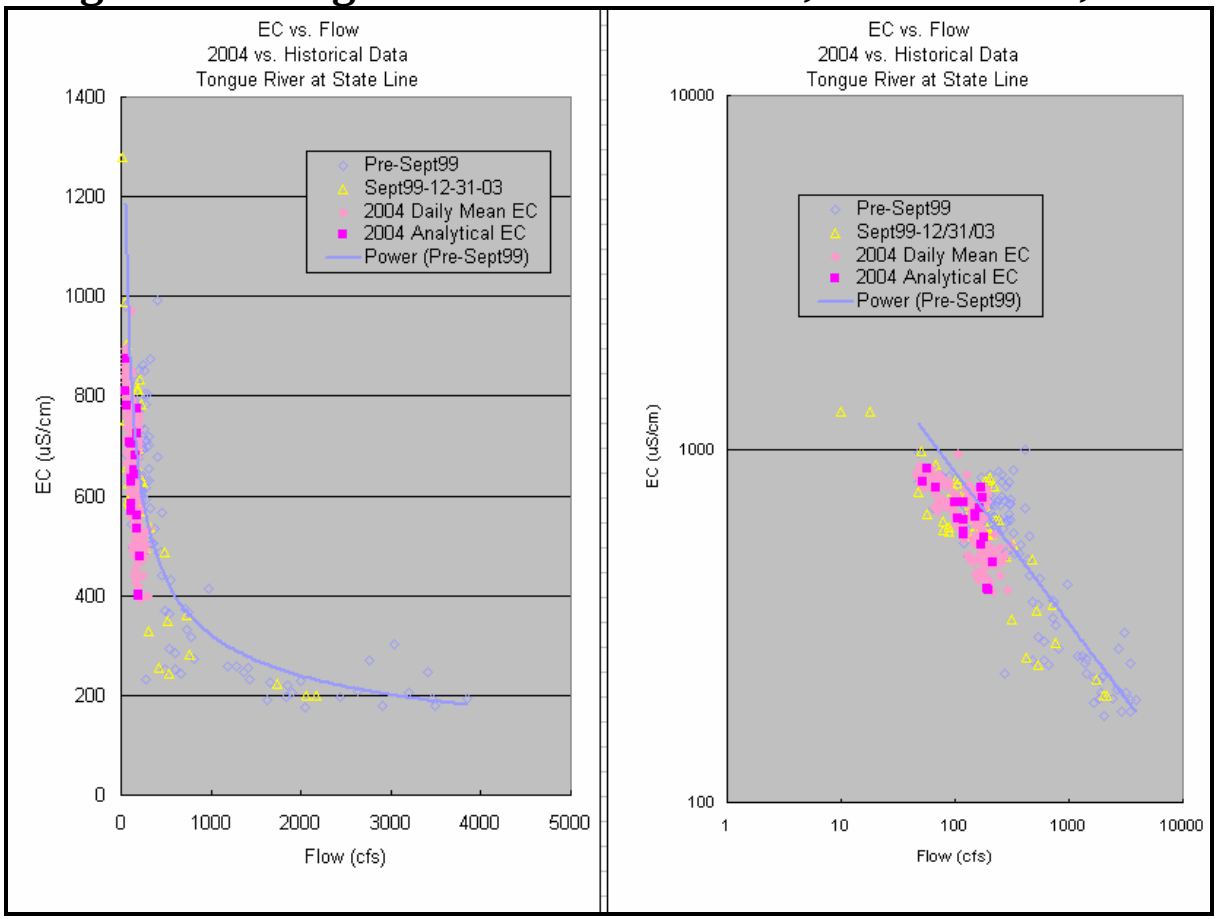
Figure 8: Tongue River at State Line, near Decker, MT



A **B**

Figure 8 shows daily mean and analytical EC values (A) and estimated and analytical SAR values (B) in time series plots for2004 for the Tongue River at the State line, near Decker. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Daily Mean EC values during 2004 had a maximum of 971 uS/cm in November, and a minimum of 393 uS/cm in June. Estimated SAR values had a maximum of 1.12 in November, and a minimum of 0.49 in June. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. Recorded values were below these standards for the entire year.

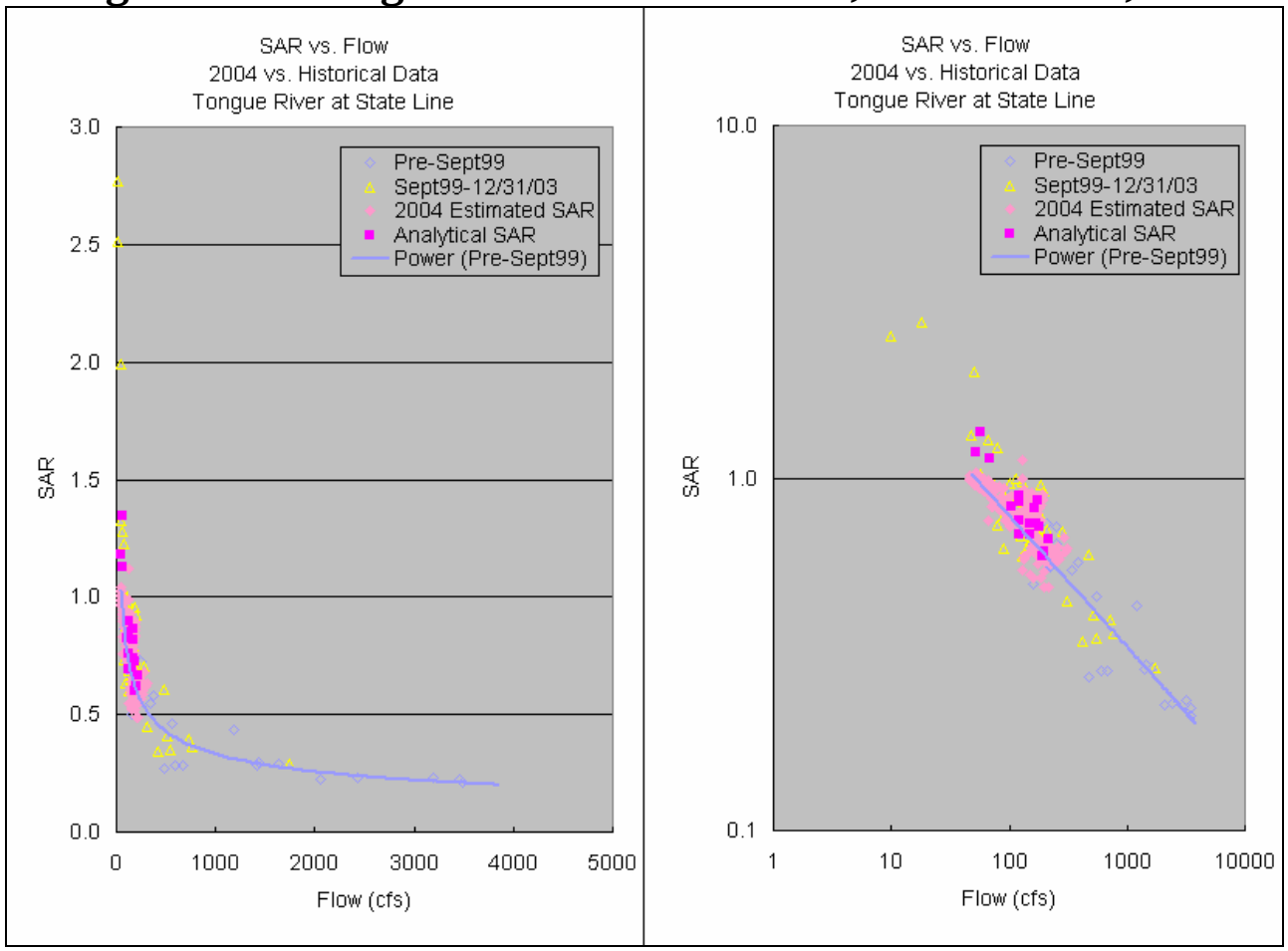
Figure 9: Tongue River at State Line, near Decker, MT



A **B**

Figure 9 shows daily mean and analytical EC values charted vs. Flow for 2004 for the Tongue River at the State Line, near Decker. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were in line with, or slightly less than, historical values during comparable flows.

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



A **B**

Figure 10 shows estimated and analytical SAR values charted vs. Flow for 2004 for the Tongue River at the State Line near Decker. These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values were in line with, or slightly greater than, historical values during comparable flows.

Figure 11: Tongue River at Tongue River Dam, near Decker, MT

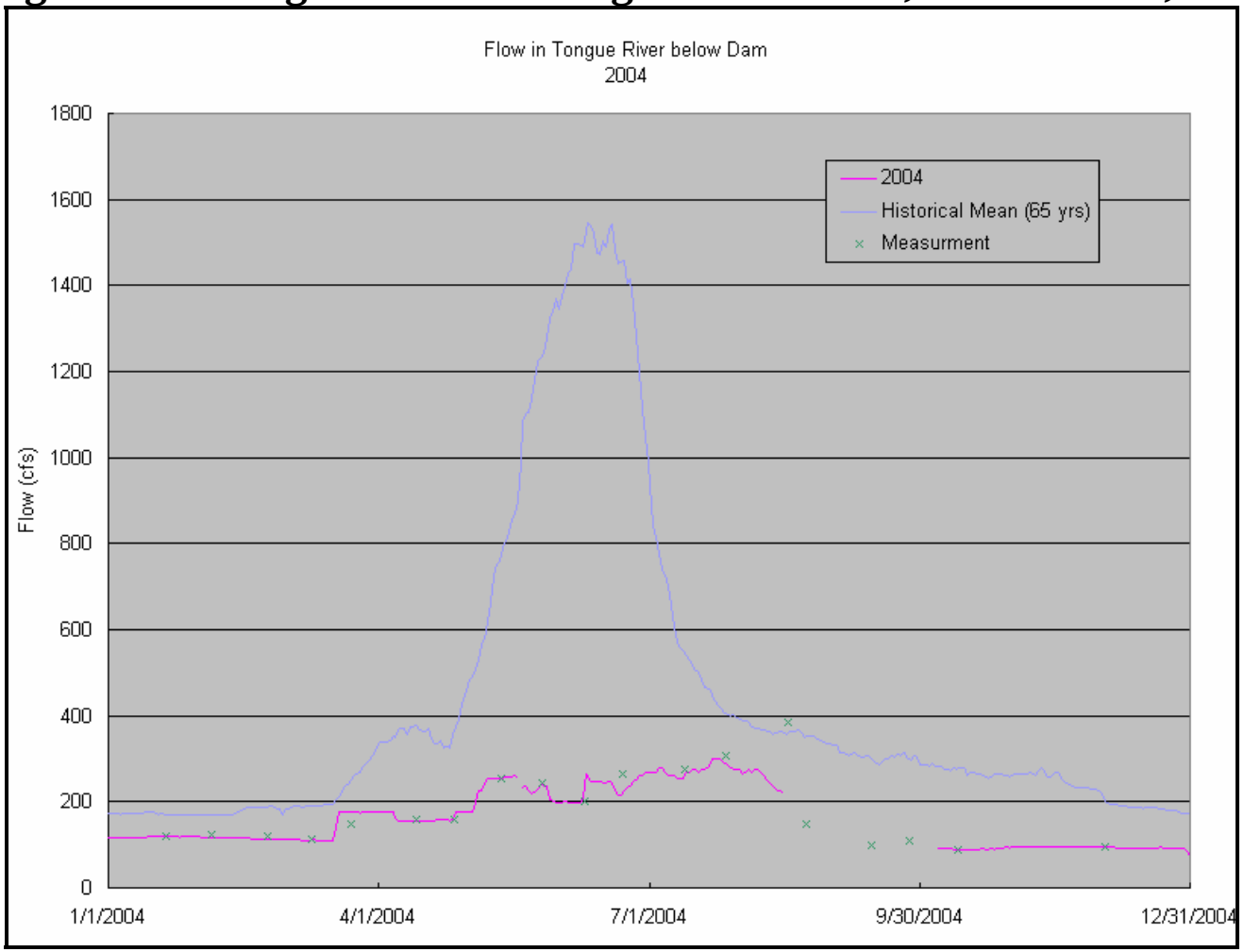
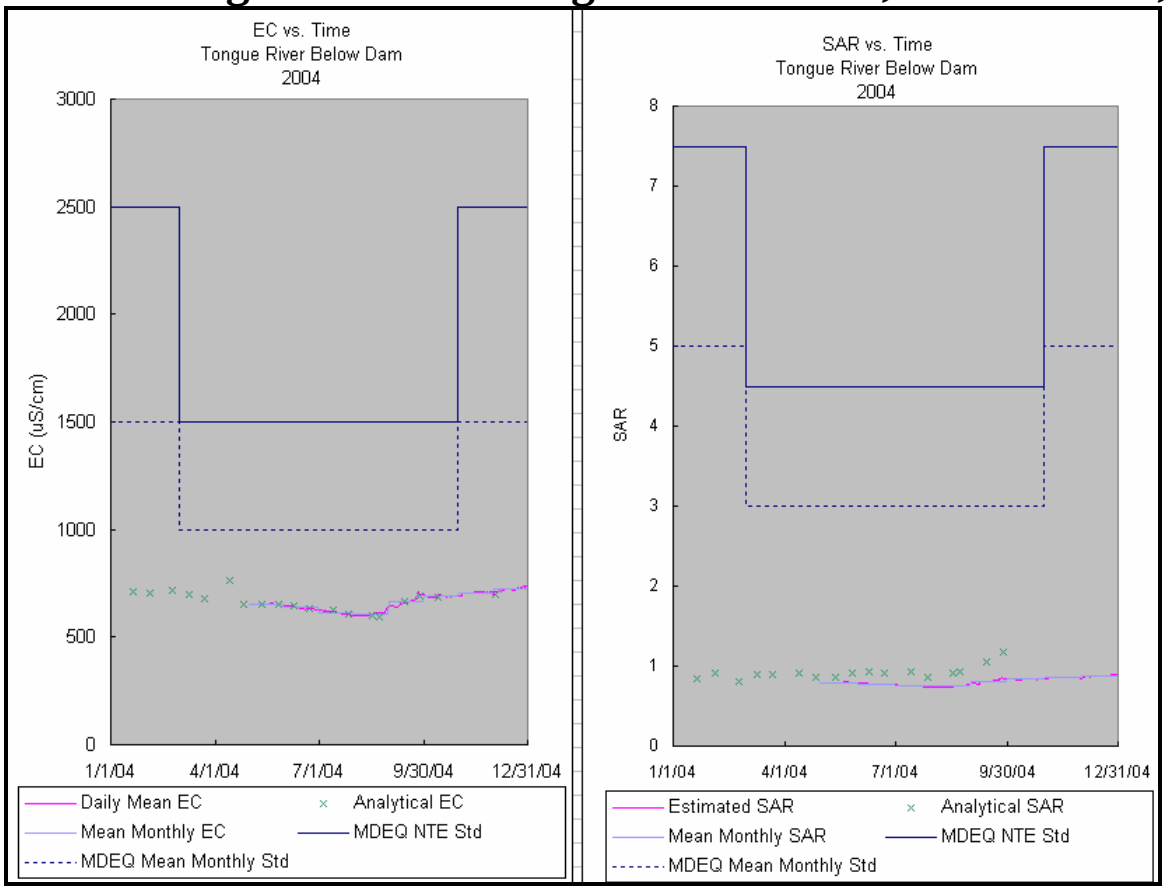


Figure 11 shows real time flow values in a time series plot for2004 for the Tongue River at Tongue River Dam, near Decker, and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 300 cfs in July, and a minimum of 73 cfs in December. The spring flow was substantially less then historical values, and flows were less than historical daily mean values for the entire year.

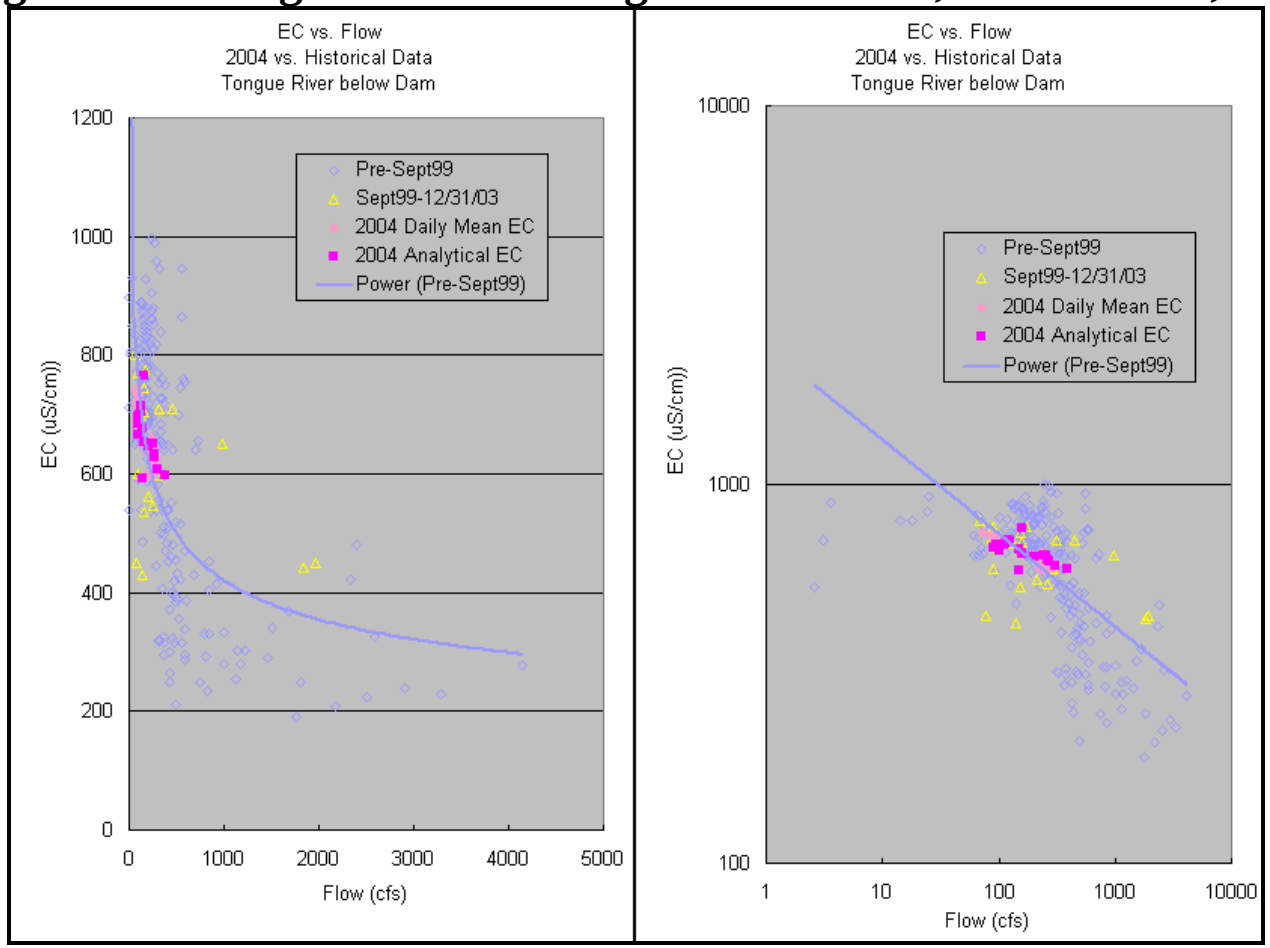
Figure 12: Tongue River at Tongue River Dam, near Decker, MT



A **B**

Figure 12 shows daily mean and analytical EC values (A), and estimated and analytical SAR values (B) in time series plots for2004 for the Tongue River at Tongue River Dam, near Decker. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Daily Mean EC values during 2004 had a maximum of 743 uS/cm in December, and a minimum of 597 uS/cm in August. Estimated SAR values had a maximum of 0.90 in December, and a minimum of 0.73 in August. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. Recorded values were below these standards for the entire year.

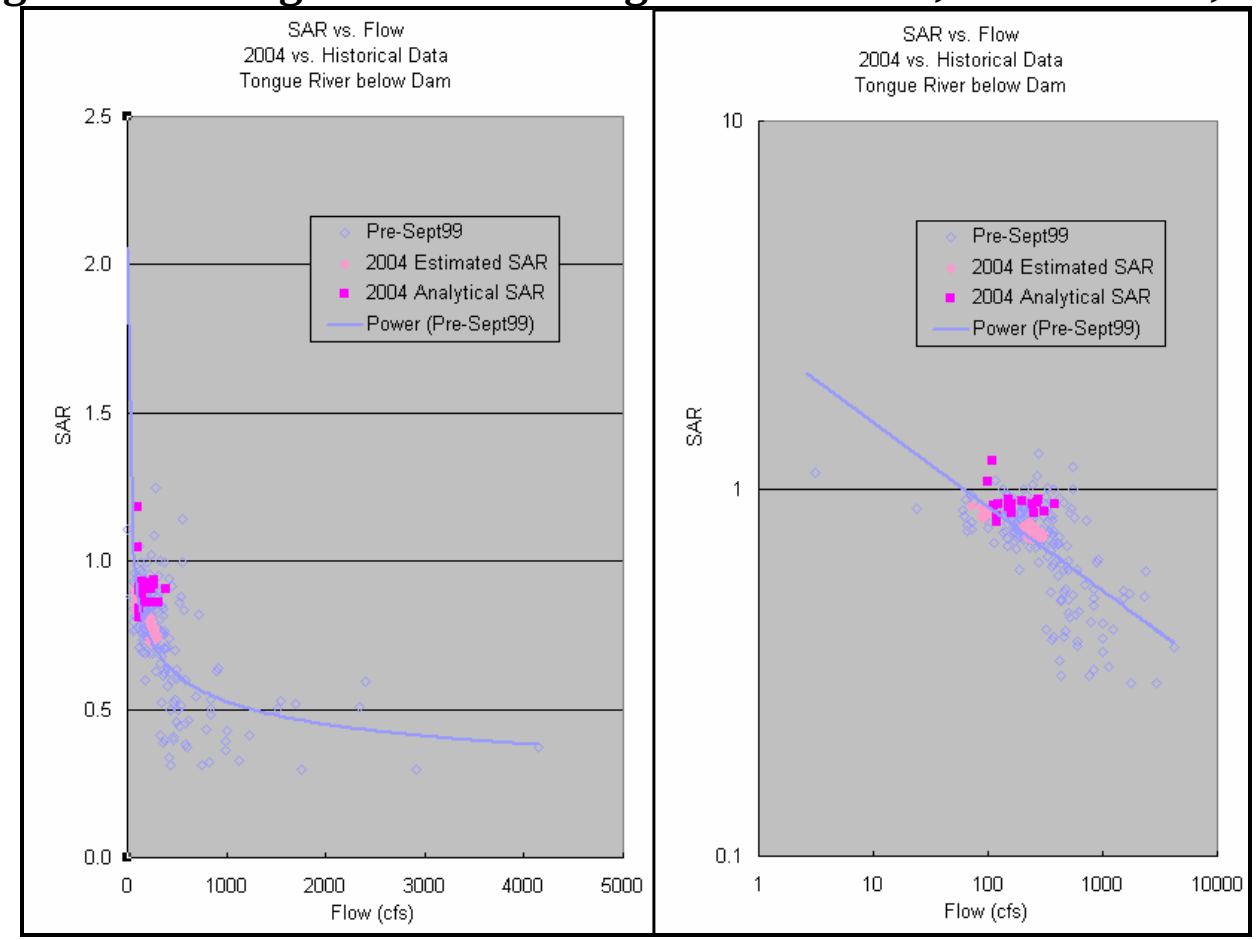
Figure 13: Tongue River at Tongue River Dam, near Decker, MT



A **B**

Figure 13 shows daily mean and analytical EC values charted vs. Flow for 2004 for the Tongue River at Tongue River Dam, near Decker. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were in line with historical values during comparable flows.

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



A **B**

Figure 14 shows estimated and analytical SAR values charted vs. Flow for 2004 for the Tongue River at Tongue River Dam, near Decker. These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values were in line with, or slightly greater than, historical values during comparable flows.

Figure 15: Tongue River at Birney Day School Bridge, near Birney, MT

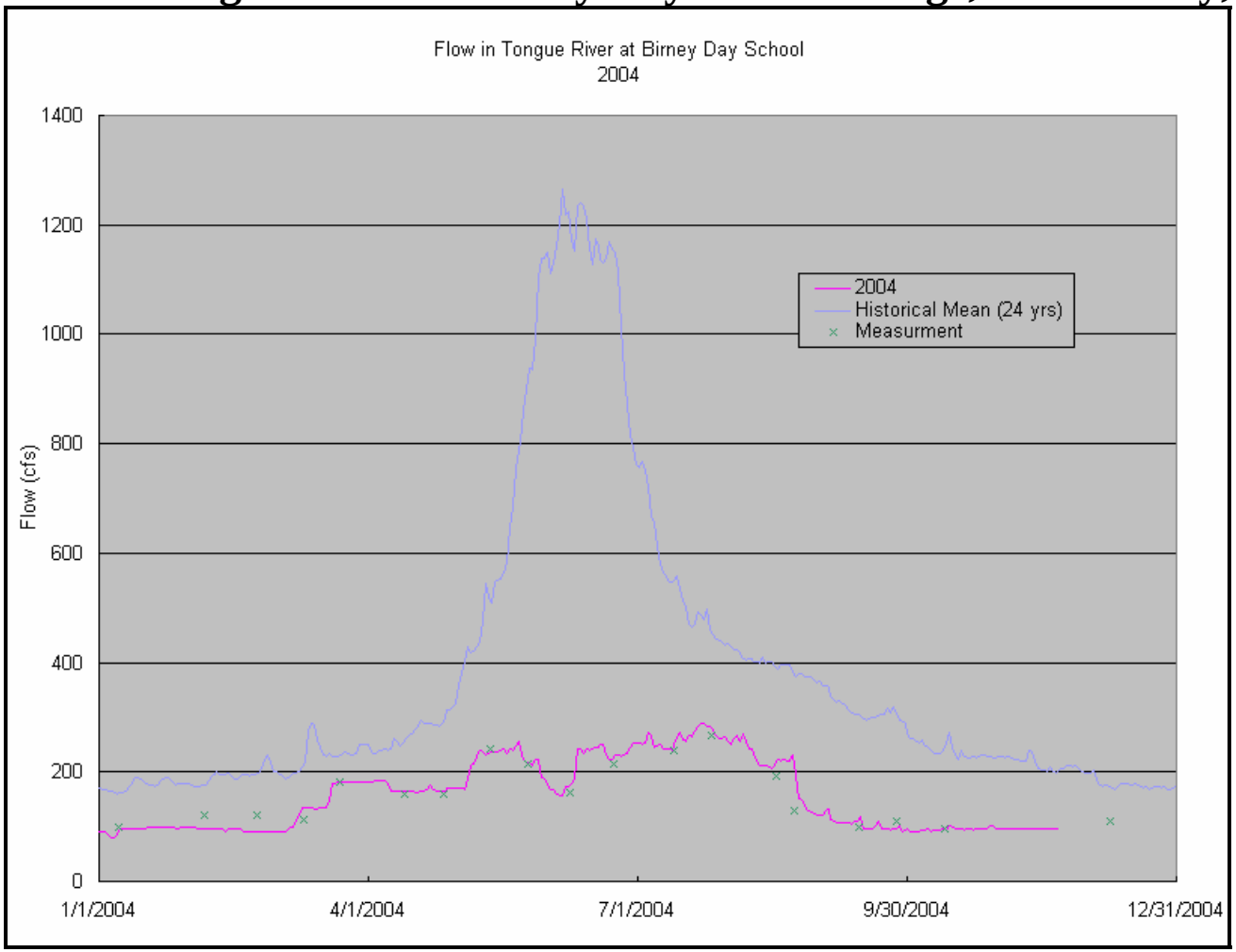
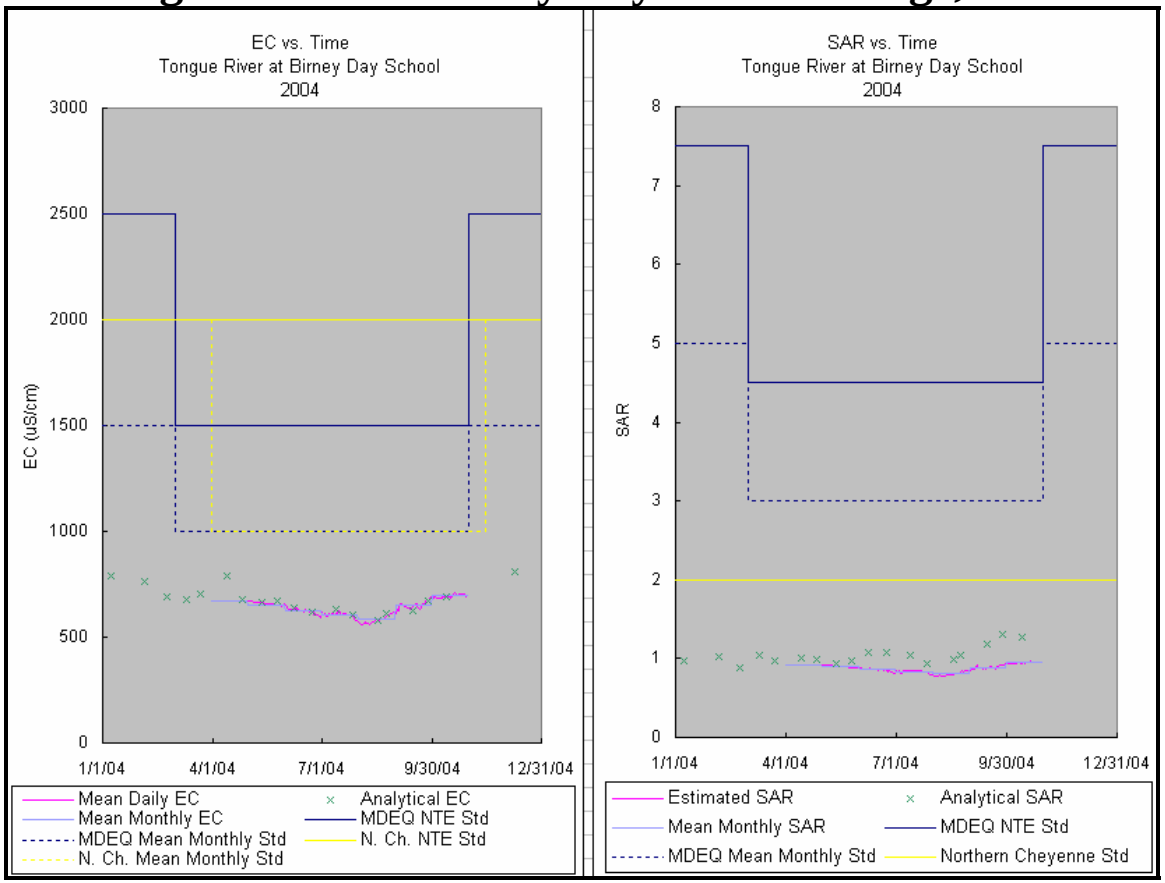


Figure 15 shows real time flow values in a time series plot for2004 for the Tongue River at Birney Day School Bridge, near Birney, MT and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 290 cfs, in June and a minimum of 80 cfs in January. The spring flow was substantially less then historical values, and flows were less than historical daily mean values for the entire year.

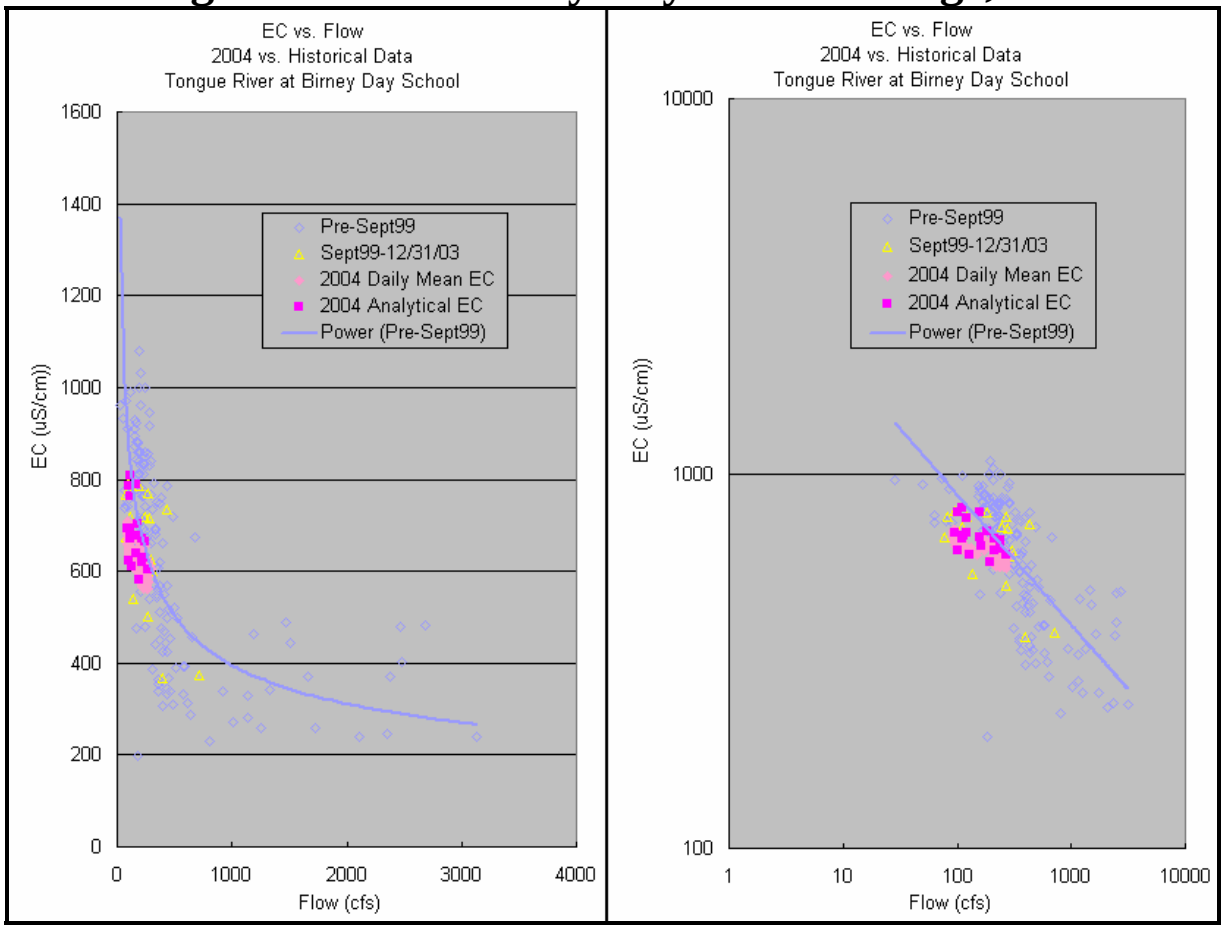
Figure 16: Tongue River at Birney Day School Bridge, near Birney, MT



A **B**

Figure 16 shows daily mean and analytical EC values (A), and estimated and analytical and SAR values (B) in time series plots for2004 for the Tongue River at Birney Day School Bridge, near Birney MT. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Daily Mean EC values during 2004 had a maximum of 709 uS/cm in October, and a minimum of 561 uS/cm in August. Estimated SAR values had a maximum of 0.97 in October, and a minimum of 0.77 in August. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ and the Northern Cheyenne Tribe. Recorded values were below these standards for the entire year.

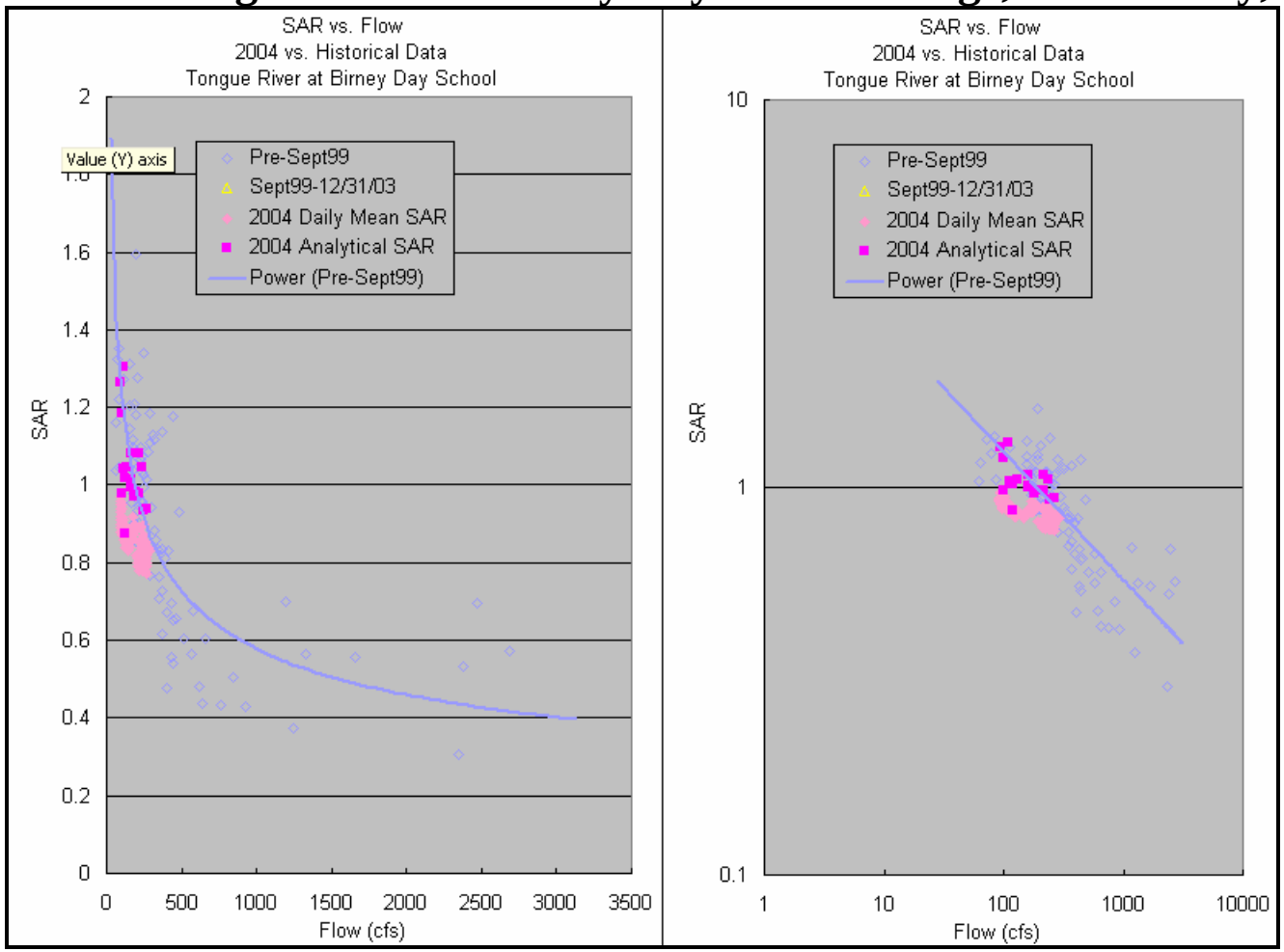
Figure 17: Tongue River at Birney Day School Bridge, near Birney, MT



A **B**

Figure 17 shows daily mean and analytical EC values charted vs. Flow for 2004 for the Tongue River at Birney Day School Bridge, near Birney MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were comparable to or slightly less than, historical values during comparable flows.

Figure 18: Tongue River at Birney Day School Bridge, near Birney, MT



A **B**

Figure 18 shows estimated and analytical SAR values charted vs. Flow for 2004 for the Tongue River at Birney Day School Bridge, near Birney MT, These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values were in line with historical values during comparable flows.

Figure 19: Tongue River below Brandenburg Bridge, near Ashland, MT

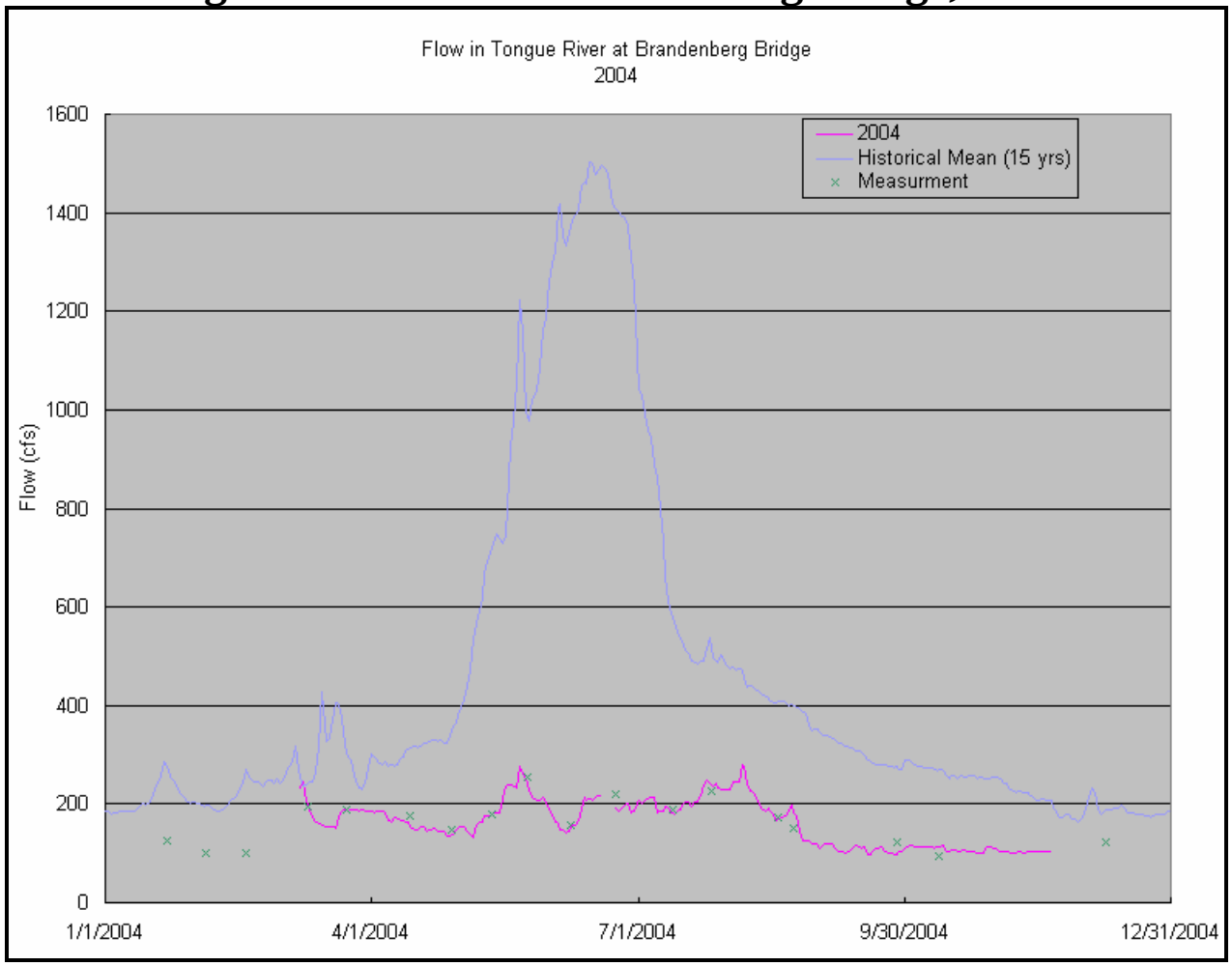
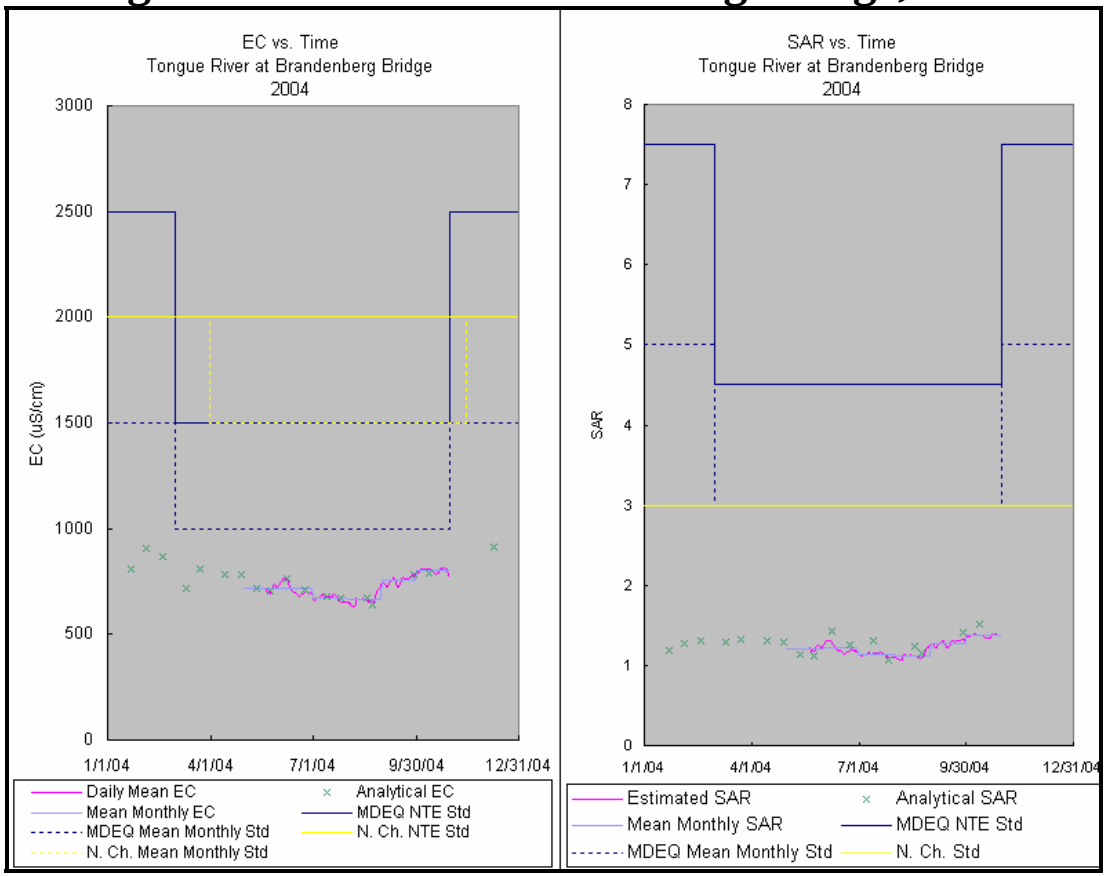


Figure 19 shows real time flow values in a time series plot for2004 for the Tongue River below Brandenburg Bridge, near Ashland, MT and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 280 cfs, in August, and a minimum of 97cfs in September. The spring flow was substantially less then historical values, and flows were less than historical daily mean values for the entire year.

Figure 20: Tongue River below Brandenburg Bridge, near Ashland, MT



A **B**

Figure 20 shows daily mean and analytical EC values (A) and estimated and analytical SAR values (B) in time series plots for2004 for the Tongue River below Brandenburg Bridge, near Ashland, MT. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Daily Mean EC values during 2004 had a maximum of 816 uS/cm in October, and a minimum of 631 uS/cm in August. Estimated SAR values had a maximum of 1.4 in October, and a minimum of 1.06 in August. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ and the Northern Cheyenne Tribe. Recorded values were below these standards for the entire year.

Figure 21: Tongue River below Brandenburg Bridge, near Ashland, MT

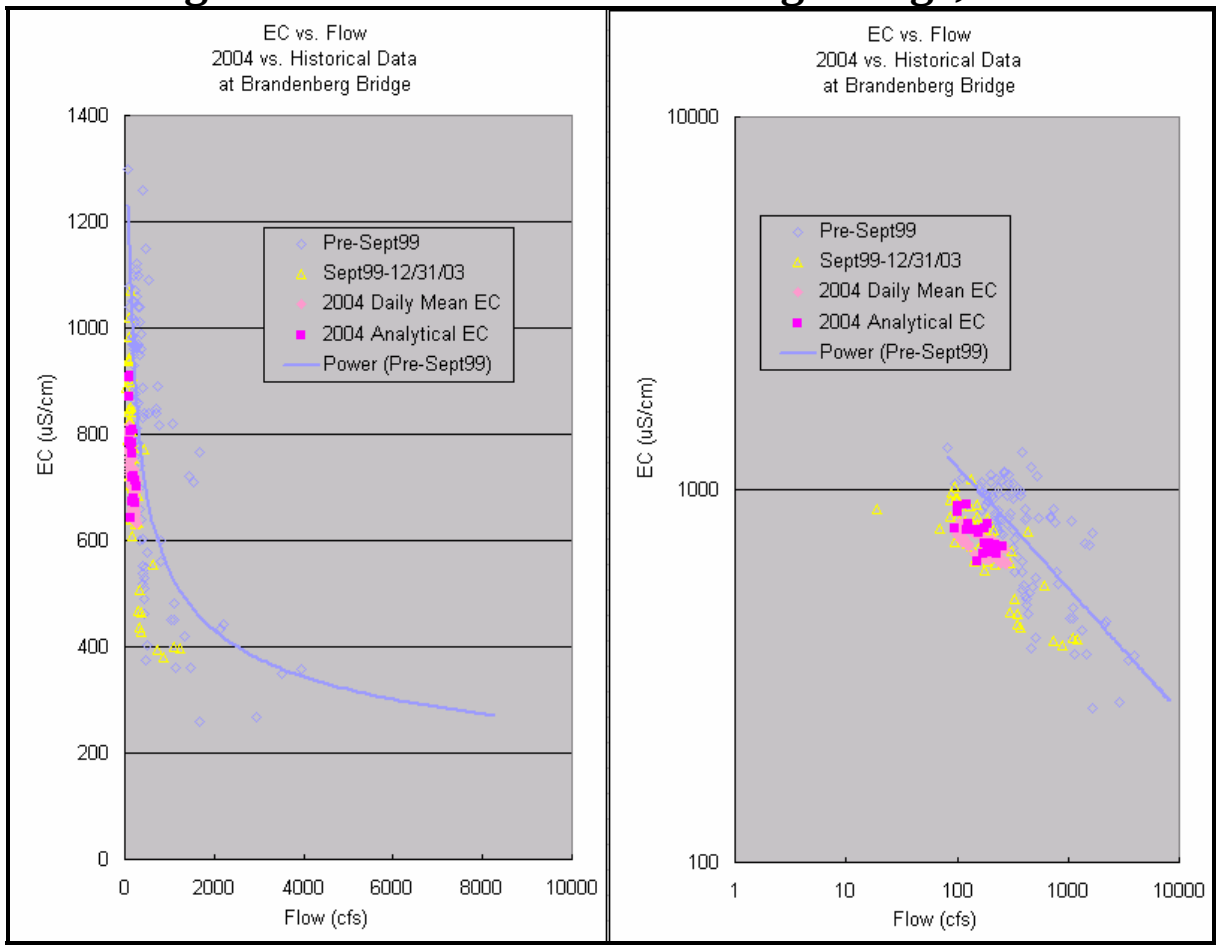


Figure 21 shows daily mean and analytical EC values charted vs. Flow for 2004 for the Tongue River below Brandenburg Bridge, near Ashland, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were in line, or slightly less than, historical values during comparable flows.

Figure 22: Tongue River below Brandenburg Bridge, near Ashland, MT

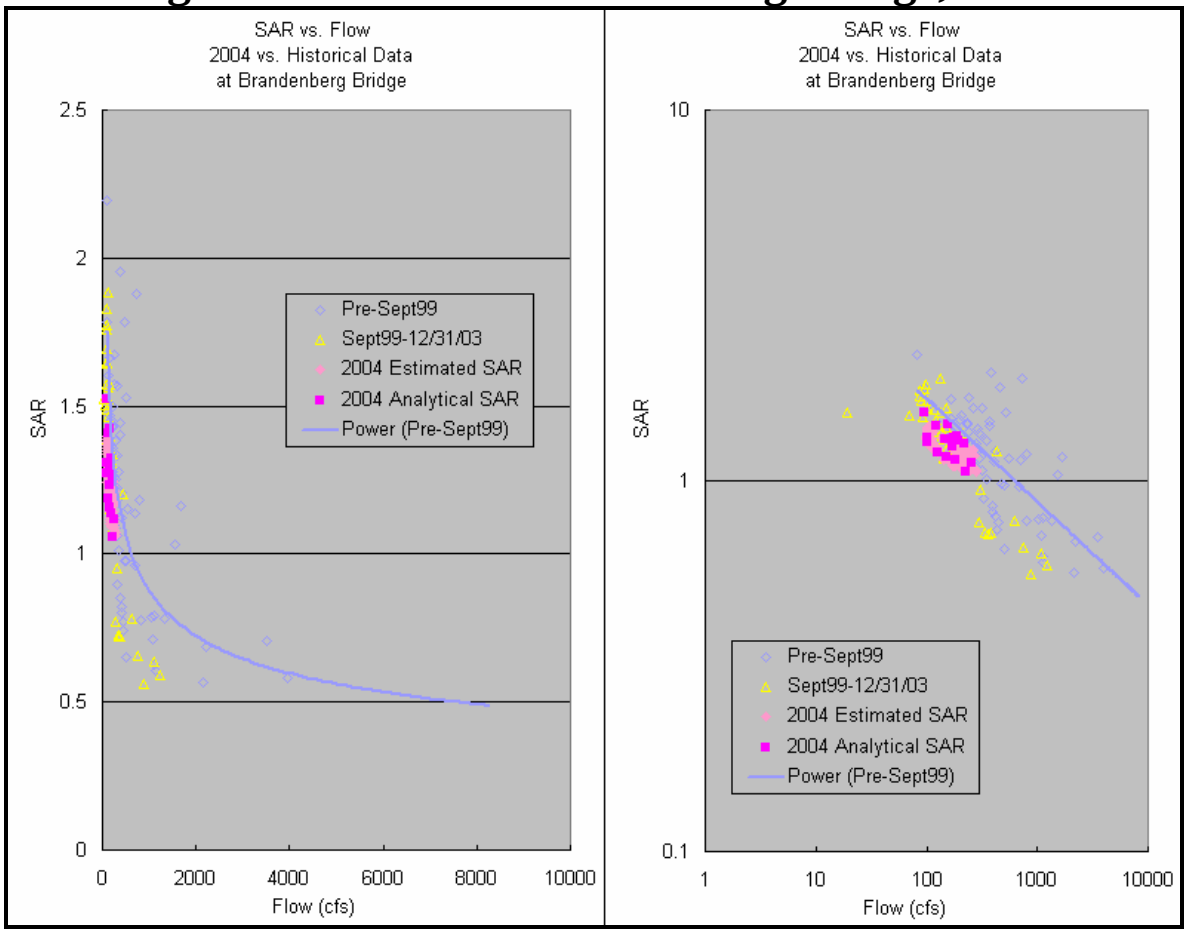


Figure 22 shows estimated and analytical SAR values charted vs. Flow for 2004 for the Tongue River below Brandenburg Bridge, near Ashland, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values were in line with, or slightly less then, historical values during comparable flows.

Figure 23: Tongue River at Miles City, MT

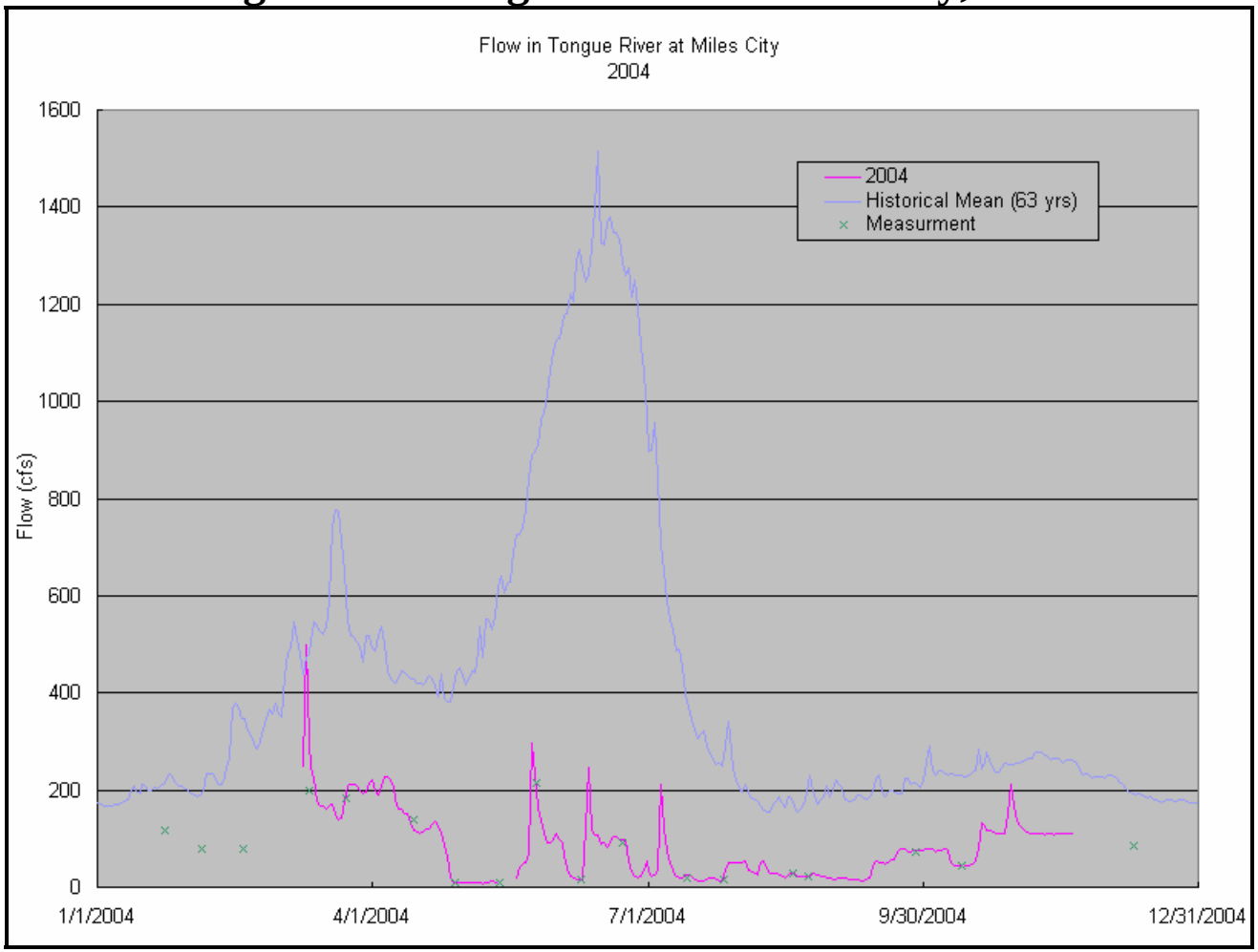
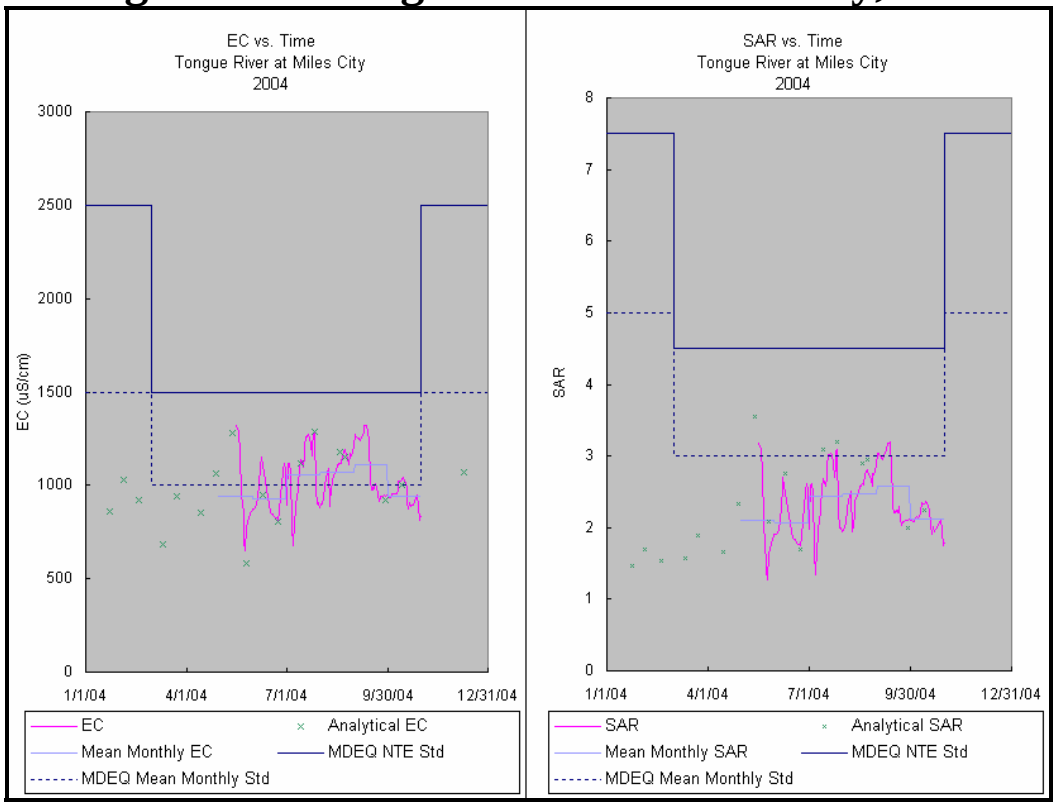


Figure 23 shows real time flow values in a time series plot for2004 for the Tongue River at Miles City, MT and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 500 cfs, in March, and a minimum of 7.6 cfs in May. The spring flow was substantially less then historical values, and flows were less than historical daily mean values for most of the year.

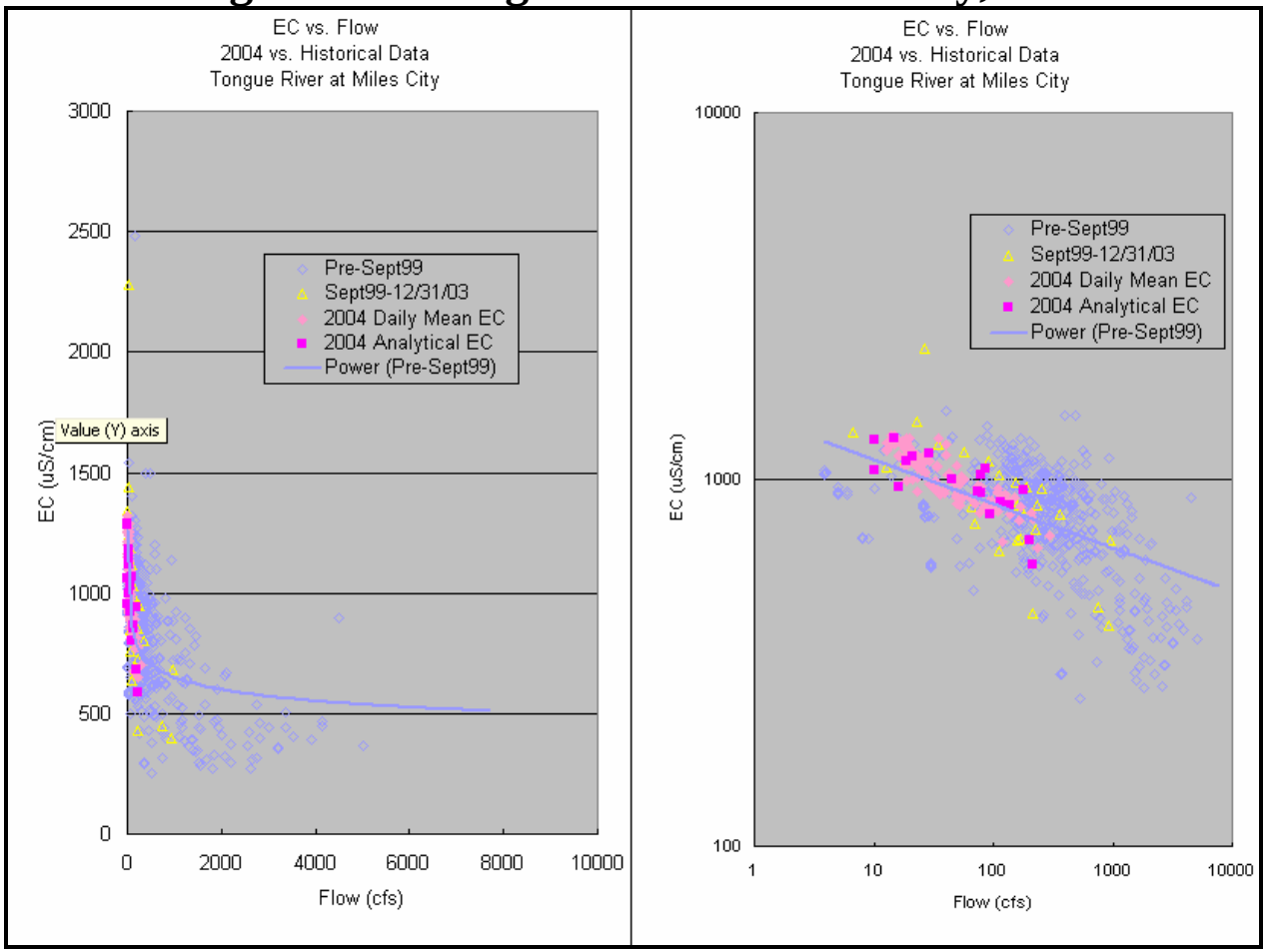
Figure 24: Tongue River at Miles City, MT



A **B**

Figure 24 shows daily mean and analytical EC values (A) and estimated and analytical SAR values (B) in time series plots for2004 for the Tongue River at Miles City, MT. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Daily Mean EC values during 2004 had a maximum of 1,320 uS/cm in September, and a minimum of 651 uS/cm in May. Estimated SAR values had a maximum of 3.19 in September, and a minimum of 1.28 in May. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ. The real time and analytical data did not exceed the instantaneous maximum standards for EC and SAR. The Mean Monthly SAR values did not exceed the Mean Monthly SAR standard. The Mean Monthly EC values were above the Mean Monthly EC standard during July, August and September, and below it for the rest of the year.

Figure 25: Tongue River at Miles City, MT



A **B**

Figure 25 shows daily mean and analytical EC values charted vs. Flow for 2004 for the Tongue River at Miles City, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were in line with historical values during comparable flows.

Figure 26: Tongue River at Miles City, MT

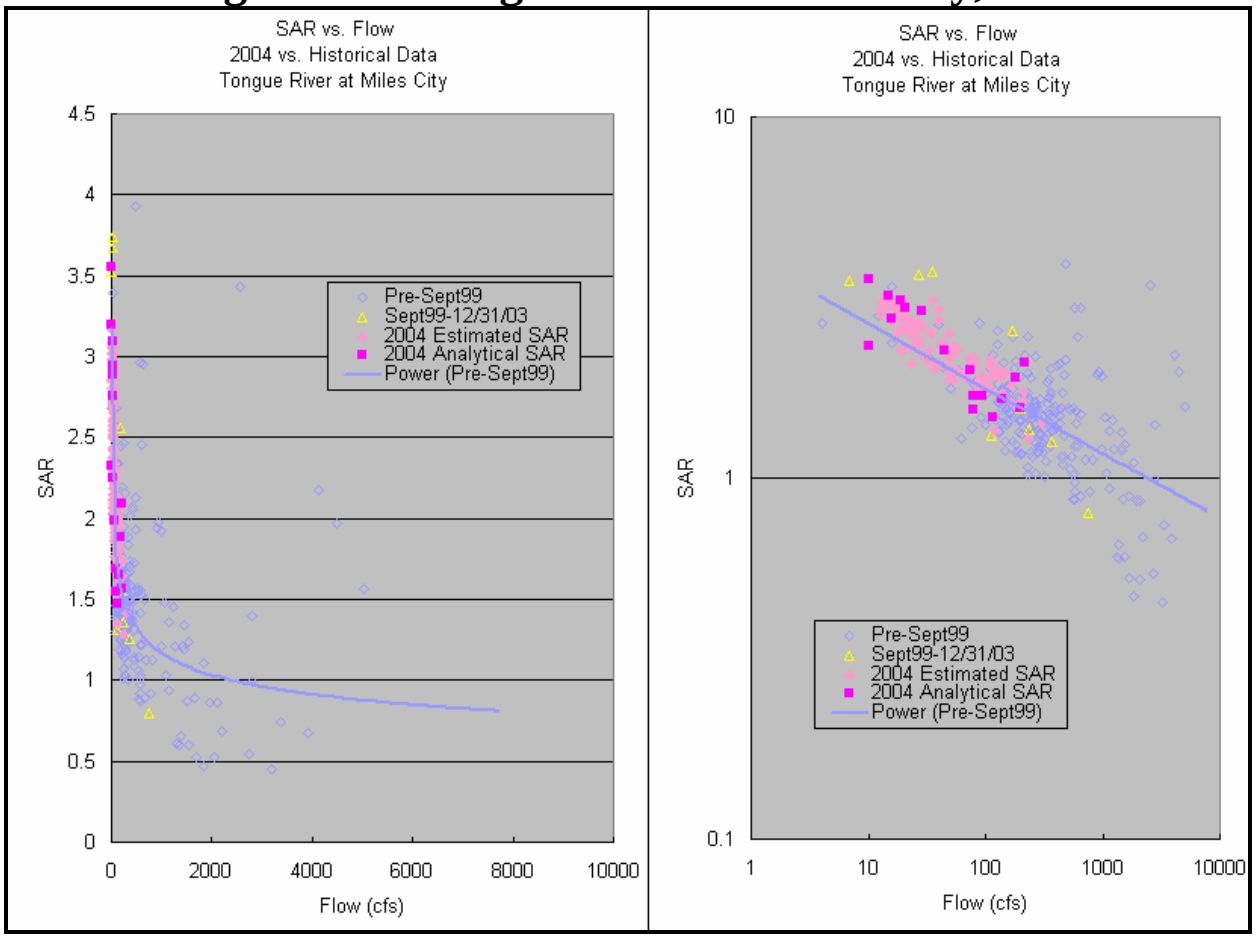


Figure 22 shows estimated and analytical SAR values charted vs. Flow for 2004 for the Tongue River at Miles City, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values were in line with or slightly more then, historical values during comparable flows.

Figure 27: Goose Creek near Acme, WY

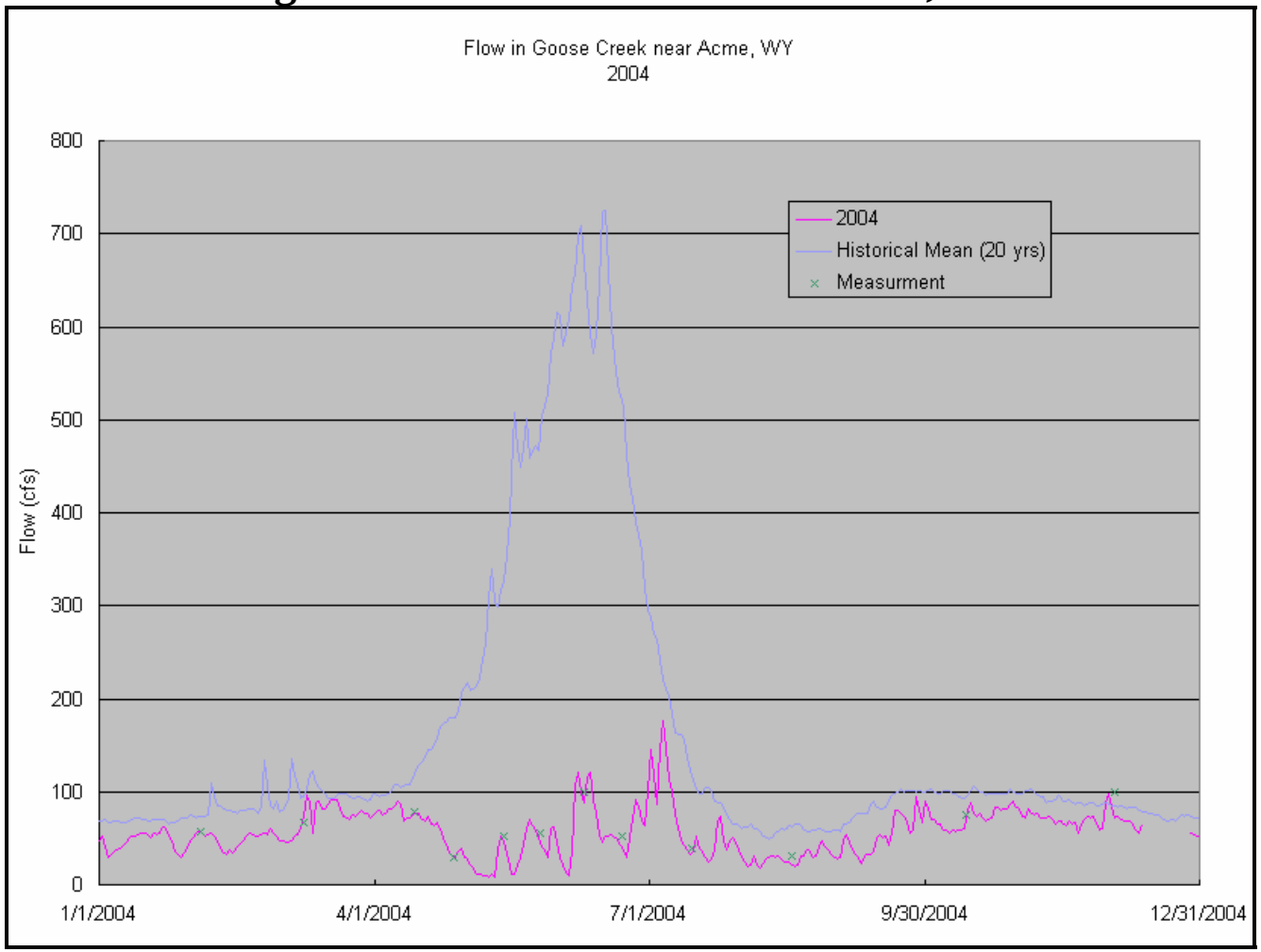
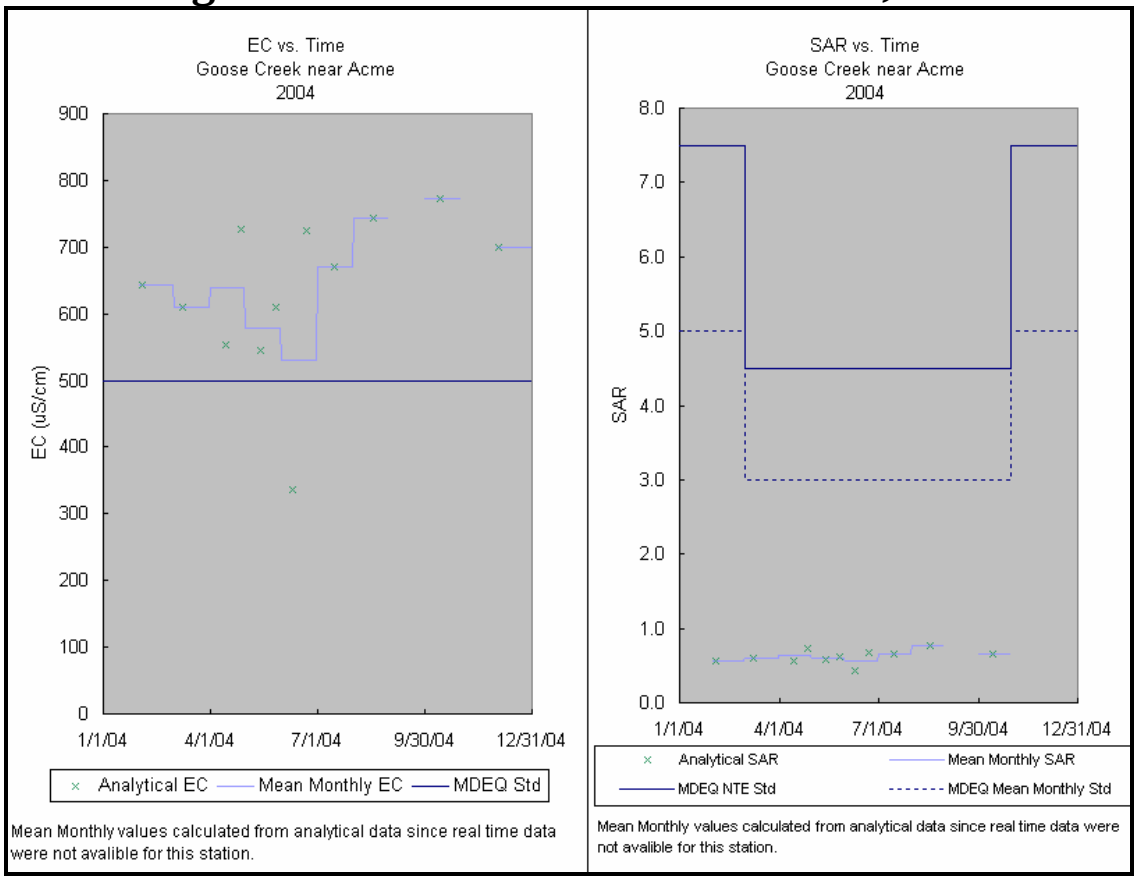


Figure 27 shows real time flow values in a time series plot for2004 for Goose Creek near Acme, WY and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 176 cfs, in July, and a minimum of 7.5 cfs in May. The spring flow was substantially less then historical values, and flows were less than historical daily mean values for most of the year.

Figure 28: Goose Creek near Acme, WY



A **B**

Figure 28 shows analytical and EC(A) and SAR (B) values in time series plots for2004 for Goose Creek near Acme, WY. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Analytical EC values during 2004 had a maximum of 772 uS/cm in October, and a minimum of 336 uS/cm in June. Analytical SAR values had a maximum of 0.77 in August, and a minimum of 0.44 in June. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ for tributaries of the Tongue River. All but one of the recorded EC values were above the instantaneous maximum EC standard. All SAR values were below the standards.

Figure 29: Goose Creek near Acme, WY

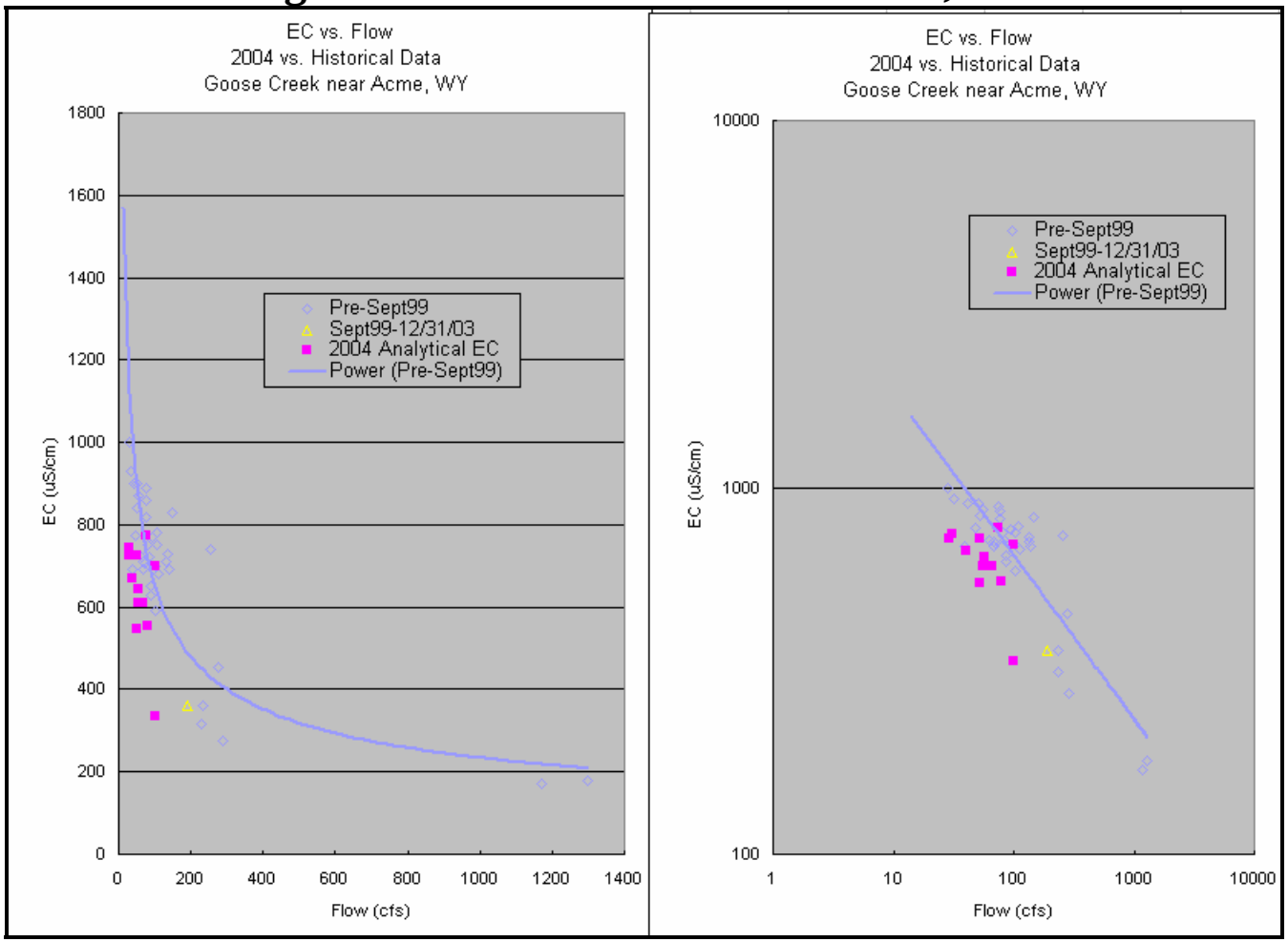
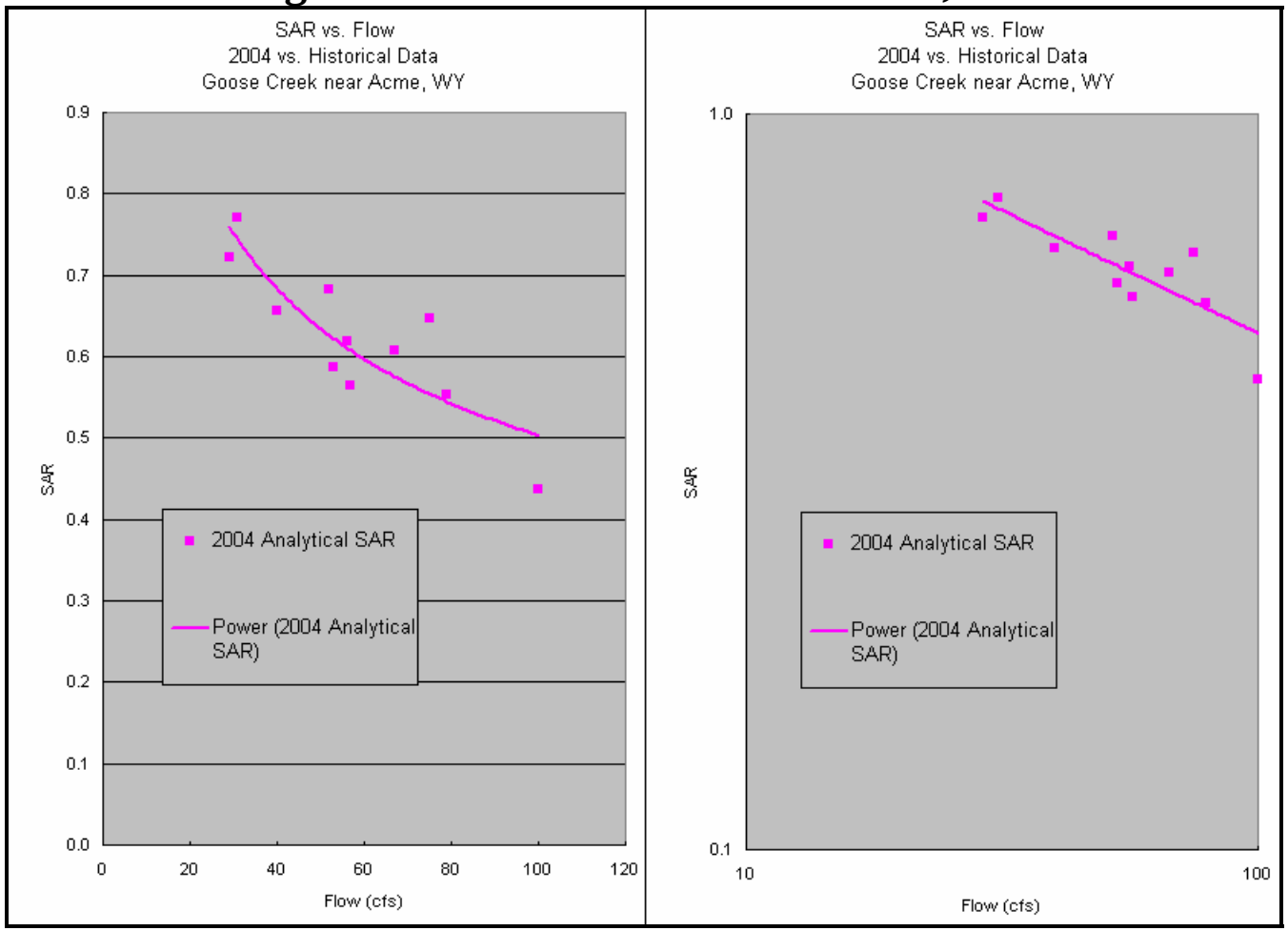


Figure 29 shows analytical EC values charted vs. Flow for 2004 for Goose Creek near Acme, WY. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were in line, or slightly less than, historical values during comparable flows.

Figure 30: Goose Creek near Acme, WY



A **B**

Figure 30 shows analytical SAR values charted vs. Flow for 2004 for Goose Creek near Acme, WY. These values are charted on both linier (A) and logarithmic (B) scales. No historical SAR data are available for comparison.

Figure 31: Prairie Dog Creek near Acme, WY

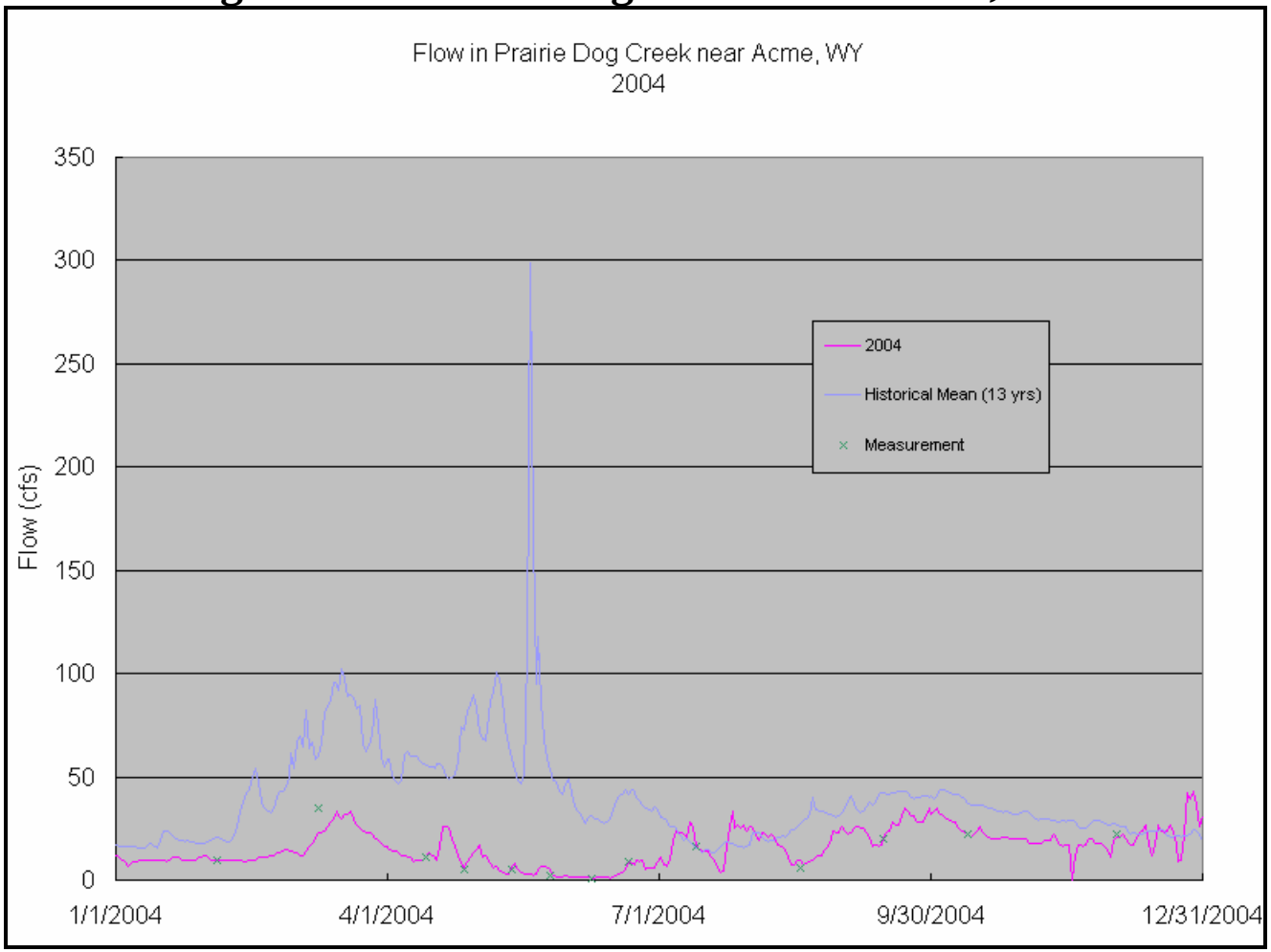
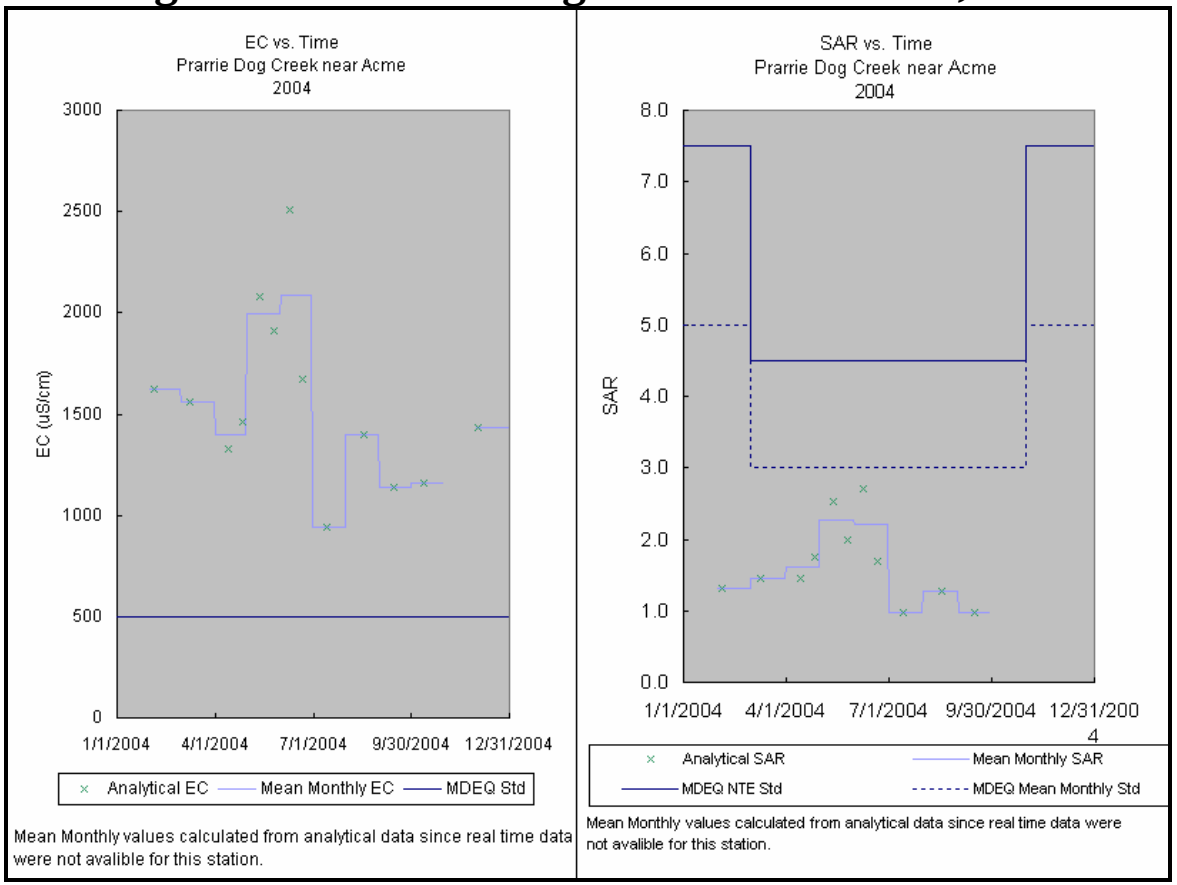


Figure 31 shows real time flow values in a time series plot for2004 for Prairie Dog Creek near Acme, WY, and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 43 cfs, in December, and a minimum of 1 cfs in June. The spring flow was less then historical values, but in July and December daily flows were above historical levels.

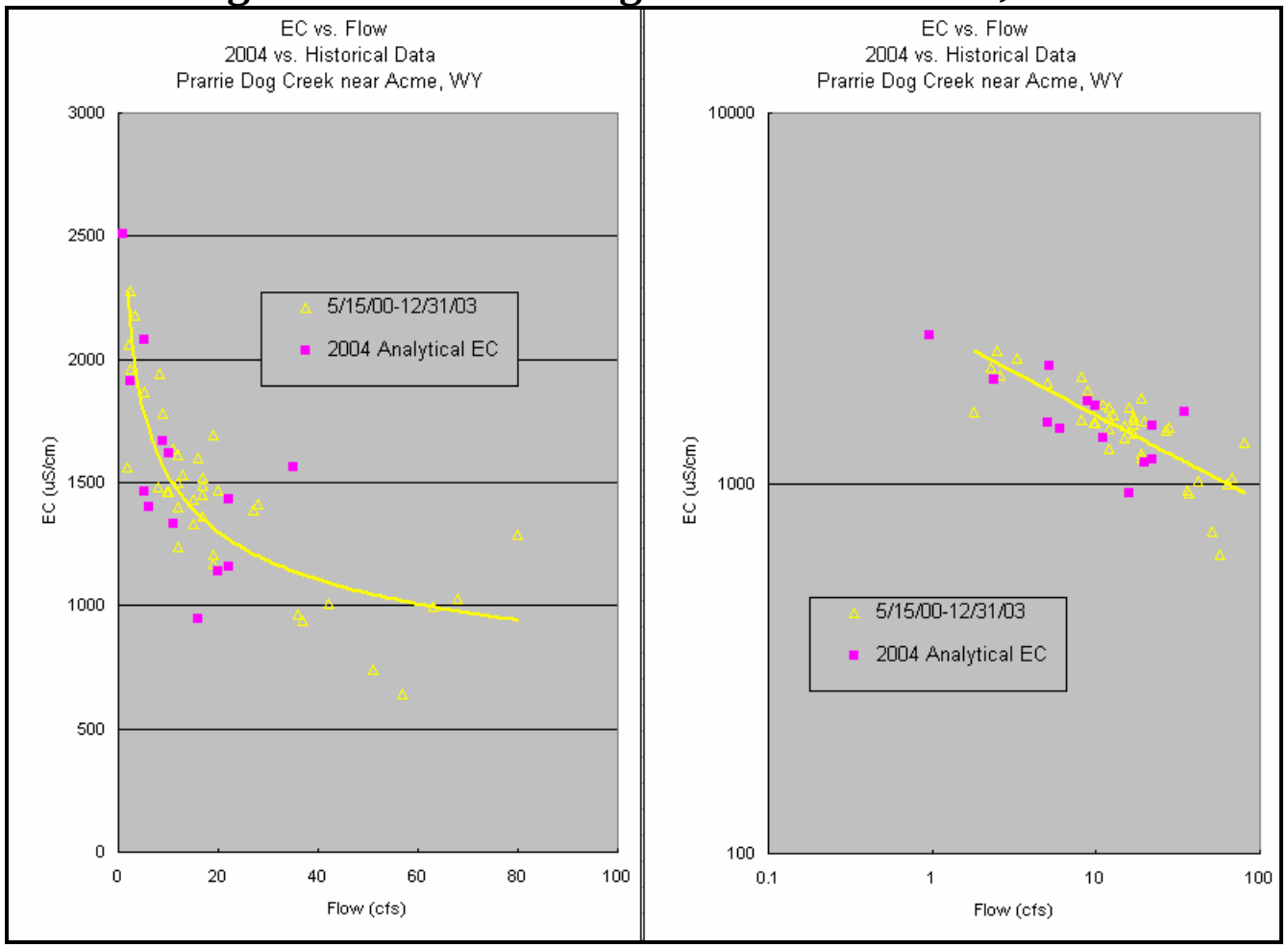
Figure 32: Prairie Dog Creek near Acme, WY



A **B**

Figure 32 shows analytical EC (A) and SAR (B) values in time series plots for2004 for Prairie Dog Creek near Acme, WY. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Analytical EC values during 2004 had a maximum of 2510 uS/cm in June, and a minimum of 944 uS/cm in July. Analytical SAR values had a maximum of 2.71 in June, and a minimum of 0.97 in July. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ for tributaries of the Tongue River. All of the EC values were above the standards. All of the SAR values were below the standards.

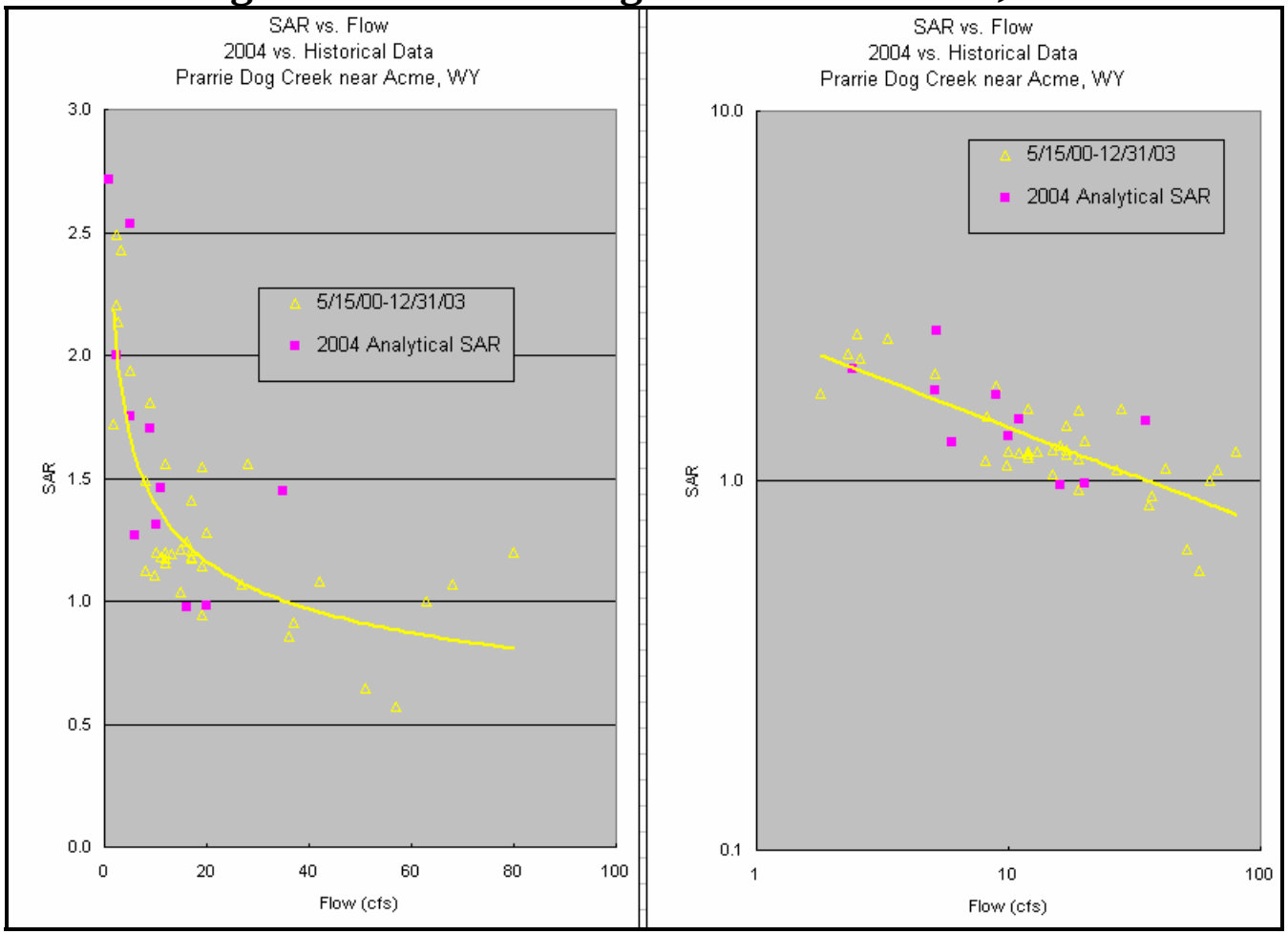
Figure 33: Prairie Dog Creek near Acme, WY



A **B**

Figure 33 shows analytical EC values charted vs. Flow for 2004 for Prairie Dog Creek near Acme, WY. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were in line with historical values during comparable flows.

Figure 34: Prairie Dog Creek near Acme, WY



A **B**

Figure 34 shows analytical SAR values charted vs. Flow for 2004 for Prairie Dog Creek near Acme, WY. These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values were in line with, historical values during comparable flows.

Figure 35: Hanging Woman Creek near Birney, MT

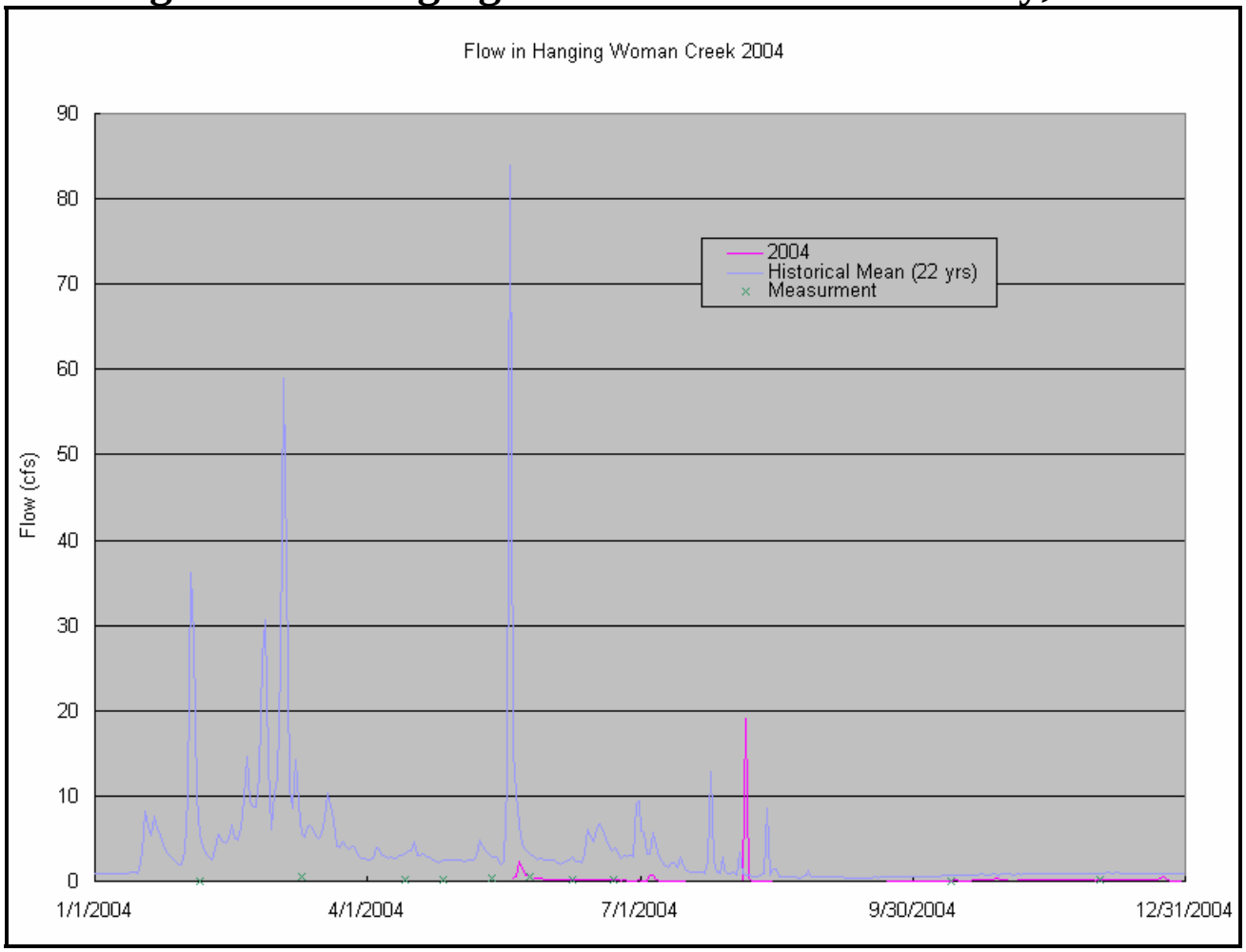
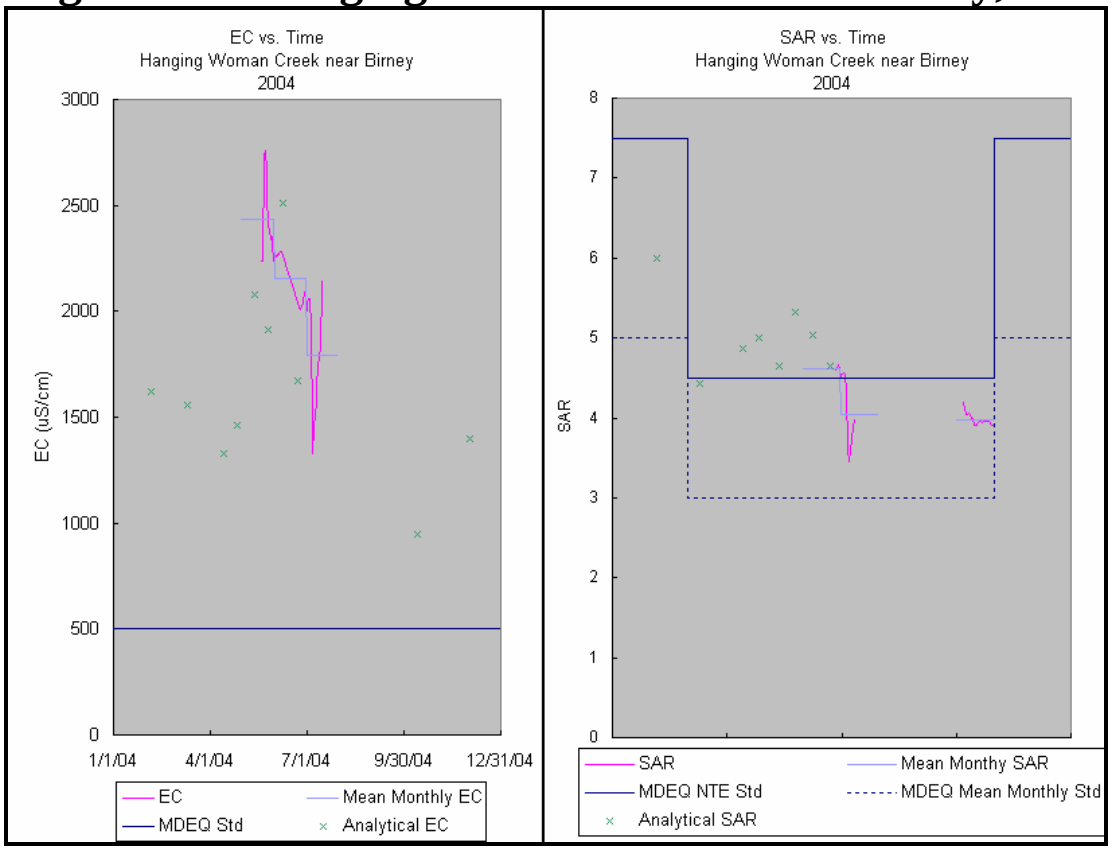


Figure 35 shows real time flow values in a time series plot for2004 for Hanging Woman Creek near Birney, MT, and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 19 cfs, in August, and a minimum of 0 cfs. The spring flow was substantially less then historical values, and flows were less than historical daily mean values for most of the year.

Figure 36: Hanging Woman Creek near Birney, MT



A **B**

Figure 36 shows daily mean and analytical EC values (A) and estimated and analytical SAR values (B) in time series plots for2004 for Hanging Women Creek near Birney, MT. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Daily Mean EC values during 2004 had a maximum of 2,760 uS/cm in May, and a minimum of 1,330 uS/cm in July. Estimated SAR values had a maximum of 4.66 in June, and a minimum of 3.46 in July. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ for tributaries of the Tongue River. The EC values were all in excess of the standard. The estimated SAR values were greater than the NTE standard on 11 days. All but two of the analytical SAR values were above the NTE standard.

Figure 37: Hanging Woman Creek near Birney, MT

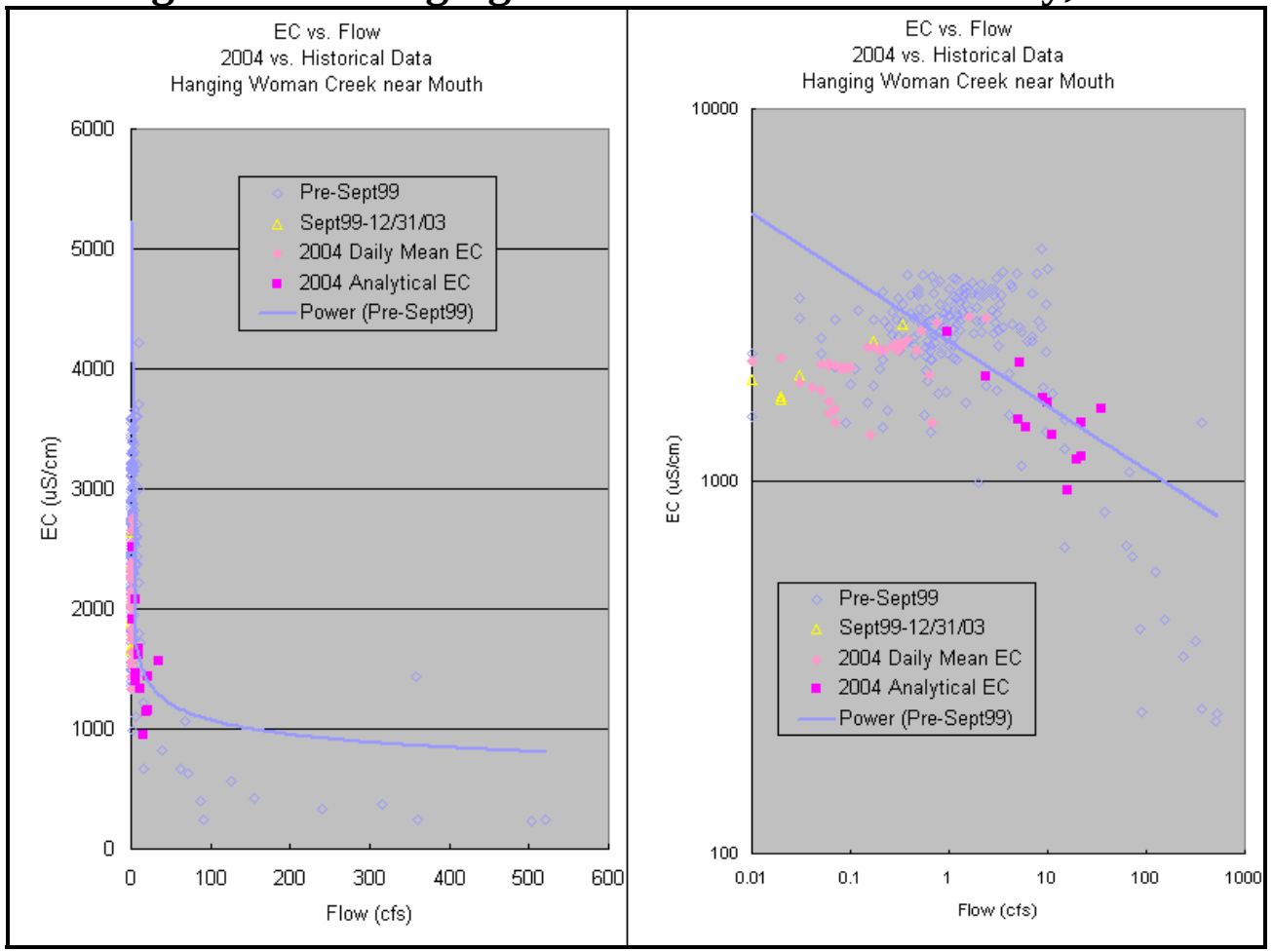
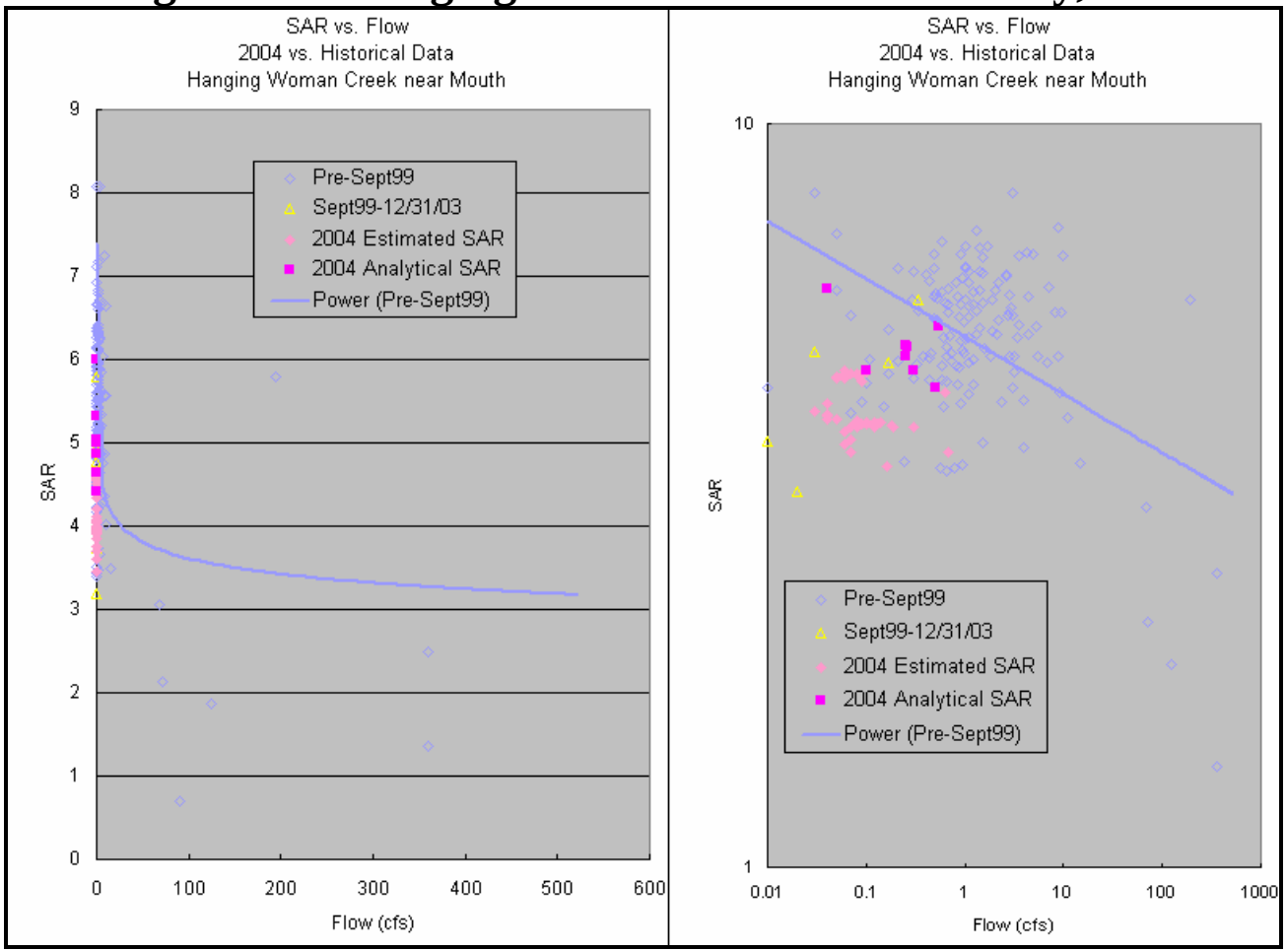


Figure 37 shows daily mean and analytical EC values charted vs. Flow for 2004 for Hanging Woman Creek near Birney, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values were in line with, or slightly less then historical values during comparable flows.

Figure 38: Hanging Woman Creek near Birney, MT



A **B**

Figure 38 shows estimated and analytical SAR values charted vs. Flow for 2004 for Hanging Woman Creek near Birney, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values were in line with, or less then historical values during comparable flows.

Figure 39: Otter Creek at Ashland, MT

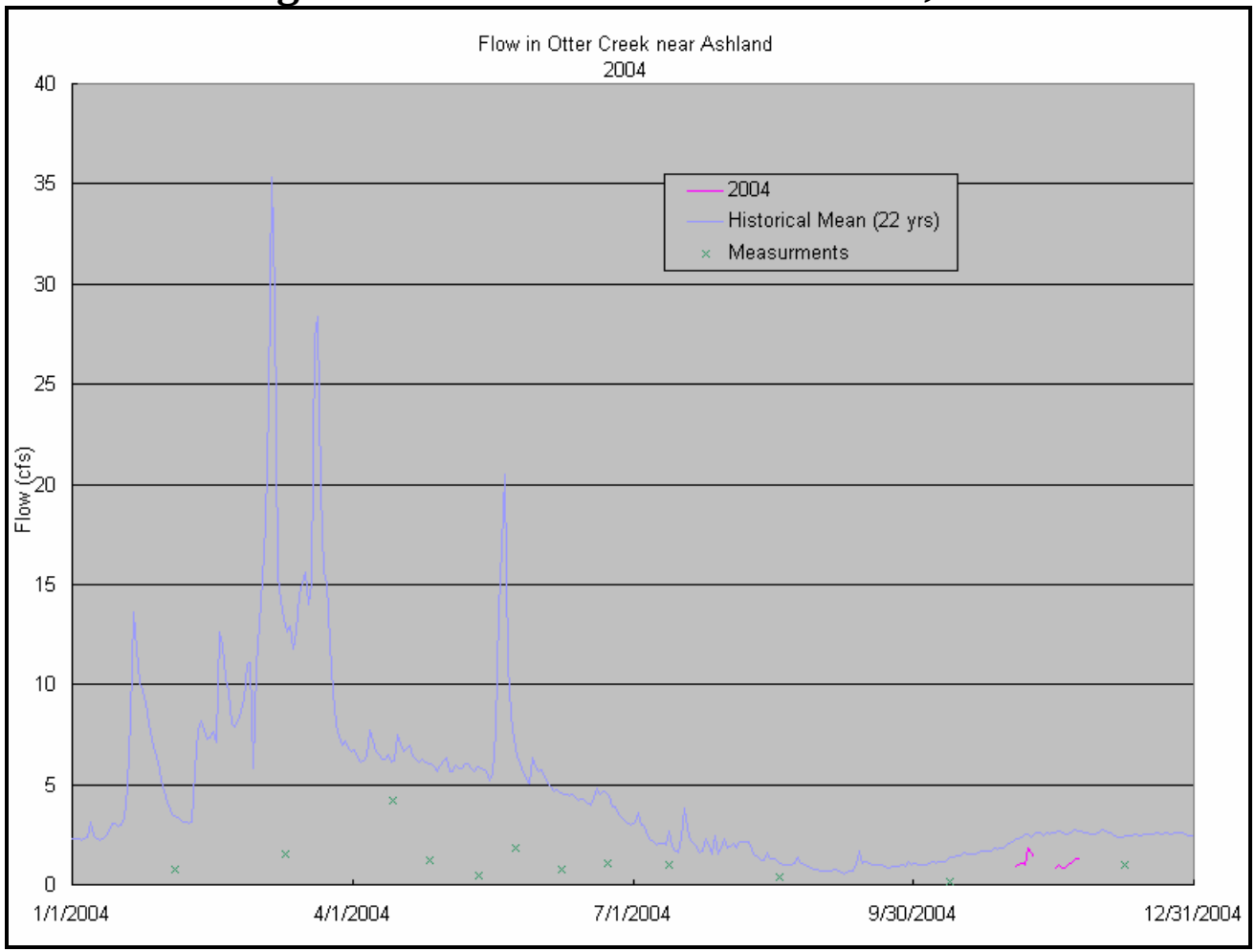
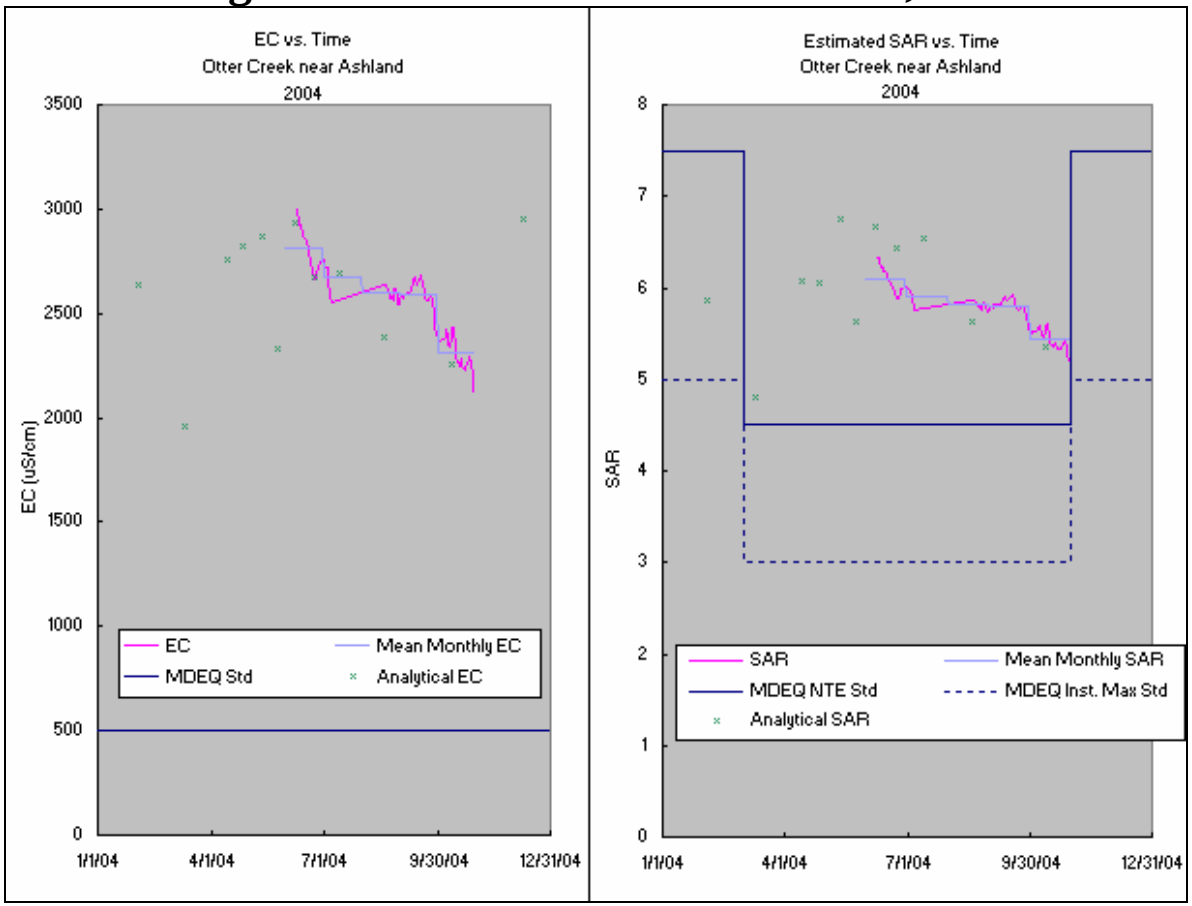


Figure 39 shows real time flow values in a time series plot for2004 for Otter Creek at Ashland, MT, and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 1.8 cfs in November, and a minimum of 0 cfs. The spring flow was substantially less then historical values, and flows were less than historical daily mean values for the entire year

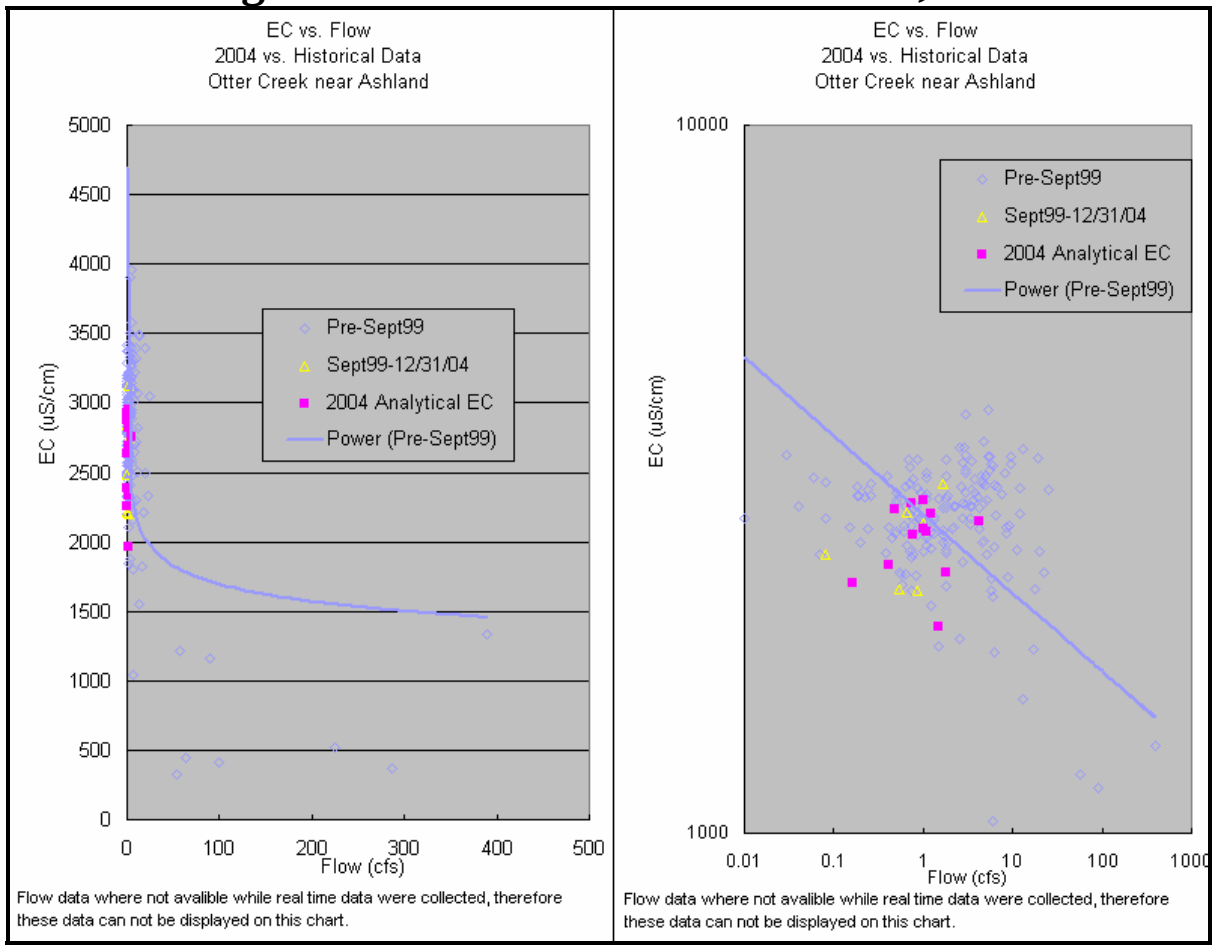
Figure 40: Otter Creek at Ashland, MT



A **B**

Figure 40 shows daily mean and analytical EC values (A) and estimated and analytical SAR values (B) in time series plots for2004 for Otter Creek at Ashland, MT. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Daily Mean EC values during 2004 had a maximum of 3,000 uS/cm in June, and a minimum of 2,120 uS/cm in October. Estimated SAR values had a maximum of 6.33 in June, and a minimum of 5.19 in October. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ for tributaries of the Tongue River. The EC values were all in excess of the standard. All but one of the SAR values were in excess of the NTE standard.

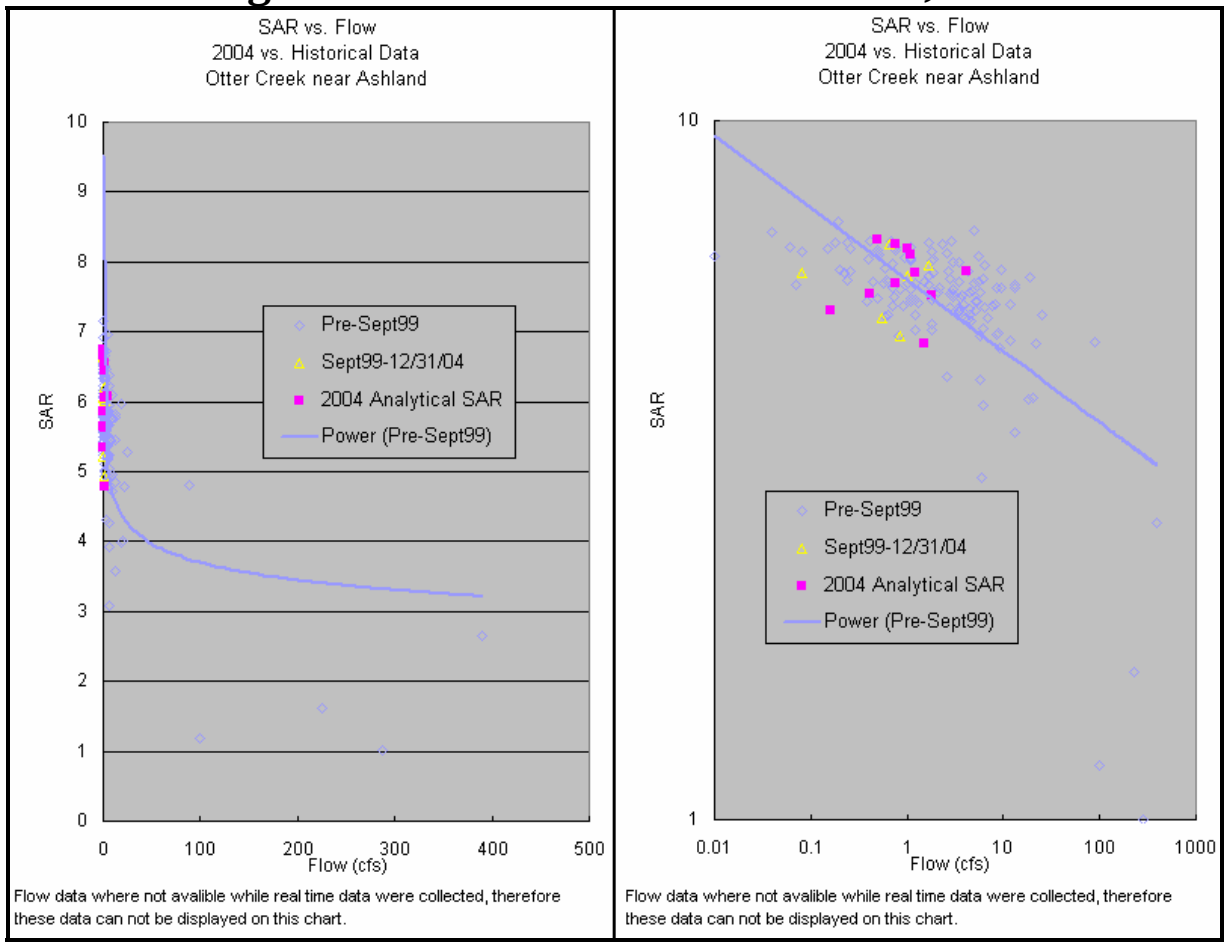
Figure 41: Otter Creek at Ashland, MT



A **B**

Figure 41 shows analytical EC values charted vs. Flow for 2004 for Otter Creek at Ashland, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values are in line with historical values during comparable flows.

Figure 42: Otter Creek at Ashland, MT



A **B**

Figure 38 shows analytical SAR values charted vs. Flow for 2004 for Otter Creek at Ashland, MT. These values are charted on both linier (A) and logarithmic (B) scales. 2004 SAR values are in line with historical values during comparable flows.

Figure 43: Pumpkin Creek near Miles City, MT

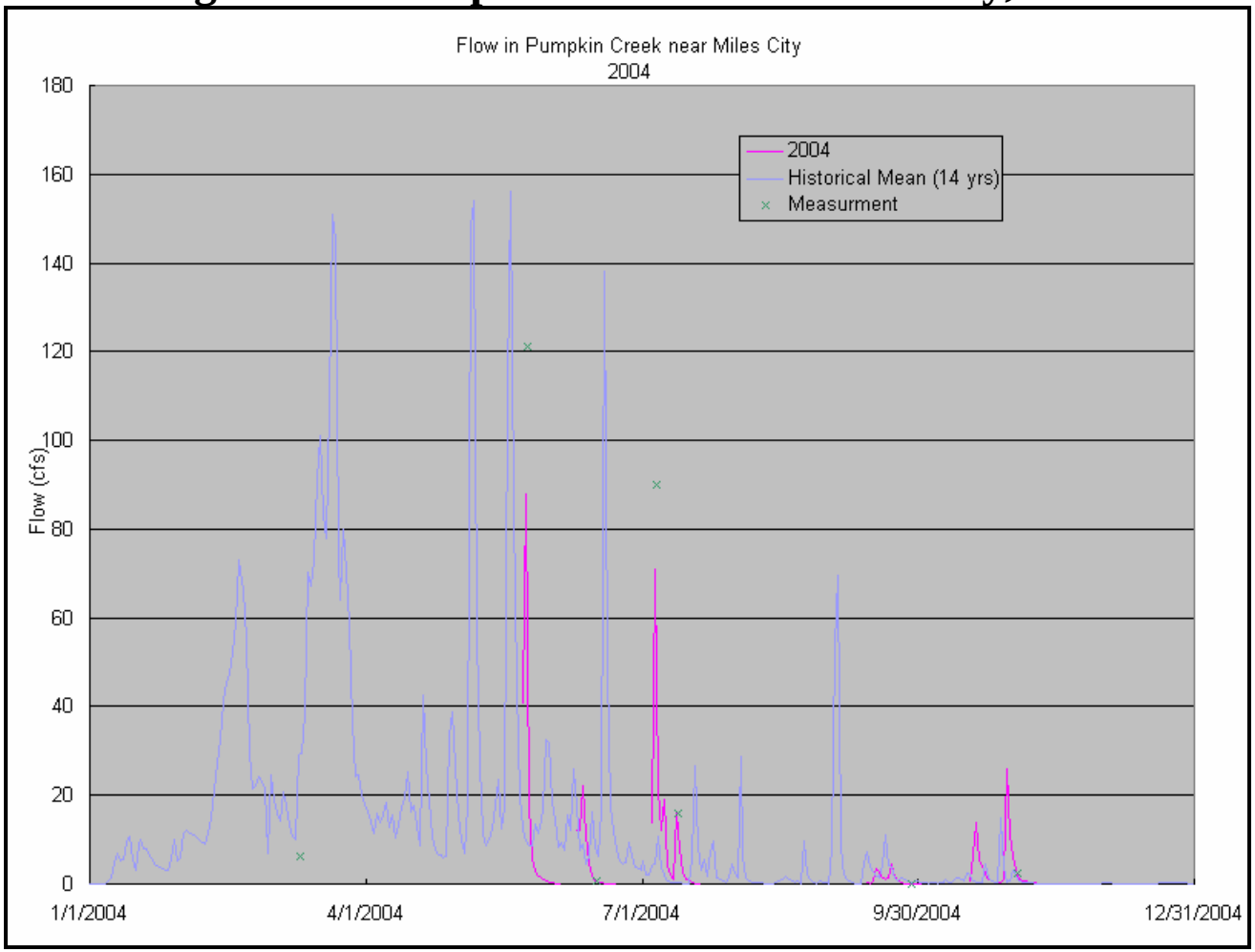
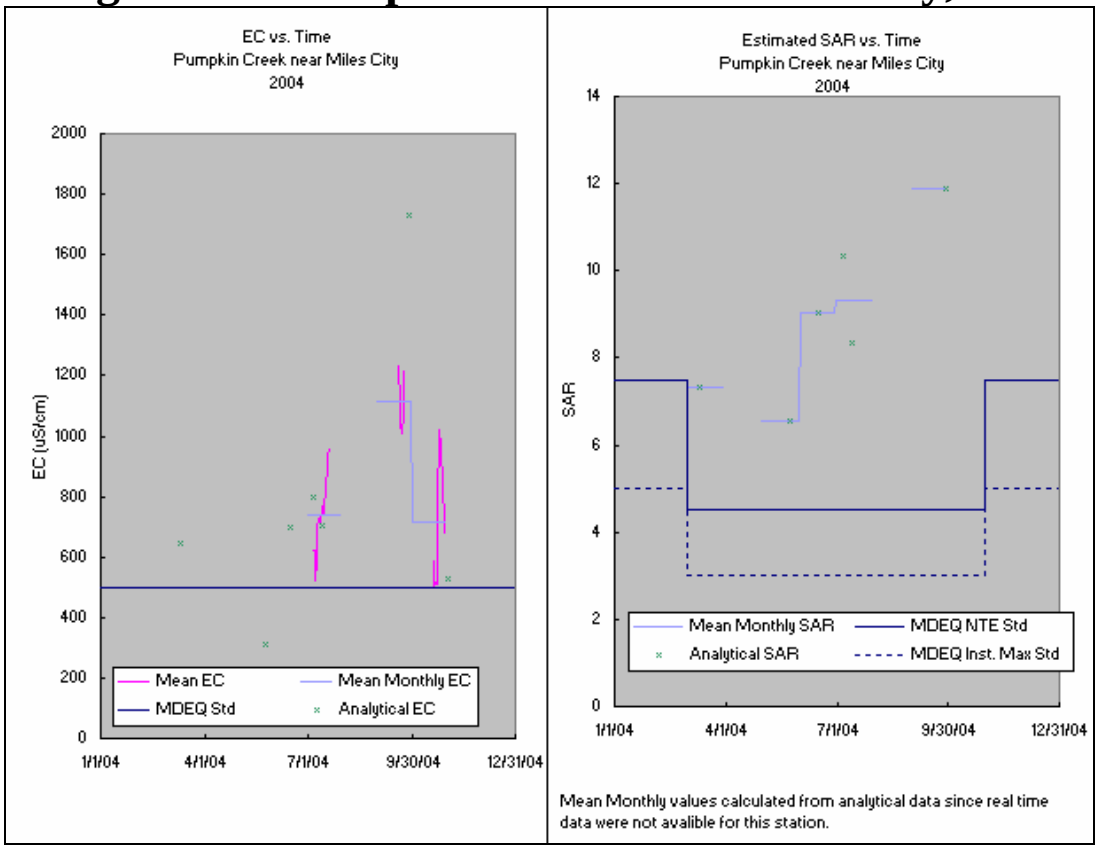


Figure 43 shows real time flow values in a time series plot for2004 for Pumpkin Creek near Miles City, MT, and field measurements of flow. The historical daily mean flow values are also shown. Flow values during 2004 had a maximum of 88 cfs in May, and a minimum of 0 cfs. The flows were generally less then historical values.

Figure 44: Pumpkin Creek near Miles City, MT



A **B**

Figure 44 shows daily mean and analytical EC values (A) and estimated and analytical SAR (B) values in time series plots for2004 for Pumpkin Creek near Miles City, MT. Mean Monthly EC and SAR values are also shown. Mean Monthly values are the simple mean of all values collected during each calendar month. Daily Mean EC values during 2004 had a maximum of 1,230 uS/cm in September, and a minimum of 498 uS/cm in October. Analytical SAR values had a maximum of 11.88 in September, and a minimum of 6.55 in May. These values are compared to the instantaneous maximum and mean monthly standards developed by the MDEQ for tributaries of the Tongue River. Most of the EC values (all but one) were greater than the standard. All of the SAR values were greater than the NTE standard.

Figure 45: Pumpkin Creek near Miles City, MT

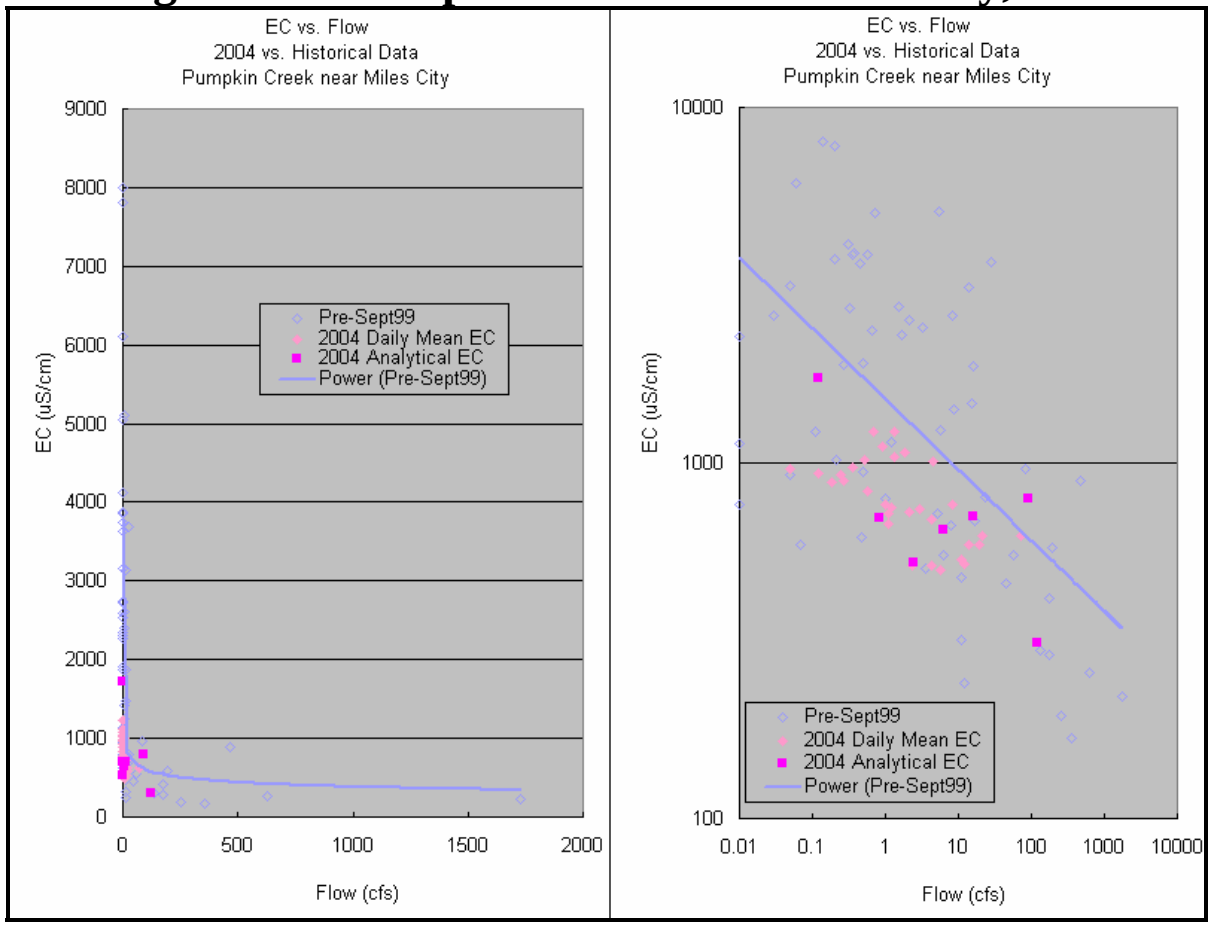
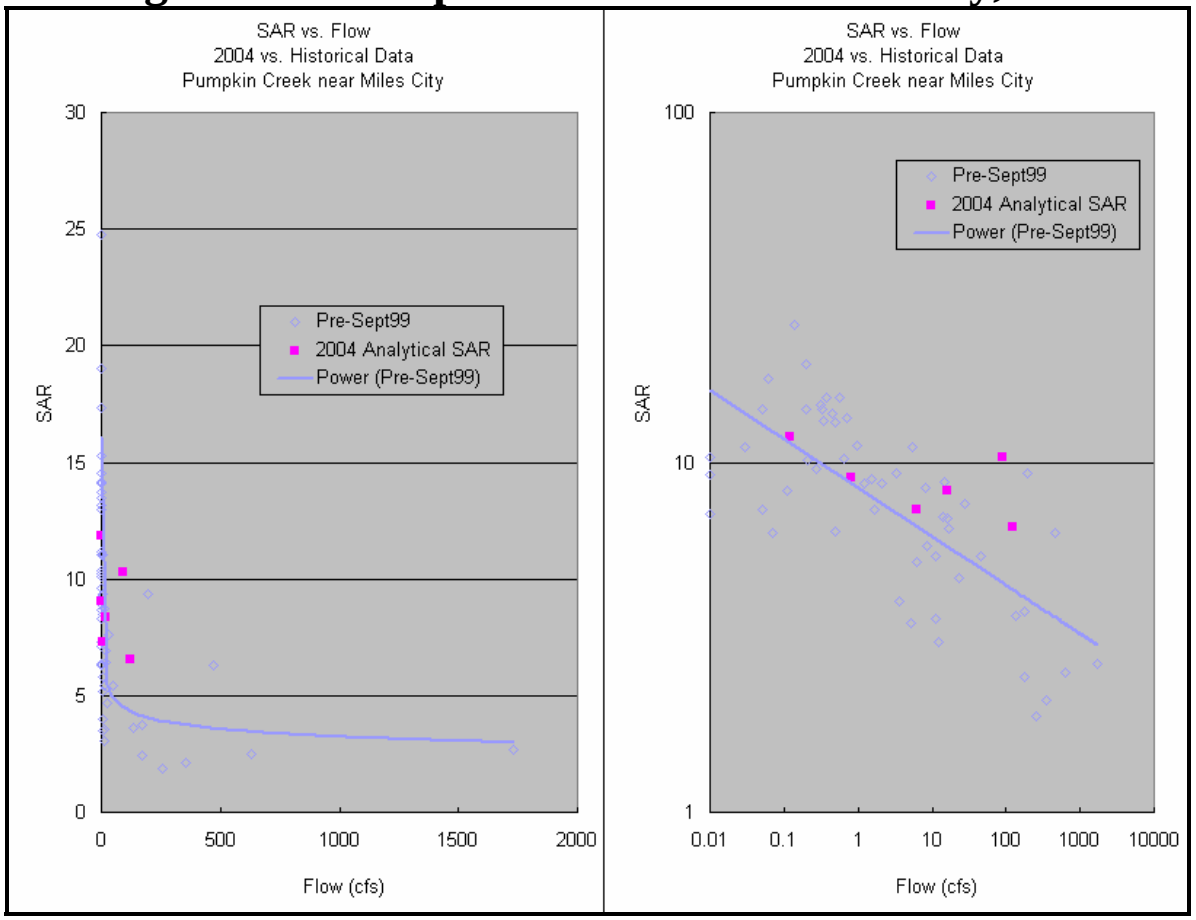


Figure 45 shows daily mean and analytical EC values charted vs. Flow for 2004 for Pumpkin Creek near Miles City, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical EC vs. Flow values are also shown. 2004 EC values are in line with, or slightly less historical values during comparable flows.

Figure 46: Pumpkin Creek near Miles City, MT



A **B**

Figure 46 shows analytical SAR values charted vs. Flow for 2004 for Pumpkin Creek near Miles City, MT. These values are charted on both linier (A) and logarithmic (B) scales. Historical SAR vs. Flow values are also shown. 2004 SAR values are in line with, or slightly greater then, historical values during comparable flows.