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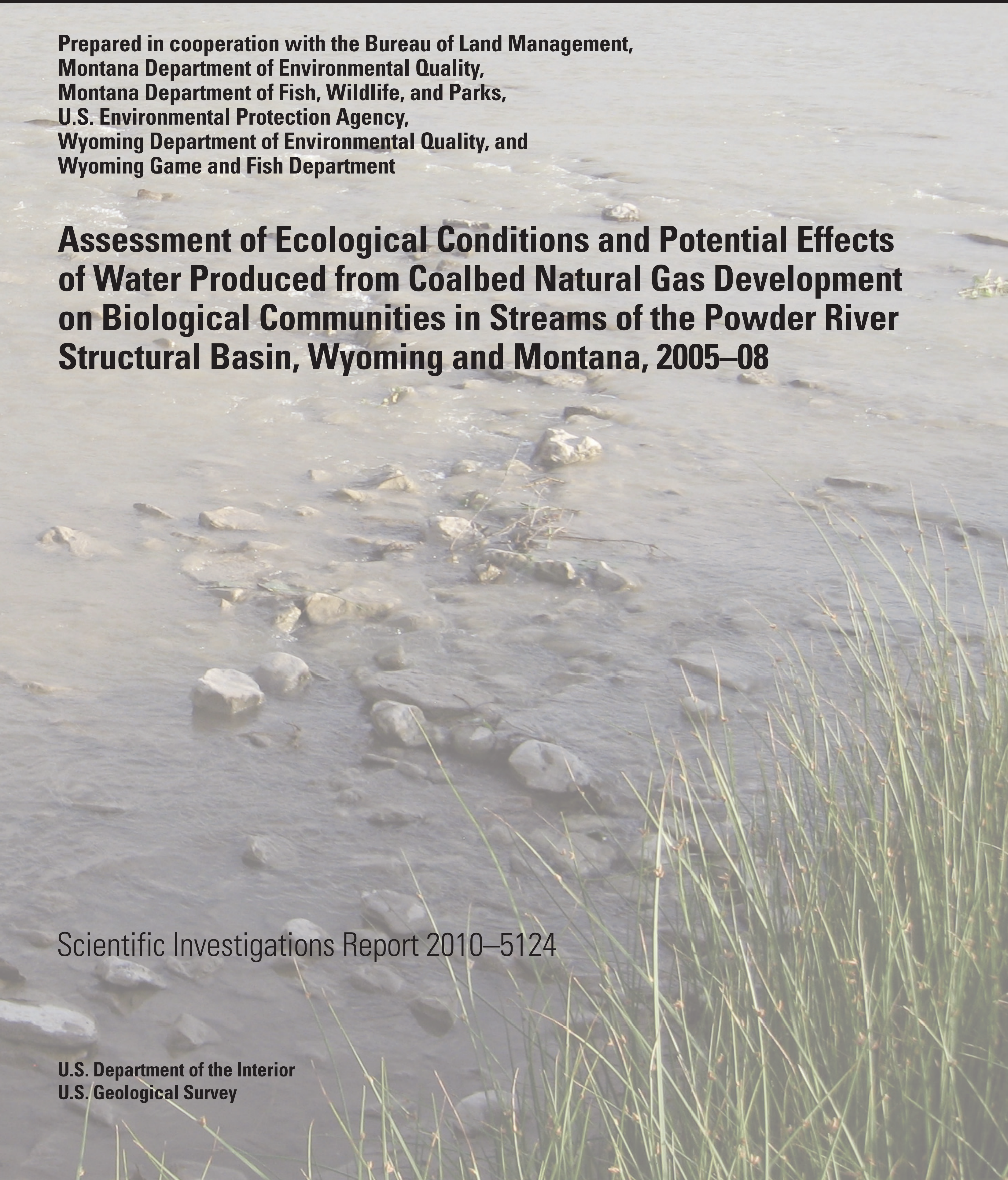

Prepared in cooperation with the Bureau of Land Management, Montana Department of Environmental Quality, Montana Department of Fish, Wildlife, and Parks, U.S. Environmental Protection Agency, Wyoming Department of Environmental Quality, and Wyoming Game and Fish Department

Assessment of Ecological Conditions and Potential Effects of Water Produced from Coalbed Natural Gas Development on Biological Communities in Streams of the Powder River Structural Basin, Wyoming and Montana, 2005–08

Scientific Investigations Report 2010–5124

U.S. Department of the Interior
U.S. Geological Survey

FRONT COVER AND BOTTOM RIGHT ON BACK COVER:
Powder River below Burger Draw, Wyo. (site P4), July 19, 2010.
Photograph by Gregory K. Boughton, U.S. Geological Survey.

BACK COVER, LEFT HALF AND MIDDLE RIGHT:
Powder River near Arvada, Wyo., July 22, 2010.
Photograph by David A. Peterson, U.S. Geological Survey.

Note: The location of Arvada is shown in figure 1. This photograph was not an established sampling site during 2005–08, and is located between sites P8 and P9.

BACK COVER, TOP RIGHT:
Little Powder River above Dry Creek near Weston, Wyo. (site P15), July 6, 2010.
Photograph by Gregory K. Boughton, U.S. Geological Survey.

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U.S. Department of the Interior
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U.S. Department of the Interior
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U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia: 2010

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Contents

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Tables

Conversion Factors and Datums

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
micrometer (µm)	0.00003937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
cubic centimeter per square meter (cm^3/m^2)	0.6566	cubic inch per square foot (in^3/ft^2)
meter per second (m/s)	3.281	foot per second (ft/s)
milligram (mg)	0.00003527	ounce, avoirdupois (oz)
milligram per square meter (mg/m^2)	0.000003278	ounce per square foot (oz/ft^2)
gram per square meter (g/m^2)	0.003278	ounce per square foot (oz/ft^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32.$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Elevation, as used in this report, refers to distance above the vertical datum.

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L). Concentrations of algal constituents are given in milligrams per square meter (mg/m^2), grams per square meters (g/m^2), billion cells per square meter, or cubic centimeters per square meter (cm^3/m^2).

The water year begins October 1 and ends September 30, and is designated by the year in which it ends. For example, water year 2005 begins October 1, 2004, and ends September 30, 2005.

Abbreviations, Initializms, and Acronyms

<	less than
≤	less than or equal to
>	greater than
≥	greater than or equal to
AFDM	ash-free dry mass
ANOVA	analysis of variance
ATG	Aquatic Task Group
BLM	Bureau of Land Management
CBNG	coalbed natural gas
D50	diameter of the 50th percentile (median) of particles
D84	diameter of the 84th percentile of particles
IBI	Index of Biotic Integrity

IWG	Interagency Working Group
MDEQ	Montana Department of Environmental Quality
NMDS	nonmetric multidimensional scaling
p	probability level
PC	principal components
PCA	principal components analysis
PRMS	Powder River main stem
QC	quality control
r	correlation coefficient
TRMT	Tongue River main stem and mountainous tributaries
TRPT	Tongue River plains tributaries
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WDEQ	Wyoming Department of Environmental Quality
WGFD	Wyoming Game and Fish Department

Assessment of Ecological Conditions and Potential Effects of Water Produced from Coalbed Natural Gas Development on Biological Communities in Streams of the Powder River Structural Basin, Wyoming and Montana, 2005–08

By David A. Peterson, Melanie L. Clark, Katharine Foster, Peter R. Wright, and Gregory K. Boughton

Abstract

Ongoing development of coalbed natural gas in the Powder River structural basin in Wyoming and Montana led to formation of an interagency task group to address concerns about the effects of the resulting production water on biological communities in streams of the area. The interagency task group developed a monitoring plan and conducted sampling of macroinvertebrate, algal, and fish communities at 47 sites during 2005–08 to document current ecological conditions and determine existing and potential effects of water produced from coalbed natural gas development on biological communities.

Macroinvertebrate, algal, and fish community composition varied between drainage basins, among sites within drainage basins, and by year. Macroinvertebrate communities of the main-stem Tongue River were characterized by higher taxa richness and higher abundance of Ephemeroptera, for example, compared to macroinvertebrate communities in plains tributaries of the Tongue River and the main-stem Powder River. Fish communities of the Tongue River were characterized by higher taxa richness and abundance of introduced species compared to the Powder River where native species were dominant.

Macroinvertebrate community metric values from sites in the middle reach of the main-stem Powder River, from below Willow Creek to below Crazy Woman Creek, differed from metric values in the upper and lower reaches of the Powder River. Metrics indicative of communitywide differences included measures of taxa richness, relative abundance, feeding mode, and tolerance. Some of the variation in the macroinvertebrate communities could be explained by variation in environmental variables, including physical (turbidity, embeddedness, bed substrate size, and streamflow) and chemical (alkalinity and specific conductance) variables. Of these environmental variables, alkalinity was the best indicator of coalbed natural gas development because of the sodium-bicarbonate signature of the production water.

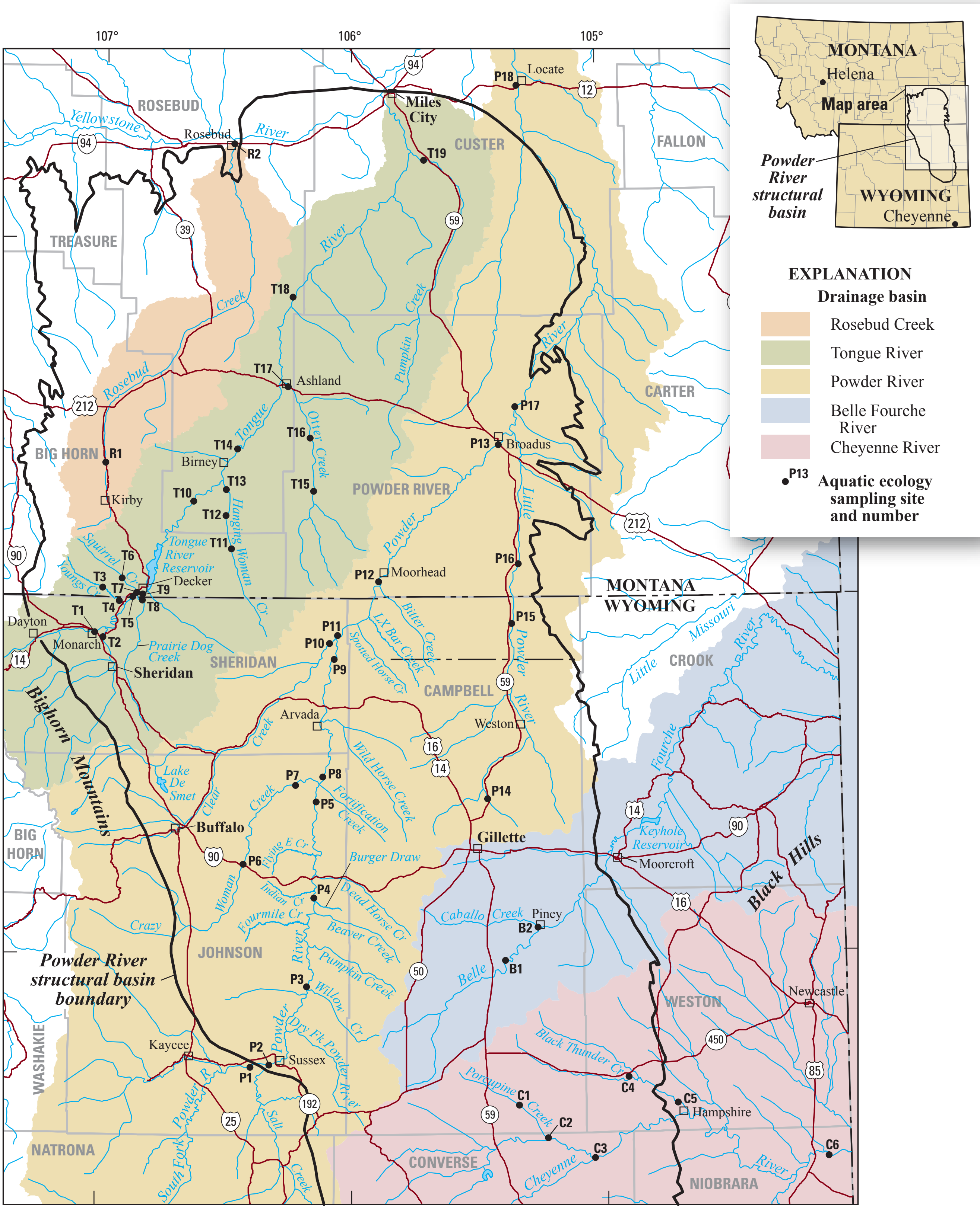
Algal samples from the main-stem Powder River generally confirmed the pattern observed in the macroinvertebrate communities. Algal communities at sites in the middle reach of the Powder River commonly were characterized by dominance by a single taxon and by low biovolume of algae compared to other sites.

In contrast to the macroinvertebrate and algal communities, species richness of fish communities was highest in the middle reach of the Powder River. Although a few significant differences in fish metrics were determined along the main-stem Powder River, the differences did not correspond to the pattern observed for the macroinvertebrate and algae communities.

Differences in biological communities were noted between years, potentially due to the effects of drought. Macroinvertebrate community metrics, such as Diptera taxa richness, were significantly different in the severe drought year of 2006 from metric values in 2005 and 2007–08. Water-quality data collected during the study indicated that, with few exceptions, water-quality constituents generally did not exceed State or Federal acute and chronic criteria for the protection of aquatic life.

Introduction

Development of energy and mineral resources in the Powder River structural basin in northeastern Wyoming and southeastern Montana (fig. 1) includes coalbed natural gas, conventional oil and gas, and coal mining. A common theme of coalbed natural gas (CBNG) development is discharge of groundwater that commonly is saline or unsuitable for irrigation of crops and has unknown effects on the aquatic communities inhabiting streams that receive the water (Bureau of Land Management, 2009).



Base from U.S. Geological Survey digital data, 1999–2004, 1:2,000,000
Roads from Federal Highway Administration digital data, 2002, 1:100,000
Albers Equal-Area Conic projection
Standard parallels 40°N and 60°N, central meridian 106°W

0 20 40 MILES
0 20 40 KILOMETERS

Figure 1. Location of aquatic ecology sampling sites in the Powder River structural basin, Wyoming and Montana, 2005–08.

A total of 44,564 CBNG wells have been permitted in the Wyoming part of the study area as of September 30, 2008, and about one-half (19,172) of those wells were producing water (fig. 2; Wyoming Oil and Gas Conservation Commission, 2010). Comparison of the cumulative production data from 2006 to those from 2008 (fig. 2) indicated that most of the development during 2007–08 occurred in the Powder River and Tongue River drainage basins. For example, cumulative water production in the Powder River drainage in Wyoming during 2008 was more than twice the amount of cumulative water production in 2006.

Substantial CBNG resources also exist in the Montana part of the study area but are largely undeveloped compared to Wyoming. Permit data from the Montana Department of Environmental Quality (MDEQ) (written commun., 2010) indicate cumulative CBNG water production as of October 2008 was about 19,237 acre-feet (acre-ft) from 150 or more wells in the Tongue River drainage basin in Montana. At maximum development in the study area, CBNG wells are expected to number 60,000 in Wyoming and more than 10,000 in Montana (Stricker and others, 2006).

To address concerns about the potential effects of CBNG development on cultural and natural resources, the U.S. Department of the Interior Bureau of Land Management (BLM) formed an Interagency Working Group (IWG) of Federal, State, and tribal agencies. The charter of the IWG states that it "…was established as the forum for government agencies to address, discuss, and find solutions to issues of common concern to all parties involved in permitting and monitoring of CBNG development" (Powder River Natural Gas Interagency Working Group, 2004). The IWG charter also provides for establishment of working groups to address technical issues as envisioned by the April 2003 Record of Decision (Bureau of Land Management, 2003). One working group, the Aquatic Task Group (ATG), was tasked with assessing potential effects of CBNG produced water on aquatic ecological resources. Agencies involved in the ATG include the BLM, the Wyoming Department of Environmental Quality (WDEQ), MDEQ, the Wyoming Game and Fish Department, the Montana Department of Fish, Wildlife, and Parks, and the U.S. Environmental Protection Agency (USEPA).

The ATG developed a monitoring plan to meet two main objectives: (1) establish current ecological conditions for aquatic biota and their habitat and (2) determine existing and potential effects of CBNG produced water on aquatic life (Bureau of Land Management, 2009). The assessment of current ecological conditions as of 2005–08 was performed by the U.S. Geological Survey (USGS) under the direction of the ATG. The determination of effects from CBNG-produced water is addressed in part by the current conditions data assessment, as well as by studies of potential effects of CBNG water on fish communities in the study area (Davis, 2008; Skaar and others, 2006) and a literature review of the effects of CBNG activities on fish communities (Davis and others, 2009). Additional information about CBNG development and monitoring is available from the BLM at *http://www.wy.blm.gov/prbgroup/*; the WDEQ at *http://deq.state.wy.us/wqd/WYPDES_Permitting/WYPDES_cbm/cbm.asp*; and the USGS at *http://wy.water.usgs.gov/*.

Purpose and Scope

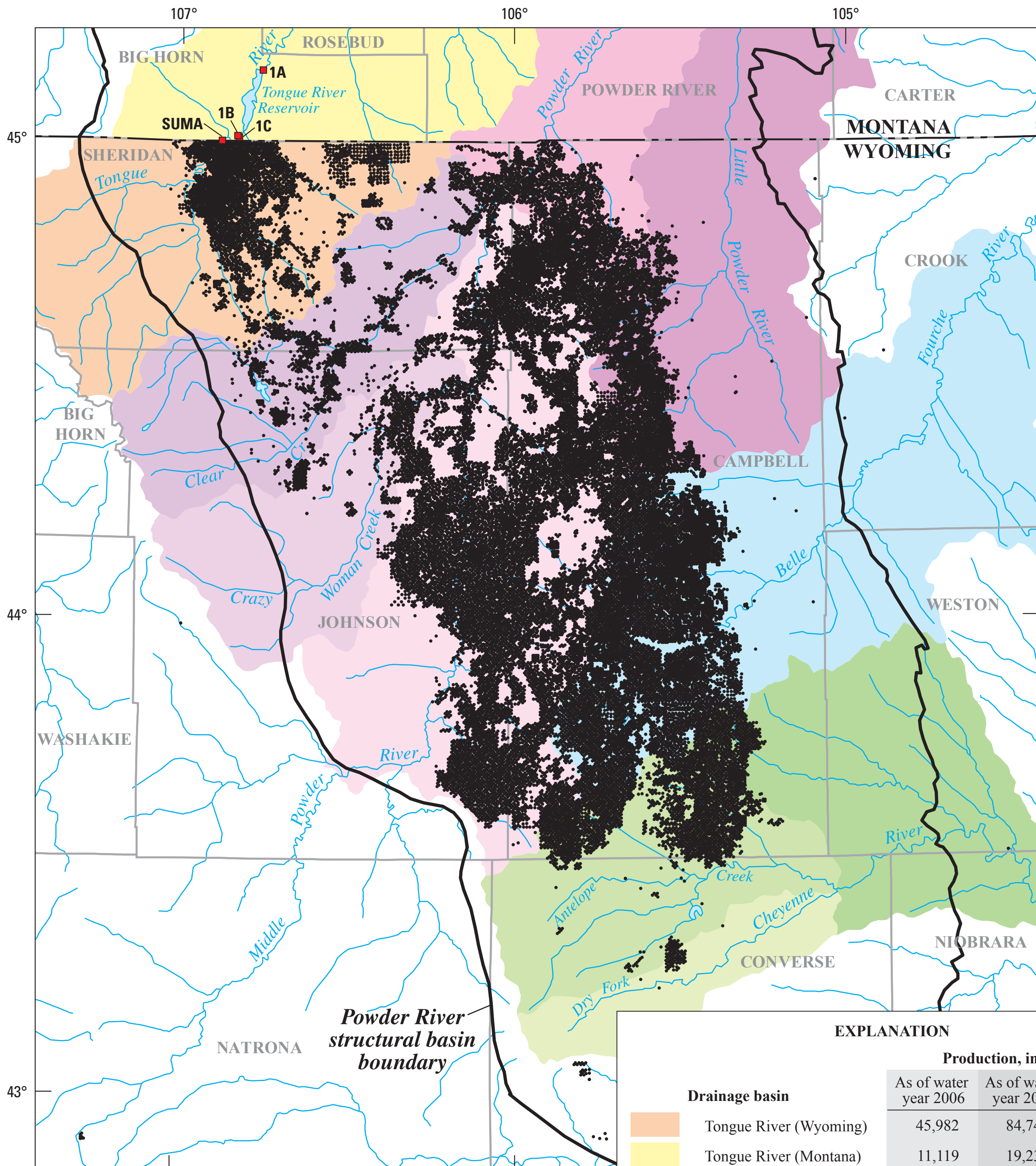
This report is a companion report to Peterson and others (2009) that was prepared in cooperation with the ATG and that described conditions for biological communities (macroinvertebrates, algae, and fish) for 2005–06 at 47 sites (fig. 1; table 1). Data collection continued in 2007–08 at these same 47 sites and included environmental variables (water quality and habitat) and biological communities (macroinvertebrate and algae sampling in 2007 and macroinvertebrate and fish sampling in 2008), but the 2007–08 data had not been published previous to this report. The types of samples and number of sites sampled varied annually due to drought and program constraints.

The purpose of this report is to (1) assess the current (2005–08) ecological conditions for environmental variables and biological communities, using new data from 2007–08 in conjunction with previously published data from 2005–06, and (2) describe potential effects of natural and anthropogenic environmental variables, including CBNG-produced water, on biological communities to the extent possible from the current conditions data.

For the sake of brevity, some of the previously published material (Peterson and others, 2009) is either omitted from this report or summarized and referenced. For example, the methods of sample collection and analysis in 2007–08 were the same as those used in 2005–06; therefore, descriptions of some collection or analytical methods that were previously published in Peterson and others (2009) are omitted from this report. Additional information about the description of the study area, reachwide habitat data from 2005, macroinvertebrate models from 2005–06, and seasonal fish community data from 2004–06 may be found in Peterson and others (2009).

Methods of Data Analysis

Biological community metrics were calculated using procedures and attributes described by Cuffney (2003) for macroinvertebrates, Porter (2008) for algae, and Bramblett and others (2005) for fish. Macroinvertebrate tolerance scores (Hilsenhoff, 1987; Cuffney, 2003) were assigned to one of three ranges: intolerant, greater than or equal to ($\geq$) 0 to less than or equal to ($\leq$) 4; moderately tolerant, greater than (>) 4 to less than (<) 7; and tolerant, $\geq$7 to $\leq$10. Statistical comparisons of macroinvertebrate and fish community metrics were performed in S+ (TIBCO Software Inc., 2008) at a probability level (p) of 0.05. Following procedures described by Helsel and Hirsch (2002), Kruskal-Wallis rank sum tests were used to test for significant differences in metrics between sites and between years, and metrics identified as containing significant differences were then subjected to further evaluation using analysis of variance (ANOVA) and Tukey's test for multiple comparisons on rank-transformed data.



EXPLANATION

Drainage basin	Production, in acre-feet: As of water year 2006	As of water year 2008	Difference
Tongue River (Wyoming)	45,982	84,743	38,761
Tongue River (Montana)	11,119	19,237	8,118
Upper Powder River	125,548	270,376	144,828
Crazy Woman Creek	375	2,134	1,759
Clear Creek	5,469	10,005	4,536
Middle Powder River	23,148	45,369	22,221
Little Powder River	67,419	88,504	21,085
Dry Fork Cheyenne	504	1,447	943
Antelope Creek	22,255	30,579	8,324
Upper Cheyenne River	28,606	31,333	2,727
Upper Belle Fourche River	178,941	203,443	24,502
Total	**509,366**	**787,169**	**277,803**

• Coalbed natural gas well

1C Combined well outfall point and identification code

Base from U.S. Geological Survey digital data, 1999–2004, 1:2,000,000
Albers Equal-Area Conic projection
Standard parallels 40°N and 60°N, central meridian 106°W
North American Datum of 1983 (NAD 83)

0 10 20 30 40 MILES

0 10 20 30 40 KILOMETERS

Figure 2. Cumulative water production as of September 30, 2008, from coalbed natural gas wells in the Powder River structural basin, Wyoming and Montana.

Table 1. Ecological sampling sites on streams in the Powder River structural basin, Wyoming and Montana, 2005–08.

[Shaded cells indicate main-stem sampling sites on the Tongue or Powder River. DMS, degrees, minutes, seconds; km^2, square kilometers; m, meters; P, plains; M, mountains]

Site number (fig. 1)	U.S. Geological Survey site identification number	Site name	Abbreviated site name	Latitude (DMS)	Longitude (DMS)	Drainage area (km^2)	Elevation (m)	Stream head-waters	Reach length (m)
R1	06295113	Rosebud Creek at reservation boundary, near Kirby, MT	Upper Rosebud Creek	45 21 40	106 59 23	319	1,152	P	200
R2	06296003	Rosebud Creek at mouth, near Rosebud, MT	Rosebud Creek at mouth	46 15 53	106 28 30	3,372	756	P	200
T1	06299980	Tongue River at Monarch, WY	Tongue River at Monarch	44 54 01	107 01 13	1,238	1,103	M	970
T2	06305700	Goose Creek near Acme, WY	Goose Creek	44 53 11	106 59 18	1,070	1,103	M	640
T3	450137106595101	Youngs Creek near reservation boundary, near Decker, MT	Upper Youngs Creek	45 01 37	106 59 15	56	1,155	P	200
T4	445832106551401	Youngs Creek above mouth, near Decker, MT	Youngs Creek at mouth	44 58 32	106 55 14	161	1,088	P	200
T5	445957106524701	Tongue River below Youngs Creek, near Decker, MT	Tongue River below Youngs Creek	44 59 57	106 52 47	3,711	1,058	M	1,000
T6	06306100	Squirrel Creek near Decker, MT	Upper Squirrel Creek	45 03 02	106 55 24	87	1,122	P	200
T7	450047106514201	Squirrel Creek above mouth at Decker, MT	Squirrel Creek at mouth	45 00 47	106 51 42	112	972	P	200
T8	06306250	Prairie Dog Creek near Acme, WY	Prairie Dog Creek	44 59 02	106 50 21	927	1,052	P	170
T9	06306300	Tongue River at State line, near Decker, MT	Tongue River at State line	45 00 32	106 50 08	3,763	1,045	M	1,000
T10	451607106372801	Tongue River at Prairie Dog Creek, near Decker, MT	Tongue River above Hanging Woman Creek	45 16 07	106 37 28	5,208	890	M	1,000
T11	06307570	Hanging Woman Creek below Horse Creek, near Birney, MT	Upper Hanging Woman Creek	45 08 04	106 29 04	831	954	P	200
T12	451340106295501	Hanging Woman Creek below Hay Gulch, near Birney, MT	Middle Hanging Woman Creek	45 13 44	106 29 57	958	997	P	200
T13	06307600	Hanging Woman Creek near Birney, MT	Hanging Woman Creek at mouth	45 17 57	106 30 28	1,217	960	P	200
T14	06307616	Tongue River at Birney Day School Bridge, near Birney, MT	Tongue River at Birney Day School	45 24 42	106 27 26	6,788	933	M	1,000
T15	451732106085001	Otter Creek below Taylor Creek, near Otter, MT	Upper Otter Creek	45 17 32	106 08 53	803	991	P	200
T16	452642106091201	Otter Creek below Tenmile Creek, near Ashland, MT	Middle Otter Creek	45 26 42	106 09 12	1,331	945	P	200
T17	06307740	Otter Creek at Ashland, MT	Otter Creek at mouth	45 35 18	106 15 17	1,831	889	P	200
T18	06307830	Tongue River below Brandenberg Bridge, near Ashland, MT	Tongue River below Brandenberg Bridge	45 50 23	106 13 09	10,225	841	M	1,000
T19	06308400	Pumpkin Creek near Miles City, MT	Pumpkin Creek	46 13 42	105 41 24	1,805	759	P	200
P1	434056106244101	Powder River above Lone Tree Draw, near Sussex, WY	Powder River above Salt Creek	43 40 56	106 24 41	5,828	1,350	P	[1]3,218
P2	434124106192401	Powder River below Salt Creek, near Sussex, WY	Powder River below Salt Creek	43 41 24	106 19 24	7,980	1,338	P	[1]3,218
P3	435453106104701	Powder River below Willow Creek, near Sussex, WY	Powder River below Willow Creek	43 54 53	106 10 47	9,808	1,311	P	[1]3,218
P4	440919106091401	Powder River above Van Houghton Draw, near Buffalo, WY	Powder River below Burger Draw	44 09 19	106 09 14	11,111	1,216	P	[1]3,218
P5	442538106082001	Powder River below Mitchell Draw, near Arvada, WY	Powder River above Crazy Woman Creek	44 25 38	106 08 20	12,564	1,152	P	[1]3,218
P6	441532106251301	Crazy Woman Creek below I-90, near Buffalo, WY	Crazy Woman Creek below I-90	44 15 32	106 25 13	1,769	1,280	M	340
P7	442817106133001	Crazy Woman Creek near Upper Station, near Arvada, WY	Crazy Woman Creek near mouth	44 28 17	106 13 30	2,385	1,167	M	490
P8	443025106061601	Powder River below Crazy Woman Creek, near Arvada, WY	Powder River below Crazy Woman Creek	44 30 25	106 06 16	15,286	1,134	P	[1]3,218
P9	444857106030401	Powder River above Ivy Creek, near Arvada, WY	Powder River above Clear Creek	44 48 57	106 03 04	17,050	1,062	P	[1]3,218
P10	06324000	Clear Creek near Arvada, WY	Clear Creek	44 52 18	106 04 56	2,875	1,069	M	750
P11	445339106032501	Powder River below Clear Creek, near Arvada, WY	Powder River below Clear Creek	44 53 39	106 03 25	20,106	1,059	P	[1]3,218
P12	06324500	Powder River at Moorhead, MT	Powder River at Moorhead	45 03 28	105 52 39	20,943	1,021	P	[1]3,218
P13	06324710	Powder River at Broadus, MT	Powder River at Broadus	45 25 37	105 24 05	22,657	919	P	[1]3,218
P14	06324790	Little Powder River at State Hwy 59, near Gillette, WY	Little Powder River at Highway 59	44 26 09	105 27 17	110	1,250	P	200
P15	06324970	Little Powder River above Dry Creek, near Weston, WY	Little Powder River above Dry Creek	44 55 37	105 21 10	3,204	1,039	P	240
P16	06325000	Little Powder River at Biddle, MT	Little Powder River at Biddle	45 06 17	105 19 51	3,991	991	P	200
P17	453209105201201	Powder River below Little Powder River, near Broadus, MT	Powder River below Little Powder River	45 32 09	105 20 12	29,503	908	P	[1]3,218
P18	06326500	Powder River near Locate, MT	Powder River near Locate	46 25 48	105 18 34	33,846	727	P	[1]3,218
C1	06364300	Porcupine Creek near Teckla, WY	Porcupine Creek	43 34 41	105 20 19	204	1,428	P	200
C2	06364700	Antelope Creek near Teckla, WY	Antelope Creek	43 29 08	105 13 39	2,484	1,366	P	280
C3	06365900	Cheyenne River near Dull Center, WY	Cheyenne River near Dull Center	43 25 45	105 02 43	3,955	1,314	P	320
C4	06375600	Little Thunder Creek near Hampshire, WY	Little Thunder Creek	43 39 20	104 54 20	606	1,341	P	200
C5	06376300	Black Thunder Creek near Hampshire, WY	Black Thunder Creek	43 34 54	104 43 11	1,386	1,244	P	200
C6	06386500	Cheyenne River near Spencer, WY	Cheyenne River near Spencer	43 25 20	104 07 36	13,649	1,105	P	220
B1	06425720	Belle Fourche River below Rattlesnake Creek, near Piney, WY	Belle Fourche River	43 59 04	105 23 16	1,282	1,384	P	200
B2	06425900	Caballo Creek at mouth, near Piney, WY	Caballo Creek	44 04 48	105 15 59	673	1,335	P	200

[1]Established reach length of 3,218 meters is maximum reach length; the actual reach length varied with each site visit depending on location of random starting point and availability of expected habitat types.

Nonmetric multidimensional scaling (NMDS) ordinations of macroinvertebrate and algal community taxonomic data were prepared in PRIMER (Clarke and Gorley, 2006). Macroinvertebrate and algal abundance data were log transformed (log $x + 1$) to approximate normality. Bray-Curtis similarity coefficients (Bray and Curtis, 1957) were computed to determine taxonomic (dis-)similarity among samples. NMDS ordinations of the Bray-Curtis similarity coefficients were used to determine relations among sites on the basis of the taxonomic composition of the communities.

Macroinvertebrate community data from samples collected in riffles were tested for relations with environmental variables using principal components analysis (PCA) and the BEST routine (Clarke and Gorley, 2006). Environmental data were log transformed (log $x + 1$) and standardized prior to running PCA to identify the most important variables distinguishing the sites (highest eigenvectors) and to identify and remove collinear (highly correlated) variables. The environmental variables selected through PCA were tested for correlation with the taxonomic composition of the macroinvertebrate communities using the BEST routine in PRIMER (Clarke and Gorley, 2006). The BEST routine tests multiple combinations of the environmental variables against the Bray-Curtis similarity coefficients of the macroinvertebrate communities to determine the highest Spearman correlation coefficients (r) using five or fewer environmental variables.

Data for major ions were either collected at the time of biological sampling or, in the case of sites that are sampled within the water-quality monitoring network, were the most recently collected samples (usually within 30 days prior) at each site. Missing values for turbidity or dissolved oxygen (less than 5 percent of total observations) were estimated for the statistical analyses from average values at the site or nearby sites on the same stream.

Quality Assurance

Quality assurance for analyses of major ions, chlorophyll, and ash-free dry mass (AFDM) included collection and analysis of quality-control (QC) samples from selected sites. The relative percent difference (RPD) in constituent concentrations between the environmental (sample 1) and the QC (sample 2) samples was calculated using the formula:

$$\text{RPD} = \text{absolute value } ((\text{sample } 1 - \text{sample } 2)/ [(\text{sample } 1 + \text{sample } 2)/2]) \times 100$$

The RPD for major ions in six pairs of environmental and QC samples was less than 5 percent, on the average. The RPD for chlorophyll and AFDM in four pairs of samples was less than 15 percent, on the average.

Quality assurance for the biological taxonomic analyses also included collection and analysis of QC samples for macroinvertebrates and algae. The taxonomic data do not lend themselves to conventional QC analyses such as RPD; therefore, the taxonomic QC samples were compared to the parent samples using Bray-Curtis similarity coefficients. The similarity coefficients of the macroinvertebrate and algae QC samples ranged from 46 to 83 percent (table 2), on a scale from 0 (no similarity) to 100 percent (complete similarity). The similarity coefficients between the parent and QC samples were higher than similarities with other environmental samples as shown in ordinations of the 2007–08 data in the following sections “Macroinvertebrate Community Composition” and “Composition” under the “Algal Communities” section and ordinations of the 2005–06 data (Peterson and others, 2009, their figs. 20 and 31).

Quality assurance for fish taxonomy was provided through voucher specimens and photographic vouchers collected as per the fish taxonomy quality-assurance plan (Walsh and Meador, 1998). Voucher specimens were sent to Dr. Robert Bramblett at Montana State University, Bozeman, Montana, for taxonomic confirmation and then sent to the Museum of Southwestern Biology at the University of New Mexico, Albuquerque, New Mexico, for curation.

Assessment of Ecological Conditions

This section of the report describes the assessment of current (2005–08) ecological conditions, including water quality, habitat, macroinvertebrate communities, algal communities, and fish communities, for streams in the Powder River structural basin. A description of the hydrology of the Powder River structural basin also is included.

Hydrology

Streamflow data were collected for the sites listed in table 1 during 2005–08 and are available from *http://waterdata.usgs.gov/wy/nwis/sw*. Streams with mountainous headwaters (table 1), such as the Tongue River, Goose Creek, and Clear Creek, tended to have perennial flow during 2005–08, whereas streams with plains headwaters, such as those in the Cheyenne and Belle Fourche River drainage basins and the upper parts of Otter Creek and Hanging Woman Creek (Tongue River drainage basin), tended to have ephemeral or intermittent streamflow. Mean values of instantaneous streamflow at the time of ecological sampling during 2005–08 from sites on the main-stem Tongue River indicated streamflow was less upstream from Tongue River Reservoir (sites T1, T5, and T9; fig. 3*A*) than downstream (sites T10, T14, and T18). Mean values of instantaneous streamflow

Table 2. Biological quality-control samples, Powder River structural basin, Wyoming and Montana, 2005–08.

Site number (fig. 1)	Abbreviated site name	Sample date	Sample type	Quality control type	Bray-Curtis similarity (percent)
T1	Tongue River at Monarch	8/15/2005	Macroinvertebrate	Replicate	61
T1	Tongue River at Monarch	8/15/2005	Algae	Replicate	51
T3	Upper Youngs Creek	6/26/2008	Macroinvertebrate	Split	54
T7	Squirrel Creek at mouth	7/12/2007	Macroinvertebrate	Replicate	58
T17	Otter Creek at mouth	6/19/2007	Algae	Replicate	46
P6	Crazy Woman Creek below I-90	7/11/2005	Macroinvertebrate	Replicate	70
P7	Crazy Woman Creek near mouth	7/12/2005	Algae	Replicate	61
P9	Powder River above Clear Creek	7/29/2008	Macroinvertebrate	Replicate	62
C4	Little Thunder Creek	6/13/2007	Algae	Split	83
B2	Caballo Creek	6/28/2005	Algae	Replicate	67

from sites on the main-stem Powder River indicated more flow within the vicinity of Clear Creek near Arvada, Wyo. (sites P9 and P11) to Moorhead, Mont. (site P12) than at reaches farther upstream or downstream (fig. 3*B*).

Throughout most of the study area, daily streamflow in the study area during 2007–08 tended to be near or above the long-term average values, in contrast to below-average values in 2005–06 (*http://waterdata.usgs.gov/wy/nwis/sw/*). Drought conditions prevailed in the study area during 2005–06 and for several years preceding the study (National Oceanic and Atmospheric Administration Satellite and Information Service, 2005). Instantaneous values of streamflow at the time of ecological sampling (table 3) indicated substantially less streamflow in 2006 than in 2005 or 2007–08 (figs. 3*C* and 3*D*). During the summer of 2006, some of the sampling sites on the main-stem Powder River (such as sites P8, P9, P12, and P17) did not have flow, with only isolated pools present to sample. Historically, infrequent days of no flow have been documented on the Powder River from Arvada, Wyo., to Moorhead, Mont. (Ringen and Daddow, 1990), which includes sites P9, P11, and P12 (fig. 1) and which may be inherent to the reach under natural conditions.

Water Quality

Water-quality data (*http://waterdata.usgs.gov/wy/nwis/qw*) that were collected during water years 2005–08 as part of ATG sampling events, as well as data for samples collected at ATG study sites that are part of other USGS monitoring efforts, were compiled for 47 study sites in the five major drainage basins of Rosebud Creek, Tongue River, Powder River, Cheyenne River, and Belle Fourche River. The water year 2005–08 data were compared to applicable State or Federal aquatic-life criteria for selected water-quality constituents and are statistically summarized in the Appendix. A subset, consisting of water-quality data collected during ecological sampling events on the Tongue River and Powder River, was used to describe how conditions varied on the two large main-stem rivers during relatively low-flow conditions of summer.

Water-Quality Characteristics

Water-quality characteristics of streams in the Powder River structural basin are variable largely because of streamflow and geology (Clark and Mason, 2007). The Tongue River drainage basin has its headwaters in the Bighorn Mountains, which are characterized by relatively high precipitation, low evaporation, and resistant igneous, metamorphic, and Paleozoic-era sedimentary rocks (Clark and Mason, 2007). In contrast, the Powder River drainage basin has a large part of its headwaters in the plains, which are characterized by relatively low precipitation, high evaporation, and soluble Tertiary-age sedimentary rocks (Clark and Mason, 2007). Different basin characteristics of the Tongue River and Powder River are reflected in the range of mean values for specific conductance, dissolved sodium, and alkalinity for ATG sampling events during the relatively low flow conditions of summer (fig. 4; table 3). Specific conductance, dissolved sodium, and alkalinity are general indicators of water-quality characteristics and also have been identified as constituents of concern for CBNG discharges because their concentrations in produced water can be large (Rice and others, 2000).

Mean specific conductance values at the time of ecological sampling for the Tongue River (456 to 756 microsiemens per centimeter at 25 degrees Celsius [µS/cm]) were small compared to the Powder River (1,970 to 4,750 µS/cm) (fig. 4). Mean specific conductance values for the Tongue River increased from Monarch, Wyo. (site T1) to the State line near Decker, Mont. (site T9), with a decrease downstream from Tongue River Reservoir (site T10) followed by another increase downstream to below Otter Creek (site T18). Mean sodium and alkalinity values on the Tongue River generally had a similar spatial pattern as specific conductance, with the largest concentrations at site T9. Potential anthropogenic influences to water quality of the Tongue River between sites T1 and T9 include CBNG produced water, irrigation return flows and diversions, treated wastewater effluent, and municipal stormwater runoff.

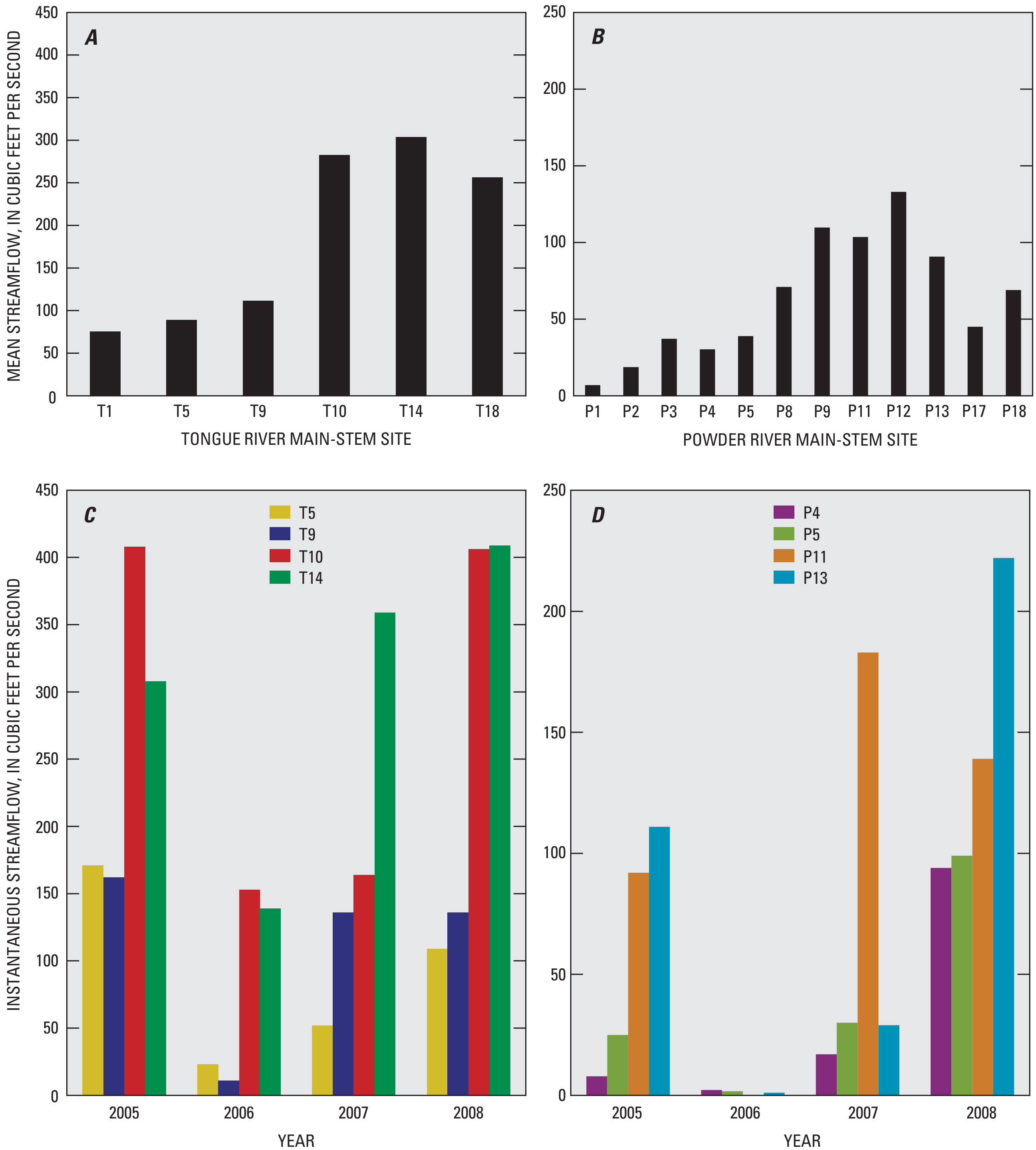


Figure 3. Streamflow at the time of ecological sampling—Mean streamflow values from 2005 to 2008 for sites on (*A*) main-stem Tongue River, and (*B*) main-stem Powder River; instantaneous streamflow values for selected sites on (*C*) main-stem Tongue River, and (*D*) main-stem Powder River, Wyoming and Montana.

Mean specific conductance for the Powder River nearly doubled between sites P1 and P2 (fig. 4) near Sussex, Wyo., as a result of inputs from Salt Creek. No CBNG discharges occur upstream from sites P1 and P2 (Wyoming Department of Environmental Quality, written commun., 2010). The water quality in this reach of the Powder River is affected by produced water from conventional oil and gas production in the Salt Creek drainage basin (Clark and Mason, 2007). The influence of Salt Creek on the Powder River was particularly evident in mean dissolved sodium concentrations, which increased downstream from 284 to 797 milligrams per liter (mg/L) between sites P1 and P2. The influence of Salt Creek becomes less pronounced downstream, however, as indicated by a decrease in mean specific conductance and sodium concentrations downstream from Salt Creek (site P2) to site P11 downstream from Clear Creek. The decreases are likely due to the effects of dilution by increased streamflow. Among all sites, mean specific conductance and dissolved sodium concentrations were lower for the Powder River from Clear Creek near Arvada, Wyo., (site P9) to Moorhead, Mont. (site P12) than those for site P1, which is on the Powder River upstream from CBNG development. An increase in mean dissolved sodium concentrations was observed between Moorhead (site P12) and Broadus, Mont. (site P13). No CBNG discharges occur between sites P12 and P13 (Montana Department of Environmental Quality, written commun., 2010) and thus are not associated with the increase in specific conductance in this reach. The spatial pattern for alkalinity is different than the patterns for specific conductance and sodium. The largest mean value for alkalinity of 583 mg/L (as calcium carbonate) was for the Powder River below Burger Draw (site P4), which receives CBNG discharges from several drainages upstream. This value is about three times larger than the mean concentration calculated for the rest of the Powder River sites. Overall, mean values of alkalinity for the Powder River were less variable when compared to mean values of specific conductance and dissolved sodium concentrations, with the exception of site P4.

Comparisons to Aquatic-Life Criteria

The State of Wyoming (Wyoming Department of Environmental Quality, 2007), State of Montana (Montana Department of Environmental Quality, 2008), and USEPA (U.S. Environmental Protection Agency, 2005) have established chronic and acute criteria for the protection of aquatic life (table 4). Aquatic life includes fish, invertebrates, amphibians, and other organisms that inhabit streams at some stage in their life cycles. Acute criteria are based on a 1-hour average concentration, not to be exceeded more than once every 3 years. Chronic criteria are based on a 4-day average concentration, not to be exceeded more than once every 3 years. For this report, constituent concentrations were compared to Wyoming numeric criteria for sites that are physically located in Wyoming and to Montana criteria for sites that are physically located in Montana. The State of Wyoming aquatic-life criteria for trace elements generally are based on dissolved concentrations in contrast to the State of Montana aquatic-life criteria that generally are based on "total recoverable" (referred to as "total" in this report) concentrations. Total concentrations occur in water at higher concentrations than dissolved concentrations because total concentrations include particulate or colloidal phases of the constituent in addition to the dissolved phase. Montana ATG study sites may appear to have poorer water quality, therefore, compared to Wyoming ATG study sites because more Montana samples had concentrations that exceeded aquatic-life standards. Because dissolved and total concentrations can vary substantially for some trace elements, constituent concentrations for both States also were compared to the USEPA national recommended aquatic-life criteria for reference. Criteria for the protection of human health were not evaluated because the focus of this report is on aquatic life.

Some of the trace-element constituents that were analyzed in water-quality samples are classified as "priority pollutants," which are constituents that require water-quality criteria to be established by the USEPA, based on section 307 of the Federal Clean Water Act (table 4). For some constituents (arsenic, chromium [VI], mercury, and selenium), the toxicity threshold for acute and chronic values is the same for all waters. For other constituents (cadmium, chromium [III], lead, nickel, and zinc), the toxicity is hardness-dependent; therefore, sample-specific criteria were calculated for comparison. Values listed for these constituents (table 4) are for example only and are based on a hardness value of 100 mg/L (as calcium carbonate). The number of exceedances and sites described in this report for hardness dependent criteria were calculated from the hardness concentration associated with each individual sample. Unlike the State of Wyoming and State of Montana equations for copper, the USEPA national recommended aquatic-life criteria for dissolved copper are not a single hardness-dependent equation; instead, values are based on a complex biotic ligand model that includes pH, hardness, and dissolved-organic carbon (U.S. Environmental Protection Agency, 2007). Chromium concentrations were compared to criteria for both chromium (III) and chromium (VI) for this report; however, the laboratory analyses for chromium were not speciated for valence states. Dissolved-mercury concentrations were not available for comparison with State of Wyoming or USEPA national recommended criteria. Total-mercury concentrations were available and were used for comparison in this report because if the total concentration is less than dissolved criteria, then the dissolved component must also have been less. The USEPA national recommended aquatic-life acute criteria for selenium currently are under review (U.S. Environmental Protection Agency, 2004).

Table 3. Environmental variables associated with ecological samples, Powder River structural basin, Wyoming and Montana, 2005–08.

[Shaded cells indicate main-stem sampling sites on the Tongue River or Powder River. m, meters; %, percent; <, less than; mm, millimeters; D_{50}, diameter of the 50th percentile of particles; D_{84}, diameter of the 84th percentile of particles; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; NTRU, nephelometric turbidity ratio units; NA, not applicable]

			Microhabitat				Pebble counts			Field measurements		
Site number (fig. 1)	Abbreviated site name	Sample date	Water depth (m)	Embed-dedness (%)	Velocity (m/s)	Substrate (% coarse)	% <2 mm	D_{50}	D_{84}	Stream-flow (ft³/s)	Specific conductance (µS/cm)	pH (standard units)
R2	Rosebud Creek at mouth	9/15/2005	0.02	54	0.16	100	NA	NA	NA	0.01	4,300	8.6
T1	Tongue River at Monarch	8/15/2005	0.09	36	0.42	100	NA	51	84	123	426	7.5
		8/23/2006	0.10	34	0.43	100	NA	NA	NA	27	535	8.2
		8/29/2007	0.12	20	0.59	100	10	34	73	76	427	8.4
T2	Goose Creek	8/17/2005	0.13	24	0.55	70	NA	22	64	69	653	8.3
		8/22/2006	0.17	48	0.60	80	NA	NA	NA	22	735	8.2
		9/11/2007	0.23	20	0.23	100	21	23	50	83	653	8.2
		8/4/2008	0.20	32	0.59	80	39	27	55	34	705	8.6
T3	Upper Youngs Creek	6/15/2005	0.10	0	0.81	100	NA	NA	NA	2.3	675	8.3
		6/28/2006	0.05	38	0.34	80	NA	NA	NA	0.36	704	8.4
		6/21/2007	0.15	13	0.71	100	34	13	46	8.5	615	8.2
		6/26/2008	0.20	30	0.65	100	59	<2	24	15	648	7.5
T4	Youngs Creek at mouth	6/14/2005	0.19	54	0.41	100	NA	NA	NA	0.99	1,690	8.4
		6/27/2006	0.16	50	0.35	50	NA	NA	NA	0.58	1,000	8.3
T5	Tongue River below Youngs Creek	8/15/2005	0.11	24	0.94	100	NA	NA	NA	171	544	7.8
		8/22/2006	0.11	28	0.62	80	NA	NA	NA	23	695	7.9
		8/29/2007	0.09	33	0.69	100	15	19	40	52	569	8.4
		8/22/2008	0.10	34	0.33	89	10	22	36	109	523	8.4
T7	Squirrel Creek at mouth	6/13/2005	0.08	10	0.24	100	NA	NA	NA	0.17	5,940	8.3
		7/12/2007	0.08	10	0.31	100	37	13	30	0.39	2,310	8.1
		6/25/2008	0.12	8	0.54	100	0	21	40	1.8	1,750	7.9
T8	Prairie Dog Creek	8/25/2006	0.09	44	0.32	78	NA	NA	NA	1.2	2,270	8.1
		9/11/2008	0.27	70	1.00	100	17	54	97	43	916	8.1
T9	Tongue River at State line	9/14/2005	0.11	24	0.49	80	NA	22	43	162	655	7.6
		8/24/2006	0.12	22	0.45	100	NA	NA	NA	11	1,060	8.4
		8/28/2007	0.12	40	0.28	100	10	14	28	136	705	8.4
		8/21/2008	0.16	34	0.51	100	6	22	57	136	604	8.2
T10	Tongue River above Hanging Woman Creek	8/16/2005	0.15	48	0.59	100	NA	NA	NA	408	363	8
		8/28/2006	0.16	48	0.70	100	NA	NA	NA	153	540	8.2
		8/28/2007	0.16	40	0.77	100	16	34	101	164	495	8.2
		9/9/2008	0.21	25	0.61	100	3	43	107	406	427	8.7
T11	Upper Hanging Woman Creek	6/22/2005	0.05	68	0.00	56	NA	NA	NA	0.03	5,000	7.9
		7/11/2007	0.05	10	0.22	100	39	7	32	0.12	4,010	8.5
T12	Middle Hanging Woman Creek	6/21/2005	0.10	2	0.19	50	NA	NA	NA	0.04	3,870	8.1
		7/10/2007	0.10	20	0.31	100	18	14	40	0.49	3,650	8.5
T13	Hanging Woman Creek at mouth	6/23/2005	0.08	20	0.15	90	NA	NA	NA	0.11	2,090	7.8
		7/10/2007	0.14	57	0.34	50	47	4.3	41	1.1	3,510	8.1
		6/24/2008	0.17	34	0.08	100	62	<2	20	0.27	2,800	8.2
T14	Tongue River at Birney Day School	9/12/2005	0.20	46	0.58	100	NA	NA	NA	308	466	8.1
		8/28/2006	0.17	36	0.63	100	NA	NA	NA	139	572	8
		8/27/2007	0.18	20	0.61	100	24	14	41	359	472	8.5
		8/21/2008	0.16	32	0.55	100	14	14	36	409	397	8.2
T16	Middle Otter Creek	6/20/2007	0.16	8	0.60	100	19	18	138	3.8	3,200	8
T17	Otter Creek at mouth	6/30/2005	0.12	34	0.44	100	NA	NA	NA	1.6	2,700	8.2
		6/28/2006	0.06	68	0.22	100	NA	NA	NA	0.82	2,890	8.4
		6/24/2008	0.16	26	0.45	100	1	14	40	2.8	3,520	8.1
T18	Tongue River below Brandenberg Bridge	9/13/2005	0.23	40	0.83	100	NA	NA	NA	330	503	8.3
		8/31/2006	0.21	26	0.74	100	NA	NA	NA	81.8	684	8.4
		8/27/2007	0.08	26	0.46	50	14	15	41	357	528	8.5
T19	Pumpkin Creek	6/23/2005	0.07	14	0.21	100	NA	NA	NA	1.1	1,140	8.4
		6/18/2007	0.08	32	0.44	100	52	<2	15	12	2,630	8.3
P1	Powder River above Salt Creek	7/20/2005	0.06	36	0.36	80	NA	10	35	2.7	2,100	7.6
		7/24/2006	0.07	38	0.30	50	NA	NA	NA	1.2	2,210	7.9
		8/30/2007	0.11	30	0.63	100	37	8.4	46	17	3,470	8.2
P2	Powder River below Salt Creek	7/21/2005	0.09	48	0.35	70	NA	13	21	13	4,990	7.9
		7/25/2006	0.11	22	0.50	50	NA	NA	NA	5.1	5,650	8.3
		8/30/2007	0.09	30	0.47	50	50	<2	21	38	3,610	8.1
P3	Powder River below Willow Creek	7/19/2005	0.05	28	0.19	100	NA	<4	16	9.3	4,810	8.1

Table 3. Environmental variables associated with ecological samples, Powder River structural basin, Wyoming and Montana, 2005–08.—Continued

[Shaded cells indicate main-stem sampling sites on the Tongue River or Powder River. m, meters; %, percent; <, less than; mm, millimeters; D_{50}, diameter of the 50th percentile of particles; D_{84}, diameter of the 84th percentile of particles; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; NTRU, nephelometric turbidity ratio units; NA, not applicable]

	Field measurements				Dissolved major ion concentrations										
Site number (fig. 1)	Water temperature (°C)	Dissolved oxygen (mg/L)	Turbidity (NTRU)	Site number	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Sodium adsorption ratio	Potassium (mg/L)	Alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Total dissolved solids (mg/L)
R2	12.5	9.3	9.1	R2	73.8	183	565	8	14.4	450	23.5	1,520	0.84	0.86	2,650
T1	14.8	7.5	30	T1	44.2	19.6	8.82	0.3	1.66	167	1.11	35.5	0.19	5.28	217
	19.6	7.7	14	T1	44	28.9	19.1	0.5	2.55	209	1.96	67.2	0.23	3.83	293
	19.8	11.6	11	T1	46.8	20.1	9.98	0.3	1.73	185	1.42	34.6	0.15	6.58	233
T2	20.5	8.3	9	T2	54.1	34.5	20.2	0.5	3.46	194	6.37	100	0.27	6.69	343
	19.7	7.3	4.5	T2	67.5	51.8	39.5	0.9	4.44	289	11.6	178	0.39	4.47	532
	12	8.3	12	T2	62.8	44.5	30.8	0.7	3.86	260	9.95	141	0.32	3.87	454
	25.2	10	3.8	T2	61.9	39.6	27.1	0.7	3.74	239	10	135	0.29	3.52	425
T3	19	7.6	62	T3	55.1	38.2	12.8	0.3	4.61	293	1.97	53.2	0.59	13.8	356
	22	7.2	85	T3	62.5	51.1	17.2	0.4	7.17	373	1.58	30.4	0.66	18.8	413
	18	8	42	T3	65.6	36.8	10.5	0.3	3.96	312	1.66	38.2	0.49	17.7	362
	19.5	7.3	59	T3	67.8	41.8	12.4	0.3	5.55	336	1.58	38.6	0.51	16.9	387
T4	12	8.1	33	T4	108	149	112	1.6	14.9	422	4.05	623	0.76	14.8	1,280
	19.5	9.2	18	T4	70.5	79.2	44.7	0.9	9.1	376	2.47	194	0.71	12.6	639
T5	19	8.2	48	T5	56.9	31.9	20.2	0.5	2.77	210	3.35	83.3	0.26	8.54	334
	19	7.3	12	T5	49	41.9	33.3	0.8	3.98	227	6.73	145	0.29	4.72	421
	19	11.4	7	T5	56.5	33.2	20.6	0.5	2.81	219	3.88	90.7	0.24	5.75	345
	19	8.1	5	T5	44.8	29.5	19.3	0.5	2.94	192	3.59	84.3	0.23	1.64	301
T7	13	9.7	6.8	T7	153	463	835	7.6	20	590	12.7	3330	0.73	7.68	5,180
	20	NA	1.2	T7	86.4	184	199	2.8	12.1	530	4.75	880	0.57	4.21	1,690
	19.5	7.7	14	T7	92.2	146	113	1.7	9.23	485	3.64	587	0.52	9.29	1,250
T8	15.3	9.1	10	T8	157	136	202	2.9	11.4	370	7.77	1040	0.41	13.4	1,790
	15.3	8.8	91	T8	72.4	39.4	33.5	0.8	4.24	198	2.48	220	0.21	10.2	501
T9	13.6	8.4	12	T9	54.2	35.7	30.8	0.8	2.92	208	3.53	136	0.29	4.89	393
	24.1	10.8	4.4	T9	49.9	46	51.6	1.3	4.32	227	6.96	200	0.47	4.44	500
	21	10.3	8.6	T9	59.1	33	27.7	0.7	3.02	203	4.16	126	0.3	7.39	382
	25	9.7	24	T9	52.6	28.1	26.3	0.7	2.85	224	4.24	109	0.3	3.53	361
T10	20	8	13	T10	37.2	17	14.7	0.5	1.92	130	1.46	54.4	0.18	3.61	209
	18.5	7.5	0.6	T10	36.2	28.8	36.5	1.1	3.62	170	3.4	111	0.3	0.67	322
	19	6.7	3.4	T10	48.6	24.2	23.9	0.7	2.91	174	2.7	87.6	0.24	3.14	298
	15	9	5	T10	39.6	19.4	19.7	0.6	2.44	152	2.16	71.4	0.22	5.47	252
T11	22.5	NA	10	T11	140	249	732	8.6	18.3	492	18	2,450	0.84	4.39	3,900
	24.5	NA	14	T11	90.1	210	695	9.2	17.9	366	15.8	2,050	0.74	1.22	3,300
T12	24.5	NA	9	T12	81.8	200	546	7.4	18	414	19.2	1,800	0.85	2.1	2,920
	27.5	NA	1.4	T12	98.5	166	554	7.9	16.5	415	17.9	1,710	0.84	2.54	2,810
T13	20.3	NA	7	T13	77.4	113	259	4.4	12	572	5.7	611	1.38	16.5	1,440
	19	8.3	9.5	T13	124	160	483	6.8	19.3	528	16.4	1,460	1.04	7.65	2,580
	25.5	11.9	4	T13	93.6	138	376	5.8	16.5	518	13.4	1,150	1.06	9.33	2,110
T14	18.5	8.3	10	T14	44.9	22.3	21.2	0.6	2.54	160	2.23	81.7	0.23	2.02	273
	23.5	10.5	NA	T14	33.7	29	35.6	1.1	3.5	175	3.39	116	0.3	1.81	328
	22.5	8.5	7	T14	33.6	16.9	14.9	0.5	2.41	124	1.75	56.6	0.19	6.27	207
	24.5	8.2	14	T14	34.7	15.4	14.5	0.5	2.16	128	1.61	51.6	0.17	5.57	203
T16	19.5	7.5	2.5	T16	129	196	391	5.1	19.4	502	10.7	1,440	0.66	7.43	2,490
T17	18	5.3	97	T17	87.3	180	442	6.2	20.1	592	12.3	1,260	0.95	14.2	2,370
	22.2	5	79	T17	55.8	141	394	6.4	19	579	11.4	1,020	1	10.6	2,000
	21.5	5.9	21	T17	84.8	147	406	6.2	19.7	490	12.1	1,290	0.78	6.44	2,260
T18	14.5	9.3	16	T18	45	23.6	23.7	0.7	2.87	156	2.51	89.6	0.24	1.81	283
	17.8	8.6	NA	T18	38.9	32.4	44.5	1.3	3.75	190	4.05	142	0.33	4.61	385
	20	8	11	T18	42.1	21.8	25.7	0.8	2.94	165	2.53	95.6	0.24	5.7	296
T19	29.4	NA	158	T19	32	14.5	181	6.7	8.69	214	3.49	294	0.41	9.93	673
	21	8.7	69	T19	64.2	65.8	334	7	10.4	281	6.58	853	0.34	8.1	1,510
P1	21.8	7.4	4.7	P1	175	74.7	209	3.3	7.33	177	92.5	722	0.48	11.9	1,400
	28.5	6.8	19	P1	170	70.8	213	3.5	8.14	225	93.3	798	0.46	4.93	1,490
	27	10.5	380	P1	287	89.4	430	5.7	14.2	181	139	1,610	0.83	7.03	2,680
P2	23	7.7	16	P2	113	75.4	932	17	20.1	288	943	1,070	1.39	7.97	3,340
	32.7	7.3	12	P2	140	79	906	15	28.7	175	915	1,310	1.99	4.46	3,490
	22.1	10.2	370	P2	177	69.7	554	8.9	15.6	238	444	1,030	1.03	12.5	2,450
P3	24.3	7.2	2.9	P3	183	111	843	12	19.8	187	733	1,330	0.96	9.27	3,350

Table 3. Environmental variables associated with ecological samples, Powder River structural basin, Wyoming and Montana, 2005–08.—Continued

[Shaded cells indicate main-stem sampling sites on the Tongue River or Powder River. m, meters; %, percent; <, less than; mm, millimeters; D_{50}, diameter of the 50th percentile of particles; D_{84}, diameter of the 84th percentile of particles; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; NTRU, nephelometric turbidity ratio units; NA, not applicable]

			Microhabitat				Pebble counts			Field measurements		
Site number (fig. 1)	Abbreviated site name	Sample date	Water depth (m)	Embed-dedness (%)	Velocity (m/s)	Substrate (% coarse)	% <2 mm	D_{50}	D_{84}	Stream-flow (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)
P3	Powder River below Willow Creek	7/26/2006	0.05	26	0.17	50	NA	NA	NA	0.22	4,650	7.8
		8/24/2007	0.09	48	0.43	100	39	7.5	21	55	4,830	8.3
		7/21/2008	0.07	36	0.31	100	0	15	35	84	2,980	8.4
P4	Powder River below Burger Draw	7/22/2005	0.08	36	0.21	100	NA	27	60	7.9	4,600	7.9
		7/27/2006	0.07	22	0.41	90	NA	NA	NA	2.2	3,210	8.7
		8/22/2007	0.07	10	0.64	100	40	16	44	17	3,750	8
		7/23/2008	0.12	20	0.40	90	23	47	76	94	2,860	8.4
P5	Powder River above Crazy Woman Creek	7/13/2005	0.07	60	0.34	50	NA	<4	12	25	3,500	8.8
		7/28/2006	0.07	14	0.31	50	NA	NA	NA	1.7	2,960	8.1
		8/23/2007	0.06	30	0.33	80	56	<2	21	30	3,190	8.2
		7/24/2008	0.07	32	0.57	100	12	18	47	99	2,810	8.2
P6	Crazy Woman Creek below I-90	7/11/2005	0.08	14	0.38	50	NA	6.5	21	37	777	7.9
		8/20/2007	0.05	30	0.20	100	20	14	42	0.29	1,740	8.2
P7	Crazy Woman Creek near mouth	7/12/2005	0.24	15	0.66	50	NA	43	133	40	894	7.7
		8/21/2007	0.06	20	0.40	100	54	<2	32	0.11	1,930	7.9
		8/20/2008	0.15	42	0.55	100	15	23	49	15	1,770	8
P8	Powder River below Crazy Woman Creek	7/23/2005	0.17	64	0.53	100	NA	<4	32	99	2,050	8.1
		8/21/2007	0.09	10	0.44	100	43	14	38	26	3,270	8.4
		7/25/2008	0.04	16	0.23	86	48	5	21	159	2,380	8.3
P9	Powder River above Clear Creek	7/24/2005	0.12	74	0.41	100	NA	NA	NA	149	2,280	7.7
		7/26/2007	0.11	30	0.38	50	79	<2	17	102	1,250	8.1
		7/29/2008	0.08	68	0.34	100	61	<2	32	188	2,680	8.4
P10	Clear Creek	9/13/2005	0.10	34	0.45	90	NA	29	89	35	1,200	8
		8/21/2006	0.08	22	0.51	80	NA	NA	NA	1.7	1,840	8
		9/10/2007	0.11	30	0.46	50	17	22	44	98	972	8.4
		8/5/2008	0.10	21	0.47	89	10	28	55	91	1,170	8.3
P11	Powder River below Clear Creek	7/25/2005	0.11	24	0.41	50	NA	NA	NA	92	1,940	8.2
		8/3/2006	0.04	42	0.25	50	NA	NA	NA	0.2	2,260	8.1
		7/26/2007	0.08	26	0.45	90	37	12	57	183	1,270	8.2
		7/30/2008	0.18	62	0.67	100	29	33	78	139	2,410	8.3
P12	Powder River at Moorhead	7/26/2005	0.11	46	0.31	100	NA	NA	NA	76	1,930	8.4
		7/26/2007	0.09	30	0.59	50	38	14	60	252	2,430	8.2
		7/30/2008	0.06	22	0.42	86	26	14	47	204	2,890	8.2
P13	Powder River at Broadus	7/19/2005	0.17	2	0.63	90	NA	NA	NA	111	1,690	8.3
		8/2/2006	0.07	69	0.38	100	NA	NA	NA	1.1	4,750	8.1
		7/25/2007	0.11	11	0.57	100	41	11	47	29	3,090	8.1
		7/31/2008	0.15	15	0.64	100	22	26	53	222	2,230	8.4
P14	Little Powder River at Highway 59	8/8/2007	0.24	50	0.30	100	7	15	55	1.2	2,050	8.1
P15	Little Powder River above Dry Creek	6/13/2005	0.11	30	0.60	100	NA	<4	21	3.8	3,480	6.8
		6/23/2006	0.09	14	0.45	100	NA	NA	NA	0.23	3,380	8.1
		8/7/2007	0.11	16	0.53	100	19	12	29	4.4	4,190	8
		8/18/2008	0.10	42	0.47	100	12	13	33	5.1	3,550	7.7
P16	Little Powder River at Biddle	6/27/2005	0.21	18	0.67	100	NA	NA	NA	7.6	2,720	7.9
		8/9/2007	0.20	26	0.55	100	28	5.8	19	8.1	4,090	8.1
P17	Powder River below Little Powder River	7/21/2005	0.10	34	0.30	70	NA	NA	NA	85	1,820	8.4
		7/25/2007	0.07	32	0.41	50	62	<2	35	50	3,180	8.2
P18	Powder River near Locate	7/22/2005	0.12	44	0.40	80	NA	NA	NA	90	1,970	8.3
		7/24/2007	0.11	12	0.54	100	36	13	54	48	2,470	8.1
C3	Cheyenne River near Dull Center	6/27/2005	0.05	34	0.10	70	NA	<4	5.3	0	3,070	8.1
C4	Little Thunder Creek	6/9/2005	0.02	32	0.05	100	NA	<4	13	0.02	1,950	7.7
C6	Cheyenne River near Spencer	6/6/2005	0.04	40	0.20	100	NA	<4	14	6.4	3,910	8
		6/15/2007	0.10	34	0.40	50	53	<2	9.8	9.2	4,550	8.1
B1	Belle Fourche River	6/29/2005	0.07	40	0.17	50	NA	<4	6.5	1	3,360	8.8

Table 3. Environmental variables associated with ecological samples, Powder River structural basin, Wyoming and Montana, 2005–08.—Continued

[Shaded cells indicate main-stem sampling sites on the Tongue River or Powder River. m, meters; %, percent; <, less than; mm, millimeters; D_{50}, diameter of the 50th percentile of particles; D_{84}, diameter of the 84th percentile of particles; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; NTRU, nephelometric turbidity ratio units; NA, not applicable]

	Field measurements				Dissolved major ion concentrations										
Site number (fig. 1)	Water temperature (°C)	Dissolved oxygen (mg/L)	Turbidity (NTRU)	Site number	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Sodium adsorption ratio	Potassium (mg/L)	Alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Total dissolved solids (mg/L)
P3	27.1	11.4	18	P3	213	105	643	9	18	160	548	1,550	0.76	3.02	3,180
	20.1	8.1	690	P3	176	83.8	821	13	21.2	205	728	1,240	1.19	12.4	3,210
	25.3	7.5	86	P3	142	64.3	405	7.1	11.3	209	344	880	0.65	9.11	1,980
P4	20.7	8	4.1	P4	115	100	866	14	21.2	318	537	1,260	0.83	6.66	3,100
	24.7	13.9	84	P4	13.9	29.1	715	25	25.7	1,540	69.6	210	1.62	5.01	1,990
	18.6	8.1	72	P4	153	77.6	624	10	17.5	251	419	1,130	1	8.74	2,580
	23	7.8	120	P4	135	62.5	407	7.3	11.9	224	287	871	0.61	8.16	1,920
P5	26.1	6.6	28	P5	122	72.6	524	9.3	13.1	233	365	1,070	0.68	8.15	2,320
	21.7	8.7	5.8	P5	78.8	50	516	11	13.4	342	212	894	0.92	4.32	1,980
	18.7	8.1	190	P5	133	68.9	517	9.1	14.8	202	316	1,010	0.84	7.82	2,190
	29.5	6.3	150	P5	135	56.8	392	7.1	12.2	225	264	871	0.67	7.42	1,870
P6	20.8	7	58	P6	79.9	40.5	51.2	1.2	2.28	122	3.49	318	0.27	10.6	580
	22.2	7.1	11	P6	168	106	181	2.7	8.69	207	11	958	0.33	7.4	1,560
P7	22.7	7	120	P7	82.5	40.7	58.3	1.3	2.82	145	3.87	309	0.21	12	596
	19.8	7.9	13	P7	168	87.8	165	2.6	9.72	188	8.92	913	0.35	3.42	1,470
	22.8	8.8	18	P7	157	83.9	136	2.2	4.46	215	8.62	795	0.3	5.79	1,320
P8	21.4	5.9	960	P8	232	46.3	97.8	1.5	12.6	92	36.1	866	0.4	7.45	1,350
	28.3	6.7	230	P8	140	70.5	532	9.2	15.7	194	326	1,060	0.87	8.51	2,270
	21.9	8	170	P8	134	57.2	309	5.6	9.98	212	191	783	0.56	7.5	1,620
P9	24	5.6	1,000	P9	287	77.5	130	1.8	12.1	101	41.4	1,120	0.42	8.88	1,740
	25	7.8	2,000	P9	82.7	37.4	171	3.9	8.49	132	68.9	510	0.76	7.04	966
	21.4	7.7	460	P9	148	65.9	352	6	10.7	224	224	931	0.61	8.08	1,870
P10	13.6	8	4.3	P10	105	47.8	52.5	1.1	4.53	195	4.52	351	0.22	6.55	689
	20.4	8.2	12	P10	168	101	159	2.4	9.75	261	6.02	878	0.3	7.19	1,490
	15	10.3	4.2	P10	97.7	41.3	51.9	1.1	4.98	165	2.75	363	0.23	3.68	663
	22.4	7.5	8.4	P10	68.3	28	38	1	2.56	141	2.55	236	0.14	4.82	467
P11	21.2	7.4	420	P11	206	59.8	143	2.3	9.54	132	61.8	867	0.39	6.64	1,430
	21.1	7.2	7.6	P11	163	119	227	3.3	11.9	159	45.5	1,090	0.39	1.1	1,750
	24	6.8	1690	P11	93.8	41.2	128	2.8	7.36	149	37.3	481	0.55	6.52	884
	22.3	7.9	230	P11	135	59.2	302	5.5	9.16	205	191	808	0.52	6.63	1,630
P12	18.2	8	619	P12	79.9	36.1	118	2.8	4.17	153	59	350	0.28	7.21	747
	23.5	6.9	NA	P12	109	53.1	352	6.9	11	188	185	793	0.7	7.35	1,630
	29	9.8	110	P12	141	79.4	331	5.5	10.5	200	169	996	0.49	6.47	1,850
P13	22.5	8.2	18	P13	130	59.3	188	3.4	6.54	198	72.9	608	0.31	9.86	1,190
	27	9.5	3.3	P13	304	162	639	7.4	18.5	250	235	2,220	0.33	11.4	3,740
	28	7.4	3	P13	190	102	428	6.2	13.4	219	179	1,290	0.5	11.5	2,340
	26.5	8.1	100	P13	143	60.3	253	4.5	8.81	220	130	777	0.48	8.46	1,510
P14	20.8	11.2	2.8	P14	144	89.7	201	3.2	22.6	259	88.6	704	0.68	9.7	1,420
P15	13.6	7.5	120	P15	189	145	528	7	21.4	344	87.9	1,540	0.7	11.2	2,730
	19.5	8.8	96	P15	131	83.7	337	5.6	15.9	280	83.5	1,080	0.61	7.06	1,910
	25.8	10.3	14	P15	194	138	636	8.5	21.8	391	47.9	1,940	0.75	15.2	3,220
	24.8	9.3	35	P15	158	104	508	7.7	19.6	367	38	1,520	0.63	10.4	2,570
P16	17.5	6.4	810	P16	152	84.8	354	5.7	22	246	52.2	1,240	0.86	7.51	2,060
	21	6.8	23	P16	219	141	625	8.1	34	324	82.3	1,990	1.03	12.7	3,300
P17	28.5	5.8	22	P17	136	62.6	206	3.7	7.37	201	76.1	664	0.33	10.8	1,280
	32.5	11.1	10	P17	164	97.8	466	7.1	16.2	236	119	1,400	0.56	13.3	2,420
P18	21.3	7.3	NA	P18	94.9	35.3	165	3.7	5.56	185	65	488	0.32	11	977
	22	7.9	3.6	P18	115	60.3	337	6.3	10.6	226	93.2	926	0.42	14	1,690
C3	21.3	5.3	4.8	C3	252	155	395	4.8	20	284	28.4	1,780	0.63	5.14	2,800
C4	14.3	8.1	41	C4	64.9	52.4	255	5.7	NA	NA	NA	NA	NA	NA	NA
C6	20.4	7.2	163	C6	323	132	970	11	11.1	281	108	2,750	0.52	8.35	4,460
	20.4	7.8	37	C6	195	90.6	653	9.7	12.6	284	99	1,900	0.62	6.58	3,130
B1	16.6	8.1	3.8	B1	112	151	341	5	9.92	90	15.7	1,490	0.58	0.37	2,180

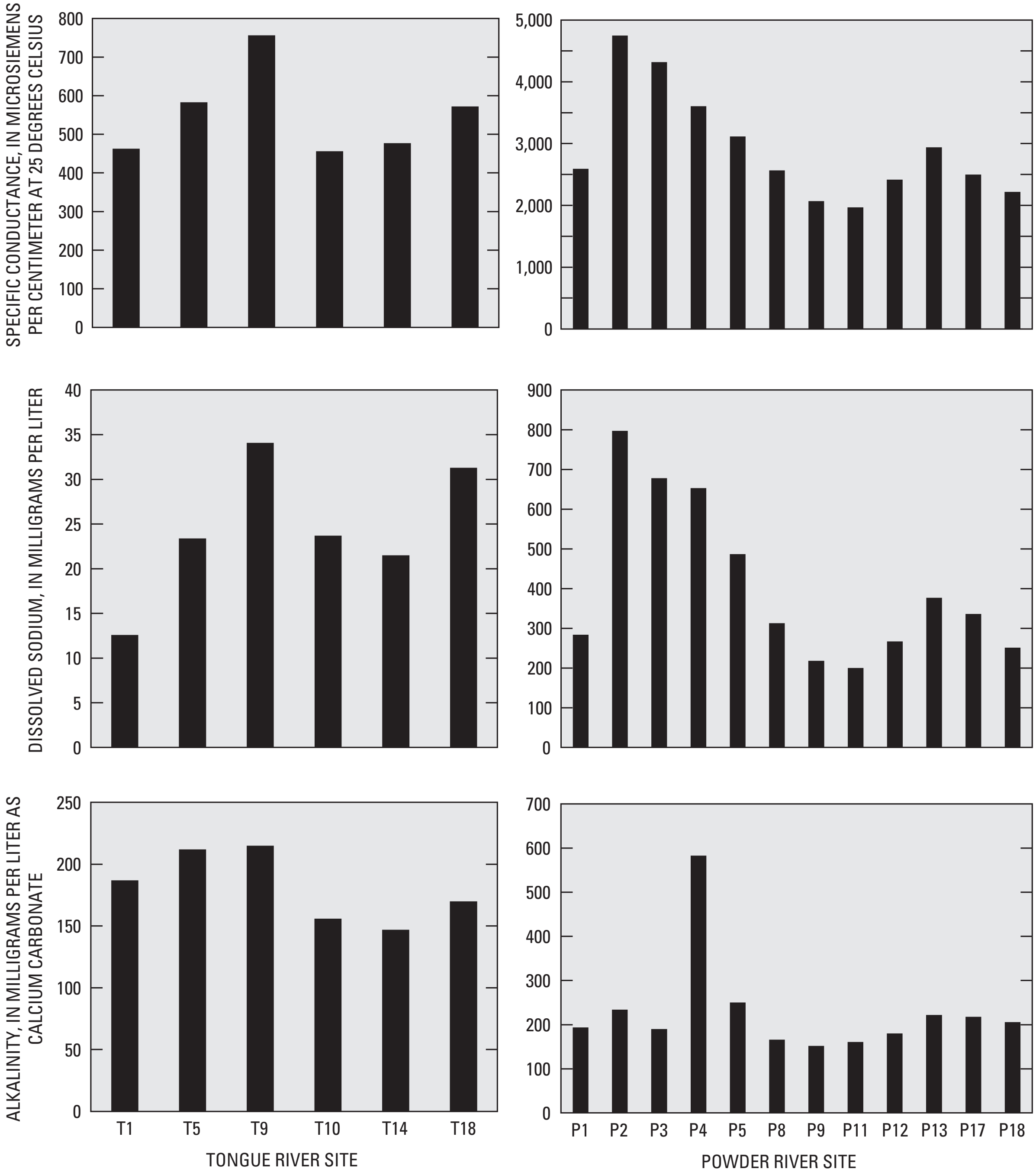


Figure 4. Mean values for specific conductance, dissolved sodium, and alkalinity for the Tongue River and Powder River during ecological sampling events, Wyoming and Montana, 2005–08.

Other water-quality constituents are classified by the USEPA as nonpriority pollutants, which do not require criteria to be established. Nonpriority pollutants evaluated for this report include pH, chloride, aluminum, iron, and manganese. The USEPA has determined that results of toxicity and bioconcentration tests for total-chloride concentrations are essentially equivalent to results for dissolved-chloride concentrations (U.S. Environmental Protection Agency, 1988); therefore, dissolved-chloride concentrations were used for comparison in this report. The State of Wyoming has established acute and chronic chloride criteria for streams other than the Powder River downstream from Salt Creek. Because Salt Creek contributes high chloride concentrations to the Powder River, a site-specific criterion was established for the Powder River downstream from Salt Creek (Wyoming Department of Environmental Quality, 2007).

Table 4. State and Federal criteria for the protection of aquatic life.

[State of Wyoming criteria are listed in Wyoming Department of Environmental Quality (2007); State of Montana criteria are listed in Montana Department of Environmental Quality (2008); Federal criteria are listed in U.S. Environmental Protection Agency (2005); --, not available; concentrations for all consitutents in micrograms per liter, unless otherwise noted; mg/L, milligrams per liter]

Constituent	State of Wyoming		State of Montana		U.S. Environmental Protection Agency	
	Aquatic-life acute value	Aquatic-life chronic value	Aquatic-life acute value	Aquatic-life chronic value	Aquatic-life acute value	Aquatic-life chronic value
Priority pollutants						
Arsenic, dissolved	340	150	--	--	340	150
Arsenic, total	--	--	340	150	--	--
Cadmium, dissolved	[1]2.0	[1].25	--	--	[1]2.0	[1].25
Cadmium, total	--	--	[1]2.1	[1].27	--	--
Chromium (III), dissolved	[1]569.8	[1]74.1	--	--	[1]570	[1]74
Chromium (III), total	--	--	[1]1,804	[1]86	--	--
Chromium (VI), dissolved	16	11	--	--	16	11
Chromium (VI), total	--	--	16	11	--	--
Copper, dissolved	[1]13.4	[1]9.0	--	--	[5]5.9	--
Copper, total	--	--	[1]14	[1]9.3	--	--
Lead, dissolved	[1]64.6	[1]2.5	--	--	[1]65	[1]2.5
Lead, total	--	--	[1]82	[1]3.2	--	--
Mercury, dissolved	1.4	.77	--	--	1.4	.77
Mercury, total	--	--	1.7	.91	--	--
Nickel, dissolved	[1]468.2	[1]52.0	--	--	[1]470	[1]52
Nickel, total	--	--	[1]469	[1]52.2	--	--
Selenium, dissolved	20	--	--	--	--	--
Selenium, total	--	5.0	20	5.0	(6)	5.0
Zinc, dissolved	[1]117.2	[1]118.1	--	--	[1]120	[1]120
Zinc, total	--	--	[1]120	[1]120	--	--
Nonpriority pollutants						
pH (standard units)	--	6.5–9.0	--	--	--	6.5–9.0
Chloride, total (mg/L)	[2]860,000	[2]230,000	--	--	860,000	230,000
Chloride, total (mg/L)	[3]984,000	--	--	--	--	--
Aluminum, dissolved	750	[4]87	750	87	--	--
Aluminum, total	--	--	--	--	750	87
Iron, dissolved	--	1,000	--	--	--	--
Iron, total	--	--	--	1,000	--	1,000
Manganese, dissolved	3,110	1,462	--	--	--	--

[1]Value is hardness dependent. Value listed is for example only and is based on a hardness of 100 mg/L (as calcium carbonate).

[2]Value applies to the Powder River upstream from Salt Creek and other streams.

[3]Value applies to the Powder River downstream from Salt Creek.

[4]Criterion only applies to samples with pH less than 7 and hardness less than 50 mg/L (as calcium carbonate).

[5]Copper criteria have a complex formula; value listed is for sample pH of 8, hardness value of 40 mg/L (as calcium carbonate), and dissolved-organic carbon of 2–16 mg/L (U.S. Environmental Protection Agency, 2007).

[6]The Federal aquatic-life acute criteria for selenium currently are under review (U.S. Environmental Protection Agency, 2004).

State of Wyoming Aquatic-Life Criteria

Water-quality constituents from 24 ATG study sites in Wyoming for water years 2005–08 were compared to State of Wyoming aquatic-life criteria (table 4). Concentrations of dissolved arsenic, dissolved cadmium, dissolved chromium (III), dissolved chromium (VI), dissolved copper, dissolved lead, total mercury, dissolved nickel, and dissolved zinc were less than aquatic-life acute and chronic criteria in all samples (table 5). Dissolved selenium concentrations were less than the acute criterion in all samples. Total selenium concentrations exceeded the chronic criterion in two samples collected from Caballo Creek (site B2) in the Belle Fourche River drainage basin.

A few samples had concentrations of nonpriority pollutants that were higher than aquatic-life criteria. One pH sample (9.8) for Porcupine Creek (site C1) in the Cheyenne River drainage basin was outside the chronic criterion range (table 5). Three samples from the Little Powder River above Dry Creek (site P15) had dissolved-chloride concentrations higher than the chronic criterion. Dissolved-chloride concentrations in all samples collected from sites on the Powder River downstream from Salt Creek were less than the site-specific acute criterion for the Powder River. Dissolved-iron concentrations exceeded the chronic criterion in four samples from Antelope Creek (site C2) and seven samples from

Table 5. Aquatic-life criteria comparison for water samples collected from study sites in the Powder River structural basin, Wyoming and Montana, water years 2005–08.

[number of samples, number of samples greater than criterion or standard/total number of samples collected; --, not applicable]

Constituent	State of Wyoming				State of Montana				U.S. Environmental Protection Agency			
	Acute		Chronic		Acute		Chronic		Acute		Chronic	
	Number of samples	Sites with exceedances	Number of samples	Sites with exceedances	Number of samples	Sites with exceedances	Number of samples	Sites with exceedances	Number of samples	Sites with exceedances	Number of samples	Sites with exceedances
Arsenic, dissolved	0/380	--	0/380	--	--	--	--	--	0/620	--	0/620	--
Arsenic, total	--	--	--	--	0/253	--	0/253	--	--	--	--	--
Cadmium, dissolved	0/46	--	0/46	--	--	--	--	--	0/153	--	0/153	--
Cadmium, total	--	--	--	--	6/207	T19, P18	24/207	T19, P12, P18	--	--	--	--
Chromium (III), dissolved	0/3	--	0/3	--	--	--	--	--	0/35	--	0/35	--
Chromium (III), total	--	--	--	--	0/207	--	4/207	T19, P18	--	--	--	--
Chromium (VI), dissolved	0/3	--	0/3	--	--	--	--	--	0/35	--	0/35	--
Chromium (VI), total	--	--	--	--	28/207	T19, P12, P18	36/207	T19, P12, P18	--	--	--	--
Copper, dissolved	0/43	--	0/43	--	--	--	--	--	5/150	T19	--	--
Copper, total	--	--	--	--	24/207	T19, P12, P18	35/207	T9, T19, P12, P18	--	--	--	--
Lead, dissolved	0/44	--	0/44	--	--	--	--	--	0/151	--	1/151	T19
Lead, total	--	--	--	--	7/207	T19, P18	36/207	T9, T19, P12, P18	--	--	--	--
Mercury, total	0/24	--	0/24	--	0/55	--	0/55	--	0/79	--	0/79	--
Nickel, dissolved	0/44	--	0/44	--	--	--	--	--	0/151	--	0/151	--
Nickel, total	--	--	--	--	2/207	T19	8/207	T19, P18	--	--	--	--
Selenium , dissolved	0/52	--	--	--	--	--	--	--	--	--	--	--
Selenium , total	--	--	2/382	B2	0/289	--	1/289	P12	--	--	3/671	P12, B2
Zinc, dissolved	0/43	--	0/43	--	--	--	--	--	0/144	--	0/144	--
Zinc, total	--	--	--	--	11/207	T19, P12, P18	11/207	T19, P12, P18	--	--	--	--
pH	1/517	C1	--	--	--	--	--	--	3/1,045	T11, T12, C1	--	--
Chloride, dissolved	0/450	--	3/450	P15	--	--	--	--	2/1,001	P2	20/1,001	P2, P3, P4, P5, P8, P12, P13,P15
Chloride, dissolved (Powder River)	0/27	--	--	--	--	--	--	--	--	--	--	--
Aluminum, dissolved	0/52	--	--	--	0/136	--	0/136	--	--	--	--	--
Aluminum, total	--	--	--	--	--	--	--	--	160/623	R1, R2, T1, T2, T8, T9, T14, T17, T18, T19, P10, P12, P15, C1, C3, C5, C6, B1	390/623	R1, R2, T1, T2, T8, T9, T13, T14, T17, T18, T19, P10, P12, P15, C1, C2, C3, C5, C6, B1, B2
Iron, dissolved	--	--	11/380	C2, C3	--	--	--	--	--	--	--	--
Iron, total	--	--	--	--	--	--	111/232	R1, R2, T9, T14, T17, T18, T19, P12, P18	--	--	140/331	R1, R2, T1, T2, T8, T9, T14, T17, T18, T19, P12, P15, P18
Manganese, dissolved	3/380	C2, B1	16/380	C2, C3, C6, B1	--	--	--	--	--	--	--	--

the Cheyenne River near Dull Center (site C3). Dissolved-manganese concentrations exceeded the acute criterion in two samples from Antelope Creek (site C2) and one sample from the Belle Fourche River (site B1). Dissolved-manganese concentrations exceeded the chronic criterion in 10 samples from Antelope Creek (site C2), 3 samples from the Cheyenne River near Dull Center (site C3), 1 sample from the Cheyenne River near Spencer (site C6), and 2 samples from the Belle Fourche River (site B1).

State of Montana Aquatic-Life Criteria

Water-quality constituents from 23 ATG study sites in Montana for water years 2005–08 were compared to State of Montana aquatic-life criteria (table 4). Concentrations of total arsenic and total mercury were less than aquatic-life acute and chronic criteria in all samples (table 5).

Concentrations of other priority pollutants exceeded aquatic-life criteria in some samples. Total-cadmium concentrations exceeded acute criteria in four samples from Pumpkin Creek in the Tongue River drainage basin (site T19) and two samples from the Powder River near Locate (site P18). Total-cadmium concentrations exceeded chronic criteria that were calculated for seven samples from Pumpkin Creek (site T19); eight samples from the Powder River at Moorhead (site P12); and nine samples from the Powder River near Locate (site P18).

No samples had concentrations of chromium (III) higher than the applicable aquatic-life acute criteria (table 5). Total-chromium concentrations exceeded chromium (III) chronic criteria in three samples from Pumpkin Creek (site T19) and one sample from the Powder River near Locate (site P18). Total-chromium concentrations exceeded the chromium (VI) acute criterion in 5 samples from Pumpkin Creek (site T19), 10 samples from the Powder River at Moorhead (site P12), and 13 samples from the Powder River near Locate (site P18). Total-chromium concentrations exceeded the chromium (VI) chronic criterion in 5 samples from Pumpkin Creek (site T19), 12 samples from the Powder River at Moorhead (site P12), and 19 samples from the Powder River near Locate (site P18); however, these comparisons assume that all of the chromium was present in the +6 valence state, which would not be typical for stream conditions.

Total-copper concentrations exceeded aquatic-life acute criteria in seven samples from Pumpkin Creek (site T19), eight samples from the Powder River at Moorhead (site P12), and nine samples from the Powder River near Locate (site P18, table 5). Total-copper concentrations exceeded chronic criteria in 1 sample from the Tongue River at State line (site T9), 8 samples from Pumpkin Creek (site T19), 9 samples from the Powder River at Moorhead (site P12), and 17 samples from the Powder River near Locate (site P18).

Total-lead concentrations exceeded aquatic-life acute criteria that were calculated for samples in four samples from Pumpkin Creek (site T19) and three samples from the Powder River near Locate (site P18). Total-lead concentrations exceeded chronic criteria in 2 samples from the Tongue River at State line (site T9), 7 samples from Pumpkin Creek (site T19), 10 samples from the Powder River at Moorhead (site P12), and 17 samples from the Powder River near Locate (site P18).

Total-nickel concentrations exceeded acute criteria in two samples from Pumpkin Creek (site T19). Total-nickel concentrations exceeded chronic criteria that were calculated for samples in five samples from Pumpkin Creek (site T19) and three samples from the Powder River near Locate (site P18). No samples had a total-selenium concentration higher than the aquatic-life acute criterion. The total-selenium concentration exceeded the chronic criterion in one sample from the Powder River at Moorhead (site P12). Total-zinc concentrations exceeded aquatic-life acute and chronic criteria in six samples from Pumpkin Creek (site T19), one sample from the Powder River at Moorhead (site P12), and four samples from the Powder River near Locate (site P18).

For nonpriority pollutants, no samples had dissolved-aluminum concentrations higher than aquatic-life acute or chronic criteria. Total-iron concentrations exceeded the chronic criterion in 1 sample from upper Rosebud Creek (site R1), 6 samples from Rosebud Creek at mouth (site R2), 4 samples from the Tongue River at State line (site T9), 3 samples from the Tongue River at Birney Day School (site T14), 7 samples from Otter Creek at mouth (site T17), 2 samples from the Tongue River below Brandenberg Bridge (site T18), 8 samples from Pumpkin Creek (site T19), 40 samples from the Powder River at Moorhead (site P12), and 40 samples from the Powder River near Locate (site P18) (table 5).

Federal Aquatic-Life Criteria

Concentrations of dissolved arsenic, dissolved cadmium, dissolved chromium (III), dissolved chromium (VI), total mercury, dissolved nickel, and dissolved zinc were less than USEPA national recommended aquatic-life acute and chronic criteria in all samples (table 5). Five samples from Pumpkin Creek (site T19), with low hardness values, exceeded the applicable dissolved-copper acute criterion of 5.9 µg/L. Dissolved-lead concentrations in all samples were less than the USEPA national recommended aquatic-life acute and chronic criteria except for one sample from Pumpkin Creek (site T19) that exceeded the chronic criterion. Total-selenium concentrations exceeded the chronic criterion in one sample from the Powder River at Moorhead (site P12) and two samples from Caballo Creek (site B2).

Some samples had concentrations of nonpriority pollutants that exceeded aquatic-life criteria (table 5). Three measurements of pH, one at each of the upper Hanging Woman Creek (site T11), middle Hanging Woman Creek (site T12), and Porcupine Creek (site C1) sites, exceeded 9.0 standard units. Dissolved-chloride concentrations exceeded the acute criterion in two samples from Powder River below Salt Creek (P2). Dissolved-chloride concentrations exceeded the chronic criterion in three samples from the Powder River below Salt Creek (P2), four samples from the Powder River above

Pumpkin Creek (site P3), three samples from the Powder River below Burger Draw (site P4), three samples from the Powder River above Crazy Woman Creek (site P5), two samples from the Powder River below Crazy Woman Creek (P8), one sample from the Powder River at Moorhead (site P12), one sample from the Powder River at Broadus (site P13), and three samples from the Little Powder River above Dry Creek (site P15). Unlike the States of Wyoming and Montana, the USEPA national recommended aquatic-life criteria for aluminum are based on total concentrations. Total-aluminum concentrations exceeded the chronic criterion, acute criterion, or both (table 5) at all 21 sites that had analyses for total aluminum (sites R1, R2, T1, T2, T8, T9, T13, T14, T17, T18, T19, P10, P12, P15, C1, C2, C3, C5, C6, B1, and B2). Total-iron concentrations exceeded the chronic criterion at 13 of the 14 sites that had analyses for total iron (sites R1, R2, T1, T2, T8, T9, T14, T17, T18, T19, P12, P15, and P18).

Habitat

Among all sites, embeddedness of the substrate, measured in conjunction with macroinvertebrate sampling in riffles during 2005–08, ranged from 0 to 74 percent (table 3). The values for embeddedness and other microhabitat data—water depth, velocity, and coarse substrate (fraction of gravel or larger size particles)—listed in table 3 represent mean values from five points accompanying each macroinvertebrate sample. Among all sites, microhabitat substrate ranged from 50 percent to 100 percent coarse substrate during 2005–08.

Pebble counts indicated a wide variation in particle size percentiles among sites during 2007–08. For example, the D_{84}, or diameter of the 84th percentile of particles, ranged from 5.3 to 138 millimeters (mm) (table 3). Pebble-count data for the D_{50}, or diameter of the 50th percentile (median) of particles, and the percentage less than 2 mm (smallest size measured) also are listed in table 3. The pebble-count data were collected from transects bankfull to bankfull across riffles according to methods by Wolman (1954) and therefore represent a slightly different aspect of the riffles than the microhabitat substrate measurements that were collected at an average depth of 0.4 feet (ft; 0.11 meter) in riffles according to methods by Moulton and others (2002). The microhabitat and pebble-count data were collected as indicators of physical variables potentially affecting macroinvertebrate communities.

Macroinvertebrate Communities

Macroinvertebrate taxonomic data from 2005–08 are available at: *http://wy.water.usgs.gov/projects/atg/htms/data.htm*. Most of the taxa identified were Chironomidae (midges:Diptera), Ephemeroptera (mayflies), and Trichoptera (caddisflies). Other identified taxa, though generally rarer, included Coleoptera (beetles), noninsects (such as worms: Oligochaeta, and snails:Gastropoda), Odonata (dragonflies and damselflies), and Plecoptera (stoneflies). The total number of taxa (taxa richness) in the ATG samples ranged from 5 taxa in Pumpkin Creek (site T19, 2005) to 47 taxa in Hanging Woman Creek (site T11, 2005) (table 6).

Macroinvertebrate Community Composition

Three stream groups of sites with relatively similar taxonomic composition were identified: Tongue River main stem and mountainous tributaries (TRMS), Tongue River plains tributaries (TRPT), and Powder River main stem (PRMS). NMDS ordinations for 2007–08 (fig. 5) and 2005–06 (Peterson and others, 2009) indicated the same general stream groups for all 4 years of sampling, with a few sites that were sometimes outliers. The TRMS group generally contained sites sampled on the main-stem Tongue River (sites T1, T5, T9, T10, T14, and T18) and tributaries originating in the Bighorn Mountains: Goose Creek (site T2), Crazy Woman Creek (sites P6 and P7), and Clear Creek (site P10). The TRPT group generally contained sites on Youngs Creek (sites T3 and T4), Squirrel Creek (site T7), Prairie Dog Creek (site T8), Hanging Woman Creek (sites T11–T13), Otter Creek (sites T16 and T17), and Pumpkin Creek (site T19). Prairie Dog Creek (site T8) plotted with the TRMS group although the headwaters are in the plains (table 1). The PRMS group generally contained sites P1–P5, P8, P9, P11–P13, P17, and P18. Sampling sites on Rosebud Creek (site R2), the Little Powder River (sites P14–P16), the Cheyenne River drainage basin (sites C3, C4, and C6), and the Belle Fourche River (site B1) tended to be outliers to the stream groups. Some of the sites, particularly the outliers, are not shown in figure 5 because they were sampled only in 2005 or 2006 (Peterson and others, 2009).

Taxa richness at sites in the TRMS group ranged from 17 to 41 taxa per sample during 2005–08 (table 6), with a mean of 29 taxa per sample. Diptera, Ephemeroptera, and Trichoptera dominated in terms of taxa richness, although on the average, relative abundance was dominated by Ephemeroptera (46 percent), Trichoptera (21 percent), and Diptera (12 percent). Ephemeroptera taxa richness and relative abundance of Ephemeroptera individuals tended to be higher at sites in the TRMS group than in the TRPT or PRMS groups (fig. 6). The Ephemeroptera *Baetis, Fallceon quilleri*, and *Tricorythodes* were the most abundant macroinvertebrates in the TRMS group. The most common functional feeding mode at sites in the TRMS group was the collector-gatherers (mean of 59 percent), with smaller proportions of filter-collectors (mean of 26 percent) and scrapers (mean of 9 percent). Other functional feeding modes such as predators and omnivores accounted for the remainder. The proportion of intolerant macroinvertebrates averaged 53 percent and generally was higher in the TRMS group than the TRPT or PRMS groups (fig. 6). The 2007 sample from the main-stem Tongue River above Hanging Woman Creek (site T10) was an outlier to the TRMS group in the ordination (fig. 5) because the community was composed primarily of noninsects and Diptera, such as the snail *Physa*, the scud *Hyallela*, and the blackfly *Simulium* that are tolerant organisms (2 percent intolerant, table 6). Site T10 plotted within ordinations of the TRMS group during 2005–06 (Peterson and others, 2009) and 2008. The macroinvertebrate communities at site T10 might be affected by Tongue River Reservoir upstream as noted in the section “Spatial and Temporal Patterns.”

Taxa richness at sites in the TRPT group was dominated by Diptera, with a mean of 16 Diptera taxa compared to a mean of 30 taxa total per sample during 2005–08. The Diptera also predominated in terms of relative abundance (table 6), accounting for an average of 52 percent of the macroinvertebrates. Although most of the Diptera taxa were Chironomidae, the blackfly larvae *Simulium* were common and sometimes numerically dominant. Trichoptera larvae, such as *Cheumatopsyche* and *Hydropsyche*, also were abundant in some of the TRPT samples. Macroinvertebrate communities in the TRPT group were characterized by distinctively lower relative abundance of intolerant macroinvertebrates than the TRMS or PRMS groups (fig. 6).

Taxa richness in the PRMS group ranged from 9 to 38 taxa and averaged 22 taxa per sample. Taxa richness in the PRMS group tended to be lower than in the TRMS or TRPT groups (fig. 6). Diptera dominated the taxa richness (average of 9 taxa per sample) and relative abundance (average of 45 percent per sample) of the PRMS group. The proportion of filterer-collectors was relatively high in the PRMS group, due in part to the dominance of the blackfly larvae *Simulium* in many of the samples. Macroinvertebrate communities in the PRMS group tended to be intermediate to those of the TRMS and TRPT groups in terms of Ephemeroptera taxa richness, relative abundance of Ephemeroptera, and relative abundance of intolerant macroinvertebrates.

Taxa richness in macroinvertebrate communities of the Little Powder River (sites P14–P16) was dominated by Diptera, whereas Trichoptera predominated in terms of relative abundance (table 6). Communities of the Little Powder River also were characterized by high relative abundance of filterer-collectors and low relative abundance of intolerant macroinvertebrates. Communities at sites on Rosebud Creek (sites R1 and R2) and in the Cheyenne (sites C1–C6) and Belle Fourche River (B1 and B2) drainage basins were characterized by low taxa richness, high proportions of filterer-collectors, and low proportions of intolerant macroinvertebrates; Diptera and noninsects often predominated in terms of taxa richness and relative abundance (table 6). Intermittent flow conditions, such as in the Cheyenne and Belle Fourche River drainage basins, and high specific-conductance values and flooding common to plains streams (Wangsness and Peterson, 1980) create a harsh environment for macroinvertebrate communities, regardless of anthropogenic effects.

Spatial and Temporal Patterns

Data from the main-stem Tongue River and main-stem Powder River were analyzed using ANOVA to examine spatial patterns, such as differences by site in the downstream direction, and temporal patterns, which were differences by year. A brief discussion of spatial and temporal patterns at sites on tributaries also is presented, but the tributaries did not have sufficient data for analysis using ANOVA. Therefore, the site groupings in this section are slightly different from the groupings used to describe macroinvertebrate community composition.

Main-Stem Tongue River

Results of ANOVA using the Tukey method for analysis of metric data from main-stem Tongue River sites T1, T5, T9, T10, T14, and T18 are listed in table 7. Macroinvertebrate community metrics did not vary significantly among main-stem Tongue River sites, with one exception. During 2005–08, the relative abundance of noninsects in the Tongue River above Hanging Woman Creek (site T10) was significantly different ($p < 0.05$) from that of the Tongue River at sites T9, T14, and T18. As shown in figure 7, the mean relative abundance of noninsects during 2005–08 was higher at site T10 (about 16 percent) than at other sites on the main-stem Tongue River (4 percent or less). The macroinvertebrate communities at site T10 might be affected by Tongue River Reservoir, which is on the main-stem Tongue River about 9 air-miles upstream from site T10. The mean relative abundance of Trichoptera decreased from site T1 to site T9 (fig. 7).

The ANOVA also indicated significant variation ($p < 0.05$) between years in the relative abundance of macroinvertebrates in the scraper feeding mode (table 7). The mean relative abundance of scrapers was higher in 2006 than other years (fig. 7). Though not significant at $p < 0.05$, the proportion of intolerant macroinvertebrates also was higher in 2006 (mean 72 percent) than in other years (mean 44–52 percent; fig. 7). The extended drought that was particularly severe in 2006 might be at least partly responsible for year-to-year differences in the metric values.

Main-Stem Powder River

Macroinvertebrate community metrics on the main-stem Powder River indicated differences at sites in the middle reach from other sites on the main-stem Powder River. The ANOVA tests indicated one or more metrics varied significantly ($p < 0.05$) at sites P3–P5 and P8 (the middle reach, from below the Willow Creek to below the Crazy Woman Creek confluences) from metrics at sites P9, P11, P12, P13, and P18 (the lower reach) from above the confluence with Clear Creek to Locate, Mont.; table 7). Graphical presentation of the mean values during 2005–08 for five metrics (fig. 8) shows that values from the middle reach (sites P3–P5 and P8) and to a lesser extent, site P2, were notably different than values at other sites on the main-stem Powder River both upstream (site P1) and

Table 6. Macroinvertebrate community metrics for streams in the Powder River structural basin, Wyoming and Montana, 2005–08.

[Shaded cells indicate main-stem sampling sites on the Tongue or Powder River. %, percent]

Site number (fig. 1)	Abbreviated site name	Sample date	Taxa richness			
			Total	Ephemeroptera richness	Trichoptera richness	Diptera richness
R2	Rosebud Creek at mouth	9/15/2005	28	4	2	9
T1	Tongue River at Monarch	8/15/2005	35	8	8	7
		8/23/2006	34	7	7	10
		8/29/2007	27	6	8	4
T2	Goose Creek	8/17/2005	26	8	4	6
		8/22/2006	29	6	4	11
		9/11/2007	32	8	5	6
		8/4/2008	23	7	3	6
T3	Upper Youngs Creek	6/15/2005	35	1	6	15
		6/28/2006	37	2	5	17
		6/21/2007	30	2	3	15
		6/26/2008	40	2	6	20
T4	Youngs Creek at mouth	6/14/2005	39	2	2	22
		6/27/2006	35	2	3	19
T5	Tongue River below Youngs Creek	8/15/2005	30	7	4	9
		8/22/2006	32	7	6	9
		8/29/2007	32	8	6	10
		8/21/2008	30	11	5	8
T7	Squirrel Creek at mouth	6/13/2005	39	2	1	25
		7/12/2007	29	4	3	18
		6/25/2008	12	1	2	8
T8	Prairie Dog Creek	8/25/2006	28	2	5	12
		9/11/2008	25	6	5	5
T9	Tongue River at State line	9/14/2005	31	5	7	13
		8/24/2006	33	6	5	9
		8/28/2007	29	11	3	10
		8/21/2008	28	9	4	8
T10	Tongue River above Hanging Woman Creek	8/16/2005	31	6	5	9
		8/28/2006	24	4	4	6
		8/28/2007	41	3	1	19
		9/9/2008	30	7	8	4
T11	Upper Hanging Woman Creek	6/22/2005	47	1	0	33
		7/11/2007	28	1	3	12
T12	Middle Hanging Woman Creek	6/21/2005	44	2	2	23
		7/10/2007	31	4	2	19
T13	Hanging Woman Creek at mouth	6/23/2005	40	3	0	21
		7/10/2007	35	4	3	18
		6/27/2008	34	2	0	22
T14	Tongue River at Birney Day School	9/12/2005	24	7	6	5
		8/28/2006	30	9	6	7
		8/27/2007	32	9	9	7
		8/21/2008	32	7	8	8
T16	Middle Otter Creek	6/20/2007	8	0	1	5
T17	Otter Creek at mouth	6/30/2005	31	1	3	16
		6/28/2006	26	2	4	13
		6/24/2008	31	1	4	17
T18	Tongue River below Brandenberg Bridge	9/13/2005	30	7	5	11
		8/31/2006	38	10	8	11
		8/27/2007	23	10	3	6
T19	Pumpkin Creek	6/23/2005	5	0	1	4
		6/18/2007	9	1	2	6
P1	Powder River above Salt Creek	7/20/2005	38	7	3	24
		7/24/2006	34	7	3	19
		8/30/2007	17	5	4	4

Table 6. Macroinvertebrate community metrics for streams in the Powder River structural basin, Wyoming and Montana, 2005–08. —Continued

[Shaded cells indicate main-stem sampling sites on the Tongue or Powder River. %, percent]

Site number (fig. 1)	Taxa relative abundance				Functional feeding mode relative abundance			Tolerance
	Ephemeroptera abundance (%)	Trichoptera abundance (%)	Diptera abundance (%)	Noninsect abundance (%)	Collector-gatherer abundance (%)	Filterer-collector abundance (%)	Scraper abundance (%)	Intolerant macro-invertebrates (%)
R2	2	19	15	14	23	19	39	4
T1	76	14	2	3	79	12	4	26
	32	33	10	3	51	12	26	49
	53	39	4	2	49	39	9	41
T2	57	16	2	10	72	15	5	41
	42	7	7	1	75	6	12	47
	54	29	5	4	57	29	8	56
	50	29	17	1	51	44	2	38
T3	34	3	47	11	44	50	3	7
	37	33	9	5	58	34	5	31
	37	5	44	5	52	39	0	9
	29	30	23	10	45	34	7	30
T4	12	7	30	41	57	19	10	1
	6	15	27	45	52	30	11	1
T5	44	30	5	2	62	31	4	54
	25	17	6	12	61	15	18	69
	41	24	7	0	63	24	6	70
	68	14	13	1	69	21	4	48
T7	1	1	79	15	59	25	4	0
	2	4	85	9	4	64	1	4
	4	1	95	0	4	95	0	0
T8	20	32	10	0	48	35	13	56
	7	79	2	1	15	80	2	87
T9	69	14	12	0	74	17	3	28
	39	13	4	9	71	11	7	79
	85	3	11	1	78	5	10	43
	64	7	10	0	78	8	8	51
T10	26	19	17	12	56	15	19	38
	7	10	3	9	77	12	10	85
	11	0	36	36	38	21	20	2
	60	12	17	7	64	24	4	53
T11	0	0	65	24	58	4	19	0
	47	4	25	22	71	19	2	2
T12	4	4	36	48	40	7	29	2
	9	32	42	16	20	36	8	35
T13	2	0	32	56	38	12	31	1
	6	3	75	6	29	25	5	12
	8	0	68	19	22	47	18	0
T14	67	26	1	0	66	26	7	72
	46	36	3	0	48	37	12	82
	63	17	11	1	68	17	12	74
	34	28	21	1	51	40	3	50
T16	0	0	100	0	1	99	0	0
T17	1	51	41	3	9	79	3	3
	0	23	69	7	7	90	1	11
	0	48	42	4	11	77	5	35
T18	39	37	16	0	40	38	7	48
	55	23	4	0	58	20	18	69
	82	10	3	0	73	11	11	83
T19	0	0	100	0	0	99	0	0
	0	3	97	0	0	99	0	1
P1	18	28	48	4	46	33	6	30
	32	26	36	1	50	37	1	38
	20	68	5	0	24	71	2	31

Table 6. Macroinvertebrate community metrics for streams in the Powder River structural basin, Wyoming and Montana, 2005–08.—Continued

[Shaded cells indicate main-stem sampling sites on the Tongue or Powder River. %, percent]

Site number (fig. 1)	Abbreviated site name	Sample date	Taxa richness			
			Total	Ephemeroptera richness	Trichoptera richness	Diptera richness
P2	Powder River below Salt Creek	7/21/2005	20	4	3	12
		7/25/2006	33	4	3	21
		8/30/2007	35	6	5	18
P3	Powder River below Willow Creek	7/19/2005	21	5	1	12
		7/26/2006	28	4	4	13
		8/24/2007	21	3	3	12
		7/21/2008	9	1	2	4
P4	Powder River below Burger Draw	7/22/2005	17	4	2	9
		7/27/2006	24	1	4	14
		8/22/2007	10	3	2	3
		7/23/2008	10	1	2	6
P5	Powder River above Crazy Woman Creek	7/13/2005	16	5	2	6
		7/28/2006	21	5	4	9
		8/23/2007	18	4	3	7
		7/24/2008	9	3	2	3
P6	Crazy Woman Creek below I-90	7/11/2005	34	8	4	12
		8/20/2007	25	4	5	5
P7	Crazy Woman Creek near mouth	7/12/2005	17	6	3	4
		8/21/2007	28	5	4	12
		8/20/2008	26	7	3	12
P8	Powder River below Crazy Woman Creek	7/23/2005	34	4	2	24
		8/21/2007	17	4	2	6
		7/25/2008	16	7	1	5
P9	Powder River above Clear Creek	7/24/2005	32	6	1	21
		7/26/2007	34	10	4	12
		7/29/2008	23	9	2	7
P10	Clear Creek	9/13/2005	17	6	4	3
		8/21/2006	34	5	6	12
		9/10/2007	31	5	4	15
		8/5/2008	28	9	5	9
P11	Powder River below Clear Creek	7/25/2005	26	12	3	6
		8/3/2006	24	3	4	9
P11	Powder River below Clear Creek	7/26/2007	29	8	5	10
		7/30/2008	21	12	2	4
P12	Powder River at Moorhead	7/26/2005	29	7	5	13
		7/26/2007	20	7	3	7
		7/30/2008	21	8	3	4
P13	Powder River at Broadus	7/19/2005	10	5	1	3
		8/2/2006	28	4	6	12
		7/25/2007	18	7	3	4
		7/31/2008	12	6	2	2
P14	Little Powder River at Highway 59	8/8/2007	29	1	2	10
P15	Little Powder River above Dry Creek	6/13/2005	12	2	2	6
		6/23/2006	29	2	4	15
		8/7/2007	19	4	3	8
		8/18/2008	21	3	2	8
P16	Little Powder River at Biddle	6/27/2005	37	2	3	22
		8/9/2007	26	4	3	11
P17	Powder River below Little Powder River	7/21/2005	20	6	3	8
		7/25/2007	26	9	3	8
P18	Powder River near Locate	7/22/2005	9	4	2	2
		7/24/2007	14	4	3	3
C3	Cheyenne River near Dull Center	6/27/2005	28	2	2	18
C4	Little Thunder Creek	6/9/2005	16	1	0	11
C6	Cheyenne River near Spencer	6/6/2005	18	1	1	12
		6/15/2007	7	0	0	7
B1	Belle Fourche River	6/29/2005	17	1	1	8

Table 6. Macroinvertebrate community metrics for streams in the Powder River structural basin, Wyoming and Montana, 2005–08.—Continued

[Shaded cells indicate main-stem sampling sites on the Tongue or Powder River. %, percent]

Site number (fig. 1)	Taxa relative abundance				Functional feeding mode relative abundance			Tolerance
	Ephemeroptera abundance (%)	Trichoptera abundance (%)	Diptera abundance (%)	Noninsect abundance (%)	Collector-gatherer abundance (%)	Filterer-collector abundance (%)	Scraper abundance (%)	Intolerant macro-invertebrates (%)
P2	9	5	86	0	13	59	3	3
	6	10	83	0	57	29	0	10
	20	44	26	2	29	52	2	16
P3	16	10	74	0	12	76	7	16
	14	57	26	1	18	73	1	19
	5	59	35	0	8	90	0	5
	0	10	89	0	0	98	0	2
P4	9	46	45	0	12	71	0	14
	1	36	56	5	5	78	5	8
	3	2	94	0	4	96	0	4
	0	4	95	0	1	99	0	1
P5	12	18	69	1	13	85	0	15
	8	59	20	0	17	64	1	31
	6	50	42	1	9	84	1	7
	1	2	97	0	1	99	0	1
P6	53	23	15	5	59	32	4	31
	14	32	2	1	53	31	10	49
P7	5	6	86	0	6	92	0	4
	23	45	13	2	36	46	4	30
	37	37	22	0	37	45	3	36
P8	6	20	70	3	24	51	0	9
	2	9	88	1	2	95	0	2
	4	2	89	1	4	90	1	5
P9	11	4	80	2	21	31	1	10
	62	22	11	1	62	27	2	61
	60	4	34	0	59	32	1	59
P10	74	20	0	0	79	20	1	94
	18	42	9	4	45	42	9	74
	60	10	14	4	69	12	5	73
	43	21	7	1	57	21	14	63
P11	49	32	16	0	40	49	10	52
	5	67	11	3	23	69	3	37
P11	59	28	5	2	64	27	4	57
	53	23	16	1	52	39	8	66
P12	34	32	29	3	37	49	3	30
	69	5	23	0	69	23	3	66
	38	5	55	1	38	57	1	41
P13	66	1	33	0	66	34	0	66
	15	55	27	2	24	54	6	19
	51	26	20	0	54	42	1	55
	56	4	39	0	55	44	0	55
P14	6	8	7	58	64	12	10	18
P15	1	2	95	0	2	96	0	1
	1	91	4	1	3	91	1	15
	2	88	8	1	3	91	0	7
	8	73	13	0	10	79	1	10
P16	3	47	36	2	13	58	8	7
	38	23	26	3	39	28	7	34
P17	59	18	21	0	69	26	1	61
	20	36	40	1	23	65	2	22
P18	74	7	19	0	74	25	0	74
	21	73	3	0	19	77	0	26
C3	3	0	44	51	35	18	42	0
C4	1	0	98	1	3	95	0	0
C6	0	0	98	1	2	94	1	0
	0	0	100	0	8	48	0	0
B1	0	1	78	19	20	77	0	1

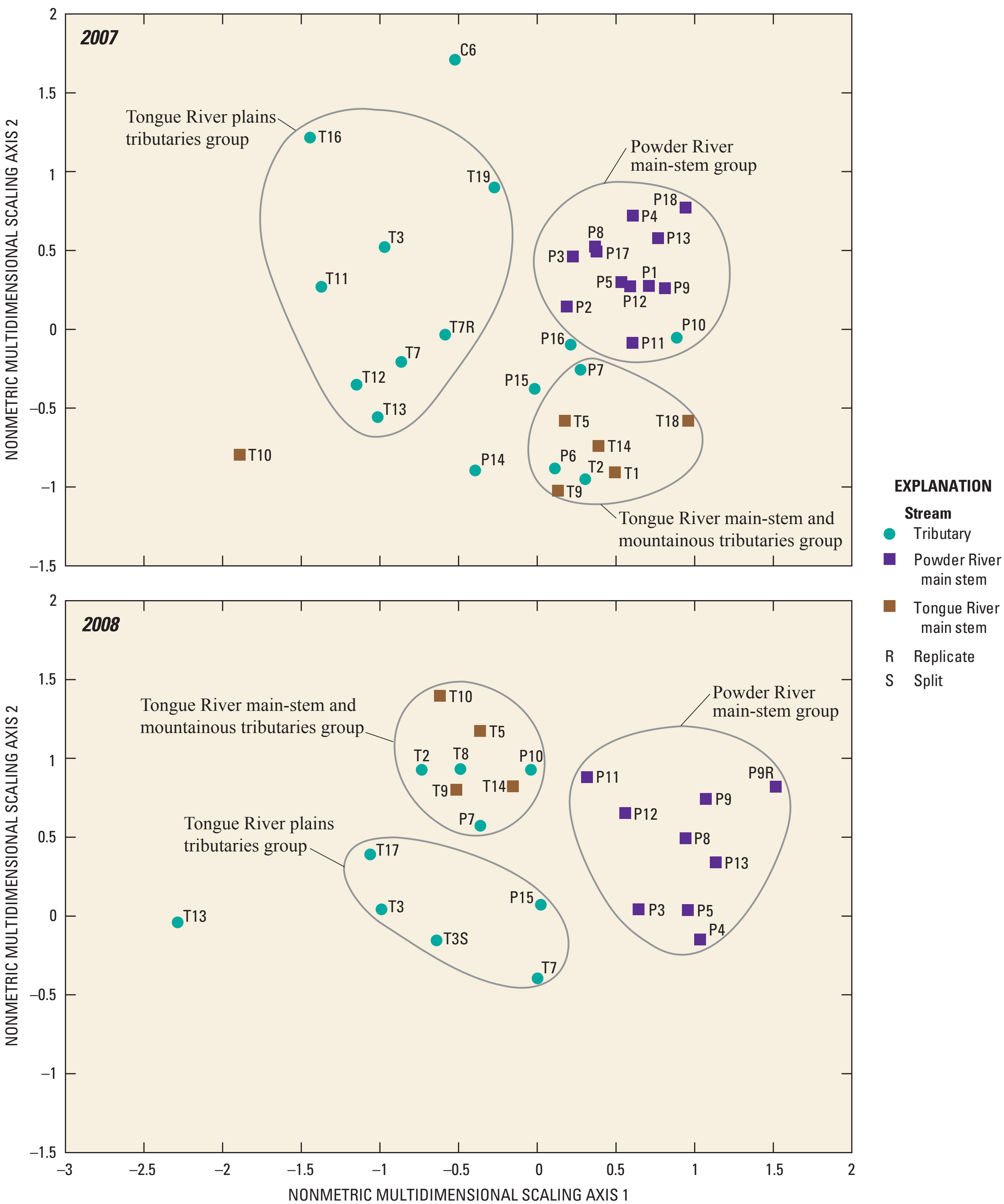


Figure 5. Similarities of macroinvertebrate community taxonomic composition within stream groups depicted by nonmetric multidimensional scaling ordinations, Powder River structural basin, Wyoming and Montana, 2007–08.

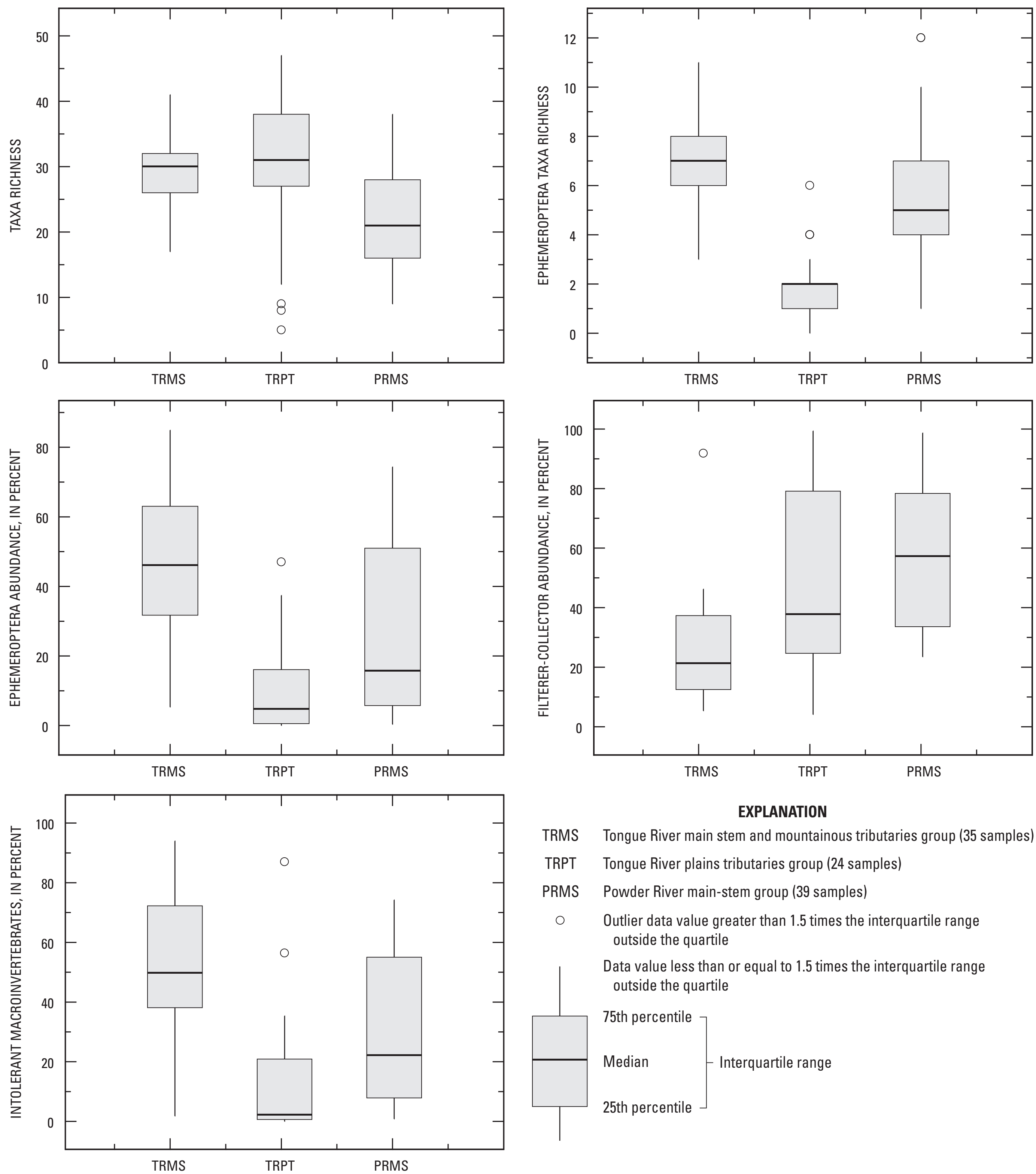


Figure 6. Selected macroinvertebrate community metrics by stream group, Powder River structural basin, Wyoming and Montana, 2005–08.

Table 7. Analysis of variance in macroinvertebrate community metrics, main-stem Tongue River and main-stem Powder River, Wyoming and Montana, 2005–08.

[Significance tested by Tukey method at probability level less than 0.05]

Metric	Main-stem Tongue River (sites T1, T5, T9, T10, T14, and T18)		Main-stem Powder River (sites P1-P5, P8, P9, P11-P13, P17, P18)	
	Significant differences between sites	Significant differences between years	Significant differences between sites	Significant differences between years
Taxa richness	None	None	None	2006 to 2008
Ephemeroptera taxa richness	None	None	P4 to P9, P4 to P11, P4 to P12	None
Trichoptera taxa richness	None	None	None	2005 to 2006, 2005 to 2007, 2006 to 2008, 2007 to 2008
Diptera taxa richness	None	None	None	2005 to 2008, 2006 to 2007, 2006 to 2008
Ephemeroptera relative abundance	None	None	P4 to P9, P4 to P12, P4 to P13, P4 to P18, P8 to P12, P8 to P13	None
Trichoptera relative abundance	None	None	None	2006 to 2008, 2007 to 2008
Diptera relative abundance	None	None	P4 to P11, P8 to P11, P8 to P18	None
Noninsect relative abundance	T10 to T9, T10 to T14, T10 to T18	None	None	None
Dominant taxa percent	None	None	None	None
Collector-gatherer relative abundance	None	None	P3 to P13, P4 to P9, P4 to P11, P4 to P12, P4 to P13, P5 to P13	None
Filterer-collector relative abundance	None	None	P3 to P9, P4 to P9, P5 to P9	None
Scraper relative abundance	None	2006 to 2008	None	None
Intolerant relative abundance	None	None	P3 to P11, P4 to P11, P4 to P12, P4 to P13, P8 to P11, P8 to P13	None

downstream (sites P9, P11–P13, P17, and P18). Metric values for Ephemeroptera taxa richness, Ephemeroptera relative abundance, and intolerant macroinvertebrate relative abundance tended to be lower, whereas Diptera relative abundance and filterer-collector relative abundance tended to be higher, at sites P3–P5 and P8 than at other sites on the main-stem Powder River (fig. 8). The affected metrics included measures of taxa richness, taxa relative abundance, feeding modes, and tolerance, which were indicative of communitywide differences.

Taxa richness, Trichoptera taxa richness, Diptera taxa richness, and relative abundance of Trichoptera varied significantly ($p < 0.05$) by year during 2005–08 (table 7). As shown in figure 8, using Diptera taxa richness as an example, the metric values in 2006 were higher than in 2005 and 2007–08. Taxa richness and the Trichoptera metrics also were higher in 2006 than the other years. As noted for the main-stem Tongue River, the extended drought and severe low-flow conditions in 2006 might be at least partly the cause of the year-to-year variation in metric values from the main-stem Powder River.

Tributaries

Macroinvertebrate communities at sites on tributaries sometimes showed variation between 2006 and other years (2005, 2007–08) that resembled the patterns observed on the Tongue River and Powder River. For example, metrics with higher values in 2006 than other years included Diptera taxa richness and scraper abundance in Goose Creek (site T2), taxa richness and Trichoptera abundance in Clear Creek (site P10), and taxa richness and Diptera richness in the Little Powder River (site P15; table 6). Comparison of metrics from upper Youngs Creek (site T3) to lower Youngs Creek (site T4) indicated lower relative abundance of Ephemeroptera and higher relative abundance of noninsects at the lower site compared to the upper site, but these data should be used with caution because only 2 years (2005–06) of data were available from site T4 and may reflect natural spatial variation with lower elevation and increased drainage area. Metrics for the lower site on Squirrel Creek (site T7) indicated relatively low taxa richness in 2008 compared to 2005 and 2007. The

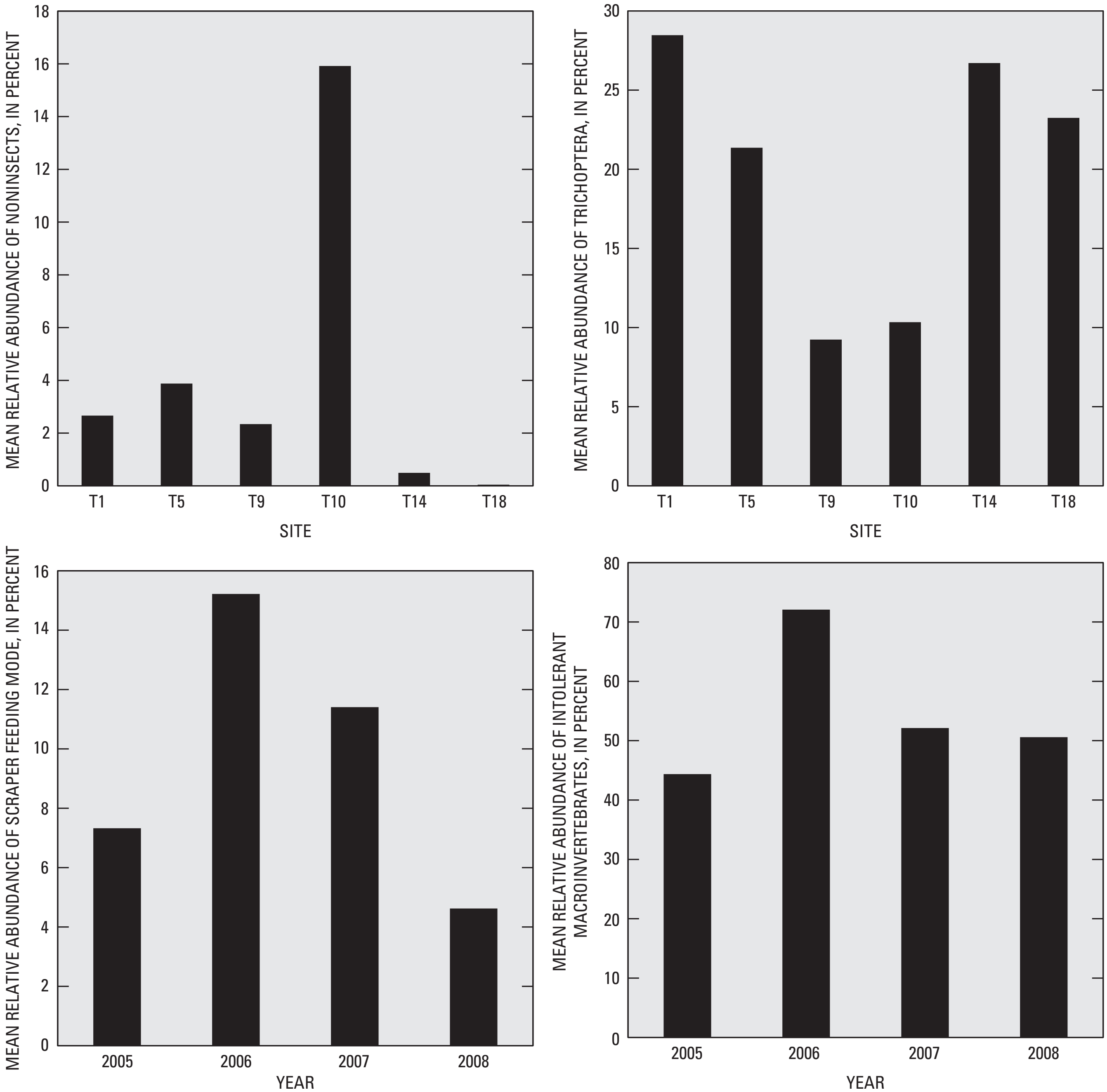


Figure 7. Mean values for selected macroinvertebrate community metrics by site and by year, main-stem Tongue River, Wyoming and Montana, 2005–08.

macroinvertebrate communities at site T7 might be affected by intermittent streamflow. The upper site on Squirrel Creek (site T6) did not have sufficient riffle habitat for sampling; therefore, no metric data are available for comparison with the lower site. Interpretation of data from other tributaries, such as Crazy Woman Creek, Hanging Woman Creek, and Otter Creek is limited by the small number of samples available and variability in community composition, which in turn might be related to intermittent streamflow at some of the sites and natural spatial variation.

Effects of Environmental Variables on Macroinvertebrate Communities

Analysis of environmental variables during 2005–08 (table 3) indicated grouping of sites, similar to the TRMS, TRPT, and PRMS stream groups observed for the macroinvertebrate communities. The PCA ordination of sites and environmental variables from 2007 is shown in figure 9 as an example. Sites on the main-stem Tongue River tended to group along the right side of the ordination (positive correlation with principal components

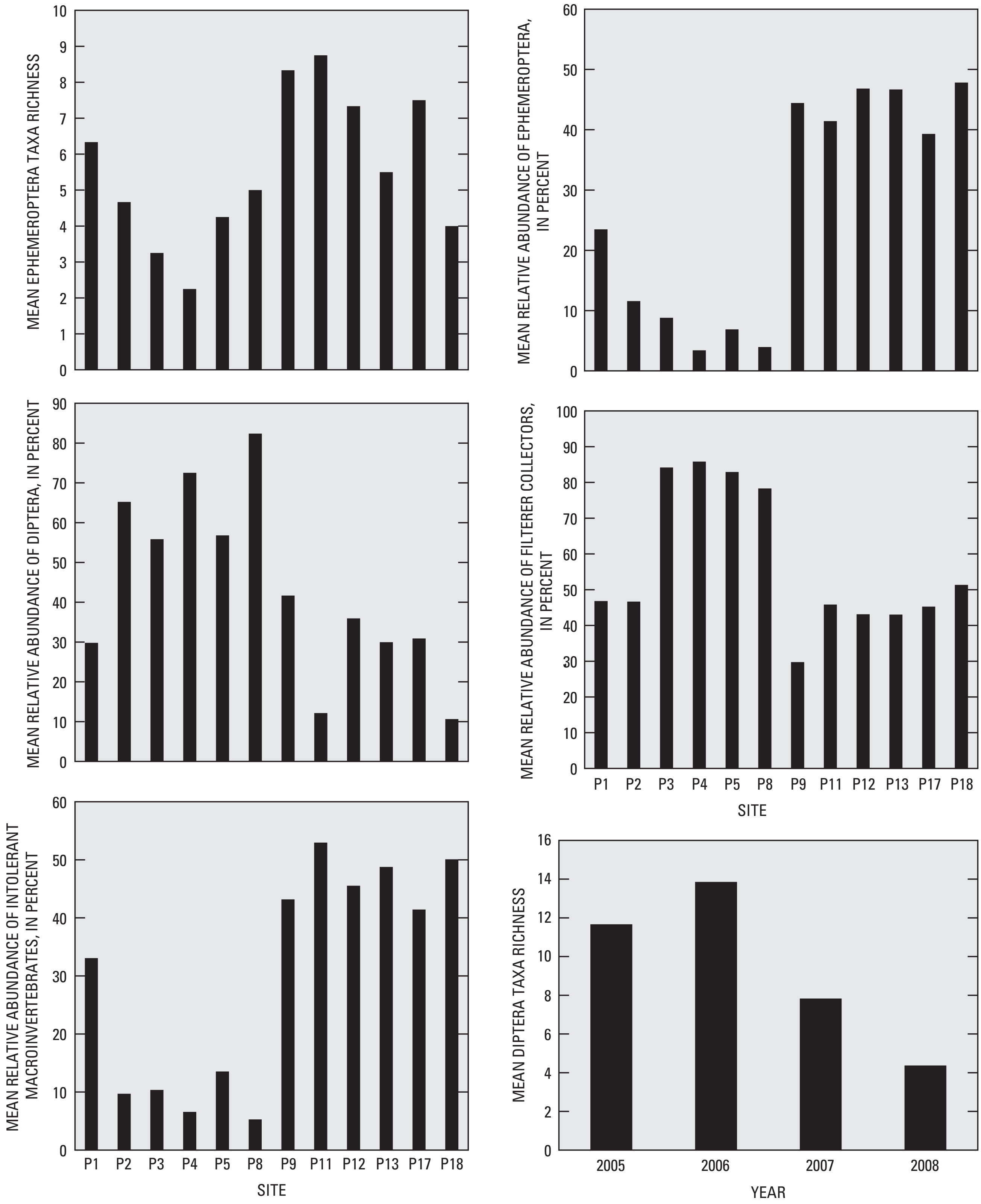
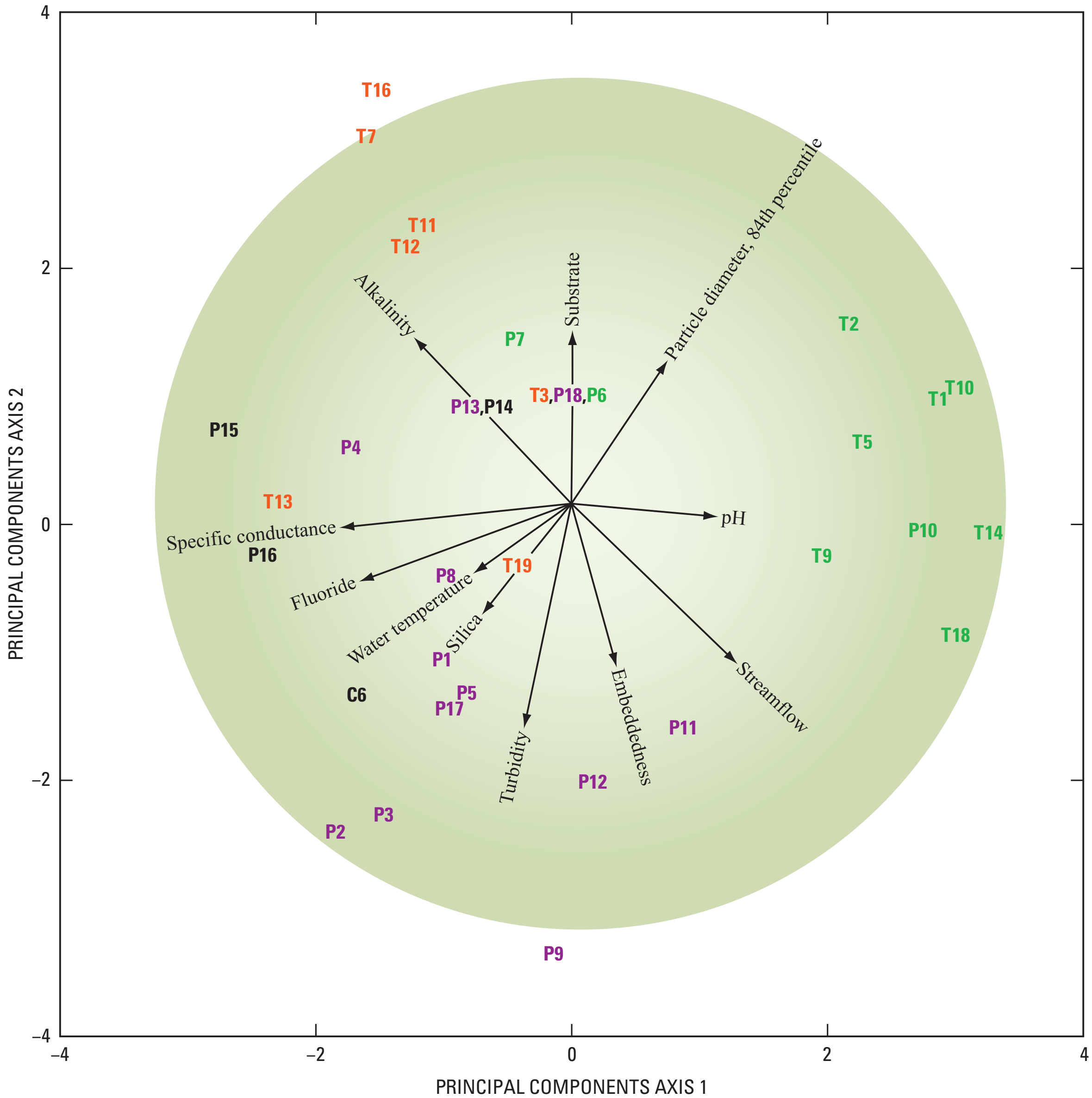


Figure 8. Mean values for selected macroinvertebrate metrics by site and by year, main-stem Powder River, Wyoming and Montana, 2005–08.



EXPLANATION

Site groups

T18 Tongue River main stem and mountainous tributaries

T13 Tongue River plains tributaries

P9 Powder River main stem

C6 Not assigned

Figure 9. Principal components ordination showing relations among sampling sites based on selected environmental variables, Powder River structural basin, Wyoming and Montana, 2007.

Table 8. Environmental variables best correlated with macroinvertebrate community taxonomic composition, by stream group and year, Powder River structural basin, Wyoming and Montana, 2005–08.

[D_{84}, diameter of the 84th percentile of particles]

Year	Spearman correlation coefficient	Environmental variables
		Main-stem Tongue River
2005	0.52	Streamflow, specific conductance, dissolved oxygen
2006	0.21	Streamflow
2007	0.89	Specific conductance, dissolved oxygen, pH, turbidity
2008	0.77	Streamflow, specific conductance, dissolved oxygen, pH, and water temperature
		Tongue River plains tributaries
2005	0.47	Streamflow and specific conductance
2006	0.54	Specific conductance, dissolved oxygen, and substrate
2007	0.61	Streamflow and specific conductance
2008	0.66	Dissolved oxygen, embeddedness, and water temperature
		Main-stem Powder River
2005	0.38	alkalinity and pH
2006	0.70	turbidity, embeddedness, and water temperature
2007	0.56	turbidity, embeddedness, D_{84}, specific conductance, and fluoride
2008	0.50	turbidity, embeddedness, D_{84}, alkalinity, and streamflow

(PC) axis 1; fig. 9), whereas sites on plains tributaries to the Tongue River tended to have positive correlation with PC axis 2 (upper left), and sites on the main-stem Powder River tended to have negative correlation with PC axis 2 (lower left). The 2007 eigenvectors indicated PC axis 1 was correlated with chemical variables such as specific conductance and fluoride; PC axis 2 was correlated with physical variables such as turbidity and embeddedness. PCA ordinations for 2005–06 and 2008 showed similar results to those for 2007, due to similarities in values of environmental variables within the stream groups.

Given the differences in environmental variables between stream groups and differences in the number of sites sampled per year, PCA ordinations were repeated separately by stream group (TRMS, TRPT, and PRMS) and by year. Collinear variables were removed on a stepwise basis for each stream group and year, but in general, the pebble count measure, D_{84}, was used as an indicator of the D_{50} and percent substrate less than 2 mm; instantaneous streamflow was used as an indicator of microhabitat depth and velocity, and specific conductance was used as an indicator of major ions including sodium, potassium, chloride, sulfate, and total dissolved solids. Calcium, magnesium, and alkalinity were often but not always correlated with specific conductance. The selected environmental variables that produced the best correlation with the macroinvertebrate community taxonomy data using the BEST routine (Clarke and Gorley, 2006) are listed in table 8.

Main-Stem Tongue River

The macroinvertebrate communities at sites along the main-stem Tongue River tended to be best correlated with streamflow, specific conductance, and dissolved-oxygen concentrations during 2005–08. Spearman correlation coefficients between the macroinvertebrate taxonomy data and environmental variables identified through PCA ranged from 0.21 in 2006 to 0.89 in 2007 (table 8). The correlation with streamflow might be attributed to the effects of consistently higher streamflow downstream from Tongue River Reservoir (sites T10, T14, and T18) than upstream from the reservoir (sites T1, T5, and T9; fig. 3*A*). Low streamflow during the drought year of 2006 (fig. 3*C*) might be a factor in the relatively low correlation coefficient of 0.21 for that year. Correlation of macroinvertebrate communities with specific conductance and dissolved-oxygen concentrations might also reflect the effects of Tongue River Reservoir. Specific-conductance values at sites upstream from the reservoir increased from site T1 to T9 and tended to be higher upstream from the reservoir than downstream (fig. 4). Dissolved-oxygen concentrations tended to be lower downstream from the reservoir than upstream (fig. 10), although it should be noted that diel changes in dissolved-oxygen concentration were not measured.

Tongue River Plains Tributaries

Among all years, macroinvertebrate communities at sampling sites on plains tributaries to the Tongue River generally were best correlated with streamflow, specific conductance, and dissolved-oxygen concentrations (table 8). In 2005 for example, Hanging Woman Creek (sites T11–T13) had lower streamflow than other plains tributary sites such as Youngs Creek (sites T3 and T4), Squirrel Creek (site T7), Otter Creek (site T17), and Pumpkin Creek (site T19) and had higher specific-conductance values than most other plains tributary sites (fig. 10) perhaps due to higher intermittency in this system. The pattern of lower streamflow and higher specific conductance in Hanging Woman Creek than other plains tributaries also was repeated in 2007. Embeddedness, which was correlated with macroinvertebrate communities during 2008, ranged from less than 10 percent in Squirrel Creek (site T7) to 70 percent in Prairie Dog Creek (site T8) during 2008 (table 3).

Main-Stem Powder River

Macroinvertebrate communities at sites along the main-stem Powder River were correlated with turbidity and embeddedness in 2006–08, as well as other variables including D_{84}, alkalinity, specific conductance, and streamflow in one or

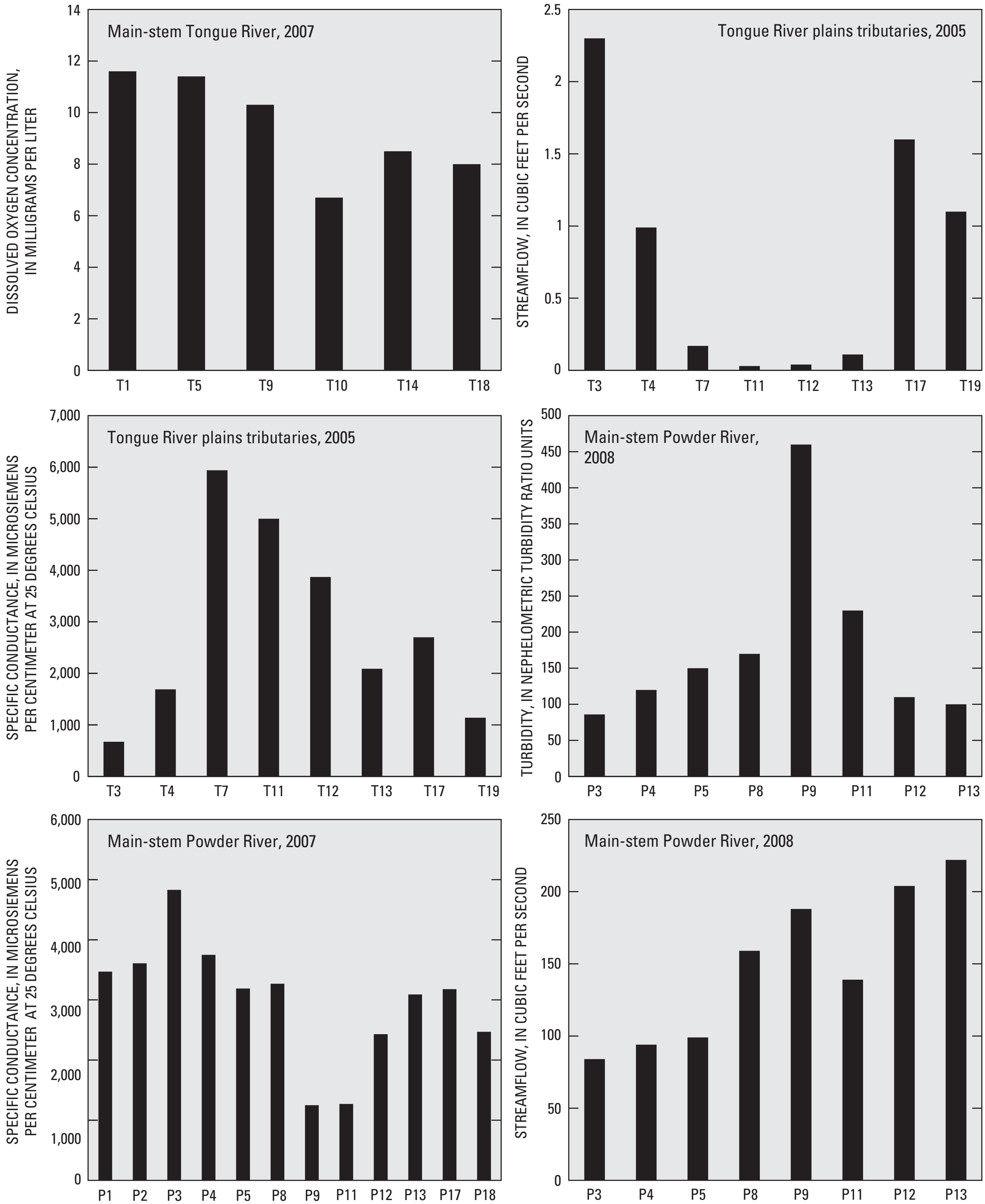


Figure 10. Selected environmental variables correlated with macroinvertebrate communities, Powder River structural basin, 2005–08.

more years during 2005–08 (table 8). Embeddedness (table 3) and turbidity (fig. 10) varied inconsistently with downstream direction along the main-stem Powder River. Turbidity values were correlated with streamflow in 2005 (r = 0.71) and 2007 (r = 0.82) but not in 2006 or 2008. Alkalinity concentrations, which were correlated with the macroinvertebrate communities in 2005 and 2008, were consistently higher in the Powder River below Burger Draw (site P4) than at other sites on the Powder River during 2005–08 (fig. 4; table 3). The Powder River at site P4 receives CBNG discharges from several drainages upstream. Specific conductance and dissolved-fluoride concentrations, which were correlated with the macroinvertebrate communities in 2007, reached maximum values in 2007 in the Powder River below Willow Creek (site P3; fig. 10 and table 3). Streamflow, which was correlated with macroinvertebrate communities in 2008, generally increased in the downstream direction along the main-stem Powder River in 2008 (fig. 10).

The BEST routine also was used to test if the environmental variables correlated with the macroinvertebrate communities of the middle reach of the Powder River (sites P3, P4, P5, and P8) were the same as those in the upper and lower reaches. The environmental data were renormalized, PCAs recalculated, and BEST correlation coefficients were recomputed using data from those four sites. The analyses confirmed that the environmental variables affecting the macroinvertebrate communities of the middle reach generally were the same as those affecting the upper and lower reaches.

As an additional test of the relations between macroinvertebrate communities and environmental variables in the main-stem Powder River, environmental variables from the PCA and BEST analyses were tested for correlation with the macroinvertebrate metrics (table 9). The maximum correlation coefficients occurred with streamflow and specific conductance. The relative abundance of Ephemeroptera increased with streamflow (r = 0.58) and decreased with specific conductance (r = –0.56). The relative abundance of intolerant macroinvertebrates also decreased with increasing specific conductance (r = –0.58). The relative abundance of Trichoptera decreased with streamflow (r = –0.52).

The correlations observed between the environmental variables and the macroinvertebrate taxonomy and metrics indicate that variation in the macroinvertebrate communities can be partially explained by variation in the environmental variables that were measured. Other potential causes for variation in the macroinvertebrate communities include natural population dynamics, sampling techniques, environmental variables that were not measured, and fluctuations in the measured environmental variables beyond those observed at the time of sampling.

Algal Communities

Algal data are available from 2005 and 2007 for standing crop (*http://waterdata.usgs.gov/wy/nwis/qw*) and algae taxonomy (*http://wy.water.usgs.gov/projects/atg/htms/data.htm*). This section describes the algal data in terms of standing crop, community composition, and community traits that include autecological or environmental indicators. Algal samples were collected from riffles where available and from pools at sites where riffles were unavailable. The reader should be aware that differences in substrate (riffles compared to pools) can affect algal biovolume and abundance of specific taxa; however, algal relations with physical and chemical environment (autecology) are not significantly affected by differences in substrate (Potapova and Charles, 2005).

Standing Crop

Concentrations of chlorophyll-*a* and ash-free dry mass (AFDM) in algae samples collected during 2005 and 2007 generally were small (table 10), indicating a relatively small amount of algal biomass in riffles. Median concentrations

Table 9. Correlation coefficients of macroinvertebrate community metrics with environmental variables, main-stem Powder River, Wyoming and Montana, 2005–08.

Metric	Embeddedness	Substrate	Streamflow	Specific conductance	pH	Water temperature	Dissolved oxygen	Turbidity	Alkalinity	Fluoride
Taxa richness	0.36	–0.39	–0.15	–0.03	–0.42	0.09	0.06	0.41	–0.05	0.09
Ephemeroptera richness	0.13	–0.24	0.43	–0.43	–0.11	0.04	–0.11	0.35	–0.32	–0.36
Trichoptera richness	0.05	–0.31	–0.27	0.06	–0.07	0.05	0.43	0.20	0.16	0.08
Diptera richness	0.38	–0.24	–0.30	0.15	–0.45	0.02	–0.05	0.25	0.04	0.26
Ephemeroptera abundance	–0.02	–0.10	0.58	–0.56	0.11	0.00	–0.17	0.33	–0.21	–0.44
Trichoptera abundance	0.03	–0.16	–0.52	0.19	–0.18	–0.16	0.41	–0.05	0.10	0.02
Diptera abundance	–0.01	0.24	–0.06	0.34	0.07	0.14	–0.20	–0.23	0.08	0.35
Noninsect abundance	0.25	0.00	–0.16	–0.23	–0.04	–0.16	0.26	0.17	0.42	–0.05
Collector-gatherer abundance	–0.03	–0.26	0.40	–0.47	–0.03	0.15	–0.23	0.29	–0.25	–0.30
Filterer-collector abundance	–0.23	0.25	–0.36	0.40	0.22	–0.08	0.22	–0.36	0.20	0.24
Scraper abundance	0.21	–0.04	–0.05	–0.05	–0.11	–0.15	0.13	0.08	0.13	–0.08
Intolerant abundance	–0.03	–0.17	0.47	–0.58	0.07	–0.01	–0.13	0.24	–0.19	–0.47

Table 10. Algal chlorophyll-*a* concentration, ash-free dry mass concentration, density, and biovolume, Powder River structural basin, Wyoming and Montana, 2005 and 2007.

[Shaded cells indicate main-stem sampling sites on the Tongue River or Powder River. mg, milligrams; m^2, square meter; g, grams; cm^3, cubic centimeters; NA, not analyzed or not available]

Site number (fig. 1)	Abbreviated site name	Sample date	Habitat	Chlorophyll-*a* (mg/m^2)	Ash-free dry mass (g/m^2)	Algal density (billion cells/m^2)	Algal biovolume (cm^3/m^2)
R1	Upper Rosebud Creek	7/9/2007	Pool	NA	NA	3.29	2.46
R2	Rosebud Creek at mouth	7/23/2007	Pool	NA	NA	2.26	0.33
T1	Tongue River at Monarch	8/15/2005	Riffle	3.9	9.3	NA	NA
		8/29/2007	Riffle	2.3	5.4	3.71	1.36
T2	Goose Creek	8/17/2005	Riffle	2.1	5.2	NA	NA
		9/11/2007	Riffle	44.1	21.6	3.86	3.84
T3	Upper Youngs Creek	6/21/2007	Riffle	17.8	12.7	3.87	0.61
T4	Youngs Creek at mouth	6/21/2007	Pool	NA	NA	2.16	0.02
T5	Tongue River below Youngs Creek	8/29/2007	Riffle	24.4	22.2	5.12	1.99
T6	Upper Squirrel Creek	7/11/2007	Pool	NA	NA	4.34	0.13
T7	Squirrel Creek at mouth	7/12/2007	Riffle	1.5	3.7	2.55	1.63
T8	Prairie Dog Creek	9/11/2007	Pool	NA	NA	3.07	0.35
T9	Tongue River at State line	9/14/2005	Riffle	47.1	49.4	NA	NA
		8/28/2007	Riffle	19.4	17.2	4.12	1.91
T10	Tongue River above Hanging Woman Creek	8/28/2007	Riffle	12.7	14.5	5.03	1.40
T11	Upper Hanging Woman Creek	7/11/2007	Riffle	11.0	12.3	3.73	0.75
T12	Middle Hanging Woman Creek	7/10/2007	Riffle	16.1	23.4	5.25	3.35
T13	Hanging Woman Creek at mouth	7/10/2007	Riffle	39.7	25.0	5.88	3.28
T14	Tongue River at Birney Day School	8/27/2007	Riffle	1.8	5.7	3.88	2.58
T15	Upper Otter Creek	6/20/2007	Pool	NA	NA	2.31	0.13
T16	Middle Otter Creek	6/20/2007	Riffle	10.1	17.8	3.62	1.10
T17	Otter Creek at mouth	6/19/2007	Pool	NA	NA	2.57	0.21
T18	Tongue River below Brandenberg Bridge	8/27/2007	Riffle	5.5	6.2	3.43	0.73
T19	Pumpkin Creek	6/18/2007	Riffle	0.6	3.8	2.49	0.06
P1	Powder River above Salt Creek	7/20/2005	Riffle	10.1	12.4	NA	NA
		8/30/2007	Riffle	18.3	14.1	4.04	0.13
P2	Powder River below Salt Creek	7/21/2005	Riffle	18.1	23.3	NA	NA
		8/30/2007	Riffle	16.6	13.1	4.11	0.11
P3	Powder River below Willow Creek	7/19/2005	Riffle	2.9	17.4	NA	NA
		8/24/2007	Riffle	6.2	15.2	3.94	0.01
P4	Powder River below Burger Draw	7/22/2005	Riffle	10.5	22.0	NA	NA
		8/22/2007	Riffle	1.0	4.5	2.46	0.0002
P5	Powder River above Crazy Woman Creek	7/13/2005	Riffle	0.7	3.5	NA	NA
		8/23/2007	Riffle	0.9	5.0	3.14	0.0002
P6	Crazy Woman Creek below I-90	7/11/2005	Riffle	1.6	21.0	NA	NA
		8/20/2007	Riffle	17.1	24.7	3.98	0.22
P7	Crazy Woman Creek near mouth	7/12/2005	Riffle	1.4	6.1	NA	NA
		8/21/2007	Riffle	18.1	22.7	3.98	0.62
P8	Powder River below Crazy Woman Creek	7/23/2005	Riffle	10.5	11.7	NA	NA
		8/21/2007	Riffle	5.8	13.9	3.39	0.02
P9	Powder River above Clear Creek	7/24/2005	Riffle	7.3	33.7	NA	NA
		7/26/2007	Riffle	1.3	18.6	2.99	0.01
P10	Clear Creek	9/13/2005	Riffle	12.3	21.8	NA	NA
		9/10/2007	Riffle	15.2	18.0	3.96	0.67
P11	Powder River below Clear Creek	7/25/2005	Riffle	54.1	22.0	NA	NA
		7/26/2007	Riffle	8.4	25.1	3.32	0.0002
P12	Powder River at Moorhead	7/26/2005	Riffle	71.3	61.6	NA	NA
		7/26/2007	Riffle	4.0	32.2	3.87	0.02
P13	Powder River at Broadus	7/25/2007	Riffle	0.5	25.1	4.23	0.43
P14	Little Powder River at Highway 59	8/8/2007	Riffle	443	87.7	3.55	0.51
P15	Little Powder River above Dry Creek	6/13/2005	Riffle	2.7	13.0	NA	NA
		8/7/2007	Riffle	5.5	11.6	3.22	0.16
P16	Little Powder River at Biddle	8/9/2007	Riffle	4.4	4.1	2.47	0.02
P17	Powder River below Little Powder River	7/25/2007	Riffle	0.2	326	3.70	0.63
P18	Powder River near Locate	7/24/2007	Riffle	4.0	6.3	2.99	0.15

Table 10. Algal chlorophyll-*a* concentration, ash-free dry mass concentration, density, and biovolume, Powder River structural basin, Wyoming and Montana, 2005 and 2007.—Continued

[Shaded cells indicate main-stem sampling sites on the Tongue River or Powder River. mg, milligrams; m^2, square meter; g, grams; cm^3, cubic centimeters; NA, not analyzed or not available]

Site number (fig. 1)	Abbreviated site name	Sample date	Habitat	Chlorophyll-*a* (mg/m^2)	Ash-free dry mass (g/m^2)	Algal density (billion cells/m^2)	Algal biovolume (cm^3/m^2)
C1	Porcupine Creek	6/12/2007	Pool	NA	NA	2.08	0.36
C2	Antelope Creek	6/14/2007	Pool	NA	NA	3.44	0.09
C3	Cheyenne River near Dull Center	6/27/2005	Riffle	4.7	16	NA	NA
		6/14/2007	Pool	NA	NA	2.26	0.12
C4	Little Thunder Creek	6/22/2005	Riffle	4.6	7.7	NA	NA
		6/13/2007	Pool	NA	NA	2.74	0.13
C5	Black Thunder Creek	6/13/2007	Pool	NA	NA	3.50	0.01
C6	Cheyenne River near Spencer	6/21/2005	Riffle	0.6	6.1	NA	NA
		6/15/2007	Riffle	4.0	11	2.99	0.45
B1	Belle Fourche River	6/29/2005	Riffle	1.2	9.3	NA	NA
		6/12/2007	Pool	NA	NA	0.65	0.05
B2	Caballo Creek	6/11/2007	Pool	NA	NA	2.74	0.09

of chlorophyll-*a* were 4.6 milligrams per square meter (mg/m^2) in 2005 and 6.2 mg/m^2 in 2007. For comparison, all chlorophyll-*a* concentrations in this study, with the exception of one, were less than the 100–150 mg/m^2 concentration range associated with nuisance algal conditions (Stevenson and others, 1996). The exception was the chlorophyll-*a* concentration of 443 mg/m^2 from the Little Powder River at site P14 in 2007 (table 10) that might have been influenced by less-than-optimal availability of riffle habitat for sampling. Median concentrations of AFDM were 14.5 grams per square meter (g/m^2) in 2005 and 2007. AFDM concentrations were less than 100 g/m^2 in all samples with the exception of the 2007 sample from the Powder River below Little Powder River (site P17), which contained 326 g/m^2 (table 10) due to senescent algae or other organic matter in the sample. Concentrations of chlorophyll-*a* and AFDM at ATG sites generally were similar to concentrations from the lower main-stem Yellowstone River and less than concentrations from the upper and middle main-stem Yellowstone River and tributaries (Peterson and Porter, 2002). Environmental variables affecting algal populations include nutrients, substrate, and light penetration (Stevenson and others, 1996).

Some of the measures of standing crop collected during 2007 (table 10) were moderately correlated with each other after removal of the outliers described previously. Chlorophyll-*a* concentrations were significantly ($p < 0.05$) correlated with AFDM ($r = 0.50$), algal density ($r = 0.66$), and algal biovolume ($r = 0.65$). AFDM concentrations were significantly correlated with algal density ($r = 0.62$, $p < 0.05$) but not biovolume. Algal density was correlated with algal biovolume in samples from riffles ($r = 0.59$, $p < 0.05$) but not in samples from pools.

The highest values of algal density in riffle samples occurred in the Tongue River drainage basin, at sites such as Hanging Woman Creek (sites T12 and T13) and the main-stem Tongue River (sites T5 and T10). Those sites also contained relatively high algal biovolume, as did Goose Creek (site T2) and Tongue River at site T14 (table 10). The lowest values of density from riffles occurred at various sites such as the main-stem Powder River (site P4), Little Powder River (site P16), and Pumpkin Creek (site T19). The lowest values of biovolume from riffle samples occurred on the main-stem Powder River (sites P3, P4, P5, P8, P9, P11, and P12), which include the middle reach. Algal communities in pools tended to have moderate densities and low biovolume values compared to communities in riffles.

Composition

Diatoms (Bacillariophyta) dominated the algal communities in terms of taxa richness, but green algae (Chlorophyta) and blue-green algae (Cyanophyta, cyanobacteria) dominated in terms of relative abundance (table 11). Algal taxa richness in both riffle and pool habitats generally was higher in 2005 than in 2007. For example, the 2005 riffle samples contained a mean of 66 taxa per sample, of which 57 were diatoms, whereas in 2007, riffle samples contained a mean of 41 taxa per sample, of which 31 were diatoms. Compared to the riffle samples, the pool samples contained similar numbers for sample taxa richness and diatom taxa richness, as well as similar differences in taxa richness between 2005 and 2007. The green and blue-green algae each averaged a few taxa per sample in riffles and pools. Among all samples, green algae averaged 26 percent of the relative abundance in 2005 and 67 percent in 2007; blue-green algae averaged 60 percent of the relative abundance in 2005 and 17 percent in 2007. Other types of algae that were less commonly identified in the algal communities included euglenoids (Euglenophyta), yellow-green algae (Chrysophyta), cryptomonads (Cryptophyta), dinoflagellates (Pyrrhophyta), and red algae (Rhodophyta).

Table 11. Algal community metrics for streams in the Powder River structural basin, Wyoming and Montana, 2005 and 2007.

[Shaded cells indicate main-stem sampling sites on the Tongue River or Powder River. %, percent; NA, not available]

Site number (fig. 1)	Abbreviated site name	Habitat	Sample date	Taxa richness and relative abundance							Community metrics			
				Sample taxa richness	Diatom taxa richness	Diatom abundance (%)	Blue-green algae taxa richness	Blue-green algae abundance (%)	Green algae taxa richness	Green algae abundance (%)	Ses-tonic (%)	Eutro-phic (%)	Motile (%)	Nitrogen fixers (%)
R1	Upper Rosebud Creek	Pool	7/9/2007	87	67	46	5	15	10	17	28	51	38	2
R2	Rosebud Creek at mouth	Pool	7/23/2007	41	28	15	2	2	7	46	91	56	12	0
T1	Tongue River at Monarch	Riffle	8/15/2005	43	34	2	4	64	5	34	NA	NA	NA	NA
		Riffle	8/29/2007	40	23	13	4	54	8	19	82	73	10	2
T2	Goose Creek	Riffle	8/17/2005	49	39	6	5	51	5	42	NA	NA	NA	NA
		Riffle	9/11/2007	54	43	54	4	34	4	4	38	69	17	18
T3	Upper Youngs Creek	Riffle	6/21/2007	51	42	6	1	<1	5	33	33	37	2	0
T4	Youngs Creek at mouth	Pool	6/21/2007	59	53	1	2	4	1	92	98	93	3	0
T5	Tongue River below Youngs Creek	Riffle	8/29/2007	53	42	15	3	33	6	50	78	82	11	3
T6	Upper Squirrel Creek	Pool	7/11/2007	21	17	1	2	3	1	54	0	0	82	0
T7	Squirrel Creek at mouth	Riffle	7/12/2007	45	29	16	6	17	7	65	80	75	6	3
T8	Prairie Dog Creek	Pool	8/16/2005	95	82	8	5	58	6	31	NA	NA	NA	NA
		Pool	9/11/2007	66	56	10	3	12	5	67	89	83	17	0
T9	Tongue River at State line	Riffle	9/14/2005	73	58	44	5	37	9	19	NA	NA	NA	NA
		Riffle	8/28/2007	63	49	17	6	72	6	7	31	82	11	5
T10	Tongue River above Hanging Woman Creek	Riffle	8/28/2007	34	24	11	2	17	7	72	77	87	8	5
T11	Upper Hanging Woman Creek	Riffle	7/11/2007	27	13	16	4	17	6	63	62	83	11	0
T12	Middle Hanging Woman Creek	Riffle	7/10/2007	66	55	32	4	15	6	52	28	77	11	8
T13	Hanging Woman Creek at mouth	Riffle	7/10/2007	63	50	11	4	27	5	56	68	73	17	0
T14	Tongue River at Birney Day School	Riffle	8/27/2007	34	21	8	3	20	8	70	88	88	3	1
T15	Upper Otter Creek	Pool	6/20/2007	73	64	5	2	4	6	90	96	95	3	0
T16	Middle Otter Creek	Riffle	6/20/2007	72	63	2	4	17	4	22	26	26	11	0
T17	Otter Creek at mouth	Pool	6/19/2007	60	48	4	3	14	3	63	96	78	19	0
T18	Tongue River below Brandenberg Bridge	Riffle	8/27/2007	60	42	15	6	15	7	63	83	78	12	0
T19	Pumpkin Creek	Riffle	6/18/2007	26	17	1	4	20	1	77	99	97	3	0
P1	Powder River above Salt Creek	Riffle	7/20/2005	69	59	3	5	77	5	20	NA	NA	NA	NA
		Riffle	8/30/2007	33	23	5	3	19	4	71	73	69	10	0
P2	Powder River below Salt Creek	Riffle	7/21/2005	42	34	29	4	41	3	30	NA	NA	NA	NA
		Riffle	8/30/2007	41	29	1	2	18	5	75	97	92	5	0
P3	Powder River below Willow Creek	Riffle	7/19/2005	63	53	3	4	77	6	20	NA	NA	NA	NA
		Riffle	8/24/2007	27	22	<1	1	37	2	62	100	99	1	0
P4	Powder River below Burger Draw	Riffle	7/22/2005	56	47	26	3	25	6	49	NA	NA	NA	NA
		Riffle	8/22/2007	1	0	0	0	0	1	100	100	100	0	0
P5	Powder River above Crazy Woman Creek	Riffle	7/13/2005	92	81	1	3	65	6	33	NA	NA	NA	NA
		Riffle	8/23/2007	1	0	0	0	0	1	100	100	100	0	0
P6	Crazy Woman Creek below I-90	Riffle	7/11/2005	115	106	11	4	54	4	34	NA	NA	NA	NA
		Riffle	8/20/2007	69	58	4	4	27	5	68	90	89	9	0
P7	Crazy Woman Creek near mouth	Riffle	7/12/2005	78	72	<1	3	92	3	8	NA	NA	NA	NA
		Riffle	8/21/2007	72	59	2	6	17	5	79	96	91	4	1

Table 11. Algal community metrics for streams in the Powder River structural basin, Wyoming and Montana, 2005 and 2007.—Continued

[Shaded cells indicate main-stem sampling sites on the Tongue River or Powder River. %, percent; NA, not available]

Site number (fig. 1)	Abbreviated site name	Habitat	Sample date	Taxa richness and relative abundance							Community metrics			
				Sample taxa richness	Diatom taxa richness	Diatom abundance (%)	Blue-green algae taxa richness	Blue-green algae abundance (%)	Green algae taxa richness	Green algae abundance (%)	Ses-tonic (%)	Eutro-phic (%)	Motile (%)	Nitrogen fixers (%)
P8	Powder River below Crazy Woman Creek	Riffle	7/23/2005	68	57	1	6	81	5	18	NA	NA	NA	NA
		Riffle	8/21/2007	46	37	<1	1	1	4	96	97	95	2	0
P9	Powder River above Clear Creek	Riffle	7/24/2005	96	82	9	5	58	8	32	NA	NA	NA	NA
		Riffle	7/26/2007	6	0	0	0	0	3	98	100	98	2	0
P10	Clear Creek	Riffle	9/13/2005	56	47	22	3	47	5	26	NA	NA	NA	NA
		Riffle	9/10/2007	55	42	9	3	15	7	73	83	86	11	0
P11	Powder River below Clear Creek	Riffle	7/25/2005	58	50	1	4	81	4	18	NA	NA	NA	NA
		Riffle	7/26/2007	1	0	0	0	0	1	100	100	100	0	0
P12	Powder River at Moorhead	Riffle	7/26/2005	79	69	3	5	73	4	23	NA	NA	NA	NA
		Riffle	7/26/2007	5	0	0	2	1	2	92	100	93	7	0
P13	Powder River at Broadus	Riffle	7/25/2007	46	35	3	2	14	6	79	87	83	14	0
P14	Little Powder River at Highway 59	Pool	6/14/2005	56	51	56	3	34	2	10	NA	NA	NA	NA
		Riffle	8/8/2007	43	34	10	3	19	3	58	83	79	17	0
P15	Little Powder River above Dry Creek	Riffle	6/13/2005	25	20	<1	3	90	2	8	NA	NA	NA	NA
		Riffle	8/7/2007	37	27	3	4	15	3	75	95	87	12	0
P16	Little Powder River at Biddle	Riffle	8/9/2007	29	17	1	5	11	6	87	93	91	7	0
P17	Powder River below Little Powder River	Riffle	7/25/2007	85	73	4	2	9	6	84	95	92	5	0
P18	Powder River near Locate	Riffle	7/24/2007	48	38	6	4	35	3	51	91	82	14	12
C1	Porcupine Creek	Pool	6/15/2005	80	74	25	3	49	3	26	NA	NA	NA	NA
		Pool	6/12/2007	47	34	5	3	27	6	65	93	91	7	0
C2	Antelope Creek	Pool	6/8/2005	60	47	26	3	30	8	43	NA	NA	NA	NA
		Pool	6/14/2007	44	34	2	3	9	4	87	97	95	5	0
C3	Cheyenne River near Dull Center	Riffle	6/27/2005	56	48	9	3	60	5	31	NA	NA	NA	NA
		Pool	6/14/2007	56	47	4	2	23	3	69	96	93	7	0
C4	Little Thunder Creek	Riffle	6/22/2005	66	61	1	4	98	1	1	NA	NA	NA	NA
		Pool	6/13/2007	52	46	4	3	15	2	78	94	96	7	4
C5	Black Thunder Creek	Pool	6/7/2005	74	59	11	4	40	9	48	NA	NA	NA	NA
		Pool	6/13/2007	17	11	<1	2	4	2	92	99	95	4	0
C6	Cheyenne River near Spencer	Riffle	6/21/2005	74	67	17	3	50	2	32	NA	NA	NA	NA
		Riffle	6/15/2007	26	18	6	2	15	4	78	94	93	2	0
B1	Belle Fourche River	Riffle	6/29/2005	69	64	9	3	78	2	13	NA	NA	NA	NA
		Pool	6/12/2007	51	40	4	2	19	4	74	92	91	7	0
B2	Caballo Creek	Pool	6/28/2005	86	77	33	4	44	5	23	NA	NA	NA	NA
		Pool	6/11/2007	39	30	2	4	12	2	83	95	92	6	0

The taxonomic composition of the algal communities showed similarities within river drainage basins and by habitat. NMDS ordinations of the Bray-Curtis similarity coefficients for algal taxonomic data from 2007 (fig. 11) and 2005 (Peterson and others, 2009) indicated two general groups of sites corresponding with riffle samples: (1) a Tongue River drainage basin group that included sites on the main stem, Tongue River plains tributaries, and Clear Creek; and (2) a Powder River drainage basin group that included sites on the main-stem Powder River, Crazy Woman Creek, and the Little Powder River. Samples collected from pool habitats in various drainage basins formed a third group of sites.

Algal communities at sites in the Tongue River drainage basin group contained an average of 50 taxa per sample in 2007. Taxa richness in the Tongue River drainage basin group was high compared to the Powder River drainage basin group and similar to the pool group (fig. 12). Green algae tended to be the most abundant algae in both the Tongue River and Powder River drainage basin groups, but the Tongue River drainage basin group generally contained more blue-green algae and less green algae than the Powder River drainage basin group. The most abundant taxa in the Tongue River drainage basin group were *Aphanocapsa* and *Oscillatoria* (blue-green algae) and *Chlorella* (green algae). The proportion of algae that are capable of fixing atmospheric nitrogen tended to be low throughout the study area but was highest in the Tongue River drainage basin group (fig. 12). The relative abundance of nitrogen fixers ranged from 0 percent at most sites to 18 percent in Goose Creek (site T2; table 11). The ability to fix atmospheric nitrogen gives a competitive edge to nitrogen fixers when dissolved-nitrogen concentrations are low or ratios of nitrogen to phosphorus are low (Porter, 2008). Given that Goose Creek receives treated sewage effluent from the city of Sheridan (Wyoming Department of Environmental Quality, 2009), the proportion of nitrogen fixers at site T2 might be a reflection of low ratios of nitrogen to phosphorus. The chlorophyll-*a* concentration in Goose Creek in 2007 was relatively high at 44.1 mg/m^2 (table 10). In 2005, the relative abundance of nitrogen fixers and the chlorophyll-*a* concentration at Goose Creek were comparatively low (Peterson and others, 2009).

Taxa richness of algal communities in the Powder River drainage basin group in 2007 ranged from 1 to 85 taxa (table 11). The green alga *Chlorella* composed 92–100 percent

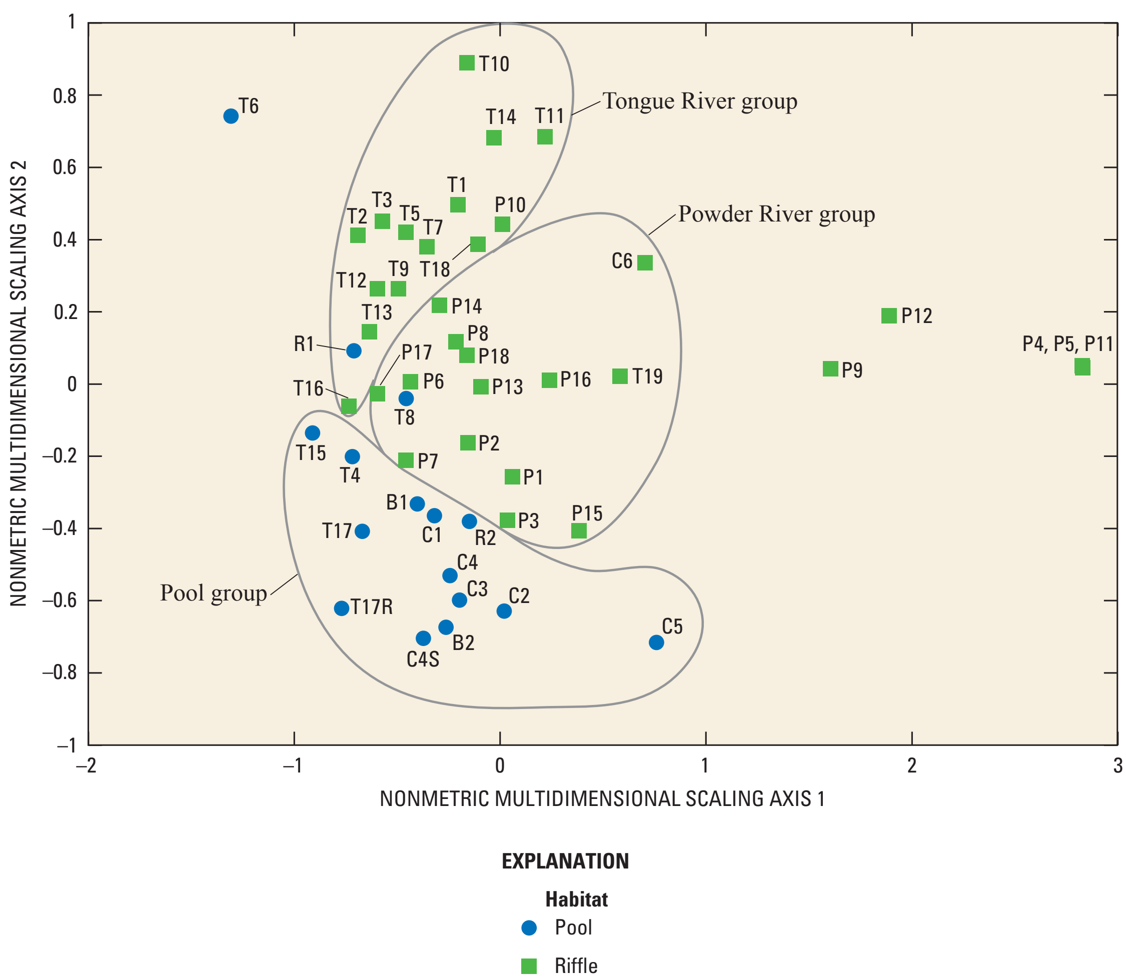


Figure 11. Similarities of algal community taxonomic composition within drainage basins and within habitats, depicted by nonmetric multidimensional scaling ordination, Powder River structural basin, Wyoming and Montana, 2007.

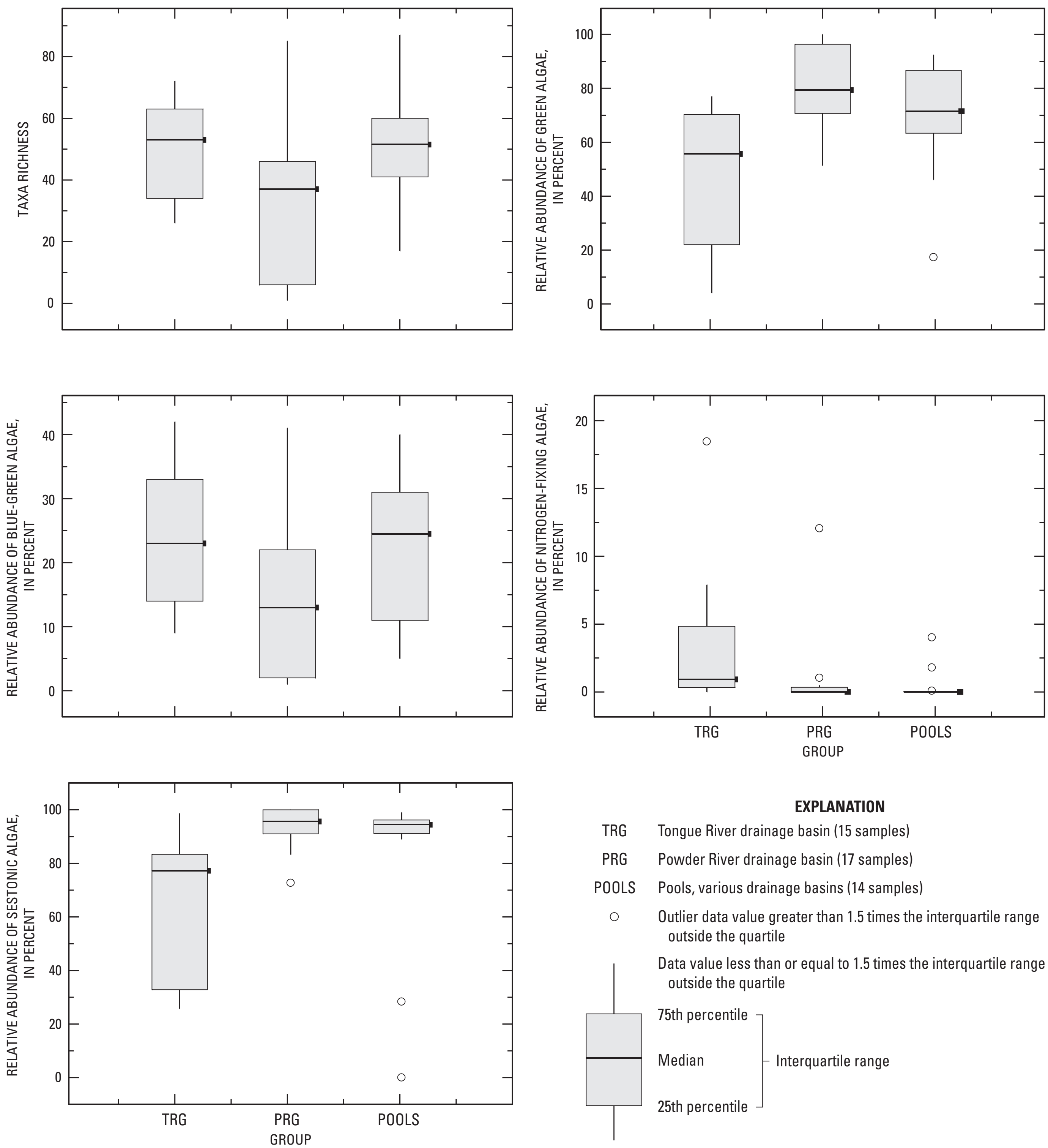


Figure 12. Algal community composition by drainage basin and habitat, Powder River structural basin, 2007.

of the algal abundance at sites P4, P5, P9, P11, and P12 in 2007, which includes the middle reach (sites P3–P5 and P8), causing these sites to be outliers from the NMDS ordination of the Powder River drainage basin group (fig. 11). For comparison, in 2005, the algal communities at sites P2 and P4 on the main-stem Powder River were dominated by a single species, the diatom *Achnanthes minutissima* (Peterson and others, 2009). Low algal taxa richness can be an indicator of effects to the community if sensitive species are stressed by natural or other factors (Barbour and others, 1999). The relative abundance of *Achnanthes minutissima* may increase in response to metal toxicity, nutrient enrichment, scouring, or grazing (Bahls, 1993). *Chlorella* is a cosmopolitan sestonic algae (planktonic or suspended) (Porter, 2008), which helps explain the generally higher relative abundance of sestonic algae in the Powder River drainage basin group than in the Tongue River drainage basin group (fig. 12). The dominance of sestonic algae might result from the influence of pools and slow-moving reaches upstream from the sample-collection points, as indicated by the similarities between the Powder River and pool groups (fig. 12). The relative abundance of eutrophic algae, which are either tolerant of or dependent on high nutrient concentrations, tended to be higher in the Powder River drainage basin group (average of 91 percent) than in the Tongue River drainage basin group (average of 74 percent).

The pool group contained sites from multiple river drainage basin basins; the common variable among these sites was that algae samples were collected from pools rather than riffles. Algal communities were dominated by green algae, including *Chlorella*, and blue-green algae such as *Aphanocapsa*. The relative abundance of sestonic algae was high in the pool group (fig. 12), consistent with the depositional habitat from which the samples were collected.

Fish Communities

Fish communities were sampled at 12 sites in the Tongue River drainage basin and at 11 sites in the Powder River drainage basin in 2008, and results for these sites are presented along with results from previous fish community sampling reported by Peterson and others (2009). Results for sites that were sampled previously (Peterson and others, 2009) but not in 2008 are not included in this report.

Tongue River Drainage Basin

Fish communities were sampled at 12 of the 19 sites on the main-stem Tongue River and Tongue River tributaries during 2005–06 and 2008 (table 12), except for Squirrel Creek at mouth (site T7), which was not sampled in 2006 because the sample reach was dry. The remaining seven sites in the Tongue River drainage basin were sampled in 2005–06 but not in 2008; results for these seven sites were presented previously by Peterson and others (2009) and are not described in this report.

Community Composition

Twenty-nine species of fish were identified in samples collected from the Tongue River drainage basin during 2005–06 and 2008 (table 12). More than one-half of the species (15) identified in the Tongue River drainage basin were native, including seven minnows (Cyprinidae), five suckers (Catostomidae), two catfish (Ictaluridae), and one sauger (Percidae; table 13). Introduced fish species included eight sunfishes (Centrarchidae), three minnows, two catfishes, and yellow perch (Percidae).

Smallmouth bass accounted for 28 percent of the relative abundance of fish captured in the main-stem Tongue River (fig. 13), with white sucker (11 percent), yellow bullhead (11 percent), and rock bass (10 percent) also abundant. In contrast, smallmouth bass composed only 9 percent of the fish captured in the tributaries to the Tongue River (fig. 13). Fathead minnow were the most common fish in the tributaries, where they composed 42 percent of the relative abundance of fish captured. Fathead minnow were relatively uncommon in the main-stem Tongue River, where they were among 16 of 23 species that composed 10 percent of the other fish captured (fig. 13). Fish communities of the main-stem Tongue River also contained yellow bullhead (11 percent; fig. 13), common carp (8 percent), shorthead redhorse (8 percent), and spottail shiner (8 percent) that were uncommon in the tributaries.

Fish species richness was greatest at sampling sites on the main-stem Tongue River. Samples from Tongue River at State line (T9) contained 18 species in 2005, 17 species in 2006, and 14 species in 2008 (table 12). Reduction in the number of species captured for each sampling year can be from normal year-to-year variation, increased turbidity (table 3), changes in sampling efficiency, or a combination of these and unknown factors. Sampling on the Tongue River below Youngs Creek (site T5), Tongue River above Hanging Woman Creek (site T10), and Tongue River at Birney Day School (site T14) resulted in the collection of 10 to 14 species each year. The Tongue River Reservoir, on the main stem between sites T9 and T10 (fig. 1), appears to affect the fish community of the river. Open-water species, such as spottail shiner and yellow perch (Baxter and Stone, 1995), were identified only at sites upstream from the reservoir at the Tongue River below Youngs Creek (site T5), Tongue River at State line (site T9), and Prairie Dog Creek (site T8). Black crappie and white crappie, also known as open-water species, were found in small numbers upstream and downstream from Tongue River Reservoir. Sauger was collected at Tongue River at State line (site T9) in 2008 but was not collected at any other sampling site in the Tongue River drainage basin. Mountain sucker was collected only at Upper Youngs Creek (site T3) in 2005 and 2008.

Tributary streams with relatively large numbers of fish species in all three sampling years were Goose Creek (site T2) and Prairie Dog Creek (site T8). Numbers of fish species collected at Goose Creek (site T2) were 11 in 2005, 8 in 2006, and 10 in 2008. Nine species were collected at Prairie Dog Creek

Table 12. Fish abundance in samples from the Tongue River drainage basin, Wyoming and Montana, 2005–06 and 2008.

[Shaded cells indicate main-stem sampling sites on the Tongue River]

Site number (fig. 1)	Abbreviated site name	Sample date	Black bullhead	Black crappie	Bluegill	Brassy minnow	Channel catfish	Common carp	Creek chub	Fathead minnow	Flathead chub	Golden shiner	Green sunfish	Lake chub
T2	Goose Creek	8/22/2005	3	0	0	0	0	18	0	1	0	0	3	0
		8/22/2006	15	0	0	0	0	30	0	0	0	0	3	0
		8/8/2008	5	0	0	0	0	21	0	0	0	0	13	0
T3	Upper Youngs Creek	6/15/2005	0	0	0	0	0	0	6	2	0	0	0	0
		6/28/2006	0	0	0	0	0	0	62	15	0	0	0	0
		6/26/2008	0	0	0	0	0	0	19	0	0	0	0	0
T4	Youngs Creek at mouth	6/14/2005	0	0	0	1	0	0	0	22	0	0	0	0
		6/27/2006	0	0	0	54	0	0	9	104	0	0	0	4
		6/26/2008	2	0	0	2	0	2	14	1	0	0	2	0
T5	Tongue River below Youngs Creek	8/29/2005	108	3	0	0	0	43	0	17	0	0	42	0
		8/24/2006	10	0	0	0	0	129	0	0	4	0	5	0
		9/11/2008	5	0	0	0	0	5	0	1	0	0	5	0
T6	Upper Squirrel Creek	6/16/2005	0	0	0	0	0	0	19	0	0	0	0	0
		6/29/2006	0	0	0	1	0	0	10	83	0	0	0	0
		6/25/2008	0	0	0	0	0	1	0	20	0	0	0	134
T7	Squirrel Creek at mouth	6/13/2005	1	0	0	0	0	0	8	3	0	0	0	1
		6/25/2008	0	0	0	0	0	1	0	1	0	0	0	0
T8	Prairie Dog Creek	8/26/2005	13	0	0	0	0	1	0	0	0	0	0	0
		8/25/2006	0	0	0	0	0	8	168	0	0	0	1	0
		9/10/2008	9	0	0	0	0	0	0	0	1	0	1	0
T9	Tongue River at State line	8/25/2005	30	25	4	1	6	89	9	0	2	0	1	0
		8/28/2006	13	3	0	0	9	99	51	0	3	0	6	0
		9/10/2008	6	0	0	0	0	8	0	4	0	17	0	0
T10	Tongue River above Hanging Woman Creek	8/30/2005	0	9	0	0	10	21	0	0	0	0	1	0
		8/29/2006	0	0	0	0	7	24	0	0	0	0	0	0
		9/9/2008	0	0	0	0	9	7	0	0	0	0	0	0
T13	Hanging Woman Creek at mouth	6/23/2005	0	0	0	0	0	0	0	85	0	0	17	0
		6/26/2006	0	0	0	0	0	0	0	266	0	0	0	0
		6/24/2008	0	0	0	0	0	4	0	199	0	130	8	0
T14	Tongue River at Birney Day School	8/31/2005	0	0	0	0	18	35	0	0	0	0	0	0
		8/30/2006	2	0	0	0	63	35	0	0	0	2	17	0
		9/8/2008	0	3	0	0	12	17	0	0	0	0	1	0
T17	Otter Creek at mouth	6/30/2005	0	0	1	114	0	31	0	360	0	0	0	0
		6/28/2006	1	0	0	0	0	122	0	931	0	0	6	0
		6/24/2008	0	0	0	0	0	0	0	382	0	0	10	0

(site T8) in 2005, and 10 species were collected in 2006 and 2008. The numbers of fish species sampled at Youngs Creek at mouth (site T4), Upper Squirrel Creek (site T6), Hanging Woman Creek at mouth (T13), and Otter Creek at mouth (T17) were somewhat variable from year to year.

With a few exceptions, fish communities sampled in all 3 years appeared to be similar on the basis of species richness. At Squirrel Creek at mouth (site T7), five fish species were collected in 2005 and two species were collected in 2008. The lack of fish species collected in 2008 may be the result of drought conditions in 2006, indicating fish species have yet to fully repopulate the site. Only one species was identified in 2006 at Hanging Woman Creek at mouth (site T13) presumably because 2006 was a drier year when compared to the other sampling years, and suitable habitat was not present for other species (table 3). Otherwise, the number of fish species found at site T13 increased overall from four species collected in 2005 to seven species collected in 2008. Otter Creek at mouth (site T17) showed a decrease in the number of fish species identified for each year with six species collected in 2005, five species collected in 2006, and three species collected in 2008.

The total abundance of fish collected at the 12 sites was 3,826 individuals in 2005, 5,705 in 2006, and 2,562 in 2008. Although 2006 was a drier year, the mean number of species collected per site was similar for the 3 years: 8.1 species in 2005, 7.7 species in 2006, and 8.1 species in 2008. The largest increases in fish abundance from 2005 to 2008 were for sand shiners, fathead minnow, lake chub, and golden shiner. The largest decreases in fish abundance from 2005 to 2008 were for common carp, channel catfish, and white sucker. The difference in abundance between years is probably related to normal year-to-year variation.

Community Structure

The structure and integrity of the fish community were assessed using the Index of Biotic Integrity (IBI) developed for small prairie streams in Montana (Bramblett and others,

Table 12. Fish abundance in samples from the Tongue River drainage basin, Wyoming and Montana, 2005–06 and 2008.—Continued

[Shaded cells indicate main-stem sampling sites on the Tongue River]

Site number (fig. 1)	Large-mouth bass	Long-nose dace	Long-nose sucker	Moun-tain sucker	Pump-kinseed	River carp-sucker	Rock bass	Sand shiner	Sauger	Short-head redhorse	Small-mouth bass	Spot-tail shiner	Stone-cat	White crappie	White sucker	Yellow bull-head	Yellow perch	Total number of species
T2	6	3	0	0	0	0	314	0	0	31	288	0	69	0	37	0	0	11
	0	8	0	0	0	0	203	0	0	0	186	0	65	0	51	0	0	8
	1	2	0	0	0	0	325	0	0	22	59	0	6	0	10	0	0	10
T3	0	69	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
	0	32	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	4
	0	14	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	4
T4	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	0	7	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	6
	0	3	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	8
T5	0	6	4	0	0	0	93	0	0	56	412	77	2	0	125	0	0	13
	0	31	4	0	4	0	116	0	0	58	217	148	11	0	57	178	0	14
	0	3	1	0	0	0	23	0	0	26	98	27	1	0	10	19	0	13
T6	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4
	0	11	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	5
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
T8	0	0	3	0	0	0	10	0	0	0	2	1	56	0	9	4	0	9
	0	5	4	0	0	0	5	0	0	13	26	0	1	0	56	0	0	10
	0	2	5	0	0	0	3	0	0	3	0	0	19	0	17	14	0	10
T9	0	5	0	0	0	0	34	0	0	42	264	40	10	1	102	0	1	18
	0	13	1	0	34	0	55	0	0	95	234	150	46	0	119	301	0	17
	0	3	0	0	20	0	10	0	1	14	148	42	5	0	14	17	0	14
T10	0	0	0	0	0	6	41	0	0	21	39	0	12	0	18	21	0	11
	0	1	0	0	0	1	52	0	0	42	60	0	23	0	57	24	0	10
	0	0	1	0	0	1	5	0	0	55	32	0	18	0	7	3	0	10
T13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	0	0	4
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0	1	0	0	0	0	0	0	0	11	0	0	0	0	2	0	0	7
T14	0	2	0	0	0	19	61	0	0	37	21	0	16	8	62	38	0	11
	0	19	4	0	0	9	69	0	0	39	138	0	46	0	111	39	0	14
	0	0	0	0	0	9	33	0	0	20	94	0	19	0	18	17	0	11
T17	0	0	0	0	0	0	0	10	0	0	0	0	0	0	6	0	0	6
	0	0	0	0	0	0	0	43	0	0	0	0	0	0	0	0	0	5
	0	0	0	0	0	0	0	115	0	0	0	0	0	0	0	0	0	3

2005). IBI scores consist of 10 metrics, some of which are adjusted by the drainage area. Because the IBI was not intended for use in rivers with large drainage areas, raw and unadjusted fish community metric values were evaluated for the main-stem Tongue River (table 14).

Testing using ANOVA with the Tukey method was performed to determine statistical differences in fish community metrics between sites and by year for the main-stem Tongue River. Results show significant differences ($p < 0.05$) among sites for percentage of invertivorous cyprinid individuals and percentage of native individuals (table 15). The Tongue River Reservoir on the main stem between Tongue River at State line (site T9) and Tongue River above Hanging Woman Creek (site T10) appears to affect the fish communities of the river. As shown in figure 14, the number of benthic invertivorous species and percentage of invertivorous cyprinids were higher upstream from the reservoir than downstream; these metrics are expected to decline as human influence increases (Bramblett and others, 2005). The number of native catostomid and ictalurid species, number of long-lived native species, and percentage of native individuals generally were higher downstream than upstream from the the reservoir; these metrics also are expected to decline as human influence increases (Bramblett and others, 2005). The causes are unknown as to why the metrics are inconsistent with regard to human influence upstream and downstream from the reservoir, but might be related to fish migration from Tongue River Reservoir.

Of the small plains streams that were sampled, the fish communities from Youngs Creek (sites T3 and T4) and Squirrel Creek (sites T6 and T7 in 2005) had some of the highest IBI scores in the study area (table 16). The highest observed IBI score of 96 occurred at site T3 on upper Youngs Creek in 2008 (fig. 15). IBI scores from sites on lower Youngs Creek (site T4) and Squirrel Creek (sites T6 and T7 in 2005) also were relatively high and ranged from 66 to 84,

Table 13. Ecological characteristics of fish species sampled in the Powder River Structural Basin, Wyoming and Montana, 2005–08.

[Modified from Bramblett and others, 2005. Trophic category: IN, invertivore; HB, herbivore; OM, omnivore; IC, invertivore-carnivore; CA, carnivore. Feeding habitat: WC, water column; BE, benthic; GE, generalist. Reproductive class: LO, litho-obligate; TR, tolerant reproductive strategists; --, not determined or not available; General tolerance: INT, intolerant; MOD, moderate; TOL, tolerant. Origin: N, native; I, introduced. mm, millimeters; NA, not applicable because species generally lives less than 3 years]

Family	Common name	Scientific name	Trophic category	Feeding habitat	Reproductive class	General tolerance	Origin	Length at 3 years (mm)
Acipenseridae	Shovelnose sturgeon	*Scapirhynchus platorynchus*	IN	BE	--	--	N	--
Cyprinidae	lake chub	*Couesius plumbeus*	IN	WC	--	MOD	N	140
	common carp	*Cyprinus carpio*	OM	BE	--	TOL	I	381
	western silvery minnow	*Hybognathus argyritis*	HB	BE	--	MOD	N	94
	brassy minnow	*Hybognathus hankinsoni*	HB	BE	--	MOD	N	81
	plains minnow	*Hybognathus placitus*	HB	BE	--	MOD	N	94
	sturgeon chub	*Macrhybopsis gelida*	IN	BE	LO	INT	N	50
	golden shiner	*Notemigonus crysoleucas*	OM	WC	--	MOD	I	102
	spottail shiner	*Notropis hudsonius*	IN	WC	LO	MOD	I	85
	sand shiner	*Notropis stramineus*	OM	GE	LO	MOD	N	61
	fathead minnow	*Pimephales promelas*	OM	GE	TR	TOL	N	76
	flathead chub	*Platygobio gracilis*	IN	GE	--	MOD	N	140
	longnose dace	*Rhinicthys cataractae*	IN	BE	LO	INT	N	71
	creek chub	*Semotilus atromaculatus*	IC	GE	LO	MOD	N	114
Catostomidae	river carpsucker	*Carpiodes carpio*	OM	BE	LO	MOD	N	229
	longnose sucker	*Catostomus catostomus*	IN	BE	LO	MOD	N	216
	white sucker	*Catostomus commersonii*	OM	BE	LO	TOL	N	229
	mountain sucker	*Catostomus platyrhynchus*	HB	BE	LO	MOD	N	102
	shorthead redhorse	*Moxostoma macrolepidotum*	IN	BE	LO	MOD	N	254
Ictaluridae	black bullhead	*Ameiurus melas*	IC	BE	TR	TOL	I	152
	yellow bullhead	*Ameiurus natalis*	IC	BE	TR	MOD	I	254
	channel catfish	*Ictalurus punctatus*	IC	BE	TR	MOD	N	254
	stonecat	*Noturus flavus*	IC	BE	LO	INT	N	140
Cyprinodontidae	northern plains killifish	*Fundulus kansae*	OM	GE	--	TOL	I	81
Centrarchidae	rock bass	*Ambloplites rupestris*	IC	GE	TR	MOD	I	89
	green sunfish	*Lepomis cyanellus*	IC	GE	--	TOL	I	102
	pumpkinseed	*Lepomis gibbosus*	IC	GE	LO	MOD	I	89
	bluegill	*Lepomis macrochirus*	IC	GE	LO	MOD	I	102
	smallmouth bass	*Micropterus dolomieu*	IC	GE	TR	MOD	I	154
	largemouth bass	*Micropterus salmoides*	IC	GE	TR	MOD	I	140
	white crappie	*Pomoxis annularis*	IC	WC	TR	MOD	I	152
	black crappie	*Pomoxis nigromaculatus*	IC	WC	TR	MOD	I	203
Percidae	yellow perch	*Perca flavescens*	IC	WC	--	MOD	I	140
	sauger	*Sander canadensis*	IC	GE	LO	MOD	N	279

although scores decreased in Youngs Creek from site T3 to site T4 in all 3 years of sampling (table 16). Squirrel Creek at mouth (site T7) had a marked decrease in the IBI score from 2005 to 2008, presumably because the site was dry in 2006 and effects were still being seen in 2008. Goose Creek (site T2) and Otter Creek at mouth (site T17) had downward trends in IBI score from 2005 to 2008 (fig. 15). Prairie Dog Creek (site T8) had IBI scores ranging from 59 to 78 with a mean of 69. Hanging Woman Creek at mouth (site T13) had some of lowest IBI scores ranging from 40 to 46 with a mean of 43.

Powder River Drainage Basin

Fish communities were sampled on the main-stem Powder River and Powder River tributaries at 11 of 18 sites during 2004–06 and 2008. The remaining seven sites in the Powder River drainage basin were sampled in 2004–06 but not in 2008; results for these seven sites were presented previously by Peterson and others (2009) and are not described in this report. For sites that had multiple sample dates during 2004–05, the sample date closest to the 2008 sample date was chosen for comparisons between years.

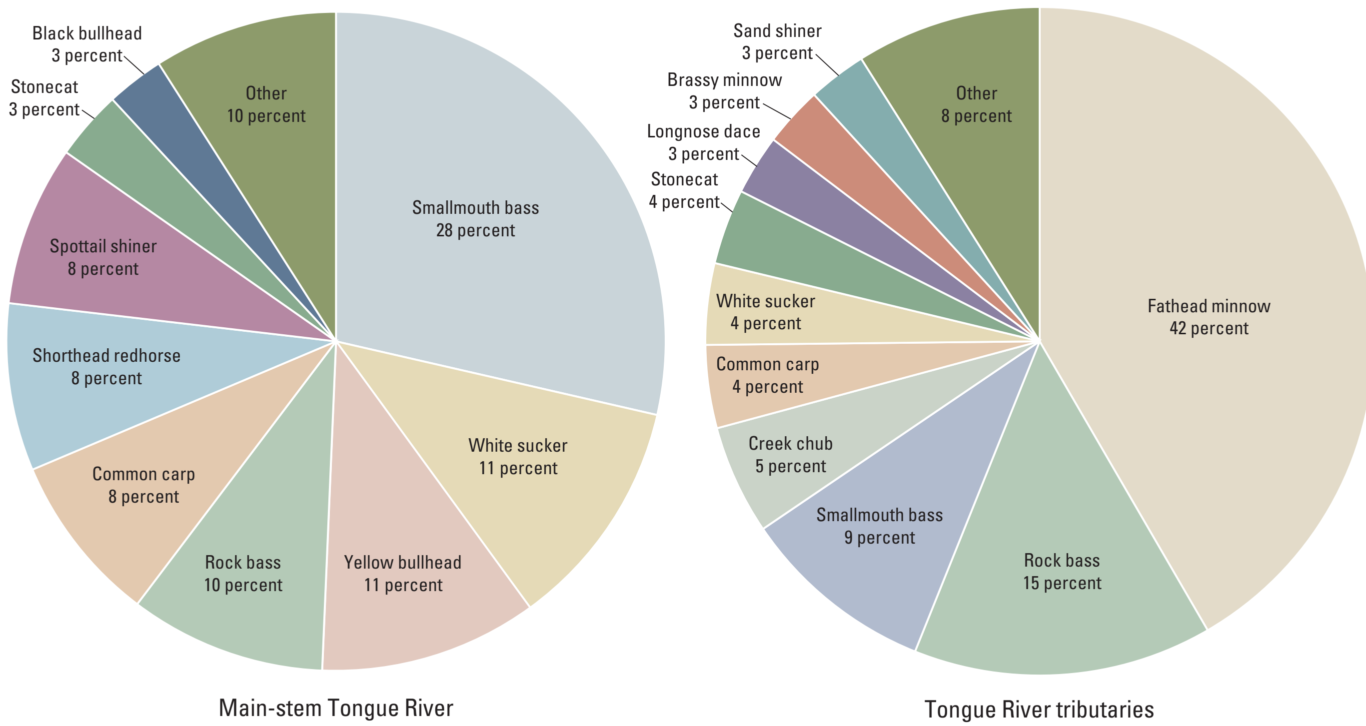


Figure 13. Relative abundance of fish by species in samples from the Tongue River drainage basin, Wyoming and Montana, 2005–06 and 2008.

Community Composition

Twenty-four species of fish were identified in samples collected during 2004–06 and 2008 (table 17). Out of the those species identified, 17 were native, including 8 minnows (Cyprinidae), 4 suckers (Catostomidae), 2 catfish (Ictaluridae), 1 goldeye (Hiodontidae), 1 shovelnose sturgeon (Acipenseridae) and 1 sauger (Percidae). Introduced fish species included four sunfishes (Centrarchidae), one minnow, one catfish, and one northern plains killifish (Cyprinodontidae).

Sand shiner were the most common fish in the Powder River drainage basin, accounting for 63 percent of the relative abundance of fish captured in the main-stem Powder River and 48 percent in the tributaries to the Powder River (fig. 16). Flathead chub composed 22 percent of the fish in the main-stem Powder River and 6 percent in the tributaries. *Hybognathus* spp. composed 5 percent of the fish in the main-stem Powder River but were uncommon in the tributaries, whereas white sucker and rock bass were more common in the tributaries than in the main stem (fig. 16). Of the two species of *Hybognathus* identified, the plains minnow (*H. placitus*) was more common than the western silvery minnow (*H. argyritis*; table 17) that is a Wyoming species of concern (Wyoming Game and Fish Department, written commun. 2008). In total, 21 fish species were captured from the main-stem Powder River during 2004–06 and 2008, and 20 species were captured from the tributaries to the Powder River during 2004–06 and 2008.

Fish species richness on the main-stem Powder River tended to be relatively high in the middle reach of the Powder River (sites P3–P5 and P8). Richness was highest at Powder River downstream from Burger Draw (P4) with 11 species in 2005, 10 species in 2006, and 13 species collected in 2008 (table 17). Other sites on the main-stem Powder River with high species richness were Powder River above Pumpkin Creek (site P3), which contained 8 to 12 species, and Powder River above Crazy Woman Creek (site P5), which contained 7 to 11 species. Four fish species were identified on the main-stem Powder River and not in tributary streams. Bluegill was collected only at Powder River below Burger Draw (site P4) in 2008. Mountain sucker was collected only at Powder River above Pumpkin Creek (site P3) in 2004. Shovelnose sturgeon was collected at Powder River at Broadus (site P13) in 2008. Sturgeon chub, which is a Wyoming species of concern (Wyoming Game and Fish Department, written commun. 2008), was collected at Powder River above Crazy Woman Creek (site P5) in 2006 and Powder River at Moorhead (site P12) in 2006 and 2008.

The tributary stream in the Powder River with relatively large numbers of fish species in 3 sampling years was Clear Creek (site P10) with 14, 14, and 11 species in 2005, 2006, and 2008, respectively. Clear Creek (site P10) was the only tributary where sauger was collected in the 3 years of sampling.

The total abundance of fish collected at the 11 sites was 6,114 in 2004, 9,462 in 2005, 23,786 in 2006, and 2,629 individuals collected in 2008. A possible cause for the large number of fish caught in 2006 is that the drought concentrated the fish in smaller areas, making them easier to catch.

Table 14. Unadjusted fish community metric values for the main-stem Tongue River, Wyoming and Montana, 2005–06 and 2008.

[Metric definitions from Bramblett and others (2005)]

Site number (fig. 1)	Abbreviated site name	Sample date	Number of					Percentage of				
			Native species	Native families	Native catostomid and ictalurid species	Benthic invertivorous species	Native long-lived species	Tolerant individuals	Invertivorous cyprinid individuals	Litho-obligate reproductive guild individuals	Tolerant reproductive guild individuals	Native individuals
T5	Tongue River below Youngs Creek	8/29/2005	6	3	4	3	4	34	8	27	64	21
		8/24/2006	6	3	4	3	4	21	19	32	54	17
		9/11/2008	6	3	4	3	8	12	13	30	65	19
T9	Tongue River at State line	8/25/2005	8	3	4	2	4	33	8	32	54	27
		8/28/2006	8	3	5	3	3	19	18	41	50	27
		9/10/2008	6	4	3	2	8	16	15	32	60	13
T10	Tongue River above Hanging Woman Creek	8/30/2005	5	3	5	1	5	20	0	29	60	34
		8/29/2006	6	3	5	2	6	28	0	43	49	45
		9/9/2008	6	2	6	2	9	10	0	59	36	66
T14	Tongue River at Birney Day School	8/31/2005	6	3	5	2	5	31	1	43	46	49
		8/30/2006	7	3	6	3	7	28	3	38	52	49
		9/8/2008	5	2	5	1	9	36	0	27	65	32

Table 15. Analysis of variance in fish community metrics, main-stem Tongue River and main-stem Powder River, Wyoming and Montana, 2005–08.

[Significance tested by Tukey method at probablility level less than 0.05; data for Powder River also include samples collected during 2004]

Metric	Main-stem Tongue River		Main-stem Powder River	
	Significant differences between sites	Significant differences between years	Significant differences between sites	Significant differences between years
Number of native species	None	None	None	None
Number of native families	None	None	None	None
Number of native catostomid and ictalurid species	None	None	None	None
Number of benthic invertivorous species	None	None	None	None
Number of native species with long lived individuals	None	None	None	None
Percentage of tolerant individuals	None	None	P3 to P8, P11 to P13	None
Percentage of invertivorous cyprinid individuals	T10 to T5, T10 to T9, T14 to T5, T14 to T9	None	None	None
Percentage of litho-obligate reproductive guild individuals	None	None	None	None
Percentage of tolerant reproductive guild individuals	None	None	None	None
Percentage of native individuals	T10 to T5, T10 to T9, T14 to T5	None	P11 to P13	None

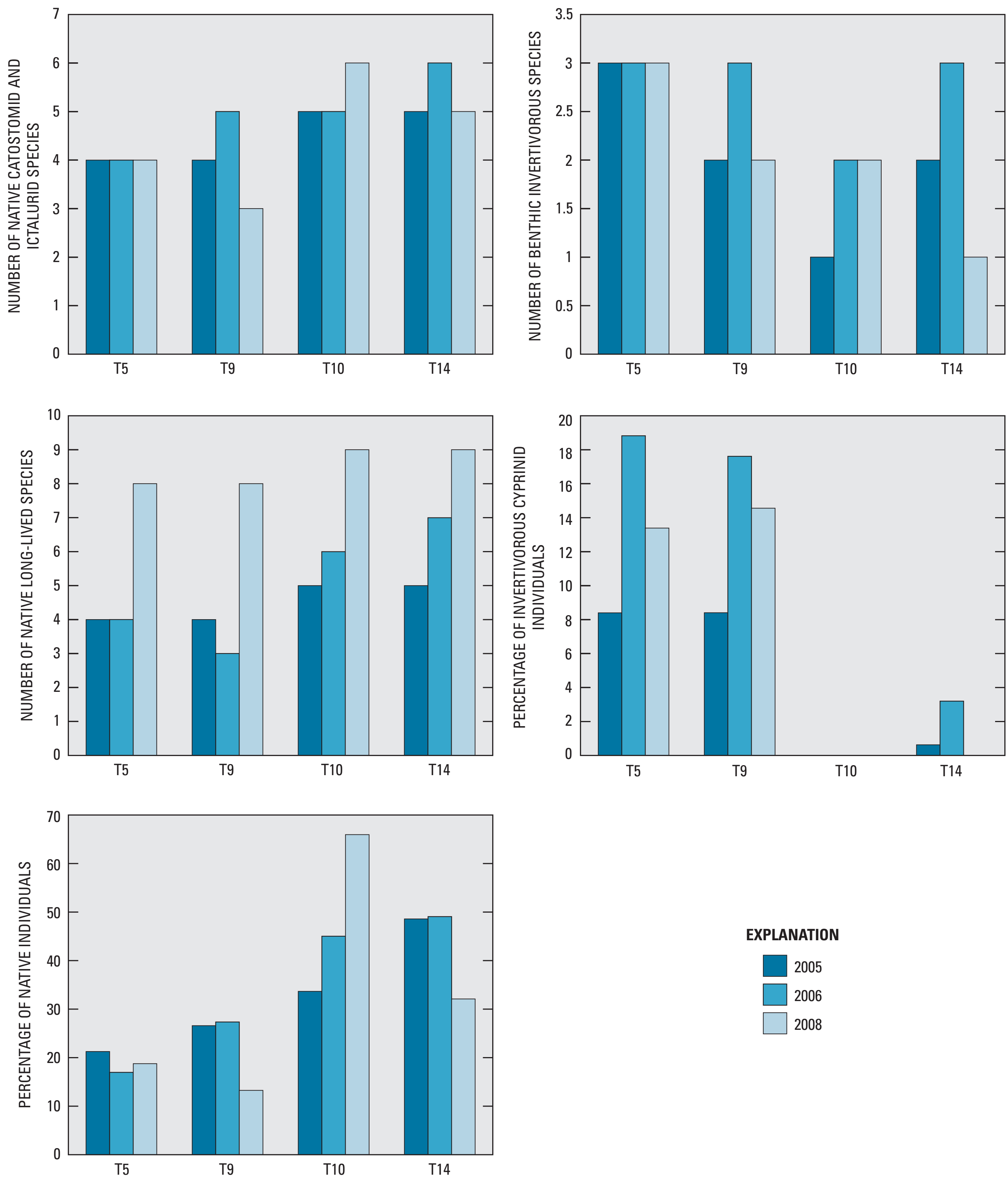


Figure 14. Selected unadjusted fish community metric values for the main-stem Tongue River, Wyoming and Montana, 2005–06 and 2008.

Table 16. Fish community metric and Index of Biotic Integrity (IBI) scores for the Tongue and Powder River tributaries, Wyoming and Montana, 2005–06 and 2008.

[Metric definitions from Bramblett and others (2005)]

Site number (fig.1)	Abbreviated site name	Sample date	Species richness and composition scores			
			Number of species	Number of families	Number of native catostomid and ictalurid species	Percentage of tolerant individuals
T2	Goose Creek	8/22/2005	6.1	7.6	7.2	9.2
		8/22/2006	5.0	7.6	6.2	8.1
		8/8/2008	5.5	7.6	7.2	8.9
T3	Upper Youngs Creek	6/15/2005	9.4	8.1	9.6	9.7
		6/28/2006	9.4	8.1	9.6	7.9
		6/26/2008	9.4	8.1	10.0	8.9
T4	Youngs Creek at mouth	6/14/2005	7.5	5.4	6.9	2.0
		6/27/2006	9.1	7.2	8.0	3.6
		6/26/2008	8.6	7.2	8.0	5.9
T6	Upper Squirrel Creek	6/16/2005	7.7	5.9	7.9	10.0
		6/29/2006	8.8	7.7	9.0	0.6
		6/25/2008	8.8	7.7	9.0	8.1
T7	Squirrel Creek at mouth	6/13/2005	8.5	7.5	8.6	6.2
		6/25/2008	6.8	5.7	0.0	0.0
T8	Prairie Dog Creek	8/26/2005	5.2	5.9	7.5	7.5
		8/25/2006	6.8	7.7	8.6	7.6
		9/10/2008	6.8	7.7	8.6	6.1
T13	Hanging Woman Creek at mouth	6/23/2005	4.8	7.5	6.0	0.0
		6/26/2006	3.7	3.8	3.8	0.0
		6/24/2008	5.4	5.6	6.0	3.7
T17	Otter Creek at mouth	6/30/2005	4.8	5.3	4.2	2.0
		6/28/2006	3.7	3.5	3.2	0.0
		6/24/2008	3.7	3.5	0.0	1.8
P7	Crazy Woman Creek near mouth	7/14/2005	5.0	7.0	4.9	8.5
		8/1/2006	6.1	7.0	6.0	6.5
		8/20/2008	8.4	8.8	8.2	8.8
P10	Clear Creek	8/24/2005	7.6	10.0	7.9	8.0
		8/21/2006	7.6	10.0	6.8	9.4
		8/5/2008	6.4	10.0	7.9	9.3
P15	Little Powder River above Dry Creek	6/23/2005	5.2	6.7	4.5	4.5
		6/23/2006	6.3	6.7	5.5	9.3
		8/19/2008	6.9	8.6	6.6	8.4

Although the number of individuals varied among years, the mean number of species collected per site was similar between sampled years: 8.8 species in 2005, 9.6 species in 2006, and 9.1 species in 2008. The mean number of species collected per site in 2004 was 10, but only five sites were sampled in that year.

Community Structure

The Index of Biotic Integrity (IBI) developed for small prairie streams in Montana (Bramblett and others, 2005) was applied to the fish community data from the tributary streams of the Powder River by using the same metrics used for the Tongue River tributaries. Because the IBI was not intended for use in rivers with large drainage areas, raw and unadjusted fish community metric values were evaluated for the main-stem Powder River (table 18).

Results of ANOVA with the Tukey method show that there was no significant difference for fish community metrics among sites or years in the main-stem Powder River except for percentage of tolerant individuals and the percentage of native individuals (table 15). The percentage of tolerant individuals generally was higher at sites P3 and P4 than at sites farther downstream, and the percentage of native individuals generally was higher at sites P5, P8, P9, P11, and P12 than at other sites on the main-stem Powder River (fig. 17).

The fish community at Crazy Woman Creek near mouth (site P7) had the highest IBI score, 81 in 2008, among the Powder River tributaries that were sampled (table 16). IBI scores from Clear Creek (site P10) and Little Powder River above Dry Creek (site P15) also had relatively high IBI scores ranging from 62 to 70 for site P10 and from 59 to 72 for two of three scores for site P15. The IBI scores for the Little Powder River above Dry Creek (site P15) trended upward from 2005 to 2008 with scores ranging from 45 to 72 (fig. 18 and table 16), with a mean of 59. Crazy Woman Creek above mouth (site P7) had IBI scores ranging from 61 to 81 with a mean of 67. Clear Creek (site P10) had relatively static IBI scores from 2005 to 2008 (fig. 18).

Table 16. Fish community metric and Index of Biotic Integrity (IBI) scores for the Tongue and Powder River tributaries, Wyoming and Montana, 2005–06 and 2008.—Continued

[Metric definitions from Bramblett and others (2005)]

Site number (fig.1)	Trophic composition scores		Reproductive guild composition scores		Fish abundance and composition scores		
	Percentage of invertivorous cyprinid individuals	Number of benthic invertivorous species	Percentage of litho-obligate reproductive guild"individuals	Percentage of tolerant reproducetive guild individuals	Percentage of native individuals	Number of native species with long-lived individuals	IBI Score
T2	0.1	8.2	2.2	9.0	1.8	7.6	59
	0.2	6.5	2.7	8.2	2.2	7.6	54
	0.1	8.2	1.0	0.4	0.9	10.0	50
T3	10.0	10.0	10.0	0.3	10.0	10.0	87
	10.0	10.0	10.0	1.5	10.0	10.0	87
	10.0	10.0	10.0	10.0	10.0	10.0	96
T4	2.8	10.0	2.5	8.6	10.0	9.9	66
	1.5	10.0	1.7	6.3	10.0	9.9	67
	7.5	10.0	8.6	8.9	8.1	9.9	83
T6	10.0	10.0	10.0	0.0	10.0	9.9	81
	1.4	9.5	1.4	9.9	10.0	8.9	67
	10.0	10.0	1.5	8.7	9.9	10.0	84
T7	8.8	9.0	7.8	3.3	9.3	9.5	78
	0.0	0.0	0.0	4.3	5.0	9.5	10
T8	0.1	6.8	8.4	3.3	6.9	7.8	59
	8.3	10.0	10.0	1.2	8.6	8.9	78
	0.6	10.0	7.5	6.0	6.4	10.0	70
T13	0.0	4.6	0.8	8.9	8.4	5.3	46
	0.0	4.6	0.0	10.0	10.0	4.3	40
	0.0	8.0	0.5	3.6	6.0	5.3	44
T17	0.0	3.8	0.4	7.8	9.4	3.6	41
	0.0	3.8	0.5	9.6	8.8	4.6	38
	0.0	0.0	2.7	1.4	9.8	5.6	29
P7	3.2	5.0	9.9	0.0	10.0	7.2	61
	1.5	5.0	10.0	0.4	9.9	8.2	61
	1.1	6.7	10.0	8.9	9.9	10.0	81
P10	0.3	4.7	6.2	4.4	6.2	10.0	65
	3.5	6.4	6.2	2.4	7.7	10.0	70
	0.4	6.4	3.8	3.3	4.8	10.0	62
P15	0.4	2.8	6.2	3.7	8.0	3.6	45
	0.5	4.5	10.0	0.3	9.5	6.7	59
	0.1	6.2	9.0	8.5	9.2	8.7	72

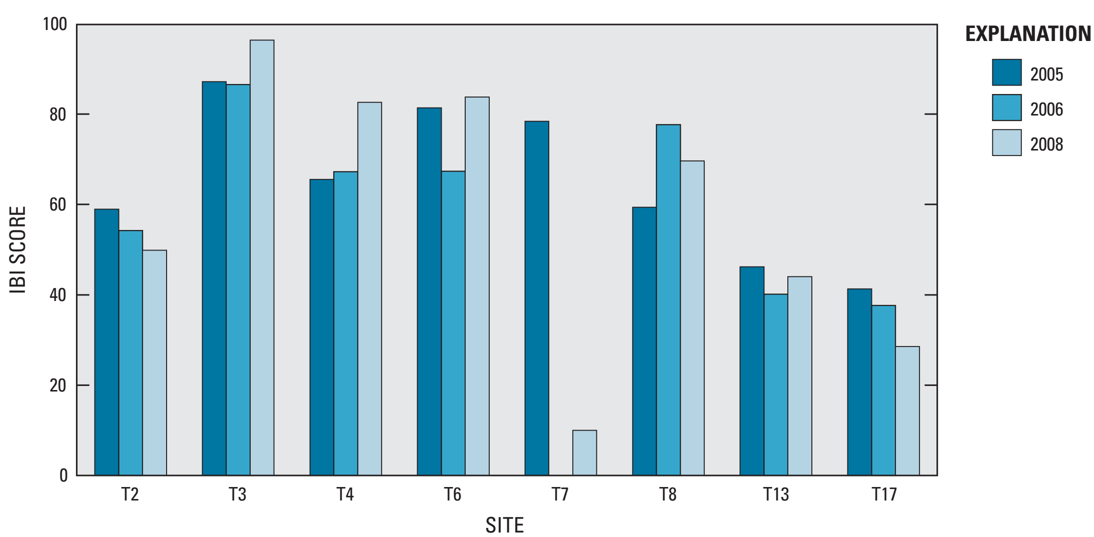


Figure 15. Index of Biotic Integrity scores (IBI) for fish communities of the Tongue River tributaries, Wyoming and Montana, 2005–06 and 2008.

Table 17. Fish abundance in samples from Powder River drainage basin, Wyoming and Montana, 2004–06 and 2008.

[Shaded cells indicate main-stem sampling sites on the Powder River. *, *Hybognathus* spp. represents genus level identifications in the field; subsamples of *Hybognathus* spp. were retained from selected samples for laboratory identification, and are subdivided by species, either plains minnow or western silvery minnow. L, species that were only identified in larval fish samples; the total number of species includes laboratory identification of larval fish and *Hybognathus* spp.]

Site number (fig.1)	Abbreviated site name	Sample date	Black bull-head	Blue-gill	Channel catfish	Common carp	Creek chub	Fat-head minnow	Flat-head chub	Gold-eye	Green sunfish	*Hybognathus* spp.*
P3	Powder River below Willow Creek	8/9/2004	0	0	14	1	0	33	223	1	0	24
		8/10/2005	0	0	9	0	0	2	703	0	0	26
		7/26/2006	0	0	9	0	0	1	161	0	0	8
		7/21/2008	14	0	8	0	0	2	61	0	0	24
P4	Powder River below Burger Draw	8/19/2005	0	0	46	1	0	2	272	3	0	174
		7/27/2006	0	0	10	0	0	13	1,079	1	0	259
		7/24/2008	2	1	1	0	0	1	54	0	2	308
P5	Powder River above Crazy Woman Creek	7/13/2004	0	0	20	0	0	1	587	0	0	328
		7/13/2005	0	0	16	0	0	3	470	3	2	245
		7/28/2006	0	0	61	0	0	3	2,384	0	0	96
		7/23/2008	0	0	3	0	0	0	116	1	0	4
P7	Crazy Woman Creek near mouth	7/14/2005	0	0	0	0	0	10	0	0	0	0
		8/1/2006	0	0	9	6	0	16	15	0	4	0
		8/20/2008	1	0	13	0	0	4	5	1	0	7
P8	Powder River below Crazy Woman Creek	8/4/2004	0	0	40	0	1	0	343	0	0	173
		8/18/2005	0	0	27	0	0	2	335	0	0	76
		8/2/2006	0	0	41	7	2	1	118	2	0	51
		7/28/2008	0	0	10	0	0	0	112	0	0	48
P9	Powder River above Clear Creek	8/5/2004	0	0	24	0	L	0	78	0	0	8
		7/24/2005	0	0	131	0	0	9	21	0	0	9
		8/4/2006	0	0	166	4	0	2	324	1	1	80
		7/29/2008	0	0	20	0	0	0	118	0	9	19
P10	Clear Creek	8/24/2005	0	0	9	29	0	22	8	15	2	0
		8/21/2006	0	0	4	14	5	0	128	6	2	0
		8/5/2008	0	0	46	22	0	0	9	27	0	0
P11	Powder River below Clear Creek	8/6/2004	0	0	31	0	0	L	157	1	0	17
		7/25/2005	0	0	228	1	0	8	43	0	0	0
		8/3/2006	0	0	2	0	0	0	112	0	0	0
		7/30/2008	0	0	8	0	0	0	26	0	0	1
P12	Powder River at Moorhead	7/18/2005	0	0	0	0	0	0	36	2	0	2
		8/2/2006	0	0	105	1	0	0	218	12	0	0
		7/31/2008	0	0	11	0	0	1	53	0	1	9
P13	Powder River at Broadus	7/19/2005	0	0	2	0	0	0	13	0	0	4
		8/2/2006	0	0	8	0	0	0	416	0	4	0
		8/1/2008	0	0	0	0	0	0	21	1	0	27
P15	Little Powder River at Highway 59	6/23/2005	12	0	2	5	3	56	3	0	27	0
		6/23/2006	3	0	4	3	0	8	1	0	18	2
		8/19/2008	0	0	16	0	0	12	0	1	17	10

Potential Effects of Water Produced from Coalbed Natural Gas Development on Biological Communities

The ecological data presented in this report were collected to identify current conditions (2005–08) for aquatic biota and their habitat. Although no specific discharges of CBNG effluent were addressed in this study, a synthesis of the water-quality, macroinvertebrate, algal, and fish data is presented addressing existing and potential effects of CBNG produced water on biological communities.

Water production associated with CBNG development during 2005–08 tended to be largest in the Powder and Tongue River drainage basins in Wyoming. Among all of the drainages in the study area, the upper Powder River drainage basin had the largest increase between 2006 and 2008 in the amount of CBNG water production (fig. 2). For example, water production for the upper Powder River drainage basin in Wyoming during 2008 was more than twice as much compared to production prior to that time. It should be noted, however, that not all of the production water reaches the streams because of various methods of treatment and disposal.

Water Quality

Most water produced during CBNG development in Wyoming is discharged into constructed reservoirs or surface drainages where the water may infiltrate, become part of the ambient streamflow, or evaporate. Concerns have been expressed regarding the quality of some waters produced during CBNG development and effects produced waters may have on water quality in streams that drain the CBNG-development area. Sodium and bicarbonate are the dominant

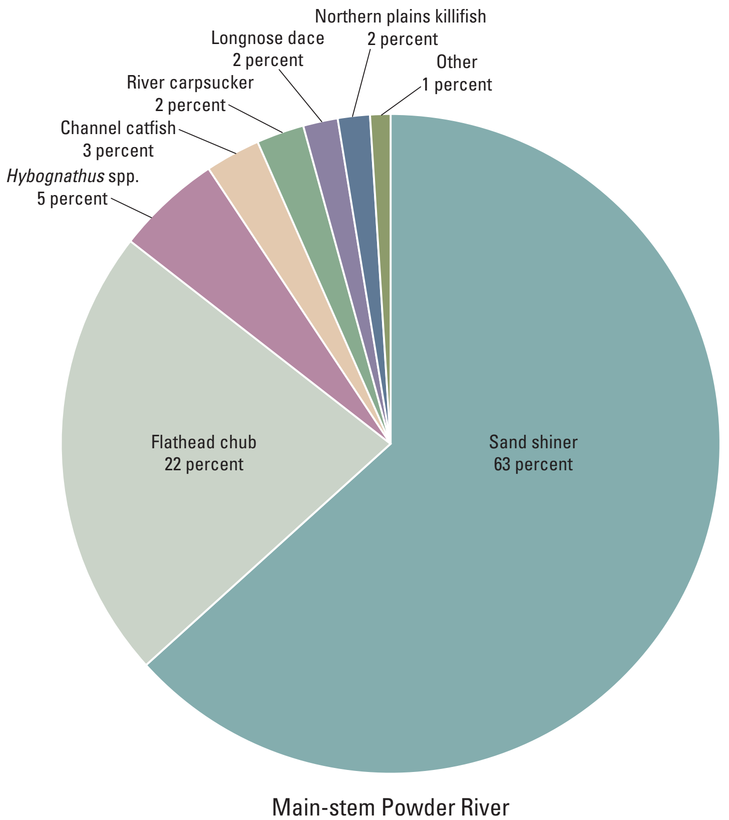
Table 17. Fish abundance in samples from Powder River drainage basin, Wyoming and Montana, 2004-06 and 2008.—Continued

[Shaded cells indicate main-stem sampling sites on the Powder River. *, *Hybognathus* spp. represents genus level identifications in the field; subsamples of *Hybognathus* spp. were retained from selected samples for laboratory identification, and are subdivided by species, either plains minnow or western silvery minnow. L, species that were only identified in larval fish samples; the total number of species includes laboratory identification of larval fish and *Hybognathus* spp.]

Site number (fig.1)	Plains minnow*	Western silvery minnow*	Long-nose dace	Moun-tain sucker	Northern plains killifish	River carp-sucker	Rock bass	Sand shiner	Sauger	Short-head redhorse	Shovel-nose sturgeon	Small-mouth bass	Stone-cat	Stur-geon chub	White sucker	Total number of species
P3	24	0	28	1	27	8	0	487	0	0	0	0	1	0	0	12
	26	0	17	0	80	70	0	847	0	0	0	0	1	0	1	10
	0	0	24	0	164	50	0	4,486	0	0	0	0	4	0	0	9
	24	0	0	0	5	1	0	51	0	0	0	0	0	0	0	8
P4	166	8	52	0	197	68	0	685	0	0	0	0	0	0	0	11
	0	0	70	0	43	46	0	3,789	0	0	0	0	2	0	0	10
	188	120	18	0	8	5	0	123	0	0	0	0	3	0	0	13
P5	319	9	15	0	8	6	0	1,294	0	0	0	0	1	0	0	10
	245	0	2	0	4	136	0	1,668	0	1	0	0	0	0	0	11
	0	0	17	0	20	75	0	3,104	0	0	0	0	0	2	0	9
	4	0	0	0	1	21	0	68	0	0	0	0	0	0	0	7
P7	0	0	3	0	0	0	0	33	0	0	0	0	1	0	8	5
	0	0	67	0	0	0	0	402	0	0	0	0	9	0	227	9
	0	7	11	0	0	0	0	129	0	3	0	1	1	0	16	13
P8	173	0	33	0	0	2	0	933	0	1	0	0	12	0	0	9
	0	0	29	0	15	4	0	875	0	0	0	0	0	0	0	8
	0	0	14	0	3	182	0	1,903	0	3	0	0	0	0	0	12
	48	0	0	0	1	9	0	160	0	0	0	0	0	0	0	6
P9	8	0	1	0	1	2	0	446	0	0	0	0	2	0	0	9
	0	0	0	0	0	4	0	370	0	0	0	0	0	0	0	6
	0	0	0	0	0	25	0	794	0	0	0	0	0	0	0	9
	10	9	0	0	1	4	0	192	0	0	0	0	2	0	0	9
P10	0	0	0	0	0	13	91	71	2	40	0	22	32	0	19	14
	0	0	1	0	0	0	76	192	1	12	0	33	45	0	13	14
	0	0	0	0	0	29	96	0	2	25	0	56	14	0	0	11
P11	17	0	2	0	0	3	0	687	0	0	0	1	7	0	0	10
	0	0	0	0	0	25	0	404	0	0	0	1	17	0	L	10
	0	0	4	0	0	3	0	289	0	0	0	0	3	0	0	6
	1	0	0	0	0	0	0	18	0	0	0	0	1	0	0	5
P12	1	1	11	0	0	0	0	14	0	0	0	0	0	0	0	6
	0	0	6	0	0	116	0	283	0	2	0	0	1	4	0	10
	9	0	2	0	0	1	0	9	0	0	0	0	12	1	0	10
P13	4	0	246	0	6	0	0	39	0	0	0	0	0	1	0	7
	0	0	55	0	28	43	0	559	0	0	0	0	0	0	0	7
	19	8	16	0	0	1	0	64	0	0	1	0	0	0	0	8
P15	0	0	0	0	0	0	0	95	0	0	0	0	0	0	13	9
	2	0	19	0	0	5	0	453	0	0	0	0	0	0	4	11
	0	10	1	0	0	1	0	150	0	4	0	0	0	0	3	10

ions in coalbed waters (Rice and others, 2000) in contrast to area stream waters, which typically have a larger ambient percentage of calcium, magnesium, and sulfate (Clark and Mason, 2007). The primary constituents of concern in CBNG produced water are sodium, sodium-adsorption ratio, specific conductance, and dissolved solids because large values for these constituents have the potential to negatively affect the water for irrigation uses (Brown and Johnston, 2005).

The potential effects of CBNG discharges on biological communities include several aspects of water quality. Increases in sodium bicarbonate concentrations in streams to potentially toxic levels as a result of CBNG produced water inputs are of concern to aquatic life (Bureau of Land Management, 2003). Larval fish that were exposed to sodium bicarbonate had lower hatch and survival rates compared to controls for both acute and chronic exposures (Skaar and others, 2006). Coalbed waters, which have a relatively constant temperature compared to streams, have the potential to increase or decrease stream temperature depending on the time of year. Turbidity associated with coalbed waters may be lower than the natural stream turbidity; however, increased concentrations of suspended sediment resulting from indirect CBNG-development activities such as road construction and channel erosion may increase stream turbidity. Increased sedimentation also has potential to affect substrate and spawning habitat. Coalbed waters typically are anoxic and reducing, which increases the solubility of some trace elements, including iron, manganese, and barium (Rice and others, 2000). The discharge of anoxic coalbed waters to streams could affect dissolved-oxygen concentrations of streams and affect the precipitation of selected trace elements, particularly iron and manganese. Data collected from ATG sites indicated that iron and manganese concentrations were higher than the chronic and, in a few cases, the acute aquatic-life criteria. The mobilization of other trace elements, including arsenic and selenium, in basin sediments from the addition of coalbed waters to the



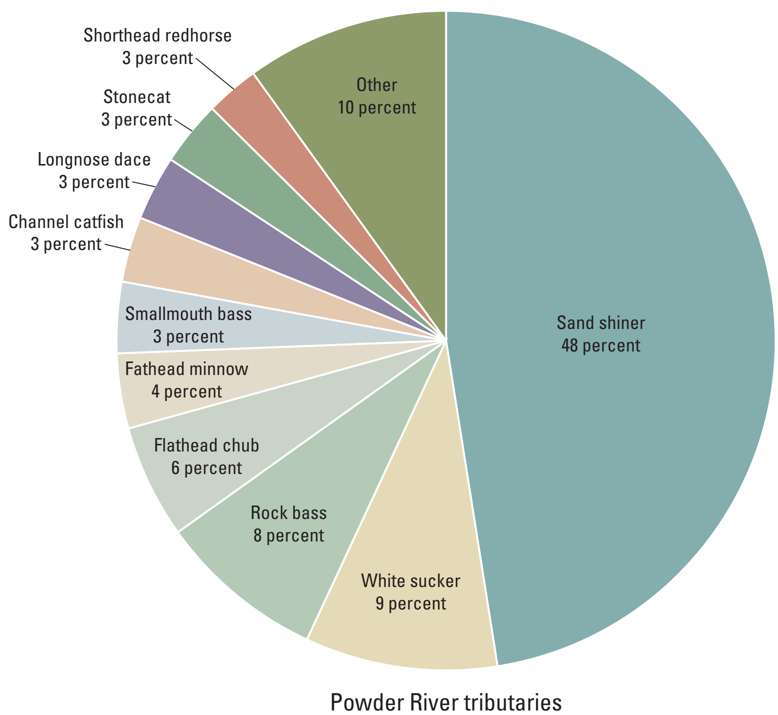


Figure 16. Relative abundance of fish by species in samples from the Powder River drainage basin, Wyoming and Montana, 2004–06 and 2008.

Table 18. Unadjusted fish community metric values for the main-stem Powder River, Wyoming and Montana, 2004–06 and 2008.

[Metric definitions from Bramblett and others (2005)]

Site number (fig. 1)	Abbreviated site name	Sample date	Number of					Percentage of				
			Native species	Native families	Native catostomid and ictalurid species	Bbenthic invertivorous species	Native long-lived species	Tolerant individuals	Invertivorous cyprinid individuals	Litho-obligate reproductive guild individuals	Tolerant reproductive guild individuals	Native individuals
P3	Powder River below Willow Creek	8/9/2004	11	4	4	1	4	7.2	29.6	61.9	5.5	96.7
		8/10/2005	9	3	4	1	4	4.7	41.0	53.3	0.6	95.4
		7/26/2006	7	3	3	1	5	3.4	3.8	93.0	0.2	96.7
		7/21/2008	6	3	2	0	3	12.7	36.7	31.3	14.5	88.6
P4	Powder River below Burger Draw	8/19/2005	10	4	2	1	6	13.3	21.6	53.9	3.2	86.8
		7/27/2006	8	4	3	1	7	1.1	21.6	73.6	0.4	99.2
		7/24/2008	9	3	3	1	5	3.2	13.6	28.3	1.5	97.5
P5	Powder River above Crazy Woman Creek	7/13/2004	9	3	3	1	3	0.4	26.6	58.2	0.9	99.6
		7/13/2005	9	4	3	2	5	0.4	18.5	71.0	0.7	99.8
		7/28/2006	7	3	2	2	5	0.4	41.7	55.5	1.1	99.7
		7/23/2008	6	4	2	0	1	0.5	54.2	42.1	1.4	99.5
P8	Powder River below Crazy Woman Creek	8/4/2004	9	3	4	2	6	0.0	24.5	63.8	2.6	100.0
		8/18/2005	7	3	2	1	4	1.2	26.7	66.6	2.1	98.9
		8/2/2006	10	4	3	2	5	0.5	5.8	90.5	1.8	99.6
		7/28/2008	5	3	2	0	1	0.3	32.9	49.7	2.9	99.7
P9	Powder River above Clear Creek	8/5/2004	8	3	3	1	5	0.2	14.1	80.2	4.3	99.8
		7/24/2005	6	3	2	0	2	1.7	3.9	68.8	25.7	100.0
		8/4/2006	7	4	2	0	6	0.5	23.2	58.7	12.0	99.6
		7/29/2008	7	3	3	0	3	2.7	32.3	54.2	5.5	97.3
P11	Powder River below Clear Creek	8/6/2004	9	4	3	1	6	0.0	17.5	77.3	3.5	99.9
		7/25/2005	9	3	4	0	5	1.2	5.9	61.3	32.6	99.7
		8/3/2006	6	3	3	1	2	0.0	28.1	72.4	0.5	100.0
		7/30/2008	5	2	2	0	0	0	48.1	35.2	14.8	100.0
P12	Powder River at Moorhead	7/18/2005	6	2	0	1	1	0.0	72.3	41.5	0.0	100.0
		8/2/2006	10	4	4	3	7	0.1	30.5	56.7	14.0	99.9
		7/31/2008	9	3	3	2	5	2	56.0	25.0	12.0	99.0
P13	Powder River at Broadus	7/19/2005	6	2	1	2	2	1.9	83.6	92.0	0.6	98.1
		8/2/2006	5	3	2	1	1	2.9	42.3	59.0	0.7	97.1
		8/1/2008	8	4	1	2	6	0	28.2	63.4	0.0	100.0

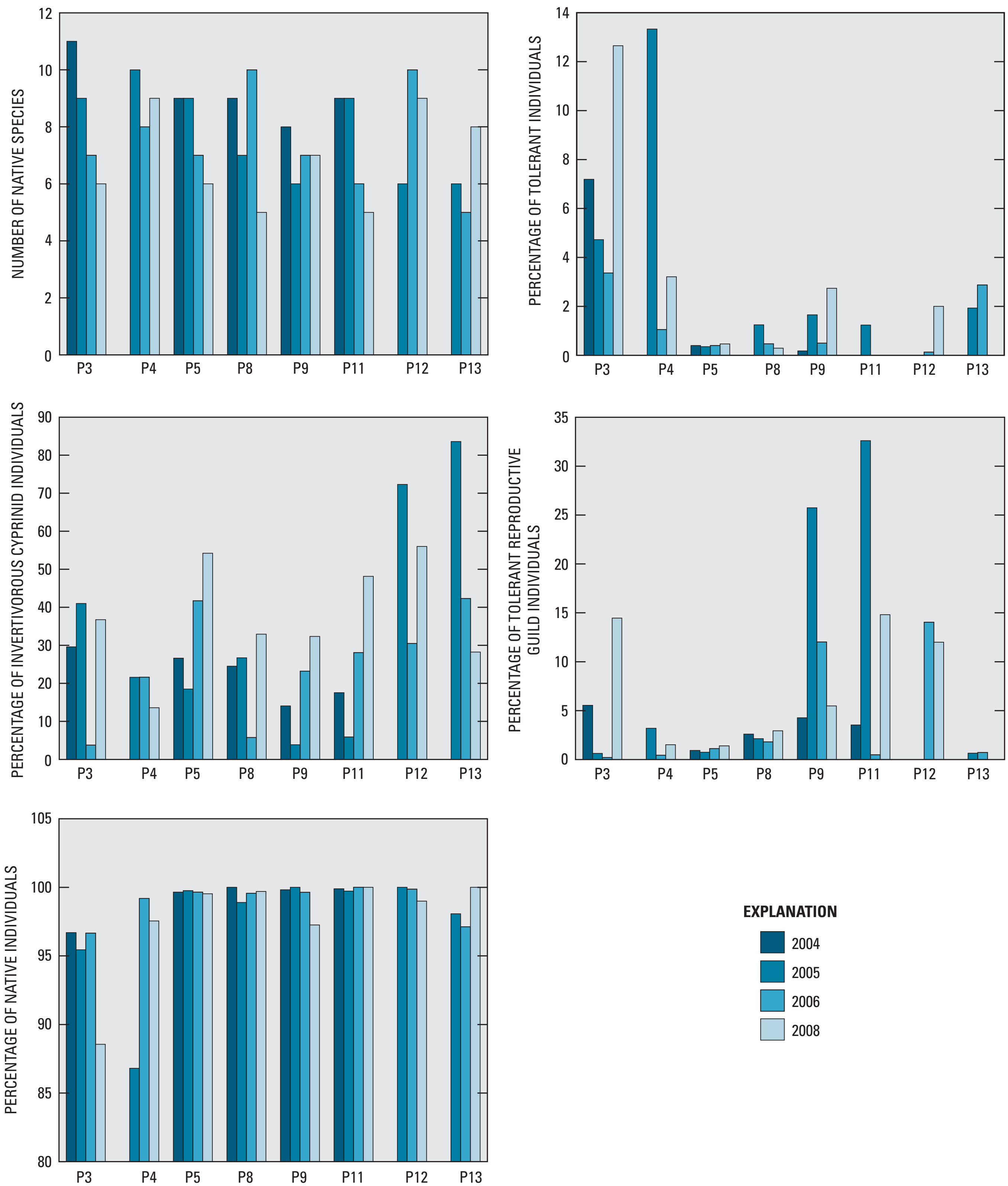


Figure 17. Selected unadjusted fish community metric values for the main-stem Powder River, Wyoming and Montana, 2004–06 and 2008.

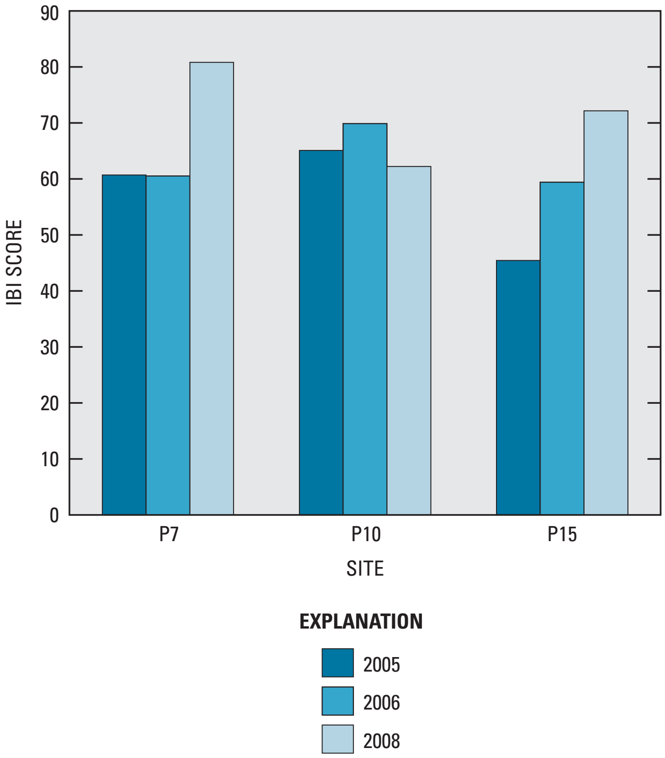


Figure 18. Index of Biotic Integrity (IBI) scores for fish communities in selected Powder River tributaries, Wyoming, 2005–06 and 2008.

surface also has been identified as a potential water-quality concern (Brinck and others, 2008). Nutrient cycling in streams also may be affected by inputs of coalbed waters, which can contain elevated concentrations of ammonia. Increases in inputs of inorganic nitrogen could increase the potential for eutrophication (Smith and others, 2009).

Macroinvertebrate Communities

Macroinvertebrate communities of the main-stem Tongue River indicated some differences in community composition in the downstream direction. For example, the relative abundance of noninsects at a site on the main-stem Tongue River downstream from Tongue River Reservoir during 2005–08 was significantly different from other sites on the main stem upstream and downstream from the reservoir. Given the differences in water quality from upstream to downstream from the reservoir, the differences in macroinvertebrate communities might be attributable to the effects of the reservoir rather than the effects of CBNG development.

Macroinvertebrate community composition in the middle reach of the main-stem Powder River, from below the confluence with Willow Creek to below the Crazy Woman Creek confluence, differed from communities in the upper and lower reaches of the Powder River. Macroinvertebrate community metric values at sampling sites in the middle reach during 2005–08 were significantly different (ANOVA, $p < 0.05$) from metric values at other sites on the main-stem Powder River. The affected metrics included taxa richness, relative abundance, feeding modes, and tolerance, which were indicative of communitywide differences. Ephemeroptera taxa richness, Ephemeroptera relative abundance, and intolerant macroinvertebrate relative abundance tended to be lower, whereas Diptera relative abundance and filterer-collector relative abundance tended to be higher, in the middle reach of the Powder River than in other reaches.

Potential causes of the observed pattern in macroinvertebrate communities of the main-stem Powder River include natural influences, coalbed natural gas development, and other development such as conventional oil and gas development in the Salt Creek drainage. For example, chloride concentrations in the Powder River downstream from Salt Creek sometimes exceeded USEPA acute and chronic criteria for the protection of aquatic life but not WDEQ site-specific criteria. Testing of relations between environmental variables and the macroinvertebrate taxonomy and metrics from the Powder River indicated some of the variation in the macroinvertebrate communities could be explained by variation in the environmental variables. The environmental variables that best correlated with the macroinvertebrates communities included physical variables (turbidity, embeddedness, D_{84}, and streamflow) and chemical variables (alkalinity and specific conductance). The Powder River is known for its relatively high transport of fine sediment (Lowry and others, 1986), which in turn can affect turbidity, embeddedness, and D_{84}. Of the environmental variables correlated with the macroinvertebrate communities, alkalinity perhaps is the best indicator of potential CBNG produced water influences because of the sodium-bicarbonate signature of CBNG water (Rice and others, 2000). Mean alkalinity concentrations at the time of ecological sampling were about 200 mg/L throughout the main-stem Powder River from upstream from Salt Creek to Locate, near the mouth at the Yellowstone River, with the exception of site P4, which is downstream from Burger Draw (fig. 4). The alkalinity concentrations in the Powder River below Burger Draw (site P4) ranged from 224 mg/L in 2008 to 1,540 mg/L during the drought year of 2006, with a mean near 600 mg/L. This site receives CBNG discharges from several upstream drainages.

Given that macroinvertebrate communities integrate responses to environmental variables over a longer time period than instantaneous samples, it is likely that the macroinvertebrate communities in the middle reach of the Powder River from Willow Creek to below the Crazy Woman Creek confluence are responding to variation in the measured environmental variables beyond those observed at the time of sampling or to other environmental variables that were not measured. Water production from CBNG development in the Powder River drainage more than doubled from 2006 to 2008. Discharge of CBNG produced water is a logical explanation for the observed patten in macroinvertebrate communities of the main-stem Powder River, but further study would be needed for confirmation as described in the section “Further Study Needs.”

Algal Communities

Similar to the pattern observed for the macroinvertebrates, the algal communities of the main-stem Powder River in 2005 and 2007 indicated differences in communities of the middle reach from those in the upper or lower reaches. Algal communities in the middle reach often were characterized by dominance by a single taxon and by low biovolume of algae compared to the upper and lower reaches of the Powder River.

Fish Communities

Fish species richness was relatively high in the middle reach of the main-stem Powder River, the same reach where macroinvertebrate and algal communities appeared to be anomalous. Although a few significant differences in fish metrics along the main-stem Powder River were noted, the differences did not correspond to the pattern observed for the macroinvertebrate and algae communities.

The Powder River fish assemblage has been described as largely intact as a result of the relatively unperturbed state of the river (Hubert, 1993). More recently, Senecal (2009) derived a reference fish assemblage for the Powder River on the basis of 1964–80 sampling data and compared the reference fish assemblage dataset to more current sampling data from 1994 and 2008. The reference fish assemblage using the combined 1964–80 dataset was composed predominantly of flathead chub, followed by *Hybognathus* spp. and sturgeon chub (Senecal, 2009). In contrast, the 2008 fish assemblage was dominated by sand shiners, *Hybognathus* spp., flathead chub, river carpsucker, channel catfish, and longnose dace (Senecal, 2009). The differences between the reference fish assemblage and the more recent fish assemblages were due to decreases in proportions of previously common species, such as sturgeon chub, and increases in proportions of two species, sand shiners and northern plains killifish. Senecal (2009) states that care must be taken with the results because the datasets used in the reference fish assemblage were collected at different times by different investigators, and lack of standardization across datasets may have contributed to discrepancies. However, results presented in this report are similar to those as presented by Senecal (2009). Slight differences in the relative abundance in the 2005–06 and 2008 samples, in order of dominance, were sand shiner, flathead chub, *Hybognathus* spp., channel catfish, river carpsucker, longnose dace, and northern plains killifish. Reasons for the increase in abundance of sand shiners are unclear.

A study conducted by Davis (2008) indicated mixed results of the effects of CBNG development on fish assemblages in the Powder River Basin during 2005–06. For example, species richness and IBI scores were similar between developed and undeveloped sites, and no strong relations existed between overall IBI scores or most IBI metric scores and the number or density of CBNG wells in a drainage area. Other evidence, however, indicated that CBNG-produced water may negatively affect fish assemblages. Conductivity was, on average, higher in streams with CBNG-produced water and was negatively related to biotic integrity. Bicarbonate, one of the primary salts in product water, appeared to be harmful to some species of fish. Altered flow regimes may present the biggest direct effect from CBNG effluent on fish assemblages (Davis, 2008; Senecal, 2009), and potential effects of CBNG development may be more apparent during wet years when more sensitive fish assemblages are present. Also, toxicity testing (Skaar and others, 2006) indicates that larval fish are more sensitive to CBNG effects than the adult and juvenile fish that were collected during this study.

Further Study Needs

The anomalous patterns of macroinvertebrate and algal communities in the middle reach of the main-stem Powder River are worthy of further study to help assess the natural or anthropogenic factors affecting the anomalous patterns. One approach to further study would be establishment of paired sampling sites upstream and downstream from known CBNG discharge points. As an aid to selecting potential sampling sites, water-quality and streamflow data from the current USGS monitoring network (*http://wy.water.usgs.gov/*) were evaluated. Fifteen tributaries to the Powder River in Wyoming are currently (2010) sampled in cooperation with the WDEQ. Instantaneous streamflow values indicate that other than the perennial tributaries (Salt Creek, Crazy Woman Creek, and Clear Creek) bracketed during this study, Pumpkin Creek (in Johnson County), Beaver Creek, and Wild Horse Creek (fig. 1) contribute the largest amount of streamflow to the Powder River. Although streamflow in Pumpkin, Beaver, and Wildhorse Creeks often was small compared to streamflow in the Powder River, these streams are of interest for biological monitoring because specific-conductance values and alkalinity concentrations measured in the tributaries commonly were higher than those measured in the Powder River. Permit data on file with the WDEQ indicate other tributaries, such as Indian Creek and Flying E Creek, also contribute treated and untreated CBNG discharges to the Powder River. One or more future biological monitoring sites could be located upstream from Willow Creek to help determine a reference condition upstream from CBNG discharges. Consideration to defining the spatial extent of the effects of tributaries and whether the effects are cumulative with distance downstream also may be warranted.

Additional analysis of data from the water-quality monitoring network in the Powder River and Tongue River drainage basins would be useful in determining long-term trends in water quality. Specific conductance in the Tongue River increased from Monarch (site T1) to the State line (site T9; fig. 4), but it is not known if the increase is due to effects of CBNG discharges or other influences such as irrigation return flows and discharge of treated sewage effluent. Long-term ecological monitoring also may be considered to identify trends and natural variability in biological communities in the Tongue and Powder River Basins.

Summary

In response to concerns about the effects of coalbed natural gas development (CBNG) on streams of the Powder River structural basin in Wyoming and Montana, an interagency Aquatic Task Group (ATG) was formed in 2004. Participants in the ATG included the Bureau of Land Management (BLM), the Montana Department of Environmental Quality (MDEQ), Montana Fish, Wildlife, and Parks, the U.S. Environmental Protection Agency (USEPA), the Wyoming Department of Environmental Quality (WDEQ), the Wyoming Game and Fish Department, and the U.S. Geological Survey (USGS). The ATG developed a monitoring plan to (1) establish current ecological conditions for aquatic biota and their habitat and (2) determine existing and potential effects of CBNG-produced water on aquatic life. The sample collection performed by the USGS during 2005–08 and described in this report was conducted under the direction of the ATG to meet objective 1 of the monitoring plan and, to the extent possible, objective 2.

Samples for environmental variables (water quality and habitat) and biological communities (macroinvertebrates, algae, and fish) were collected from 47 sites in 2005–08. The types of samples and number of sites sampled varied annually due to drought and program constraints.

Current ecological conditions (2005–08) are described in this report for water quality, habitat, macroinvertebrates, algae, and fish communities. Water-quality data collected during water years 2005–08 indicated most constituents generally did not exceed acute or chronic criteria for the protection of aquatic life set by the States of Wyoming and Montana and the USEPA. Comparison of data from sites in Wyoming to WDEQ criteria indicated that pH and concentrations of selenium, iron, and manganese at a few sites in the Cheyenne and Belle Fourche River drainage basins exceeded criteria. Chloride concentrations exceeded the WDEQ chronic criterion in a few samples from the Little Powder River. Chloride concentrations were relatively high in the main-stem Powder River downstream from Salt Creek but did not exceed the WDEQ site-specific acute chloride criterion. Comparison of water-quality data from sites in Montana to MDEQ criteria indicated numerous exceedances for trace elements, particularly in samples from Pumpkin Creek and the main-stem Powder River at Moorhead and Locate, Montana.

Macroinvertebrate communities showed similarities within stream groups. Macroinvertebrate community composition at sites on the main-stem Tongue River and mountainous tributaries such as Clear Creek (TRMS group) were characterized by high Ephemeroptera taxa richness, high relative abundance of Ephemeroptera, dominance of the collector-gatherer feeding mode, and a high proportion of intolerant macroinvertebrates compared to communities at sites on the Tongue River plains tributaries (TRPT group) and main-stem Powder River (PRMS group). Among the Tongue River sites, the Tongue River above Hanging Woman Creek contained significantly ($p < 0.05$) different (higher) relative abundance of noninsects than other sites on the main-stem Tongue River during 2005–08, perhaps due to the influence of Tongue River Reservoir. The relative abundance of the scraper feeding mode at sites on the main-stem Tongue River was significantly different (higher) in 2006 than in 2005 or 2007–08. Significant differences between 2006 and other years also were noted for metrics including Diptera taxa richness and relative abundance of Trichoptera at sites on the main-stem Powder River and some tributaries. Streamflow and climatic data indicated 2006 was a particularly severe year of a multiyear drought in the study area.

Macroinvertebrate community composition varied significantly ($p < 0.05$) among sites on the main-stem Powder River during 2005–08. Macroinvertebrate community metric values from sites in the middle reach of the main-stem Powder River, from below Willow Creek to below Crazy Woman Creek, differed from metric values in the upper and lower reaches of the Powder River. Metric values for Ephemeroptera taxa richness, Ephemeroptera relative abundance, and intolerant macroinvertebrate relative abundance tended to be lower, whereas Diptera relative abundance and filterer-collector relative abundance tended to be higher at sites in the middle reach of the main-stem Powder River than at upstream and downstream sites on the main-stem Powder River. The affected metrics included measures of taxa richness, relative abundance, feeding modes, and tolerance, which were indicative of communitywide differences.

Algal samples from the main-stem Powder River generally confirmed the pattern observed in the macroinvertebrate communities. Algal communities in the middle reach of the Powder River often were characterized by dominance of a single taxon and low biovolume compared to other sites in the study area, which might be indicative of anthropogenic disturbances. Diatoms composed the majority of the taxa identified in 2005 and 2007, whereas green and blue-green algae commonly dominated in terms of relative abundance at sites throughout the study area.

Fish communities of the main-stem Tongue River and tributaries contained 29 fish species, of which 15 were native, during 2005–06 and 2008. Communities at the main-stem Tongue River sites were dominated by smallmouth bass, white sucker, yellow bullhead, and rock bass. Significant differences in fish Index of Biotic Integrity metrics from the Tongue River upstream from Hanging Woman Creek to those from other sites on the main-stem Tongue River might have been related to fish migration from Tongue River Reservoir. Fish Index of Biotic Integrity scores from upper Youngs Creek and upper Squirrel Creek were among the highest in the study area.

Fish communities of the main-stem Powder River and tributaries contained 24 fish species, of which 17 were native. The most abundant fish were native species including sand shiner and flathead chub. Species richness on the main-stem Powder River was highest downstream from Burger Draw, where 13 species were collected in 2008. Although a few significant differences in fish metrics along the main-stem Powder River were noted, the differences did not correspond to the pattern observed for the macroinvertebrate and algae communities.

Potential causes of the anomalous pattern in macroinvertebrate communities of the middle reach of the main-stem Powder River include natural influences, discharge of production water from CBNG development, and other human activities. Relations between environmental variables and the macroinvertebrate taxonomy and metrics from the Powder River indicated some of the variation in the macroinvertebrate communities could be explained by variation in physical variables (specifically, turbidity, embeddedness, particle size, and streamflow) and chemical variables (alkalinity, pH, and specific conductance). Of those environmental variables, alkalinity perhaps is the best indicator of CBNG development because of the sodium-bicarbonate signature of CBNG water. Mean alkalinity concentrations at the time of biological sampling were similar throughout the main-stem Powder River, with the exception of the site downstream from Burger Draw in Wyoming that had a relatively high mean alkalinity concentration, perhaps due to the influences of several CBNG discharges upstream. Given that macroinvertebrate communities integrate responses to environmental variables over a longer time period than instantaneous samples, it is likely that the macroinvertebrate communities in the middle Powder River reach between the Willow and Crazy Woman Creek confluences are responding to variation in the measured environmental variables beyond those observed at the time of sampling, or to other environmental variables that were not measured. The recent (2006–08) large increase in CBNG production in the Powder River drainage is a logical explanation for the observed patten in macroinvertebrate communities of the main-stem Powder River, but further study would be needed for confirmation.

The fish community composition of the main-stem Powder River observed in this study was similar to that observed by other investigators during about the same timeframe but may represent a departure from historical (1964–80) conditions. Potential causes for the departure include natural variation and the effects of resource development. Toxicity testing by other investigators indicates larval fish are more sensitive to sodium bicarbonate from CBNG discharges in the study area than the adult and juvenile fish that were sampled during this study.

In conclusion, the assessment of the current condition (2005–08) of biological communities in the Powder River structural basin indicated anomalous conditions for macroinvertebrate and algal communities in the middle reach of the Powder River compared to the upper and lower reaches. The anomalous conditions occurred at the lower trophic levels represented by macroinvertebrates and algae, whereas the higher trophic levels represented by the fish community generally did not vary significantly along the Powder River during 2005–08. Although CBNG development might have led to the observed patterns, further study of macroinvertebrate and algal communities in the middle reach of the Powder River is needed for confirmation. The sampling design proposed for further study is based on paired sampling locations, upstream and downstream from CBNG discharge points.

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Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
R1	06295113	Streamflow, in cubic feet per second	33	0.02	8.545	1.05	5.6	10.95	51
R1	06295113	Turbidity, nephelometric turbidity ratio units	1	--	--	--	--	--	6
R1	06295113	Dissolved oxygen, in mg/L	31	5.3	9.245	7.6	9.1	10.7	12.5
R1	06295113	Dissolved oxygen, percent saturation	31	64	93.32	88	99	101	115
R1	06295113	pH, in standard units	32	7.9	8.28	8.1	8.3	8.4	8.6
R1	06295113	Specific conductance, at 25 degrees Celsius, in µS/cm	31	791	960.8	882	944	1,020	1,170
R1	06295113	Temperature, water deg C	33	0	10.70	3.75	10	16.25	25.5
R1	06295113	Hardness, in mg/L as $CaCO_3$	32	390	505.9	470	510	550	610
R1	06295113	Calcium, dissolved, in mg/L	32	53.5	74.03	67.75	76.2	80.5	89.3
R1	06295113	Magnesium, dissolved, in mg/L	32	59.2	78.05	69.15	80.9	84.175	94.5
R1	06295113	Potassium, dissolved, in mg/L	32	6.04	8.362	7.062	7.935	9.352	12.1
R1	06295113	Sodium-adsorption ratio (unitless)	32	0.4	0.672	0.5	0.6	0.875	1
R1	06295113	Sodium, dissolved, in mg/L	32	20.1	35.40	26.2	31.9	46.675	52.6
R1	06295113	Alkalinity, in mg/L as $CaCO_3$	32	285	432.7	382.25	414.5	490	565
R1	06295113	Chloride, dissolved, in mg/L	32	2.54	3.811	3.117	3.72	4.538	6
R1	06295113	Fluoride, dissolved, in mg/L	32	0.52	0.703	0.582	0.665	0.85	0.93
R1	06295113	Silica, dissolved, in mg/L	32	2.14	13.66	11.175	13.9	16.275	21.6
R1	06295113	Sulfate, dissolved, in mg/L	32	83.5	143.8	122.5	137	174.75	204
R1	06295113	Dissolved solids, calculated, in mg/L	31	474	617.9	561	627	670	765
R1	06295113	Dissolved solids, tons/day	31	0.04	12.87	1.81	7.58	13.9	77.2
R1	06295113	*Ammonia, dissolved, in mg/L as N	10	--	0.012	0.006	0.008	0.012	0.044
R1	06295113	**Nitrate plus nitrite, dissolved, in mg/L as N	14	--	--	--	--	--	0.018
R1	06295113	*Nitrite, dissolved, in mg/L as N	14	--	0.001	0.001	0.001	0.001	0.003
R1	06295113	Orthophosphate, dissolved, in mg/L as P	14	0.004	0.01	0.007	0.009	0.014	0.026
R1	06295113	Phosphorus, total, in mg/L	14	0.023	0.041	0.03	0.038	0.05	0.072
R1	06295113	Total nitrogen, total, in mg/L	14	0.27	0.424	0.338	0.435	0.505	0.58
R1	06295113	Aluminum, dissolved, in µg/L	22	0.9	3.045	1.4	2.2	4.25	9.8
R1	06295113	Aluminum, total, in µg/L	22	10	123.8	40.5	84	136	865
R1	06295113	Arsenic, dissolved, in µg/L	22	0.58	1.425	0.877	1.35	1.775	3.3
R1	06295113	Arsenic, total, in µg/L	22	0.87	1.608	1.1	1.7	2	2.4
R1	06295113	Barium, dissolved, in µg/L	22	62	94.55	84	94.5	105.5	128
R1	06295113	Barium, total, in µg/L	22	70.1	98.04	85.575	95.3	114.25	135
R1	06295113	**Beryllium, dissolved, in µg/L	22	--	--	--	--	--	<0.06
R1	06295113	**Beryllium, total, in µg/L	22	--	--	--	--	--	0.09
R1	06295113	**Cadmium, dissolved, in µg/L	8	--	--	--	--	--	<0.04
R1	06295113	**Cadmium, total, in µg/L	8	--	--	--	--	--	<0.04
R1	06295113	*Chromium, dissolved, in µg/L	8	--	0.071	0.045	0.068	0.088	0.12
R1	06295113	*Chromium, total, in µg/L	8	--	0.348	0.253	0.325	0.477	0.5
R1	06295113	Copper, dissolved, in µg/L	8	0.9	2.287	1	2.25	3.3	4.7
R1	06295113	Copper, total, in µg/L	8	0.9	2.062	1.325	1.6	3.15	4.3
R1	06295113	Iron, dissolved, in µg/L	22	11	22.82	15	19.5	28.5	67
R1	06295113	Iron, total, in µg/L	22	35	392.3	165.25	280.5	474	2,340
R1	06295113	Lead, dissolved, in µg/L	8	0.07	0.191	0.07	0.13	0.3	0.56
R1	06295113	Lead, total, in µg/L	8	0.09	0.211	0.105	0.16	0.332	0.41
R1	06295113	Manganese, dissolved, in µg/L	22	3.3	32.02	8.25	33.25	41.6	83.7
R1	06295113	Manganese, total, in µg/L	22	4.4	45.76	10.775	41.4	58.65	167
R1	06295113	Nickel, dissolved, in µg/L	8	1.35	2.255	1.41	1.7	3.362	4.7
R1	06295113	Nickel, total, in µg/L	8	1.1	2.305	1.56	2.36	3.148	3.23
R1	06295113	Selenium, dissolved, in µg/L	22	0.05	0.284	0.2	0.275	0.3	0.9
R1	06295113	Selenium, total, in µg/L	22	0.1	0.353	0.27	0.29	0.348	1.1
R1	06295113	Zinc, dissolved, in µg/L	7	1.7	4.771	3	5.1	5.5	8
R1	06295113	*Zinc, total, in µg/L	8	--	2.236	1.142	2	2.375	6
R1	06295113	Suspended sediment, <0.0625 mm, percent	32	40	70.13	56.25	71.5	81.75	96
R1	06295113	Suspended sediment, in mg/L	32	18	58.25	31.75	47	83.5	137
R1	06295113	Suspended sediment, tons/day	32	0	1.940	0.102	0.35	2.35	16
R2	06296003	Streamflow, in cubic feet per second	14	0.08	37.50	0.285	8.9	36	226
R2	06296003	Turbidity, nephelometric turbidity ratio units	1	--	--	--	--	--	45
R2	06296003	Dissolved oxygen, in mg/L	9	7.6	10.08	8.7	9.5	11.65	13.1
R2	06296003	Dissolved oxygen, percent saturation	9	92	98.56	96.5	99	100	105
R2	06296003	pH, in standard units	11	8.2	8.46	8.3	8.5	8.6	8.8

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
R2	06296003	Specific conductance, at 25 degrees Celsius, in µS/cm	14	427	2,245	1,768	2,315	2,923	3,500
R2	06296003	Temperature, water deg C	14	0	11.82	3.25	11	19.25	30
R2	06296003	Hardness, in mg/L as $CaCO_3$	11	35	688.5	670	790	870	1,100
R2	06296003	Calcium, dissolved, in mg/L	11	8.77	75.34	68.8	79.5	95.3	131
R2	06296003	Magnesium, dissolved, in mg/L	11	3.18	121.9	120	139	149	196
R2	06296003	Potassium, dissolved, in mg/L	11	4.24	11.65	11.5	12.3	14.4	16.2
R2	06296003	Sodium-adsorption ratio (unitless)	11	2.8	4.800	3	3.9	6.2	8.6
R2	06296003	Sodium, dissolved, in mg/L	11	76.1	269.2	166	203	399	565
R2	06296003	Alkalinity, in mg/L as $CaCO_3$	11	118	400.8	384	430	452	629
R2	06296003	Chloride, dissolved, in mg/L	11	1.27	13.35	8.92	12.6	16.5	31
R2	06296003	Fluoride, dissolved, in mg/L	11	0.36	0.653	0.61	0.7	0.73	0.84
R2	06296003	Silica, dissolved, in mg/L	11	0.86	7.511	4.47	6.68	10.9	16.5
R2	06296003	Sulfate, dissolved, in mg/L	11	70.9	833.4	617	802	1,180	1,520
R2	06296003	Dissolved solids, calculated, in mg/L	11	244	1,573	1,230	1,550	2,220	2,650
R2	06296003	Dissolved solids, tons/day	11	1.1	85.10	18	64.3	154	201
R2	06296003	**Ammonia, dissolved, in mg/L as N	3	--	--	--	--	--	0.011
R2	06296003	**Nitrate plus nitrite, dissolved, in mg/L as N	3	--	--	--	--	--	<0.016
R2	06296003	**Nitrite, dissolved, in mg/L as N	3	--	--	--	--	--	<0.002
R2	06296003	**Orthophosphate, dissolved, in mg/L as P	3	--	--	--	--	--	<0.006
R2	06296003	Phosphorus, total, in mg/L	3	0.038	--	--	--	--	0.172
R2	06296003	Total nitrogen, total, in mg/L	3	0.42	--	--	--	--	1.11
R2	06296003	Aluminum, dissolved, in µg/L	10	1.5	8.690	2.3	3.3	7.25	48.8
R2	06296003	Aluminum, total, in µg/L	10	228	12,618	309.25	983.5	16,705	59,800
R2	06296003	Arsenic, dissolved, in µg/L	10	0.76	1.040	0.8	0.95	1.325	1.5
R2	06296003	**Arsenic, total, in µg/L	10	--	3.170	1.075	1.6	4.15	11
R2	06296003	Barium, dissolved, in µg/L	10	23	80.00	39.25	71	121	147
R2	06296003	Barium, total, in µg/L	10	47.5	314.9	65.125	129.5	339	1,440
R2	06296003	**Beryllium, dissolved, in µg/L	10	--	--	--	--	--	<0.12
R2	06296003	*Beryllium, total, in µg/L	10	--	1.889	0.03	0.103	1.862	11.4
R2	06296003	**Cadmium, dissolved, in µg/L	4	--	--	--	--	--	<0.08
R2	06296003	**Cadmium, total, in µg/L	4	--	--	--	--	--	<0.08
R2	06296003	**Chromium, dissolved, in µg/L	4	--	--	--	--	--	1.5
R2	06296003	Chromium, total, in µg/L	4	0.5	--	--	--	--	4
R2	06296003	Copper, dissolved, in µg/L	4	4.3	--	--	--	--	9.1
R2	06296003	Copper, total, in µg/L	4	4.6	--	--	--	--	15.8
R2	06296003	*Iron, dissolved, in µg/L	10	--	174.2	3.718	8.308	32.507	1,630
R2	06296003	Iron, total, in µg/L	10	261	14,257	410	1,115	18,310	70,100
R2	06296003	**Lead, dissolved, in µg/L	4	--	--	--	--	--	0.13
R2	06296003	Lead, total, in µg/L	4	0.38	--	--	--	--	4.02
R2	06296003	Manganese, dissolved, in µg/L	10	0.8	23.80	2.175	15.35	38.15	83.5
R2	06296003	Manganese, total, in µg/L	10	43.6	368.1	59.525	99.8	403	1,870
R2	06296003	Nickel, dissolved, in µg/L	4	4.45	--	--	--	--	5.33
R2	06296003	Nickel, total, in µg/L	4	3.84	--	--	--	--	10.3
R2	06296003	Selenium, dissolved, in µg/L	10	0.09	0.748	0.298	0.53	1.225	1.8
R2	06296003	Selenium, total, in µg/L	10	0.31	1.073	0.328	0.715	1.925	2.7
R2	06296003	Zinc, dissolved, in µg/L	4	3.5	--	--	--	--	8.2
R2	06296003	Zinc, total, in µg/L	4	4	--	--	--	--	18
R2	06296003	Suspended sediment, <0.0625 mm, percent	10	76	94.70	92.75	99	99	99
R2	06296003	Suspended sediment, in mg/L	10	80	1,980	87	165	1,895	11,900
R2	06296003	Suspended sediment, tons/day	10	0.05	908.7	1.143	5.95	1,035	4,970
T1	06299980	Streamflow, in cubic feet per second	50	32	321.6	71.5	111	234.25	2,520
T1	06299980	Turbidity, nephelometric turbidity ratio units	1	--	--	--	--	--	14
T1	06299980	Dissolved oxygen, in mg/L	49	6.8	10.40	8.95	10.1	11.6	15
T1	06299980	Dissolved oxygen, percent saturation	49	80	102.8	94	99	110.5	159
T1	06299980	pH, in standard units	49	7.7	8.26	8	8.3	8.5	8.7
T1	06299980	Specific conductance, at 25 degrees Celsius, in µS/cm	50	186	372.3	292.75	407.5	441	535
T1	06299980	Temperature, water deg C	50	0	9.736	3.625	9	15.5	26
T1	06299980	Hardness, in mg/L as $CaCO_3$	49	84	178.9	140	200	210	250
T1	06299980	Calcium, dissolved, in mg/L	49	22.1	42.38	35.1	46.6	50.35	57.7
T1	06299980	Magnesium, dissolved, in mg/L	49	7.04	17.70	12.6	19.9	21.25	28.9

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
T1	06299980	Potassium, dissolved, in mg/L	49	0.72	1.543	1.175	1.37	1.665	4.2
T1	06299980	Sodium-adsorption ratio (unitless)	49	0.1	0.318	0.2	0.3	0.4	0.7
T1	06299980	Sodium, dissolved, in mg/L	49	2.45	9.867	6	9.98	12.65	25.5
T1	06299980	Alkalinity, in mg/L as $CaCO_3$	49	81	158.0	125.5	178	187	212
T1	06299980	Chloride, dissolved, in mg/L	49	0.54	1.442	1.04	1.35	1.75	3.6
T1	06299980	Fluoride, dissolved, in mg/L	49	0.08	0.162	0.14	0.17	0.19	0.23
T1	06299980	Silica, dissolved, in mg/L	49	3.63	6.464	5.29	6.58	7.55	9.54
T1	06299980	Sulfate, dissolved, in mg/L	49	8.26	41.52	22.55	44.3	55.25	110
T1	06299980	Dissolved solids, calculated, in mg/L	46	103	213.4	160.5	235	255	332
T1	06299980	Dissolved solids, tons/day	46	25.3	150.0	54.8	70.8	126	1,140
T1	06299980	Dissolved solids, residue on evaporation, in mg/L	11	114	231.0	187	252	274	310
T1	06299980	*Ammonia, dissolved, in mg/L as N	18	--	0.013	0.005	0.007	0.012	0.085
T1	06299980	*Nitrate plus nitrite, dissolved, in mg/L as N	18	--	0.048	0.008	0.016	0.064	0.222
T1	06299980	*Nitrite, dissolved, in mg/L as N	18	--	0.002	0.001	0.001	0.002	0.004
T1	06299980	*Orthophosphate, dissolved, in mg/L as P	18	--	0.009	0.003	0.005	0.009	0.039
T1	06299980	Phosphorus, total, in mg/L	18	0.005	0.045	0.009	0.018	0.053	0.26
T1	06299980	Total nitrogen, total, in mg/L	18	0.1	0.337	0.175	0.235	0.39	1.21
T1	06299980	*Aluminum, dissolved, in µg/L	18	--	2.309	1.252	1.628	2.425	9.6
T1	06299980	Aluminum, total, in µg/L	29	22	279.8	34.5	52	204.5	2,810
T1	06299980	Arsenic, dissolved, in µg/L	29	0.2	0.408	0.3	0.35	0.5	0.8
T1	06299980	*Arsenic, total, in µg/L	29	--	0.66	0.457	0.56	0.755	2
T1	06299980	Barium, dissolved, in µg/L	18	25	43.11	41	44	47.25	57
T1	06299980	Barium, total, in µg/L	29	32.9	47.39	41.15	44.3	48.7	90.2
T1	06299980	**Beryllium, dissolved, in µg/L	18	--	--	--	--	--	<0.06
T1	06299980	*Beryllium, total, in µg/L	29	--	0.044	0.015	0.029	0.046	0.32
T1	06299980	Boron, dissolved, in µg/L	15	15	32.53	30	31	35	53
T1	06299980	**Cadmium, dissolved, in µg/L	16	--	--	--	--	--	<0.04
T1	06299980	**Cadmium, total, in µg/L	16	--	--	--	--	--	0.12
T1	06299980	Chromium, dissolved, in µg/L	1	--	--	--	--	--	0.13
T1	06299980	*Chromium, total, in µg/L	16	--	1.172	0.881	1	1.251	3
T1	06299980	Copper, dissolved, in µg/L	13	0.7	1.033	0.8	0.9	1.2	1.8
T1	06299980	Copper, total, in µg/L	16	0.7	1.663	1	1.15	1.7	6.9
T1	06299980	Iron, dissolved, in µg/L	29	6	20.21	13	17	29.5	41
T1	06299980	Iron, total, in µg/L	18	55	439.7	86.75	175.5	510	2,450
T1	06299980	*Lead, dissolved, in µg/L	14	--	0.092	0.053	0.065	0.085	0.43
T1	06299980	Lead, total, in µg/L	16	0.04	0.569	0.06	0.125	0.4	5.43
T1	06299980	Lithium, dissolved, in µg/L	15	3.9	9.707	8.5	9.5	10.3	16.6
T1	06299980	Manganese, dissolved, in µg/L	29	1.8	9.948	5.2	6.1	10	34.1
T1	06299980	Manganese, total, in µg/L	18	3.1	27.51	8.1	22.75	43.825	86.6
T1	06299980	Mercury, total, ng/L	5	0.28	--	--	--	--	3.8
T1	06299980	**Mercury, total, µg/L	3	--	--	--	--	--	<0.01
T1	06299980	Nickel, dissolved, in µg/L	15	0.23	1.163	0.47	1.09	1.79	2.27
T1	06299980	Nickel, total, in µg/L	16	0.85	1.656	0.923	1.35	2.003	5.34
T1	06299980	*Selenium, dissolved, in µg/L	18	--	0.282	0.168	0.225	0.305	0.8
T1	06299980	Selenium, total, in µg/L	29	0.08	0.301	0.18	0.21	0.32	1.2
T1	06299980	Strontium, dissolved, in µg/L	15	93	207.3	189	217	238	253
T1	06299980	*Zinc, dissolved, in µg/L	14	--	1.279	0.467	0.755	2.175	3.3
T1	06299980	*Zinc, total, in µg/L	16	--	2.864	1	1.224	2.75	19
T1	06299980	Suspended sediment, <0.0625 mm, percent	33	36	85.67	78.5	91	95	99
T1	06299980	Suspended sediment, in mg/L	33	4	32.15	9.5	17	35	266
T1	06299980	Suspended sediment, tons/day	33	0.65	47.46	1.95	3.7	18	826
T2	06305700	Streamflow, in cubic feet per second	38	5.1	200.5	42.75	67.5	159	1,350
T2	06305700	Turbidity, nephelometric turbidity ratio units	2	3.8	--	--	--	--	4.5
T2	06305700	Dissolved oxygen, in mg/L	38	6	10.86	8.925	10.5	12.875	15.9
T2	06305700	Dissolved oxygen, percent saturation	38	62	113.2	95.5	104.5	126	194
T2	06305700	pH, in standard units	37	7.8	8.31	8.05	8.3	8.55	9
T2	06305700	Specific conductance, at 25 degrees Celsius, in µS/cm	38	130	595.6	539	663	723.75	860
T2	06305700	Temperature, water deg C	38	0	11.85	5.25	10.75	19.175	28
T2	06305700	Hardness, in mg/L as $CaCO_3$	37	57	281.9	250	320	350	420
T2	06305700	Calcium, dissolved, in mg/L	37	13.2	54.05	49.85	61.1	67.25	76.2

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
T2	06305700	Magnesium, dissolved, in mg/L	37	5.76	35.51	29.8	39.6	44.65	56.6
T2	06305700	Potassium, dissolved, in mg/L	37	0.83	2.810	2.3	2.72	3.65	4.82
T2	06305700	Sodium-adsorption ratio (unitless)	37	0.2	0.589	0.5	0.6	0.7	1.2
T2	06305700	Sodium, dissolved, in mg/L	37	3.96	23.36	18.35	24.7	30.25	48.2
T2	06305700	Alkalinity, in mg/L as $CaCO_3$	37	50	208.0	181.5	236	257.5	300
T2	06305700	Chloride, dissolved, in mg/L	37	0.88	6.786	4.685	6.39	8.905	18.2
T2	06305700	Fluoride, dissolved, in mg/L	37	0.07	0.271	0.24	0.29	0.33	0.4
T2	06305700	Silica, dissolved, in mg/L	37	1.25	7.339	5.45	7.66	9.265	12.6
T2	06305700	Sulfate, dissolved, in mg/L	37	13.8	111.3	95.4	118	138.5	210
T2	06305700	Dissolved solids, calculated, in mg/L	36	77	367.4	313	412.5	451.5	559
T2	06305700	Dissolved solids, tons/day	36	7.7	122.9	55.45	73.3	159.75	914
T2	06305700	*Ammonia, dissolved, in mg/L as N	17	--	0.024	0.007	0.012	0.023	0.11
T2	06305700	*Nitrate plus nitrite, dissolved, in mg/L as N	17	--	0.208	0.017	0.139	0.326	1.04
T2	06305700	*Nitrite, dissolved, in mg/L as N	17	--	0.007	0.001	0.003	0.007	0.033
T2	06305700	Orthophosphate, dissolved, in mg/L as P	17	0.016	0.091	0.06	0.086	0.117	0.188
T2	06305700	Phosphorus, total, in mg/L	17	0.071	0.147	0.105	0.142	0.185	0.28
T2	06305700	Total nitrogen, total, in mg/L	17	0.31	0.637	0.415	0.52	0.85	1.44
T2	06305700	*Aluminum, dissolved, in µg/L	17	--	2.570	0.936	1.322	2.35	14.4
T2	06305700	Aluminum, total, in µg/L	17	13	218.9	27.5	60	193	2,090
T2	06305700	Arsenic, dissolved, in µg/L	17	0.27	0.575	0.38	0.51	0.785	1.2
T2	06305700	*Arsenic, total, in µg/L	17	--	0.893	0.56	0.72	1.148	2
T2	06305700	Barium, dissolved, in µg/L	17	18	49.71	48	52	55	60
T2	06305700	Barium, total, in µg/L	17	25.1	53.62	50.15	53.6	60.05	67.7
T2	06305700	**Beryllium, dissolved, in µg/L	17	--	--	--	--	--	0.1
T2	06305700	**Beryllium, total, in µg/L	17	--	--	--	--	--	0.22
T2	06305700	Boron, dissolved, in µg/L	14	46	83.79	68	80.5	97	131
T2	06305700	**Cadmium, dissolved, in µg/L	15	--	--	--	--	--	<0.04
T2	06305700	*Cadmium, total, in µg/L	15	--	0.026	0.01	0.019	0.03	0.1
T2	06305700	Chromium, dissolved, in µg/L	1	--	--	--	--	--	0.15
T2	06305700	*Chromium, total, in µg/L	15	--	1.523	1	1.015	2	4
T2	06305700	Copper, dissolved, in µg/L	15	0.69	1.354	1.1	1.3	1.6	2.2
T2	06305700	Copper, total, in µg/L	15	1.2	2.347	1.5	1.9	2.7	6.7
T2	06305700	Iron, dissolved, in µg/L	17	12	32.94	16	33	47	59
T2	06305700	Iron, total, in µg/L	17	74	463.8	163	193	449.5	3,180
T2	06305700	Lead, dissolved, in µg/L	15	0.04	0.095	0.06	0.08	0.12	0.24
T2	06305700	Lead, total, in µg/L	15	0.08	0.498	0.11	0.15	0.44	3.53
T2	06305700	Lithium, dissolved, in µg/L	14	9.4	17.77	15.575	16.9	21.875	26
T2	06305700	Manganese, dissolved, in µg/L	17	6.7	28.65	12.45	21.7	40.85	67.1
T2	06305700	Manganese, total, in µg/L	17	9.3	52.54	29.75	43.9	76.75	118
T2	06305700	Mercury, total, ng/L	5	0.45	--	--	--	--	1.01
T2	06305700	**Mercury, total, µg/L	3	--	--	--	--	--	<0.01
T2	06305700	Nickel, dissolved, in µg/L	14	0.52	1.822	0.89	1.86	2.388	3.32
T2	06305700	Nickel, total, in µg/L	15	1.1	2.198	1.55	2.1	2.58	5.21
T2	06305700	Selenium, dissolved, in µg/L	17	0.2	0.49	0.325	0.42	0.55	1.3
T2	06305700	Selenium, total, in µg/L	17	0.19	0.556	0.355	0.41	0.75	1.6
T2	06305700	Strontium, dissolved, in µg/L	14	228	444.4	429.25	455	504.25	537
T2	06305700	Zinc, dissolved, in µg/L	14	1.9	3.100	2.45	2.9	3.925	4.8
T2	06305700	Zinc, total, in µg/L	15	3	4.933	3	4	5	17
T2	06305700	Suspended sediment, <0.0625 mm, percent	31	36	76.94	64	82	88	97
T2	06305700	Suspended sediment, in mg/L	31	2	25.58	7	17	27	216
T2	06305700	Suspended sediment, tons/day	31	0.18	36.92	0.83	1.9	8.4	787
T3	450137106595101	Streamflow, in cubic feet per second	4	0.36	--	--	--	--	15
T3	450137106595101	Turbidity, nephelometric turbidity ratio units	4	42	--	--	--	--	85
T3	450137106595101	Dissolved oxygen, in mg/L	4	7.2	--	--	--	--	8
T3	450137106595101	Dissolved oxygen, percent saturation	3	92	--	--	--	--	96
T3	450137106595101	pH, in standard units	4	7.5	--	--	--	--	8.4
T3	450137106595101	Specific conductance, at 25 degrees Celsius, in µS/cm	4	615	--	--	--	--	704
T3	450137106595101	Temperature, water deg C	4	18	--	--	--	--	22
T3	450137106595101	Hardness, in mg/L as $CaCO_3$	4	290	--	--	--	--	370
T3	450137106595101	Calcium, dissolved, in mg/L	4	55.1	--	--	--	--	67.8

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
T3	450137106595101	Magnesium, dissolved, in mg/L	4	36.8	--	--	--	--	51.1
T3	450137106595101	Potassium, dissolved, in mg/L	4	3.96	--	--	--	--	7.17
T3	450137106595101	Sodium-adsorption ratio (unitless)	4	0.3	--	--	--	--	0.4
T3	450137106595101	Sodium, dissolved, in mg/L	4	10.5	--	--	--	--	17.2
T3	450137106595101	Alkalinity, in mg/L as $CaCO_3$	4	293	--	--	--	--	373
T3	450137106595101	Chloride, dissolved, in mg/L	4	1.58	--	--	--	--	1.97
T3	450137106595101	Fluoride, dissolved, in mg/L	4	0.49	--	--	--	--	0.66
T3	450137106595101	Silica, dissolved, in mg/L	4	13.8	--	--	--	--	18.8
T3	450137106595101	Sulfate, dissolved, in mg/L	4	30.4	--	--	--	--	53.2
T3	450137106595101	Dissolved solids, calculated, in mg/L	4	356	--	--	--	--	413
T3	450137106595101	Dissolved solids, tons/day	4	0.4	--	--	--	--	15.4
T4	445832106551401	Streamflow, in cubic feet per second	4	0.58	--	--	--	--	6.1
T4	445832106551401	Turbidity, nephelometric turbidity ratio units	4	18	--	--	--	--	58
T4	445832106551401	Dissolved oxygen, in mg/L	4	8	--	--	--	--	9.2
T4	445832106551401	Dissolved oxygen, percent saturation	3	86	--	--	--	--	115
T4	445832106551401	pH, in standard units	4	7.9	--	--	--	--	8.4
T4	445832106551401	Specific conductance, at 25 degrees Celsius, in µS/cm	4	863	--	--	--	--	1,690
T4	445832106551401	Temperature, water deg C	4	12	--	--	--	--	21.8
T4	445832106551401	Hardness, in mg/L as $CaCO_3$	4	420	--	--	--	--	880
T4	445832106551401	Calcium, dissolved, in mg/L	4	70.5	--	--	--	--	108
T4	445832106551401	Magnesium, dissolved, in mg/L	4	56.8	--	--	--	--	149
T4	445832106551401	Potassium, dissolved, in mg/L	4	6.06	--	--	--	--	14.9
T4	445832106551401	Sodium-adsorption ratio (unitless)	4	0.6	--	--	--	--	1.6
T4	445832106551401	Sodium, dissolved, in mg/L	4	29.1	--	--	--	--	112
T4	445832106551401	Alkalinity, in mg/L as $CaCO_3$	4	359	--	--	--	--	422
T4	445832106551401	Chloride, dissolved, in mg/L	4	2.25	--	--	--	--	4.05
T4	445832106551401	Fluoride, dissolved, in mg/L	4	0.59	--	--	--	--	0.76
T4	445832106551401	Silica, dissolved, in mg/L	4	12.6	--	--	--	--	16.9
T4	445832106551401	Sulfate, dissolved, in mg/L	4	139	--	--	--	--	623
T4	445832106551401	Dissolved solids, calculated, in mg/L	4	542	--	--	--	--	1,280
T4	445832106551401	Dissolved solids, tons/day	4	1	--	--	--	--	8.92
T5	445957106524701	Streamflow, in cubic feet per second	4	23	--	--	--	--	171
T5	445957106524701	Turbidity, nephelometric turbidity ratio units	4	5	--	--	--	--	48
T5	445957106524701	Dissolved oxygen, in mg/L	4	7.3	--	--	--	--	11.4
T5	445957106524701	Dissolved oxygen, percent saturation	4	91	--	--	--	--	139
T5	445957106524701	pH, in standard units	4	7.8	--	--	--	--	8.4
T5	445957106524701	Specific conductance, at 25 degrees Celsius, in µS/cm	4	523	--	--	--	--	695
T5	445957106524701	Temperature, water deg C	4	19	--	--	--	--	19
T5	445957106524701	Hardness, in mg/L as $CaCO_3$	4	230	--	--	--	--	290
T5	445957106524701	Calcium, dissolved, in mg/L	4	44.8	--	--	--	--	56.9
T5	445957106524701	Magnesium, dissolved, in mg/L	4	29.5	--	--	--	--	41.9
T5	445957106524701	Potassium, dissolved, in mg/L	4	2.77	--	--	--	--	3.98
T5	445957106524701	Sodium-adsorption ratio (unitless)	4	0.5	--	--	--	--	0.8
T5	445957106524701	Sodium, dissolved, in mg/L	4	19.3	--	--	--	--	33.3
T5	445957106524701	Alkalinity, in mg/L as $CaCO_3$	4	192	--	--	--	--	227
T5	445957106524701	Chloride, dissolved, in mg/L	4	3.35	--	--	--	--	6.73
T5	445957106524701	Fluoride, dissolved, in mg/L	4	0.23	--	--	--	--	0.29
T5	445957106524701	Silica, dissolved, in mg/L	4	1.64	--	--	--	--	8.54
T5	445957106524701	Sulfate, dissolved, in mg/L	4	83.3	--	--	--	--	145
T5	445957106524701	Dissolved solids, calculated, in mg/L	4	301	--	--	--	--	421
T5	445957106524701	Dissolved solids, tons/day	4	25.9	--	--	--	--	154
T6	06306100	Streamflow, in cubic feet per second	4	0.12	--	--	--	--	2.3
T6	06306100	Turbidity, nephelometric turbidity ratio units	4	2.1	--	--	--	--	15
T6	06306100	Dissolved oxygen, in mg/L	3	7.7	--	--	--	--	13.2
T6	06306100	Dissolved oxygen, percent saturation	3	85	--	--	--	--	173
T6	06306100	pH, in standard units	4	7.8	--	--	--	--	8.5
T6	06306100	Specific conductance, at 25 degrees Celsius, in µS/cm	4	1,290	--	--	--	--	1,570
T6	06306100	Temperature, water deg C	4	13.5	--	--	--	--	22
T6	06306100	Hardness, in mg/L as $CaCO_3$	4	670	--	--	--	--	760
T6	06306100	Calcium, dissolved, in mg/L	4	85.2	--	--	--	--	99.5

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
T6	06306100	Magnesium, dissolved, in mg/L	4	110	--	--	--	--	124
T6	06306100	Potassium, dissolved, in mg/L	4	7.88	--	--	--	--	9.54
T6	06306100	Sodium-adsorption ratio (unitless)	4	0.8	--	--	--	--	1.2
T6	06306100	Sodium, dissolved, in mg/L	4	50	--	--	--	--	77.8
T6	06306100	Alkalinity, in mg/L as $CaCO_3$	4	408	--	--	--	--	514
T6	06306100	Chloride, dissolved, in mg/L	4	2.68	--	--	--	--	3.49
T6	06306100	Fluoride, dissolved, in mg/L	4	0.43	--	--	--	--	0.56
T6	06306100	Silica, dissolved, in mg/L	4	11.2	--	--	--	--	21.1
T6	06306100	Sulfate, dissolved, in mg/L	4	327	--	--	--	--	409
T6	06306100	Dissolved solids, calculated, in mg/L	4	842	--	--	--	--	1,030
T6	06306100	Dissolved solids, tons/day	4	0.33	--	--	--	--	5.25
T7	450047106514201	Streamflow, in cubic feet per second	3	0.17	--	--	--	--	1.8
T7	450047106514201	Turbidity, nephelometric turbidity ratio units	3	1.2	--	--	--	--	14
T7	450047106514201	Dissolved oxygen, in mg/L	2	7.7	--	--	--	--	9.7
T7	450047106514201	Dissolved oxygen, percent saturation	2	96	--	--	--	--	107
T7	450047106514201	pH, in standard units	3	7.9	--	--	--	--	8.3
T7	450047106514201	Specific conductance, at 25 degrees Celsius, in µS/cm	3	1,750	--	--	--	--	5,940
T7	450047106514201	Temperature, water deg C	3	13	--	--	--	--	20
T7	450047106514201	Hardness, in mg/L as $CaCO_3$	3	830	--	--	--	--	2,300
T7	450047106514201	Calcium, dissolved, in mg/L	3	86.4	--	--	--	--	153
T7	450047106514201	Magnesium, dissolved, in mg/L	3	146	--	--	--	--	463
T7	450047106514201	Potassium, dissolved, in mg/L	3	9.23	--	--	--	--	20
T7	450047106514201	Sodium-adsorption ratio (unitless)	3	1.7	--	--	--	--	7.6
T7	450047106514201	Sodium, dissolved, in mg/L	3	113	--	--	--	--	835
T7	450047106514201	Alkalinity, in mg/L as $CaCO_3$	3	485	--	--	--	--	590
T7	450047106514201	Chloride, dissolved, in mg/L	3	3.64	--	--	--	--	12.7
T7	450047106514201	Fluoride, dissolved, in mg/L	3	0.52	--	--	--	--	0.73
T7	450047106514201	Silica, dissolved, in mg/L	3	4.21	--	--	--	--	9.29
T7	450047106514201	Sulfate, dissolved, in mg/L	3	587	--	--	--	--	3,330
T7	450047106514201	Dissolved solids, calculated, in mg/L	3	1,250	--	--	--	--	5,180
T7	450047106514201	Dissolved solids, tons/day	3	1.76	--	--	--	--	6.22
T8	06306250	Streamflow, in cubic feet per second	55	0.21	29.22	13	21	38	127
T8	06306250	Turbidity, nephelometric turbidity ratio units	3	10	--	--	--	--	120
T8	06306250	Dissolved oxygen, in mg/L	55	7.2	10.12	8	10.5	11.8	14.5
T8	06306250	Dissolved oxygen, percent saturation	53	82	103.2	93	99	109.5	165
T8	06306250	pH, in standard units	54	7.6	8.24	8.1	8.3	8.4	8.5
T8	06306250	Specific conductance, at 25 degrees Celsius, in µS/cm	55	768	1,404	1,150	1,400	1,600	2,500
T8	06306250	Temperature, water deg C	55	0	11.24	4.5	10.5	18.4	26.5
T8	06306250	Hardness, in mg/L as $CaCO_3$	51	330	672.7	540	680	800	1,200
T8	06306250	Calcium, dissolved, in mg/L	51	65.6	128.2	106	130	153	209
T8	06306250	Magnesium, dissolved, in mg/L	51	39.4	85.64	68.2	85.7	101	167
T8	06306250	Potassium, dissolved, in mg/L	51	3.8	7.807	6.23	7.37	8.67	17.8
T8	06306250	Sodium-adsorption ratio (unitless)	51	0.6	1.361	1.1	1.3	1.5	2.9
T8	06306250	Sodium, dissolved, in mg/L	51	29.7	82.50	58.9	74.5	103	216
T8	06306250	Alkalinity, in mg/L as $CaCO_3$	51	177	312.0	267	317	354	443
T8	06306250	Chloride, dissolved, in mg/L	51	2.08	4.773	3.85	4.71	5.57	7.97
T8	06306250	Fluoride, dissolved, in mg/L	51	0.2	0.305	0.27	0.31	0.34	0.41
T8	06306250	Silica, dissolved, in mg/L	51	6.6	12.08	10.7	12.3	14.1	16
T8	06306250	Sulfate, dissolved, in mg/L	51	213	506.2	383	491	592	1,160
T8	06306250	Dissolved solids, calculated, in mg/L	51	501	1,016	810	997	1,180	2,030
T8	06306250	Dissolved solids, tons/day	51	1.01	75.51	42.6	52.6	73.5	398
T8	06306250	Dissolved solids, residue on evaporation, in mg/L	39	526	1,072	853	1,080	1,250	2,160
T8	06306250	*Ammonia, dissolved, in mg/L as N	17	--	0.026	0.008	0.014	0.029	0.106
T8	06306250	*Nitrate plus nitrite, dissolved, in mg/L as N	17	--	0.268	0.063	0.24	0.431	0.729
T8	06306250	*Nitrite, dissolved, in mg/L as N	17	--	0.002	0.001	0.002	0.003	0.005
T8	06306250	*Orthophosphate, dissolved, in mg/L as P	17	--	0.013	0.005	0.012	0.021	0.028
T8	06306250	Phosphorus, total, in mg/L	17	0.013	0.127	0.027	0.058	0.236	0.34
T8	06306250	Total nitrogen, total, in mg/L	17	0.29	0.821	0.49	0.83	1	1.73
T8	06306250	*Aluminum, dissolved, in µg/L	17	--	1.543	1.054	1.36	1.85	3.1
T8	06306250	Aluminum, total, in µg/L	36	35	1,084	125.25	304.5	1,550	9,480

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
T8	06306250	Arsenic, dissolved, in µg/L	36	0.31	0.72	0.543	0.75	0.9	1.1
T8	06306250	*Arsenic, total, in µg/L	34	--	1.629	0.98	1.4	2	6.1
T8	06306250	Barium, dissolved, in µg/L	17	27	39.47	35	40	44	54
T8	06306250	Barium, total, in µg/L	36	37.2	58.84	45	50.35	63.375	210
T8	06306250	**Beryllium, dissolved, in µg/L	17	--	--	--	--	--	0.12
T8	06306250	*Beryllium, total, in µg/L	36	--	0.1	0.02	0.046	0.13	0.84
T8	06306250	Boron, dissolved, in µg/L	14	70	107.7	86.25	108.5	127.75	166
T8	06306250	**Cadmium, dissolved, in µg/L	15	--	--	--	--	--	<0.04
T8	06306250	*Cadmium, total, in µg/L	15	--	0.056	0.02	0.033	0.08	0.18
T8	06306250	Chromium, dissolved, in µg/L	1	--	--	--	--	--	0.22
T8	06306250	*Chromium, total, in µg/L	15	--	3.270	2	2.7	4	9
T8	06306250	Copper, dissolved, in µg/L	15	0.57	2.757	1.9	2.7	3.4	5.1
T8	06306250	Copper, total, in µg/L	15	2.5	6.293	4	6	8.7	14.6
T8	06306250	*Iron, dissolved, in µg/L	36	--	14.26	6	7.5	11.75	100
T8	06306250	Iron, total, in µg/L	17	136	2,553	339	800	4,365	8,170
T8	06306250	*Lead, dissolved, in µg/L	15	--	0.093	0.048	0.068	0.093	0.33
T8	06306250	Lead, total, in µg/L	15	0.08	1.586	0.14	0.39	2.72	6.54
T8	06306250	Lithium, dissolved, in µg/L	14	17.8	32.04	23.125	30.55	40.525	62.5
T8	06306250	Manganese, dissolved, in µg/L	36	9.2	47.28	22.5	35.2	65.75	137
T8	06306250	Manganese, total, in µg/L	17	58.3	241.2	88.05	168	421	537
T8	06306250	Mercury, total, ng/L	5	0.92	--	--	--	--	9.76
T8	06306250	**Mercury, total, µg/L	3	--	--	--	--	--	<0.01
T8	06306250	Nickel, dissolved, in µg/L	15	1	2.960	1.46	3.17	3.76	5.56
T8	06306250	Nickel, total, in µg/L	15	2.7	5.369	4	4.8	6.76	10.9
T8	06306250	Selenium, dissolved, in µg/L	17	0.23	0.874	0.63	0.78	1.15	1.7
T8	06306250	Selenium, total, in µg/L	36	0.12	0.92	0.632	0.85	1.2	2
T8	06306250	Strontium, dissolved, in µg/L	14	920	1,658	1,296	1,770	1,943	2,520
T8	06306250	*Zinc, dissolved, in µg/L	15	--	3.065	1.2	2	2.5	15.9
T8	06306250	Zinc, total, in µg/L	15	2	9.140	3	8	12	27
T8	06306250	Suspended sediment, <0.0625 mm, percent	34	43	82.03	76.75	87	92	97
T8	06306250	Suspended sediment, in mg/L	34	21	122.4	60	84	174	431
T8	06306250	Suspended sediment, tons/day	34	0.02	12.60	1.7	4.1	14.5	119
T9	06306300	Streamflow, in cubic feet per second	67	12	530.9	137	181	347	5,430
T9	06306300	Turbidity, nephelometric turbidity ratio units	2	4.4	--	--	--	--	24
T9	06306300	Dissolved oxygen, in mg/L	63	5.6	10.21	8.6	10.3	11.6	15.9
T9	06306300	Dissolved oxygen, percent saturation	63	76	107.9	94	105	121	164
T9	06306300	pH, in standard units	65	7.7	8.35	8.2	8.4	8.5	8.7
T9	06306300	Specific conductance, at 25 degrees Celsius, in µS/cm	67	186	594.4	455	634	730	1,060
T9	06306300	Temperature, water deg C	66	0	13.09	6.5	13.25	21.5	26.5
T9	06306300	Hardness, in mg/L as $CaCO_3$	64	83	261.1	210	280	310	400
T9	06306300	Calcium, dissolved, in mg/L	64	20.1	53.02	44.475	55.5	63.05	78.9
T9	06306300	Magnesium, dissolved, in mg/L	64	7.83	31.23	23.025	34.2	38.475	50
T9	06306300	Potassium, dissolved, in mg/L	64	1	2.750	1.995	2.805	3.1	7.34
T9	06306300	Sodium-adsorption ratio (unitless)	64	0.2	0.719	0.5	0.7	0.875	1.5
T9	06306300	Sodium, dissolved, in mg/L	64	4.97	27.72	17.825	28.25	35.45	65.2
T9	06306300	Acid neutralizing capacity, in mg/L as $CaCO_3$	42	81	200.2	171.25	212	235.25	273
T9	06306300	Alkalinity, in mg/L as $CaCO_3$	64	73	193.8	161.25	206	235.75	276
T9	06306300	Chloride, dissolved, in mg/L	64	0.83	3.923	2.67	3.83	4.832	7.93
T9	06306300	Fluoride, dissolved, in mg/L	63	0.08	0.273	0.2	0.29	0.32	0.61
T9	06306300	Silica, dissolved, in mg/L	63	2.37	5.852	3.97	5.77	7.63	10.3
T9	06306300	Sulfate, dissolved, in mg/L	64	20.5	117.4	79.175	124.5	149.25	237
T9	06306300	Dissolved solids, calculated, in mg/L	60	108	364.3	270.75	385.5	451.5	571
T9	06306300	Dissolved solids, tons/day	62	26.2	357.0	160.5	188.5	333.5	3,580
T9	06306300	Dissolved solids, residue on evaporation, in mg/L	43	118	381.1	281	411	466	561
T9	06306300	*Ammonia, dissolved, in mg/L as N	20	--	0.02	0.006	0.012	0.025	0.083
T9	06306300	*Nitrate plus nitrite, dissolved, in mg/L as N	20	--	0.071	0.009	0.03	0.07	0.434
T9	06306300	*Nitrite, dissolved, in mg/L as N	20	--	0.002	0.001	0.001	0.003	0.009
T9	06306300	*Orthophosphate, dissolved, in mg/L as P	20	--	0.011	0.003	0.007	0.013	0.057
T9	06306300	Phosphorus, total, in mg/L	20	0.019	0.084	0.029	0.041	0.08	0.53
T9	06306300	Total nitrogen, total, in mg/L	20	0.22	0.483	0.282	0.355	0.425	1.99

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
T9	06306300	*Aluminum, dissolved, in µg/L	20	--	4.096	1.1	1.7	4.175	25.1
T9	06306300	Aluminum, total, in µg/L	29	18	536.3	70.5	140	363.5	5,810
T9	06306300	Arsenic, dissolved, in µg/L	28	0.3	0.523	0.41	0.49	0.595	0.91
T9	06306300	*Arsenic, total, in µg/L	29	--	0.88	0.59	0.75	0.915	3
T9	06306300	Barium, dissolved, in µg/L	20	24	47.15	41	48.5	55.5	67
T9	06306300	Barium, total, in µg/L	29	35	59.01	47.5	55.3	60.3	155
T9	06306300	**Beryllium, dissolved, in µg/L	20	--	--	--	--	--	<0.06
T9	06306300	*Beryllium, total, in µg/L	29	--	0.064	0.005	0.014	0.05	0.75
T9	06306300	Boron, dissolved, in µg/L	15	35	64.27	54	62	69	99
T9	06306300	Boron, total, in µg/L	3	61	--	--	--	--	79
T9	06306300	**Cadmium, dissolved, in µg/L	20	--	--	--	--	--	0.05
T9	06306300	*Cadmium, total, in µg/L	24	--	0.034	0.006	0.015	0.022	0.35
T9	06306300	Chromium, dissolved, in µg/L	6	0.06	0.097	0.068	0.085	0.12	0.18
T9	06306300	*Chromium, total, in µg/L	24	--	1.377	0.407	0.965	2	7
T9	06306300	Copper, dissolved, in µg/L	20	0.51	1.456	0.993	1.35	1.675	2.8
T9	06306300	*Copper, total, in µg/L	24	--	2.572	1.325	1.75	2.2	15.2
T9	06306300	Iron, dissolved, in µg/L	29	6	25.14	12.5	19	33	80
T9	06306300	Iron, total, in µg/L	20	66	903.1	178	367	810	7,530
T9	06306300	*Lead, dissolved, in µg/L	20	--	0.109	0.064	0.078	0.102	0.37
T9	06306300	Lead, total, in µg/L	24	0.06	1.090	0.132	0.26	0.73	10.8
T9	06306300	Lithium, dissolved, in µg/L	14	10	19.28	15.475	19.1	22.2	36.6
T9	06306300	Manganese, dissolved, in µg/L	30	0.5	15.72	7.15	11.15	24.65	52.6
T9	06306300	Manganese, total, in µg/L	20	13.7	61.66	28.7	50.25	59.675	290
T9	06306300	Mercury, total, ng/L	5	0.59	--	--	--	--	2.35
T9	06306300	**Mercury, total, µg/L	4	--	--	--	--	--	0.01
T9	06306300	Nickel, dissolved, in µg/L	21	0.22	1.493	0.67	1.5	2.09	3.06
T9	06306300	Nickel, total, in µg/L	24	0.63	2.400	1.2	1.82	2.395	12.1
T9	06306300	Selenium, dissolved, in µg/L	20	0.15	0.384	0.222	0.3	0.5	1
T9	06306300	Selenium, total, in µg/L	29	0.09	0.388	0.22	0.31	0.395	1.6
T9	06306300	Strontium, dissolved, in µg/L	15	219	470.2	443	508	532	567
T9	06306300	Zinc, dissolved, in µg/L	18	0.81	1.928	1.275	1.7	2.3	4.8
T9	06306300	*Zinc, total, in µg/L	24	--	5.739	2	2.2	4.875	44
T9	06306300	Suspended sediment, <0.0625 mm, percent	56	31	79.30	69.5	85	92	99
T9	06306300	Suspended sediment, in mg/L	56	11	57.57	20.5	35.5	52.75	697
T9	06306300	Suspended sediment, tons/day	56	1.1	263.5	6.95	15.5	31.75	10,200
T10	451607106372801	Streamflow, in cubic feet per second	4	153	--	--	--	--	408
T10	451607106372801	Turbidity, nephelometric turbidity ratio units	4	0.6	--	--	--	--	13
T10	451607106372801	Dissolved oxygen, in mg/L	4	6.7	--	--	--	--	9
T10	451607106372801	Dissolved oxygen, percent saturation	4	81	--	--	--	--	101
T10	451607106372801	pH, in standard units	4	8	--	--	--	--	8.7
T10	451607106372801	Specific conductance, at 25 degrees Celsius, in µS/cm	4	363	--	--	--	--	540
T10	451607106372801	Temperature, water deg C	4	15	--	--	--	--	20
T10	451607106372801	Hardness, in mg/L as $CaCO_3$	4	160	--	--	--	--	220
T10	451607106372801	Calcium, dissolved, in mg/L	4	36.2	--	--	--	--	48.6
T10	451607106372801	Magnesium, dissolved, in mg/L	4	17	--	--	--	--	28.8
T10	451607106372801	Potassium, dissolved, in mg/L	4	1.92	--	--	--	--	3.62
T10	451607106372801	Sodium-adsorption ratio (unitless)	4	0.5	--	--	--	--	1.1
T10	451607106372801	Sodium, dissolved, in mg/L	4	14.7	--	--	--	--	36.5
T10	451607106372801	Alkalinity, in mg/L as $CaCO_3$	4	130	--	--	--	--	174
T10	451607106372801	Chloride, dissolved, in mg/L	4	1.46	--	--	--	--	3.4
T10	451607106372801	Fluoride, dissolved, in mg/L	4	0.18	--	--	--	--	0.3
T10	451607106372801	Silica, dissolved, in mg/L	4	0.67	--	--	--	--	5.47
T10	451607106372801	Sulfate, dissolved, in mg/L	4	54.4	--	--	--	--	111
T10	451607106372801	Dissolved solids, calculated, in mg/L	4	209	--	--	--	--	322
T10	451607106372801	Dissolved solids, tons/day	4	132	--	--	--	--	276
T11	06307570	Streamflow, in cubic feet per second	3	0	--	--	--	--	0.12
T11	06307570	Turbidity, nephelometric turbidity ratio units	3	3.9	--	--	--	--	14
T11	06307570	Dissolved oxygen, in mg/L	1	--	--	--	--	--	10
T11	06307570	Dissolved oxygen, percent saturation	1	--	--	--	--	--	123
T11	06307570	pH, in standard units	3	7.9	--	--	--	--	9.3

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
T11	06307570	Specific conductance, at 25 degrees Celsius, in µS/cm	3	4,010	--	--	--	--	5,000
T11	06307570	Temperature, water deg C	3	18.5	--	--	--	--	24.5
T11	06307570	Hardness, in mg/L as $CaCO_3$	3	950	--	--	--	--	1,400
T11	06307570	Calcium, dissolved, in mg/L	3	18.9	--	--	--	--	140
T11	06307570	Magnesium, dissolved, in mg/L	3	210	--	--	--	--	249
T11	06307570	Potassium, dissolved, in mg/L	3	13.7	--	--	--	--	18.3
T11	06307570	Sodium-adsorption ratio (unitless)	3	8.6	--	--	--	--	10
T11	06307570	Sodium, dissolved, in mg/L	3	695	--	--	--	--	732
T11	06307570	Alkalinity, in mg/L as $CaCO_3$	3	335	--	--	--	--	492
T11	06307570	Chloride, dissolved, in mg/L	3	15.8	--	--	--	--	18.3
T11	06307570	Fluoride, dissolved, in mg/L	3	0.74	--	--	--	--	0.84
T11	06307570	Silica, dissolved, in mg/L	3	1.22	--	--	--	--	4.39
T11	06307570	Sulfate, dissolved, in mg/L	3	2,050	--	--	--	--	2,450
T11	06307570	Dissolved solids, calculated, in mg/L	3	3,300	--	--	--	--	3,900
T11	06307570	Dissolved solids, tons/day	2	0.32	--	--	--	--	1.07
T12	451340106295501	Streamflow, in cubic feet per second	3	0.04	--	--	--	--	0.49
T12	451340106295501	Turbidity, nephelometric turbidity ratio units	2	1.4	--	--	--	--	3.1
T12	451340106295501	Dissolved oxygen, in mg/L	1	--	--	--	--	--	14.8
T12	451340106295501	Dissolved oxygen, percent saturation	1	--	--	--	--	--	206
T12	451340106295501	pH, in standard units	3	8.1	--	--	--	--	9.3
T12	451340106295501	Specific conductance, at 25 degrees Celsius, in µS/cm	3	3,650	--	--	--	--	3,970
T12	451340106295501	Temperature, water deg C	3	24.5	--	--	--	--	27.5
T12	451340106295501	Hardness, in mg/L as $CaCO_3$	3	930	--	--	--	--	1,000
T12	451340106295501	Calcium, dissolved, in mg/L	3	40	--	--	--	--	98.5
T12	451340106295501	Magnesium, dissolved, in mg/L	3	166	--	--	--	--	213
T12	451340106295501	Potassium, dissolved, in mg/L	3	16.5	--	--	--	--	20
T12	451340106295501	Sodium-adsorption ratio (unitless)	3	7.4	--	--	--	--	9.2
T12	451340106295501	Sodium, dissolved, in mg/L	3	546	--	--	--	--	662
T12	451340106295501	Alkalinity, in mg/L as $CaCO_3$	3	323	--	--	--	--	415
T12	451340106295501	Chloride, dissolved, in mg/L	3	17.9	--	--	--	--	20
T12	451340106295501	Fluoride, dissolved, in mg/L	3	0.81	--	--	--	--	0.85
T12	451340106295501	Silica, dissolved, in mg/L	3	0.41	--	--	--	--	2.54
T12	451340106295501	Sulfate, dissolved, in mg/L	3	1,710	--	--	--	--	1,920
T12	451340106295501	Dissolved solids, calculated, in mg/L	3	2,810	--	--	--	--	3,070
T12	451340106295501	Dissolved solids, tons/day	3	0.32	--	--	--	--	3.72
T13	06307600	Streamflow, in cubic feet per second	37	0	1.978	0.1	0.25	0.81	43
T13	06307600	Turbidity, nephelometric turbidity ratio units	2	4	--	--	--	--	140
T13	06307600	Dissolved oxygen, in mg/L	37	1.5	8.289	6.65	7.9	10	13.6
T13	06307600	Dissolved oxygen, percent saturation	36	37	90.25	68.25	84.5	105.75	184
T13	06307600	pH, in standard units	36	7.6	8.10	8	8.1	8.2	8.7
T13	06307600	Specific conductance, at 25 degrees Celsius, in µS/cm	37	921	2,493	2,080	2,300	2,980	3,890
T13	06307600	Temperature, water deg C	37	0	11.91	4.25	12	18.25	28.6
T13	06307600	Hardness, in mg/L as $CaCO_3$	35	240	771.7	660	770	930	1,000
T13	06307600	Calcium, dissolved, in mg/L	35	39.9	102.4	89.2	103	112	195
T13	06307600	Magnesium, dissolved, in mg/L	35	34	125.9	110	124	150	176
T13	06307600	Potassium, dissolved, in mg/L	35	9.47	15.32	13.2	15.3	17.1	21.6
T13	06307600	Sodium-adsorption ratio (unitless)	35	2.5	4.843	3.9	4.5	5.9	7.2
T13	06307600	Sodium, dissolved, in mg/L	35	87.2	313.7	238	273	402	530
T13	06307600	Alkalinity, in mg/L as $CaCO_3$	35	146	566.4	535	578	607	751
T13	06307600	Chloride, dissolved, in mg/L	35	4.38	11.86	9.07	11.5	14.7	18.6
T13	06307600	Fluoride, dissolved, in mg/L	35	0.28	1.261	1.1	1.29	1.46	1.89
T13	06307600	Silica, dissolved, in mg/L	35	6.61	13.87	9.33	13.3	16.9	27
T13	06307600	Sulfate, dissolved, in mg/L	35	317	868.1	584	716	1,170	1,550
T13	06307600	Dissolved solids, calculated, in mg/L	35	591	1,792	1,440	1,630	2,210	2,730
T13	06307600	Dissolved solids, tons/day	35	0.03	6.525	0.45	1.08	5.53	68.6
T13	06307600	*Ammonia, dissolved, in mg/L as N	15	--	0.018	0.011	0.015	0.028	0.045
T13	06307600	*Nitrate plus nitrite, dissolved, in mg/L as N	15	--	0.026	0.009	0.014	0.026	0.141
T13	06307600	*Nitrite, dissolved, in mg/L as N	15	--	0.002	0.001	0.001	0.002	0.005
T13	06307600	*Orthophosphate, dissolved, in mg/L as P	15	--	0.009	0.004	0.009	0.013	0.023
T13	06307600	Phosphorus, total, in mg/L	15	0.02	0.037	0.024	0.037	0.046	0.059

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
T13	06307600	Total nitrogen, total, in mg/L	15	0.31	0.489	0.39	0.49	0.57	0.63
T13	06307600	*Aluminum, dissolved, in µg/L	14	--	1.660	0.875	1.107	1.85	6.5
T13	06307600	Aluminum, total, in µg/L	14	19	73.64	40.75	71	108.25	126
T13	06307600	Arsenic, dissolved, in µg/L	14	0.53	1.074	0.75	0.985	1.35	1.9
T13	06307600	*Arsenic, total, in µg/L	14	--	1.279	0.812	1.1	1.492	2.6
T13	06307600	Barium, dissolved, in µg/L	14	18	45.07	41.75	46	49	71
T13	06307600	Barium, total, in µg/L	14	23.2	46.66	42.2	48	55.125	65.3
T13	06307600	**Beryllium, dissolved, in µg/L	14	--	--	--	--	--	<0.12
T13	06307600	**Beryllium, total, in µg/L	14	--	--	--	--	--	<0.12
T13	06307600	Boron, dissolved, in µg/L	9	197	251.4	235.5	257	265.5	294
T13	06307600	**Cadmium, dissolved, in µg/L	12	--	--	--	--	--	<0.08
T13	06307600	*Cadmium, total, in µg/L	12	--	0.04	0.015	0.023	0.039	0.2
T13	06307600	**Chromium, dissolved, in µg/L	3	--	--	--	--	--	0.42
T13	06307600	*Chromium, total, in µg/L	12	--	2.485	0.678	2	3.75	6
T13	06307600	*Copper, dissolved, in µg/L	12	--	3.012	2.175	2.7	3.125	9.5
T13	06307600	*Copper, total, in µg/L	12	--	4.672	1.62	3.5	8.15	11.8
T13	06307600	Iron, dissolved, in µg/L	14	18	38.21	25	30.5	45.25	107
T13	06307600	Iron, total, in µg/L	14	295	484.6	331.75	430.5	626.5	772
T13	06307600	**Lead, dissolved, in µg/L	12	--	--	--	--	--	<0.24
T13	06307600	Lead, total, in µg/L	12	0.08	0.148	0.093	0.13	0.188	0.28
T13	06307600	Lithium, dissolved, in µg/L	9	61.4	95.70	86.45	100	104.5	119
T13	06307600	Manganese, dissolved, in µg/L	14	45.3	117.9	75.575	104	140.5	228
T13	06307600	Manganese, total, in µg/L	14	57.1	123.8	79.375	113.5	143.5	234
T13	06307600	Mercury, total, ng/L	4	0.65	--	--	--	--	1.06
T13	06307600	**Mercury, total, µg/L	3	--	--	--	--	--	<0.01
T13	06307600	Nickel, dissolved, in µg/L	12	1.8	3.303	2.15	3.345	4.265	5.03
T13	06307600	Nickel, total, in µg/L	12	1.6	4.003	2.727	3.91	4.935	8.57
T13	06307600	Selenium, dissolved, in µg/L	14	0.15	0.531	0.215	0.515	0.725	1.2
T13	06307600	Selenium, total, in µg/L	14	0.14	0.551	0.22	0.36	0.925	1.2
T13	06307600	Strontium, dissolved, in µg/L	9	1,240	1,404	1,340	1,430	1,475	1,540
T13	06307600	*Zinc, dissolved, in µg/L	12	--	3.015	1.925	2.24	3.525	6.5
T13	06307600	*Zinc, total, in µg/L	12	--	3.085	2	2.858	4	5
T13	06307600	Suspended sediment, <0.0625 mm, percent	30	8	62.63	50.75	63	79	98
T13	06307600	Suspended sediment, in mg/L	30	17	72.20	42	61.5	98.5	171
T13	06307600	Suspended sediment, tons/day	30	0	0.632	0.018	0.025	0.055	17
T14	06307616	Streamflow, in cubic feet per second	67	63	482.7	96	227	457	3,230
T14	06307616	Turbidity, nephelometric turbidity ratio units	1	--	--	--	--	--	14
T14	06307616	Dissolved oxygen, in mg/L	63	6.9	9.705	8.2	9.2	11	14.5
T14	06307616	Dissolved oxygen, percent saturation	61	65	102.4	95.5	102	111	137
T14	06307616	pH, in standard units	64	7.9	8.40	8.3	8.4	8.5	8.7
T14	06307616	Specific conductance, at 25 degrees Celsius, in µS/cm	67	263	583.5	436	623	715	807
T14	06307616	Temperature, water deg C	67	0	13.94	8	14	20.5	27
T14	06307616	Hardness, in mg/L as $CaCO_3$	63	110	244.0	180	260	300	370
T14	06307616	Calcium, dissolved, in mg/L	63	26.6	47.78	35.9	49.7	56.4	69.6
T14	06307616	Magnesium, dissolved, in mg/L	63	11	30.26	19.9	33.2	38	47
T14	06307616	Potassium, dissolved, in mg/L	63	1.42	3.202	2.54	3.38	3.69	4.67
T14	06307616	Sodium-adsorption ratio (unitless)	63	0.4	0.924	0.6	1	1.2	1.4
T14	06307616	Sodium, dissolved, in mg/L	63	9.04	33.99	19.8	39.4	44.8	54.5
T14	06307616	Alkalinity, in mg/L as $CaCO_3$	63	99	190.9	144	198	226	282
T14	06307616	Chloride, dissolved, in mg/L	63	1.15	3.685	2.23	4.04	4.83	7.59
T14	06307616	Fluoride, dissolved, in mg/L	63	0.14	0.295	0.21	0.33	0.36	0.43
T14	06307616	Silica, dissolved, in mg/L	63	0.76	3.558	1.81	3.1	5.46	7.82
T14	06307616	Sulfate, dissolved, in mg/L	63	32	121.5	73.5	142	157	184
T14	06307616	Dissolved solids, calculated, in mg/L	60	162	359.0	257.5	387	444	532
T14	06307616	Dissolved solids, tons/day	60	65.2	362.7	122.25	213.5	321.75	2,270
T14	06307616	*Ammonia, dissolved, in mg/L as N	20	--	0.013	0.005	0.007	0.012	0.095
T14	06307616	*Nitrate plus nitrite, dissolved, in mg/L as N	20	--	0.023	0.007	0.009	0.022	0.16
T14	06307616	*Nitrite, dissolved, in mg/L as N	20	--	0.002	0.001	0.001	0.002	0.007
T14	06307616	*Orthophosphate, dissolved, in mg/L as P	20	--	0.005	0.003	0.004	0.006	0.013
T14	06307616	Phosphorus, total, in mg/L	20	0.007	0.036	0.009	0.018	0.053	0.13

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
T14	06307616	Total nitrogen, total, in mg/L	20	0.22	0.386	0.262	0.315	0.47	0.94
T14	06307616	*Aluminum, dissolved, in µg/L	20	--	2.511	1.106	2.15	3.075	7
T14	06307616	Aluminum, total, in µg/L	20	8	165.9	20.25	43	166.25	990
T14	06307616	Arsenic, dissolved, in µg/L	20	0.6	0.9	0.738	0.83	0.952	1.6
T14	06307616	*Arsenic, total, in µg/L	20	--	1.228	0.978	1.198	1.475	1.7
T14	06307616	Barium, dissolved, in µg/L	20	30	51.70	43.5	54.5	59.75	63
T14	06307616	Barium, total, in µg/L	20	40	56.59	50.325	56.95	62.7	72.9
T14	06307616	**Beryllium, dissolved, in µg/L	20	--	--	--	--	--	<0.06
T14	06307616	*Beryllium, total, in µg/L	20	--	0.037	0.024	0.034	0.045	0.09
T14	06307616	Boron, dissolved, in µg/L	14	43	69.29	60	69.5	82	88
T14	06307616	**Cadmium, dissolved, in µg/L	18	--	--	--	--	--	0.05
T14	06307616	*Cadmium, total, in µg/L	18	--	0.017	0.004	0.009	0.02	0.09
T14	06307616	Chromium, dissolved, in µg/L	4	0.07	--	--	--	--	0.19
T14	06307616	*Chromium, total, in µg/L	18	--	1.280	0.729	1	1.9	3
T14	06307616	Copper, dissolved, in µg/L	18	0.63	1.969	0.972	1.4	2.65	5.8
T14	06307616	*Copper, total, in µg/L	18	--	2.405	1.375	1.75	3.05	7.2
T14	06307616	Iron, dissolved, in µg/L	20	4	16.75	11.25	15	22.75	33
T14	06307616	Iron, total, in µg/L	20	39	369.3	71.5	124	421.5	1,960
T14	06307616	*Lead, dissolved, in µg/L	18	--	0.09	0.05	0.067	0.113	0.24
T14	06307616	*Lead, total, in µg/L	18	--	0.323	0.044	0.065	0.368	1.67
T14	06307616	Lithium, dissolved, in µg/L	14	10.9	22.76	19.85	22.65	26.1	29.5
T14	06307616	Manganese, dissolved, in µg/L	20	3.3	10.42	5.8	7.65	17.15	25.2
T14	06307616	Manganese, total, in µg/L	20	7.5	43.42	12.225	32.7	60.45	157
T14	06307616	Mercury, total, ng/L	5	0.18	--	--	--	--	1.25
T14	06307616	**Mercury, total, µg/L	3	--	--	--	--	--	<0.01
T14	06307616	Nickel, dissolved, in µg/L	17	0.79	1.611	0.935	1.7	2.05	3.33
T14	06307616	Nickel, total, in µg/L	18	0.84	2.143	1.597	2.06	2.592	3.9
T14	06307616	Selenium, dissolved, in µg/L	20	0.17	0.346	0.28	0.345	0.393	0.6
T14	06307616	*Selenium, total, in µg/L	20	--	0.381	0.262	0.33	0.398	0.9
T14	06307616	Strontium, dissolved, in µg/L	14	300	504.2	439.75	498.5	600.25	611
T14	06307616	Zinc, dissolved, in µg/L	15	0.5	2.223	1	1.4	3.8	5.8
T14	06307616	*Zinc, total, in µg/L	18	--	2.145	1	1.715	2	7.1
T14	06307616	Suspended sediment, <0.0625 mm, percent	56	28	77.71	73.5	81	87	92
T14	06307616	Suspended sediment, in mg/L	56	2	28.25	12.25	22	37.5	132
T14	06307616	Suspended sediment, tons/day	56	0.34	66.96	3.5	9.9	28.75	1,150
T15	451732106085001	Streamflow, in cubic feet per second	3	0.1	--	--	--	--	1.4
T15	451732106085001	Turbidity, nephelometric turbidity ratio units	3	2.4	--	--	--	--	5.5
T15	451732106085001	Dissolved oxygen, in mg/L	3	7.8	--	--	--	--	18.4
T15	451732106085001	Dissolved oxygen, percent saturation	2	96	--	--	--	--	177
T15	451732106085001	pH, in standard units	3	7.7	--	--	--	--	8.6
T15	451732106085001	Specific conductance, at 25 degrees Celsius, in µS/cm	3	3,470	--	--	--	--	4,000
T15	451732106085001	Temperature, water deg C	3	19	--	--	--	--	26.5
T15	451732106085001	Hardness, in mg/L as $CaCO_3$	3	1,200	--	--	--	--	1,500
T15	451732106085001	Calcium, dissolved, in mg/L	3	91.2	--	--	--	--	159
T15	451732106085001	Magnesium, dissolved, in mg/L	3	233	--	--	--	--	257
T15	451732106085001	Potassium, dissolved, in mg/L	3	18.3	--	--	--	--	20.3
T15	451732106085001	Sodium-adsorption ratio (unitless)	3	5.2	--	--	--	--	5.9
T15	451732106085001	Sodium, dissolved, in mg/L	3	418	--	--	--	--	516
T15	451732106085001	Alkalinity, in mg/L as $CaCO_3$	3	464	--	--	--	--	583
T15	451732106085001	Chloride, dissolved, in mg/L	3	9.39	--	--	--	--	14
T15	451732106085001	Fluoride, dissolved, in mg/L	3	0.64	--	--	--	--	0.77
T15	451732106085001	Silica, dissolved, in mg/L	3	12.9	--	--	--	--	14.3
T15	451732106085001	Sulfate, dissolved, in mg/L	3	1,390	--	--	--	--	1,950
T15	451732106085001	Dissolved solids, calculated, in mg/L	3	2,480	--	--	--	--	3,270
T15	451732106085001	Dissolved solids, tons/day	3	0.75	--	--	--	--	12.4
T16	452642106091201	Streamflow, in cubic feet per second	2	0.26	--	--	--	--	3.8
T16	452642106091201	Turbidity, nephelometric turbidity ratio units	2	2.5	--	--	--	--	4.4
T16	452642106091201	Dissolved oxygen, in mg/L	2	6.4	--	--	--	--	7.5
T16	452642106091201	Dissolved oxygen, percent saturation	1	--	--	--	--	--	83
T16	452642106091201	pH, in standard units	2	8	--	--	--	--	8.8

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
T16	452642106091201	Specific conductance, at 25 degrees Celsius, in µS/cm	2	3,200	--	--	--	--	3,600
T16	452642106091201	Temperature, water deg C	2	19.5	--	--	--	--	21.5
T16	452642106091201	Hardness, in mg/L as $CaCO_3$	2	1,100	--	--	--	--	1,100
T16	452642106091201	Calcium, dissolved, in mg/L	2	52	--	--	--	--	129
T16	452642106091201	Magnesium, dissolved, in mg/L	2	196	--	--	--	--	246
T16	452642106091201	Potassium, dissolved, in mg/L	2	19.4	--	--	--	--	19.4
T16	452642106091201	Sodium-adsorption ratio (unitless)	2	5.1	--	--	--	--	6.1
T16	452642106091201	Sodium, dissolved, in mg/L	2	391	--	--	--	--	475
T16	452642106091201	Alkalinity, in mg/L as $CaCO_3$	2	438	--	--	--	--	502
T16	452642106091201	Chloride, dissolved, in mg/L	2	10.7	--	--	--	--	12.9
T16	452642106091201	Fluoride, dissolved, in mg/L	2	0.65	--	--	--	--	0.66
T16	452642106091201	Silica, dissolved, in mg/L	2	1.16	--	--	--	--	7.43
T16	452642106091201	Sulfate, dissolved, in mg/L	2	1,440	--	--	--	--	1,730
T16	452642106091201	Dissolved solids, calculated, in mg/L	2	2,490	--	--	--	--	2,800
T16	452642106091201	Dissolved solids, tons/day	2	1.97	--	--	--	--	25.6
T17	06307740	Streamflow, in cubic feet per second	45	0.15	3.247	1	1.7	3.05	33
T17	06307740	Turbidity, nephelometric turbidity ratio units	3	21	--	--	--	--	79
T17	06307740	Dissolved oxygen, in mg/L	42	5	9.343	7.35	8.3	10.075	22.2
T17	06307740	Dissolved oxygen, percent saturation	40	64	96.40	81.25	95.5	106	171
T17	06307740	pH, in standard units	43	7.9	8.39	8.3	8.4	8.5	8.9
T17	06307740	Specific conductance, at 25 degrees Celsius, in µS/cm	45	1,730	2,841	2,510	2,880	3,115	3,700
T17	06307740	Temperature, water deg C	45	0	14.16	7.5	14	22	29
T17	06307740	Hardness, in mg/L as $CaCO_3$	43	480	822.1	720	820	910	1,100
T17	06307740	Calcium, dissolved, in mg/L	43	50.1	79.69	67.3	79	87.5	122
T17	06307740	Magnesium, dissolved, in mg/L	43	84	151.1	132	151	165	206
T17	06307740	Potassium, dissolved, in mg/L	43	11.7	18.88	17.4	18.6	20.4	25.8
T17	06307740	Sodium-adsorption ratio (unitless)	43	4.6	6.005	5.5	6.1	6.4	6.9
T17	06307740	Sodium, dissolved, in mg/L	43	233	396.4	334	406	443	520
T17	06307740	Alkalinity, in mg/L as $CaCO_3$	43	350	549.8	508	554	592	807
T17	06307740	Chloride, dissolved, in mg/L	43	7.12	11.79	10.1	11.7	13.1	16.1
T17	06307740	Fluoride, dissolved, in mg/L	43	0.58	0.9	0.83	0.91	0.97	1.2
T17	06307740	Silica, dissolved, in mg/L	43	5.8	10.77	8.02	9.9	14	22.3
T17	06307740	Sulfate, dissolved, in mg/L	43	624	1,102	903	1,070	1,290	1,600
T17	06307740	Dissolved solids, calculated, in mg/L	43	1,230	2,102	1,820	2,110	2,300	2,850
T17	06307740	Dissolved solids, tons/day	43	0.68	19.19	5.26	9.96	17.1	162
T17	06307740	*Ammonia, dissolved, in mg/L as N	20	--	0.025	0.006	0.011	0.031	0.127
T17	06307740	*Nitrate plus nitrite, dissolved, in mg/L as N	20	--	0.062	0.009	0.016	0.045	0.423
T17	06307740	*Nitrite, dissolved, in mg/L as N	20	--	0.003	0.001	0.001	0.003	0.011
T17	06307740	*Orthophosphate, dissolved, in mg/L as P	20	--	0.006	0.004	0.005	0.007	0.013
T17	06307740	Phosphorus, total, in mg/L	20	0.016	0.063	0.031	0.054	0.093	0.185
T17	06307740	Total nitrogen, total, in mg/L	20	0.31	0.737	0.562	0.755	0.91	1.29
T17	06307740	*Aluminum, dissolved, in µg/L	19	--	1.984	1.5	1.8	2.112	4.9
T17	06307740	Aluminum, total, in µg/L	19	37	349.5	104	299	522	1,020
T17	06307740	Arsenic, dissolved, in µg/L	19	0.69	2.227	1.2	1.4	1.7	7.5
T17	06307740	*Arsenic, total, in µg/L	19	--	2.458	1.3	1.7	2.3	8.2
T17	06307740	Barium, dissolved, in µg/L	19	11	33.21	25	31	39	61
T17	06307740	Barium, total, in µg/L	19	11.2	41.14	29	38	50.4	76.8
T17	06307740	**Beryllium, dissolved, in µg/L	19	--	--	--	--	--	<0.12
T17	06307740	*Beryllium, total, in µg/L	19	--	0.047	0.034	0.04	0.06	0.1
T17	06307740	Boron, dissolved, in µg/L	14	357	495.6	407	498	541.5	744
T17	06307740	*Cadmium, dissolved, in µg/L	17	--	0.026	0.02	0.023	0.03	0.04
T17	06307740	*Cadmium, total, in µg/L	17	--	0.034	0.02	0.03	0.05	0.06
T17	06307740	**Chromium, dissolved, in µg/L	3	--	--	--	--	--	0.45
T17	06307740	*Chromium, total, in µg/L	17	--	3.381	1.068	3	5.5	9
T17	06307740	*Copper, dissolved, in µg/L	17	--	3.893	1.3	3.3	4.9	11.3
T17	06307740	*Copper, total, in µg/L	17	--	6.654	3.4	5.4	7.7	20.1
T17	06307740	*Iron, dissolved, in µg/L	19	--	20.40	12.82	16.646	28	43
T17	06307740	Iron, total, in µg/L	19	220	849.4	361	802	1,100	2,220
T17	06307740	*Lead, dissolved, in µg/L	17	--	0.085	0.051	0.07	0.095	0.26
T17	06307740	Lead, total, in µg/L	17	0.05	0.801	0.22	0.67	1.14	2.24

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
T17	06307740	Lithium, dissolved, in µg/L	14	80	111.1	94.1	107.5	128.75	162
T17	06307740	Manganese, dissolved, in µg/L	19	6.5	49.53	11.4	49.6	68.5	137
T17	06307740	Manganese, total, in µg/L	19	55.7	108.3	69.2	89.7	141	208
T17	06307740	Mercury, total, ng/L	6	0.5	2.367	1.415	1.935	3.613	4.94
T17	06307740	**Mercury, total, µg/L	3	--	--	--	--	--	<0.01
T17	06307740	Nickel, dissolved, in µg/L	17	1.4	3.502	2.61	3.06	4.41	7.94
T17	06307740	Nickel, total, in µg/L	17	2.58	4.911	3.75	4.3	6.15	8.61
T17	06307740	Selenium, dissolved, in µg/L	19	0.61	1.075	0.75	1	1.4	1.9
T17	06307740	Selenium, total, in µg/L	19	0.45	1.126	0.82	0.94	1.5	2.1
T17	06307740	Strontium, dissolved, in µg/L	14	1,120	1,675	1,325	1,695	1,978	2,430
T17	06307740	*Zinc, dissolved, in µg/L	17	--	2.844	1.8	2.6	3.8	5.4
T17	06307740	*Zinc, total, in µg/L	17	--	5.782	3	6	7	13
T17	06307740	Suspended sediment, <0.0625 mm, percent	38	45	81.63	73.5	82	95.25	98
T17	06307740	Suspended sediment, in mg/L	38	26	95.84	45	97.5	137	186
T17	06307740	Suspended sediment, tons/day	38	0.01	0.591	0.17	0.36	0.67	3.4
T18	06307830	Streamflow, in cubic feet per second	53	60	376.3	98.5	194	382.5	2,360
T18	06307830	Turbidity, nephelometric turbidity ratio units	1	--	--	--	--	--	6.8
T18	06307830	Dissolved oxygen, in mg/L	50	7.4	10.03	8.375	9.3	11.125	16.5
T18	06307830	Dissolved oxygen, percent saturation	50	76	105.1	100.75	104	111	132
T18	06307830	pH, in standard units	52	8	8.42	8.3	8.5	8.5	8.7
T18	06307830	Specific conductance, at 25 degrees Celsius, in µS/cm	53	337	689.4	570.5	730	835	926
T18	06307830	Temperature, water deg C	53	0	14.59	7.75	15	23	29
T18	06307830	Hardness, in mg/L as $CaCO_3$	52	150	273.3	222.5	280	327.5	380
T18	06307830	Calcium, dissolved, in mg/L	52	32.5	51.16	43.5	50.7	58.675	69.8
T18	06307830	Magnesium, dissolved, in mg/L	52	16.2	35.41	26.35	35.8	43.9	51.7
T18	06307830	Potassium, dissolved, in mg/L	52	2.24	4.067	3.453	3.945	4.807	7.31
T18	06307830	Sodium-adsorption ratio (unitless)	52	0.5	1.235	0.925	1.35	1.5	1.8
T18	06307830	Sodium, dissolved, in mg/L	52	13.5	47.97	32.375	51.5	62.475	80.4
T18	06307830	Alkalinity, in mg/L as $CaCO_3$	52	115	208.7	176.75	218.5	245.5	288
T18	06307830	Chloride, dissolved, in mg/L	52	1.69	4.276	3.155	4.835	5.405	5.9
T18	06307830	Fluoride, dissolved, in mg/L	52	0.17	0.327	0.26	0.34	0.39	0.45
T18	06307830	Silica, dissolved, in mg/L	52	1.41	4.732	3.572	4.555	5.775	7.58
T18	06307830	Sulfate, dissolved, in mg/L	52	53.5	159.5	122.75	167	206.75	241
T18	06307830	Dissolved solids, calculated, in mg/L	52	196	432.8	347.5	456	535.75	602
T18	06307830	Dissolved solids, tons/day	52	89.3	352.3	145.25	231.5	317.25	1,930
T18	06307830	*Ammonia, dissolved, in mg/L as N	18	--	0.007	0.005	0.006	0.008	0.028
T18	06307830	**Nitrate plus nitrite, dissolved, in mg/L as N	18	--	--	--	--	--	0.27
T18	06307830	*Nitrite, dissolved, in mg/L as N	18	--	0.002	0.001	0.001	0.002	0.013
T18	06307830	**Orthophosphate, dissolved, in mg/L as P	18	--	--	--	--	--	0.007
T18	06307830	Phosphorus, total, in mg/L	18	0.007	0.049	0.014	0.023	0.045	0.3
T18	06307830	Total nitrogen, total, in mg/L	18	0.17	0.423	0.245	0.305	0.425	1.36
T18	06307830	*Aluminum, dissolved, in µg/L	17	--	2.531	1.211	2	3.8	6.1
T18	06307830	Aluminum, total, in µg/L	17	44	452.3	88.5	151	370.5	3,550
T18	06307830	Arsenic, dissolved, in µg/L	17	0.6	0.828	0.695	0.8	0.885	1.3
T18	06307830	*Arsenic, total, in µg/L	17	--	1.349	0.99	1.1	1.45	3
T18	06307830	Barium, dissolved, in µg/L	17	46	55.65	50	55	60.5	68
T18	06307830	Barium, total, in µg/L	17	51.5	65.88	55.4	58.5	69.85	140
T18	06307830	**Beryllium, dissolved, in µg/L	17	--	--	--	--	--	<0.06
T18	06307830	*Beryllium, total, in µg/L	17	--	0.081	0.037	0.05	0.093	0.4
T18	06307830	Boron, dissolved, in µg/L	14	56	90.14	69	87	114	123
T18	06307830	**Cadmium, dissolved, in µg/L	15	--	--	--	--	--	<0.04
T18	06307830	**Cadmium, total, in µg/L	15	--	--	--	--	--	0.17
T18	06307830	Chromium, dissolved, in µg/L	1	--	--	--	--	--	0.14
T18	06307830	*Chromium, total, in µg/L	15	--	1.896	1	1.103	2.05	8
T18	06307830	Copper, dissolved, in µg/L	15	0.61	1.938	1.3	1.8	2.6	3.4
T18	06307830	Copper, total, in µg/L	15	1.1	3.320	1.5	2	4.6	13.1
T18	06307830	*Iron, dissolved, in µg/L	17	--	12.75	4.279	10	14.5	64
T18	06307830	Iron, total, in µg/L	17	120	902.5	189.5	365	593.5	6,880
T18	06307830	*Lead, dissolved, in µg/L	15	--	0.096	0.06	0.075	0.16	0.2
T18	06307830	Lead, total, in µg/L	15	0.1	0.879	0.15	0.27	0.48	6.98

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
T18	06307830	Lithium, dissolved, in µg/L	14	14.5	23.89	19.675	23.25	26.3	42.6
T18	06307830	Manganese, dissolved, in µg/L	17	1	8.041	3.4	7	10.8	24.9
T18	06307830	Manganese, total, in µg/L	17	12.3	63.73	16.25	33	63.5	397
T18	06307830	Mercury, total, ng/L	5	0.83	--	--	--	--	2.02
T18	06307830	**Mercury, total, µg/L	3	--	--	--	--	--	<0.01
T18	06307830	Nickel, dissolved, in µg/L	15	0.89	2.016	1.4	2.03	2.7	3.47
T18	06307830	Nickel, total, in µg/L	15	1.54	2.899	1.86	2.29	2.93	10.7
T18	06307830	Selenium, dissolved, in µg/L	17	0.16	0.318	0.25	0.29	0.39	0.61
T18	06307830	*Selenium, total, in µg/L	17	--	0.437	0.275	0.37	0.435	1.4
T18	06307830	Strontium, dissolved, in µg/L	14	346	580.7	499.75	587	684.25	787
T18	06307830	Zinc, dissolved, in µg/L	15	0.39	2.393	0.9	1.6	3	9.4
T18	06307830	Zinc, total, in µg/L	15	1	4.407	2	2	3	27
T18	06307830	Suspended sediment, <0.0625 mm, percent	45	46	82.84	77.5	86	90	96
T18	06307830	Suspended sediment, in mg/L	45	3	65.69	23	37	56.5	513
T18	06307830	Suspended sediment, tons/day	45	0.57	126.4	7.55	13	36	1,570
T19	06308400	Streamflow, in cubic feet per second	37	0.01	44.25	0.23	2.5	13.35	584
T19	06308400	Dissolved oxygen, in mg/L	36	6	9.644	7.925	9.4	11.35	14.2
T19	06308400	Dissolved oxygen, percent saturation	35	71	96.63	87	97	102	121
T19	06308400	pH, in standard units	36	7.9	8.39	8.2	8.35	8.6	9
T19	06308400	Specific conductance, at 25 degrees Celsius, in µS/cm	37	263	1,270	509.5	1,010	1,650	4,430
T19	06308400	Temperature, water deg C	37	0	12.96	5.25	13	19.75	30
T19	06308400	Hardness, in mg/L as $CaCO_3$	37	4	181.5	36	110	205	970
T19	06308400	Calcium, dissolved, in mg/L	37	0.97	31.97	8.695	24.8	38.35	132
T19	06308400	Magnesium, dissolved, in mg/L	37	0.366	24.64	2.99	11.9	26.2	167
T19	06308400	Potassium, dissolved, in mg/L	37	1.48	7.578	4.42	7.23	8.91	22.4
T19	06308400	Sodium-adsorption ratio (unitless)	37	2.6	8.332	6.05	7.7	10	15
T19	06308400	Sodium, dissolved, in mg/L	37	35.9	221.3	96.05	180	304.5	745
T19	06308400	Alkalinity, in mg/L as $CaCO_3$	37	80	210.4	115	185	287	435
T19	06308400	Chloride, dissolved, in mg/L	37	0.91	4.370	1.74	3.18	5.76	14.5
T19	06308400	Fluoride, dissolved, in mg/L	37	0.17	0.405	0.33	0.4	0.47	0.66
T19	06308400	Silica, dissolved, in mg/L	36	0.74	7.469	6.543	7.665	8.672	12.9
T19	06308400	Sulfate, dissolved, in mg/L	37	40.2	450.1	134	294	588	2,090
T19	06308400	Dissolved solids, calculated, in mg/L	37	157	874.8	344	640	1,120	3,420
T19	06308400	Dissolved solids, tons/day	37	0.04	38.25	0.445	3.49	27.85	554
T19	06308400	*Ammonia, dissolved, in mg/L as N	14	--	0.017	0.008	0.013	0.017	0.082
T19	06308400	*Nitrate plus nitrite, dissolved, in mg/L as N	14	--	0.383	0.019	0.113	0.465	2.27
T19	06308400	*Nitrite, dissolved, in mg/L as N	14	--	0.009	0.002	0.004	0.018	0.024
T19	06308400	*Orthophosphate, dissolved, in mg/L as P	14	--	0.022	0.004	0.007	0.013	0.171
T19	06308400	Phosphorus, total, in mg/L	14	0.045	0.584	0.06	0.271	0.902	2.6
T19	06308400	Total nitrogen, total, in mg/L	14	0.68	2.436	0.858	1.74	3.89	7
T19	06308400	Aluminum, dissolved, in µg/L	14	1.6	9.364	1.85	10.3	14.825	18.9
T19	06308400	Aluminum, total, in µg/L	14	124	17,083	352.25	5,865	34,275	63,900
T19	06308400	Arsenic, dissolved, in µg/L	14	0.78	1.200	0.97	1.2	1.425	1.6
T19	06308400	*Arsenic, total, in µg/L	14	--	5.618	1.316	2.7	7.95	29
T19	06308400	Barium, dissolved, in µg/L	14	13	66.71	21.5	56.5	77.25	247
T19	06308400	Barium, total, in µg/L	14	65	382.1	93.175	153.5	667.25	1,310
T19	06308400	**Beryllium, dissolved, in µg/L	14	--	--	--	--	--	<0.12
T19	06308400	*Beryllium, total, in µg/L	14	--	2.313	0.064	0.435	4.755	8.73
T19	06308400	Boron, dissolved, in µg/L	10	46	144.0	53.75	121	259.5	274
T19	06308400	*Cadmium, dissolved, in µg/L	13	--	0.034	0.023	0.03	0.041	0.06
T19	06308400	*Cadmium, total, in µg/L	13	--	0.666	0.029	0.2	1.565	2.2
T19	06308400	Chromium, dissolved, in µg/L	3	0.14	--	--	--	--	0.5
T19	06308400	*Chromium, total, in µg/L	13	--	27.83	1.4	11	47	123
T19	06308400	Copper, dissolved, in µg/L	13	2.3	7.815	5.25	6	11.05	17
T19	06308400	Copper, total, in µg/L	13	4.4	51.25	8.4	19.5	102.1	159
T19	06308400	*Iron, dissolved, in µg/L	14	--	36.85	9.889	23	52.5	147
T19	06308400	Iron, total, in µg/L	14	94	21,353	385.75	5,340	42,275	97,700
T19	06308400	*Lead, dissolved, in µg/L	13	--	0.383	0.128	0.18	0.43	1.68
T19	06308400	Lead, total, in µg/L	13	0.23	41.52	0.795	13.5	77.35	181
T19	06308400	Lithium, dissolved, in µg/L	10	3.1	15.28	4.575	9	28.325	38.5

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
T19	06308400	Manganese, dissolved, in µg/L	14	0.7	5.279	1.825	4.2	6.425	15.9
T19	06308400	Manganese, total, in µg/L	14	25.8	401.3	44.2	91.05	760.25	1,620
T19	06308400	Mercury, total, ng/L	4	2.65	--	--	--	--	357
T19	06308400	**Mercury, total, µg/L	2	--	--	--	--	--	0.474
T19	06308400	Nickel, dissolved, in µg/L	13	3.1	5.742	4.3	6.08	7.18	7.88
T19	06308400	Nickel, total, in µg/L	13	3.2	51.78	6.875	18	102.3	186
T19	06308400	Selenium, dissolved, in µg/L	14	0.41	1.447	0.68	1.2	1.925	3.5
T19	06308400	Selenium, total, in µg/L	14	0.44	1.505	0.673	1.2	1.95	3.6
T19	06308400	Strontium, dissolved, in µg/L	10	23	494.5	131	216	993.5	1,610
T19	06308400	*Zinc, dissolved, in µg/L	13	--	7.891	2.05	2.582	13.2	34.5
T19	06308400	Zinc, total, in µg/L	13	3.9	152.1	5.05	48	312.5	603
T19	06308400	Suspended sediment, <0.0625 mm, percent	33	89	97.79	98.5	99	99	99
T19	06308400	Suspended sediment, in mg/L	33	12	3,600	58	666	5,505	20,100
T19	06308400	Suspended sediment, tons/day	33	0	694.1	0.055	2.7	131.5	12,400
P1	434056106244101	Streamflow, in cubic feet per second	3	1.2	--	--	--	--	17
P1	434056106244101	Turbidity, nephelometric turbidity ratio units	3	6.7	--	--	--	--	380
P1	434056106244101	Dissolved oxygen, in mg/L	3	6.7	--	--	--	--	10.5
P1	434056106244101	Dissolved oxygen, percent saturation	2	101	--	--	--	--	156
P1	434056106244101	pH, in standard units	3	7.8	--	--	--	--	8.2
P1	434056106244101	Specific conductance, at 25 degrees Celsius, in µS/cm	3	2,090	--	--	--	--	3,470
P1	434056106244101	Temperature, water deg C	3	27	--	--	--	--	32.8
P1	434056106244101	Hardness, in mg/L as $CaCO_3$	3	710	--	--	--	--	1,100
P1	434056106244101	Calcium, dissolved, in mg/L	3	170	--	--	--	--	287
P1	434056106244101	Magnesium, dissolved, in mg/L	3	70.8	--	--	--	--	89.4
P1	434056106244101	Potassium, dissolved, in mg/L	3	7.33	--	--	--	--	14.2
P1	434056106244101	Sodium-adsorption ratio (unitless)	3	3.3	--	--	--	--	5.7
P1	434056106244101	Sodium, dissolved, in mg/L	3	209	--	--	--	--	430
P1	434056106244101	Alkalinity, in mg/L as $CaCO_3$	3	177	--	--	--	--	225
P1	434056106244101	Chloride, dissolved, in mg/L	3	92.5	--	--	--	--	139
P1	434056106244101	Fluoride, dissolved, in mg/L	3	0.46	--	--	--	--	0.83
P1	434056106244101	Silica, dissolved, in mg/L	3	4.93	--	--	--	--	11.9
P1	434056106244101	Sulfate, dissolved, in mg/L	3	722	--	--	--	--	1,610
P1	434056106244101	Dissolved solids, calculated, in mg/L	3	1,400	--	--	--	--	2,680
P1	434056106244101	Dissolved solids, tons/day	3	4.64	--	--	--	--	125
P2	434124106192401	Streamflow, in cubic feet per second	3	5.1	--	--	--	--	38
P2	434124106192401	Turbidity, nephelometric turbidity ratio units	3	12	--	--	--	--	370
P2	434124106192401	Dissolved oxygen, in mg/L	3	7.3	--	--	--	--	10.2
P2	434124106192401	Dissolved oxygen, percent saturation	2	118	--	--	--	--	138
P2	434124106192401	pH, in standard units	3	7.8	--	--	--	--	8.3
P2	434124106192401	Specific conductance, at 25 degrees Celsius, in µS/cm	3	3,610	--	--	--	--	5,650
P2	434124106192401	Temperature, water deg C	3	22.1	--	--	--	--	32.7
P2	434124106192401	Hardness, in mg/L as $CaCO_3$	3	590	--	--	--	--	730
P2	434124106192401	Calcium, dissolved, in mg/L	3	113	--	--	--	--	177
P2	434124106192401	Magnesium, dissolved, in mg/L	3	69.7	--	--	--	--	79
P2	434124106192401	Potassium, dissolved, in mg/L	3	15.6	--	--	--	--	28.7
P2	434124106192401	Sodium-adsorption ratio (unitless)	3	8.9	--	--	--	--	17
P2	434124106192401	Sodium, dissolved, in mg/L	3	554	--	--	--	--	932
P2	434124106192401	Alkalinity, in mg/L as $CaCO_3$	3	175	--	--	--	--	288
P2	434124106192401	Chloride, dissolved, in mg/L	3	444	--	--	--	--	943
P2	434124106192401	Fluoride, dissolved, in mg/L	3	1.03	--	--	--	--	1.99
P2	434124106192401	Silica, dissolved, in mg/L	3	4.46	--	--	--	--	12.5
P2	434124106192401	Sulfate, dissolved, in mg/L	3	1,030	--	--	--	--	1,310
P2	434124106192401	Dissolved solids, calculated, in mg/L	3	2,450	--	--	--	--	3,490
P2	434124106192401	Dissolved solids, tons/day	3	48.3	--	--	--	--	253
P3	435453106104701	Streamflow, in cubic feet per second	4	0.22	--	--	--	--	84
P3	435453106104701	Turbidity, nephelometric turbidity ratio units	4	3.1	--	--	--	--	690
P3	435453106104701	Dissolved oxygen, in mg/L	4	6.2	--	--	--	--	11.4
P3	435453106104701	Dissolved oxygen, percent saturation	3	106	--	--	--	--	172
P3	435453106104701	pH, in standard units	4	7.8	--	--	--	--	8.4
P3	435453106104701	Specific conductance, at 25 degrees Celsius, in µS/cm	4	2,980	--	--	--	--	4,940

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
P3	435453106104701	Temperature, water deg C	4	20.1	--	--	--	--	29.1
P3	435453106104701	Hardness, in mg/L as $CaCO_3$	4	620	--	--	--	--	960
P3	435453106104701	Calcium, dissolved, in mg/L	4	142	--	--	--	--	213
P3	435453106104701	Magnesium, dissolved, in mg/L	4	64.3	--	--	--	--	111
P3	435453106104701	Potassium, dissolved, in mg/L	4	11.3	--	--	--	--	21.2
P3	435453106104701	Sodium-adsorption ratio (unitless)	4	7.1	--	--	--	--	13
P3	435453106104701	Sodium, dissolved, in mg/L	4	405	--	--	--	--	843
P3	435453106104701	Alkalinity, in mg/L as $CaCO_3$	4	160	--	--	--	--	209
P3	435453106104701	Chloride, dissolved, in mg/L	4	344	--	--	--	--	733
P3	435453106104701	Fluoride, dissolved, in mg/L	4	0.65	--	--	--	--	1.19
P3	435453106104701	Silica, dissolved, in mg/L	4	3.02	--	--	--	--	12.4
P3	435453106104701	Sulfate, dissolved, in mg/L	4	880	--	--	--	--	1,550
P3	435453106104701	Dissolved solids, calculated, in mg/L	4	1,980	--	--	--	--	3,350
P3	435453106104701	Dissolved solids, tons/day	4	1.89	--	--	--	--	476
P4	440919106091401	Streamflow, in cubic feet per second	4	2.2	--	--	--	--	94
P4	440919106091401	Turbidity, nephelometric turbidity ratio units	4	3.2	--	--	--	--	120
P4	440919106091401	Dissolved oxygen, in mg/L	4	7.5	--	--	--	--	13.9
P4	440919106091401	Dissolved oxygen, percent saturation	3	102	--	--	--	--	198
P4	440919106091401	pH, in standard units	4	8	--	--	--	--	8.7
P4	440919106091401	Specific conductance, at 25 degrees Celsius, in µS/cm	4	2,860	--	--	--	--	4,610
P4	440919106091401	Temperature, water deg C	4	18.6	--	--	--	--	30.3
P4	440919106091401	Hardness, in mg/L as $CaCO_3$	4	150	--	--	--	--	700
P4	440919106091401	Calcium, dissolved, in mg/L	4	13.9	--	--	--	--	153
P4	440919106091401	Magnesium, dissolved, in mg/L	4	29.1	--	--	--	--	100
P4	440919106091401	Potassium, dissolved, in mg/L	4	11.9	--	--	--	--	25.7
P4	440919106091401	Sodium-adsorption ratio (unitless)	4	7.3	--	--	--	--	25
P4	440919106091401	Sodium, dissolved, in mg/L	4	407	--	--	--	--	866
P4	440919106091401	Alkalinity, in mg/L as $CaCO_3$	4	224	--	--	--	--	1,540
P4	440919106091401	Chloride, dissolved, in mg/L	4	69.6	--	--	--	--	537
P4	440919106091401	Fluoride, dissolved, in mg/L	4	0.61	--	--	--	--	1.62
P4	440919106091401	Silica, dissolved, in mg/L	4	5.01	--	--	--	--	8.74
P4	440919106091401	Sulfate, dissolved, in mg/L	4	210	--	--	--	--	1,260
P4	440919106091401	Dissolved solids, calculated, in mg/L	4	1,920	--	--	--	--	3,100
P4	440919106091401	Dissolved solids, tons/day	4	12.1	--	--	--	--	487
P5	442538106082001	Streamflow, in cubic feet per second	4	1.7	--	--	--	--	99
P5	442538106082001	Turbidity, nephelometric turbidity ratio units	4	5.8	--	--	--	--	190
P5	442538106082001	Dissolved oxygen, in mg/L	4	5.9	--	--	--	--	8.7
P5	442538106082001	Dissolved oxygen, percent saturation	3	97	--	--	--	--	115
P5	442538106082001	pH, in standard units	4	7.8	--	--	--	--	8.2
P5	442538106082001	Specific conductance, at 25 degrees Celsius, in µS/cm	4	2,810	--	--	--	--	3,550
P5	442538106082001	Temperature, water deg C	4	18.7	--	--	--	--	32.9
P5	442538106082001	Hardness, in mg/L as $CaCO_3$	4	400	--	--	--	--	620
P5	442538106082001	Calcium, dissolved, in mg/L	4	78.8	--	--	--	--	135
P5	442538106082001	Magnesium, dissolved, in mg/L	4	50	--	--	--	--	72.6
P5	442538106082001	Potassium, dissolved, in mg/L	4	12.2	--	--	--	--	14.8
P5	442538106082001	Sodium-adsorption ratio (unitless)	4	7.1	--	--	--	--	11
P5	442538106082001	Sodium, dissolved, in mg/L	4	392	--	--	--	--	524
P5	442538106082001	Alkalinity, in mg/L as $CaCO_3$	4	202	--	--	--	--	342
P5	442538106082001	Chloride, dissolved, in mg/L	4	212	--	--	--	--	365
P5	442538106082001	Fluoride, dissolved, in mg/L	4	0.67	--	--	--	--	0.92
P5	442538106082001	Silica, dissolved, in mg/L	4	4.32	--	--	--	--	8.15
P5	442538106082001	Sulfate, dissolved, in mg/L	4	871	--	--	--	--	1,070
P5	442538106082001	Dissolved solids, calculated, in mg/L	4	1,870	--	--	--	--	2,320
P5	442538106082001	Dissolved solids, tons/day	4	9.19	--	--	--	--	500
P6	441532106251301	Streamflow, in cubic feet per second	3	0	--	--	--	--	37
P6	441532106251301	Turbidity, nephelometric turbidity ratio units	3	11	--	--	--	--	240
P6	441532106251301	Dissolved oxygen, in mg/L	3	6.8	--	--	--	--	8.8
P6	441532106251301	Dissolved oxygen, percent saturation	2	96	--	--	--	--	114
P6	441532106251301	pH, in standard units	3	7.9	--	--	--	--	8.2
P6	441532106251301	Specific conductance, at 25 degrees Celsius, in µS/cm	3	827	--	--	--	--	3,500

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
P6	441532106251301	Temperature, water deg C	3	19.7	--	--	--	--	25.4
P6	441532106251301	Hardness, in mg/L as $CaCO_3$	3	370	--	--	--	--	1,700
P6	441532106251301	Calcium, dissolved, in mg/L	3	79.9	--	--	--	--	290
P6	441532106251301	Magnesium, dissolved, in mg/L	3	40.5	--	--	--	--	245
P6	441532106251301	Potassium, dissolved, in mg/L	3	2.28	--	--	--	--	13
P6	441532106251301	Sodium-adsorption ratio (unitless)	3	1.2	--	--	--	--	3.5
P6	441532106251301	Sodium, dissolved, in mg/L	3	51.2	--	--	--	--	334
P6	441532106251301	Alkalinity, in mg/L as $CaCO_3$	3	122	--	--	--	--	207
P6	441532106251301	Chloride, dissolved, in mg/L	3	3.49	--	--	--	--	21.8
P6	441532106251301	Fluoride, dissolved, in mg/L	3	0.27	--	--	--	--	0.45
P6	441532106251301	Silica, dissolved, in mg/L	3	1.61	--	--	--	--	10.6
P6	441532106251301	Sulfate, dissolved, in mg/L	3	318	--	--	--	--	2,050
P6	441532106251301	Dissolved solids, calculated, in mg/L	3	580	--	--	--	--	3,060
P6	441532106251301	Dissolved solids, tons/day	2	1.22	--	--	--	--	57.3
P7	442817106133001	Streamflow, in cubic feet per second	4	0	--	--	--	--	40
P7	442817106133001	Turbidity, nephelometric turbidity ratio units	4	13	--	--	--	--	120
P7	442817106133001	Dissolved oxygen, in mg/L	4	6.7	--	--	--	--	8.8
P7	442817106133001	Dissolved oxygen, percent saturation	3	84	--	--	--	--	118
P7	442817106133001	pH, in standard units	4	7	--	--	--	--	8
P7	442817106133001	Specific conductance, at 25 degrees Celsius, in µS/cm	4	891	--	--	--	--	3,410
P7	442817106133001	Temperature, water deg C	4	17.6	--	--	--	--	27.2
P7	442817106133001	Hardness, in mg/L as $CaCO_3$	4	370	--	--	--	--	1,400
P7	442817106133001	Calcium, dissolved, in mg/L	4	82.5	--	--	--	--	295
P7	442817106133001	Magnesium, dissolved, in mg/L	4	40.7	--	--	--	--	152
P7	442817106133001	Potassium, dissolved, in mg/L	4	2.82	--	--	--	--	27
P7	442817106133001	Sodium-adsorption ratio (unitless)	4	1.3	--	--	--	--	3.1
P7	442817106133001	Sodium, dissolved, in mg/L	4	58.3	--	--	--	--	262
P7	442817106133001	Alkalinity, in mg/L as $CaCO_3$	4	145	--	--	--	--	390
P7	442817106133001	Chloride, dissolved, in mg/L	4	3.87	--	--	--	--	30
P7	442817106133001	Fluoride, dissolved, in mg/L	4	0.21	--	--	--	--	0.51
P7	442817106133001	Silica, dissolved, in mg/L	4	3.42	--	--	--	--	12
P7	442817106133001	Sulfate, dissolved, in mg/L	4	309	--	--	--	--	1,440
P7	442817106133001	Dissolved solids, calculated, in mg/L	4	596	--	--	--	--	2,450
P7	442817106133001	Dissolved solids, tons/day	3	0.44	--	--	--	--	64.1
P8	443025106061601	Streamflow, in cubic feet per second	4	0	--	--	--	--	159
P8	443025106061601	Turbidity, nephelometric turbidity ratio units	4	17	--	--	--	--	960
P8	443025106061601	Dissolved oxygen, in mg/L	4	5.3	--	--	--	--	8
P8	443025106061601	Dissolved oxygen, percent saturation	3	82	--	--	--	--	105
P8	443025106061601	pH, in standard units	4	7	--	--	--	--	8.4
P8	443025106061601	Specific conductance, at 25 degrees Celsius, in µS/cm	4	1,760	--	--	--	--	3,990
P8	443025106061601	Temperature, water deg C	4	21.9	--	--	--	--	28.3
P8	443025106061601	Hardness, in mg/L as $CaCO_3$	4	570	--	--	--	--	1,100
P8	443025106061601	Calcium, dissolved, in mg/L	4	134	--	--	--	--	290
P8	443025106061601	Magnesium, dissolved, in mg/L	4	46.3	--	--	--	--	97.6
P8	443025106061601	Potassium, dissolved, in mg/L	4	9.98	--	--	--	--	15.7
P8	443025106061601	Sodium-adsorption ratio (unitless)	4	1.5	--	--	--	--	9.2
P8	443025106061601	Sodium, dissolved, in mg/L	4	97.8	--	--	--	--	596
P8	443025106061601	Alkalinity, in mg/L as $CaCO_3$	4	92	--	--	--	--	332
P8	443025106061601	Chloride, dissolved, in mg/L	4	36.1	--	--	--	--	348
P8	443025106061601	Fluoride, dissolved, in mg/L	4	0.4	--	--	--	--	0.87
P8	443025106061601	Silica, dissolved, in mg/L	4	7.45	--	--	--	--	8.51
P8	443025106061601	Sulfate, dissolved, in mg/L	4	783	--	--	--	--	1,460
P8	443025106061601	Dissolved solids, calculated, in mg/L	4	1,350	--	--	--	--	3,010
P8	443025106061601	Dissolved solids, tons/day	3	158	--	--	--	--	695
P9	444857106030401	Streamflow, in cubic feet per second	4	0	--	--	--	--	188
P9	444857106030401	Turbidity, nephelometric turbidity ratio units	4	20	--	--	--	--	2,000
P9	444857106030401	Dissolved oxygen, in mg/L	4	5.2	--	--	--	--	7.8
P9	444857106030401	Dissolved oxygen, percent saturation	3	68	--	--	--	--	109
P9	444857106030401	pH, in standard units	4	7.7	--	--	--	--	8.4
P9	444857106030401	Specific conductance, at 25 degrees Celsius, in µS/cm	4	1,250	--	--	--	--	2,680

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
P9	444857106030401	Temperature, water deg C	4	21.4	--	--	--	--	29
P9	444857106030401	Hardness, in mg/L as $CaCO_3$	4	360	--	--	--	--	1,100
P9	444857106030401	Calcium, dissolved, in mg/L	4	82.7	--	--	--	--	287
P9	444857106030401	Magnesium, dissolved, in mg/L	4	37.4	--	--	--	--	100
P9	444857106030401	Potassium, dissolved, in mg/L	4	8.37	--	--	--	--	12.1
P9	444857106030401	Sodium-adsorption ratio (unitless)	4	1.8	--	--	--	--	6.2
P9	444857106030401	Sodium, dissolved, in mg/L	4	130	--	--	--	--	472
P9	444857106030401	Alkalinity, in mg/L as $CaCO_3$	4	101	--	--	--	--	592
P9	444857106030401	Chloride, dissolved, in mg/L	4	41.4	--	--	--	--	224
P9	444857106030401	Fluoride, dissolved, in mg/L	4	0.42	--	--	--	--	0.88
P9	444857106030401	Silica, dissolved, in mg/L	4	7.04	--	--	--	--	9.86
P9	444857106030401	Sulfate, dissolved, in mg/L	4	510	--	--	--	--	1,210
P9	444857106030401	Dissolved solids, calculated, in mg/L	4	966	--	--	--	--	2,560
P9	444857106030401	Dissolved solids, tons/day	3	266	--	--	--	--	951
P10	06324000	Streamflow, in cubic feet per second	98	0.24	172.1	51	78.5	104	2,230
P10	06324000	Turbidity, nephelometric turbidity ratio units	2	8.4	--	--	--	--	12
P10	06324000	Dissolved oxygen, in mg/L	97	7	10.46	8.55	10.6	12.2	14.4
P10	06324000	Dissolved oxygen, percent saturation	96	77	104.0	96	102	109	162
P10	06324000	pH, in standard units	98	7.7	8.23	8.1	8.2	8.4	8.8
P10	06324000	Specific conductance, at 25 degrees Celsius, in µS/cm	98	175	1,010	861.25	1,010	1,170	2,020
P10	06324000	Temperature, water deg C	98	0	10.32	0.075	9.75	18.125	30
P10	06324000	Hardness, in mg/L as $CaCO_3$	96	67	440.0	352.5	450	527.5	840
P10	06324000	Calcium, dissolved, in mg/L	96	17.7	101.0	81.375	105	121	170
P10	06324000	Magnesium, dissolved, in mg/L	96	5.49	45.69	36.025	46.1	54.825	101
P10	06324000	Potassium, dissolved, in mg/L	96	1.13	4.381	3.65	4.12	4.965	9.75
P10	06324000	Sodium-adsorption ratio (unitless)	96	0.3	1.137	1	1.1	1.2	2.4
P10	06324000	Sodium, dissolved, in mg/L	96	6.53	56.71	44.875	55.6	65.275	159
P10	06324000	Alkalinity, in mg/L as $CaCO_3$	96	48	183.5	154	189	217	301
P10	06324000	Chloride, dissolved, in mg/L	96	0.69	3.489	3.013	3.67	4.202	6.02
P10	06324000	Fluoride, dissolved, in mg/L	96	0.06	0.192	0.18	0.2	0.22	0.3
P10	06324000	Silica, dissolved, in mg/L	94	0.63	6.913	4.608	6.72	9.315	13.7
P10	06324000	Sulfate, dissolved, in mg/L	96	32.9	360.1	287	349.5	415.25	878
P10	06324000	Dissolved solids, calculated, in mg/L	94	100	691.9	566.25	695.5	803	1,490
P10	06324000	Dissolved solids, tons/day	96	1.04	188.7	116.25	158	196	1,330
P10	06324000	Dissolved solids, residue on evaporation, in mg/L	96	90	750.6	622.25	744.5	875.75	1,660
P10	06324000	Ammonia, dissolved, in mg/L as N	1	--	--	--	--	--	<0.04
P10	06324000	Nitrate plus nitrite, dissolved, in mg/L as N	1	--	--	--	--	--	<0.06
P10	06324000	Nitrite, dissolved, in mg/L as N	1	--	--	--	--	--	<0.008
P10	06324000	Orthophosphate, dissolved, in mg/L as P	1	--	--	--	--	--	<0.02
P10	06324000	Total nitrogen, total, in mg/L	1	--	--	--	--	--	0.32
P10	06324000	Aluminum, total, in µg/L	96	16	325.6	40.75	64.5	128.25	8,820
P10	06324000	Arsenic, dissolved, in µg/L	94	0.22	0.526	0.4	0.5	0.62	0.87
P10	06324000	Arsenic, total, in µg/L	72	0.34	0.917	0.62	0.81	1.1	3.1
P10	06324000	Barium, total, in µg/L	96	25	42.15	32.75	36.35	45.15	197
P10	06324000	*Beryllium, total, in µg/L	96	--	0.05	0.014	0.027	0.05	0.83
P10	06324000	Iron, dissolved, in µg/L	94	4	28.62	16	23	40	102
P10	06324000	Manganese, dissolved, in µg/L	94	3.9	19.26	10	14.6	21.85	106
P10	06324000	Selenium, total, in µg/L	96	0.09	0.568	0.403	0.495	0.65	1.3
P11	445339106032501	Streamflow, in cubic feet per second	4	0.2	--	--	--	--	183
P11	445339106032501	Turbidity, nephelometric turbidity ratio units	4	7.5	--	--	--	--	1,690
P11	445339106032501	Dissolved oxygen, in mg/L	4	6.8	--	--	--	--	7.9
P11	445339106032501	Dissolved oxygen, percent saturation	3	92	--	--	--	--	105
P11	445339106032501	pH, in standard units	4	8.1	--	--	--	--	8.4
P11	445339106032501	Specific conductance, at 25 degrees Celsius, in µS/cm	4	1,270	--	--	--	--	2,410
P11	445339106032501	Temperature, water deg C	4	21.1	--	--	--	--	24
P11	445339106032501	Hardness, in mg/L as $CaCO_3$	4	400	--	--	--	--	900
P11	445339106032501	Calcium, dissolved, in mg/L	4	93.8	--	--	--	--	206
P11	445339106032501	Magnesium, dissolved, in mg/L	4	41.2	--	--	--	--	119
P11	445339106032501	Potassium, dissolved, in mg/L	4	7.36	--	--	--	--	11.9
P11	445339106032501	Sodium-adsorption ratio (unitless)	4	2.3	--	--	--	--	5.5

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
P11	445339106032501	Sodium, dissolved, in mg/L	4	128	--	--	--	--	302
P11	445339106032501	Alkalinity, in mg/L as $CaCO_3$	4	132	--	--	--	--	205
P11	445339106032501	Chloride, dissolved, in mg/L	4	37.3	--	--	--	--	191
P11	445339106032501	Fluoride, dissolved, in mg/L	4	0.39	--	--	--	--	0.55
P11	445339106032501	Silica, dissolved, in mg/L	4	1.1	--	--	--	--	6.64
P11	445339106032501	Sulfate, dissolved, in mg/L	4	481	--	--	--	--	1,090
P11	445339106032501	Dissolved solids, calculated, in mg/L	4	884	--	--	--	--	1,750
P11	445339106032501	Dissolved solids, tons/day	4	0.94	--	--	--	--	613
P12	06324500	Streamflow, in cubic feet per second	98	0	375.0	90.75	192	297	5,220
P12	06324500	Turbidity, nephelometric turbidity ratio units	2	41	--	--	--	--	110
P12	06324500	Dissolved oxygen, in mg/L	98	6.2	10.24	8.675	9.9	11.9	15.7
P12	06324500	Dissolved oxygen, percent saturation	98	75	102.1	97	101.5	106.25	148
P12	06324500	pH, in standard units	97	7.6	8.29	8.2	8.3	8.4	8.7
P12	06324500	Specific conductance, at 25 degrees Celsius, in µS/cm	98	500	1,855	1,525	1,855	2,083	4,300
P12	06324500	Temperature, water deg C	98	0	10.77	0	11.5	17.625	30
P12	06324500	Hardness, in mg/L as $CaCO_3$	96	140	500.5	432.5	520	570	1,000
P12	06324500	Calcium, dissolved, in mg/L	96	33.6	111.8	94.85	114.5	130	180
P12	06324500	Magnesium, dissolved, in mg/L	96	13.8	53.83	43.125	54.25	60.55	148
P12	06324500	Potassium, dissolved, in mg/L	96	2.65	8.060	6.97	7.97	8.86	19.2
P12	06324500	Sodium-adsorption ratio (unitless)	96	1.5	4.183	3.45	4.2	4.6	9
P12	06324500	Sodium, dissolved, in mg/L	96	46.7	218.6	162.5	217.5	257	520
P12	06324500	Acid neutralizing capacity, in mg/L as $CaCO_3$	91	119	276.7	201	265	327	697
P12	06324500	Alkalinity, in mg/L as $CaCO_3$	96	81	227.6	176.5	216.5	259.75	441
P12	06324500	Chloride, dissolved, in mg/L	96	10	103.7	70.325	104	127.5	232
P12	06324500	Fluoride, dissolved, in mg/L	96	0.23	0.524	0.44	0.54	0.62	0.99
P12	06324500	Silica, dissolved, in mg/L	96	0.4	7.314	5.795	7.06	9.04	14.1
P12	06324500	Sulfate, dissolved, in mg/L	96	129	595.5	476.5	567.5	665.5	1,640
P12	06324500	Dissolved solids, calculated, in mg/L	96	302	1,237	979.75	1,255	1,428	2,650
P12	06324500	Dissolved solids, tons/day	96	4.29	916.9	383.25	640.5	1,045	8,880
P12	06324500	Dissolved solids, residue on evaporation, in mg/L	96	314	1,310	1,060	1,315	1,495	2,820
P12	06324500	*Ammonia, dissolved, in mg/L as N	95	--	0.041	0.008	0.015	0.065	0.221
P12	06324500	*Nitrate plus nitrite, dissolved, in mg/L as N	95	--	0.301	0.058	0.222	0.462	2.33
P12	06324500	*Nitrite, dissolved, in mg/L as N	95	--	0.006	0.001	0.002	0.007	0.078
P12	06324500	*Orthophosphate, dissolved, in mg/L as P	95	--	0.006	0.004	0.005	0.007	0.021
P12	06324500	Phosphorus, total, in mg/L	96	0.01	0.318	0.068	0.192	0.398	4
P12	06324500	Total nitrogen, total, in mg/L	96	0.31	1.187	0.69	0.86	1.168	9.41
P12	06324500	Aluminum, total, in µg/L	96	43	7,035	983.25	3,555	7,620	52,400
P12	06324500	Arsenic, dissolved, in µg/L	96	0.17	0.746	0.59	0.7	0.87	1.7
P12	06324500	Arsenic, total, in µg/L	60	0.72	4.655	1.2	3.1	6.45	19.5
P12	06324500	Barium, total, in µg/L	96	37.5	162.4	60.5	92.2	164.75	910
P12	06324500	*Beryllium, total, in µg/L	96	--	0.69	0.07	0.315	0.68	5.92
P12	06324500	Boron, total, in µg/L	48	58	199.6	164	197.5	223.75	392
P12	06324500	Cadmium, total, in µg/L	48	0.01	0.521	0.062	0.18	0.445	5
P12	06324500	Chromium, total, in µg/L	48	0.26	12.00	1.425	5.3	11.25	74.2
P12	06324500	Copper, total, in µg/L	48	1.2	20.56	5.45	10.5	25.15	102
P12	06324500	*Iron, dissolved, in µg/L	96	--	6.425	4	5.155	7.258	44
P12	06324500	Iron, total, in µg/L	48	86	17,606	1,470	6,910	14,700	121,000
P12	06324500	Lead, total, in µg/L	48	0.12	16.29	1.35	5.83	14	134
P12	06324500	Manganese, dissolved, in µg/L	96	0.3	4.175	1.625	3.45	5.55	30.2
P12	06324500	Manganese, total, in µg/L	48	14.4	371.1	38.125	124.5	356.75	3,330
P12	06324500	Mercury, total, µg/L	4	0.016	--	--	--	--	0.182
P12	06324500	Nickel, total, in µg/L	48	1.8	23.15	5.083	9.375	19.35	149
P12	06324500	Selenium, total, in µg/L	96	0.33	1.937	1.2	1.5	2.275	11.3
P12	06324500	Zinc, total, in µg/L	48	2	67.70	6.875	26.25	67.75	418
P12	06324500	Suspended sediment, <0.0625 mm, percent	91	45	89.44	85	96	98	99
P12	06324500	Suspended sediment, in mg/L	91	11	1,044	179	417	866	11,000
P12	06324500	Suspended sediment, tons/day	91	0.02	2,884	44	208	740	102,000
P13	06324710	Streamflow, in cubic feet per second	4	1.1	--	--	--	--	222
P13	06324710	Turbidity, nephelometric turbidity ratio units	4	3	--	--	--	--	100
P13	06324710	Dissolved oxygen, in mg/L	4	7.4	--	--	--	--	9.5

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
P13	06324710	Dissolved oxygen, percent saturation	3	108	--	--	--	--	136
P13	06324710	pH, in standard units	4	8.1	--	--	--	--	8.4
P13	06324710	Specific conductance, at 25 degrees Celsius, in µS/cm	4	1,690	--	--	--	--	4,750
P13	06324710	Temperature, water deg C	4	22.5	--	--	--	--	28
P13	06324710	Hardness, in mg/L as $CaCO_3$	4	570	--	--	--	--	1,400
P13	06324710	Calcium, dissolved, in mg/L	4	130	--	--	--	--	304
P13	06324710	Magnesium, dissolved, in mg/L	4	59.3	--	--	--	--	162
P13	06324710	Potassium, dissolved, in mg/L	4	6.54	--	--	--	--	18.5
P13	06324710	Sodium-adsorption ratio (unitless)	4	3.4	--	--	--	--	7.4
P13	06324710	Sodium, dissolved, in mg/L	4	188	--	--	--	--	639
P13	06324710	Alkalinity, in mg/L as $CaCO_3$	4	198	--	--	--	--	250
P13	06324710	Chloride, dissolved, in mg/L	4	72.9	--	--	--	--	235
P13	06324710	Fluoride, dissolved, in mg/L	4	0.31	--	--	--	--	0.5
P13	06324710	Silica, dissolved, in mg/L	4	8.46	--	--	--	--	11.5
P13	06324710	Sulfate, dissolved, in mg/L	4	608	--	--	--	--	2,220
P13	06324710	Dissolved solids, calculated, in mg/L	4	1,190	--	--	--	--	3,740
P13	06324710	Dissolved solids, tons/day	4	11.1	--	--	--	--	907
P14	06324790	Streamflow, in cubic feet per second	2	0.27	--	--	--	--	1.2
P14	06324790	Turbidity, nephelometric turbidity ratio units	2	1.5	--	--	--	--	2.8
P14	06324790	Dissolved oxygen, in mg/L	2	10	--	--	--	--	11.2
P14	06324790	Dissolved oxygen, percent saturation	1	--	--	--	--	--	147
P14	06324790	pH, in standard units	2	8.1	--	--	--	--	8.5
P14	06324790	Specific conductance, at 25 degrees Celsius, in µS/cm	2	2,050	--	--	--	--	2,060
P14	06324790	Temperature, water deg C	2	20.8	--	--	--	--	22.8
P14	06324790	Hardness, in mg/L as $CaCO_3$	3	730	--	--	--	--	1,100
P14	06324790	Calcium, dissolved, in mg/L	3	144	--	--	--	--	239
P14	06324790	Magnesium, dissolved, in mg/L	3	89.7	--	--	--	--	115
P14	06324790	Potassium, dissolved, in mg/L	3	22.6	--	--	--	--	38.8
P14	06324790	Sodium-adsorption ratio (unitless)	3	1.5	--	--	--	--	3.2
P14	06324790	Sodium, dissolved, in mg/L	3	106	--	--	--	--	201
P14	06324790	Alkalinity, in mg/L as $CaCO_3$	3	146	--	--	--	--	259
P14	06324790	Chloride, dissolved, in mg/L	3	41.3	--	--	--	--	88.6
P14	06324790	Fluoride, dissolved, in mg/L	3	0.68	--	--	--	--	0.93
P14	06324790	Silica, dissolved, in mg/L	3	9.7	--	--	--	--	23.4
P14	06324790	Sulfate, dissolved, in mg/L	3	704	--	--	--	--	1,030
P14	06324790	Dissolved solids, calculated, in mg/L	3	1,420	--	--	--	--	1,690
P14	06324790	Dissolved solids, tons/day	2	1.14	--	--	--	--	4.57
P15	06324970	Streamflow, in cubic feet per second	50	0.02	10.80	1.35	3.1	10.175	95
P15	06324970	Turbidity, nephelometric turbidity ratio units	2	35	--	--	--	--	96
P15	06324970	Dissolved oxygen, in mg/L	49	4.6	10.14	8.65	10.5	12.1	13.6
P15	06324970	Dissolved oxygen, percent saturation	48	55	102.8	95.25	101.5	112	136
P15	06324970	pH, in standard units	50	7.6	8.12	8	8.1	8.3	8.5
P15	06324970	Specific conductance, at 25 degrees Celsius, in µS/cm	50	500	3,116	2,285	3,310	3,945	5,170
P15	06324970	Temperature, water deg C	50	0	10.99	0.5	12.2	19.5	24.8
P15	06324970	Hardness, in mg/L as $CaCO_3$	48	81	800.4	565	865	990	1,400
P15	06324970	Calcium, dissolved, in mg/L	48	18.7	154.5	111.5	161	187.5	298
P15	06324970	Magnesium, dissolved, in mg/L	48	8.24	100.6	69.275	111.5	125.75	186
P15	06324970	Potassium, dissolved, in mg/L	48	6.53	18.21	15.35	18.5	21.3	28.3
P15	06324970	Sodium-adsorption ratio (unitless)	48	1.9	6.748	5.325	7	8	10
P15	06324970	Sodium, dissolved, in mg/L	48	54.5	445.1	326	479.5	589.25	836
P15	06324970	Acid neutralizing capacity, in mg/L as $CaCO_3$	47	98	357.2	276	370	420	728
P15	06324970	Alkalinity, in mg/L as $CaCO_3$	48	82	347.2	263	361.5	410.25	734
P15	06324970	Chloride, dissolved, in mg/L	48	6.75	69.70	38.1	52.6	79.425	298
P15	06324970	Fluoride, dissolved, in mg/L	48	0.21	0.662	0.555	0.675	0.748	1.09
P15	06324970	Silica, dissolved, in mg/L	48	1.92	9.288	7.483	9.12	11.15	15.2
P15	06324970	Sulfate, dissolved, in mg/L	48	138	1,334	901.75	1,395	1,770	2,420
P15	06324970	Dissolved solids, calculated, in mg/L	48	299	2,340	1,625	2,525	3,033	4,200
P15	06324970	Dissolved solids, tons/day	48	0.2	54.88	8.868	24.9	62.975	422
P15	06324970	Dissolved solids, residue on evaporation, in mg/L	48	324	2,485	1,725	2,635	3,188	4,400
P15	06324970	*Ammonia, dissolved, in mg/L as N	38	--	0.018	0.009	0.012	0.02	0.128

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
P15	06324970	*Nitrate plus nitrite, dissolved, in mg/L as N	38	--	0.052	0.014	0.027	0.05	0.49
P15	06324970	*Nitrite, dissolved, in mg/L as N	38	--	0.002	0.001	0.001	0.002	0.012
P15	06324970	*Orthophosphate, dissolved, in mg/L as P	38	--	0.009	0.004	0.006	0.009	0.102
P15	06324970	Total nitrogen, total, in mg/L	38	0.33	0.836	0.46	0.565	0.928	3.95
P15	06324970	Aluminum, total, in µg/L	48	91	1,564	242.5	430	1,435	33,900
P15	06324970	Arsenic, dissolved, in µg/L	48	0.43	0.93	0.69	0.84	1.1	2.3
P15	06324970	*Arsenic, total, in µg/L	47	--	1.725	1	1.3	1.8	15.4
P15	06324970	Barium, total, in µg/L	48	27.8	87.12	44.525	64.95	85.275	582
P15	06324970	*Beryllium, total, in µg/L	48	--	0.236	0.058	0.081	0.138	6.27
P15	06324970	Boron, total, in µg/L	48	55	214.6	148.5	194.5	261.25	615
P15	06324970	*Cadmium, total, in µg/L	47	--	0.088	0.021	0.04	0.05	2.2
P15	06324970	*Chromium, total, in µg/L	47	--	2.027	0.6	0.86	1.7	39
P15	06324970	*Copper, total, in µg/L	47	--	10.18	2.35	6.4	12.8	96.9
P15	06324970	*Iron, dissolved, in µg/L	48	--	18.21	9.139	14	18.024	136
P15	06324970	Iron, total, in µg/L	47	18	1,768	325	748	1,430	36,500
P15	06324970	Lead, total, in µg/L	47	0.13	4.346	0.32	0.83	2.69	130
P15	06324970	Manganese, dissolved, in µg/L	48	1.1	134.2	69.15	118.5	175.5	508
P15	06324970	Manganese, total, in µg/L	48	66.5	201.2	115.25	182.5	224.75	664
P15	06324970	Nickel, total, in µg/L	47	1.9	7.214	3.6	5.77	7.3	73
P15	06324970	Selenium, total, in µg/L	48	0.28	0.958	0.535	0.64	1.35	2.5
P15	06324970	*Zinc, total, in µg/L	47	--	17.27	3.9	7	12	410
P15	06324970	Suspended sediment, <0.0625 mm, percent	25	55	89.76	83	96	98	100
P15	06324970	Suspended sediment, in mg/L	45	35	308.2	72	128	157	7,750
P15	06324970	Suspended sediment, tons/day	45	0	13.43	0.47	1.2	4.1	322
P16	06325000	Streamflow, in cubic feet per second	2	7.6	--	--	--	--	8.1
P16	06325000	Turbidity, nephelometric turbidity ratio units	2	23	--	--	--	--	810
P16	06325000	Dissolved oxygen, in mg/L	2	6.4	--	--	--	--	6.8
P16	06325000	Dissolved oxygen, percent saturation	2	76	--	--	--	--	87
P16	06325000	pH, in standard units	2	7.9	--	--	--	--	8.1
P16	06325000	Specific conductance, at 25 degrees Celsius, in µS/cm	2	2,720	--	--	--	--	4,090
P16	06325000	Temperature, water deg C	2	17.5	--	--	--	--	21
P16	06325000	Hardness, in mg/L as $CaCO_3$	2	730	--	--	--	--	1,100
P16	06325000	Calcium, dissolved, in mg/L	2	152	--	--	--	--	219
P16	06325000	Magnesium, dissolved, in mg/L	2	84.8	--	--	--	--	141
P16	06325000	Potassium, dissolved, in mg/L	2	22	--	--	--	--	34
P16	06325000	Sodium-adsorption ratio (unitless)	2	5.7	--	--	--	--	8.1
P16	06325000	Sodium, dissolved, in mg/L	2	354	--	--	--	--	625
P16	06325000	Alkalinity, in mg/L as $CaCO_3$	2	246	--	--	--	--	324
P16	06325000	Chloride, dissolved, in mg/L	2	52.2	--	--	--	--	82.3
P16	06325000	Fluoride, dissolved, in mg/L	2	0.86	--	--	--	--	1.03
P16	06325000	Silica, dissolved, in mg/L	2	7.51	--	--	--	--	12.7
P16	06325000	Sulfate, dissolved, in mg/L	2	1,240	--	--	--	--	1,990
P16	06325000	Dissolved solids, calculated, in mg/L	2	2,060	--	--	--	--	3,300
P16	06325000	Dissolved solids, tons/day	2	42.1	--	--	--	--	72.5
P17	453209105201201	Streamflow, in cubic feet per second	3	0.01	--	--	--	--	85
P17	453209105201201	Turbidity, nephelometric turbidity ratio units	3	4.2	--	--	--	--	22
P17	453209105201201	Dissolved oxygen, in mg/L	3	5.8	--	--	--	--	11.1
P17	453209105201201	Dissolved oxygen, percent saturation	2	84	--	--	--	--	112
P17	453209105201201	pH, in standard units	3	8.1	--	--	--	--	8.4
P17	453209105201201	Specific conductance, at 25 degrees Celsius, in µS/cm	3	1,820	--	--	--	--	3,180
P17	453209105201201	Temperature, water deg C	3	25	--	--	--	--	32.5
P17	453209105201201	Hardness, in mg/L as $CaCO_3$	3	600	--	--	--	--	830
P17	453209105201201	Calcium, dissolved, in mg/L	3	136	--	--	--	--	189
P17	453209105201201	Magnesium, dissolved, in mg/L	3	62.6	--	--	--	--	97.8
P17	453209105201201	Potassium, dissolved, in mg/L	3	7.37	--	--	--	--	16.2
P17	453209105201201	Sodium-adsorption ratio (unitless)	3	3.7	--	--	--	--	7.1
P17	453209105201201	Sodium, dissolved, in mg/L	3	206	--	--	--	--	466
P17	453209105201201	Alkalinity, in mg/L as $CaCO_3$	3	201	--	--	--	--	289
P17	453209105201201	Chloride, dissolved, in mg/L	3	76.1	--	--	--	--	128
P17	453209105201201	Fluoride, dissolved, in mg/L	3	0.33	--	--	--	--	0.56

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
P17	453209105201201	Silica, dissolved, in mg/L	3	10.8	--	--	--	--	15.4
P17	453209105201201	Sulfate, dissolved, in mg/L	3	664	--	--	--	--	1,400
P17	453209105201201	Dissolved solids, calculated, in mg/L	3	1,280	--	--	--	--	2,420
P17	453209105201201	Dissolved solids, tons/day	3	0.06	--	--	--	--	326
P18	06326500	Streamflow, in cubic feet per second	50	0.2	501.1	90	168.5	401	4,300
P18	06326500	Dissolved oxygen, in mg/L	44	7.2	10.46	8.55	10.35	12.1	15
P18	06326500	Dissolved oxygen, percent saturation	43	76	99.07	94	100	105	133
P18	06326500	pH, in standard units	49	7.6	8.28	8.2	8.3	8.4	8.7
P18	06326500	Specific conductance, at 25 degrees Celsius, in µS/cm	49	634	2,060	1,760	2,050	2,485	3,580
P18	06326500	Temperature, water deg C	50	0	9.566	0	8.5	18	26
P18	06326500	Hardness, in mg/L as $CaCO_3$	48	120	510.4	422.5	535	590	860
P18	06326500	Calcium, dissolved, in mg/L	48	29.6	113.4	96.9	117	132.5	197
P18	06326500	Magnesium, dissolved, in mg/L	48	11.8	55.28	43.725	60.05	67.875	98.2
P18	06326500	Potassium, dissolved, in mg/L	48	3.16	8.922	7.812	8.565	10.29	14.2
P18	06326500	Sodium-adsorption ratio (unitless)	48	2.2	5.260	4.425	5.05	5.7	9.4
P18	06326500	Sodium, dissolved, in mg/L	48	65.2	273.3	212.5	257.5	343	520
P18	06326500	Acid neutralizing capacity, in mg/L as $CaCO_3$	46	124	309.3	234.5	287.5	345.75	738
P18	06326500	Alkalinity, in mg/L as $CaCO_3$	48	101	242.4	196	225	262.25	500
P18	06326500	Chloride, dissolved, in mg/L	48	20.9	95.09	65.05	103	123.25	185
P18	06326500	Fluoride, dissolved, in mg/L	48	0.26	0.481	0.41	0.475	0.55	0.78
P18	06326500	Silica, dissolved, in mg/L	48	3.3	9.315	7.125	8.8	11.15	16.2
P18	06326500	Sulfate, dissolved, in mg/L	48	149	732.1	579.25	714	925.25	1,320
P18	06326500	Dissolved solids, calculated, in mg/L	48	388	1,434	1,198	1,395	1,758	2,590
P18	06326500	Dissolved solids, tons/day	48	1.24	1,274	431	650.5	1,448	7,670
P18	06326500	*Ammonia, dissolved, in mg/L as N	48	--	0.025	0.006	0.012	0.035	0.162
P18	06326500	*Nitrate plus nitrite, dissolved, in mg/L as N	48	--	0.32	0.071	0.258	0.434	2.36
P18	06326500	*Nitrite, dissolved, in mg/L as N	48	--	0.003	0.001	0.002	0.003	0.043
P18	06326500	*Orthophosphate, dissolved, in mg/L as P	48	--	0.009	0.004	0.005	0.008	0.115
P18	06326500	Phosphorus, total, in mg/L	48	0.008	0.455	0.05	0.175	0.55	5.37
P18	06326500	Total nitrogen, total, in mg/L	48	0.27	1.624	0.46	0.895	1.588	14.2
P18	06326500	*Arsenic, total, in µg/L	48	--	5.765	1.4	2.85	8	23.6
P18	06326500	Barium, total, in µg/L	48	40.2	253.9	64.575	106.2	249.5	1,700
P18	06326500	Boron, total, in µg/L	48	50	199.1	159	193	220	544
P18	06326500	*Cadmium, total, in µg/L	48	--	0.626	0.04	0.15	0.608	5.74
P18	06326500	*Chromium, total, in µg/L	48	--	18.26	1.25	4.2	18.175	184
P18	06326500	*Copper, total, in µg/L	48	--	35.27	4.4	12.8	31.375	368
P18	06326500	Iron, total, in µg/L	48	59	22,594	1,615	5,225	23,375	186,000
P18	06326500	Lead, total, in µg/L	48	0.09	27.07	1.112	4.29	20.825	383
P18	06326500	Manganese, total, in µg/L	48	7.7	593.9	37.825	151	591.25	6,020
P18	06326500	**Mercury, total, µg/L	4	--	--	--	--	--	0.289
P18	06326500	Nickel, total, in µg/L	48	0.32	37.09	4.502	10.65	29.025	402
P18	06326500	Selenium, total, in µg/L	48	0.16	1.780	0.918	1.6	2.4	4.7
P18	06326500	Zinc, total, in µg/L	48	1.6	95.45	7	24	100.5	960
P18	06326500	Suspended sediment, <0.0625 mm, percent	47	28	86.13	81	89	96	99
P18	06326500	Suspended sediment, in mg/L	47	16	2,326	182	411	2,270	22,700
P18	06326500	Suspended sediment, tons/day	47	0.07	8,990	40	224	1,520	166,000
C1	06364300	Streamflow, in cubic feet per second	21	0	0.279	0.03	0.12	0.175	2.6
C1	06364300	Turbidity, nephelometric turbidity ratio units	2	1.8	--	--	--	--	13
C1	06364300	Dissolved oxygen, in mg/L	17	5.3	9.594	8.4	9.7	10.8	13.1
C1	06364300	Dissolved oxygen, percent saturation	14	43	95.14	89.75	98	104	124
C1	06364300	pH, in standard units	17	7.8	8.31	8.15	8.2	8.35	9.8
C1	06364300	Specific conductance, at 25 degrees Celsius, in µS/cm	16	2,240	3,128	2,768	2,975	3,488	5,080
C1	06364300	Temperature, water deg C	17	0	9.353	1	5.5	18.25	23.5
C1	06364300	Hardness, in mg/L as $CaCO_3$	15	470	587.3	480	580	690	800
C1	06364300	Calcium, dissolved, in mg/L	15	60.9	99.52	78.1	96.2	115	142
C1	06364300	Magnesium, dissolved, in mg/L	15	58.9	82.05	67.5	80.1	97.5	109
C1	06364300	Potassium, dissolved, in mg/L	15	6.98	9.666	7.72	8.86	10.3	14.6
C1	06364300	Sodium-adsorption ratio (unitless)	15	6.7	8.587	7.5	8.7	9.6	11
C1	06364300	Sodium, dissolved, in mg/L	15	359	476.6	406	460	551	625
C1	06364300	Alkalinity, in mg/L as $CaCO_3$	15	257	376.7	325	360	429	543

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
C1	06364300	Chloride, dissolved, in mg/L	15	12.6	18.85	15.7	17.4	22.8	26.4
C1	06364300	Fluoride, dissolved, in mg/L	15	0.9	1.252	1.1	1.19	1.39	1.79
C1	06364300	Silica, dissolved, in mg/L	15	0.16	2.207	0.55	1.9	3.08	5.45
C1	06364300	Sulfate, dissolved, in mg/L	15	890	1,205	983	1,180	1,290	1,800
C1	06364300	Dissolved solids, calculated, in mg/L	15	1,580	2,122	1,790	2,080	2,380	2,920
C1	06364300	Dissolved solids, tons/day	15	0.13	1.132	0.45	0.9	1.38	4.79
C1	06364300	Dissolved solids, residue on evaporation, in mg/L	15	1,610	2,215	1,880	2,170	2,490	3,190
C1	06364300	Aluminum, total, in µg/L	15	55	246.9	99	174	377	754
C1	06364300	Arsenic, dissolved, in µg/L	15	1.3	2.127	1.7	2	2.3	4.5
C1	06364300	Arsenic, total, in µg/L	8	2.1	2.450	2.125	2.25	2.825	3.2
C1	06364300	Barium, total, in µg/L	15	19.5	51.13	26.3	51.4	74.5	101
C1	06364300	**Beryllium, total, in µg/L	15	--	--	--	--	--	<0.12
C1	06364300	*Iron, dissolved, in µg/L	15	--	28.91	12	28	31	117
C1	06364300	Manganese, dissolved, in µg/L	15	47.2	150.8	72.9	118	166	515
C1	06364300	Selenium, total, in µg/L	15	0.1	0.759	0.14	0.21	1.5	1.8
C2	06364700	Streamflow, in cubic feet per second	51	0	0.029	0	0	0.07	0.12
C2	06364700	Turbidity, nephelometric turbidity ratio units	3	2.4	--	--	--	--	9.3
C2	06364700	Dissolved oxygen, in mg/L	23	3.4	6.426	5.1	5.6	7.5	11.6
C2	06364700	Dissolved oxygen, percent saturation	20	41	68.25	46.5	61	79.75	166
C2	06364700	pH, in standard units	23	7.1	7.55	7.3	7.6	7.7	8.1
C2	06364700	Specific conductance, at 25 degrees Celsius, in µS/cm	23	1,820	2,994	2,910	3,090	3,130	3,200
C2	06364700	Temperature, water deg C	23	0.5	10.55	3.5	9.5	15	29.1
C2	06364700	Hardness, in mg/L as $CaCO_3$	20	730	1,332	1,300	1,300	1,400	1,500
C2	06364700	Calcium, dissolved, in mg/L	20	192	317.7	308.5	321.5	336.25	361
C2	06364700	Magnesium, dissolved, in mg/L	20	61.1	132.2	132.25	136	138.75	151
C2	06364700	Potassium, dissolved, in mg/L	20	14.7	19.54	18.775	19.8	20.9	21.7
C2	06364700	Sodium-adsorption ratio (unitless)	20	1.9	3.050	2.825	3.15	3.275	3.7
C2	06364700	Sodium, dissolved, in mg/L	20	121	257.2	239.5	268	282.75	308
C2	06364700	Alkalinity, in mg/L as $CaCO_3$	20	320	388.9	353.5	396	417.5	438
C2	06364700	Chloride, dissolved, in mg/L	20	7.62	20.39	19.725	21.05	22.45	23.3
C2	06364700	Fluoride, dissolved, in mg/L	20	0.64	0.712	0.673	0.71	0.738	0.79
C2	06364700	Silica, dissolved, in mg/L	20	15.3	19.09	17.6	18.75	20.95	24.4
C2	06364700	Sulfate, dissolved, in mg/L	20	655	1,442	1,420	1,480	1,530	1,570
C2	06364700	Dissolved solids, calculated, in mg/L	20	1,280	2,442	2,395	2,525	2,580	2,620
C2	06364700	Dissolved solids, tons/day	20	0.04	0.524	0.312	0.56	0.728	0.92
C2	06364700	Dissolved solids, residue on evaporation, in mg/L	20	1,390	2,676	2,665	2,735	2,830	2,850
C2	06364700	*Ammonia, dissolved, in mg/L as N	12	--	0.025	0.02	0.026	0.032	0.034
C2	06364700	**Nitrate plus nitrite, dissolved, in mg/L as N	12	--	--	--	--	--	<0.06
C2	06364700	**Nitrite, dissolved, in mg/L as N	12	--	--	--	--	--	<0.008
C2	06364700	*Orthophosphate, dissolved, in mg/L as P	12	--	0.01	0.007	0.009	0.013	0.015
C2	06364700	Total nitrogen, total, in mg/L	12	0.24	0.379	0.29	0.325	0.447	0.7
C2	06364700	Aluminum, total, in µg/L	20	11	38.40	15.25	39	55.75	119
C2	06364700	Arsenic, dissolved, in µg/L	20	0.42	0.646	0.505	0.62	0.7	1.1
C2	06364700	*Arsenic, total, in µg/L	12	--	0.907	0.778	0.89	0.983	1.3
C2	06364700	Barium, total, in µg/L	20	22.4	40.29	24.85	27.35	34	192
C2	06364700	**Beryllium, total, in µg/L	20	--	--	--	--	--	<0.18
C2	06364700	Iron, dissolved, in µg/L	20	14	431.6	25	207.5	592.5	1,700
C2	06364700	Manganese, dissolved, in µg/L	20	402	1,735	1,045	1,545	2,100	4,850
C2	06364700	*Selenium, total, in µg/L	20	--	0.741	0.135	0.22	1.475	2.4
C3	06365900	Streamflow, in cubic feet per second	50	0	0.103	0	0.01	0.04	4.3
C3	06365900	Turbidity, nephelometric turbidity ratio units	2	6	--	--	--	--	49
C3	06365900	Dissolved oxygen, in mg/L	30	5.1	7.547	6.475	7.85	8.575	9.7
C3	06365900	Dissolved oxygen, percent saturation	26	41	70.96	63.75	71.5	80.25	95
C3	06365900	pH, in standard units	31	7.2	7.69	7.5	7.8	7.9	8.1
C3	06365900	Specific conductance, at 25 degrees Celsius, in µS/cm	29	263	3,814	3,275	3,870	4,185	6,560
C3	06365900	Temperature, water deg C	31	0	7.158	0	3.5	12.9	30.6
C3	06365900	Hardness, in mg/L as $CaCO_3$	29	65	1,448	1,250	1,500	1,650	2,100
C3	06365900	Calcium, dissolved, in mg/L	29	16.2	322.6	277	332	371.5	479
C3	06365900	Magnesium, dissolved, in mg/L	29	6.01	157.0	136.5	162	181.5	226
C3	06365900	Potassium, dissolved, in mg/L	29	8.49	18.65	15	20	21.85	28.1

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
C3	06365900	Sodium-adsorption ratio (unitless)	29	0.9	4.886	4.45	4.9	5.4	7.1
C3	06365900	Sodium, dissolved, in mg/L	29	17.1	435.5	372	438	502	732
C3	06365900	Alkalinity, in mg/L as $CaCO_3$	29	46	337.8	299.5	340	399.5	458
C3	06365900	Chloride, dissolved, in mg/L	29	3.28	27.17	26.15	28.3	31.05	34.4
C3	06365900	Fluoride, dissolved, in mg/L	29	0.18	0.632	0.59	0.64	0.69	0.86
C3	06365900	Silica, dissolved, in mg/L	29	3.67	12.46	9.235	12.2	15.6	22.2
C3	06365900	Sulfate, dissolved, in mg/L	29	64.4	1,966	1,655	1,950	2,265	3,100
C3	06365900	Dissolved solids, calculated, in mg/L	29	148	3,142	2,670	3,220	3,510	4,860
C3	06365900	Dissolved solids, tons/day	28	0.02	0.344	0.14	0.26	0.377	2.05
C3	06365900	Dissolved solids, residue on evaporation, in mg/L	29	175	3,415	2,905	3,430	3,845	5,180
C3	06365900	Aluminum, total, in µg/L	29	4	599.0	22	35	64.5	16,100
C3	06365900	Arsenic, dissolved, in µg/L	29	0.45	0.729	0.525	0.59	0.95	1.4
C3	06365900	*Arsenic, total, in µg/L	20	--	1.190	0.762	0.965	1.3	3.9
C3	06365900	Barium, total, in µg/L	29	14.8	39.17	20.25	25.6	30.8	258
C3	06365900	**Beryllium, total, in µg/L	29	--	--	--	--	--	1.33
C3	06365900	Iron, dissolved, in µg/L	29	16	594.7	42	533	972.5	2,540
C3	06365900	Manganese, dissolved, in µg/L	29	36.5	848.6	429	777	1,063	2,350
C3	06365900	Selenium, total, in µg/L	29	0.07	0.674	0.18	0.26	1.3	2.4
C4	06375600	Streamflow, in cubic feet per second	51	0	0.458	0	0	0.01	13
C4	06375600	Turbidity, nephelometric turbidity ratio units	3	19	--	--	--	--	42
C4	06375600	Dissolved oxygen, in mg/L	14	3.4	7.371	5.475	7.7	9.325	10.8
C4	06375600	Dissolved oxygen, percent saturation	11	46	88.55	67	93	112	124
C4	06375600	pH, in standard units	14	7.5	8.18	7.68	8.2	8.48	8.9
C4	06375600	Specific conductance, at 25 degrees Celsius, in µS/cm	14	232	1,798	858.75	1,610	2,075	6,370
C4	06375600	Temperature, water deg C	14	8	17.84	14.225	19	21.7	24.1
C4	06375600	Hardness, in mg/L as $CaCO_3$	11	59	339.7	160	350	550	720
C4	06375600	Calcium, dissolved, in mg/L	11	13.1	65.97	34.7	64.9	114	130
C4	06375600	Magnesium, dissolved, in mg/L	11	6.47	42.51	16.6	42.8	63.8	94.9
C4	06375600	Sodium-adsorption ratio (unitless)	11	0.9	4.264	2	4.3	5.8	8.3
C4	06375600	Sodium, dissolved, in mg/L	11	15.2	195.7	57.3	183	277	508
C4	06375600	Dissolved solids, residue on evaporation, in mg/L	11	145	1,046	394	987	1,380	2,460
C4	06375600	**Ammonia, dissolved, in mg/L as N	9	--	--	--	--	--	0.046
C4	06375600	**Nitrate plus nitrite, dissolved, in mg/L as N	9	--	--	--	--	--	0.36
C4	06375600	**Nitrite, dissolved, in mg/L as N	9	--	--	--	--	--	0.019
C4	06375600	**Orthophosphate, dissolved, in mg/L as P	9	--	--	--	--	--	<0.02
C4	06375600	Total nitrogen, total, in mg/L	9	0.64	1.211	0.76	1.04	1.405	2.78
C5	06376300	Streamflow, in cubic feet per second	51	0	1.520	0	0	0	24
C5	06376300	Turbidity, nephelometric turbidity ratio units	2	48	--	--	--	--	3,310
C5	06376300	Dissolved oxygen, in mg/L	12	5	7.850	6.55	7.7	8.85	11.3
C5	06376300	Dissolved oxygen, percent saturation	10	69	93.30	85.25	87.5	102.75	124
C5	06376300	pH, in standard units	12	7.5	7.98	7.73	7.95	8.28	8.5
C5	06376300	Specific conductance, at 25 degrees Celsius, in µS/cm	12	197	510.8	226.5	424	723.75	1,410
C5	06376300	Temperature, water deg C	12	0.5	16.79	15.55	17.35	22.15	24.4
C5	06376300	Hardness, in mg/L as $CaCO_3$	10	40	113.1	47.75	104	162.5	240
C5	06376300	Calcium, dissolved, in mg/L	10	8.9	26.39	11.225	24.2	37.35	58.5
C5	06376300	Magnesium, dissolved, in mg/L	10	4.23	11.48	4.86	10.59	16.725	23.3
C5	06376300	Potassium, dissolved, in mg/L	10	4.22	7.485	5.493	7.595	9.023	11.1
C5	06376300	Sodium-adsorption ratio (unitless)	10	0.9	1.720	1.1	1.75	2.3	2.4
C5	06376300	Sodium, dissolved, in mg/L	10	14.1	43.20	20.575	38.45	63.475	84.9
C5	06376300	Alkalinity, in mg/L as $CaCO_3$	10	34	80.20	44.5	75.5	121.25	139
C5	06376300	Chloride, dissolved, in mg/L	10	0.84	3.954	1.872	3.82	5.905	7.72
C5	06376300	Fluoride, dissolved, in mg/L	10	0.2	0.27	0.228	0.265	0.303	0.36
C5	06376300	Silica, dissolved, in mg/L	10	0.68	5.217	3.257	5.455	6.948	8.74
C5	06376300	Sulfate, dissolved, in mg/L	10	42.2	130.4	50.725	106.65	198.75	288
C5	06376300	Dissolved solids, calculated, in mg/L	10	113	276.5	123.75	257	394.75	555
C5	06376300	Dissolved solids, tons/day	10	0.05	4.286	0.225	1.88	9.032	15.9
C5	06376300	Dissolved solids, residue on evaporation, in mg/L	10	134	307.9	162.75	282.5	427.5	590
C5	06376300	Aluminum, total, in µg/L	10	117	10,456	4,793	10,650	14,725	25,800
C5	06376300	Arsenic, dissolved, in µg/L	10	0.49	0.781	0.623	0.76	0.903	1.2
C5	06376300	Arsenic, total, in µg/L	8	0.93	3.741	2.525	3.9	4.575	6.4

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Mini-mum	Mean	25th percentile	Median	75th percentile	Maxi-mum
C5	06376300	Barium, total, in µg/L	10	71.1	195.1	112.5	170	263.25	426
C5	06376300	*Beryllium, total, in µg/L	10	--	1.011	0.298	0.965	1.528	2.79
C5	06376300	Iron, dissolved, in µg/L	10	5	34.30	15.5	27	51.25	98
C5	06376300	Manganese, dissolved, in µg/L	10	1.1	6.530	1.4	3	10.925	18.8
C5	06376300	Selenium, total, in µg/L	10	0.57	1.213	0.8	1.05	1.825	2.1
C6	06386500	Streamflow, in cubic feet per second	44	0	5.893	0.012	0.12	1.275	121
C6	06386500	Turbidity, nephelometric turbidity ratio units	2	3.4	--	--	--	--	160
C6	06386500	Dissolved oxygen, in mg/L	35	4.6	8.903	7.6	8.7	10.4	11.6
C6	06386500	Dissolved oxygen, percent saturation	33	43	99.21	88.5	102	110.5	149
C6	06386500	pH, in standard units	35	7.6	8.07	7.9	8.1	8.3	8.4
C6	06386500	Specific conductance, at 25 degrees Celsius, in µS/cm	36	541	4,497	3,498	4,995	5,515	7,100
C6	06386500	Temperature, water deg C	36	0	13.75	2.125	13.5	23.85	30.5
C6	06386500	Hardness, in mg/L as $CaCO_3$	34	120	1,015	772.5	1,100	1,300	1,700
C6	06386500	Calcium, dissolved, in mg/L	34	31.1	236.7	178.5	247.5	307.75	407
C6	06386500	Magnesium, dissolved, in mg/L	34	10.7	102.0	79.25	112	129.75	171
C6	06386500	Potassium, dissolved, in mg/L	34	6.36	11.74	10.45	11.85	13.45	15.3
C6	06386500	Sodium-adsorption ratio (unitless)	34	2.3	9.594	7.625	10.5	11.25	14
C6	06386500	Sodium, dissolved, in mg/L	34	59	719.3	500.75	815	917.25	1,190
C6	06386500	Alkalinity, in mg/L as $CaCO_3$	34	87	258.7	240.25	262.5	285.5	397
C6	06386500	Chloride, dissolved, in mg/L	34	5.27	88.75	65.6	97	110.75	148
C6	06386500	Fluoride, dissolved, in mg/L	34	0.3	0.564	0.53	0.57	0.623	0.72
C6	06386500	Silica, dissolved, in mg/L	34	1.79	7.235	5.507	7.44	9.14	10.8
C6	06386500	Sulfate, dissolved, in mg/L	34	150	2,193	1,593	2,485	2,815	3,490
C6	06386500	Dissolved solids, calculated, in mg/L	34	329	3,513	2,583	3,930	4,500	5,590
C6	06386500	Dissolved solids, tons/day	34	0.11	18.57	0.535	3.995	16.825	181
C6	06386500	Dissolved solids, residue on evaporation, in mg/L	34	363	3,737	2,858	4,125	4,743	5,990
C6	06386500	**Ammonia, dissolved, in mg/L as N	2	--	--	--	--	--	<0.04
C6	06386500	**Nitrate plus nitrite, dissolved, in mg/L as N	2	--	--	--	--	--	<0.06
C6	06386500	**Nitrite, dissolved, in mg/L as N	2	--	--	--	--	--	<0.008
C6	06386500	**Orthophosphate, dissolved, in mg/L as P	2	--	--	--	--	--	<0.02
C6	06386500	Total nitrogen, total, in mg/L	2	0.53	--	--	--	--	0.6
C6	06386500	Aluminum, total, in µg/L	34	18	1,875	71.25	130.5	428	34,400
C6	06386500	Arsenic, dissolved, in µg/L	34	0.46	0.976	0.637	0.735	1.225	2.2
C6	06386500	*Arsenic, total, in µg/L	28	--	1.671	0.905	1.1	1.7	10.3
C6	06386500	Barium, total, in µg/L	34	17.3	59.57	22.325	27.75	61.05	513
C6	06386500	*Beryllium, total, in µg/L	34	--	0.261	0.03	0.065	0.122	4.36
C6	06386500	*Iron, dissolved, in µg/L	34	--	22.22	11.965	16.381	19.84	140
C6	06386500	Manganese, dissolved, in µg/L	34	5.7	407.0	176.75	383.5	536.5	1,620
C6	06386500	Selenium, total, in µg/L	34	0.13	1.027	0.558	0.67	1.2	3.3
B1	06425720	Streamflow, in cubic feet per second	50	0	1.291	0	0.58	1.8	11
B1	06425720	Turbidity, nephelometric turbidity ratio units	2	4.3	--	--	--	--	5.7
B1	06425720	Dissolved oxygen, in mg/L	36	2.1	8.256	7.4	8.45	9.8	12.3
B1	06425720	Dissolved oxygen, percent saturation	34	17	82.03	68	87	97.5	136
B1	06425720	pH, in standard units	37	7.5	8.08	7.8	8.1	8.3	8.8
B1	06425720	Specific conductance, at 25 degrees Celsius, in µS/cm	37	1,760	3,068	2,630	2,920	3,335	6,210
B1	06425720	Temperature, water deg C	37	0	7.457	0	4.5	14.65	29.8
B1	06425720	Hardness, in mg/L as $CaCO_3$	35	560	946.9	800	890	1,100	2,200
B1	06425720	Calcium, dissolved, in mg/L	35	65.2	174.4	134	162	195	394
B1	06425720	Magnesium, dissolved, in mg/L	35	67.4	124.5	107	120	137	300
B1	06425720	Potassium, dissolved, in mg/L	29	8.47	13.66	11.3	12.6	15.3	26.7
B1	06425720	Sodium-adsorption ratio (unitless)	35	3.7	5.429	4.8	5.4	6.1	7.6
B1	06425720	Sodium, dissolved, in mg/L	35	200	385.2	319	372	445	825
B1	06425720	Alkalinity, in mg/L as $CaCO_3$	29	90	295.5	227	282	314.5	778
B1	06425720	Chloride, dissolved, in mg/L	29	10.2	23.51	17.5	20.4	28.5	62.1
B1	06425720	Fluoride, dissolved, in mg/L	29	0.51	0.786	0.69	0.78	0.875	1.21
B1	06425720	Silica, dissolved, in mg/L	29	0.37	2.489	1.245	1.83	3.07	9.68
B1	06425720	Sulfate, dissolved, in mg/L	29	745	1,480	1,285	1,450	1,585	3,180
B1	06425720	Dissolved solids, calculated, in mg/L	29	1,270	2,388	2,110	2,260	2,600	5,270
B1	06425720	Dissolved solids, tons/day	29	0.9	10.57	3.195	8.08	12.2	40.6
B1	06425720	Dissolved solids, residue on evaporation, in mg/L	35	1,370	2,550	2,150	2,450	2,810	5,720

Appendix. Summary statistics for water-quality constituents, Powder River structural basin, Wyoming and Montana, water years 2005–08.—Continued

[--, value cannot be calculated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; $CaCO_3$, calcium carbonate; as N, as nitrogen; as P, as phosphorus; µg/L, micrograms per liter; ng/L, nanograms per liter; mm, millimeters; *, constituent statistics were estimated using a log-probability regression; **, too many non-detected constituent concentrations to estimate statistics with log-probablity regression]

Site number (fig. 1)	Site identification number	Constituent	Sample size	Minimum	Mean	25th percentile	Median	75th percentile	Maximum
B1	06425720	Aluminum, total, in µg/L	29	3	165.6	66.5	98	155	1,820
B1	06425720	Arsenic, dissolved, in µg/L	29	0.46	0.955	0.705	0.81	1.045	2
B1	06425720	Arsenic, total, in µg/L	26	0.77	1.325	1	1.25	1.5	2.7
B1	06425720	Barium, total, in µg/L	29	20	37.61	29.8	35.1	42.95	81.5
B1	06425720	**Beryllium, total, in µg/L	29	--	--	--	--	--	0.15
B1	06425720	Iron, dissolved, in µg/L	29	15	56.48	26	47	81	185
B1	06425720	Manganese, dissolved, in µg/L	29	40.1	394.1	106.5	165	312.5	4,090
B1	06425720	Selenium, total, in µg/L	29	0.13	0.479	0.215	0.32	0.565	1.8
B2	06425900	Streamflow, in cubic feet per second	51	0	0.541	0	0	0.2	4.8
B2	06425900	Turbidity, nephelometric turbidity ratio units	2	21	--	--	--	--	160
B2	06425900	Dissolved oxygen, in mg/L	20	4.7	9.505	8.2	9.85	11.125	12.4
B2	06425900	Dissolved oxygen, percent saturation	19	58	93.16	86	94	101	137
B2	06425900	pH, in standard units	21	7.8	8.19	8	8.2	8.3	8.6
B2	06425900	Specific conductance, at 25 degrees Celsius, in µS/cm	21	1,100	2,865	2,155	2,480	3,315	5,370
B2	06425900	Temperature, water deg C	21	0	8.819	1.5	8.8	15.3	23.9
B2	06425900	Hardness, in mg/L as $CaCO_3$	19	340	981.1	670	820	1,100	2,200
B2	06425900	Calcium, dissolved, in mg/L	19	67.1	175.7	124	148	208	392
B2	06425900	Magnesium, dissolved, in mg/L	19	40.9	133.2	84.7	109	162	300
B2	06425900	Potassium, dissolved, in mg/L	19	7.93	20.44	14.6	18	22.8	42.7
B2	06425900	Sodium-adsorption ratio (unitless)	19	2.3	4.279	3.5	4.4	4.9	6.4
B2	06425900	Sodium, dissolved, in mg/L	19	110	313.8	218	272	366	640
B2	06425900	Alkalinity, in mg/L as $CaCO_3$	19	161	303.9	214	292	340	778
B2	06425900	Chloride, dissolved, in mg/L	19	10.9	46.50	29.7	45.2	63.2	81.5
B2	06425900	Fluoride, dissolved, in mg/L	19	0.53	0.943	0.78	0.86	1.1	1.84
B2	06425900	Silica, dissolved, in mg/L	19	0.15	3.798	0.9	3.2	6.14	11
B2	06425900	Sulfate, dissolved, in mg/L	19	384	1,309	810	1,110	1,580	3,210
B2	06425900	Dissolved solids, calculated, in mg/L	19	730	2,184	1,520	1,820	2,510	4,780
B2	06425900	Dissolved solids, tons/day	19	0.28	5.603	0.93	2.06	10.1	18.8
B2	06425900	Dissolved solids, residue on evaporation, in mg/L	19	761	2,394	1,640	2,030	2,840	5,280
B2	06425900	*Ammonia, dissolved, in mg/L as N	13	--	0.023	0.012	0.017	0.025	0.067
B2	06425900	**Nitrate plus nitrite, dissolved, in mg/L as N	13	--	--	--	--	--	<0.06
B2	06425900	**Nitrite, dissolved, in mg/L as N	13	--	--	--	--	--	<0.002
B2	06425900	*Orthophosphate, dissolved, in mg/L as P	13	--	0.006	0.004	0.005	0.007	0.012
B2	06425900	Total nitrogen, total, in mg/L	13	0.45	0.687	0.49	0.59	0.935	1.09
B2	06425900	Aluminum, total, in µg/L	19	45	173.8	76	115	208	697
B2	06425900	Arsenic, dissolved, in µg/L	19	0.55	1.204	0.69	1.1	1.5	3.3
B2	06425900	Arsenic, total, in µg/L	13	0.66	1.241	0.785	1.2	1.7	2.3
B2	06425900	Barium, total, in µg/L	19	23.4	49.03	35.7	44.3	62.3	84.3
B2	06425900	**Beryllium, total, in µg/L	19	--	--	--	--	--	<0.18
B2	06425900	*Iron, dissolved, in µg/L	19	--	28.64	16	24	38	70
B2	06425900	Manganese, dissolved, in µg/L	19	6.1	76.89	15	55.9	109	258
B2	06425900	Selenium, total, in µg/L	19	0.39	2.245	0.56	1.7	2.5	11.6

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