E. COLI TOTAL MAXIMUM DAILY LOADS FOR THE BIG HORN RIVER WATERSHED

Topical Report RSI-2289

prepared for

Wyoming Department of Environmental Quality
Herschler Building
122 West 25th Street
Cheyenne, Wyoming 82002

October 2013

RESPEC
CONSULTING & SERVICES

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by

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Total Maximum Daily Load Summary	
Waterbody Name/Description	Owl Creek (from the confluence with the Big Horn River to a point 3.8 miles upstream)
Assessment Unit I.D.	WYBH100800070305_01
Size of Impaired Waterbody	3.8 miles (6.1 kilometers)
Size of Watershed (Cumulative)	517.7 square miles (1,338.3 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800070305
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 169 cfs	**169–76 cfs**	**76–31 cfs**	**31–4 cfs**	**< 4 cfs**
Load Allocation	682	415	178	49	8
Wasteload Allocation	0	0	0	0	0
Margin of Safety	98	70	53	39	3
Total Maximum Daily Load	780	485	231	88	11

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Kirby Creek (from the confluence with Big Horn River to a point 21.8 miles upstream)
Assessment Unit I.D.	WYBH100800070500_01
Size of Impaired Waterbody	21.8 miles (34.9 kilometers)
Size of Watershed (Cumulative)	225.0 square miles (582.8 square kilometers)
Location	10-digit Hydrologic Unit Code (HUC): 1008000705
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	2C
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 34.8 cfs	**34.8–5.3 cfs**	**5.3–2.3 cfs**	**2.3–0.4 cfs**	**0.4–0.2 cfs**
Load Allocation	339.6	82.6	12.0	4.9	1.0
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Margin of Safety	45.3	9.9	3.7	1.9	0.3
Total Maximum Daily Load	384.9	92.5	15.7	6.8	1.3

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Nowater Creek (from the confluence with Big Horn River to a point 6.6 miles upstream)
Assessment Unit I.D.	WYBH100800070809_01
Size of Impaired Waterbody	6.6 miles (10.6 kilometers)
Size of Watershed (Cumulative)	421.6 square miles (1,091.9 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800070805
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	3B
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 94 cfs	**94–48 cfs**	**48–39 cfs**	**39–34 cfs**	**< 34 cfs**
Load Allocation	567	235	138	114	81
Wasteload Allocation	0	0	0	0	0
Margin of Safety	82	38	9	7	22
Total Maximum Daily Load	649	273	147	121	103

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Fifteen Mile Creek (from the confluence with Big Horn River to a point 2.2 miles upstream)
Assessment Unit I.D.	WYBH100800070909_01
Size of Impaired Waterbody	2.2 miles (3.5 kilometers)
Size of Watershed (Cumulative)	521.3 square miles (1,350.3 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800071104
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	3B
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 69 cfs	**69–16 cfs**	**16–8 cfs**	**8–4 cfs**	**< 4 cfs**
Load Allocation	407	142	41	17	9
Wasteload Allocation	0	0	0	0	0
Margin of Safety	77	52	6	8	2
Total Maximum Daily Load	484	194	47	25	11

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Big Horn River (from the confluence with the Nowood River to a point 36.1 miles upstream)
Assessment Unit I.D.	WYBH100800071000_01
Size of Impaired Waterbody	36.1 miles (58.1 kilometers)
Size of Watershed (Cumulative)	3,281.3 square miles (8,498.4 square kilometers)
Location	10-digit Hydrologic Unit Codes (HUC): 1008000704 and 1008000712
Impaired Designated Use(s)	Recreation
Impairment	*E. coli*
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 4,513 cfs	**4,513–890 cfs**	**890–629 cfs**	**629–458 cfs**	**< 458 cfs**
Load Allocation	17,138	9,281	2,130	1,464	1,048
Wasteload Allocation	239	239	239	239	239
Margin of Safety	3,935	3,196	329	198	135
Total Maximum Daily Load	21,312	12,716	2,698	1,901	1,422

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Big Horn River (from the confluence with the Greybull River upstream to the confluence with the Nowood River)
Assessment Unit I.D.	WYBH100800071000_02
Size of Impaired Waterbody	22.1 miles (35.4 kilometers)
Size of Watershed (Cumulative)	5,481.3 square miles (14,196.6 square kilometers)
Location	10-digit Hydrologic Unit Code (HUC): 1008000712
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 5,450 cfs	**5,450–1,462 cfs**	**1,462–941 cfs**	**941–586 cfs**	**< 586 cfs**
Load Allocation	21,081	11,950	3,692	2,366	1,619
Wasteload Allocation	11	11	11	11	11
Margin of Safety	4,300	4,460	635	455	182
Total Maximum Daily Load	25,392	16,421	4,338	2,832	1,812

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Sage Creek (from the confluence with the Big Horn River to a point 7.4 miles upstream)
Assessment Unit I.D.	WYBH100800071001_01
Size of Impaired Waterbody	7.4 miles (11.8 kilometers)
Size of Watershed (Cumulative)	5.2 square miles (13.5 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800071201
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	3B
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 9.8 cfs	**9.8–8.5 cfs**	**8.5–8.1 cfs**	**8.1–7.5 cfs**	**< 7.5 cfs**
Load Allocation	33	29	25	24	19
Wasteload Allocation	0	0	0	0	0
Margin of Safety	3	1	1	1	4
Total Maximum Daily Load	36	30	26	25	23

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Slick Creek (from the confluence with the Big Horn River to a point 5.8 miles upstream)
Assessment Unit I.D.	WYBH100800071001_02
Size of Impaired Waterbody	5.8 miles (9.3 kilometers)
Size of Watershed (Cumulative)	24.9 square miles (64.4 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800071201
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	3B
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 45 cfs	**45–39 cfs**	**39–38 cfs**	**38–35 cfs**	**< 35 cfs**
Load Allocation	152	132	119	111	86
Wasteload Allocation	0	0	0	0	0
Margin of Safety	13	6	3	6	21
Total Maximum Daily Load	165	138	122	117	107

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Paint Rock Creek (from the confluence with the Nowood River to a point 5.2 miles upstream)
Assessment Unit I.D.	WYBH100800080603_01
Size of Impaired Waterbody	5.2 miles (8.4 kilometers)
Size of Watershed (Cumulative)	372.2 square miles (964.0 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800080607
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 631 cfs	**631–184 cfs**	**184–58 cfs**	**58–17 cfs**	**< 17 cfs**
Load Allocation	2,555	1,377	410	127	47
Wasteload Allocation	0	0	0	0	0
Margin of Safety	165	484	134	38	5
Total Maximum Daily Load	2,720	1,861	544	165	52

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Nowood River (from the confluence with the Big Horn River to a point 13.4 miles upstream)
Assessment Unit I.D.	WYBH100800080705_01
Size of Impaired Waterbody	13.4 miles (21.6 kilometers)
Size of Watershed (Cumulative)	2,012.4 square miles (5,212.1 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800080705
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 1,146 cfs	**1,146–408 cfs**	**408–130 cfs**	**130–40 cfs**	**< 40 cfs**
Load Allocation	5,078	2,420	878	283	95
Wasteload Allocation	1	1	1	1	1
Margin of Safety	691	1,009	323	88	26
Total Maximum Daily Load	5,770	3,430	1,202	372	122

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Greybull River (from the confluence with the Big Horn River to Sheets Flats Bridge)
Assessment Unit I.D.	WYBH100800090405_01
Size of Impaired Waterbody	44.7 miles (71.9 kilometers)
Size of Watershed (Cumulative)	1,149.4 square miles (2,977.0 square kilometers)
Location	10-digit Hydrologic Unit Code (HUC): 1008000904
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 560 cfs	**560–137 cfs**	**137–90 cfs**	**90–78 cfs**	**< 78 cfs**
Load Allocation	2,737	1,147	380	257	199
Wasteload Allocation	2	2	2	2	2
Margin of Safety	474	437	17	19	39
Total Maximum Daily Load	3,213	1,586	399	278	240

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Granite Creek (from the confluence with Shell Creek upstream 5.8 miles, near the Antelope Butte Ski Area)
Assessment Unit I.D.	WYBH100800100102_01
Size of Impaired Waterbody	5.8 miles (9.3 kilometers)
Size of Watershed (Cumulative)	15.9 square miles (41.3 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800100102
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 59 cfs	**59–14 cfs**	**14–4 cfs**	**4–1 cfs**	**< 1 cfs**
Load Allocation	251.5	115.8	29.8	9.5	3.9
Wasteload Allocation	0	0	0	0	0
Margin of Safety	33.8	55.1	10.0	2.2	0.3
Total Maximum Daily Load	285.3	170.9	39.8	11.7	4.2

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Beaver Creek (from the confluence with Shell Creek to a point 7.9 miles upstream)
Assessment Unit I.D.	WYBH100800100204_01
Size of Impaired Waterbody	7.9 miles (12.7 kilometers)
Size of Watershed (Cumulative)	83.4 square miles (216.1 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800100204
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli)*
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 157 cfs	**157–37 cfs**	**37–11 cfs**	**11–5 cfs**	**< 5 cfs**
Load Allocation	716	321	84	27	14
Wasteload Allocation	0	0	0	0	0
Margin of Safety	50	151	23	6	2
Total Maximum Daily Load	766	472	107	33	16

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Shell Creek (from the confluence with the Big Horn River to a point 5.3 miles upstream)
Assessment Unit I.D.	WYBH100800100206_01
Size of Impaired Waterbody	5.3 miles (8.5 kilometers)
Size of Watershed (Cumulative)	565.8 square miles (1,465.3 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800100206
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli)*
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 908 cfs	**908–252 cfs**	**252–77 cfs**	**77–33 cfs**	**< 33 cfs**
Load Allocation	3,888	1,810	557	185	85
Wasteload Allocation	0	0	0	0	0
Margin of Safety	384	845	179	37	15
Total Maximum Daily Load	4,272	2,655	736	222	100

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Big Horn River (from the confluence with the Greybull River to a point 10.5 miles downstream)
Assessment Unit I.D.	WYBH100800100301_01
Size of Impaired Waterbody	10.5 miles (16.9 kilometers)
Size of Watershed (Cumulative)	7,731.9 square miles (20,025.6 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800100301
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (written for *E. coli*)
Stream Class	2AB
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 7,361 cfs	**7,361–2,227 cfs**	**2,227–1,329 cfs**	**1,329–890 cfs**	**< 890 cfs**
Load Allocation	29,092	16,200	5,431	3,477	2,225
Wasteload Allocation	2	2	2	2	2
Margin of Safety	2,529	5,701	1,004	528	522
Total Maximum Daily Load	31,623	21,903	6,437	4,007	2,749

cfu/day = colony-forming units per day
cfs = cubic feet per second

Total Maximum Daily Load Summary	
Waterbody Name/Description	Dry Creek (from the confluence with the Big Horn River to a point 4.7 miles upstream)
Assessment Unit I.D.	WYBH100800110204_01
Size of Impaired Waterbody	4.7 miles (7.6 kilometers)
Size of Watershed (Cumulative)	435.2 square miles (1,127.1 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 100800110204
Impaired Designated Use(s)	Recreation
Impairment	Fecal Coliform (being written for *E. coli*)
Stream Class	2ABww
Cause(s) of Impairment	Unknown
Cycle Most Recently Listed	2012
Total Maximum Daily Load Water-Quality Targets	Indicator Name: *E. coli* Primary Contact Recreation: Summer Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 126 organisms per 100 milliliters (org/100 mL). These criteria apply from May 1 through September 30. Winter Recreation Season: a geometric mean of not less than five samples obtained during separate 24-hour periods for any 30-day period 630 org/ 100 mL. These criteria apply from October 1 through April 30.
Analytical Approach	HSPF, Load Duration Curves

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 173 cfs	**173–118 cfs**	**118–88 cfs**	**88–27 cfs**	**< 27 cfs**
Load Allocation	769	429	312	154	45
Wasteload Allocation	0	0	0	0	0
Margin of Safety	267	103	43	112	36
Total Maximum Daily Load	1,036	532	355	266	81

cfu/day = colony-forming units per day
cfs = cubic feet per second

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1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations (40 CFR 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies not meeting applicable water-quality standards or guidelines for the protection of designated uses under technology-based controls. TMDLs specify the maximum pollutant amount a waterbody can receive and still meet water-quality standards. Based on a calculation of the total allowable load, TMDLs allocate pollutant loads to sources to incorporate a margin of safety (MOS). TMDL pollutant load reduction goals for significant sources provide a scientific basis for restoring surface water quality by linking the development and implementation of control actions to the attainment and maintenance of water-quality standards and designated uses.

The intent of this document is to clearly identify the components of a TMDL, support adequate public participation, and facilitate the EPA review. The TMDL was developed in accordance with Section 303(d) of the CWA and guidance developed by the EPA. This TMDL document addresses *E. coli* impairments in the Big Horn River Watershed.

Substantial conservation accomplishments and best management practices (BMPs) have already been implemented in the project area. These accomplishments can be attributed to the local watershed planning and implementation efforts of proactive, locally led, conservation districts that have developed mutually beneficial partnerships with the following individuals and organizations: farmers, ranchers, residents, commodity groups and companies, school districts, city and county governments, irrigation districts and canal companies, weed departments, coordinated resource management groups, grazing associations, the Wyoming Association of Conservation Districts (WACD), the Wyoming Department of Environmental Quality (WDEQ), the Wyoming Water Development Commission (WWDC), the Wyoming Department of Agriculture (WDA), the Wyoming Game and Fish Department (WGFD), the Wyoming Wildlife and Natural Resource Trust (WWNRT), the University of Wyoming (UW), the Cooperative Extension Service (CES), the Wyoming Office of State Lands and Investments (OSLI), the National Wild Turkey Federation (NWTF), the National Fish and Wildlife Foundation (NFWF), The Nature Conservancy (TNC), the Natural Resources Conservation Service (NRCS), the Farm Service Agency (FSA), the Resource Conservation and Development (RC&D), the National Park Service (NPS), the Bureau of Land Management (BLM), and the U.S. Forest Service (USFS).

Ten watershed plans have been developed in the Big Horn River Watershed. In 1996, the WACD, the NRCS, and the WDA recognized the need to lead watershed management efforts and to represent local interests in state and federal watershed planning. The WACD formed the Watershed Strategic Planning Task Force and developed a “Watershed Strategic Plan” and conducted a watershed survey [Wyoming Association of Conservation Districts, 2000]. This strategic plan and subsequent activities provided various levels of assistance to districts, with

many districts already initiating watershed planning and management efforts. In addition to the water-quality management plans in the Big Horn River Watershed, watershed management and rehabilitation plans were developed as part of the WWDC Level I studies in Kirby Creek, Cottonwood/Grass Creeks, Nowood River, and Shell Valley Watersheds.

Modeling bacteria concentrations and developing TMDLs for the entire watershed will provide a framework for the WDEQ's and watershed managers' management decisions. TMDLs will also provide reasonable assurance that bacteria impairments will be addressed by continuing to implement BMPs, and future impairments will be readily addressed with an in-place model and TMDL. Furthermore, outcomes from the developed TMDLs, such as increased BMP implementation, will protect the recreational designated use and will not impair any other designated uses assigned to these waterbodies.

1.1 CLEAN WATER ACT 303(D) LISTING INFORMATION

There are 16 impaired stream segments within the Big Horn River Watershed that are downstream of Boysen Reservoir and upstream of the Big Horn Reservoir on the 2012 303(d) Impaired Waters List [Wyoming Department of Environmental Quality, 2012]. For the purpose of this TMDL, the project area is defined as the Wedding of the Waters on the Big Horn River, which is located just south of Thermopolis, Wyoming, to 10.5 miles downstream of the confluence of the Greybull River with the Big Horn River (just south of the upstream end of Big Horn Reservoir). The 16 stream segments include Owl Creek, Kirby Creek, Nowater Creek, Fifteen Mile Creek, three segments of the Big Horn River, Sage Creek, Slick Creek, Paint Rock Creek, Nowood River, Greybull River, Granite Creek, Beaver Creek, Shell Creek, and Dry Creek. The project area and the impaired stream segments are shown in Figure 1-1.

The state of Wyoming classifies streams based on their existing and designated uses. Within the project area, streams are classified as 2AB, 2ABww, 2C, and 3B streams. Streams within the project are classified as 2AB streams, except for Dry Creek (classified as a 2ABww stream); Kirby Creek (classified as a 2C stream); and Fifteen Mile Creek, Nowater Creek, Sage Creek, and Slick Creek (classified as 3B streams).

The Wyoming Department of Environmental Quality [2007] states that:

> *Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending on the predominance of cold-water or warm-water species present. All Class 2AB waters are designated as cold-water game fisheries unless they are identified as a warm-water game fishery by a "ww" notation in the "Wyoming Surface Water Classification List." Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are*

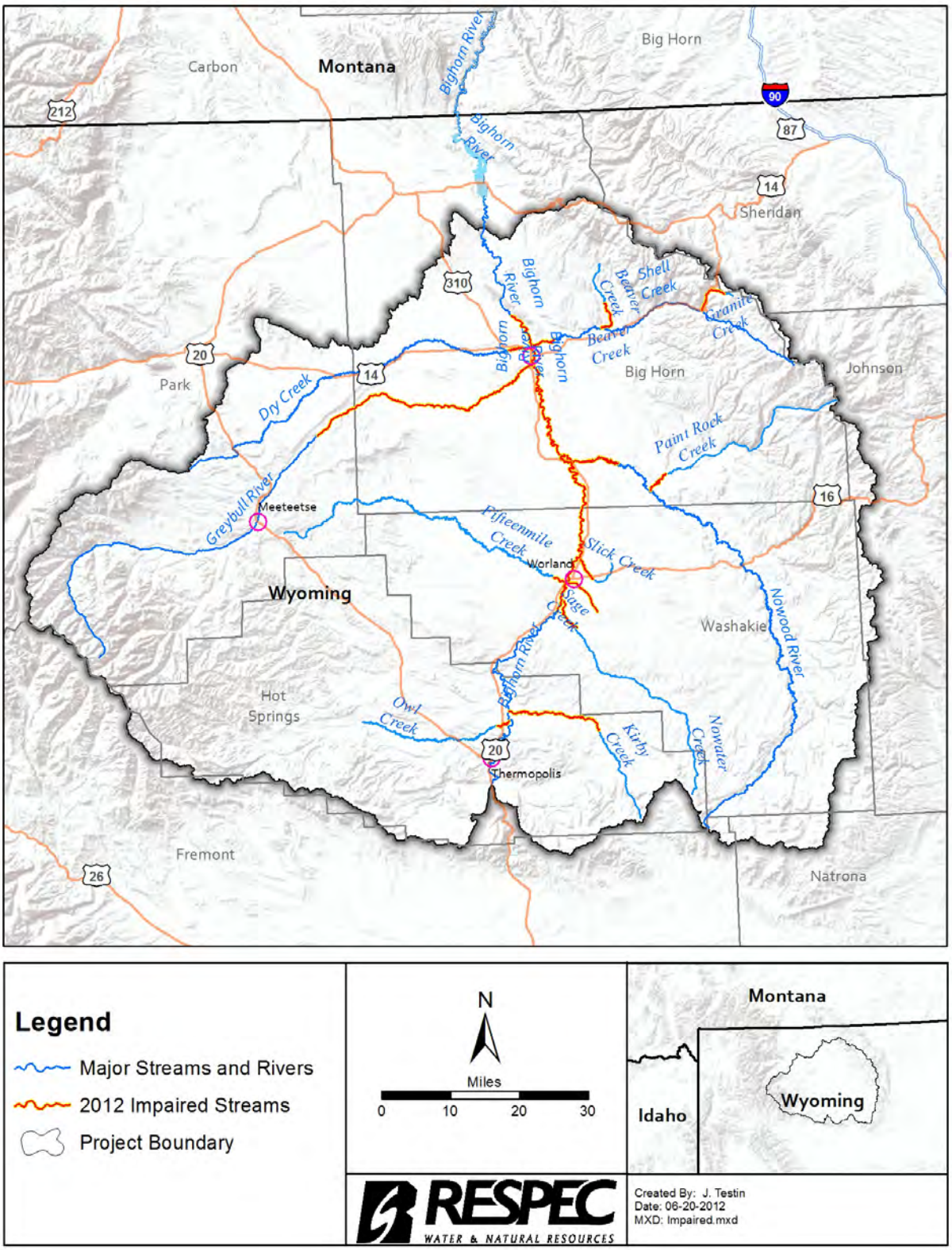

Figure 1-1. Big Horn River Watershed Project Area and the Bacteria-Impaired Segments.

protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value uses.

Class 2C waters are those known to support or that have the potential to support only nongame fish populations or spawning and nursery areas at least seasonally (including their perennial tributaries and adjacent wetlands). Class 2C waters include all permanent and seasonal nongame fisheries and are considered "warm water." Uses designated on Class 2C waters include nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value

Class 3B waters are tributary waters (including adjacent wetlands) that do not support fish populations or drinking water supplies and where those uses are not attainable. Class 3B waters are intermittent and ephemeral streams with sufficient hydrology to normally support and sustain communities of aquatic life, including invertebrates, amphibians, or other flora and fauna that inhabit waters of the state at some stage of their life cycles. In general, Class 3B waters are characterized by frequent linear wetland occurrences or impoundments in, or adjacent to, the stream channel over its entire length. Such characteristics will be a primary indicator used in identifying Class 3B waters.

The WDEQ set the primary contact recreation use *E. coli* targets during the summer recreation season as a geometric mean of 126 organisms per 100 milliliters (org/100 mL) based on a minimum of five samples collected during separate 24-hour periods for any 30-day period. Note that the water-quality targets are in org/100 mL and the laboratory results are often reported as colony-forming-units (cfu), which is interchangeable for org. For this project, all results were reported as cfu; therefore, the TMDL was reported as cfu/100 mL. This standard is applicable from May 1 through September 30. From October 1 through April 30, the winter recreation season standard applies, which has *E. coli* targets set as a geometric mean of 630 org/100 mL based on a minimum of five samples obtained during separate 24-hour periods for any 30-day period. Other applicable water-quality standards in these Class 2AB and Class 2C stream segments are summarized in the Wyoming Water Quality Rules and Regulations [Wyoming Deparment of Environmental Quality, 2007].

Water-quality standards for Wyoming surface water also include a regulatory policy concerning antidegredation that states "water uses in existence on or after November 28, 1975, and the level of water quality necessary to protect those uses shall be maintained and protected" [Wyoming Department of Environmental Quality, 2007].

1.2 WATERSHED CHARACTERISTICS

The Big Horn River Watershed (Hydrologic Unit Codes [HUC] 10080007, 10080008, 10080009, 10080010, and 10080011) is located in parts of Hot Springs, Washakie, Park, and Big

Horn counties in north-central Wyoming (Figure 1-1). The project area drains approximately 5 million acres (not including drainage upstream or downstream).

1.2.1 Land Cover/Land Use

A summary of land cover/land use was completed using the 2006 National Land Cover Dataset (NLCD). The NLCD is a 21-category multilayer land cover classification dataset that is derived from Landsat imagery and ancillary data that provides consistent land cover data for all 50 states [Multi-Resolution Land Characteristics Consortium, 2001]. The Big Horn River Watershed TMDL project area contains forest, rangeland, irrigated, suburban, and urban areas. Approximately 50 percent of the land cover/land use of the Big Horn Watershed project area consists of scrub/shrub, 33 percent consists of grassland/herbaceous, and 9 percent consists of evergreen forest, as shown in Figure 1-2. The remaining land-use categories each make up less than 2 percent of the total area. Land use for the Big Horn River Watershed project area is provided in Table 1-1.

1.2.2 Precipitation

Precipitation varies throughout the Big Horn River Watershed. An average annual precipitation obtained from the U.S. Department of Agriculture's Geospatial Data Gateway ranges from 35 inches in higher elevations of the Big Horn River Watershed to 7 inches in lower elevations near the Big Horn River, as illustrated in Figure 1-3. Maximum precipitation generally occurs in the spring and early summer months. The seasonal precipitation pattern is described further in Chapter 4.0.

1.2.3 Water Use

The largest consumptive use of water in the Big Horn Basin is from agricultural irrigation, and its primary source is surface water. Agriculture irrigation occurs on approximately 4 percent of the project area (a majority of the cropland and hayland acres in Table 1-1). Boysen Reservoir, which is just above the project boundary, stores water from the Big Horn River upstream of the project area. Boysen Reservoir supplies a majority of the water entering the project area and is used to supply water to irrigators served by the Big Horn Canal, Kirby Canal, the Lucerne Canals, the Upper Hanover Canal, the Lower Hanover Canal, the Highland Hanover Canal, and the Upper Bluff Canal. The Upper Sunshine, Lower Sunshine, and Roach Reservoirs capture water for irrigators in the Greybull Valley Irrigation District. Irrigation water is delivered to these irrigated lands through approximately 1,138 miles of canals, laterals, and ditches. Seven major irrigation districts and several smaller irrigation diversions are located in the project area [MHW Americas, Inc. et al., 2010].

1.2.4 Geology and Soils

This study area is located in the Big Horn Basin between the Big Horn Mountains and the Absaroka Range in west-central Wyoming. In general, the area is dominated by weakly consolidated to fully unconsolidated Tertiary- and Quaternary-age sedimentary deposits. These deposits were derived from sediment that eroded from the surrounding mountain ranges

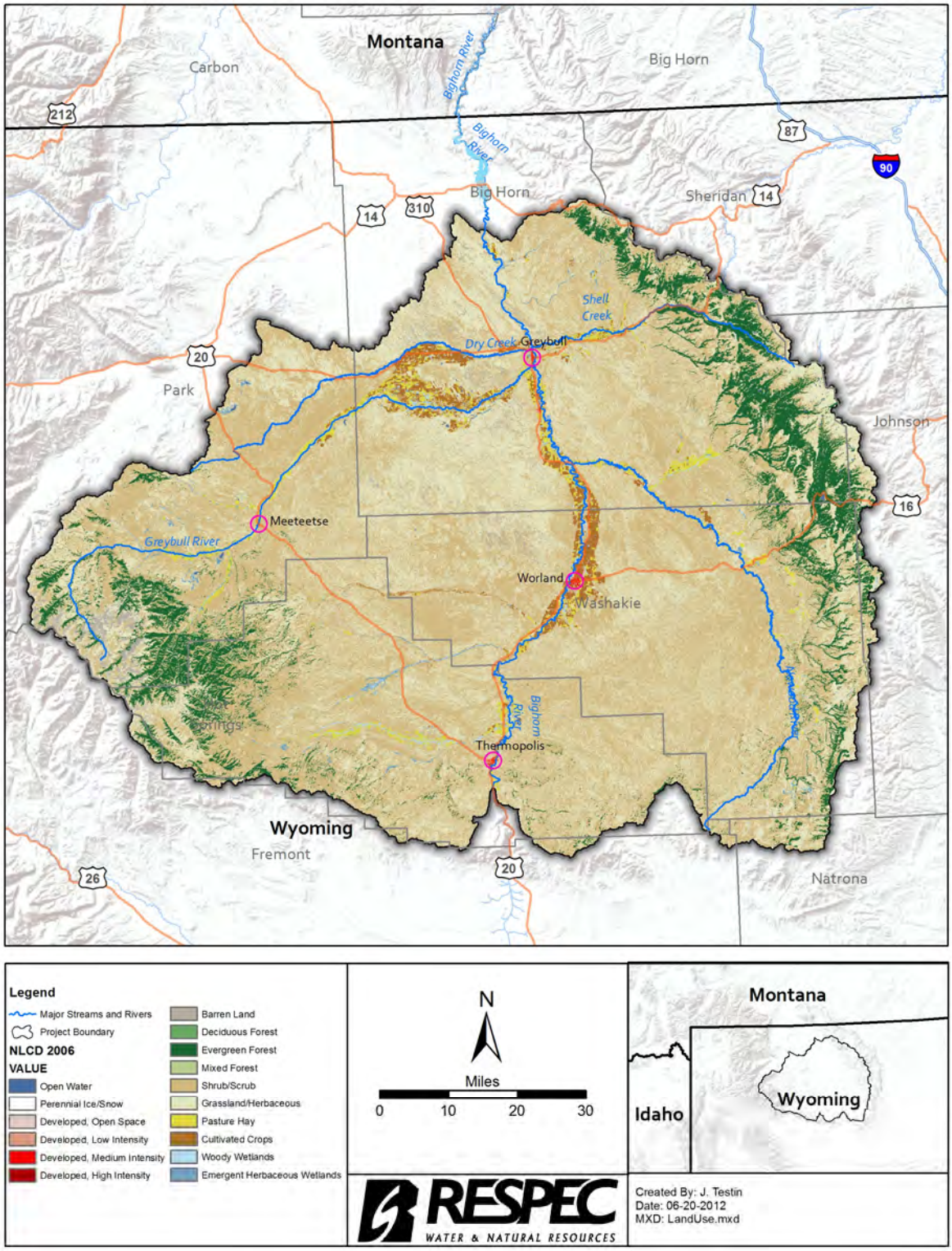

Figure 1-2. Predominant Land Cover.

Table 1-1. Percentage of Land Use for Each National Land Cover Dataset Land-Use Category By Impaired Total Maximum Daily Load Reach

NLCD Land-Use Category	Total Project Area Acres	Total Project Area Percent	Percent Land Use By Impaired Reach															
			Owl Creek	Kirby Creek	Nowater Creek	Fifteen Mile Creek	Big Horn River (Upstream of Nowood)	Big Horn River (Nowood to Greybull)	Sage Creek	Slick Creek	Paint Rock Creek	Nowood River	Greybull River	Granite Creek	Beaver Creek	Shell Creek	Big Horn River (Downstream of Greybull)	Dry Creek
Open Water	5,399	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perennial Ice/Snow	318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Developed, Open Space	23,563	0	0	0	0	0	1	1	0	2	0	0	1	2	0	1	1	1
Developed, Low Intensity	12,404	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0
Developed, Medium Intensity	1,685	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Developed, High Intensity	226	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barren Land	74,670	2	1	0	1	3	1	1	1	1	1	1	5	0	1	1	2	2
Deciduous Forest	4,867	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Evergreen Forest	396,495	8	10	1	0	0	4	7	0	0	25	13	11	34	21	18	8	0
Mixed Forest	2,487	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrub/Scrub	2,551,847	52	59	61	60	49	56	53	44	39	44	51	45	40	48	47	52	55
Grassland/Herbaceous	1,641,376	33	25	37	38	48	34	34	28	36	26	32	28	23	24	29	33	35
Pasture/Hay	94,266	2	3	0	1	0	1	2	5	5	3	2	4	0	2	2	2	1
Cultivated Crops	73,039	2	0	0	0	0	2	1	14	15	0	0	3	0	1	1	1	4
Woody Wetlands	46,569	1	2	1	0	0	1	1	2	1	1	1	2	1	1	1	1	1
Emergent Herbaceous Wetland	21,261	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1
Total	**4,950,472**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

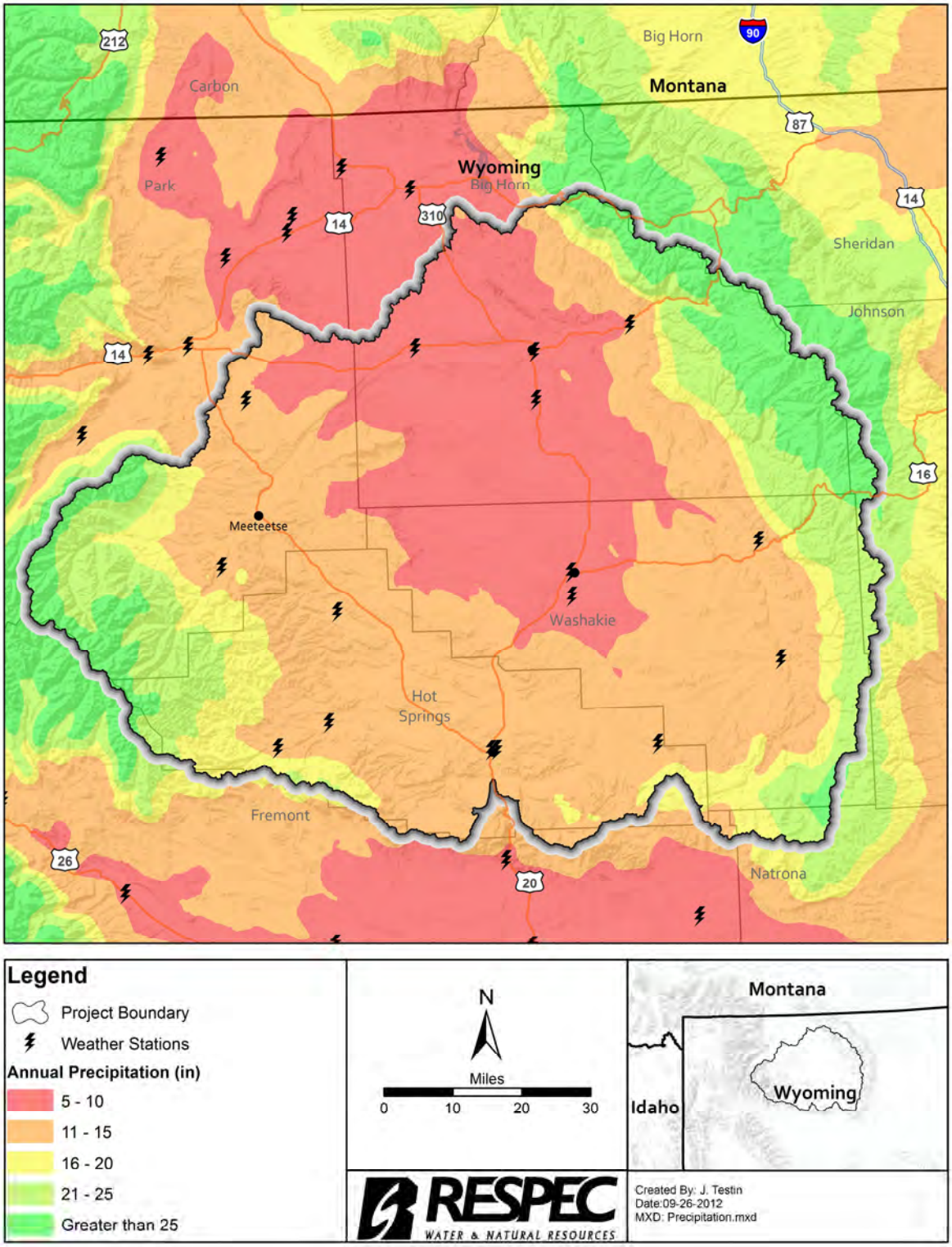

Figure 1-3. Average Annual Precipitation Within the Project Area.

following their uplift approximately 65–70 million years ago, as part of the Laramide orogeny. The surface geology is displayed in Figure 1-4.

The Willwood Formation lies beneath approximately 50 percent of the watershed and contains mixed clastic material of Eocene age. This rock primarily consists of variegated claystone, sandstone, and shale with lenticular quartzite conglomerate. A succession of uplifted sedimentary units surrounds the centralized Willwood Formation and ranges from the early Tertiary through Cambrian ages.

There are two areas of igneous rocks exposed on the eastern and western edges of the watershed. The rocks on the east consist of Quartz diorite and Granite Gneiss of Middle Precambrian age. While the igneous rocks on the west are the much younger Mount Wallace Formation, extrusive basalt of the Eocene age.

Soils throughout the nonmountanous, more central areas of the project area consist mainly of entisols and aridisols. Entisols, which are more prominent in the project area than ardisols, have high runoff potential when thorughly wet. Ardisols have moderately low runoff pontential when thoroughly wet. The mountainous areas of the project area are interlaced with inceptisols, alfisols (which both have moderately low runoff potential), and mollisols (which have low runoff potential).

1.2.5 Elevation and Slope

Elevations range from approximately 3,650 feet to over 13,150 feet, as shown in Figure 1-5. The lowest elevations are generally throughout the center and along the Big Horn River with the lowest elevation at the northern portion near the outlet of the project area. The highest elevations exist in the mountain ranges on the eastern and western portions of the watershed. Generally, the drainage flows from south to north. Precipitation patterns are highly driven by elevation in the project area. The average slope for the project area is approximately 16 percent.

1.2.6 Socioeconomics

A majority of the Big Horn Project area is located in Park, Big Horn, Hot Springs, and Washakie counties. Populations from years 2000 to 2010 in Park, Big Horn, and Washakie counties have increased by approximately 9 percent, 3 percent, and 4 percent, respectively, and the population in Hot Springs County has decreased by approximately 1 percent. The overall population change in the cities and towns in the project area between 2000 and 2011 was small (an approximate 1-percent increase occurred), as shown in Table 1-2. The percent change in the individual towns ranged from –14 percent to 61 percent. Table 1-3 shows employment by industry as a percent of the total employment in counties in the project area. In general, service-related industries are slightly higher than nonservice-related industries. Table 1-4 shows average annual wages by industry sector. Average annual wages in the mining sector were the highest [Headwaters Ecomonics, 2012a; 2012b; 2012c; 2012d].

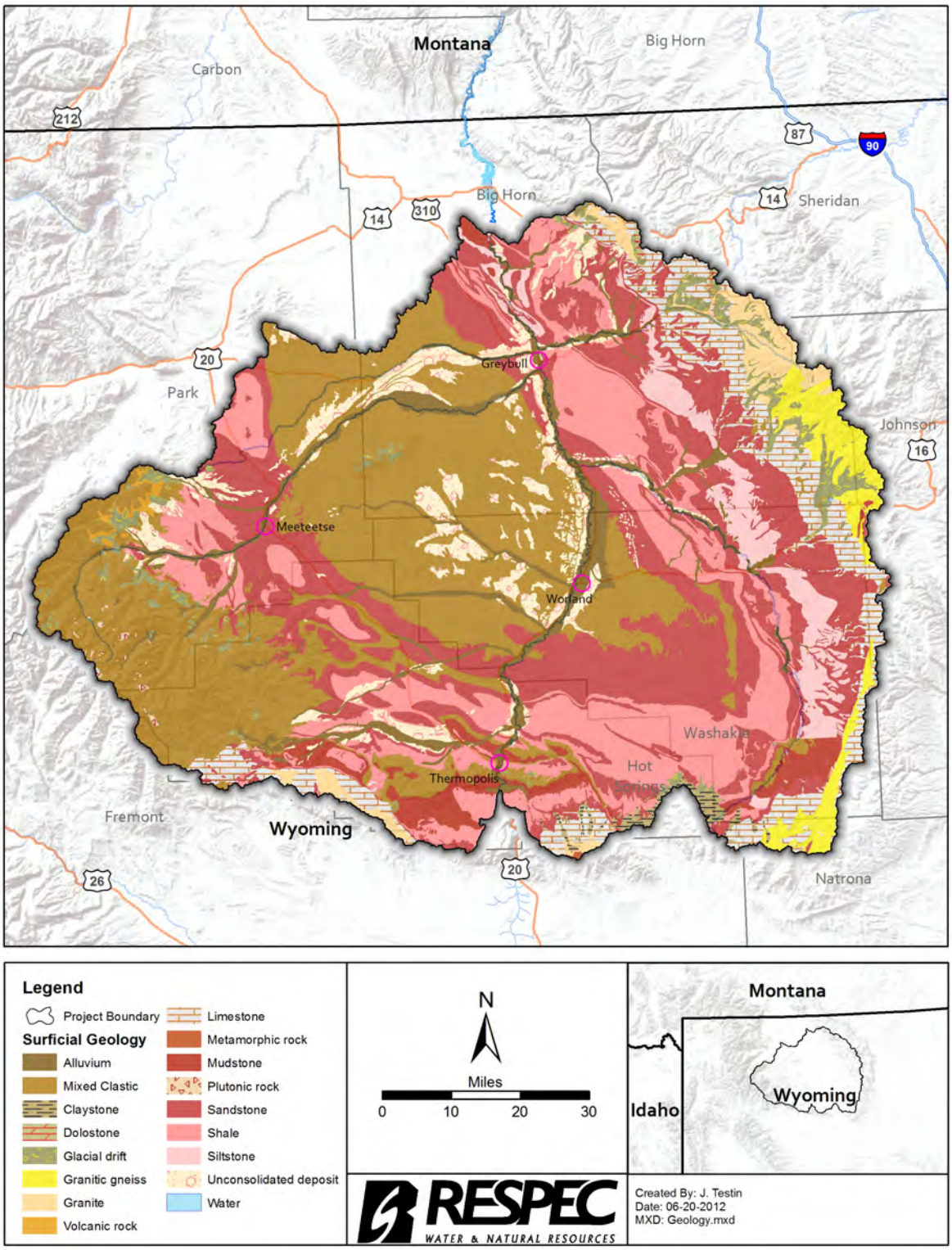

Figure 1-4. Geology Within the Project Area.

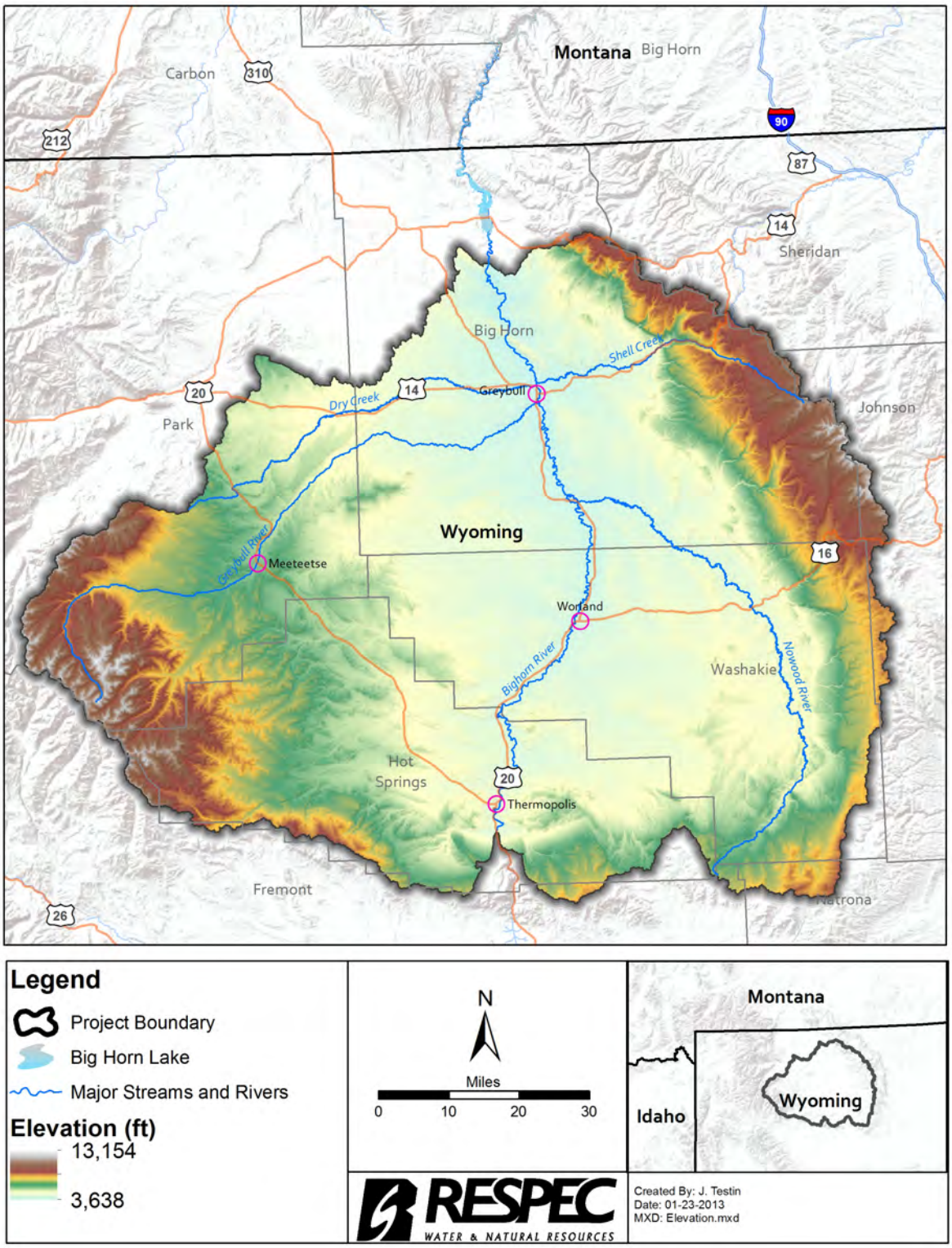

Figure 1-5. Elevation Within the Project Area.

Table 1-2. Census (2000 and 2010) Populations for Cities and Towns in the Big Horn Project Area

City or Town	2000 Population	2010 Population	Population Change (%)
Basin	1,238	1,285	4
Burlington	250	288	15
East Thermopolis	274	254	–7
Greybull	1,815	1,847	2
Kirby	57	92	61
Manderson	104	114	10
Meeteetse	351	327	–7
Ten Sleep	304	260	–14
Thermopolis	3,172	3,009	–5
Worland	5,250	5,487	5

Table 1-3. Percent of Total Employment by Industry (2000) in Big Horn, Hot Springs, Park, and Washakie Counties [Headwaters Ecomonics, 2012a; 2012b; 2012c; 2012d]

Industry Sector	Big Horn (%)	Hot Springs (%)	Park (%)	Washakie (%)
Nonservices-Related	39.9	22.7	23.2	28.8
Farm	10.7	6.6	5.5	5.7
Agricultural services, forestry, fishing, and other	4.1	1.8	1.9	2.5
Mining (including fossil fuels)	13.9	6.6	3.3	4.0
Construction	6.3	5.3	8.2	6.4
Manufacturing (including forest products)	4.9	2.4	4.4	10.1
Services-Related	40.4	58.8	57.5	55.5
Transportation and public utilities	4.3	3.7	3.3	6.6
Wholesale trade	2.6	3.9	2.2	2.2
Retail trade	11.6	14.7	17.0	15.6
Finance, insurance, and real estate	4.5	4.6	7.1	6.5
Services	17.4	31.9	28.0	24.6
Government	22.4	19.1	19.2	15.7

Table 1-4. Average Annual Wages by Industry Sector in Big Horn, Hot Springs, Park, and Washakie Counties [Headwaters Ecomonics, 2012a, 2012b, 2012c, and 2012d]

Industry Sector	Average Annual Wages			
	Big Horn ($)	Hot Springs ($)	Park ($)	Washakie ($)
Total	**$35,952**	**$32,329**	**$36,997**	**$36,480**
Private	$35,630	$30,898	$34,903	$35,479
Nonservice-Related	$45,340	$53,200	$51,879	$44,997
Natural resources and mining	$51,316	$63,318	$73,187	$49,665
Agriculture, forestry, fishing, and hunting	$29,071	N/A	$27,729	$27,468
Mining (including fossil fuels)	$55,766	N/A	$100,745	$66,389
Construction	$36,177	$36,728	$39,101	$39,753
Manufacturing (including forest products)	$38,830	$35,289	$37,382	$45,505
Services-Related	$27,449	$23,566	$29,874	$30,955
Trade, transportation, and utilities	$26,760	$28,550	$29,783	$36,111
Information	$45,058	$15,875	$31,534	$40,354
Financial activities	$39,866	$31,077	$37,004	$34,307
Professional and business services	$32,593	$31,714	$44,140	$37,218
Education and health services	$22,193	$28,831	$39,395	$33,541
Leisure and hospitality	$11,623	$12,892	$18,397	$11,175
Other services	$29,039	$19,179	$27,270	$18,691
Government	$36,499	$46,542	$43,030	$39,873
Federal government	$44,727	$46,542	$50,734	$55,046
State government	$43,779	N/A	$49,266	$49,049
Local government	$34,560	N/A	$39,933	$33,568

1.2.7 Ownership

Public lands make up approximately 71 percent of the project area with private lands and tribal lands on approximately 25 percent and 4 percent, respectively. No impaired waterbodies

are on tribal lands. The majority (51 percent) of the project area is managed by the BLM and the remaining 20 percent is managed by the USFS, the OSLI, the WGFD, and the NPS).

1.3 SUMMARY OF AVAILABLE DISCHARGE DATA

Throughout the project area, there are several entities involved in gathering and reporting discharge data from (1) streams/rivers, (2) irrigation deliveries and wasteways, and (3) reservoir inflows and outflows. Table 1-5 provides a site description, the type of waterbody monitored, the reporting agency, the format, the numbers of samples, and dates that the data were available. These sites are also identified in Figure 1-6. A total of 34 stations with discharge data were available within the project area. This dataset was used for creating and calibrating the hydrology model and ultimately formed the foundation for setting the TMDL for the impaired stream segments. Discharge data were available from the U.S. Geological Survey (USGS), the Wyoming State Engineers Office (WYSEO), the Greybull Valley Irrigation District (GVID), the Big Horn Canal Irrigation District (BHCID), the WWDC, and the U.S. Bureau of Reclamation (USBOR). A statistical summary of daily average discharge data for stream/river sites is listed in Table 1-6. Because the period of record varies by site, data should not be compared on a site-by-site basis.

1.4 SUMMARY OF AVAILABLE WATER-QUALITY DATA

Several entities are collecting *E. coli* data throughout the Big Horn River Watershed TMDL project area. The USGS began sampling at numerous locations throughout the project area from 2000 to 2003. The South Big Horn Conservation District (SBHCD) began collecting *E. coli* grab samples from locations on the Big Horn River, Beaver Creek, Dry Creek, Greybull River, Nowood River, Paint Rock Creek, and Shell Creek starting in 2002. The Washakie County Conservation District (WCCD) began collecting *E. coli* data in 2005, and the Meeteetse Conservation District (MCD) has collected *E. coli* samples from various locations within the Greybull River subbasin since 2006. The Hot Springs Conservation District (HSCD) collected *E. coli* data on Kirby Creek and Owl Creek since late 2006. Table 1-7 provides the water-quality site I.D.s for sites with bacteria data, the total number of samples, the number of geometric mean samples within that dataset, the percent exceedance of the summer recreation season criterion, geometric mean concentration ranges, and sample date ranges that are available for samples collected during the summer recreation season. A geometric mean sample is defined as five individual bacteria samples separated by more than 24 hours but collected within a 30-day time period. Table 1-8 provides the same information for data available for the winter recreation season. Figure 1-7 displays the locations of all the sites with available *E. coli* data. All data (flow and water quality) used for the TMDL analysis are available for download on the WDEQ TMDL's Big Horn River website (*http://deq.state.wy.us/wqd/watershed/TMDL/BigHornTMDL/BigHornTMDL.htm*). A copy may be requested by contacting the the WDEQ's TMDL program coordinator.

Table 1-5. Sites With Available Flow Data Within the Big Horn Total Maximum Daily Load Project Area (Page 1 of 2)

Site I.D.	Description	Type	Agency	Format	Number of Samples	Date Range	
BHR080	Big Horn River at Basin, WY	Stream/River	USGS	Average	2,638	01/26/2000	09/30/2010
				Instantaneous	48	01/25/2000	10/19/2010
SHE190	Shell Creek near Shell, WY	Stream/River	USGS	Average	2,128	04/01/2000	09/30/2010
				Instantaneous	1	07/18/2000	07/18/2000
BHR030	Big Horn River at Kane, WY	Stream/River	USGS	Average	3,311	02/17/2000	09/30/2010
				Instantaneous	77	01/26/2000	10/19/2010
COT150	Cottonwood Creek at High Island Ranch near Hamilton Dome	Stream/River	USGS	Average	2,745	01/01/2000	09/30/2010
				Instantaneous	1	07/14/2000	07/14/2000
GRE160	Greybull River at Meeteetse, WY	Stream/River	USGS	Average	2,005	04/01/2000	09/30/2010
				Instantaneous	44	01/26/2000	10/21/2010
KIRCAN	Kirby Can (KCWY)	Irrigation Canal/Drain	WYSEO	Average	1,950	04/01/2000	10/15/2010
OWL	Up Lucern (LPWY Up)	Irrigation Canal/Drain	WYSEO	Average	1,811	04/01/2000	09/30/2010
UBH	Low Lucrn (LPWY Low)	Irrigation Canal/Drain	WYSEO	Average	1,809	04/01/2000	09/30/2010
HAN303	UHan Comp	Irrigation Canal/Drain	WYSEO	Average	1,470	04/01/2003	10/10/2010
HAN304	UHan Tot (UHWY)	Irrigation Canal/Drain	WYSEO	Average	1,811	04/04/2000	10/11/2010
BLU305	Bluff (BCWY)	Irrigation Canal/Drain	WYSEO	Average	1,969	04/01/2000	10/11/2010
BLU306	UBlf N	Irrigation Canal/Drain	WYSEO	Average	593	06/15/2007	10/15/2010
BLU307	UBlf S	Irrigation Canal/Drain	WYSEO	Average	593	06/15/2007	10/15/2010
BLU308	Ublf Comb (UBWY)	Irrigation Canal/Drain	WYSEO	Average	593	06/15/2007	10/15/2010
HAN309	HH Weir2	Irrigation Canal/Drain	WYSEO	Average	1,424	04/01/2003	10/10/2010

Table 1-5. Sites With Available Flow Data Within the Big Horn Total Maximum Daily Load Project Area (Page 2 of 2)

Site I.D.	Description	Type	Agency	Format	Number of Samples	Date Range	
HAN310	HH East	Irrigation Canal/Drain	WYSEO	Average	874	04/13/2006	10/10/2010
HAN311	HH Maddn	Irrigation Canal/Drain	WYSEO	Average	859	04/15/2006	10/10/2010
HAN312	HH West	Irrigation Canal/Drain	WYSEO	Average	868	04/12/2006	10/10/2010
HAN313	HH Total (HHWY)	Irrigation Canal/Drain	WYSEO	Average	1,916	04/01/2000	10/10/2010
HAN314	Tiedown (TFWY)	Irrigation Canal/Drain	WYSEO	Average	798	10/01/2006	10/10/2010
BHC315	Big Horn Canyon (BHWY)	Irrigation Canal/Drain	WYSEO	Average	1,982	04/01/2000	10/08/2010
HAN316	Low Han (LHWY)	Irrigation Canal/Drain	WYSEO	Average	1,878	04/01/2000	10/10/2010
ROA020	Roach	Irrigation Canal/Drain	GVID	Average	1,577	04/25/2003	12/31/2010
SUN020	Lower Sunshine	Irrigation Canal/Drain	GVID	Average	1,371	07/22/2003	12/31/2010
BHC320	Big Horn Canal Return	Irrigation Canal/Drain	BHCID	Average	166	04/19/2009	10/01/2010
GRS220	Upper Grass Creek	Stream/River	WWDC	Average	100	03/03/2009	06/10/2009
GRS020	Lower Grass Creek	Stream/River	WWDC	Average	100	03/03/2009	06/10/2009
COT020	Cottonwood Creek	Stream/River	WWDC	Average	64	04/07/2009	06/09/2009
BFF010	Buffalo Creek	Stream/River	WWDC	Average	245	03/12/2009	11/11/2009
BCC020	Big Cottonwood Creek	Stream/River	WWDC	Average	245	03/13/2009	11/12/2009
BBC010	Brokenback Creek	Stream/River	WWDC	Average	244	03/13/2009	11/11/2009
OTT100	Otter Creek	Stream/River	WWDC	Average	212	04/14/2009	11/11/2009
OCAW	Owl Creek	Stream/River	USBOR	Average	1,236	01/01/2005	12/31/2010
BHRW	Big Horn River near Worland	Stream/River	USBOR	Average	1,478	01/01/2005	12/31/2010

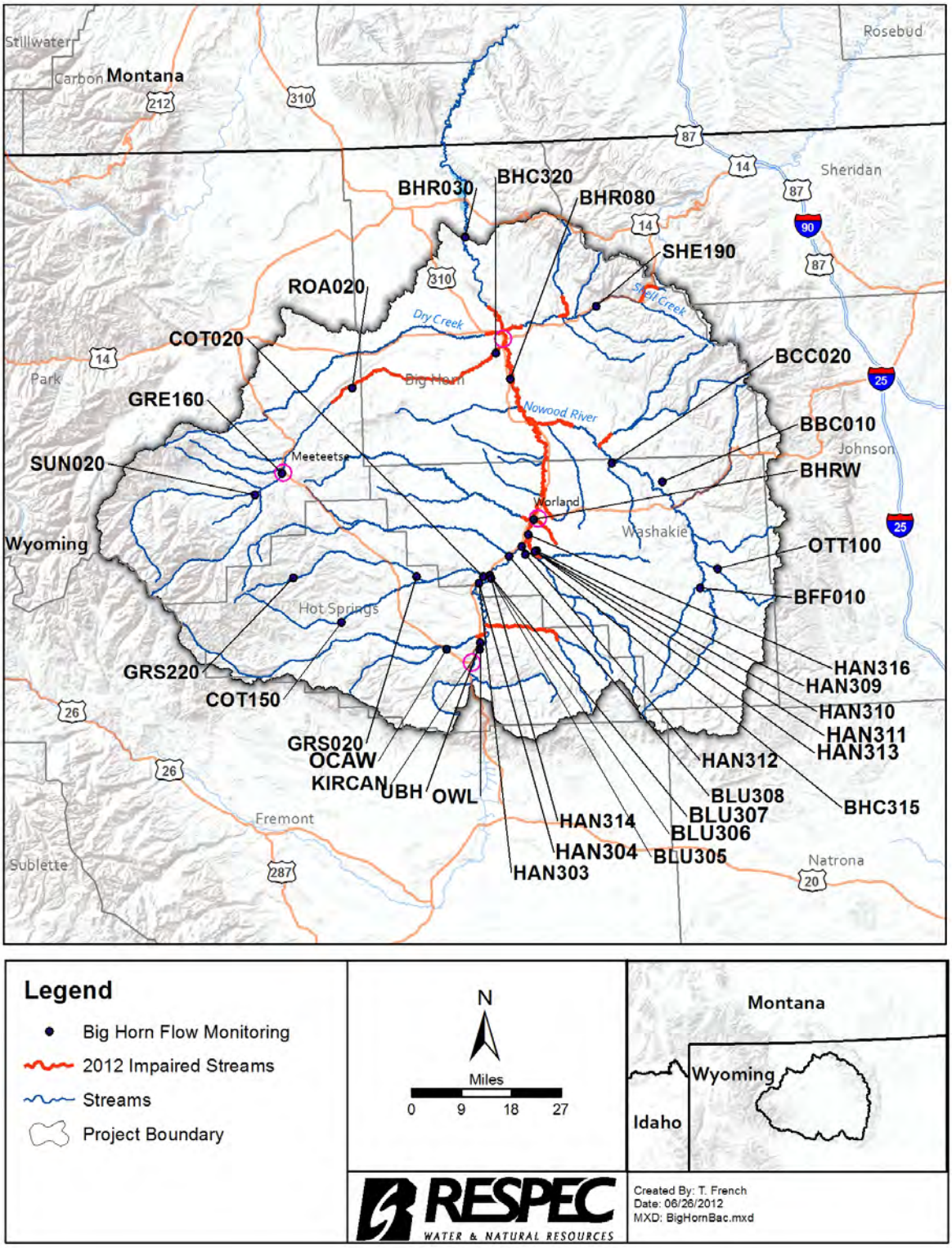

Figure 1-6. Discharge Monitoring Stations Within the Project Area.

Table 1-6. Statistical Summary of Stream/River Daily Average Discharge Data

Site I.D.	Description	Agency	Minimum Discharge (cfs)	25th Percentile Discharge (cfs)	Median Discharge (cfs)	75th Percentile Discharge (cfs)	Maximum Discharge (cfs)	Average Discharge (cfs)	No. of Samples	Date Range	
BBC010	Brokenback Creek	WWDC	1	2	3	5	6	3	244	03/13/2009	11/11/2009
BCC020	Big Cottonwood Creek	WWDC	0	0	0	1	19	1	245	03/13/2009	11/12/2009
BFF010	Buffalo Creek	WWDC	0	0	1	5	28	3	245	03/12/2009	11/11/2009
BHR030	Big Horn River at Kane, WY	USGS	360	759	1,020	1,370	13,400	1,444	3,311	02/17/2000	09/30/2010
BHR080	Big Horn River at Basin, WY	USGS	295	643	847	1,170	11,500	1,271	2,638	01/26/2000	09/30/2010
BHRW	Big Horn River near Worland	USBOR	58	265	484	850	7,453	883	1,478	01/01/2005	12/31/2010
COT020	Cottonwood Creek	WWDC	4	12	16	25	78	20	64	04/07/2009	06/09/2009
COT150	Cottonwood Creek at High Island Ranch Near Hamilton Dome	USGS	0	0	2	7	191	8	2,745	01/01/2000	09/30/2010
GRE160	Greybull River at Meeteetse, WY	USGS	12	141	293	501	2,480	361	2,005	04/01/2000	09/30/2010
GRS020	Lower Grass Creek	WWDC	0	0	1	1	2	1	100	03/03/2009	06/10/2009
GRS220	Upper Grass Creek	WWDC	0	1	6	8	12	5	100	03/03/2009	06/10/2009
OCAW	Owl Creek	USBOR	0	6	12	42	504	35	1,236	01/01/2005	12/31/2010
OTT100	Otter Creek	WWDC	26	28	30	31	57	31	212	04/14/2009	11/11/2009
SHE190	Shell Creek near Shell, WY	USGS	22	60	93	144	1,370	158	2,128	04/1/2000	09/30/2010

cfs= cubic feet per second

Table 1-7. Summer Recreation Season for *E. coli* Total Maximum Daily Load Development Data Availability (Page 1 of 3)

Map Identifier	Total Number of Samples	Total Number of Geometric Mean Samples	Percent Exceedance of 126 cfu/ 100 mL	Geometric Mean Concentration Range	Date Range
BEAVER_CREEK_1	48	4	100	316–502	05/28/2002–05/12/2010
BEAVER_CREEK_2	38	3	100	322–906	05/28/2002–09/16/2008
BEAVER_CREEK_3	47	4	100	273–960	05/28/2002–05/12/2010
BIG_HORN_RIVER_1	5	0	N/A[(a)]	N/A	07/14/2000–08/05/2002
BIG_HORN_RIVER_2	19	2	100	274–947	05/09/2005–06/30/2008
BIG_HORN_RIVER_3	49	5	80	104–665	05/14/2002–05/11/2010
BIG_HORN_RIVER_4	5	0	N/A	N/A	07/18/2000–08/05/2002
BIG_HORN_RIVER_5	6	0	N/A	N/A	07/25/2002–09/04/2002
BIG_HORN_RIVER_6	12	0	N/A	N/A	05/31/2000–08/05/2002
DRY_CREEK_1	41	4	50	84–249	06/22/2004–05/12/2010
DRY_CREEK_2	43	4	100	207–950	06/04/2003–05/12/2010
DRY_CREEK_3	53	5	100	319–1,526	07/19/2000–05/12/2010
EAST_KIRBY_CREEK_1	23	1	0	42–42	05/13/2008–06/09/2010
EAST_KIRBY_CREEK_2	23	2	0	11–31	05/13/2008–06/09/2010
EAST_KIRBY_CREEK_3	24	2	0	11–33	05/13/2008–06/09/2010
EAST_KIRBY_CREEK_4	19	3	0	61–115	05/13/2008–06/16/2010
FIFTEEN_MILE_CREEK_1	24	3	100	472–2,420	05/18/2005–07/02/2008
GRANITE_CREEK_1	42	5	1	136–398	05/04/2005-08/09/2007
GREYBULL_RIVER_1	18	2	0	43–88	05/12/2006–05/31/2007
GREYBULL_RIVER_2	97	45	9	15–274	07/19/2000–09/27/2010

Table 1-7. Summer Recreation Season for *E. coli* Total Maximum Daily Load Development Data Availability (Page 2 of 3)

Map Identifier	Total Number of Samples	Total Number of Geometric Mean Samples	Percent Exceedance of 126 cfu/ 100 mL	Geometric Mean Concentration Range	Date Range
GREYBULL_RIVER_3	94	43	44	25–475	05/12/2006–09/27/2010
GREYBULL_RIVER_4	61	31	35	50–574	05/07/2008–09/27/2010
GREYBULL_RIVER_5	5	0	N/A	N/A	05/12/2006–05/31/2006
GREYBULL_RIVER_6	67	8	13	5–342	05/02/2003–05/11/2010
GREYBULL_RIVER_7	57	6	100	257–718	05/02/2003–09/16/2008
GREYBULL_RIVER_8	75	9	67	9–662	05/14/2002–05/11/2010
KIRBY_CREEK_1	27	2	50	102–158	05/04/2007–06/16/2010
KIRBY_CREEK_2	21	1	100	131–131	05/04/2007–06/23/2010
KIRBY_CREEK_3	5	0	N/A	N/A	05/04/2007–05/13/2008
KIRBY_CREEK_4	14	0	N/A	N/A	05/13/2009–06/23/2010
KIRBY_CREEK_5	20	1	100	151–151	05/04/2007–06/23/2010
KIRBY_CREEK_6	21	0	N/A	N/A	05/04/2007–06/13/2010
KIRBY_CREEK_7	14	0	N/A	N/A	05/04/2007–06/13/2010
KIRBY_CREEK_8	13	0	N/A	N/A	05/08/2009–06/13/2010
NOWATER_CREEK_1	25	3	100	610–1,956	07/15/2000–07/01/2008
NOWOOD_RIVER_1	41	19	37	29–490	05/03/2005–09/29/2008
NOWOOD_RIVER_2	51	5	40	17–201	05/14/2002–05/12/2010
NOWOOD_RIVER_3	51	5	40	52–808	05/14/2002–05/12/2010
PAINT_ROCK_CREEK_1	62	5	20	75–195	05/14/2002–05/11/2010
PAINT_ROCK_CREEK_2	51	5	40	86–277	07/17/2000–05/12/2010

Table 1-7. Summer Recreation Season for *E. coli* Total Maximum Daily Load Development Data Availability (Page 3 of 3)

Map Identifier	Total Number of Samples	Total Number of Geometric Mean Samples	Percent Exceedance of 126 cfu/ 100 mL	Geometric Mean Concentration Range	Date Range
ROACH_GULCH_ RESERVOIR_1	18	3	0	8–15	05/07/2008–09/29/2008
SAGE_CREEK_1	24	3	100	511–856	05/18/2005–07/01/2008
SHELL_CREEK_1	113	3	100	192–582	05/28/2002–05/12/2010
SHELL_CREEK_2	40	3	100	314–429	06/04/2003–05/12/2010
SHELL_CREEK_3	45	2	100	348–581	07/18/2000–05/12/2010
SLICK_CREEK_1	25	3	100	321–939	07/17/2000–07/02/2008
SUNSHINE_DIVERSION_1	61	33	0	16–97	05/07/2008–09/27/2010
SUNSHINE_ RESERVOIR_1	5	0	N/A	N/A	07/19/2006–08/16/2006
WEST_KIRBY_CREEK_1	11	0	N/A	N/A	07/15/2007–06/19/2010
WEST_KIRBY_CREEK_2	28	2	0	27–41	05/18/2007–06/19/2010
WEST_KIRBY_CREEK_3	20	1	0	12–12	05/19/2008–06/19/2010
WEST_KIRBY_CREEK_4	24	2	0	39–39	07/15/2007–06/16/2010
WIND_RIVER_1	3	0	N/A	N/A	07/17/2001–09/20/2001
WOOD_RIVER_1	33	4	25	17–150	05/12/2006–06/02/2008
WOOD_RIVER_ SUNSHINE_DIVERSION	62	35	0	22–116	05/07/2008–09/27/2010

(a) N/A = Not Applicable

Table 1-8. Winter Recreation Season for *E. coli* Total Maximum Daily Load Development Data Availability (Page 1 of 3)

Map Identifier	Total Number of Samples	Total Number of Geometric Mean Samples	Percent Exceedance of 126 cfu/ 100 mL	Geometric Mean Concentration Range	Date Range
BEAVER_CREEK_1	30	2	0	72–85	10/01/2002–10/24/2010
BEAVER_CREEK_2	18	1	0	212–212	10/01/2002–04/26/2008
BEAVER_CREEK_3	30	2	50	315–1,533	10/01/2002–10/24/2010
BIG_HORN_RIVER_1	6	0	N/A[(a)]	N/A	12/27/2000–02/03/2003
BIG_HORN_RIVER_2	1	0	N/A	N/A	10/03/2005–10/03/2005
BIG_HORN_RIVER_3	29	2	0	67–280	10/04/2002–10/22/2010
BIG_HORN_RIVER_4	6	0	N/A	N/A	12/27/2000–02/03/2003
BIG_HORN_RIVER_5	2	0	N/A	N/A	10/02/2002–11/06/2002
BIG_HORN_RIVER_6	11	0	N/A	N/A	10/12/2000–02/03/2003
DRY_CREEK_1	24	2	0	9–50	04/05/2004–10/22/2010
DRY_CREEK_2	25	2	0	53–246	04/07/2003–10/22/2010
DRY_CREEK_3	27	2	0	12–173	10/02/2002–10/23/2010
EAST_KIRBY_CREEK_1	6	0	N/A	N/A	04/11/2008–10/07/2009
EAST_KIRBY_CREEK_2	6	0	N/A	N/A	04/11/2008–10/07/2009
EAST_KIRBY_CREEK_3	6	0	N/A	N/A	04/11/2008–10/07/2009
EAST_KIRBY_CREEK_4	6	0	N/A	N/A	04/11/2008–10/07/2009
FIFTEEN_MILE_CREEK_1	1	0	N/A	N/A	10/06/2005–10/06/2005
GRANITE_CREEK_1	38	0	N/A	N/A	11/04/2004-03/07/2007
GREYBULL_RIVER_1	3	0	N/A	N/A	10/06/2006–10/18/2006

Table 1-8. Winter Recreation Season for *E. coli* Total Maximum Daily Load Development Data Availability (Page 2 of 3)

Map Identifier	Total Number of Samples	Total Number of Geometric Mean Samples	Percent Exceedance of 126 cfu/ 100 mL	Geometric Mean Concentration Range	Date Range
GREYBULL_RIVER_2	54	1	0	3–3	12/19/2000–04/28/2010
GREYBULL_RIVER_3	17	0	N/A	N/A	10/06/2006–04/28/2010
GREYBULL_RIVER_4	9	0	N/A	N/A	04/21/2008–04/28/2010
GREYBULL_RIVER_6	38	2	0	11–14	04/07/2003–10/22/2010
GREYBULL_RIVER_7	27	1	0	462–462	04/07/2003–04/26/2008
GREYBULL_RIVER_8	40	2	0	0–186	10/04/2002–10/24/2010
KIRBY_CREEK_1	10	0	N/A	N/A	04/21/2007–10/01/2009
KIRBY_CREEK_2	9	0	N/A	N/A	04/21/2007–10/01/2009
KIRBY_CREEK_3	2	0	N/A	N/A	04/21/2007–04/26/2007
KIRBY_CREEK_4	2	0	N/A	N/A	04/28/2009–10/02/2009
KIRBY_CREEK_5	8	0	N/A	N/A	04/21/2007–10/02/2009
KIRBY_CREEK_6	6	0	N/A	N/A	04/21/2007–10/02/2009
KIRBY_CREEK_7	5	0	N/A	N/A	04/21/2007–10/02/2009
KIRBY_CREEK_8	3	0	N/A	N/A	04/28/2009–10/02/2009
NOWATER_CREEK_1	1	0	N/A	N/A	10/07/2005–10/07/2005
NOWOOD_RIVER_1	1	0	N/A	N/A	10/04/2005–10/04/2005
NOWOOD_RIVER_2	28	2	0	66–149	10/04/2002–10/22/2010
NOWOOD_RIVER_3	29	2	0	36–251	10/04/2002–10/22/2010
OWL_CREEK_1	4	0	N/A	N/A	10/02/2008–10/08/2009
OWL_CREEK_2	4	0	N/A	N/A	10/02/2008–10/08/2009

Table 1-8. Winter Recreation Season for *E. coli* Total Maximum Daily Load Development Data Availability (Page 3 of 3)

Map Identifier	Total Number of Samples	Total Number of Geometric Mean Samples	Percent Exceedance of 126 cfu/ 100 mL	Geometric Mean Concentration Range	Date Range
PAINT_ROCK_CREEK_1	32	2	0	5–39	10/04/2002–10/22/2010
PAINT_ROCK_CREEK_2	28	2	50	310–853	10/04/2002–10/22/2010
ROACH_GULCH_ RESERVOIR_1	1	0	N/A	N/A	10/01/2008–10/01/2008
SAGE_CREEK_1	1	0	N/A	N/A	10/06/2005–10/06/2005
SHELL_CREEK_1	74	2	0	51–62	10/01/2002–10/24/2010
SHELL_CREEK_2	27	2	0	45–72	04/08/2003–10/24/2010
SHELL_CREEK_3	31	2	0	13–71	10/01/2002–10/24/2010
SLICK_CREEK_1	1	0	N/A	N/A	10/03/2005–10/03/2005
SUNSHINE_DIVERSION_1	11	0	N/A	N/A	04/16/2008–04/28/2010
WEST_KIRBY_CREEK_1	3	0	N/A	N/A	03/07/2008–11/05/2008
WEST_KIRBY_CREEK_2	10	0	N/A	N/A	04/18/2007–11/10/2008
WEST_KIRBY_CREEK_3	8	0	N/A	N/A	11/15/2007–11/18/2008
WEST_KIRBY_CREEK_4	9	0	N/A	N/A	10/25/2007–10/01/2009
WIND_RIVER_1	5	0	N/A	N/A	10/25/2001–02/26/2002
WOOD_RIVER_1	9	0	N/A	N/A	10/06/2006–04/28/2008
WOOD_RIVER_ SUNSHINE_DIVERSION	10	0	N/A	N/A	04/21/2008–04/28/2010

(a) N/A = Not Applicable

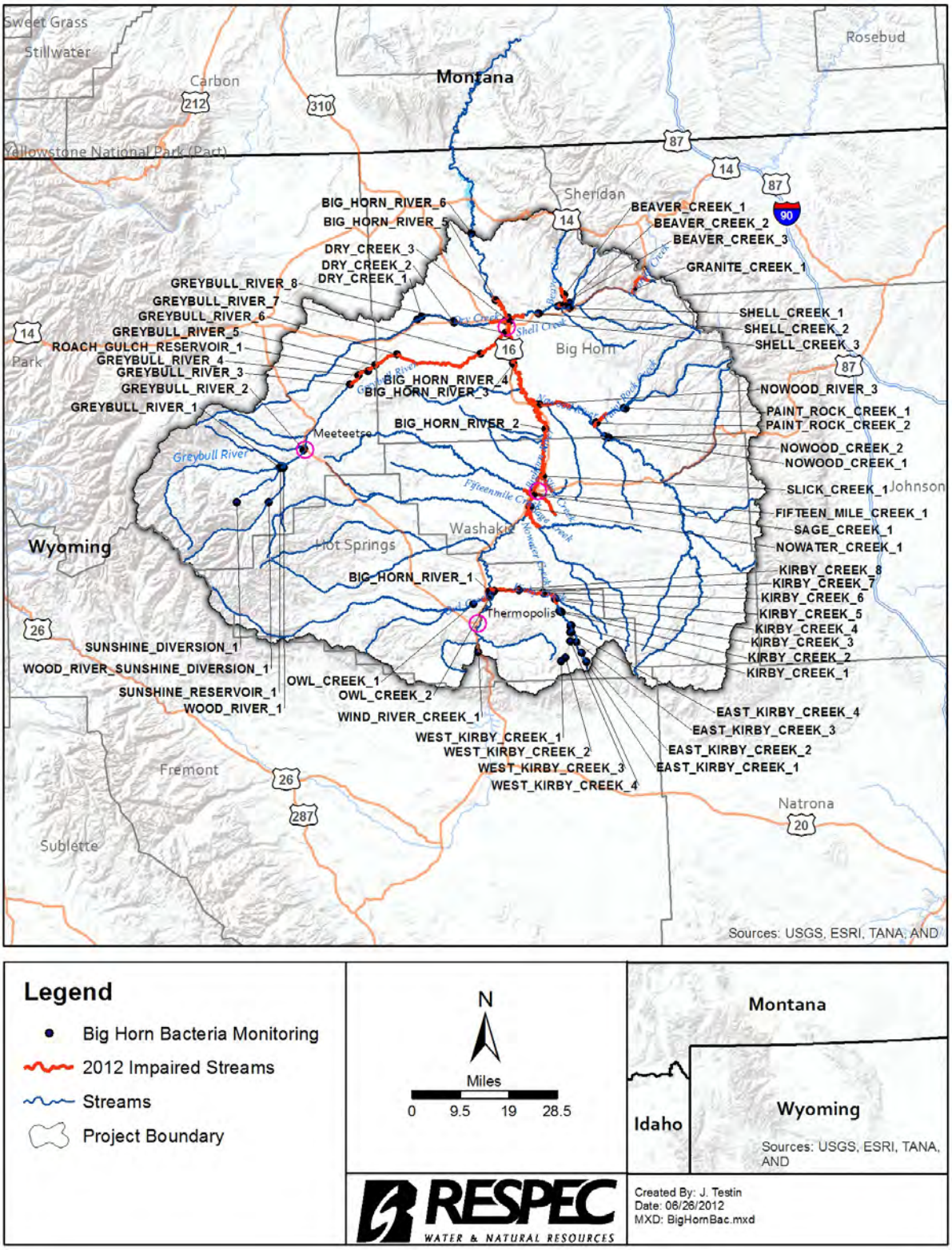

Figure 1-7. Water-Quality Monitoring Stations Within the Project Area.

Data collected from May 1 through September 30 from each site were used to calculate geometric means for computing percent exceedance of the summer recreation season *E. coli* criterion of 126 org/100 mL. Data collected from October 1 through April 30 from each project site were used to calculate geometric means for computing percent exceedance of the winter recreation season *E. coli* criterion of 630 org/100 mL. Not all sites with available *E. coli* data had samples taken at the frequency necessary to calculate a geometric mean. Many of the calibration sites had *E. coli* data collected during the winter recreation season throughout the assessment period; however, there were few instances in which at least five samples were collected in a 30-day period (necessary to generate a representative geometric mean sample). Based on the available data, the winter recreation season is not the critical time period with few-to-no exceedances of the criterion during the winter months. All waterbodies will meet the water-quality standards for the winter recreation season when they meet the TMDL for the summer recreation season.

2.0 SIGNIFICANT SOURCES

Bacteria sources in the project area include both point and nonpoint sources of bacteria. Point sources include wastewater treatment facilities (WWTF) and nonpoint sources consist of sources that can be transported through washoff.

2.1 POINT SOURCES

Multiple permitted WWTFs are located within the Big Horn project area. These include the towns of Basin (WY0020028), Burlington (WY0034606), Greybull (WY0020583), Manderson (WY0052442), Meeteetse (WY0020044), Ten Sleep (WY0020168), Thermopolis (WY0020192), the city of Worland (WY0020176), and Deer Haven Lodge (WY0023400). Table 2-1 lists the WWTFs, the county they are located in, the TMDL reach they ultimately discharge to, their typical or design flow, their bacteria limits, and their wasteload allocation (WLA). The bacteria limits are the same as the 30-day geometric mean standard for the summer and winter recreation seasons for all WWTFs, except for Thermopolis and Deer Haven Lodge. For receiving waters that have a perennial flow, like the Big Horn River, a WLA calculation is performed to calculate the effluent limit. This involves a mass balance approach to determine the maximum allowable concentration in the effluent, so that when mixed with the receiving stream, the in-stream standard of the constituent is not violated. The mass balance approach uses the upstream 7Q10 (the lowest 7-day average flow that occurs on average once every 10 years) of the receiving stream, the maximum effluent discharge volume, the upstream background concentration of the constituent, and in-stream standards to calculate the maximum allowable concentration of the constituent in the effluent. Considering that Thermopolis and Deer Haven Lodge immediately discharge to stretches of stream that support their uses, that there are no other point sources in the immediate areas that contribute to the impairments, and that the facilities are many miles upstream of impaired reaches, it was determined that the mass balance approach was appropriate for calculating the effluent limit. There are multiple Wyoming Pollution Discharge Elimination System- (WYPDES-) permitted non-WWTFs in the watershed. However, non-WWTFs are not expected to have bacteria in their effluent.

Six permitted, concentrated animal feeding operations (CAFO) with a total of eight discharge points are located within the Big Horn project area. They are not allowed to discharge, except in the case of a chronic or catastrophic storm event that would cause an overflow from the runoff and/or wastewater control structure.

2.2 NONPOINT SOURCES

Based on a review of available land-use information and communication with state and local authorities, the primary nonpoint sources of bacteria within the Big Horn River Watershed include agricultural runoff, wildlife contributions, and human sources. The **Bacteria Source Load Calculator Version 4.0 (BSLC)**, developed by the Center for TMDL and Watershed Studies [2007], was

Table 2-1. Point Sources in the Project Area

WWTF	WYPDES Permit	County	TMDL Stream Impacted	Flow (mgd)[a]	May–September Monthly Average *E. coli* Discharge Limit (cfu/100 mL)	October–April Monthly Average *E. coli* Discharge Limit (cfu/100 mL)	May–September *E. coli* Waste Load Allocation (10^9 cfu/day)	October–April *E. coli* Waste Load Allocation (10^9 cfu/day)
Basin	WY0020028	Big Horn	Big Horn River	2.4	126	630	11.4	57.2
Burlington	WY0034606	Big Horn	Greybull River	0.24	126	630	1.1	5.7
Greybull	WY0020583	Big Horn	Big Horn River	0.5	126	630	2.4	11.9
Manderson	WY0052442	Big Horn	Nowood River	0.02	126	630	0.1	0.5
Meeteetse	WY0020044	Park	Greybull River	0.1	126	630	0.5	2.4
Ten Sleep	WY0020168	Washakie	Nowood River	0.2	126	630	0.9	4.8
Thermopolis	WY0020192	Hot Springs	Big Horn River	0.8	7,593	33,563	229.9	1,016.4
Worland	WY0020176	Washakie	Big Horn River	1.95	126	630	9.3	46.5
Deer Haven Lodge	WY0023400	Washakie	Nowood River	0.001	2,577	19,335	0.1	0.7

(a) mgd – million gallons per day.

used to develop and distribute bacteria loadings from specific sources (livestock, wildlife, and human/septics) to proper land uses (i.e., forest, rangeland, cropland, and riparian) throughout the watershed. The *E. coli* loadings were loaded into an **HSPF** model application to assess the fate and transport of the bacteria loadings. The **HSPF** model application was then calibrated to optimize alignment among (1) the bacteria accumulation that was determined using **BSLC**, (2) the loads predicted to be transported throughout the system, and (3) the observed in-stream concentrations.

2.2.1 Livestock

Manure from livestock is a potential source of bacteria to a stream. Livestock in the project area are predominantly cattle and sheep. Other livestock include horses, poultry, goats, and pigs. Livestock population estimates in the project area were taken from the 2007 Agricultural Consensus [U.S. Department of Agriculture, 2007], and county populations were distributed to hydrozones based on area-weighted densities. Livestock populations were distributed seasonally by moving sheep and cattle from forest to cropland in winter months. The livestock estimations in the project area are summarized in Table 2-2 with estimated cfu per animal per day [Wagner and Moench, 2009]. Livestock contribute bacteria loads directly by defecating in the stream and indirectly by defecating on pastures or cropland that can be washed off during precipitation events, snow melt, or irrigation applications.

Table 2-2. Project Area Livestock Estimates

Livestock	Estimated Project Area Population	Fecal Bacteria per Animal (cfu/day)	Fecal Bacteria in Watershed (cfu/day)
Cattle and Calves	61,057	8.55×10^{9}	5.22×10^{14}
Goats	1,402	4.32×10^{9}	6.06×10^{12}
Horses and Ponies	7,019	3.64×10^{8}	2.55×10^{12}
Poultry	1,970	3.34×10^{8}	6.58×10^{11}
Hogs and Pigs	1,555	1.95×10^{10}	3.03×10^{13}
Sheep and Lambs	21,168	5.80×10^{10}	1.23×10^{15}

2.2.2 Wildlife

Wildlife, including waterfowl and large game species, also contribute bacteria loads directly by defecating while wading or swimming in the stream and indirectly by defecating on lands that are washed off during precipitation events. The big game estimations identified in Table 2-3 (elk, big horn sheep, moose, and mule deer) were based on area-weighted herd unit data from the WGFD's 2005–2009 annual job completion reports. Estimations were distributed

seasonally by normalizing the herd unit data using observation data from the WGFD's 2005–2009 annual job completion reports. Whitetail deer and wild turkeys were estimated by the WGFD [McWhirter, 2012], waterfowl were estimated by Mr. Larry Roberts of the WGFD [Roberts, 2013], and other small game estimations were estimated using suggested densities from the Center for TMDL and Watershed Studies [2007].

Table 2-3. Project Area Wildlife Estimates

Big Horn River Watershed Wildlife Populations	Estimated Watershed Population	Fecal Bacteria per Animal (cfu/day)	Fecal Bacteria in the Watershed (cfu/day)
Whitetail Deer	13,921	1.68×10^{9}	2.34×10^{13}
Raccoons	53,937	5.00×10^{7}	2.70×10^{12}
Muskrats	24,654	2.50×10^{7}	6.16×10^{11}
Beavers	6,147	2.00×10^{5}	1.23×10^{9}
Geese–Peak	9,466	8.00×10^{8}	7.57×10^{12}
Geese–Nesting	2,705	8.00×10^{8}	2.16×10^{12}
Ducks–Peak	10,044	2.40×10^{9}	2.41×10^{13}
Ducks–Nesting	2,877	2.40×10^{9}	6.90×10^{12}
Wild Turkey	5,052	9.30×10^{7}	4.70×10^{11}
Antelope	12,739	1.41×10^{9}	1.80×10^{13}
Big Horn Sheep	1,129	1.83×10^{9}	2.07×10^{12}
Elk	12,290	7.64×10^{9}	9.39×10^{13}
Moose	588	1.27×10^{10}	7.47×10^{12}
Mule Deer	45,359	1.68×10^{9}	7.62×10^{13}

2.2.3 Human

In general, human bacterial sources in urban settings can include cross connections between sanitary sewers and storm drain systems, overflows from sanitary sewer systems, and wet weather discharges from centralized wastewater collection and treatment facilities. Outside of city limits, septic systems are a potential human source of bacteria loads because much of the land beyond city limits is rural. The number of septic systems were estimated using county population, urban population, and average household size from the 2010 Census. It was assumed that, if a household is not in an area that has a WWTF, then it has a septic system. Using this assumption with the "2010 Census data," the number of septic systems in the project area was estimated to be approximately 2,660 [U.S. Census Bureau, 2012]. The **BSLC**

recommends a fecal coliform production rate of 2.0×10^9 cfu/person/day. Therefore, humans account for 5.32×10^{12} cfu/day.

2.2.4 Domestic Animals

Pet waste could be a contributor to bacteria in the project area. Pet waste may not be properly disposed of along the stream and within the stormwater drainage network, and it can be washed off during precipitation events. According to a source water protection practices bulletin from the U.S. Environmental Protection Agency [2001], pets are significant contributors to source water bacteria contamination. It was assumed that there was one pet per household (7,268 households were estimated using census data [U.S. Census Bureau, 2012] in the watershed), and the fecal coliform production rate for a pet suggested by the **BLSC** was 4.5×10^8 cfu/day. Therefore, pets account for 3.27×10^{12} cfu/day in the watershed.

2.3 SOURCE ASSESSMENT MODELING RESULTS

An **HSPF** model application was developed for the project area to determine the contribution of *E. coli* bacteria from identified sources in the project area and to evaluate different scenarios of implementing BMPs to control these sources. The model application was also used to enhance existing limited datasets and to create representative timeseries at ungaged locations. The Big Horn drainage basin was represented in the model using 105 subwatersheds and a boundary condition that represented releases from Boysen Reservoir. **HSPF** is a comprehensive watershed model of hydrology and water quality that includes modeling both land surface and subsurface hydrologic and water-quality processes, which are linked and closely integrated with corresponding stream and reservoir processes. **HSPF** is considered a premier, high-level model among those currently available for comprehensive watershed assessments. Because the model is continuous, the framework can be used to determine the critical environmental conditions (e.g., flow-variable and seasonal) for the impaired segments by providing continuous flow and load predictions at any point in the system. The nonpoint sources in the study area were modeled in **HSPF** by estimating per-acre bacteria accumulation rates and maximum bacteria storage rates for each source. The accumulation and storage rates were calculated using the **BSLC.** The buildup and washoff of bacteria were simulated based on these rates and precipitation. Failing on-site wastewater treatment systems, as well as livestock and wildlife in streams, are direct sources that were modeled similar to point sources, because the bacteria loads that they produce are independent of rainfall/runoff processes. The **BSLC** was used to calculate bacteria loadings that represent livestock in streams and human sources, which were then used as inputs to the **HSPF** model. **HSPF** is capable of simulating the fate and transport of bacteria in a variety of ways. Furthermore, unlike other watershed-scale models, **HSPF** can include subsurface concentrations in addition to surface concentrations, where appropriate.

2.3.1 Model Methods

The primary components of developing an **HSPF** model application include the following:

- Gathering and developing time-series data
- Characterizing and segmenting the watershed
- Calibrating and validating the model.

The watershed model was first set up and calibrated to predict the range of flows that have historically occurred throughout the watershed to assist in developing the Load Duration Curves (LDCs). Subsequently, the watershed model application was used to predict bacteria loadings. The modeling period was from 2005 through 2010.

2.3.1.1 Collecting and Developing Time-Series Data

Data requirements for developing and calibrating an **HSPF** model application are both spatially and temporally extensive. Data used in developing the model application included:

- Meteorological time series
- Stream flow and water-quality boundary conditions
- Channel geometry
- Point-source loads (WWTFs).

Precipitation, potential evapotranspiration, air temperature, wind speed, solar radiation, dew-point temperature, and cloud cover data are needed for **HSPF** to calculate hydrology (including snow processes).

A boundary condition was used at Boysen Reservoir to account for stream flow and water-quality constituents from areas that were not modeled in this application. Water-quality time series at the boundary condition was developed using an *E. coli* concentration of 10 cfu/100 mL (because concentrations are very low coming out of the reservoir) and by calculating a continuous time series of load using boundary condition flows.

Observed flow and water-quality data are needed to compare and calibrate to simulated results. Continuous stream flow from USGS gaging stations and water-quality data from all monitoring sites discussed in Chapter 1.0 were used to calibrate the model to existing observed conditions.

2.3.1.2 Characterizing and Segmenting the Watershed

The purpose of segmenting a watershed is to divide the project area into individual land and channel segments, or pieces, that are assumed to demonstrate relatively homogeneous hydrologic and hydraulic and water-quality behaviors. The segmentation provides the basis for assigning similar or identical input and/or parameter values or functions to where they can be

applied logically to all portions of a land area or channel length contained in a model segment. Because HSPF and most watershed models differentiate between land and channel portions of a watershed and each is modeled separately, each watershed undergoes a segmentation process to produce separate land and channel segments that are linked together to represent the entire watershed area.

The river reach segmentation requires considering river travel time, riverbed slope continuity, temporal and spatial cross sections, morphologic changes or obstructions, confluence of tributaries, TMDL reach endpoints, and the calibration and verification of gage locations for flow and bacteria. Once the segmentation was finalized, each reach segment was analyzed to compute the tributary areas of the land-use categories and the hydraulic characteristics of the reach. The reach hydraulic behavior is specified in an F-table, which is an expanded rating curve that contains the reach surface area, volume, and discharge as functions of depth. F-tables were developed for each reach segment using cross-sectional data. Unsurveyed tributaries were assigned the geometry of hydraulically similar channels.

Land segmentation was used to assign unique parameters to areas of land in the HSPF model application. For the land segmentation, subbasins were delineated to capture hydrologic and water-quality variability. Land segmentation was based on the boundaries defined by meteorological characteristics and land use. Land use and land cover affect the hydrologic and water-quality responses of a watershed. The land use and land cover affect infiltration, surface runoff, and water losses from evaporation or transpiration by vegetation. The movement of water through the system is affected significantly by vegetation (e.g., crops, pasture, or open) and associated characteristics. Land use clearly impacts the rate of accumulation of pollutants, such as bacteria. The 2001 NLCD was aggregated into multiple categories and integrated with riparian areas, irrigation areas, and feedlots, which resulted in 12 total land cover categories, as shown in Figure 2-1. The urban categories were divided into pervious and impervious areas based on an estimated percentage of effective impervious area. The term “effective” implies that the impervious region is directly connected to a local hydraulic conveyance system (e.g., open channel or river), and the resulting overland flow will not run onto pervious areas and will not have the opportunity to infiltrate along its respective overland flow path before reaching a stream or waterbody.

2.3.1.3 Calibrating and Validating the Model

Hydrology

Once the initial model was developed, the calibration and validation process was initiated. Discharge time series locations used for calibration and validation are shown in Figure 1-6. For this project, the entire simulation period (2005 through 2010), excluding 2005, was used in the calibration of the model. The initial year (2005) was simulated so the model could adjust to existing conditions. The period had dry years (2006 and 2007) and wet years (2009 and 2010), which made it a good calibration and validation period, because the model response could be validated during both wet and dry years.

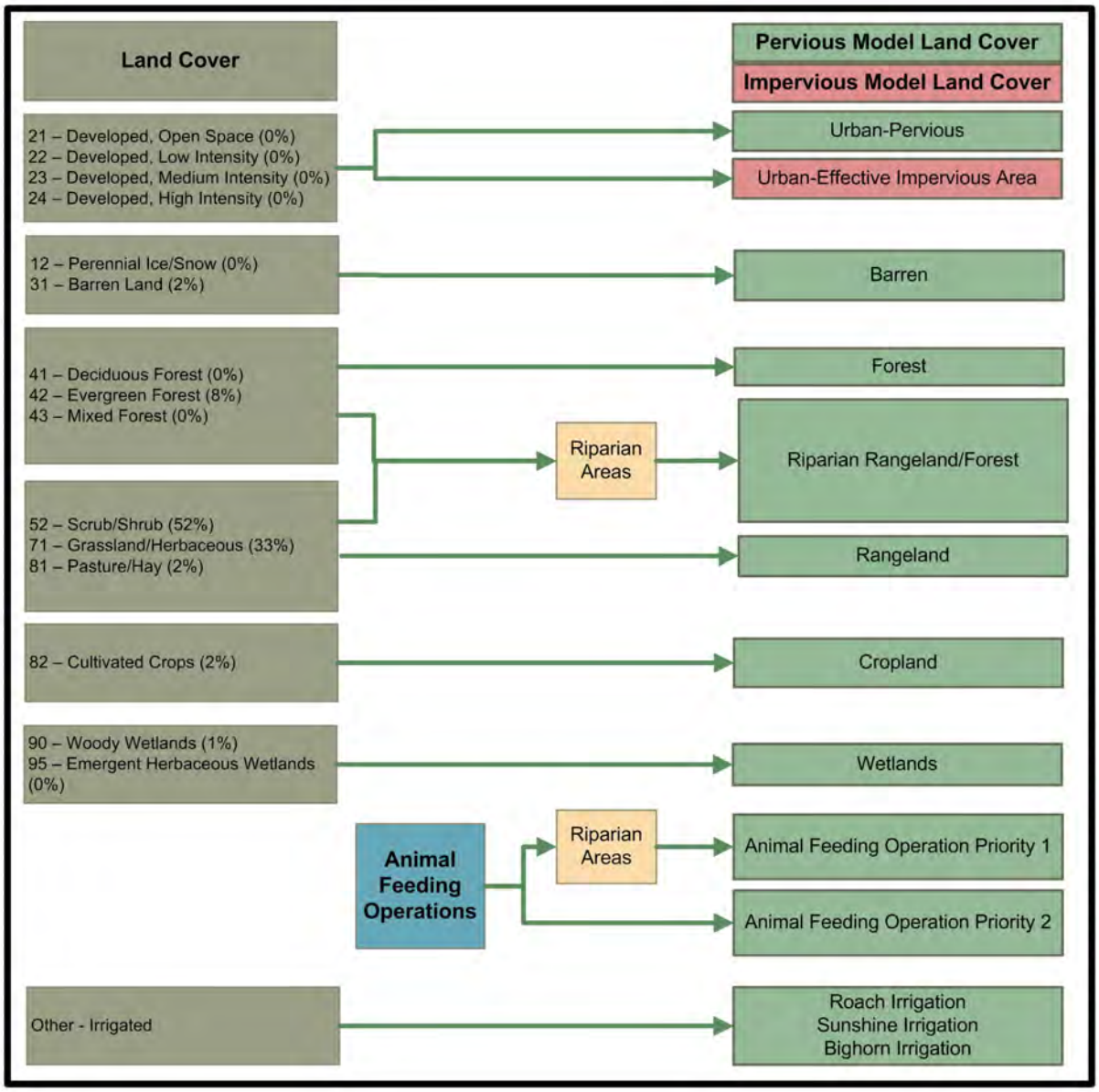

Figure 2-1. Model Land Cover Representation.

Hydrologic calibration is an iterative process intended to match simulated flow to observed flow by methodically adjusting model parameters. Water-quality simulations are highly dependent on the hydrology process. Therefore, water-quality calibration cannot begin until the hydrology calibration is considered acceptable. **HSPF** hydrologic calibration is divided into the following four sequential phases of adjusting appropriate parameters to improve performance:

- Annual runoff
- Seasonal or monthly runoff
- Low- and high-flow distribution
- Individual storm hydrographs.

By iteratively adjusting specific calibration parameter values within accepted ranges, the simulation results are improved until an acceptable comparison of simulated results and measured data is achieved. The procedures and parameter adjustments involved in these phases are more completely described in Donigian et al. [1984] and Lumb et al. [1994].

Bacteria

Several parameters are available for adjusting *E. coli* loadings and concentrations in the model. To achieve calibration under base flow conditions, adjustments are typically made to parameters that represent continuous discharges and do not depend on transport via runoff mechanisms (i.e., direct sources with estimated loadings). Direct sources include contributions of *E. coli* from direct deposition from livestock or wildlife and bacteria from failing septic systems, leaking wastewater collection system infrastructure, or cross connections between sanitary and storm sewer lines. Direct sources could also represent other mechanisms that are difficult to quantify explicitly, including the resuspension of bacteria associated with sediment and illicit discharges. Calibration under runoff conditions can be achieved through adjusting parameters that relate to bacteria washoff from land surfaces. Calibrating the in-stream concentrations was also accomplished by adjusting the first-order decay rate for bacteria.

2.3.2 Model Results

The modeled hydrology performance was evaluated using a weight-of-evidence approach based on criteria developed from over 30 years of modeling experience with **HSPF**. This approach uses a variety of graphical comparisons and statistical tests, that include annual and monthly runoff errors, low-flow and high-flow distribution errors, and storm volume and peak flow errors. Some graphical comparisons for calibration include monthly and average flow volume comparisons, daily time-series comparisons, and concentration-duration plots. Concentration-duration curves for the summer recreation season that compare observed and simulated concentrations for all segments are provided in Appendix A. These curves display observed concentration values (labeled “Observed”), simulated values recorded at the same time as the observed values (labeled “Paired Simulated”), and the concentration-duration curve for the entire simulation period (labeled “All Simulated”). Model performance at these flow gages and at multiple tributary gages was evaluated using a weight-of-evidence approach that uses both

visual and statistical methods. The performance criteria are described in more detail in Donigian [2002].

The model application simulates hydrology at the outlet of the project area (USGS Gage 06279500) very well with daily and monthly coefficients of determination (R^2) of 0.90 and 0.94, respectively. A review of other mainstem gages upstream of the confluence with Greybull River shows that the performance of the model is also excellent, with the R^2 values ranging from 0.94 to 0.98, respectively. Figures 2-2 and 2-3 are flow time-series plots comparing observed and simulated data at USGS 06274300 and USGS 06279500, respectively. For the performance of the *E. coli* calibration, a visual evaluation was used. Using statistics would be misleading because the *E. coli* is variable. Figure 2-4 illustrates the simulated and observed concentrations of *E. coli* at the water-quality monitoring site BIG_HORN_RIVER_3 near USGS 06274300. Observed data are shown as blue circles, and the simulated results are represented with a solid red line.

2.3.3 Source Assessment

It is difficult to predetermine nonpoint bacteria loading sources using observed data, which are often limited. The calibrated model application is highly effective in quantifying load contribution from a variety of point and nonpoint sources in a watershed and can help quantify source contributions when paired flow and concentration data are limited.

Source assessment modeling results, provided in Table 2-4, were summarized by land-use categories for overland load washed into the stream through rainfall/runoff processes, direct defecation of livestock or wildlife into streams, and on-site wastewater treatment tank failures (i.e., septics). Pie charts of the source assessments for each reach are attached as Appendix B. For all impaired segments, point sources were an insignificant portion (less than 1 percent) of the load and, therefore, are not shown in the table or the pie charts. The Big Horn River (downstream of the Greybull River) is the most downstream reach assessed by the model and is essentially a culmination of all water-quality processes that occur upstream of this TMDL reach. Modeling indicates that 97 percent of the loading within the project area originates from overland runoff, and the remaining 3 percent is from direct stream loading. Rangeland, which accounts for 85 percent of the land use in the project area, contributes 44 percent of the overall load. Direct defecation from livestock or wildlife accounts for nearly all of the direct source loading.

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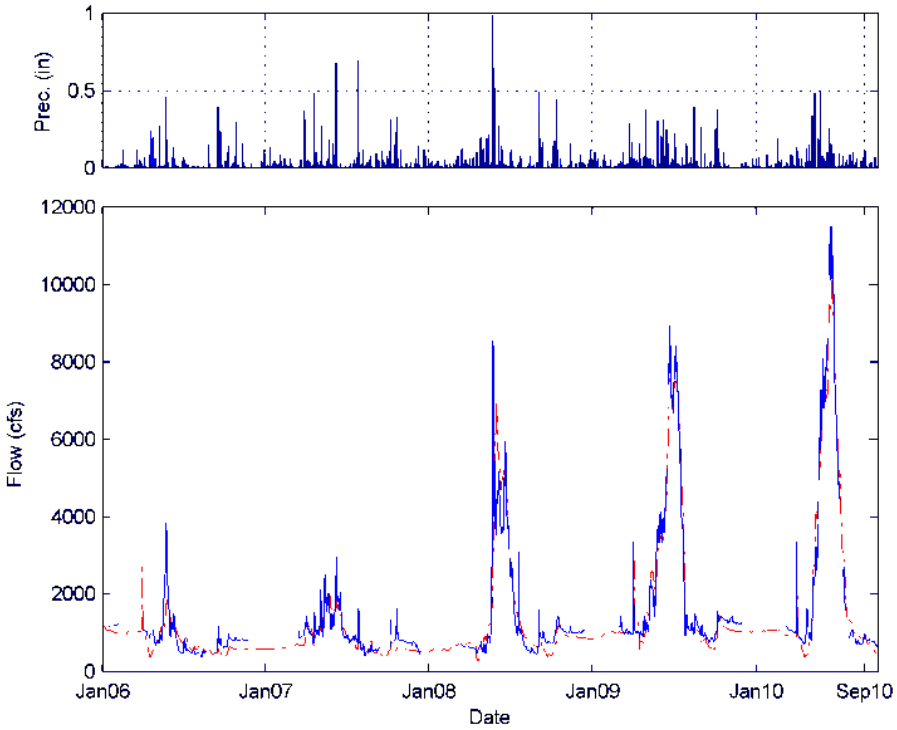

Figure 2-2. Simulated and Observed Discharge at USGS 06274300.

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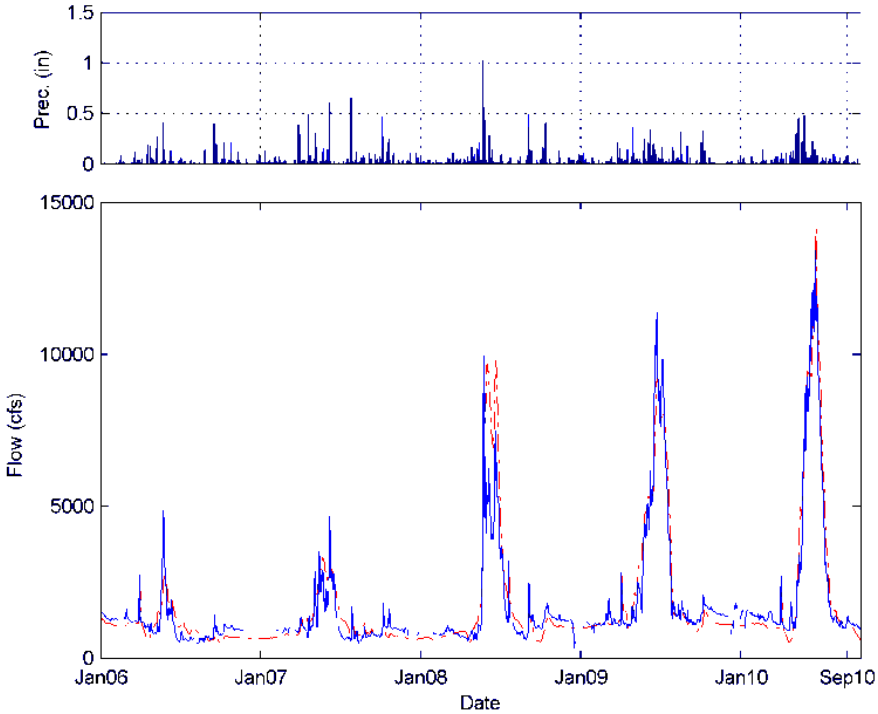


Figure 2-3. Simulated and Observed Discharge at USGS 06279500.

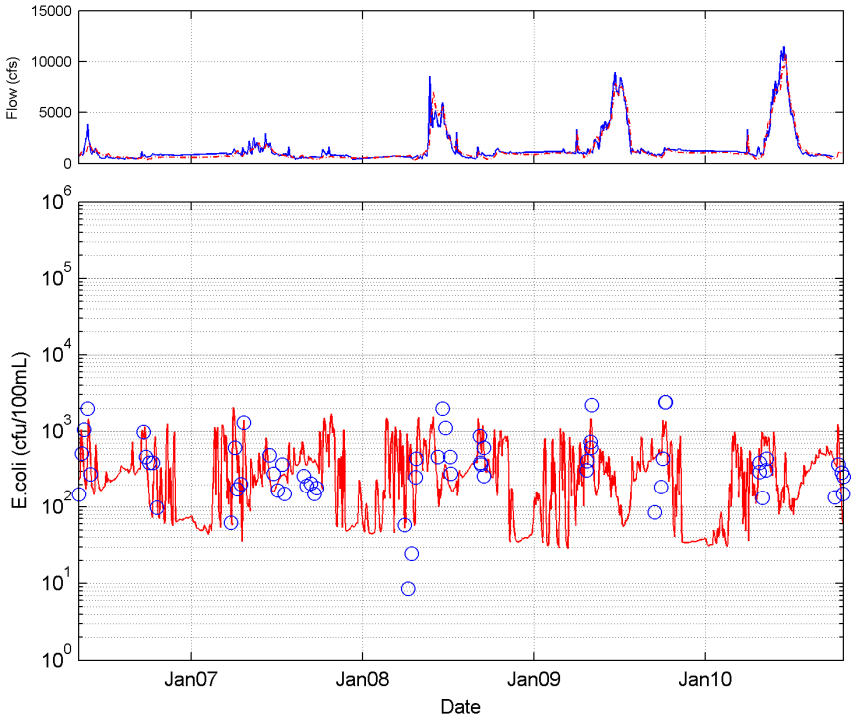


Figure 2-4. Simulated and Observed *E. coli* Concentrations at BIG_HORN_RIVER_3.

Table 2-4. *E. coli* Loading Sources by Land Use Based on HSPF Model Results for the Recreational Season

Source Land Use	Load Contributions (%)															
	Owl Creek	Kirby Creek	Nowater Creek	Fifteen Mile Creek	Big Horn River (Upstream of Nowood)	Big Horn River (Nowood to Greybull)	Sage Creek	Slick Creek	Paint Rock Creek	Nowood River	Greybull River	Granite Creek	Beaver Creek	Shell Creek	Big Horn River (Downstream of Greybull)	Dry Creek
Rangeland	93.5	98.35	11.63	65.95	17.57	30.86	1.43	1.04	78.8	71.77	54.49	91.34	75	78.74	43.77	60.45
Forest	2.81	0.14	0.00	0.03	0.23	3.29	0.00	0.00	17.41	12.1	0.38	5.99	12.85	10.28	4.07	0.11
Cropland	0.23	0.07	77.07	10.4	69.68	53.95	75.99	82.48	2.23	3.86	33.68	0.00	6.56	6.49	32.91	37.07
Urban/ Residential	0.73	0.23	0.25	0.41	8.74	8.14	3.53	0.46	0.15	9.11	3.85	2.57	5.39	3.54	16.63	2.27
Other	0.02	0.01	0.00	0.15	0.01	0.01	0.00	0.00	0.03	0.02	1.84	0.02	0.01	0.02	0.11	0.03
Total Overland Load	**97.29**	**98.8**	**88.95**	**76.94**	**96.23**	**96.25**	**80.95**	**83.98**	**98.62**	**96.86**	**94.24**	**99.92**	**99.81**	**99.07**	**97.49**	**99.93**
Direct Sources																
Direct Defecation (stream)	2.62	1.16	10.56	21.36	3.55	3.53	17.5	14.73	1.34	3.03	4.98	0.08	0.2	0.87	2.32	0.07
Septics	0.09	0.04	0.48	1.7	0.24	0.21	1.54	1.3	0.05	0.12	0.76	0	0.01	0.07	0.18	0.01
Total Direct Load	**2.71**	**1.2**	**11.04**	**23.06**	**3.79**	**3.74**	**19.04**	**16.03**	**1.39**	**3.15**	**5.74**	**0.08**	**0.21**	**0.94**	**2.5**	**0.08**

3.0 TOTAL MAXIMUM DAILY LOAD AND ALLOCATIONS

To ensure that all applicable bacteria criteria are met and to aid in implementing the TMDL, load allocations were calculated for each of the five flow zones by using the geometric mean summer and winter recreation season criterion. The methods used to calculate the TMDL allocations are discussed in more detail in this chapter.

The TMDL is in effect from May 1 through September 30 for the summer recreation season standard of 126 org/100 mL and from October 1 through March 30 for the winter recreation season standard of 630 org/100 mL. Because the flow data and *E. coli* geometric mean data are insufficient at many of the TMDL endpoints within the Big Horn TMDL project area, an **HSPF** model was used during the summer recreation season to simulate geometric mean flows and geometric mean bacteria concentrations at each segment endpoint. The **HSPF** model was again used to simulate flows during the winter recreation season but was not used to simulate bacteria concentrations during the winter recreation season, because the data for developing thorough, calibrated predictions was insufficient (shown in Table 1-7).

The LDC is a dynamic expression of the allowable daily load for any given flow within each specified season. The TMDL was developed using the LDC approach and resulted in a flow variable target that considered the entire flow regime within the summer recreation season (May 1–September 30) and within the winter recreation season (October 1–April 30). To aid in interpreting and implementing each TMDL, the TMDL and LDC flow intervals were grouped into five flow zones that included high flows (0–10 percent), moist conditions (10–40 percent), midrange flows (40–60 percent), dry conditions (60–90 percent), and low flows (90–100 percent) in adherence to guidance provided by the EPA [2007].

The Wyoming Department of Environmental Quality [2007]states:

> *To aid in implementation prioritization, load allocations were calculated for each of the five flow zones using summer and winter recreation season criteria. This TMDL is written on the geometric mean during the summer and winter recreation seasons because an exceedance of the single-sample maxima shall not be cause for listing a waterbody on the State 303(d) list or development of a TMDL.*

TMDL tables were constructed for each impaired reach throughout the Big Horn TMDL project area. The summer recreation season TMDL tables in this section are in effect from May 1 through September 30, and the winter recreation season TMDL tables are in effect from October 1 through April 30. Only data from each applicable time period were used to develop the TMDL allocations and load reduction goals. The methods used to calculate the TMDL allocations are discussed in detail in this chapter.

3.1 LOADING CAPACITY

The TMDL (loading capacity) is the sum of the load allocation (LA), the wasteload allocation (WLA), and margin of safety (MOS), shown in Equation 3-1.

$$\text{TMDL} = \text{LA} + \text{WLA} + \text{MOS}. \tag{3-1}$$

E. coli bacteria loading capacities were calculated as the product of the 95th percentile flow in each flow zone, the applicable criterion, and a unit conversion factor.

3.2 MARGIN OF SAFETY

An explicit MOS identified using a duration curve framework is an unallocated load intended to account for uncertainty (e.g., loads from tributary streams and effectiveness of controls). An explicit MOS was calculated as the difference between the loading capacity at the midpoint of each of the five flow zones and the loading capacity at the minimum flow in each zone. A substantial MOS is provided using this method, because the loading capacity is typically much less at the minimum flow of a zone when compared to the midpoint [U.S. Environmental Protection Agency, 2007]. Because the allocations are a direct function of flow, accounting for potential flow variability is an appropriate way to address the MOS.

3.3 WASTELOAD ALLOCATION

The WLA is the sum of the permitted point-source allocations within each reach. The WLAs were calculated as the product of the total design flows in each reach, the specified bacteria limits (summer or winter recreation season criteria), and a unit conversion factor. Information about applicable point sources of *E. coli* bacteria, including the design flow and bacteria concentration limits used to calculate the WLAs, is included in Table 2-1. WLAs and reaches they contribute to are included in Table 3-1. The six CAFOs in the watershed were not included in the WLAs, because they are not allowed to discharge except in the case of a chronic or catastrophic storm event that would cause an overflow from the runoff and/or wastewater control structure.

3.4 LOAD ALLOCATION

The LA represents the load allowed from nonpoint sources and accounts for uncertainty in the loading capacity. The LA was calculated as the loading capacity minus the MOS and the WLA.

Table 3-1. Big Horn Total Maximum Daily Load *E. coli* Point-Source Allocations

Reach	Contributing Facilities	WLA Summer Recreation Season (expressed as 10^9 cfu/day)		WLA Winter Recreation Season (expressed as 10^9 cfu/day)	
Big Horn River (upstream of Nowood River)	Thermopolis WWTF	239.2	229.9	1,062.9	1,016.4
	Worland Wastewater Lagoon		9.3		46.5
Big Horn River (Nowood River to Greybull River)	Basin Wastewater Lagoon	11.4	11.4	57.2	57.2
Nowood River	Ten Sleep Wastewater Lagoon	1.1	0.9	6.0	4.8
	Deer Haven Lodge		0.1		0.7
	Manderson Wastewater Lagoon		0.1		0.5
Greybull River	Meeteetse Wastewater Lagoon	1.6	0.5	8.1	2.4
	Burlington Wastewater Lagoon		1.1		5.7
Big Horn River (Greybull River downstream)	Greybull Wastewater Lagoon	2.4	2.4	11.9	11.9

3.5 LOAD DURATION CURVES/TOTAL MAXIMUM DAILY LOAD TABLES

Evaluating the impairment status of a waterbody with respect to the criterion for *E. coli* bacteria requires calculating the geometric mean from at least five samples collected over a 30-day period taken in separate 24-hour periods. Data of this resolution were rarely available for the impaired streams within the Big Horn River TMDL project boundary. Thus, the HSPF model was used to develop calibrated, synthesized data, which were used to calculate exceedances of *E. coli* standards during the summer recreation season. A list of the sites with available water-quality data in each impaired reach is provided in Table 3-2. Note that the most downstream reach (Big Horn River [Greybull River downstream]) did not have water-quality data but was assumed to be calibrated when all major upstream reaches and tributaries were calibrated. The HSPF model application was not used to simulate concentrations during the winter recreation season, because the data to develop a thorough, calibrated set of model predictions were insufficient, and this is evident when reviewing Table 1-8. Instead, actual geometric mean data that were collected were used to assess the impairment status.

Table 3-2. Water-Quality Monitoring Sites Used for Developing Load Duration Curves

TMDL Reach	*E. coli* Sites Used For Calibration
Owl Creek	Owl_Creek_1, Owl_Creek_2
Kirby Creek	Kirby_Creek_5, Kirby_Creek_7
Nowater Creek	Nowater_Creek_1
Fifteen Mile Creek	Fifteen_Mile_Creek_1
Big Horn River (upstream of Nowood River)	Big_Horn_River_2
Big Horn River (Nowood River to Greybull River)	Big_Horn_River_3, Big_Horn_River_4
Sage Creek	Sage_Creek_1
Slick Creek	Slick_Creek_1
Paint Rock Creek	Paint_Rock_Creek_2
Nowood River	Nowood_River_3
Greybull River	Greybull_River_3, Greybull_River_4, Greybull_River_5, Greybull_River_6, Greybull_River_7, Greybull_River_8, Roach_Gulch_Reservoir_1
Granite Creek	Granite_Creek_1
Beaver Creek	Beaver_Creek_1, Beaver_Creek_2
Shell Creek	Shell_Creek_1, Shell_Creek_2, Shell_Creek_3
Dry Creek	Dry_Creek_1, Dry_Creek_2, Dry_Creek_3
Big Horn River (Greybull River downstream)	N/A

LDCs include the loading capacity curve (shown as a green solid line) that is constructed using the product of a running 30-day average simulated flow, the applicable criterion (summer or winter recreation season criterion), and a unit conversion factor. Because the Wyoming water-quality standards state that "an exceedance of the single-sample maximum effluent limitations shall not be cause for listing a waterbody on the State 303(d) list or development of a TMDL" [Wyoming Department of Environmental Quality, 2007], no single-sample maximum TMDL tables are included in this document. The WLAs listed in Table 3-1 are shown as dashed tan lines in applicable LDCs. Not all impaired reaches contain a WLA. Boxplots of the simulated geometric mean data are also included in each flow zone. Loads that plot above the curve exceed the water-quality criterion, while those below the curve are in compliance.

The locations of the water-quality monitoring sites in the project area where observed data were collected are illustrated in Figure 1-7. Water-quality monitoring sites and flow-monitoring sites used to calibrate the model application were subsequently used to develop each load duration curve that is provided in Table 3-2. The summer and winter recreation season LDCs for each impaired reach are discussed in the following sections.

TMDL tables were generated for *E. coli* bacteria loads, for each of the impaired segments within the Big Horn River TMDL project area by using the information from the LDC. Within each segment, two tables were generated: (1) *E. coli* summer recreation season and (2) *E. coli* winter recreation season. As stated earlier, *E. coli* summer recreation season tables were generated using simulated concentration and flow data and winter recreation season tables were generated using simulated flow and observed concentration data. The TMDL for each flow zone is set by multiplying the 95th percentile flow by the water-quality criteria and a conversion factor. The current load for each flow zone is the 95th simulated load during the summer recreation season and the 95th percentile actual load (where available) during the winter recreation season. The load reduction required to meet the TMDL is then calculated by subtracting the TMDL from the current load. The overall percent reduction required for the segment was calculated by multiplying the percentage of time in each flow zone (10 percent for high, 30 percent for moist, 20 percent for midrange, 30 percent for dry, and 10 percent for low) by the difference of the current load and the load reduction in that flow zone and summing across all five flow zones. The following sections discuss the tables by impaired stream reach.

Table 3-3 provides an overview of the overall load reductions and the load reductions that were required by flow zone for each TMDL-impaired reach during the summer recreation season. The overall load reductions required range from 30 percent in Kirby Creek to 91 percent in Beaver Creek. All reaches required reductions in both the high- and low-flow zones with the exception of Paint Rock Creek, which only required reductions in the upper flow zones. Bacteria loads exceeding the criteria in the upper flow zones generally reflect potential indirect source contributions driven by rainfall/runoff processes. Bacteria loads exceeding the criteria in the lower flow zones generally indicate potential direct source load contributions or sources in close proximity to the stream that may include direct defecation by livestock or wildlife in the stream channel or failing septic systems [U.S. Environmental Protection Agency, 2007]. Low-flow exceedances can also be caused by runoff from snow melt or irrigation applications. For the winter recreation season, the limited data indicate that the TMDL is met in all reaches, except Paint Rock Creek, and that reductions of current loads are not required in any reaches, except Paint Rock Creek. A 1 percent reduction is required in the high-flow zone in Paint Rock Creek during the winter recreation season. LDCs for the summer recreation season and TMDL tables for the summer and winter recreation seasons are provided in Figures 3-1 through 3-16 and Tables 3-4 through 3-35 and are grouped by TMDL reach.

Table 3-3. Overview of the Overall Summer Recreation Season Load Reductions

TMDL Reach	Overall Reduction Required (%)	Load Reductions Required By Flow Zone (%)				
		High	Moist	Midrange	Dry	Low
Owl Creek	78	86	77	0	0	83
Kirby Creek	30	42	0	0	1	81
Nowater Creek	90	84	89	92	93	92
Fifteen Mile Creek	76	81	50	75	85	98
Big Horn River (upstream of Nowood River)	67	44	65	79	84	83
Big Horn River (Nowood River to Greybull River)	59	36	63	59	70	71
Sage Creek	88	90	89	86	87	86
Slick Creek	87	89	88	88	86	86
Paint Rock Creek	84	85	85	70	0	0
Nowood River	81	78	83	83	0	62
Greybull River	54	51	49	66	66	58
Granite Creek	90	93	90	0	11	9
Beaver Creek	91	93	92	9	48	71
Shell Creek	86	89	86	82	55	74
Big Horn River (Greybull River downstream)	43	41	48	26	33	28
Dry Creek	84	88	80	85	83	23

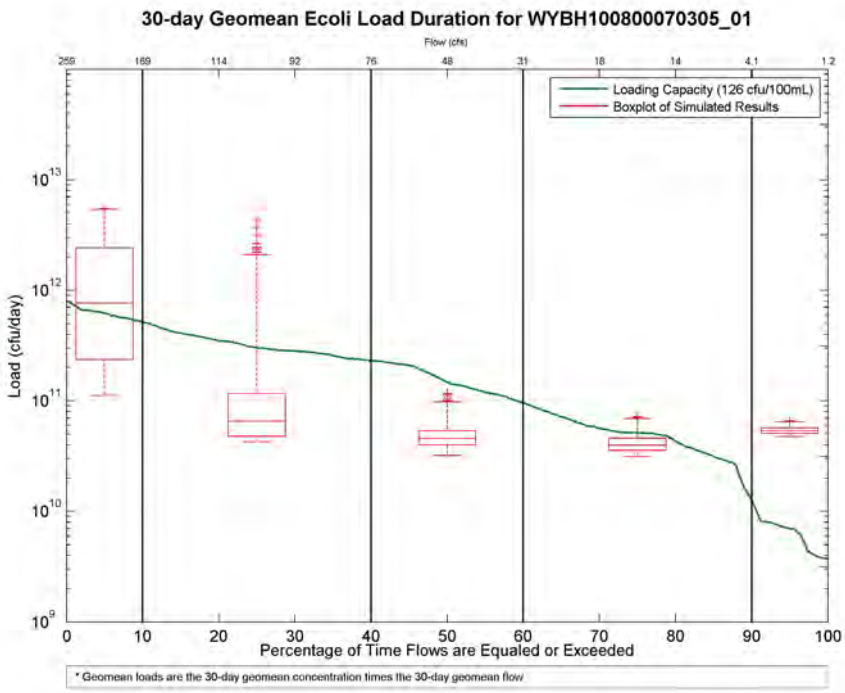


Figure 3-1. Owl Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-4. Summer Recreation Season Total Maximum Daily Load Table for Owl Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 169 cfs	**169–76 cfs**	**76–31 cfs**	**31–4 cfs**	**< 4 cfs**
LA	682	415	178	49	8
WLA	0	0	0	0	0
MOS	98	70	53	39	3
TMDL	780	485	231	88	11
Current Load[(a)]	5,439	2,128	98	69	65
Load Reduction	4,659	1,643	0	0	54
% Reduction	86	77	0	0	83
Overall Reduction Required = 78%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-5. Winter Recreation Season Total Maximum Daily Load Table for Owl Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 20 cfs	**20–11 cfs**	**11–8 cfs**	**8–3 cfs**	**< 3 cfs**
LA	666	263	150	87	42
WLA	0	0	0	0	0
MOS	48	30	25	32	4
TMDL	714	293	175	119	46
Current Load[(a)]	N/A	N/A	N/A	N/A	N/A
Load Reduction	N/A	N/A	N/A	N/A	N/A
% Reduction	N/A	N/A	N/A	N/A	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

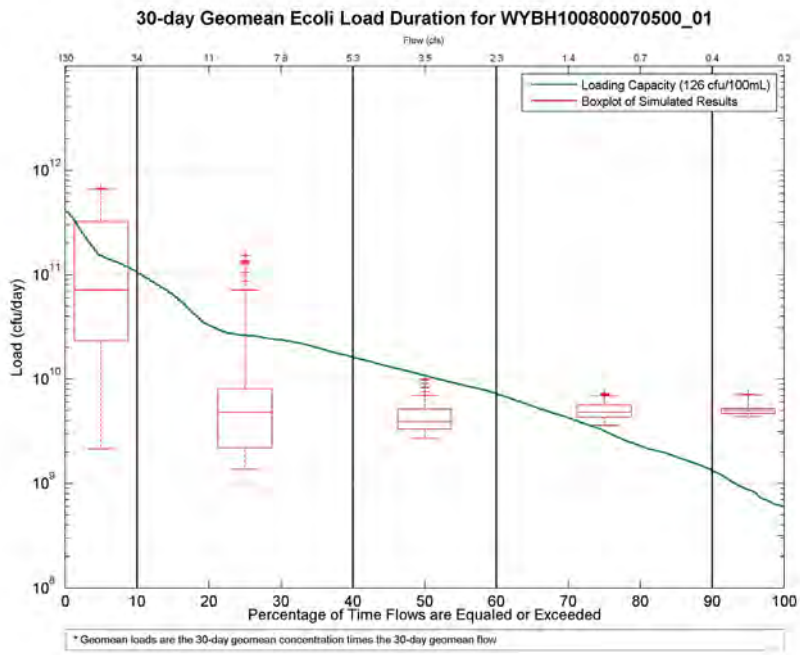


Figure 3-2. Kirby Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-6. Summer Recreation Season Total Maximum Daily Load Table for Kirby Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 34.8 cfs	**34.8–5.3 cfs**	**5.3–2.3 cfs**	**2.3–0.4 cfs**	**0.4–0.2 cfs**
LA	339.6	82.6	12.0	4.9	1.0
WLA	0.0	0.0	0.0	0.0	0.0
MOS	45.3	9.9	3.7	1.9	0.3
TMDL	384.9	92.5	15.7	6.8	1.3
Current Load[(a)]	659.3	74.4	7.2	6.9	7.0
Load Reduction	274.4	0.0	0.0	0.1	5.7
% Reduction	42	0	0	1	81
Overall Reduction Required = 30%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-7. Winter Recreation Season Total Maximum Daily Load Table for Kirby Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 10 cfs	**10–4 cfs**	**4–2 cfs**	**2–1 cfs**	**< 1 cfs**
LA	251	122	38	20	6
WLA	0	0	0	0	0
MOS	48	17	17	6	2
TMDL	299	139	55	26	8
Current Load[(a)]	N/A	4	4	N/A	N/A
Load Reduction	N/A	0	0	N/A	N/A
% Reduction	N/A	0	0	N/A	N/A
Overall Reduction Required = 0%					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

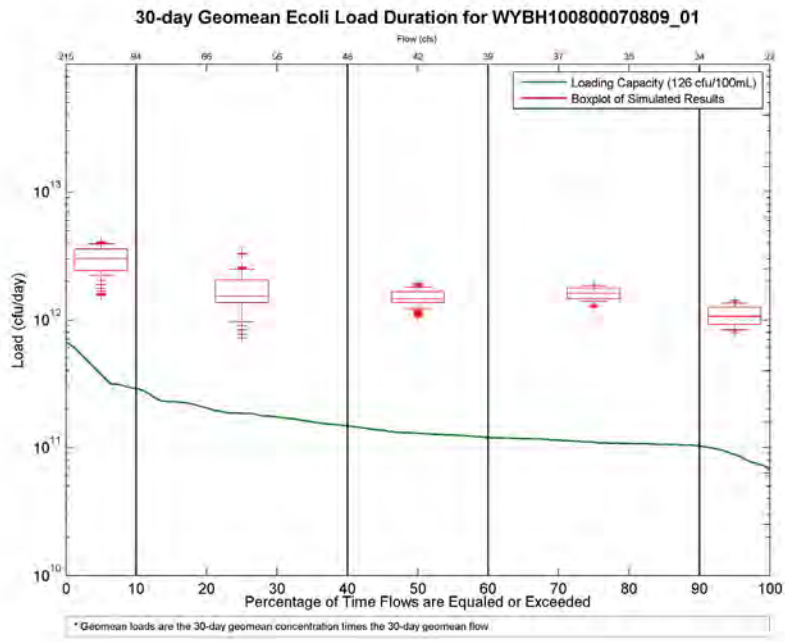


Figure 3-3. Nowater Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-8. Summer Recreation Season Total Maximum Daily Load Table for Nowater Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 94 cfs	**94–48 cfs**	**48–39 cfs**	**39–34 cfs**	**< 34 cfs**
LA	567	235	138	114	81
WLA	0	0	0	0	0
MOS	82	38	9	7	22
TMDL	649	273	147	121	103
Current Load[(a)]	3,936	2,480	1,800	1,851	1,358
Load Reduction	3,287	2,207	1,653	1,730	1,255
% Reduction	84	89	92	93	92
Overall Reduction Required = 90%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-9. Winter Recreation Season Total Maximum Daily Load Table for Nowater Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 21 cfs	**21–11 cfs**	**11–6 cfs**	**6–2 cfs**	**< 2 cfs**
LA	755	239	133	78	19
WLA	0	0	0	0	0
MOS	53	62	24	18	7
TMDL	808	301	157	96	26
Current Load[(a)]	N/A	N/A	N/A	N/A	N/A
Load Reduction	N/A	N/A	N/A	N/A	N/A
% Reduction	N/A	N/A	N/A	N/A	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

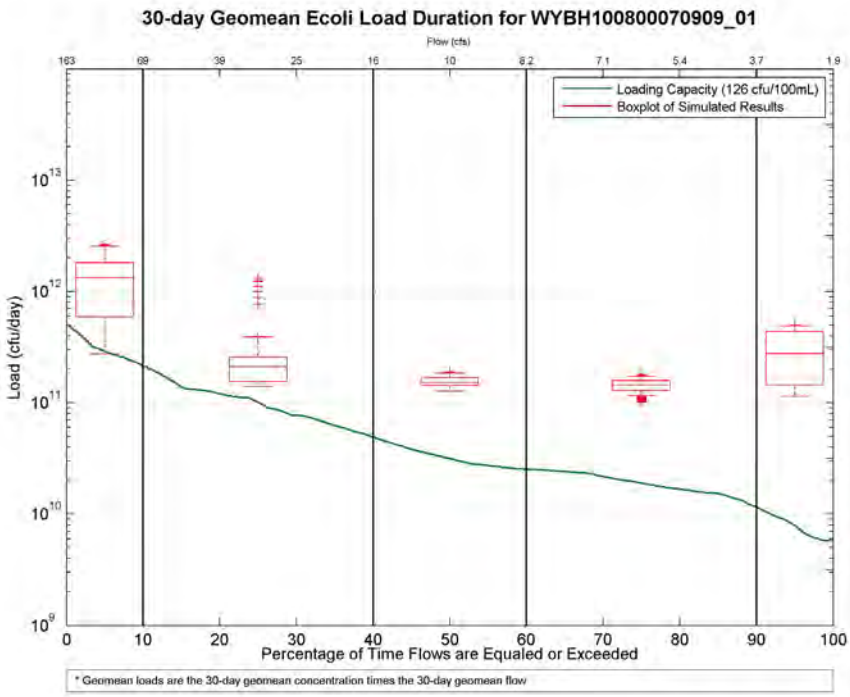


Figure 3-4. Fifteen Mile Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-10. Summer Recreation Season Total Maximum Daily Load Table for Fifteen Mile Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 69 cfs	**69–16 cfs**	**16–8 cfs**	**8–4 cfs**	**< 4 cfs**
LA	407	142	41	17	9
WLA	0	0	0	0	0
MOS	77	52	6	8	2
TMDL	484	194	47	25	11
Current Load[(a)]	2,555	390	185	172	493
Load Reduction	2,071	196	138	147	482
% Reduction	81	50	75	85	98
Overall Reduction Required = 76%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-11. Winter Recreation Season Total Maximum Daily Load Table for Fifteen Mile Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 9 cfs	**9–6 cfs**	**6–5 cfs**	**5–1 cfs**	**< 1 cfs**
LA	404	131	87	41	13
WLA	0	0	0	0	0
MOS	25	13	11	33	5
TMDL	429	144	98	74	18
Current Load[(a)]	N/A	N/A	N/A	N/A	N/A
Load Reduction	N/A	N/A	N/A	N/A	N/A
% Reduction	N/A	N/A	N/A	N/A	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

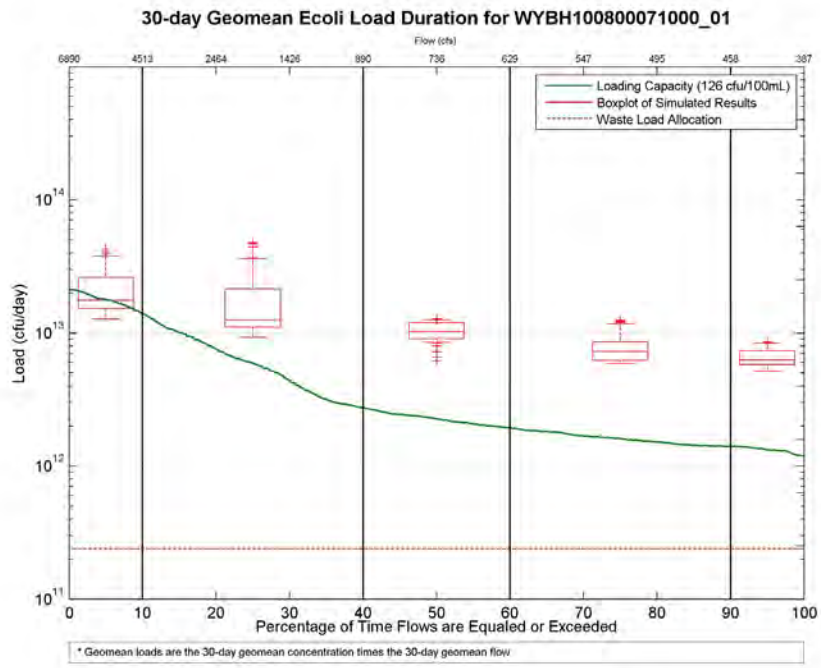


Figure 3-5. Big Horn River (Upstream of Nowood) Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-12. Summer Recreation Season Total Maximum Daily Load Table for the Big Horn River (Upstream of Nowood)

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 4,513 cfs	**4,513–890 cfs**	**890–629 cfs**	**629–458 cfs**	**< 458 cfs**
LA	17,138	9,281	2,130	1,464	1,048
WLA	239	239	239	239	239
MOS	3,935	3,196	329	198	135
TMDL	21,312	12,716	2,698	1,901	1,422
Current Load[(a)]	38,251	36,389	12,566	11,730	8,402
Load Reduction	16,939	23,673	9,868	9,829	6,980
% Reduction	44	65	79	84	83
Overall Reduction Required = 67%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-13. Winter Recreation Season Total Maximum Daily Load Table for the Big Horn River (Upstream of Nowood)

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	Moist	Midrange	Dry	Low
	> 1,016 cfs	1,016–842 cfs	842–594 cfs	594–505 cfs	< 505 cfs
LA	16,048	13,255	8,369	7,190	3,243
WLA	1,063	1,063	1,063	1,063	1,063
MOS	249	1,436	3,580	949	3,526
TMDL	17,360	15,754	13,012	9,202	7,832
Current Load[(a)]	N/A	N/A	N/A	N/A	N/A
Load Reduction	N/A	N/A	N/A	N/A	N/A
% Reduction	N/A	N/A	N/A	N/A	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

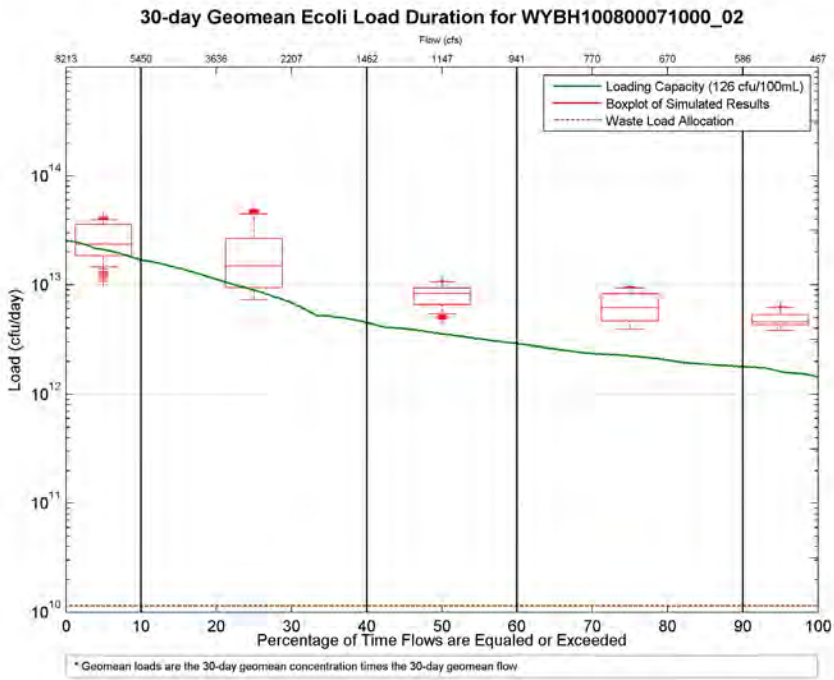


Figure 3-6. Big Horn River (Nowood to Greybull) Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-14. Summer Recreation Season Total Maximum Daily Load Table for the Big Horn River (Nowood to Greybull)

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 5,450 cfs	**5,450–1,462 cfs**	**1,462–941 cfs**	**941–586 cfs**	**< 586 cfs**
LA	21,081	11,950	3,692	2,366	1,619
WLA	11	11	11	11	11
MOS	4,300	4,460	635	455	182
TMDL	25,392	16,421	4,338	2,832	1,812
Current Load[(a)]	39,844	44,804	10,600	9,372	6,183
Load Reduction	14,452	28,383	6,262	6,540	4,371
% Reduction	36	63	59	70	71
Overall Reduction Required = 59%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-15. Winter Recreation Season Total Maximum Daily Load Table for the Big Horn River (Nowood to Greybull)

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 1,070 cfs	**1,070–944 cfs**	**944–758 cfs**	**758–578 cfs**	**< 578 cfs**
LA	18,163	15,192	12,116	10,688	8,520
WLA	57	57	57	57	57
MOS	656	1,247	2,384	562	338
TMDL	18,876	16,496	14,557	11,307	8,915
Current Load[(a)]	N/A	7,058	4,747	1,040	N/A
Load Reduction	N/A	0	0	0	N/A
% Reduction	N/A	0	0	0	N/A
Overall Reduction Required = 0%					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

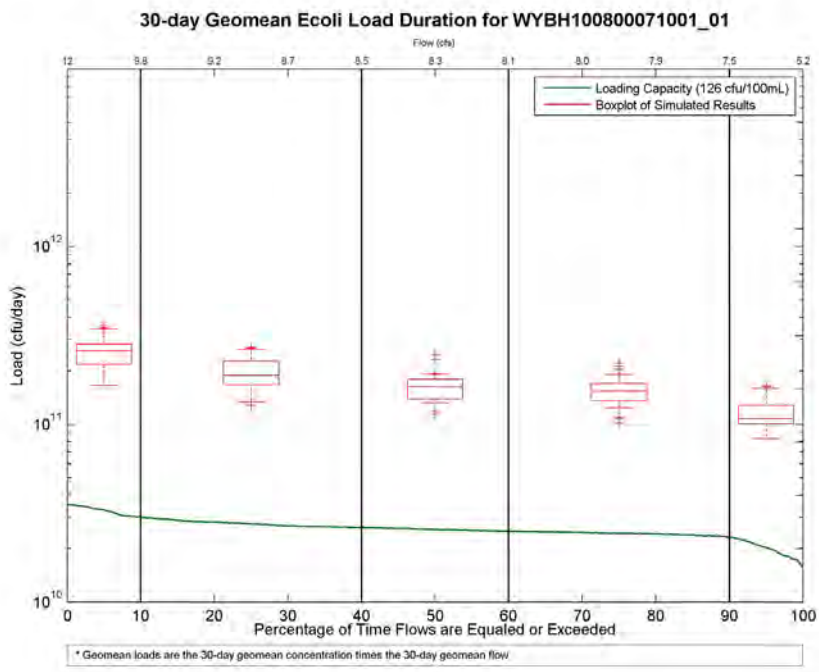


Figure 3-7. Sage Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-16. Summer Recreation Season Total Maximum Daily Load Table for Sage Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 9.8 cfs	**9.8–8.5 cfs**	**8.5–8.1 cfs**	**8.1–7.5 cfs**	**< 7.5 cfs**
LA	33	29	25	24	19
WLA	0	0	0	0	0
MOS	3	1	1	1	4
TMDL	36	30	26	25	23
Current Load[(a)]	345	264	191	191	161
Load Reduction	309	234	165	166	138
% Reduction	90	89	86	87	86
Overall Reduction Required = 88%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-17. Winter Recreation Season Total Maximum Daily Load Table for Sage Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 0.294 cfs	**0.294–0.090 cfs**	**0.090–0.040 cfs**	**0.040–0.003 cfs**	**< 0.003 cfs**
LA	25.034	3.647	0.944	0.410	0.028
WLA	0.000	0.000	0.000	0.000	0.000
MOS	4.731	0.648	0.435	0.127	0.004
TMDL	29.765	4.295	1.379	0.537	0.032
Current Load[(a)]	N/A	N/A	N/A	N/A	N/A
Load Reduction	N/A	N/A	N/A	N/A	N/A
% Reduction	N/A	N/A	N/A	N/A	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

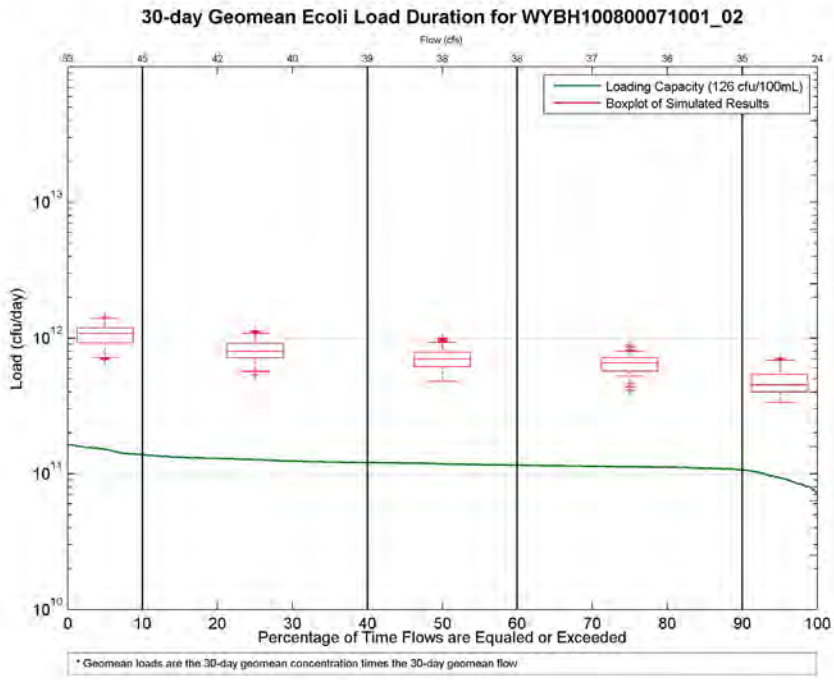


Figure 3-8. Slick Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-18. Summer Recreation Season Total Maximum Daily Load Table for Slick Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 45 cfs	**45–39 cfs**	**39–38 cfs**	**38–35 cfs**	**< 35 cfs**
LA	152	132	119	111	86
WLA	0	0	0	0	0
MOS	13	6	3	6	21
TMDL	165	138	122	117	107
Current Load[(a)]	1,450	1,131	986	842	751
Load Reduction	1,285	993	864	725	644
% Reduction	89	88	88	86	86
Overall Reduction Required = 87%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-19. Winter Recreation Season Total Maximum Daily Load Table for Slick Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 1.31 cfs	**1.31–0.35 cfs**	**0.35–0.19 cfs**	**0.19–0.02 cfs**	**< 0.02 cfs**
LA	116.06	14.72	4.14	2.00	0.23
WLA	0.00	0.00	0.00	0.00	0.00
MOS	20.33	3.68	1.07	0.73	0.03
TMDL	136.39	18.40	5.21	2.73	0.26
Current Load[(a)]	N/A	N/A	N/A	N/A	N/A
Load Reduction	N/A	N/A	N/A	N/A	N/A
% Reduction	N/A	N/A	N/A	N/A	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

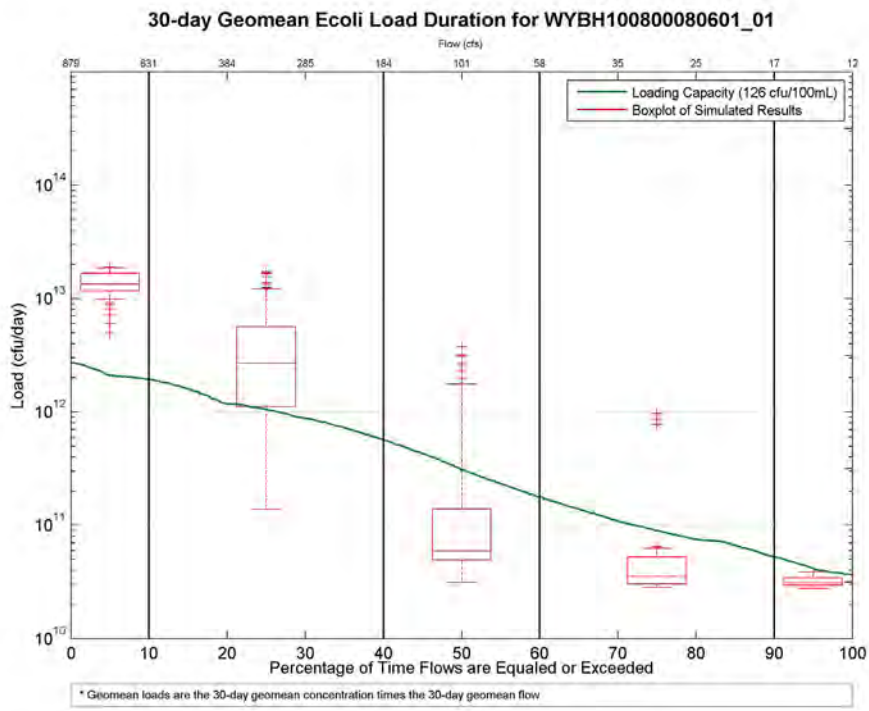


Figure 3-9. Paint Rock Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-20. Summer Recreation Season Total Maximum Daily Load Table for Paint Rock Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 631 cfs	**631–184 cfs**	**184–58 cfs**	**58–17 cfs**	**< 17 cfs**
LA	2,555	1,377	410	127	47
WLA	0	0	0	0	0
MOS	165	484	134	38	5
TMDL	2,720	1,861	544	165	52
Current Load[(a)]	18,634	12,204	1,831	63	39
Load Reduction	15,914	10,343	1,287	0	0
% Reduction	85	85	70	0	0
Overall Reduction Required = 84%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-21. Winter Recreation Season Total Maximum Daily Load Table for Paint Rock Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 19 cfs	**19–12 cfs**	**12–9 cfs**	**9–5 cfs**	**< 5 cfs**
LA	465	228	167	115	76
WLA	0	0	0	0	0
MOS	42	58	11	23	7
TMDL	507	286	178	138	83
Current Load[(a)]	512	N/A	27	N/A	N/A
Load Reduction	5	N/A	0	N/A	N/A
% Reduction	1	N/A	0	N/A	N/A
Overall Reduction Required = 1%					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

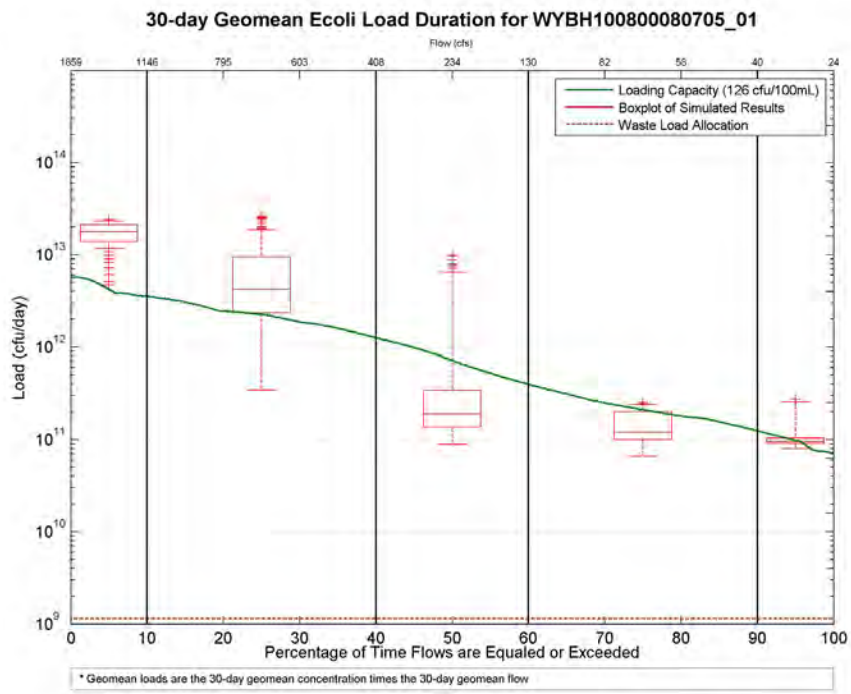


Figure 3-10. Nowood River Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-22. Summer Recreation Season Total Maximum Daily Load Table for the Nowood River

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 1,146 cfs	**1,146–408 cfs**	**408–130 cfs**	**130–40 cfs**	**< 40 cfs**
LA	5,078	2,420	878	283	95
WLA	1	1	1	1	1
MOS	691	1,009	323	88	26
TMDL	5,770	3,430	1,202	372	122
Current Load[(a)]	25,653	20,200	7,009	305	319
Load Reduction	19,883	16,770	5,807	0	197
% Reduction	78	83	83	0	62
Overall Reduction Required = 81%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-23. Winter Recreation Season Total Maximum Daily Load Table for the Nowood River

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 191 cfs	**191–68 cfs**	**68–51 cfs**	**51–24 cfs**	**< 24 cfs**
LA	5,035	2,347	902	673	336
WLA	6	6	6	6	6
MOS	721	547	131	98	26
TMDL	5,762	2,900	1,039	777	368
Current Load[(a)]	2,043	N/A	N/A	N/A	63
Load Reduction	0	N/A	N/A	N/A	0
% Reduction	0	N/A	N/A	N/A	0
Overall Reduction Required = 0%					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

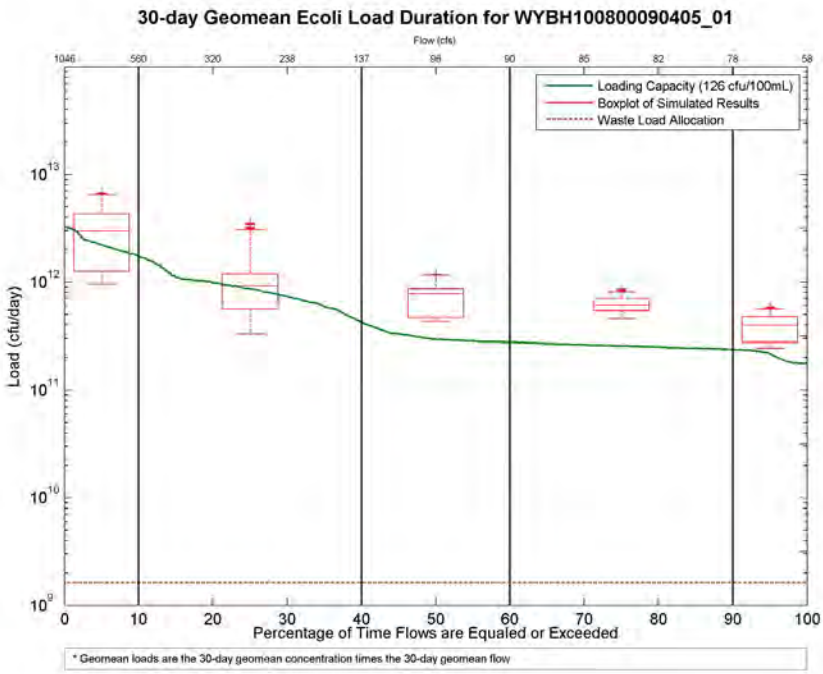


Figure 3-11. Greybull River Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-24. Summer Recreation Season Total Maximum Daily Load Table for the Greybull River

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 560 cfs	**560–137 cfs**	**137–90 cfs**	**90–78 cfs**	**< 78 cfs**
LA	2,737	1,147	380	257	199
WLA	2	2	2	2	2
MOS	474	437	17	19	39
TMDL	3,213	1,586	399	278	240
Current Load[(a)]	6,570	3,120	1,173	814	567
Load Reduction	3,357	1,534	774	536	327
% Reduction	51	49	66	66	58
Overall Reduction Required = 54%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-25. Winter Recreation Season Total Maximum Daily Load Table for the Greybull River

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 60 cfs	**60–48 cfs**	**48–41 cfs**	**41–30 cfs**	**< 30 cfs**
LA	2,028	836	674	538	422
WLA	8	8	8	8	8
MOS	225	59	52	83	39
TMDL	2,261	903	734	629	469
Current Load[(a)]	520	335	76	128	75
Load Reduction	0	0	0	0	0
% Reduction	0	0	0	0	0
Overall Reduction Required = 0%					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

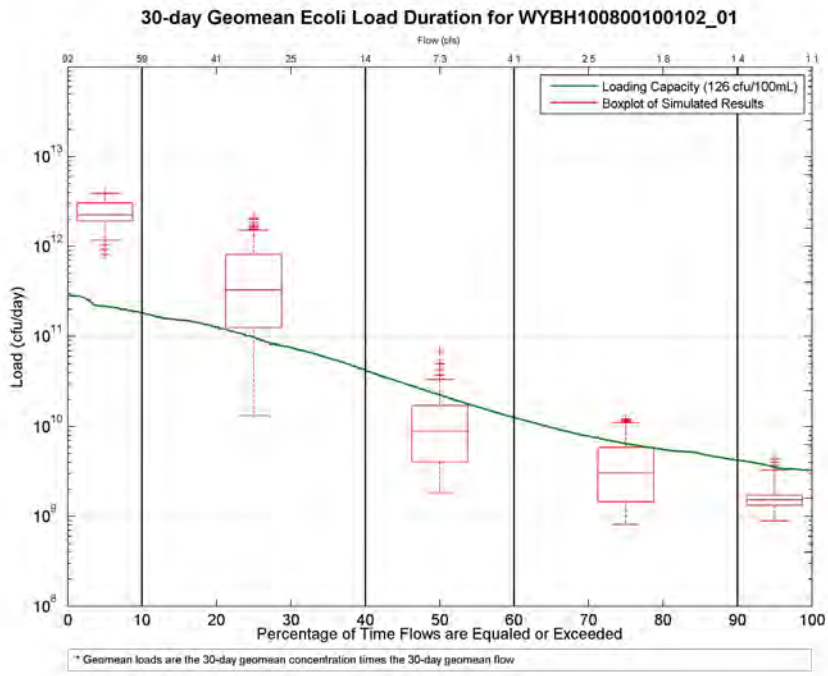


Figure 3-12. Granite Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-26. Summer Recreation Season Total Maximum Daily Load Table for Granite Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 59 cfs	**59–14 cfs**	**14–4 cfs**	**4–1 cfs**	**< 1 cfs**
LA	251.5	115.8	29.8	9.5	3.9
WLA	0.0	0.0	0.0	0.0	0.0
MOS	33.8	55.1	10.0	2.2	0.3
TMDL	285.3	170.9	39.8	11.7	4.2
Current Load[(a)]	4,167.3	1,676.4	39.0	13.2	4.6
Load Reduction	3,882.0	1,505.5	0.0	1.5	0.4
% Reduction	93	90	0	11	9
Overall Reduction Required = 90%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-27. Winter Recreation Season Total Maximum Daily Load Table for Granite Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 1.3 cfs	**1.3–0.8 cfs**	**0.8–0.5 cfs**	**0.5–0.3 cfs**	**< 0.3 cfs**
LA	26	17	9	6	3
WLA	0	0	0	0	0
MOS	4	3	2	2	1
TMDL	30	20	11	8	4
Current Load[(a)]	N/A	N/A	N/A	N/A	N/A
Load Reduction	N/A	N/A	N/A	N/A	N/A
% Reduction	N/A	N/A	N/A	N/A	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

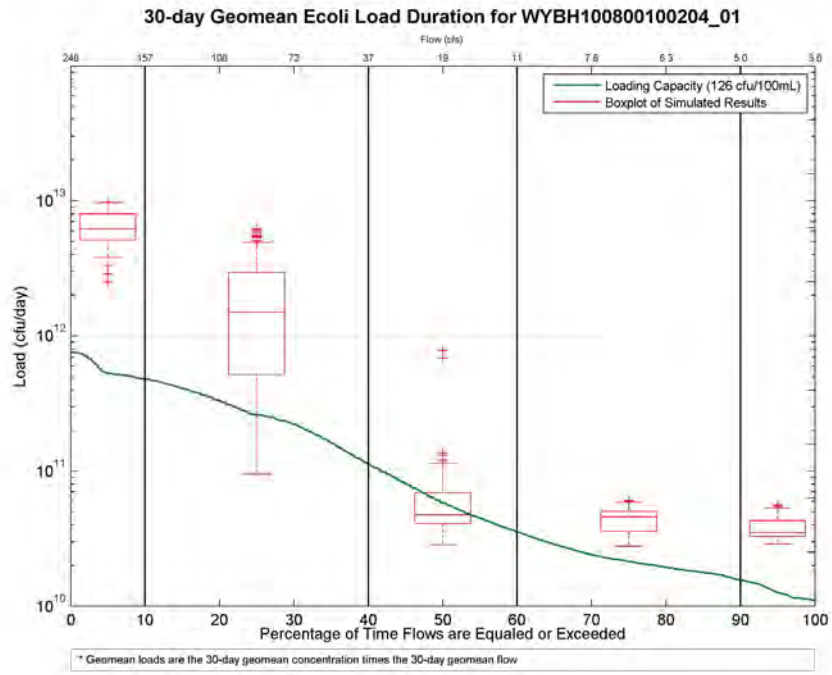


Figure 3-13. Beaver Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-28. Summer Recreation Season Total Maximum Daily Load Table for Beaver Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 157 cfs	**157–37 cfs**	**37–11 cfs**	**11–5 cfs**	**< 5 cfs**
LA	716	321	84	27	14
WLA	0	0	0	0	0
MOS	50	151	23	6	2
TMDL	766	472	107	33	16
Current Load[(a)]	10,767	5,599	118	63	56
Load Reduction	10,001	5,127	11	30	40
% Reduction	93	92	9	48	71
Overall Reduction Required = 91%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-29. Winter Recreation Season Total Maximum Daily Load Table for Beaver Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 5 cfs	**5–3 cfs**	**3–2 cfs**	**2–1 cfs**	**< 1 cfs**
LA	189	62	40	25	16
WLA	0	0	0	0	0
MOS	21	10	4	8	3
TMDL	210	72	44	33	19
Current Load[(a)]	41	12	26	26	N/A
Load Reduction	0	0	0	0	N/A
% Reduction	0	0	0	0	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

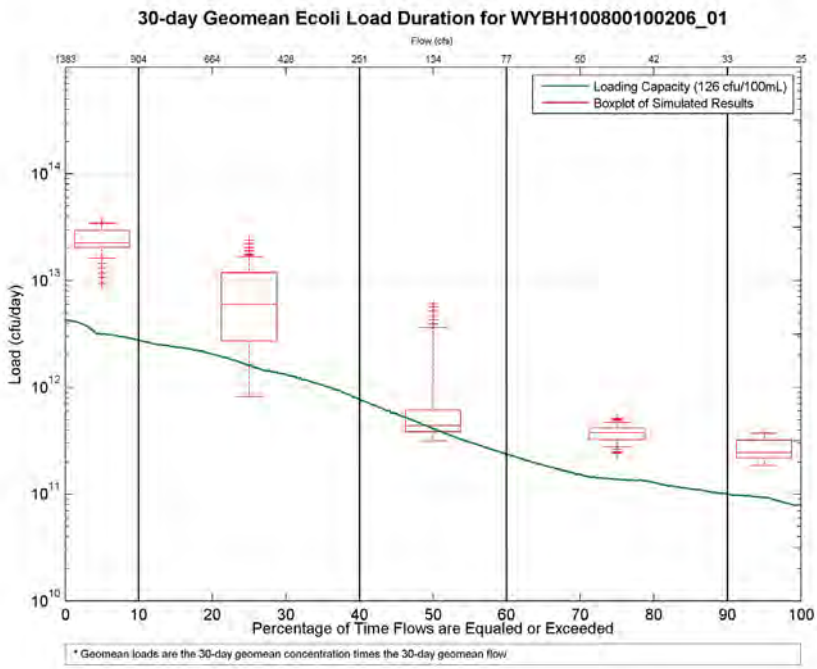


Figure 3-14. Shell Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-30. Summer Recreation Season Total Maximum Daily Load Table for Shell Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 904 cfs	**904–251 cfs**	**251–77 cfs**	**77–33 cfs**	**< 33 cfs**
LA	3,888	1,810	557	185	85
WLA	0	0	0	0	0
MOS	384	845	179	37	15
TMDL	4,272	2,655	736	222	100
Current Load[(a)]	38,191	19,006	4,086	493	384
Load Reduction	33,919	16,351	3,350	271	284
% Reduction	89	86	82	55	74
Overall Reduction Required = 86%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-31. Winter Recreation Season Total Maximum Daily Load Table for Shell Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 57 cfs	**57–47 cfs**	**47–42 cfs**	**42–37 cfs**	**< 37 cfs**
LA	1,059	811	689	608	435
WLA	0	0	0	0	0
MOS	59	57	29	46	132
TMDL	1,118	868	718	654	567
Current Load[(a)]	615	168	319	274	N/A
Load Reduction	0	0	0	0	N/A
% Reduction	0	0	0	0	N/A
Overall Reduction Required = 0%					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

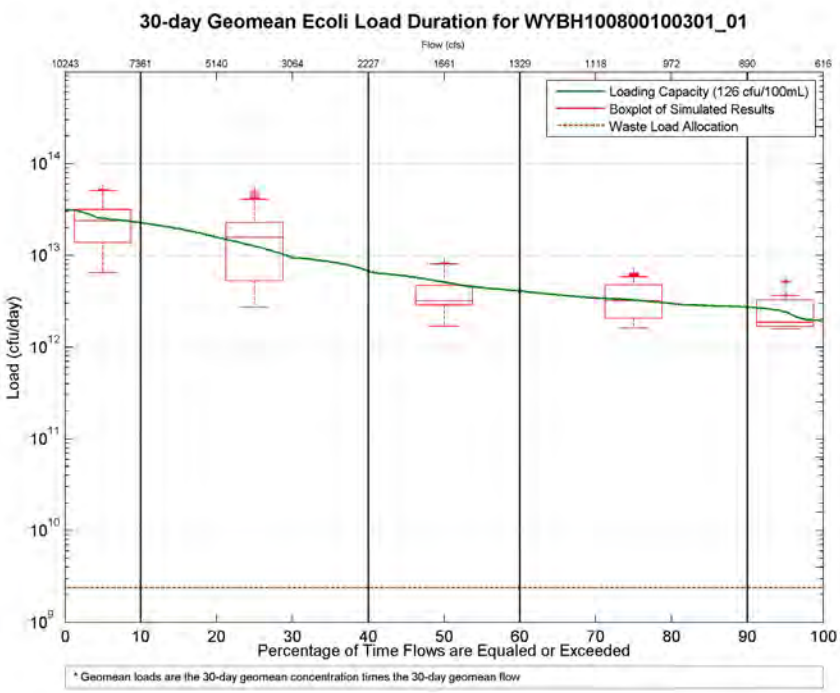


Figure 3-15. Big Horn River (Downstream of Greybull River) Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-32. Summer Recreation Season Total Maximum Daily Load Table for the Big Horn River (Downstream of Greybull River)

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 7,361 cfs	**7,361–2,227 cfs**	**2,227–1,329 cfs**	**1,329–890 cfs**	**< 890 cfs**
LA	29,092	16,200	5,431	3,477	2,225
WLA	2	2	2	2	2
MOS	2,529	5,701	1,004	528	522
TMDL	31,623	21,903	6,437	4,007	2,749
Current Load[(a)]	54,024	42,191	8,680	5,984	3,795
Load Reduction	22,401	20,288	2,243	1,977	1,046
% Reduction	41	48	26	33	28
Overall Reduction Required = 43%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-33. Winter Recreation Season Total Maximum Daily Load Table for Big Horn River (Downstream of Greybull River)

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 1,158 cfs	**1,158–1,057 cfs**	**1,057–908 cfs**	**908–672 cfs**	**< 672 cfs**
LA	20,810	16,896	14,938	12,548	10,047
WLA	12	12	12	12	12
MOS	1,216	914	1,380	802	372
TMDL	22,038	17,822	16,330	13,362	10,431
Current Load[(a)]	N/A	N/A	N/A	N/A	N/A
Load Reduction	N/A	N/A	N/A	N/A	N/A
% Reduction	N/A	N/A	N/A	N/A	N/A
Overall Reduction Required = N/A					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

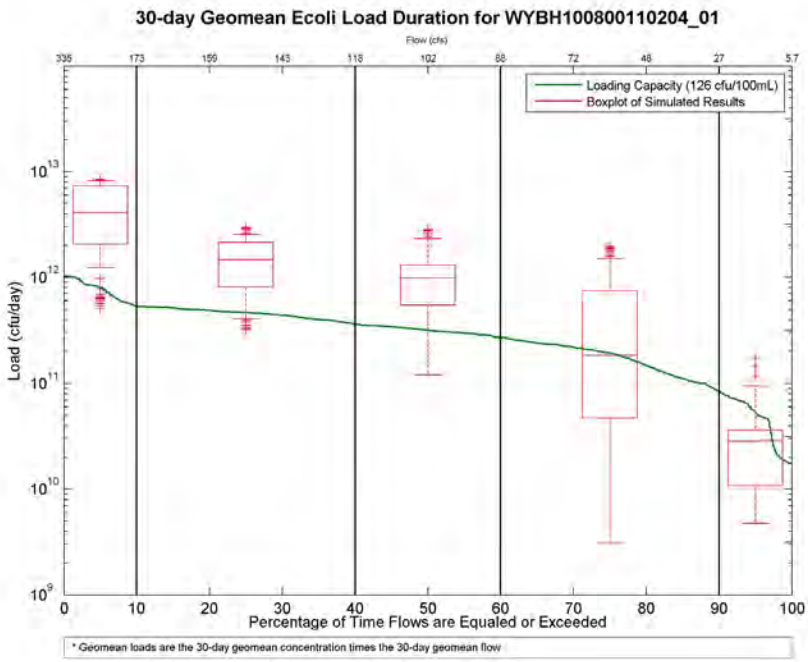


Figure 3-16. Dry Creek Load Duration Curve Representing Geometric Mean *E. coli* Loads Based on Summer Recreation Season Criterion.

Table 3-34. Summer Recreation Season Total Maximum Daily Load Table for Dry Creek

***E. coli* Total Maximum Daily Load Component (expressed as 10^9 cfu/day)**	**Flow Zone**				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 173 cfs	**173–118 cfs**	**118–88 cfs**	**88–27 cfs**	**< 27 cfs**
LA	769	429	312	154	45
WLA	0	0	0	0	0
MOS	267	103	43	112	36
TMDL	1,036	532	355	266	81
Current Load[(a)]	8,353	2,599	2,383	1,536	105
Load Reduction	7,317	2,067	2,028	1,270	24
% Reduction	88	80	85	83	23
Overall Reduction Required = 84%					

(a) Current load is the 95th percentile of the simulated load for each flow zone.

Table 3-35. Winter Recreation Season Total Maximum Daily Load Table for Dry Creek

E. coli Total Maximum Daily Load Component (expressed as 10^9 cfu/day)	Flow Zone				
	High	**Moist**	**Midrange**	**Dry**	**Low**
	> 18 cfs	**18–10 cfs**	**10–6 cfs**	**6–2 cfs**	**< 2 cfs**
LA	714	231	133	74	20
WLA	0	0	0	0	0
MOS	123	41	26	12	14
TMDL	837	272	159	86	34
Current Load[(a)]	200	70	49	N/A	N/A
Load Reduction	0	0	0	N/A	N/A
% Reduction	0	0	0	N/A	N/A
Overall Reduction Required = 0%					

(a) Current load is the 95th percentile of the observed load for each flow zone (if available).

4.0 SEASONALITY

Monthly precipitation, stream flows, and *E. coli* concentrations in the Big Horn River Watershed displayed seasonal variation. Precipitation data from the High Plains Regional Climate Center from 2000 through 2011 were used to display the variation in average monthly precipitation from lower elevation (Worland), medium elevation (Ten Sleep), and high elevation (Burgess Junction), as shown in Figure 4-1. The figure illustrates that average monthly precipitation is generally the highest in spring (April, May, and June) and fall (September and October). Short-duration, high-intensity rainstorms are common during the summer months. These localized summer storms can cause significant runoff and increased bacteria concentrations for a relatively short period of time and only slightly increase stream flows. Snow accumulation and melt processes are represented in the HSPF model application using a degree day method.

RSI-1984-12-025

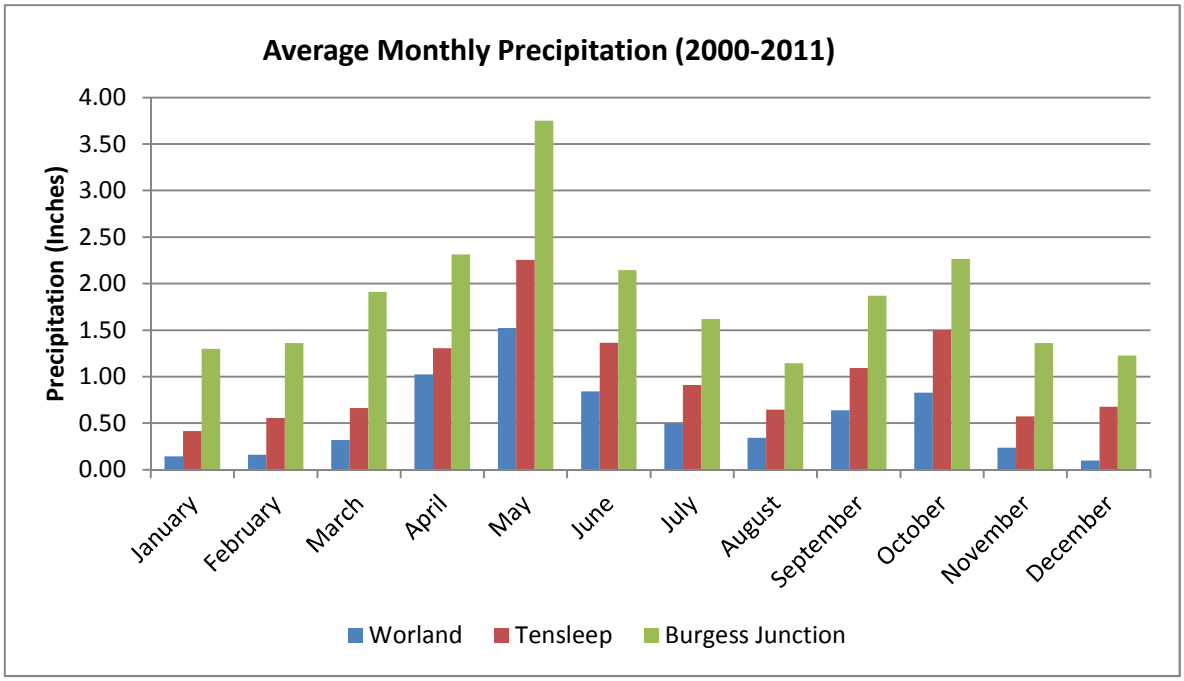
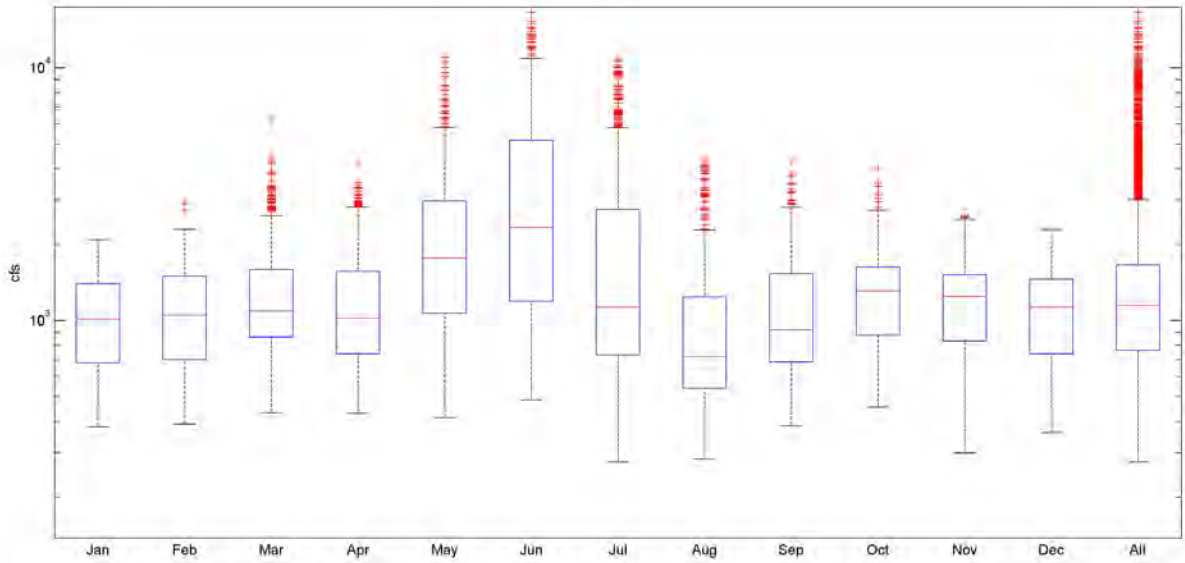


Figure 4-1. Average Monthly Precipitation at Worland, Ten Sleep, and Burgess Junction.

Boxplots of flow data at USGS 06274300 and USGS 06278500 are shown in Figures 4-2 and 4-3, respectively. USGS 06274300 was chosen as a representative mainstem site because it is on the Big Horn River near the downstream end of the project area. USGS 06278500 on Shell Creek near Shell, Wyoming, was chosen as a representative tributary site. Flows were typically highest during the late spring and early summer months and lowest during fall and winter

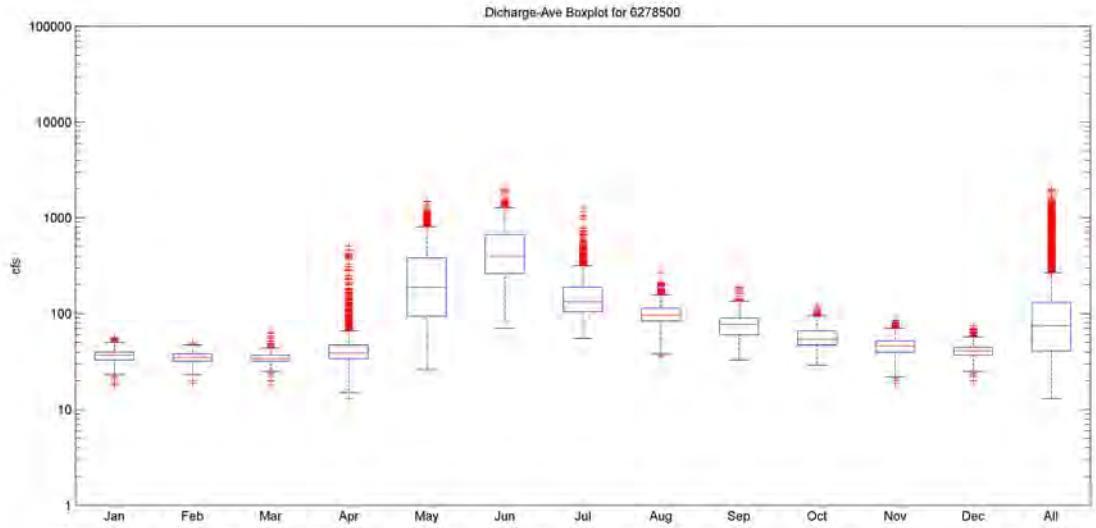
RSI-1984-12-026



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
n	806	735	806	780	806	780	806	806	780	837	810	809	9561
Min	380	390	432	430	413	486	276	283	383	454	300	360	276
Max	2090	2900	6280	4160	11000	16600	10800	4400	4300	4020	2620	2300	16600
q1	680	700	860	739.5	1070	1195	732	541	686	873	832	740	763
Median	1015	1050	1090	1020	1770	2335	1130	720	919.5	1310	1250	1130	1150
q3	1400	1500	1590	1570	2980	5165	2760	1240	1535	1630	1520	1460	1660
Mean	1071	1111	1332	1265	2279.5	3627.6	2122	1012	1151	1344	1249	1137	1557.1

Figure 4-2. Monthly Boxplot of Flow at USGS 06274300.

RSI-1984-13-003



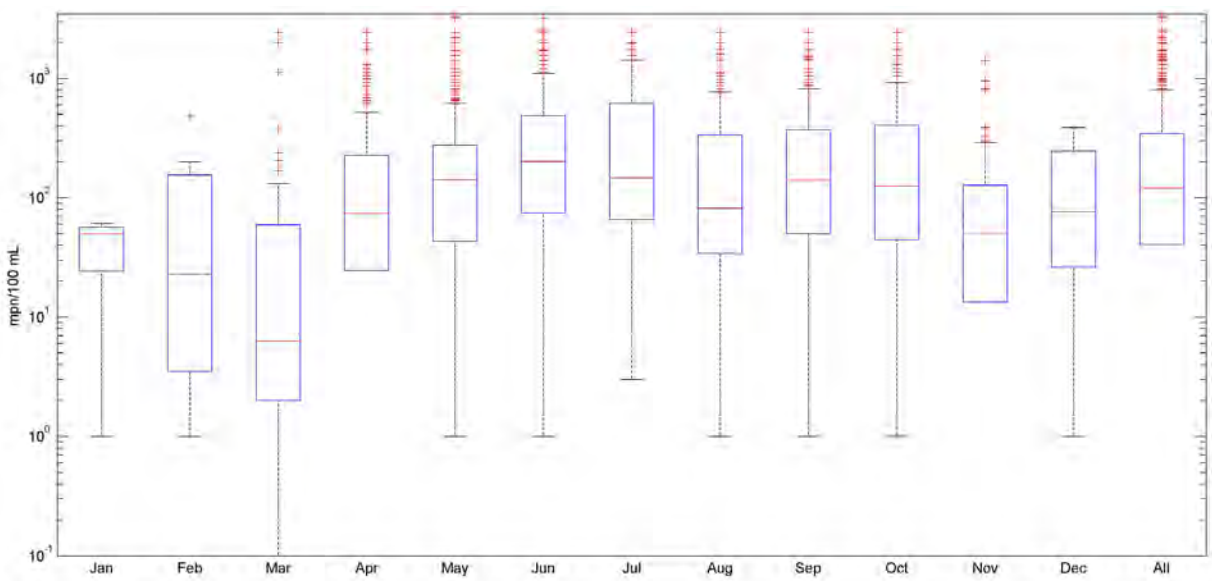
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
n	961	875	1071	2070	2139	2070	2139	2139	2069	1064	930	961	18488
Min	18	19	18	13	26	70	55	36	33	29	19	20	13
Max	56	50	63	505	1490	1980	1260	267	188	120	91	74	1980
q1	33	32	32	34	94	262	104	83	60	47	40	37	41
Median	37	35	34	39	188	402	133	96	77	54	46	41	75
q3	40	38	37	47	381	668	189	113	90	66	52	45	132
Mean	37	35	35	50	275	488	166	99	77	57	47	41	145
90th%	44	42	41	73	633	923	285	129	108	81	62	52	364
95th%	47	42	43	108	795	1080	379	141	116	89	67	57	580

Figure 4-3. Monthly Boxplot of Flow at USGS 06278500.

months at both sites. At USGS 06274300, the greatest median flows occurred in May (1,770 cfs) and June (2,335 cfs), and the smallest median flows occurred in August (720 cfs) and September (920 cfs). At USGS 06278500, the greatest medin flow occurred in June (402 cfs) and the smallest median flow in March (34 cfs).

Figure 4-4 includes boxplots created with *E. coli* data from all of the sites that had bacteria data calculations of monthly median bacteria concentrations. The boxplots show that the higher average and median bacteria concentrations occurred in the spring and summer months. The highest median bacteria concentrations occurred in June (201 cfu/100 mL) and July (147 cfu/100 mL), and the lowest occurred in February (23 cfu/ 100mL) and March (6 cfu/100 mL). Because higher flows and bacteria concentrations occur during the late spring to early summer months, it can be assumed that bacteria loads are also highest during this time period, which is critical for water quality (in relation to bacteria) in the project area.

RSI-1984-12-027



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
n	4	12	65	335	463	389	305	245	519	299	67	12	2715
Min	1	1	0.1	0	1	1	3	1	1	1	0	1	0
Max	61	480	2420	2420	3300	3200	2420	2420	2420	2420	1400	387	3300
q1	24.1	3.5	2	24.6	42.92	74.88	65.4	34.4	50	44.33	13.4	26.1	40.4
Median	49.6	23	6.3	73.8	140.8	201.1	146.7	81.6	140	125.4	51	76.3	120
q3	56.5	155	59.08	226.7	275.5	488.4	613.1	335	371	404.8	127.5	246	344.8
Mean	40.3	93.9	156.8	241.5	288	418.5	426.3	325.3	327.1	361.1	136.7	131	326.6

Figure 4-4. Boxplot of Monthly *E. coli* Concentrations From All Available *E. coli* Data.

Using the LDC approach to develop the TMDL allocations for five flow zones accounts for the seasonal variability in the flow and *E. coli* loads caused by the seasonal nature of flow (e.g., the high-flow zone contains flows that primarily occur in May and June). The nature of the bacteria standard causes this *E. coli* TMDL to be seasonal, because the summer recreation season criterion (126 org/100 mL) is lower (i.e., more protective) from May 1 through September 30 than the winter recreation season criterion (630 org/100 mL) from October 1 through April 30.

Accounting for seasonality is also critical for a bacteria TMDL because of the seasonal differences in land-use practices. Within the project area, livestock are commonly moved from lower elevations to higher elevations in the mountains in the summer. This change in land management during the summer months introduces a seasonal component to bacteria accumulation rates in the watershed. Irrigation diversions and subsequent return flows to the streams also largely impact seasonal hydrology. Irrigation is a seasonal land-use practice that creates artificial seasonality in stream flow. Again, this seasonal pattern is addressed by developing TMDL allocations in five flow zones with the LDC approach.

Seasonality was also addressed in the TMDL analysis and source allocation by using a continuous simulation. Bacteria accumulation within the model accounted for seasonality (i.e., wildlife migration or cattle grazing allotment rotations) by adjusting livestock and wildlife numbers within the watershed. Model calibration also accounts for seasonality by calibrating to duration curves, daily time series, and monthly averages.

5.0 PUBLIC PARTICIPATION

The efforts to facilitate public education, review, and comment while developing the Big Horn River Watershed TMDLs included presentations on the findings of the assessment at public meetings to stakeholders in the watershed, quarterly newsletters, a project website, public announcements, and a 30-day public notice period for review and comment. The findings from these public meetings and comments were taken into consideration when developing the TMDLs. The public notice was published in the *Casper Star Tribune*, *Northern Wyoming Daily News*, and *Cody Enterprise* for 1 day during the week of August 19–23. A notice of the public comment period was also sent to approximately 400 individual emails on WDEQ's ListServe email service. Copies of the TMDL were made available at each conservation district and online at the WDEQ TMDL website. Comments received during the public comment period and responses to those comments are presented in Appendix C.

A Public Involvement Plan was developed specifically for this project to aid in facilitating and documenting all public outreach throughout the project. Public information objectives provided information about the project, the opportunity to comment and ask questions, and an opportunity to participate on the project's Technical Steering Committee.

A total of eight public meetings were held during the project. Two project kick-off meetings were held near the start of the project and two public meetings were held at the end of each of the project's three phases. The public meetings were held as informal, open-house meetings where the project team presented information followed by an open discussion of issues and concerns. Public meetings for this project were open to the general public with a special emphasis on watershed stakeholders. The locations of the public meetings were moved throughout the watershed to maximize public involvement. Table 5-1 lists the locations and dates of the public meetings:

Table 5-1. Schedule of Public Meetings

No. of Meetings	Project Phase	Dates	Locations
2	Kick-Off Meetings	March 1 and 2, 2011	Thermopolis and Greybull
2	Watershed Characterization Phase	July 12 and 13, 2011	Worland and Meeteetse
2	TMDL Analysis Phase	February 21 and 22, 2012	Thermopolis and Greybull
2	TMDL Implementation Recommendations Phase	July 11 and 12, 2012	Worland and Greybull

The purpose of the Technical Steering Committee was to establish a group of stakeholders that monitored the project's progress and provided guidance to the project team. Conference calls were scheduled almost every month to discuss project progress, address technical concerns, and assist the project team by providing information about the watershed. An email was sent a week before each meeting to remind participants, and a toll-free, call-in number was provided. A total of 11 Technical Steering Committee meetings were held on the following dates:

April 27, 2011	November 29, 2011
May 25, 2011	January 2, 2012
June 23, 2011	February 14, 2012
August 23, 2011	April 12, 2012
September 27, 2011	June 21, 2012
October 25, 2011	

The following communication tools were used to disseminate project information and promote community engagement:

- **WDEQ Project Website for the Public.** A public website (*http://deq.state.wy.us/wqd/watershed/TMDL/BigHornTMDL/BigHornTMDL.htm*) was established by the WDEQ, and it provided project information and upcoming meeting dates and locations.
- **Project Website for the Project Team.** A project website, using Microsoft SharePoint software, was created for project team members and members of the Technical Steering Committee. The website was used to upload and download files and maintain a project schedule/calendar. Access to the SharePoint project website was assigned individually through a designated login and password.
- **Public Announcements.** Public announcements were distributed to five local newspapers and two radio stations to announce upcoming public meetings. The public announcements included the date, time, and location of each public meeting. Public announcements were distributed both 1 month and 2 weeks before each set of scheduled public meetings.
- **Email Contact List.** An email contact list was maintained and updated throughout the project to facilitate distributing information to those who needed to be kept informed. The email contact list included contact information collected from attendees at the scheduled public meetings and contact information for members of stakeholder groups. Email was the primary means for contacting stakeholders.
- **PowerPoint Presentations.** A presentation discussing the project background, project status, and public involvement opportunities was prepared for each set of public meetings. A total of four PowerPoint presentations were prepared for public meetings. Public meeting PowerPoint presentations were available after each meeting on the public

website. In addition, PowerPoint presentations were prepared for Technical Steering Committee meetings as needed.

- **Information Banners.** Displays that explained project background information and project status in more detail were developed for public meetings.
- **Quarterly Update Newsletters.** Project updates were provided quarterly in a newsletter format to the local conservation districts for inclusion in district newsletters and/or on district websites. The quarterly update newsletters were also emailed to individuals and agencies included in the project's email contact list. A total of five quarterly update newsletters were distributed.
- **Fact Sheets.** A fact sheet summarizing the information from the presentation for each of the four sets of public meetings was prepared. The fact sheets summarized the TMDL project background, status, and conclusions and recommendations developed during each phase. The fact sheets were distributed during the public meetings.
- **Sign-In Sheets.** Sign-in sheets that identified attendees and collected contact information for the email contact list were available at the public meetings.
- **Comment Cards.** Comment cards were distributed at the public meetings as an additional forum for the public and other stakeholders to provide input regarding the TMDL project.
- **Watershed Tour.** A tour of the watershed was conducted on July 12 and 13, 2011, to familiarize the project team and stakeholders with the watershed and the BMPs that have been implemented in the watershed. The Technical Steering Committee, the WDEQ, and the project team attended the watershed tour.

6.0 MONITORING STRATEGY

Monitoring is necessary both during and after the implementation of management practices, to ensure attainment of the TMDLs. Currently, the conservation districts have approved sampling and analysis plans that are in place to ensure that chemical, physical, and biological data are valid under the "Credible Data Law" [Wyoming Department of Environmental Quality, 2007]. The conservation districts have been monitoring key locations in the watershed by typically collecting five individual samples in a 30-day period and meeting the data needs for evaluating the geometric mean criteria. The locations that the conservation districts have been sampling are well positioned to evaluate the TMDL in the future. Most of the goals of the Big Horn River Watershed TMDL would be met if the conservation districts continue with their current monitoring efforts.

Additional monitoring and evaluation efforts for the critical areas identified as part of this TMDL assessment should be targeted. In particular, identifying locations in the watershed where land use transitions from one type to another would be helpful in further clarifying the sources of bacteria loading in the watershed. Transition locations in the streams and river, where land switches from range to irrigated lands or where the mountains transition to the prairie rangelands, are important. Two examples of high-priority locations for future monitoring are on Ten Sleep and Shell Creek at the foothills of the Big Horn Mountains. A detailed monitoring plan that identifies additional monitoring sites should be completed as part of future efforts in the project area. Additionally, in-stream monitoring directly upstream and downstream of permitted discharges would help develop a greater understanding of point sources–especially those with effluent concentration limits higher than the in-stream concentration criteria.

Time-series discharge data are often the missing component in the load-based assessment, because flow is required to calculate loading. For this project, insufficient flow data were addressed by using **HSPF**; however, the lack of continuous flow data complicated model calibration and increased inaccuracies. Future monitoring should include additional synoptic discharge measurements at both existing water-quality sampling locations and at new sites to fill in data gaps at diversions, confluences, irrigation returns, and upstream and downstream segment endpoints in the watershed. Continuous-stage recorders should be installed at key locations in the watershed, and stage-discharge relationships should be developed to convert continuous stage to continuous flow. Relatively low-cost, low-maintenance technologies are available to record continuous stage. Synoptic and continuous flow data will increase accuracy in future load calculations and the evaluation of BMPs and implementation practices.

Monitoring BMP effectiveness is necessary to determine the efficiency and effectiveness of implementation strategies that are targeted to reduce bacteria loads or transport. Monitoring strategies depend on the type of BMP but would probably include upstream and downstream

water-quality sampling and discharge measurements. Optimally, historic water-quality data and flow data would exist for segments immediately upstream and downstream of BMPs to allow for continued data collection and a robust trend analysis and BMP effectiveness analysis. BMPs located in areas with limited historical data should also be evaluated by monitoring upstream and downstream bacteria loads. Analyzing BMP effectiveness will provide data that improves the understanding of bacteria implementation and management measures. This data will increase the knowledge base that would help watershed managers select better future BMPs that are targeted toward specific and unique watershed characteristics.

The WDEQ will use this monitoring strategy to reevaluate the TMDL as the implementation proceeds. This will occur at a minimum of every 5 years, as outlined in the WDEQ TMDL work plan [Wyoming Department of Environmental Quality, 2012]. The WDEQ will notify the EPA, and a new public review will be made available if any changes or adjustments are needed after the reevaluation.

7.0 RESTORATION STRATEGY

A variety of BMPs could be considered in developing a water-quality management implementation plan for the Big Horn River Watershed. While several types of control measures are available for reducing bacteria loads, the control measures listed and discussed below are recommended to address the identified sources. Based on water-quality monitoring and HSPF model results, there is reasonable assurance that the recommended control measures would achieve the required load reductions and attain the TMDL goal.

The eight incremental management scenarios that were simulated for each bacteria-impaired segment by using the HSPF model include the following:

1. 100 percent removal of failing on-site wastewater treatment systems (septics)
2. 75 percent removal of direct defecation
3. Conversion of existing surface irrigated fields to sprinkler
4. 90 percent removal of cropland loading
5. 90 percent removal of riparian loading
6. 90 percent removal of rangeland loading
7. 75 percent removal of urban/residential loading
8. 90 percent removal of forest loading.

The cumulative and individual percent reductions of the total load expected from BMP implementation, based on model results, are provided in Table 7-1 by TMDL reach. Each simulated BMP has a value for the individual percent reduction for that individual BMP as well as the cumulative percent reduction value for implementing multiple BMPs in order from left to right in the table. This table demonstrates reasonable assurance that the required TMDL reductions can be attained and also provides watershed managers the ability to easily assess the relative efficiency of implementing the individual BMPs within the stream/stream segment that they are attempting to rehabilitate. Table 7-2 provides the cumulative percent load reduction and the needed load reduction to meet the TMDL for each impaired reach. In general, the greatest reductions in the watershed occur by removing rangeland loading and by increasing irrigation efficiency. Repairing or replacing septic systems and reducing direct defecation and forest loadings had a minimal impact in reducing overall stream loadings.

Table 7-1. Individual and Cumulative Percent Reductions from Simulated *E. coli* Best Management Practices

TMDL Impaired Stream	100% Removal of Septics		75% Removal of Direct Defecation		Irrigation Efficiency (Flood to Pivot)		90% Removal of Cropland Loading		90% Removal of Riparian Loading		90% Removal of Rangeland Loading		75% Removal of Urban Loading		90% Removal of Forest Loading	
	Individual (%)	Cumulative (%)	Individual (%)	Cumulative (%)	Individual (%)	Cumulative (%)	Individual (%)	Cumulative (%)	Individual (%)	Cumulative (%)	Individual (%)	Cumulative (%)	Individual (%)	Cumulative (%)	Individual (%)	Cumulative (%)
Owl Creek	0	0	1	1	0	1	0	2	25	27	61	88	0	88	1	90
Kirby Creek	0	0	1	1	0	1	0	1	13	13	76	89	0	89	0	90
Nowater Creek	0	0	7	7	54	61	22	83	2	85	9	93	0	94	0	94
Fifteen Mile Creek	1	1	12	13	7	20	3	23	13	36	50	86	0	86	0	86
Big Horn River (upstream of Nowood River)	0	0	1	1	50	52	21	72	5	78	9	87	7	94	0	94
Big Horn River (Nowood River to Greybull River)	0	0	1	1	39	40	16	57	12	69	16	85	7	92	2	93
Sage Creek	1	1	9	10	56	66	23	89	1	89	0	90	3	93	0	93
Slick Creek	1	1	8	9	60	69	23	92	0	92	1	93	0	93	0	93
Paint Rock Creek	0	0	0	0	0	0	2	2	24	27	54	81	0	81	9	90
Nowood River	0	0	1	1	0	1	3	5	32	37	38	75	8	83	6	90
Greybull River	0	0	0	0	33	33	9	43	10	53	36	89	3	92	0	92
Granite Creek	0	0	0	0	0	0	0	0	33	33	51	84	2	86	4	90
Beaver Creek	0	0	0	0	1	2	1	2	21	23	59	82	1	83	7	90
Shell Creek	0	0	0	0	4	4	2	6	17	23	59	82	2	84	6	90
Dry Creek	0	0	0	0	34	34	3	37	19	55	35	90	3	93	0	93
Big Horn River (Greybull River downstream)	0	0	1	1	25	26	9	35	11	46	29	74	15	90	2	92

Table 7-2. Summary of Cumulative Simulated Percent Load Reductions and the Required Percent Load Reductions Needed to Meet the Total Maximum Daily Load for Each Impaired Stream Reach

TMDL Impaired Stream	Cumulative Simulated Load Reductions (%)	Required Load Reductions Needed to Meet the TMDL (%)
Owl Creek	90	78
Kirby Creek	90	30
Nowater Creek	94	90
Fifteen Mile Creek	86	76
Big Horn River (upstream of Nowood River)	94	67
Big Horn River (Nowood River to Greybull River)	93	59
Sage Creek	93	88
Slick Creek	93	87
Paint Rock Creek	90	84
Nowood River	90	81
Greybull River	92	54
Granite Creek	90	90
Beaver Creek	90	91
Shell Creek	90	86
Dry Creek	93	84
Big Horn River (Greybull River downstream)	92	43

8.0 REFERENCES

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APPENDIX A

CONCENTRATION-DURATION CURVES

RSI-1984-12-028

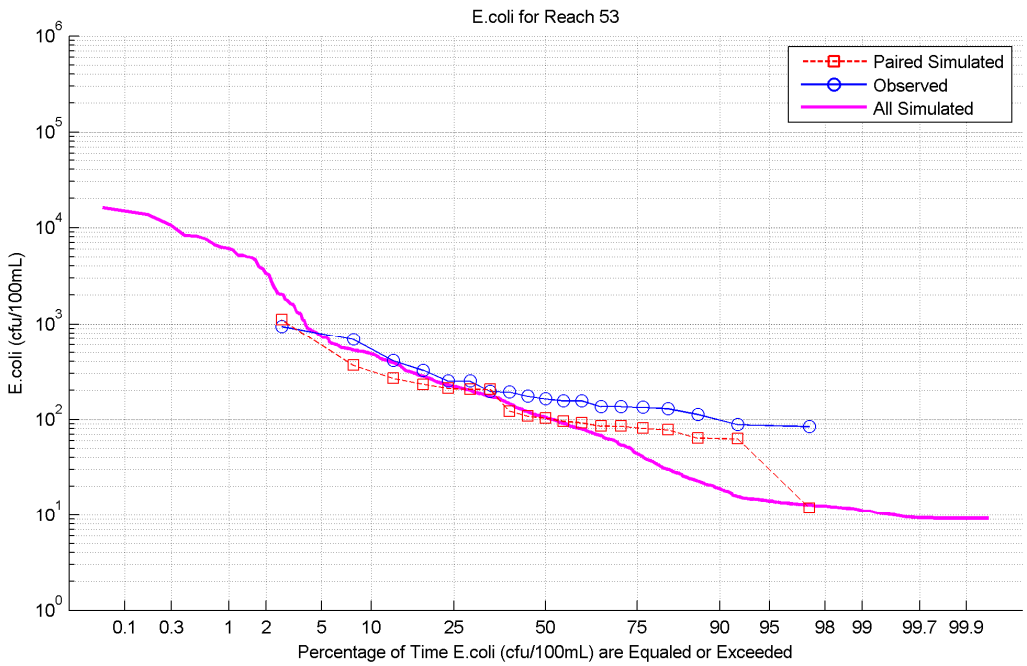

Figure A-1. Concentration-Duration Curve for Owl Creek.

RSI-1984-12-029

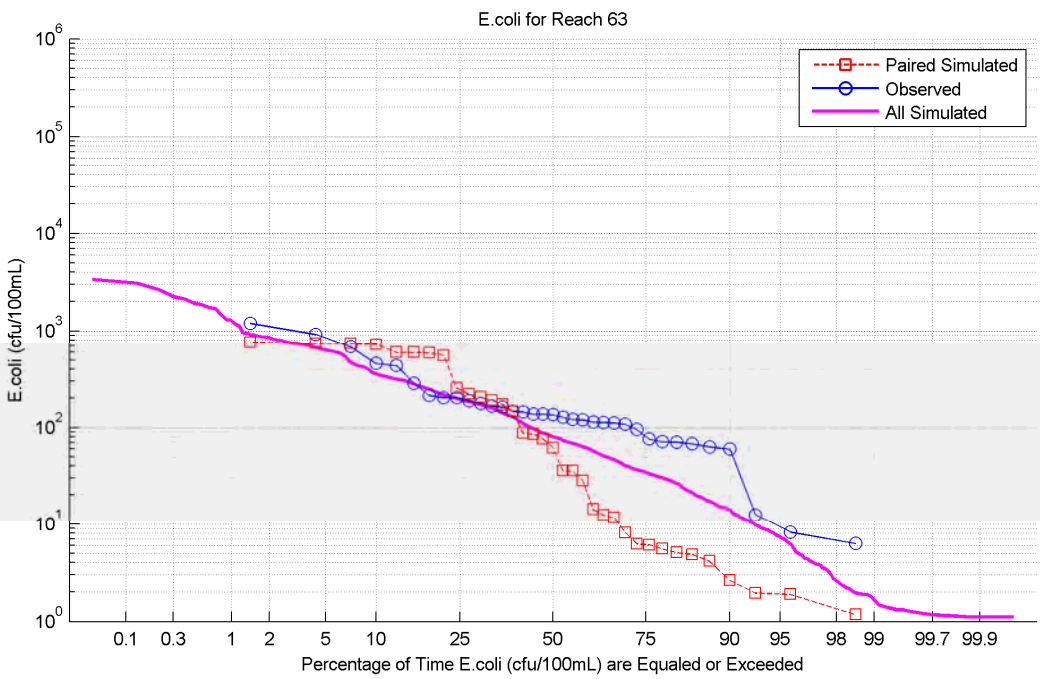

Figure A-2. Concentration-Duration Curve for Kirby Creek.

RSI-1984-12-030

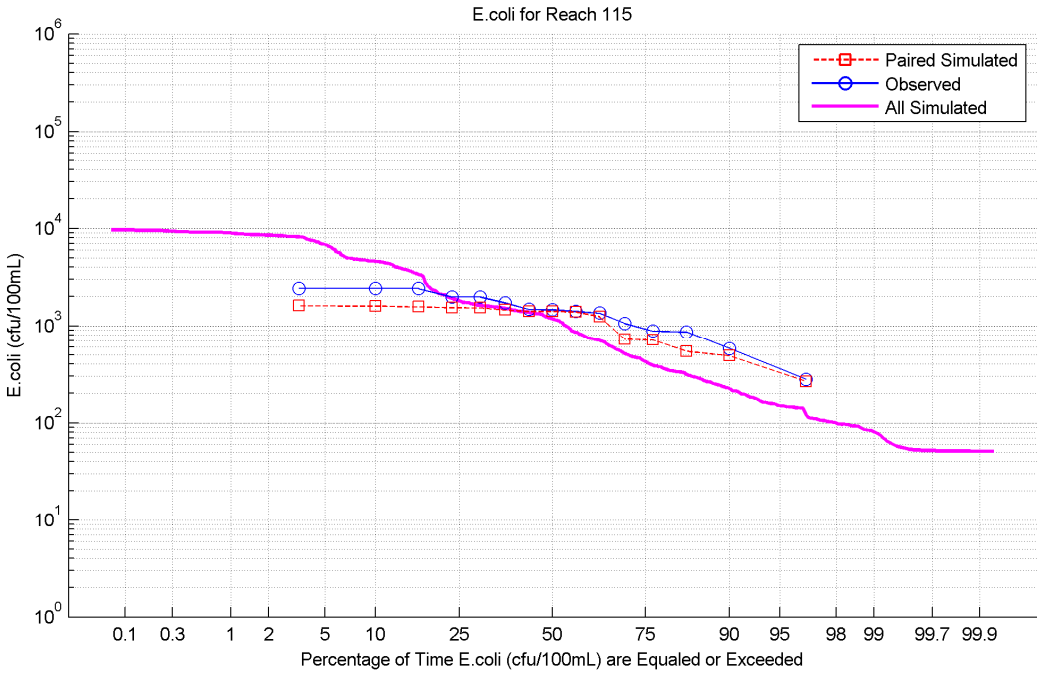

Figure A-3. Concentration-Duration Curve for Nowater Creek.

RSI-1984-12-031

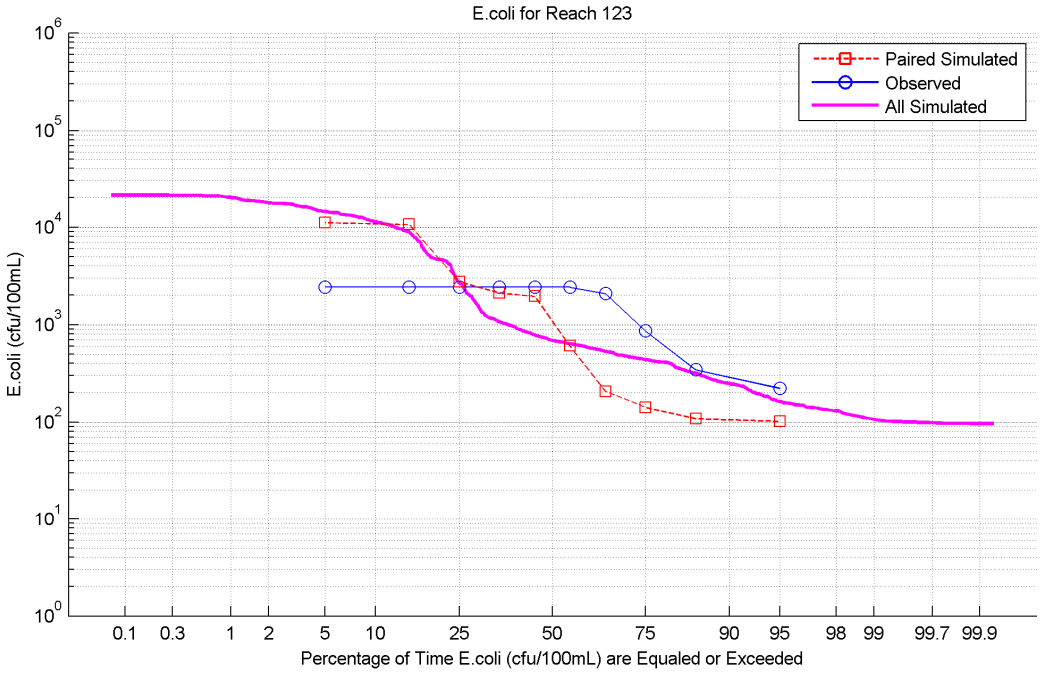

Figure A-4. Concentration-Duration Curve for Fifteen Mile Creek.

RSI-1984-12-032

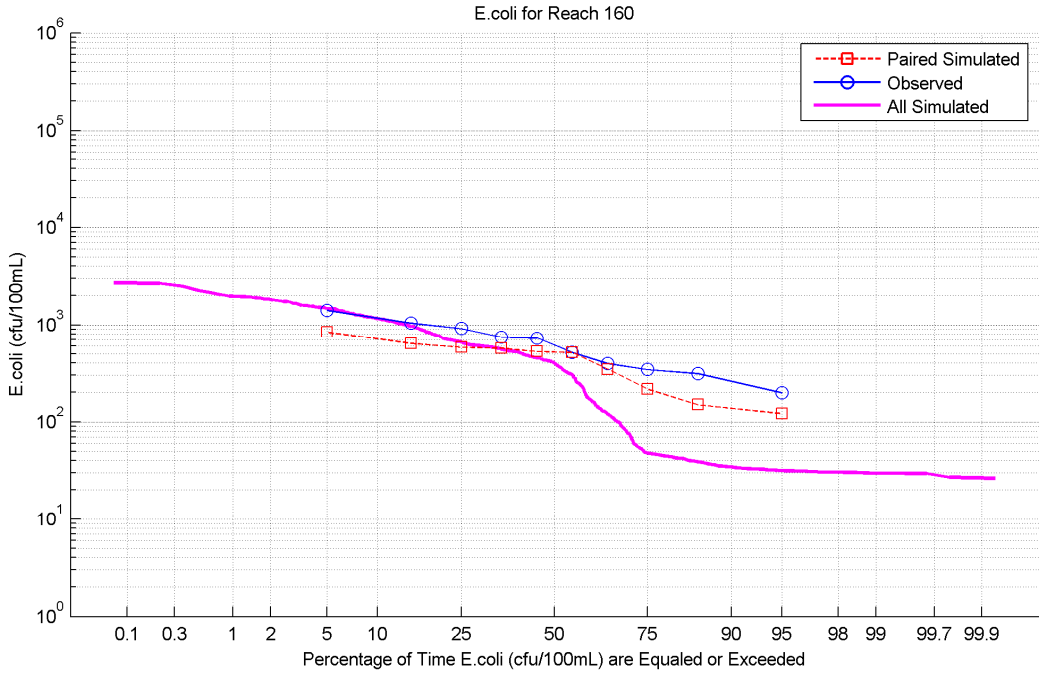

Figure A-5. Concentration-Duration Curve for the Big Horn River (Upstream of Nowood).

RSI-1984-12-033

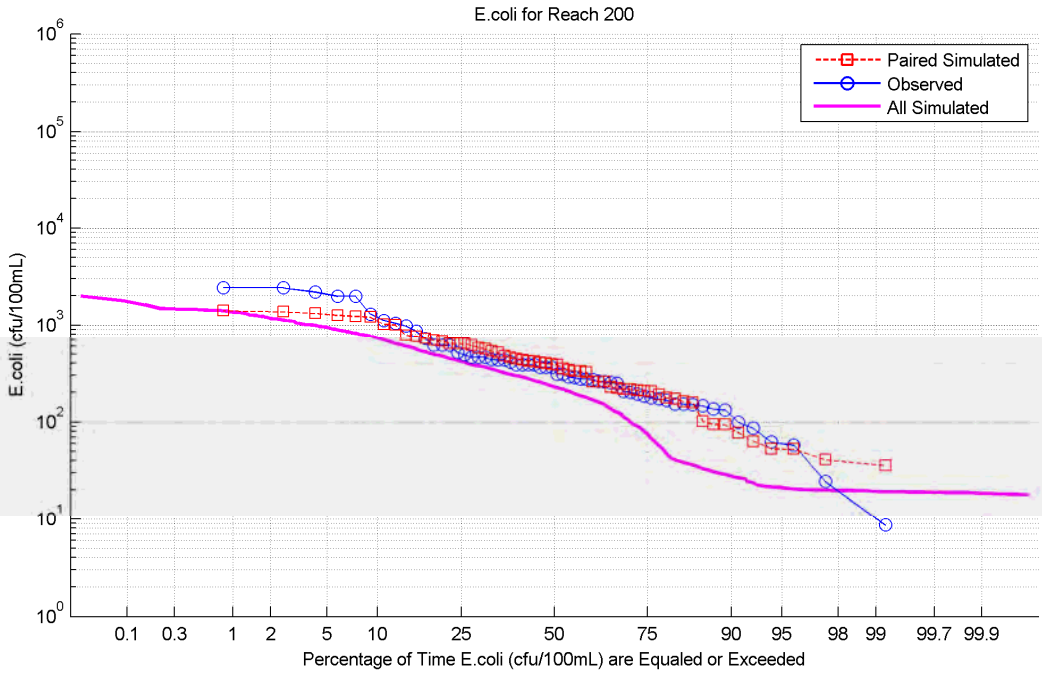

Figure A-6. Concentration-Duration Curve for the Big Horn River (Nowood River to Greybull River).

RSI-1984-12-034

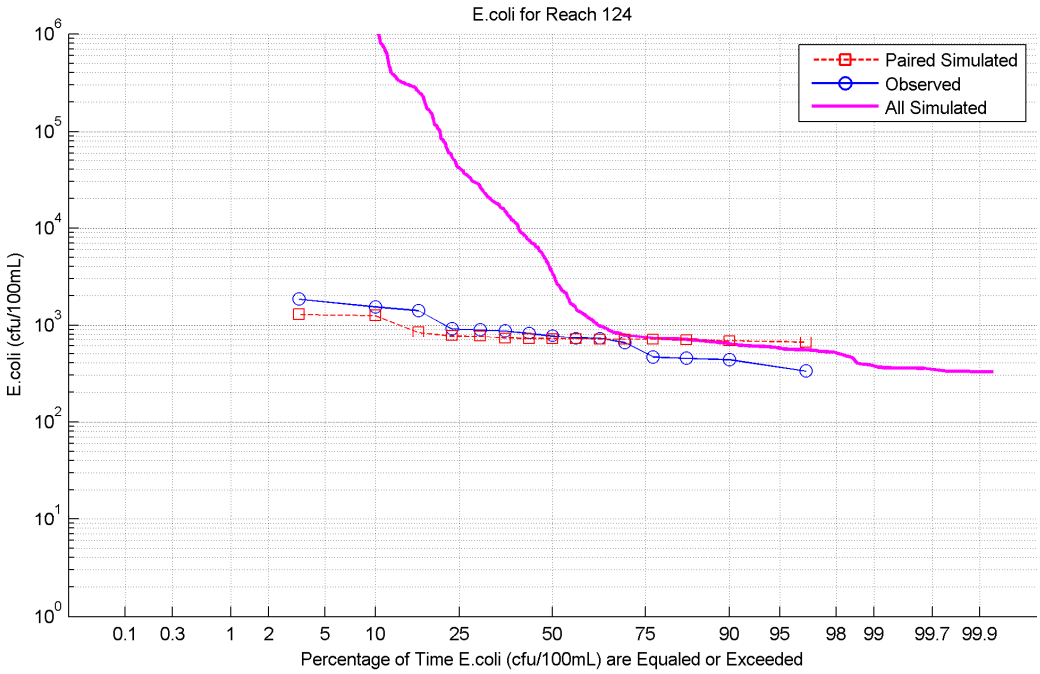

Figure A-7. Concentration-Duration Curve for Sage Creek.

RSI-1984-12-035

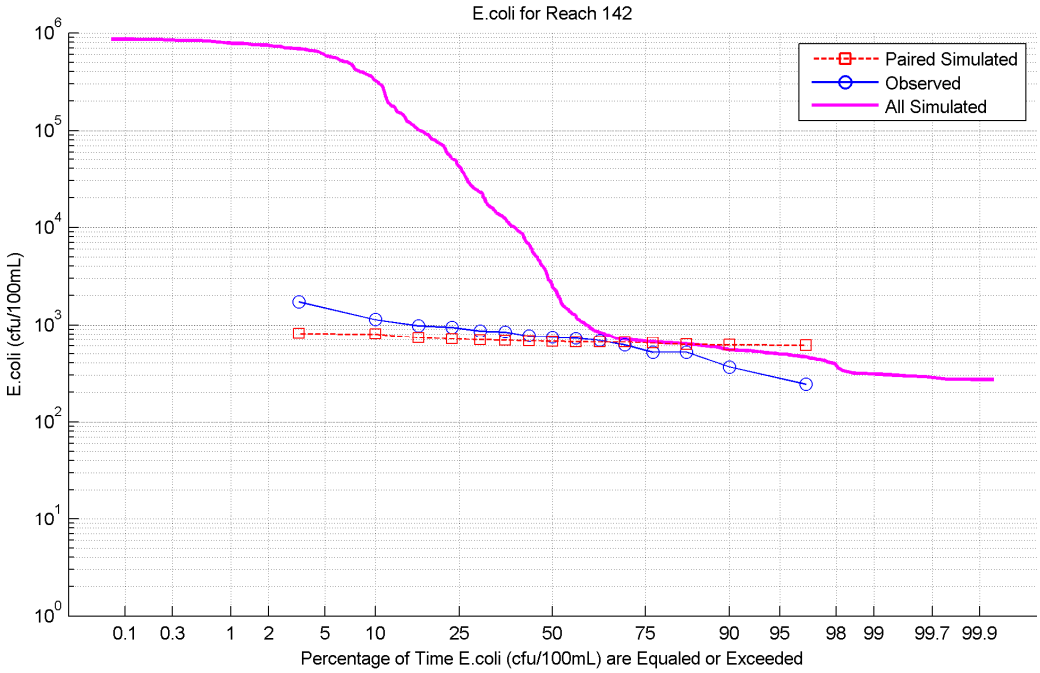

Figure A-8. Concentration-Duration Curve for Slick Creek.

RSI-1984-12-036

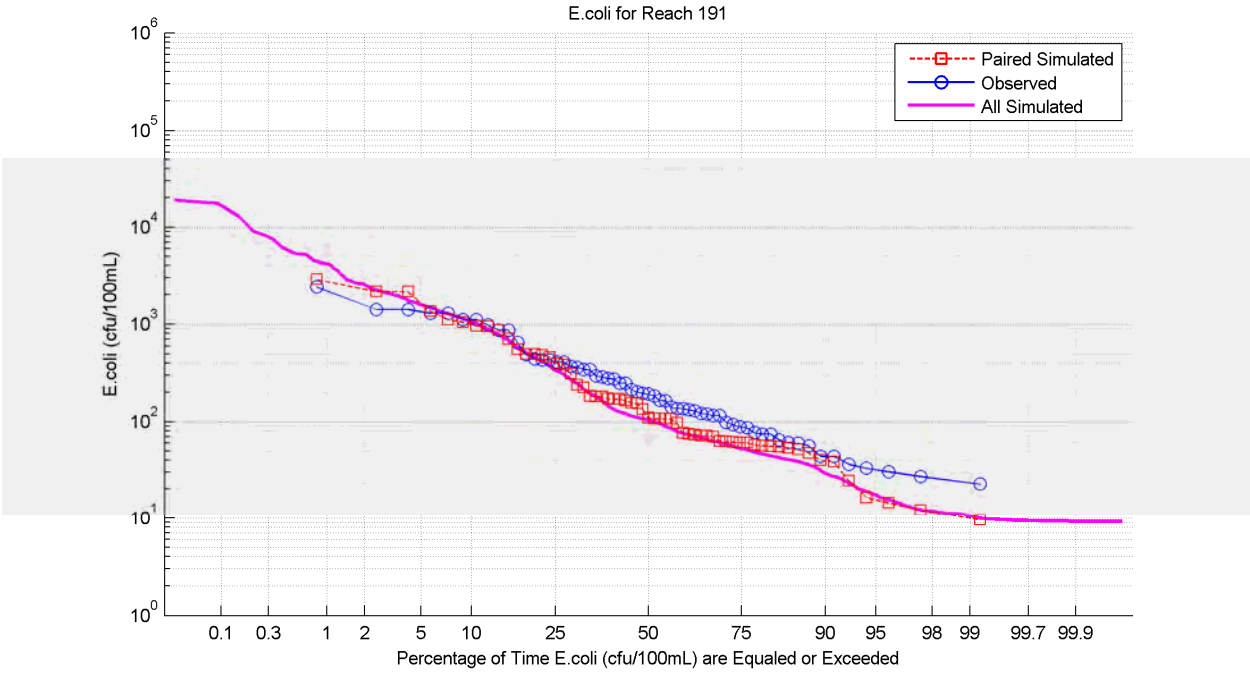

Figure A-9. Concentration-Duration Curve for Paint Rock Creek.

RSI-1984-12-037

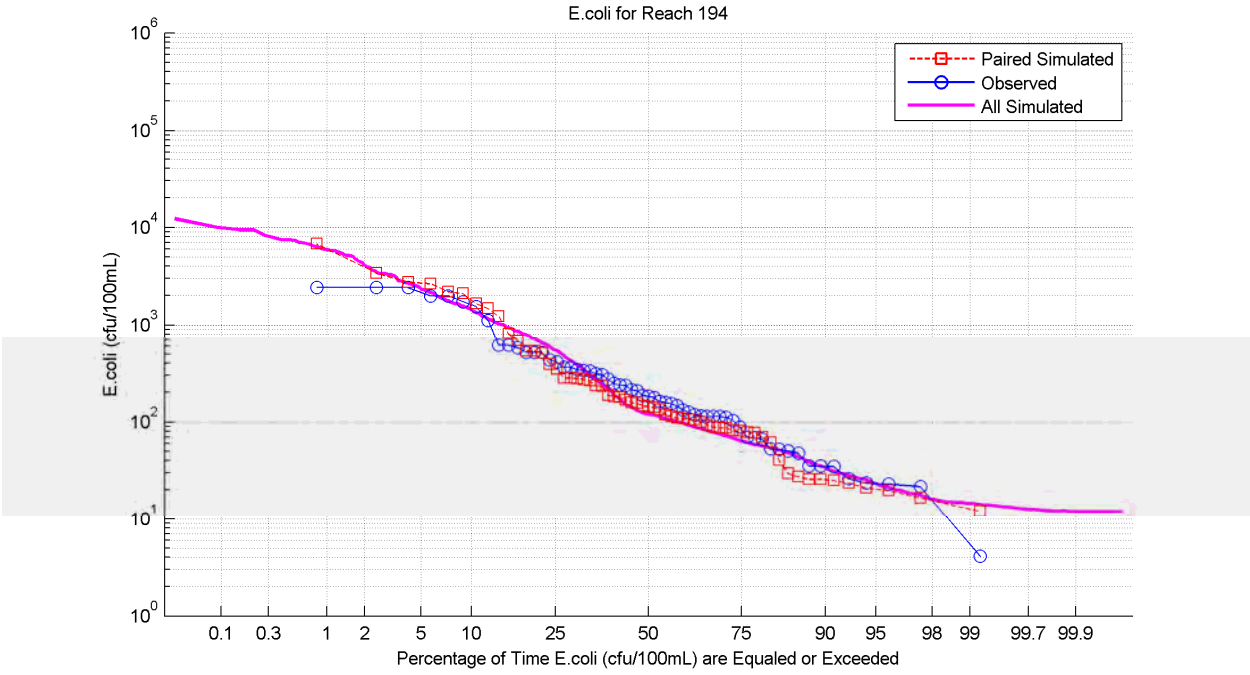

Figure A-10. Concentration-Duration Curve for the Nowood River.

RSI-1984-12-038

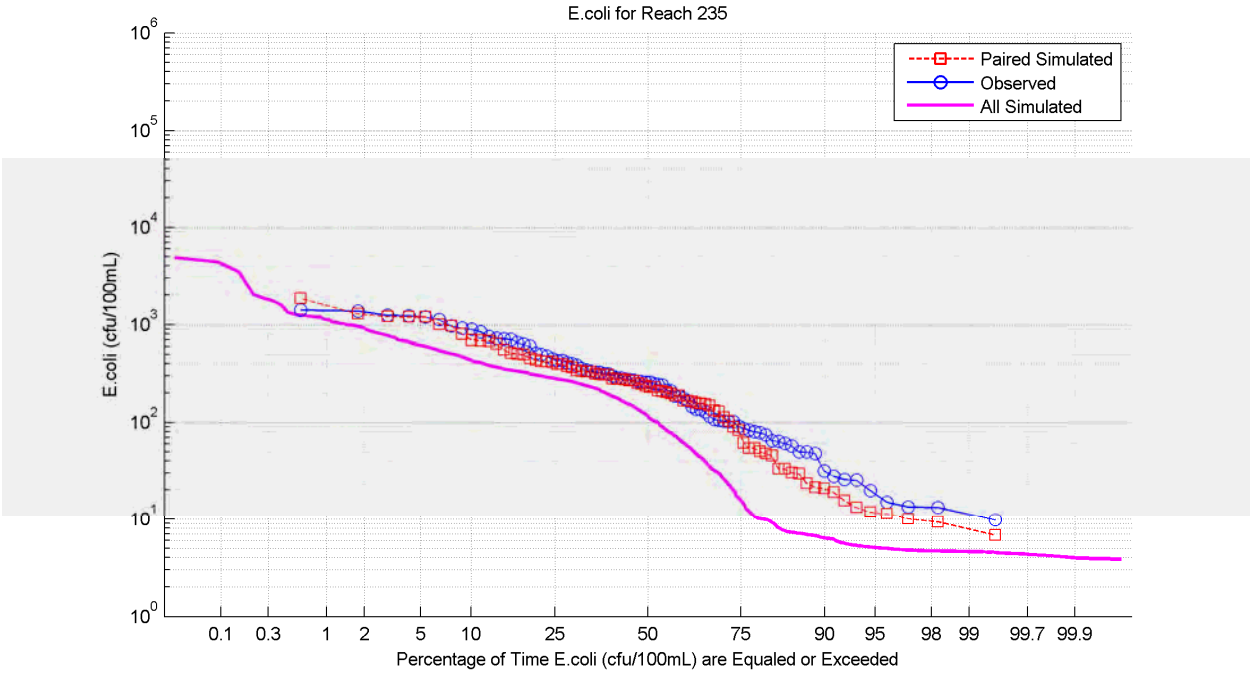

Figure A-11. Concentration-Duration Curve for the Greybull River.

RSI-1984-12-039

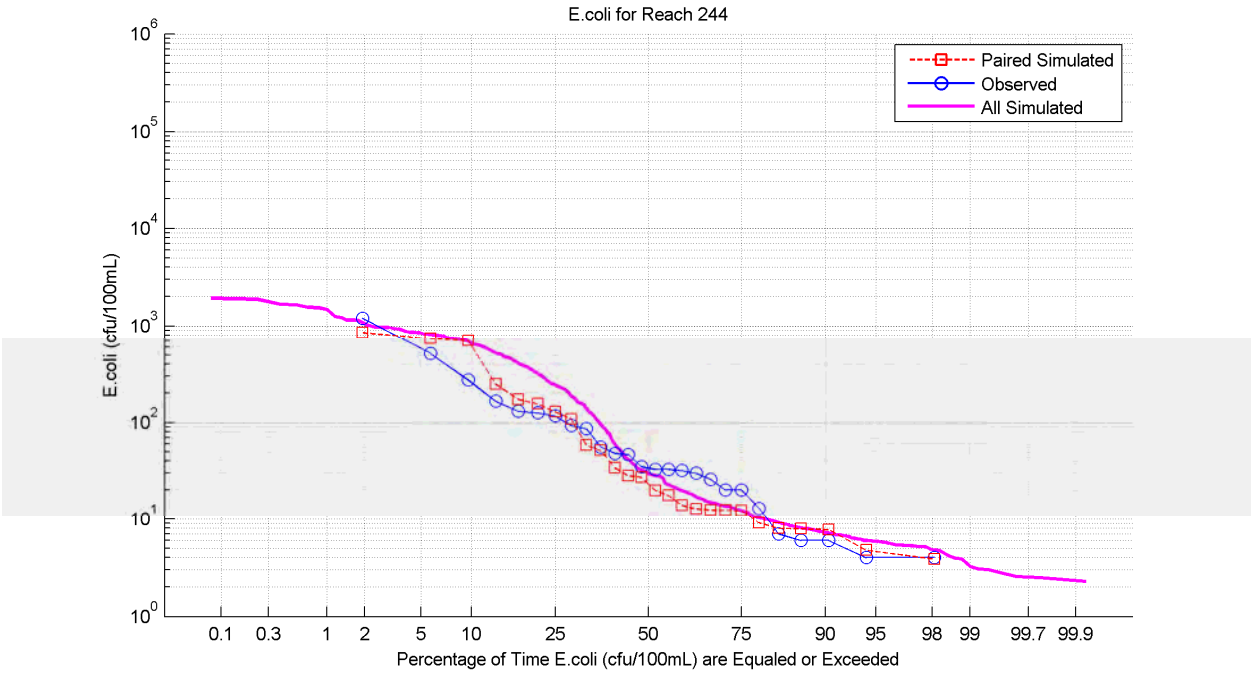

Figure A-12. Concentration-Duration Curve for Granite Creek.

RSI-1984-12-040

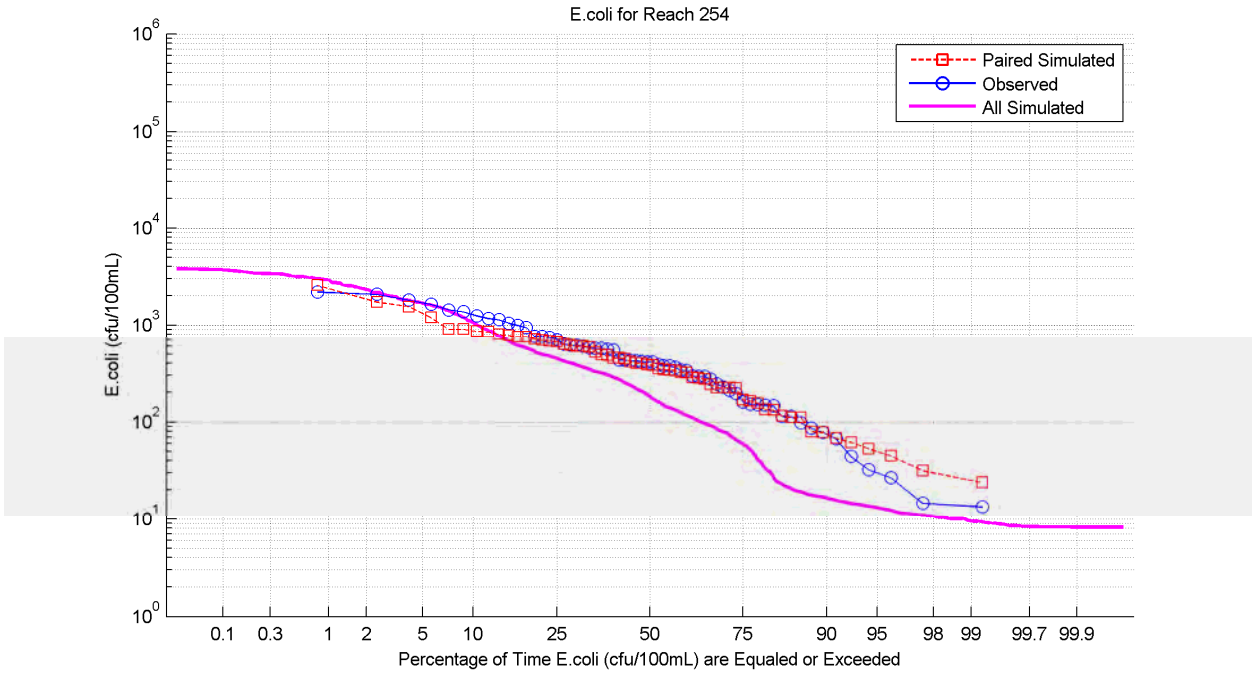

Figure A-13. Concentration-Duration Curve for Beaver Creek.

RSI-1984-12-041

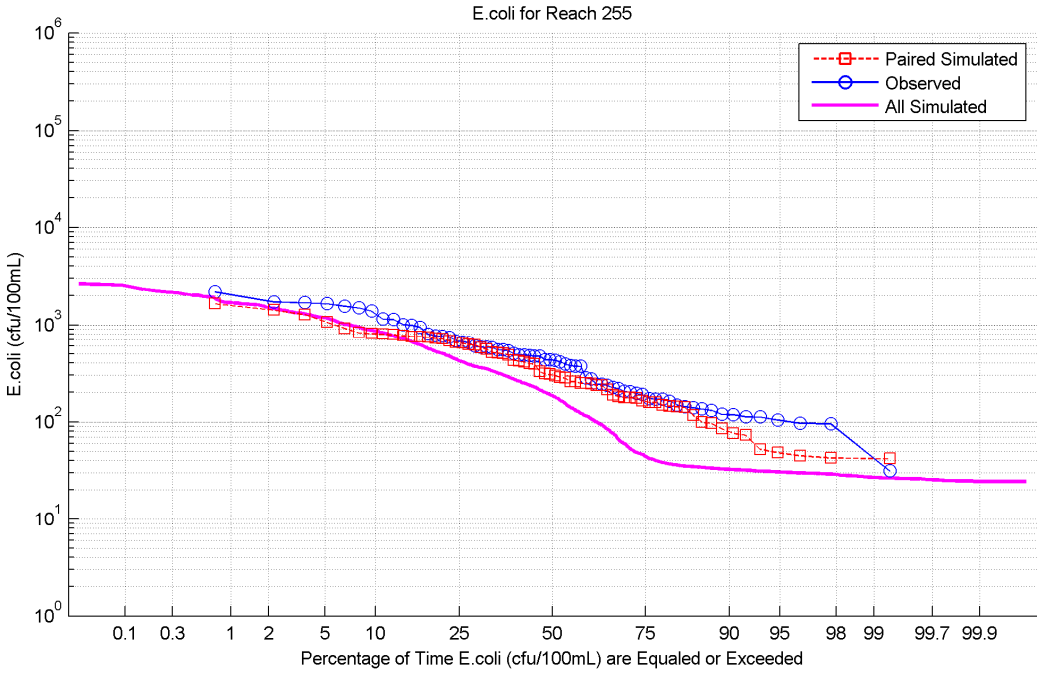

Figure A-14. Concentration-Duration Curve for Shell Creek.

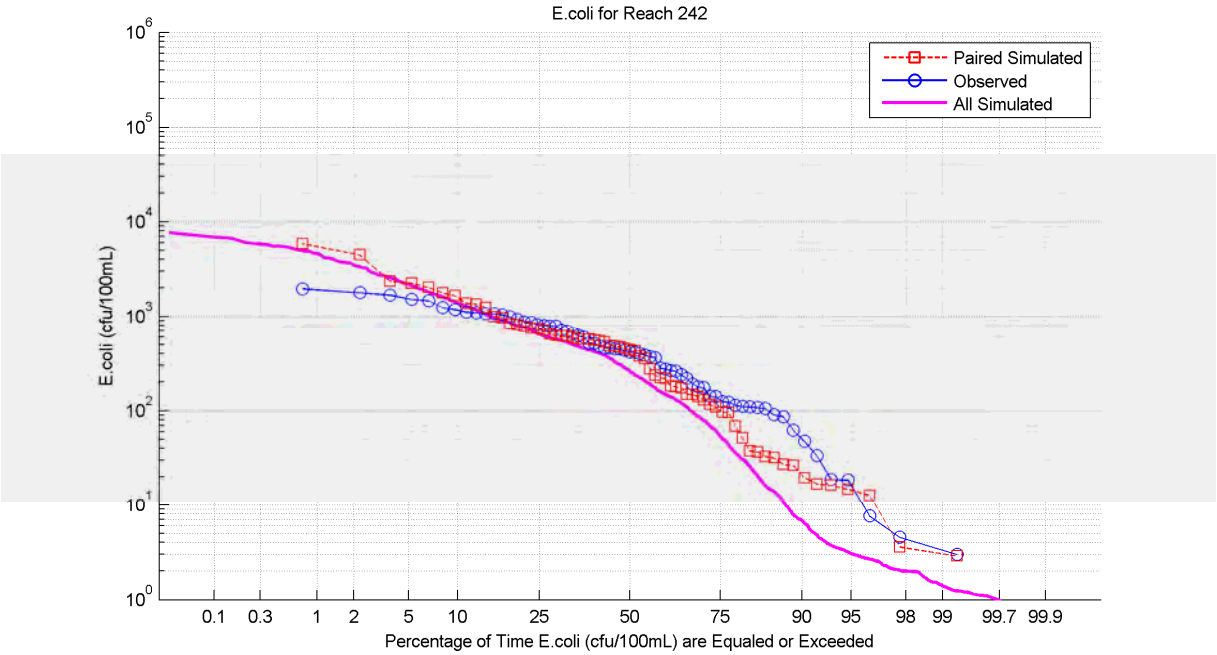

Figure A-15. Concentration-Duration Curve for Dry Creek.

APPENDIX B

SOURCE ALLOCATION PIE CHARTS

RSI-1984-12-043

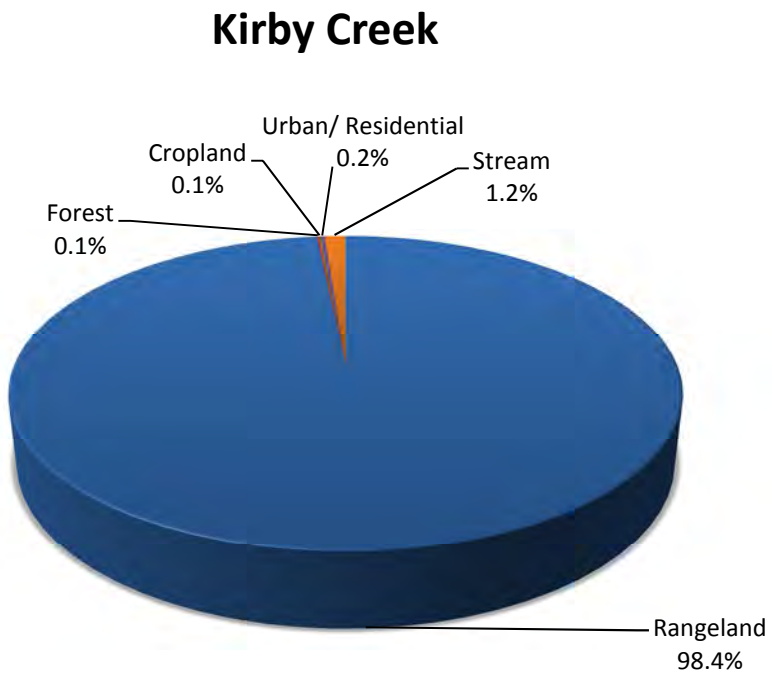

Figure B-1. Source Allocations for Kirby Creek.

RSI-1984-12-044

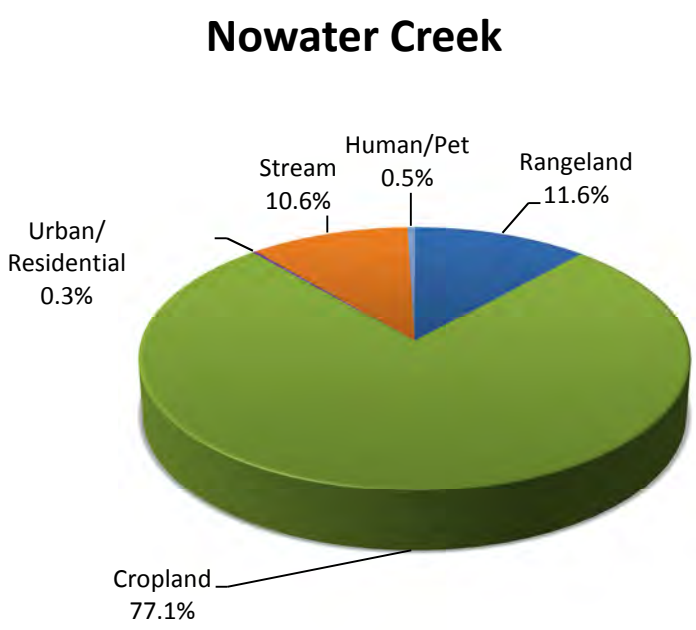

Figure B-2. Source Allocations for Nowater Creek.

RSI-1984-12-045

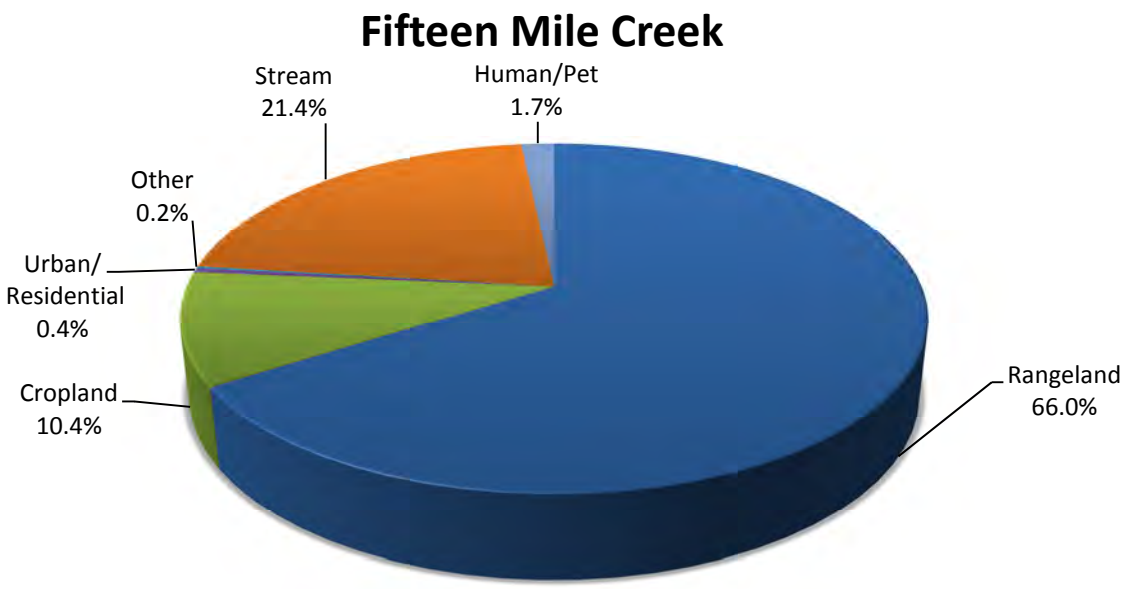

Figure B-3. Source Allocations for Fifteen Mile Creek.

RSI-1984-12-046

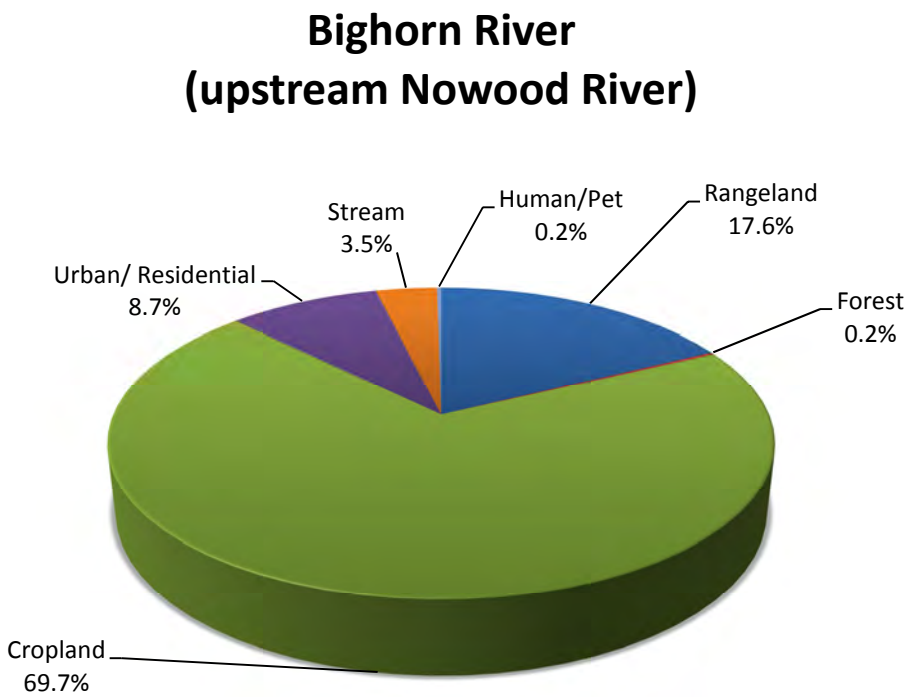

Figure B-4. Source Allocations for Big Horn River (Upstream of Nowood River).

RSI-1984-12-047

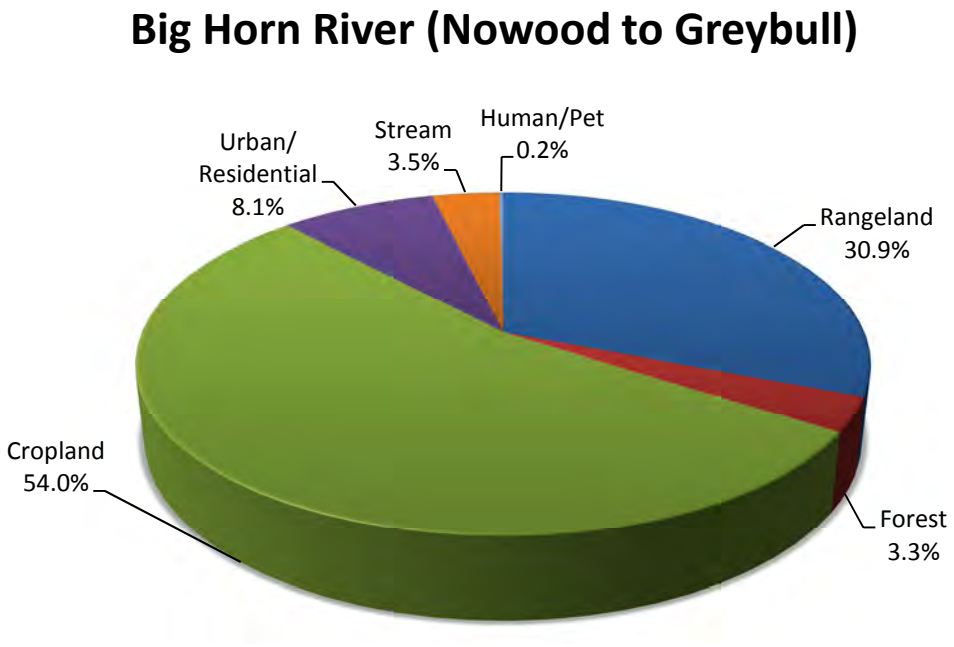

Figure B-5. Source Allocations for Big Horn River (Nowood to Greybull).

RSI-1984-12-048

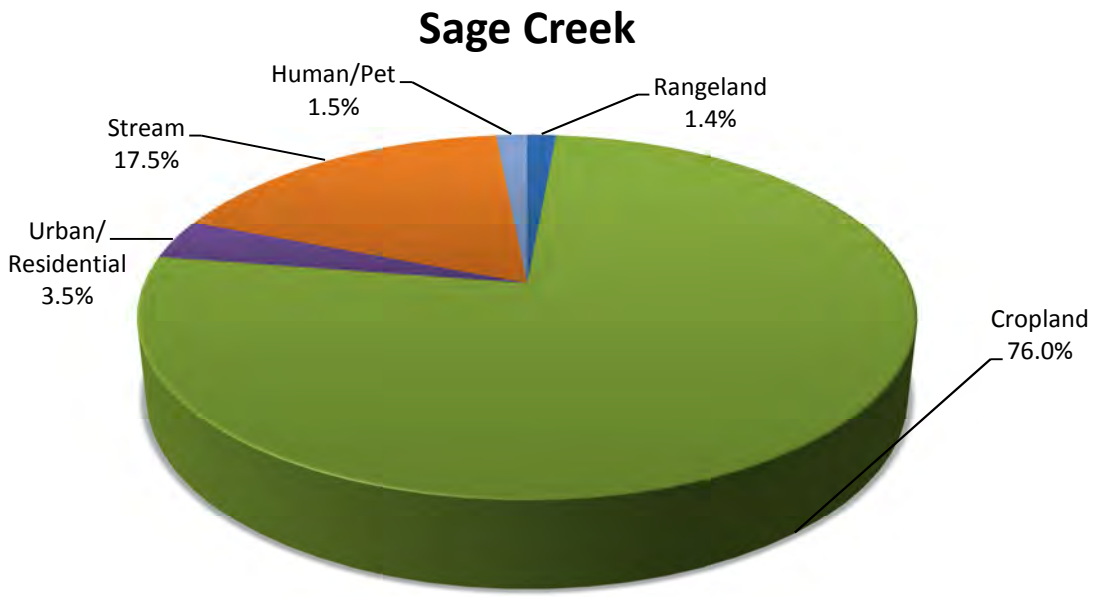

Figure B-6. Source Allocations for Sage Creek.

RSI-1984-12-049

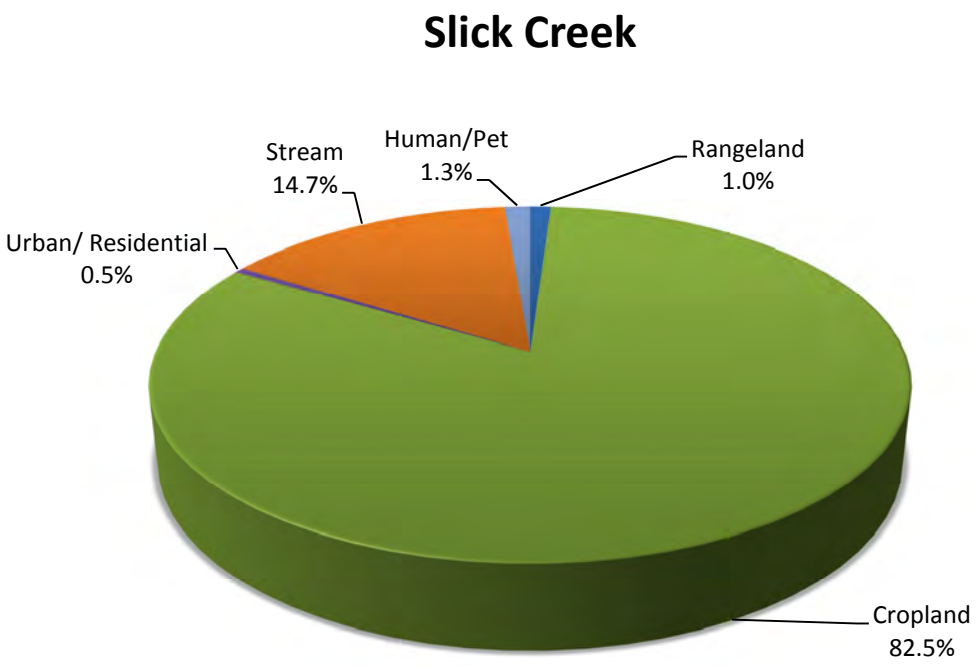

Figure B-7. Source Allocations for Slick Creek.

RSI-1984-12-050

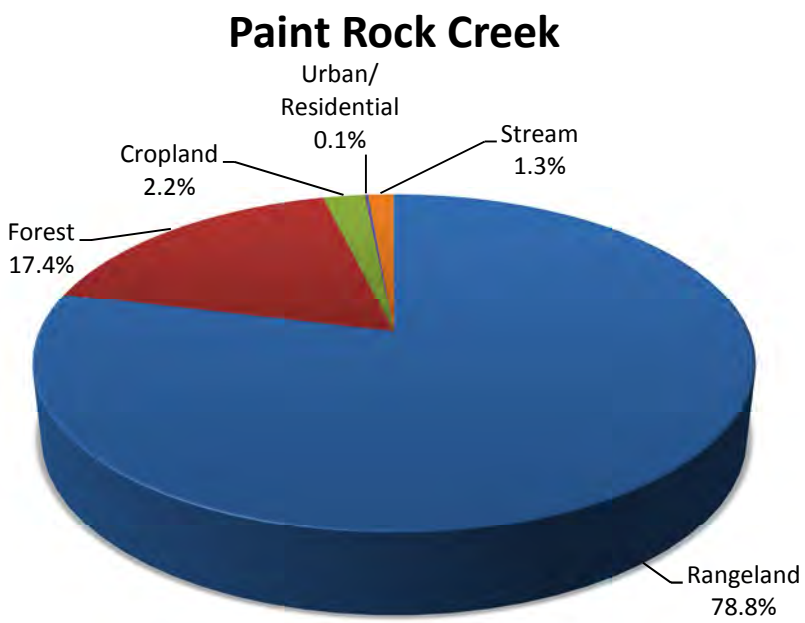

Figure B-8. Source Allocations for Paint Rock Creek.

RSI-1984-12-051

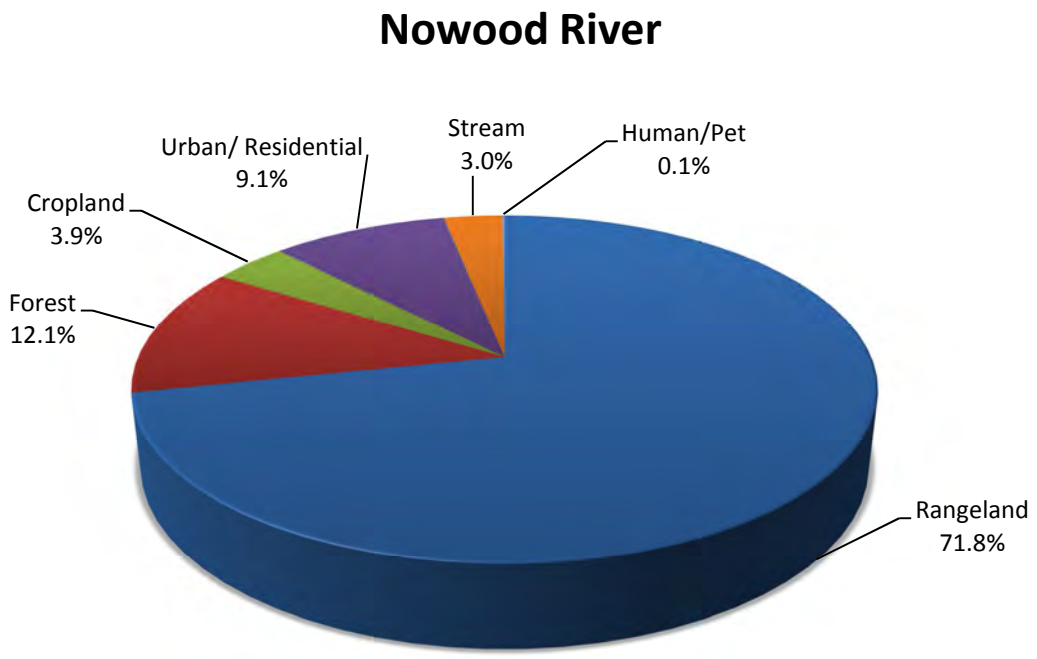

Figure B-9. Source Allocations for Nowood River.

RSI-1984-12-052

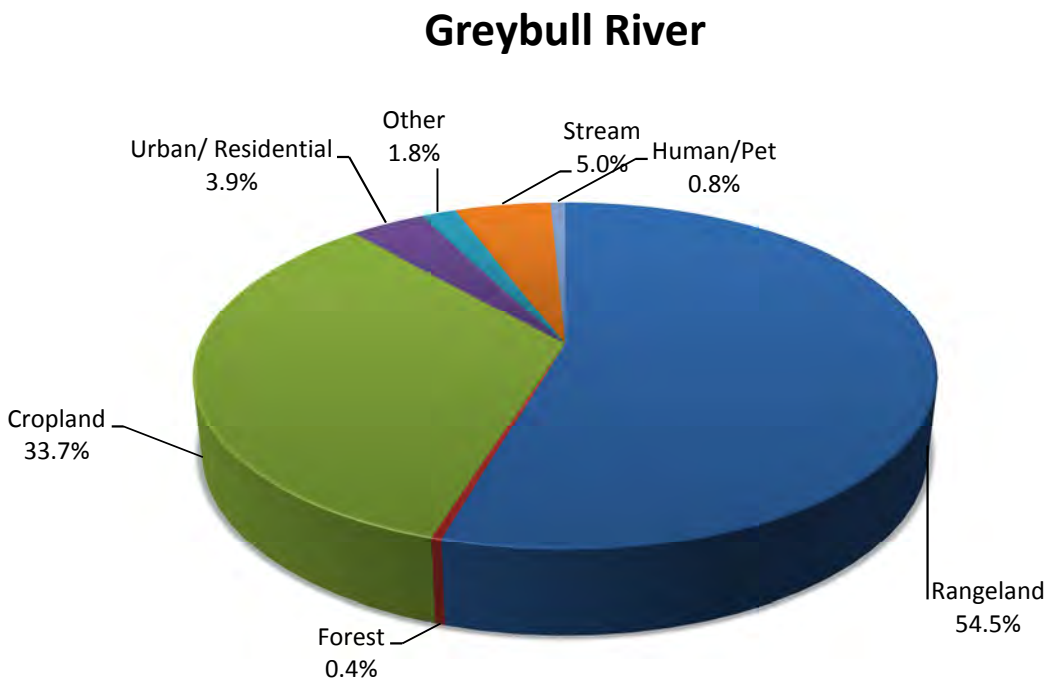

Figure B-10. Source Allocations for Greybull River.

RSI-1984-12-053

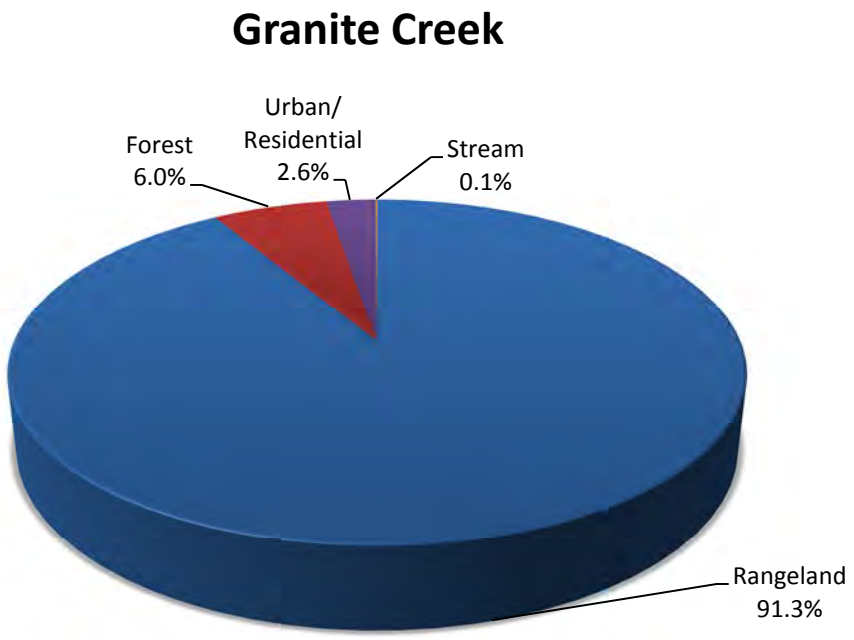

Figure B-11. Source Allocations for Granite Creek.

RSI-1984-12-054

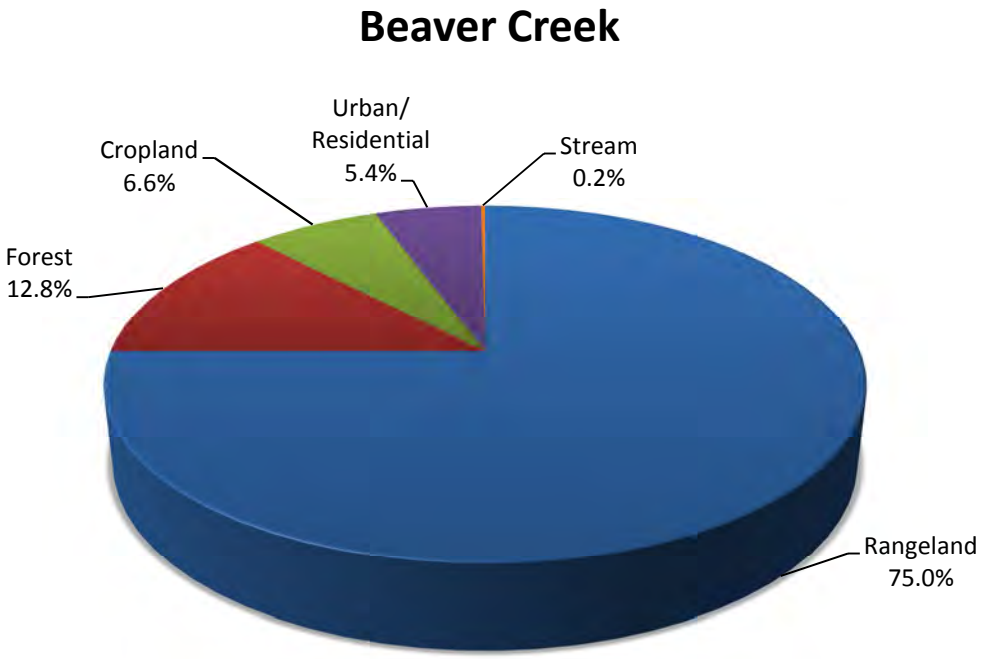

Figure B-12. Source Allocations for Beaver Creek.

RSI-1984-12-055

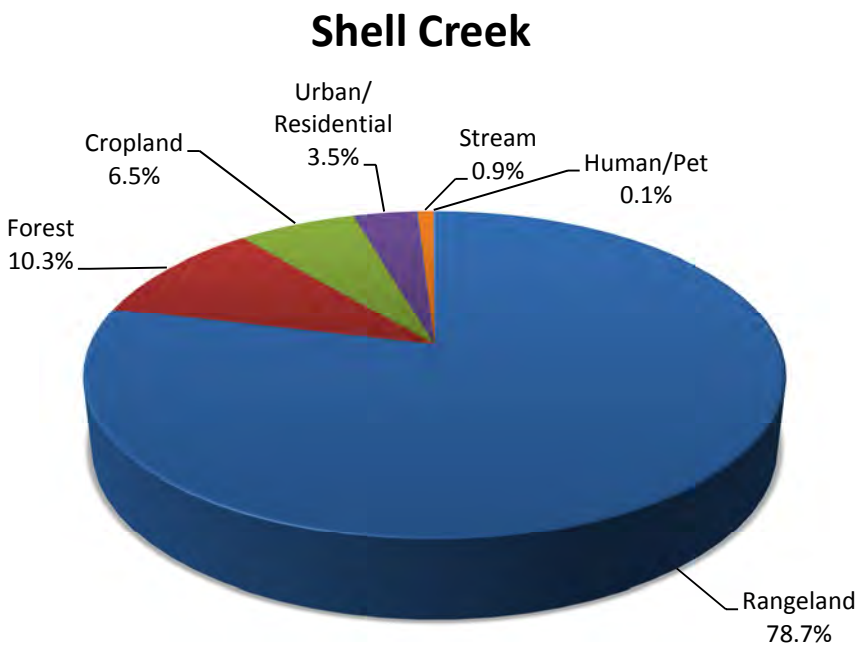

Figure B-13. Source Allocations for Shell Creek.

RSI-1984-12-056

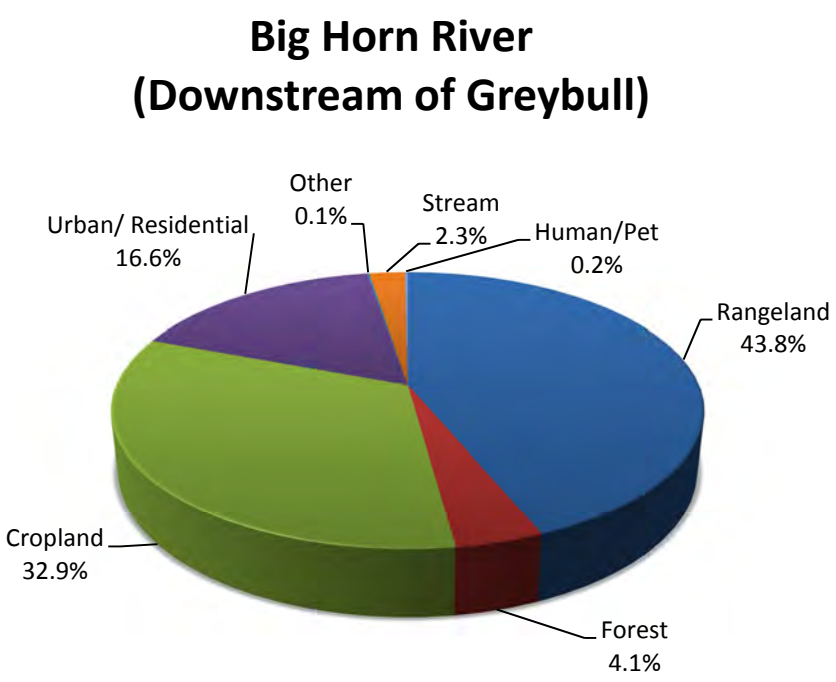

Figure B-14. Source Allocations for Big Horn River (Downstream of Greybull).

RSI-1984-12-057

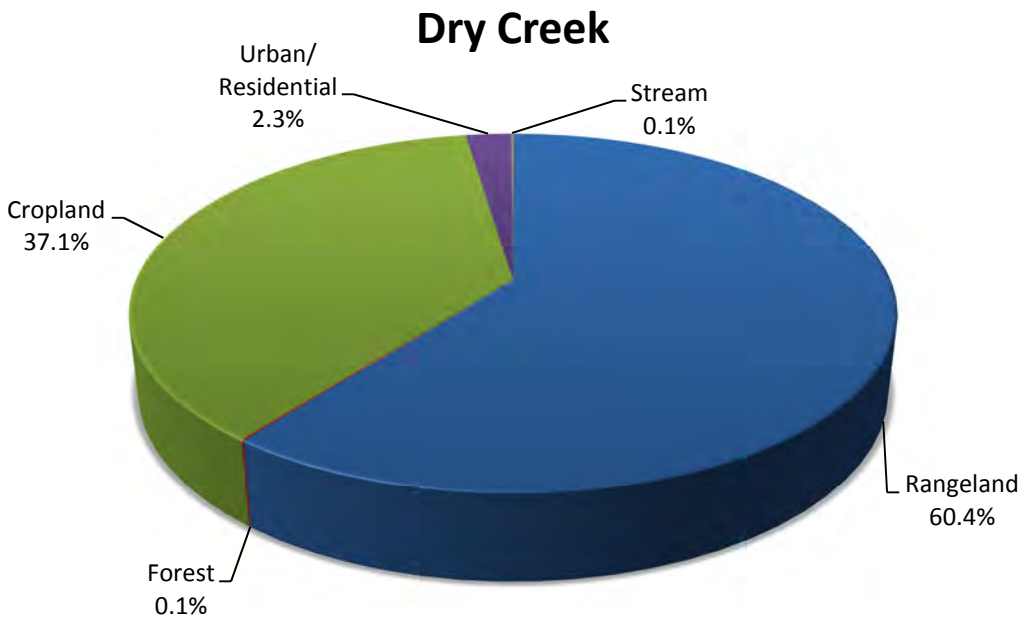

Figure B-15. Source Allocations for Dry Creek.

RSI-1984-12-058

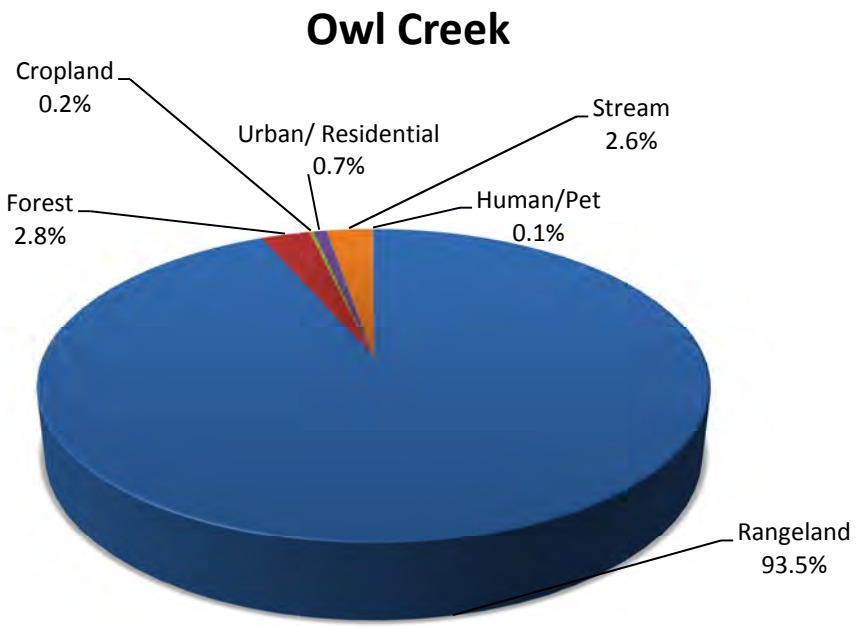

Figure B-16. Source Allocations for Owl Creek.

APPENDIX C

PUBLIC COMMENTS AND RESPONSES

Department of Environmental Quality

To protect, conserve and enhance the quality of Wyoming's environment for the benefit of current and future generations.

Matthew H. Mead, Governor **Todd Parfitt, Director**

October 14, 2013

Steffen Cornell
Meeteetse Conservation District
P.O. Box 237
Meeteetse, WY 82433

Dear Mr. Cornell,

The WDEQ would like to thank you for submitting comments on the Big Horn E. coli TMDL. These comments have been reviewed and this letter documents the responses addressing them. The responses are as follows:

Pg. 14. **Summary of Available Discharge Data.**
"Table 1-5 provides a site description, the type of waterbody monitored, the reporting agency, the numbers of samples, and dates that the data were available. These sites are also identified in Figure 1-5."
Comment: It appears as though the sites are actually identified in Figure 1-6.

Response: The callout for the Figure was updated.

Pg. 14. **Summary of Available Water Quality Data.**
"All water quality data used for the TMDL analysis are included on a CD in the appendices."
Comment: We could not locate this data and it would be helpful in better understanding the derived geometric means referenced in other places in the document.

Response: The data will be stored on WDEQ TMDL's Bighorn River's website and a digital copy is available upon request. The document now states: All data (flow and water quality) used for the TMDL analysis are available for download on the WDEQ TMDL's Big Horn River website (http://deq.state.wy.us/wqd/watershed/TMDL/BigHornTMDL/BigHornTMDL.htm). A copy may be requested by contacting WDEQ's TMDL program coordinator.

Pg. 32. **Collecting and Developing Time-Series Data**
Comment: MCD is concerned about the accuracy of simulated flows produced by the HSPF model. How are channel geometries used as stated and where was this type of data obtained? Channel geometries can change drastically throughout the entire reach of a stream depending on factors such as slope and bed composition. Is one cross section of a stream enough to derive an accurate flow rate for streams or tributaries without gages? Specifically reference which data or

table or figure illustrates the data used to calibrate the model to existing observed conditions as mentioned under this section.

Response: HSPF is a large scale model and represents the flow throughout the system. The best available cross section is used to represent each reach and the model is driven by precipitation and parameterization. As much as possible, consistent parameterization by land use is used so that there is confidence in the results at any ungaged streams and tributaries. We have calibration figures at all gaged streams and all data available for calibration during the model period was used. Sites with flow data are shown in the document in Table 1-5.

Pg. 33. **Calibrating and Validating the Model.**
Comment: The same "Figure 1-5" is referenced here again in addition to its reference in a different section that discusses a topic not related to hydrology. It would appear that figure titles and numbers need to be double checked throughout to avoid confusion.

Response: The callout for the Figure was updated.

Pg. B-6 **Source Load Allocation for Greybull River**
Comment: We would like to see a pie chart or know how the source load allocation is broken up by the individual land uses in Table 1-1 after page 9. What specific land uses comprise "Rangeland" for instance?

Response: Figure 2-1 in the Model Methods section shows how the NLCD land cover categories were aggregated into model land cover categories.

Comment: It appears that the model indicates that there is not a single flow zone for the Greybull River in which a sample could be collected that would not be above threshold (reference Table 3-24). Simulated Current Load for all flow zones significantly exceeds the TMDL value. We know and have data to support that this is not true. Geometric mean data reported in Table 1-7 indicates that exceedances in the impaired reach should occur approximately thirty to sixty percent of the time.

Response: Figure 3-11 shows that in the high and moist flow zones, that the model simulated values lower than the standard approximately 50 percent of the time.

Comment: It appears that figure 4-3 on page 79 takes into account all of the individual sample data collected, these data were analyzed statistically, and that the model used each of those samples to generate an arithmetic mean to determine the necessary reductions needed to meet the TMDL requirements. Based on what we know of how streams are designated as impaired, geometric means should be statistically analyzed (not the individual samples).

Response: Individual samples were used for calibration of the model, but geometric means were used for all analyses.

Comment: It has been agreed upon by other entities that we've spoken with in regards to the TMDL that the document could provide more clarity on the methods used to derive many of the figures so that they can be better understood and general confusion about how to interpret the data is reduced as much as possible. We have requested the numbers and parameters used in the model numerous times but have yet to receive any information on this.

Response: Section 2.3 was expanded to include much more detailed model methods and results.

Comment: We eagerly anticipate more validation of the model by seeing the results when it is run on an unimpaired reach of stream to show that no reductions are necessary to meet appropriate CFU levels that comply with the streams designated usage.

Response: We calibrated the model on all reaches where data were available, including unimpaired reaches. We are not able to compare the model to locations that do not have observed data.

Thank you

Kevin Hyatt

Kevin Hyatt
TMDL Coordinator

KH/rm/13-1005

ENCLOSURE 2

EPA REGION 8 TMDL REVIEW FORM AND DECISION DOCUMENT

TMDL Document Info:

Document Name:	**E. Coli Total Maximum Daily Loads for the Big Horn River Watershed, Wyoming**
Submitted by:	**Kevin Hyatt, Wyoming Department of Environmental Quality**
Date Received:	**August 14, 2013**
Review Date:	**September 13, 2013**
Reviewer:	**Vern Berry, US Environmental Protection Agency**
Rough Draft / Public Notice / Final Draft?	**Public Notice**
Notes:	

Reviewers Final Recommendation(s) to EPA Administrator (used for final draft review only):

- ☐ Approve
- ☐ Partial Approval
- ☐ Disapprove
- ☐ Insufficient Information

Approval Notes to the Administrator:

This document provides a standard format for EPA Region 8 to provide comments to state TMDL programs on TMDL documents submitted to EPA for either formal or informal review. All TMDL documents are evaluated against the TMDL review elements identified in the following 8 sections:

1. Problem Description
   1.1. TMDL Document Submittal
   1.2. Identification of the Waterbody, Impairments, and Study Boundaries
   1.3. Water Quality Standards
2. Water Quality Target
3. Pollutant Source Analysis
4. TMDL Technical Analysis
   4.1. Data Set Description
   4.2. Waste Load Allocations (WLA)
   4.3. Load Allocations (LA)
   4.4. Margin of Safety (MOS)
   4.5. Seasonality and variations in assimilative capacity
5. Public Participation
6. Monitoring Strategy
7. Restoration Strategy
8. Daily Loading Expression

Under Section 303(d) of the Clean Water Act, waterbodies that are not attaining one or more water quality standard (WQS) are considered "impaired." When the cause of the impairment is determined to be a pollutant, a TMDL analysis is required to assess the appropriate maximum allowable pollutant loading rate. A TMDL document consists of a technical analysis conducted to: (1) assess the maximum pollutant loading rate that a waterbody is able to assimilate while maintaining water quality standards; and (2) allocate that assimilative capacity among the known sources of that pollutant**.** A well written TMDL document will describe a path forward that may be used by those who implement the TMDL recommendations to attain and maintain WQS.

Each of the following eight sections describes the factors that EPA Region 8 staff considers when reviewing TMDL documents. Also included in each section is a list of EPA's review elements relative to that section, a brief summary of the EPA reviewer's findings, and the reviewer's comments and/or suggestions. Use of the verb "must" in this review form denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term "should" below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable.

This review form is intended to ensure compliance with the Clean Water Act and that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Problem Description

A TMDL document needs to provide a clear explanation of the problem it is intended to address. Included in that description should be a definitive portrayal of the physical boundaries to which the TMDL applies, as well as a clear description of the impairments that the TMDL intends to address and the associated pollutant(s) causing those impairments. While the existence of one or more impairment and stressor may be known, it is important that a comprehensive evaluation of the water quality be conducted prior to development of the TMDL to ensure that all water quality problems and associated stressors are identified. Typically, this step is conducted prior to the 303(d) listing of a waterbody through the monitoring and assessment program. The designated uses and water quality criteria for the waterbody should be examined against available data to provide an evaluation of the water quality relative to all applicable water quality standards. If, as part of this exercise, additional WQS problems are discovered and additional stressor pollutants are identified, consideration should be given to concurrently evaluating TMDLs for those additional pollutants. If it is determined that insufficient data is available to make such an evaluation, this should be noted in the TMDL document.

1.1 TMDL Document Submittal

When a TMDL document is submitted to EPA requesting review or approval, the submittal package should include a notification identifying the document being submitted and the purpose of the submission.

Review Elements:

☒ Each TMDL document submitted to EPA should include a notification of the document status (e.g., pre-public notice, public notice, final), and a request for EPA review.

☐ Each TMDL document submitted to EPA for final review and approval should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute**.** The submittal letter should contain such identifying information as the name and location of the waterbody and the pollutant(s) of concern, which matches similar identifying information in the TMDL document for which a review is being requested.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information ☐ N/A

Summary: *The notification of the availability of the public notice draft TMDL document was submitted to EPA via email received on August 14, 2013. The email included the draft TMDL document, details of the public notice, and requests the submittal of comments to WDEQ by September 16, 2013.*

Comments: *None.*

1.2 Identification of the Waterbody, Impairments, and Study Boundaries

The TMDL document should provide an unambiguous description of the waterbody to which the TMDL is intended to apply and the impairments the TMDL is intended to address. The document should also clearly delineate the physical boundaries of the waterbody and the geographical extent of the watershed area studied. Any additional information needed to tie the TMDL document back to a current 303(d) listing should also be included.

Review Elements:

☒ The TMDL document should clearly identify the pollutant and waterbody segment(s) for which the TMDL is being established. If the TMDL document is submitted to fulfill a TMDL development requirement for a waterbody on the state's current EPA approved 303(d) list, the TMDL document submittal should clearly identify the waterbody and associated impairment(s) as they appear on the State's/Tribe's current EPA approved 303(d) list, including a full waterbody description, assessment unit/waterbody ID, and the priority ranking of the waterbody. This information is necessary to ensure that the administrative record and the national TMDL tracking database properly link the TMDL document to the 303(d) listed waterbody and impairment(s).

☒ One or more maps should be included in the TMDL document showing the general location of the waterbody and, to the maximum extent practical, any other features necessary and/or relevant to the understanding of the TMDL analysis, including but not limited to: watershed boundaries, locations of major pollutant sources, major tributaries included in the analysis, location of sampling points, location of discharge gauges, land use patterns, and the location of nearby waterbodies used to provide surrogate information or reference conditions. Clear and concise descriptions of all key features and their relationship to the waterbody and water quality data should be provided for all key and/or relevant features not represented on the map

☒ If information is available, the waterbody segment to which the TMDL applies should be identified/geo-referenced using the National Hydrography Dataset (NHD). If the boundaries of the TMDL do not correspond to the Waterbody ID(s) (WBID), Entity ID information or reach code (RCH_Code) information should be provided. If NHD data is not available for the waterbody, an alternative geographical referencing system that unambiguously identifies the physical boundaries to which the TMDL applies may be substituted.

Recommendation:

☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary:

Physical Setting and Listing History*:*

This TMDL document includes sixteen (16) impaired stream segments within the Big Horn River basin in Wyoming. These stream segments are part of smaller sub-basins that include the following: Upper Big Horn River (HUC 10080007); Nowood River (HUC 10080008); Greybull River (HUC 10080009); Big Horn Lake (HUC 10080010); and Dry River (HUC 10080011). The sixteen impaired segments are located in parts of Hot Springs, Washakie, Park and Big Horn Counties in north-central Wyoming which cover a watershed area of approximately 5 million acres.

The sixteen impaired segments included in this TMDL document are: ***1)*** *Owl Creek from the confluence with the Big Horn River to a point 3.8 miles upstream (3.8 miles; WYBH100800070305_01);* ***2)*** *Kirby Creek from the confluence with the Big Horn River to a point 21.8 miles upstream (21.8 miles; WYBH100800070500_01);* ***3)*** *Nowater Creek from the confluence with the Big Horn River to a point 6.6 miles upstream (6.6 miles; WYBH100800070809_01);* ***4)*** *Fifteen Mile Creek from the confluence with the Big Horn River to a point 2.2 miles upstream (2.2 miles; WYBH100800070909_01);* ***5)*** *Big Horn River from the confluence with the Nowood River to a point 36.1 miles upstream (36.1 miles; WYBH100800071000_01);* ***6)*** *Big Horn River from the confluence with the Greybull River upstream to the confluence with the Nowood River (22.1 miles; WYBH100800071000_02);* ***7)*** *Sage Creek from the confluence with the Big Horn River to a point 7.4 miles upstream (7.4 miles; WYBH100800071001_01);* ***8)*** *Slick Creek from the confluence with the Big Horn River to a point 5.8 miles upstream (5.8 miles; WYBH100800071001_02);* ***9)*** *Paint Rock Creek from the confluence with the Nowood River to a point 5.2 miles upstream (5.2 miles; WYBH100800080603_01);* ***10)*** *Nowood River from the confluence with the Big Horn River to a point 13.4 miles upstream (13.4 miles; WYBH100800080705_01);* ***11)*** *Greybull River from the confluence with the Big Horn River to Sheets Flats Bridge (44.7 miles; WYBH100800090405_01);* ***12)*** *Granite Creek from the confluence with Shell Creek to a point 5.8 miles upstream near the Antelope Butte ski area (5.8 miles; WYBH100800100102_01);* ***13)*** *Beaver Creek from the confluence with Shell Creek to a point 7.9 miles upstream (7.9 miles; WYBH100800100204_01);* ***14)*** *Shell Creek from the confluence with the Big Horn River to a point 5.3 miles upstream (5.3 miles; WYBH100800100206_01);* ***15)*** *Big Horn River from the confluence with the Greybull River to a point 10.5 miles downstream (10.5 miles; WYBH100800100301_01);* ***16)*** *Dry Creek from the confluence with the Big Horn River to a point 4.7 miles upstream (4.7 miles; WYBH100800110204_01).*

These segments are listed as impaired for either E. coli or fecal coliform bacteria and are a high priority for TMDL development.

The Wyoming Surface Water Classification List, Table A assigns the following classifications for the stream segments in this TMDL document:

Class2AB *– Owl Creek; Big Horn River (all 3 segments); Paint Rock Creek; Nowood River, Greybull River; Granite Creek; Beaver Creek and Shell Creek*

Class 2ABww *– Dry Creek*

Class 2C *– Kirby Creek*

Class 3B *– Nowater Creek; Fifteen Mile Creek; Sage Creek; and Slick Creek*

The designated uses for Class 2AB, 2ABww, 2C and 3B streams are discussed in the Water Quality Standards section below.

Impairment status*:*
The 2012 Wyoming Integrated Report identifies the 16 stream segments as impaired based on the following information:

Stream Segment	Designated Use / Support Status	Impairment Cause	TMDL Priority
Owl Creek WYBH100800070305_01	*Recreation / Threatened*	*Fecal coliform*	*High*
Kirby Creek WYBH100800070500_01	*Recreation / Threatened*	*Fecal coliform*	*High*
Nowater Creek WYBH100800070809_01	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Fifteen Mile Creek WYBH100800070909_01	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Big Horn River WYBH100800071000_01	*Recreation / Not Supporting*	*E. coli*	*High*
Big Horn River WYBH100800071000_02	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Sage Creek WYBH100800071001_01	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Slick Creek WYBH100800071001_02	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Paint Rock Creek WYBH100800080603_01	*Recreation / Threatened*	*Fecal coliform*	*High*
Nowood River WYBH100800080705_01	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Greybull River WYBH100800090405_01	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Granite Creek WYBH100800100102_01	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Beaver Creek WYBH100800100204_01	*Recreation / Threatened*	*Fecal coliform*	*High*
Shell Creek WYBH100800100206_01	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Big Horn River WYBH10080010030101	*Recreation / Not Supporting*	*Fecal coliform*	*High*
Dry Creek WYBH100800110204_01	*Recreation / Threatened*	*Fecal coliform*	*High*

Comments:

1) It appears that a portion of the TMDL project area within the Big Horn River Watershed may be Wind River tribal lands. Section 1.2.7, Ownership, lists 4 percent of the TMDL project area as "tribal lands." EPA's review of the TMDLs within the Big Horn River Watershed extend to all impaired or threatened waters with the exception of those waters that are within Indian Country, as defined in 18 U.S.C. Section 1151. EPA is taking no action with respect to those waters at this time. EPA, or eligible Indian Tribes, as appropriate, will retain responsibilities under Section 303(d) for those waters.

WDEQ Response: WDEQ is taking no action with response to tribal waters. The sentence "No impaired waterbodies are on tribal lands." was added to Section 1.2.7 (Ownership).

2) Section 1.1, page 2, second paragraph, should include Fifteen Mile Creek in the list of streams classified as 3B.

WDEQ Response: Fifteen Mile Creek was added to the list of streams classified as 3B.

1.3 Water Quality Standards

TMDL documents should provide a complete description of the water quality standards for the waterbodies addressed, including a listing of the designated uses and an indication of whether the uses are being met, not being met, or not assessed. If a designated use was not assessed as part of the TMDL analysis (or not otherwise recently assessed), the documents should provide a reason for the lack of assessment (e.g., sufficient data was not available at this time to assess whether or not this designated use was being met).

Water quality criteria (WQC) are established as a component of water quality standard at levels considered necessary to protect the designated uses assigned to that waterbody. WQC identify quantifiable targets and/or qualitative water quality goals which, if attained and maintained, are intended to ensure that the designated uses for the waterbody are protected. TMDLs result in maintaining and attaining water quality standards by determining the appropriate maximum pollutant loading rate to meet water quality criteria, either directly, or through a surrogate measurable target. The TMDL document should include a description of all applicable water quality criteria for the impaired designated uses and address whether or not the criteria are being attained, not attained, or not evaluated as part of the analysis. If the criteria were not evaluated as part of the analysis, a reason should be cited (e.g. insufficient data were available to determine if this water quality criterion is being attained).

Review Elements:

☒ The TMDL must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the anti-degradation policy. (40 C.F.R. §130.7(c)(1)).

☒ The purpose of a TMDL analysis is to determine the assimilative capacity of the waterbody that corresponds to the existing water quality standards for that waterbody, and to allocate that assimilative capacity between the identified sources. Therefore, <u>all TMDL documents must be written to meet the existing water quality standards</u> for that waterbody (CWA §303(d)(1)(C)). *Note: In some circumstances, the load reductions determined to be necessary by the TMDL analysis may prove to be infeasible and may possibly indicate that the existing water quality standards and/or assessment methodologies may be erroneous. However, the TMDL must still be determined based on existing water quality standards. Adjustments to water quality standards and/or assessment methodologies may be evaluated separately, from the TMDL.*

☒ The TMDL document should describe the relationship between the pollutant of concern and the water quality standard the pollutant load is intended to meet. This information is necessary for EPA to evaluate whether or not attainment of the prescribed pollutant loadings will result in attainment of the water quality standard in question.

☒ If a standard includes multiple criteria for the pollutant of concern, the document should demonstrate that the TMDL value will result in attainment of all related criteria for the pollutant. For example, both acute and chronic values (if present in the WQS) should be addressed in the document, including consideration of magnitude, frequency and duration requirements.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *All sixteen (16) segments included in the Big Horn River TMDL document are impaired based on fecal coliform or E. coli bacteria concentrations impacting the recreational uses. These segments are listed as "not supporting" or as "threatened" due to exceedences of the fecal coliform or E. coli bacteria standard which was in effect at the time of the TMDL listing.*

Effective 2008, the WDEQ revised the State water quality standards. In these revisions the WDEQ eliminated the fecal coliform bacteria standards, retaining only the E. coli bacteria standards for the protection of recreational uses. These changes in the water quality standards were recommended by the US Environmental Protection Agency as E. coli is believed to be a better indicator of recreational use risk (i.e., incidence of gastrointestinal disease).

The sixteen (16) bacteria impaired segments in the Big Horn watershed include Class 2AB, 2ABww, 2C and 3B streams. The designated uses for each classification are as follows:

> *Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending upon the predominance of cold water or warm water species present. All Class 2AB waters are designated as cold water game fisheries unless identified as a warm water game fishery by a "ww" notation in the "Wyoming Surface Water Classification List". Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, and aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses.*
>
> *Class 2C waters are those known to support or have the potential to support only nongame fish populations or spawning and nursery areas at least seasonally including their perennial tributaries and adjacent wetlands. Class 2C waters include all permanent and seasonal nongame fisheries and are considered "warm water". Uses designated on Class 2C waters*

include nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value.

Class 3B waters are tributary waters including adjacent wetlands that are not known to support fish populations or drinking water supplies and where those uses are not attainable. Class 3B waters are intermittent and ephemeral streams with sufficient hydrology to normally support and sustain communities of aquatic life including invertebrates, amphibians, or other flora and fauna which inhabit waters of the state at some stage of their life cycles. In general, 3B waters are characterized by frequent linear wetland occurrences or impoundments within or adjacent to the stream channel over its entire length. Such characteristics will be a primary indicator used in identifying Class 3B waters.

Numeric criteria for E. coli as established for Wyoming Class 2AB, 2ABww, 2C and 3B streams have been established and are presented in the Table below. Discussion of additional applicable water quality standards for these stream segments can be found on pages 1 – 4 of the TMDL document.

Wyoming Bacteria Water Quality Standards for Class 2AB, 2C and 3B Streams.

Parameter	Standard	
	Geometric Mean[1]	**Maximum[2]**
E. coli Bacteria (May 1 – Sept 30)	126 organisms per100 mL	235-576 organisms per 100 mL
E. coli Bacteria (Oct 1 – April 30)	630 organisms per 100 mL	

[1] Expressed as a geometric mean of not less than 5 samples collected during any 30-day period.
[2] The value is based on the type of summer recreational season contact use which includes: high use swimming areas (235); moderate full body contact (298); lightly used full body contact (410); and infrequently used full body contact (576). The appropriate recreational use category is determined by the administrator as needed, on a case by case basis.
Note: Although the WDEQ E. coli standards are expressed as the number of organisms per 100 mL of the sample, most laboratories report bacteria analytical results as the number of colony forming units (cfu) per 100 mL.

Comments:

1) We recommend revising the paragraph that describes the numeric E. coli criterion (page 4, near the bottom of the page) so that it is clearer. The revised paragraph could begin with a sentence such as: "WDEQ's approved and established water quality standards for E. coli are:…", or by using a table similar to that included above. This discussion or table should include a description of the Single Sample Maximum Concentration use categories [WDEQ, WQ Rules and Regulations, Chapter 1, page 1-23] and values, as well as any WDEQ Administrator's single sample summer recreational use determinations made for the segments included in this TMDL document.

WDEQ Response: The description of the Wyoming *E. coli* standard stated on page 4 is correct. The description describes the *E. coli* criterion that is used to determine if the recreational designated use is impaired. Single-sample maximum values may be used to postrecreational use advisories in public recreation areas and to derive single-sample maximum effluent limitations on point-source discharges. An exceedance of the single-sample maxima shall not be cause for listing a waterbody on the state 303(d) list or development of a TMDL or watershed plan. The appropriate recreational use category (i through iv) shall be determined by the administrator as needed, on a case-by-case basis. In making

such a determination, the administrator may consider such site-specific circumstances as type and frequency of use, time of year, public access, proximity to populated areas and local interests [Wyoming Department of Environmental Quality, 2007].

Wyoming Department of Environmental Quality, 2007. *Water Quality Rules and Regulations*, prepared by Wyoming Department of Environmental Quality, Cheyenne, WY.

2) We recommend deleting the term "impairment" within the first sentence of the existing paragraph (page 4, near the bottom of the page) […E. coli impairment…] because the determination of impairment is an independent action from the statement of the applicable water quality standards.

WDEQ Response: The term "impairment" was deleted from the sentence.

2. Water Quality Targets

TMDL analyses establish numeric targets that are used to determine whether water quality standards are being achieved. Quantified water quality targets or endpoints should be provided to evaluate each listed pollutant/water body combination addressed by the TMDL, and should represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the water quality target. For pollutants with narrative standards, the narrative standard should be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include a variety of targets representing water column sediment such as TSS, embeddedness, stream morphology, up-slope conditions and a measure of biota).

Review Elements:

☐ The TMDL should identify a numeric water quality target(s) for each waterbody pollutant combination. The TMDL target is a quantitative value used to measure whether or not the applicable water quality standard is attained. *Generally, the pollutant of concern and the numeric water quality target are, respectively, the chemical causing the impairment and the numeric criteria for that chemical (e.g., chromium) contained in the water quality standard. Occasionally, the pollutant of concern is different from the parameter that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as a numerical dissolved oxygen criterion). In such cases, the TMDL should explain the linkage between the pollutant(s) of concern, and express the quantitative relationship between the TMDL target and pollutant of concern. In all cases, TMDL targets must represent the attainment of current water quality standards.*

☐ When a numeric TMDL target is established to ensure the attainment of a narrative water quality criterion, the numeric target, the methodology used to determine the numeric target, and the link between the pollutant of concern and the narrative water quality criterion should all be described in the TMDL document. Any additional information supporting the numeric target and linkage should also be included in the document.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The water quality targets for these TMDLs are based on the numeric water quality standards for E. coli bacteria established to protect the recreational beneficial uses for the sixteen (16) impaired stream segments in the Big Horn River watershed.*

Bacteria analytical results are typically expressed in coliform forming units (cfu) per 100 milliliters (mL) of the water sample. Therefore, the E. coli target for each impaired segment is: 126 cfu/100 mL during the summer recreation season from May 1 to September 30, and 630 cfu/100 mL during the off-

season from October 1 to April 30. Both values are calculated as the geometric mean of five or more samples for any 30-day period.

Comments:

1) We recommend including a sentence that clearly states the E. coli TMDL targets being used for these impaired stream segments.

WDEQ Response: The words "numeric criterion for *E. coli* impairment" were changed to "*E. coli* targets."

2) We recommend adding a sentence that states that the E. coli TMDL targets being used for these stream segments (i.e., based on the recreational use) will protect all other designated uses for these stream segments because it is the most sensitive use for bacteria.

WDEQ Response: Recreational use protection involves maintaining a level of water quality which is safe for human contact. It does not guarantee the availability of water for any recreational purpose [Wyoming Department of Environmental Quality, 2012]. The criterion that is used to evaluate the recreation use is *E. coli*. The *E. coli* limit has been determined by EPA to protect human health [U.S. Environmental Protection Agency, 1986]. Wyoming also supports that this *E. coli* limit is protective of the Wyoming recreation use, but does not use it to make any determination of other uses.

Wyoming Department of Environmental Quality, 2012. *Wyoming's Methods for Determining Surface Water Quality Conditions and TMDL Prioritization*, 13-0352, prepared by the Wyoming Department of Environmental Quality, Water-Quality Division, Cheyenne, WY.

U.S. Environmental Protection Agency, 1986. *Quality Criteria for Water 1986*, EPA 440/5-86-001, Office of Water Regulations and Standards, Washington DC.

3) The waterbody summary tables at the beginning of the TMDL document contain TMDL "Criteria Threshold Values" which appear to be the same as the applicable E. coli water quality standards. We assume the term is also meant to be equivalent to, or similar to, TMDL water quality targets. If the criteria threshold values are also the TMDL target values, we recommend adding a sentence to the document that makes this point clear.

WDEQ Response: Instead of adding a sentence explaining that these are the same, the phrase "Criteria Threshold Values" in the summary tables was changed to "Water-Quality Targets"

3. Pollutant Source Analysis

A TMDL analysis is conducted when a pollutant load is known or suspected to be exceeding the loading capacity of the waterbody. Logically then, a TMDL analysis should consider all sources of the pollutant of concern in some manner. The detail provided in the source assessment step drives the rigor of the pollutant load allocation. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each identified source (or source category) when the relative load contribution from each source has been estimated. Therefore, the pollutant load from each identified source (or source category) should be specified and quantified. This may be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach may be appropriate. The approach should be clearly defined in the document.

Review Elements:

☒ The TMDL should include an identification of the point and nonpoint sources of the pollutant of concern, including the geographical location of the source(s) and the quantity of the loading, e.g., lbs/per day. This information is necessary for EPA to evaluate the WLA, LA and MOS components of the TMDL.

☒ The level of detail provided in the source assessment should be commensurate with the nature of the watershed and the nature of the pollutant being studied. Where it is possible to separate natural background from nonpoint sources, the TMDL should include a description of both the natural background loads and the nonpoint source loads.

☒ Natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g. measured in stream) unless it can be demonstrated that the anthropogenic sources of the pollutant of concern have been identified, characterized, and quantified.

☒ The sampling data relied upon to discover, characterize, and quantify the pollutant sources should be included in the document (e.g. a data appendix) along with a description of how the data were analyzed to characterize and quantify the pollutant sources. A discussion of the known deficiencies and/or gaps in the data set and their potential implications should also be included.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The TMDL document includes the landuse breakdown for the watershed based on the 2006 National Land Cover Dataset (NLCD) data. In 2006, the dominant land use in the Big Horn River watershed was agriculture. Approximately 50 percent of the landcover in the watershed was scrub / shrub, 33 percent was grassland / herbaceous, 9 percent was forest and the remaining 8 percent was cropland, pasture hay, wetlands, developed space or barren.*

Section 2.0, Significant Sources beginning on page 21, provides the pollutant source analysis for the listed segments in the Big Horn River watershed. There are eight (8) known municipal wastewater treatment facilities (WWTFs) that have point sources discharges located within the drainage area of

these listed stream segments. These WWTFs are located in towns of Basin, Burlington, Greybull, Manderson, Meeteetse, Ten Sleep, Thermopolis and the city of Worland. The Deer Haven Lodge outside of Ten Sleep, WY also has a domestic wastewater discharge.

Six permitted, concentrated animal feeding operations, with a total of eight discharge points, are located within the Big Horn project area. They are not allowed to discharge, except in the case of a chronic or catastrophic storm event that would cause an overflow from the runoff and/or wastewater control structure.

Nonpoint source bacterial pollution to these segments originates from various agricultural, wildlife and human sources in the watershed. Livestock (predominately cattle and sheep), wildlife, septic systems as well as pet wastes are all potential bacteria contributors in the Big Horn River watershed. The Bacteria Source Load Calculator was used to develop and distribute bacteria loadings from the sources to the proper landuses in the watershed. The E. coli loadings were incorporated into the HSPF model to assess the fate and transport of the bacteria loadings throughout the watershed. The source assessment modeling results, provided in Table 2-4 of the TMDL document, are summarized by land-use categories for overland load washed into the stream through rainfall/runoff processes, direct defecation of wildlife or livestock into streams, and on-site wastewater treatment tank failures (i.e., septics). Pie charts of the source assessments for each impaired stream segment are included in Appendix B of the TMDL document. For all impaired segments, point sources were a small portion (less than 1 percent) of the load and, therefore, are not shown in Table 2-4 or the in the Appendix B pie charts.

Comments:

1) The TMDL document does not mention the number of AFOs within the watershed. Well managed and permitted CAFOs are a low risk for bacterial contamination, however smaller AFOs located near streams can cause significant localized bacteria problems. This information is helpful, but not required for the TMDL approval; however it will be particularly important during the BMP implementation step of the process.

WDEQ Response: AFOs will be addressed during implementation. AFOs were accounted for in the BSLC and model calibration process as described in Section 2.3.1 (Model Methods).

2) Table 2-2, Livestock Loading Estimates, shows higher bacterial loads per animal, and for the entire watershed, from sheep than from cattle. Other literature sources estimate bacteria loading from sheep to be 2-10 times lower per animal than cattle. EPA's CAFO definitions require 10,000 sheep vs only 1,000 cattle. This is a ratio of 10 sheep for every 1 cattle (e.g., an animal unit = 1 cattle = 10 sheep). Please, check the calculations that went into the data contained in Table 2-2 for errors.

WDEQ Response: Calculations were done to check the data contained in Table 2-2. No errors were found. We also verified numbers using the Education Program for Improved Water Quality in Copano Bay Task Two Report [Wagner and Moench, 2009].

Wagner, K. and E. Moench, 2009. *Education Program for Improved Water Quality in Copano Bay Task Two Report*, prepared by Texas Water Resources Institute, College Station, TX, for Texas State Soil and Water Conservation Board, Temple, TX.

4. TMDL Technical Analysis

TMDL determinations should be supported by an analysis of the available data, discussion of the known deficiencies and/or gaps in the data set, and an appropriate level of technical analysis**.** This applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader.

A TMDL analysis determines the maximum pollutant loading rate that may be allowed to a waterbody without violating water quality standards. The TMDL analysis should demonstrate an understanding of the relationship between the rate of pollutant loading into the waterbody and the resultant water quality impacts. This stressor → response relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and load allocations needs to be clearly articulated and supported by an appropriate level of technical analysis. Every effort should be made to be as detailed as possible, and to base all conclusions on the best available scientific principles.

The pollutant loading allocation is at the heart of the TMDL analysis. TMDLs apportion responsibility for taking actions by allocating the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways, such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or division of responsibility.

The pollutant loading allocation that will result in achievement of the water quality target is expressed in the form of the standard TMDL equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

Where:

TMDL	=	Total Maximum Daily Load (also called the Loading Capacity)
LAs	=	Load Allocations
WLAs	=	Wasteload Allocations
MOS	=	Margin Of Safety

Review Elements:

☒ A TMDL must identify the loading capacity of a waterbody for the applicable pollutant, taking into consideration temporal variations in that capacity. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

☒ The total loading capacity of the waterbody should be clearly demonstrated to equate back to the pollutant load allocations through a balanced TMDL equation. In instances where numerous LA, WLA and seasonal TMDL capacities make expression in the form of an equation cumbersome, a

table may be substituted as long as it is clear that the total TMDL capacity equates to the sum of the allocations.

☒ The TMDL document should describe the methodology and technical analysis used to establish and quantify the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

☒ It is necessary for EPA staff to be aware of any assumptions used in the technical analysis to understand and evaluate the methodology used to derive the TMDL value and associated loading allocations. Therefore, the TMDL document should contain a description of any important assumptions (including the basis for those assumptions) made in developing the TMDL, including but not limited to:

- the spatial extent of the watershed in which the impaired waterbody is located and the spatial extent of the TMDL technical analysis;
- the distribution of land use in the watershed (e.g., urban, forested, agriculture);
- a presentation of relevant information affecting the characterization of the pollutant of concern and its allocation to sources such as population characteristics, wildlife resources, industrial activities etc…;
- present and future growth trends, if taken into consideration in determining the TMDL and preparing the TMDL document (e.g., the TMDL could include the design capacity of an existing or planned wastewater treatment facility);
- an explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments; chlorophyll *a* and phosphorus loadings for excess algae; length of riparian buffer; or number of acres of best management practices.

☒ The TMDL document should contain documentation supporting the TMDL analysis, including an inventory of the data set used, a description of the methodology used to analyze the data, a discussion of strengths and weaknesses in the analytical process, and the results from any water quality modeling used. This information is necessary for EPA to review the loading capacity determination, and the associated load, wasteload, and margin of safety allocations.

☒ TMDLs must take critical conditions (e.g., steam flow, loading, and water quality parameters, seasonality, etc…) into account as part of the analysis of loading capacity (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable critical conditions and describe the approach used to determine both point and nonpoint source loadings under such critical conditions. In particular, the document should discuss the approach used to compute and allocate nonpoint source loadings, e.g., meteorological conditions and land use distribution.

☐ Where both nonpoint sources and NPDES permitted point sources are included in the TMDL loading allocation, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document must include a demonstration that nonpoint source loading reductions needed to implement the load allocations are actually practicable [40 CFR 130.2(i) and 122.44(d)].

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The technical analysis should describe the cause and effect relationship between the identified pollutant sources, the numeric targets, and achievement of water quality standards. It should also include a description of the analytical processes used, results from water quality modeling, assumptions and other pertinent information. The technical analysis for the Big Horn River watershed TMDLs describes how the E. coli loads were derived in order to meet the applicable water quality standards for the 303(d) impaired stream segments.*

The TMDL loads and loading capacities were derived using the load duration curve (LDC) approach. To better correlate the relationship between the pollutant of concern and the hydrology of each Section 303(d) listed waterbody, LDCs were developed for each stream segment.

The available water-quantity and water-quality data within the Big Horn River watershed area is limited spatially and/or temporally, therefore the Hydrological Simulation Program – FORTRAN (HSPF) model was used to simulate continuous hydrology and bacteria data. Data used in developing the model for this watershed included meteorological time series (precipitation, potential evapotranspiration, air temperature, wind speed, solar radiation, dew point, and cloud cover), stream flow and bacteria data at calibration stations, channel geometry, and spatial data (such as elevation and land use). The time period for model calibration and verification was from 2005 to 2010. In-stream flow monitoring points, illustrated in Figure 1-6 of the TMDL document, were used for hydrologic calibration of the HSPF model. Model calibration of water quality data was completed using multiple tools that compared the observed data to the model simulated results. Concentration-duration curves for the primary contact recreation season that compare observed and simulated concentrations for all of the impaired segments in the watershed are included in Appendix A of the TMDL document.

The HSPF model determined the contribution of E. coli bacteria from identified sources in the Big Horn River watershed and evaluated the implementation of BMPs to control these sources. The Big Horn River drainage basin was represented in the model using 105 sub-watersheds. The nonpoint sources in the study area were modeled in HSPF by estimating per-acre bacteria accumulation rates and maximum bacteria storage rates for each source. The accumulation and storage rates were calculated using the Bacteria Source Load Calculator (BSLC) developed by the Center for TMDL and Watershed Studies at Virginia Tech. The buildup and washoff of bacteria were simulated based on these rates and precipitation. Failing on-site wastewater treatment systems, as well as livestock and wildlife in streams, are direct sources that were modeled similar to point sources, because the bacteria loads that they produce are independent of rainfall/runoff processes. The BSLC was used to calculate bacteria loadings that represent livestock in streams and human sources, which were then used as inputs to the HSPF model. The source assessment modeling results were summarized by land use categories for overland load washed into the stream through rainfall/runoff processes, direct defecation of wildlife or livestock into streams, and on-site wastewater treatment tank failures (i.e., septics). The Big Horn River (downstream of the Greybull River) is the most downstream reach assessed by the model and is essentially a culmination of all water-quality processes that occur upstream of this TMDL reach. Modeling indicates that 97 percent of the loading within the project area originates from overland runoff and the remaining 3 percent is from direct stream loading. Rangeland, which accounts for 85 percent of the land use in the project area, contributes 46 percent of the overall load. Direct defecation from wildlife or livestock accounts for nearly the entire direct source loading.

The TMDLs for each impaired segment were developed using the load duration curve (LDC) approach and resulted in flow-variable targets that considered the entire flow regime within the primary contact recreation season (May 1–September 30) and within the secondary contact recreation season (October 1–April 30). The LDCs are dynamic expressions of the allowable daily loads for any given flow within each specified season. To aid in interpreting and implementing each TMDL, the TMDL and LDC flow intervals were grouped into five flow zones that included high flows (0–10 percent), moist conditions (10–40 percent), midrange flows (40–60 percent), dry conditions (60– 90 percent), and low flows (90–100 percent) in adherence to guidance provided by the EPA.

The TMDLs are in effect from May 1 through September 30 for the primary contact standard of 126 cfu/100 mL and from October 1 through March 30 for the secondary contact standard of 630 cfu/100 mL. Because the flow data and E. coli geometric mean data are insufficient at many of the TMDL endpoints within the Big Horn TMDL project area, the HSPF model was used during the primary contact recreation season to simulate geometric mean flows and geometric mean bacteria concentrations at each impaired stream segment endpoint. The HSPF model was again used to simulate flows during the secondary contact recreation season but was not used to simulate bacteria concentrations because of insufficient available data for developing thorough, calibrated predictions.

The LDCs for each impaired stream segment as well as the TMDL loading tables (e.g., loading capacity, wasteload allocation, load allocation, margin of safety) are included in Section 3.5 of the TMDL document.

Comments: *None.*

4.1 Data Set Description

TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis. An inventory of the data used for the TMDL analysis should be provided to document, for the record, the data used in decision making. This also provides the reader with the opportunity to independently review the data. The TMDL analysis should make use of all readily available data for the waterbody under analysis unless the TMDL writer determines that the data are not relevant or appropriate. For relevant data that were known but rejected, an explanation of why the data were not utilized should be provided (e.g., samples exceeded holding times, data collected prior to a specific date were not considered timely, etc…).

Review Elements:

☒ TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and appropriate water quality criteria.

☒ The TMDL document submitted should be accompanied by the data set utilized during the TMDL analysis. If possible, it is preferred that the data set be provided in an electronic format and referenced in the document. If electronic submission of the data is not possible, the data set may be included as an appendix to the document.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The locations of the water-quality monitoring sites in the project area where data was collected are illustrated in Figure 1-7. The data collected from the water-quality monitoring sites and the flow monitoring sites was subsequently used to develop each load duration curve. A list of the water quality monitoring sites that were used to develop the load duration curves is provided in Table 3-2 of the TMDL document. A summary of the E. coli water quality data from the Big Horn River watershed is included in Tables 1-7 and 1-8 of the TMDL document. The flow data summary information is included in Table 1-6. The full E. coli water quality data set for the Big Horn River watershed was emailed to EPA.*

Comments: *None.*

4.2 Waste Load Allocations (WLA):

Waste Load Allocations represent point source pollutant loads to the waterbody. Point source loads are typically better understood and more easily monitored and quantified than nonpoint source loads. Whenever practical, each point source should be given a separate waste load allocation. All NPDES permitted dischargers that discharge the pollutant under analysis directly to the waterbody should be identified and given separate waste load allocations. The finalized WLAs are required to be incorporated into future NPDES permit renewals.

Review Elements:

☒ EPA regulations require that a TMDL include WLAs, which identify the portion of the loading capacity allocated to individual existing and future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit. If no allocations are to be made to point sources, then the TMDL should include a value of zero for the WLA.

☐ All NPDES permitted dischargers given WLA as part of the TMDL should be identified in the TMDL, including the specific NPDES permit numbers, their geographical locations, and their associated waste load allocations.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The WLAs provided in Table 3-1 of the TMDL document are the sum of the permitted point-source allocations within each reach. The WLAs were calculated as the product of the total design flows in each reach, the specified criteria (primary or secondary recreation criteria), and a unit conversion factor. Information about applicable point sources of E. coli bacteria was included in Table 2-1.*

There are eight (8) known municipal wastewater treatment facilities (WWTFs) that have point sources discharges located within the drainage area of these listed stream segments. These WWTFs are located in towns of Basin, Burlington, Greybull, Manderson, Meeteetse, Ten Sleep, Thermopolis and the city of Worland. The Deer Haven Lodge outside of Ten Sleep, WY also has a domestic wastewater discharge.

Six permitted, concentrated animal feeding operations (CAFO) with a total of eight discharge points are located within the Big Horn project area. They are not allowed to discharge except in the case of a chronic or catastrophic storm event that would cause an overflow from the runoff and/or wastewater control structure.

Comments:
1) WLAs for each of the point sources listed in Table 2-1 need to be broken out separately and included as separate values in a table, such as Table 3-1. The numeric values and assumptions used to calculate the WLAs for each of the point sources need to be included in the TMDL document or an appendix (e.g., point source design flow or average discharge flow, discharge concentration, number of lagoon cells, size of each cell, assumptions about annual discharge frequency, discharge duration, etc.).

WDEQ Response: WLAs for each point source were broken out separately in Table 3-1. Design flows, concentrations used to calculate WLAs, and calculated WLAs are included in Table 2-1. A sentence about this table was updated in the Wasteload Allocation Section.

2) Additional information needs to be provided in the TMDL document to explain the basis and derivation of the E. coli discharge limits, in Table 2-1, for Thermopolis and Deer Haven Lodge and the impacts of those discharges on downstream water quality. The allowable discharge concentrations from these facilities are well above the applicable E. coli water quality standards and have the potential to cause localized in-stream water quality exceedances. Reasonable assurance may need to be included for the Big Horn River (Thermopolis) and Nowood River (Deer Haven Lodge) if the point source discharges are being given less stringent WLAs based on the assumption that additional NPS load reductions will occur.

WDEQ Response: The text was updated to read: For receiving waters that have a perennial flow, like the Big Horn River, a WLA calculation is performed to calculate the effluent limit. This involves a mass balance approach to determine the maximum allowable concentration in the effluent, so that when mixed with the receiving stream, the in-stream standard of the constituent is not violated. The mass balance approach uses the upstream 7Q10 (the lowest 7-day average flow that occurs on average once every 10 years) of the receiving stream, the maximum effluent discharge volume, the upstream background concentration of the constituent, and in-stream standards to calculate the maximum allowable concentration of the constituent in the effluent. Considering that Thermopolis and Deer Haven Lodge immediately discharge to stretches of stream that support their uses, that there are no other point sources in the immediate areas that contribute to the impairments, and that the facilities are many miles upstream of impaired reaches, it was determined that the mass balance approach was appropriate for calculating the effluent limit.

4.3 Load Allocations (LA):

Load allocations include the nonpoint source, natural, and background loads. These types of loads are typically more difficult to quantify than point source loads, and may include a significant degree of uncertainty. Often it is necessary to group these loads into larger categories and estimate the loading rates based on limited monitoring data and/or modeling results. The background load represents a composite of all upstream pollutant loads into the waterbody. In addition to the upstream nonpoint and upstream natural load, the background load often includes upstream point source loads that are not given specific waste load allocations in this particular TMDL analysis. In instances where nonpoint source loading rates are particularly difficult to quantify, a performance-based allocation approach, in which a detailed monitoring plan and adaptive management strategy are employed for the application of BMPs, may be appropriate.

Review Elements:

☒ EPA regulations require that TMDL expressions include LAs which identify the portion of the loading capacity attributed to nonpoint sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Load

allocations may be included for both existing and future nonpoint source loads. Where possible, load allocations should be described separately for natural background and nonpoint sources.

☒ Load allocations assigned to natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g., measured in stream) unless it can be demonstrated that the anthropogenic sources of the pollutant of concern have been identified and given proper load or waste load allocations.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The TMDL document includes the landuse breakdown for the watershed based on the 2006 National Land Cover Dataset (NLCD) data. In 2006, the dominant land use in the Big Horn River watershed was agriculture. Approximately 50 percent of the landcover in the watershed was scrub / shrub, 33 percent was grassland / herbaceous, 9 percent was forest and the remaining 8 percent was cropland, pasture hay, wetlands, developed space or barren.*

Nonpoint source bacterial pollution to these segments originates from various agricultural, wildlife and human sources in the watershed. Livestock (predominately cattle and sheep), wildlife, septic systems as well as pet wastes are all potential bacteria contributors in the Big Horn River watershed. The Bacteria Source Load Calculator was used to develop and distribute bacteria loadings from the sources to the proper landuses in the watershed. The E. coli loadings were incorporated into the HSPF model to assess the fate and transport of the bacteria loadings throughout the watershed.

The HSPF modeling results, summarized in Table 2-4, show that a significant percentage of the E. coli loading is contributed by rangeland land use in 10 of the 16 impaired segment drainage areas, and by cropland land use in 5 of the 16 impaired segment drainage areas.

Comments: *None.*

4.4 Margin of Safety (MOS):

Natural systems are inherently complex. Any mathematical relationship used to quantify the stressor → response relationship between pollutant loading rates and the resultant water quality impacts, no matter how rigorous, will include some level of uncertainty and error. To compensate for this uncertainty and ensure water quality standards will be attained, a margin of safety is required as a component of each TMDL. The MOS may take the form of a explicit load allocation (e.g., 10 lbs/day), or may be implicitly built into the TMDL analysis through the use of conservative assumptions and values for the various factors that determine the TMDL pollutant load → water quality effect relationship. Whether explicit or implicit, the MOS should be supported by an appropriate level of discussion that addresses the level of uncertainty in the various components of the TMDL technical analysis, the assumptions used in that analysis, and the relative effect of those assumptions on the final TMDL. The discussion should demonstrate that the MOS used is sufficient to ensure that the water quality standards would be attained if the TMDL pollutant loading rates are met. In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be

necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

Review Elements:

☒ TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d) (1) (C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

☐ If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS should be identified and described. The document should discuss why the assumptions are considered conservative and the effect of the assumption on the final TMDL value determined.

☒ If the MOS is explicit, the loading set aside for the MOS should be identified. The document should discuss how the explicit MOS chosen is related to the uncertainty and/or potential error in the linkage analysis between the WQS, the TMDL target, and the TMDL loading rate.

☐ If, rather than an explicit or implicit MOS, the TMDL relies upon a phased approach to deal with large and/or unquantifiable uncertainties in the linkage analysis, the document should include a description of the planned phases for the TMDL as well as a monitoring plan and adaptive management strategy.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The Big Horn River watershed TMDL document includes explicit MOSs for each of the listed segments in the watershed. An explicit MOS was calculated using information from the load duration curve for each impaired segment. The MOS values were derived using the difference between the loading capacity at the midpoint of each of the five flow zones and the loading capacity at the minimum flow in each zone. A substantial MOS is provided using this method, because the loading capacity is typically much less at the minimum flow of a zone when compared to the midpoint. Because the allocations are a direct function of flow, accounting for potential flow variability is an appropriate way to address the MOS.*

Comments*: None.*

4.5 Seasonality and variations in assimilative capacity:

The TMDL relationship is a factor of both the loading rate of the pollutant to the waterbody and the amount of pollutant the waterbody can assimilate and still attain water quality standards. Water quality standards often vary based on seasonal considerations. Therefore, it is appropriate that the TMDL analysis consider seasonal variations, such as critical flow periods (high flow, low flow), when establishing TMDLs, targets, and allocations.

Review Elements:

☒ The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variability as a factor. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *By using the load duration curve approach to develop the TMDL allocations seasonal variability in E. coli loading is taken into account. The highest steam flows typically occur during late spring, and the lowest stream flows typically occur during the winter months. The TMDLs also consider seasonality because the primary E. coli criteria are in effect from May 1 to September 30, as defined by the main recreation season in Wyoming.*

Comments: *None.*

5. Public Participation

EPA regulations require that the establishment of TMDLs be conducted in a process open to the public, and that the public be afforded an opportunity to participate. To meaningfully participate in the TMDL process it is necessary that stakeholders, including members of the general public, be able to understand the problem and the proposed solution. TMDL documents should include language that explains the issues to the general public in understandable terms, as well as provides additional detailed technical information for the scientific community. Notifications or solicitations for comments regarding the TMDL should be made available to the general public, widely circulated, and clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for approval, a copy of the comments received by the state and the state responses to those comments should be included with the document.

Review Elements:

☒ The TMDL must include a description of the public participation process used during the development of the TMDL (40 C.F.R. §130.7(c)(1)(ii)).

☐ TMDLs submitted to EPA for review and approval should include a summary of significant comments and the State's/Tribe's responses to those comments.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The TMDL document includes a summary of the public participation process that has occurred. It describes the opportunities the public had to be involved in the TMDL development process. The efforts that were taken to facilitate public education, review, and comment during developing the Big Horn River watershed TMDLs included presentations on the findings of the assessment at public meetings to stakeholders in the watershed, quarterly newsletters, a project website, public announcements, and a 30-day public notice period for review and comment. The findings from these public meetings and comments were taken into consideration when developing the TMDLs.*

A Public Involvement Plan was developed specifically for the Big Horn River watershed TMDL project to aid in facilitating and documenting all public outreach throughout the project. Public information objectives during the TMDL project were to provide information to stakeholders, provide stakeholders the opportunity to comment and ask questions, and provide an opportunity for stakeholders to participate on the project's Technical Steering Committee. A total of eight public meetings were held during the project. The locations of the public meetings were moved throughout the watershed to maximize public involvement. Additional outreach activities are detailed in Section 5.0 of the TMDL document.

Comments: *None.*

6. Monitoring Strategy

TMDLs may have significant uncertainty associated with the selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL document to articulate the means by which the TMDL will be evaluated in the field, and to provide for future supplemental data that will address any uncertainties that may exist when the document is prepared.

Review Elements:

☐ When a TMDL involves both NPDES permitted point source(s) and nonpoint source(s) allocations, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document should include a monitoring plan that describes the additional data to be collected to determine if the load reductions provided for in the TMDL are occurring.

☐ Under certain circumstances, a phased TMDL approach may be utilized when limited existing data are relied upon to develop a TMDL, and the State believes that the use of additional data or data based on better analytical techniques would likely increase the accuracy of the TMDL load calculation and merit development of a second phase TMDL. EPA recommends that a phased TMDL document or its implementation plan include a monitoring plan and a scheduled timeframe for revision of the TMDL. These elements would not be an intrinsic part of the TMDL and would not be approved by EPA, but may be necessary to support a rationale for approving the TMDL. http://www.epa.gov/owow/tmdl/tmdl_clarification_letter.pdf

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *After implementation of the recommended best management practices, monitoring will be necessary to ensure attainment of the TMDLs within the Big Horn River watershed. The conservation districts have been monitoring key locations in the watershed to collect the data needed to evaluate the progress towards meeting the geometric mean E. coli criteria. The monitoring data is needed to ensure that the goals of the Big Horn River watershed TMDL will be met if the implementation efforts continue as planned. Additional monitoring recommendations are included in Section 6.0 of the TMDL document.*

Comments: *None.*

7. Restoration Strategy

The overall purpose of the TMDL analysis is to determine what actions are necessary to ensure that the pollutant load in a waterbody does not result in water quality impairment. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document. During the TMDL analytical process, information is often gained that may serve to point restoration efforts in the right direction and help ensure that resources are spent in the most efficient manner possible. For example, watershed models used to analyze the linkage between the pollutant loading rates and resultant water quality impacts might also be used to conduct "what if" scenarios to help direct BMP installations to locations that provide the greatest pollutant reductions. Once a TMDL has been written and approved, it is often the responsibility of other water quality programs to see that it is implemented. The level of quality and detail provided in the restoration strategy will greatly influence the future success in achieving the needed pollutant load reductions.

Review Elements:

☐ EPA is not required to and does not approve TMDL implementation plans. However, in cases where a WLA is dependent upon the achievement of a LA, "reasonable assurance" is required to demonstrate the necessary LA called for in the document is practicable). A discussion of the BMPs (or other load reduction measures) that are to be relied upon to achieve the LA(s), and programs and funding sources that will be relied upon to implement the load reductions called for in the document, may be included in the implementation/restoration section of the TMDL document to support a demonstration of "reasonable assurance".

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *A variety of BMPs were considered for purposes of developing a water-quality management implementation plan for the Big Horn River watershed. The control measures listed below are recommended to address the nonpoint sources identified in the source assessment section of the TMDL. Based on water-quality monitoring and HSPF model results, it is likely that the recommended control measures would achieve the required load reductions and attain the TMDL E. coli targets for the impaired stream segments in the Big Horn River watershed.*

The eight incremental management scenarios that were simulated for each bacteria impaired segment using the HSPF model include the following:
1. 100 percent removal of failing on-site wastewater treatment systems (septics)
2. 75 percent removal of direct defecation
3. Conversion of existing surface irrigated fields to sprinkler
4. 90 percent removal of cropland loading
5. 90 percent removal of riparian loading
6. 90 percent removal of rangeland loading
7. 75 percent removal of urban/residential loading
8. 90 percent removal of forest loading.

Cumulative and individual percent reductions of the total load expected from BMP implementation, based on model results, are provided in Table 7-1 of the TMDL document for each impaired stream segment. Table 7-2 provides the cumulative percent load reduction and the load reductions percentages necessary to meet the TMDL for each impaired reach. In general, the control practices with the greatest E. coli reduction potential in the watershed are removing rangeland loading and increasing irrigation efficiency. Repairing or replacing septic systems, reducing direct defecation and reducing forest loadings are predicted to have a minimal impact in reducing overall E. coli loadings to the impaired stream segments.

Comments: *None.*

8. Daily Loading Expression

The goal of a TMDL analysis is to determine what actions are necessary to attain and maintain WQS. The appropriate averaging period that corresponds to this goal will vary depending on the pollutant and the nature of the waterbody under analysis. When selecting an appropriate averaging period for a TMDL analysis, primary concern should be given to the nature of the pollutant in question and the achievement of the underlying WQS. However, recent federal appeals court decisions have pointed out that the title TMDL implies a "daily" loading rate. While the most appropriate averaging period to be used for developing a TMDL analysis may vary according to the pollutant, a daily loading rate can provide a more practical indication of whether or not the overall needed load reductions are being achieved. When limited monitoring resources are available, a daily loading target that takes into account the natural variability of the system can serve as a useful indicator for whether or not the overall load reductions are likely to be met. Therefore, a daily expression of the required pollutant loading rate is a required element in all TMDLs, in addition to any other load averaging periods that may have been used to conduct the TMDL analysis. The level of effort spent to develop the daily load indicator should be based on the overall utility it can provide as an indicator for the total load reductions needed.

Review Elements:

☒ The document should include an expression of the TMDL in terms of a daily load. However, the TMDL may also be expressed in temporal terms other than daily (e.g., an annual or monthly load). If the document expresses the TMDL in additional "non-daily" terms the document should explain why it is appropriate or advantageous to express the TMDL in the additional unit of measurement chosen.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The Big Horn River watershed TMDL document includes daily loads for E. coli expressed as colony forming units per day for the listed stream segments in the watershed. The daily TMDL loads for each segment are included in the Load Duration Curves / Total Maximum Daily Loads Tables section (Section 3.5) of the document.*

Comments: *None.*