

WWE
MEMORANDUM

To: Big Dry Creek Watershed Association Board of Directors

From: Wright Water Engineers, Inc.
Jane Clary and Noah Greenberg

Date: April 10, 2012

Re: Big Dry Creek Water Quality Summary for 2011

This memorandum summarizes the water quality monitoring program conducted by the Big Dry Creek Watershed Association (BDCWA) during 2011 and discusses these topics:

- Data summary and comparison to stream standards
- Key constituents of interest
 - a. *E. coli*
 - b. Selenium
 - c. Nutrients
 - d. Temperature
- Flow conditions
- Quality assurance/quality control

Data Summary and Comparison to Stream Standards

During 2011, the City and County of Broomfield and the cities of Northglenn, Thornton, and Westminster (Cities) worked together to collect water quality and flow data along the main stem of Big Dry Creek (Figure 1), consistent with the on-going BDCWA monitoring program (BDCWA 2003). The Cities and BDCWA also helped to fund operation of the U.S. Geological Survey (USGS) gauging station at Westminster behind Front Range Community College. A clear understanding of the hydrologic regime for Big Dry Creek is important due to its significant effect on pollutant loading and instream concentrations. Figure 2 provides a conceptual summary of the key discharges and diversions along the creek, along with the USGS gauging station locations.

Water quality samples were collected and analyzed for a variety of constituents, resulting in over 2,700 records being added into the BDCWA water quality database. Metals were monitored on a quarterly basis with the exception of selenium, which was monitored monthly. All other constituents were monitored on a monthly basis. The Big Dry Creek monitoring program is an ambient-based program. Table 1 summarizes field conditions on sampling dates, as recorded at various locations in the watershed.

Table 1. Summary of Field Conditions During 2011 Sampling Events

Date	Rain (in) @ Standley Lake Dam	Rain (in) @ Fort Lupton CoAgMet	Standley Release (cfs)	USGS West. Flow (cfs)	USGS Ft. Lupton Flow (cfs)	Comment
01/13/11	0.00	0.07	0.0	2.0	65.0	No Standley releases this month. Upstream sites frozen.
02/10/11	0.00	0.00	0.0	2.1	65.0	No Standley releases this month. Upstream sites frozen.
03/10/11	0.00	0.00	0.0	1.1	22.0	No Standley releases this month.
04/20/11	0.10	0.03	6.0	9.2	39.0	Minimal Standley releases April 19-22 @ 6 cfs.
05/12/11	0.70	0.70	0.0	90.0	259.0	No Standley releases this month. Rainfall preceding day @ Fort Lupton was 1.07".
06/09/11	0.10	0.00	0.0	9.6	37.0	Regular Standley releases (avg. rate 63 cfs, 19 days in June).
07/14/11	0.05	0.05	45.0	118.0	307.0	Regular Standley releases (avg. rate 54 cfs, 31 days in July). Rainfall 7/11-7/13 totaled 1.7".
08/04/11	0.00	0.00	15.0	16.0	1.3	Regular Standley releases (avg. rate 25 cfs, 31 days in August)
09/08/11	0.00	0.00	42.0	41.0	33.0	Regular Standley releases (diminishing rates, 24 cfs down to 9 cfs later in month, avg. rate 16 cfs, 22 days in Sept.)
10/13/11	0.00	0.00	0.0	1.6	29.0	No Standley releases this month.
11/10/11	NA	0.00	NA	2.3	33.0	Standley releases not yet available.
12/08/11	NA	0.01	NA	1.8	41.0	Standley releases not yet available. Upstream sites frozen and low water levels at bdc2.0.

General Notes: USGS flow data were obtained from the USGS NWIS website. Standley Lake precip. & release data recorded by dam tender. Fort Lupton precip. obtained from CoAgMet (www.coagmet.com).

Based on information in Table 1, the following field conditions are noteworthy:

- Standley Lake releases occurred during June through September, with minor releases in April.
- May and July sampling conditions are influenced by stormwater runoff (stream flows of 259 cfs and 307 cfs, respectively at Fort Lupton gage).
- During the August sampling event, flows at the Fort Lupton gage were unusually low (1.3 cfs).

Other changes that occurred during 2011 include:

- For sampling safety reasons, sampling location bdc4.0 was moved downstream beginning in April 2011 and is named bdc4.5. For purposes of this technical summary, bdc4.0 and bdc4.5 data are represented as one sample location called bdc4.0. Similarly, bdc2.0 was moved approximately 50 feet upstream of for sampling safety reasons.
- A substantial Russian olive removal effort occurred along a portion of Big Dry Creek in the Westminster Open Space in the fall of 2011. This habitat change may influence water quality and aquatic life results in 2012. (Russian olive is considered an invasive species.)

An overview of water quality samples collected during 2011 is provided in these tables and attachments:

- Table 2 identifies the Colorado Water Quality Control Commission (CWQCC) stream standards for Segment 1 of Big Dry Creek, the frequency with which standards were exceeded and whether the stream attained the standard for each constituent.
- Table 3 provides a summary of the numbers of samples collected and the average, minimum and maximum concentrations for each constituent. The relevant regulatory statistic (e.g., 85th percentile as explained below) for constituents with stream standards is also provided, along with a range of percentile values.
- Attachment 1 provides a summary of the instream data collected during 2011 for each monitoring station. These data have been added to the BDCWA water quality database.
- Attachment 2 provides a summary of quality assurance (QA) samples collected in accordance with the Big Dry Creek Sampling and Analysis Plan (BDCWA 2003).
- Attachment 3 provides a summary of grab samples from municipal wastewater treatment plant (WWTP) discharges to Big Dry Creek during 2011. These samples were collected in accordance with Colorado Discharge Permit System (CDPS) permit requirements and are provided as a courtesy from the City and County of Broomfield and the City of Westminster to provide supplemental information on the quality of discharges to Big Dry Creek at the time of instream sample collection. Although Broomfield, Westminster and Northglenn are permitted to discharge to Big Dry Creek, Northglenn rarely discharges to the creek and did not discharge to Big Dry Creek during 2011.

Table 2.
Comparison of 2011 Big Dry Creek Data to Stream Standards

PARAMETER	STANDARD TYPE	STREAM STANDARD	UNIT	# OF INSTREAM SAMPLES ¹	# OF VALUES GREATER THAN STD ³	DOES 85th (or 50th) PERCENTILE VALUE FOR 2011 EXCEED STANDARD? ⁴	% OF SAMPLES EXCEEDING STANDARD	# SAMPLE EVENTS (DAYS) STANDARD EXCEEDED	COMMENT
PHYSICAL AND BIOLOGICAL									
DO		5	mg/L	87	0	NO	0%	0	
pH		6.5-9.0	SU	87	0	NO	0%	0	
<i>E. coli</i>	(P=Potential Primary Contact)	205	#/100mL	87					
Jan-Feb		205	#/100mL	9	8	YES	89%	2	
Mar-Apr		205	#/100mL	16	2	NO	13%	2	
May-Jun		205	#/100mL	16	16	YES	100%	2	
Jul-Aug		205	#/100mL	16	13	YES	81%	2	
Sept-Oct		205	#/100mL	16	12	YES	75%	2	
Nov-Dec		205	#/100mL	14	9	YES	64%	2	
Ammonia	acute	TVS	mg/L	87	0	NO		0	
Ammonia	chronic	0.1	mg/L	87	0	NO		0	
Chlorine	acute	0.019	mg/L	N/A	N/A	N/A	N/A	N/A	
Chlorine	chronic	0.011	mg/L	N/A	N/A	N/A	N/A	N/A	
Cyanide		0.005	mg/L	22	0	NO	0%	0	June 2011 samples not provided.
Sulfide		0.002	mg/L	N/A	N/A	N/A	N/A	N/A	
Boron		0.75	mg/L	30	0	NO	0%	0	
Nitrite		4.5	mg/L	87	0	NO	0%	0	
METALS (DISSOLVED UNLESS OTHERWISE NOTED)²									
Arsenic (Trec)	Acute	340	µg/L	30	0	NO	0%	0	
Arsenic (Trec)	Chronic	100	µg/L	30	0	NO	0%	0	
Beryllium	Chronic	100	µg/L	N/A	N/A	N/A	N/A	N/A	
Cadmium	Acute	7.8	µg/L	30	0	NO	0%	0	
Cadmium	Chronic	1.0	µg/L	30	0	NO	0%	0	
Chromium III	Acute	1526	µg/L	30	0	NO	0%	0	
Chromium III	Chronic	199	µg/L	30	0	NO	0%	0	
Chromium VI	Acute	16	µg/L	30	0	NO	0%	0	
Chromium VI	Chronic	11	µg/L	30	0	NO	0%	0	
Copper	Acute	42	µg/L	30	0	NO	0%	0	
Copper	Chronic	25	µg/L	30	0	NO	0%	0	
Iron (Trec)	Chronic	1000	µg/L	30	0	NO	0%	0	
Lead	Acute	232	µg/L	30	0	NO	0%	0	
Lead	Chronic	9.1	µg/L	30	0	NO	0%	0	
Mercury (tot)	Acute	0.01	µg/L	12	0	N/A	N/A	N/A	
Manganese	Acute	4457	µg/L	30	0	NO	0%	0	
Manganese	Chronic	2463	µg/L	30	0	NO	0%	0	
Nickel	Acute	1296	µg/L	30	0	NO	0%	0	
Nickel	Chronic	144	µg/L	30	0	NO	0%	0	
Selenium (Irrigation 4/1-10/31)	Acute	18.4	µg/L	56	0	NO	0%	0	Max = 11 ug/L
Selenium (Irrigation)	Chronic	7.4	µg/L	56	1	NO	2%	1	85th% = 4.6 ug/L
Selenium (Non-irrigation 11/1-3/31)	Acute	19.1	µg/L	31	0	NO	0%	0	Max = 12 ug/L
Selenium (Non-irrigation)	Chronic	15.0	µg/L	31	0	NO	0%	0	85th% = 10.5 ug/L
Silver	Acute	16	µg/L	30	0	NO	0%	0	
Silver	Chronic	2.5	µg/L	30	0	NO	0%	0	
Zinc	Acute	400	µg/L	30	0	NO	0%	0	
Zinc	Chronic	347	µg/L	30	0	NO	0%	0	

¹Based on data collected at all in-stream sampling locations along Segment 1 of Big Dry Creek.

²The hardness-based metal standards in this table are calculated using a hardness value of 333 mg/L.

³May include multiple exceedances that occurred on the same day at different stations for some parameters.

⁴The 85th percentile value is used by the CWQCD to assess whether streams attain most water quality standards. The 50th percentile value is used for metals with standards in the total form. Geometric mean is used for E. coli. For regulatory purposes, the last five years of data would be included to assess standards attainment.

Table 3. Big Dry Creek Instream Sample Summary 2011

Parameter	Sample Fraction	Units	Det. Limit	# Non-detects	Min	Max	Mean	Std. Dev.	15th %	25th %	50th % (Median)	75th %	85th %
ALKALINITY, TOTAL	Total	mg/L	1	0	49	298	160	60	91	114	160	198	215
ARSENIC	Total Recovrble	mg/L	0.001	30	<DL	<DL	<DL	NA	<DL	<DL	<DL	<DL	<DL
BORON	Total	mg/L	0.01	0	0.05	0.42	0.28	0.10	0.16	0.24	0.31	0.36	0.38
CADMIUM	Dissolved	mg/L	0.0003	30	<DL	<DL	<DL	NA	<DL	<DL	<DL	<DL	<DL
CALCIUM	Total	mg/L	1	0	29	172	89	32	53	59	90	114	120
CARBON, TOTAL ORGANIC	Total	mg/L	0.15	0	2.22	9.62	6.46	1.66	5.06	5.93	6.65	7.36	8.10
CHLORIDE	Dissolved	mg/L	0.2	0	21.1	595.0	133.9	95.6	50.3	79.6	120.6	156.3	189.4
CHROMIUM	Dissolved	mg/L	0.0004	30	<DL	<DL	<DL	NA	<DL	<DL	<DL	<DL	<DL
CHLOROPHYLL A, COR.		ug/L	0.1	0	0.05	32.60	7.47	5.63	2.49	3.30	5.70	11.05	13.13
CHLOROPHYLL A, UNCOR.		ug/L	0.1	0	0.1	36.5	9.3	6.4	3.7	4.4	7.3	13.3	15.9
Cond.		uS/cm		0	202	3590	1254	597	645	756	1297	1617	1707
COPPER	Dissolved	mg/L	0.0007	0	0.0030	0.0120	0.0065	0.0024	0.0040	0.0050	0.0060	0.0080	0.0090
CYANIDE	Total	mg/L	0.004	22	<DL	<DL	<DL	NA	<DL	<DL	<DL	<DL	<DL
DO	Dissolved	mg/L		0	7.0	16.2	9.8	1.8	7.9	8.3	9.6	11.1	11.8
E. coli		#/100 ml	1	1	<DL	2420	735	712	103	173	517	1046	1428
IRON	Total Recovrble	mg/L	0.04	0	0.11	1.62	0.66	0.43	0.23	0.31	0.59	0.82	0.96
LEAD	Dissolved	mg/L	0.001	30	<DL	<DL	<DL	NA	<DL	<DL	<DL	<DL	<DL
MAGNESIUM	Dissolved	mg/L	0.15	0	5.68	59.27	25.98	12.28	12.10	14.39	25.91	33.12	35.26
MANGANESE	Dissolved	mg/L	0.0002	0	0.0090	0.8000	0.1529	0.2363	0.0168	0.0300	0.0470	0.1375	0.3183
MERCURY		ug/L											
NICKEL	Dissolved	mg/L	0.001	5	<DL	0.003	0.002	0.001	0.001	0.002	0.002	0.003	0.003
AMMONIA	Total	mg/L	0.05	7	<DL	0.84	0.16	0.15	0.06	0.07	0.11	0.21	0.30
NITRITE		mg/L	0.01	17	<DL	0.19	0.04	0.04	0.01	0.01	0.02	0.03	0.08
NITRITE/NITRATE		mg/L	0.05	2	<DL	9.11	3.46	2.92	0.31	0.59	2.90	6.21	7.30
PH		SU		0	7.07	8.45	7.82	0.29	7.56	7.66	7.81	8.02	8.12
PHOSPHORUS	Total	mg/L	0.05	3	<DL	1.83	0.35	0.31	0.09	0.12	0.25	0.50	0.65
PHOSPHORUS, ORTHOPHOSPHATE AS P	Dissolved	mg/L	0.01	17	<DL	0.93	0.17	0.21	0.005	0.013	0.09	0.24	0.38
POTASSIUM	Dissolved	mg/L	0.07	0	1.97	12.69	6.46	2.81	3.89	4.23	5.78	8.61	9.72
SELENIUM	Dissolved	mg/L	0.0008	6	<DL	0.0115	0.0041	0.0025	0.0014	0.0022	0.0040	0.0055	0.0060
SILVER	Dissolved	mg/L	0.0002	6	<DL	<DL	<DL	NA	<DL	<DL	<DL	<DL	<DL
SODIUM	Dissolved	mg/L	0.8	0	16.5	551.6	149.2	90.7	61.0	84.8	151.4	188.5	206.0
TDS	Filterable	mg/L		0	156.0	2223.0	785.1	391.1	371.5	468.5	800.0	1004.5	1065.4
TSS		mg/L	2	0	3.8	1000.0	82.4	157.0	12.0	16.5	35.0	70.0	111.0
SULFATE	Dissolved	mg/L	0.1	0	44.2	728.0	268.5	136.0	120.8	165.3	276.0	351.0	386.0
TEMPERATURE		°C		0	0.1	24.8	11.7	6.4	3.7	7.5	11.3	16.5	18.4
TURBIDITY		NTU		0	1.8	902.0	63.5	124.0	10.1	12.5	24.2	62.8	87.9
ZINC	Dissolved	mg/L	0.001	9	<DL	0.053	0.014	0.015	0.001	0.001	0.009	0.022	0.034

Attainment of stream standards is evaluated based on comparison of specific statistical values to chronic stream standards and determining whether acute standards are exceeded in any samples. For most constituents, the relevant statistic for comparison to the chronic standard is the 85th percentile value. Exceptions include use of the 50th percentile value for metals with standards in the total recoverable form, the geometric mean¹ for *E. coli*, and the 15th percentile value for dissolved oxygen (DO) and the lower acceptable range for pH. More complex evaluation approaches are required for *E. coli*, selenium and temperature, as described further in this memorandum. (*It should be noted that from a regulatory perspective, five years of data would be used in such a comparison.*) The time periods evaluated in this memorandum vary, depending on the nature of the water quality and/or regulatory issue. For constituents with current or historic water quality concerns, five to ten years of data may be included in the discussion, whereas for most other constituents, new data collected during 2011 are the primary focus.

To calculate hardness-based stream standards, a hardness value of 333 mg/L was used, consistent with the value used by the Colorado Water Quality Control Division (CWQCD) wastewater discharge permits for Broomfield, Westminster and Northglenn. The mean hardness value for the stream as a whole during 2011 was 328 mg/L, which is relatively consistent with previous analyses conducted by BDCWA. Hardness values have a significant effect on certain metals standards. For example, a hardness value of 250 mg/L results in a chronic zinc standard of 271 µg/L, whereas a hardness value of 350 mg/L results in a chronic zinc standard of 362 µg/L (i.e., the higher the hardness value, the less stringent the water quality standard is for certain metals.)

Segment 1 (the main stem) of Big Dry Creek is listed on the 2012 303(d) List for Colorado for non-attainment of stream standards for *E. coli* and selenium. (This was also the case for the 2010 and 2008 303(d) Lists.) The most current Big Dry Creek data are consistent with these listings, showing attainment of all currently applicable standards with the exception of selenium and *E. coli*. A brief synopsis of these two issues includes:

- **Selenium:** At the December 2007 CWQCC Rulemaking Hearing, irrigation and non-irrigation season site-specific standards were assigned to Big Dry Creek. A specific standards assessment method was also developed that is to be based on data collected at monitoring locations bdc1.5, bdc2.0, and bdc4.0 (i.e., the instream locations upstream of the WWTP discharges). The 2011 Big Dry Creek data set meets the non-irrigation season (winter) chronic and acute standards and the irrigation season acute and chronic standards; however, attainment of the stream standard is based on evaluation of five years of data. When considering the last five years of data (2007-2011), the stream does not attain the chronic irrigation season standard by a small margin of 0.4 µg/L. Review of Standley Lake release patterns for the last five year period indicates that the “fringe” month of October is more comparable to the non-irrigation season. If October selenium data are analyzed with the non-irrigation season data set, then both the irrigation and non-irrigation standards

¹ The geometric mean is calculated as the nth root of the product of n values. The geometric mean is used for regulatory purposes because it lessens the impact of extremely high or low values, relative to the arithmetic mean.

would be obtained. (See the selenium discussion later in this memorandum for more information.)

- *E. coli*: Big Dry Creek does not meet the *E. coli* standard during 2011 using current CWQCD assessment procedures, which assess attainment on a bimonthly interval. *E. coli* exceeds the stream standard during all bimonthly intervals except March-April. When considering the last five-year period, the standard is attained during the non-recreation season, but exceeded during the May-June, Jul-August and September-October intervals. A Total Maximum Daily Load (TMDL) process has been initiated by the CWQCD and the U.S. Environmental Protection Agency (EPA) for Big Dry Creek with regard to *E. coli*. BDCWA is working cooperatively with the CWQCD and EPA to ensure that the most complete and scientifically sound data set and assumptions are used in this process. Special studies related to sources of *E. coli* in the watershed were conducted by Wright Water Engineers (WWE) and BDCWA during 2007 and 2008 and provided to the CWQCD. A draft TMDL is anticipated during 2012.

More detailed discussion for selenium and *E. coli* follows, along with discussion of several other constituents of regulatory interest.

SELENIUM

In December 2007, BDCWA, CWQCD and EPA worked together to develop an ambient-based site-specific standard for Big Dry Creek based on the “natural or irreversible human-induced conditions” related to selenium in the creek. As a result, the stream standards for selenium in Big Dry Creek changed from a chronic stream standard of 4.6 µg/L and acute standard of 18.4 µg/L to seasonal ambient-based standards. (The complete study on which this standard is based can be downloaded from the Big Dry Creek website www.bigdrycreek.org.) The new standards and method of assessing attainment of the standards are described in the Statement of Basis and Purpose in Regulation 38 (CWQCD 2008b) as:

The Big Dry Creek Cities presented evidence that the natural or irreversible human-induced ambient water quality levels for selenium in Big Dry Creek Segment 1 at times exceed the relevant table value standard, and an ambient quality based standard, calculated in a manner consistent with Basic Standards requirements, is adequate to protect classified uses. The Commission accepts the Big Dry Creek Cities’ evidence as accurate. The Commission expressly finds that the natural or irreversible human-induced ambient water quality levels for selenium in Big Dry Creek Segment 1 exceed the relevant table value standard. Moreover, the proposed ambient quality based standard is adequate to protect classified uses and represents the highest reasonably attainable standard, based on analysis of available data that show elevated instream conditions are attributable to natural or irreversible human induced conditions.

Strong seasonal variation associated with highly managed flow conditions (e.g., releases of irrigation water from Standley Lake) significantly influences selenium concentrations,

particularly in the portion of the stream above the wastewater treatment plants. As a result, the Commission adopts seasonal ambient quality based site-specific standards for selenium applicable to Big Dry Creek Segment 1. During the irrigation season (April through October), ambient standards are 7.4 µg/L chronic (dis) and TVS µg/L acute (dis). Ambient-based non-irrigation season (November through March) standards are 15 µg/L chronic (dis) and 19.1 µg/L acute (dis). These calculations are based on the 85% (chronic) and the 95% (acute for the non-irrigation season) of the ambient selenium data collected at three specific instream monitoring locations (bdc1.5, bdc2.0 and bdc4.0) upstream of the three municipal wastewater treatment plant discharges, however, it is the Commission's intent that the existing spatial variability of selenium in Big Dry Creek be maintained. This composite approach was jointly developed by the Cities and the Water Quality Control Division as a reasonable method to establish the ambient based standards and to assess attainment of future stream standards for Segment 1 of Big Dry Creek. The ambient quality based site-specific standards for selenium (acute and chronic) shall apply to the entirety of Big Dry Creek Segment 1. The Commission also removes the temporary modification currently in place for selenium in Big Dry Creek Segment 1.

Based on these revised standards, the 2011 data set attains both the non-irrigation season (winter) and irrigation season standards for Big Dry Creek. The irrigation season data set for the most recent five years (2007 through 2011) slightly exceeds the irrigation season chronic standard. WWTP grab samples collected during this time period were below chronic and acute stream standards. Statistically significant increases in selenium concentrations over time are not present in the data set.

Table 4 provides the most recent five-year period covering 2007-2011. Figure 3 provides the last five years of monthly data at bdc1.5, bdc2.0 and bdc4.0. Instream selenium concentrations are influenced by the flow regime at the time of sample collection, which is the basis for the irrigation and non-irrigation season standards. When Standley Lake is not releasing water to Big Dry Creek, instream flows at bdc1.5 are typically dominated by groundwater inflows, which are known to have high selenium concentrations due to the geology in the vicinity of bdc1.5. The months of April and October are “fringe” months with regard to irrigation releases from Standley Lake. For this five-year period, Standley Lake rarely released flows in October, which is believed to be the reason that the chronic irrigation season 85th percentile value of 7.8 ug/L slightly exceeds the chronic selenium standard of 7.4 ug/L. The non-irrigation season chronic standard and the acute standards for both the irrigation and non-irrigation seasons are attained. If the month of October is moved to the non-irrigation season month, then the acute and chronic stream standards would be attained for the 2007-2011 time period as shown in Table 4. Sampling locations bdc2.0 and bdc4.0 are less affected by releases from Standley Lake due to dilution of instream flows with WWTP discharges from Broomfield and Westminster. (See the Flow discussion at the end of this memorandum for more information on Standley Lake release patterns.)

Table 4. Big Dry Creek Instream Selenium Data Summary (2007-2011)

	Irrigation Season			Non-irrigation Season			
	2007-2011 (per Reg. 38)	2007-2011 (w/out Oct.)	Dec. 2007 Standard		2007-2011 (per Reg. 38)	2007-2011 (w/Oct)	Dec. 2007 Standard
All Sites (85 th %)	6.9	6.1	NA	All Sites (85 th %)	8.3	8.1	NA
bdc1.5, 2.0, 4.0 (85 th %)	7.8	7.1	7.4 (ch)	bdc1.5, 2.0, 4.0 (85 th %)	12.7	12.7	15.0 (ch)
bdc1.5, 2.0, 4.0 (Max)	15.6	13.0	18.4 (ac)	bdc1.5, 2.0, 4.0 (95 th %)	16.0	16.0	19.1 (ac)

Bacteria

BDCWA now has twelve years of *E. coli* data collected on a monthly basis at eight instream locations, as well as grab samples from the WWTPs (Tables 5 through 7 and Figures 4a-c & 5). During 2009, the CWQCD changed its standards assessment procedure for *E. coli* to include an assessment of standards during the recreation season (May-October) in addition to the historically used annual assessment procedure. In 2010, additional refinement to the assessment methodology was adopted in the Basic Standards (CWQCC 2010a), which was subsequently integrated into 2012 303(d) Listing Methodology (CWQCD 2011). The new methodology assesses attainment of the stream standard in bimonthly time steps (e.g., January-February, July-August). If the geometric mean of a single two-month period exceeds the standard, then the stream does not attain recreational water quality standards. These changes result in more stringent criteria, which will be very difficult to meet, given the open space corridor with abundant wildlife in the upper watershed and the agricultural uses in the lower watershed. Table 5 summarizes annual *E. coli* data, whereas Tables 6 and 7 summarize bimonthly data for the last five years and 2011 only, respectively. CWQCD prefers that five or more samples be collected in each bimonthly time period. When this sample frequency is not available, then a longer period of record for each bimonthly time period may be used. (Note: BDCWA conducted weekly *E. coli* monitoring in 2003, but has monitored *E. coli* on a monthly basis since that time.)

From a regulatory perspective, data collected from 2007 through 2011 would be considered in evaluating attainment of the *E. coli* stream standard. Historic data from 2000 through 2006 are provided in Table 5 to show the influence of the drought (which peaked in 2002) on *E. coli* concentrations. The historic data are also of interest to show significant reductions in the Broomfield WWTP's effluent concentrations following WWTP upgrades and expansion in the 2001-2004 time period. Significant reductions in Westminster's WWTP effluent concentrations are also apparent in 2008-2011, following plant upgrades including UV treatment and other operational changes.

Table 5
Annual Summary of Big Dry Creek *E. coli* Data
(grey-shaded cells exceed the stream standard; bold values are highest annual geometric mean)

Annual Geometric Mean <i>E. coli</i> (#/100 mL)										
Year	bdc0.5	bdc1.0	bdc1.5	bdc10.0 (Broom. WWTP)	bdc2.0	bdc11.0 (West. WWTP)	bdc3.0 (I-25)	bdc4.0	bdc5.0	bdc6.0
2000	212	151	389	--	574	--	294	500	212	323
2001	477	118	332	215	649	68	387	634	442	510
2002	858	230	363	364	934	16	536	441	451	572
2003	191	210	293	27	615	24	382	225	249	339
2004	279	181	217	18	346	28	205	187	156	377
2005	152	122	281	26	328	35	204	113	182	301
2006	76	241	316	20	309	48	214	163	179	333
2007	196	177	257	14	324	66	230	231	198	364
2008	266	197	267	10	461	6	439	376	290	380
2009	61	78	147	5	207	14	251	137	149	197
2010	111	191	193	12	483	16	376	280	235	368
2011	64	228	323	6	622	8	518	537	380	730

Notes: Broom. = Broomfield; West. = Westminster; Northglenn excluded due to infrequent discharge. For consistency between sampling years, the 2003 weekly samples were converted to monthly geometric means prior to calculating the annual geometric mean for 2003. The 2009-2011 Broomfield and Westminster geometric means are based on Discharge Monitoring Report (DMR) values.

Table 6
Bimonthly Summary of Instream Big Dry Creek *E. coli* Data
(Values are geometric means [#/100 mL] of 2007-2011 data set at each location)

Station	Recreation Season					
	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sept-Oct	Nov-Dec
bdc0.5	36	34	525	461	137	56
bdc1.0	35	48	512	685	187	25
bdc1.5	65	78	684	758	374	121
bdc2.0	289	88	684	891	593	356
bdc3.0	213	93	437	754	689	382
bdc4.0	176	54	378	689	418	259
bdc5.0	112	50	530	599	457	193
bdc6.0	174	180	1032	607	457	165
All Sites	139	67	565	670	381	163

Note: Shaded values exceed the stream standard. Bold values are the highest bimonthly value per station.

Table 7. 2011 *E. coli* Data

Station ID		Recreation Season										
		Jan-Feb #/100 mL		Mar-Apr #/100 mL		May-Jun #/100 mL		Jul-Aug #/100 mL		Sept-Oct #/100 mL		Nov-Dec #/100 mL
bdc0.5	Jan	Ice	Mar	12	May	2420	Jul	162	Sep	9	Nov	35
bdc0.5	Feb	Ice	Apr	<1	Jun	866	Aug	78	Oct	179	Dec	Ice
bdc1.0	Jan	Ice	Mar	7	May	1300	Jul	1046	Sep	649	Nov	44
bdc1.0	Feb	Ice	Apr	111	Jun	2420	Aug	461	Oct	50	Dec	--
bdc1.5	Jan	Ice	Mar	24	May	1733	Jul	727	Sep	727	Nov	57
bdc1.5	Feb	Ice	Apr	152	Jun	>2420	Aug	240	Oct	214	Dec	517
bdc2.0	Jan	1120	Mar	88	May	1300	Jul	1046	Sep	1203	Nov	326
bdc2.0	Feb	614	Apr	105	Jun	2420	Aug	921	Oct	687	Dec	921
bdc3.0	Jan	366	Mar	196	May	1120	Jul	649	Sep	921	Nov	411
bdc3.0	Feb	462	Apr	81	Jun	921	Aug	1046	Oct	770	Dec	687
bdc4.0	Jan	436	Mar	119	May	1733	Jul	1414	Sep	>2420	Nov	517
bdc4.0	Feb	462	Apr	146	Jun	921	Aug	411	Oct	184	Dec	770
bdc5.0	Jan	276	Mar	53	May	161	Jul	1203	Sep	1986	Nov	184
bdc5.0	Feb	273	Apr	161	Jun	1733	Aug	179	Oct	291	Dec	435
bdc6.0	Jan	123	Mar	816	May	870	Jul	1553	Sep	>2420	Nov	435
bdc6.0	Feb	Ice	Apr	870	Jun	>2420	Aug	365	Oct	613	Dec	167
G. Mean		392		111		1319		538		438		266

Based on review of the data, the following observations are noteworthy:

- Geometric mean concentrations for 2011 were generally within the range of annual geometric mean values observed for the period of record, with the exception of site bdc6.0. At bdc6.0, the 2011 geometric mean was the highest annual value observed during the 2000-2011 record. The bimonthly geometric mean concentrations during 2011 were generally higher than the 5-year bimonthly geometric means, with the exception of the July-August time period.
- Neither the 2011 data set nor the 2007-2011 data meet stream standards for the May-June, July-August and September-October assessment periods—essentially the entire May-October potential recreational season. This is true evaluating the stream as a whole, as well as at all individual monitoring locations. Additionally, bdc2.0, bdc3.0 and bdc4.0 (128th Avenue to York Street) exceeded the standard during the November-December assessment period, although by a smaller margin than in the recreational season months. Station bdc2.0 also exceeds the January-February assessment period standard by a small margin.

- For 2007-2011, the highest *E. coli* concentrations for all stations were experienced during the July-August assessment period, with the exception of bdc6.0, which experienced the highest concentrations in May-June.
- Based on review of geometric mean concentrations from 2007-2011, *E. coli* concentrations are consistently the lowest in grab samples from the Broomfield and Westminster WWTP discharges (Table 5), which are well below the stream standard.
- Over the last several years, various explanatory relationships between *E. coli* and variables such as flow, temperature, total organic carbon, DO and other variables have been evaluated, but without fully explaining *E. coli* trends (WWE 2009, WWE 2011). *E. coli* concentrations are generally higher in summer months for the stream as whole when stream temperatures are higher (Figure 5).

Metals (excluding selenium)

With the exception of selenium, Big Dry Creek attains instream standards for metals. A few specific observations regarding metals based on Tables 2 and 3 and Attachment 1 include:

- Total recoverable iron concentrations during 2011 attained the stream standard of 1 mg/L based on the 50th percentile value for the overall stream and at individual monitoring stations. In 2008, the CWQCD removed Segment 1 of Big Dry Creek from the Monitoring and Evaluation List for iron. The 50th percentile at all monitoring stations for the past five years continues to meet the iron standard.
- In 2008, BDCWA changed its monitoring approach for mercury and is now using the EPA 1631e analysis method at one monitoring location at 120th Avenue. This analysis method has much lower detection limits, providing more meaningful data, but is also much more costly, thus limiting analysis to one location. All samples collected at this location were below the stream standard.
- Dissolved cadmium, chromium, lead and silver were not detected in samples collected during 2011.

Nutrients

Nationally, statewide and locally, control of nutrient loading to streams is a significant issue. Water quality criteria and standards continue to emerge and are becoming more stringent. In February 2012, the CWQCC held a rulemaking hearing to adopt nutrient criteria for Colorado. The rule will be finalized in May 2012 and will include instream/lake nutrient criteria for Regulation 31 (Basic Standards) and a nutrients management control regulation (Regulation 85, which pertains to dischargers of nutrients). Under the interim nutrient criteria added to Regulation 31, criteria expected to be applicable to Big Dry Creek in the future include a median annual total phosphorus standard of 0.17 mg/L and a median annual total nitrogen concentration of 2.01 mg/L. Both criteria have a once every five years allowable exceedance frequency. Additionally, streams with

recreational uses have a not-to-exceed 150 mg/m² chlorophyll-a limit for attached algae. These limits would not be expected to be applied to Big Dry Creek prior to May 31, 2022. Under current conditions, Big Dry Creek would not attain either the phosphorus or nitrogen standards of these standards. Municipal wastewater dischargers to Big Dry Creek will also be affected by discharge permit limits for total phosphorus and total inorganic nitrogen proposed in Regulation 85. Additionally, Big Dry Creek is likely to be affected by a downstream TMDL for Barr Lake and Milton Reservoir that is targeting reductions in phosphorus loading.

Big Dry Creek data for ammonia, nitrate, total nitrogen and phosphorus are discussed further below.

Ammonia

After a five-year transition period from an unionized ammonia standard to a total ammonia standard, a total ammonia standard became effective on Big Dry Creek on January 1, 2012. In June 2005, the CWQCC adopted revised ammonia criteria for the Basic Standards based on EPA's 1999 *Update of Ambient Water Quality Criteria for Ammonia*. The new criteria are in the form of total ammonia and are more stringent for warm water streams than the previous standards. During the March 13, 2007 Rulemaking Hearing, the WQCD proposed temporary modifications to WWTP discharge permits, including the cities of Broomfield, Westminster and Northglenn, to remain at the "old" ammonia standard until December 31, 2011. This proposal was based on the CWQCC's acknowledgement that there is substantial uncertainty regarding the appropriateness of and cost of compliance with the new criteria. The temporary modification allowed time to reassess what standards are appropriate on a site-specific basis and also provided dischargers additional time to address treatment facility modifications that may be needed (CWQCD 2007).

Total ammonia concentrations for Big Dry Creek are plotted in Figure 6, along with the chronic standards effective beginning in 2012. Both chronic and acute standards for total ammonia are calculated using a formula based on pH and temperature. During 2011, the stream attained both chronic and acute total ammonia standards.

Nitrate

Regulation 38 does not assign a nitrate standard to Big Dry Creek; however, Big Dry Creek nitrate concentrations are well below the agricultural nitrate standard of 100 mg/L identified in the Colorado Basic Standards (Regulation 31). Additionally, although Big Dry Creek does not have a drinking water classification (with a corresponding in-stream nitrate standard of 10 mg/L), the Middle South Platte River Segment 1 downstream of Big Dry Creek has a drinking water classification and a nitrate standard of 10 mg/L. This standard is applied based on a single day combined total of nitrite and nitrate at the point of intake to the domestic water supply. At bdc6.0, upstream of the confluence with the South Platte River, Figure 7 shows a maximum reported value of 6.3 mg/L during 2011. Nitrate concentrations in WWTP discharges to Big Dry Creek are typically higher than values at bdc6.0, but dilution from instream flows and natural losses associated with the nitrogen cycle result in lower nitrate concentrations by the time these flows reach the confluence with the South Platte River.

Total Nitrogen (Estimated)

Figure 8 plots the sum of nitrate/nitrite plus total ammonia for purposes of general comparison to interim nutrient criteria expected to be finalized in the May 2012, as a result of the March 2012 Rulemaking Hearing (CWQCD 2012a&b). The initially proposed total nitrogen standard is 2.01 mg/L of total nitrogen, which includes ammonia, nitrate/nitrite, and organic nitrogen (which is not currently monitored on Big Dry Creek). Upstream of the WWTP discharges to Big Dry Creek, the median nitrate/nitrite plus total ammonia value is 0.375 mg/L during 2011. For the stream as a whole, the median value was 3.05 mg/L in 2011. Under current conditions, the total nitrogen standard would not be attained on Big Dry Creek from the Broomfield WWTP discharge to the South Platte River. A seasonal pattern is also evident in the instream data, with lower values present in the summer.

Phosphorus in Relation to Barr-Milton TMDL

The Barr-Milton Watershed Association (BMW) is addressing pH exceedances in the Barr-Milton reservoir system. These pH exceedances are attributed to excessive algal growth caused by nutrient loading. BMW has established a database for modeling conditions in the reservoirs and has included water quality data from Big Dry Creek, as well as many other tributaries upstream of the Barr-Milton system. BDCWA representatives are participating in various aspects of the BMW effort. In August 2009, AECOM released the final report titled "Watershed and Lake Modeling for a TMDL Evaluation of Barr Lake and Milton Reservoir," which forms the underlying basis for ongoing work in development of a TMDL. A draft TMDL has been developed, but is not yet finalized. In this draft, Big Dry Creek was identified as contributing approximately 5.9 percent of the phosphorus loading to Milton Reservoir. Big Dry Creek has been targeted for a 20 percent total phosphorus load reduction from 2,301 kg/yr down to 1,840 kg/yr. Because Big Dry Creek is identified as a nonpoint source of loading, "application of BMPs to the greatest extent feasible" is the recommended approach for achieving these reductions.

As a result of the Barr Milton TMDL process, BDCWA reviewed phosphorus data collected along Big Dry Creek, with primary focus on monitoring station bdc6.0, which is the downstream-most instream monitoring location on Big Dry Creek in the agricultural portion of Weld County. Several key observations at bdc6.0 are summarized in Figures 9-12. Although instantaneous flow measurements are conducted by BDCWA on a monthly basis, the USGS Fort Lupton gauging station is combined with the bdc6.0 water quality data to estimate loads because the USGS gauge it is a more comprehensive data set. Several key observations at bdc6.0 include:

- As shown in Figures 9a&b, total instream phosphorus concentrations have decreased significantly since 2002, with the average 2011 concentration (0.62 mg/L) less than half of the 2002 average concentration (1.57 mg/L). For purposes of the BMW modeling, 2003-2004 was used as a baseline. Average phosphorus concentrations at bdc6.0 in 2011 were approximately 40% lower than in 2004.
- Phosphorus loading has also decreased substantially. Pollutant loads are calculated based on pollutant concentration multiplied by flow volume (Figures 10a&b). During 2011,

phosphorus loading at bdc6.0 decreased by approximately 40% relative to 2004 (based on monthly flow and phosphorus concentration averages).

- Both Broomfield and Westminster WWTP discharges show substantial reductions in total phosphorus concentrations since 2004 (Figures 11a&b and Figures 12a&b, respectively). Both WWTPs have implemented major upgrades in recent years and have been in the process of optimizing plant operations following these upgrades. Westminster reports that its WWTP is designed to reduce total phosphorus below 1 mg/L, and Broomfield reports that eventually 0.5 mg/L of total phosphorus may be feasible. Key observations include:
 - In 2011, average total phosphorus was 0.11 mg/L for Broomfield (down from 0.17 mg/L in 2010) and 1.41 mg/L for Westminster (up from 1.03 mg/L in 2010).
 - The Westminster 2010-2011 concentrations were higher than in 2009-20120 for several reasons. First, Westminster collected a higher percentage (almost 50%) of its samples on Sundays in 2010 and much of 2011 to confirm that concentrations tended to be higher on Sundays than weekdays (and they were). Secondly, phosphorus removal competes with other operational parameters that have permit limits; therefore, highest priority tends to focus on constituents regulated in permits. Although these two factors may explain why the 2010-2011 concentrations at the Westminster WWTP were higher, it is also possible that this variability and range of values may be normal and generally within the 1 mg/L total phosphorus design criterion for the WWTP. Since Westminster only has three complete years of data since the upgrades were implemented, additional monitoring will help to refine expectations regarding long-term effluent conditions from the plant (Personal Communication with David Meyer, City of Westminster, February 2011).
 - For a relative sense of how these concentrations compare to other WWTP discharges in the metro Denver area, AECOM (2009) reports that total phosphorus concentrations in Littleton-Englewood and Metro effluent range between 2.5 and 3.0 mg/L. For purposes of a general frame of reference, WWTPs discharging to Front Range reservoirs such as Chatfield, Bear Creek and Cherry Creek have total phosphorus discharge permit limits ranging from 0.2 to 1 mg/L. (Northglenn WWTP data were not provided at the time this memorandum was completed; however, historically, Northglenn has discharged infrequently to Big Dry Creek. During 2009, however, Northglenn discharged to Big Dry Creek during January-June due to temporary operational adjustments due to repairs being made to Bull Reservoir, with total phosphorus values in the BDCWA grab samples averaging 2.15 mg/L total phosphorus. Northglenn did not discharge to Big Dry Creek in 2010 or 2011.)
- In addition to phosphorus concentration reductions at the Broomfield and Westminster WWTPs, both cities have implemented significant reclaimed water programs. Figure 13 shows annual volumes discharged to Big Dry Creek for 2004-2011. Since 2004,

Broomfield's annual discharges to Big Dry Creek have decreased by approximately 15 percent. Although Westminster's discharges have not decreased, they have also not increased to the extent that they would have due to growth in the absence of the reuse program. The current and future effects of reclaimed water programs have not been fully evaluated for purposes of this memorandum, but are important considerations should more in-depth analysis be conducted related to Big Dry Creek phosphorus loading to the South Platte River.

- As previously shown in Figure 2, the hydrology of Big Dry Creek is highly managed and complex. Future evaluation of measures to reduce phosphorus loading from Big Dry Creek must consider these complexities. Other hydrology-related considerations include:
 - It is important to be aware that bdc6.0 is located upstream from the USGS gauge. Instantaneous flow measurements at bdc6.0 and the average daily flow measurements at the USGS Fort Lupton gauge vary substantially. On average, flows at the USGS gauge are approximately 20 percent higher; however, there is large variation in the magnitude of the difference between individual pairs of flow measurements.
 - It is important that the water quality sample location used for modeling Big Dry Creek phosphorus contributions to the South Platte River be located upstream of the Lupton Bottoms discharge to Big Dry Creek. Sampling location bdc6.0 is upstream of Lupton Bottoms, but Metro Wastewater Reclamation District has also collected some water quality samples below Lupton Bottoms ditch, which may be influenced by South Platte water discharged from the Lupton Bottoms ditch.

Phosphorus in Relation to Colorado's Interim Total Phosphorus Standards

Total phosphorus concentrations in Big Dry Creek are also of interest with regard to nutrient criteria proposed in the nutrient rulemaking hearing in March 2012 and that are expected to be adopted by the CWQCC in May 2012. The CWQCD's proposed interim total phosphorus standard for warmwater streams in Colorado is 0.17 mg/L (CWQCD 2012a). For comparison, Figure 14 shows that Big Dry Creek would have substantial difficulty meeting this proposed standard from I-25 to the South Platte River, with the median phosphorus concentration during 2011 ranging from 0.32 to 0.55 mg/L in this reach (also see Figure 9b for a longer period of record at bdc6.0). Nonetheless, the 2011 median value is approximately two-thirds of the five-year (2007-2011) median of 0.75 mg/L, showing substantial reductions in phosphorus concentrations due to recent phosphorus reductions in the Broomfield and Westminster WWTP discharges. Based on conditions described in nutrient-related criteria being added to Regulation 31, nutrient criteria are not expected to apply to Big Dry Creek for at least 10 years (May 31, 2022).

Temperature

The currently applicable classification for temperature standards on Big Dry Creek is Warm Stream Tier I (WS-I), due to the presence of the Johnny darter in some locations in the upper portion of the

stream. Attainment of standards is assessed based on comparison of the maximum weekly average temperature (MWAT) and Daily Maximum (DM) temperature to seasonal temperature standards established for March-November and December-February. Values above these standards are allowed under these conditions:

- The DM may exceed the acute temperature standard once every three years. The DM means the highest two-hour average water temperature recorded during a given 24-hour period.
- The MWAT may exceed the chronic standard once every three years (1E3). The MWAT is calculated as the largest mathematical mean of multiple, equally spaced, daily temperatures over a seven-day consecutive period, with a minimum of three data points spaced equally through the day.
- Values measured during conditions meeting air temperature or low-flow excursion criteria defined in Regulation 31 are not considered exceedances.

The WQCD determines whether temperature limits are to be included in permits in accordance with the Basic Standards 31.14 (14) "Integration into Discharge Permits." Currently, the municipal WWTP dischargers to Big Dry Creek are required to "report only" under terms of the current permits. Additional instream monitoring data have been collected at several instream locations in support of this effort using HOBO data loggers recording temperature measurements at 15-minute intervals. These data sets have not been fully evaluated for purposes of this memorandum; however, the cities report that attainment of the standard will be challenging during certain time periods.

In lieu of evaluating the cities' daily temperature data, the comments provided below are based on the BDCWA monthly instream grab samples collected between 2007 through 2011, as summarized in Figures 15a&b. Key observations include:

- All monthly temperature measurements during the December-February timeframe were below the Daily Maximum (DM) limit of 14.5 C.
- During the March-November timeframe, the majority of measurements were below the DM limit of 29.0 C and the MWAT of 24.2. The observed June temperature at site bdc0.5 (below Standley Lake dam) was 24.82, which is greater than the MWAT.

For a more robust evaluation of temperatures on Big Dry Creek in the vicinities of the WWTP discharges, 15-minute incremental temperature data collected as part of CDPS DMRs should be reviewed.

Flow

The hydrology of Big Dry Creek is discussed below in terms of 1) annual streamflows relative to period of record, 2) release and diversion patterns, and 3) stormwater.

Streamflows

USGS flow data for the Westminster and Fort Lupton gauges are shown in Figures 16 through 18. During 2011, average daily flows at the Westminster gauge ranged from 0.86 cubic feet per second (cfs) to 295 cfs with an average of 27.9 cfs. Average daily flows for the Fort Lupton gauge data ranged from 0.4 cfs to 421 cfs with an average of 37.40 cfs. The average Westminster flows were the highest observed in the past 10 years, whereas the Fort Lupton flows were more typical.

Figures 17a&b identify peak stream flows for the period of record at both gauges. The 2011 peak flow at the Westminster gauge was the highest value recorded during the 24-year monitoring period at that station. The peak flow observed at the Fort Lupton gage is within previously observed ranges for the period of record.

Seasonal Flow Regime

In 2011, as part of an on-going effort to update the Big Dry Creek Watershed Management Plan, more detailed evaluation of Standley Lake discharges, irrigation diversions and WWTP discharges were completed for the 2005-2009 time period (WWE 2011). Table 8 summarizes average monthly instream flows, major discharges/releases to the creek and ditch diversions. This analysis will be updated every two years, so has not been updated for purposes of this memorandum (see WWE [2011] for more detailed findings). Key findings from this analysis include:

- Significant seasonal variation in release patterns from Standley Lake is present in accordance with releases for irrigation purposes. During April through September, Standley Lake releases comprise 30 to 70 percent of the flows measured at the USGS gauge. October is a “fringe” month for irrigation, but is more similar to the non-irrigation season than the irrigation season. During October through March, Standley Lake releases comprise approximately 5-10 percent of the flows at the Westminster gauge.
- With regard to relative percentages of WWTP discharges, during the winter months, WWTP flows comprise roughly half of the flows present at bdc6.0. During April to August, this relative balance decreases down to approximately 25 percent of the flows at bdc6.0, with the exception of May.

The balance of water sources water balance in the creek during different seasons affects water quality conditions in the creek. For example, in the absence of Standley Lake releases, the selenium standard is exceeded in the upper watershed. With regard to nutrient loading, it is important to recognize that winter months are dominated by wastewater contributions and relatively low flow conditions. Summer months have higher flows with lower relative contributions from wastewater.

**Table 8. Summary of Measured Hydrologic Influences on Big Dry Creek
 (2005-2009 in average cfs/month)**

Measured Flow	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Standley Release	Inflow	0.2	0.4	0.2	0.9	17.3	17.8	13.7	12.4	11.7	0.3	0.3	0.5
USGS West 6720820	Instream	2.9	3.2	4.1	12.1	30.6	30.1	18.8	21.8	15.7	6.8	3.2	2.8
Broom. WWTP	Inflow	6.2	6.2	7.1	7.9	7.5	6.2	5.4	6.2	6.2	6.7	5.6	6.0
Bull Canal Diversion ¹	Diversion	0.2	0.4	0.2	0.9	17.3	17.8	13.7	12.4	11.7	0.3	0.3	0.5
Whipple Ditch (@Bull Canal)	Diversion					5.0	4.5			2.4			
West. WWTP	Inflow	9.6	9.4	9.0	8.8	8.4	7.4	6.5	7.3	7.3	8.5	9.9	10.0
Thornton Golf Course	Diversion	0.1	0.4	0.4	0.5	0.5	0.7	0.9	0.7	0.4	0.4	0.3	
German Ditch	Diversion				9.3	6.4	5.5	6.9	5.9	3.3	3.5		
Big Dry Creek Ditch	Diversion				1.0	4.0	4.4	4.1	4.3	1.9	3.9		
Yoxall Ditch	Diversion				1.2	1.9	2.0	2.0	1.8	1.3	1.2		
Lupton Bottom Ditch ²	Inflow/ Outflow			7.5	19.2	48.9	61.3	75.1	61.0	50.9	24.0	5.7	
USGS Ft. Lupton 6720990	Instream	25.5	25.9	34.8	62.2	36.6	47.7	40.7	44.9	32.2	37.7	35.2	31.7

¹Bull Canal diversion is assumed to be equal to the Standley Lake discharge.

²Inflow/Outflow indicates that Lupton Bottom Flows are carried in Big Dry Creek and subsequently diverted upstream of the USGS Fort Lupton gauge. Although from a water quantity perspective, the net effect should not be significant, from a water quality perspective, this is a substantial flow volume of South Platte River water that mixes with Big Dry Creek water. This is important from a TMDL perspective.

Stormwater

During 2008, the Urban Drainage and Flood Control District, the cities of Westminster and Thornton, and Adams County initiated a master drainage plan update for the main stem of Big Dry Creek from Standley Lake dam to the Weld County line. Alternatives analysis has been completed, with a Conceptual Design Plan being finalized in 2012. The plan identifies measures to minimize flooding and stream degradation on the creek.

Quality Assurance/Quality Control

During 2011, quality assurance/quality control (QA/QC) procedures were followed using the guidelines set forth in the Big Dry Creek Sampling and Analysis Plan (BDCWA 2003). Under this program, field blanks are analyzed for the full suite of constituents in March, a full set of duplicate analyses are completed in September, and during June and December, field duplicates are analyzed at four locations (bdc1.5, bdc2.0, bdc3.0 and bdc5.0) for constituents of concern (selenium, *E. coli*, ammonia and iron) (Table 9).

Table 9. Field Quality Control Program

Month	QC Sample Type	Site
March	Field blanks (complete set)	6.0 –maximum equip. use
June	Field duplicates for Constituents of Concern (Represents high flows)	1.5 – Selenium 2.0 – <i>E. coli</i> 3.0 – NH ₃ 5.0 – Fe (TRec)
September	Field duplicates, full set	5.0 –most constituents detected at this site
December	Field duplicates for Constituents of Concern (Represents low flows)	1.5–Selenium 2.0– <i>E.coli</i> 3.0–NH ₃ 5.0 – Fe (TRec)

During 2011, the minimum set of QA samples was collected, along with some additional samples for metals. Attachment 2 summarizes analysis of field blank and replicate samples for 2011. Analysis of relative percent difference (RPD) for the sample replicates generally shows acceptable accuracy for most constituents. Several noteworthy comments for sample pairs with higher RPD values include:

- RPD values for *E. coli* are high relative to other constituents; however, this is not unusual for *E. coli* analysis. RPDs for the three replicate sets were 20%, 38%, and 20% with an average of 26%.
- Total recoverable iron had one relatively high RPD of 57%, averaging 23% for the three replicate pairs. Again, this is not unusual for iron, which is typically associated with sediment particles.
- Copper had one high RPD value out of the three field duplicate samples collected. The three RPDs were 120% (June 2011), 0% and 0%. The cause of the high RPD in June was explored, but not resolved.

The monitoring plan was followed in terms of sample analyses conducted with the exception of analyses for cyanide, which were inadvertently omitted in June 2011.

RECOMMENDATIONS

1. Participate in 303(d) listing methodology work group for 2014, which is expected to begin this spring/summer. Topics of interest to Big Dry Creek include discussion of assessment methodology for site-specific standards that could potentially include an allowance for statistical variability for site-specific standards. Other topics include aquatic life criteria and recreational water quality criteria assessment methodologies.

2. Consider addition of total Kjeldahl nitrogen (TKN) to monitoring suite, given potential future total nitrogen standards on Big Dry Creek.
3. Explore habitat enhancements in the vicinity of bdc2.0 that may help to reduce *E. coli* concentrations and improve aquatic life conditions.

CONCLUSIONS

1. Water quality in Big Dry Creek attained stream standards for currently assigned stream standards, with the exceptions of *E. coli* and selenium. Although *E. coli* is elevated at multiple locations on the stream, the highest concentrations occur at bdc2.0 in the Westminster Open Space and at bdc6.0 in the agricultural area where cattle grazing occurs.
2. Phosphorus concentrations and loads to Big Dry Creek are generally decreasing due to enhanced treatment processes at the Broomfield and Westminster WWTPs, along with reuse programs that continue to be implemented at these WWTPs. Values observed in 2011 were slightly higher than those observed in 2010.
3. Based on the interim warmwater instream nitrogen and phosphorus standards that are expected to be adopted by the CWQCC in May 2012, Big Dry Creek would not attain either standard. Although these standards would not be expected to affect Big Dry Creek for 10 years or more, addressing nutrient sources on Big Dry Creek should be an increasing area of focus for BDCWA.
4. Attainment of the current site-specific selenium standard will likely require shifting the month of October to the non-irrigation season, since Standley Lake releases and instream flows during October are more similar to the non-irrigation season. (Alternatively, the standard could be slightly increased, as a result of a more complete data set than what was available at the time of the standard change.)

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Wright Water Engineers, In. 2009a. Technical Memorandum Regarding Big Dry Creek Water Quality Summary for 2008. April 17, 2009.

Wright Water Engineers, Inc. 2009b. Overview of *E. coli* Source Characterization Efforts for Big Dry Creek (2006-2008). (Notebook compendium of special studies conducted from 2006-2008.) Prepared for the Big Dry Creek Watershed Association. March.

Wright Water Engineers, In. 2011. Technical Memorandum Regarding Big Dry Creek Water Quality Summary for 2010.

FIGURES

Figure 1. Big Dry Creek Watershed Location Map

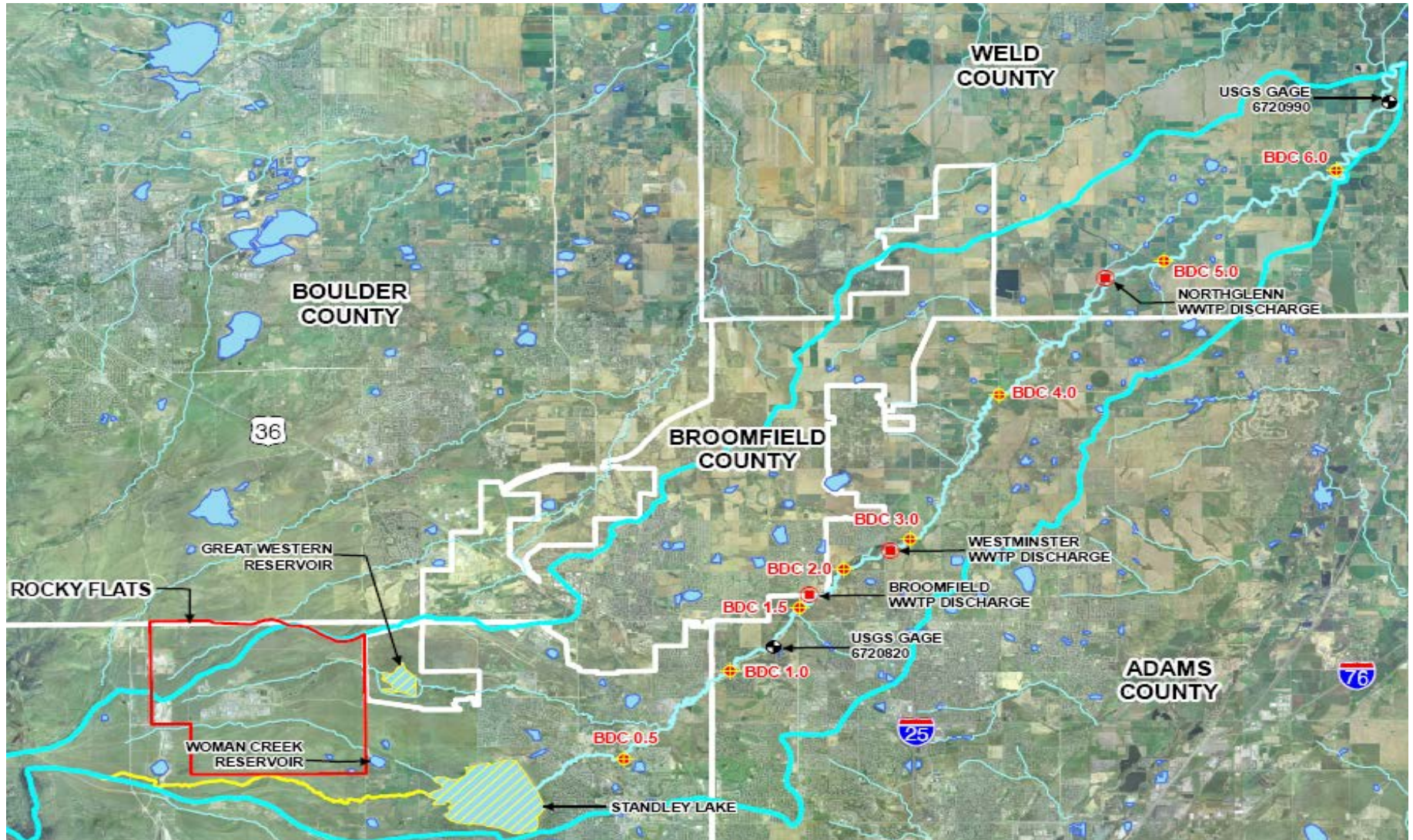


Figure 2. Hydrologic Influences on Big Dry Creek Flows (based on average AF/YR for 2005-2009)
 (concept diagram; not to scale; important seasonal variations not reflected in this diagram)

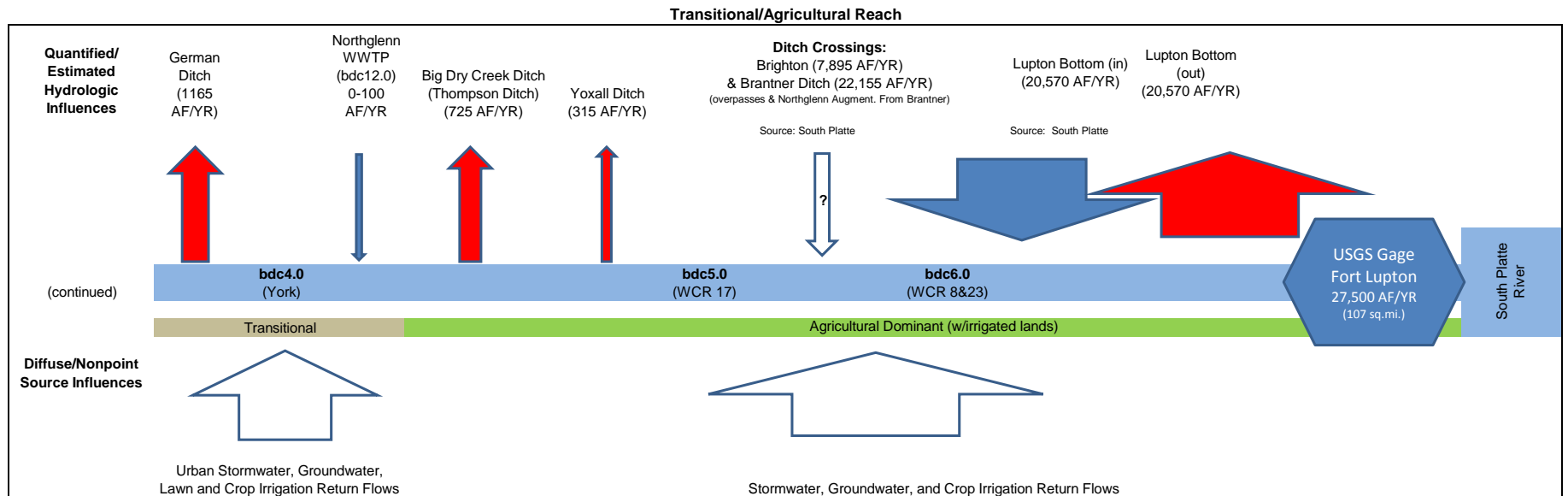
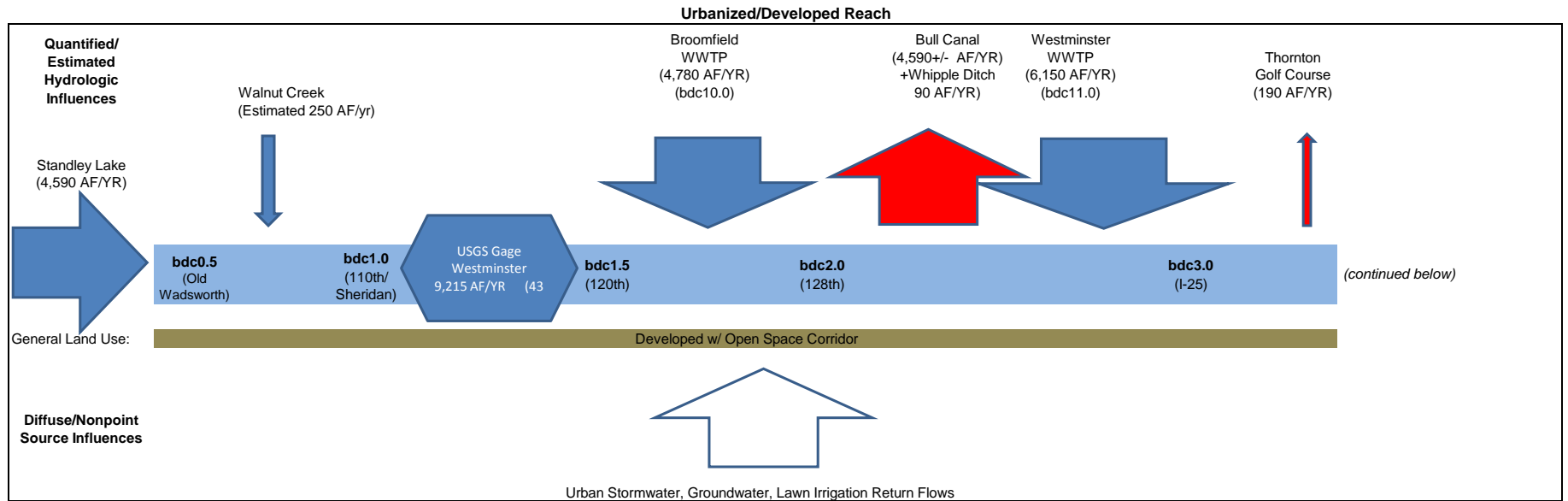


Figure 3. Big Dry Creek Selenium at bdc1.5, 2.0 and 4.0 (2007-2011)

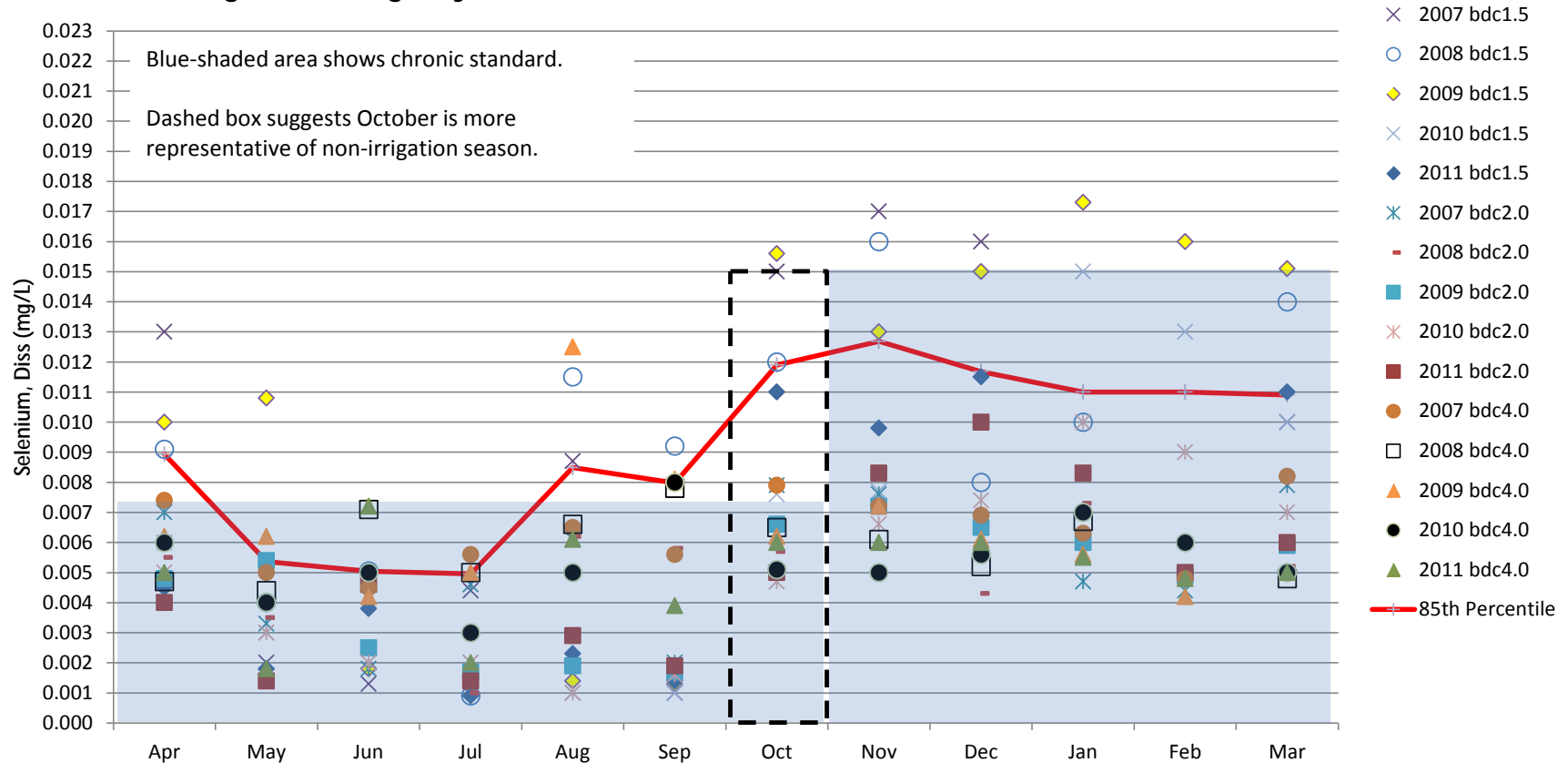


Figure 4a. 2011 Geometric Mean E. coli (#/100mL) at All Stations

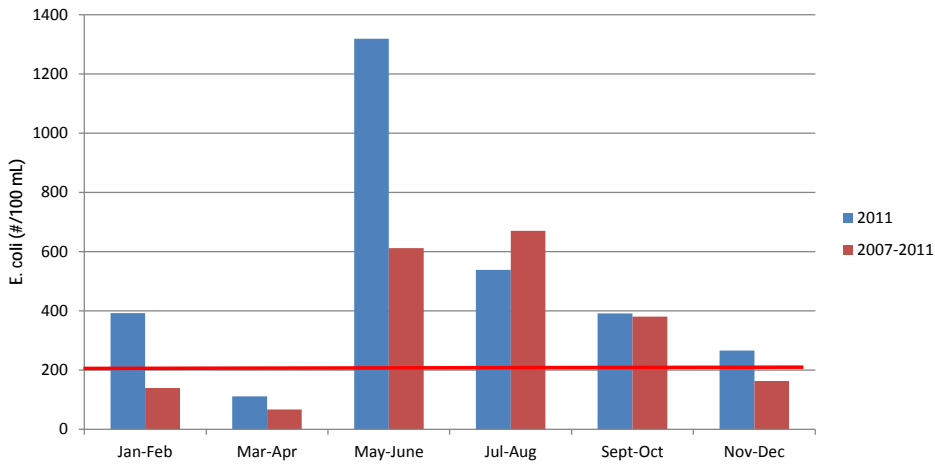


Figure 4b. Geometric Mean E. coli 2007-2011 by Month & Station

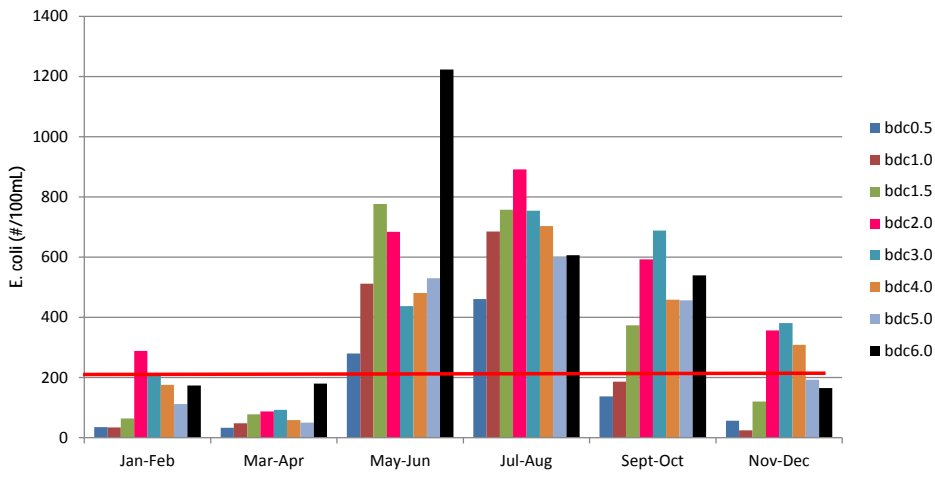


Figure 4c. Geometric Mean E. coli 2007-2011 by Station and Month

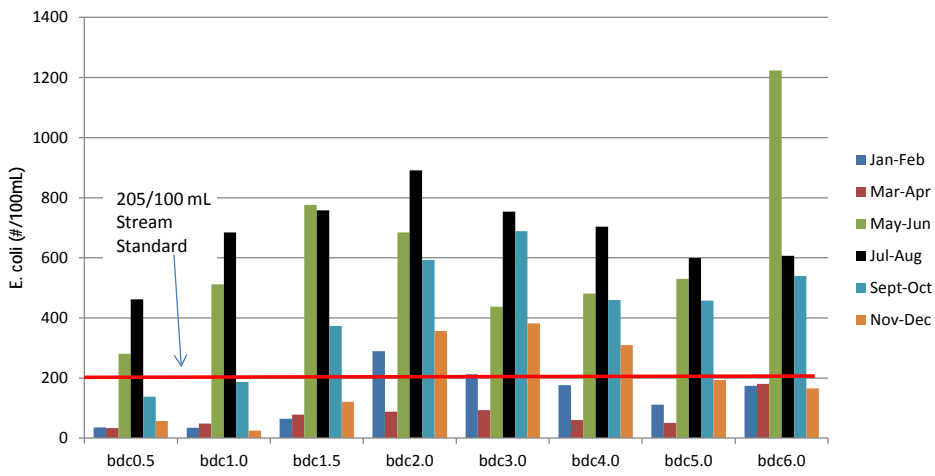


Figure 5. Data Exploration
E. coli vs. Temperature (2007-2011)

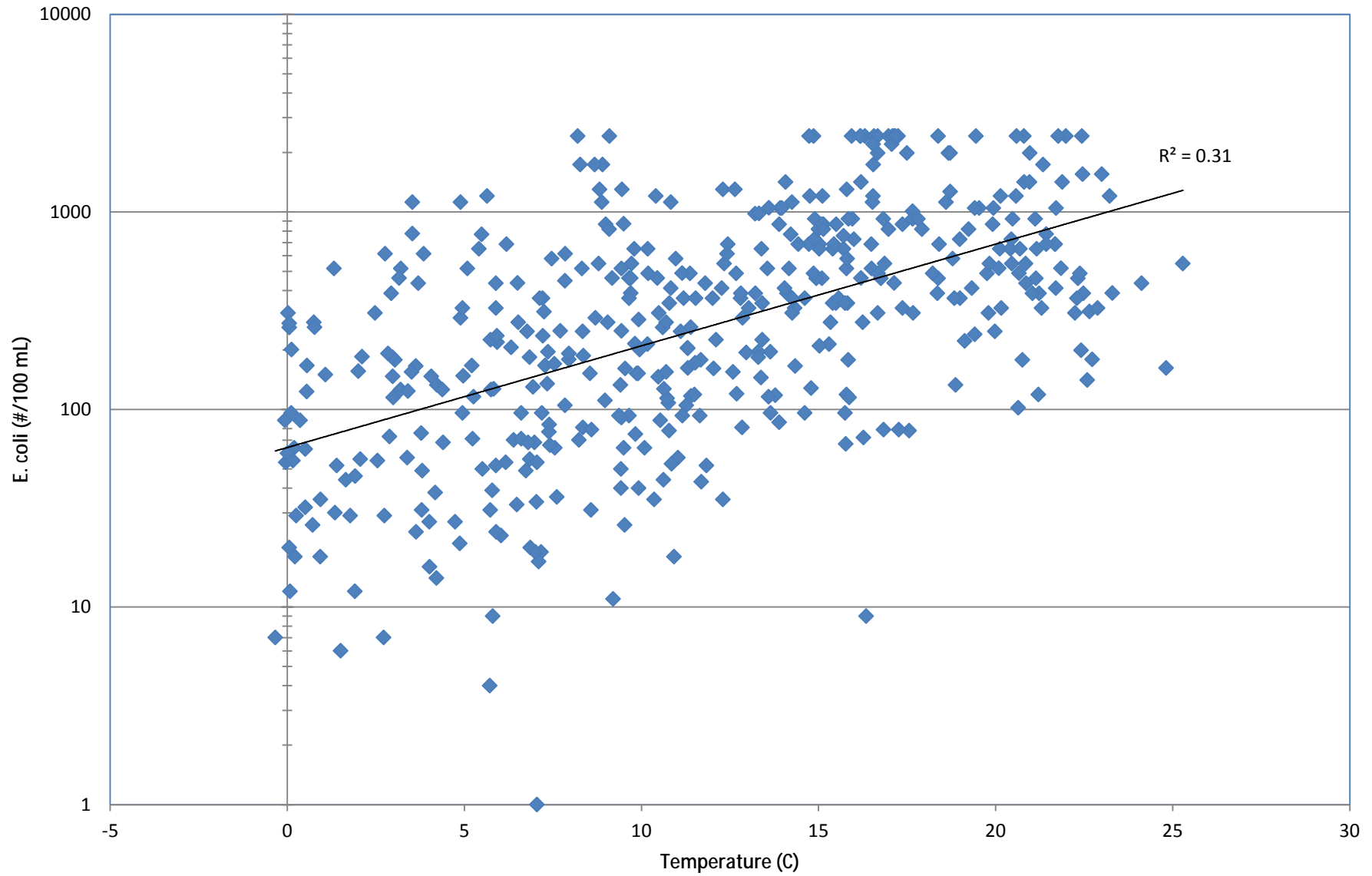


Figure 6. 2011 Big Dry Creek Instream Total Ammonia Compared to "New" Ammonia Standards

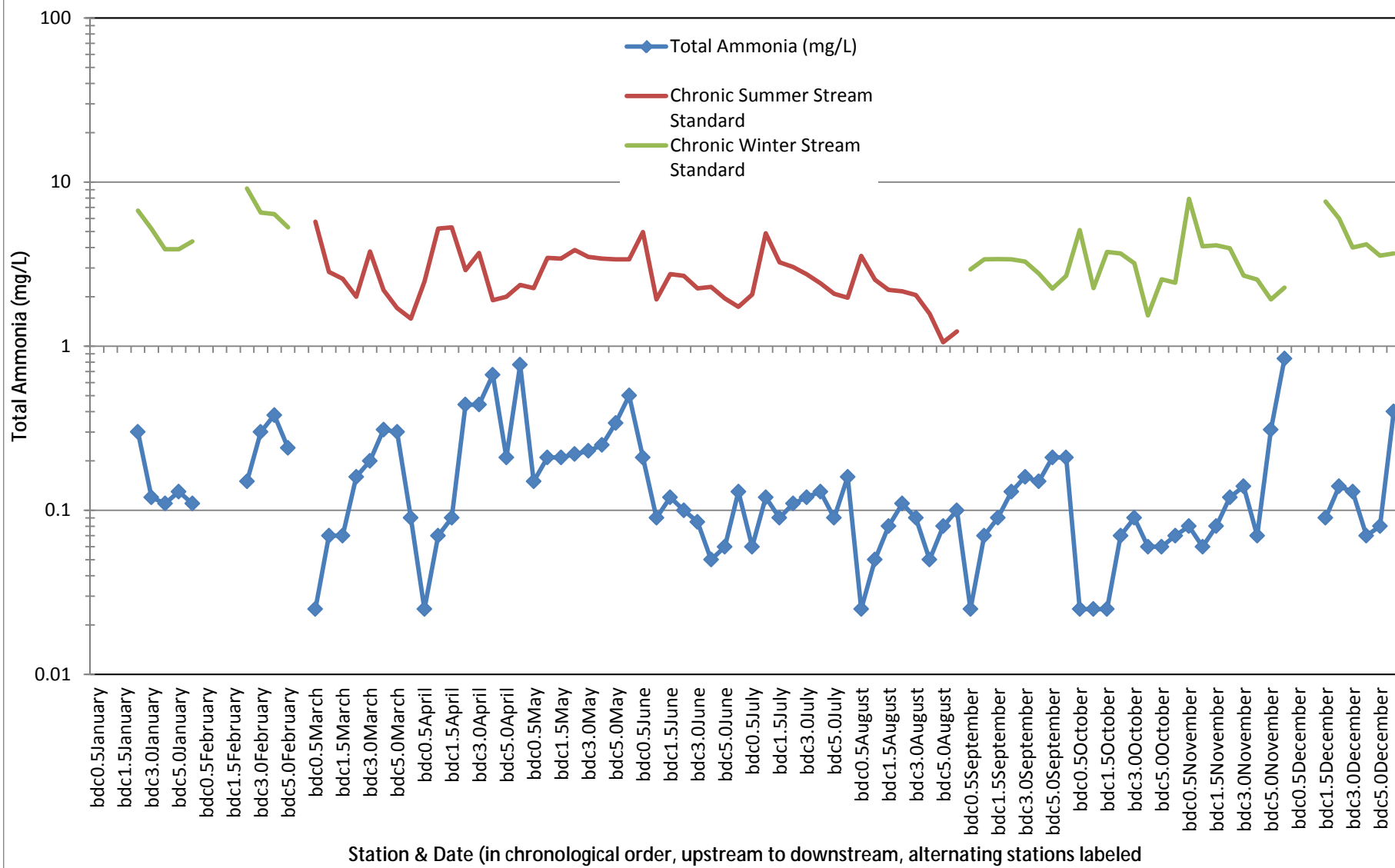


Figure 7. Big Dry Creek Median and Maximum Nitrate 2011

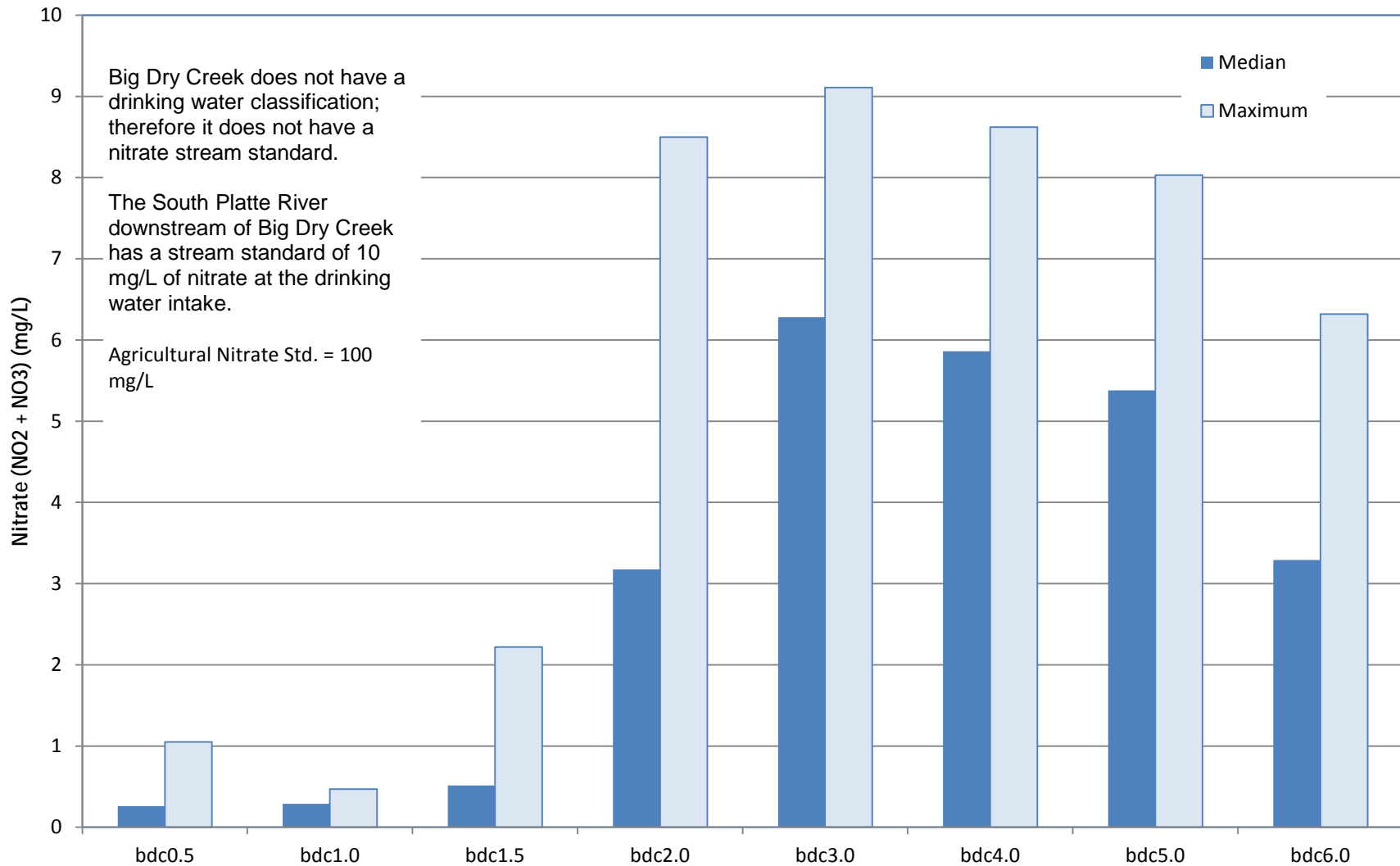


Figure 8. 2011 Big Dry Creek Total Ammonia + NO3/NO2

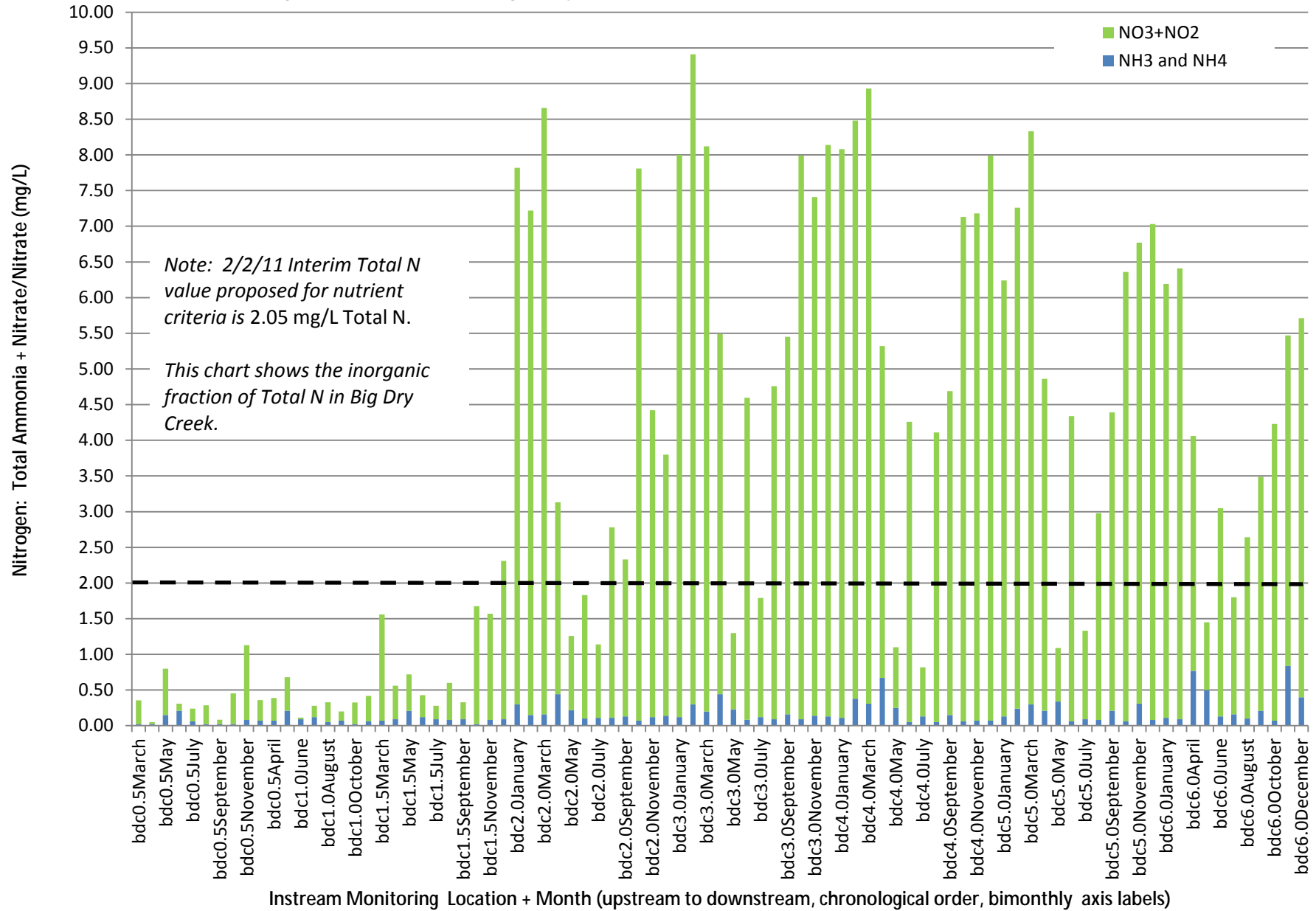


Figure 9a.
Big Dry Creek Instream Total Phosphorus at bdc6.0

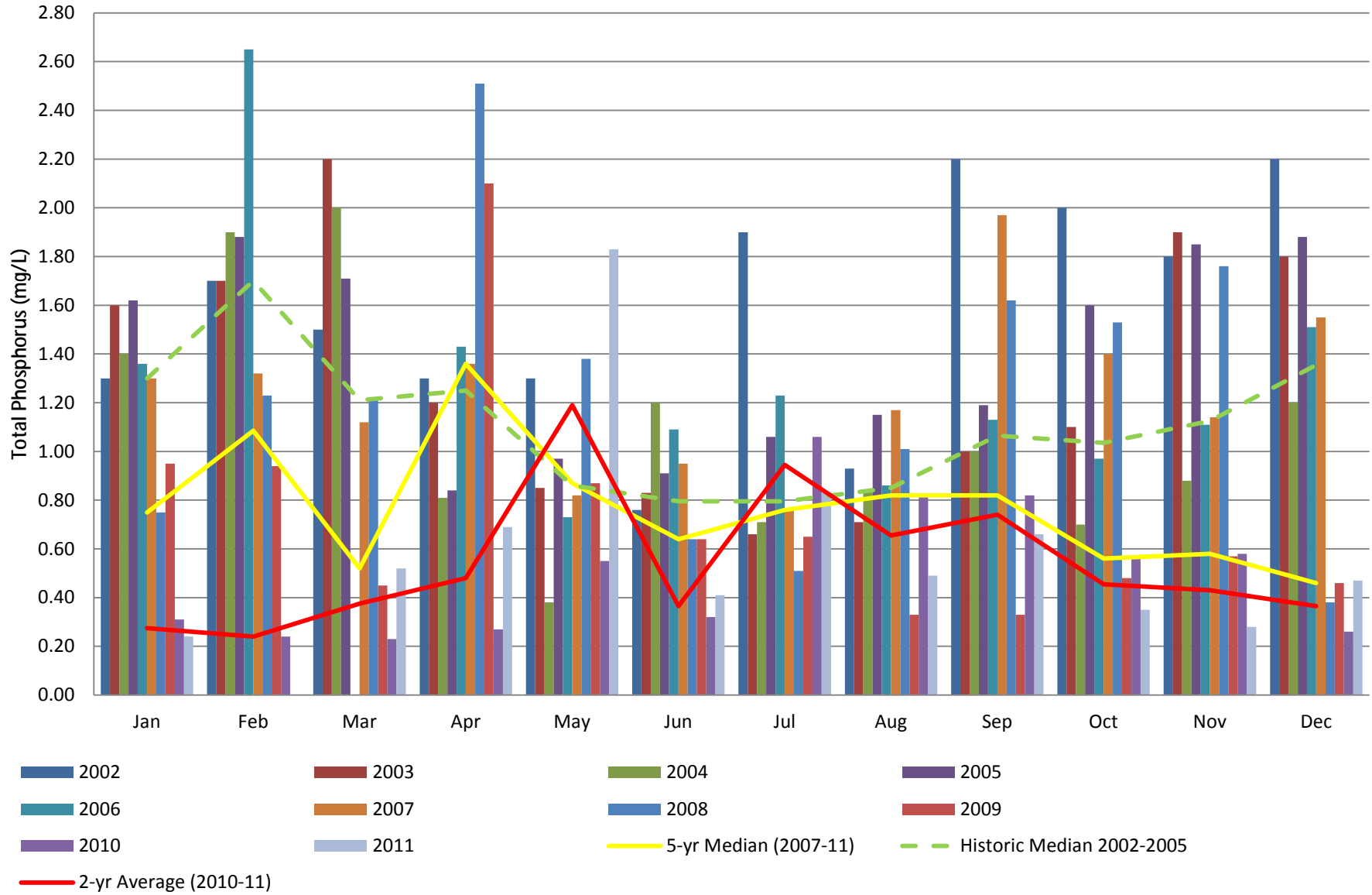
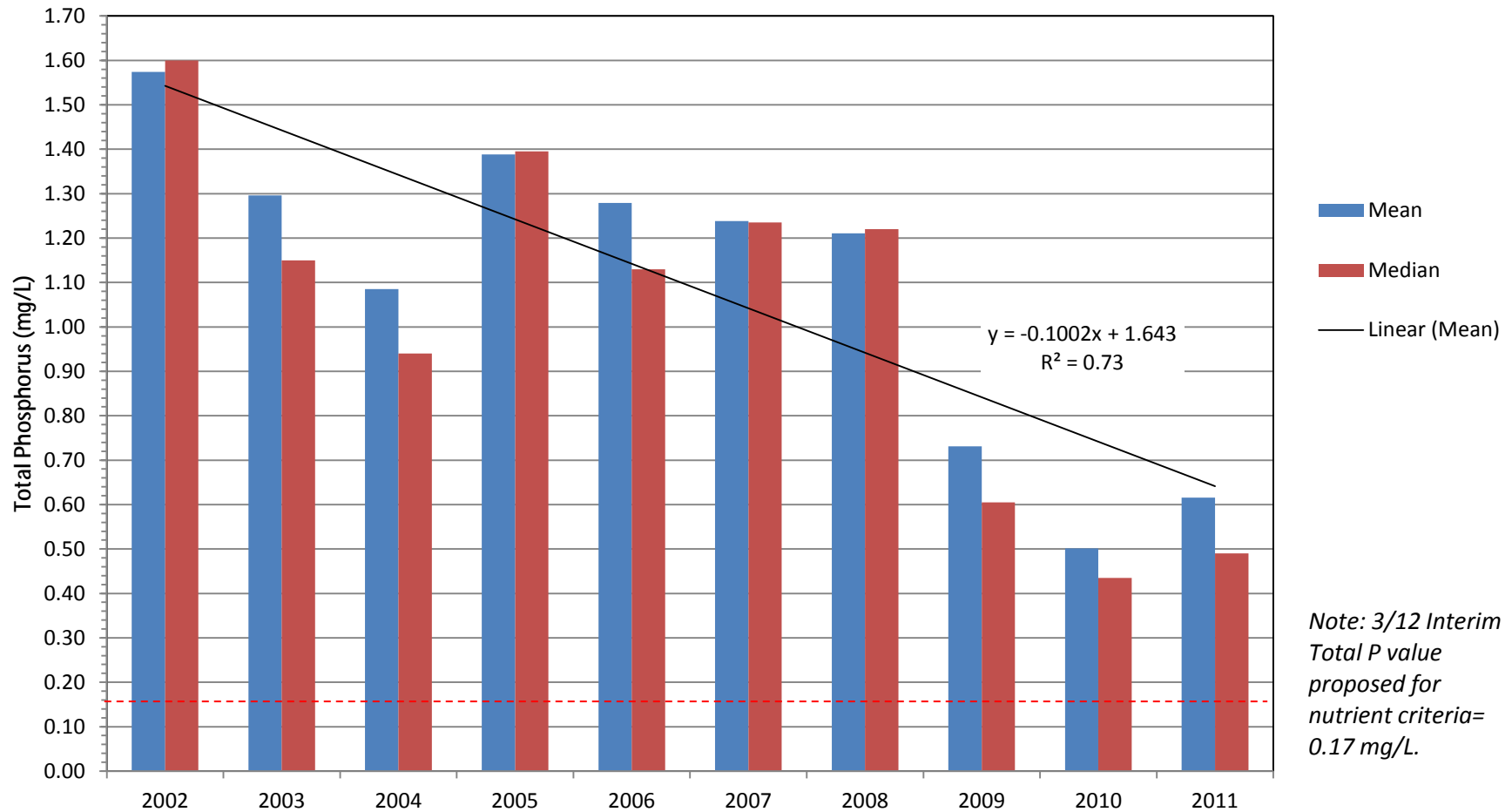
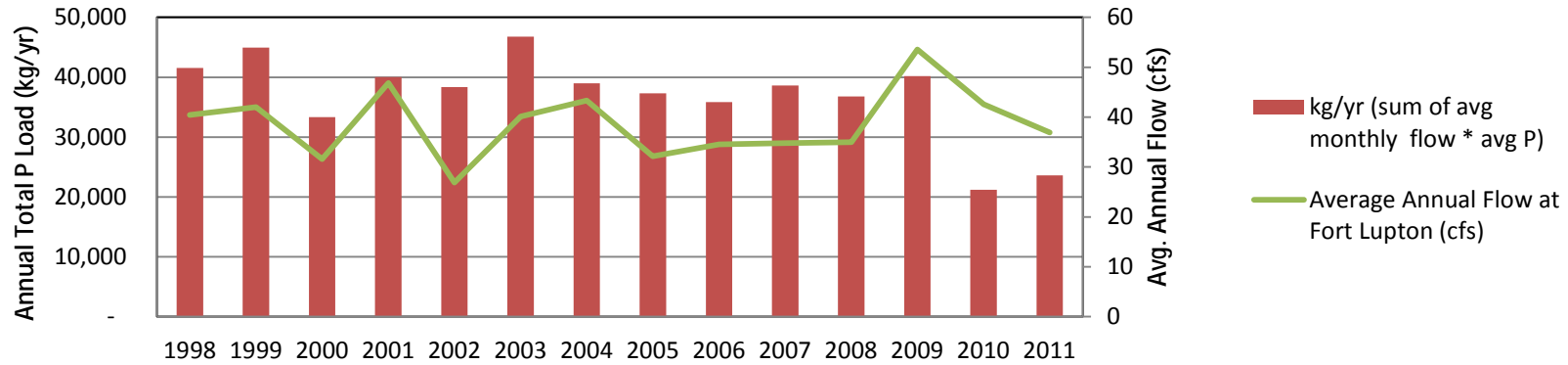


Figure 9b. Big Dry Creek Instream Total Phosphorus at bdc6.0 (2002-2011)



**Figure 10a. Estimated Total P Loading at bdc6.0
(using Fort Lupton Gage & bdc6.0 Total P)**



**Figure 10b. Estimated Total P Loading at bdc6.0
(using Fort Lupton Gage & bdc6.0 Total P)**

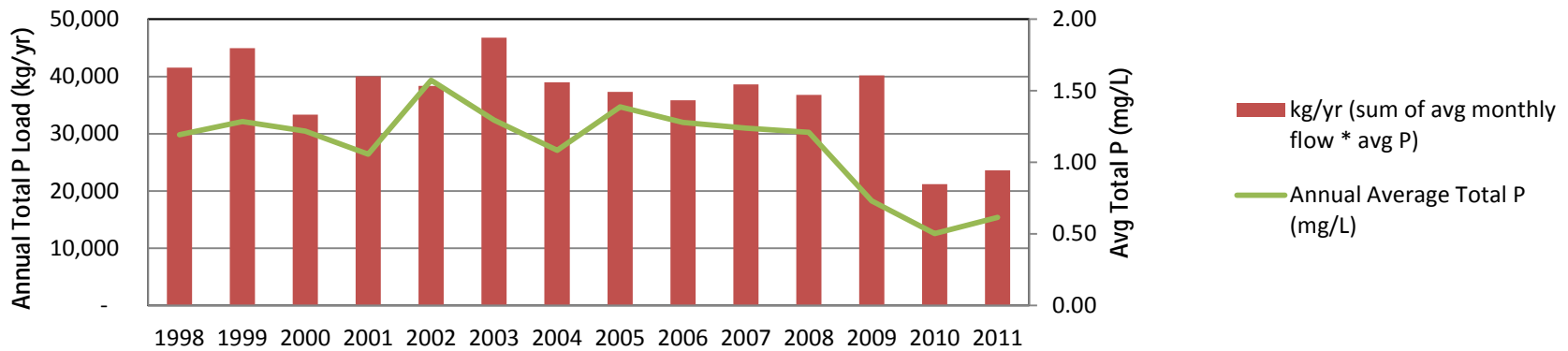


Figure 11a.

Total Phosphorus in Broomfield WWTP Discharge

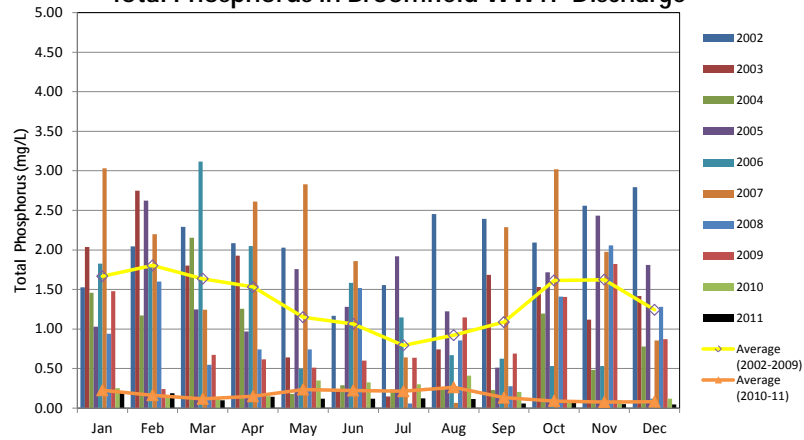


Figure 12a.

Total Phosphorus in Westminster WWTP Discharge

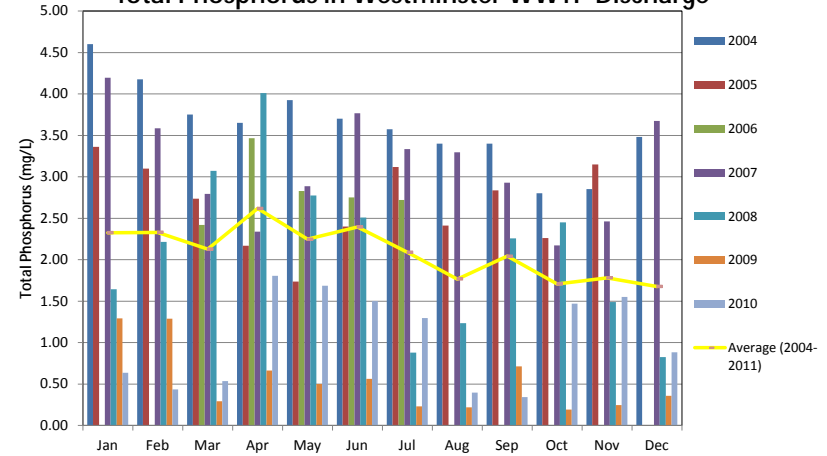


Figure 11b. Average Total Phosphorus Concentration in Broomfield WWTP Discharge

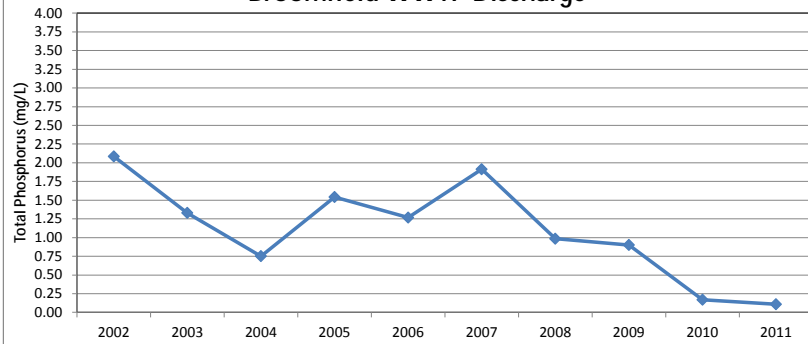
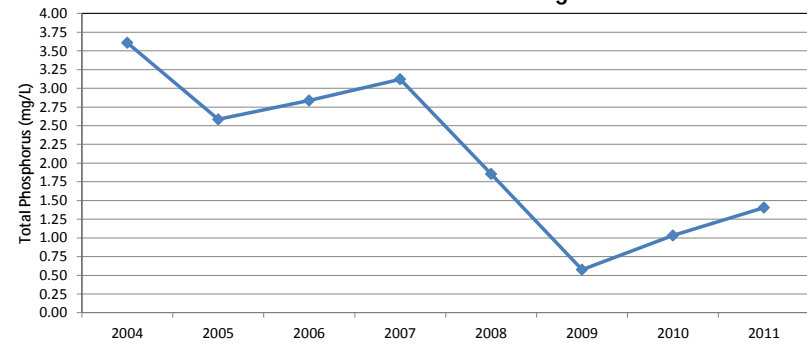


Figure 12b. Average Total Phosphorus Concentration in Westminster WWTP Discharge



Only 5 months available for 2007

Figure 13.

Total Broomfield and Westminster WWTP Discharges to Big Dry Creek

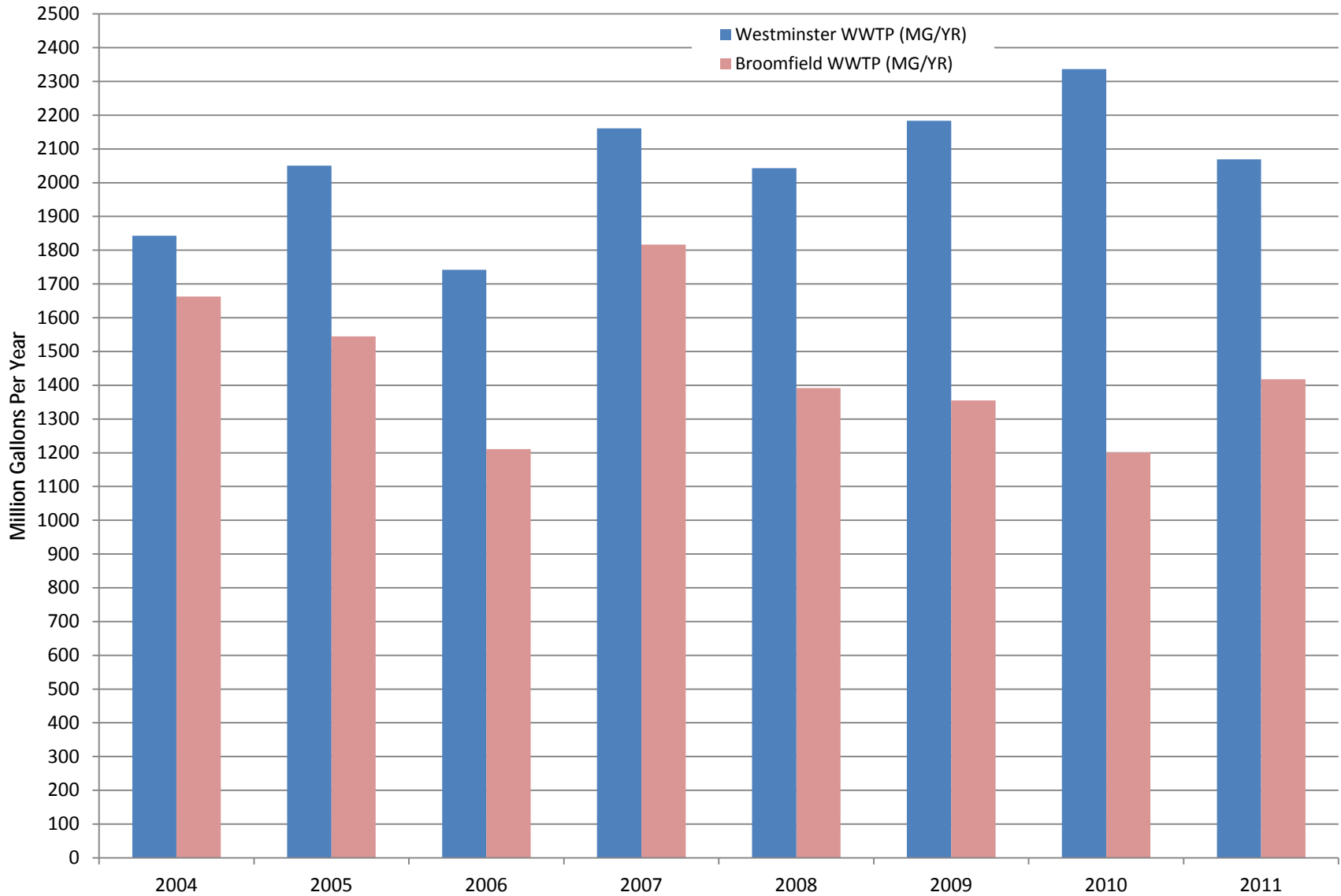


Figure 14. Big Dry Creek Median Total Phosphorus in 2011

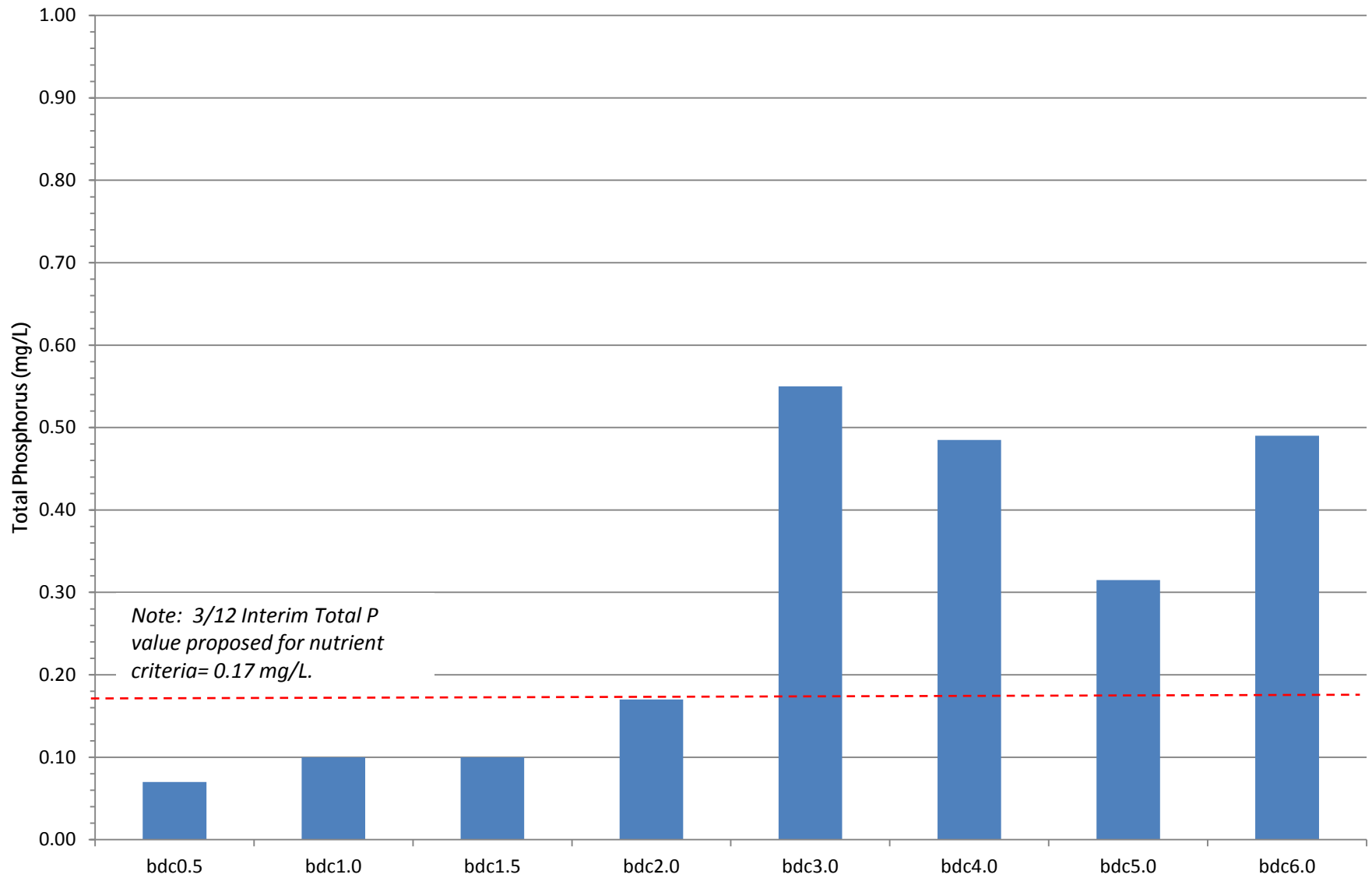


Figure 15a. Big Dry Creek Instream Temperatures (Dec-Feb) 2007-2011

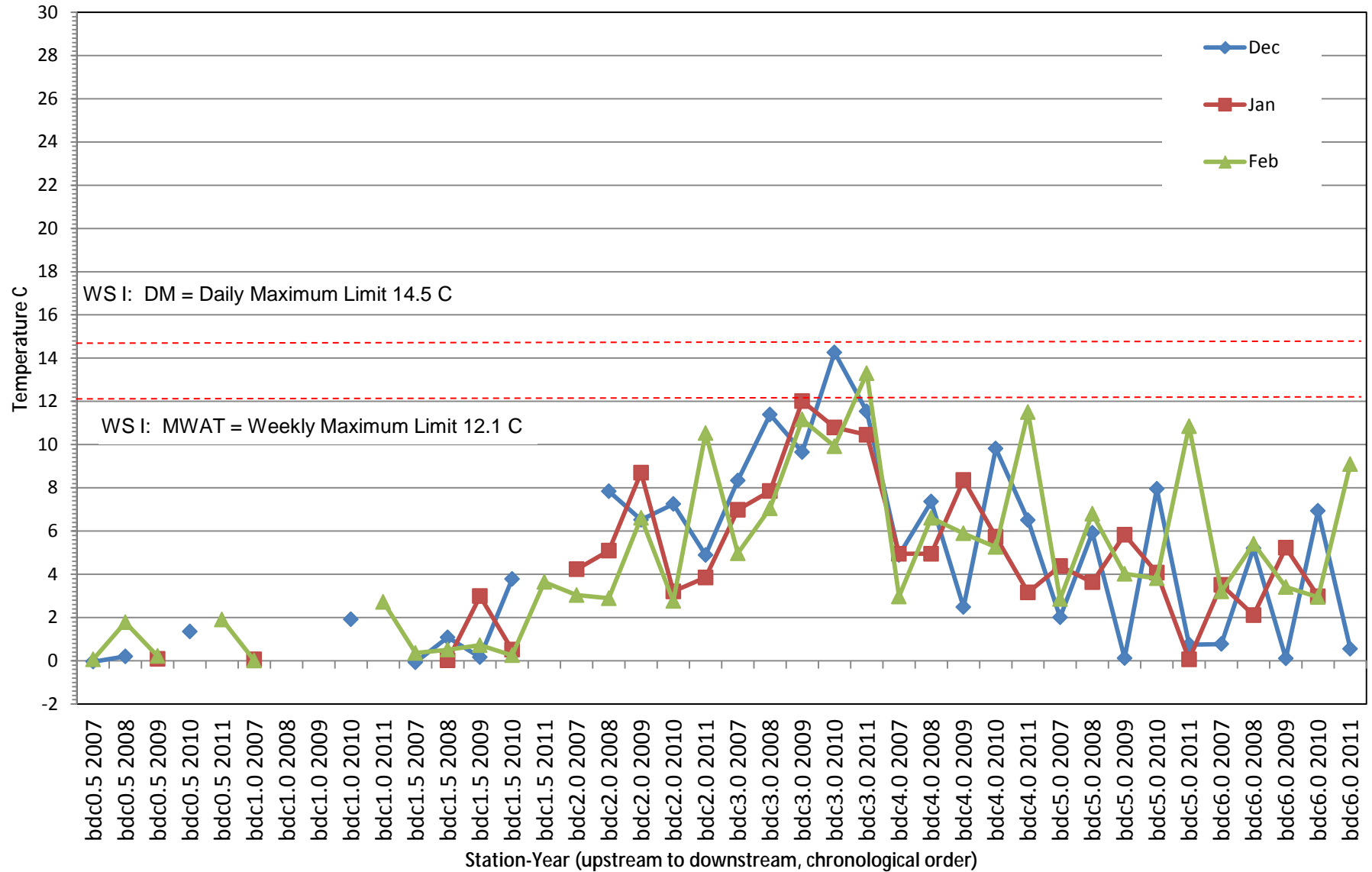
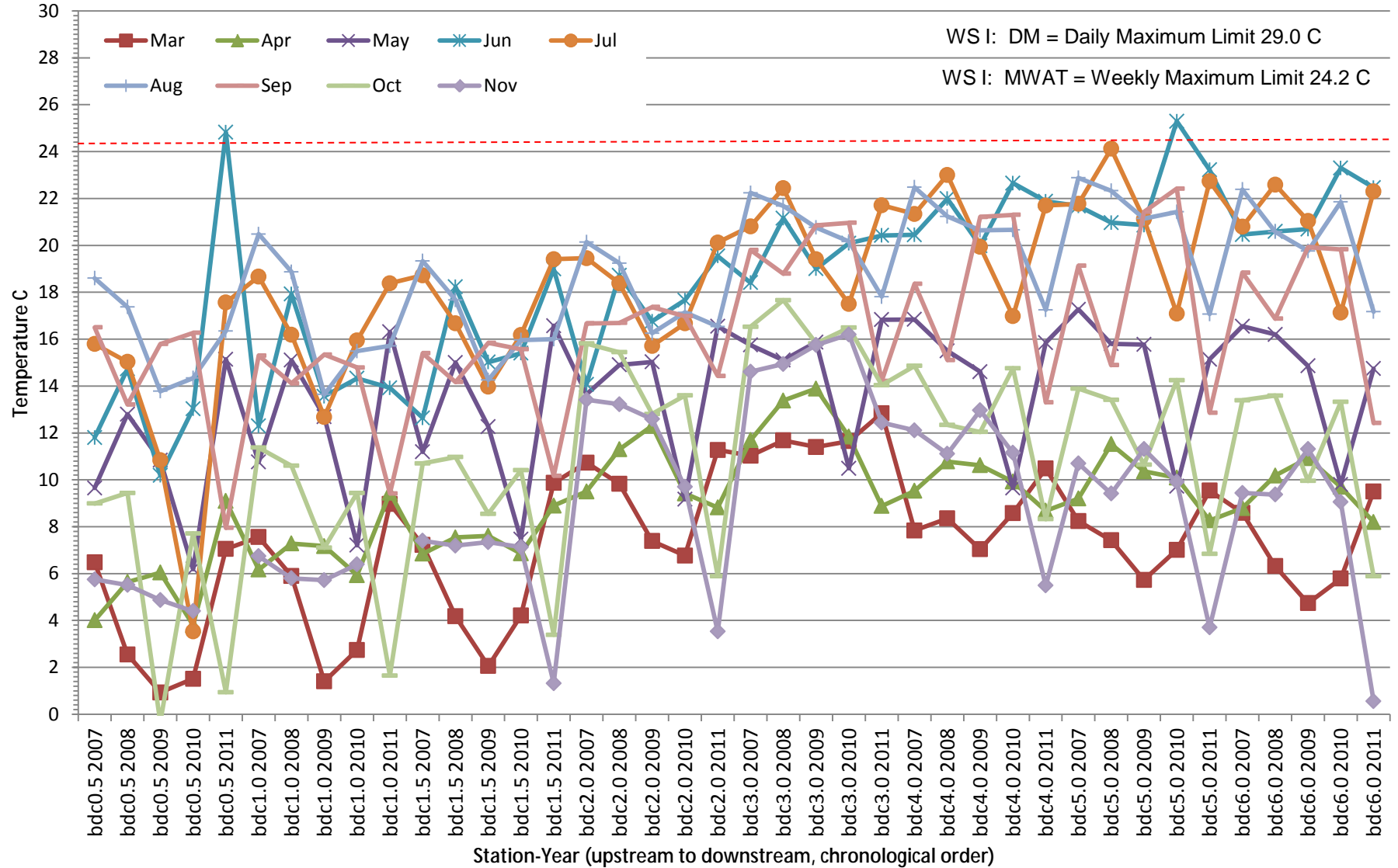
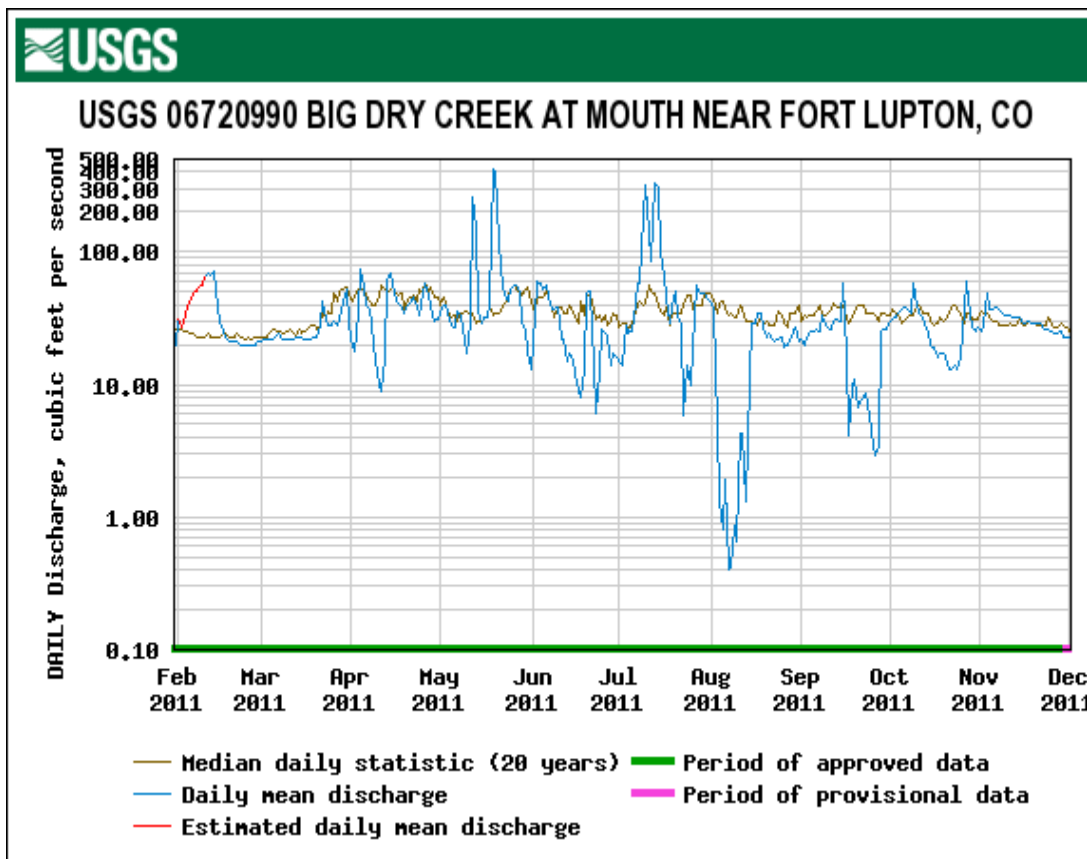
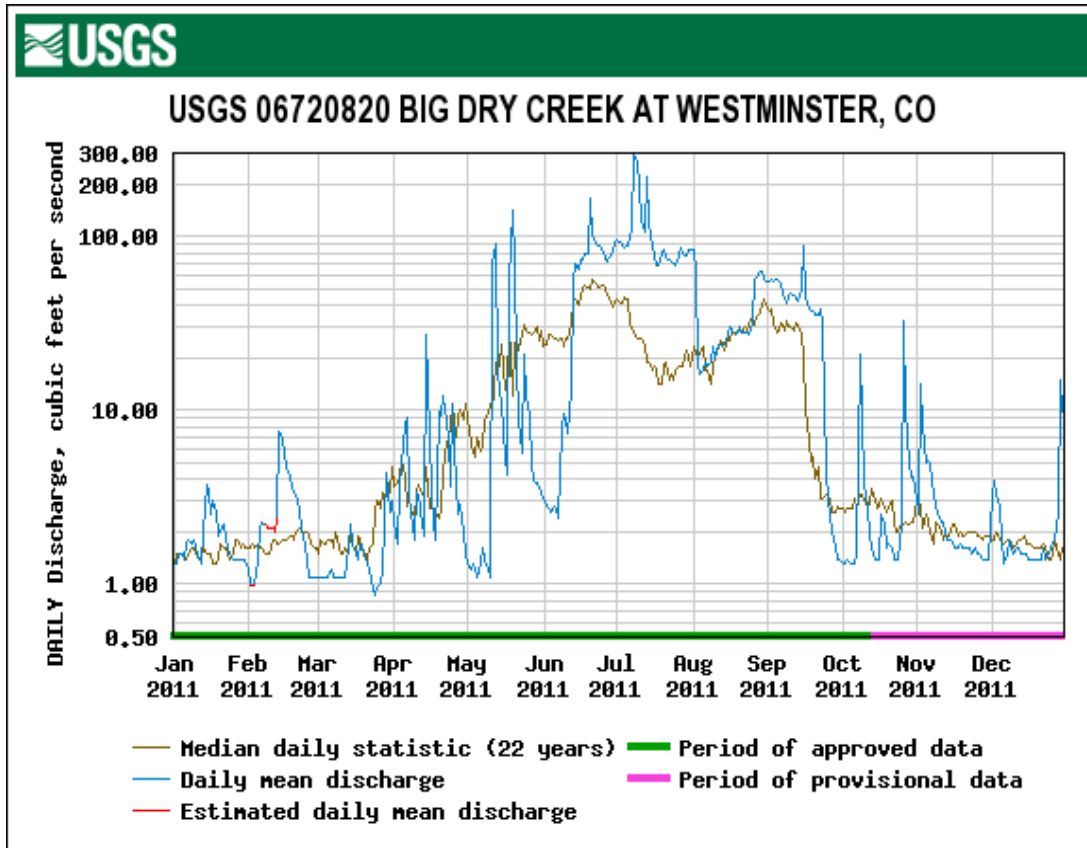


Figure 15b.
Big Dry Creek Instream Temperatures (Mar-Nov) 2007-2011



Figures 16 a & b. USGS 2009 Streamflows on Big Dry Creek



Figures 17 a & b. USGS Peak Annual Streamflows on Big Dry Creek

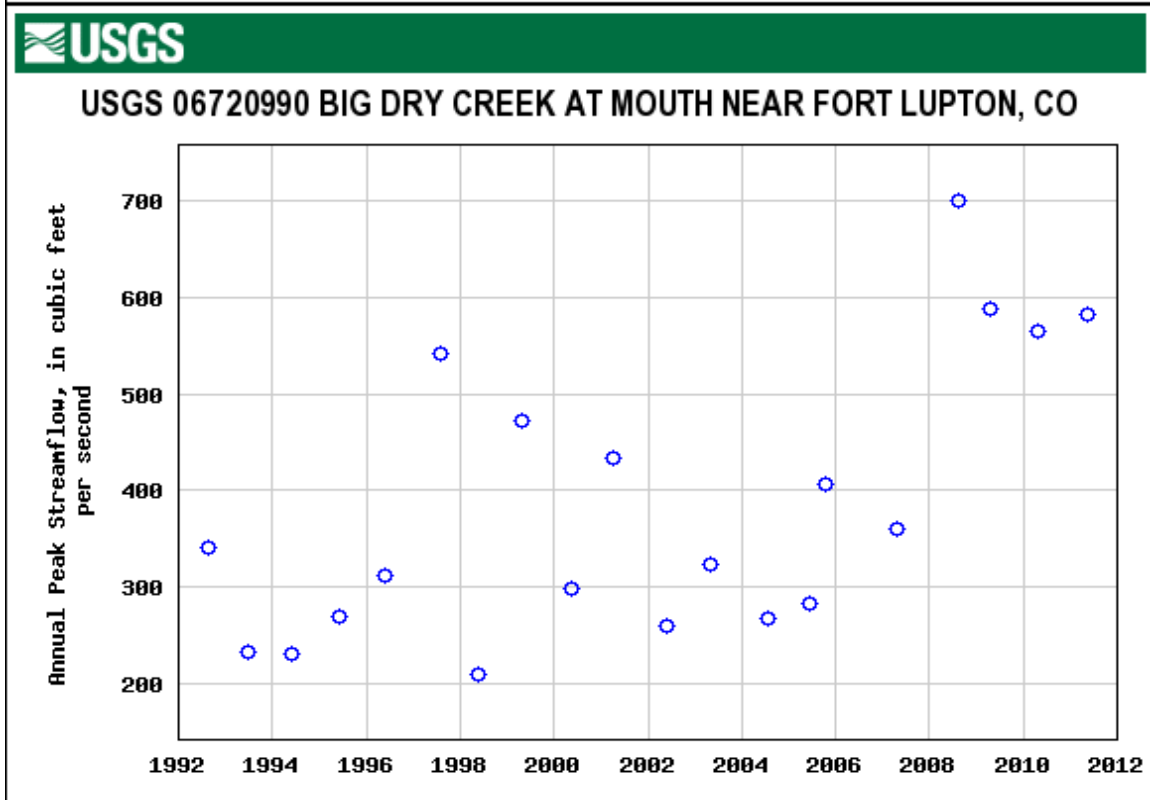
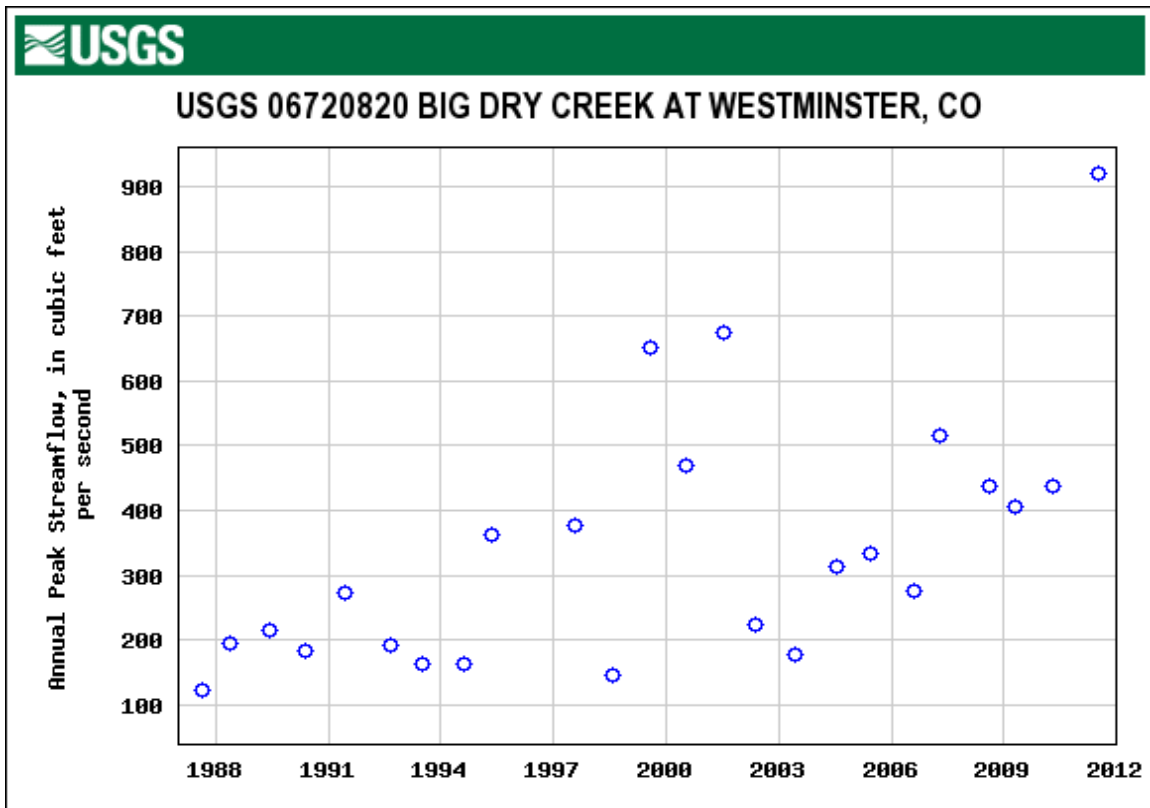
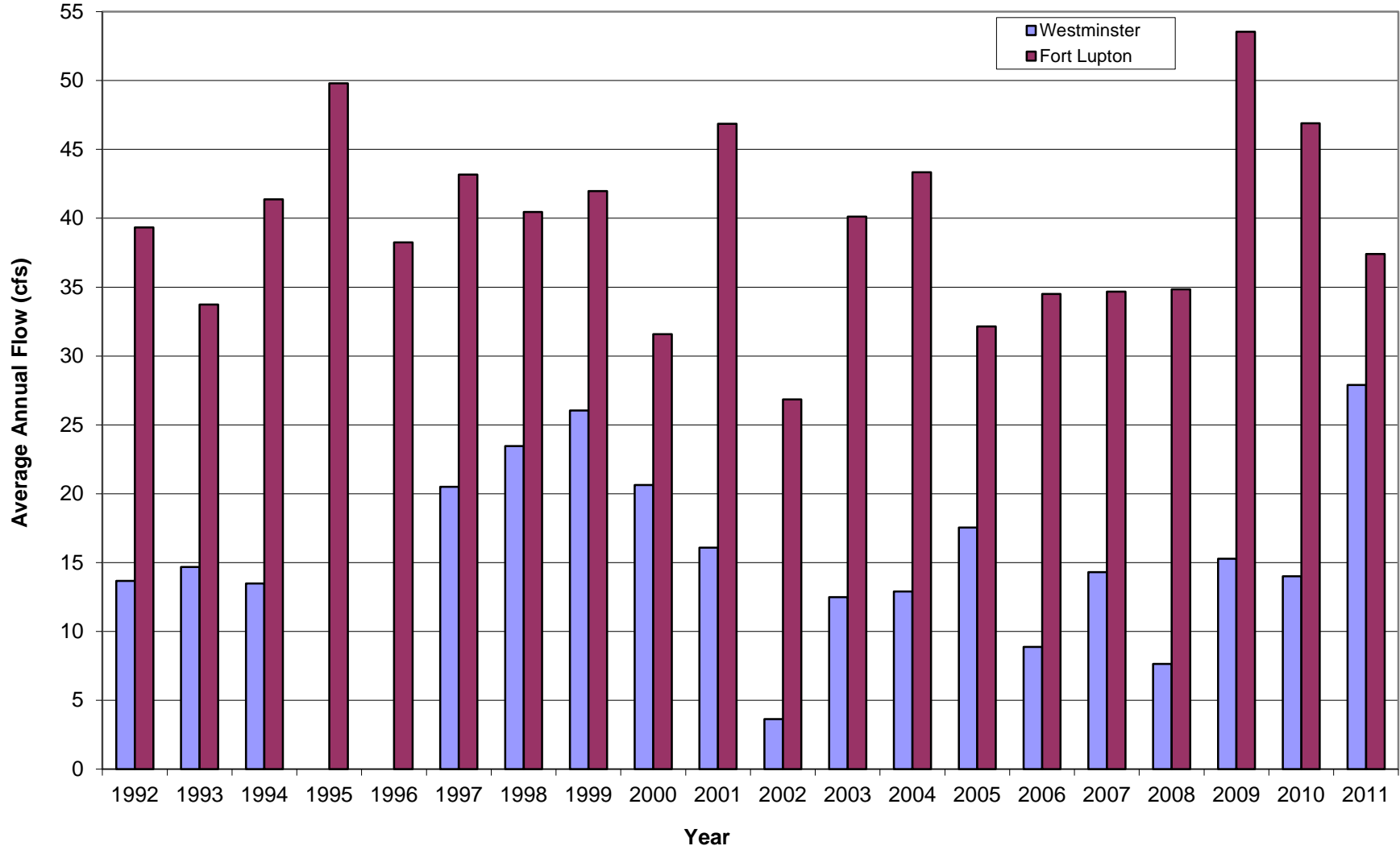


Figure 18.
Average Annual Flows on Big Dry Creek at USGS Westminster and Fort Lupton Gages
(plotted as calendar years)



ATTACHMENTS

Attachment 1. Big Dry Creek 2011 Water Quality Data

	Trip Start Date	ALK-ALINITY	ARSENIC	BORON	CADMIUM	CALCIUM	CARBON, TOTAL ORGANIC	CHLORIDE	CHROMIUM	CHLORO-PHYLL A, COR.	CHLORO-PHYLL A, UNCOR.	COND.	COPPER	CYANIDE	DO	E. coli	FLOW	IRON	LEAD	MAGNESIUM
	Sample Fraction	Total	Total Rec.	Total	Dissolved	Total	Total	Dissolved	Dissolved	ug/L	ug/L	uS/cm	Dissolved	Total	Dissolved	#/100 ml	cfs	Total Rec.	Dissolved	Dissolved
Station ID	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	uS/cm	mg/L	mg/L	mg/L	#/100 ml	cfs	mg/L	mg/L	mg/L
	Det. Limit		0.001	0.01	0.0003		0.15	0.2	0.0004	0.1	0.1		0.0007	0.004				0.04	0.001	0.15
bdc0.5	10-Mar-11	272	0.0005	0.30	0.00015	130	5.64	316.0	0.0002	1.8	2.8	2522	0.0080	0.002	11.8	12		0.11	0.0005	55.57
bdc0.5	20-Apr-11	73				46	2.22	62.0		6.2	7.0	444			11.0	1	7.3			9.48
bdc0.5	12-May-11	70				29	8.29	48.8		3.0	3.9	466			10.8	2420				7.50
bdc0.5	09-Jun-11	274	0.0005	0.30	0.00015	120	7.17	187.4	0.0002	3.8	4.6	2105	0.0060		10.2	866		0.12	0.0005	50.20
bdc0.5	14-Jul-11	63				39	2.77	28.0		1.7	2.6	202			7.0	162				7.16
bdc0.5	04-Aug-11	62				37	2.25	29.0		1.2	1.9	355			7.7	78	14.5			7.66
bdc0.5	08-Sep-11	49	0.0005	0.05	0.00015	34	2.33	21.1	0.0002	0.9	2.2	284	0.0040	0.002	7.2	9		0.53	0.0005	5.68
bdc0.5	13-Oct-11	250				117	5.36	150.0		8.5	9.6	1731			7.4	179				39.45
bdc0.5	10-Nov-11	271				147	5.26	179.2		1.1	1.8	1960			11.2	35				43.16
bdc0.5	08-Dec-11																			
bdc1.0	13-Jan-11																			
bdc1.0	10-Feb-11																			
bdc1.0	10-Mar-11	272	0.0005	0.33	0.00015	151	6.05	432.0	0.0002	9.6	10.8	2583	0.0080	0.002	11.9	7		0.60	0.0005	55.39
bdc1.0	20-Apr-11	153				72	8.34	156.0		13.9	16.2	1145			7.9	111	10.2			22.17
bdc1.0	12-May-11	83				45	8.32	71.5		9.4	11.7	770			9.0	1300				10.94
bdc1.0	09-Jun-11	122	0.0005	0.11	0.00015	58	6.40	54.9	0.0002	13.1	19.0	682	0.0080		8.4	2420		1.48	0.0005	13.93
bdc1.0	14-Jul-11	81				40	4.02	29.5		4.1	5.8	385			9.9	1046				7.57
bdc1.0	04-Aug-11	84				53	2.60	40.2		1.6	4.3	475			9.1	461	14.1			10.06
bdc1.0	08-Sep-11	64	0.0005	0.09	0.00015	43	3.07	38.6	0.0002	4.3	5.9	418	0.0030	0.002	8.1	649		0.80	0.0005	7.81
bdc1.0	13-Oct-11	200				120	7.24	133.4		12.3	12.8	1468			8.6	50				30.98
bdc1.0	10-Nov-11	210				116	6.40	206.0		2.4	3.0	1706			12.7	44				32.22
bdc1.0	08-Dec-11																			
bdc1.5	13-Jan-11																			
bdc1.5	10-Feb-11																			
bdc1.5	10-Mar-11	298	0.0005	0.42	0.00015	165	6.02	370.0	0.0002	6.5	7.7	2576	0.0090	0.002	11.3	24		0.51	0.0005	59.27
bdc1.5	20-Apr-11	177				90	9.62	210.0		15.8	18.8	1499			9.1	152	7.1			24.19
bdc1.5	12-May-11	89				48	8.77	88.5		11.0	14.1	715			9.3	1733				12.45
bdc1.5	09-Jun-11	177	0.0005	0.18	0.00015	80	6.98	108.0	0.0002	20.9	23.1	1073	0.0050		10.3	2420	9.9	0.64	0.0005	25.23
bdc1.5	14-Jul-11	81				44	4.65	31.3		6.5	7.4	430			10.9	727				8.14
bdc1.5	04-Aug-11	103				52	2.85	48.9		2.2	4.1	587			8.4	240				12.87
bdc1.5	08-Sep-11	80	0.0005	0.10	0.00015	53	3.54	31.8	0.0002	4.2	6.3	485	0.0030	0.002	8.0	727		0.96	0.0005	9.97
bdc1.5	13-Oct-11	240				122	6.71	142.6		16.0	16.8	1743			8.3	214				41.35
bdc1.5	10-Nov-11	245				139	6.25	196.4		3.5	4.2	1933			12.3	57				39.80
bdc1.5	08-Dec-11	295	0.0005	0.40	0.00015	172	5.90	595.0	0.0002	4.6	5.4	3590	0.0050	0.002	10.2	517		0.30	0.0005	53.35
bdc2.0	13-Jan-11	223				125	6.79	206.0		1.5	2.4	1750			10.7	1120	1.6			34.88
bdc2.0	10-Feb-11	185				98	7.17	342.0		4.9	8.1	1800			10.7	614	1.7			29.95
bdc2.0	10-Mar-11	154	0.0005	0.30	0.00015	84	7.43	169.4	0.0002	2.6	3.4	1324	0.0100	0.002	10.7	88		0.54	0.0005	27.24
bdc2.0	20-Apr-11	152				76	9.12	188.6		19.4	20.6	1309			7.5	105				29.06
bdc2.0	12-May-11	87				54	8.80	84.0		11.9	15.4	672			8.5	1300				11.86
bdc2.0	09-Jun-11	210	0.0005	0.25	0.00015	101	7.78	144.0	0.0002	13.1	15.1	1392	0.0060		9.6	2203		0.35	0.0005	32.48
bdc2.0	14-Jul-11	92				48	6.12	39.9		3.7	4.2	536			10.3	1046				10.64
bdc2.0	04-Aug-11	114				61	3.92	59.7		3.3	4.8	710			7.5	649				15.34
bdc2.0	08-Sep-11	91	0.0005	0.15	0.00015	53	5.07	50.4	0.0002	5.7	7.8	602	0.0030	0.002	7.6	1203		0.74	0.0005	12.12
bdc2.0	13-Oct-11	157				83	7.31	96.0		6.3	6.8	1189			7.3	687	12.6			25.06
bdc2.0	10-Nov-11	216				124	6.50	156.6		5.1	6.3	1673			10.9	326				35.07
bdc2.0	08-Dec-11	292	0.0005	0.39	0.00015	156	5.96	415.0	0.0002	7.8	9.6	2672	0.0040	0.002	11.2	775		1.62	0.0005	46.56
bdc3.0	13-Jan-11	150				106	7.17	133.2		4.9	5.1	1297			9.9	366	17.8			24.82
bdc3.0	10-Feb-11	124				86	7.73	175.8		1.6	2.1	1245			9.4	462	16.2			19.96
bdc3.0	10-Mar-11	121	0.0005	0.28	0.00015	72	7.62	115.2	0.0002	1.7	2.7	1011	0.0120	0.002	9.8	196		0.28	0.0005	19.25
bdc3.0	20-Apr-11	138				79	8.22	161.4		13.9	15.2	1258			8.8	81	45.2			24.42
bdc3.0	12-May-11	102				55	8.77	84.5		9.6	12.6	744			8.9	1120				14.30
bdc3.0	09-Jun-11	193	0.0005	0.31	0.00015	110	8.07	134.0	0.0002	12.3	13.8	1414	0.0070		9.4	921	23.6	0.22	0.0005	32.55
bdc3.0	14-Jul-11	108				58	6.39	49.8		3.6	4.0	671			9.7	649				13.99
bdc3.0	04-Aug-11	152				86	5.18	79.8		2.8	3.7	1009			7.9	1046	15.0			24.11

Attachment 1. Big Dry Creek 2011 Water Quality Data

	Trip Start Date	ALK-ALINITY	ARSENIC	BORON	CADMIUM	CALCIUM	CARBON, TOTAL ORGANIC	CHLORIDE	CHROMIUM	CHLORO-PHYLL A, COR.	CHLORO-PHYLL A, UNCOR.	COND.	COPPER	CYANIDE	DO	E. coli	FLOW	IRON	LEAD	MAGNESIUM	
bdc3.0	08-Sep-11	113	0.0005	0.24	0.00015	71	6.23	80.4	0.0002	3.3	7.7	883	0.0070	0.002	7.9	921		0.57	0.0005	17.47	
bdc3.0	13-Oct-11	160				90	7.38	96.4		4.9	5.7	1292			7.5	770	11.1			28.84	
bdc3.0	10-Nov-11	141				98	7.05	103.2		2.9	3.8	1238			9.2	411	21.9			24.35	
bdc3.0	08-Dec-11	137	0.0005	0.36	0.00015	84	6.91	145.2	0.0002	3.6	4.6	1320	0.0070	0.002	9.5	687	19.4	0.25	0.0005	23.18	
bdc4.0	13-Jan-11	174				123	6.78	153.8		8.9	10.6	1509			11.3	436				30.44	
bdc4.0	10-Feb-11	163				104	6.89	262.0		3.4	5.3	1622			11.0	462				28.37	
bdc4.0	10-Mar-11	141	0.0005	0.32	0.00015	82	7.25	128.8	0.0002	2.5	3.3	1184	0.0100	0.002	12.4	119		0.43	0.0005	24.75	
bdc4.5	20-Apr-11	155				82	8.09	148.6		10.7	12.2	1314			9.0	146				26.79	
bdc4.5	12-May-11	99				57	8.79	82.5		11.1	13.8	747			8.5	1733				13.92	
bdc4.5	09-Jun-11	216	0.0005	0.36	0.00015	119	7.74	144.0	0.0002	15.9	17.5	1634	0.0090		9.7	921		0.22	0.0005	38.24	
bdc4.5	14-Jul-11	123				53	6.65	44.1		2.5	4.5	650			9.9	1414				13.51	
bdc4.5	04-Aug-11	169				98	5.16	96.3		2.1	3.2	1260			8.5	411				30.01	
bdc4.5	08-Sep-11	131	0.0005	0.25	0.00015	81	7.04	82.5	0.0002	8.2	10.9	1016	0.0050	0.002	8.0	2420		0.69	0.0005	21.32	
bdc4.5	13-Oct-11	168				100	6.90	102.8		5.7	6.6	1439			7.9	184				30.89	
bdc4.5	10-Nov-11	176				103	6.87	120.6		5.9	7.0	1458			12.1	517				30.89	
bdc4.5	08-Dec-11	165	0.0005	0.36	0.00015	114	6.55	196.8	0.0002	8.1	9.4	1671	0.0050	0.002	11.5	770		0.39	0.0005	31.09	
bdc5.0	13-Jan-11	195				115	6.15	154.8		8.7	12.0	1612			12.0	276				34.16	
bdc5.0	10-Feb-11	168				96	6.64	228.0		5.1	8.9	1540			12.2	273				28.75	
bdc5.0	10-Mar-11	153	0.0005	0.32	0.00015	81	6.99	124.6	0.0002	4.3	5.5	1197	0.0100	0.002	11.8	53		0.87	0.0005	25.76	
bdc5.0	20-Apr-11	178				97	7.53	152.0		13.6	15.2	1425			16.2	161				30.73	
bdc5.0	12-May-11	107				45	8.85	80.0		13.1	18.5	756			8.6	1733				14.17	
bdc5.0	09-Jun-11	211	0.0005	0.38	0.00015	115	7.34	136.0	0.0002	14.7	15.9	1633	0.0080		12.8	816		0.15	0.0005	39.44	
bdc5.0	14-Jul-11	143				60	6.77	52.5		3.9	4.1	756			9.6	1203				15.85	
bdc5.0	04-Aug-11	203				100	4.99	103.0		3.0	4.5	1351			8.2	179				35.05	
bdc5.0	08-Sep-11	138	0.0005	0.24	0.00015	77	6.63	79.4	0.0002	13.4	22.5	976	0.0060	0.002	7.6	2203		1.48	0.0005	20.39	
bdc5.0	13-Oct-11	180				96	6.44	102.2		6.0	7.3	1428			8.7	291				32.08	
bdc5.0	10-Nov-11	188				118	6.52	124.4		5.1	6.8	1545			11.1	184				33.69	
bdc5.0	08-Dec-11	180	0.0005	0.38	0.00015	113	6.23	183.4	0.0002	12.0	15.1	1720	0.0050	0.002	12.4	435		0.82	0.0005	33.90	
bdc6.0	13-Jan-11	210				127	6.19	161.6		8.2	10.3	1624			12.2	123				34.65	
bdc6.0	10-Feb-11																				
bdc6.0	10-Mar-11	185	0.0005	0.34	0.00015	95	6.67	143.6	0.0002	7.4	9.4	1352	0.0060	0.002	14.0	816		0.96	0.0005	31.00	
bdc6.0	20-Apr-11	195				93	8.58	136.4		17.6	20.9	1378			10.2	870				29.66	
bdc6.0	12-May-11	105				60	9.18	78.0		12.6	16.8	784			7.9	2420				14.48	
bdc6.0	09-Jun-11	197	0.0005	0.31	0.00015	106	6.60	110.2	0.0002	17.4	20.1	1443	0.0070		11.1	2420		0.80	0.0005	34.61	
bdc6.0	14-Jul-11	130				68	6.68	62.0		3.2	4.5	867			10.1	1553				18.13	
bdc6.0	04-Aug-11	168				95	4.59	81.9		8.2	9.9	1050			8.6	365				25.91	
bdc6.0	08-Sep-11	171	0.0005	0.30	0.00015	90	6.53	90.6	0.0002	0.1	0.1	1159	0.0030	0.002	7.5	2420		1.55	0.0005	25.80	
bdc6.0	13-Oct-11	201				100	5.71	97.8		9.4	11.0	1354			8.2	613				29.80	
bdc6.0	10-Nov-11	215				122	6.05	132.4		5.1	6.5	1651			11.1	435				36.96	
bdc6.0	08-Dec-11	198	0.0005	0.39	0.00015	111	5.84	151.2	0.0002	32.6	36.5	1663	0.0050	0.002	13.1	167		0.75	0.0005	34.01	
	Count	87	30	30	30	87	87	87	30	87	87	87	30	22	87	87	17	30	30	87	
	# Non-detects	0	30	0	30	0	0	0	30	0	0	0	0	22	0	1		0	30	0	
	min	49	<DL	0.05	<DL	29	2.22	21.1	<DL	0.05	0.1	202	0.0030	<DL	7.0	<DL	1.6	0.11	<DL	5.68	
	max	298	<DL	0.42	<DL	172	9.62	595.0	<DL	32.60	36.5	3590	0.0120	<DL	16.2	2420	45.2	1.62	<DL	59.27	
	mean	160	<DL	0.28	<DL	89	6.46	133.9	<DL	7.47	9.3	1254	0.0065	<DL	9.8	735	14.7	0.66	<DL	25.98	
	std dev.	60	NA	0.10	NA	32	1.66	95.6	NA	5.63	6.4	597	0.0024	NA	1.8	712	10.0	0.43	NA	12.28	
	5th%	71	<DL	0.09	<DL	41	2.79	31.5	<DL	1.53	2.3	422	0.0030	<DL	7.5	27	1.7	0.13	<DL	7.70	
	15th%	91	<DL	0.16	<DL	53	5.06	50.3	<DL	2.49	3.7	645	0.0040	<DL	7.9	103	7.2	0.23	<DL	12.10	
	25th%	114	<DL	0.24	<DL	59	5.93	79.6	<DL	3.30	4.4	756	0.0050	<DL	8.3	173	9.9	0.31	<DL	14.39	
	50th%	160	<DL	0.31	<DL	90	6.65	120.6	<DL	5.70	7.3	1297	0.0060	<DL	9.6	517	14.1	0.59	<DL	25.91	
	75th%	198	<DL	0.36	<DL	114	7.36	156.3	<DL	11.05	13.3	1617	0.0080	<DL	11.1	1046	17.8	0.82	<DL	33.12	
	85th%	215	<DL	0.38	<DL	120	8.10	189.4	<DL	13.13	15.9	1707	0.0090	<DL	11.8	1428	20.9	0.96	<DL	35.26	
	95th%	272	<DL	0.40	<DL	145	8.80	334.2	<DL	16.98	20.5	2397	0.0100	<DL	12.6	2420	27.9	1.52	<DL	49.11	

Attachment 1. Big Dry Creek 2011 Water Quality Data

	Trip Start Date	MAN-GANESE	NICKEL	AMMONIA, TOTAL	NO2	NO2/NO3	PH	PHOS-PHORUS	PHOS-PHORUS, ORTHOPHOSPHATE AS P	POTASSIUM	SELENIUM	SILVER	SODIUM	TDS	TSS	SULFATE	TEMP.	TURBIDITY	ZINC	
	Sample Fraction	Dissolved	Dissolved					Total	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved			Dissolved			Dissolved	
Station ID	Units	mg/L	mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	°C	NTU	mg/L	
	Det. Limit	0.0002	0.001	0.05	0.01	0.05		0.05	0.010	0.07	0.0008	0.0002	0.8		2	0.1			0.001	
bdc0.5	10-Mar-11	0.8000	0.002	0.025	0.005	0.33	7.07	0.06	0.005	3.98	0.0061	0.0001	390.4	1759.0	3.8	728.0	1.9	2.9	0.0005	
bdc0.5	20-Apr-11			0.025	0.005	0.025	7.99	0.07	0.005	2.66	0.0004		32.6	244.0	8.6	81.2	7.1	6.1		
bdc0.5	12-May-11			0.15	0.02	0.65	8.05	0.21	0.12	4.42	0.0004		48.7	268.0	17.0	75.6	9.1	23.1		
bdc0.5	09-Jun-11	0.7700	0.003	0.21	0.01	0.10	7.27	0.09	0.010	4.13	0.0027	0.0001	284.2	1365.0	5.2	558.0	15.1	3.0	0.0005	
bdc0.5	14-Jul-11			0.06	0.005	0.18	7.59	0.08	0.013	2.55	0.0004		21.6	198.0	12.0	58.0	24.8	13.3		
bdc0.5	04-Aug-11			0.025	0.005	0.26	7.51	0.06	0.005	2.43	0.0004		24.3	213.0	8.8	64.0	17.6	11.3		
bdc0.5	08-Sep-11	0.3200	0.001	0.025	0.01	0.06	7.77	0.07	0.013	1.97	0.0004	0.0001	16.5	156.0	16.0	44.2	16.4	17.0	0.0005	
bdc0.5	13-Oct-11			0.025	0.005	0.43	7.76	0.07	0.005	4.48	0.0048		210.4	1085.0	18.0	392.0	8.0	1.8		
bdc0.5	10-Nov-11			0.08	0.01	1.05	7.36	0.025	0.005	4.19	0.0058		239.3	1210.0	8.8	424.0	0.9	4.2		
bdc0.5	08-Dec-11																			
bdc1.0	13-Jan-11																			
bdc1.0	10-Feb-11																			
bdc1.0	10-Mar-11	0.8000	0.003	0.07	0.005	0.29	7.89	0.08	0.005	3.90	0.0050	0.0001	368.2	1723.0	24.0	578.0	2.7	12.2	0.0005	
bdc1.0	20-Apr-11			0.07	0.02	0.32	7.26	0.10	0.005	3.90	0.0027		145.6	674.0	20.0	204.0	9.0	21.1		
bdc1.0	12-May-11			0.21	0.02	0.47	7.73	0.25	0.11	4.11	0.0014		69.3	372.0	90.0	126.5	9.5	85.7		
bdc1.0	09-Jun-11	0.0400	0.001	0.09	0.005	0.025	8.08	0.17	0.014	2.65	0.0014	0.0001	61.6	375.0	61.0	105.0	16.3	78.5	0.0005	
bdc1.0	14-Jul-11			0.12	0.005	0.16	7.36	0.18	0.04	2.89	0.0004		28.8	221.0	120.0	63.0	13.9	87.7		
bdc1.0	04-Aug-11			0.05	0.005	0.28	7.78	0.10	0.005	2.54	0.0009		38.3	290.0	38.0	92.5	18.4	31.7		
bdc1.0	08-Sep-11	0.1500	0.001	0.07	0.02	0.13	7.68	0.11	0.014	2.36	0.0008	0.0001	28.8	221.0	43.0	90.0	15.7	40.0	0.0005	
bdc1.0	13-Oct-11			0.025	0.005	0.30	8.26	0.10	0.005	4.85	0.0040		162.2	899.0	9.0	328.0	9.4	7.3		
bdc1.0	10-Nov-11			0.06	0.005	0.36	7.98	0.025	0.005	4.32	0.0047		201.8	1015.0	3.8	308.0	1.7	6.8		
bdc1.0	08-Dec-11																			
bdc1.5	13-Jan-11																			
bdc1.5	10-Feb-11																			
bdc1.5	10-Mar-11	0.3600	0.002	0.07	0.005	1.49	7.96	0.09	0.005	3.82	0.0110	0.0001	367.6	1779.0	16.0	664.0	3.6	10.7	0.0005	
bdc1.5	20-Apr-11			0.09	0.01	0.47	7.23	0.11	0.005	6.49	0.0045		164.3	903.0	23.0	285.0	9.9	24.2		
bdc1.5	12-May-11			0.21	0.02	0.51	7.74	0.27	0.10	4.33	0.0018		79.6	418.0	93.0	135.5	8.9	87.8		
bdc1.5	09-Jun-11	0.1000	0.002	0.12	0.005	0.31	7.81	0.12	0.005	3.41	0.0038	0.0001	118.9	659.0	31.0	204.0	16.6	32.1	0.0005	
bdc1.5	14-Jul-11			0.09	0.01	0.19	7.51	0.20	0.05	3.04	0.0009		33.8	248.0	140.0	72.5	19.0	99.4		
bdc1.5	04-Aug-11			0.08	0.005	0.52	7.84	0.09	0.012	2.66	0.0023		55.4	367.0	57.0	127.0	19.4	50.1		
bdc1.5	08-Sep-11	0.0890	0.001	0.09	0.02	0.24	7.66	0.09	0.013	2.57	0.0014	0.0001	38.9	273.0	48.0	68.0	16.0	47.0	0.0005	
bdc1.5	13-Oct-11			0.025	0.005	1.65	7.89	0.08	0.005	4.34	0.0110		202.2	1130.0	16.0	416.0	10.2	10.8		
bdc1.5	10-Nov-11			0.08	0.005	1.49	7.97	0.025	0.005	4.16	0.0098		233.5	1192.0	8.4	414.0	3.4	8.3		
bdc1.5	08-Dec-11	0.3150	0.003	0.09	0.02	2.22	7.41	0.18	0.005	4.41	0.0115	0.0001	551.6	2223.0	10.0	481.5	1.3	14.6	0.0040	
bdc2.0	13-Jan-11			0.30	0.12	7.72	7.56	0.25	0.04	8.61	0.0083		211.4	1096.0	130.0	374.0	4.9	85.0		
bdc2.0	10-Feb-11			0.15	0.09	7.07	7.11	0.23	0.04	9.79	0.0050		257.1	1135.0	81.0	286.0	3.9	71.1		
bdc2.0	10-Mar-11	0.0760	0.003	0.16	0.14	8.50	8.13	0.18	0.04	10.95	0.0060	0.0001	170.6	868.0	16.0	278.0	10.5	10.2	0.0370	
bdc2.0	20-Apr-11			0.44	0.10	2.69	7.87	0.16	0.005	4.11	0.0040		190.3	773.0	22.0	218.0	11.3	21.0		
bdc2.0	12-May-11			0.22	0.03	1.04	7.63	0.29	0.09	4.64	0.0014		73.2	382.0	110.0	122.5	8.8	98.3		
bdc2.0	09-Jun-11	0.0500	0.002	0.10	0.02	1.73	7.83	0.12	0.012	5.21	0.0046	0.0001	153.4	862.0	17.0	288.0	16.6	15.1	0.0038	
bdc2.0	14-Jul-11			0.11	0.02	1.03	7.54	0.24	0.07	4.21	0.0014		46.6	314.0	110.0	101.0	19.5	101.0		
bdc2.0	04-Aug-11			0.11	0.005	2.67	7.82	0.13	0.02	4.80	0.0029		70.1	446.0	72.0	149.0	20.1	49.6		
bdc2.0	08-Sep-11	0.0350	0.001	0.13	0.02	2.20	7.63	0.10	0.02	4.93	0.0019	0.0001	53.6	342.0	41.0	105.0	16.5	41.0	0.0080	
bdc2.0	13-Oct-11			0.07	0.02	7.74	7.68	0.12	0.02	9.08	0.0050		126.7	737.0	12.0	232.0	14.4	8.7		
bdc2.0	10-Nov-11			0.12	0.01	4.30	8.00	0.08	0.02	5.72	0.0083		182.9	1033.0	18.0	354.0	5.9	15.2		
bdc2.0	08-Dec-11	0.2200	0.003	0.14	0.03	3.66	7.67	0.24	0.02	5.68	0.0100	0.0001	378.0	1664.0	65.0	460.0	3.5	64.2	0.0070	
bdc3.0	13-Jan-11			0.12	0.03	7.88	7.52	0.29	0.14	11.67	0.0039		147.5	813.0	17.0	276.0	11.5	12.0		
bdc3.0	10-Feb-11			0.30	0.11	9.11	7.32	0.28	0.06	11.76	0.0030		151.4	760.0	16.0	218.0	10.5	12.8		
bdc3.0	10-Mar-11	0.0580	0.002	0.20	0.10	7.92	7.65	1.14	0.89	12.69	0.0030	0.0001	121.2	659.0	14.0	204.0	13.3	5.8	0.0530	
bdc3.0	20-Apr-11			0.44	0.08	5.05	7.67	0.60	0.41	8.94	0.0036		152.4	754.0	26.0	228.0	12.8	17.3		
bdc3.0	12-May-11			0.23	0.03	1.07	7.72	0.34	0.10	4.81	0.0020		84.1	447.0	190.0	153.0	8.9	139.0		
bdc3.0	09-Jun-11	0.0300	0.002	0.09	0.03	4.51	7.95	0.24	0.12	7.89	0.0046	0.0001	160.0	890.0	9.2	321.0	16.8	10.2	0.0180	
bdc3.0	14-Jul-11			0.12	0.02	1.67	7.59	0.62	0.43	5.19	0.0018		65.6	400.0	100.0	140.0	20.4	89.2		
bdc3.0	04-Aug-11			0.09	0.02	4.67	7.78	0.50	0.32	6.29	0.0044		113.9	656.0	39.0	252.0	21.7	38.6		

Attachment 1. Big Dry Creek 2011 Water Quality Data

	Trip Start Date	MAN-GANESE	NICKEL	AMMONIA, TOTAL	NO2	NO2/NO3	PH	PHOS-PHORUS	PHOS-PHORUS, ORTHOPHOSPHATE AS P	POTASSIUM	SELENIUM	SILVER	SODIUM	TDS	TSS	SULFATE	TEMP.	TURBIDITY	ZINC
bdc3.0	08-Sep-11	0.0270	0.002	0.16	0.02	5.29	7.58	1.14	0.93	7.82	0.0029	0.0001	92.3	536.0	40.0	173.0	17.8	39.0	0.0180
bdc3.0	13-Oct-11			0.09	0.03	7.90	7.81	0.23	0.09	9.32	0.0050		144.8	800.0	26.0	282.0	14.2	15.7	
bdc3.0	10-Nov-11			0.14	0.02	7.27	7.95	0.72	0.57	8.79	0.0043		139.5	751.0	16.0	248.0	14.0	10.8	
bdc3.0	08-Dec-11	0.0530	0.002	0.13	0.03	8.01	7.72	0.78	0.37	11.20	0.0039	0.0001	156.7	819.0	19.0	242.0	12.4	13.7	0.0420
bdc4.0	13-Jan-11			0.11	0.03	7.97	8.01	0.42	0.24	10.54	0.0055		177.1	951.0	50.0	348.0	6.5	26.0	
bdc4.0	10-Feb-11			0.38	0.15	8.10	7.61	0.22	0.07	10.88	0.0048		215.9	1007.0	37.0	298.0	3.2	29.9	
bdc4.0	10-Mar-11	0.0500	0.002	0.31	0.19	8.62	8.07	1.02	0.82	11.82	0.0050	0.0001	144.8	783.0	15.0	268.0	11.5	8.4	0.0400
bdc4.5	20-Apr-11			0.67	0.12	4.65	8.16	0.54	0.39	8.17	0.0050		156.4	799.0	30.0	270.0	10.5	22.9	
bdc4.5	12-May-11			0.25	0.03	0.85	7.74	0.62	0.13	4.70	0.0018		85.4	457.0	480.0	159.5	8.7	330.0	
bdc4.5	09-Jun-11	0.0120	0.002	0.05	0.03	4.21	7.98	0.29	0.16	7.67	0.0072	0.0001	190.0	1064.0	9.6	416.0	15.9	7.4	0.0140
bdc4.5	14-Jul-11			0.13	0.02	0.69	7.62	0.45	0.19	4.26	0.0020		64.7	399.0	240.0	147.0	21.9	176.0	
bdc4.5	04-Aug-11			0.05	0.02	4.06	7.98	0.25	0.16	5.97	0.0061		140.6	846.0	17.0	355.0	21.7	17.4	
bdc4.5	08-Sep-11	0.0130	0.002	0.15	0.03	4.54	7.77	0.67	0.51	6.50	0.0039	0.0001	105.4	614.0	58.0	229.0	17.3	51.0	0.0110
bdc4.5	13-Oct-11			0.06	0.03	7.07	8.34	0.19	0.09	8.62	0.0060		164.0	903.0	24.0	328.0	13.3	17.1	
bdc4.5	10-Nov-11			0.07	0.03	7.11	8.23	0.52	0.44	8.42	0.0060		167.2	920.0	19.0	332.0	8.3	12.7	
bdc4.5	08-Dec-11	0.0440	0.002	0.07	0.04	7.92	7.96	0.65	0.39	9.71	0.0060	0.0001	205.5	1037.0	18.0	334.0	5.5	14.3	0.0300
bdc5.0	13-Jan-11			0.13	0.03	6.11	8.01	0.26	0.10	8.85	0.0062		190.0	1018.0	69.0	380.0	0.8	42.0	
bdc5.0	10-Feb-11			0.24	0.08	7.02	7.78	0.32	0.07	10.16	0.0046		200.9	967.0	210.0	304.0	0.1	72.3	
bdc5.0	10-Mar-11	0.0200	0.002	0.30	0.15	8.03	8.23	0.95	0.73	11.46	0.0049	0.0001	149.8	798.0	30.0	276.0	10.9	18.1	0.0360
bdc5.0	20-Apr-11			0.21	0.08	4.65	8.13	0.46	0.29	7.70	0.0056		172.2	888.0	38.0	320.0	9.5	26.2	
bdc5.0	12-May-11			0.34	0.03	0.75	7.75	1.00	0.15	5.06	0.0020		90.7	483.0	850.0	171.0	8.3	556.0	
bdc5.0	09-Jun-11	0.0300	0.003	0.06	0.03	4.28	8.12	0.30	0.19	7.87	0.0063	0.0001	187.6	1046.0	8.0	410.0	15.1	5.7	0.0160
bdc5.0	14-Jul-11			0.09	0.01	1.24	7.68	0.63	0.26	4.83	0.0024		76.8	480.0	330.0	178.5	23.2	240.0	
bdc5.0	04-Aug-11			0.08	0.02	2.90	8.20	0.22	0.08	5.67	0.0053		157.2	912.0	42.0	377.0	22.7	31.1	
bdc5.0	08-Sep-11	0.0090	0.002	0.21	0.03	4.18	7.94	0.66	0.40	6.29	0.0034	0.0001	99.6	587.0	140.0	218.0	17.1	132.0	0.0100
bdc5.0	13-Oct-11			0.06	0.03	6.30	8.04	0.18	0.09	8.49	0.0045		162.6	890.0	35.0	324.0	12.9	24.4	
bdc5.0	10-Nov-11			0.31	0.02	6.46	8.45	0.31	0.19	7.92	0.0060		176.4	953.0	30.0	354.0	6.8	11.3	
bdc5.0	08-Dec-11	0.0320	0.003	0.08	0.03	6.95	8.07	0.28	0.15	8.81	0.0060	0.0001	210.4	1078.0	39.0	354.0	3.7	30.1	0.0270
bdc6.0	13-Jan-11			0.11	0.03	6.08	7.93	0.24	0.08	8.59	0.0055		189.4	1002.0	50.0	386.0	0.6	30.0	
bdc6.0	10-Feb-11																		
bdc6.0	10-Mar-11	0.0101	0.002	0.09	0.05	6.32	8.32	0.52	0.38	10.34	0.0031	0.0001	168.4	911.0	19.0	328.0	9.1	21.8	0.0148
bdc6.0	20-Apr-11			0.77	0.15	3.29	8.02	0.69	0.47	11.17	0.0040		163.0	861.0	71.0	302.0	9.5	51.5	
bdc6.0	12-May-11			0.50	0.04	0.95	7.75	1.83	0.18	6.31	0.0020		96.8	497.0	1000.0	181.0	8.2	902.0	
bdc6.0	09-Jun-11	0.0300	0.003	0.13	0.04	2.92	8.21	0.41	0.25	6.84	0.0048	0.0001	159.7	906.0	37.0	368.0	14.7	22.2	0.0080
bdc6.0	14-Jul-11			0.16	0.02	1.64	7.77	0.83	0.33	5.78	0.0025		88.1	551.0	460.0	204.5	22.5	343.0	
bdc6.0	04-Aug-11			0.10	0.09	2.54	8.12	0.49	0.26	5.71	0.0027		115.1	684.0	66.0	254.0	22.3	61.4	
bdc6.0	08-Sep-11	0.0150	0.003	0.21	0.05	3.28	7.80	0.66	0.29	6.52	0.0035	0.0001	120.8	697.0	290.0	270.0	17.2	251.0	0.0070
bdc6.0	13-Oct-11			0.07	0.04	4.16	8.09	0.35	0.20	8.87	0.0036		151.1	856.0	54.0	296.0	12.4	30.3	
bdc6.0	10-Nov-11			0.84	0.01	4.63	8.35	0.28	0.16	7.52	0.0059		186.0	1037.0	40.0	386.0	5.9	16.3	
bdc6.0	08-Dec-11	0.0300	0.003	0.40	0.02	5.31	8.05	0.47	0.15	8.34	0.0050	0.0001	190.6	1007.0	110.0	344.0	0.6	71.3	0.0230
	Count	30	30	87	87	87	87	87	87	87	87	30	87	87	87	87	87	87	30
	# Non-detects	0	5	7	17	2	0	3	17	0	6	30	0	0	0	0	0	0	9
	min	0.0090	<DL	<DL	<DL	<DL	7.07	<DL	<DL	1.97	<DL	<DL	16.5	156.0	3.8	44.2	0.1	1.8	<DL
	max	0.8000	0.003	0.84	0.19	9.11	8.45	1.83	0.93	12.69	0.0115	<DL	551.6	2223.0	1000.0	728.0	24.8	902.0	0.053
	mean	0.1529	0.002	0.16	0.04	3.46	7.82	0.35	0.17	6.46	0.0041	<DL	149.2	785.1	82.4	268.5	11.7	63.5	0.014
	std dev.	0.2363	0.001	0.15	0.04	2.92	0.29	0.31	0.21	2.81	0.0025	NA	90.7	391.1	157.0	136.0	6.4	124.0	0.015
	5th%	0.0109	0.001	0.03	0.01	0.14	7.29	0.06	0.005	2.55	0.0004	<DL	29.9	227.9	8.5	69.4	1.1	5.7	0.001
	15th%	0.0168	0.001	0.06	0.01	0.31	7.56	0.09	0.005	3.89	0.0014	<DL	61.0	371.5	12.0	120.8	3.7	10.1	0.001
	25th%	0.0300	0.002	0.07	0.01	0.59	7.66	0.12	0.013	4.23	0.0022	<DL	84.8	468.5	16.5	165.3	7.5	12.5	0.001
	50th%	0.0470	0.002	0.11	0.02	2.90	7.81	0.25	0.09	5.78	0.0040	<DL	151.4	800.0	35.0	276.0	11.3	24.2	0.009
	75th%	0.1375	0.003	0.21	0.03	6.21	8.02	0.50	0.24	8.61	0.0055	<DL	188.5	1004.5	70.0	351.0	16.5	62.8	0.022
	85th%	0.3183	0.003	0.30	0.08	7.30	8.12	0.65	0.38	9.72	0.0060	<DL	206.0	1065.4	111.0	386.0	18.4	87.9	0.034
	95th%	0.7865	0.003	0.44	0.13	8.02	8.25	0.99	0.55	11.39	0.0094	<DL	342.6	1574.3	318.0	475.1	22.2	247.7	0.041

2011 Mercury Data for Big Dry Creek

Trip ID	Station ID	Trip Start Date	MERCURY
2011	bdc & 120th	07-Jan-11	0.00204
2011	bdc & 120th	04-Feb-11	0.00221
2011	bdc & 120th	03-Mar-11	0.00198
2011	bdc & 120th	01-Apr-11	0.00191
2011	bdc & 120th	04-May-11	0.00153
2011	bdc & 120th	03-Jun-11	0.00194
2011	bdc & 120th	08-Jul-11	0.00758
2011	bdc & 120th	05-Aug-11	0.00497
2011	bdc & 120th	02-Sep-11	0.00639
2011	bdc & 120th	07-Oct-11	0.00913
2011	bdc & 120th	04-Nov-11	0.00237
2011	bdc & 120th	07-Dec-11	0.00155