RECLAMATION

Managing Water in the West

Arkansas Valley Conduit and Long-Term Excess Capacity Master Contract

DRAFT ENVIRONMENTAL IMPACT STATEMENT

DES12-39

APPENDICES: VOLUME 2

Prepared by:
United States Department of the Interior
Bureau of Reclamation
Great Plains Region
Eastern Colorado Area Office

August 2012

ARKANSAS VALLEY CONDUIT AND LONG-TERM EXCESS CAPACITY MASTER CONTRACT DRAFT ENVIRONMENTAL IMPACT STATEMENT

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Appendices - Volume 2

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Appendix E.1 - Alluvial Groundwater Effects

Introduction

Appendix E.1 supplements the Chapter 4 – *Groundwater Hydrology* section in the EIS. This appendix contains further information on methodology and quantitative effects of alternatives on alluvial aquifers in the Upper Arkansas River and Fountain Creek basins. Groundwater levels could be affected by changes in groundwater pumping and changes in river stage. Methodology and effects for the Lower Arkansas River Basin are in Appendix F.3.

Groundwater Effects Related to Pumping

Methods and groundwater effects related to alluvial pumping changes are described in this section. Alluvial groundwater pumping effects analyses were completed for four aquifers in the Upper Arkansas River and Fountain Creek basins: the Upper Arkansas River Aquifer, Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer (Figure 1).

Methods

The analysis used a steady state (i.e., groundwater effects reach an equilibrium and do not change with time) equation for groundwater flow to a well. Average annual groundwater pumping rates, as well as rates for normal, dry, and wet years, were used in the equation to evaluate annual groundwater levels. The alluvial aquifers were assumed to remain hydraulically connected with the river to provide a constant water supply, consistent with studies done in the region (Survey 2003). Equation 1 (Dietz 1943) was used to simulate steady state drawdown:

Equation 1

$$s = \frac{Q}{2\pi K b} G(x, y)$$

Where,

s = drawdown at a point (x,y)
Q = volumetric pumping rate (gpd)
K is the aquifer hydraulic conductivity (ft/d)
b = saturated thickness of the aquifer (ft)
G(x,y) = Green’s function for the aquifers boundary conditions.

The river was represented as a single linear boundary condition for the analysis, yielding the following form of Green's function (Equation 2):

Equation 2

$$G(x,y) = \frac{1}{2}\ln\frac{(x_1 + x_w)^2 + (y_1 - y_w)^2}{(x_1 - x_w)^2 + (y_1 - y_w)^2}$$

Where,

x_1 and y_1 = coordinates of the observation point in the aquifer
x_w and y_w = coordinates of the pumping well.

The aquifer was assumed to be homogeneous (aquifer hydraulic conductivity and thickness was assumed to be constant throughout) because of data limitations. This approach is consistent with previous studies of the region (Reclamation 2008). The assumed hydraulic conductivity and thickness for the aquifers are summarized in Table 1.

Table 1. Assumed Homogeneous Aquifer Properties

Aquifer	Saturated Thickness (feet)	Hydraulic Conductivity (feet/day)
Upper Arkansas River Aquifer	100(1)	280(4)
Fountain Creek Aquifer	50(2)	480(3)
Widefield Aquifer	25(3)	830(3)
Windmill Gulch Aquifer	25(3)	830(3)

Notes: Above parameters were found at the following sources:
(1) Survey 2003
(2) Reclamation 2008
(3) Steve Smith 2006
(4) Watts 2005

Since the number and location of pumping wells in each aquifer was unknown, a single hypothetical well 400 feet from the river was assumed to pump the water for each region. By assuming a single pumping well, the worst case scenario (i.e. greatest possible change in drawdown) for groundwater pumping from each region was assessed, and the assumption is consistent with previous studies (Reclamation 2008). An aptly designed well field with multiple, properly spaced wells would have less drawdown than those shown in this analysis.

A pumping rate was estimated for a typical dry, wet, and normal year within the study period, as well as an overall average pumping rate for the years 1982-2009. Total pumping per year was calculated for each alternative using the Daily Model results. The total pumping for each aquifer under each alternative is summarized in Table 2 and Table 3. Pumping becomes greater during dry years than during wet years. This is because demand can be met with surface water supplies during wet years, and groundwater pumping is not needed. During dry and normal years, groundwater pumping is needed to meet water demands in these regions (see Appendix D.4).

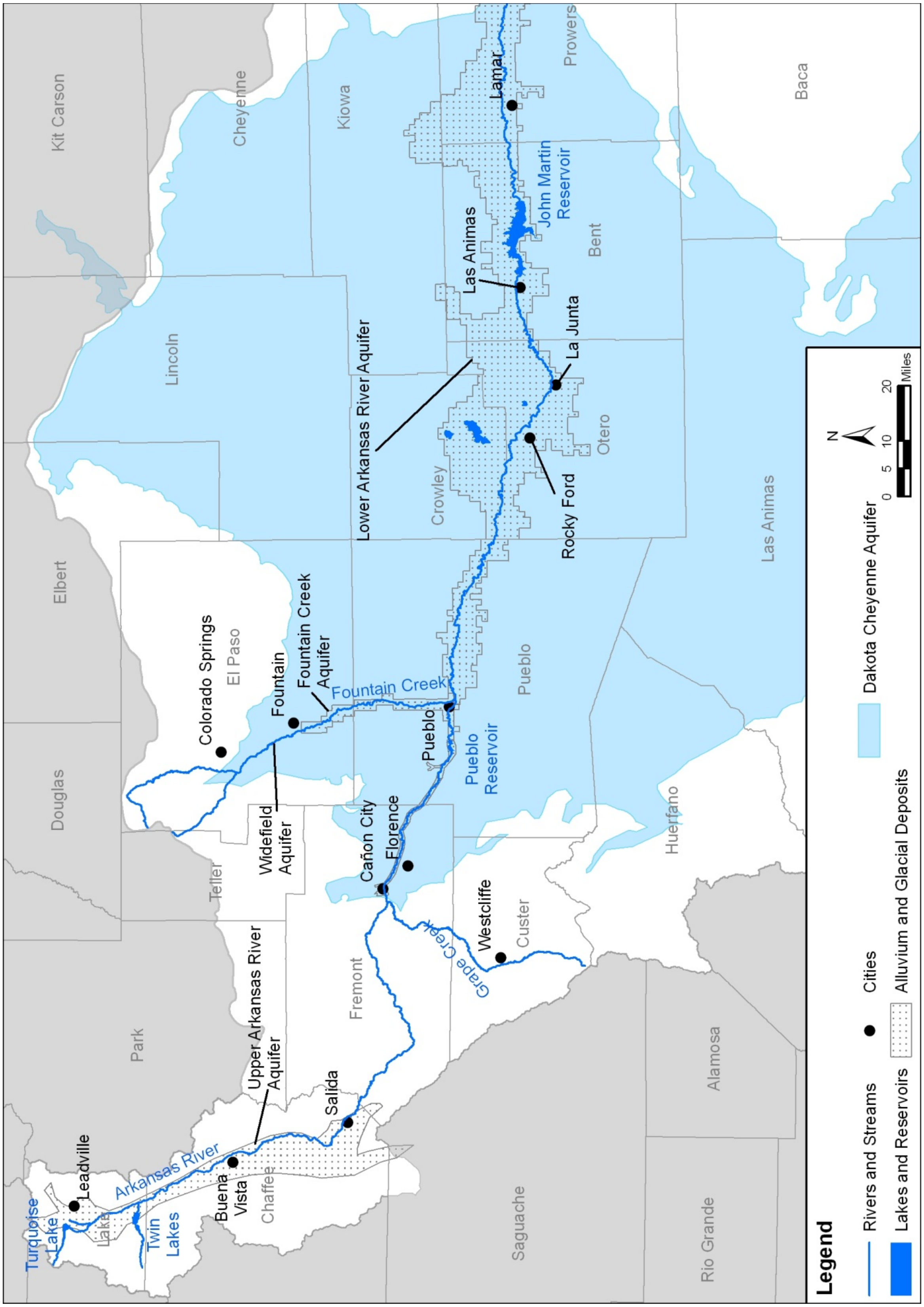


Figure 1. Groundwater Study Area

Effects were reported based on the highest amount of drawdown, which occurs next to the assumed well, 400 feet from the river. Farther from the well, impacts to the aquifer from pumping diminish. An example of such a drawdown cone is shown in Figure 2.

Water table level changes can increase risk of basement flooding in residential homes, especially in residential areas with water table depths less than 10 feet. Additional analysis of the Fountain Creek Alluvial Aquifer quantified homes that could be at risk from rising groundwater conditions.

Data from current water well applications received by the state engineer was obtained from the Colorado Division of Water Resources (DWR). From these records water levels were interpolated by finding the closest subset of wells with static water level data to a point and applying a weight based on proportionate areas.

Table 2. Annual Alluvial Pumping – Direct Effects

Aquifer	Existing Condition	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Overall Average Alluvial Pumping (acre-feet/year)[(1)]								
Upper Arkansas River Aquifer	2,144	4,279	4,279	4,279	4,279	4,279	4,279	4,279
Fountain Creek Aquifer	0	1,718	259	241	1,372	264	295	344
Widefield Aquifer	0	534	169	153	424	169	179	225
Windmill Gulch Aquifer	0	117	51	51	96	52	60	60
Dry Year Alluvial Pumping (acre-feet/year) [(1)]								
Upper Arkansas River Aquifer	2,160	4,314	4,314	4,314	4,314	4,314	4,314	4,314
Fountain Creek Aquifer	0	7,316	3,658	3,113	7,316	3,663	3,669	3,706
Widefield Aquifer	0	2,602	1,410	951	2,603	1,411	1,584	1,938
Windmill Gulch Aquifer	0	240	240	240	240	240	240	240
Normal Year Alluvial Pumping (acre-feet/year) [(1)]								
Upper Arkansas River Aquifer	2,155	4,303	4,303	4,303	4,303	4,303	4,303	4,303
Fountain Creek Aquifer	0	4,006	927	904	3,882	971	929	1,066
Widefield Aquifer	0	1,291	746	742	1,241	736	738	778
Windmill Gulch Aquifer	0	240	240	240	240	240	240	240
Wet Year Alluvial Pumping (acre-feet/year) [(1)]								
Upper Arkansas River Aquifer	2,155	4,303	4,303	4,303	4,303	4,303	4,303	4,303
Fountain Creek Aquifer	0	0	0	0	0	0	0	0
Widefield Aquifer	0	0	0	0	0	0	0	0
Windmill Gulch Aquifer	0	0	0	0	0	0	0	0

Notes:
(1) Data is from the Daily Model analysis (Appendix D.4).

Table 3. Annual Alluvial Pumping – Cumulative Effects

Aquifer	Existing Condition	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Overall Average Alluvial Pumping (acre-feet/year) [(1)]								
Upper Arkansas River Aquifer	2,144	4,279	4,279	4,279	4,279	4,279	4,279	4,279
Fountain Creek Aquifer	0	2,399	1,831	1,817	2,415	1,835	1,874	1,815
Widefield Aquifer	0	1,087	810	797	1,078	810	830	809
Windmill Gulch Aquifer	0	157	154	150	154	154	154	154
Dry Year Alluvial Pumping (acre-feet/year) [(1)]								
Upper Arkansas River Aquifer	2,160	4,314	4,314	4,314	4,314	4,314	4,314	4,314
Fountain Creek Aquifer	0	6,216	4,928	4,928	6,217	4,928	5,045	4,958
Widefield Aquifer	0	2,879	2,252	2,252	2,872	2,252	2,276	2,255
Windmill Gulch Aquifer	0	240	240	240	240	240	240	240
Normal Year Alluvial Pumping (acre-feet/year) [(1)]								
Upper Arkansas River Aquifer	2,155	4,303	4,303	4,303	4,303	4,303	4,303	4,303
Fountain Creek Aquifer	0	4,094	3,202	3,179	4,041	3,166	3,206	3,200
Widefield Aquifer	0	2,001	1,498	1,476	1,977	1,475	1,496	1,497
Windmill Gulch Aquifer	0	240	240	240	240	240	240	240
Wet Year Alluvial Pumping (acre-feet/year) [(1)]								
Upper Arkansas River Aquifer	2,155	4,303	4,303	4,303	4,303	4,303	4,303	4,303
Fountain Creek Aquifer	0	0	0	0	0	0	0	0
Widefield Aquifer	0	0	0	0	0	0	0	0
Windmill Gulch Aquifer	0	0	0	0	0	0	0	0

Notes:
(1) Data is from the Daily Model analysis (Appendix D.4).

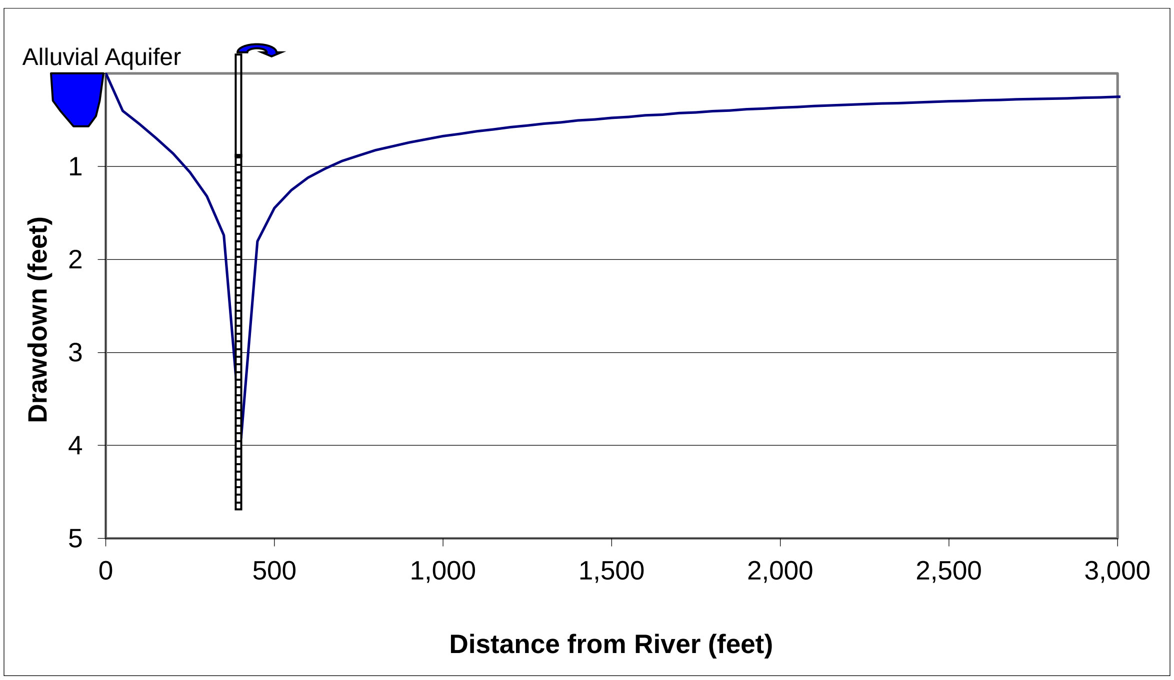


Figure 1. Example Drawdown Cone in an Alluvial Aquifer

Results

Groundwater effects are presented in tabular format for an overall average, dry, wet, and normal years for each aquifer in the study area (Table 4 to Table 11). Effects were calculated for both direct and cumulative effects.

Groundwater pumping in all alternatives would not affect Upper Arkansas River Aquifer groundwater levels for direct and cumulative effects, compared to the No Action. The No Action Alternative would decrease water table levels, compared to existing conditions, because of additional groundwater pumping to meet future municipal demand by Master Contract participants.

Groundwater pumping in all alternatives would generally increase groundwater levels (decrease drawdown) in the Fountain Creek Basin alluvial aquifers (Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer) for direct and cumulative effects, compared to the No Action. During a typical wet year pumping would not be needed in all alternatives, including the No Action, since demand would be met from other sources, and would not affect groundwater levels. During normal and dry years there would be a greater need for groundwater pumping for most action alternatives when compared with wet years, with the exception of the JUP North Alternative. The No Action Alternative would decrease water table levels, compared to existing conditions, because of additional groundwater pumping demand.

All alternatives would not affect basement flooding in the Fountain Creek Basin. Regions that have the possibility of being affected by rising groundwater levels have water table levels within 10 feet of the surface. A map of the water table levels for the Fountain Creek Basin was constructed from well data (Figure 3). As can be seen from the map, only 6 percent of the Fountain Creek Alluvial Aquifer has a water table within 10 feet of the ground surface. Of this 6 percent, approximately 46 percent lies below municipal areas. Despite the shallow water level in these locations, the results show that while the action alternatives would increase water table levels, compared to the No Action, levels would still be at or below existing conditions and would not increase basement flooding risk in existing residential areas.

Table 4. Overall Average Groundwater Pumping Effects on Groundwater Levels – Direct Effects

Aquifer	Existing Condition (1)	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Drawdown (2) (feet)								
Upper Arkansas River Aquifer	9.72	19.41	19.41	19.41	19.41	19.41	19.41	19.41
Fountain Creek Aquifer	0.00	9.09	1.37	1.27	7.26	1.40	1.56	1.82
Widefield Aquifer	0.00	3.27	1.04	0.93	2.60	1.04	1.09	1.37
Windmill Gulch Aquifer	0.00	0.71	0.31	0.31	0.59	0.32	0.37	0.37
Effects – Change in Drawdown (3) [feet) (%)] (No Action Baseline)								
Upper Arkansas River Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fountain Creek Aquifer	---	---	-7.72 (-84.9%)	-7.82 (-86%)	-1.83 (-20.2%)	-7.69 (-84.6%)	-7.53 (-82.8%)	-7.27 (-80%)
Widefield Aquifer	---	---	-2.23 (-68.3%)	-2.33 (-71.4%)	-0.67 (-20.6%)	-2.23 (-68.3%)	-2.17 (-66.5%)	-1.89 (-58%)
Windmill Gulch Aquifer	---	---	-0.4 (-55.9%)	-0.4 (-55.9%)	-0.13 (-18%)	-0.4 (-55.7%)	-0.35 (-48.6%)	-0.35 (-48.6%)
Effects – Change in Drawdown [feet) (%] (Existing Conditions Baseline)								
Upper Arkansas River Aquifer	---	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---

Notes:
(1) Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer do not have Existing Conditions effects because simulated Existing Conditions drawdown is 0 ft.
(2) Drawdown is shown at the well 400 ft. from the river.
(3) Negative effects are to be interpreted as a decrease in drawdown, or an increase in groundwater levels.

Table 5. Normal Year Groundwater Pumping Effects on Groundwater Levels – Direct Effects

Aquifer	Existing Condition (1)	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Drawdown (2) (feet)								
Upper Arkansas River Aquifer	9.77	19.52	19.52	19.52	19.52	19.52	19.52	19.52
Fountain Creek Aquifer	0.00	21.20	4.91	4.78	20.54	5.14	4.91	5.64
Widefield Aquifer	0.00	7.90	4.57	4.54	7.60	4.50	4.51	4.76
Windmill Gulch Aquifer	0.00	1.47	1.47	1.47	1.47	1.47	1.47	1.47
Effects – Change in Drawdown (3) [feet) (%)] (No Action Baseline)								
Upper Arkansas River Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fountain Creek Aquifer	---	---	-16.29 (-76.8%)	-16.41 (-77.4%)	-0.66 (-3.1%)	-16.06 (-75.8%)	-16.28 (-76.8%)	-15.55 (-73.4%)
Widefield Aquifer	---	---	-3.33 (-42.2%)	-3.36 (-42.5%)	-0.3 (-3.8%)	-3.4 (-43%)	-3.38 (-42.9%)	-3.14 (-39.7%)
Windmill Gulch Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Effects – Change in Drawdown [feet) (%] (Existing Conditions Baseline)								
Upper Arkansas River Aquifer	---	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---

Notes:
(1) Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer do not have Existing Conditions effects because simulated Existing Conditions drawdown is 0 ft.
(2) Drawdown is shown at the well 400 ft. from the river.
(3) Negative effects are to be interpreted as a decrease in drawdown, or an increase in groundwater levels.

Table 6. Dry Year Groundwater Pumping Effects on Groundwater Levels – Direct Effects

Aquifer	Existing Condition [1]	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Drawdown [2] (feet)								
Upper Arkansas River Aquifer	9.80	19.57	19.57	19.57	19.57	19.57	19.57	19.57
Fountain Creek Aquifer	0.00	33.33	19.36	16.47	33.33	19.38	19.41	19.61
Widefield Aquifer	0.00	15.93	8.63	5.82	15.93	8.63	9.70	11.86
Windmill Gulch Aquifer	0.00	1.47	1.47	1.47	1.47	1.47	1.47	1.47
Effects – Change in Drawdown [3] [feet) (%)] (No Action Baseline)								
Upper Arkansas River Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fountain Creek Aquifer	---	---	-13.98 (-41.9%)	-16.86 (-50.6%)	0 (0%)	-13.95 (-41.8%)	-13.92 (-41.8%)	-13.73 (-41.2%)
Widefield Aquifer	---	---	-7.3 (-45.8%)	-10.11 (-63.5%)	0 (0%)	-7.29 (-45.8%)	-6.23 (-39.1%)	-4.06 (-25.5%)
Windmill Gulch Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Effects – Change in Drawdown [feet) (%] (Existing Conditions Baseline)								
Upper Arkansas River Aquifer	---	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---

Notes:

(1) Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer do not have Existing Conditions effects because simulated Existing Conditions drawdown is 0 ft.

(2) Drawdown is shown at the well 400 ft. from the river.

(3) Negative effects are to be interpreted as a decrease in drawdown, or an increase in groundwater levels.

Table 7. Wet Year Groundwater Pumping Effects on Groundwater Levels – Direct Effects

Aquifer	Existing Condition [1]	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Drawdown [2] (feet)								
Upper Arkansas River Aquifer	9.77	19.52	19.52	19.52	19.52	19.52	19.52	19.52
Fountain Creek Aquifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Widefield Aquifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Windmill Gulch Aquifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Effects – Change in Drawdown [3] [feet) (%)] (No Action Baseline)								
Upper Arkansas River Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---
Effects – Change in Drawdown [feet) (%] (Existing Conditions Baseline)								
Upper Arkansas River Aquifer	---	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---

Notes:

(1) Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer do not have Existing Conditions effects because simulated Existing Conditions drawdown is 0 ft.

(2) Drawdown is shown at the well 400 ft. from the river.

(3) Negative effects are to be interpreted as a decrease in drawdown, or an increase in groundwater levels.

Table 8. Overall Average Groundwater Pumping Effects on Groundwater Levels – Cumulative Effects

Aquifer	Existing Condition (1)	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Drawdown (2) (feet)								
Upper Arkansas River Aquifer	9.72	19.41	19.41	19.41	19.41	19.41	19.41	19.41
Fountain Creek Aquifer	0.00	12.70	9.69	9.61	12.78	9.71	9.91	9.60
Widefield Aquifer	0.00	6.66	4.95	4.88	6.60	4.96	5.08	4.95
Windmill Gulch Aquifer	0.00	0.96	0.94	0.92	0.94	0.94	0.94	0.94
Effects – Change in Drawdown (3) [feet) (%)] (No Action Baseline)								
Upper Arkansas River Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fountain Creek Aquifer	---	---	-3.01 (-23.7%)	-3.08 (-24.3%)	0.08 (0.6%)	-2.99 (-23.5%)	-2.78 (-21.9%)	-3.09 (-24.4%)
Widefield Aquifer	---	---	-1.7 (-25.6%)	-1.78 (-26.7%)	-0.06 (-0.9%)	-1.7 (-25.5%)	-1.58 (-23.7%)	-1.7 (-25.6%)
Windmill Gulch Aquifer	---	---	-0.02 (-1.6%)	-0.04 (-4.3%)	-0.02 (-1.6%)	-0.02 (-1.6%)	-0.02 (-1.6%)	-0.02 (-1.6%)
Effects – Change in Drawdown [feet) (%] (Existing Conditions Baseline)								
Upper Arkansas River Aquifer	---	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)	9.68 (99.6%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---

Notes:
(1) Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer do not have Existing Conditions effects because simulated Existing Conditions drawdown is 0 ft.
(2) Drawdown is shown at the well 400 ft. from the river.
(3) Negative effects are to be interpreted as a decrease in drawdown, or an increase in groundwater levels.

Table 9. Normal Year Groundwater Pumping Effects on Groundwater Levels – Cumulative Effects

Aquifer	Existing Condition [1]	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Drawdown [2] (feet)								
Upper Arkansas River Aquifer	9.77	19.52	19.52	19.52	19.52	19.52	19.52	19.52
Fountain Creek Aquifer	0.00	21.66	16.94	16.82	21.38	16.75	16.96	16.93
Widefield Aquifer	0.00	12.25	9.17	9.03	12.10	9.03	9.15	9.16
Windmill Gulch Aquifer	0.00	1.47	1.47	1.47	1.47	1.47	1.47	1.47
Effects – Change in Drawdown [3] [feet) (%)] (No Action Baseline)								
Upper Arkansas River Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fountain Creek Aquifer	---	---	-4.72 (-21.8%)	-4.84 (-22.3%)	-0.28 (-1.3%)	-4.91 (-22.7%)	-4.7 (-21.7%)	-4.73 (-21.8%)
Widefield Aquifer	---	---	-3.08 (-25.2%)	-3.22 (-26.3%)	-0.15 (-1.2%)	-3.22 (-26.3%)	-3.09 (-25.3%)	-3.08 (-25.2%)
Windmill Gulch Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Effects – Change in Drawdown [feet) (%] (Existing Conditions Baseline)								
Upper Arkansas River Aquifer	---	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---

Notes:

(1) Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer do not have Existing Conditions effects because simulated Existing Conditions drawdown is 0 ft.

(2) Drawdown is shown at the well 400 ft. from the river.

(3) Negative effects are to be interpreted as a decrease in drawdown, or an increase in groundwater levels.

Table 10. Dry Year Groundwater Pumping Effects on Groundwater Levels – Cumulative Effects

Aquifer	Existing Condition [1]	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Drawdown [2] (feet)								
Upper Arkansas River Aquifer	9.80	19.57	19.57	19.57	19.57	19.57	19.57	19.57
Fountain Creek Aquifer	0.00	32.89	26.08	26.07	32.90	26.07	26.70	26.23
Widefield Aquifer	0.00	16.67	13.78	13.78	16.67	13.78	13.93	13.80
Windmill Gulch Aquifer	0.00	1.47	1.47	1.47	1.47	1.47	1.47	1.47
Effects – Change in Drawdown [3] [feet) (%)] (No Action Baseline)								
Upper Arkansas River Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fountain Creek Aquifer	---	---	-6.81 (-20.7%)	-6.81 (-20.7%)	0.01 (0%)	-6.81 (-20.7%)	-6.19 (-18.8%)	-6.65 (-20.2%)
Widefield Aquifer	---	---	-2.88 (-17.3%)	-2.89 (-17.3%)	0 (0%)	-2.89 (-17.3%)	-2.73 (-16.4%)	-2.87 (-17.2%)
Windmill Gulch Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Effects – Change in Drawdown [feet) (%] (Existing Conditions Baseline)								
Upper Arkansas River Aquifer	---	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)	9.77 (99.7%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---

Notes:

(1) Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer do not have Existing Conditions effects because simulated Existing Conditions drawdown is 0 ft.

(2) Drawdown is shown at the well 400 ft. from the river.

(3) Negative effects are to be interpreted as a decrease in drawdown, or an increase in groundwater levels.

Table 11. Wet Year Groundwater Pumping Effects on Groundwater Levels – Cumulative Effects

Aquifer	Existing Condition [1]	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Drawdown [2] (feet)								
Upper Arkansas River Aquifer	9.77	19.52	19.52	19.52	19.52	19.52	19.52	19.52
Fountain Creek Aquifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Widefield Aquifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Windmill Gulch Aquifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Effects – Change in Drawdown [3] [feet) (%)] (No Action Baseline)								
Upper Arkansas River Aquifer	---	---	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---
Effects – Change in Drawdown [feet) (%] (Existing Conditions Baseline)								
Upper Arkansas River Aquifer	---	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)	9.74 (99.7%)
Fountain Creek Aquifer	---	---	---	---	---	---	---	---
Widefield Aquifer	---	---	---	---	---	---	---	---
Windmill Gulch Aquifer	---	---	---	---	---	---	---	---

Notes:

(1) Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer do not have Existing Conditions effects because simulated Existing Conditions drawdown is 0 ft.

(2) Drawdown is shown at the well 400 ft. from the river.

(3) Negative effects are to be interpreted as a decrease in drawdown, or an increase in groundwater levels.

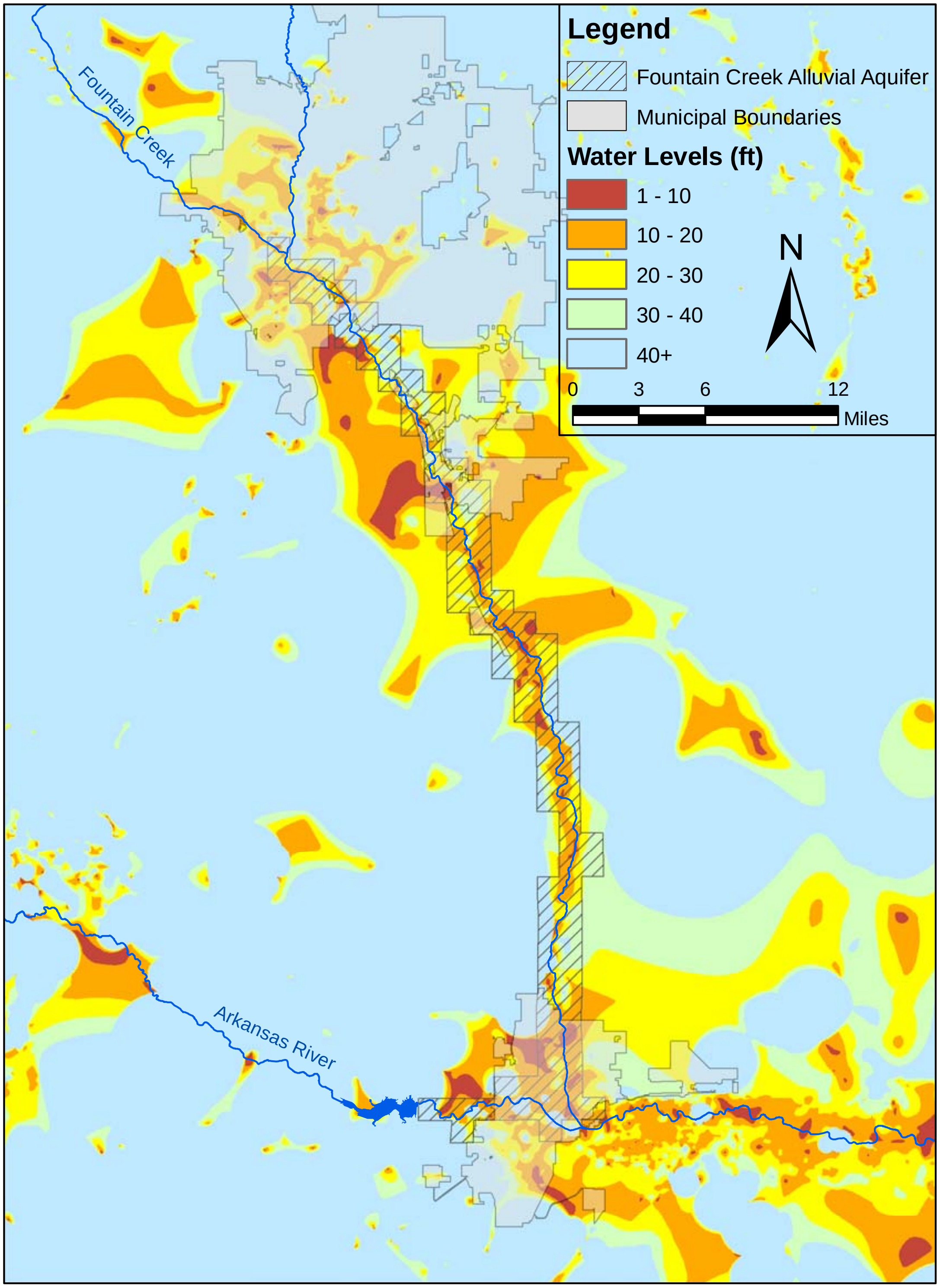


Figure 2. Map of Groundwater Depths in the Fountain Creek Alluvial Aquifer

Groundwater Effects Related to Changes in River Stage

Methods and groundwater effects related to river stage (elevation) changes are described in this section. Effects analyses were completed for four aquifers in the Upper Arkansas River and Fountain Creek basins: the Upper Arkansas River Aquifer, Fountain Creek Aquifer, Widefield Aquifer, and Windmill Gulch Aquifer.

Methods

Effects of changes in river levels on alluvial groundwater levels were calculated at several streamflow gage locations on the Upper Arkansas River and Fountain Creek basins, including the Arkansas River near Wellsville (07093700), Arkansas River above Pueblo (07099400), Fountain Creek at Security (07105800), and Fountain Creek at Pueblo (07106500).

Groundwater levels at each location were calculated assuming steady flow (does not change with time) in an unconfined aquifer. An equation for head in an unconfined aquifer was derived using Darcy's Law for groundwater and the Dupuit assumptions (the change in head is equal to the slope of the water table and for small changes in head the aquifer is horizontal). Applying Darcy's Law to a section of unconfined aquifer with steady one-dimensional groundwater flow in a direction perpendicular to the surface yields the following steady state equation (Fetter 1988):

Equation 3

$$h^2 = h_1^2 - \frac{(h_1^2 - h_2^2)x}{L} + \frac{W}{K}(L - x)x$$

Where,

h = head in the aquifer at a distance x from the river (ft)
h_1 and h_2 = head in the aquifer at a distance of 0 and L from the river (ft)
W = net volumetric rate of addition or withdrawal of water from the aquifer (e.g. infiltration, evaporation, or alluvial groundwater pumping (gpd)
K = hydraulic conductivity of the alluvial aquifer material. (ft/d)

Head in the aquifer at the river (distance of 0) was calculated by adding the saturated thickness of the aquifer to the average monthly river stage. The average monthly river stage was calculated from Daily Model output. At distance L the head in the aquifer was assumed to be equal to the saturated thickness of the aquifer.

Evapotranspiration, groundwater recharge, and groundwater discharge from the alluvial aquifer were assumed to remain the same throughout the analysis. In addition, since pumping was considered separately in the previous analysis, W was set equal to 0 at all locations. These assumptions allow effects to be assessed for just river level changes, as the second term in the equation drops out. The aquifer was assumed to be isotropic (uniform in all orientations), have a uniform thickness, and homogeneous (same properties throughout), consistent with prior studies (Reclamation 2008). The assumed hydraulic conductivity and aquifer thickness, and aquifer width at each location are summarized in Table 12.

Table 12. Aquifer Properties at Gage Locations

Gage Location	Aquifer Width (feet)	Saturated Thickness (feet)	Hydraulic Conductivity (feet/day)
Arkansas River Near Wellsville (07093700)	5092[1]	100[3]	280[2]
Arkansas River Above Pueblo (07099400)	6427[4]	250[4]	530[3]
Fountain Creek At Security (07105800)	8054[4]	25[4]	830[4]
Fountain Creek At Pueblo (07106500)	11275[4]	40[4]	1000[4]

Notes: Above Parameters were found at the following sources:
(1) CDSS Map Viewer
(2) Watts 2005
(3) Survey 2003
(4) Steve Smith 2006

Results

Groundwater effects caused by changes in river levels are presented in tabular format for an overall monthly average simulated head for each gage (Table 13 to Table 20). Effects were calculated for both direct and cumulative effects. In general, changes in river stage would not affect groundwater levels for all alternatives, compared to No Action. Changes would also be negligible in dry, wet, and normal years. The No Action Alternative, compared to the existing conditions, would not significantly change groundwater levels.

Table 13. Overall Average Effects of River Levels on Groundwater at the Fountain Creek At Security Gage – Direct Effects

Month	Existing Conditions	No Action		Comanche South		Pueblo Dam South		JUP North		Pueblo Dam North		River South		Master Contract Only	
Simulated Head in Aquifer (feet)															
Jan	25.7	25.8		25.8		25.8		25.8		25.8		25.8		25.8	
Feb	25.8	25.8		25.8		25.8		25.8		25.8		25.8		25.8	
Mar	25.9	25.9		25.9		25.9		25.9		25.9		25.9		25.9	
Apr	26.0	26.0		26.0		26.0		26.0		26.0		26.0		26.0	
May	26.2	26.2		26.2		26.2		26.2		26.2		26.2		26.2	
Jun	26.1	26.1		26.1		26.1		26.1		26.1		26.1		26.1	
Jul	26.0	26.0		26.0		26.0		26.0		26.0		26.0		26.0	
Aug	26.1	26.1		26.1		26.1		26.1		26.1		26.1		26.1	
Sep	25.8	25.8		25.8		25.8		25.8		25.8		25.8		25.8	
Oct	25.8	25.8		25.8		25.8		25.8		25.8		25.8		25.8	
Nov	25.8	25.8		25.8		25.8		25.8		25.8		25.8		25.8	
Dec	25.7	25.7		25.7		25.7		25.7		25.7		25.7		25.7	
Average	25.9	25.9		25.9		25.9		25.9		25.9		25.9		25.9	
Effects - Simulated Drawdown (feet) (%) (No Action Alternative Baseline)															
No Measureable Effects															
Effects - Simulated Drawdown (feet) (%) (Existing Conditions Baseline)															
Jan	---	0.0	(0.0)	0.0	(0.1)	0.0	(0.1)	0.0	(0.0)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)
Feb	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Mar	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Apr	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
May	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Jun	---	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)
Jul	---	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)
Aug	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Sep	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Oct	---	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)
Nov	---	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)
Dec	---	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)	0.0	(0.1)
Average	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)

Table 14. Overall Average Effects of River Levels on Groundwater at the Fountain Creek At Pueblo Gage – Direct Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Head in Aquifer (feet)								
Jan	41.8	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Feb	41.9	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Mar	41.9	41.9	42.0	42.0	41.9	42.0	42.0	42.0
Apr	41.9	41.9	41.9	41.9	41.9	41.9	41.9	41.9
May	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0
Jun	41.9	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Jul	41.6	41.7	41.7	41.7	41.7	41.7	41.7	41.7
Aug	41.9	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Sep	41.6	41.6	41.6	41.6	41.6	41.6	41.6	41.6
Oct	41.8	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Nov	41.9	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Dec	41.8	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Average	41.8	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Effects - Simulated Drawdown (feet) (%) (No Action Alternative Baseline)								
Jan	---	---	0.0 (0.1)	0.0 (0.1)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Feb	---	---	0.0 (0.1)	0.0 (0.1)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Mar	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Apr	---	---	0.0 (0.1)	0.0 (0.1)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
May	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jun	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jul	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Aug	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Sep	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Oct	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Nov	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dec	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Average	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Effects - Simulated Drawdown (feet) (%) (Existing Conditions Baseline)								
Jan	---	0.0 (0.1)	0.1 (0.2)	0.1 (0.2)	0.0 (0.1)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Feb	---	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Mar	---	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Apr	---	0.0 (0.1)	0.1 (0.2)	0.1 (0.2)	0.0 (0.1)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
May	---	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
Jun	---	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Jul	---	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
Aug	---	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Sep	---	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Oct	---	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Nov	---	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
Dec	---	0.1 (0.1)	0.1 (0.2)	0.1 (0.2)	0.1 (0.1)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Average	---	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)

Table 15. Overall Average Effects of River Levels on Groundwater at the Arkansas River Near Wellsville Gage – Direct Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Head in Aquifer (feet)								
Jan	103.4	103.4	103.4	103.4	103.4	103.4	103.4	103.4
Feb	103.3	103.3	103.2	103.2	103.3	103.2	103.2	103.2
Mar	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2
Apr	103.2	103.2	103.2	103.2	103.3	103.2	103.2	103.2
May	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4
Jun	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7
Jul	104.8	104.8	104.8	104.8	104.8	104.8	104.8	104.8
Aug	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1
Sep	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5
Oct	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5
Nov	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5
Dec	103.4	103.4	103.4	103.4	103.4	103.4	103.4	103.4
Average	103.8	103.8	103.8	103.8	103.8	103.8	103.8	103.8
Effects - Simulated Drawdown (feet) (%) (No Action Alternative Baseline)								
No Measureable Effects								
Effects - Simulated Drawdown (feet) (%) (Existing Conditions Baseline)								
No Measureable Effects								

Table 16. Overall Average Effects of River Levels on Groundwater at the Arkansas River Above Pueblo Gage – Direct Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Head in Aquifer (feet)								
Jan	252.0	252.0	252.0	252.0	252.0	252.0	252.0	252.0
Feb	252.1	252.1	252.0	252.0	252.0	252.0	252.1	252.0
Mar	252.3	252.3	252.2	252.2	252.2	252.2	252.3	252.2
Apr	253.0	252.9	252.9	252.9	252.9	252.9	252.9	252.9
May	253.9	253.9	253.8	253.8	253.8	253.8	253.9	253.9
Jun	255.1	255.0	255.0	255.0	255.0	255.0	255.1	255.1
Jul	254.2	254.2	254.1	254.1	254.1	254.1	254.2	254.2
Aug	253.4	253.3	253.3	253.3	253.3	253.3	253.3	253.3
Sep	252.5	252.5	252.4	252.4	252.4	252.4	252.5	252.4
Oct	252.4	252.4	252.3	252.3	252.4	252.3	252.3	252.3
Nov	252.3	252.2	252.2	252.2	252.2	252.2	252.2	252.2
Dec	252.0	252.0	252.0	252.0	252.0	252.0	252.0	252.0
Average	252.9	252.9	252.9	252.9	252.9	252.9	252.9	252.9
Effects - Simulated Drawdown (feet) (%) (No Action Alternative Baseline)								
Jan	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Feb	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Mar	---	---	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Apr	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
May	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jun	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jul	---	---	0.0 (0.0)	0.0 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Aug	---	---	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Sep	---	---	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Oct	---	---	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Nov	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dec	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Average	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Effects - Simulated Drawdown (feet) (%) (Existing Conditions Baseline)								
Jan	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Feb	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Mar	---	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)
Apr	---	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)
May	---	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Jun	---	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Jul	---	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	-0.1 (0.0)
Aug	---	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)
Sep	---	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Oct	---	-0.1 (0.0)	-0.1 (-0.1)	-0.1 (-0.1)	-0.1 (0.0)	-0.1 (-0.1)	-0.1 (0.0)	-0.1 (0.0)
Nov	---	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Dec	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Average	---	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	-0.1 (0.0)

Table 17. Overall Average Effects of River Levels on Groundwater at the Fountain Creek At Security Gage – Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Head in Aquifer (feet)								
Jan	25.7	26.2	26.2	26.2	26.2	26.2	26.2	26.2
Feb	25.8	26.3	26.3	26.3	26.3	26.3	26.3	26.3
Mar	25.9	26.3	26.3	26.3	26.3	26.3	26.3	26.3
Apr	26.0	26.4	26.4	26.4	26.4	26.4	26.4	26.4
May	26.2	26.5	26.5	26.5	26.5	26.5	26.5	26.5
Jun	26.1	26.5	26.5	26.5	26.5	26.5	26.5	26.5
Jul	26.0	26.4	26.4	26.4	26.4	26.4	26.4	26.4
Aug	26.1	26.5	26.5	26.5	26.5	26.5	26.5	26.5
Sep	25.8	26.3	26.3	26.3	26.3	26.3	26.3	26.3
Oct	25.8	26.3	26.3	26.3	26.3	26.3	26.3	26.3
Nov	25.8	26.3	26.3	26.3	26.3	26.3	26.3	26.3
Dec	25.7	26.2	26.2	26.2	26.2	26.2	26.2	26.2
Average	25.9	26.3	26.3	26.3	26.3	26.3	26.3	26.3
Effects - Simulated Drawdown (feet) (%) (No Action Alternative Baseline)								
No Measureable Effects								
Effects - Simulated Drawdown (feet) (%) (Existing Conditions Baseline)								
Jan	---	0.5 (1.9)	0.5 (1.9)	0.5 (1.9)	0.5 (1.9)	0.5 (1.9)	0.5 (1.9)	0.5 (1.9)
Feb	---	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)
Mar	---	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)
Apr	---	0.4 (1.6)	0.4 (1.6)	0.4 (1.6)	0.4 (1.6)	0.4 (1.6)	0.4 (1.6)	0.4 (1.6)
May	---	0.4 (1.4)	0.4 (1.4)	0.4 (1.4)	0.4 (1.4)	0.4 (1.4)	0.4 (1.4)	0.4 (1.4)
Jun	---	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)
Jul	---	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)
Aug	---	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)	0.4 (1.5)
Sep	---	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)
Oct	---	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.9)	0.5 (1.8)
Nov	---	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)	0.5 (1.8)
Dec	---	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)
Average	---	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)	0.4 (1.7)

Table 18. Overall Average Effects of River Levels on Groundwater at the Fountain Creek At Pueblo Gage – Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Head in Aquifer (feet)								
Jan	41.8	42.1	42.1	42.1	42.1	42.1	42.1	42.1
Feb	41.9	42.1	42.1	42.1	42.1	42.1	42.1	42.1
Mar	41.9	42.2	42.1	42.1	42.2	42.1	42.1	42.1
Apr	41.9	42.3	42.3	42.3	42.3	42.3	42.3	42.3
May	42.0	42.6	42.6	42.6	42.6	42.6	42.6	42.6
Jun	41.9	42.5	42.5	42.5	42.5	42.5	42.5	42.5
Jul	41.6	42.2	42.2	42.2	42.2	42.2	42.2	42.2
Aug	41.9	42.2	42.2	42.2	42.2	42.2	42.3	42.2
Sep	41.6	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Oct	41.8	42.1	42.0	42.1	42.1	42.0	42.1	42.1
Nov	41.9	42.1	42.1	42.1	42.1	42.1	42.1	42.1
Dec	41.8	42.0	42.0	42.0	42.0	42.0	42.0	42.0
Average	41.8	42.2	42.2	42.2	42.2	42.2	42.2	42.2
Effects - Simulated Drawdown (feet) (%) (No Action Alternative Baseline)								
Jan	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Feb	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Mar	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Apr	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
May	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jun	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jul	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Aug	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Sep	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (-0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Oct	---	---	0.0 (-0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (-0.1)	0.0 (0.0)	0.0 (0.0)
Nov	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dec	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Average	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Effects - Simulated Drawdown (feet) (%) (Existing Conditions Baseline)								
Jan	---	0.3 (0.6)	0.3 (0.6)	0.3 (0.6)	0.2 (0.6)	0.3 (0.6)	0.3 (0.6)	0.3 (0.6)
Feb	---	0.2 (0.4)	0.2 (0.5)	0.2 (0.5)	0.2 (0.4)	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)
Mar	---	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)
Apr	---	0.4 (1.1)	0.4 (1.1)	0.4 (1.1)	0.5 (1.1)	0.4 (1.1)	0.5 (1.1)	0.4 (1.1)
May	---	0.6 (1.5)	0.6 (1.5)	0.6 (1.5)	0.6 (1.5)	0.6 (1.5)	0.6 (1.5)	0.6 (1.5)
Jun	---	0.6 (1.5)	0.7 (1.6)	0.7 (1.6)	0.6 (1.5)	0.7 (1.6)	0.6 (1.5)	0.6 (1.6)
Jul	---	0.6 (1.4)	0.6 (1.4)	0.6 (1.4)	0.6 (1.3)	0.6 (1.4)	0.6 (1.4)	0.6 (1.4)
Aug	---	0.4 (0.9)	0.4 (0.9)	0.4 (0.9)	0.4 (0.9)	0.4 (0.9)	0.4 (1.0)	0.4 (0.9)
Sep	---	0.3 (0.8)	0.3 (0.8)	0.3 (0.8)	0.3 (0.8)	0.3 (0.8)	0.4 (0.9)	0.3 (0.8)
Oct	---	0.3 (0.7)	0.3 (0.6)	0.3 (0.7)	0.3 (0.7)	0.3 (0.6)	0.3 (0.7)	0.3 (0.7)
Nov	---	0.3 (0.6)	0.3 (0.6)	0.2 (0.6)	0.2 (0.6)	0.3 (0.6)	0.3 (0.6)	0.3 (0.6)
Dec	---	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)	0.2 (0.6)	0.2 (0.6)
Average	---	0.4 (0.9)	0.4 (0.9)	0.4 (0.9)	0.4 (0.9)	0.4 (0.9)	0.4 (0.9)	0.4 (0.9)

Table 19. Overall Average Effects of River Levels on Groundwater at the Arkansas River Near Wellsville Gage – Cumulative Effects

Month	Existing Conditions	No Action		Comanche South		Pueblo Dam South		JUP North		Pueblo Dam North		River South		Master Contract Only	
Simulated Head in Aquifer (feet)															
Jan	103.4	103.4		103.5		103.5		103.4		103.5		103.4		103.4	
Feb	103.3	103.2		103.2		103.2		103.2		103.2		103.2		103.2	
Mar	103.2	103.2		103.2		103.2		103.2		103.2		103.2		103.2	
Apr	103.2	103.3		103.3		103.3		103.3		103.3		103.3		103.3	
May	104.4	104.2		104.2		104.2		104.2		104.2		104.2		104.2	
Jun	105.7	105.5		105.5		105.5		105.5		105.5		105.5		105.5	
Jul	104.8	104.7		104.7		104.7		104.7		104.7		104.7		104.7	
Aug	104.1	104.1		104.1		104.1		104.0		104.1		104.1		104.1	
Sep	103.5	103.4		103.4		103.4		103.4		103.4		103.4		103.4	
Oct	103.5	103.5		103.5		103.5		103.5		103.5		103.5		103.5	
Nov	103.5	103.6		103.6		103.6		103.6		103.6		103.6		103.6	
Dec	103.4	103.5		103.5		103.5		103.5		103.5		103.5		103.5	
Average	103.8	103.8		103.8		103.8		103.8		103.8		103.8		103.8	
Effects - Simulated Drawdown (feet) (%) (No Action Alternative Baseline)															
No Measurable Effects															
Effects - Simulated Drawdown (feet) (%) (Existing Conditions Baseline)															
Jan	---	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)
Feb	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Mar	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Apr	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
May	---	-0.1	(-0.1)	-0.2	(-0.1)	-0.2	(-0.1)	-0.1	(-0.1)	-0.2	(-0.1)	-0.1	(-0.1)	-0.1	(-0.1)
Jun	---	-0.2	(-0.2)	-0.2	(-0.2)	-0.2	(-0.2)	-0.2	(-0.2)	-0.2	(-0.2)	-0.2	(-0.2)	-0.2	(-0.2)
Jul	---	-0.1	(-0.1)	-0.1	(-0.1)	-0.1	(-0.1)	-0.1	(-0.1)	-0.1	(-0.1)	-0.1	(-0.1)	-0.1	(-0.1)
Aug	---	-0.1	(-0.1)	0.0	(0.0)	0.0	(0.0)	-0.1	(-0.1)	0.0	(0.0)	0.0	(0.0)	-0.1	(-0.1)
Sep	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Oct	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Nov	---	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)
Dec	---	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)	0.1	(0.1)
Average	---	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)

Table 20. Overall Average Effects of River Levels on Groundwater at the Arkansas River Above Pueblo Gage – Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Head in Aquifer (feet)								
Jan	252.0	251.9	251.9	251.9	251.9	251.9	251.9	251.9
Feb	252.1	252.0	252.0	252.0	252.0	252.0	252.0	252.0
Mar	252.3	252.0	252.0	252.0	252.0	252.0	252.0	252.0
Apr	253.0	252.4	252.4	252.4	252.4	252.4	252.4	252.4
May	253.9	253.3	253.3	253.3	253.3	253.3	253.3	253.3
Jun	255.1	254.7	254.6	254.6	254.7	254.6	254.7	254.7
Jul	254.2	253.9	253.9	253.9	253.8	253.9	253.9	253.9
Aug	253.4	253.1	253.0	253.0	253.0	253.0	253.1	253.1
Sep	252.5	252.1	252.1	252.1	252.1	252.1	252.1	252.1
Oct	252.4	252.0	252.0	252.0	252.0	252.0	252.0	252.0
Nov	252.3	252.0	252.0	252.0	252.0	252.0	252.0	252.0
Dec	252.0	251.9	251.9	251.9	251.9	251.9	251.9	251.9
Average	252.9	252.6	252.6	252.6	252.6	252.6	252.6	252.6
Effects - Simulated Drawdown (feet) (%) (No Action Alternative Baseline)								
Jan	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Feb	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Mar	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Apr	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
May	---	---	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Jun	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jul	---	---	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Aug	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Sep	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Oct	---	---	0.0 (0.0)	-0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Nov	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dec	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Average	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Effects - Simulated Drawdown (feet) (%) (Existing Conditions Baseline)								
Jan	---	-0.1 (-0.1)	-0.2 (-0.1)	-0.2 (-0.1)	-0.2 (-0.1)	-0.2 (-0.1)	-0.1 (-0.1)	-0.1 (-0.1)
Feb	---	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)	-0.1 (0.0)
Mar	---	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)
Apr	---	-0.6 (-0.2)	-0.6 (-0.2)	-0.6 (-0.2)	-0.6 (-0.2)	-0.6 (-0.2)	-0.6 (-0.2)	-0.6 (-0.2)
May	---	-0.6 (-0.2)	-0.6 (-0.3)	-0.6 (-0.3)	-0.6 (-0.2)	-0.6 (-0.3)	-0.6 (-0.2)	-0.6 (-0.2)
Jun	---	-0.4 (-0.2)	-0.5 (-0.2)	-0.5 (-0.2)	-0.4 (-0.2)	-0.5 (-0.2)	-0.4 (-0.2)	-0.4 (-0.2)
Jul	---	-0.3 (-0.1)	-0.3 (-0.1)	-0.4 (-0.1)	-0.4 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)
Aug	---	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)
Sep	---	-0.4 (-0.1)	-0.4 (-0.2)	-0.4 (-0.2)	-0.4 (-0.2)	-0.4 (-0.2)	-0.4 (-0.1)	-0.4 (-0.2)
Oct	---	-0.4 (-0.2)	-0.5 (-0.2)	-0.5 (-0.2)	-0.4 (-0.2)	-0.5 (-0.2)	-0.4 (-0.2)	-0.4 (-0.2)
Nov	---	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)
Dec	---	-0.1 (0.0)	-0.1 (-0.1)	-0.1 (-0.1)	-0.1 (-0.1)	-0.1 (-0.1)	-0.1 (0.0)	-0.1 (0.0)
Average	---	-0.3 (-0.1)	-0.4 (-0.1)	-0.4 (-0.1)	-0.4 (-0.1)	-0.4 (-0.1)	-0.3 (-0.1)	-0.3 (-0.1)

References

n.d. Retrieved from ArcGIS Desktop Help 9.33.

CDSS Map Viewer. n.d. Retrieved January 13, 2012, from Colorado Division of Water Resources Web Site: http://water.state.co.us/DataMaps/GISandMaps/MapViewer/Pages/default.aspx

Dietz, D. 1943. De toepassing van invloedsfuncties bij het berekenen van de verlaging van het grondwater ten gevolge van wateronttrekking. Water. Volume 27(6), pp. 51-54.

Fetter, C. 1988. Applied Hydrogeology, Second Edition. Columbus, Ohio: Merrill Publishing Company.

U.S. Department of the Interior, Bureau of Reclamation (Reclamation). 2008. Southern Delivery System Final Environmental Impact Statement. Loveland, CO.

Steve Smith. 2006. Alluvial and Denver Basin Aquifers Ground Water Effects Analysis Southern Delivery System Environmental Impact Statement.

Survey, C. G. 2003. Ground Water Atlas of Colorado. Denver, CO: Department of Natural Resources.

Watts, K. R. 2005. Hydrogeology and Quality of Ground Water in the Upper Arkansas River Basin from Buena Vista to Salida, Colorado, 2000-2003. U.S. Geological Survey.

Appendix F.1 – Water Quality Affected Environment Supplemental Information

Introduction

Appendix F.1 supplements the Water Quality portion of Chapter 3 - Affected Environment in the EIS. This appendix contains additional information about water quality resources that could be affected by implementation of the proposed AVC, Master Contract, and Interconnect alternatives.

Water Quality Standards and Thresholds

The Colorado Department of Public Health and Environment (Health Department) is responsible for: 1) assigning use classifications to state water segments, 2) establishing water quality standards for each water segment, and 3) reporting on attainment of water quality standards. Water use classifications for streams, lakes, and reservoirs identify protected uses for stream segments, lakes, and reservoirs, using numerical standards for specific pollutants to protect these uses. Nonattainment of water quality standards is reported every two years via the State's 303(d) list (Attachment F.1-1). The list gets its name from section 303(d) of the federal Clean Water Act, which requires states to periodically submit a list of impaired waters to EPA.

Table Value Standards are site specific standards that may apply to a river segment based on research-based criteria, and are appropriate to protect applicable classified uses.

Ambient Quality-Based Standards are site specific standards where evidence has been presented that the natural or irreversible man-induced ambient water quality levels are higher than table value standards, but are determined adequate to protect classified uses.

Acute water quality standards protect beneficial uses under short-term, high concentration events.

Chronic water quality standards protect uses for longer periods of time, generally for 30 days.

The Safe Drinking Water Act was adopted by Congress in 1974 to protect public health by regulating the quality of public drinking water supplies. It controls the quality of water "at the tap" rather than addressing water quality in-stream or regulating pollution sources. The EPA developed national drinking water standards known as maximum contaminant levels. These standards set numerical limitations for many of the most significant contaminants in public water system drinking water. Secondary drinking water standards set limits on chemicals that cause aesthetic problems with drinking water, such as taste and odor problems.

Colorado has adopted state drinking water standards identical to the maximum contaminant levels established by the EPA (Colorado Foundation for Water Education 2003). The Health Department has also adopted several site-specific numeric standards, including acute and chronic table value standards and ambient quality-based standards. Following Health Department guidelines, in most cases, the 85th percentile of the available surface water data was compared to the numeric water quality standard to determine attainment of water quality standards (Health Department 2012a).

Several published studies from U.S. Geological Survey, Health Department, EPA, Colorado State University, and others were reviewed for water quality information in the study area. To evaluate water quality in this EIS, existing data from the U.S. Geological Survey and Health Department were reviewed and compared to the water quality thresholds shown in Table 1. For some constituents, standards were not available, and other values were used for comparison.

Table 1. Standards and Thresholds Used in Water Quality Analysis

Parameter[1]	Drinking Water Quality Standards and Thresholds (5 CCR 1003-1)	Site Specific or Other Water Quality Standards and Thresholds
Dissolved Selenium	Drinking Water Primary MCL = 50 µg/L.	Chronic = 4.6 µg/L Acute = 18.4 µg/L Site-specific ambient- and attainability-based underlying standards[2]
Salinity	Drinking Water Secondary MCL[3] = 500 mg/L total dissolved solids.	Agricultural High Salinity Hazard[3] = 750 µS/cm specific conductance (Richards 1954).
Radionuclides	Adjusted Gross Alpha Activity Drinking Water Primary MCL = 15 pCi/L. Combined Radium 226/228 Drinking Water Primary MCL= 5 pCi/L. Uranium Drinking Water Primary MCL = 30 µg/L.	Uranium Standard for Arkansas River Basin = Lowest practicable level (Health Department 2012a).
Bacteria	Total Coliforms Drinking Water Primary MCL = No more than 5.0 percent of the samples collected during a month are total coliform-positive	Escherichia coli (E. coli) = 126 colonies / 100 milliliter (recreation class E) (Health Department 2012a).
Sulfate	Drinking Water Secondary MCL[3] = 250 mg/L.	250 mg/L or quality as of Nov. 30, 2010 for waters with an actual water supply use.[4]
Total Recoverable Iron	Iron Drinking Water Secondary MCL[3] = 0.3 mg/L.	1,000 µg/L in Arkansas River between Lake Fork and Lake Creek. Regulated as the least restrictive level of 300 µg/L or existing water quality as of January 1, 2000 in rest of study area
Copper	Drinking Water Primary Action Level = 1.3 mg/L. Drinking Water Secondary MCL[3] = 1 mg/L.	Standards are site-specific (Health Department 2012a).
Zinc	Drinking Water Secondary MCL[3] = 5 mg/L.	Site-specific standards (Health Department 2012a).
Cadmium	Drinking Water Primary MCL = 5 µg/L.	Site-specific standards (Health Department 2012a).
Suspended Sediment	N/A	N/A
Temperature	N/A	Maximum weekly average temperature (in ^{o}C) varies by water body type, use classification, expected fish species, and season (Health Department 2012a).
Nutrients	Nitrite Drinking Water Primary MCL: 1 mg/L as nitrogen. Nitrate Drinking Water Primary MCL: 10 mg/L as nitrogen.	Ammonia: Standard is calculated as a function of pH and temperature Nitrite: 0.05 mg/L for the upper Arkansas River, 1.0 mg/L for Fountain Creek, 0.5 mg/L for lower Arkansas River Nitrate: 10 mg/L
Emerging Contaminants	N/A	N/A

Notes:

(1) Not all water quality standards are summarized; only those used in this water quality assessment.

(2) Site-specific ambient- and attainability-based underlying standards for selenium have been adopted for several segments in the study area based on data of natural selenium sources not exacerbated by human activity. In other segments, temporary modifications are in place as underlying standards are not being met because of correctable human-induced conditions or significant uncertainty regarding the appropriate long-term underlying standard (Health Department 2012a).

(3) Guideline is not an enforceable standard, but provides information on water quality levels above which there may be negative effects.

(4) Site-specific ambient-based underlying standards for sulfate have been adopted for several segments in the study area (Health Department 2012a).

Water Quality Constituents

Water bodies and stream segments are evaluated in this EIS to determine how the proposed alternatives would affect water quality. The following sections supplement Chapter 3 affected environment information by providing additional background technical material and data related to streamflow water quality, reservoir water quality, and other water quality concerns.

Selenium

Marine shale rock formations and soil derived of marine shales underlie much of the Fountain Creek basin between Colorado Springs and the Arkansas River, and the Arkansas River basin between Pueblo Reservoir and John Martin Reservoir (U.S. Geological Survey 1992). Surface and sub-surface water from lawn watering, irrigation, and precipitation contacts and dissolves selenium-containing rock and soils in the study area. Ortiz et al. (1998) found that over 90 percent of the selenium measured in Arkansas River downstream from Pueblo Reservoir was in the dissolved phase.

The Arkansas River between Fountain Creek and the Kansas state line are impaired for selenium; total maximum daily loads (TMDLs) have not been completed. The instream table value standard for selenium is lower than the primary drinking water standard of 50 µg/L because of aquatic life stream classifications. Selenium loading "results from natural sources and is not exacerbated by land use or other reversible, anthropogenic factors" (Health Department 2012a). Table 2 shows dissolved selenium concentrations and water quality standards in Fountain Creek and the Lower Arkansas River.

Table 2. Dissolved Selenium in Fountain Creek and the Lower Arkansas River

Stream Segment	Dissolved Selenium Concentration			Hardness (mg/L as $CaCO_3$)	Chronic Water Quality Standard (µg/L)	Acute Water Quality Standard (µg/L)	Sample Period (# of Samples)
	Median (µg/L)	85th Percentile (µg/L) (1)(2)	Maximum (µg/L) (2)				
Fountain Creek, Hwy 47 to Arkansas River (WBID COARFO02b)	10.9	16.5	26.3	338.94	28.1	42.3	2005-2010 (28)
Arkansas River, Wildhorse Creek to Fountain Creek (WBID COARMA03)	8.0	17.4 (3)	93.4	371.36	17.4	50.9	2001-2006 (14)
Arkansas River, Fountain Creek to Colorado Canal (WBID COARLA01a)	11.2	**16.4**	34.0	320.26	14.1	19.1	2003-2009 (13)
Arkansas River, Colorado Canal head gate to John Martin Reservoir (WBID COARLA01b)	9.6	**13.0**	31.0	400.00	4.6	18.4	2003-2009 (37)
Arkansas River, below John Martin Reservoir (WBID COARLA01c)	11.0	**27.1**	34.0	400.00	4.6	18.4	2003-2009 (27)

Source: Health Department 2012a, 2012b

Notes:

(1) Exceedences are indicated in **bold**.

(2) The maximum measured value is compared to the acute water quality standard. The 85th percentile value is compared to the chronic water quality standard.

(3) Data in 2006 indicates a decreasing trend in selenium concentrations. Large exceedences in 2005 would typically no longer be used to evaluate ambient water quality.

Salinity

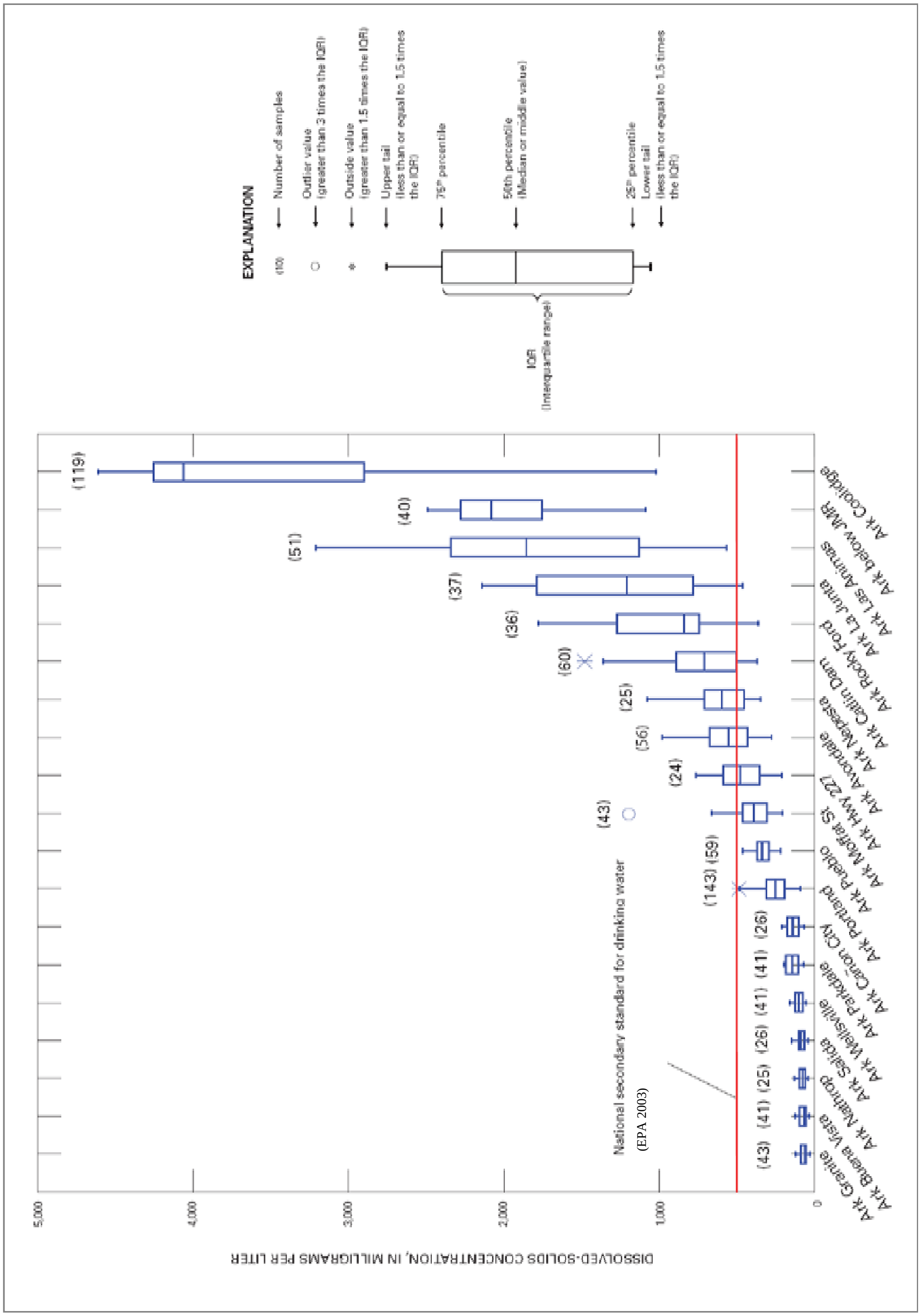
The secondary drinking water standard (5 CCR 1003-1) for salinity is 500 mg/L total dissolved solids. Salinity levels above this standard affect the taste and odor of drinking water, and can have deleterious effects on treatment processes. The total dissolved solids concentrations of the Arkansas River and tributaries are in Table 3. The spatial distribution of total dissolved solids concentrations in the Arkansas River Basin is shown in Figure 1. Diversions from the Arkansas River below the City of Pueblo could exceed the secondary drinking water standard.

The term **"total solids"** is matter suspended or dissolved in water, and is related to both specific conductance and turbidity. Total solids is the term used for material left in a container after evaporation and drying of a water sample. Total Solids includes both **total suspended solids**, the portion of total solids retained by a filter, and **total dissolved solids**, the portion that passes through a filter.

Table 3. Historical Total Dissolved Solids Concentrations at selected sites in the Arkansas River Basin, 1976–2007

Source Agency	Site Number	Site Name	Number of Samples	Total Dissolved Solids (milligrams per liter)			
				Minimum	Mean	Median	Maximum
USGS	07081200	Ark Leadville	27	28	110	116	174
USGS	07083700	Ark Malta	3	77	96	94	116
USGS	07086000	Ark Granite	43	33	74	64	122
USGS	07087200	Ark Buena Vista	41	34	77	68	126
USGS	07091200	Ark Nathrop	25	44	81	76	131
USGS	07091500	Ark Salida	26	45	91	90	147
USGS	07093700	Ark Wellsville	41	57	105	102	163
USGS	07094500	Ark Parkdale	41	72	143	146	201
USGS	07096000	Ark Canon City	26	69	140	143	214
USGS	07097000	Ark Portland	143	95	252	254	489
USGS	07099400	Ark Pueblo	59	220	333	340	464
USGS	381628104381700	Wild Horse Creek	20	2,330	3,075	3,070	3,530
USGS	07099970	Ark Moffat St	43	210	405	390	1,190
USGS	07106500	Fnt Pueblo	42	332	846	834	1,070
USGS	381510104350601	Ark Hwy 227	24	213	468	447	766
USGS	381530104333200	Salt Creek	20	364	436	444	486
USGS	07108900	St. Charles River	21	242	1,521	1,800	2,450
USGS	07109500	Ark Avondale	56	279	565	553	983
USGS	07116500	Huerfano River	12	774	3,159	2,770	5,640
USGS	07117000	Ark Nepesta	25	348	599	590	1,080
USGS	07117600	Chicosa Creek	1	2,360	2,360	2,360	2,360
USGS	380715103564701	Apishapa River	13	586	1,385	1,280	2,190
USGS	07119700	Ark Catlin Dam	60	371	726	691	1,480
USGS	07120500	Ark Rocky Ford	36	365	952	830	1,780
USGS	380111103382101	Timpas Creek	18	692	1,473	1,400	2,890
USGS	07123000	Ark La Junta	37	465	1,335	1,210	2,140
USGS	380421103193101	Horse Creek	13	2,110	3,247	3,390	4,130
USGS	07124000	Ark Las Animas	51	567	1,797	1,850	3,210
USGS	07128500	Purgatoire River	39	774	3,074	3,340	5,010
USGS	07130500	Ark Below JMR	40	1,090	1,969	2,080	2,490
USGS	07137500	Ark Coolidge	119	1,020	3,570	4,060	4,610

Source: Miller et al. 2010



Source: Miller et al. 2010

Figure 1. Spatial Distribution of Dissolved-solids Concentrations in the Arkansas River from Granite, Colorado, to Coolidge, Kansas, 1976–2007

Radionuclides

Naturally occurring radionuclides are caused by erosion and chemical weathering of naturally occurring mineral deposits. The concentration of radionuclides is known to be a problem in groundwater sources for drinking water, such as the Dakota-Cheyenne aquifer (Malcolm Pirnie 2009). Several AVC participants currently have wells that withdraw water from this aquifer.

Radium is produced when other radioactive substances, such as uranium and thorium, break down over time. Radium is commonly found in two forms, as Radium 226 and Radium 228. Radium 226 is an alpha emitter and decays to radon. Radium 228 is a beta emitter and decays to Radium 224. The primary drinking water standard for combined radium (Radium 226 and Radium 228) is 5 pCi/L.

Gross alpha particle activity is a measurement of all alpha activity present. It is an indication for overall level of radioactivity. As uranium and radium degrade, alpha particles may be emitted, adding to the total gross alpha particle activity count. Alpha particles are typically blocked by the skin and do not pose a risk if a person is exposed from external sources. Showering and bathing do not pose a significant risk. If these particles are inhaled or consumed through eating or drinking, the emissions may directly contact sensitive tissues and increase the risk of cancer (Malcolm Pirnie 2009). The primary drinking water standard for gross alpha particle activity is 15 pCi/L.

Uranium is notably present in several areas of the Arkansas River Basin. The largest increase in median dissolved-uranium concentrations occurs between Rocky Ford and La Junta, where it more than doubles. This large change likely results from groundwater and surface water interactions and changes in geology. Concentrations of dissolved uranium in groundwater vary over about five orders of magnitude in the Arkansas River Basin and typically increase downstream along the Arkansas River (Miller et al. 2010). The Arkansas River from John Martin Reservoir to Kansas is impaired by uranium; a TMDL has not been completed (Table 4).

Table 4. Dissolved Uranium in Fountain Creek and the Lower Arkansas River

Stream Segment	Dissolved Uranium Concentration			Hardness (mg/L as $CaCO_3$)	Chronic Water Quality Standard (µg/L) [3]	Acute Water Quality Standard (µg/L) [3]	Sample Period (# of Samples)
	Median (µg/L)	85th Percentile (µg/L) [1][2]	Maximum (µg/L) [2]				
Fountain Creek, Hwy 47 to Arkansas River (WBID COARFO02b)	8.00	11.30	12.00	338.94	30	9,223	2003-2009 (19)
Arkansas River, Wildhorse Creek to Fountain Creek (WBID COARMA03)	6.00	8.31	24.50	371.36	30	10,200	2005-2006 (8)
Arkansas River, Fountain Creek to Colorado Canal (WBID COARLA01a)	8.00	9.82	12.20	320.26	30	8,851	1998-2006 (9)
Arkansas River, Colorado Canal to John Martin Reservoir (WBID COARLA01b)	10.00	12.97	79.00	400.00	30	11,070	2003-2009 (30)
Arkansas River, below John Martin Reservoir (WBID COARLA01c)	40.50	**74.65**	78.00	400.00	30	11,070	2003-2009 (8)

Source: Health Department 2012a, 2012b

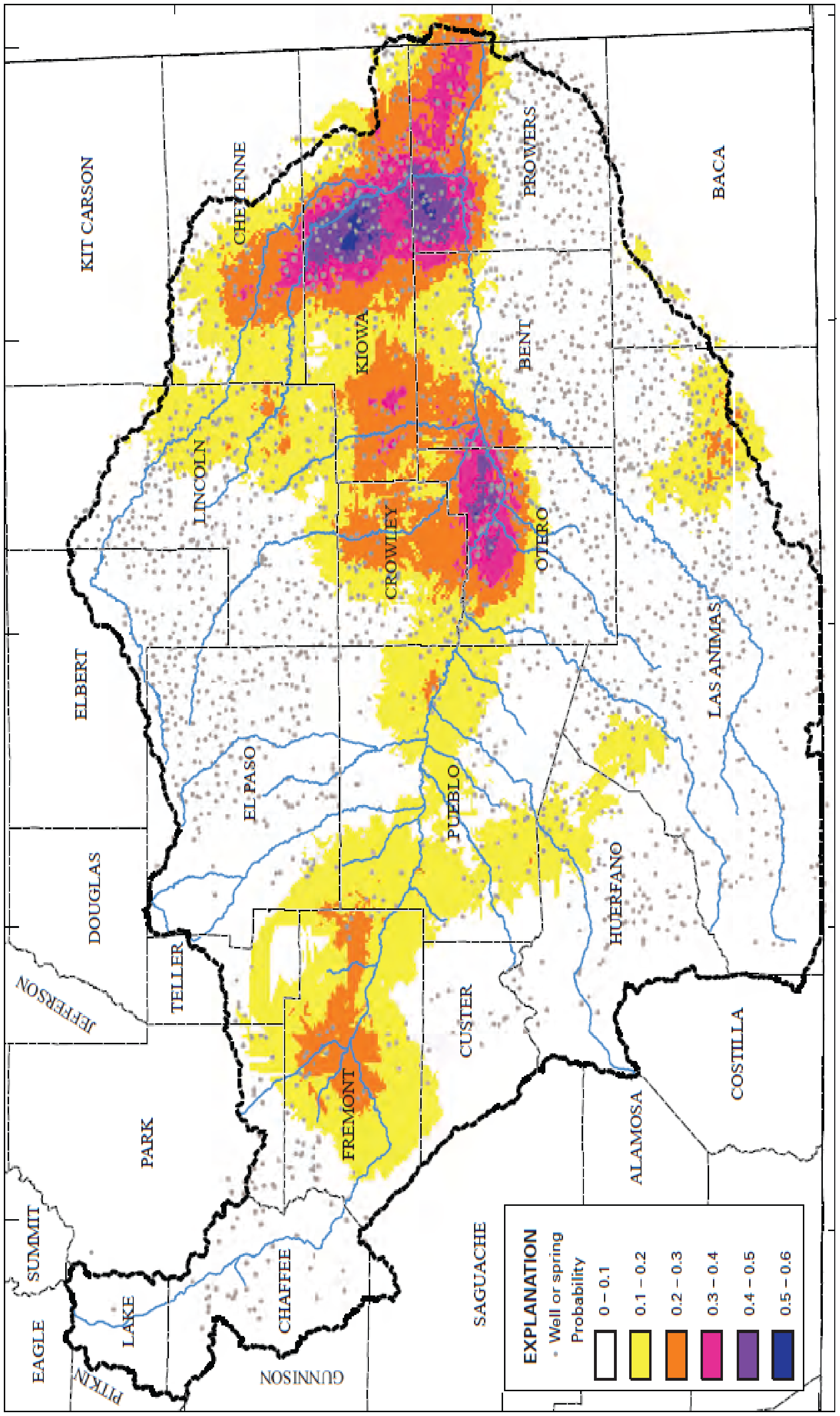
Notes:

(1) Exceedences are in **bold**.

(2) The maximum measured value is compared to the acute water quality standard. The 85th percentile value is compared to the chronic water quality standard.

(3) From Basic Standards Regulation Section 31.16, "When applying the table value standards for uranium to individual segments, the Commission shall consider the need to maintain radioactive materials at the lowest practical level as required by Section 31.11(2) of the Basic Standards regulation".

As shown in Figure 2, probabilities of exceeding the primary drinking water standard for uranium (30 µg/L) in groundwater are greatest in Otero, Kiowa, Cheyenne, and Prowers counties, where probabilities commonly range from 30 to 60. These areas coincide with those where bedrock formations (suspected sources of uranium) are present at the surface or are directly overlain by alluvial deposits (Miller et al. 2010).



Source: Miller et al. 2010

Figure 2. Probability of Exceeding Primary Drinking Water Standards for Dissolved Uranium in Groundwater

Bacteria

Most segments of Fountain Creek are impaired by *E. coli*; TMDLs have not been completed (Table 5). Birds are the suspected dominant source of *E. coli* in Upper Fountain Creek (upstream from Monument Creek), although human sources were sporadically found to contribute to *E. coli* concentrations (U.S. Geological Survey 2009). Although raw sewage spills have contaminated Fountain Creek for short periods in the past, wastewater treatment facility effluent data show that average bacteria concentrations in wastewater effluent are well below bacteria water quality standards (EPA 2007) and that effluent discharged to Fountain Creek likely dilutes bacterial densities during storm flows when bacterial densities are typically highest. In comparison, *E. coli* concentrations in the Lower Arkansas River meet standards (Health Department 2012b).

Table 5. *E. coli* Concentrations in Fountain Creek and the Lower Arkansas River

Stream Segment	Geometric Mean (count per 100 mL)(1)	Seasonal (count per 100 mL)(1)(2)	Water Quality Standard (per 100 mL)	Sample Period (# of Samples)
Fountain Creek, Hwy 47 to Arkansas River (WBID COARFO02b)	N/A	**240** (3)	126	2005-2009 (15)
Arkansas River, Wildhorse Creek to Fountain Creek (WBID COARMA03)	48	N/A	126	2002-2006 (12)
Arkansas River, Fountain Creek to Colorado Canal (WBID COARLA01a)	48	N/A	126	1998-2006 (12)
Arkansas River, Colorado Canal to John Martin Reservoir (WBID COARLA01b)	20	82(3)	126	2003-2009 (27)
Arkansas River, John Martin Reservoir to the Stateline (WBID COARLA01c)	14	39(4)	126	2003-2009 (23)

Source: Health Department 2012a, 2012b
Notes:
(1) Exceedences are in **bold**.
(2) Seasonal values correspond to months with recreational or biological concern.
(3) Season is May through October.
(4) Season is April through October.

Sulfate

The Arkansas River is sulfate impaired from Fountain Creek to the Colorado Canal; a TMDL has not been completed (Table 6). A temporary modification to the sulfate water quality standard is in place for this river segment because the Health Department and the City of Pueblo believe that some sulfate reduction is possible through implementation of best management practices (Health Department 2010a).

Table 6. Sulfate Concentrations in Fountain Creek and the Lower Arkansas River

Stream Segment	85th Percentile (milligrams per liter)[1]	Water Quality Standard (milligrams per liter)	Sample Period (# of Samples)
Fountain Creek, Hwy 47 to Arkansas River (WBID COARFO02b)	440	485	2005-2009 (16)
Arkansas River, Wildhorse Creek to Fountain Creek (WBID COARMA03)	152	250	2005-2006 (4)
Arkansas River, Fountain Creek to Colorado Canal (WBID COARLA01a)	**331**	329	2003-2009 (23)
Arkansas River, Colorado Canal to John Martin Reservoir (WBID COARLA01b)	417	902	2003-2009 (23)
Arkansas River, John Martin Reservoir to the Stateline (WBID COARLA01c)	2,110	250	2003-2009 (27)

Source: Health Department 2012a, 2012b

Notes:

(1) Exceedences are in **bold**. The 85th percentile measured value is compared to the water quality standard.

Total Recoverable Iron and Other Metals

Total recoverable iron is a measure of the amount of iron in a waterbody. Alluvial groundwater from Fountain Creek to the Colorado Canal head gate is impaired for total recoverable iron (Health Department 2006). Tributaries to the Arkansas River from Pueblo Reservoir to John Martin Reservoir, such as Timpas Creek and Horse Creek, are included in the 2010 impaired streams list for total recoverable iron. Concentrations of total recoverable iron tend to be higher in lower Fountain Creek and other tributaries than in the Arkansas River (Ortiz et al. 1998).

The likely source of iron is erosion in tributaries, which contribute sediment and associated particulate iron to the Arkansas River. Particulate contaminants such as metals (e.g., iron) can be associated with suspended sediments. Total recoverable iron tends to adsorb to sediments and is transported at high levels during storm events (Edelmann et al. 2002). Ortiz et al. (1998) also noted elevated concentrations of total recoverable iron in the Arkansas River between Pueblo Reservoir and John Martin Reservoir. They found that between Avondale and Las Animas, concentrations were substantially higher during snowmelt runoff and post-snowmelt runoff seasons, probably due to the resuspension of settled material during high flows and tributary inflow. Additionally, the Apishapa and Purgatoire Rivers had stormflow total iron concentrations 200 to 300 times higher than any measurements in the main stem, on the order of 200,000 μg/L. Table 7 summarizes total recoverable iron data in Fountain Creek and the Lower Arkansas River.

Table 7. Total Recoverable Iron Concentrations in Fountain Creek and the Lower Arkansas River

Stream Segment	Median (µg/L)[1]	Hardness (mg/L as $CaCO_3$)	Water Quality Standard (µg/L)	Sample Period (# of Samples)
Fountain Creek, Hwy 47 to Arkansas River (WBID COARFO02b)	3,450	338.94	5,280	2005-2010 (28)
Arkansas River, Wildhorse Creek to Fountain Creek (WBID COARMA03)	112	371.36	1,000	2005-2006 (4)
Arkansas River, Fountain Creek to Colorado Canal (WBID COARLA01a)	2,765	320.26	2,765	1998- 2006 (18)
Arkansas River, Colorado Canal head gate to John Martin Reservoir (WBID COARLA01b)	1,200	400.00	1,950	2003- 2009 (23)
Arkansas River, John Martin Reservoir to the Stateline (WBID COARLA01c)	230	400.00	1,000	2003- 2009 (27)

Source: U.S. Geological Survey 2011; Health Department 2012a, 2012b
Notes:
(1) The median measured value is compared to the water quality standard.

Lake Creek exceeded water quality standards for copper (Table 8), and was listed on the 2010 impaired waters list, but has been removed from the 2012 impaired list. A TMDL for copper was recently completed for Lake Creek to address impairment of Aquatic Life Cold 1 designated use (Health Department 2010b). There are no permitted dischargers in this stream segment, and hydrothermally altered natural background copper supplies most of the pollutant. The TMDL consists of a load allocation (i.e. non-point source load) and a 10 percent margin of safety (Table 9). Improvements in the Lake Creek watershed were not identified in the TMDL.

Hydrothermal alteration is a change of rocks or minerals caused by hydrothermal processes, such as fluids accompanying or heated by magma. Ore deposits, such as lead, zinc, and copper, can occur in areas of hydrothermal alteration.

The Upper Arkansas River is not on the 2012 impaired waters list, though several TMDLs have been completed for this river segment, in response to previous years' impaired waters listings, for managing cadmium, zinc, and lead from mine drainage. Table 10 lists the dissolved metals ambient levels and targets assessed in the TMDL. Table 11 through Table 15 list the load allocations for these stream segments. The Upper Arkansas River could be relisted on the impaired waters list if load allocations and water quality standards are exceeded.

Table 8. Dissolved Copper Concentrations on Lake Creek

Stream Segment	Dissolved Copper Concentration			Hardness (mg/L as $CaCO_3$)	Chronic Water Quality Standard (µg/L)	Acute Water Quality Standard (µg/L)	Sample Period (# of Samples)
	Median (µg/L)	85th Percentile (µg/L) (1)(2)	Maximum (µg/L) (2)				
Mainstem of Lake Creek and all Tributaries and Wetlands (WBID COARUA10)	7.00	**12.65**	44.00	44.52	4.49	6.27	2000-2004 (30)

Source: Health Department 2012a, 2012b
Notes:
(1) Exceedences are in **bold**.
(2) The maximum measured value is compared to the acute water quality standard. The 85th percentile value is compared to the chronic water quality standard.

Table 9. Total Maximum Daily Load Allocations for Copper in Lake Creek

Month	Dissolved Copper Loading						Percent Reduction Needed to Attain Chronic Copper Table Value Standard
	Ambient Stream Concentration (lbs/day)	TMDL Allowable Load (lbs/day)	10% Margin of Safety (lbs/day)	TMDL with 10% Margin of Safety (lbs/day)	Waste Load Allocation (lbs/day)(1)	Load Allocation (lbs/day)	
Jan	1.05	0.70	0.07	0.63	0.00	0.86	40
Feb	1.68	0.55	0.05	0.49	0.00	0.68	71
Mar	3.35	0.73	0.07	0.66	0.00	0.90	80
Apr	2.50	1.58	0.16	1.42	0.00	1.47	43
May	16.97	19.40	1.94	17.46	0.00	9.38	0
Jun	46.59	32.70	3.27	29.43	0.00	19.53	37
Jul	11.77	10.02	1.00	9.02	0.00	9.64	23
Aug	5.52	5.35	0.54	4.82	0.00	5.51	13
Sep	2.17	2.49	0.25	2.24	0.00	2.84	0
Oct	1.31	1.74	0.17	1.57	0.00	2.12	0
Nov	2.90	1.62	0.16	1.45	0.00	1.40	50
Dec	0.88	1.00	0.10	0.90	0.00	1.18	0

Source: Health Department 2010b
Notes:
(1) Waste load allocation is zero because there are no permitted dischargers in this reach.

Table 10. Dissolved Metals Ambient Levels and Targets Used in the Arkansas River between Lake Fork Creek and Pueblo Reservoir TMDLs

Stream Segment	Pollutant	85th Percentile (µg/L)	Chronic Water Quality Standard (µg/L)	Sample Period (# of Samples)
Mainstem of the Arkansas River between Lake Fork Creek and Lake Creek (WBID COARUA02c)	Dissolved Cadmium	0.70	1.2	2000-2005 (320)
	Dissolved Zinc	149	284	
Mainstem of the Arkansas River between Lake Creek and Pueblo Reservoir (WBID COARUA03)	Dissolved Cadmium	0.41	0.33	1999-2005 (218)
	Dissolved Zinc	98	95	
	Dissolved Lead	0.00	1.78	

Source: Health Department 2009a

Table 11. Total Maximum Daily Load Allocations for Dissolved Cadmium in the Arkansas River between Lake Fork Creek and Lake Creek

Month	Dissolved Cadmium Loading			
	Total Maximum Daily Limit (lbs/day)	Total Discharger Waste Load Allocation (lbs/day)	Abandoned Mine Waste Load Allocation (lbs/day)	Total Load Allocation (lbs/day)
Jan	0.113	0.002	0.100	0.011
Feb	0.106	0.002	0.093	0.010
Mar	0.109	0.002	0.096	0.011
Apr	0.158	0.002	0.140	0.016
May	0.583	0.002	0.522	0.058
Jun	1.406	0.002	1.264	0.140
Jul	0.695	0.002	0.623	0.069
Aug	0.336	0.002	0.301	0.033
Sep	0.235	0.002	0.210	0.023
Oct	0.181	0.002	0.161	0.018
Nov	0.147	0.002	0.131	0.015
Dec	0.138	0.002	0.122	0.014

Source: Health Department 2009a

Table 12. Total Maximum Daily Load Allocations for Dissolved Zinc in the Arkansas River between Lake Fork Creek and Lake Creek

Month	Dissolved Zinc Loading			
	Total Maximum Daily Limit (lbs/day)	Total Discharger Waste Load Allocation (lbs/day)	Abandoned Mine Waste Load Allocation (lbs/day)	Total Load Allocation (lbs/day)
Jan	28.5	0.78	25.0	2.78
Feb	26.9	0.78	23.5	2.61
Mar	27.4	0.78	24.0	2.67
Apr	39.2	0.78	34.6	3.85
May	139.3	0.78	124.7	13.85
Jun	340.4	0.78	305.6	33.96
Jul	173.1	0.78	155.1	17.23
Aug	84.2	0.78	75.1	8.34
Sep	59.7	0.78	53.1	5.89
Oct	45.7	0.78	40.4	4.49
Nov	37.3	0.78	32.8	3.65
Dec	35.4	0.78	31.2	3.47

Source: Health Department 2009a

Table 13. Total Maximum Daily Load Allocations for Dissolved Cadmium in the Arkansas River between Lake Creek and Pueblo Reservoir

Month	Dissolved Cadmium Loading		
	Total Maximum Daily Limit (lbs/day)	Total Waste Load Allocation (lbs/day)	Total Load Allocation (lbs/day)
Jan	0.83	0.027	0.80
Feb	0.75	0.027	0.73
Mar	0.68	0.027	0.65
Apr	0.61	0.027	0.58
May	1.07	0.027	1.04
Jun	2.13	0.027	2.10
Jul	1.26	0.027	1.24
Aug	1.25	0.027	1.23
Sep	0.80	0.027	0.77
Oct	0.79	0.027	0.76
Nov	0.85	0.027	0.82
Dec	0.91	0.027	0.88

Source: Health Department 2009a

Table 14. Total Maximum Daily Load Allocations for Dissolved Zinc in the Arkansas River between Lake Creek and Pueblo Reservoir

Month	Dissolved Zinc Loading		
	Total Maximum Daily Limit (lbs/day)	Total Waste Load Allocation (lbs/day)	Total Load Allocation (lbs/day)
Jan	238	7.55	231
Feb	219	7.55	211
Mar	198	7.55	191
Apr	176	7.55	169
May	295	7.55	287
Jun	589	7.55	581
Jul	344	7.55	337
Aug	356	7.55	349
Sep	232	7.55	225
Oct	233	7.55	225
Nov	245	7.55	237
Dec	265	7.55	258

Source: Health Department 2009a

Table 15. Total Maximum Daily Load Allocations for Dissolved Lead in the Arkansas River between Lake Creek and Pueblo Reservoir

	Dissolved Lead Loading		
Month	Total Maximum Daily Limit (lbs/day)	Total Waste Load Allocation (lbs/day)	Total Load Allocation (lbs/day)
Jan	4.7	0.244	4.5
Feb	4.3	0.244	4.0
Mar	3.9	0.244	3.7
Apr	3.4	0.244	3.2
May	5.2	0.244	4.9
Jun	9.9	0.244	9.7
Jul	6.0	0.244	5.8
Aug	6.8	0.244	6.5
Sep	4.7	0.244	4.4
Oct	4.7	0.244	4.4
Nov	4.8	0.244	4.6
Dec	5.4	0.244	5.1

Source: Health Department 2009a

Suspended Sediment

Suspended sediments in surface water bodies are influence by climate (i.e. rainfall) and properties of exposed rock and soil (e.g. construction sites, logging areas). Suspended sediments reduce the clarity of the stream, impact its visual appeal, affect benthic invertebrates, and can reduce the conveyance capacity of the river channel once deposited. There are no quantitative in-stream water quality guidelines for suspended sediment, sediment discharge, or sediment yield, and there is no threshold above which suspended sediment concentrations are considered a water quality concern in this analysis.

There are limited sediment data for the Arkansas River main stem. Between 1990 and 1993, United States Geological Survey collected 24 to 28 sediment samples at various gages in the Arkansas River Basin (Figure 3). Concentrations upstream from Pueblo Reservoir tended to be lower than in the Arkansas River between Pueblo Reservoir and John Martin Reservoir. Increases in concentration at the Arkansas River at Portland gage are likely caused by changing geology and agricultural land use (Ortiz et al. 1998). Pueblo Reservoir causes sediment to settle so concentrations decrease downstream from Pueblo Reservoir. Ortiz et al. (1998) found that thunderstorms can generate large sediment loads in the Arkansas River between the Fountain Creek confluence and John Martin Reservoir.

Fountain Creek is a sand-bed stream characterized by high rates of erosion and deposition, and the water tends to be cloudy. Suspended sediment concentrations in Fountain Creek have been linked to urban development (Von Guerard 1989). The median suspended sediment concentration in Fountain Creek from 2000 through 2009 was 290 mg/L, though concentrations tend to be at least 10 times greater during storm events (Figure 4). Several tributaries to Fountain Creek, such as Sand Creek and Cottonwood Creek, contribute substantial amounts of sediment to Fountain Creek. Sand Creek contributes 23 to 37 percent of the sediment load at the Fountain Creek at Security gage (Mau et al. 2007). This sediment transport eventually contributes to sediment loads entering the Arkansas River.

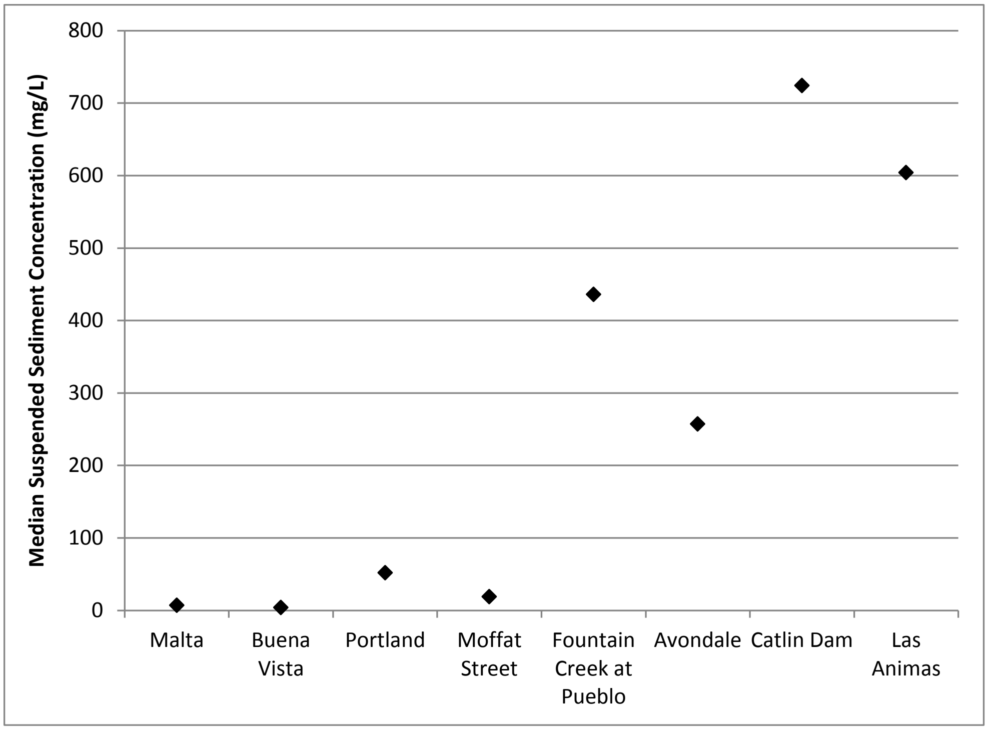


Figure 3. Median Suspended Sediment Concentrations at U.S. Geological Survey Gages, 1990 to 1993

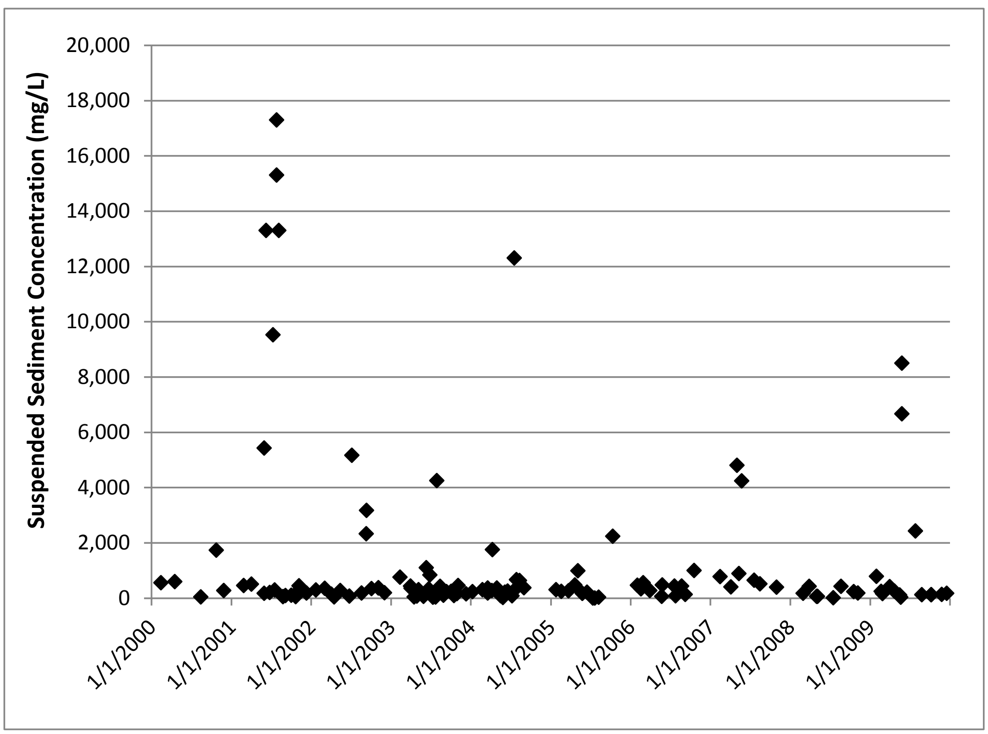
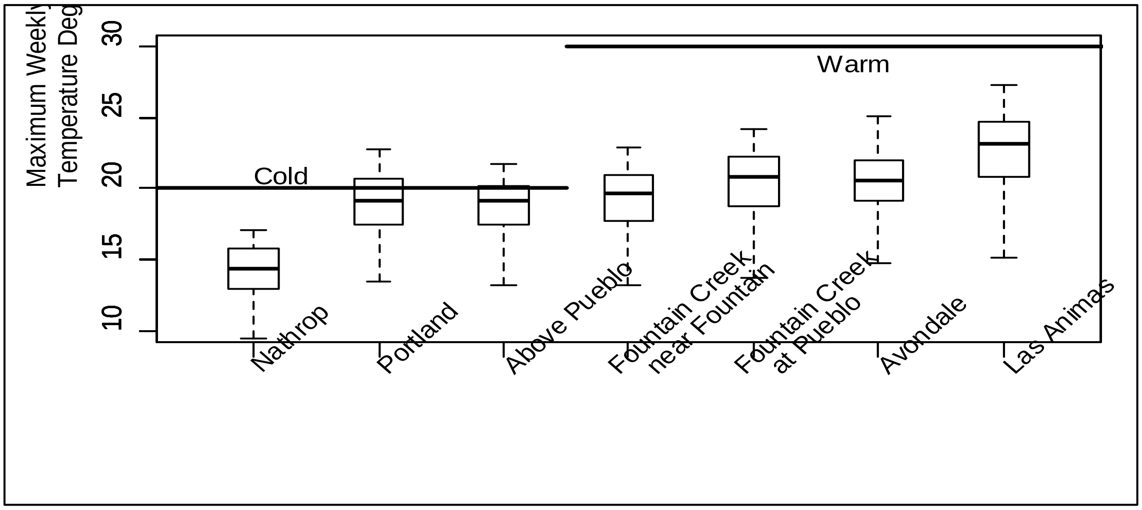


Figure 4. Suspended Sediment Concentrations for Fountain Creek at Pueblo Gage, 2000-2009

Temperature

The Arkansas River from the headwaters to the Wildhorse Creek confluence is classified as cold water Class I, with the remaining river classified as warm water Class I or Class II (see Chapter 3 and Appendix F). A boxplot showing maximum weekly average temperature statistics at Arkansas River and Fountain Creek gages and warm and cold water fishery standards is presented in Figure 5.



Source: USGS 2011

Figure 5. Boxplot of Summertime Maximum Weekly Average Temperatures at Arkansas River and Fountain Creek U.S. Geological Survey Gages

Nutrients

Regulated nutrients in the study area include ammonia, nitrate, and nitrite. Typical historical concentrations of ammonia are presented in Table 16. Nitrate and nitrite concentrations in the Lower Arkansas River are unavailable. Nutrients and trophic state in reservoirs are discussed in the Reservoir Water Quality section below.

Table 16. Ammonia Concentrations in Fountain Creek and the Lower Arkansas River

Stream Segment	85th Percentile (milligrams per liter)[1]	Water Quality Standard (milligrams per liter)	Sample Period (# of Samples)
Fountain Creek, Hwy 47 to Arkansas River (WBID COARFO02b)	0.05	N/A	2003-2009 (56)
Arkansas River, Wildhorse Creek to Fountain Creek (WBID COARMA03)	0.05	N/A	2005-2006 (4)
Arkansas River, Fountain Creek to Colorado Canal (WBID COARLA01a)	0.65	N/A	1998-2006 (38)
Arkansas River, Colorado Canal head gate to John Martin Reservoir (WBID COARLA01b)	0.11	N/A	2003-2009 (23)
Arkansas River, John Martin Reservoir to the Stateline (WBID COARLA01c)	0.11	N/A	2003-2009 (27)

Source: Health Department 2012a, 2012b
Key: N/A = not available
Notes:
(1) Exceedences are in **bold**. The 85th percentile measured value is compared to the water quality standard.

Reservoir Water Quality

Reservoir water quality is generally determined by the water quality of inflows; by a number of physical reservoir characteristics such as depth, temperature, evaporation rates, and circulation patterns; by residence time (i.e. the amount of time a unit volume of water is in the reservoir); and by activity of aquatic organisms. Changes in magnitude and timing of inflows and outflows can alter reservoir stratification characteristics, which can in turn affect water quality. Reservoir water quality and trophic state (i.e. biological condition) is greatly affected by nutrient levels in reservoir inflows as well as temperature and solar intensity. High temperatures and high nutrient levels lead to algae growth and reduced dissolved oxygen, which can inhibit beneficial uses of a reservoir.

Upper Arkansas River Basin Reservoirs

Turquoise Lake and Twin Lakes water quality is generally good, though Twin Lakes is listed on the 2012 impairment list. Historical dissolved copper concentration data for Twin Lakes Reservoir is in Table 17.

Table 17. Dissolved Copper Concentration in Twin Lakes Reservoir

Reservoir Site	Dissolved Copper Concentration			Hardness (mg/L as $CaCO_3$)	Chronic Water Quality Standard (µg/L)	Acute Water Quality Standard (µg/L)	Sample Period (# of Samples)
	Median (µg/L)	85th Percentile (µg/L)(1)(2)	Maximum (µg/L)(2)				
Twin Lakes Reservoir (Site Number 7174a)	3.0	7.6	10.0	27.8	8.0	4.0	2005-2010 (6)
Twin Lakes Reservoir (Site Number 7174b)	8.0	**9.0**	9.0	23.8	8.0	3.5	2006-2010 (5)

Source: Health Department 2012a, 2012b

Notes:

(1) Exceedences are in **bold**.

(2) The maximum measured value is compared to the acute water quality standard. The 85th percentile value is compared to the chronic water quality standard.

Pueblo Reservoir

The quality of inflows to Pueblo Reservoir from the Upper Arkansas River tends to be good with no impairments listed for streamflow into the reservoir in the 2012 303(d) list. Table 18 provides a summary of historical water quality values for Pueblo Reservoir releases. Historical uranium concentrations at the Arkansas River above Pueblo gage (indicative of Pueblo Reservoir release concentrations) are in Figure 6.

Table 18. Summary of Historical Water Quality Data for Pueblo Reservoir Releases

Parameter	Average Annual Water Quality[1]				Standard[2][3]
	1st Quarter (Jan-Mar)	2nd Quarter (Apr-Jun)	3rd Quarter (Jul-Sep)	4th Quarter (Oct-Nov)	
Temperature, C	8.6	13.4	20.5	13.0	N/A
Dissolved Oxygen , mg/L	11.5	10.0	8.5	9.3	6.0 mg/L
Turbidity, NTU	1.7	3.4	6.3	5.1	Treatment technique[4]
pH, standard units	8.4	8.3	8.0	8.3	6.5 to 9.0[3]
Alkalinity, mg/L as $CaCO_3$	127	120	98	121	N/A
Hardness, mg/L as $CaCO_3$	208	199	156	201	N/A
Total Dissolved Solids, mg/L	337	321	253	311	500[3]
Total Organic Carbon, mg/L	2.0	2.2	2.3	2.2	Treatment technique[5]
Sodium, mg/L	23.3	24.0	16.0	21.4	N/A
Nitrate, mg/L as N	0.27	0.22	0.22	0.15	10[2]
Chloride, mg/L	9.2	8.9	8.0	9.4	250[3]
Bromide[6], mg/L	0.027	0.026	0.024	0.028	N/A
Fluoride, mg/L	0.59	0.50	0.46	0.51	4.0[2]/2.0[3]
Sulfate, mg/L	130	123	97	123	250[3]
Silica, mg/L as SiO_2	12	9.6	10	12	N/A
Iron, mg/L	0.008	0.016	0.010	0.009	0.3[3]
Manganese, mg/L	0.004	0.007	0.010	0.020	0.05[3]
Arsenic, mg/L	< 0.001	< 0.001	< 0.001	< 0.001	0.01[2]
Selenium, mg/L	0.004	0.004	0.003	0.004	0.05[2]

Source: USGS 2010; BWWP 2011
Key: N/A – not applicable, NTU – nephelometric turbidity units
Notes:

(1) Samples collected at varying frequencies from 1986 to 2010. Not all parameters measured in each sample.
(2) Enforceable primary drinking water maximum contaminant level.
(3) Non-enforceable secondary drinking water maximum contaminant level.
(4) Less than 0.3 NTU in 95 percent of monthly filter effluent samples and less than 1 NTU in all filter effluent samples.
(5) Removal of constituent for conventional treatment facilities varies with source water total organic carbon and alkalinity concentrations (per Stage 1 Disinfectants and Disinfection Byproducts Rule).
(6) Bromide calculated based on correlation with chloride concentration (Magazinovic, 2004).

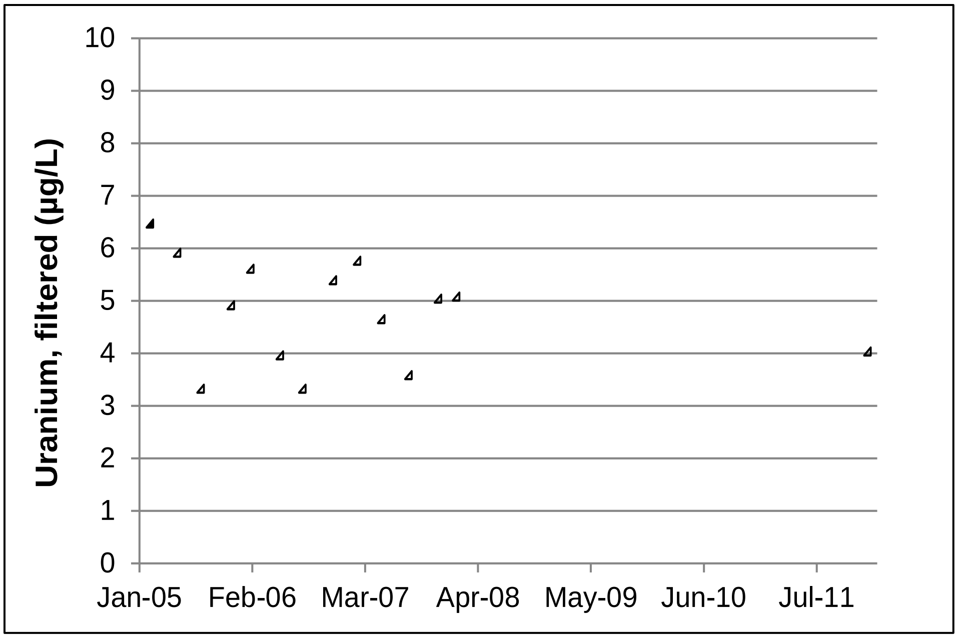


Figure 6. Historical Uranium Concentrations at the Arkansas River Above Pueblo Gage

Lower Arkansas River Basin Reservoirs

Salinity levels in Lake Henry and Lake Meredith typically exceed agricultural tolerances and secondary drinking water guidelines in Lake Henry and Lake Meredith (Table 19). Lake Henry, Lake Meredith, and John Martin Reservoir are on the 2012 impaired list for selenium.

Table 19. Lower Arkansas River Basin Reservoir Water Quality

Parameter	Lake Henry 85th Percentile (1)	Lake Meredith 85th Percentile (1)	John Martin Reservoir 85th Percentile (1)
Total Dissolved Solids, mg /L	1,007	2,955	2,225
Selenium, µg /L	**13.6**	**5.4**	**9.7**

Source: Health Department 2012a, 2012b
Notes:
(1) Exceedences are indicated in **bold**. The 85th percentile measured value is compared to the water quality standard.

Reverse Osmosis Brine Reject Concentrate

La Junta and Las Animas use reverse osmosis in their water treatment process and discharge their brine reject concentrate to the Arkansas River. The quality of reverse osmosis brine reject concentrate for Las Animas is in Table 20, respectively. No data is readily available on La Junta's reverse osmosis process waste stream characteristics. Both entities release the reverse osmosis rejection concentrate to the Arkansas River under permits issued by the Health Department.

Table 20. Las Animas RO Rejection Concentrate Water Quality

Parameter	Unit	Measured Value
Uranium	µg /L	87
Alpha emitting Radium	pCi/L	0.36
Gross Alpha	pCi/L	36
Gross Beta	pCi/L	17
Radium 228	pCi/L	14

Source: Health Department 2009b

References

Board of Public Water Works of Pueblo (BWWP). 2011. Pueblo Reservoir Water Quality Data. Personal Communication.

Colorado Department of Public Health and the Environment (Health Department). 2006. Regulation #42, Site-Specific Water Quality Classifications and Standards for Groundwater. Amended February 13, 2006, effective March 30, 2006.

Colorado Department of Public Health and Environment (Health Department). 2009a. Total Maximum Daily Load Assessment, Arkansas River/Lake Creek/Chalk Creek/Evans Gulch, Lake/Chaffee County, Colorado. June.

Colorado Department of Public Health and the Environment (Health Department). 2009b. City of Las Animas PWSID CO0106300 Abatement and Disposal Strategy (CO-RADS) Report. February.

Colorado Department of Public Health and the Environment (Health Department). 2010a. Regulation #93, Section 303(d) List Water-Quality-Limited Segments Requiring TMDLs. Adopted March 9, 2010, effective April 30, 2010.

Colorado Department of Public Health and the Environment (Health Department). 2010b. Total Maximum Daily Load (TMDL) Assessment, Lake Creek, Lake County, Colorado. June 2010.

Colorado Department of Public Health and the Environment (Health Department). 2012a. Regulation #32, Classifications and Numeric Standards for the Arkansas River Basin and Tables. Amended November 14, 2011; effective January 1, 2012.

Colorado Department of Public Health and Environment (Health Department). 2012b. Data sheets for Arkansas River ambient water quality for the 2012 303(d) list rationale. From A. Konowal and R. Anthony, July 18.

Colorado Foundation for Water Education. 2003. Citizen's Guide to Colorado Water Quality Protection. Available: https://www.cfwe.org/flip/catalog.php?catalog=quality.

Edelmann, P; S. Ferguson; R. Stogner, Sr.; M. August; W. Payne; J. Bruce. 2002. Evaluation of Water Quality, Suspended Sediment, and Stream Morphology with an Emphasis on Effects of Stormflow on Fountain and Monument Creek Basins, Colorado Springs and Vicinity, Colorado, 1981 through 2001, U.S. Geological Survey Water-Resources Investigations Report 2002-4104.

EPA – See U.S. Environmental Protection Agency

Health Department – See Colorado Department of Public Health and Environment

Magazinovic, R. S., B. C. Nicholson, D.E. Mulcahy, and D. E. Davey. 2004. Bromide levels in natural waters: its relationship to levels of both chloride and total dissolved solids and the implications for water treatment, Chemosphere, 57, 2004, pp. 329-335.

Malcolm, Pirnie. 2009. Colorado Radionuclide Abatement and Disposal Strategy (CO-RADS) Phase 2 and 3 Summary Report, prepared for Colorado Department of Health and Environment. March.

Mau, D.P., R.W. Stogner, and P. Edelmann. 2007. Characterization of Stormflows and Wastewater Treatment-Plant Effluent Discharges on Water Quality, Suspended Sediment, and Stream Morphology for Fountain and Monument Creek Watersheds, Colorado 1981-2006. U.S. Geological Survey Scientific Investigations Report 2007-5104.

Miller, L.D, K.R. Watts, R.F. Ortiz, and T. Ivahnenko. 2010. Occurrence and Distribution of Dissolved Solids, Selenium, and Uranium in Groundwater and Surface Water in the Arkansas River Basin from the Headwaters to Coolidge, Kansas, 1970-2009. U.S. Geological Survey Scientific Investigations Report 2010-5069

Ortiz, R.F., M.E. Lewis, and M.J. Radell. 1998. Water-quality Assessment of the Arkansas River Basin, Southeastern, Colorado, 1990-1993. U.S. Geological Survey Water-Resources Investigations Report 97-4111.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. United States Salinity Laboratory Staff. U.S. Department of Agriculture Handbook 60.

U.S. Environmental Protection Agency (EPA). 2003. National secondary drinking water regulations: U.S. Environmental Protection Agency. Accessed April 26, 2009, at http://www.epa.gov/safewater/contaminants/index.html#sec.

U.S. Environmental Protection Agency (EPA). 2007. EPA – Envirofacts warehouse – PCS Available: http://www.epa.gov/enviro/html/pcs/pcs_query.html. Downloaded multiple times in 2007.

U.S. Geological Survey. 1992. The digital geologic map of Colorado in ARC/INFO Format. Open-File Report 92-507. Denver, CO.

U.S. Geological Survey. 2009. Sources of Fecal *E. Coli* to Upper Fountain Creek Summary of Final Project Results. September 9.

U.S. Geological Survey. 2010. National Water Information System, U.S. Geological Survey Station 07099400. Accessed November 12, 2010. http://waterdata.usgs.gov/nwis

U.S. Geological Survey. 2011. Surface-water data for the nation. Available: http://waterdata.usgs.gov/nwis/sw. Accessed March 2011.

Von Guerard, P. 1989. Suspended sediment and sediment-source areas in the Fountain Creek drainage basin upstream from Widefield, southeastern Colorado. U.S. Geological Survey Water-Resources Investigation Report 88-4136. Denver.

Attachment F.1-1

Colorado's 2012 Section 303(D) List of Impaired Waters and Monitoring and Evaluation List (Arkansas River Basin)

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

WATER QUALITY CONTROL COMMISSION

5 CCR 1002-93

REGULATION #93

COLORADO'S SECTION 303(D) LIST OF IMPAIRED WATERS AND MONITORING AND EVALUATION LIST

ADOPTED:	**MARCH 17, 2004**
EFFECTIVE:	**MAY 3, 2004**
ADOPTED:	**MARCH 14, 2006**
EFFECTIVE:	**APRIL 30, 2006**
ADOPTED:	**MARCH 11, 2008**
EFFECTIVE:	**APRIL 30, 2008**
ADOPTED:	**MARCH 9, 2010**
EFFECTIVE:	**APRIL 30, 2010**
ADOPTED:	**FEBRUARY 13, 2012**
EFFECTIVE:	**MARCH 30, 2012**

DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

WATER QUALITY CONTROL COMMISSION

5 CCR 1002-93

REGULATION #93

COLORADO'S SECTION 303(D) LIST OF IMPAIRED WATERS AND MONITORING AND EVALUATION LIST

93.1 Authority

These regulations are promulgated pursuant to section 25-8-101 et seq C.R.S. as amended, and in particular, 25-8-202 (1) (a), (b), (i), (2) and (6); 25-8-203 and 25-8-204.

93.2 Purpose

This regulation establishes Colorado's List of Water-Quality-Limited Segments Requiring Total Maximum Daily Loads ("TMDLs") and Colorado's Monitoring and Evaluation List.

(1) The list of Water-Quality-Limited Segments Requiring TMDLs fulfills requirements of section 303(d) of the federal Clean Water Act which requires that states submit to the U.S. Environmental Protection Agency a list of those waters for which technology-based effluent limitations and other required controls are not stringent enough to implement water quality standards.

(2) Colorado's Monitoring and Evaluation List identifies water bodies where there is reason to suspect water quality problems, but there is also uncertainty regarding one or more factors, such as the representative nature of the data. Water bodies that are impaired, but it is unclear whether the cause of impairment is attributable to pollutants as opposed to pollution, are also placed on the Monitoring and Evaluation List. This Monitoring and Evaluation list is a state-only document that is not subject to EPA approval.

93.3 Water Bodies Requiring TMDLs or Identified for Monitoring and Evaluation

Only those segments where a Clean Water Section 303(d) Impairment has been determined require TMDLs. For these segments, TMDLs are only required for those parameters that are identified as impairments. Listings marked with an asterisk (*) are carryover from the 1998 303(d) List. Consequently they are all high priority.

WBID	Segment Description	Portion	Colorado's Monitoring & Evaluation Parameter(s)	Clean Water Act Section 303(d) Impairment	303(d) Priority
COAR	**Arkansas River Basin**				

WBID	Segment Description	Portion	Colorado's Monitoring & Evaluation Parameter(s)	Clean Water Act Section 303(d) Impairment	303(d) Priority
COARFO01a	Fountain Creek and tributaries above Monument Creek	all		*E. coli*	H
COARFO02a	Fountain Creek, Monument Creek to Hwy 47	all	Fe(Trec)	*E. coli*	H
COARFO02b	Fountain Creek from Hwy 47 to the Arkansas River	all		*E.coli* (May-October)	H
COARFO04	All tribs to Fountain Creek, which are not on National Forest or Air Force Academy Land	all		*E.coli*	H
COARFO04	All tribs to Fountain Creek, which are not on National Forest or Air Force Academy Land	Sand Creek	Aquatic Life		
COARFO06	Monument Creek from National Forest to Fountain Creek	All (for *E. coli*)		*E.coli* (May-October)	H
COARFO07a	Pikeview Reservoir, Willow Springs Ponds #1 and #2	Willow Springs Ponds #1 & #2		Aquatic Life Use (PCE FCA)	M
COARLA01a	Arkansas River, Fountain Creek to Colorado Canal headgate	all		Se, SO_4	L
COARLA01b	Arkansas River, Colorado Canal headgate to John Martin Reservoir	all		Se	L
COARLA01c	Arkansas River, John Martin Reservoir to stateline	all		Se, U	L
COARLA04	Apishapa River, Timpas Creek, Lorencito Canyon	Apishapa River, Timpas Creek		Se	L
COARLA04	Apishapa River, Timpas Creek, Lorencito Canyon	Timpas Creek		Fe(Trec)	H

WBID	Segment Description	Portion	Colorado's Monitoring & Evaluation Parameter(s)	Clean Water Act Section 303(d) Impairment	303(d) Priority
COARLA05b	Trinidad Reservoir, Long Canyon Reservoir, and Lake Dorothey	Trinidad Reservoir		Aquatic Life Use (Hg Fish Tissue), D.O. (Temperature)	H
COARLA07	Purgatoire River, I-25 to Arkansas River	all	Sediment	Se	L
COARLA09a	Mainstem of Adobe Creek and Gageby Creek…	all		Se	L
COARLA09a	Mainstem of Adobe Creek and Gageby Creek…	Horse Creek		Fe(Trec)	H
COARLA09a	Mainstem of Adobe Creek and Gageby Creek…	Adobe Creek		*E. coli*	H
COARLA09b	Apache Creek, Breckenridge Creek, Little Horse Creek, Bob Creek, Wildhorse Creek, Wolf Creek, Big Sandy Creek	all		Se	L
COARLA09c	Rule Creek, Muddy Creek, Caddoa Creek, Clay Creek, Cat Creek…	As specified to right	Zn (Rule Creek)	Fe(Trec), Se (Chicosa Creek)	L
COARLA10	Two Buttes Res., Two Buttes Pond, Hasty Lake, Holbrook Res., Burchfield Lake, Nee-Skah (Queens) Res., Adobe Creek Res., Neeso Pah Res., Nee Nosha Res., Nee Gronda Res.	Adobe Creek Res., Nee Gronda Res		Se	L
COARLA11	John Martin Reservoir	all		Se	L
COARLA12	Lake Henry, Lake Meredith	all		Se	L
COARMA04a	Wildhorse Creek	all	NO_2	*E. coli*, Se	H/L

WBID	Segment Description	Portion	Colorado's Monitoring & Evaluation Parameter(s)	Clean Water Act Section 303(d) Impairment	303(d) Priority
COARMA06	St. Charles River and tributaries, CF&I diversion to Arkansas River	all	U	Se	L
COARMA07	Greenhorn Creek, including all tributiaries, from source to Greenhorn Highline Diversion Dam; Graneros Creek; North Muddy Creek	all	Cu, Zn		
COARMA09	Greenhorn Creek, including tributaries, from Greenhorn Highline Diversion Dam to the St. Charles River	all	Se		
COARMA10	Sixmile Creek	all		Fe(Trec), Se	L
COARMA12	Huerfano River, from Muddy Creek to the Arkansas River	all		Se	L
COARMA14	Cucharas River, from Walsenburg PWS diversion to the outlet of Cucharas Reservoir	all		Se	L
COARMA16	Huajatolla Reservoir, Diagre Reservoir, Walsenburg Lower Town Lake, Horseshoe Lake and Martin Lake (Ohem Lake)	Horseshoe Lake		Aquatic Life Use (Hg Fish Tissue)	H
COARMA18a	Boggs Creek	all		Se, Zn, U	H
COARUA05	All tributaries to the Arkansas River from the source to immediately below the confluence with Browns Creek	Lake Fork below Sugarloaf Dam to the confluence with the Arkansas River	Aquatic Life		
COARUA08b	Iowa Gulch from ASARCO water supply intake to Paddock #1 Ditch (Iowa Ditch)	all		Cd, Pb, Zn	M

WBID	Segment Description	Portion	Colorado's Monitoring & Evaluation Parameter(s)	Clean Water Act Section 303(d) Impairment	303(d) Priority
COARUA10	Mainstem of Lake Creek and all tributaries, lakes and reservoirs from source to Arkansas River (including Twin Lakes Reservoir)	all, excluding Twin Lakes Reservoir		pH, D.O.	H
COARUA10	Mainstem of Lake Creek and all tributaries, lakes and reservoirs from source to Arkansas River (including Twin Lakes Reservoir)	Twin Lake West		Cu	H
COARUA14b	Tributaries to the Arkansas River, from Pueblo Reservoir to Colorado Canal headgate	Teller Reservoir	Aquatic Life Use (Hg Fish Tissue)		
COARUA15	Grape Creek including De Weese Res., Texas, Badger, Hayden, Hamilton, Stout and Big Cottonwood Creeks, Newland Creek	De Weese Reservoir		D.O.	H
COARUA20	Fourmile Creek and tributaries, Cripple Creek to Arkansas River	North Fork Wilson Creek below Independence Mine		As	
COARUA21a	Mainstem of Cripple Creek from the source to a point 1.5 miles upstream of the confluence with Fourmile Creek.	all		Aquatic Life (provisional)	L
COARUA27	Mainstem of Eightmile Creek, including all tributaries, wetlands, lake and reservoirs, from the source to the mouth of Phantom Canyon; Brush Hollow Reservoir	Brush Hollow Reservoir		Aquatic Life Use (Hg Fish Tissue), D.O.	H
COGU	**Gunnison River Basin**				

Appendix F.2 – Water Quality Analyses

This appendix presents the water quality effects analyses for different constituents and areas of concern within the study area.

Salinity Analysis

This section describes how the AVC EIS alternatives effects on salinity were evaluated through development, calibration, and application of a model simulating changes in salinity due to physical and operational changes in river flow.

Methods

Triana et al. (2010) developed the GeoDSS, a geo-referenced Decision Support System for Agro-environmental enhancement of Colorado's Lower Arkansas River Basin. The GeoDSS features tools for calibration and simulation of flows and water quality in river basins. The GeoDSS flow modeling is based on MODSIM, a generalized River Basin Management Decision Support System (Labadie 2006). GeoDSS includes a water quality module for conservative constituent simulation that allows estimating unmeasured concentration of inflows based on the simulated concentrations and the measured concentration at control points (i.e., gage stations with measured concentration).

As discussed in Chapter 3, salinity is a concern in the Lower Arkansas River and Fountain Creek, particularly in the Arkansas River downstream from the Avondale gage, as well as in Fountain Creek from Jimmy Camp Creek to the Arkansas River. The salinity model encompasses the area of concern and also extends far enough upstream to simulate physical and operational changes associated with the alternatives. The model includes the Arkansas River from Pueblo Reservoir to the Arkansas River at Las Animas gage and Fountain Creek downstream from Colorado Springs.

Figure 1 depicts the salinity model study area, United States Geological Survey (USGS) and Colorado Division of Water Resources gages with salinity measurements used in model development, and approximated location of the wastewater treatment facilities (WWTFs) accounted for in the model. Although some of the stream gages are operated by the Colorado Division of Water Resources, all of the data were obtained from the USGS, and therefore, the USGS gage names and numbers are referenced.

Salinity is the amount of mineral salts dissolved in water. It can be measured directly by determining the concentration of total dissolved solids (TDS). An indirect measurement of salinity is specific conductance, or how well water can conduct electricity. Salinity is directly correlated with specific conductance; however, the relationship between specific conductance and TDS changes with location and concentration levels. Specific conductance is easily measured with a probe and is the most common measure of salinity in the study area. Therefore, these relationships were used to estimate TDS at the controls points. The unit of measure of salinity used in this model is TDS in milligrams per liter (mg/L).

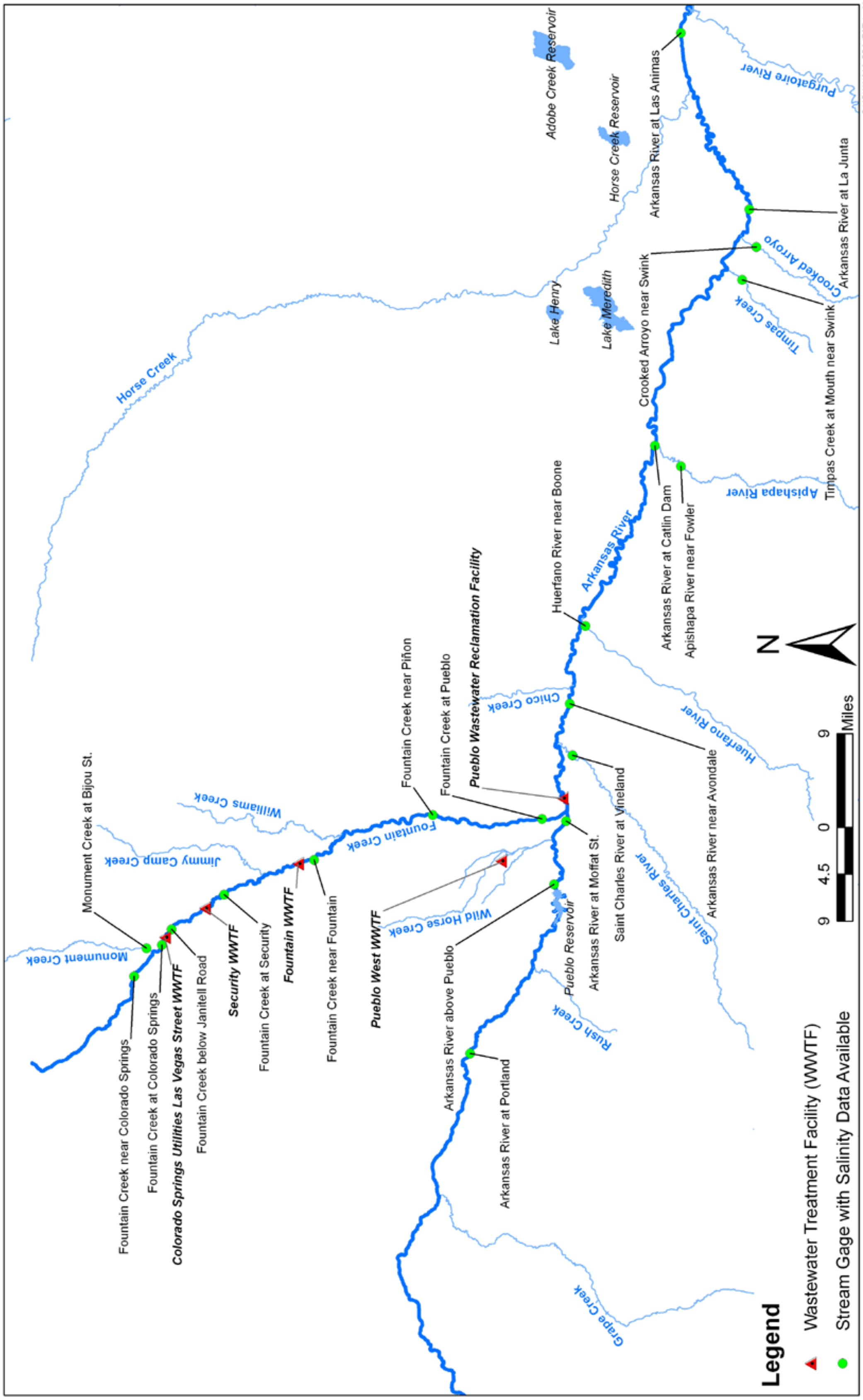


Figure 1. **Salinity Model Study Area and Control Point/Gage Locations**

A mass balance approach was selected to model salinity in the Lower Arkansas River Basin. The GeoDSS was coupled with the MODSIM Daily Model to evaluate effects of the alternatives on salinity concentrations based on simulated changes in flow conditions from the Daily Model. The salinity model, implemented in the GeoDSS water quality module, was calibrated to match measured concentrations at control points, estimating the concentration of measured and unmeasured inflows without defined/measured concentration. The salinity model was used to compare salinity among alternatives. It should not be used as an absolute prediction of future water quality, but as an indication of relative water quality effect among alternatives.

Model Study Period

Changes in salinity were analyzed using a 10-year model study period, from 1999 through 2009, based on the original GeoDSS study period extended through the Daily Model study period. Weekly time steps were selected as the model interval to reasonably capture the concentration variability based on the limited data availability throughout the study area.

Table 1summarizes the period of record for stream gages salinity measurements available at the time of model construction at regular and irregular measurement intervals. *Regular* measurements refer to data taken at constant intervals of time and *irregular* measurement refers to samples taken during field visits at variable intervals. Table 1 lists number of measurements available for each station, data type and abbreviations used in this appendix.

Table 1. Daily Salinity Data Period of Record for Stream Gages

Gage Name	Abbreviation	Measurement Interval	Number of Measurements	Daily Salinity Data Period of Record
Arkansas River at Portland	7097000	Irregular	6,659	Oct/1990 - Sep/2009
Arkansas River above Pueblo	ARKPUECO	Irregular	651	Oct/1965 - Dec/2010
Arkansas River above Pueblo	ARKPUECO	Regular	8,480	Apr/1986 - Sep/2009
Arkansas River at Moffat St.	ARKMOFCO	Irregular	287	Oct/1988 - Dec/2010
Arkansas River at Moffat St.	ARKMOFCO	Regular	7,572	Oct/1988 - Sep/2009
Fountain Creek near Colorado Springs	07103700	Regular	6,940	Oct/1990 - Sep/2009
Fountain Creek near Colorado Springs	07103700	Irregular	841	Oct/1971 - Dec/2010
Monument Creek at Bijou St.	07104905	Regular	6,940	Oct/1990 - Sep/2009
Fountain Creek at Colorado Springs	07105500	Irregular	997	Nov/1970 - Dec/2010
Fountain Creek below Janitell Road	07105530	Regular	6,940	Oct/1990 - Sep/2009
Fountain Creek at Security	07105800	Irregular	715	Nov/1970 - Dec/2010
Fountain Creek near Fountain	07106000	Irregular	236	Jun/1905 - Oct/2010
Fountain Creek near Fountain	07106000	Regular	6,940	Oct/1990 - Sep/2009
Fountain Creek near Piñon	FOUPINCO	Irregular	1,419	Apr/1973 - Nov/2011
Fountain Creek at Pueblo	FOUPUECO	Irregular	1,458	Nov/1963 - Dec/2010
Fountain Creek at Pueblo	FOUPUECO	Regular	6,940	Oct/1990 - Sep/2009
Saint Charles River at Vineland St.	STCHARCO	Regular	6,940	Oct/1990 - Sep/2009
Arkansas River near Avondale	ARKAVOCO	Irregular	1,866	Feb/1969 - Dec/2010
Arkansas River near Avondale	ARKAVOCO	Regular	8,837	Jul/1979 - Sep/2009
Huerfano River near Boone	HUEBOOCO	Irregular	386	Apr/1976 - Nov/2011
Arkansas River at Catlin Dam	ARKCATCO	Irregular	6,609	Oct/1990 - Sep/2009
Apishapa River near Fowler	APIFOWCO	Irregular	520	Nov/1963 - Nov/2011
Timpas Creek at Mouth	TIMSWICO	Irregular	525	Mar/1967 - Nov/2011
Crooked Arroyo near Swink	CANSWKCO	Irregular	289	Dec/1968-Sep/1993
Arkansas River at La Junta	ARKLAJCO	Irregular	131	Oct/1961 - Nov/2009
Arkansas River at Las Animas	ARKLASCO	Irregular	9,400	Nov/1945 - Sep/2009
Arkansas River at Las Animas	ARKLASCO	Regular	6,422	Dec/1985 - Sep/2005

Historical salinity data for gages with missing data were simulated using flow and salinity relationships derived from available data. This was done so that the baseline salinity model could be calibrated to evaluate changes in concentration for the alternatives for the selected study period.

General Model Organization

The model was designed for a relative comparison of the effects of the alternatives on the salinity of the system. The approach established a baseline salinity condition based on historical measurements of specific conductance and relationships between flow and specific conductance at control points (gages with measured concentrations). Unknown sources of salinity were estimated based on mass balance computations in river segments between control points.

The main assumption of the salinity modeling was that the changes in salt loads in the system would be driven mainly by changes in flows, and the underlying physical processes that are the source of the salinity loading to the system would remain relatively unchanged for the alternatives. For example, groundwater return flows were assumed to have the same historical concentration and salt load changes were a function of return flow changes.
Regression equations to represent the relationship between specific conductance and flow were used at control points to fill in missing data. The locations in the main rivers where regression

equations were used include: the Monument Creek at Bijou St. gage, Fountain Creek near Colorado Springs gage, Fountain Creek below Janitell Road gage, Fountain Creek at Pueblo gage, Arkansas River at Portland gage, Arkansas River at Moffat St. gage, Arkansas River above Pueblo gage, Arkansas River near Avondale gage, Arkansas River at Catlin Dam gage, and Arkansas River at Las Animas gage. Historical regression equations were also used to predict salinity in large tributaries, including the St. Charles River, Timpas Creek, Huerfano River, Crooked Arroyo and Apishapa River. Figure 2 shows a schematic of the model under existing conditions with the control points used to calibrate the different segments.

For most upstream nodes where proposed operations are unlikely to affect historical conditions, the filled historical concentrations were used as a starting point to estimate specific conductance in the study area. In other places in the model, the filled historical concentrations were used to estimate the unmeasured concentration of inflows including groundwater returns and surface runoff. Full mix of the salinity loadings was assumed at each point in the GeoDSS modeling network, generating a node outflow concentration that was carried out to the next downstream node. Outflows were assigned with the full-mixed concentration computed at the location where they are taken out of the system.

Some WWTFs were explicitly modeled with a specified salinity concentration assigned to their return flow. Other WWTF simulated in the Daily Model were simulated with a calibrated concentration based on the mass balance of the segment where they are located. The WWTFs modeled explicitly were Colorado Springs Utilities at Las Vegas Street, Security, Fountain and Pueblo West.

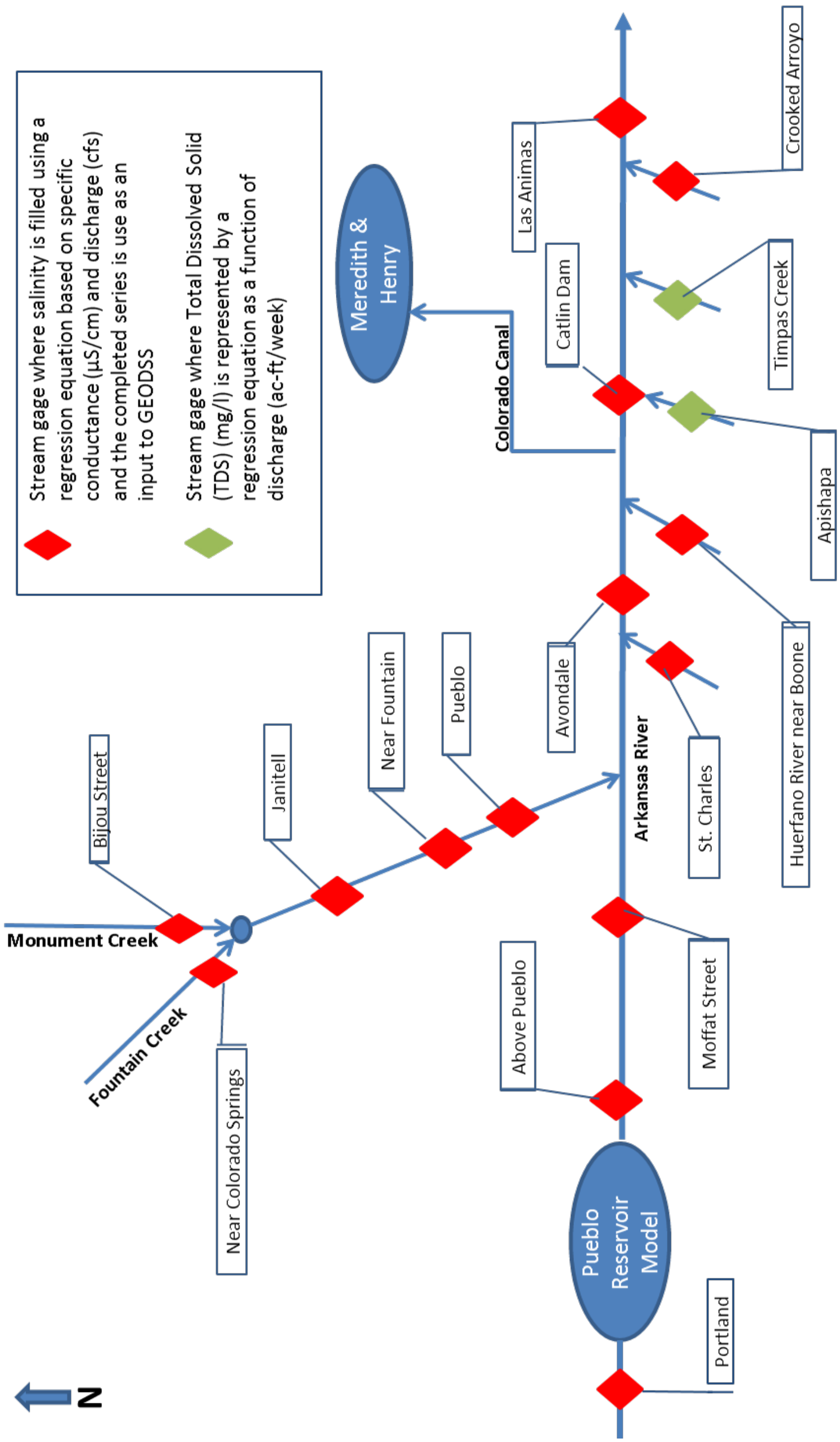


Figure 2. Salinity Model Schematic for Existing Conditions

Specific Conductance and Total Dissolved Solids. The use of specific conductance has the benefit of a large amount of historical data. However, specific conductance is not actually a unit based on mass. Specific conductance measures how well water conducts electricity, which is related to ions associated with the breakdown of dissolved solids. Thus, relationships are used to relate measurements of specific conductance to dissolved solids, which vary at different locations in the study area. Recent representations of TDS based on specific conductance (USGS 2010) were used to estimate the TDS at the different locations in the study area. For locations without defined relationships, a nearby gage with similar drainage characteristics was selected. Table 2 shows the selection of relationship for the modeled control points used to estimate TDS.

Table 2. Summary of Relationship to Estimate Total Dissolved Solids at the Modeled Gages

Gage	USGS Equation
Fountain Creek near Colorado Springs	TDS = 0.7186 * SC - 56.053
Monument Creek at Bijou St.	TDS = 0.7186 * SC - 56.053
Fountain Creek below Janitell	TDS = 0.7186 * SC - 56.053
Fountain Creek near Fountain	TDS = 0.7186 * SC - 56.053
Fountain Creek at Pueblo	TDS = 0.7701 * SC - 98.323
Arkansas River at Portland	TDS = 0.6426 * SC - 6.7052
Arkansas River above Pueblo	TDS = 0.7213 * SC - 38.816
Arkansas River at Moffat St.	TDS = 0.7213 * SC - 38.816
Saint Charles River at Vineland	TDS = 0.9717 * SC - 174.3
Arkansas River near Avondale	TDS = 0.793 * SC - 89.256
Huerfano River near Boone	TDS = 0.9371 * SC +167.89
Apishapa River near Fowler	TDS = 0.9609 * SC - 259.69
Arkansas River at Catlin Dam	TDS = 0.8652 * SC - 145.43
Arkansas River near Rocky Ford	TDS = 0.8652 * SC - 145.43
Timpas Creek at Mouth	TDS = 0.9527 * SC - 280.28
Crooked Arroyo near Swink	TDS = 0.9527 * SC - 280.28
Arkansas River at Las Animas	TDS = 0.9126 * SC - 230.95

Key: TDS = total dissolved solid in mg/l, SC = specific conductance in µS/cm

Notes:

(1) Relationship between specific conductance and TDS from a nearby gage was used for the locations where no relationship was available from the report.

(2) Regression between the two variables at the Fountain Creek near Fountain gage was used for all the other stations upstream of the gage, regression at the Arkansas River above Pueblo was used for the Arkansas River at Moffat St. gage, regression at the Arkansas River at Catlin Dam gage was used for the Arkansas river at Rocky ford gage, and regression at the Timpas Creek near Swink gage was used for the Crooked Arroyo near Swink gage.

The relationship between the two variables at the Fountain Creek at Pueblo gage was used for the Arkansas River at Moffat St. gage, while the relationship at Timpas Creek near Swink gage was used for the Crooked Arroyo near Swink.

Salinity and Flow Relationships for Missing Salinity Data. Missing specific conductance data were estimated for model development using the regression equation producing the highest correlation and smallest mean absolute error (MAE) between measured flow and specific conductance. Seven-parameter relationship between flow and concentration developed by Cohn (1992) was used as a regression equation alternative. If there was no regression equation with an R^2 greater than 0.5, the missing data were computed via interpolation.

The seven-parameter regression equation includes two flow terms, two sinusoidal terms to account for seasonality, and two time terms to account for any temporal trends. The regression equation (Equation 1) takes the following form:

Equation 1

$$\ln(SC)=\beta_0 + \beta_1 \ln(Q/Qc) + \beta_2 [\ln(Q/Qc)]^2 + \beta_3(T-Tc) + \beta_4(T-Tc)^2 + \beta_5 \sin(2\Pi T) + \beta_6 \cos(2\Pi T) + E$$

where
SC = specific conductance (μS/cm)
β_x = constants
Q = streamflow (cfs)
T = time (years), note, initial time equal to 10/1/1980 for all equations in this study
Qc, Tc = centering terms for flow and time, defined in Cohn et al. (1992)
Π = constant, pi
E = independent, random error

The seven-term equation methodology was successfully used by USGS (2004) to study dissolved concentrations in the vicinity of Pueblo. In the current study, this seven-term regression model was implemented to represent missing specific conductance for: Fountain Creek near Colorado Springs and Fountain Creek below Janitell Road gages; Monument Creek at Bijou St gage; Arkansas River at Portland and Arkansas River near Rocky Ford gages; as well as Crooked Arroyo near Swink gage and Huerfano near Boone gage.

Table 3 summarizes the methods used to fill model control point missing data. Table 4 summarizes the seven term regression coefficients for the gages that use this equation type.

In cases where interpolation was used, each interpolated data point was verified for integration with the surrounding specific conductance and flow data. When interpolation resulted in data outside of the historical range, the mean of the two closest recorded specific conductance measurements was used for the missing day.

The performance of the regression equations was evaluated using the coefficient of determination between the predicted and measured values. Plots were used to visually illustrate the comparison between estimated and measured concentration and the performance of the equations over the period of measured data. Since these equations were used to fill-in missing data, the correlation and mean absolute error provide insight on the expected level of error during the fill-in process.

Table 3. Summary of Method Used to Estimate Missing Daily Specific Conductance Data

Gage	Curve Type	Missing Data (%)	Equation	Method	R^2	MAE (mg/L)
Fountain Creek near Colorado Springs	-	93	7 Term Regression	Regression	0.77	23.46
Monument Creek at Bijou St.	-	97	7 Term Regression	Regression	0.67	49.12
Fountain Creek below Janitell Road	*	59	7 Term Regression	Regression	0.60	47.07
Fountain Creek near Fountain	-	7	None	Interpolation	-	-
Fountain Creek at Pueblo	Log	3	SC = -207.3Ln(Q) + 2147.9	Regression	0.62	58.87
Arkansas River at Portland	-	4	7 Term Regression	Regression	0.63	26.37
Arkansas River above Pueblo	-	3	None	Interpolation	-	-
Arkansas River at Moffat St.	Power	14	$SC = 1851.1(Q)^{-0.215}$	Regression	0.58	67.61
Saint Charles River at Vineland	Power	97	$SC = 5525.7(Q)^{-0.416}$	Regression	0.81	228.30
Arkansas River near Avondale	Log	6	SC=-249.4Ln(Q)+2421.6	Regression	0.68	65.55
Huerfano River near Boone	-	92	7 Term Regression	Regression	0.79	467.47
Apishapa River near Fowler	Log	99	TDS = = -518.3Ln(Q*) + 3777.5	Regression	0.72	262.35
Arkansas River at Catlin Dam	-	7	None	Interpolation	-	-
Arkansas River near Rocky Ford	-	98	7 Term Regression	Regression	0.83	116.11
Timpas Creek at Mouth	Power	88	$TDS = 19140(Q^*)^{-0.393}$	Regression	0.62	251.70
Crooked Arroyo near Swink	-	94	7 Term Regression	Regression	0.75	248.34
Arkansas River at Las Animas	-	-	None	Interpolation	-	-

Key: SC = specific conductance in µS/cm, TDS = Total Dissolved Solids in mg/L, Q = streamflow in cfs,
R^2 = coefficient of determination of estimated Vs. measured concentration,
MAE = Mean Absolute Error = average(abs(Yobs-Yexp))

Table 4. Summary of Coefficients for the Seven Term Regression Equation Between Flow and TDS

Gage	β_0	β_1	β_2	β_3	β_4	β_5	β_6
Arkansas River at Portland	5.488	-0.474	-0.037	-0.007	-0.003	-0.018	0.050
Fountain Creek near Colorado Springs	5.029	-0.003	0.066	0.006	0.000 NS	0.044	-0.065
Monument Creek at Bijou St.	6.124	-0.286	-0.024	0.017	-0.001	0.111	0.052
Fountain Creek below Janitell Road	5.639	-0.423	-0.033	0.007	-0.001	0.175	0.023
Huerfano near Boone	6.300	-0.580	-0.036	0.000 NS	0.000 NS	-0.084	0.171
Arkansas River near Rocky Ford	6.885	-0.235	-0.017	-0.004	0.001	0.005	0.074
Crooked Arroyo near Swink	7.143	-0.424	-0.055	0.002	0.000 NS	0.072	0.063

Key: NS = not significant

Regression equations for Timpas Creek and Apishapa River gages were used directly in GeoDSS to estimate salinity for all the simulated time steps. Figure 3 and Figure 4 show the flow and salinity (total dissolved solids) relationship for gages using simple regressions. The black solid line represents the selected regression equation.

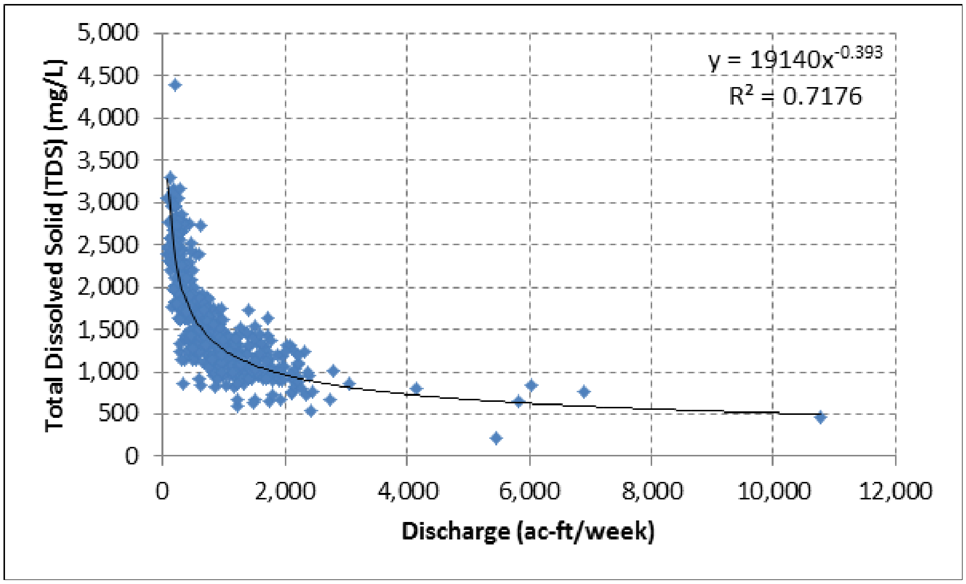


Figure 3. Timpas Creek Near Swink Salinity and Flow Relationship

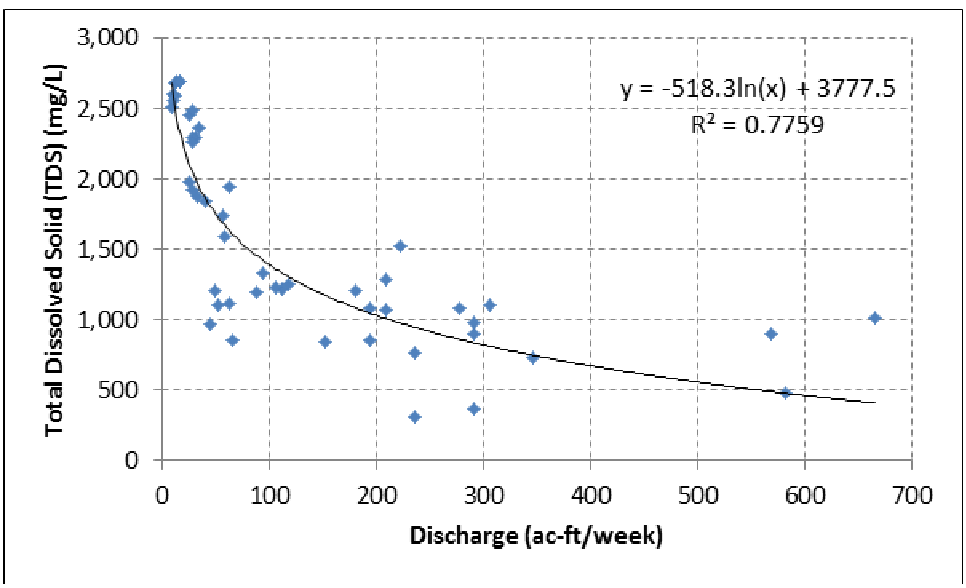


Figure 4. Apishapa River Near Fowler Salinity and Flow Relationship

Figure 5 through Figure 8 show the performance of the regression equations used to estimate missing salinity data for the Fountain Creek and Monument Creek gages graphically comparing the estimated and measured TDS values. Red line on these plots represents the best linear fit with zero intercept to the estimated and predicted values.

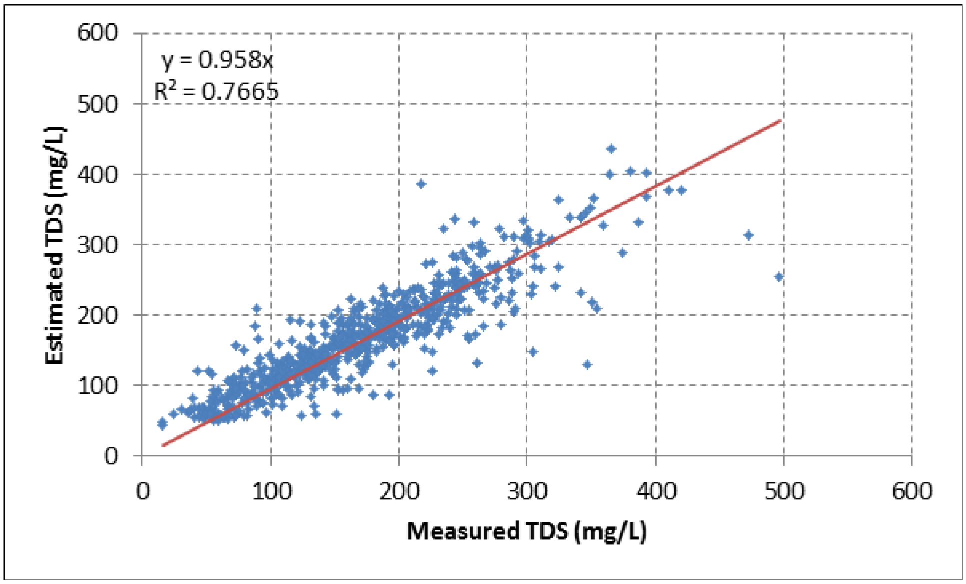


Figure 5. Fountain Creek Near Colorado Springs Estimated TDS Performance

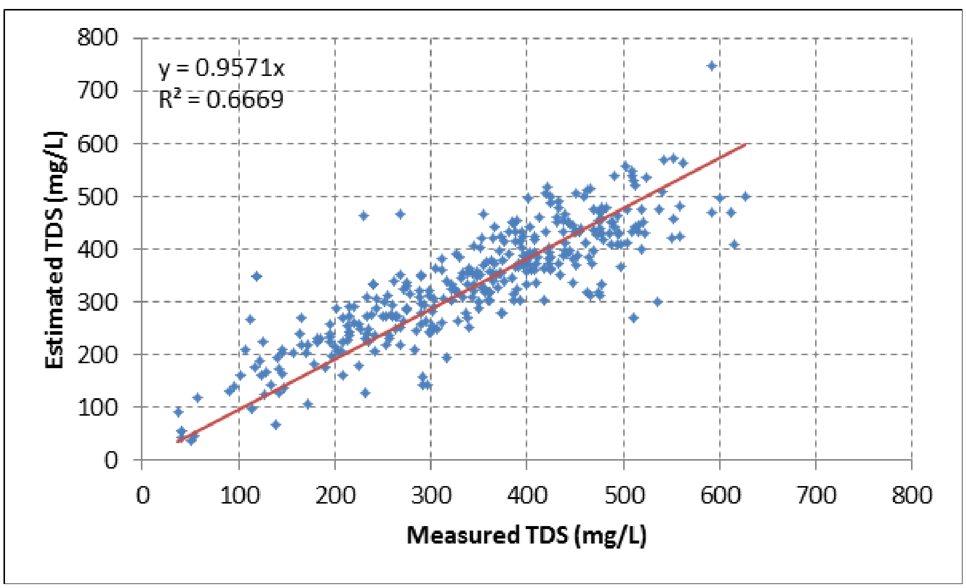


Figure 6. Monument Creek At Bijou St. Estimated TDS Performance

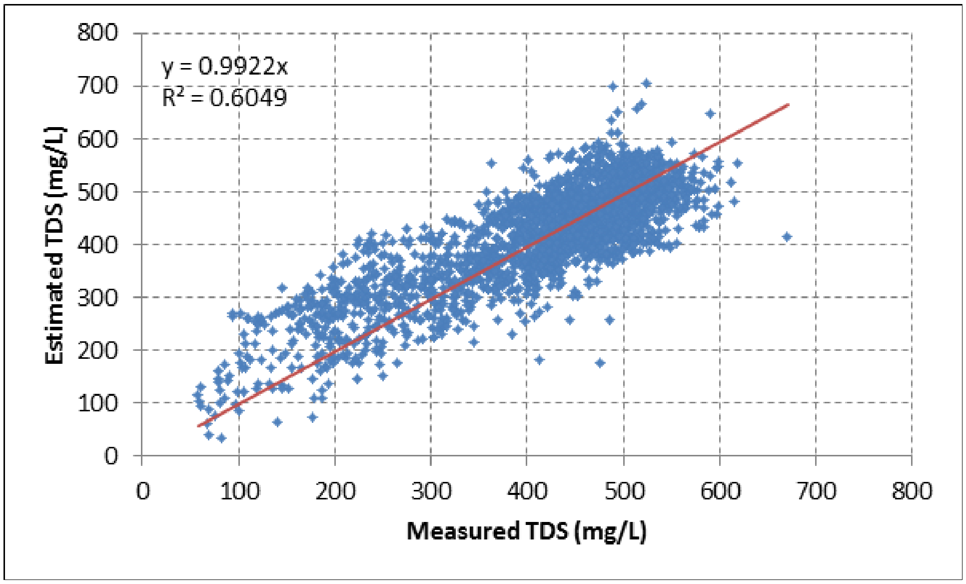


Figure 7. Fountain Creek Below Janitell Road Estimated TDS Performance

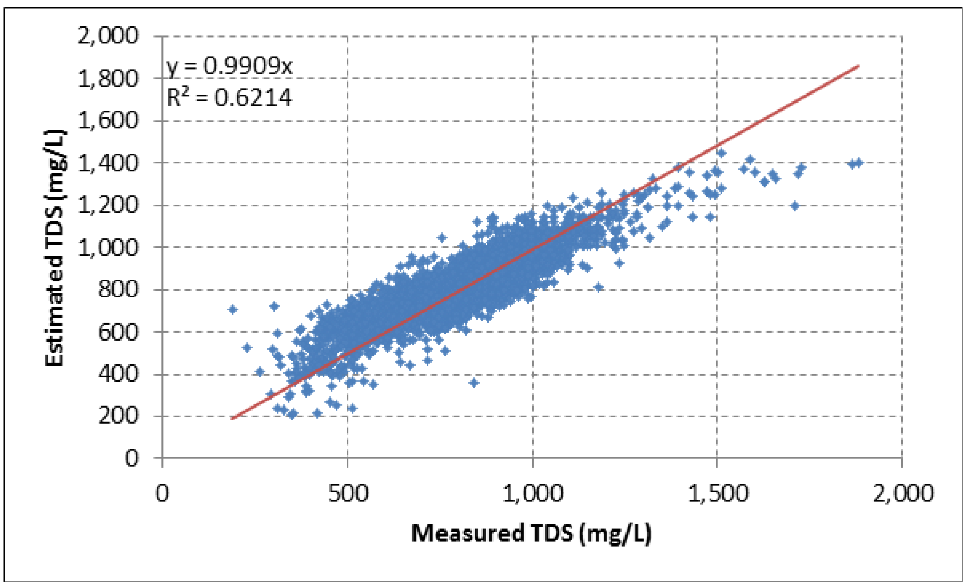


Figure 8. Fountain Creek At Pueblo Estimated TDS Performance

Figure 9 through Figure 12 show the performance of the regression equations used to estimate missing salinity data for the Arkansas River gages, graphically comparing the estimated and measured values with the best linear fit with zero intercept and the corresponding correlation coefficient.

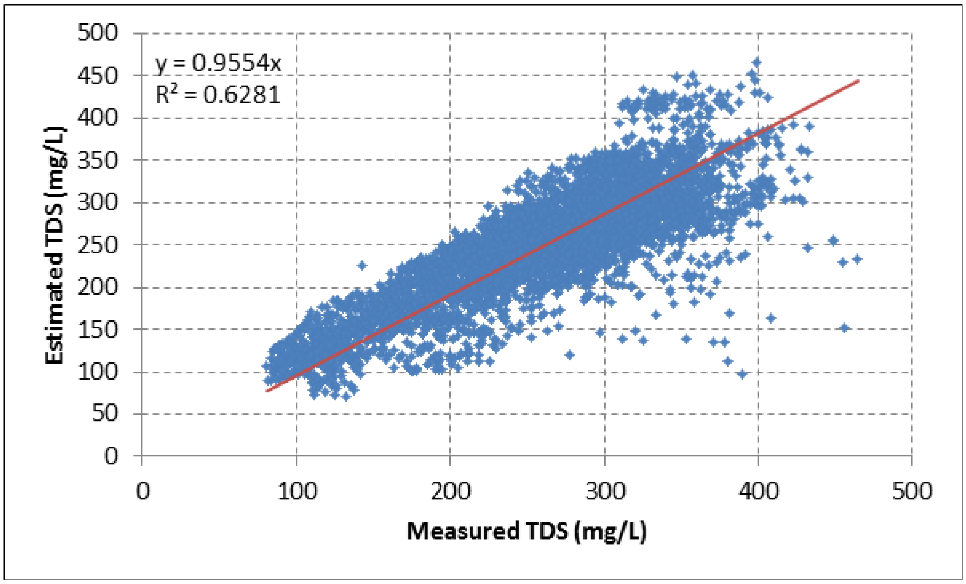


Figure 9. Arkansas River At Portland Estimated TDS Performance

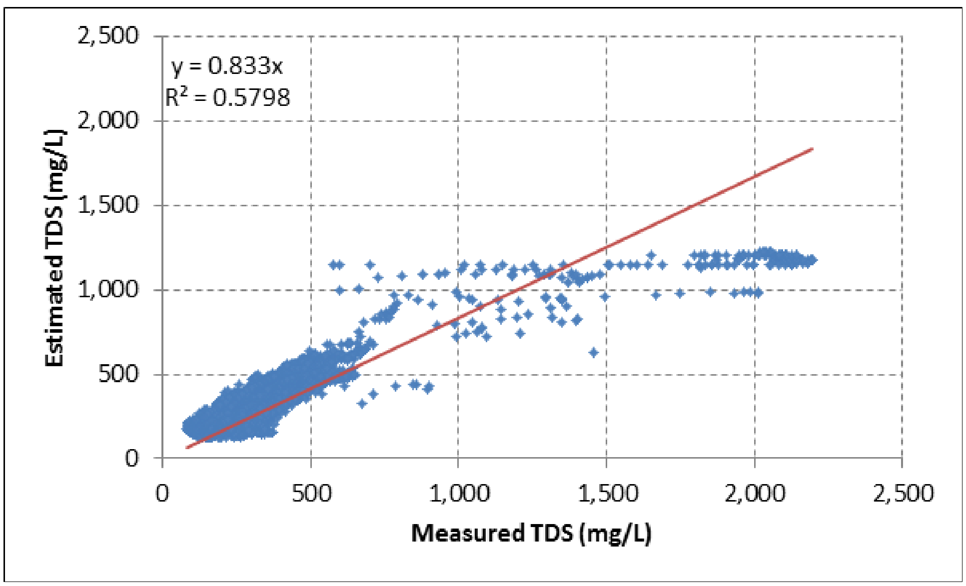


Figure 10. Arkansas River At Moffat St. Estimated TDS Performance

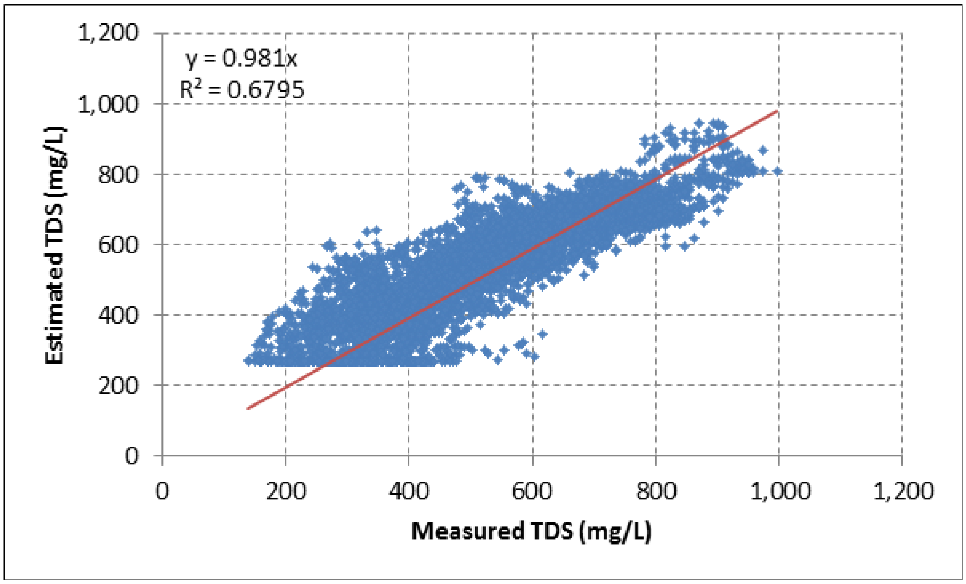


Figure 11. Arkansas River Near Avondale Estimated TDS Performance

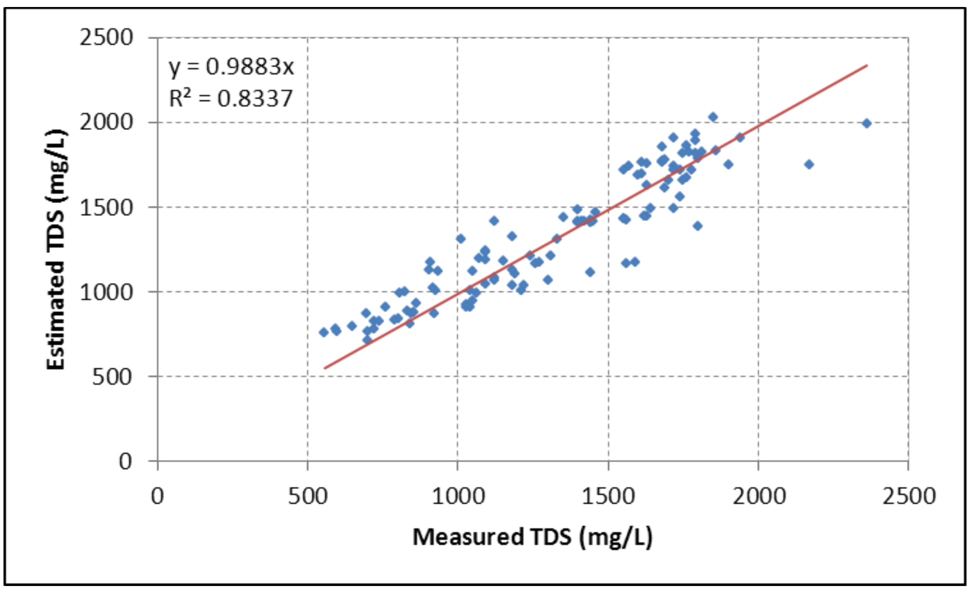


Figure 12. Arkansas River Near Rocky Ford Estimated TDS Performance

The performance of the regression equations for Saint Charles River, Huerfano River and Crooked Arroyo are shown in Figure 13 through Figure 15. These regression equations were used to estimate missing salinity data for the corresponding tributaries to the Arkansas River. These figures graphically compare the measured and estimated concentration, showing the best linear fit between the estimated and measured data and the corresponding coefficient of correlation.

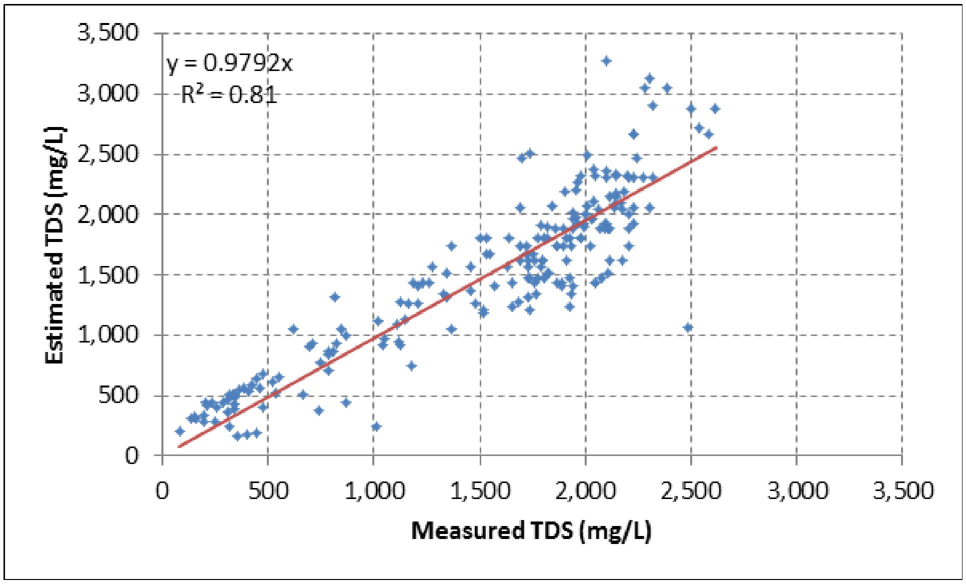


Figure 13. Saint Charles River Estimated TDS Performance

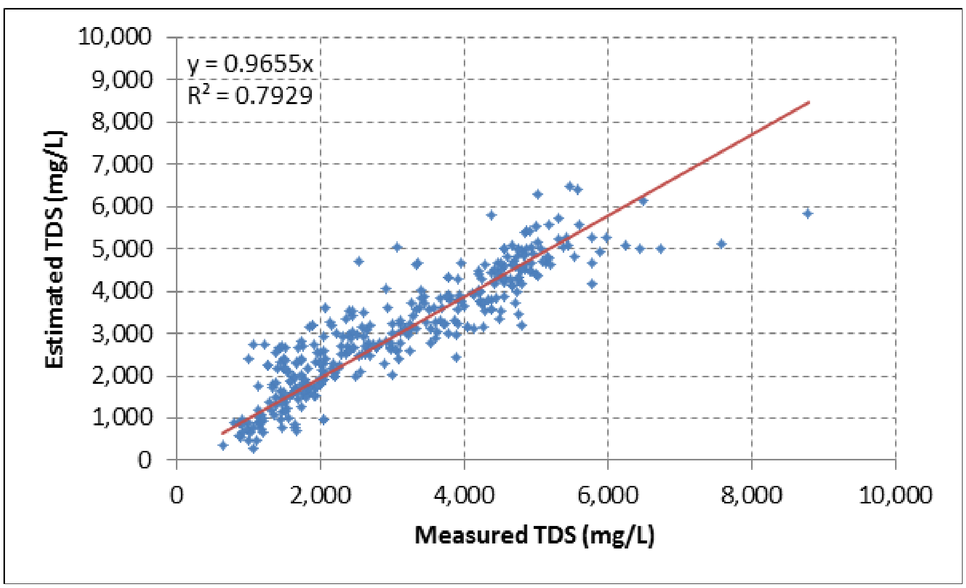


Figure 14. Huerfano River Near Boone Estimated TDS Performance

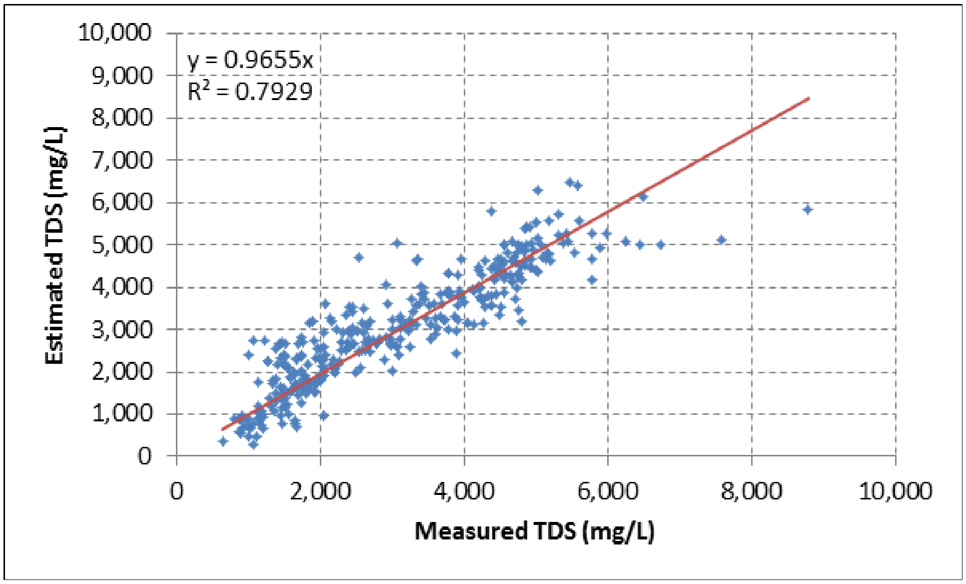


Figure 15. Crooked Arroyo Near Swink Estimated TDS Performance

Pueblo Reservoir Salinity Transport. Salinity at the Portland gage was assumed to remain unchanged under the different alternatives, since the changes in flows and drainage conditions upstream from Pueblo Reservoir under the different alternatives would be negligible (see Appendix D.4). Although salinity contributions between the Arkansas River at Portland gage and the reservoir would not be expected to change significantly, changes in storage volumes, releases, chemical and physical processes in the reservoir could change the salinity concentration of the reservoir outflows, which are inflows to the salinity model. The USGS developed a model to simulate the transit of different water quality constituents through Pueblo Reservoir (Ortiz 2012), with a model study period of water year 2000 to water year 2002 using a daily time step.

The outflow TDS results of the USGS model were analyzed to estimate the expected changes in reservoir outflow concentration for each alternative. The model predicted relatively small changes in the daily concentration among the alternatives (Figure 16). Table 5 summarizes simulated monthly average change in Pueblo Reservoir outflow concentration for the different alternatives with respect to the No Action.

The expected changes in concentration for the different alternatives is considered negligible (see Chapter 4 – *Water Quality*). For that reason and the uncertainty associated with estimating weekly Pueblo Reservoir outflow concentrations outside of the USGS modeled period, the concentration for the Pueblo Reservoir releases for all the alternatives is assumed constant for the comparative analysis of salinity effects. The historical observed concentrations at the Arkansas River above Pueblo gage are assumed to represent Pueblo Reservoir releases for this analysis.

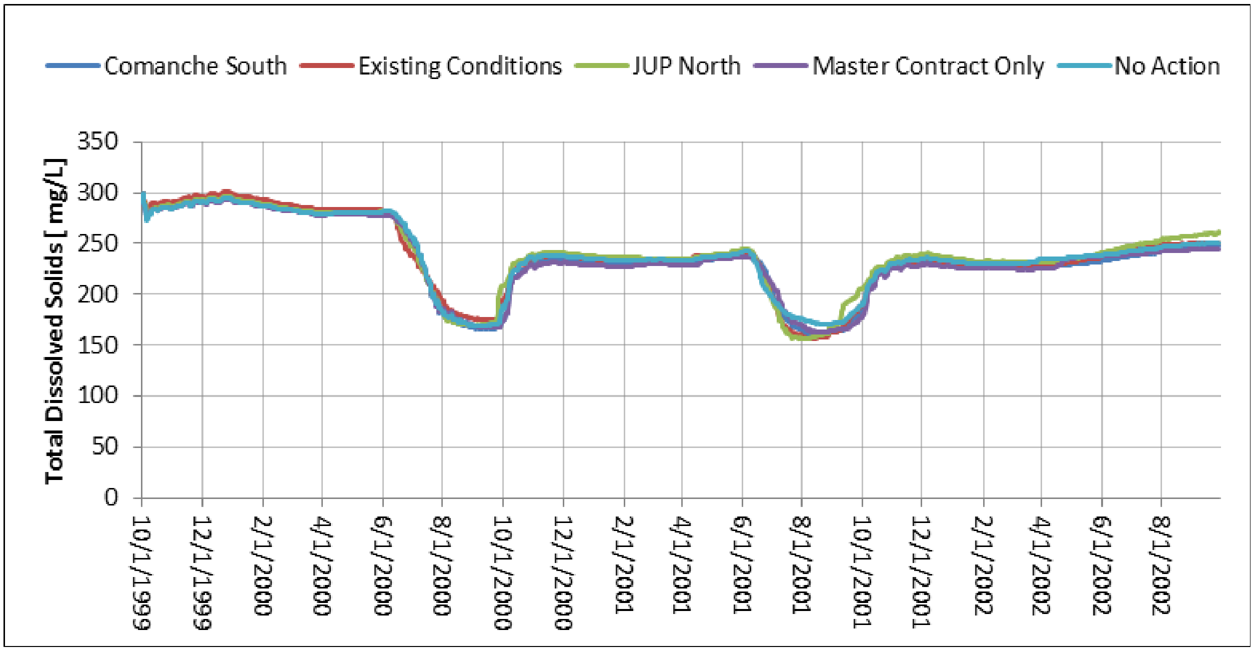


Figure 16. **USGS Daily Modeled Concentration for Pueblo Reservoir Outflow (Ortiz 2012)**

Table 5. Summary of Relative Weekly Changes in Modeled TDS at the Arkansas River above Pueblo Gage with respect to the No Action from USGS Model (Ortiz 2012)

Month	Comanche South (%)	Pueblo Dam South	JUP North (%)	Pueblo Dam North (%)	River South (%)	Master Contract Only (%)
Jan	0.97	0.97	-0.94	0.97	0.97	1.78
Feb	0.85	0.85	-0.76	0.85	0.85	1.55
Mar	0.86	0.86	-0.31	0.86	0.86	1.67
Apr	1.37	1.37	0.02	1.37	1.37	1.73
May	1.12	1.12	-0.35	1.12	1.12	0.79
Jun	-0.10	-0.10	-0.61	-0.10	-0.10	0.19
Jul	1.61	1.61	2.27	1.61	1.61	0.38
Aug	2.99	2.99	1.84	2.99	2.99	1.86
Sep	2.52	2.52	-3.88	2.52	2.52	2.98
Oct	1.63	1.63	-2.43	1.63	1.63	2.51
Nov	1.10	1.10	-1.17	1.10	1.10	1.89
Dec	1.07	1.07	-1.10	1.07	1.07	1.90
Average	**1.34**	**1.34**	**-0.61**	**1.34**	**1.34**	**1.60**

General Segment Mass Balance Format. The salinity model used mass balance principles over discrete segments. Stream gages located at either end of a segment have average daily historical streamflow and specific conductance records. When multiplied, the flow and concentration represent a salinity load. The salinity load at the upstream gage plus the salinity load into the segment minus the salinity load diverted out of the segment is equal to the salinity load at the downstream end of the segment. The concentration at the downstream end of the segment is equal to the salinity load at that point divided by the streamflow.

Calibration of the model included estimating unknown concentrations of inflows, such that the resulting difference between calibration and measured salinity loads at the downstream point of the segment did not improve. The model uses only inflows with unmeasured or non-estimated concentration to adjust the mass balance in the segment; therefore, these calibrated concentrations are not strictly tied to a physical salinity source. In some cases the calibrated concentration requires higher concentration values, larger than the river observed concentrations, to correct deficient salinity loading estimates or to compensate for low unmeasured inflows in relation with the missing salt loading in the segment. In this analysis, the unknown concentration upper limit was assumed as 4,500 mg/L to keep the calibration process realistic. The exception is inflow concentration to the segment upstream of the Fountain Creek at Pueblo gage for which the calibration concentration upper limit was assumed as 6,000 mg/L due to indication of large salinity loads reported at the downstream gage.

Equation 2 is describes the mass balance analysis in an individual node. This equation was applied in the model for each node sequentially from the upstream end of the segment to the downstream end of the segment, using the node outflow concentration results sequentially from the upstream nodes to the downstream nodes.

Equation 2

$$[Q_{in}*C_{in}] + [Q_{unmeasured\ in}*C_{unmeasured\ in}] = [Q_{unmesured\ out}*C_{out}] + [Q_{out}*C_{out}]$$

Where: Q_{in} = inflow with measured concentration
C_{in} = Measured/Estimated Concentration of inflows
$Q_{unmeasured\ in}$ = inflow with unmeasured concentration, includes unmeasured gains to the segment – solved for by balancing flows at bottom gage
$C_{unmeasured\ in}$ = Estimated/Calibrated Concentration of inflows – generally unknown
$Q_{unmeasured\ out}$ = unmeasured losses outflow, solved for by balancing flows at bottom gage
Q_{out} = measured outflow, includes measured diversions – from hydrologic model
C_{out} = concentration of outflows – computed by the model at each point based on the salt load entering the node and the total outflow.

Measured outflows are typically measured diversions for agriculture, municipalities and industry, as well as diversion for storage. Note that the GeoDSS internally assumes salinity loadings associated with unmeasured inflows in a segment at the upstream end of the segment and salinity loadings associated with unmeasured outflows in the segment at the downstream end of the segment.

Due to the expected variability of transit losses and wetted stream widths along the river reaches in the study area, those quantities were assumed to be part of the unmeasured segment losses, which are determined during the calibration process. Concentrations of the unmeasured segment losses are simulated by the model based on the upstream mass balance.

Some measured inflows have measured concentrations, other measured inflows use regression equations based on historical streamflow and specific conductance to estimate salt loadings and some measured inflows such as the WWTF assume a concentration of the effluent based on typical source-effluent data. Measured inflows without measured/estimated concentration are assigned with a concentration during the calibration process using Equation 2. Figure 17 shows a schematic of a typical segment in the model.

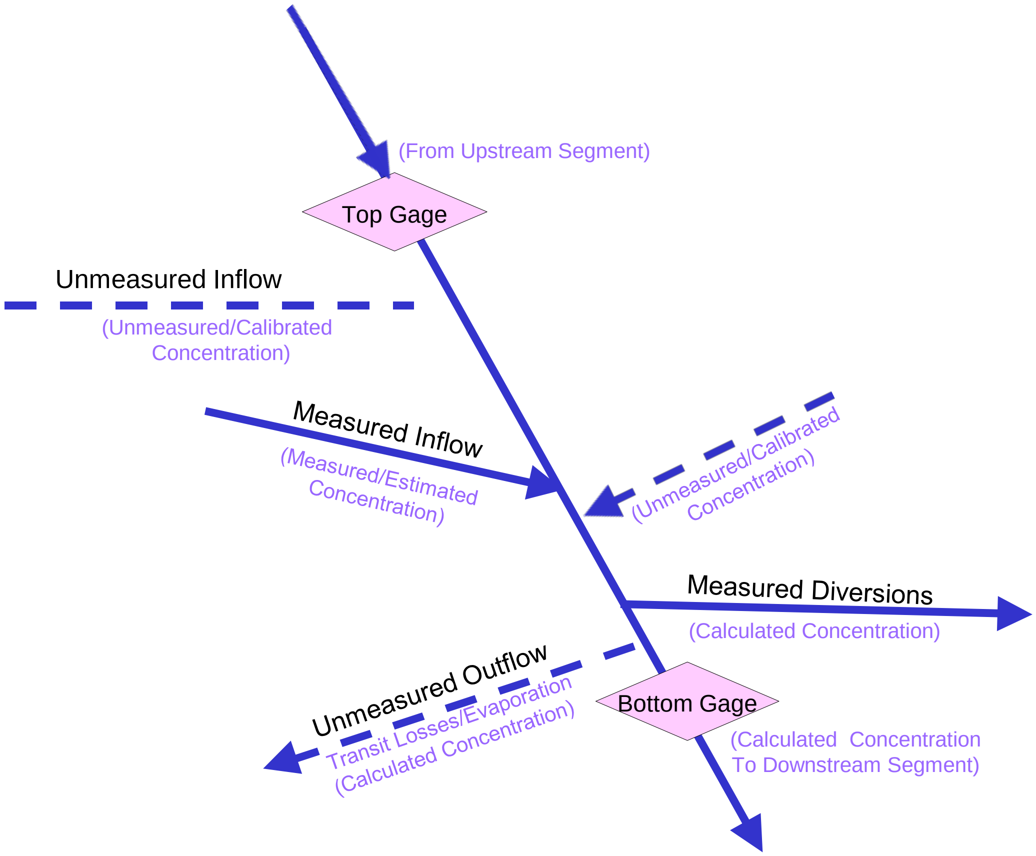


Figure 17. Example Salinity Model Segment

GeoDSS Calibration and Simulation. For this study, the calibration of the salinity model includes two stages: (1) flow replication and (2) salinity calibration. The objective of the first calibration stage is to duplicate in GeoDSS, by segments between gauges, the simulated flows in the Daily Model. The flow replication is performed for the historical conditions and all the simulated alternatives. The objective of the second state of calibration is to estimate unmeasured concentrations to match as close as possible measured concentrations at the control points (i.e., gages with measured concentration).

The original GeoDSS network (Triana, Labadie and Gates 2010) was extended to mimic the major inflows and outflow from the network as modeled in the Daily Model. Due to the complexity of the Daily Model, only the major inflows and outflows were explicitly represented in the GeoDSS network. During the flow replication stage, Daily Model simulated flows at the gages are used to quantify inflows and outflows that are not explicitly modeled in the GeoDSS, lumping those inflows and outflows into the unmeasured gains and losses of the segment, respectively.

During the salinity calibration, historical flows, inflows with measured TDS and measured TDS at the control points are used to solve for unmeasured concentrations on a weekly basis until the resulting difference between calibration and measured salinity loads at the downstream point of the segment could not be improved. Since the computation is performed from the upstream end to the downstream end of the network carrying over the resulting outflow concentration from one segment to the next, an iterative procedure is used in GeoDSS to adjust unmeasured concentrations within the specified bounds to closely match the measured concentrations at the control points.

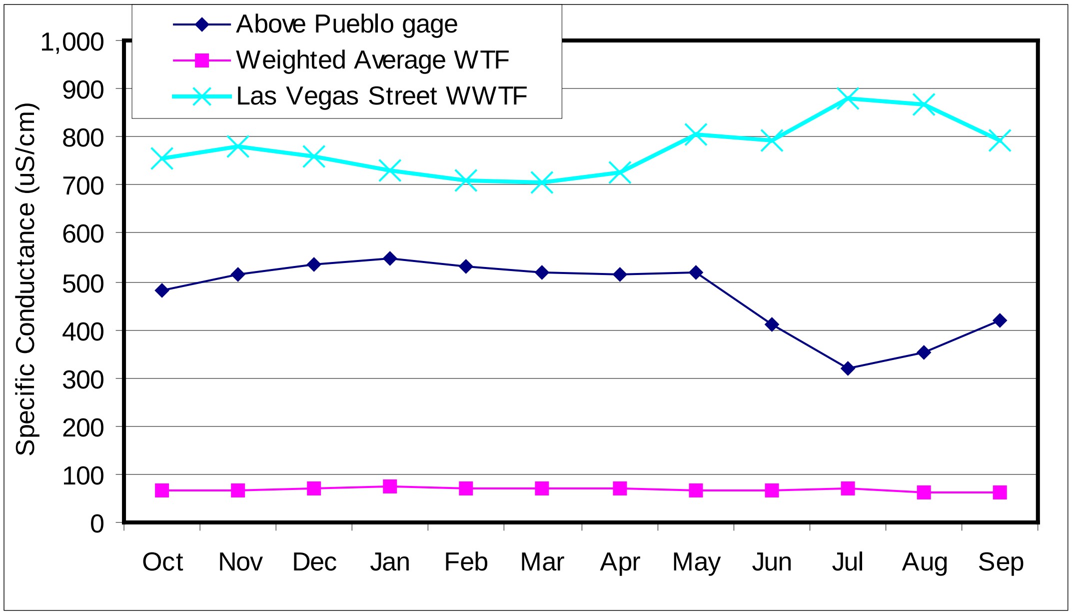
The salinity simulation run type is used for alternatives salinity modeling and effects analysis, the calibrated weekly inflow concentrations from the Salinity Calibration are used in combination with the corresponding Daily Model replicated inflows for each alternative to estimate the alternatives salinity loadings and resulting concentrations throughout the network. Table 6 shows a summary of the run types with the known and unknown (i.e., solved for) variables in each case.

Table 6. Summary of Salinity Modeling Steps with Known and Unknown Variables

Modeling Step	Known Variables	Unknown Variables (solved for)
Flow Replication (historical and all alternatives)	Daily Model Simulated • Gage Flows • Diversion • Explicit Returns	Unmeasured gains and losses and other Daily Model inflows/outflows not explicitly modeled in GeoDSS
Salinity Calibration (only historical calibration)	All flows throughout the network including unmeasured flows (Flow Calibration) Concentration at the measured/estimated nodes	Unmeasured Concentrations Calibrated to match the downstream control point concentration
Salinity Simulation (all alternatives)	All flow including unmeasured gains and losses (Flow Calibration) All Concentrations including calibrated concentration at unmeasured points (Salinity Calibration)	Simulated Concentrations at all nodes in the network

Waste Water Treatment Facilities Discharges. The concentration for the WWTF effluents were modeled based on assumptions from the Southern Delivery Systems Final EIS (Reclamation 2008), because it covered part of the same study area on the Arkansas River. The Southern Delivery System EIS (Reclamation 2008) derived an increase in TDS between the weighted average of the raw water specific conductance and the WWTF effluent of 707 µS/cm (452 mg/L), based on data from Las Vegas Street WWTF effluent.

Figure 18 depicts the monthly mean specific conductance in the Las Vegas WWTF effluent, as well as a weighted average for the Colorado Springs water treatment facilities and the Arkansas River Above Pueblo gage as an indication of the representative salinity of the Pueblo Reservoir outflow salinity; Pueblo Reservoir would be the source of AVC project water. This monthly mean specific conductance was used to model historical conditions.



Source: Reclamation (2008)
Figure 18. Colorado Springs Source Water and WWTF Effluent Salinity

Criteria for Determining Significance of Effects

Table 7 lists significance criteria used to describe the intensity of salinity effects. Potential effects on water quality were evaluated for each action alternative compared to the No Action Alternative. Effects were analyzed assuming best management practices and resource protection measures described in Chapter 2 and Appendix B.5 would be incorporated.

Table 7. Water Quality Effect and Intensity Description

Effect Intensity	Intensity Description
Negligible	Chemical, physical, or biological effects to water quality would be below or near detectable limits, and would be within historical or desired water quality conditions.
Minor	Chemical, physical, or biological effects to water quality would be detectable, but would be within 10% of historical water quality conditions for parameters and stream segments meeting water quality standards. The alternative would not cause a water quality violation, but existing violations would continue. Water and wastewater treatment facilities would continue to meet water quality standards without changes to treatment processes.
Moderate	Chemical, physical, or biological effects to water quality would be detectable and the historical baseline would be exceeded by 10 – 20% for parameters and stream segments meeting water quality standards. A new water quality violation would not result, but existing violations would continue and increase by less than 5%. Slight modifications to water and wastewater treatment facility processes could be needed to meet water quality standards.
Major	Chemical, physical, or biological effects to water quality would exceed the historical baseline by more than 20% for parameters and stream segments meeting water quality standards (more than 5% for stream segments violating water quality standards). A new violation in a water quality standard is likely. Substantial modifications to existing water and wastewater treatment facility processes could be needed to meet water quality standards.

Notes:
(1) Short-term effect – recovers in three years or less after alternative implementation.
(2) Long-term effect – takes more than three years to recover after alternative implementation.

Results

The salinity model segment assumptions, inflow concentrations, and alternatives' simulation results are presented in this section.

Calibration

This section presents modeling assumptions and the calibrated concentration for the different modeled segments. Segments are named by the downstream gage.

The calibrated concentration corresponds to representative values assigned to the unknown salinity inflows to the segment. In segments with multiple calibrated concentrations the weighted concentration is presented as representative for these segments. These values were calculated during the salinity calibration process to simulate a concentration at the downstream control point as close as possible to the measured concentration. Note that in GeoDSS the values of calibrated concentration are only calculated for inflows greater than zero with unmeasured concentration. Outflow concentrations, including the unmeasured losses, correspond to the simulated concentration at the diversion point, computed mixing the salt loads throughout the segment.

The flow replication step uses all the gages in the network independently of the existence of measured salinity. This creates *intermediate gages* in the salinity calibration that provide additional sources of unmeasured inflows and outflows to the segment, but are not used for salinity calibration purposes because they do not have a complete record of measured/estimated concentration. The GeoDSS treats unmeasured inflows at the intermediate gages in the calibration process independently of the other unmeasured inflows in the corresponding segment, resulting in potentially different calibrated concentrations at the unmeasured inflows in the segment. When the intermediate gage has some salinity measurements (i.e., discrete data), those time steps with salinity data are used to calibrate inflows upstream of the intermediate gage. In time steps with no salinity data at the intermediate gages, the GeoDSS iterative process adjusts the inflows upstream of the intermediate gage to match the segment downstream measured concentration.

The average monthly measured/estimated salinity concentration for the most upstream nodes in both Arkansas River and Fountain Creek are summarized in Table 8.

Table 8. Monthly Simulated Salinity Concentration for Upstream Boundary Gages

Month	Arkansas River above Pueblo	Fountain Creek near Colorado Springs	Monument Creek at Bijou St.
Jan	341.5	246.3	472.4
Feb	344.4	248.4	438.8
Mar	337.4	227.0	397.5
Apr	336.6	180.0	319.8
May	344.1	161.3	309.3
Jun	268.4	184.3	358.4
Jul	230.5	185.5	375.7
Aug	265.9	174.4	404.0
Sep	308.2	185.1	460.4
Oct	312.3	172.2	467.1
Nov	329.9	212.4	487.4
Dec	340.9	232.1	494.9

Fountain Creek below Janitell Road Segment. This segment is the most upstream segment in Fountain Creek and used measured concentration at the Fountain Creek below Janitell Road gage to calibrate the segment concentrations. It is bounded upstream by four gages (i.e., Fountain Creek near Colorado Springs gage, Monument Creek at Bijou St. gage, and Cheyenne Creek at Evans Ave. gage) and includes Fountain Creek at Colorado Springs gage as an intermediate gage.

Assumptions. Las Vegas Street WWTF effluent monthly concentrations were assumed from the Southern Delivery System Final EIS (Reclamation 2008) as shown in Figure 18. Since none of the Southern Delivery System alternatives will affect the future potential increase in concentration of effluent from Colorado Springs when Southern Delivery System is fully operational, the same monthly concentrations are used in the direct and cumulative effects analysis. This results in having a lower concentration for the cumulative effects no action alternative than what may be expected given increased Arkansas Basin water delivered to Southern Delivery System participants, but it will not affect relative comparison of alternatives.

Calibrated Concentration. The Fountain Creek at Colorado Springs gage was included as a salinity source to this segment. This gage has only discrete salinity data; no continuous monitoring is performed at the gage. In the modeling approach for this gage, discrete data was used in the model to estimate salt load to nodes upstream in the segment in weeks with available data. For weeks when concentration was not measured, the resulting concentration at the gage was a function of the upstream mass loads and the next downstream measured concentration. This approach allowed using the measured discrete data in the model without the need to develop a relationship for all the simulated weeks. The results were checked for reasonableness, since an iterative process takes place in using this modeling approach. Figure 19 shows the calibration results for both periods with and without measured concentration at the Fountain Creek at Colorado Springs gage.

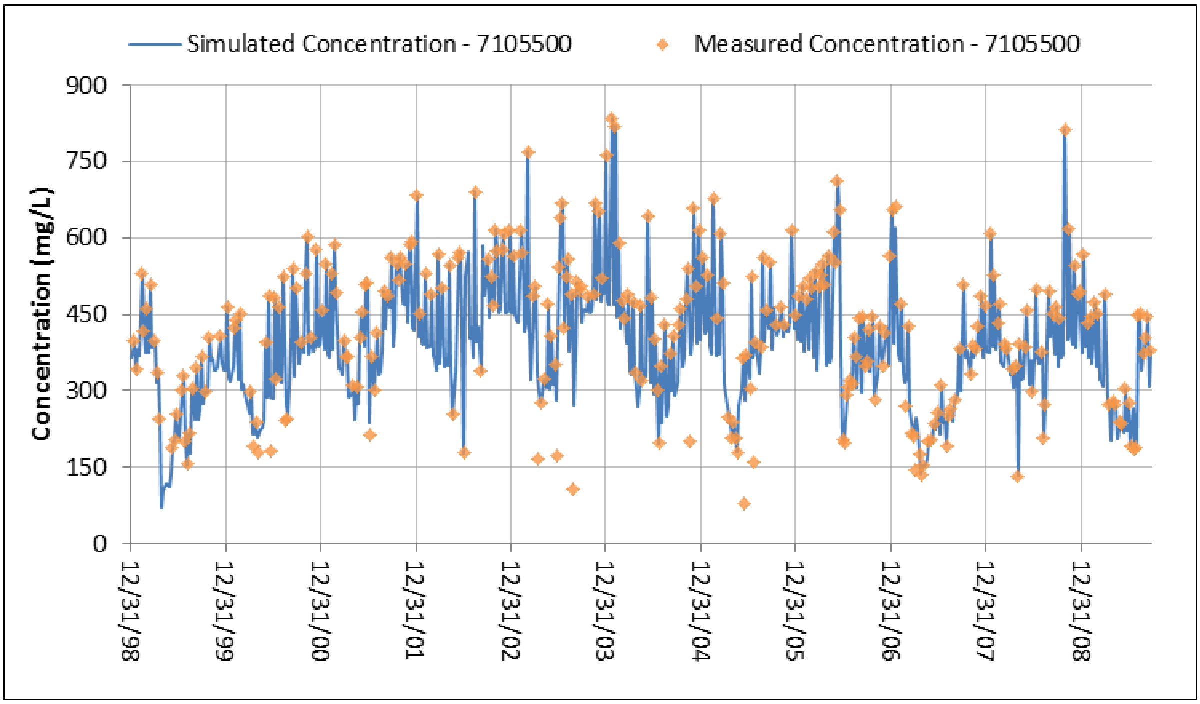


Figure 19. Modeled and Measured Salinity Concentration for Fountain Creek at Colorado Springs Gage Calibration

The specific conductance of Las Vegas Street WWTF effluent was specified in the mass balance as discussed above. Figure 20 depicts the weekly average calculated salinity concentration for inflows between the three gages with unmeasured concentration. Note that the unmeasured losses are assigned with the in-stream concentrations, which are typically much lower than the inflow concentrations.

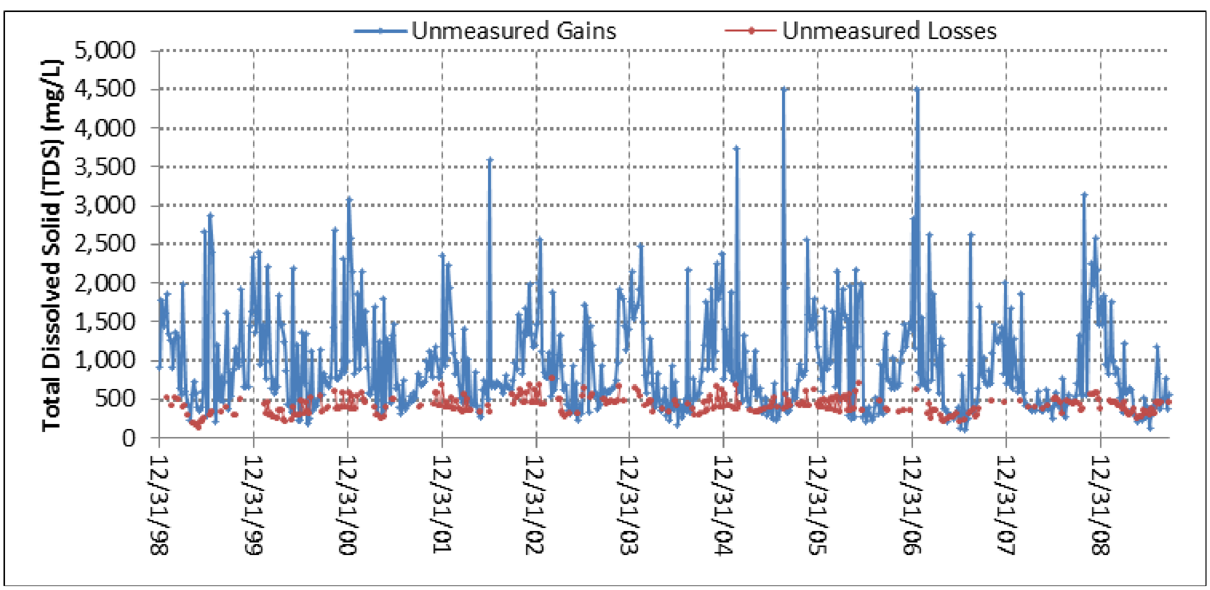


Figure 20. Weekly Calibrated and Simulated Salinity Concentration to Janitell Segment for Unmeasured Inflows and Outflows

Fountain Creek near Fountain Segment. This segment used measured concentration at the Fountain Creek near Fountain gage to calibrate unknown concentrations. The segment includes the Fountain Creek at Security gage as an intermediate gage, with discrete salinity concentration data. The upstream gages include Fountain Creek below Janitell Road gage, Jimmy Camp Creek at Fountain gage and Little Fountain Creek near Fountain gage.

Assumptions. The effluent concentration for Fountain and Security WWTFs was assumed based on their weighted blend of source water (Reclamation 2008). The assumed effluent salinity for Fountain and Security is shown in Table 9.

Table 9. Estimated Fountain and Security Water Supply and Wastewater Salinity

Month	Estimated Wastewater (µS/cm)	Estimated Wastewater (mg/L)
Jan	1,429	971
Feb	1,433	974
Mar	1,435	975
Apr	1,437	977
May	1,443	981
Jun	1,444	982
Jul	1,384	938
Aug	1,382	937
Sep	1,394	946
Oct	1,411	958
Nov	1,423	967
Dec	1,431	972
Mean	**1,420**	**965**

In the future, Fountain and Security may change their alluvial ground water pumping rates or locations. However, a simplifying assumption that the effluent salinity concentration for these WWTF will remain the same was made, because none of the alternatives is expected to affect this concentration and their historical combined average effluent release to Fountain Creek is less than 5 cfs. This represents a small percentage of the flow in the Fountain Creek, which averages about 150 cfs between the Janitell and Fountain gages.

Calibrated Concentration. Figure 21 depicts the weekly average calculated salinity concentration for inflows and between Fountain Creek below Janitell Road and Fountain Creek near Fountain gages.

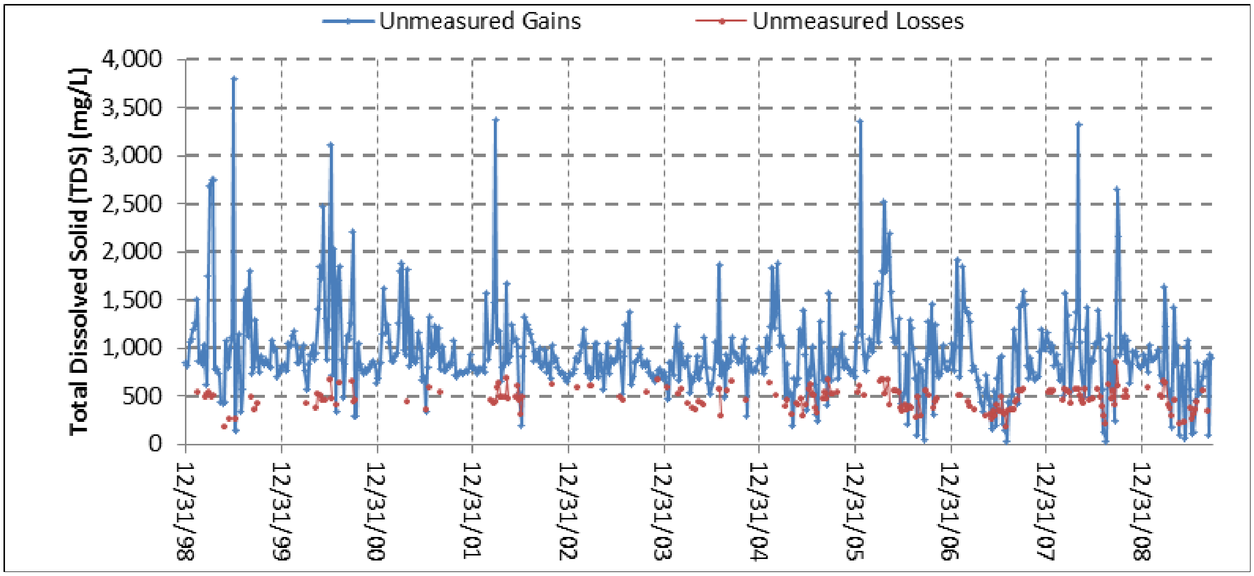


Figure 21. Weekly Calibrated and Simulated Salinity Concentration for Fountain Creek near Fountain Segment Unmeasured Inflows and Outflows

Figure 22 compares the measured and simulated concentration for the Fountain Creek near Fountain gage.

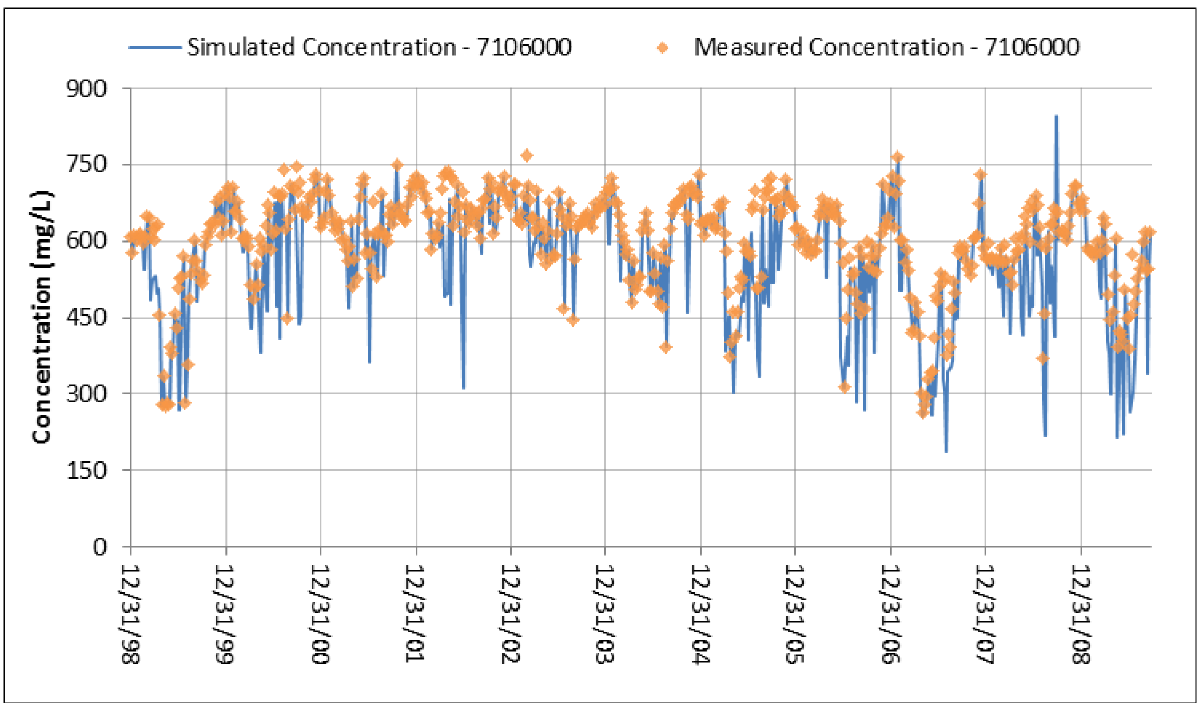


Figure 22. Weekly Comparison of Measured and Simulated Salinity Concentration for Fountain Creek near Fountain Gage Calibration

Fountain Creek at Pueblo Segment. This segment used measured concentration at the Fountain Creek at Pueblo gage to calibrate unknown concentrations. The segment upstream gage is Fountain Creek near Fountain and includes Fountain Creek near Piñon gage as intermediate gage with discrete salinity data. The only inflow with unmeasured concentration in this segment is the inflow simulated at Williams Creek.

Calibrated Concentration. Figure 23 depicts the weekly average calculated salinity concentration for inflows with unmeasured concentration between Fountain Creek near Fountain and Fountain Creek at Pueblo gages.

This segment has numerous weeks (i.e., about 60 percent of the modeled weeks) where a net loss were calculated in the calibration process between Fountain Creek near Piñon and Fountain Creek at Pueblo gages, which makes the salinity calibration difficult. The upper bound of the calibrated concentration was set larger than other segments (6,000 mg/L) to try to accommodate for this situation. GeoDSS is unable to better calibrate weeks with net losses in the segment because it only adjusts the inflows unmeasured concentrations while the outflow are assigned with the in-stream calculated concentration, generating an under prediction of the concentration in this segment. Figure 24 shows the comparison of the calibrated and the measured concentration for this segment.

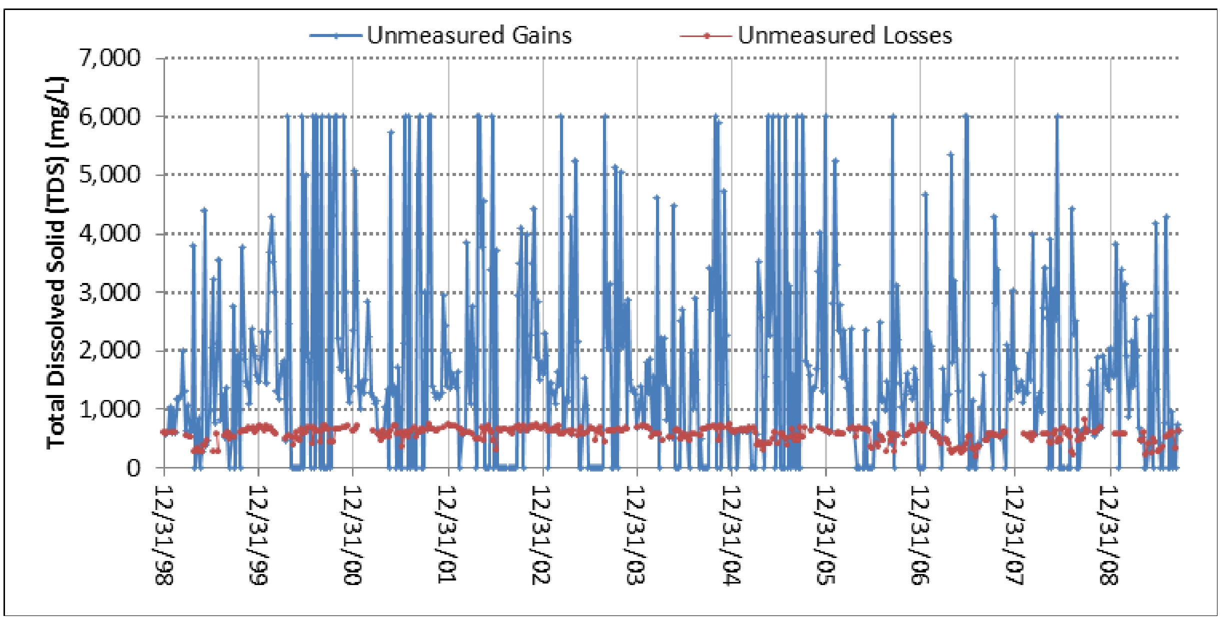


Figure 23. Weekly Calibrated and Simulated Salinity Concentration to Fountain Creek at Pueblo Segment for Unmeasured Inflows and Outflows

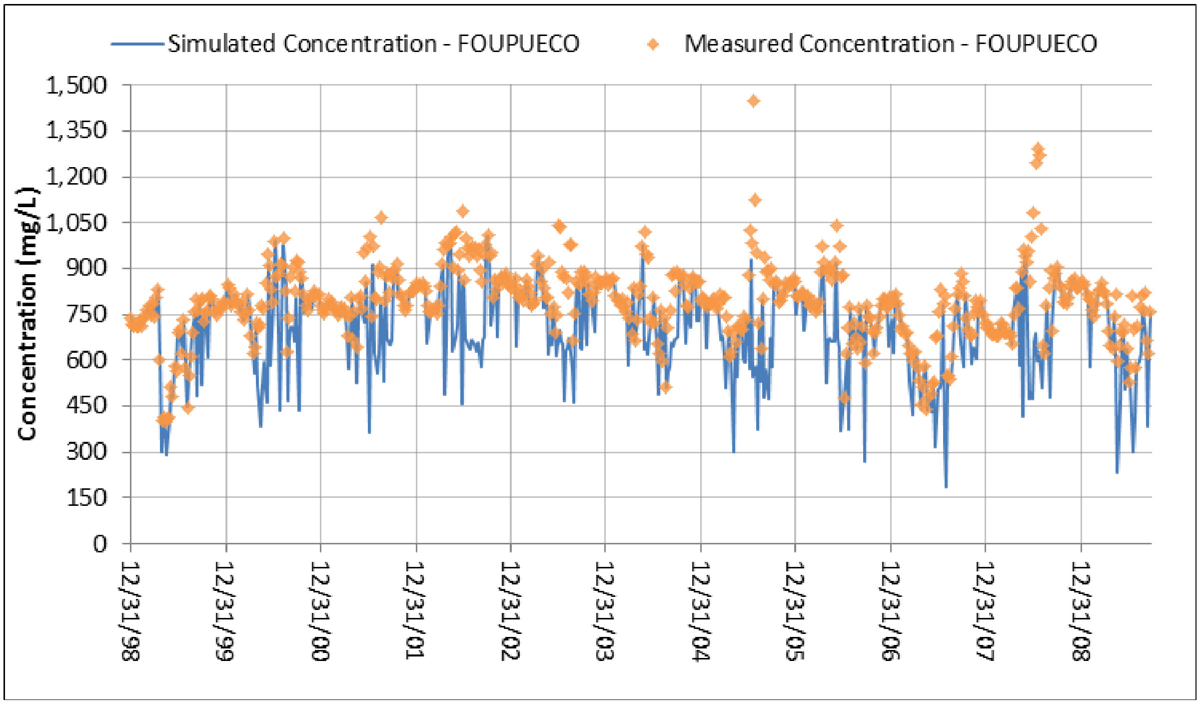


Figure 24. Weekly Comparison of Measured and Simulated Salinity Concentration for Fountain Creek at Pueblo Gage Calibration

Since the calibrated concentration is used as the baseline for the existing conditions, the relative comparison of alternatives is not going to be significantly affected by the concentration under prediction simulated at the Fountain Creek at Pueblo gage.

Arkansas River at Moffat St. Segment. This segment used measured concentration at the Arkansas River at Moffat St. gage to calibrate unknown concentrations. The concentration measured at the Arkansas River above Pueblo gage, was assumed as the concentration of Pueblo Reservoir releases, is the upstream gage for this segment. Figure 25 depicts the weekly average calculated salinity concentration for inflows between Pueblo Reservoir and Arkansas River above Pueblo gage.

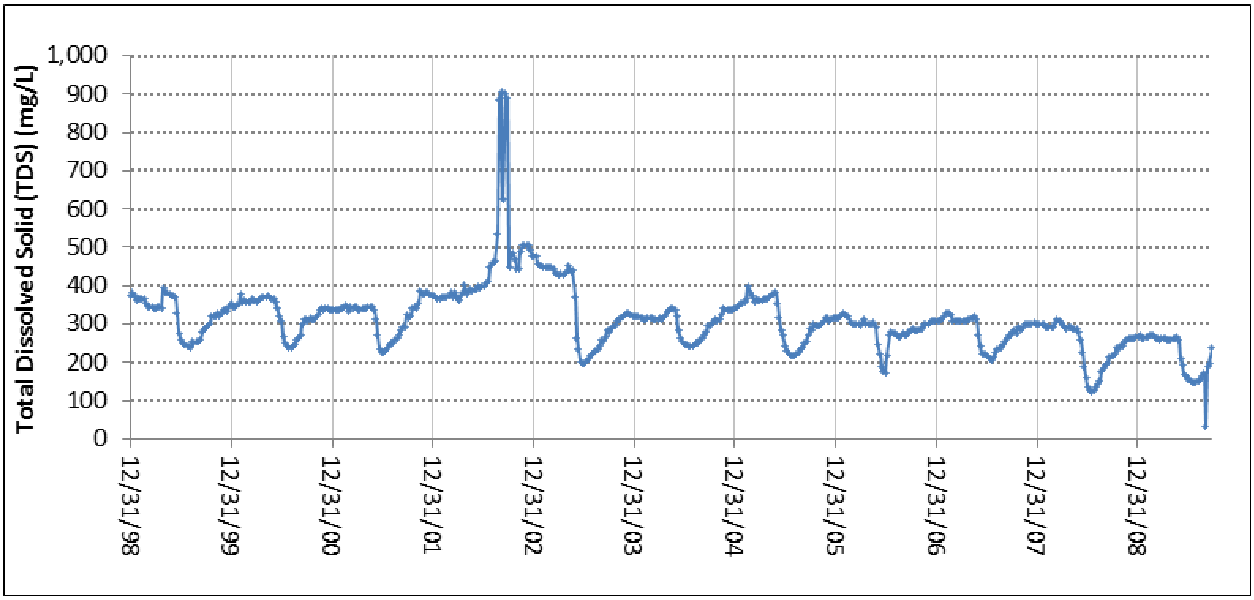


Figure 25. Weekly Measured Salinity Concentration at the Arkansas River above Pueblo Gage

Assumptions. This segment includes the Pueblo West WWTF effluent that is discharge through Wildhorse Creek. It is assumed that the concentration of the effluent remains the same as it flows down Wildhorse Creek. The assumed effluent salinity for Pueblo West WWTF, based on Reclamation (2008), is shown in Table 10.

Table 10. Pueblo West Raw Water and Estimated Wastewater Specific Conductance

Month	Raw Water from Pueblo Reservoir (µS/cm)	Wastewater (µS/cm)	Wastewater (mg/L)
Jan	461	1,168	804
Feb	473	1,180	812
Mar	480	1,187	817
Apr	485	1,192	821
May	504	1,211	835
Jun	508	1,215	838
Jul	325	1,032	706
Aug	319	1,026	701
Sep	355	1,062	727
Oct	407	1,114	765
Nov	443	1,150	791
Dec	468	1,175	809
Mean	**435**	**1,143**	**785**

Source: Reclamation (2008)

Calibrated Concentration. Figure 26 depicts the weekly average calculated salinity concentration for inflows between Arkansas River above Pueblo and Arkansas River at Moffat St. gages. This segment includes changes in salinity concentrations from a portion of the city of Pueblo.

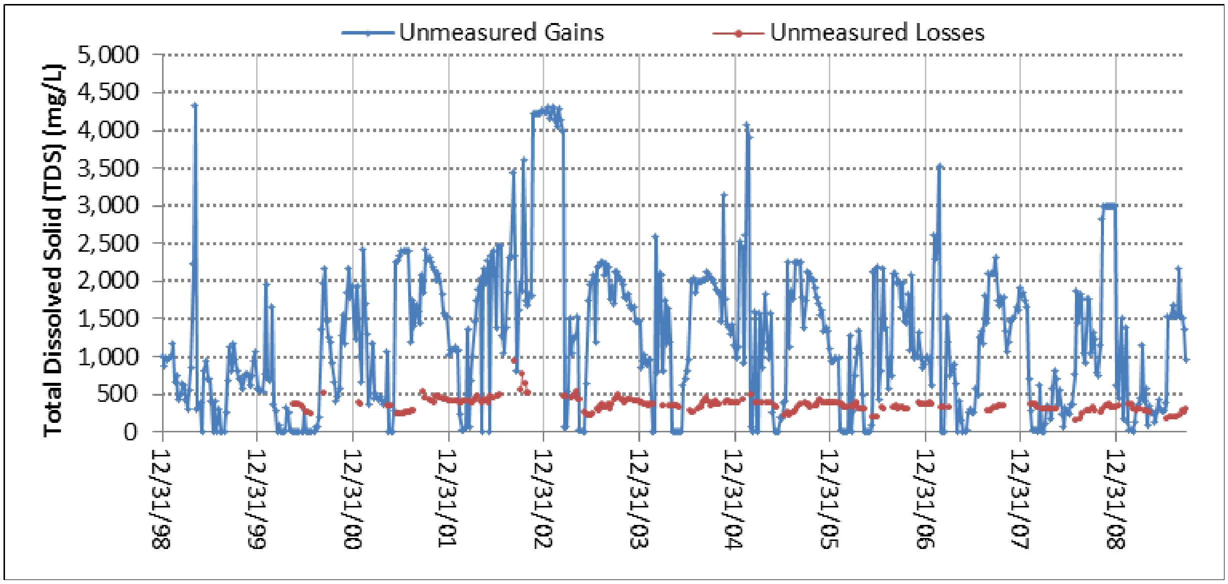


Figure 26. Weekly Calibrated and Simulated Salinity Concentration to Arkansas River at Moffat St. Segment for Unmeasured Inflows and Outflows

Comparison of the simulated and historical measured concentration at the Arkansas River at Moffat St. gage is shown in Figure 27. Simulated concentration agreed with the measured concentration for most of the simulated period with larger errors shown at the end of 2002 and beginning of 2003. This period recorded unusual high salinity and extremely low flows values at the Arkansas River at Moffat St. gage. The period where the calibrated concentration is lower than the recorded values has flow lower than 2 cfs. Since the high salinity concentration at the end of 2002 are not observed at the Arkansas River above Pueblo gage, water reported to the Moffat St. gage is most likely only return flows within this reach. Note that with the extremely low flows in the river the salt loadings to the system in this period are extremely low; therefore, the under prediction of the concentration in this period will have no significant effect in the comparative analysis of salinity values in the comparative analysis of the alternatives. The low salinity loading to the system is corroborated by the observed concentration at the Arkansas River near Avondale gage, where concentrations at the end of 2002 and beginning of 2003 do not show extreme values (see next section Figure 29).

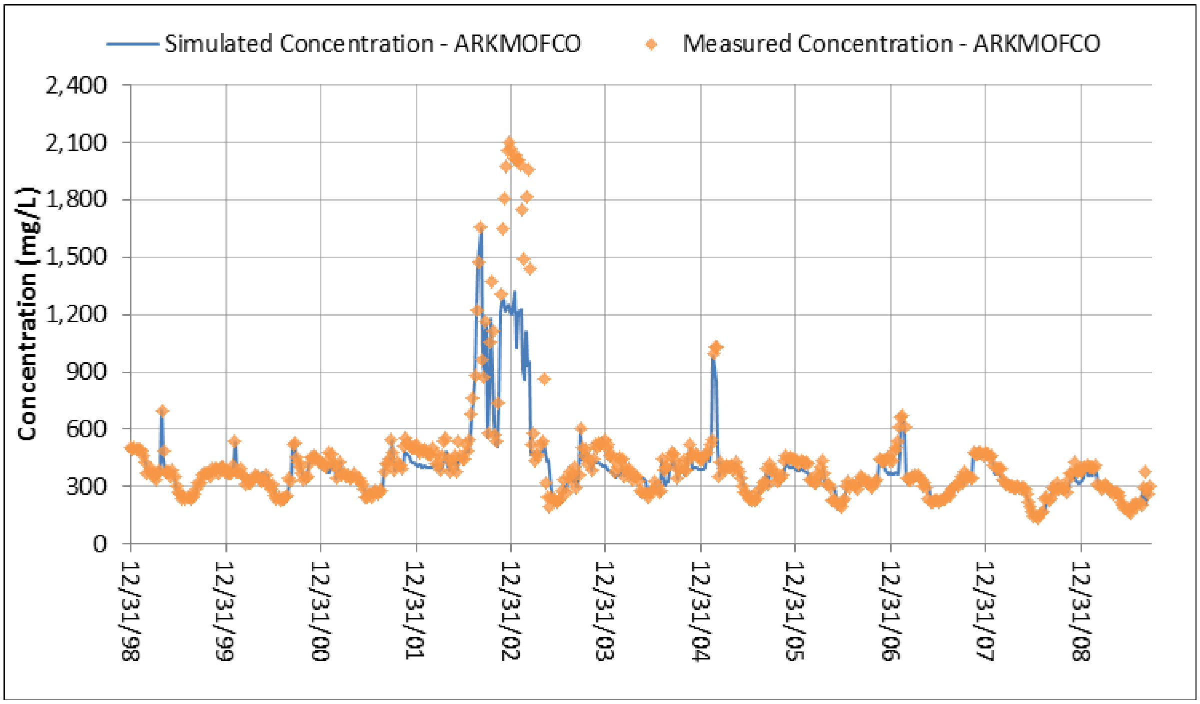


Figure 27. Weekly Comparison of Measured and Simulated Salinity Concentration for Arkansas River at Moffat Gage Calibration

Arkansas River near Avondale Segment. This segment used measured concentration at the Arkansas River near Avondale gage to calibrate unknown concentrations. The segment combines inflows from Fountain Creek and the Arkansas River and receives tributary inflows from the Saint Charles River. This segment also receives the effluent from the Pueblo WWTF.

Calibrated Concentration. Figure 28 depicts the weekly average calculated salinity concentration for inflows with unmeasured concentration between Arkansas River at Moffat St. and Arkansas River near Avondale gages. With exception of few points, the calibrated concentration has values in the same range throughout the simulation indicating a relative uniform source of salinity in this segment, downstream of the Fountain at Pueblo gage and Arkansas River at Moffat St. gage.

Measured concentration matches simulated concentration well, in part due to the number of simulated inflows with unmeasured concentration that allows flexibility in the calibration. Figure 29 shows the comparison of the calibrated and simulated concentration at the Arkansas River near Avondale gage.

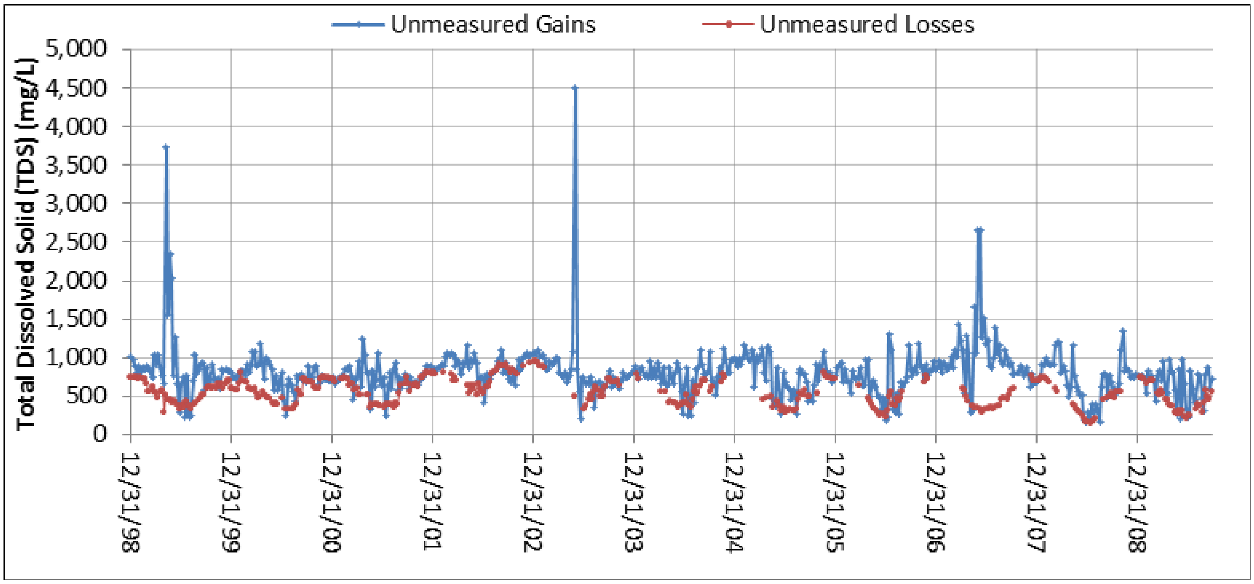


Figure 28. Weekly Calibrated and Simulated Salinity Concentration to Arkansas River near Avondale Segment for Unmeasured Inflows and Outflows

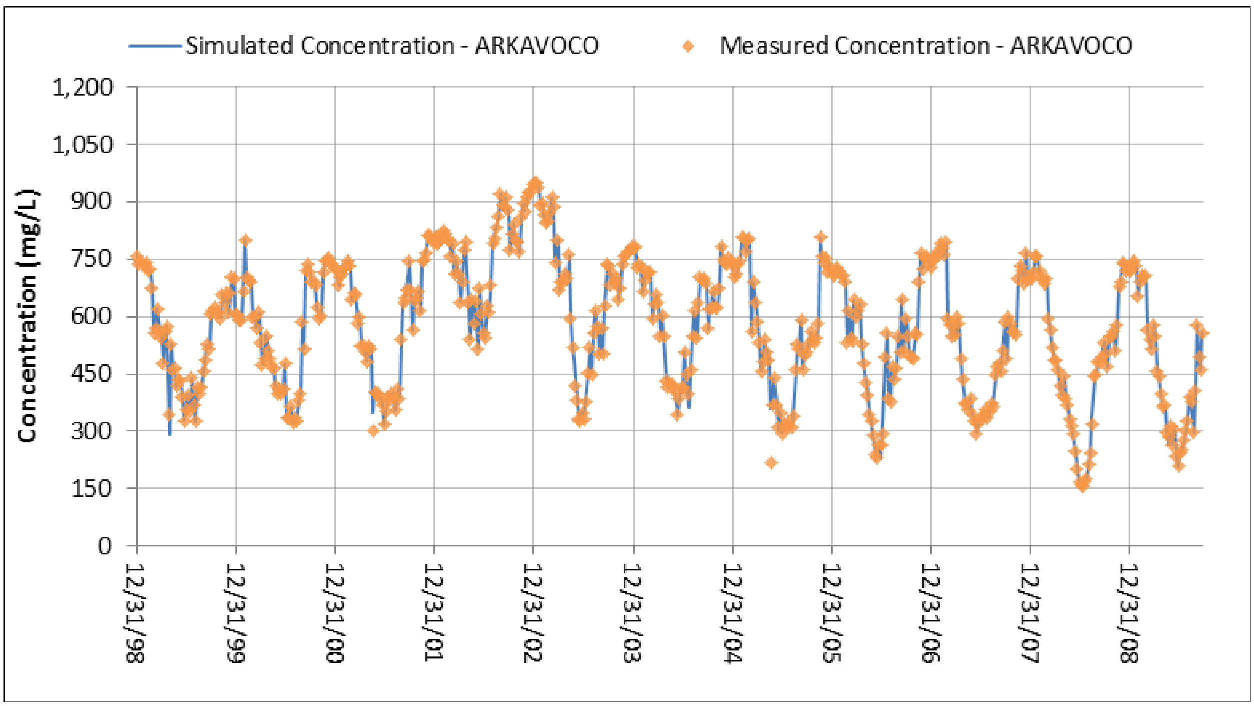


Figure 29. Weekly Comparison of Measured and Simulated Salinity Concentration for Arkansas River near Avondale Gage Calibration

Arkansas River at Catlin Dam Segment. This segment used measured concentration at the Arkansas River at Catlin Dam gage to calibrate unknown concentrations. This segment receives contributions from the Huerfano River and Apishapa River.

Calibrated Concentration. Figure 30 depicts the representative weekly average salinity concentration for inflows between Arkansas River near Avondale and Arkansas River at Catlin Dam gages. The representative concentration is the flow weighted concentration entering the segment. The results indicate a large source of salinity added to the Arkansas River in this segment. The average concentration of unmeasured gains to this segment is about 1,700 mg/L.

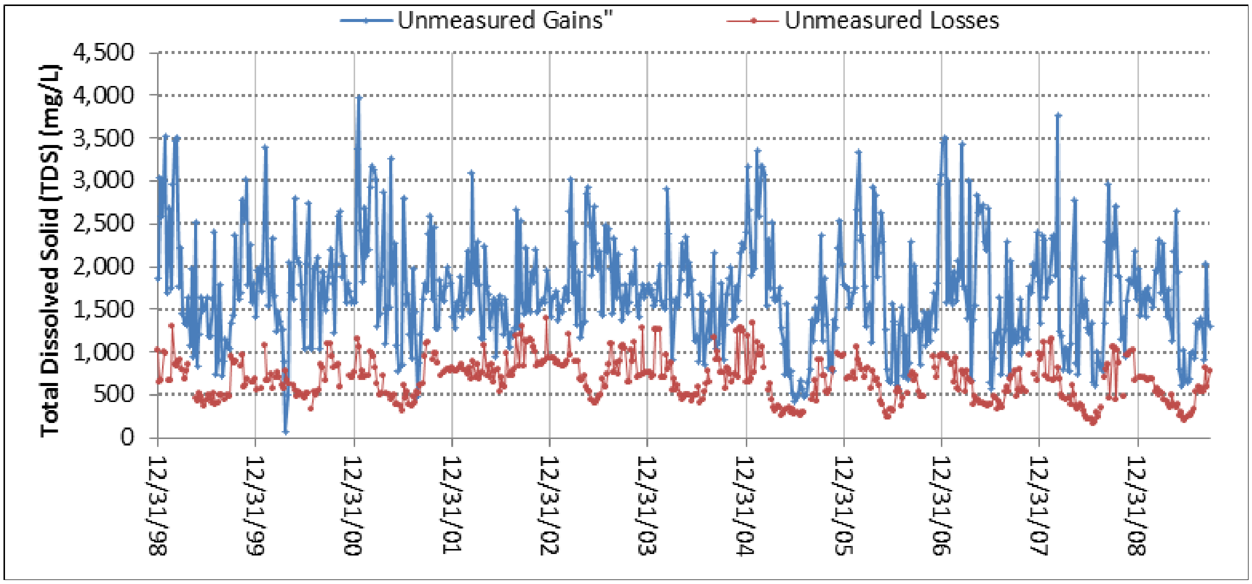


Figure 30. Weekly Calibrated and Simulated Salinity Concentration to Arkansas River at Catlin Dam Segment for Unmeasured Inflows and Outflows

The calibration of inflow unmeasured concentrations was able to adequately reproduce the measured concentration at the Arkansas River at Catlin Dam gage. Figure 31 compares simulated and measured concentrations for the Arkansas River at Catlin Dam gage.

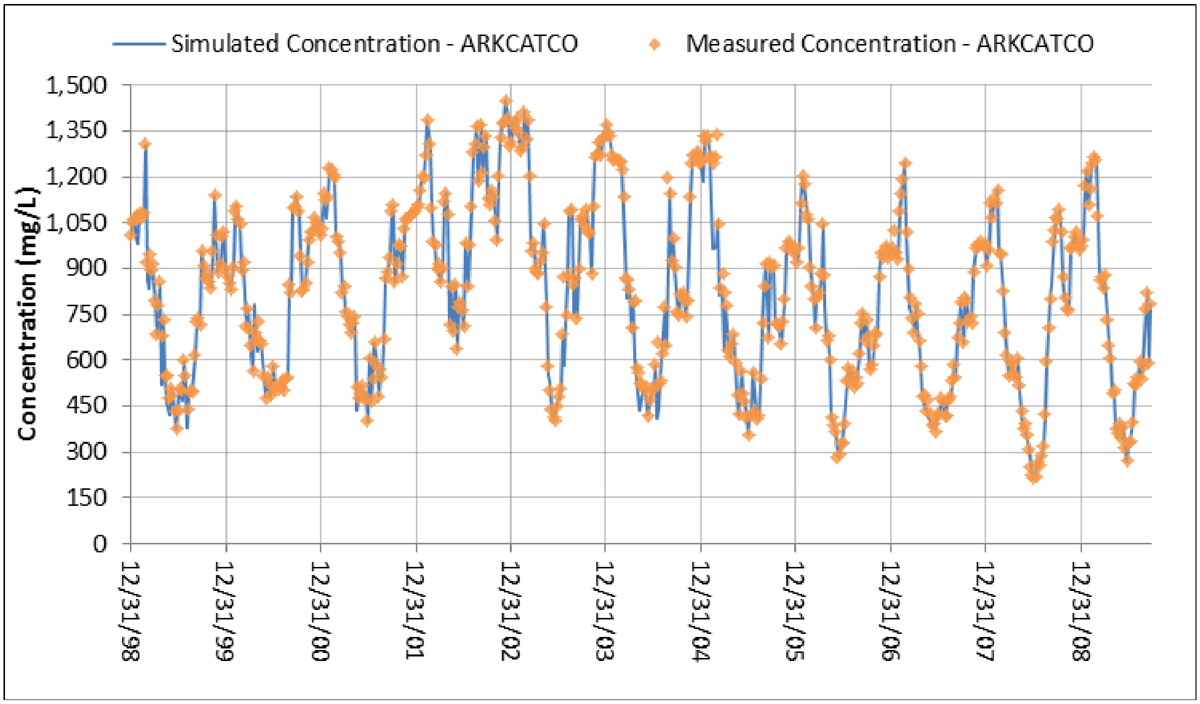


Figure 31. Weekly Comparison of Measured and Simulated Salinity Concentration for Arkansas River at Catlin Gage Calibration

Arkansas River near Rocky Ford Segment. This segment used measured/estimated concentration at the Arkansas River near Rocky Ford gage to calibrate unknown concentrations. Although this segment simulates several return flow nodes, it does not receive major measured tributaries. Calibration to the estimated historical concentration at this gage helps as an intermediate control point to calibrate the next downstream segment to the Arkansas River at Las Animas gage.

Calibrated Concentration. Figure 32 depicts the weekly average calculated salinity concentration for inflows between Arkansas River at Catlin Dam and Arkansas River near Rocky Ford gages. Large variability is shown in the calibrated concentration, indicating what could be intermittent sources of salinity loads to the river in this segment. Trends of low and high calibrated concentrations apparent between the first two thirds and the last third of the simulation and the end of the simulation, are likely due to effects of missing data and the fill-in process.

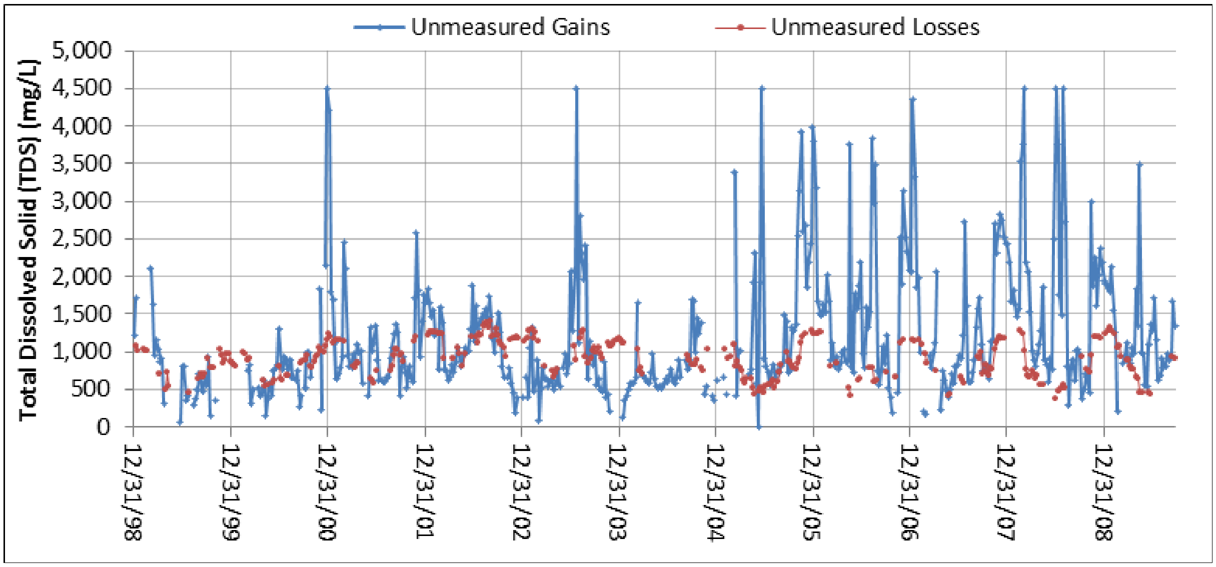


Figure 32. Weekly Calibrated and Simulated Salinity Concentration to Arkansas River near Rocky Ford Segment for Unmeasured Inflows and Outflows

Figure 33 shows the result of this section calibration, comparing the measured/estimated and simulated concentration at the Arkansas River near Rocky Ford gage. Simulated concentration matches historical estimated concentration for most of the simulation period. The larger calibration errors in the beginning of the simulation correspond with periods of net losses in the segment and corresponding low calibrated salt loadings to the segment.

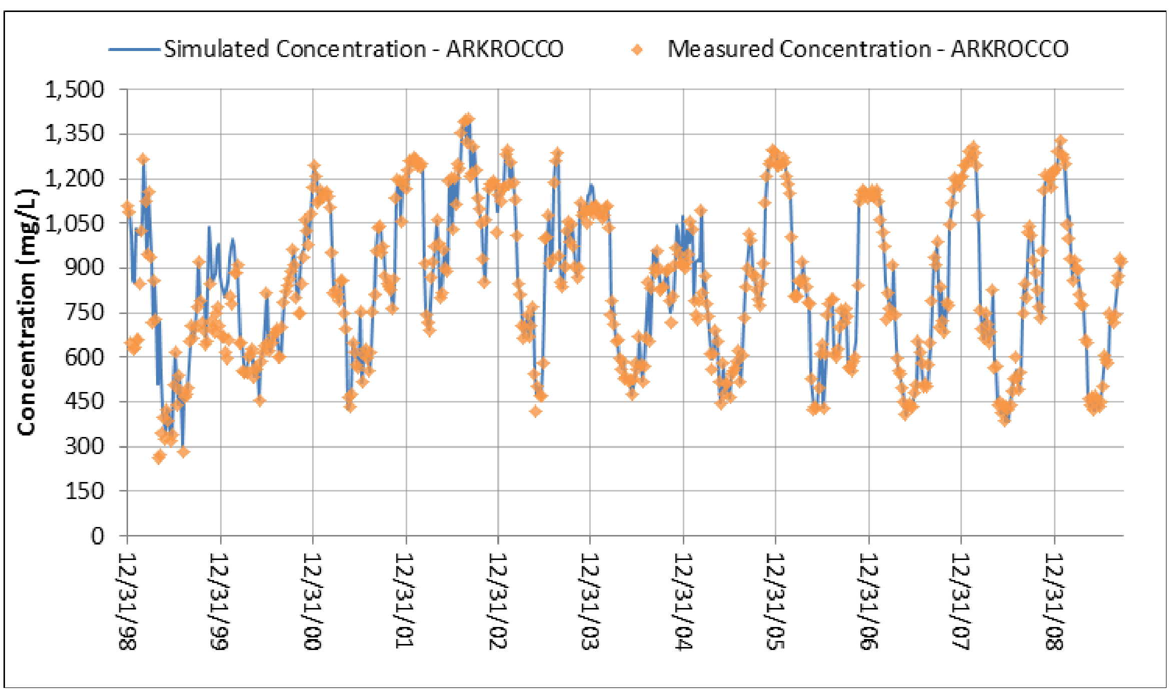


Figure 33. Weekly Comparison of Measured and Simulated Salinity Concentration for Arkansas River near Rocky Ford Gage Calibration

Arkansas River at Las Animas Segment. This segment uses measured concentrations at the Arkansas River at Las Animas gage to calibrate unknown concentrations. This segment receives Timpas Creek, Crooked Arroyo, and several unmeasured tributaries. This is the most downstream segment simulated by the model and is located just upstream from the confluence of the Purgatory River with the Arkansas River.

Assumptions. Flows in Horse Creek were neglected since they were not modeled in the Daily Model, and were assumed to be blended with the other unmeasured inflows in the segment.

Calibrated Concentration. Figure 34 depicts the weekly average calculated salinity concentration for inflows between Arkansas River near Rocky Ford and Arkansas River at Las Animas gages. Results show a relative uniform unmeasured salinity load in this segment, with exception of the first year of simulation where larger values were present. The overall average salinity load concentration was 1,178 mg/L.

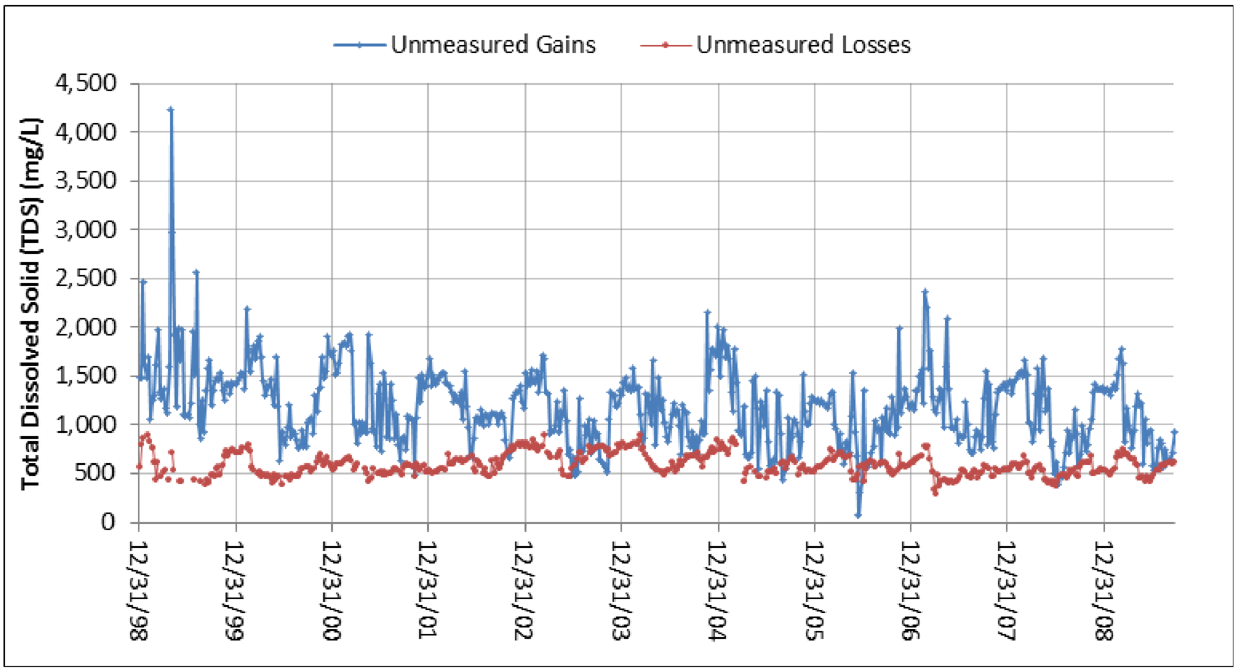


Figure 34. Weekly Calibrated and Simulated Salinity Concentration to Arkansas River at Las Animas Segment for Unmeasured Inflows and Outflows

Simulated concentration at this segment included the accumulated effect of the calibrated salinity load that cascades from the upstream end of the model to this segment. Figure 35 shows the comparison of the simulated and measured concentration at the Arkansas River at Las Animas. The results show a good overall performance of the model in mimicking the concentration at the intermediate control points and at the downstream end of the simulated area.

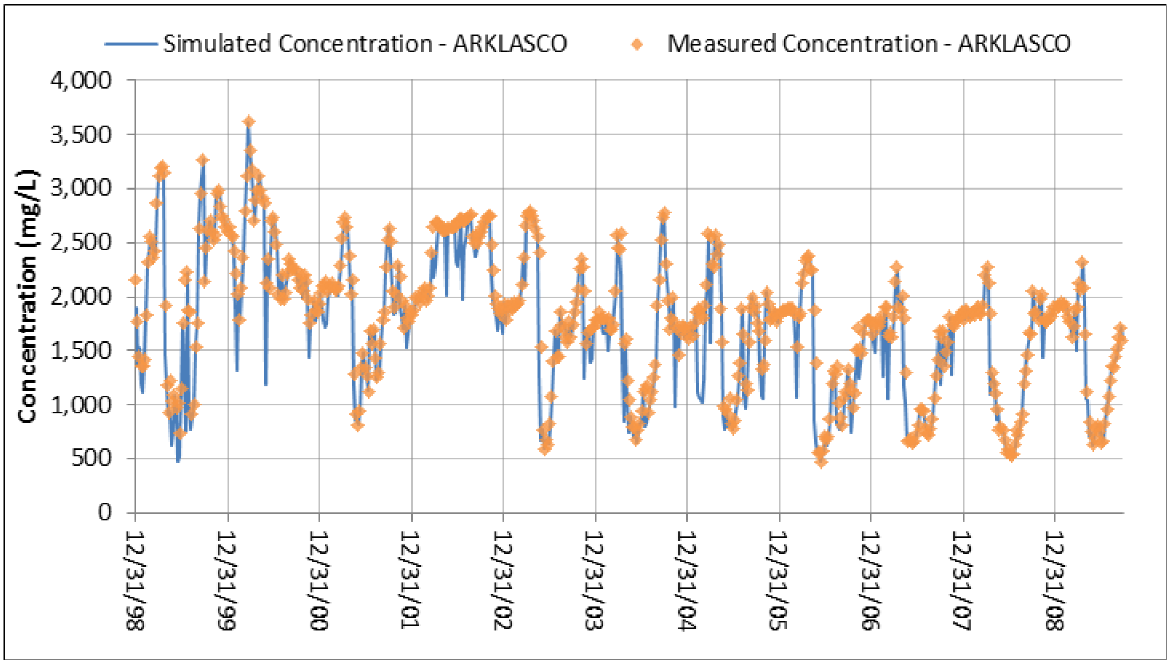


Figure 35. Weekly Comparison of Measured and Simulated Salinity Concentration for Arkansas River at Las Animas Gage Calibration

Calibration Summary

The calibration of the GeoDSS water quality model to represent salinity loading and transport in the study area was evaluated comparing the mean and selected percentiles of the simulated and measured concentrations at the gages that serve as control points. Table 11 shows the statistics per control point of the simulated and measured concentrations, including percent change of each statistic and the average mean error.

Table 11. Summary Statistics – Salinity Concentration Calibration Performance for Control Points in the Study Area

Gage	Mean (mg/L)	Percentile [mg/L] 15	25	50	75	85	Average Mean Error (mg/L)
715530- Fountain Creek below Janitell Road							
Simulated	449.4	349.4	382.7	454.0	509.3	555.9	*±6.1 (1%)*
Measured	443.9	344.1	374.3	441.0	509.9	556.2	
Percent Difference	-1%	-2%	-2%	-3%	0%	0%	
7106000-Fountain Creek near Fountain							
Simulated	574.0	454.2	518.5	604.5	656.3	678.3	*±30.6 (5%)*
Measured	603.8	515.5	564.3	621.7	668.8	688.2	
Percent Difference	5%	12%	8%	3%	2%	1%	
FOUPUECO-Fountain Creek at Pueblo							
Simulated	711.7	576.3	638.5	739.3	807.0	845.6	*±82.1 (10%)*
Measured	793.8	689.3	736.7	799.4	857.7	890.7	
Percent Difference	15%	23%	21%	14%	8%	6%	
ARKPUECO-Arkansas River above Pueblo							
Simulated	312.8	241.2	263.4	309.5	348.9	373.0	*±0 (0%)*
Measured	312.8	241.2	263.4	309.5	348.9	373.0	
Percent Difference	0%	0%	0%	0%	0%	0%	
ARKMOFCO-Arkansas River at Moffat St.							
Simulated	392.3	265.1	299.0	359.7	413.5	457.5	*±43.7 (10%)*
Measured	430.5	257.2	297.6	370.7	448.7	494.1	
Percent Difference	9%	-3%	0%	3%	8%	7%	
ARKAVOCO-Arkansas River near Avondale							
Simulated	576.8	371.0	442.7	587.8	718.2	751.2	*±1.2 (0%)*
Measured	576.8	374.0	442.7	588.0	718.5	751.3	
Percent Difference	0%	1%	0%	0%	0%	0%	
ARKCATCO-Arkansas River at Catlin Dam							
Simulated	819.3	487.8	566.2	831.9	1041.1	1132.8	*±10.2 (1%)*
Measured	828.4	500.0	575.7	843.4	1058.4	1143.7	
Percent Difference	1%	2%	2%	1%	2%	1%	
ARKROCCO-Arkansas River near Rocky Ford							
Simulated	852.0	552.1	634.5	849.1	1077.2	1166.0	*±16.3 (2%)*
Measured	838.3	549.6	619.2	816.7	1064.0	1165.5	
Percent Difference	-2%	0%	-2%	-4%	-1%	0%	
ARKLASCO-Arkansas River at Las Animas							
Simulated	1732.9	908.0	1236.3	1792.3	2122.1	2483.4	*±82 (5%)*
Measured	1814.2	1050.6	1422.8	1848.5	2206.0	2558.7	
Percent Difference	4%	14%	13%	3%	4%	3%	

Notes:

Average mean error: $AME = \frac{\sum \left| SimVal - ObsVal \right|}{N}$

Where: SimVal = simulated value, ObsVal = observed value, N = number of observations, From Galloway and Green (2002).

In general, results show good representation of the measured concentration at the control points, with larger errors at the downstream Fountain Creek and Arkansas River gages. The largest percent difference (around 20 percent under prediction) is at the 15^{th} and 25^{th} percentiles for the Fountain at Pueblo gage, where low unmeasured inflows to the model limit performance. The Las Animas gage shows the largest percent difference in the Arkansas River, with around 14 percent under prediction at the 15^{th} and 25^{th} percentiles.

The model results reflect the cascading effect of calibration errors because the GeoDSS uses the simulated concentration at the gages to represent salt loading to the next downstream segment. In many cases calibration self-corrects those errors in the next downstream segment, adjusting that downstream segment unmeasured concentrations to try to match the downstream gage concentration. For example, this is the case in the Arkansas River at Avondale where discrepancies between measured and simulated at the Fountain Creek at Pueblo gage are adjusted.

The average mean error for all the control points is less than 10 percent. The average percent difference of the mean shows slight under prediction of concentration in the simulation, except the Fountain Creek below Janitell Road and Arkansas River near Rocky Ford gages, which show a slight over prediction of concentrations. The calibrated salinity model provides a reasonable baseline to compare the relative effects on salinity for the alternatives.

Simulation of Alternatives. Changes in salinity loadings and concentrations for the direct and cumulative effects were analyzed for the each of the alternatives. The calibrated salinity model was used as the base to simulate alternatives. Calibrated concentrations of unmeasured inflows were assumed constant for all scenarios, while the unmeasured flow gains and losses to each scenario were based on the Daily Model simulated flows.

Changes in salinity loads to the system under each alternative were simulated according to the changes of flow simulated in the Daily Model and the calibrated concentrations. Salt loads were routed and mixed with other simulated salt loads from upstream to downstream, allowing simulation of salinity concentration at all the diversion and control points (gages). Table 12 shows the assumed concentration at the Arkansas River above Pueblo, Fountain Creek near Colorado Springs and Monument Creek at Bijou St. gages, which are the most upstream gages in the simulated area

Table 12. Simulated Salinity Concentration for Upstream Model Boundary Gages

Gage	Mean	Concentration Statistics (mg/L)				
		15^{th}	25^{th}	50^{th}	75^{th}	85^{th}
Arkansas River above Pueblo	313	241	263	310	349	373
Fountain Creek near Colorado Springs	200	128	154	197	242	278
Monument Creek at Bijou St.	414	313	352	427	476	516

Direct and Indirect Effects. A comparative analysis with the No Action Alternative and existing conditions was performed to estimate the changes in salinity under each of the alternatives for the direct effects analysis. For each control point, statistics of the simulated concentration and relative changes with respect to the No Action Alternative and the existing conditions are presented, as well as the monthly statistics of the simulated concentration for the different alternatives and their percent change with respect to No Action and existing conditions for the direct effect analysis. Table 13 and Table 14 summarize direct and indirect salinity effects in the Arkansas River and Fountain Creek.

Table 13. Summary of Mean Direct and Indirect Salinity Effects

Gage	Existing Condi-tions	No Action	Coman-che South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Mean Concentration (mg/L)								
Arkansas River at Moffat St.	391	406	420	420	418	420	389	407
Arkansas River near Avondale	564	582	591	591	587	591	584	586
Arkansas River at Catlin Dam	780	791	804	804	804	804	799	792
Arkansas River at Las Animas	1,684	1,624	1,623	1,625	1,632	1,623	1,621	1,616
Fountain Creek near Fountain	596	658	662	662	658	662	661	663
Fountain Creek at Pueblo	698	746	746	746	746	746	746	747
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Arkansas River at Moffat St.	---	---	14 (3.4)	14 (3.5)	13 (3.1)	14 (3.4)	-17 (-4.2)	1 (0.4)
Arkansas River near Avondale	---	---	8.6 (1.5)	8.6 (1.5)	4.5 (0.8)	8.5 (1.5)	1.7 (0.3)	4 (0.7)
Arkansas River at Catlin Dam	---	---	13 (1.6)	13 (1.7)	13 (1.7)	13 (1.7)	8 (1.0)	2 (0.2)
Arkansas River at Las Animas	---	---	-1 (-0.1)	1 (0.1)	8 (0.5)	-1 (-0.1)	-3 (-0.2)	-8 (-0.5)
Fountain Creek near Fountain	---	---	4 (0.6)	4 (0.6)	0 (0.0)	4 (0.6)	3 (0.5)	5 (0.8)
Fountain Creek at Pueblo	---	---	0 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Arkansas River at Moffat St.	---	14 (3.7)	28 (7.3)	29 (7.3)	27 (6.9)	28 (7.3)	-3 (-0.7)	16 (4.1)
Arkansas River near Avondale	---	19 (3.3)	27 (4.8)	27 (4.8)	23 (4.1)	27 (4.8)	20 (3.6)	23 (4.0)
Arkansas River at Catlin Dam	---	11 (1.4)	24 (3.0)	24 (3.1)	24 (3.0)	24 (3.1)	19 (2.4)	12 (1.6)
Arkansas River at Las Animas	---	-61 (-3.6)	-62 (-3.7)	-59 (-3.5)	-52 (-3.1)	-62 (-3.7)	-63 (-3.8)	-68 (-4.0)
Fountain Creek near Fountain	---	62 (10.4)	66 (11.1)	66 (11.0)	62 (10.4)	66 (11.0)	65 (10.9)	67 (11.2)
Fountain Creek at Pueblo	---	48 (6.8)	48 (6.9)	48 (6.9)	48 (6.8)	48 (6.8)	47 (6.8)	49 (7.0)

Table 14. Summary of 85th Percentile Direct and Indirect Salinity Effects

Gage	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
85th Percentile Concentration (mg/L)								
Arkansas River at Moffat St.	446	478	504	506	498	501	473	479
Arkansas River near Avondale	733	753	764	764	758	764	760	760
Arkansas River at Catlin Dam	1,062	1,056	1,094	1,087	1,078	1,092	1,083	1,060
Arkansas River at Las Animas	2,323	2,170	2,185	2,186	2,206	2,175	2,185	2,172
Fountain Creek near Fountain	733	801	802	802	799	802	802	802
Fountain Creek at Pueblo	870	906	905	905	905	905	905	905
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Arkansas River at Moffat St.	---	---	26 (5.5)	28 (5.9)	21 (4.3)	24 (5.0)	-5 (-1.1)	1 (0.2)
Arkansas River near Avondale	---	---	11.3 (1.5)	11.6 (1.5)	5.5 (0.7)	11.5 (1.5)	7.8 (1.0)	7.5 (1.0)
Arkansas River at Catlin Dam	---	---	38 (3.6)	31 (2.9)	22 (2.1)	36 (3.4)	27 (2.5)	4 (0.4)
Arkansas River at Las Animas	---	---	15 (0.7)	15 (0.7)	36 (1.7)	5 (0.2)	15 (0.7)	2 (0.1)
Fountain Creek near Fountain	---	---	1 (0.1)	1 (0.1)	-2 (-0.2)	1 (0.1)	1 (0.1)	1 (0.1)
Fountain Creek at Pueblo	---	---	-1 (-0.1)	-1 (-0.1)	-1 (-0.1)	-1 (-0.1)	-1 (-0.1)	-1 (-0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Arkansas River at Moffat St.	---	31 (7.0)	58 (12.9)	60 (13.4)	52 (11.6)	55 (12.3)	26 (5.9)	32 (7.3)
Arkansas River near Avondale	---	19 (2.6)	31 (4.2)	31 (4.2)	25 (3.4)	31 (4.2)	27 (3.7)	27 (3.7)
Arkansas River at Catlin Dam	---	-6 (-0.6)	32 (3.0)	25 (2.4)	16 (1.5)	30 (2.8)	21 (2.0)	-2 (-0.1)
Arkansas River at Las Animas	---	-153 (-6.6)	-138 (-6.0)	-138 (-5.9)	-117 (-5.0)	-148 (-6.4)	-138 (-5.9)	-151 (-6.5)
Fountain Creek near Fountain	---	68 (9.3)	69 (9.4)	69 (9.4)	66 (9.1)	69 (9.4)	69 (9.4)	69 (9.4)
Fountain Creek at Pueblo	---	36 (4.1)	35 (4.0)	35 (4.0)	35 (4.0)	35 (4.0)	34 (4.0)	35 (4.0)

Table 15 and Table 16 show the statistics and relative change with respect to the No Action Alternative and the existing conditions for the Arkansas River at Moffat St. gage. All alternatives, except River South and Master Contract Only, would have negligible to minor adverse effects to river salinity when compared with the No Action Alternative. Occasional moderate increases in salinity would occur in dry years. The largest percent changes occur in January, February, March, September and October. All alternatives increase salinity during various months, compared to existing conditions, though changes are of similar magnitude as effects compared to the No Action.

Table 15. Direct Effects Simulated Salinity Concentration Comparison for Arkansas River at Moffat St. Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	391	406	420	420	418	420	389	407
15th percentile	264	267	267	267	267	267	262	267
25th percentile	299	303	304	304	304	304	303	303
50th percentile	365	375	385	385	381	385	367	379
75th percentile	419	438	452	452	451	452	432	439
85th percentile	446	478	504	506	498	501	473	479
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	14 (3.4)	14 (3.5)	13 (3.1)	14 (3.4)	-17 (-4.2)	1 (0.4)
15th percentile	---	---	0 (0.1)	0 (0.1)	0 (0.1)	0 (0.1)	-5 (-1.7)	0 (0.1)
25th percentile	---	---	1 (0.3)	1 (0.3)	1 (0.3)	1 (0.3)	-1 (-0.3)	0 (0.0)
50th percentile	---	---	10 (2.6)	10 (2.7)	6 (1.7)	10 (2.6)	-7 (-1.9)	4 (1.1)
75th percentile	---	---	14 (3.3)	14 (3.3)	13 (3.0)	14 (3.2)	-5 (-1.2)	1 (0.3)
85th percentile	---	---	26 (5.5)	28 (5.9)	21 (4.3)	24 (5.0)	-5 (-1.1)	1 (0.2)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	14 (3.7)	28 (7.3)	29 (7.3)	27 (6.9)	28 (7.3)	-3 (-0.7)	16 (4.1)
15th percentile	---	2 (0.9)	3 (1.0)	3 (1.0)	3 (1.0)	3 (1.0)	-2 (-0.8)	3 (1.0)
25th percentile	---	4 (1.4)	5 (1.7)	5 (1.7)	5 (1.7)	5 (1.7)	3 (1.1)	4 (1.4)
50th percentile	---	10 (2.8)	20 (5.5)	20 (5.5)	17 (4.5)	20 (5.5)	3 (0.8)	14 (3.9)
75th percentile	---	19 (4.5)	33 (7.9)	33 (7.9)	32 (7.7)	33 (7.8)	13 (3.2)	20 (4.8)
85th percentile	---	31 (7.0)	58 (12.9)	60 (13.4)	52 (11.6)	55 (12.3)	26 (5.9)	32 (7.3)

Table 16. Direct Effects Monthly Simulated Salinity Concentration for Arkansas River at Moffat St. Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	472	483	508	508	503	508	463	488
Feb	516	537	566	566	567	566	485	537
Mar	393	406	426	427	425	426	389	411
Apr	367	379	387	387	388	387	376	379
May	351	354	356	356	355	356	354	355
Jun	277	279	280	280	280	280	278	279
Jul	265	271	275	274	274	275	265	271
Aug	333	345	356	356	356	356	320	346
Sep	407	425	446	447	443	446	401	425
Oct	404	433	454	454	445	454	426	440
Nov	452	473	485	485	486	485	448	470
Dec	484	511	527	528	525	527	486	512
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	25 (5.2)	25 (5.3)	20 (4.2)	25 (5.2)	-20 (-4.0)	5 (1.0)
Feb	---	---	29 (5.4)	29 (5.6)	30 (5.7)	29 (5.4)	-52 (-9.7)	0 (0.1)
Mar	---	---	20 (4.8)	21 (5.1)	19 (4.5)	20 (4.8)	-17 (-4.2)	5 (1.1)
Apr	---	---	8 (2.2)	8 (2.3)	9 (2.6)	8 (2.2)	-3 (-0.8)	0 (0.1)
May	---	---	2 (0.5)	2 (0.5)	1 (0.4)	2 (0.5)	0 (-0.1)	1 (0.3)
Jun	---	---	1 (0.3)	1 (0.3)	1 (0.3)	1 (0.3)	-1 (-0.4)	0 (0.0)
Jul	---	---	4 (1.2)	3 (1.1)	3 (0.9)	4 (1.2)	-6 (-2.4)	0 (0.0)
Aug	---	---	11 (3.1)	11 (3.0)	11 (3.2)	11 (3.0)	-25 (-7.3)	1 (0.3)
Sep	---	---	21 (4.8)	22 (5.1)	18 (4.2)	21 (5.0)	-24 (-5.6)	0 (-0.1)
Oct	---	---	21 (5.0)	21 (4.9)	12 (2.8)	21 (5.0)	-7 (-1.6)	7 (1.8)
Nov	---	---	12 (2.5)	12 (2.4)	13 (2.6)	12 (2.5)	-25 (-5.3)	-3 (-0.7)
Dec	---	---	16 (3.3)	17 (3.4)	14 (2.9)	16 (3.3)	-25 (-4.9)	1 (0.3)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	11 (2.2)	36 (7.6)	36 (7.6)	31 (6.6)	36 (7.6)	-9 (-1.9)	16 (3.2)
Feb	---	21 (3.9)	50 (9.6)	50 (9.7)	51 (9.9)	50 (9.6)	-31 (-6.1)	21 (4.0)
Mar	---	13 (3.5)	33 (8.5)	34 (8.8)	32 (8.2)	33 (8.4)	-4 (-0.8)	18 (4.7)
Apr	---	12 (3.0)	20 (5.3)	20 (5.4)	21 (5.7)	20 (5.2)	9 (2.2)	12 (3.1)
May	---	3 (1.0)	5 (1.5)	5 (1.4)	4 (1.3)	5 (1.5)	3 (0.9)	4 (1.2)
Jun	---	2 (0.7)	3 (1.1)	3 (1.1)	3 (1.1)	3 (1.1)	1 (0.3)	2 (0.8)
Jul	---	6 (2.3)	10 (3.5)	9 (3.4)	9 (3.3)	10 (3.5)	0 (-0.2)	6 (2.3)
Aug	---	12 (3.6)	23 (6.8)	23 (6.8)	23 (7.0)	23 (6.7)	-13 (-4.0)	13 (3.9)
Sep	---	18 (4.4)	39 (9.5)	40 (9.7)	36 (8.9)	39 (9.6)	-6 (-1.4)	18 (4.4)
Oct	---	29 (7.1)	50 (12.5)	50 (12.4)	41 (10.1)	50 (12.5)	22 (5.5)	36 (9.0)
Nov	---	21 (4.7)	33 (7.3)	33 (7.3)	34 (7.4)	33 (7.3)	-4 (-0.9)	18 (3.9)
Dec	---	27 (5.6)	43 (9.0)	44 (9.1)	41 (8.6)	43 (9.0)	2 (0.4)	28 (5.9)

Table 17 and Table 18 show the statistics and relative change for the Arkansas River near Avondale gage. All alternatives would have predominantly negligible adverse effects on Arkansas River near Avondale gage salinity concentrations, with occasion minor effects occurring in various months, compared to the No Action. All alternatives increase salinity levels at the Arkansas River near Avondale gage, compared to existing conditions, caused by additional municipal discharges and streamflow changes.

Table 17. Direct Effects Simulated Salinity Concentration Comparison for Arkansas River near Avondale Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	564	582	591	591	587	591	584	586
15th percentile	371	378	382	382	381	382	379	380
25th percentile	437	445	451	451	447	451	447	448
50th percentile	576	597	607	605	601	607	598	600
75th percentile	687	713	724	723	718	724	721	720
85th percentile	733	753	764	764	758	764	760	760
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	8.6 (1.5)	8.6 (1.5)	4.5 (0.8)	8.5 (1.5)	1.7 (0.3)	4 (0.7)
15th percentile	---	---	3.6 (1.0)	3.6 (0.9)	3.2 (0.8)	4 (1.1)	0.6 (0.2)	2 (0.5)
25th percentile	---	---	5.6 (1.2)	5.3 (1.2)	1.8 (0.4)	5.5 (1.2)	2.2 (0.5)	2.3 (0.5)
50th percentile	---	---	9.7 (1.6)	7.8 (1.3)	4.2 (0.7)	9.6 (1.6)	1.2 (0.2)	2.6 (0.4)
75th percentile	---	---	11.5 (1.6)	10.4 (1.5)	4.8 (0.7)	11.5 (1.6)	8.1 (1.1)	7.2 (1.0)
85th percentile	---	---	11.3 (1.5)	11.6 (1.5)	5.5 (0.7)	11.5 (1.5)	7.8 (1.0)	7.5 (1.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	19 (3.3)	27 (4.8)	27 (4.8)	23 (4.1)	27 (4.8)	20 (3.6)	23 (4.0)
15th percentile	---	7 (1.8)	10 (2.8)	10 (2.8)	10 (2.7)	11 (2.9)	7 (2.0)	9 (2.4)
25th percentile	---	8 (1.9)	14 (3.2)	14 (3.1)	10 (2.3)	14 (3.2)	10 (2.4)	11 (2.4)
50th percentile	---	21 (3.7)	31 (5.4)	29 (5.1)	26 (4.4)	31 (5.4)	23 (3.9)	24 (4.2)
75th percentile	---	26 (3.8)	37 (5.4)	36 (5.3)	31 (4.5)	37 (5.4)	34 (5.0)	33 (4.8)
85th percentile	---	19 (2.6)	31 (4.2)	31 (4.2)	25 (3.4)	31 (4.2)	27 (3.7)	27 (3.7)

Table 18. Direct Effects Monthly Simulated Salinity Concentration for Arkansas River near Avondale Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	707	728	743	744	735	743	732	737
Feb	744	767	777	777	774	777	766	771
Mar	627	650	670	670	659	668	661	662
Apr	525	552	561	561	555	561	560	559
May	430	438	442	442	439	442	441	440
Jun	347	352	354	355	354	354	353	353
Jul	368	382	387	386	385	387	382	384
Aug	477	488	494	494	490	494	486	490
Sep	579	609	616	616	614	616	603	608
Oct	621	645	660	660	652	660	657	655
Nov	667	687	691	691	692	691	681	684
Dec	715	733	739	739	738	739	730	733
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	15 (2.0)	16 (2.1)	7 (0.9)	15 (2.0)	4 (0.4)	9 (1.2)
Feb	---	---	10 (1.2)	10 (1.2)	7 (0.9)	10 (1.2)	-1 (-0.1)	4 (0.5)
Mar	---	---	20 (3.0)	20 (3.0)	9 (1.4)	18 (2.8)	11 (1.6)	12 (1.9)
Apr	---	---	9 (1.7)	9 (1.7)	3 (0.6)	9 (1.7)	8 (1.4)	7 (1.4)
May	---	---	4 (0.8)	4 (0.8)	1 (0.3)	4 (0.8)	3 (0.7)	2 (0.5)
Jun	---	---	2 (0.5)	3 (0.6)	2 (0.4)	2 (0.5)	1 (0.1)	1 (0.2)
Jul	---	---	5 (1.3)	4 (1.1)	3 (0.7)	5 (1.3)	0 (0.0)	2 (0.6)
Aug	---	---	6 (1.2)	6 (1.3)	2 (0.4)	6 (1.3)	-2 (-0.4)	2 (0.3)
Sep	---	---	7 (1.2)	7 (1.2)	5 (0.8)	7 (1.2)	-6 (-0.9)	-1 (-0.1)
Oct	---	---	15 (2.3)	15 (2.2)	7 (1.0)	15 (2.3)	12 (1.8)	10 (1.6)
Nov	---	---	4 (0.7)	4 (0.7)	5 (0.8)	4 (0.7)	-6 (-0.8)	-3 (-0.3)
Dec	---	---	6 (0.9)	6 (0.9)	5 (0.7)	6 (0.9)	-3 (-0.4)	0 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	21 (3.0)	36 (5.1)	37 (5.2)	28 (4.0)	36 (5.1)	25 (3.5)	30 (4.2)
Feb	---	23 (3.1)	33 (4.4)	33 (4.4)	30 (4.1)	33 (4.4)	22 (3.0)	27 (3.7)
Mar	---	23 (3.7)	43 (6.9)	43 (6.9)	32 (5.2)	41 (6.6)	34 (5.4)	35 (5.7)
Apr	---	27 (5.1)	36 (6.9)	36 (6.9)	30 (5.7)	36 (6.9)	35 (6.6)	34 (6.6)
May	---	8 (1.8)	12 (2.7)	12 (2.7)	9 (2.2)	12 (2.7)	11 (2.5)	10 (2.4)
Jun	---	5 (1.5)	7 (2.1)	8 (2.1)	7 (1.9)	7 (2.1)	6 (1.6)	6 (1.7)
Jul	---	14 (3.9)	19 (5.3)	18 (5.0)	17 (4.7)	19 (5.3)	14 (3.9)	16 (4.5)
Aug	---	11 (2.4)	17 (3.6)	17 (3.7)	13 (2.7)	17 (3.7)	9 (2.0)	13 (2.7)
Sep	---	30 (5.1)	37 (6.4)	37 (6.4)	35 (5.9)	37 (6.4)	24 (4.2)	29 (5.0)
Oct	---	24 (3.9)	39 (6.3)	39 (6.2)	31 (4.9)	39 (6.3)	36 (5.7)	34 (5.6)
Nov	---	20 (3.0)	24 (3.7)	24 (3.7)	25 (3.8)	24 (3.7)	14 (2.1)	17 (2.6)
Dec	---	18 (2.5)	24 (3.3)	24 (3.4)	23 (3.2)	24 (3.3)	15 (2.0)	18 (2.5)

The monthly concentration statistics at the Arkansas River at Catlin Dam and Arkansas River near Rocky Ford gages show smaller percent changes with respect to the No Action alternative than the Arkansas River near Avondale gage concentrations (Table 19 through Table 22). Effects for both gages would be predominantly negligible, with occasional minor increases in concentration. The Arkansas River at Catlin Dam concentrations would slightly decrease with respect to the No Action Alternative in November, except for the JUP North Alternative. The Master Contract Only Alternative would decrease the average concentration in months after August. All alternatives would slightly increase salinity concentrations in most months, compared to existing conditions.

Table 19. Direct Effects Simulated Salinity Concentration Comparison for Arkansas River at Catlin Dam Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	780	791	804	804	804	804	799	792
15th percentile	468	469	473	473	473	473	471	470
25th percentile	538	557	568	568	567	568	567	564
50th percentile	795	818	828	830	828	828	823	820
75th percentile	968	975	992	988	987	991	988	974
85th percentile	1,062	1,056	1,094	1,087	1,078	1,092	1,083	1,060
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	13 (1.6)	13 (1.7)	13 (1.7)	13 (1.7)	8 (1.0)	2 (0.2)
15th percentile	---	---	4 (0.8)	4 (0.8)	4 (0.9)	4 (0.8)	2 (0.4)	1 (0.1)
25th percentile	---	---	11 (2.0)	11 (2.0)	9 (1.6)	11 (1.9)	10 (1.7)	7 (1.3)
50th percentile	---	---	10 (1.2)	12 (1.4)	10 (1.2)	10 (1.2)	5 (0.6)	2 (0.3)
75th percentile	---	---	17 (1.8)	13 (1.3)	12 (1.2)	16 (1.6)	13 (1.3)	-1 (-0.1)
85th percentile	---	---	38 (3.6)	31 (2.9)	22 (2.1)	36 (3.4)	27 (2.5)	4 (0.4)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	11 (1.4)	24 (3.0)	24 (3.1)	24 (3.0)	24 (3.1)	19 (2.4)	12 (1.6)
15th percentile	---	1 (0.2)	5 (1.1)	5 (1.1)	6 (1.2)	5 (1.1)	3 (0.6)	2 (0.4)
25th percentile	---	19 (3.6)	30 (5.6)	30 (5.6)	29 (5.3)	30 (5.6)	29 (5.4)	26 (4.9)
50th percentile	---	23 (2.9)	33 (4.1)	34 (4.3)	33 (4.1)	32 (4.1)	27 (3.4)	25 (3.2)
75th percentile	---	7 (0.8)	25 (2.6)	20 (2.1)	19 (2.0)	23 (2.4)	20 (2.1)	6 (0.7)
85th percentile	---	-6 (-0.6)	32 (3.0)	25 (2.4)	16 (1.5)	30 (2.8)	21 (2.0)	-2 (-0.1)

Table 20. Direct Effects Monthly Simulated Salinity Concentration for Arkansas River at Catlin Dam Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	1,010	1,019	1,044	1,046	1,044	1,044	1,037	1,023
Feb	1,081	1,072	1,105	1,106	1,091	1,105	1,097	1,083
Mar	899	915	934	933	926	935	933	927
Apr	716	734	747	749	749	747	748	741
May	540	550	556	556	555	556	555	553
Jun	431	438	441	441	441	441	439	437
Jul	496	510	518	515	514	518	514	517
Aug	631	637	643	643	643	643	638	635
Sep	836	856	869	870	872	870	862	853
Oct	863	892	902	902	905	902	899	891
Nov	918	925	923	924	942	924	915	907
Dec	996	995	1,016	1,018	1,020	1,017	1,003	996
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	25 (2.5)	27 (2.7)	25 (2.5)	25 (2.5)	18 (1.8)	4 (0.4)
Feb	---	---	33 (3.1)	34 (3.2)	19 (1.8)	33 (3.1)	25 (2.3)	11 (1.0)
Mar	---	---	19 (2.1)	18 (2.0)	11 (1.2)	20 (2.1)	18 (1.9)	12 (1.3)
Apr	---	---	13 (1.8)	15 (2.1)	15 (2.1)	13 (1.8)	14 (2.0)	7 (1.0)
May	---	---	6 (1.0)	6 (0.9)	5 (0.9)	6 (1.1)	5 (0.8)	3 (0.5)
Jun	---	---	3 (0.6)	3 (0.7)	3 (0.7)	3 (0.6)	1 (0.3)	-1 (-0.2)
Jul	---	---	8 (1.6)	5 (1.1)	4 (0.9)	8 (1.7)	4 (0.9)	7 (1.5)
Aug	---	---	6 (0.8)	6 (0.9)	6 (0.8)	6 (0.8)	1 (0.0)	-2 (-0.4)
Sep	---	---	13 (1.5)	14 (1.6)	16 (1.8)	14 (1.5)	6 (0.7)	-3 (-0.4)
Oct	---	---	10 (1.1)	10 (1.1)	13 (1.4)	10 (1.1)	7 (0.8)	-1 (-0.1)
Nov	---	---	-2 (-0.2)	-1 (-0.1)	17 (1.9)	-1 (-0.1)	-10 (-1.1)	-18 (-1.9)
Dec	---	---	21 (2.1)	23 (2.2)	25 (2.4)	22 (2.1)	8 (0.8)	1 (0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	9 (0.9)	34 (3.4)	36 (3.5)	34 (3.3)	34 (3.4)	27 (2.6)	13 (1.3)
Feb	---	-9 (-0.9)	24 (2.2)	25 (2.3)	10 (0.9)	24 (2.2)	16 (1.4)	2 (0.1)
Mar	---	16 (1.8)	35 (3.9)	34 (3.8)	27 (3.0)	36 (3.9)	34 (3.7)	28 (3.1)
Apr	---	18 (2.4)	31 (4.3)	33 (4.6)	33 (4.6)	31 (4.3)	32 (4.5)	25 (3.4)
May	---	10 (2.0)	16 (3.0)	16 (2.9)	15 (2.9)	16 (3.1)	15 (2.8)	13 (2.5)
Jun	---	7 (1.6)	10 (2.2)	10 (2.3)	10 (2.3)	10 (2.2)	8 (1.9)	6 (1.4)
Jul	---	14 (2.7)	22 (4.3)	19 (3.8)	18 (3.6)	22 (4.4)	18 (3.6)	21 (4.2)
Aug	---	6 (1.0)	12 (1.8)	12 (2.0)	12 (1.8)	12 (1.9)	7 (1.1)	4 (0.7)
Sep	---	20 (2.5)	33 (4.0)	34 (4.1)	36 (4.3)	34 (4.0)	26 (3.2)	17 (2.1)
Oct	---	29 (3.3)	39 (4.4)	39 (4.4)	42 (4.8)	39 (4.4)	36 (4.1)	28 (3.2)
Nov	---	7 (0.7)	5 (0.6)	6 (0.6)	24 (2.6)	6 (0.7)	-3 (-0.4)	-11 (-1.2)
Dec	---	-1 (-0.1)	20 (2.0)	22 (2.1)	24 (2.3)	21 (2.0)	7 (0.7)	0 (0.0)

Table 21. Direct Effects Simulated Salinity Concentration Comparison for Arkansas River near Rocky Ford Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	823	830	839	839	838	839	835	831
15th percentile	530	531	539	540	536	539	540	536
25th percentile	617	616	636	631	631	631	635	628
50th percentile	824	831	838	839	839	837	831	830
75th percentile	1,012	1,012	1,029	1,029	1,035	1,028	1,023	1,013
85th percentile	1,120	1,125	1,135	1,139	1,137	1,137	1,132	1,123
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	9 (1.1)	10 (1.2)	9 (1.0)	10 (1.1)	6 (0.7)	1 (0.1)
15th percentile	---	---	7 (1.4)	8 (1.6)	5 (1.0)	8 (1.5)	9 (1.7)	5 (0.9)
25th percentile	---	---	20 (3.3)	15 (2.4)	15 (2.4)	15 (2.4)	18 (3.0)	12 (2.0)
50th percentile	---	---	6 (0.8)	8 (0.9)	8 (1.0)	6 (0.7)	0 (0.0)	-1 (-0.1)
75th percentile	---	---	17 (1.7)	17 (1.7)	23 (2.3)	16 (1.6)	11 (1.1)	1 (0.1)
85th percentile	---	---	11 (0.9)	14 (1.3)	13 (1.1)	12 (1.1)	7 (0.6)	-2 (-0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	7 (0.9)	16 (2.0)	17 (2.0)	16 (1.9)	17 (2.0)	13 (1.6)	8 (1.0)
15th percentile	---	1 (0.2)	8 (1.6)	9 (1.8)	6 (1.2)	9 (1.7)	10 (1.9)	6 (1.1)
25th percentile	---	-1 (-0.2)	19 (3.1)	14 (2.3)	14 (2.3)	14 (2.2)	18 (2.8)	11 (1.8)
50th percentile	---	7 (0.9)	14 (1.6)	15 (1.8)	15 (1.8)	13 (1.6)	7 (0.8)	6 (0.7)
75th percentile	---	0 (0.0)	17 (1.7)	17 (1.7)	23 (2.3)	16 (1.6)	11 (1.0)	1 (0.1)
85th percentile	---	5 (0.4)	16 (1.4)	19 (1.7)	18 (1.6)	17 (1.5)	12 (1.1)	3 (0.3)

Table 22. Direct Effects Monthly Simulated Salinity Concentration for Arkansas River near Rocky Ford Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	1,040	1,039	1,061	1,063	1,062	1,062	1,056	1,044
Feb	1,034	1,018	1,046	1,047	1,029	1,047	1,040	1,027
Mar	929	942	955	953	940	955	953	949
Apr	715	727	735	737	738	735	735	730
May	575	582	587	586	585	587	586	586
Jun	542	547	549	549	549	549	548	547
Jul	642	661	662	660	661	663	660	665
Aug	727	728	729	730	730	730	729	727
Sep	873	887	896	897	898	896	890	880
Oct	849	875	880	880	883	880	877	873
Nov	935	940	941	942	954	942	936	928
Dec	1,049	1,050	1,065	1,066	1,070	1,066	1,055	1,051
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	22 (2.2)	24 (2.4)	23 (2.2)	23 (2.2)	17 (1.6)	5 (0.5)
Feb	---	---	28 (2.7)	29 (2.8)	11 (1.0)	29 (2.8)	22 (2.2)	9 (0.9)
Mar	---	---	13 (1.4)	11 (1.2)	-2 (-0.1)	13 (1.4)	11 (1.2)	7 (0.8)
Apr	---	---	8 (1.1)	10 (1.3)	11 (1.5)	8 (1.1)	8 (1.1)	3 (0.4)
May	---	---	5 (0.8)	4 (0.7)	3 (0.5)	5 (0.9)	4 (0.7)	4 (0.7)
Jun	---	---	2 (0.2)	2 (0.2)	2 (0.3)	2 (0.2)	1 (0.1)	0 (-0.1)
Jul	---	---	1 (0.1)	-1 (-0.1)	0 (0.0)	2 (0.3)	-1 (-0.1)	4 (0.6)
Aug	---	---	1 (0.2)	2 (0.3)	2 (0.3)	2 (0.3)	1 (0.1)	-1 (-0.2)
Sep	---	---	9 (1.0)	10 (1.1)	11 (1.3)	9 (1.1)	3 (0.4)	-7 (-0.7)
Oct	---	---	5 (0.6)	5 (0.6)	8 (1.0)	5 (0.6)	2 (0.3)	-2 (-0.2)
Nov	---	---	1 (0.1)	2 (0.2)	14 (1.5)	2 (0.2)	-4 (-0.5)	-12 (-1.2)
Dec	---	---	15 (1.4)	16 (1.5)	20 (1.9)	16 (1.5)	5 (0.4)	1 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-1 (-0.1)	21 (2.0)	23 (2.2)	22 (2.1)	22 (2.1)	16 (1.5)	4 (0.4)
Feb	---	-16 (-1.6)	12 (1.1)	13 (1.2)	-5 (-0.5)	13 (1.2)	6 (0.6)	-7 (-0.7)
Mar	---	13 (1.3)	26 (2.7)	24 (2.6)	11 (1.2)	26 (2.8)	24 (2.5)	20 (2.2)
Apr	---	12 (1.6)	20 (2.7)	22 (3.0)	23 (3.2)	20 (2.7)	20 (2.7)	15 (2.1)
May	---	7 (1.3)	12 (2.1)	11 (1.9)	10 (1.8)	12 (2.1)	11 (2.0)	11 (1.9)
Jun	---	5 (0.9)	7 (1.1)	7 (1.2)	7 (1.2)	7 (1.2)	6 (1.0)	5 (0.9)
Jul	---	19 (2.9)	20 (3.1)	18 (2.9)	19 (2.9)	21 (3.2)	18 (2.8)	23 (3.5)
Aug	---	1 (0.1)	2 (0.3)	3 (0.4)	3 (0.3)	3 (0.4)	2 (0.2)	0 (-0.1)
Sep	---	14 (1.5)	23 (2.6)	24 (2.6)	25 (2.8)	23 (2.6)	17 (1.9)	7 (0.8)
Oct	---	26 (3.0)	31 (3.7)	31 (3.7)	34 (4.1)	31 (3.7)	28 (3.4)	24 (2.9)
Nov	---	5 (0.5)	6 (0.7)	7 (0.8)	19 (2.0)	7 (0.8)	1 (0.1)	-7 (-0.7)
Dec	---	1 (0.1)	16 (1.5)	17 (1.6)	21 (2.0)	17 (1.5)	6 (0.5)	2 (0.1)

Table 23 and Table 24 show statistics and relative change with respect to the No Action Alternative and the existing conditions for the Arkansas River at Las Animas gage. Effects would be predominantly negligible, with occasional minor increases in concentration. Comparison of monthly concentrations at the Arkansas River at Las Animas gage shows a mixed tendency, where March and April show the largest percent of reduction in concentration, and October shows the largest percent of increase in concentration compared with the No Action Alternative. Concentrations of all alternatives would decrease slightly compared to existing conditions.

Table 23. Direct Effects Simulated Salinity Concentration Comparison for Arkansas River at Las Animas Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	1,684	1,624	1,623	1,625	1,632	1,623	1,621	1,616
15th percentile	875	867	873	873	864	874	865	859
25th percentile	1,181	1,157	1,152	1,156	1,162	1,152	1,154	1,150
50th percentile	1,753	1,707	1,712	1,717	1,730	1,712	1,714	1,709
75th percentile	2,038	1,959	1,954	1,963	1,965	1,952	1,961	1,954
85th percentile	2,323	2,170	2,185	2,186	2,206	2,175	2,185	2,172
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	-1 (-0.1)	1 (0.1)	8 (0.5)	-1 (-0.1)	-3 (-0.2)	-8 (-0.5)
15th percentile	---	---	6 (0.7)	5 (0.6)	-4 (-0.4)	7 (0.8)	-2 (-0.2)	-9 (-1.0)
25th percentile	---	---	-5 (-0.4)	-1 (-0.1)	5 (0.4)	-5 (-0.4)	-3 (-0.2)	-7 (-0.6)
50th percentile	---	---	5 (0.3)	10 (0.6)	23 (1.4)	5 (0.3)	7 (0.4)	2 (0.1)
75th percentile	---	---	-5 (-0.2)	4 (0.2)	6 (0.3)	-7 (-0.4)	2 (0.1)	-5 (-0.2)
85th percentile	---	---	15 (0.7)	15 (0.7)	36 (1.7)	5 (0.2)	15 (0.7)	2 (0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	-61 (-3.6)	-62 (-3.7)	-59 (-3.5)	-52 (-3.1)	-62 (-3.7)	-63 (-3.8)	-68 (-4.0)
15th percentile	---	-8 (-0.9)	-2 (-0.2)	-2 (-0.3)	-12 (-1.3)	-1 (-0.1)	-10 (-1.1)	-17 (-1.9)
25th percentile	---	-24 (-2.0)	-29 (-2.4)	-25 (-2.1)	-19 (-1.6)	-29 (-2.4)	-26 (-2.2)	-31 (-2.6)
50th percentile	---	-46 (-2.6)	-42 (-2.4)	-37 (-2.1)	-23 (-1.3)	-41 (-2.3)	-39 (-2.2)	-45 (-2.6)
75th percentile	---	-79 (-3.9)	-83 (-4.1)	-74 (-3.6)	-73 (-3.6)	-86 (-4.2)	-77 (-3.8)	-83 (-4.1)
85th percentile	---	-153 (-6.6)	-138 (-6.0)	-138 (-5.9)	-117 (-5.0)	-148 (-6.4)	-138 (-5.9)	-151 (-6.5)

Table 24. Direct Effects Monthly Simulated Salinity Concentration for Arkansas River at Las Animas Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	1,801	1,798	1,824	1,825	1,815	1,824	1,822	1,808
Feb	1,732	1,707	1,733	1,733	1,699	1,734	1,734	1,724
Mar	1,994	1,860	1,775	1,781	1,854	1,776	1,781	1,763
Apr	2,215	2,086	2,033	2,045	2,105	2,028	2,024	2,032
May	1,376	1,296	1,307	1,308	1,306	1,307	1,309	1,309
Jun	1,043	1,003	1,006	1,006	1,008	1,006	1,006	1,002
Jul	1,252	1,181	1,195	1,197	1,192	1,194	1,191	1,182
Aug	1,389	1,304	1,315	1,319	1,320	1,320	1,307	1,304
Sep	1,869	1,811	1,799	1,797	1,806	1,792	1,803	1,815
Oct	1,901	1,829	1,884	1,885	1,838	1,887	1,881	1,866
Nov	1,832	1,818	1,786	1,789	1,826	1,788	1,779	1,791
Dec	1,847	1,842	1,857	1,857	1,860	1,857	1,853	1,843
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	26 (1.4)	27 (1.5)	17 (1.0)	26 (1.5)	24 (1.4)	10 (0.6)
Feb	---	---	26 (1.5)	26 (1.5)	-8 (-0.5)	27 (1.6)	27 (1.6)	17 (1.0)
Mar	---	---	-85 (-4.6)	-79 (-4.3)	-6 (-0.3)	-84 (-4.5)	-79 (-4.3)	-97 (-5.2)
Apr	---	---	-53 (-2.6)	-41 (-2.0)	19 (0.9)	-58 (-2.8)	-62 (-3.0)	-54 (-2.6)
May	---	---	11 (0.9)	12 (0.9)	10 (0.8)	11 (0.9)	13 (1.0)	13 (1.1)
Jun	---	---	3 (0.2)	3 (0.3)	5 (0.4)	3 (0.2)	3 (0.3)	-1 (-0.1)
Jul	---	---	14 (1.2)	16 (1.3)	11 (0.9)	13 (1.0)	10 (0.9)	1 (0.0)
Aug	---	---	11 (0.8)	15 (1.2)	16 (1.2)	16 (1.2)	3 (0.2)	0 (0.0)
Sep	---	---	-12 (-0.7)	-14 (-0.8)	-5 (-0.3)	-19 (-1.0)	-8 (-0.4)	4 (0.2)
Oct	---	---	55 (3.0)	56 (3.1)	9 (0.5)	58 (3.2)	52 (2.9)	37 (2.1)
Nov	---	---	-32 (-1.7)	-29 (-1.6)	8 (0.4)	-30 (-1.6)	-39 (-2.2)	-27 (-1.5)
Dec	---	---	15 (0.8)	15 (0.8)	18 (1.0)	15 (0.8)	11 (0.6)	1 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-3 (-0.2)	23 (1.3)	24 (1.4)	14 (0.8)	23 (1.3)	21 (1.2)	7 (0.4)
Feb	---	-25 (-1.4)	1 (0.1)	1 (0.1)	-33 (-1.9)	2 (0.2)	2 (0.1)	-8 (-0.4)
Mar	---	-134 (-6.7)	-219 (-11.0)	-21 (-10.7)	-140 (-7.0)	-218 (-11.0)	-213 (-10.7)	-231 (-11.6)
Apr	---	-129 (-5.8)	-182 (-8.2)	-170 (-7.7)	-110 (-5.0)	-187 (-8.5)	-191 (-8.7)	-183 (-8.3)
May	---	-80 (-5.9)	-69 (-5.0)	-68 (-5.0)	-70 (-5.1)	-69 (-5.0)	-67 (-4.9)	-67 (-4.9)
Jun	---	-40 (-3.8)	-37 (-3.6)	-37 (-3.5)	-35 (-3.4)	-37 (-3.6)	-37 (-3.6)	-41 (-3.9)
Jul	---	-71 (-5.6)	-57 (-4.5)	-55 (-4.4)	-60 (-4.7)	-58 (-4.7)	-61 (-4.8)	-70 (-5.6)
Aug	---	-85 (-6.1)	-74 (-5.3)	-70 (-5.0)	-69 (-4.9)	-69 (-5.0)	-82 (-5.9)	-85 (-6.1)
Sep	---	-58 (-3.1)	-70 (-3.8)	-72 (-3.9)	-63 (-3.4)	-77 (-4.1)	-66 (-3.5)	-54 (-2.9)
Oct	---	-72 (-3.8)	-17 (-0.9)	-16 (-0.9)	-63 (-3.3)	-14 (-0.7)	-20 (-1.1)	-35 (-1.9)
Nov	---	-14 (-0.7)	-46 (-2.5)	-43 (-2.3)	-6 (-0.3)	-44 (-2.4)	-53 (-2.9)	-41 (-2.2)
Dec	---	-5 (-0.3)	10 (0.5)	10 (0.5)	13 (0.7)	10 (0.5)	6 (0.3)	-4 (-0.3)

Table 25 though Table 23 show statistics and relative change with respect to the No Action Alternative and existing conditions of simulated salinity for Fountain Creek gages. All alternatives would have mostly negligible effects on Fountain Creek salinity, compared to the No Action, though occasional minor increases would occur. On Fountain Creek, compared with the No Action Alternative, simulated concentration would increase the most in February, March and October, with smaller differences during the summer months especially in September. The alternatives would increase salinity concentrations compared to existing conditions because of additional municipal discharge.

Table 25. Direct Effects Simulated Salinity Concentration Comparison for Fountain Creek near Fountain Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	596	658	662	662	658	662	661	663
15th percentile	427	513	517	517	513	517	513	517
25th percentile	497	571	572	571	572	571	567	572
50th percentile	615	665	668	668	661	668	668	668
75th percentile	698	742	756	756	742	756	756	756
85th percentile	733	801	802	802	799	802	802	802
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	4 (0.6)	4 (0.6)	0 (0.0)	4 (0.6)	3 (0.5)	5 (0.8)
15th percentile	---	---	4 (0.8)	3 (0.6)	0 (0.0)	3 (0.7)	0 (0.0)	4 (0.8)
25th percentile	---	---	1 (0.1)	0 (0.0)	1 (0.2)	0 (0.0)	-4 (-0.7)	1 (0.3)
50th percentile	---	---	3 (0.4)	3 (0.4)	-4 (-0.6)	3 (0.4)	3 (0.4)	3 (0.4)
75th percentile	---	---	14 (1.8)	14 (1.8)	0 (0.0)	14 (1.8)	14 (1.8)	14 (1.9)
85th percentile	---	---	1 (0.1)	1 (0.1)	-2 (-0.2)	1 (0.1)	1 (0.1)	1 (0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	62 (10.4)	66 (11.1)	66 (11.0)	62 (10.4)	66 (11.0)	65 (10.9)	67 (11.2)
15th percentile	---	86 (20.2)	91 (21.2)	90 (21.0)	86 (20.2)	90 (21.0)	86 (20.2)	91 (21.2)
25th percentile	---	74 (14.9)	75 (15.0)	74 (14.8)	75 (15.0)	74 (14.8)	70 (14.0)	75 (15.2)
50th percentile	---	50 (8.1)	52 (8.5)	52 (8.5)	46 (7.4)	52 (8.5)	52 (8.5)	53 (8.5)
75th percentile	---	44 (6.4)	58 (8.3)	58 (8.3)	44 (6.4)	58 (8.3)	58 (8.3)	59 (8.4)
85th percentile	---	68 (9.3)	69 (9.4)	69 (9.4)	66 (9.1)	69 (9.4)	69 (9.4)	69 (9.4)

Table 26. Direct Effects Monthly Simulated Salinity Concentration for Fountain Creek near Fountain Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	637	703	712	712	701	711	703	713
Feb	630	687	699	700	688	700	700	701
Mar	609	661	678	674	664	674	676	677
Apr	538	650	651	651	649	651	658	658
May	509	586	596	596	590	596	596	593
Jun	532	596	598	598	596	598	598	598
Jul	522	611	611	612	611	611	611	611
Aug	551	573	572	572	571	572	572	572
Sep	607	709	702	702	703	702	695	707
Oct	695	727	734	734	734	734	734	734
Nov	665	700	700	701	700	700	700	700
Dec	678	706	703	703	703	703	703	703
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	9 (1.2)	9 (1.2)	-2 (-0.2)	8 (1.2)	0 (0.0)	10 (1.4)
Feb	---	---	12 (1.8)	13 (1.8)	1 (0.2)	13 (1.8)	13 (1.8)	14 (2.0)
Mar	---	---	17 (2.5)	13 (1.9)	3 (0.4)	13 (1.9)	15 (2.2)	16 (2.3)
Apr	---	---	1 (0.2)	1 (0.1)	-1 (-0.2)	1 (0.1)	8 (1.3)	8 (1.3)
May	---	---	10 (1.6)	10 (1.6)	4 (0.6)	10 (1.6)	10 (1.6)	7 (1.1)
Jun	---	---	2 (0.3)	2 (0.3)	0 (0.0)	2 (0.3)	2 (0.3)	2 (0.3)
Jul	---	---	0 (0.1)	1 (0.1)	0 (0.0)	0 (0.1)	0 (0.1)	0 (0.1)
Aug	---	---	-1 (-0.2)	-1 (-0.2)	-2 (-0.3)	-1 (-0.2)	-1 (-0.2)	-1 (0.0)
Sep	---	---	-7 (-1.0)	-7 (-1.0)	-6 (-0.9)	-7 (-1.0)	-14 (-2.0)	-2 (-0.2)
Oct	---	---	7 (1.0)	7 (1.0)	7 (1.0)	7 (1.0)	7 (1.0)	7 (1.0)
Nov	---	---	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dec	---	---	-3 (-0.3)	-3 (-0.3)	-3 (-0.4)	-3 (-0.3)	-3 (-0.3)	-3 (-0.3)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	66 (10.3)	75 (11.6)	75 (11.6)	64 (10.1)	74 (11.6)	66 (10.3)	76 (11.8)
Feb	---	57 (9.2)	69 (11.1)	70 (11.1)	58 (9.3)	70 (11.1)	70 (11.1)	71 (11.3)
Mar	---	52 (8.6)	69 (11.2)	65 (10.6)	55 (9.0)	65 (10.6)	67 (10.9)	68 (11.1)
Apr	---	112 (20.9)	113 (21.1)	113 (21.0)	111 (20.6)	113 (21.0)	120 (22.4)	120 (22.4)
May	---	77 (15.2)	87 (17.0)	87 (17.0)	81 (15.9)	87 (17.0)	87 (17.0)	84 (16.4)
Jun	---	64 (12.0)	66 (12.3)	66 (12.4)	64 (12.0)	66 (12.3)	66 (12.4)	66 (12.3)
Jul	---	89 (17.1)	89 (17.2)	90 (17.2)	89 (17.1)	89 (17.2)	89 (17.2)	89 (17.2)
Aug	---	22 (4.0)	21 (3.8)	21 (3.8)	20 (3.6)	21 (3.7)	21 (3.8)	21 (3.9)
Sep	---	102 (16.8)	95 (15.6)	95 (15.6)	96 (15.7)	95 (15.6)	88 (14.5)	100 (16.5)
Oct	---	32 (4.6)	39 (5.6)	39 (5.6)	39 (5.6)	39 (5.6)	39 (5.6)	39 (5.6)
Nov	---	35 (5.3)	35 (5.3)	36 (5.3)	35 (5.3)	35 (5.3)	35 (5.3)	35 (5.3)
Dec	---	28 (4.2)	25 (3.8)	25 (3.8)	25 (3.7)	25 (3.8)	25 (3.8)	25 (3.8)

Table 27. Direct Effects Simulated Salinity Concentration Comparison for Fountain Creek at Pueblo Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	698	746	746	746	746	746	746	747
15th percentile	522	565	563	563	571	563	563	564
25th percentile	582	632	641	638	632	638	635	643
50th percentile	706	757	762	760	757	760	757	763
75th percentile	822	857	855	855	855	855	854	857
85th percentile	870	906	905	905	905	905	905	905
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	0 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)
15th percentile	---	---	-2 (-0.3)	-2 (-0.4)	6 (1.0)	-2 (-0.4)	-2 (-0.3)	-1 (-0.2)
25th percentile	---	---	9 (1.4)	6 (0.9)	-1 (-0.1)	6 (0.9)	3 (0.5)	11 (1.7)
50th percentile	---	---	5 (0.6)	3 (0.4)	0 (0.0)	3 (0.4)	0 (0.0)	6 (0.7)
75th percentile	---	---	-2 (-0.2)	-2 (-0.2)	-2 (-0.2)	-2 (-0.2)	-3 (-0.4)	0 (0.0)
85th percentile	---	---	-1 (-0.1)	-1 (-0.1)	-1 (-0.1)	-1 (-0.1)	-1 (-0.1)	-1 (-0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	48 (6.8)	48 (6.9)	48 (6.9)	48 (6.8)	48 (6.8)	47 (6.8)	49 (7.0)
15th percentile	---	43 (8.2)	41 (7.8)	40 (7.8)	48 (9.3)	41 (7.8)	41 (7.9)	42 (8.0)
25th percentile	---	50 (8.6)	59 (10.2)	56 (9.6)	50 (8.5)	56 (9.6)	53 (9.1)	61 (10.5)
50th percentile	---	51 (7.2)	55 (7.8)	54 (7.6)	50 (7.1)	53 (7.6)	50 (7.1)	56 (8.0)
75th percentile	---	35 (4.2)	33 (4.0)	33 (4.0)	33 (4.0)	33 (4.0)	31 (3.8)	35 (4.3)
85th percentile	---	36 (4.1)	35 (4.0)	35 (4.0)	35 (4.0)	35 (4.0)	34 (4.0)	35 (4.0)

Table 28. Direct Effects Monthly Simulated Salinity Concentration for Fountain Creek at Pueblo Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	738	789	789	788	787	788	780	789
Feb	749	794	797	797	794	797	797	798
Mar	711	751	761	758	754	758	760	761
Apr	669	760	753	752	759	753	757	758
May	601	666	671	671	670	671	672	669
Jun	620	677	679	679	677	679	679	679
Jul	609	686	686	686	686	686	686	686
Aug	640	655	653	653	653	653	653	654
Sep	652	745	737	737	739	737	731	742
Oct	827	833	840	840	840	839	840	840
Nov	770	789	789	789	789	789	789	789
Dec	805	813	807	807	810	807	807	807
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	0 (0.0)	-1 (-0.1)	-2 (-0.2)	-1 (-0.1)	-9 (-1.1)	0 (0.1)
Feb	---	---	3 (0.4)	3 (0.4)	0 (0.1)	3 (0.4)	3 (0.4)	4 (0.5)
Mar	---	---	10 (1.3)	7 (0.9)	3 (0.4)	7 (0.9)	9 (1.2)	10 (1.4)
Apr	---	---	-7 (-0.9)	-8 (-1.0)	-1 (-0.2)	-7 (-0.9)	-3 (-0.3)	-2 (-0.3)
May	---	---	5 (0.7)	5 (0.7)	4 (0.6)	5 (0.7)	6 (0.9)	3 (0.5)
Jun	---	---	2 (0.2)	2 (0.2)	0 (0.0)	2 (0.2)	2 (0.3)	2 (0.3)
Jul	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Aug	---	---	-2 (-0.2)	-2 (-0.2)	-2 (-0.3)	-2 (-0.2)	-2 (-0.2)	-1 (-0.1)
Sep	---	---	-8 (-1.0)	-8 (-1.0)	-6 (-0.8)	-8 (-1.0)	-14 (-1.9)	-3 (-0.3)
Oct	---	---	7 (0.8)	7 (0.8)	7 (0.8)	6 (0.8)	7 (0.8)	7 (0.8)
Nov	---	---	0 (-0.1)	0 (-0.1)	0 (0.0)	0 (-0.1)	0 (-0.1)	0 (-0.1)
Dec	---	---	-6 (-0.8)	-6 (-0.8)	-3 (-0.4)	-6 (-0.8)	-6 (-0.8)	-6 (-0.8)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	51 (6.9)	51 (6.8)	50 (6.8)	49 (6.7)	50 (6.8)	42 (5.7)	51 (6.9)
Feb	---	45 (6.0)	48 (6.4)	48 (6.4)	45 (6.1)	48 (6.4)	48 (6.4)	49 (6.6)
Mar	---	40 (5.7)	50 (7.1)	47 (6.7)	43 (6.1)	47 (6.7)	49 (7.0)	50 (7.2)
Apr	---	91 (13.5)	84 (12.5)	83 (12.4)	90 (13.4)	84 (12.5)	88 (13.2)	89 (13.2)
May	---	65 (10.9)	70 (11.7)	70 (11.7)	69 (11.6)	70 (11.7)	71 (11.9)	68 (11.4)
Jun	---	57 (9.2)	59 (9.4)	59 (9.4)	57 (9.2)	59 (9.4)	59 (9.5)	59 (9.5)
Jul	---	77 (12.6)	77 (12.6)	77 (12.6)	77 (12.6)	77 (12.6)	77 (12.6)	77 (12.6)
Aug	---	15 (2.3)	13 (2.1)	13 (2.1)	13 (2.0)	13 (2.1)	13 (2.1)	14 (2.2)
Sep	---	93 (14.3)	85 (13.2)	85 (13.2)	87 (13.4)	85 (13.2)	79 (12.1)	90 (13.9)
Oct	---	6 (0.7)	13 (1.5)	13 (1.5)	13 (1.6)	12 (1.5)	13 (1.6)	13 (1.5)
Nov	---	19 (2.4)	19 (2.4)	19 (2.4)	19 (2.4)	19 (2.4)	19 (2.4)	19 (2.4)
Dec	---	8 (1.0)	2 (0.2)	2 (0.3)	5 (0.7)	2 (0.3)	2 (0.3)	2 (0.3)

Cumulative Effects Analysis. A comparative analysis contrasting the No Action Alternative and existing condition scenarios was performed to estimate changes in salinity under each of the alternatives for the cumulative effects analysis. Cumulative effects simulation uses the results of the Daily Model, which reflects all the simulated operations under these conditions in the streamflows. Since it is assumed that the concentration of WWTF effluent is the same for all alternatives, changes in salt loadings from the WWTFs are based only on the estimated changes in effluent flow.

Table 29 and Table 30 show statistics and relative change with respect to the No Action Alternative and the existing conditions for the Arkansas River at Moffat St. gage. All alternatives, except River South and Master Contract Only, would have negligible to minor adverse effects to river salinity when compared with the No Action Alternative. Monthly changes in concentration in the Arkansas River upstream of the confluence with Fountain Creek would have the greatest percent changes in January, February and August to October. All alternatives increase salinity, compared to existing conditions, because of streamflow changes caused by exchanges through this reach.

Table 29. Cumulative Effects Simulated Salinity Concentration Comparison for Arkansas River at Moffat St. Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	391	439	454	454	453	454	419	440
15th percentile	264	275	280	280	280	280	272	276
25th percentile	299	324	328	327	327	328	322	324
50th percentile	365	411	423	423	422	423	393	409
75th percentile	419	476	493	495	494	495	464	478
85th percentile	446	525	541	541	538	540	513	527
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	15 (3.3)	15 (3.4)	14 (3.1)	15 (3.4)	-20 (-4.6)	1 (0.2)
15th percentile	---	---	5 (1.8)	4 (1.5)	4 (1.6)	4 (1.6)	-3 (-1.2)	0 (0.1)
25th percentile	---	---	4 (1.3)	4 (1.1)	3 (1.0)	4 (1.3)	-2 (-0.5)	0 (0.2)
50th percentile	---	---	12 (3.0)	12 (2.9)	12 (2.8)	12 (3.0)	-18 (-4.3)	-1 (-0.3)
75th percentile	---	---	17 (3.6)	18 (3.9)	17 (3.7)	18 (3.9)	-13 (-2.7)	1 (0.3)
85th percentile	---	---	16 (3.0)	16 (3.1)	13 (2.5)	15 (2.9)	-12 (-2.4)	2 (0.3)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	48 (12.3)	63 (16.0)	63 (16.0)	62 (15.8)	63 (16.1)	28 (7.1)	49 (12.5)
15th percentile	---	11 (4.2)	16 (6.1)	15 (5.8)	16 (5.9)	16 (5.9)	8 (2.9)	11 (4.3)
25th percentile	---	25 (8.2)	29 (9.6)	28 (9.4)	28 (9.3)	29 (9.7)	23 (7.7)	25 (8.4)
50th percentile	---	46 (12.6)	58 (16.0)	58 (15.9)	58 (15.8)	58 (16.0)	28 (7.8)	45 (12.3)
75th percentile	---	57 (13.6)	74 (17.7)	76 (18.0)	75 (17.8)	76 (18.0)	44 (10.6)	58 (14.0)
85th percentile	---	79 (17.6)	94 (21.1)	95 (21.2)	92 (20.5)	94 (21.1)	66 (14.8)	80 (18.0)

Table 30. Cumulative Effects Monthly Simulated Salinity Concentration for Arkansas River at Moffat Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	472	503	525	525	523	525	478	504
Feb	516	523	554	554	553	554	475	524
Mar	393	426	441	442	442	441	400	425
Apr	367	409	419	419	418	419	402	410
May	351	394	399	398	401	399	388	397
Jun	277	291	292	293	293	293	289	290
Jul	265	290	295	295	297	296	283	292
Aug	333	392	406	407	405	407	363	392
Sep	407	502	526	525	524	526	475	503
Oct	404	513	540	540	530	540	499	518
Nov	452	516	528	527	530	528	491	516
Dec	484	541	555	555	555	555	513	541
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	22 (4.2)	22 (4.3)	20 (4.0)	22 (4.3)	-25 (-5.1)	1 (0.1)
Feb	---	---	31 (6.0)	31 (6.0)	30 (5.7)	31 (5.9)	-48 (-9.1)	1 (0.2)
Mar	---	---	15 (3.4)	16 (3.6)	16 (3.6)	15 (3.5)	-26 (-6.1)	-1 (-0.3)
Apr	---	---	10 (2.4)	10 (2.3)	9 (2.1)	10 (2.4)	-7 (-1.7)	1 (0.2)
May	---	---	5 (1.1)	4 (1.1)	7 (1.7)	5 (1.2)	-6 (-1.6)	3 (0.7)
Jun	---	---	1 (0.4)	2 (0.6)	2 (0.6)	2 (0.6)	-2 (-0.6)	-1 (-0.2)
Jul	---	---	5 (1.8)	5 (1.8)	7 (2.3)	6 (2.0)	-7 (-2.6)	2 (0.6)
Aug	---	---	14 (3.6)	15 (3.8)	13 (3.3)	15 (3.9)	-29 (-7.3)	0 (0.1)
Sep	---	---	24 (4.6)	23 (4.6)	22 (4.2)	24 (4.6)	-27 (-5.4)	1 (0.1)
Oct	---	---	27 (5.2)	27 (5.2)	17 (3.3)	27 (5.4)	-14 (-2.8)	5 (1.0)
Nov	---	---	12 (2.2)	11 (2.2)	14 (2.7)	12 (2.2)	-25 (-4.8)	0 (0.0)
Dec	---	---	14 (2.6)	14 (2.6)	14 (2.6)	14 (2.6)	-28 (-5.2)	0 (-0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	31 (6.6)	53 (11.0)	53 (11.1)	51 (10.8)	53 (11.1)	6 (1.2)	32 (6.7)
Feb	---	7 (1.3)	38 (7.3)	38 (7.3)	37 (7.1)	38 (7.3)	-41 (-8.0)	8 (1.4)
Mar	---	33 (8.6)	48 (12.3)	49 (12.5)	49 (12.5)	48 (12.4)	7 (2.0)	32 (8.3)
Apr	---	42 (11.3)	52 (14.0)	52 (13.9)	51 (13.7)	52 (14.0)	35 (9.5)	43 (11.6)
May	---	43 (12.4)	48 (13.7)	47 (13.7)	50 (14.3)	48 (13.8)	37 (10.6)	46 (13.3)
Jun	---	14 (5.1)	15 (5.5)	16 (5.7)	16 (5.7)	16 (5.7)	12 (4.4)	13 (4.8)
Jul	---	25 (9.3)	30 (11.4)	30 (11.3)	32 (11.9)	31 (11.5)	18 (6.5)	27 (10.0)
Aug	---	59 (17.6)	73 (21.9)	74 (22.1)	72 (21.4)	74 (22.2)	30 (9.0)	59 (17.8)
Sep	---	95 (23.4)	119 (29.1)	118 (29.1)	117 (28.6)	119 (29.1)	68 (16.7)	96 (23.5)
Oct	---	109 (27.0)	136 (33.6)	136 (33.6)	126 (31.2)	136 (33.8)	95 (23.4)	114 (28.2)
Nov	---	64 (14.1)	76 (16.7)	75 (16.6)	78 (17.3)	76 (16.7)	39 (8.7)	64 (14.1)
Dec	---	57 (11.9)	71 (14.8)	71 (14.8)	71 (14.8)	71 (14.8)	29 (6.1)	57 (11.8)

All alternatives would negligibly affect salinity concentrations at the Arkansas River near Avondale gage, compared to the No Action (Table 31 and Table 32). Concentrations increase and decrease for all alternatives compared to existing conditions, depending on month and year.

Table 31. Cumulative Effects Simulated Salinity Concentration Comparison for Arkansas River near Avondale Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	564	606	610	609	610	609	606	607
15th percentile	371	425	431	430	431	430	424	424
25th percentile	437	513	514	513	511	514	515	519
50th percentile	576	633	639	637	638	637	631	635
75th percentile	687	707	711	709	711	709	711	707
85th percentile	733	745	748	745	746	744	743	741
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	4 (0.7)	3 (0.4)	3 (0.6)	2 (0.4)	-1 (-0.1)	0 (0.0)
15th percentile	---	---	6 (1.5)	5 (1.1)	5 (1.3)	5 (1.1)	-1 (-0.3)	-1 (-0.3)
25th percentile	---	---	1 (0.3)	0 (0.1)	-1 (-0.3)	2 (0.3)	2 (0.4)	6 (1.3)
50th percentile	---	---	6 (1.0)	4 (0.7)	5 (0.8)	4 (0.6)	-1 (-0.2)	2 (0.4)
75th percentile	---	---	4 (0.6)	2 (0.3)	4 (0.5)	2 (0.3)	4 (0.6)	0 (0.0)
85th percentile	---	---	3 (0.4)	0 (0.0)	2 (0.2)	-1 (-0.1)	-2 (-0.2)	-4 (-0.5)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	43 (7.6)	47 (8.3)	45 (8.1)	46 (8.2)	45 (8.0)	42 (7.5)	43 (7.6)
15th percentile	---	54 (14.5)	60 (16.2)	59 (15.8)	59 (16.0)	59 (15.8)	53 (14.2)	53 (14.2)
25th percentile	---	76 (17.3)	77 (17.6)	76 (17.4)	74 (17.0)	77 (17.7)	78 (17.8)	82 (18.8)
50th percentile	---	57 (9.9)	63 (10.9)	61 (10.6)	62 (10.8)	61 (10.6)	55 (9.6)	59 (10.3)
75th percentile	---	20 (3.0)	24 (3.5)	23 (3.3)	24 (3.5)	22 (3.2)	24 (3.5)	20 (2.9)
85th percentile	---	12 (1.6)	14 (2.0)	11 (1.6)	13 (1.8)	11 (1.5)	10 (1.3)	8 (1.1)

Table 32. Cumulative Effects Monthly Simulated Salinity Concentration for Arkansas River near Avondale Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	707	708	712	712	712	712	705	707
Feb	744	712	717	717	718	717	709	712
Mar	627	664	661	661	665	661	659	659
Apr	525	598	601	601	599	605	600	602
May	430	525	527	514	525	515	524	522
Jun	347	441	444	443	440	442	443	442
Jul	368	420	428	427	426	428	416	424
Aug	477	526	540	540	542	530	524	528
Sep	579	649	652	651	650	651	657	649
Oct	621	661	666	666	663	666	665	664
Nov	667	685	688	688	689	689	684	685
Dec	715	716	717	717	719	717	713	715
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	4 (0.6)	4 (0.6)	4 (0.5)	4 (0.6)	-3 (-0.4)	-1 (-0.1)
Feb	---	---	5 (0.6)	5 (0.7)	6 (0.8)	5 (0.7)	-3 (-0.5)	0 (0.0)
Mar	---	---	-3 (-0.4)	-3 (-0.4)	1 (0.2)	-3 (-0.4)	-5 (-0.7)	-5 (-0.7)
Apr	---	---	3 (0.4)	3 (0.4)	1 (0.1)	7 (1.1)	2 (0.3)	4 (0.7)
May	---	---	2 (0.3)	-11 (-2.0)	0 (-0.1)	-10 (-2.0)	-1 (-0.2)	-3 (-0.7)
Jun	---	---	3 (0.6)	2 (0.6)	-1 (-0.1)	1 (0.3)	2 (0.5)	1 (0.3)
Jul	---	---	8 (1.9)	7 (1.8)	6 (1.6)	8 (1.9)	-4 (-0.8)	4 (1.0)
Aug	---	---	14 (2.8)	14 (2.7)	16 (3.2)	4 (0.8)	-2 (-0.3)	2 (0.4)
Sep	---	---	3 (0.5)	2 (0.4)	1 (0.3)	2 (0.4)	8 (1.3)	0 (0.0)
Oct	---	---	5 (0.7)	5 (0.7)	2 (0.3)	5 (0.7)	4 (0.5)	3 (0.3)
Nov	---	---	3 (0.5)	3 (0.4)	4 (0.5)	4 (0.5)	-1 (-0.2)	0 (0.0)
Dec	---	---	1 (0.3)	1 (0.2)	3 (0.4)	1 (0.3)	-3 (-0.4)	-1 (-0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	1 (0.1)	5 (0.8)	5 (0.8)	5 (0.7)	5 (0.7)	-2 (-0.2)	0 (0.0)
Feb	---	-32 (-4.2)	-27 (-3.6)	-27 (-3.6)	-26 (-3.5)	-27 (-3.6)	-35 (-4.7)	-32 (-4.3)
Mar	---	37 (5.9)	34 (5.5)	34 (5.5)	38 (6.1)	34 (5.5)	32 (5.2)	32 (5.2)
Apr	---	73 (14.0)	76 (14.4)	76 (14.5)	74 (14.1)	80 (15.2)	75 (14.4)	77 (14.7)
May	---	95 (22.1)	97 (22.5)	84 (19.6)	95 (21.9)	85 (19.7)	94 (21.9)	92 (21.3)
Jun	---	94 (26.9)	97 (27.7)	96 (27.7)	93 (26.8)	95 (27.3)	96 (27.6)	95 (27.3)
Jul	---	52 (14.2)	60 (16.3)	59 (16.2)	58 (16.0)	60 (16.3)	48 (13.3)	56 (15.3)
Aug	---	49 (10.2)	63 (13.3)	63 (13.2)	65 (13.7)	53 (11.2)	47 (9.9)	51 (10.7)
Sep	---	70 (12.0)	73 (12.5)	72 (12.4)	71 (12.3)	72 (12.4)	78 (13.4)	70 (12.0)
Oct	---	40 (6.5)	45 (7.3)	45 (7.3)	42 (6.8)	45 (7.2)	44 (7.1)	43 (6.9)
Nov	---	18 (2.8)	21 (3.2)	21 (3.2)	22 (3.3)	22 (3.3)	17 (2.5)	18 (2.8)
Dec	---	1 (0.1)	2 (0.3)	2 (0.3)	4 (0.5)	2 (0.3)	-2 (-0.3)	0 (0.0)

Table 33 and Table 34 show statistics and relative comparison with respect to the No Action Alternative and existing conditions for cumulative effects at the Arkansas River at Catlin Dam gage. Concentrations changes would be predominately negligible. All alternatives would increase salinity concentrations compared to existing conditions because of additional municipal discharge.

Table 33. Cumulative Effects Simulated Salinity Concentration Comparison for Arkansas River at Catlin Dam Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	780	820	828	827	827	826	829	819
15th percentile	468	518	536	540	532	533	523	527
25th percentile	538	632	642	634	649	643	637	646
50th percentile	795	873	873	869	871	868	871	870
75th percentile	968	977	981	986	983	982	992	976
85th percentile	1,062	1,059	1,069	1,069	1,069	1,068	1,081	1,050
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	8 (0.9)	7 (0.8)	7 (0.9)	6 (0.7)	9 (1.1)	-1 (-0.1)
15th percentile	---	---	18 (3.4)	22 (4.2)	14 (2.6)	15 (2.9)	4 (0.9)	9 (1.7)
25th percentile	---	---	11 (1.7)	3 (0.4)	17 (2.7)	12 (1.8)	5 (0.8)	14 (2.2)
50th percentile	---	---	0 (0.0)	-4 (-0.5)	-2 (-0.2)	-5 (-0.6)	-2 (-0.2)	-3 (-0.3)
75th percentile	---	---	5 (0.5)	9 (0.9)	7 (0.7)	5 (0.5)	15 (1.6)	-1 (-0.1)
85th percentile	---	---	10 (0.9)	10 (1.0)	10 (0.9)	9 (0.8)	22 (2.1)	-9 (-0.9)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	40 (5.1)	48 (6.1)	46 (6.0)	47 (6.0)	46 (5.9)	49 (6.3)	39 (5.1)
15th percentile	---	50 (10.7)	68 (14.5)	72 (15.4)	64 (13.6)	65 (13.9)	55 (11.7)	59 (12.6)
25th percentile	---	94 (17.4)	104 (19.4)	96 (17.9)	111 (20.6)	105 (19.5)	99 (18.3)	108 (20.0)
50th percentile	---	78 (9.8)	78 (9.8)	73 (9.2)	76 (9.6)	72 (9.1)	76 (9.5)	75 (9.4)
75th percentile	---	9 (0.9)	14 (1.4)	18 (1.8)	16 (1.6)	14 (1.4)	24 (2.5)	8 (0.9)
85th percentile	---	-3 (-0.3)	7 (0.6)	8 (0.7)	7 (0.7)	6 (0.6)	19 (1.8)	-12 (-1.1)

Table 34. Cumulative Effects Monthly Simulated Salinity Concentration for Arkansas River at Catlin Dam Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	1,010	1,020	1,029	1,031	1,028	1,030	1,031	1,017
Feb	1,081	976	967	967	970	969	999	977
Mar	899	906	906	903	907	903	906	905
Apr	716	826	831	831	828	832	832	823
May	540	650	666	655	653	650	666	650
Jun	431	520	522	523	519	522	522	521
Jul	496	539	553	550	554	554	543	547
Aug	631	677	692	691	695	687	684	677
Sep	836	891	907	907	901	904	924	897
Oct	863	948	959	959	959	960	951	944
Nov	918	938	945	945	950	945	941	932
Dec	996	980	988	989	992	988	990	976
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	9 (0.8)	11 (1.0)	8 (0.7)	10 (1.0)	11 (1.0)	-3 (-0.3)
Feb	---	---	-9 (-0.9)	-9 (-0.9)	-6 (-0.6)	-7 (-0.8)	23 (2.4)	1 (0.1)
Mar	---	---	0 (0.0)	-3 (-0.3)	1 (0.1)	-3 (-0.4)	0 (-0.1)	-1 (-0.1)
Apr	---	---	5 (0.5)	5 (0.6)	2 (0.2)	6 (0.7)	6 (0.7)	-3 (-0.4)
May	---	---	16 (2.4)	5 (0.9)	3 (0.4)	0 (0.0)	16 (2.5)	0 (0.1)
Jun	---	---	2 (0.6)	3 (0.6)	-1 (-0.1)	2 (0.4)	2 (0.5)	1 (0.4)
Jul	---	---	14 (2.6)	11 (2.1)	15 (2.9)	15 (2.8)	4 (0.7)	8 (1.6)
Aug	---	---	15 (2.2)	14 (2.0)	18 (2.6)	10 (1.5)	7 (1.0)	0 (0.0)
Sep	---	---	16 (1.8)	16 (1.8)	10 (1.1)	13 (1.5)	33 (3.7)	6 (0.6)
Oct	---	---	11 (1.2)	11 (1.1)	11 (1.1)	12 (1.3)	3 (0.3)	-4 (-0.4)
Nov	---	---	7 (0.7)	7 (0.7)	12 (1.3)	7 (0.7)	3 (0.3)	-6 (-0.7)
Dec	---	---	8 (0.8)	9 (0.9)	12 (1.1)	8 (0.8)	10 (1.0)	-4 (-0.4)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	10 (1.0)	19 (1.9)	21 (2.1)	18 (1.7)	20 (2.0)	21 (2.1)	7 (0.7)
Feb	---	-105 (-9.7)	-114 (-10.6)	-114 (-10.6)	-111 (-10.3)	-112 (-10.4)	-82 (-7.6)	-104 (-9.6)
Mar	---	7 (0.8)	7 (0.8)	4 (0.4)	8 (0.9)	4 (0.4)	7 (0.7)	6 (0.7)
Apr	---	110 (15.4)	115 (16.0)	115 (16.1)	112 (15.6)	116 (16.2)	116 (16.2)	107 (14.9)
May	---	110 (20.4)	126 (23.3)	115 (21.4)	113 (20.9)	110 (20.4)	126 (23.3)	110 (20.5)
Jun	---	89 (20.5)	91 (21.2)	92 (21.3)	88 (20.5)	91 (21.0)	91 (21.1)	90 (21.0)
Jul	---	43 (8.5)	57 (11.3)	54 (10.9)	58 (11.6)	58 (11.5)	47 (9.4)	51 (10.3)
Aug	---	46 (7.3)	61 (9.7)	60 (9.5)	64 (10.1)	56 (8.9)	53 (8.4)	46 (7.3)
Sep	---	55 (6.6)	71 (8.5)	71 (8.6)	65 (7.9)	68 (8.2)	88 (10.6)	61 (7.3)
Oct	---	85 (9.8)	96 (11.1)	96 (11.1)	96 (11.1)	97 (11.2)	88 (10.2)	81 (9.3)
Nov	---	20 (2.2)	27 (2.9)	27 (3.0)	32 (3.5)	27 (2.9)	23 (2.5)	14 (1.5)
Dec	---	-16 (-1.6)	-8 (-0.8)	-7 (-0.7)	-4 (-0.5)	-8 (-0.8)	-6 (-0.6)	-20 (-2.0)

Table 35 and Table 36 show statistics and relative comparison with the No Action Alternative and existing conditions for the Arkansas River near Rocky Ford gage. Concentrations changes would be predominately negligible for all alternatives, compared to the No Action. All alternatives would increase salinity concentrations compared to existing conditions because of additional municipal discharge

Table 35. Cumulative Effects Simulated Salinity Concentration Comparison for Arkansas River near Rocky Ford Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	823	854	858	857	860	857	862	852
15th percentile	530	577	581	578	578	576	584	587
25th percentile	617	666	669	670	672	671	673	664
50th percentile	824	864	864	862	861	861	867	856
75th percentile	1,012	1,021	1,029	1,029	1,034	1,025	1,039	1,016
85th percentile	1,120	1,117	1,127	1,127	1,128	1,127	1,134	1,119
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	4 (0.4)	3 (0.3)	5 (0.6)	3 (0.3)	8 (0.9)	-2 (-0.2)
15th percentile	---	---	4 (0.8)	1 (0.2)	1 (0.2)	-1 (-0.1)	7 (1.3)	10 (1.7)
25th percentile	---	---	3 (0.4)	4 (0.6)	5 (0.8)	5 (0.7)	6 (0.9)	-2 (-0.4)
50th percentile	---	---	-1 (-0.1)	-2 (-0.2)	-3 (-0.3)	-3 (-0.4)	3 (0.4)	-9 (-1.0)
75th percentile	---	---	8 (0.8)	7 (0.7)	12 (1.2)	4 (0.4)	18 (1.7)	-6 (-0.6)
85th percentile	---	---	9 (0.8)	10 (0.9)	11 (0.9)	9 (0.8)	16 (1.4)	2 (0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	32 (3.9)	35 (4.3)	35 (4.2)	37 (4.5)	35 (4.2)	39 (4.8)	30 (3.6)
15th percentile	---	47 (8.8)	51 (9.6)	48 (9.0)	48 (9.0)	46 (8.7)	54 (10.2)	57 (10.7)
25th percentile	---	49 (8.0)	52 (8.4)	53 (8.7)	55 (8.9)	54 (8.8)	56 (9.0)	47 (7.6)
50th percentile	---	40 (4.8)	39 (4.8)	38 (4.6)	37 (4.5)	37 (4.5)	43 (5.2)	31 (3.8)
75th percentile	---	9 (0.9)	17 (1.7)	17 (1.6)	22 (2.1)	13 (1.3)	27 (2.7)	4 (0.4)
85th percentile	---	-2 (-0.2)	7 (0.6)	7 (0.7)	8 (0.7)	7 (0.6)	14 (1.2)	-1 (-0.1)

Table 36. Cumulative Effects Monthly Simulated Salinity Concentration for Arkansas River near Rocky Ford Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	1,040	1,057	1,066	1,068	1,064	1,067	1,067	1,056
Feb	1,034	914	891	891	892	894	945	912
Mar	929	914	911	910	913	910	914	912
Apr	715	800	804	804	802	806	803	799
May	575	691	696	692	694	690	695	686
Jun	542	615	623	622	623	621	620	616
Jul	642	687	697	696	702	696	690	694
Aug	727	754	759	758	767	757	761	754
Sep	873	928	935	935	933	934	948	924
Oct	849	900	909	908	910	907	904	895
Nov	935	962	969	969	974	969	966	960
Dec	1,049	1,048	1,053	1,054	1,057	1,053	1,054	1,043
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	9 (0.8)	11 (1.0)	7 (0.7)	10 (0.9)	10 (0.9)	-1 (-0.1)
Feb	---	---	-23 (-2.5)	-23 (-2.5)	-22 (-2.4)	-20 (-2.2)	31 (3.3)	-2 (-0.2)
Mar	---	---	-3 (-0.3)	-4 (-0.5)	-1 (-0.2)	-4 (-0.5)	0 (-0.1)	-2 (-0.3)
Apr	---	---	4 (0.5)	4 (0.5)	2 (0.3)	6 (0.6)	3 (0.4)	-1 (-0.2)
May	---	---	5 (0.7)	1 (0.2)	3 (0.5)	-1 (0.0)	4 (0.6)	-5 (-0.7)
Jun	---	---	8 (1.3)	7 (1.2)	8 (1.4)	6 (1.1)	5 (0.9)	1 (0.2)
Jul	---	---	10 (1.5)	9 (1.2)	15 (2.2)	9 (1.3)	3 (0.5)	7 (0.9)
Aug	---	---	5 (0.7)	4 (0.6)	13 (1.7)	3 (0.4)	7 (0.9)	0 (0.0)
Sep	---	---	7 (0.8)	7 (0.8)	5 (0.6)	6 (0.6)	20 (2.1)	-4 (-0.4)
Oct	---	---	9 (1.0)	8 (0.9)	10 (1.1)	7 (0.8)	4 (0.5)	-5 (-0.6)
Nov	---	---	7 (0.7)	7 (0.7)	12 (1.2)	7 (0.7)	4 (0.4)	-2 (-0.3)
Dec	---	---	5 (0.5)	6 (0.5)	9 (0.8)	5 (0.5)	6 (0.6)	-5 (-0.5)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	17 (1.6)	26 (2.5)	28 (2.7)	24 (2.3)	27 (2.5)	27 (2.6)	16 (1.5)
Feb	---	-120 (-11.6)	-143 (-13.8)	-143 (-13.8)	-142 (-13.7)	-140 (-13.5)	-89 (-8.7)	-122 (-11.8)
Mar	---	-15 (-1.6)	-18 (-1.9)	-19 (-2.1)	-16 (-1.8)	-19 (-2.1)	-15 (-1.7)	-17 (-1.8)
Apr	---	85 (11.9)	89 (12.4)	89 (12.5)	87 (12.2)	91 (12.6)	88 (12.3)	84 (11.6)
May	---	116 (20.1)	121 (21.0)	117 (20.4)	119 (20.7)	115 (20.1)	120 (20.9)	111 (19.3)
Jun	---	73 (13.3)	81 (14.8)	80 (14.7)	81 (14.9)	79 (14.6)	78 (14.4)	74 (13.6)
Jul	---	45 (7.0)	55 (8.6)	54 (8.3)	60 (9.3)	54 (8.4)	48 (7.5)	52 (8.0)
Aug	---	27 (3.6)	32 (4.4)	31 (4.2)	40 (5.4)	30 (4.0)	34 (4.6)	27 (3.6)
Sep	---	55 (6.2)	62 (7.1)	62 (7.1)	60 (6.9)	61 (6.9)	75 (8.5)	51 (5.8)
Oct	---	51 (6.0)	60 (7.1)	59 (7.0)	61 (7.2)	58 (6.9)	55 (6.6)	46 (5.4)
Nov	---	27 (2.9)	34 (3.7)	34 (3.7)	39 (4.2)	34 (3.7)	31 (3.4)	25 (2.6)
Dec	---	-1 (-0.1)	4 (0.4)	5 (0.4)	8 (0.7)	4 (0.4)	5 (0.5)	-6 (-0.6)

Table 37 and Table 38 show the statistics and relative comparison with the No Action Alternative and existing conditions for the Arkansas River at Las Animas gage. Concentration changes would be predominately negligible for all alternatives, compared to the No Action. All alternatives would decrease salinity concentrations compared to existing conditions.

Table 37. Cumulative Effects Simulated Salinity Concentration Comparison for Arkansas River at Las Animas Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	1,684	1,604	1,603	1,601	1,601	1,603	1,602	1,601
15th percentile	875	891	870	871	885	870	885	883
25th percentile	1,181	1,150	1,147	1,146	1,153	1,147	1,162	1,154
50th percentile	1,753	1,690	1,668	1,664	1,681	1,663	1,684	1,683
75th percentile	2,038	1,926	1,921	1,921	1,924	1,921	1,926	1,919
85th percentile	2,323	2,152	2,153	2,153	2,152	2,164	2,139	2,142
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	-1 (-0.1)	-3 (-0.2)	-3 (-0.2)	-1 (0.0)	-2 (-0.1)	-3 (-0.2)
15th percentile	---	---	-21 (-2.4)	-20 (-2.3)	-6 (-0.7)	-21 (-2.3)	-6 (-0.6)	-8 (-0.9)
25th percentile	---	---	-3 (-0.3)	-4 (-0.4)	3 (0.3)	-4 (-0.3)	12 (1.0)	4 (0.4)
50th percentile	---	---	-22 (-1.3)	-26 (-1.6)	-9 (-0.5)	-26 (-1.6)	-6 (-0.3)	-7 (-0.4)
75th percentile	---	---	-5 (-0.2)	-5 (-0.3)	-2 (-0.1)	-5 (-0.2)	0 (0.0)	-7 (-0.4)
85th percentile	---	---	1 (0.0)	1 (0.0)	0 (0.0)	11 (0.5)	-13 (-0.6)	-11 (-0.5)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	-80 (-4.8)	-82 (-4.9)	-83 (-4.9)	-84 (-5.0)	-81 (-4.8)	-83 (-4.9)	-83 (-5.0)
15th percentile	---	16 (1.8)	-6 (-0.6)	-5 (-0.5)	9 (1.1)	-5 (-0.6)	10 (1.1)	8 (0.9)
25th percentile	---	-31 (-2.6)	-34 (-2.9)	-35 (-2.9)	-28 (-2.4)	-34 (-2.9)	-19 (-1.6)	-27 (-2.3)
50th percentile	---	-64 (-3.6)	-86 (-4.9)	-90 (-5.1)	-73 (-4.1)	-90 (-5.1)	-69 (-3.9)	-70 (-4.0)
75th percentile	---	-112 (-5.5)	-116 (-5.7)	-117 (-5.7)	-114 (-5.6)	-116 (-5.7)	-112 (-5.5)	-119 (-5.8)
85th percentile	---	-171 (-7.4)	-170 (-7.3)	-170 (-7.3)	-171 (-7.4)	-160 (-6.9)	-184 (-7.9)	-182 (-7.8)

Table 38. Cumulative Effects Monthly Simulated Salinity Concentration for Arkansas River at Las Animas Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	1,801	1,792	1,805	1,803	1,804	1,804	1,804	1,791
Feb	1,732	1,580	1,528	1,527	1,534	1,531	1,615	1,581
Mar	1,994	1,761	1,744	1,750	1,775	1,749	1,741	1,741
Apr	2,215	2,007	2,017	2,002	2,003	2,009	1,978	1,981
May	1,376	1,266	1,275	1,270	1,280	1,275	1,266	1,263
Jun	1,043	970	962	961	966	960	965	973
Jul	1,252	1,239	1,239	1,242	1,225	1,252	1,214	1,255
Aug	1,389	1,332	1,337	1,337	1,338	1,336	1,338	1,334
Sep	1,869	1,811	1,801	1,802	1,802	1,801	1,784	1,807
Oct	1,901	1,893	1,909	1,909	1,885	1,910	1,902	1,899
Nov	1,832	1,822	1,832	1,832	1,808	1,831	1,829	1,817
Dec	1,847	1,826	1,835	1,835	1,836	1,834	1,837	1,825
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	13 (0.7)	11 (0.6)	12 (0.6)	12 (0.7)	12 (0.7)	-1 (-0.1)
Feb	---	---	-52 (-3.3)	-53 (-3.3)	-46 (-2.9)	-49 (-3.1)	35 (2.2)	1 (0.0)
Mar	---	---	-17 (-1.0)	-11 (-0.6)	14 (0.8)	-12 (-0.7)	-20 (-1.2)	-20 (-1.1)
Apr	---	---	10 (0.5)	-5 (-0.3)	-4 (-0.2)	2 (0.1)	-29 (-1.4)	-26 (-1.3)
May	---	---	9 (0.8)	4 (0.4)	14 (1.2)	9 (0.7)	0 (0.0)	-3 (-0.2)
Jun	---	---	-8 (-0.8)	-9 (-0.9)	-4 (-0.4)	-10 (-1.0)	-5 (-0.5)	3 (0.3)
Jul	---	---	0 (0.0)	3 (0.2)	-14 (-1.1)	13 (1.0)	-25 (-2.0)	16 (1.2)
Aug	---	---	5 (0.4)	5 (0.4)	6 (0.5)	4 (0.3)	6 (0.4)	2 (0.2)
Sep	---	---	-10 (-0.6)	-9 (-0.5)	-9 (-0.5)	-10 (-0.6)	-27 (-1.5)	-4 (-0.2)
Oct	---	---	16 (0.8)	16 (0.8)	-8 (-0.4)	17 (0.9)	9 (0.5)	6 (0.3)
Nov	---	---	10 (0.6)	10 (0.5)	-14 (-0.8)	9 (0.5)	7 (0.4)	-5 (-0.2)
Dec	---	---	9 (0.5)	9 (0.5)	10 (0.6)	8 (0.5)	11 (0.6)	-1 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-9 (-0.5)	4 (0.2)	2 (0.1)	3 (0.2)	3 (0.2)	3 (0.2)	-10 (-0.5)
Feb	---	-152 (-8.8)	-204 (-11.8)	-205 (-11.8)	-198 (-11.4)	-201 (-11.6)	-117 (-6.7)	-151 (-8.7)
Mar	---	-233 (-11.7)	-250 (-12.6)	-244 (-12.3)	-219 (-11.0)	-245 (-12.3)	-253 (-12.7)	-253 (-12.7)
Apr	---	-208 (-9.4)	-198 (-9.0)	-213 (-9.7)	-212 (-9.6)	-206 (-9.3)	-237 (-10.7)	-234 (-10.6)
May	---	-110 (-8.0)	-101 (-7.3)	-106 (-7.7)	-96 (-7.0)	-101 (-7.4)	-110 (-8.0)	-113 (-8.2)
Jun	---	-73 (-7.1)	-81 (-7.8)	-82 (-7.9)	-77 (-7.4)	-83 (-8.0)	-78 (-7.5)	-70 (-6.7)
Jul	---	-13 (-1.0)	-13 (-1.0)	-10 (-0.8)	-27 (-2.1)	0 (0.0)	-38 (-3.0)	3 (0.2)
Aug	---	-57 (-4.1)	-52 (-3.7)	-52 (-3.8)	-51 (-3.6)	-53 (-3.8)	-51 (-3.7)	-55 (-3.9)
Sep	---	-58 (-3.1)	-68 (-3.7)	-67 (-3.6)	-67 (-3.6)	-68 (-3.7)	-85 (-4.6)	-62 (-3.3)
Oct	---	-8 (-0.4)	8 (0.4)	8 (0.4)	-16 (-0.9)	9 (0.4)	1 (0.0)	-2 (-0.1)
Nov	---	-10 (-0.5)	0 (0.0)	0 (0.0)	-24 (-1.3)	-1 (0.0)	-3 (-0.1)	-15 (-0.8)
Dec	---	-21 (-1.2)	-12 (-0.7)	-12 (-0.7)	-11 (-0.6)	-13 (-0.7)	-10 (-0.6)	-22 (-1.2)

Table 39 to Table 42 show statistics and relative comparison with respect to the No Action Alternative and existing conditions for gages on Fountain Creek. Fountain Creek, with respect to the No Action Alternative, would have negligible percent changes in simulated concentration. The alternatives would increase salinity concentrations in the drier summer months, compared to existing conditions, because of the influence of higher municipal discharges.

Table 39. Cumulative Effects Simulated Salinity Concentration Comparison for Fountain Creek near Fountain Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	596	609	610	607	608	606	608	609
15th percentile	427	493	485	485	487	484	487	493
25th percentile	497	530	530	528	529	528	531	532
50th percentile	615	585	587	586	586	586	587	587
75th percentile	698	642	644	643	642	643	647	644
85th percentile	733	683	683	680	683	681	686	683
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	1 (0.2)	-2 (-0.3)	-1 (-0.1)	-3 (-0.5)	-1 (-0.1)	0 (0.0)
15th percentile	---	---	-8 (-1.6)	-8 (-1.6)	-5 (-1.1)	-9 (-1.7)	-5 (-1.1)	0 (0.0)
25th percentile	---	---	0 (0.1)	-2 (-0.3)	-1 (-0.1)	-2 (-0.3)	2 (0.3)	2 (0.3)
50th percentile	---	---	2 (0.3)	1 (0.2)	1 (0.1)	1 (0.2)	2 (0.3)	2 (0.3)
75th percentile	---	---	2 (0.3)	1 (0.1)	0 (0.0)	1 (0.2)	5 (0.8)	2 (0.3)
85th percentile	---	---	0 (0.0)	-2 (-0.3)	0 (0.0)	-2 (-0.3)	3 (0.4)	0 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	13 (2.1)	14 (2.3)	11 (1.8)	12 (2.0)	10 (1.6)	12 (2.0)	13 (2.2)
15th percentile	---	66 (15.4)	58 (13.5)	58 (13.5)	60 (14.1)	57 (13.4)	60 (14.1)	66 (15.4)
25th percentile	---	33 (6.6)	33 (6.6)	31 (6.3)	32 (6.4)	31 (6.3)	34 (6.9)	34 (6.9)
50th percentile	---	-30 (-4.9)	-28 (-4.6)	-29 (-4.7)	-30 (-4.8)	-29 (-4.7)	-28 (-4.6)	-29 (-4.7)
75th percentile	---	-55 (-7.9)	-54 (-7.7)	-55 (-7.8)	-55 (-7.9)	-54 (-7.8)	-50 (-7.2)	-53 (-7.6)
85th percentile	---	-50 (-6.8)	-50 (-6.9)	-52 (-7.2)	-50 (-6.8)	-52 (-7.1)	-47 (-6.4)	-50 (-6.9)

Table 40. Cumulative Effects Monthly Simulated Salinity Concentration for Fountain Creek near Fountain Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	637	611	612	611	611	611	609	609
Feb	630	587	592	592	590	592	588	588
Mar	609	606	602	600	602	600	603	604
Apr	538	585	585	586	585	598	587	597
May	509	650	641	610	641	611	637	634
Jun	532	680	681	681	676	678	684	684
Jul	522	579	584	584	574	584	570	582
Aug	551	550	574	574	575	550	554	553
Sep	607	610	611	611	609	610	619	615
Oct	695	606	598	597	600	595	608	604
Nov	665	604	603	603	603	605	606	605
Dec	678	621	620	620	620	620	620	621
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	1 (0.2)	0 (0.1)	0 (0.1)	0 (0.0)	-2 (-0.2)	-2 (-0.3)
Feb	---	---	5 (0.9)	5 (0.8)	3 (0.4)	5 (0.8)	1 (0.2)	1 (0.2)
Mar	---	---	-4 (-0.8)	-6 (-1.1)	-4 (-0.8)	-6 (-1.0)	-3 (-0.5)	-2 (-0.4)
Apr	---	---	0 (0.0)	1 (0.1)	0 (0.0)	13 (2.2)	2 (0.4)	12 (2.1)
May	---	---	-9 (-1.4)	-40 (-6.1)	-9 (-1.4)	-39 (-6.0)	-13 (-2.0)	-16 (-2.4)
Jun	---	---	1 (0.1)	1 (0.1)	-4 (-0.6)	-2 (-0.3)	4 (0.7)	4 (0.6)
Jul	---	---	5 (0.9)	5 (1.0)	-5 (-0.8)	5 (1.0)	-9 (-1.5)	3 (0.6)
Aug	---	---	24 (4.2)	24 (4.2)	25 (4.5)	0 (0.0)	4 (0.6)	3 (0.5)
Sep	---	---	1 (0.2)	1 (0.2)	-1 (-0.1)	0 (0.0)	9 (1.4)	5 (0.8)
Oct	---	---	-8 (-1.3)	-9 (-1.4)	-6 (-0.9)	-11 (-1.7)	2 (0.4)	-2 (-0.2)
Nov	---	---	-1 (-0.1)	-1 (-0.2)	-1 (-0.1)	1 (0.1)	2 (0.2)	1 (0.1)
Dec	---	---	-1 (0.0)	-1 (0.0)	-1 (-0.1)	-1 (0.0)	-1 (-0.1)	0 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-26 (-4.2)	-25 (-4.0)	-26 (-4.1)	-26 (-4.1)	-26 (-4.2)	-28 (-4.4)	-28 (-4.4)
Feb	---	-43 (-6.8)	-38 (-6.0)	-38 (-6.0)	-40 (-6.4)	-38 (-6.0)	-42 (-6.6)	-42 (-6.6)
Mar	---	-3 (-0.5)	-7 (-1.3)	-9 (-1.6)	-7 (-1.3)	-9 (-1.5)	-6 (-1.1)	-5 (-0.9)
Apr	---	47 (8.8)	47 (8.9)	48 (9.0)	47 (8.8)	60 (11.3)	49 (9.2)	59 (11.1)
May	---	141 (27.6)	132 (25.8)	101 (19.8)	132 (25.8)	102 (19.9)	128 (25.1)	125 (24.5)
Jun	---	148 (27.8)	149 (27.9)	149 (27.9)	144 (27.0)	146 (27.5)	152 (28.6)	152 (28.5)
Jul	---	57 (10.9)	62 (12.0)	62 (12.0)	52 (10.1)	62 (12.0)	48 (9.3)	60 (11.6)
Aug	---	-1 (-0.1)	23 (4.1)	23 (4.1)	24 (4.4)	-1 (-0.1)	3 (0.5)	2 (0.4)
Sep	---	3 (0.5)	4 (0.7)	4 (0.7)	2 (0.3)	3 (0.5)	12 (1.9)	8 (1.3)
Oct	---	-89 (-12.9)	-97 (-14.1)	-98 (-14.1)	-95 (-13.7)	-100 (-14.4)	-87 (-12.6)	-91 (-13.1)
Nov	---	-61 (-9.1)	-62 (-9.2)	-62 (-9.3)	-62 (-9.2)	-60 (-9.0)	-59 (-8.9)	-60 (-9.1)
Dec	---	-57 (-8.4)	-58 (-8.4)	-58 (-8.4)	-58 (-8.5)	-58 (-8.4)	-58 (-8.4)	-57 (-8.4)

Table 41. Cumulative Effects Simulated Salinity Concentration Comparison for Fountain Creek at Pueblo Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	698	662	663	660	662	659	661	662
15th percentile	522	513	513	511	513	513	517	517
25th percentile	582	560	560	560	560	559	561	563
50th percentile	706	644	647	647	641	647	647	646
75th percentile	822	718	720	717	718	717	722	718
85th percentile	870	764	768	766	769	764	761	766
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	1 (0.2)	-1 (-0.2)	0 (0.0)	-3 (-0.4)	-1 (-0.1)	0 (0.0)
15th percentile	---	---	0 (0.0)	-2 (-0.4)	0 (-0.1)	0 (-0.1)	3 (0.7)	3 (0.7)
25th percentile	---	---	0 (-0.1)	-1 (-0.1)	0 (0.0)	-1 (-0.2)	1 (0.1)	2 (0.4)
50th percentile	---	---	3 (0.4)	2 (0.4)	-3 (-0.5)	3 (0.4)	3 (0.4)	2 (0.3)
75th percentile	---	---	1 (0.2)	-1 (-0.1)	0 (0.0)	-1 (-0.1)	4 (0.6)	0 (0.0)
85th percentile	---	---	4 (0.6)	2 (0.2)	5 (0.6)	0 (0.0)	-3 (-0.4)	2 (0.2)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	-36 (-5.2)	-35 (-5.0)	-38 (-5.4)	-36 (-5.2)	-39 (-5.6)	-37 (-5.3)	-36 (-5.2)
15th percentile	---	-9 (-1.7)	-9 (-1.7)	-11 (-2.1)	-9 (-1.8)	-9 (-1.8)	-5 (-1.1)	-5 (-1.1)
25th percentile	---	-22 (-3.7)	-22 (-3.8)	-22 (-3.8)	-22 (-3.7)	-23 (-3.9)	-21 (-3.6)	-19 (-3.3)
50th percentile	---	-62 (-8.8)	-59 (-8.4)	-60 (-8.5)	-65 (-9.2)	-59 (-8.4)	-60 (-8.4)	-60 (-8.5)
75th percentile	---	-104 (-12.7)	-103 (-12.5)	-105 (-12.8)	-104 (-12.6)	-105 (-12.8)	-100 (-12.2)	-104 (-12.7)
85th percentile	---	-106 (-12.2)	-102 (-11.7)	-105 (-12.0)	-101 (-11.7)	-106 (-12.2)	-109 (-12.6)	-104 (-12.0)

Table 42. Cumulative Effects Monthly Simulated Salinity Concentration for Fountain Creek at Pueblo Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	738	675	676	675	676	674	671	672
Feb	749	660	662	662	662	662	660	659
Mar	711	659	654	653	654	653	656	657
Apr	669	641	638	639	638	650	642	649
May	601	665	657	626	656	627	653	650
Jun	620	700	701	700	697	698	703	704
Jul	609	618	625	625	614	624	610	623
Aug	640	600	623	623	624	601	602	602
Sep	652	635	640	640	636	639	646	641
Oct	827	685	684	683	683	681	688	686
Nov	770	681	683	683	682	684	682	682
Dec	805	708	706	706	710	706	707	707
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	1 (0.1)	0 (0.1)	1 (0.2)	-1 (-0.1)	-4 (-0.6)	-3 (-0.5)
Feb	---	---	2 (0.2)	2 (0.3)	2 (0.3)	2 (0.2)	0 (0.0)	-1 (-0.2)
Mar	---	---	-5 (-0.8)	-6 (-1.0)	-5 (-0.8)	-6 (-0.9)	-3 (-0.6)	-2 (-0.4)
Apr	---	---	-3 (-0.5)	-2 (-0.4)	-3 (-0.5)	9 (1.4)	1 (0.1)	8 (1.3)
May	---	---	-8 (-1.3)	-39 (-5.9)	-9 (-1.3)	-38 (-5.8)	-12 (-1.8)	-15 (-2.3)
Jun	---	---	1 (0.2)	0 (0.1)	-3 (-0.4)	-2 (-0.2)	3 (0.5)	4 (0.5)
Jul	---	---	7 (1.1)	7 (1.1)	-4 (-0.6)	6 (1.0)	-8 (-1.3)	5 (0.9)
Aug	---	---	23 (3.9)	23 (3.8)	24 (4.0)	1 (0.2)	2 (0.4)	2 (0.4)
Sep	---	---	5 (0.7)	5 (0.7)	1 (0.1)	4 (0.6)	11 (1.7)	6 (0.8)
Oct	---	---	-1 (-0.2)	-2 (-0.3)	-2 (-0.4)	-4 (-0.6)	3 (0.4)	1 (0.1)
Nov	---	---	2 (0.4)	2 (0.3)	1 (0.2)	3 (0.5)	1 (0.1)	1 (0.1)
Dec	---	---	-2 (-0.3)	-2 (-0.3)	2 (0.2)	-2 (-0.3)	-1 (-0.1)	-1 (-0.2)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-63 (-8.6)	-62 (-8.5)	-63 (-8.5)	-62 (-8.4)	-64 (-8.6)	-67 (-9.1)	-66 (-9.0)
Feb	---	-89 (-11.9)	-87 (-11.7)	-87 (-11.6)	-87 (-11.6)	-87 (-11.7)	-89 (-11.9)	-90 (-12.1)
Mar	---	-52 (-7.2)	-57 (-7.9)	-58 (-8.2)	-57 (-7.9)	-58 (-8.1)	-55 (-7.7)	-54 (-7.5)
Apr	---	-28 (-4.2)	-31 (-4.7)	-30 (-4.6)	-31 (-4.7)	-19 (-2.9)	-27 (-4.1)	-20 (-3.0)
May	---	64 (10.7)	56 (9.3)	25 (4.2)	55 (9.3)	26 (4.3)	52 (8.7)	49 (8.2)
Jun	---	80 (12.8)	81 (13.0)	80 (12.9)	77 (12.4)	78 (12.6)	83 (13.4)	84 (13.4)
Jul	---	9 (1.4)	16 (2.6)	16 (2.5)	5 (0.8)	15 (2.4)	1 (0.1)	14 (2.3)
Aug	---	-40 (-6.3)	-17 (-2.6)	-17 (-2.7)	-16 (-2.6)	-39 (-6.2)	-38 (-6.0)	-38 (-5.9)
Sep	---	-17 (-2.5)	-12 (-1.7)	-12 (-1.8)	-16 (-2.3)	-13 (-1.9)	-6 (-0.8)	-11 (-1.7)
Oct	---	-142 (-17.1)	-143 (-17.3)	-144 (-17.4)	-144 (-17.4)	-146 (-17.6)	-139 (-16.7)	-141 (-17.0)
Nov	---	-89 (-11.6)	-87 (-11.3)	-87 (-11.3)	-88 (-11.5)	-86 (-11.2)	-88 (-11.5)	-88 (-11.5)
Dec	---	-97 (-12.0)	-99 (-12.2)	-99 (-12.3)	-95 (-11.8)	-99 (-12.3)	-98 (-12.1)	-98 (-12.2)

Selenium Analysis

This section describes methods and results of the selenium analysis. All references in this appendix to selenium are to the dissolved form, because it is the regulated and most commonly monitored form of selenium.

Methods

Selenium data are not frequently collected in the study area. Despite limited data, selenium in the study area was evaluated using a conservative constituent mass balance approach. Historical data was reconstructed using relationships between salinity and selenium. Results from the detailed salinity model were used to support the estimation of selenium for missing data periods.

The mass balance approach to simulate selenium concentrations throughout the study area was carried out using the GeoDSS for the Lower Arkansas River. Methods for modeling selenium are the same as used to model salinity (see this Appendix F.2 – *Salinity Analysis*). Due to simplified modeling assumptions, the results of the selenium analysis are more appropriate to gain an understanding of the relative direction and magnitude of effects between the alternatives than to describe absolute future selenium conditions.

The results of the selenium analysis followed the same pattern as the salinity analysis because the historical relationships between salinity and selenium are all monotonically increasing (i.e., when salinity increases, selenium increases). Results are presented by percentile and as monthly averages. The 85^{th} percentile of available samples is the statistic used by Health Department to evaluate exceedences of the chronic dissolved selenium Water Quality Standard (WQS) (Health Department 2005).

The significance criteria in Table 7 were used to evaluate selenium effects.

Model Study Period

Similar to salinity, the selenium study period is a 10-year model study period, from 1999 through 2009, based on the original GeoDSS study period extended through the Daily Model study period. Weekly time steps were selected as the model interval to reasonably capture the concentration variability based on the limited data availability throughout the studied area.

Table 43 summarizes the period of record for stream gages where selenium measurements were available. *Irregular* measurement refers to samples taken at field visits at irregular intervals. Table 43 also provides the number of measurements available for each station, data type and the abbreviation used in this report.

Table 43. Daily Selenium Data Period of Record for Stream Gages

Gage Name	Abbreviation	Measurement Interval	Number of Measurements	Daily Selenium Data Period of Record
Fountain Creek at Colorado Springs	7105500	Irregular	134	Apr/1981 - Oct/2010
Fountain Creek at Security	7105800	Irregular	89	Nov/1998- Oct/2010
Fountain Creek at Pueblo	FOUPUECO	Irregular	139	Apr/1981 - Oct/2010
Arkansas River above Pueblo	ARKPUECO	Irregular	52	Apr/1982 - Feb/2008
Arkansas River at Moffat St.	ARKMOFCO	Irregular	72	Apr/1990 - Feb/2008
Arkansas River near Avondale	ARKAVOCO	Irregular	63	June/1976 - Aug/2010
Arkansas River at Catlin Dam	ARKCATCO	Irregular	85	Apr/1990 - Aug/2010
Arkansas River at Las Animas	ARKLASCO	Irregular	57	Apr/1990 - Aug/2010

Figure 36 shows a schematic of the selenium model control points used for GeoDSS calibration. Weekly selenium concentration of unmeasured inflows was estimated to match, as close as possible, the estimated concentration at the control points.

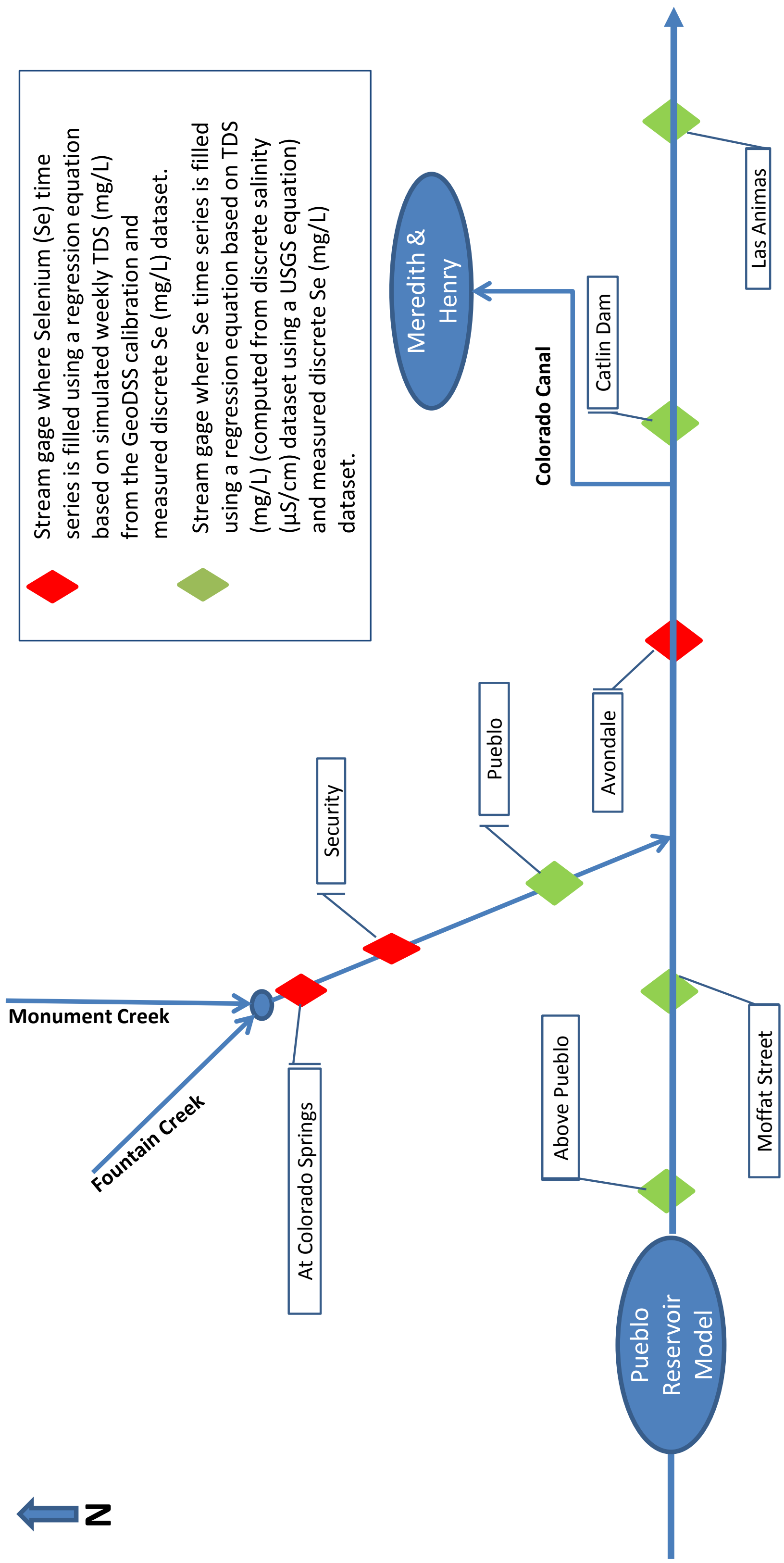


Figure 36 Selenium Model Control Points Schematic for Existing Conditions

Selenium and Salinity Relationships

Dissolved selenium and salinity (measured as specific conductance) are historically related in surface water in the lower Arkansas River, and many of the factors that affect salinity concentrations would likely affect selenium concentrations. Bossong (2001) studied the correlation between salinity and dissolved selenium at locations within the Fountain Creek Basin. They found strong positive correlations between dissolved selenium at the Fountain Creek below Janitell Road, Fountain Creek near Fountain, and Fountain Creek at Pueblo gages. Correlations between salinity and selenium concentrations have been found throughout the arid Western United States (Seiler et al. 2003).

Based on those findings, in this analysis, specific relationships for the study area were derived to perform the analysis of dissolved selenium building upon the detailed salinity modeling presented in the previous section of this appendix. Historical relationships between measured and simulated salinity (as TDS) and selenium were evaluated to select the relationship with stronger correlation to represent the selenium concentration at the different control points in the study area.

Measured salinity was obtained from the USGS published data using the specific conductance to TDS conversion equations shown in Table 2. The simulated TDS dataset was obtained from the historical calibration in GeoDSS. It was assumed that average weekly simulated TDS concentration obtained from the historical calibration in GeoDSS was representative of TDS concentration at a USGS gage and therefore could be used to derive the relationship with measured selenium concentration. Measured selenium corresponds to the USGS published discrete sampling of filtered selenium in µg/L.

The development of selenium and TDS relationships usually has limited number of data points available, making this process challenging and requiring professional judgment to find relationships that are expected to perform better for the historical range of TDS values. A logarithmic transformation of the data was performed to develop the relationships.

Figure 37 through Figure 39 present the selenium and TDS relationships for modeled gages in Fountain Creek. The relationship for Fountain Creek at Colorado Springs gage, shown in Figure 37, was derived using the average weekly simulated TDS concentration dataset obtained from the GeoDSS historical calibration and the discrete measured selenium concentration. Figure 37 shows the relationship and the selected equation to estimate selenium at Fountain Creek at Colorado Springs gage. The coefficient of determination (R^2) for this case is 0.73.

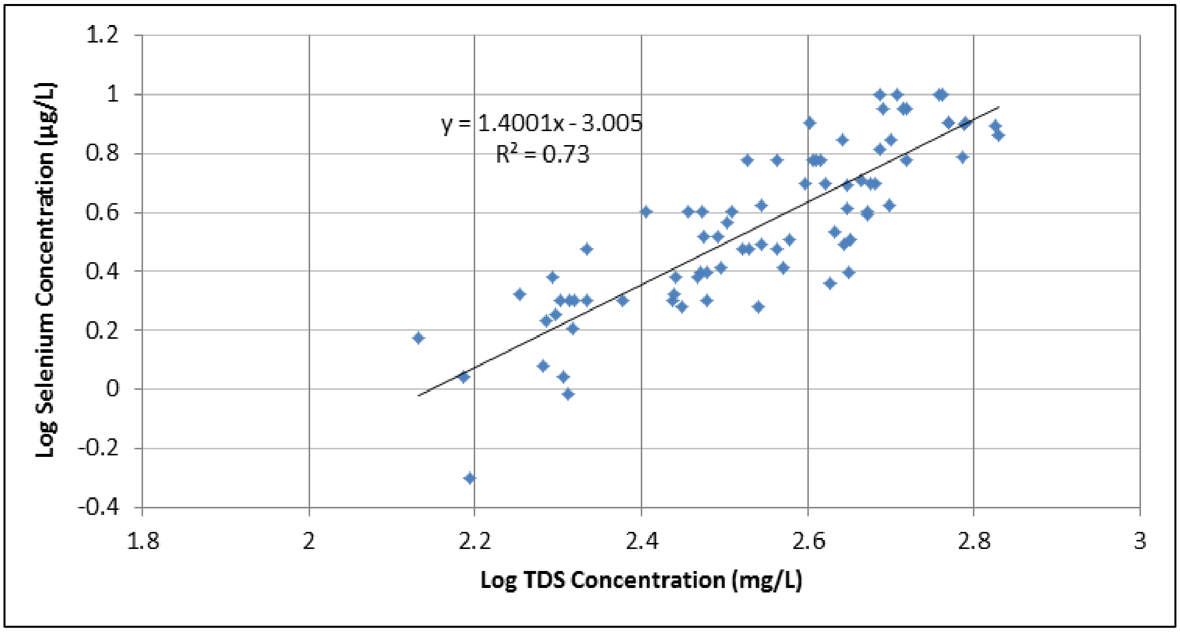


Figure 37. TDS and Selenium Concentration Relationship for Fountain Creek at Colorado Springs Gage

TDS and selenium relationship for Fountain Creek at Security was based on the average weekly simulated TDS concentration from the GeoDSS historical calibration and the available selenium measured concentration. Figure 38 shows the relationship between the two variables, the regression equation and corresponding R^2. Although there is not a strong correlation between TDS and selenium at this gage, due to the limited amount of selenium data between the Security gage and Fountain Creek at Pueblo gage this relationship was used to represent the selenium concentration change at the upstream end of the Security to Pueblo segment of Fountain Creek.

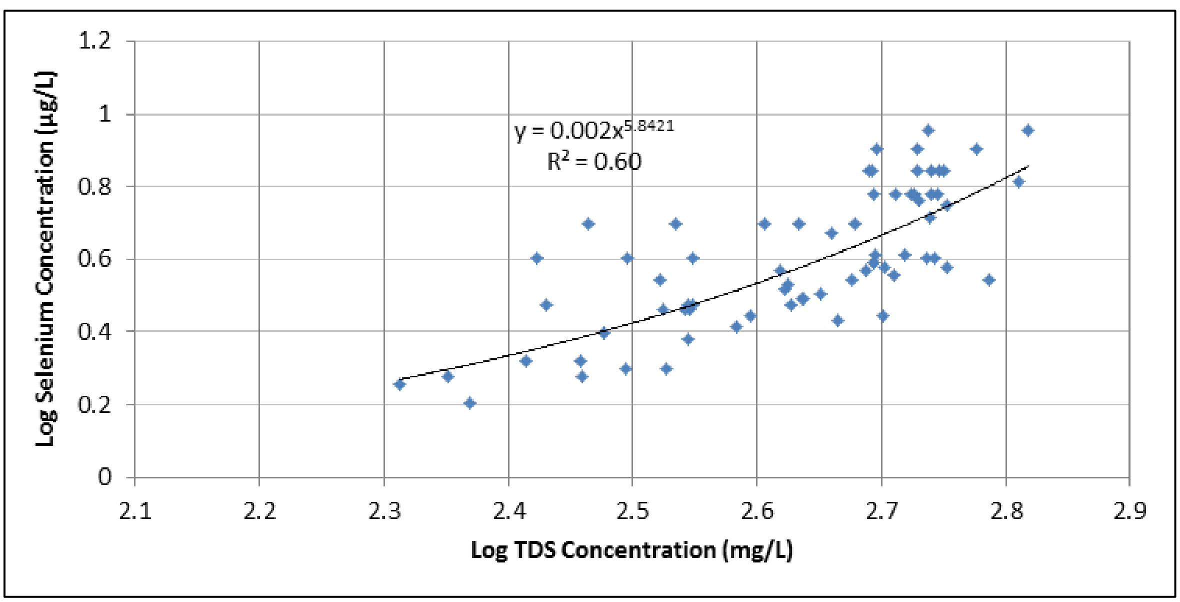


Figure 38. TDS and Selenium Concentration Relationship for Fountain Creek at Security Gage

The TDS and selenium relationship for the Fountain Creek at Pueblo gage was based on the average USGS measured TDS and selenium. Figure 39 shows the selected relationship, the regression equations and corresponding R^2.

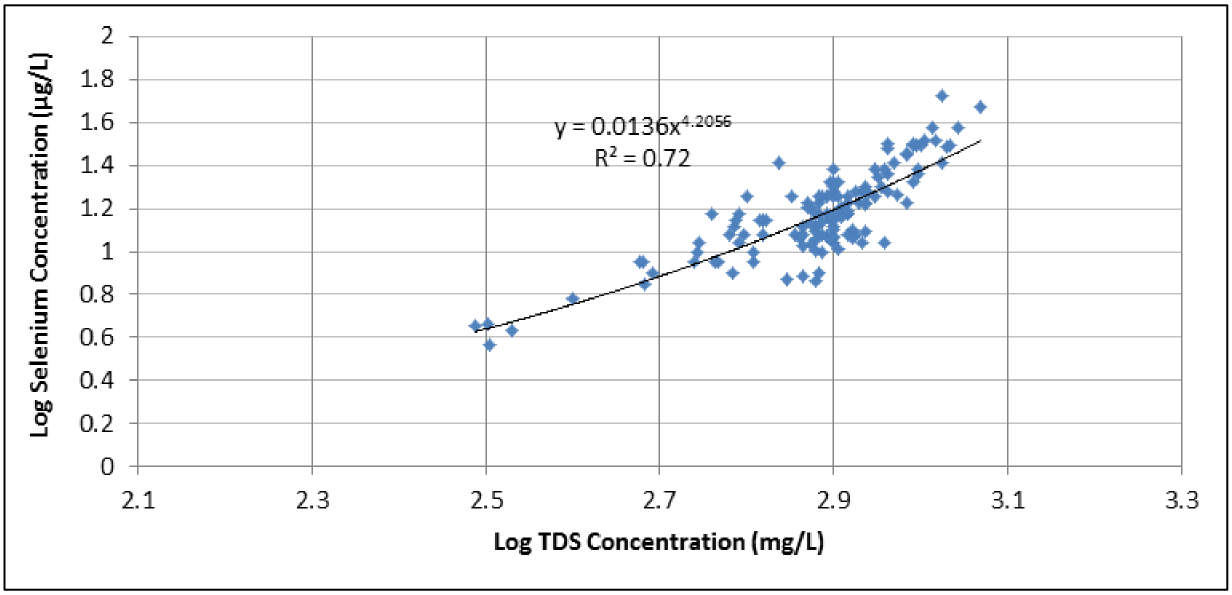


Figure 39. TDS and Selenium Concentration Relationship for Fountain Creek at Pueblo Gage

Figure 40 through Figure 44 show the relationships between TDS and selenium for the Arkansas River gages. The TDS and selenium relationship for the Arkansas River above Pueblo gage was derived from average USGS measured TDS and measured selenium samples. A linear relationship was selected to be conservative in prediction of selenium values outside the observed range, especially for high TDS values observed in 2002 for which there is no measured selenium data. Although the prediction error outside the range of observed values used to develop the relationships is higher, the error in selenium load estimates in those high concentration periods is small due to the extremely low flows (less than 2 cfs) that occurred in that period. Figure 40 shows relationship for the corresponding TDS and selenium measured points and the selected regression equation and coefficient of determination.

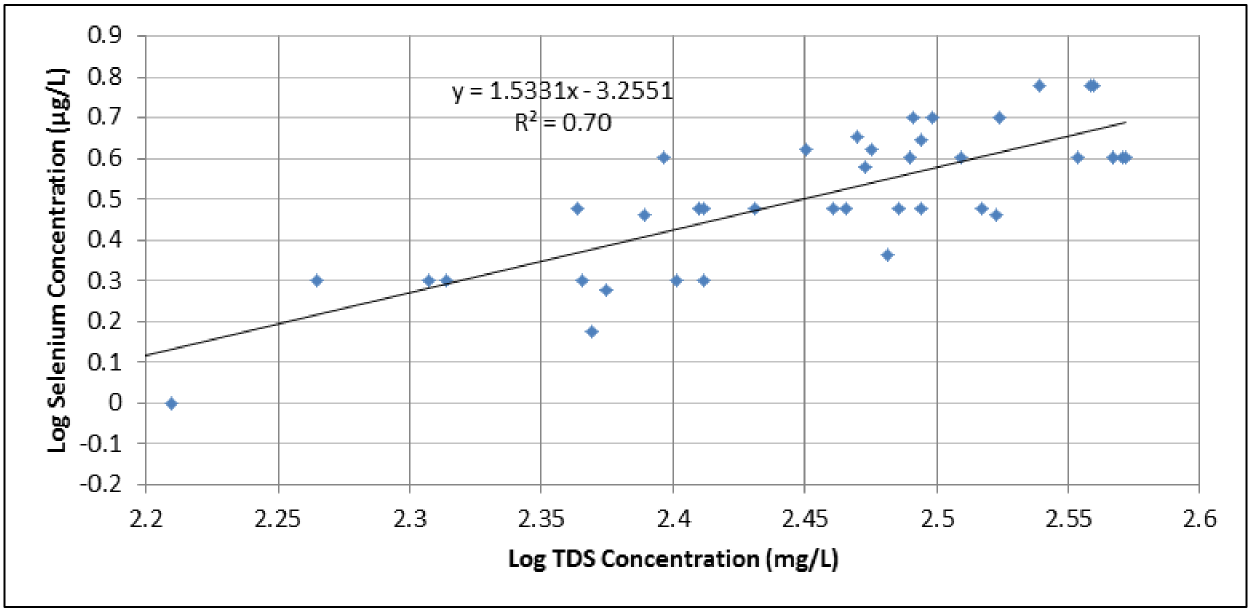


Figure 40. TDS and Selenium Concentration Relationship for Arkansas River above Pueblo Gage

TDS and selenium relationship for the Arkansas River at Moffat St. gage was derived from the average USGS measured TDS and selenium samples. Figure 41 shows the relationship between the two variables and corresponding R^2.

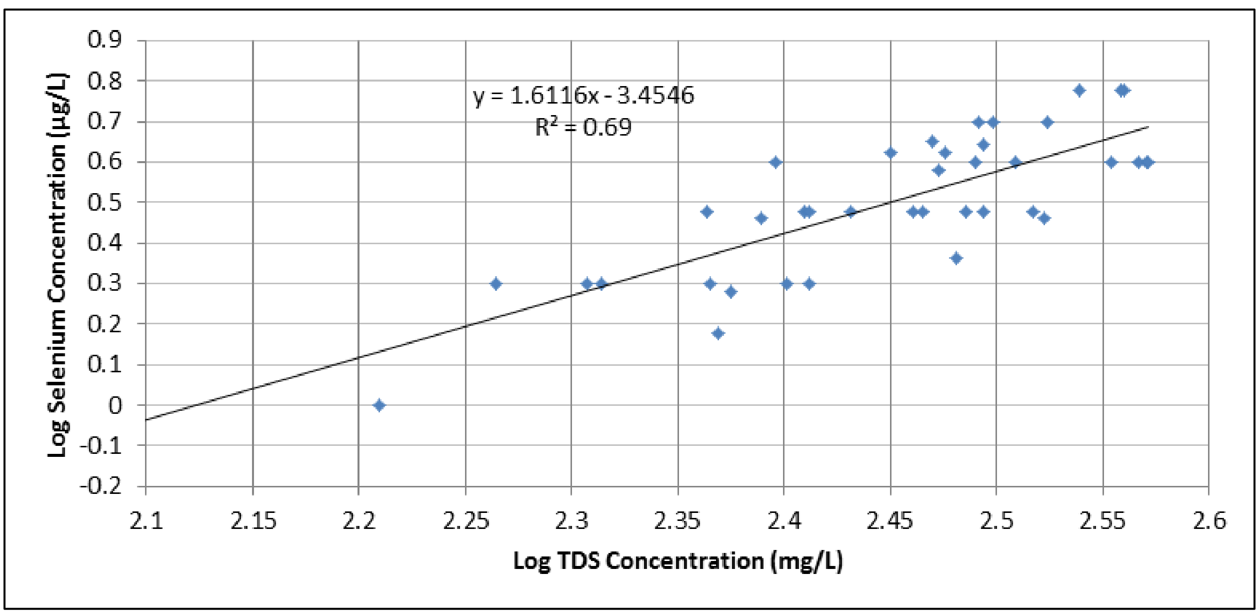


Figure 41. TDS and Selenium Concentration Relationship for the Arkansas River at Moffat St. Gage

The relationship between TDS and selenium at the Arkansas River near Avondale gage was based on the average weekly simulated TDS concentration from the GeoDSS historical calibration run and discrete measured Selenium concentration. Figure 42 shows the relationship between the two variables and corresponding regression equation and R^2.

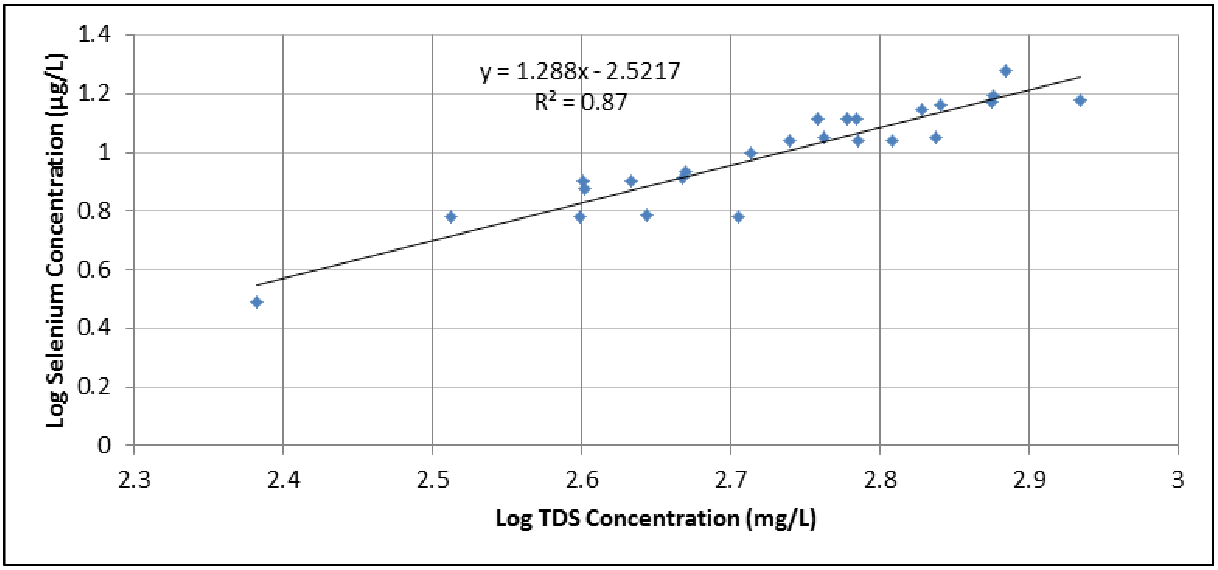


Figure 42. TDS and Selenium Concentration Relationship for Arkansas River near Avondale Gage

The TDS and selenium relationship for the Arkansas River at Catlin Dam gage was based on the average USGS measured TDS and selenium samples. Figure 43 shows the corresponding relationship between the two variables and corresponding R^2.

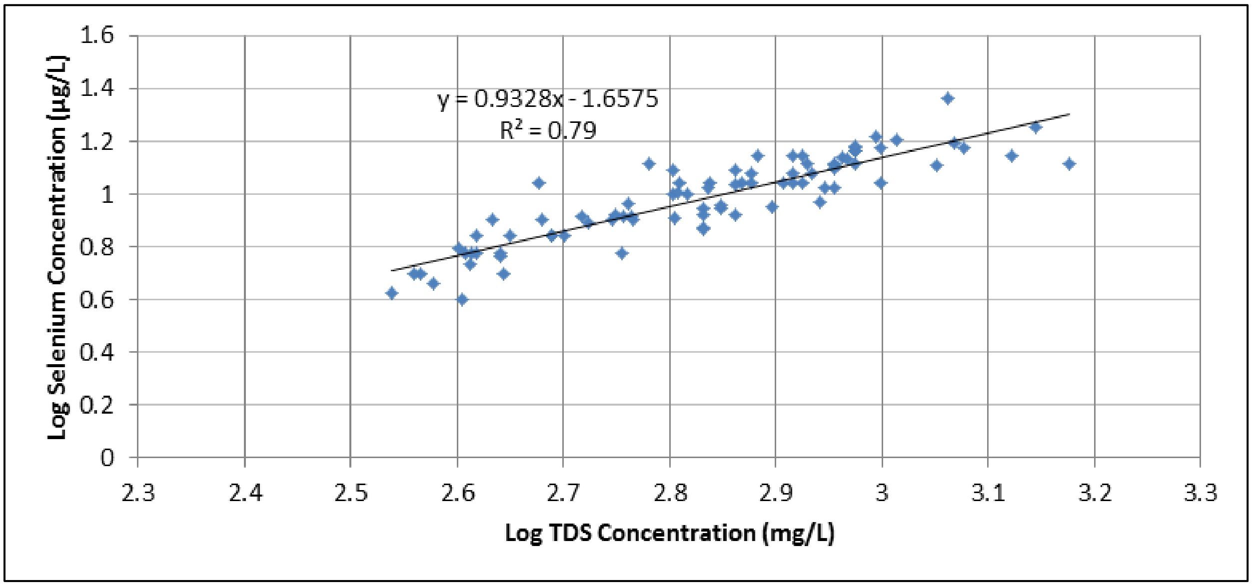


Figure 43. TDS and Selenium Concentration Relationship for Arkansas River at Catlin Dam Gage

The TDS and selenium relationship for the Arkansas River at Las Animas gage was based on the average USGS measured TDS and the selenium samples. Figure 44 shows the relationship between the two variables and corresponding R^2.

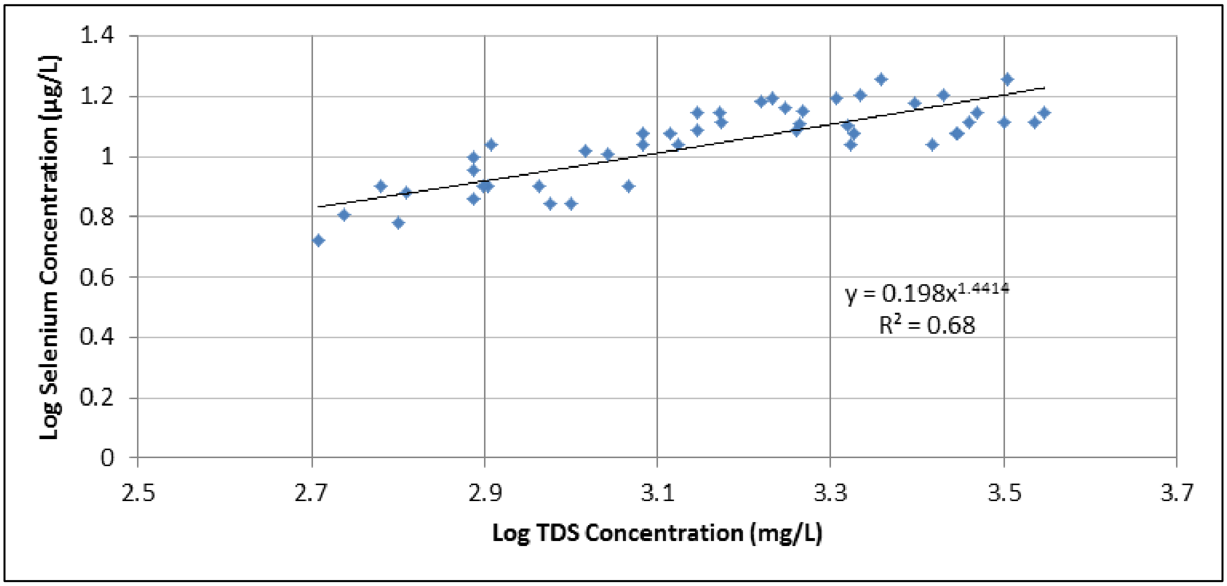


Figure 44. TDS and Selenium Concentration Relationship for Arkansas River at Las Animas Gage

Boundary Conditions

Selenium concentration at the Arkansas River above Pueblo gage was assumed as the upstream boundary condition for the AVC selenium analysis on the Arkansas River. Based on the Pueblo Reservoir total dissolved solids modeling by USGS (Ortiz 2012) and the relationship between selenium and salinity, the expected change of selenium concentrations among the alternatives is relatively small. Historical reconstructed selenium concentration at the Arkansas River above Pueblo gage was assumed to be the same for the comparative analysis of the alternatives with the selenium mass loading changing based only on the changes in reservoir releases volumes. Figure 45 shows the weekly historical reconstructed selenium concentration for the Arkansas River above Pueblo gage in this analysis.

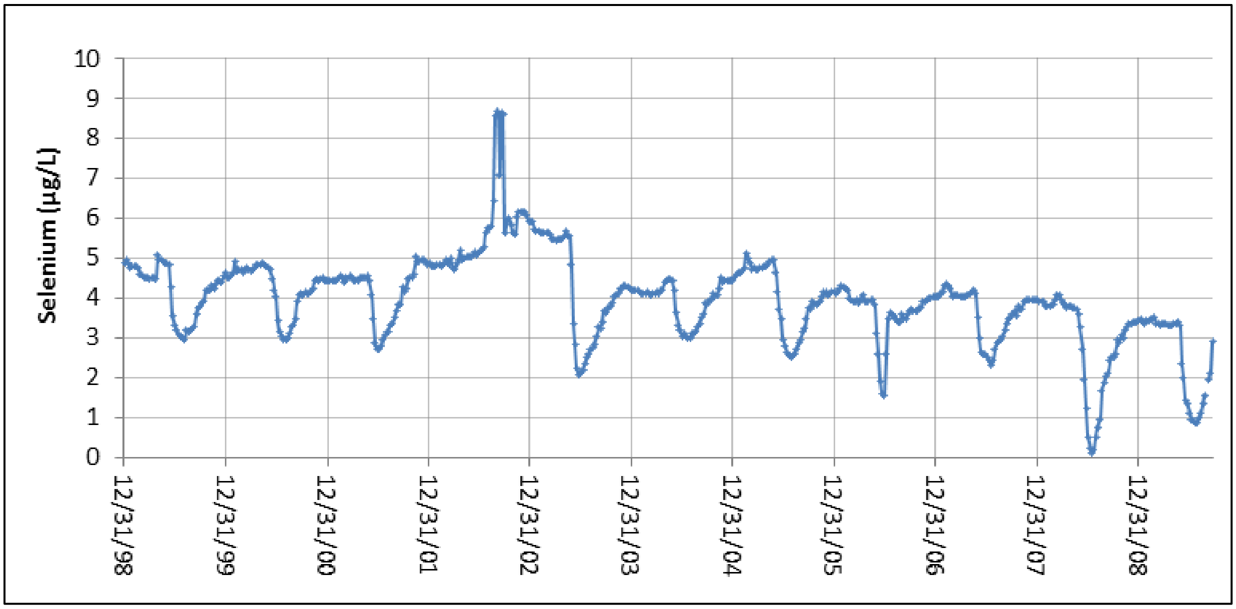


Figure 45. Historical Reconstructed Selenium Concentration for the Arkansas River above Pueblo Gage

The Fountain Creek at Colorado Springs gage is the upstream boundary in Fountain Creek. It is assumed that historical reconstructed concentration represents the selenium concentration at this location for all the alternatives because none of the alternatives would affect selenium concentration upstream of this point. The selenium loadings to the system at the Fountain Creek at Colorado Springs gage will change based on the predicted changes in flows for each of the alternatives. Figure 46 show the reconstructed historical concentration for the Fountain Creek at Colorado Springs gage.

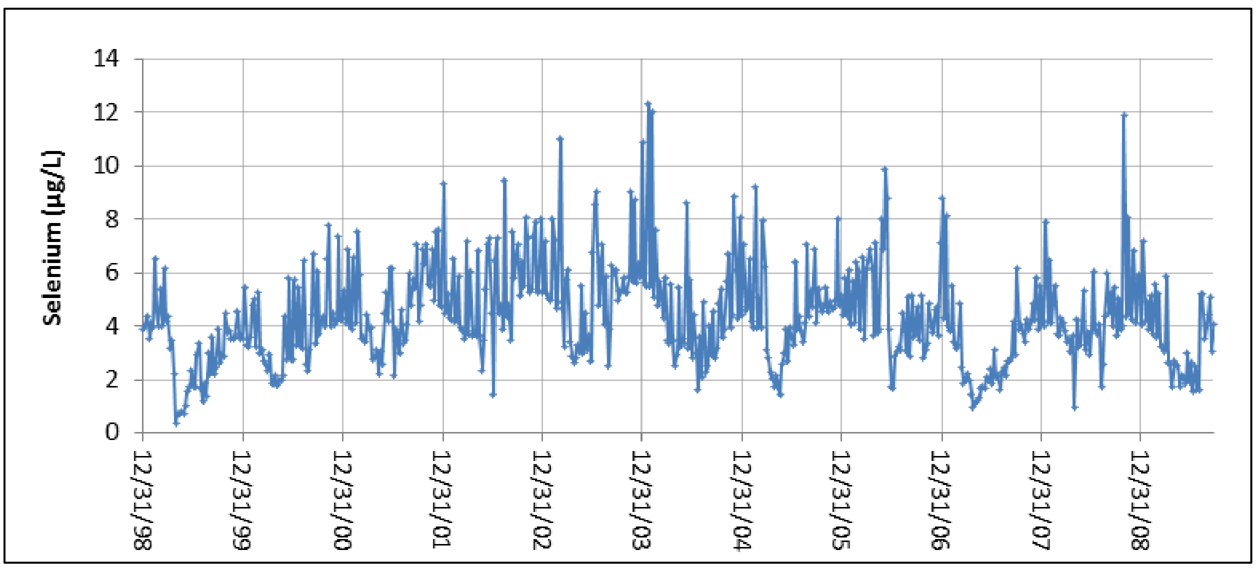


Figure 46. Historical Reconstructed Selenium Concentration for the Fountain Creek at Colorado Springs Gage

Larger variability of concentration was observed at the upstream boundary in Fountain Creek than in the Arkansas River. The larger variability is potentially caused by the city of Colorado Springs diverse return flows compared with the smoothing action of Pueblo Reservoir on this constituent. The monthly average selenium concentration for the most upstream nodes in Arkansas River and Fountain Creek are summarized in Table 44.

Table 44. Historical Reconstructed Selenium Concentration for Upstream Boundary Gages

Month	Selenium Concentration (µg/L)	
	Arkansas River above Pueblo	Fountain Creek at Colorado Springs
Jan	4.4	5.4
Feb	4.5	5.2
Mar	4.4	4.4
Apr	4.4	3.3
May	4.5	2.9
Jun	3.3	4.0
Jul	2.6	3.7
Aug	3.1	3.8
Sep	3.7	4.5
Oct	4.0	4.9
Nov	4.3	5.1
Dec	4.4	5.5

Table 45 shows the reconstructed historical concentration statistics at the upstream boundaries of the model corresponding to the Arkansas River above Pueblo gage and Fountain Creek at Colorado Springs gage.

Table 45. Simulated Selenium Concentration for Upstream Model Boundary Gages

Gage	Mean (µg/L)	Concentration Statistic (µg/L)				
		15	25	50	75	85
Arkansas River above Pueblo	4.0	3.0	3.4	4.1	4.6	4.9
Fountain Creek near Colorado Springs	4.4	2.6	3.1	4.1	5.4	6.2

Results

This section presents modeling assumptions and the calibrated concentration for the different modeled segments. The segments are named by the downstream gage.

As in salinity modeling, the calibrated concentration corresponds to a value assigned to the unknown selenium inflows to the segment. These values were calculated during the calibration process to simulate a concentration at the downstream station as close as possible to the measured concentration. Note that the values of calibrated concentration were only calculated for periods with net unmeasured gains to the segment; therefore, there were periods with no calibrated concentration that correspond to period with net unmeasured losses in the segment.

Concentration of the unmeasured losses corresponds to the simulated concentration at the downstream end of the segment that was computed by mixing the salt loads to the segment.

Calibration and Baseline Conditions

This section shows calibration results for selenium modeling of the study area. These results include calibrated concentrations by segment, computed for unmeasured concentrations to match as close as possible downstream concentration at the control point of the segment. Calibration results are summarized and presented as the flow-weighted concentration for the segment's inflows and the concentration computed for the unmeasured losses of the segment. The simulated and reconstructed historical concentrations per segment are compared to observe the result of the calibration mimicking historical concentration at the segment control point. The calibrated concentrations for historical inflows and outflows with unmeasured concentration are assumed to remain unchanged.

Calibrated concentrations are not necessarily associated with a physical selenium source because they are uniformly assigned to all the net inflows with unmeasured concentration in the segment and those inflows are not necessarily correlated with the missing selenium loads between the upstream end and the downstream end of the segment. The calibrated concentrations are constrained by an upper bound to keep the calibration from selecting unreasonable values to exactly match the segment downstream concentration. For this analysis, it was assumed that the calibration upper bound is 60 µg/L, which is about four times higher than the observed selenium concentration in the study area.

Selenium loadings from the WWTF in the study area were not explicitly estimated for this analysis. Selenium loading from the WWTF was estimated using the same methodology for segment inflows with unmeasured concentrations, assigning the segment calibrated concentration to the simulated WWTF effluent. Changes in selenium loadings from the WWTF for the alternatives were simulated based on changes in the WWTF effluent flow rate.

Arkansas River at Moffat St. Segment. This segment covers the Arkansas River from the Arkansas River above Pueblo gage, which is the boundary condition for the selenium analysis, to the Arkansas River at Moffat St. gage. This segment collects return flows from the west and central section of the City of Pueblo and the Pueblo West WWTF. Increases in selenium through transit in the segment streams are accounted for in the calibration of unmeasured concentrations. Figure 47 shows the weighted selenium concentration for the inflows with unmeasured concentration and the unmeasured losses at the Arkansas River at Moffat St. segment. Note that concentrations of unmeasured losses and inflows calibrated concentration are only computed for cases where flows are greater than zero, creating discontinuities in the plots.

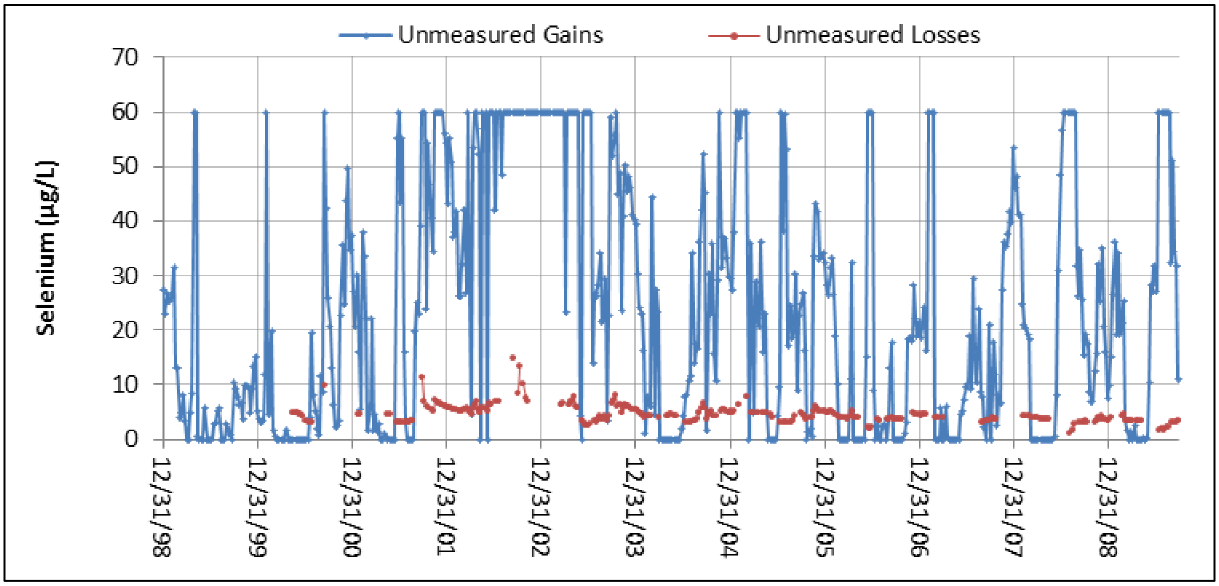


Figure 47. Selenium Calibrated Concentration for the Arkansas River at Moffat St. Segment

Results show an irregular selenium concentration of the unmeasured inflows, with several occasions resulting at the calibration upper bound for the segment (60 µg/L), especially during the extremely high concentrations recorded during extremely low flows in 2002 and 2003. Figure 48 compares weekly calibrated and measured concentration at the Arkansas River at Moffat St. gage.

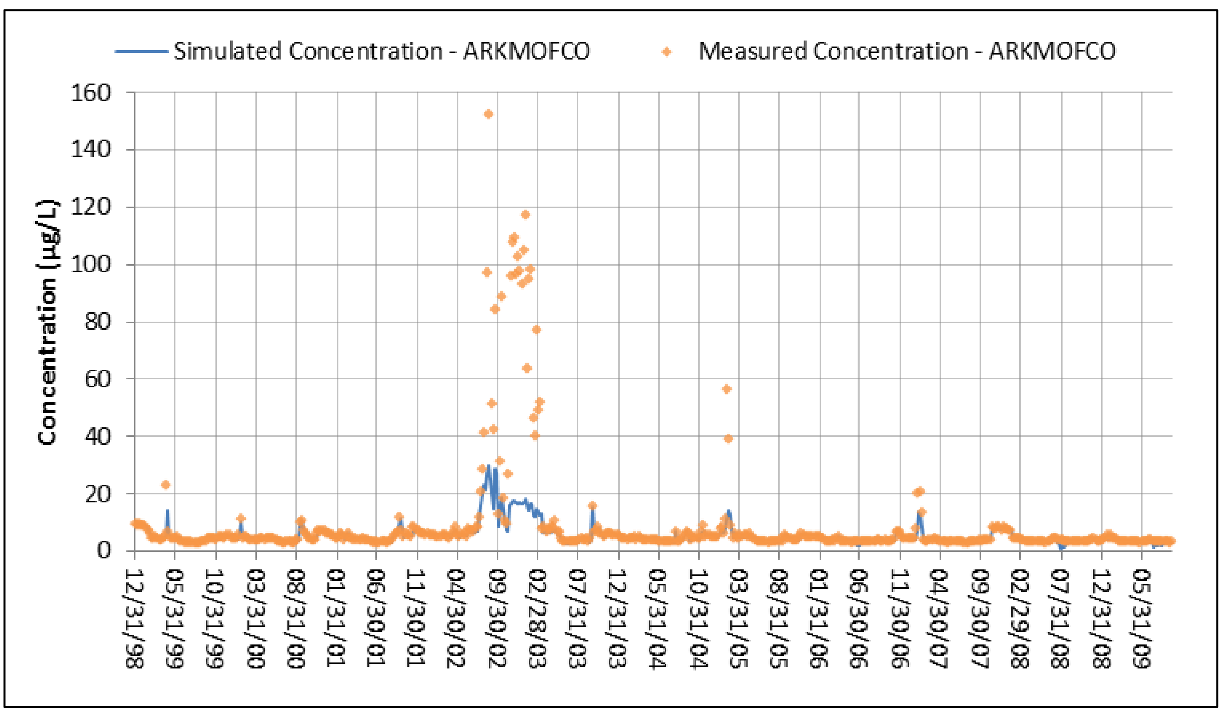


Figure 48. Comparison of Historical and Simulated Selenium Concentration for Arkansas River at Moffat St. Gage

In general, calibration results show a good match of the lower estimated selenium concentration with under prediction of the high peaks in 2002 and 2003. In this case the calibrated concentration upper bound is constraining the calibrate concentration to match closely high peaks from 2002 and 2003. These results are considered appropriate for this analysis because (1) the calibrated concentration upper bound is sufficient to represent the majority of the processes in the segment; (2) the frequency of the high peaks is low such that they do not affect the calculation of the 85% percentile (7.4 µg/L) that is used in the selenium effects analysis; and (3) there is a large uncertainty about the magnitude of the selenium at the 2002 and 2003 peaks because they are outside of the observed data value range. For these reasons, the use of the calibrated concentrations for the comparative analysis of the alternatives is considered a valid approach for analyzing the selenium relative effects.

Fountain Creek at Security Segment. This is the first segment modeled on Fountain Creek, and includes the estimated concentration at Fountain Creek at Colorado Springs gage, which is the model upstream boundary in Fountain Creek. Selenium concentration for unmeasured contributors was estimated to match the segment downstream estimated concentration. Figure 49 shows the weekly calibrated and simulated concentration for the segment unmeasured gains and losses, respectively.

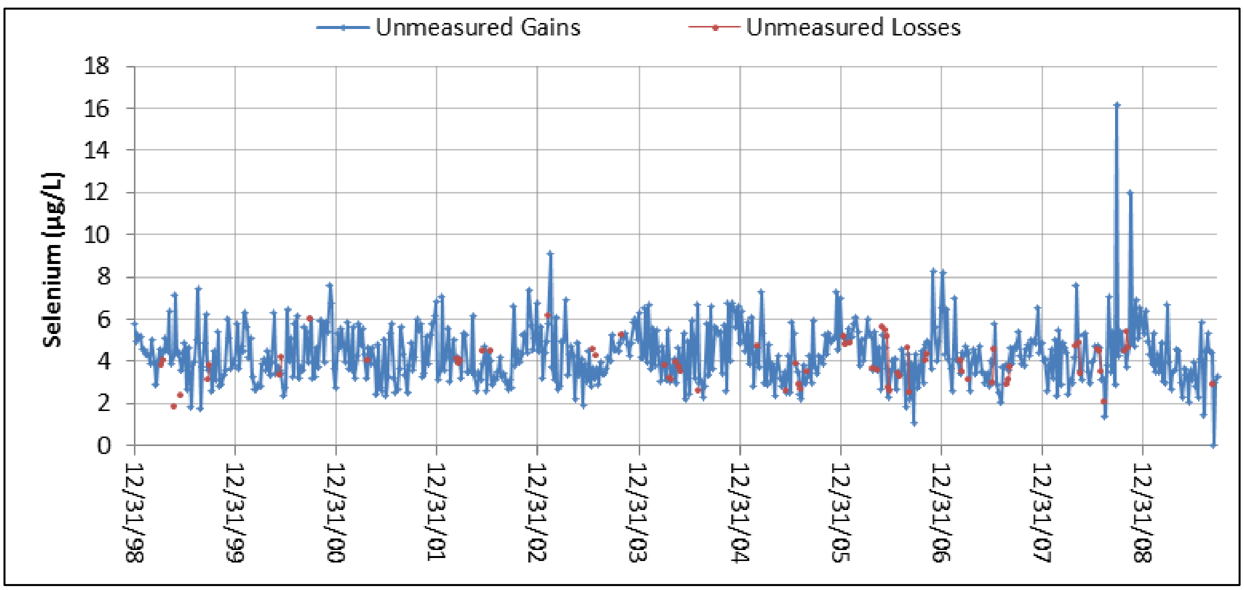


Figure 49. Selenium Calibrated Concentration for the Fountain Creek at Security Segment

Results show relative small variability on the unmeasured gains concentration throughout the modeled period and about the same range of concentration for the gains and losses, indicating a small increase in selenium concentration from the upstream end to the downstream end of the segment. Figure 50 shows the calibration results for the Fountain Creek at Security gage.

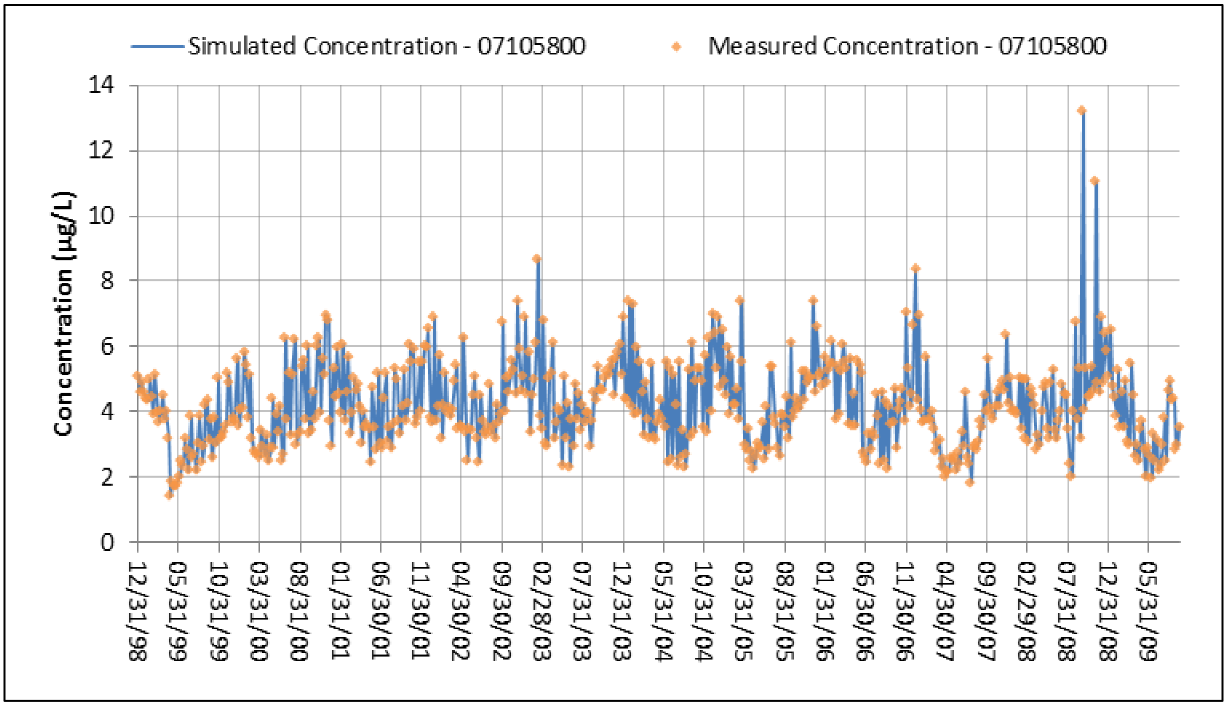


Figure 50. Comparison of Historical and Simulated Selenium Concentration for Fountain Creek at Security Gage

The flow amount and number of inflows with unmeasured concentration allow having an excellent match of the selenium concentration at this control point.

Fountain Creek at Pueblo Segment. This is the most downstream segment on Fountain Creek before it flows into the Arkansas River. This segment includes limited number of inflows with unmeasured concentrations and the assumed calibration concentration upper bound limits the ability to match closer the reconstructed historical concentration at the downstream control point of the segment. Figure 51 shows the calibrated selenium concentration for the inflows with unmeasured concentrations and the calculated concentration for the unmeasured losses only for periods with net unmeasured losses in the Fountain Creek at Pueblo segment.

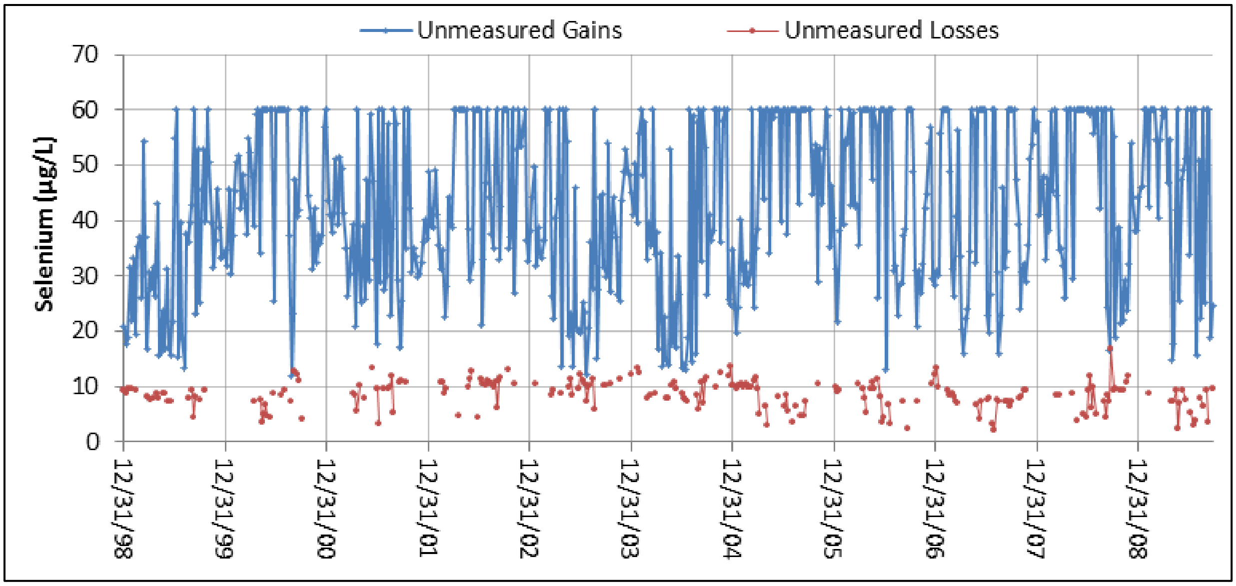


Figure 51. Selenium Calibrated Concentration for the Fountain Creek at Pueblo Segment

Figure 52 compares the calibrated selenium concentration and the historical estimated concentration at Fountain Creek at Pueblo gage. Although high historical estimated concentration values at the control point of this segment were underestimated during the calibration, the majority of these peaks are above the 85th percentile (18.7 µg/L); thus, the calibration is considered appropriate to perform the comparative selenium effects for the alternatives.

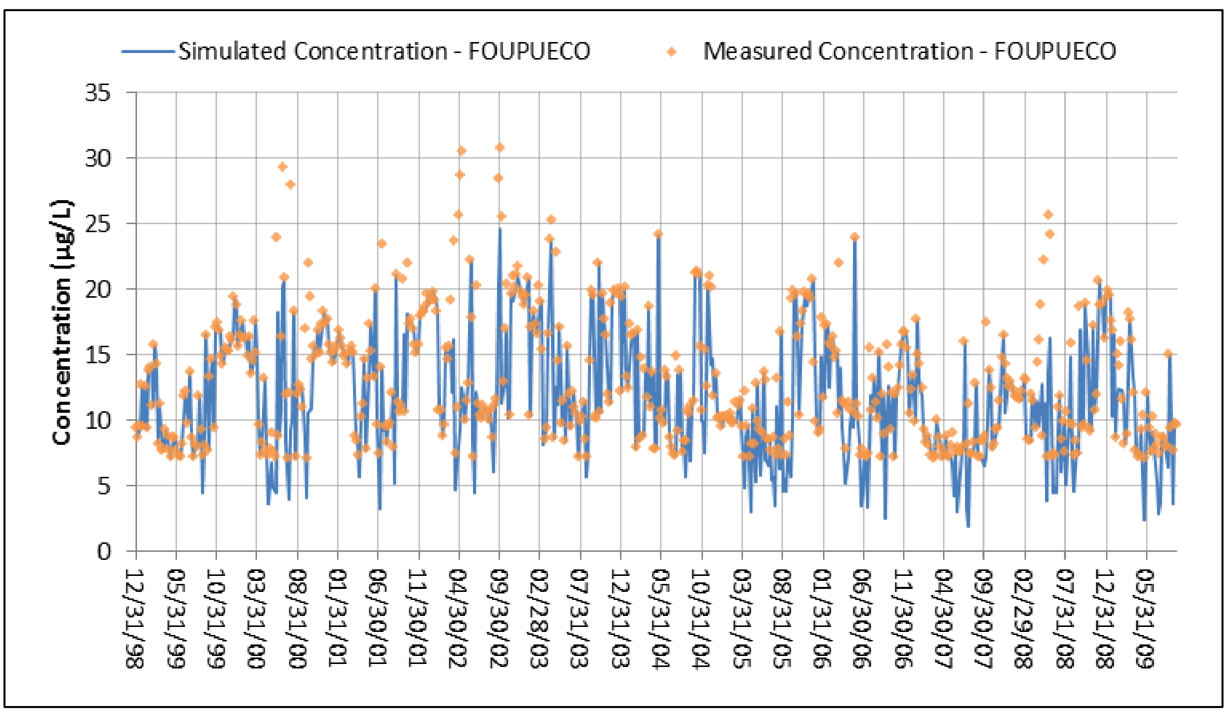


Figure 52. Comparison of Historical and Simulated Selenium Concentration for Fountain Creek at Pueblo Gage

Arkansas River at Avondale Segment. This segment contains the confluence of Fountain Creek and the Arkansas River. The calibration of the segment took into account the mixing of the simulated selenium loads at Fountain Creek at Pueblo gage and the Arkansas River at Moffat St. gage with the historical estimated concentrations from the Saint Charles River. Figure 53 shows the calibrated concentration for inflows with unmeasured concentrations to the segment, as well as the calculated concentration of the unmeasured losses only for periods with net unmeasured losses in the segment.

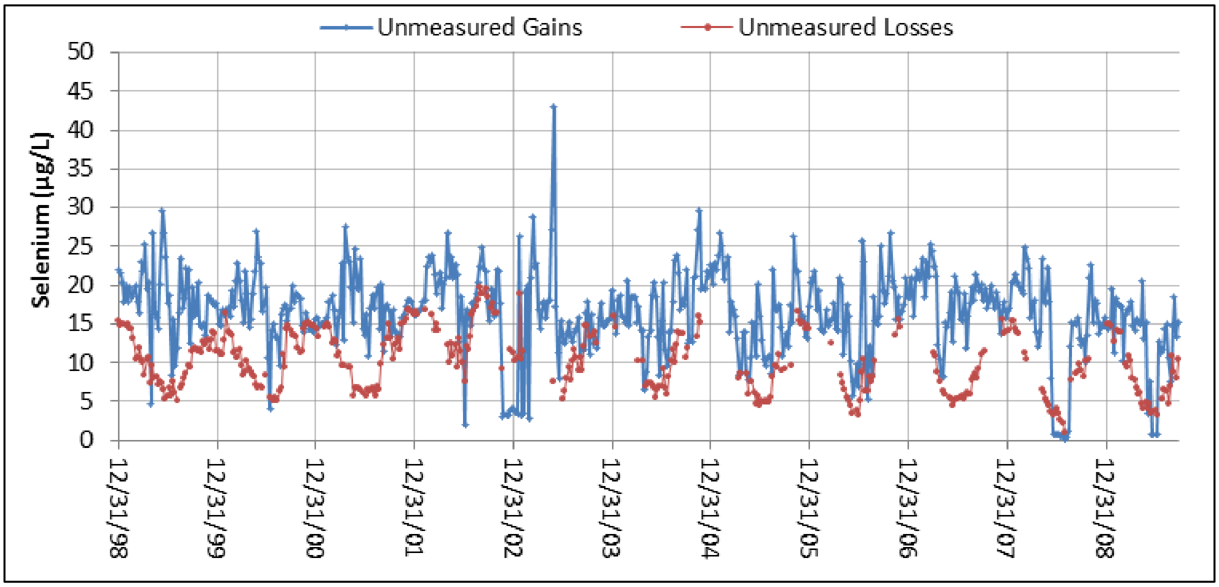


Figure 53. Selenium Calibrated Concentration for the Arkansas River near Avondale Segment

The segment contains seven return flow points with unmeasured concentration, allowing flexibility in the calibration process to provide a good match of the historical downstream concentration. Note that the calibration process self corrects the underestimation of concentration observed at the Fountain Creek at Pueblo gage. Figure 54 shows the comparison between the calibrated and reconstructed historical selenium concentration for the Arkansas River near Avondale control point. Results show a tight fit between the historical and calibrated concentration, with the exception of the dry period of 2002 and 2003.

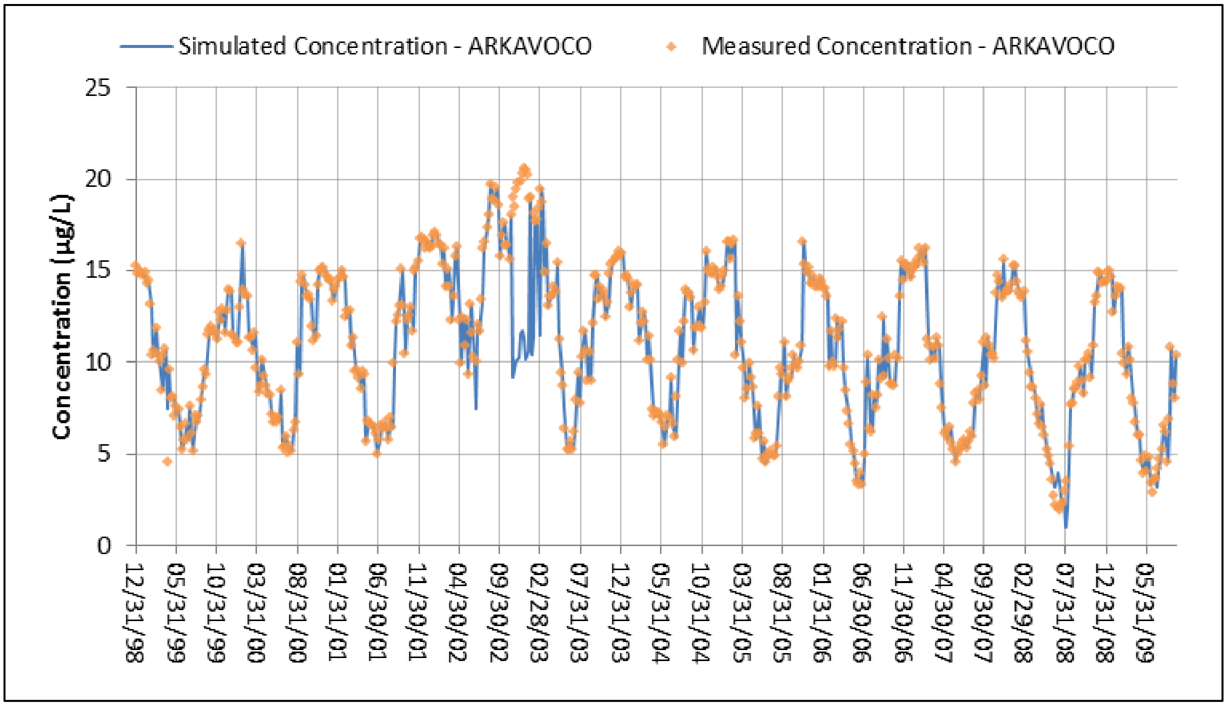


Figure 54. Comparison of Historical and Simulated Selenium Concentration for Arkansas River near Avondale Gage

Arkansas River at Catlin Dam Segment. This segment collects the Apishapa River and Huerfano River contributions. Selenium concentrations on these tributaries were estimated as part of the calibration process. The representative selenium concentrations of the segment inflows without measured concentration has large variability but similar magnitude with the in-segment computed concentration for the unmeasured losses, indicating selenium loads in this segment with similar concentration to the stream concentration. Zero calibrated concentration for unmeasured gains indicates cases in which the simulated balance of selenium in the segment has a lower concentration than the historical concentration at the downstream gage. Figure 55 shows the representative selenium concentration for the inflows with unmeasured concentrations and simulated concentration of unmeasured losses of this segment.

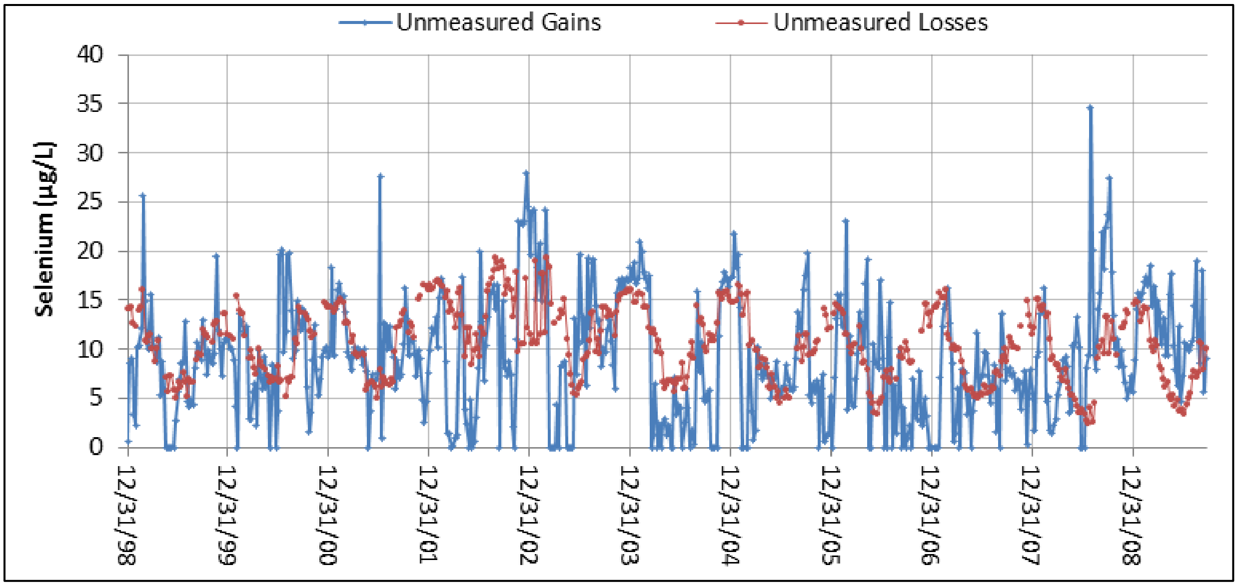


Figure 55. Selenium Calibrated Concentration for the Arkansas River at Catlin Dam Segment

The number of inflows without measured/estimated concentration to this segment allowed flexibility in the calibration procedure to match closely the downstream concentration, further offsetting errors observed at the Arkansas River near Avondale gage during the 2002 and 2003 periods. Figure 56 compares calibrated concentration and the historical estimated concentration for the Arkansas River at Catlin Dams gage.

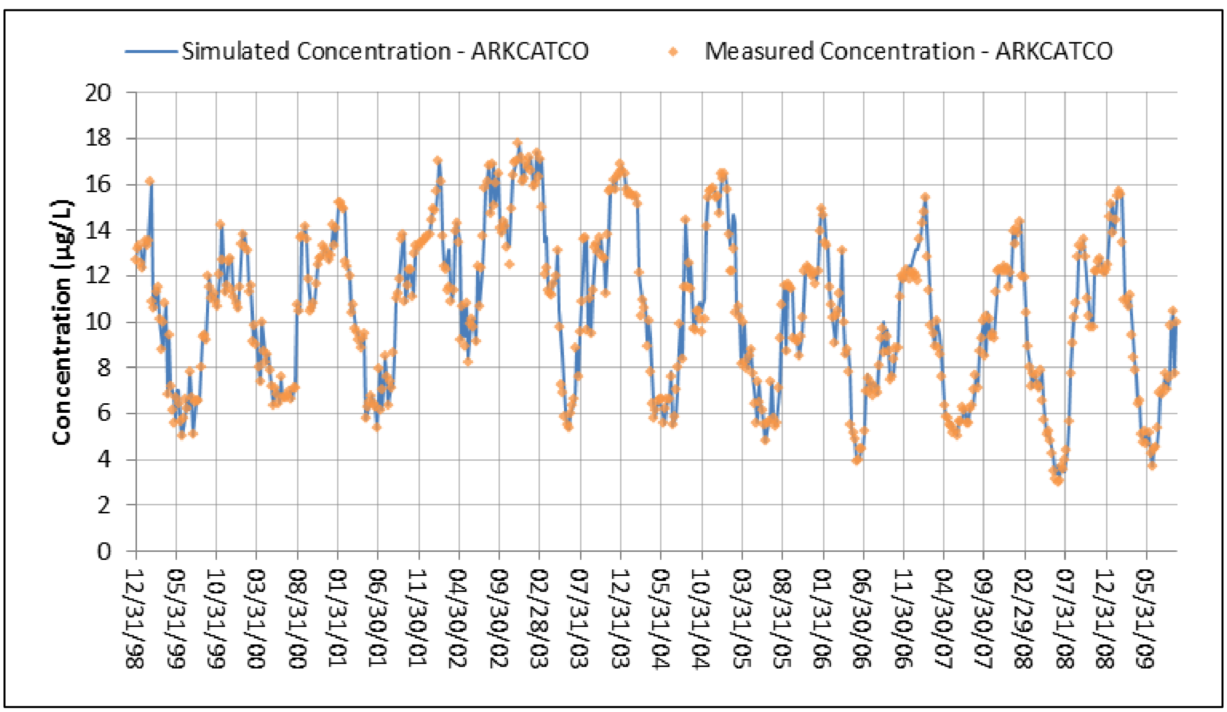


Figure 56. Comparison of Historical and Simulated Selenium Concentration for the Arkansas River at Catlin Dam Gage

Arkansas River at Las Animas Segment. This segment receives loads from the flow-measured tributaries Timpas Creek and Crooked Arroyo, which in this case, do not have selenium measurements. Intermediate gages on the Arkansas River in this segment allowed estimating unmeasured flow gains and losses between those gages, gains which are a source of unmeasured selenium loadings. Figure 57 shows the weekly calibrated concentration for the segment based on the concentrations for each of the segment inflows with unmeasured selenium, and the computed concentration for unmeasured losses for periods with net losses in this segment.

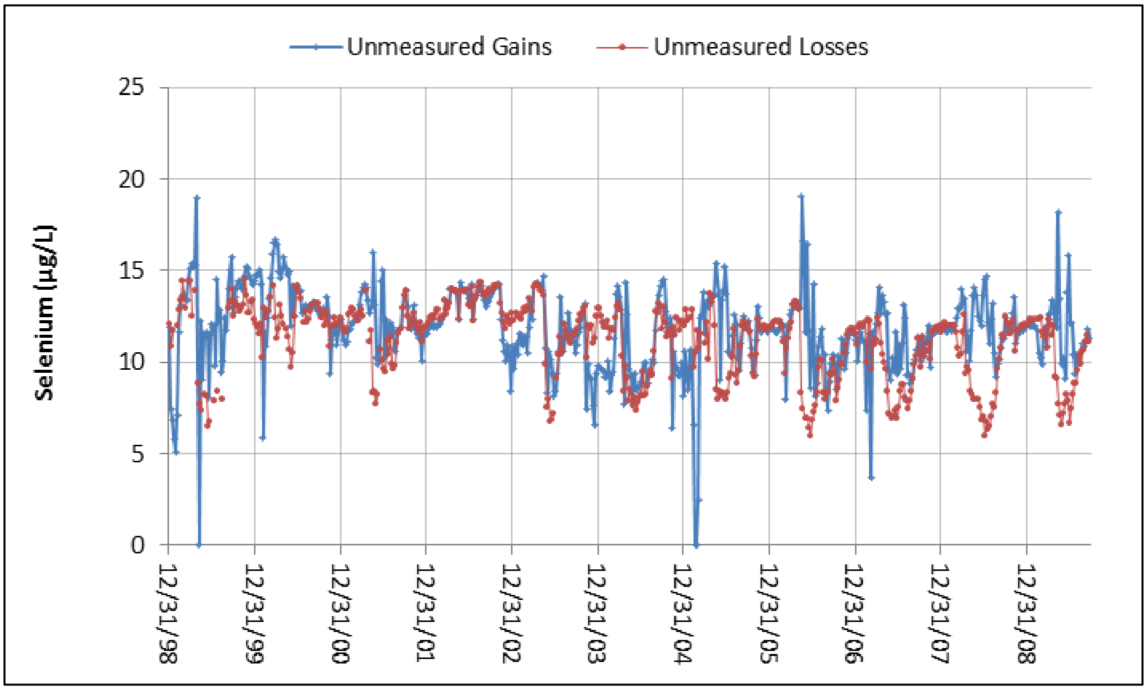


Figure 57. Selenium Calibrated Concentration for the Arkansas River at Las Animas Segment

The unmeasured concentration assigned in the calibration process allowed a close match of the historical reconstructed concentration at the Arkansas River at Las Animas gage. Figure 58 shows the comparison between the simulated and the historical concentration for the Arkansas River at Las Animas gage.

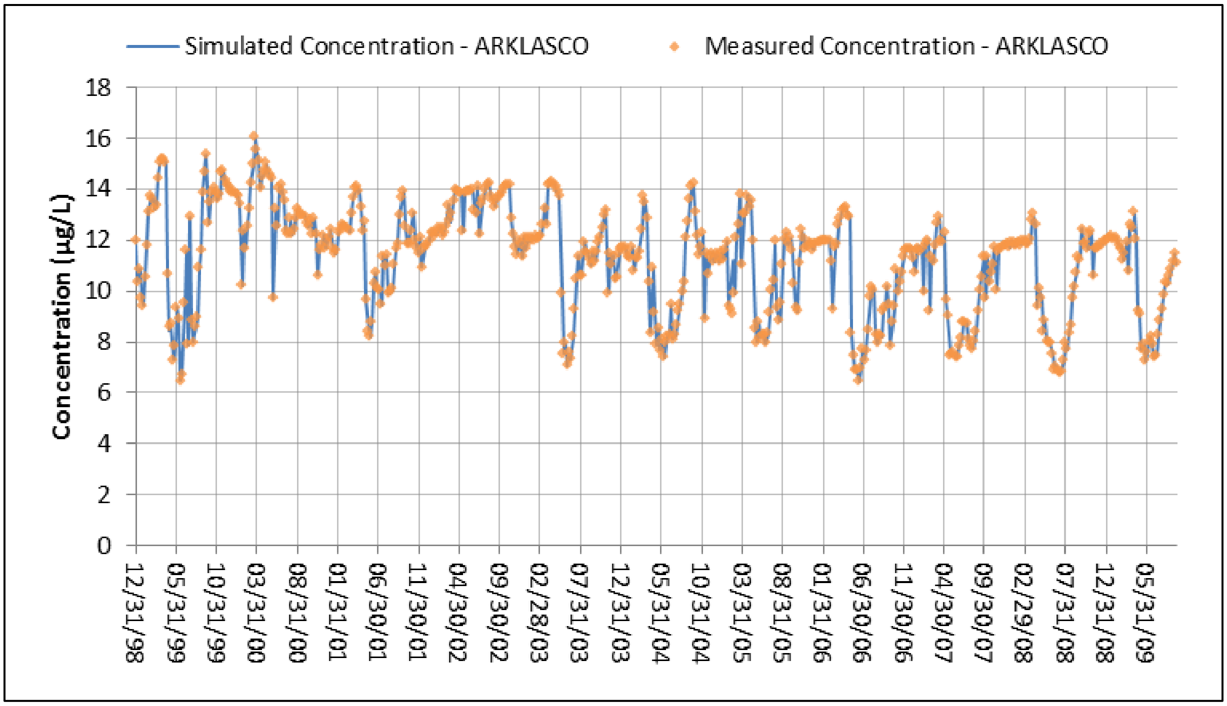


Figure 58. Comparison of Historical and Simulated Selenium Concentration for the Arkansas River at Las Animas Gage

Simulation of Alternatives

Changes in selenium loadings for the direct and cumulative effects scenarios were analyzed for the alternatives. The calibrated selenium model was used as the base for the simulation of the alternatives. Following a methodology similar to salinity, calibrated selenium concentrations of inflows without measured selenium were assumed to be representative of the sources of selenium while the inflows and outflows to each alternative for the direct and cumulative effects are based on the Daily Model simulated flows.

Changes in selenium loads to the system under each alternative were simulated according to the changes of flow simulated in the Daily Model and the calibrated concentrations (e.g., WWTF and agricultural return flows). Selenium loads were routed and mixed with other simulated selenium loads from upstream to downstream, allowing simulation of selenium concentration at the diversion and control points (gages).

According to the methodology adopted, changes in selenium loads from the WWTFs were assumed to change only due to changes in effluent flows and using calibrated concentrations at these locations for all cases. Based on the assumption that WWTF concentrations are the same in future conditions as historical, only effluent flow changes determine the simulated changes in selenium loadings from the WWTF. None of the alternatives is expected to significantly affect the selenium concentration of the WWTFs effluent relative to other alternatives; therefore, it is believed that this approach is appropriate to evaluate the selenium effects in this study.

Similarly, changes in selenium loadings from agricultural return flows in this analysis are based on the simulated changes in flows due to changes in agricultural irrigation in the project area.

The underlying assumption in this methodology is that the calibrated concentration of this selenium source remains unchanged for the different alternatives, which is considered an appropriate assumption for the relative comparison of alternatives performed in this section.

Direct Effects Analysis. A comparative analysis with the No Action Alternative and Existing Condition was performed to estimate the changes in selenium concentration under each alternative. The results are summarized comparing the statistics of the simulated concentration and the relative changes of the statistics for the control points in the study area. Monthly statistics of the simulated concentration for the different alternatives and their percent change with respect to No Action and existing conditions for the direct effect analysis is also presented to observe the temporal changes in selenium under each alternative. Table 13 shows a summary of direct and indirect selenium effects in the Arkansas River and Fountain Creek.

Table 46. Summary of Direct and Indirect Selenium Effects

Gage	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Mean Concentration (µg/L)								
Arkansas River at Moffat St.	5.4	5.6	5.8	5.8	5.8	5.8	5.3	5.6
Arkansas River near Avondale	10.3	10.2	10.4	10.4	10.3	10.4	10.3	10.3
Arkansas River at Catlin Dam	10.0	10.0	10.1	10.1	10.0	10.1	10.0	10.0
Arkansas River at Las Animas	11.2	11.1	11.1	11.1	11.1	11.2	11.1	11.1
Fountain Creek at Pueblo	12.4	11.6	11.7	11.7	11.6	11.7	11.7	11.7
85^{th} Percentile Concentration (µg/L)								
Arkansas River at Moffat St.	6.8	7.2	7.5	7.6	7.5	7.5	7.1	7.3
Arkansas River near Avondale	14.2	14.0	14.4	14.4	14.2	14.3	14.2	14.1
Arkansas River at Catlin Dam	13.9	13.8	14.0	14.0	14.0	14.1	14.0	14.0
Arkansas River at Las Animas	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Fountain Creek at Pueblo	18.4	16.4	16.6	16.6	16.3	16.6	16.6	16.7

Table 47 and Table 48 show the statistics and relative change with respect to the No Action Alternative and the existing conditions for the Arkansas River at Moffat St. gage. All alternatives, except River South and Master Contract Only, would have minor adverse effects to selenium, compared to the No Action. Monthly changes in concentration would have the largest percent changes in January to March, August and September. The River South and Master Contract Only alternatives would have negligible effects because AVC participant supplies would not bypass this gage for these alternatives. All alternatives would increase selenium concentrations, compared to existing conditions.

Table 47. Simulated Selenium Concentration Comparison for Arkansas River at Moffat St. Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	5.4	5.6	5.8	5.8	5.8	5.8	5.3	5.6
15th percentile	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
25th percentile	3.5	3.5	3.6	3.6	3.5	3.5	3.5	3.5
50th percentile	4.4	4.5	4.5	4.5	4.5	4.5	4.4	4.5
75th percentile	5.8	6.1	6.5	6.5	6.4	6.5	5.9	6.2
85th percentile	6.8	7.2	7.5	7.6	7.5	7.5	7.1	7.3
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.2 (3.6)	0.2 (3.6)	0.2 (3.6)	0.2 (3.6)	-0.3 (-5.4)	0.0 (0.0)
15th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	---	0.1 (2.9)	0.1 (2.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
50th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	-0.1 (-2.2)	0.0 (0.0)
75th percentile	---	---	0.4 (6.6)	0.4 (6.6)	0.3 (4.9)	0.4 (6.6)	-0.2 (-3.3)	0.1 (1.6)
85th percentile	---	---	0.3 (4.2)	0.4 (5.6)	0.3 (4.2)	0.3 (4.2)	-0.1 (-1.4)	0.1 (1.4)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.2 (3.7)	0.4 (7.4)	0.4 (7.4)	0.4 (7.4)	0.4 (7.4)	-0.1 (-1.9)	0.2 (3.7)
15th percentile	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	0.0 (0.0)	0.1 (2.9)	0.1 (2.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
50th percentile	---	0.1 (2.3)	0.1 (2.3)	0.1 (2.3)	0.1 (2.3)	0.1 (2.3)	0.0 (0.0)	0.1 (2.3)
75th percentile	---	0.3 (5.2)	0.7 (12.1)	0.7 (12.1)	0.6 (10.3)	0.7 (12.1)	0.1 (1.7)	0.4 (6.9)
85th percentile	---	0.4 (5.9)	0.7 (10.3)	0.8 (11.8)	0.7 (10.3)	0.7 (10.3)	0.3 (4.4)	0.5 (7.4)

Table 48. Direct Effects Monthly Simulated Selenium Concentration for Arkansas River at Moffat St. Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	6.5	6.7	7.1	7.1	7.0	7.1	6.4	6.8
Feb	7.4	7.7	8.1	8.1	8.1	8.1	6.9	7.7
Mar	5.0	5.1	5.3	5.3	5.3	5.3	5.0	5.2
Apr	4.7	4.9	4.9	5.0	5.0	4.9	4.8	4.8
May	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Jun	3.7	3.8	3.8	3.8	3.8	3.8	3.7	3.8
Jul	3.6	3.7	3.8	3.8	3.8	3.8	3.5	3.7
Aug	4.8	5.1	5.4	5.4	5.4	5.4	4.4	5.1
Sep	6.0	6.3	6.7	6.7	6.7	6.7	5.6	6.3
Oct	5.4	5.8	6.1	6.1	6.0	6.1	5.7	5.9
Nov	6.3	6.6	6.8	6.8	6.8	6.8	6.2	6.6
Dec	6.9	7.3	7.5	7.6	7.5	7.5	6.9	7.3
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.4 (5.5)	0.4 (5.6)	0.3 (4.4)	0.4 (5.5)	-0.3 (-4.3)	0.1 (1.1)
Feb	---	---	0.4 (4.9)	0.4 (5.2)	0.4 (5.4)	0.4 (4.9)	-0.8 (-10.2)	0 (0.1)
Mar	---	---	0.2 (3.5)	0.2 (3.7)	0.2 (3.6)	0.2 (3.4)	-0.1 (-3.4)	0.1 (0.7)
Apr	---	---	0 (1.6)	0.1 (1.8)	0.1 (3.7)	0 (1.5)	-0.1 (-0.7)	-0.1 (-0.7)
May	---	---	0 (0.7)	0 (0.7)	0 (0.5)	0 (0.7)	0 (0.2)	0 (0.4)
Jun	---	---	0 (0.6)	0 (0.6)	0 (0.5)	0 (0.5)	-0.1 (-1.2)	0 (0.0)
Jul	---	---	0.1 (2.4)	0.1 (2.3)	0.1 (2.0)	0.1 (2.4)	-0.2 (-6.1)	0 (0.0)
Aug	---	---	0.3 (5.6)	0.3 (5.5)	0.3 (5.4)	0.3 (5.2)	-0.7 (-14.4)	0 (0.8)
Sep	---	---	0.4 (6.9)	0.4 (7.2)	0.4 (6.2)	0.4 (7.1)	-0.7 (-10.8)	0 (-0.3)
Oct	---	---	0.3 (5.1)	0.3 (5.1)	0.2 (2.6)	0.3 (5.1)	-0.1 (-1.8)	0.1 (1.9)
Nov	---	---	0.2 (2.9)	0.2 (2.9)	0.2 (2.9)	0.2 (2.9)	-0.4 (-6.0)	0 (-0.8)
Dec	---	---	0.2 (3.9)	0.3 (4.0)	0.2 (3.5)	0.2 (3.9)	-0.4 (-5.5)	0 (0.3)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.2 (3.0)	0.6 (8.7)	0.6 (8.7)	0.5 (7.6)	0.6 (8.7)	-0.1 (-1.4)	0.3 (4.1)
Feb	---	0.3 (4.2)	0.7 (9.3)	0.7 (9.6)	0.7 (9.8)	0.7 (9.3)	-0.5 (-6.5)	0.3 (4.2)
Mar	---	0.1 (3.3)	0.3 (6.9)	0.3 (7.1)	0.3 (7.0)	0.3 (6.8)	0 (-0.2)	0.2 (4.0)
Apr	---	0.2 (2.5)	0.2 (4.2)	0.3 (4.3)	0.3 (6.3)	0.2 (4.1)	0.1 (1.8)	0.1 (1.8)
May	---	0 (1.3)	0 (2.0)	0 (2.0)	0 (1.8)	0 (2.0)	0 (1.4)	0 (1.7)
Jun	---	0.1 (1.2)	0.1 (1.8)	0.1 (1.8)	0.1 (1.8)	0.1 (1.8)	0 (0.0)	0.1 (1.3)
Jul	---	0.1 (2.8)	0.2 (5.2)	0.2 (5.2)	0.2 (4.8)	0.2 (5.2)	-0.1 (-3.4)	0.1 (2.8)
Aug	---	0.3 (5.2)	0.6 (11.0)	0.6 (10.9)	0.6 (10.9)	0.6 (10.7)	-0.4 (-10.0)	0.3 (6.0)
Sep	---	0.3 (5.6)	0.7 (12.8)	0.7 (13.2)	0.7 (12.1)	0.7 (13.1)	-0.4 (-5.8)	0.3 (5.2)
Oct	---	0.4 (7.9)	0.7 (13.4)	0.7 (13.4)	0.6 (10.8)	0.7 (13.4)	0.3 (5.9)	0.5 (10.0)
Nov	---	0.3 (5.4)	0.5 (8.4)	0.5 (8.4)	0.5 (8.5)	0.5 (8.4)	-0.1 (-1.0)	0.3 (4.5)
Dec	---	0.4 (5.4)	0.6 (9.5)	0.7 (9.6)	0.6 (9.1)	0.6 (9.5)	0 (-0.4)	0.4 (5.8)

Table 49 and Table 50 show the statistics summary for the simulated selenium concentrations at Arkansas River near Avondale gage. All alternatives would have negligible effects to selenium, compared to the No Action, as effects are around 2 percent or less. Monthly simulated concentration effects have the greatest percent changes in January, March, and October. All alternatives would not substantially change selenium concentrations, compared to existing conditions.

Table 49. Simulated Selenium Concentration Comparison for Arkansas River near Avondale Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	10.3	10.2	10.4	10.4	10.3	10.4	10.3	10.3
15th percentile	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
25th percentile	7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.4
50th percentile	10.1	10.4	10.5	10.5	10.4	10.5	10.4	10.4
75th percentile	13.3	13.1	13.4	13.4	13.3	13.4	13.3	13.3
85th percentile	14.2	14.0	14.4	14.4	14.2	14.3	14.2	14.1
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.2 (2.0)	0.2 (2.0)	0.1 (1.0)	0.2 (2.0)	0.1 (1.0)	0.1 (1.0)
15th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
50th percentile	---	---	0.1 (1.0)	0.1 (1.0)	0.0 (0.0)	0.1 (1.0)	0.0 (0.0)	0.0 (0.0)
75th percentile	---	---	0.3 (2.3)	0.3 (2.3)	0.2 (1.5)	0.3 (2.3)	0.2 (1.5)	0.2 (1.5)
85th percentile	---	---	0.4 (2.9)	0.4 (2.9)	0.2 (1.4)	0.3 (2.1)	0.2 (1.4)	0.1 (0.7)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	-0.1 (-1.0)	0.1 (1.0)	0.1 (1.0)	0.0 (0.0)	0.1 (1.0)	0.0 (0.0)	0.0 (0.0)
15th percentile	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	0.1 (1.4)	0.1 (1.4)	0.1 (1.4)	0.1 (1.4)	0.1 (1.4)	0.1 (1.4)	0.1 (1.4)
50th percentile	---	0.3 (3.0)	0.4 (4.0)	0.4 (4.0)	0.3 (3.0)	0.4 (4.0)	0.3 (3.0)	0.3 (3.0)
75th percentile	---	-0.2 (-1.5)	0.1 (0.8)	0.1 (0.8)	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)
85th percentile	---	-0.2 (-1.4)	0.2 (1.4)	0.2 (1.4)	0.0 (0.0)	0.1 (0.7)	0.0 (0.0)	-0.1 (-0.7)

Table 50. Direct Effects Monthly Simulated Selenium Concentration for Arkansas River near Avondale Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	13.2	12.9	13.3	13.3	13.1	13.3	13.1	13.2
Feb	14.6	14.3	14.5	14.5	14.4	14.5	14.4	14.4
Mar	11.8	11.8	12.1	12.1	12.0	12.1	12.0	12.0
Apr	9.4	9.6	9.8	9.8	9.7	9.8	9.8	9.8
May	7.3	7.3	7.4	7.4	7.4	7.4	7.4	7.4
Jun	5.6	5.6	5.7	5.7	5.7	5.7	5.6	5.6
Jul	5.9	6.1	6.2	6.2	6.1	6.2	6.0	6.1
Aug	8.3	8.2	8.3	8.3	8.2	8.3	8.2	8.2
Sep	10.6	10.7	10.8	10.8	10.7	10.8	10.5	10.6
Oct	11.7	11.8	12.1	12.1	11.9	12.1	12.1	12.0
Nov	12.4	12.4	12.5	12.5	12.5	12.5	12.4	12.4
Dec	13.5	13.2	13.3	13.4	13.2	13.3	13.2	13.2
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.4 (2.9)	0.4 (3.0)	0.2 (1.0)	0.4 (2.9)	0.2 (1.1)	0.3 (2.2)
Feb	---	---	0.2 (1.0)	0.2 (1.0)	0.1 (0.7)	0.2 (1.0)	0.1 (0.2)	0.1 (0.5)
Mar	---	---	0.3 (3.1)	0.3 (3.3)	0.2 (1.6)	0.3 (2.9)	0.2 (2.3)	0.2 (2.1)
Apr	---	---	0.2 (1.7)	0.2 (1.7)	0.1 (0.6)	0.2 (1.7)	0.2 (2.0)	0.2 (1.5)
May	---	---	0.1 (1.1)	0.1 (1.1)	0.1 (0.5)	0.1 (1.1)	0.1 (1.1)	0.1 (0.7)
Jun	---	---	0.1 (0.9)	0.1 (0.9)	0.1 (0.7)	0.1 (0.9)	0 (-0.1)	0 (0.2)
Jul	---	---	0.1 (2.0)	0.1 (1.6)	0 (1.2)	0.1 (2.0)	-0.1 (-0.9)	0 (0.8)
Aug	---	---	0.1 (1.4)	0.1 (1.5)	0 (0.2)	0.1 (1.5)	0 (-0.5)	0 (0.4)
Sep	---	---	0.1 (1.3)	0.1 (1.3)	0 (0.8)	0.1 (1.3)	-0.2 (-1.1)	-0.1 (-0.1)
Oct	---	---	0.3 (2.7)	0.3 (2.6)	0.1 (1.1)	0.3 (2.7)	0.3 (2.6)	0.2 (2.0)
Nov	---	---	0.1 (0.8)	0.1 (0.8)	0.1 (0.9)	0.1 (0.8)	0 (-0.5)	0 (-0.4)
Dec	---	---	0.1 (1.4)	0.2 (1.4)	0 (0.6)	0.1 (1.4)	0 (0.2)	0 (0.4)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.3 (-1.8)	0.1 (1.1)	0.1 (1.2)	-0.1 (-0.8)	0.1 (1.1)	-0.1 (-0.7)	0 (0.3)
Feb	---	-0.3 (-1.7)	-0.1 (-0.8)	-0.1 (-0.7)	-0.2 (-1.0)	-0.1 (-0.8)	-0.2 (-1.5)	-0.2 (-1.2)
Mar	---	0 (0.0)	0.3 (3.1)	0.3 (3.3)	0.2 (1.6)	0.3 (2.9)	0.2 (2.3)	0.2 (2.1)
Apr	---	0.2 (2.4)	0.4 (4.1)	0.4 (4.1)	0.3 (2.9)	0.4 (4.1)	0.4 (4.5)	0.4 (3.9)
May	---	0 (0.3)	0.1 (1.4)	0.1 (1.4)	0.1 (0.8)	0.1 (1.4)	0.1 (1.4)	0.1 (1.0)
Jun	---	0 (-0.2)	0.1 (0.7)	0.1 (0.8)	0.1 (0.5)	0.1 (0.7)	0 (-0.3)	0 (0.0)
Jul	---	0.2 (2.2)	0.3 (4.2)	0.3 (3.8)	0.2 (3.4)	0.3 (4.2)	0.1 (1.3)	0.2 (3.0)
Aug	---	-0.1 (-0.6)	0 (0.8)	0 (0.8)	-0.1 (-0.4)	0 (0.8)	-0.1 (-1.1)	-0.1 (-0.2)
Sep	---	0.1 (0.7)	0.2 (2.0)	0.2 (2.0)	0.1 (1.5)	0.2 (2.0)	-0.1 (-0.4)	0 (0.6)
Oct	---	0.1 (0.4)	0.4 (3.1)	0.4 (3.0)	0.2 (1.5)	0.4 (3.1)	0.4 (3.1)	0.3 (2.5)
Nov	---	0 (0.1)	0.1 (0.8)	0.1 (0.8)	0.1 (0.9)	0.1 (0.8)	0 (-0.5)	0 (-0.3)
Dec	---	-0.3 (-2.2)	-0.2 (-0.8)	-0.1 (-0.8)	-0.3 (-1.6)	-0.2 (-0.8)	-0.3 (-2.0)	-0.3 (-1.8)

Table 51 and Table 52 show the statistics summary for the simulated selenium concentrations at Arkansas River at Catlin Dam gage. All alternatives would have negligible effects to selenium, compared to the No Action, as changes are around 2 percent or less. The Arkansas River at Catlin Dam gage concentrations in August and September would slightly increase with respect to the No Action Alternative, except for the River South, which would decrease. All alternatives would not substantially change selenium concentrations, compared to existing conditions.

Table 51. Simulated Selenium Concentration Comparison for Arkansas River at Catlin Dam Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	10.0	10.0	10.1	10.1	10.0	10.1	10.0	10.0
15th percentile	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
25th percentile	7.1	7.2	7.2	7.2	7.1	7.2	7.2	7.2
50th percentile	9.8	9.8	10.0	10.0	9.9	10.0	9.9	10.0
75th percentile	12.5	12.4	12.6	12.7	12.6	12.7	12.5	12.6
85th percentile	13.9	13.8	14.0	14.0	14.0	14.1	14.0	14.0
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.1 (1.0)	0.1 (1.0)	0.0 (0.0)	0.1 (1.0)	0.0 (0.0)	0.0 (0.0)
15th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	---	0.0 (0.0)	0.0 (0.0)	-0.1 (-1.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
50th percentile	---	---	0.2 (2.0)	0.2 (2.0)	0.1 (1.0)	0.2 (2.0)	0.1 (1.0)	0.2 (2.0)
75th percentile	---	---	0.2 (1.6)	0.3 (2.4)	0.2 (1.6)	0.3 (2.4)	0.1 (0.8)	0.2 (1.6)
85th percentile	---	---	0.2 (1.4)	0.2 (1.4)	0.2 (1.4)	0.3 (2.2)	0.2 (1.4)	0.2 (1.4)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.0 (0.0)	0.1 (1.0)	0.1 (1.0)	0.0 (0.0)	0.1 (1.0)	0.0 (0.0)	0.0 (0.0)
15th percentile	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	0.1 (1.4)	0.1 (1.4)	0.1 (1.4)	0.0 (0.0)	0.1 (1.4)	0.1 (1.4)	0.1 (1.4)
50th percentile	---	0.0 (0.0)	0.2 (2.0)	0.2 (2.0)	0.1 (1.0)	0.2 (2.0)	0.1 (1.0)	0.2 (2.0)
75th percentile	---	-0.1 (-0.8)	0.1 (0.8)	0.2 (1.6)	0.1 (0.8)	0.2 (1.6)	0.0 (0.0)	0.1 (0.8)
85th percentile	---	-0.1 (-0.7)	0.1 (0.7)	0.1 (0.7)	0.1 (0.7)	0.2 (1.4)	0.1 (0.7)	0.1 (0.7)

Table 52. Direct Effects Monthly Simulated Selenium Concentration for Arkansas River at Catlin Dam Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	13.1	13.0	13.3	13.3	13.1	13.3	13.1	13.2
Feb	14.6	14.4	14.6	14.6	14.5	14.6	14.5	14.5
Mar	10.8	10.6	10.7	10.7	10.8	10.7	10.7	10.7
Apr	9.0	9.1	9.2	9.2	9.1	9.2	9.2	9.2
May	7.0	7.0	7.1	7.1	7.0	7.1	7.0	7.0
Jun	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Jul	6.4	6.5	6.6	6.5	6.5	6.6	6.4	6.6
Aug	8.3	8.2	8.3	8.3	8.2	8.3	8.2	8.2
Sep	10.6	10.6	10.7	10.7	10.7	10.7	10.5	10.6
Oct	11.0	11.0	11.3	11.3	11.1	11.3	11.3	11.3
Nov	11.6	11.6	11.7	11.7	11.7	11.7	11.6	11.6
Dec	12.8	12.6	12.8	12.8	12.7	12.8	12.6	12.7
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.3 (2.4)	0.3 (2.4)	0.1 (1.1)	0.3 (2.3)	0.1 (1.0)	0.2 (1.6)
Feb	---	---	0.2 (1.6)	0.2 (1.4)	0.1 (0.8)	0.2 (1.6)	0.1 (0.6)	0.1 (0.9)
Mar	---	---	0.1 (1.6)	0.1 (1.7)	0.2 (2.2)	0.1 (1.5)	0.1 (1.1)	0.1 (1.2)
Apr	---	---	0.1 (1.1)	0.1 (1.1)	0 (0.3)	0.1 (1.1)	0.1 (1.5)	0.1 (1.3)
May	---	---	0.1 (0.9)	0.1 (0.8)	0 (0.2)	0.1 (0.9)	0 (0.8)	0 (0.6)
Jun	---	---	0 (0.7)	0 (0.7)	0 (0.5)	0 (0.7)	0 (-0.1)	0 (0.3)
Jul	---	---	0.1 (1.6)	0 (1.1)	0 (0.7)	0.1 (1.8)	-0.1 (-0.5)	0.1 (1.2)
Aug	---	---	0.1 (0.4)	0.1 (0.4)	0 (-0.1)	0.1 (0.4)	0 (-0.9)	0 (-0.2)
Sep	---	---	0.1 (0.5)	0.1 (0.5)	0.1 (0.4)	0.1 (0.6)	-0.1 (-1.2)	0 (0.0)
Oct	---	---	0.3 (2.4)	0.3 (2.3)	0.1 (0.6)	0.3 (2.4)	0.3 (2.2)	0.3 (1.9)
Nov	---	---	0.1 (0.6)	0.1 (0.6)	0.1 (0.6)	0.1 (0.6)	0 (-0.3)	0 (0.0)
Dec	---	---	0.2 (1.1)	0.2 (1.1)	0.1 (0.5)	0.2 (1.1)	0 (0.1)	0.1 (0.3)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.1 (-1.1)	0.2 (1.2)	0.2 (1.3)	0 (-0.1)	0.2 (1.2)	0 (-0.2)	0.1 (0.4)
Feb	---	-0.2 (-1.3)	0 (0.3)	0 (0.1)	-0.1 (-0.5)	0 (0.3)	-0.1 (-0.7)	-0.1 (-0.4)
Mar	---	-0.2 (-2.1)	-0.1 (-0.5)	-0.1 (-0.4)	0 (0.1)	-0.1 (-0.6)	-0.1 (-1.0)	-0.1 (-0.8)
Apr	---	0.1 (0.9)	0.2 (1.9)	0.2 (2.0)	0.1 (1.2)	0.2 (2.0)	0.2 (2.4)	0.2 (2.2)
May	---	0 (0.1)	0.1 (1.0)	0.1 (0.9)	0 (0.3)	0.1 (1.0)	0 (0.9)	0 (0.7)
Jun	---	0 (-0.2)	0 (0.5)	0 (0.5)	0 (0.3)	0 (0.5)	0 (-0.3)	0 (0.0)
Jul	---	0.1 (1.7)	0.2 (3.4)	0.1 (2.8)	0.1 (2.4)	0.2 (3.5)	0 (1.3)	0.2 (3.0)
Aug	---	-0.1 (-0.2)	0 (0.1)	0 (0.2)	-0.1 (-0.3)	0 (0.1)	-0.1 (-1.1)	-0.1 (-0.4)
Sep	---	0 (0.6)	0.1 (1.1)	0.1 (1.1)	0.1 (1.0)	0.1 (1.1)	-0.1 (-0.6)	0 (0.6)
Oct	---	0 (0.4)	0.3 (2.8)	0.3 (2.7)	0.1 (0.9)	0.3 (2.7)	0.3 (2.6)	0.3 (2.3)
Nov	---	0 (0.1)	0.1 (0.8)	0.1 (0.8)	0.1 (0.8)	0.1 (0.8)	0 (-0.2)	0 (0.1)
Dec	---	-0.2 (-1.7)	0 (-0.6)	0 (-0.6)	-0.1 (-1.2)	0 (-0.7)	-0.2 (-1.6)	-0.1 (-1.4)

Table 53 and Table 54 show the statistics summary for the simulated selenium concentrations at Arkansas River at Las Animas gage. All alternatives would have negligible effects to selenium, compared to the No Action. All alternatives would not substantially change selenium concentrations, compared to existing conditions.

Table 53. Simulated Selenium Concentration Comparison for Arkansas River at Las Animas Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	11.2	11.1	11.1	11.1	11.1	11.2	11.1	11.1
15th percentile	8.4	8.3	8.4	8.4	8.3	8.4	8.3	8.3
25th percentile	9.7	9.7	9.6	9.6	9.7	9.6	9.6	9.6
50th percentile	11.7	11.6	11.7	11.7	11.6	11.7	11.6	11.7
75th percentile	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5
85th percentile	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.9)	0.0 (0.0)	0.0 (0.0)
15th percentile	---	---	0.1 (1.2)	0.1 (1.2)	0.0 (0.0)	0.1 (1.2)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	---	-0.1 (-1.0)	-0.1 (-1.0)	0.0 (0.0)	-0.1 (-1.0)	-0.1 (-1.0)	-0.1 (-1.0)
50th percentile	---	---	0.1 (0.9)	0.1 (0.9)	0.0 (0.0)	0.1 (0.9)	0.0 (0.0)	0.1 (0.9)
75th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
85th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	-0.1 (-0.9)	-0.1 (-0.9)	-0.1 (-0.9)	-0.1 (-0.9)	0.0 (0.0)	-0.1 (-0.9)	-0.1 (-0.9)
15th percentile	---	-0.1 (-1.2)	0.0 (0.0)	0.0 (0.0)	-0.1 (-1.2)	0.0 (0.0)	-0.1 (-1.2)	-0.1 (-1.2)
25th percentile	---	0.0 (0.0)	-0.1 (-1.0)	-0.1 (-1.0)	0.0 (0.0)	-0.1 (-1.0)	-0.1 (-1.0)	-0.1 (-1.0)
50th percentile	---	-0.1 (-0.9)	0.0 (0.0)	0.0 (0.0)	-0.1 (-0.9)	0.0 (0.0)	-0.1 (-0.9)	0.0 (0.0)
75th percentile	---	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)
85th percentile	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

Table 54. Direct Effects Monthly Simulated Selenium Concentration for Arkansas River at Las Animas Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	11.7	11.6	11.7	11.7	11.7	11.7	11.7	11.7
Feb	11.8	11.8	11.9	11.8	11.7	11.9	11.8	11.8
Mar	12.3	12.1	12.0	12.0	12.2	12.0	12.0	12.0
Apr	12.9	12.8	12.8	12.8	12.8	12.8	12.8	12.8
May	10.1	10.0	10.0	10.0	10.0	10.1	10.0	10.0
Jun	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Jul	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Aug	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
Sep	11.8	11.7	11.7	11.7	11.7	11.7	11.7	11.7
Oct	11.8	11.8	11.9	11.9	11.9	11.9	11.9	11.9
Nov	11.7	11.7	11.8	11.8	11.8	11.8	11.7	11.7
Dec	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.1 (0.7)	0.1 (0.8)	0.1 (0.3)	0.1 (0.7)	0.1 (0.3)	0.1 (0.5)
Feb	---	---	0.1 (0.8)	0 (0.7)	-0.1 (-0.2)	0.1 (0.9)	0 (0.2)	0 (0.6)
Mar	---	---	-0.1 (-1.0)	-0.1 (-1.0)	0.1 (0.2)	-0.1 (-1.1)	-0.1 (-1.3)	-0.1 (-1.1)
Apr	---	---	0 (0.1)	0 (0.1)	0 (0.2)	0 (0.1)	0 (0.1)	0 (0.0)
May	---	---	0 (0.4)	0 (0.4)	0 (0.1)	0.1 (0.5)	0 (0.2)	0 (0.3)
Jun	---	---	0 (0.2)	0 (0.2)	0 (0.2)	0 (0.2)	0 (0.0)	0 (0.0)
Jul	---	---	0 (0.4)	0 (0.3)	0 (0.3)	0 (0.4)	0 (-0.2)	0 (0.2)
Aug	---	---	0 (0.2)	0 (0.3)	0 (0.1)	0 (0.2)	0 (0.0)	0 (0.0)
Sep	---	---	0 (-0.1)	0 (-0.1)	0 (-0.1)	0 (-0.1)	0 (-0.4)	0 (-0.1)
Oct	---	---	0.1 (0.5)	0.1 (0.4)	0.1 (0.1)	0.1 (0.5)	0.1 (0.4)	0.1 (0.2)
Nov	---	---	0.1 (0.0)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0 (-0.2)	0 (-0.1)
Dec	---	---	0 (0.4)	0 (0.3)	0 (0.2)	0 (0.3)	0 (0.1)	0 (0.2)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.1 (-0.4)	0 (0.4)	0 (0.4)	0 (-0.1)	0 (0.4)	0 (0.0)	0 (0.2)
Feb	---	0 (-0.4)	0.1 (0.4)	0 (0.3)	-0.1 (-0.6)	0.1 (0.5)	0 (-0.2)	0 (0.2)
Mar	---	-0.2 (-1.5)	-0.3 (-2.6)	-0.3 (-2.6)	-0.1 (-1.4)	-0.3 (-2.6)	-0.3 (-2.8)	-0.3 (-2.6)
Apr	---	-0.1 (-0.9)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.9)
May	---	-0.1 (-1.2)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-1.1)	0 (-0.8)	-0.1 (-1.0)	-0.1 (-0.9)
Jun	---	0 (-0.7)	0 (-0.5)	0 (-0.5)	0 (-0.5)	0 (-0.5)	0 (-0.7)	0 (-0.7)
Jul	---	0 (-0.4)	0 (0.0)	0 (-0.1)	0 (-0.1)	0 (0.0)	0 (-0.6)	0 (-0.2)
Aug	---	0 (-0.5)	0 (-0.2)	0 (-0.2)	0 (-0.4)	0 (-0.2)	0 (-0.4)	0 (-0.5)
Sep	---	-0.1 (-0.1)	-0.1 (-0.2)	-0.1 (-0.2)	-0.1 (-0.2)	-0.1 (-0.2)	-0.1 (-0.5)	-0.1 (-0.2)
Oct	---	0 (0.0)	0.1 (0.4)	0.1 (0.4)	0.1 (0.0)	0.1 (0.4)	0.1 (0.3)	0.1 (0.2)
Nov	---	0 (0.4)	0.1 (0.5)	0.1 (0.5)	0.1 (0.5)	0.1 (0.5)	0 (0.2)	0 (0.3)
Dec	---	0 (-0.3)	0 (0.0)	0 (0.0)	0 (-0.1)	0 (0.0)	0 (-0.2)	0 (-0.1)

Table 55 and Table 56 show the statistics summary for the simulated selenium concentrations at Fountain Creek at Pueblo gage. All alternatives would have predominantly negligible effects to selenium, compared to the No Action, as effects are around 2 percent or less. The late winter and early spring months would have the largest percent changes in concentration. All alternatives would decrease selenium concentrations, compared to existing conditions.

Table 55. Simulated Selenium Concentration Comparison for Fountain Creek at Pueblo Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	12.4	11.6	11.7	11.7	11.6	11.7	11.7	11.7
15th percentile	7.3	7.5	7.5	7.5	7.5	7.5	7.5	7.5
25th percentile	8.4	8.3	8.4	8.4	8.3	8.4	8.4	8.5
50th percentile	11.5	10.6	10.7	10.7	10.6	10.7	10.7	10.7
75th percentile	16.1	14.8	14.7	14.8	14.8	14.7	14.6	14.8
85th percentile	18.4	16.4	16.6	16.6	16.3	16.6	16.6	16.7
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.1 (0.9)	0.1 (0.9)	0.0 (0.0)	0.1 (0.9)	0.1 (0.9)	0.1 (0.9)
15th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	---	0.1 (1.2)	0.1 (1.2)	0.0 (0.0)	0.1 (1.2)	0.1 (1.2)	0.2 (2.4)
50th percentile	---	---	0.1 (0.9)	0.1 (0.9)	0.0 (0.0)	0.1 (0.9)	0.1 (0.9)	0.1 (0.9)
75th percentile	---	---	-0.1 (-0.7)	0.0 (0.0)	0.0 (0.0)	-0.1 (-0.7)	-0.2 (-1.4)	0.0 (0.0)
85th percentile	---	---	0.2 (1.2)	0.2 (1.2)	-0.1 (-0.6)	0.2 (1.2)	0.2 (1.2)	0.3 (1.8)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	-0.8 (-6.5)	-0.7 (-5.6)	-0.7 (-5.6)	-0.8 (-6.5)	-0.7 (-5.6)	-0.7 (-5.6)	-0.7 (-5.6)
15th percentile	---	0.2 (2.7)	0.2 (2.7)	0.2 (2.7)	0.2 (2.7)	0.2 (2.7)	0.2 (2.7)	0.2 (2.7)
25th percentile	---	-0.1 (-1.2)	0.0 (0.0)	0.0 (0.0)	-0.1 (-1.2)	0.0 (0.0)	0.0 (0.0)	0.1 (1.2)
50th percentile	---	-0.9 (-7.8)	-0.8 (-7.0)	-0.8 (-7.0)	-0.9 (-7.8)	-0.8 (-7.0)	-0.8 (-7.0)	-0.8 (-7.0)
75th percentile	---	-1.3 (-8.1)	-1.4 (-8.7)	-1.3 (-8.1)	-1.3 (-8.1)	-1.4 (-8.7)	-1.5 (-9.3)	-1.3 (-8.1)
85th percentile	---	-2.0 (-10.9)	-1.8 (-9.8)	-1.8 (-9.8)	-2.1 (-11.4)	-1.8 (-9.8)	-1.8 (-9.8)	-1.7 (-9.2)

Table 56. Direct Effects Monthly Simulated Selenium Concentration for Fountain Creek at Pueblo Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	14.2	13.3	13.6	13.5	13.2	13.5	13.2	13.6
Feb	14.2	13.3	13.5	13.5	13.3	13.5	13.5	13.5
Mar	12.5	11.6	11.8	11.8	11.7	11.8	11.8	11.9
Apr	10.8	11.0	10.8	10.8	10.9	10.8	11.0	11.0
May	9.4	9.1	9.4	9.4	9.2	9.4	9.4	9.3
Jun	10.1	9.6	9.7	9.7	9.6	9.7	9.7	9.7
Jul	9.3	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Aug	10.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Sep	10.3	9.9	9.7	9.7	9.8	9.7	9.5	9.9
Oct	16.0	14.5	14.7	14.7	14.7	14.7	14.7	14.7
Nov	15.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Dec	17.1	15.0	15.1	15.1	14.9	15.1	15.1	15.1
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.3 (2.2)	0.2 (2.1)	-0.1 (-0.1)	0.2 (2.1)	-0.1 (-0.4)	0.3 (2.5)
Feb	---	---	0.2 (1.0)	0.2 (1.0)	0 (-0.1)	0.2 (1.0)	0.2 (1.0)	0.2 (1.3)
Mar	---	---	0.2 (1.6)	0.2 (1.4)	0.1 (0.6)	0.2 (1.2)	0.2 (1.7)	0.3 (2.1)
Apr	---	---	-0.2 (-1.3)	-0.2 (-1.5)	-0.1 (-0.4)	-0.2 (-1.4)	0 (-0.1)	0 (-0.1)
May	---	---	0.3 (2.7)	0.3 (2.7)	0.1 (1.1)	0.3 (2.7)	0.3 (2.8)	0.2 (2.0)
Jun	---	---	0.1 (0.5)	0.1 (0.5)	0 (0.0)	0.1 (0.5)	0.1 (0.6)	0.1 (0.5)
Jul	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.1)
Aug	---	---	0 (-0.2)	0 (-0.2)	0 (-0.3)	0 (-0.2)	0 (-0.2)	0 (0.1)
Sep	---	---	-0.2 (-2.0)	-0.2 (-2.0)	-0.1 (-1.7)	-0.2 (-2.0)	-0.4 (-4.2)	0 (-0.2)
Oct	---	---	0.2 (1.3)	0.2 (1.3)	0.2 (1.3)	0.2 (1.3)	0.2 (1.3)	0.2 (1.3)
Nov	---	---	0 (0.1)	0 (0.1)	0 (0.0)	0 (0.1)	0 (0.1)	0 (0.0)
Dec	---	---	0.1 (0.0)	0.1 (0.1)	-0.1 (-1.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.1)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.9 (-6.5)	-0.6 (-4.5)	-0.7 (-4.5)	-1 (-6.7)	-0.7 (-4.5)	-1 (-6.9)	-0.6 (-4.2)
Feb	---	-0.9 (-6.5)	-0.7 (-5.5)	-0.7 (-5.6)	-0.9 (-6.6)	-0.7 (-5.5)	-0.7 (-5.5)	-0.7 (-5.3)
Mar	---	-0.9 (-6.5)	-0.7 (-5.0)	-0.7 (-5.2)	-0.8 (-5.9)	-0.7 (-5.4)	-0.7 (-5.0)	-0.6 (-4.5)
Apr	---	0.2 (1.3)	0 (0.0)	0 (-0.2)	0.1 (0.9)	0 (-0.1)	0.2 (1.2)	0.2 (1.2)
May	---	-0.3 (-2.7)	0 (-0.1)	0 (-0.1)	-0.2 (-1.7)	0 (-0.1)	0 (0.0)	-0.1 (-0.8)
Jun	---	-0.5 (-4.6)	-0.4 (-4.1)	-0.4 (-4.1)	-0.5 (-4.6)	-0.4 (-4.1)	-0.4 (-4.1)	-0.4 (-4.1)
Jul	---	0.1 (0.6)	0.1 (0.7)	0.1 (0.7)	0.1 (0.6)	0.1 (0.7)	0.1 (0.7)	0.1 (0.7)
Aug	---	-1 (-9.6)	-1 (-9.8)	-1 (-9.8)	-1 (-9.9)	-1 (-9.8)	-1 (-9.8)	-1 (-9.5)
Sep	---	-0.4 (-2.9)	-0.6 (-4.9)	-0.6 (-4.9)	-0.5 (-4.6)	-0.6 (-4.9)	-0.8 (-7.0)	-0.4 (-3.1)
Oct	---	-1.5 (-9.1)	-1.3 (-7.9)	-1.3 (-7.9)	-1.3 (-7.9)	-1.3 (-7.9)	-1.3 (-7.9)	-1.3 (-7.9)
Nov	---	-1 (-6.4)	-1 (-6.4)	-1 (-6.3)	-1 (-6.4)	-1 (-6.4)	-1 (-6.4)	-1 (-6.4)
Dec	---	-2.1 (-11.8)	-2 (-11.8)	-2 (-11.7)	-2.2 (-12.6)	-2 (-11.8)	-2 (-11.8)	-2 (-11.7)

Cumulative Effects Analysis. A comparative analysis with the No Action Alternative and existing conditions was performed to estimate the changes in selenium under each of the alternatives for the cumulative effects analysis. Cumulative effects simulation uses the results of the Daily Model, which reflects all the simulated operations under these conditions in the streamflows.

Selenium simulation results are summarized using the statistics of the simulated concentration and relative change between each alternative and the No Action and existing conditions for the control points in the study area. Additionally, results are also summarized in monthly statistics of the simulated concentration for the different alternatives, indicating the percent changes for the alternatives under the cumulative effects analysis.

Table 57 and Table 58 summarize results for the Arkansas River at Moffat St. gage. The Comanche South, Pueblo Dam South, and JUP North, and Pueblo Dan North alternatives would have mostly minor adverse effects. Monthly changes in selenium would have the largest percent changes in the months of January, February and July to October. The Pueblo Dam South Alternative would have a moderate adverse increase in the 85th percentile, compared to No Action. All alternatives would increase selenium concentrations in late summer and fall months, compared to existing conditions, because of decreases in streamflow.

Table 57. Cumulative Effects Simulated Selenium Concentration Comparison for Arkansas River at Moffat St. Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	5.4	6.1	6.3	6.3	6.3	6.3	5.7	6.1
15th percentile	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
25th percentile	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6
50th percentile	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5
75th percentile	5.8	6.8	7.1	7.1	7.1	7.1	6.4	6.8
85th percentile	6.8	8.1	8.9	9.0	8.7	8.9	7.9	8.2
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.2 (3.3)	0.2 (3.3)	0.2 (3.3)	0.2 (3.3)	-0.4 (-6.6)	0.0 (0.0)
15th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
50th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
75th percentile	---	---	0.3 (4.4)	0.3 (4.4)	0.3 (4.4)	0.3 (4.4)	-0.4 (-5.9)	0.0 (0.0)
85th percentile	---	---	0.8 (9.9)	0.9 (11.1)	0.6 (7.4)	0.8 (9.9)	-0.2 (-2.5)	0.1 (1.2)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.7 (13.0)	0.9 (16.7)	0.9 (16.7)	0.9 (16.7)	0.9 (16.7)	0.3 (5.6)	0.7 (13.0)
15th percentile	---	0.1 (3.1)	0.1 (3.1)	0.1 (3.1)	0.1 (3.1)	0.1 (3.1)	0.1 (3.1)	0.1 (3.1)
25th percentile	---	0.1 (2.9)	0.1 (2.9)	0.1 (2.9)	0.1 (2.9)	0.1 (2.9)	0.1 (2.9)	0.1 (2.9)
50th percentile	---	0.1 (2.3)	0.1 (2.3)	0.1 (2.3)	0.1 (2.3)	0.1 (2.3)	0.1 (2.3)	0.1 (2.3)
75th percentile	---	1.0 (17.2)	1.3 (22.4)	1.3 (22.4)	1.3 (22.4)	1.3 (22.4)	0.6 (10.3)	1.0 (17.2)
85th percentile	---	1.3 (19.1)	2.1 (30.9)	2.2 (32.4)	1.9 (27.9)	2.1 (30.9)	1.1 (16.2)	1.4 (20.6)

Table 58. Cumulative Effects Monthly Simulated Selenium Concentration for Arkansas River at Moffat St. Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	6.5	7.0	7.3	7.3	7.3	7.3	6.6	7.0
Feb	7.4	7.4	7.8	7.8	7.8	7.8	6.7	7.4
Mar	5.0	5.4	5.5	5.5	5.5	5.5	5.1	5.3
Apr	4.7	5.2	5.4	5.4	5.3	5.4	5.2	5.2
May	4.6	5.2	5.3	5.3	5.3	5.3	5.1	5.3
Jun	3.7	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Jul	3.6	4.1	4.2	4.3	4.2	4.3	3.8	4.1
Aug	4.8	6.0	6.3	6.4	6.3	6.4	5.2	6.0
Sep	6.0	7.5	7.9	7.9	7.8	7.9	6.7	7.5
Oct	5.4	6.7	7.0	7.0	6.9	7.0	6.5	6.7
Nov	6.3	7.1	7.3	7.3	7.4	7.3	6.7	7.1
Dec	6.9	7.8	8.0	8.0	8.0	8.0	7.3	7.8
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.3 (4.4)	0.3 (4.5)	0.3 (4.1)	0.3 (4.4)	-0.4 (-5.6)	0 (0.2)
Feb	---	---	0.4 (6.1)	0.4 (6.1)	0.4 (5.8)	0.4 (6.1)	-0.7 (-10.0)	0 (0.3)
Mar	---	---	0.1 (2.7)	0.1 (3.0)	0.1 (2.7)	0.1 (2.8)	-0.3 (-5.2)	-0.1 (-0.2)
Apr	---	---	0.2 (3.2)	0.2 (3.1)	0.1 (2.0)	0.2 (3.0)	0 (-0.8)	0 (0.4)
May	---	---	0.1 (1.0)	0.1 (0.9)	0.1 (0.9)	0.1 (1.1)	-0.1 (-1.6)	0.1 (0.7)
Jun	---	---	0 (0.6)	0 (0.8)	0 (0.9)	0 (0.9)	0 (-1.2)	0 (-0.5)
Jul	---	---	0.1 (3.2)	0.2 (3.5)	0.1 (3.3)	0.2 (3.4)	-0.3 (-6.5)	0 (0.7)
Aug	---	---	0.3 (5.2)	0.4 (5.6)	0.3 (4.7)	0.4 (5.8)	-0.8 (-13.3)	0 (-0.1)
Sep	---	---	0.4 (5.6)	0.4 (5.5)	0.3 (5.1)	0.4 (5.6)	-0.8 (-9.7)	0 (0.0)
Oct	---	---	0.3 (4.8)	0.3 (4.8)	0.2 (3.1)	0.3 (4.9)	-0.2 (-2.9)	0 (0.7)
Nov	---	---	0.2 (2.6)	0.2 (2.6)	0.3 (3.4)	0.2 (2.6)	-0.4 (-5.4)	0 (0.1)
Dec	---	---	0.2 (3.2)	0.2 (3.1)	0.2 (3.1)	0.2 (3.1)	-0.5 (-5.9)	0 (-0.2)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.5 (7.8)	0.8 (12.5)	0.8 (12.6)	0.8 (12.2)	0.8 (12.6)	0.1 (1.8)	0.5 (8.0)
Feb	---	0 (-0.3)	0.4 (5.8)	0.4 (5.8)	0.4 (5.5)	0.4 (5.8)	-0.7 (-10.3)	0 (0.0)
Mar	---	0.4 (7.4)	0.5 (10.3)	0.5 (10.7)	0.5 (10.3)	0.5 (10.4)	0.1 (1.8)	0.3 (7.2)
Apr	---	0.5 (9.6)	0.7 (13.1)	0.7 (13.0)	0.6 (11.8)	0.7 (13.0)	0.5 (8.8)	0.5 (10.1)
May	---	0.6 (14.7)	0.7 (15.8)	0.7 (15.7)	0.7 (15.8)	0.7 (15.9)	0.5 (12.8)	0.7 (15.5)
Jun	---	0.3 (8.1)	0.3 (8.7)	0.3 (8.9)	0.3 (9.0)	0.3 (9.0)	0.3 (6.8)	0.3 (7.5)
Jul	---	0.5 (14.3)	0.6 (17.9)	0.7 (18.3)	0.6 (18.1)	0.7 (18.2)	0.2 (6.9)	0.5 (15.1)
Aug	---	1.2 (24.6)	1.5 (31.1)	1.6 (31.6)	1.5 (30.5)	1.6 (31.8)	0.4 (8.0)	1.2 (24.4)
Sep	---	1.5 (25.3)	1.9 (32.4)	1.9 (32.2)	1.8 (31.7)	1.9 (32.3)	0.7 (13.2)	1.5 (25.3)
Oct	---	1.3 (23.8)	1.6 (29.7)	1.6 (29.7)	1.5 (27.6)	1.6 (29.8)	1.1 (20.1)	1.3 (24.7)
Nov	---	0.8 (13.0)	1 (15.9)	1 (15.9)	1.1 (16.9)	1 (16.0)	0.4 (6.9)	0.8 (13.2)
Dec	---	0.9 (12.6)	1.1 (16.2)	1.1 (16.2)	1.1 (16.2)	1.1 (16.2)	0.4 (5.9)	0.9 (12.4)

Table 59 and Table 60 show selenium modeling results for the Arkansas River near Avondale gage. All alternatives would have negligible effects to selenium, compared to No Action, as effects are around 2 percent or less. Simulated concentration at the Arkansas River near Avondale gage for the alternatives compared with No Action would have a relatively small percent change with the largest increase in concentration during July and August, except for the River South Alternative, which would slightly decrease in January, February, July and August. All alternatives would increase selenium concentrations in late spring months, compared to existing conditions because of streamflow changes.

Table 59. Cumulative Effects Simulated Selenium Concentration Comparison for Arkansas River near Avondale Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	10.3	10.4	10.5	10.4	10.5	10.4	10.5	10.4
15th percentile	6.0	6.7	6.9	6.9	6.9	6.8	6.8	6.8
25th percentile	7.3	8.3	8.4	8.4	8.4	8.4	8.4	8.4
50th percentile	10.1	10.6	10.7	10.6	10.7	10.6	10.6	10.6
75th percentile	13.3	12.7	12.8	12.8	12.8	12.7	12.8	12.7
85th percentile	14.2	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.1 (1.0)	0.0 (0.0)	0.1 (1.0)	0.0 (0.0)	0.1 (1.0)	0.0 (0.0)
15th percentile	---	---	0.2 (3.0)	0.2 (3.0)	0.2 (3.0)	0.1 (1.5)	0.1 (1.5)	0.1 (1.5)
25th percentile	---	---	0.1 (1.2)	0.1 (1.2)	0.1 (1.2)	0.1 (1.2)	0.1 (1.2)	0.1 (1.2)
50th percentile	---	---	0.1 (0.9)	0.0 (0.0)	0.1 (0.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
75th percentile	---	---	0.1 (0.8)	0.1 (0.8)	0.1 (0.8)	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)
85th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.1 (1.0)	0.2 (1.9)	0.1 (1.0)	0.2 (1.9)	0.1 (1.0)	0.2 (1.9)	0.1 (1.0)
15th percentile	---	0.7 (11.7)	0.9 (15.0)	0.9 (15.0)	0.9 (15.0)	0.8 (13.3)	0.8 (13.3)	0.8 (13.3)
25th percentile	---	1.0 (13.7)	1.1 (15.1)	1.1 (15.1)	1.1 (15.1)	1.1 (15.1)	1.1 (15.1)	1.1 (15.1)
50th percentile	---	0.5 (5.0)	0.6 (5.9)	0.5 (5.0)	0.6 (5.9)	0.5 (5.0)	0.5 (5.0)	0.5 (5.0)
75th percentile	---	-0.6 (-4.5)	-0.5 (-3.8)	-0.5 (-3.8)	-0.5 (-3.8)	-0.6 (-4.5)	-0.5 (-3.8)	-0.6 (-4.5)
85th percentile	---	-0.7 (-4.9)	-0.7 (-4.9)	-0.7 (-4.9)	-0.7 (-4.9)	-0.7 (-4.9)	-0.7 (-4.9)	-0.7 (-4.9)

Table 60. Cumulative Effects Monthly Simulated Selenium Concentration for Arkansas River near Avondale Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	13.2	12.3	12.4	12.4	12.4	12.4	12.3	12.3
Feb	14.6	12.9	13.0	13.0	13.0	13.0	12.8	12.9
Mar	11.8	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Apr	9.4	10.2	10.2	10.2	10.2	10.3	10.3	10.3
May	7.3	9.3	9.4	9.1	9.4	9.1	9.4	9.3
Jun	5.6	7.5	7.6	7.6	7.5	7.5	7.7	7.5
Jul	5.9	6.5	6.6	6.6	6.6	6.6	6.4	6.5
Aug	8.3	8.6	8.7	8.7	8.8	8.6	8.5	8.6
Sep	10.6	11.1	11.1	11.1	11.1	11.1	11.4	11.1
Oct	11.7	11.4	11.5	11.5	11.4	11.5	11.5	11.5
Nov	12.4	11.8	11.9	11.9	11.9	11.9	11.8	11.8
Dec	13.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.1 (0.3)	0 (-0.3)	0 (-0.3)
Feb	---	---	0.1 (0.7)	0.1 (0.7)	0.1 (0.8)	0.1 (0.7)	-0.1 (-0.1)	0 (0.0)
Mar	---	---	0 (-0.3)	0 (-0.4)	0 (0.1)	0 (-0.4)	0 (0.0)	0 (-0.6)
Apr	---	---	0 (-0.1)	0 (-0.2)	0 (-0.1)	0.1 (0.4)	0.1 (0.8)	0.1 (0.3)
May	---	---	0.1 (0.4)	-0.2 (-2.5)	0.1 (0.1)	-0.2 (-2.4)	0.1 (0.2)	0 (-0.7)
Jun	---	---	0.1 (1.1)	0.1 (1.2)	0 (0.3)	0 (0.7)	0.2 (3.2)	0 (0.7)
Jul	---	---	0.1 (2.6)	0.1 (2.3)	0.1 (2.3)	0.1 (2.5)	-0.1 (-1.7)	0 (1.0)
Aug	---	---	0.1 (1.9)	0.1 (1.7)	0.2 (2.4)	0 (0.9)	-0.1 (-0.2)	0 (0.4)
Sep	---	---	0 (-0.5)	0 (-0.6)	0 (-0.1)	0 (-0.7)	0.3 (2.6)	0 (-0.5)
Oct	---	---	0.1 (0.8)	0.1 (1.0)	0 (0.3)	0.1 (0.8)	0.1 (0.4)	0.1 (0.6)
Nov	---	---	0.1 (0.7)	0.1 (0.6)	0.1 (0.6)	0.1 (0.8)	0 (0.2)	0 (0.2)
Dec	---	---	0 (0.0)	0 (-0.1)	0 (0.5)	0 (-0.1)	0 (0.0)	-0.1 (-0.3)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.9 (-6.3)	-0.8 (-6.0)	-0.8 (-6.0)	-0.8 (-5.9)	-0.8 (-6.1)	-0.9 (-6.6)	-0.9 (-6.6)
Feb	---	-1.7 (-11.9)	-1.6 (-11.2)	-1.6 (-11.2)	-1.6 (-11.2)	-1.6 (-11.2)	-1.8 (-11.9)	-1.7 (-11.9)
Mar	---	-0.3 (-2.1)	-0.3 (-2.4)	-0.3 (-2.5)	-0.3 (-2.0)	-0.3 (-2.5)	-0.3 (-2.1)	-0.3 (-2.7)
Apr	---	0.8 (8.6)	0.8 (8.4)	0.8 (8.4)	0.8 (8.4)	0.9 (9.0)	0.9 (9.4)	0.9 (8.9)
May	---	2 (28.1)	2.1 (28.7)	1.8 (25.0)	2.1 (28.3)	1.8 (25.0)	2.1 (28.3)	2 (27.3)
Jun	---	1.9 (32.6)	2 (34.1)	2 (34.2)	1.9 (33.0)	1.9 (33.6)	2.1 (36.9)	1.9 (33.6)
Jul	---	0.6 (9.3)	0.7 (12.1)	0.7 (11.9)	0.7 (11.9)	0.7 (12.0)	0.5 (7.5)	0.6 (10.4)
Aug	---	0.3 (3.7)	0.4 (5.7)	0.4 (5.5)	0.5 (6.2)	0.3 (4.6)	0.2 (3.4)	0.3 (4.1)
Sep	---	0.5 (5.3)	0.5 (4.7)	0.5 (4.6)	0.5 (5.1)	0.5 (4.6)	0.8 (8.0)	0.5 (4.8)
Oct	---	-0.3 (-2.8)	-0.2 (-2.0)	-0.2 (-1.8)	-0.3 (-2.5)	-0.2 (-2.0)	-0.2 (-2.4)	-0.2 (-2.2)
Nov	---	-0.6 (-4.7)	-0.5 (-4.1)	-0.5 (-4.2)	-0.5 (-4.2)	-0.5 (-4.0)	-0.6 (-4.5)	-0.6 (-4.6)
Dec	---	-1 (-7.3)	-1 (-7.3)	-1 (-7.4)	-1 (-6.9)	-1 (-7.4)	-1 (-7.3)	-1.1 (-7.6)

Table 61 and Table 62 show the statistics of the simulated selenium concentration for the alternatives for the Arkansas River at Catlin Dam gage. All alternatives would have negligible effects to selenium, compared to the No Action. Compared with the No Action Alternative, the selenium concentration simulated at the Arkansas River at Catlin Dam for the alternatives would increase after July and slightly decrease or not change before July, with the exception of River South, which would increase or not change in concentration from February to June. All alternatives would increase selenium concentrations in late spring months, compared to existing conditions, because of changes in streamflow.

Table 61. Cumulative Effects Simulated Selenium Concentration Comparison for Arkansas River at Catlin Dam Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
15th percentile	6.0	6.7	6.6	6.6	6.5	6.5	6.6	6.6
25th percentile	7.1	7.6	7.5	7.5	7.5	7.5	7.6	7.6
50th percentile	9.8	10.3	10.3	10.3	10.3	10.3	10.3	10.3
75th percentile	12.5	12.1	12.2	12.1	12.1	12.1	12.1	12.1
85th percentile	13.9	13.3	13.2	13.1	13.2	13.1	13.3	13.2
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
15th percentile	---	---	-0.1 (-1.5)	-0.1 (-1.5)	-0.2 (-3.0)	-0.2 (-3.0)	-0.1 (-1.5)	-0.1 (-1.5)
25th percentile	---	---	-0.1 (-1.3)	-0.1 (-1.3)	-0.1 (-1.3)	-0.1 (-1.3)	0.0 (0.0)	0.0 (0.0)
50th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
75th percentile	---	---	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
85th percentile	---	---	-0.1 (-0.8)	-0.2 (-1.5)	-0.1 (-0.8)	-0.2 (-1.5)	0.0 (0.0)	-0.1 (-0.8)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
15th percentile	---	0.7 (11.7)	0.6 (10.0)	0.6 (10.0)	0.5 (8.3)	0.5 (8.3)	0.6 (10.0)	0.6 (10.0)
25th percentile	---	0.5 (7.0)	0.4 (5.6)	0.4 (5.6)	0.4 (5.6)	0.4 (5.6)	0.5 (7.0)	0.5 (7.0)
50th percentile	---	0.5 (5.1)	0.5 (5.1)	0.5 (5.1)	0.5 (5.1)	0.5 (5.1)	0.5 (5.1)	0.5 (5.1)
75th percentile	---	-0.4 (-3.2)	-0.3 (-2.4)	-0.4 (-3.2)	-0.4 (-3.2)	-0.4 (-3.2)	-0.4 (-3.2)	-0.4 (-3.2)
85th percentile	---	-0.6 (-4.3)	-0.7 (-5.0)	-0.8 (-5.8)	-0.7 (-5.0)	-0.8 (-5.8)	-0.6 (-4.3)	-0.7 (-5.0)

Table 62. Cumulative Effects Monthly Simulated Selenium Concentration for Arkansas River at Catlin Dam Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	13.1	12.6	12.6	12.6	12.6	12.6	12.6	12.5
Feb	14.6	12.9	12.8	12.8	12.8	12.8	12.9	12.9
Mar	10.8	10.5	10.4	10.4	10.5	10.4	10.4	10.4
Apr	9.0	9.5	9.5	9.5	9.5	9.5	9.5	9.5
May	7.0	8.3	8.2	8.0	8.2	8.0	8.3	8.2
Jun	5.6	7.0	7.0	7.0	7.0	7.0	7.1	7.0
Jul	6.4	6.8	6.9	6.9	6.9	6.9	6.7	6.9
Aug	8.3	8.4	8.5	8.4	8.5	8.4	8.3	8.4
Sep	10.6	10.8	10.8	10.8	10.8	10.8	11.0	10.9
Oct	11.0	10.4	10.5	10.5	10.4	10.5	10.5	10.5
Nov	11.6	11.1	11.2	11.2	11.1	11.2	11.1	11.1
Dec	12.8	12.0	12.0	12.0	12.1	12.0	12.0	12.0
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0 (0.2)	0 (0.2)	0 (0.3)	0 (0.2)	0 (0.0)	-0.1 (-0.2)
Feb	---	---	-0.1 (-0.7)	-0.1 (-0.6)	-0.1 (-0.6)	-0.1 (-0.6)	0 (0.4)	0 (0.1)
Mar	---	---	-0.1 (-0.6)	-0.1 (-0.6)	0 (0.0)	-0.1 (-0.6)	-0.1 (-0.7)	-0.1 (-0.3)
Apr	---	---	0 (-0.5)	0 (-0.6)	0 (0.0)	0 (-0.4)	0 (0.1)	0 (0.3)
May	---	---	-0.1 (-0.5)	-0.3 (-3.5)	-0.1 (-1.0)	-0.3 (-3.3)	0 (0.5)	-0.1 (-1.1)
Jun	---	---	0 (0.4)	0 (0.4)	0 (-0.1)	0 (0.3)	0.1 (2.3)	0 (0.9)
Jul	---	---	0.1 (2.1)	0.1 (1.8)	0.1 (2.1)	0.1 (2.2)	-0.1 (-1.1)	0.1 (1.1)
Aug	---	---	0.1 (1.2)	0 (1.0)	0.1 (1.4)	0 (0.4)	-0.1 (-0.4)	0 (0.2)
Sep	---	---	0 (-0.4)	0 (-0.4)	0 (-0.1)	0 (-0.4)	0.2 (1.8)	0.1 (0.4)
Oct	---	---	0.1 (1.1)	0.1 (1.2)	0 (-0.1)	0.1 (0.9)	0.1 (1.0)	0.1 (1.3)
Nov	---	---	0.1 (1.0)	0.1 (1.0)	0 (0.2)	0.1 (1.1)	0 (0.2)	0 (0.4)
Dec	---	---	0 (-0.1)	0 (-0.1)	0.1 (0.3)	0 (-0.1)	0 (0.0)	0 (-0.3)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.5 (-4.2)	-0.5 (-4.0)	-0.5 (-4.0)	-0.5 (-3.9)	-0.5 (-4.0)	-0.5 (-4.2)	-0.6 (-4.4)
Feb	---	-1.7 (-11.6)	-1.8 (-12.1)	-1.8 (-12.1)	-1.8 (-12.1)	-1.8 (-12.1)	-1.7 (-11.2)	-1.7 (-11.5)
Mar	---	-0.3 (-2.8)	-0.4 (-3.4)	-0.4 (-3.4)	-0.3 (-2.8)	-0.4 (-3.4)	-0.4 (-3.5)	-0.4 (-3.1)
Apr	---	0.5 (5.9)	0.5 (5.3)	0.5 (5.3)	0.5 (5.9)	0.5 (5.5)	0.5 (6.0)	0.5 (6.2)
May	---	1.3 (18.1)	1.2 (17.5)	1 (14.0)	1.2 (17.0)	1 (14.2)	1.3 (18.7)	1.2 (16.8)
Jun	---	1.4 (24.6)	1.4 (25.1)	1.4 (25.2)	1.4 (24.5)	1.4 (24.9)	1.5 (27.5)	1.4 (25.8)
Jul	---	0.4 (6.7)	0.5 (8.9)	0.5 (8.6)	0.5 (8.9)	0.5 (9.0)	0.3 (5.5)	0.5 (7.8)
Aug	---	0.1 (1.2)	0.2 (2.5)	0.1 (2.2)	0.2 (2.6)	0.1 (1.6)	0 (0.9)	0.1 (1.4)
Sep	---	0.2 (2.1)	0.2 (1.7)	0.2 (1.7)	0.2 (2.0)	0.2 (1.7)	0.4 (4.0)	0.3 (2.6)
Oct	---	-0.6 (-5.7)	-0.5 (-4.6)	-0.5 (-4.5)	-0.6 (-5.8)	-0.5 (-4.8)	-0.5 (-4.7)	-0.5 (-4.4)
Nov	---	-0.5 (-4.3)	-0.4 (-3.3)	-0.4 (-3.4)	-0.5 (-4.1)	-0.4 (-3.2)	-0.5 (-4.1)	-0.5 (-3.9)
Dec	---	-0.8 (-6.3)	-0.8 (-6.3)	-0.8 (-6.3)	-0.7 (-5.9)	-0.8 (-6.3)	-0.8 (-6.3)	-0.8 (-6.5)

Table 63 and Table 64 show the summary of the selenium modeling at the Arkansas River at Las Animas gage. All alternatives would have negligible effects to selenium, compared to the No Action. Selenium concentrations for the alternatives at Las Animas gage in the Arkansas River would decrease with respect to the No Action Alternative during February, March and April. All alternatives would not substantially change selenium concentrations, compared to existing conditions.

Table 63. Cumulative Effects Simulated Selenium Concentration Comparison for Arkansas River at Las Animas Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	11.2	11.1	11.1	11.1	11.1	11.1	11.1	11.1
15th percentile	8.4	8.7	8.7	8.7	8.7	8.7	8.6	8.6
25th percentile	9.7	9.8	9.7	9.7	9.7	9.7	9.7	9.8
50th percentile	11.7	11.5	11.5	11.5	11.5	11.5	11.6	11.5
75th percentile	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5
85th percentile	13.3	13.2	13.2	13.2	13.2	13.2	13.2	13.2
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
15th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	-0.1 (-1.1)	-0.1 (-1.1)
25th percentile	---	---	-0.1 (-1.0)	-0.1 (-1.0)	-0.1 (-1.0)	-0.1 (-1.0)	-0.1 (-1.0)	0.0 (0.0)
50th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.9)	0.0 (0.0)
75th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
85th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	-0.1 (-0.9)	-0.1 (-0.9)	-0.1 (-0.9)	-0.1 (-0.9)	-0.1 (-0.9)	-0.1 (-0.9)	-0.1 (-0.9)
15th percentile	---	0.3 (3.6)	0.3 (3.6)	0.3 (3.6)	0.3 (3.6)	0.3 (3.6)	0.2 (2.4)	0.2 (2.4)
25th percentile	---	0.1 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (1.0)
50th percentile	---	-0.2 (-1.7)	-0.2 (-1.7)	-0.2 (-1.7)	-0.2 (-1.7)	-0.2 (-1.7)	-0.1 (-0.9)	-0.2 (-1.7)
75th percentile	---	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)
85th percentile	---	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)	-0.1 (-0.8)

Table 64. Cumulative Effects Monthly Simulated Selenium Concentration for Arkansas River at Las Animas Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	11.7	11.5	11.6	11.6	11.5	11.6	11.5	11.5
Feb	11.8	10.9	10.7	10.7	10.7	10.8	11.0	10.9
Mar	12.3	11.7	11.7	11.7	11.8	11.7	11.7	11.7
Apr	12.9	13.0	13.0	12.9	13.0	12.9	13.0	13.0
May	10.1	10.7	10.7	10.6	10.7	10.6	10.7	10.6
Jun	8.7	9.2	9.3	9.3	9.3	9.3	9.3	9.3
Jul	9.5	9.7	9.7	9.7	9.7	9.7	9.6	9.7
Aug	10.1	10.2	10.2	10.2	10.2	10.2	10.1	10.1
Sep	11.8	11.8	11.7	11.7	11.7	11.7	11.8	11.8
Oct	11.8	11.7	11.7	11.7	11.7	11.7	11.7	11.7
Nov	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
Dec	11.8	11.6	11.6	11.6	11.6	11.6	11.6	11.6
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	9 (1.5)	9 (1.5)	5 (0.8)	8 (1.5)	2 (0.3)	4 (0.7)
Feb	---	---	4 (1.0)	4 (0.9)	3 (0.8)	4 (1.1)	1 (0.2)	2 (0.5)
Mar	---	---	6 (1.2)	5 (1.2)	2 (0.4)	6 (1.2)	2 (0.5)	2 (0.5)
Apr	---	---	10 (1.6)	8 (1.3)	4 (0.7)	10 (1.6)	1 (0.2)	3 (0.4)
May	---	---	11 (1.6)	10 (1.5)	5 (0.7)	11 (1.6)	8 (1.1)	7 (1.0)
Jun	---	---	11 (1.5)	12 (1.5)	5 (0.7)	12 (1.5)	8 (1.0)	8 (1.0)
Jul	---	---	9 (1.5)	9 (1.5)	5 (0.8)	8 (1.5)	2 (0.3)	4 (0.7)
Aug	---	---	4 (1.0)	4 (0.9)	3 (0.8)	4 (1.1)	1 (0.2)	2 (0.5)
Sep	---	---	6 (1.2)	5 (1.2)	2 (0.4)	6 (1.2)	2 (0.5)	2 (0.5)
Oct	---	---	10 (1.6)	8 (1.3)	4 (0.7)	10 (1.6)	1 (0.2)	3 (0.4)
Nov	---	---	11 (1.6)	10 (1.5)	5 (0.7)	11 (1.6)	8 (1.1)	7 (1.0)
Dec	---	---	11 (1.5)	12 (1.5)	5 (0.7)	12 (1.5)	8 (1.0)	8 (1.0)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.2 (-1.1)	-0.1 (-1.0)	-0.1 (-1.0)	-0.2 (-1.0)	-0.1 (-1.0)	-0.2 (-1.1)	-0.2 (-1.1)
Feb	---	-0.9 (-7.5)	-1.1 (-9.0)	-1.1 (-9.0)	-1.1 (-8.9)	-1 (-8.8)	-0.8 (-7.0)	-0.9 (-7.5)
Mar	---	-0.6 (-4.7)	-0.6 (-5.2)	-0.6 (-5.2)	-0.5 (-4.5)	-0.6 (-5.2)	-0.6 (-5.1)	-0.6 (-4.9)
Apr	---	0.1 (0.7)	0.1 (0.5)	0 (0.4)	0.1 (0.7)	0 (0.5)	0.1 (0.6)	0.1 (0.6)
May	---	0.6 (5.6)	0.6 (5.6)	0.5 (5.1)	0.6 (5.8)	0.5 (5.1)	0.6 (5.6)	0.5 (5.0)
Jun	---	0.5 (5.8)	0.6 (6.0)	0.6 (6.0)	0.6 (6.0)	0.6 (6.0)	0.6 (5.9)	0.6 (6.0)
Jul	---	0.2 (1.5)	0.2 (1.9)	0.2 (1.9)	0.2 (1.9)	0.2 (1.9)	0.1 (1.1)	0.2 (1.7)
Aug	---	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.4)	0.1 (0.2)	0 (0.1)	0 (0.1)
Sep	---	0 (0.0)	-0.1 (-0.2)	-0.1 (-0.2)	-0.1 (-0.2)	-0.1 (-0.2)	0 (0.3)	0 (0.1)
Oct	---	-0.1 (-1.2)	-0.1 (-1.0)	-0.1 (-1.0)	-0.1 (-1.4)	-0.1 (-1.0)	-0.1 (-1.0)	-0.1 (-1.0)
Nov	---	0 (-0.4)	0 (-0.2)	0 (-0.2)	0 (-0.4)	0 (-0.1)	0 (-0.3)	0 (-0.3)
Dec	---	-0.2 (-1.6)	-0.2 (-1.6)	-0.2 (-1.6)	-0.2 (-1.5)	-0.2 (-1.6)	-0.2 (-1.5)	-0.2 (-1.6)

Table 65 and Table 66 show the results for the Fountain Creek at Pueblo gage. All alternatives would have negligible effects to selenium, compared to the No Action, as effects are around two percent or less. At the Fountain Creek at Pueblo gage the relative comparison of the simulated concentration between the alternatives and No Action would not show a clear tendency with relatively small percent change, except a consistent concentration reduction pattern for all the alternatives in May. All alternatives would decrease cumulative selenium concentrations in Fountain Creek, compared to existing conditions, because of increases in streamflow.

Table 65. Cumulative Effects Simulated Selenium Concentration Comparison for Fountain Creek at Pueblo Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	12.4	9.3	9.3	9.3	9.3	9.3	9.4	9.3
15th percentile	7.3	5.5	5.5	5.5	5.5	5.5	5.5	5.5
25th percentile	8.4	6.3	6.3	6.2	6.3	6.2	6.3	6.3
50th percentile	11.5	8.2	8.3	8.2	8.1	8.2	8.2	8.3
75th percentile	16.1	11.2	11.4	11.3	11.4	11.3	11.2	11.2
85th percentile	18.4	12.8	13.0	12.8	12.9	12.8	12.9	12.9
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (1.1)	0.0 (0.0)
15th percentile	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
25th percentile	---	---	0.0 (0.0)	-0.1 (-1.6)	0.0 (0.0)	-0.1 (-1.6)	0.0 (0.0)	0.0 (0.0)
50th percentile	---	---	0.1 (1.2)	0.0 (0.0)	-0.1 (-1.2)	0.0 (0.0)	0.0 (0.0)	0.1 (1.2)
75th percentile	---	---	0.2 (1.8)	0.1 (0.9)	0.2 (1.8)	0.1 (0.9)	0.0 (0.0)	0.0 (0.0)
85th percentile	---	---	0.2 (1.6)	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)	0.1 (0.8)	0.1 (0.8)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	-3.1 (-25.0)	-3.1 (-25.0)	-3.1 (-25.0)	-3.1 (-25.0)	-3.1 (-25.0)	-3.0 (-24.2)	-3.1 (-25.0)
15th percentile	---	-1.8 (-24.7)	-1.8 (-24.7)	-1.8 (-24.7)	-1.8 (-24.7)	-1.8 (-24.7)	-1.8 (-24.7)	-1.8 (-24.7)
25th percentile	---	-2.1 (-25.0)	-2.1 (-25.0)	-2.2 (-26.2)	-2.1 (-25.0)	-2.2 (-26.2)	-2.1 (-25.0)	-2.1 (-25.0)
50th percentile	---	-3.3 (-28.7)	-3.2 (-27.8)	-3.3 (-28.7)	-3.4 (-29.6)	-3.3 (-28.7)	-3.3 (-28.7)	-3.2 (-27.8)
75th percentile	---	-4.9 (-30.4)	-4.7 (-29.2)	-4.8 (-29.8)	-4.7 (-29.2)	-4.8 (-29.8)	-4.9 (-30.4)	-4.9 (-30.4)
85th percentile	---	-5.6 (-30.4)	-5.4 (-29.3)	-5.6 (-30.4)	-5.5 (-29.9)	-5.6 (-30.4)	-5.5 (-29.9)	-5.5 (-29.9)

Table 66. Cumulative Effects Monthly Simulated Selenium Concentration for Fountain Creek at Pueblo Gage

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	14.2	10.2	10.1	10.1	10.2	10.1	10.1	10.1
Feb	14.2	10.0	10.1	10.1	10.1	10.1	10.0	10.0
Mar	12.5	9.0	8.9	8.9	8.9	8.9	8.9	8.9
Apr	10.8	8.3	8.3	8.3	8.3	8.4	8.4	8.5
May	9.4	10.8	10.7	10.0	10.7	10.0	10.6	10.5
Jun	10.1	11.0	11.1	11.1	11.0	11.0	11.4	11.1
Jul	9.3	7.4	7.5	7.5	7.3	7.5	7.3	7.5
Aug	10.1	7.2	7.5	7.5	7.4	7.2	7.2	7.2
Sep	10.3	7.3	7.3	7.3	7.3	7.3	7.6	7.4
Oct	16.0	9.4	9.3	9.3	9.3	9.3	9.3	9.4
Nov	15.0	9.9	10.0	10.0	9.9	10.0	10.0	10.0
Dec	17.1	11.4	11.3	11.2	11.4	11.2	11.4	11.3
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	-0.1 (-0.1)	-0.1 (-0.1)	0 (0.2)	-0.1 (-0.4)	-0.1 (-0.7)	-0.1 (-0.7)
Feb	---	---	0.1 (1.6)	0.1 (1.5)	0.1 (0.9)	0.1 (1.5)	0 (0.2)	0 (0.2)
Mar	---	---	-0.1 (-0.7)	-0.1 (-0.9)	-0.1 (-0.7)	-0.1 (-0.9)	-0.1 (-0.3)	-0.1 (-0.3)
Apr	---	---	0 (-0.8)	0 (-0.7)	0 (-0.5)	0.1 (1.2)	0.1 (0.4)	0.2 (1.4)
May	---	---	-0.1 (-1.2)	-0.8 (-7.4)	-0.1 (-1.2)	-0.8 (-7.4)	-0.2 (-2.0)	-0.3 (-2.8)
Jun	---	---	0.1 (0.5)	0.1 (0.6)	0 (-0.3)	0 (0.1)	0.4 (3.3)	0.1 (1.2)
Jul	---	---	0.1 (1.2)	0.1 (1.3)	-0.1 (-0.9)	0.1 (1.0)	-0.1 (-1.6)	0.1 (1.0)
Aug	---	---	0.3 (4.0)	0.3 (3.7)	0.2 (3.6)	0 (0.4)	0 (0.6)	0 (0.6)
Sep	---	---	0 (-0.6)	0 (-0.7)	0 (-0.6)	0 (-0.9)	0.3 (3.4)	0.1 (0.5)
Oct	---	---	-0.1 (-0.8)	-0.1 (-0.5)	-0.1 (-0.5)	-0.1 (-1.2)	-0.1 (-0.9)	0 (0.4)
Nov	---	---	0.1 (0.7)	0.1 (0.6)	0 (0.3)	0.1 (1.1)	0.1 (0.3)	0.1 (0.4)
Dec	---	---	-0.1 (-1.2)	-0.2 (-1.2)	0 (0.1)	-0.2 (-1.3)	0 (0.2)	-0.1 (-0.5)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-4 (-28.5)	-4.1 (-28.5)	-4.1 (-28.5)	-4 (-28.3)	-4.1 (-28.7)	-4.1 (-29.0)	-4.1 (-29.0)
Feb	---	-4.2 (-30.0)	-4.1 (-28.8)	-4.1 (-28.9)	-4.1 (-29.4)	-4.1 (-28.9)	-4.2 (-29.9)	-4.2 (-29.9)
Mar	---	-3.5 (-28.0)	-3.6 (-28.5)	-3.6 (-28.7)	-3.6 (-28.5)	-3.6 (-28.6)	-3.6 (-28.2)	-3.6 (-28.2)
Apr	---	-2.5 (-23.0)	-2.5 (-23.5)	-2.5 (-23.5)	-2.5 (-23.3)	-2.4 (-22.0)	-2.4 (-22.7)	-2.3 (-21.9)
May	---	1.4 (15.1)	1.3 (13.7)	0.6 (6.6)	1.3 (13.8)	0.6 (6.7)	1.2 (12.8)	1.1 (11.9)
Jun	---	0.9 (9.3)	1 (9.9)	1 (10.0)	0.9 (9.0)	0.9 (9.4)	1.3 (12.9)	1 (10.6)
Jul	---	-1.9 (-20.6)	-1.8 (-19.6)	-1.8 (-19.6)	-2 (-21.3)	-1.8 (-19.8)	-2 (-21.8)	-1.8 (-19.8)
Aug	---	-2.9 (-28.8)	-2.6 (-26.0)	-2.6 (-26.2)	-2.7 (-26.3)	-2.9 (-28.5)	-2.9 (-28.4)	-2.9 (-28.4)
Sep	---	-3 (-28.3)	-3 (-28.8)	-3 (-28.8)	-3 (-28.8)	-3 (-29.0)	-2.7 (-25.9)	-2.9 (-28.0)
Oct	---	-6.6 (-41.2)	-6.7 (-41.7)	-6.7 (-41.5)	-6.7 (-41.5)	-6.7 (-41.9)	-6.7 (-41.7)	-6.6 (-41.0)
Nov	---	-5.1 (-33.8)	-5 (-33.4)	-5 (-33.4)	-5.1 (-33.7)	-5 (-33.1)	-5 (-33.6)	-5 (-33.6)
Dec	---	-5.7 (-33.2)	-5.8 (-34.0)	-5.9 (-34.1)	-5.7 (-33.2)	-5.9 (-34.1)	-5.7 (-33.1)	-5.8 (-33.6)

Sulfate and Uranium Analysis

This section describes the methods and results of the sulfate and uranium analysis. All references in this appendix to sulfate and uranium are to filtered sulfate in mg/L and filtered uranium in μg/L, respectively.

Methods

The analyses of sulfate and uranium were based on field measurements of sulfate and uranium, and their relationship with TDS. Sulfate and uranium data were obtained from the USGS published data at various USGS gaging stations located throughout the Arkansas River Basin study area.

Regression equations between TDS and the respective constituent were developed and applied to the salinity analysis results (see this Appendix F.2 – *Salinity Analysis*).

The significance criteria in Table 7 were used to evaluate sulfate and uranium effects.

Sulfate and Salinity Relationships

The estimated TDS data, using the measured specific conductance and the site-specific USGS relationships described in previous sections (USGS, 2010), were used to derive a relationship with measured sulfate. Measured sulfate corresponds to the USGS published discrete sampling of sulfate in mg/L.

Scatter plots were created to observe the relationship between sulfate and the TDS. For each site, regression equations were developed to predict the concentration of sulfate with TDS concentration as the explanatory variable. TDS was derived from the measured specific conductance using USGS site-specific relationships (as previously described in Table 2).

Figure 59 to Figure 68 shows relationship between TDS and sulfate at various USGS gaging stations located in the Arkansas River Basin study area. The coefficient of determination (R^2) values indicate a positive correlation between sulfate and salinity concentrations.

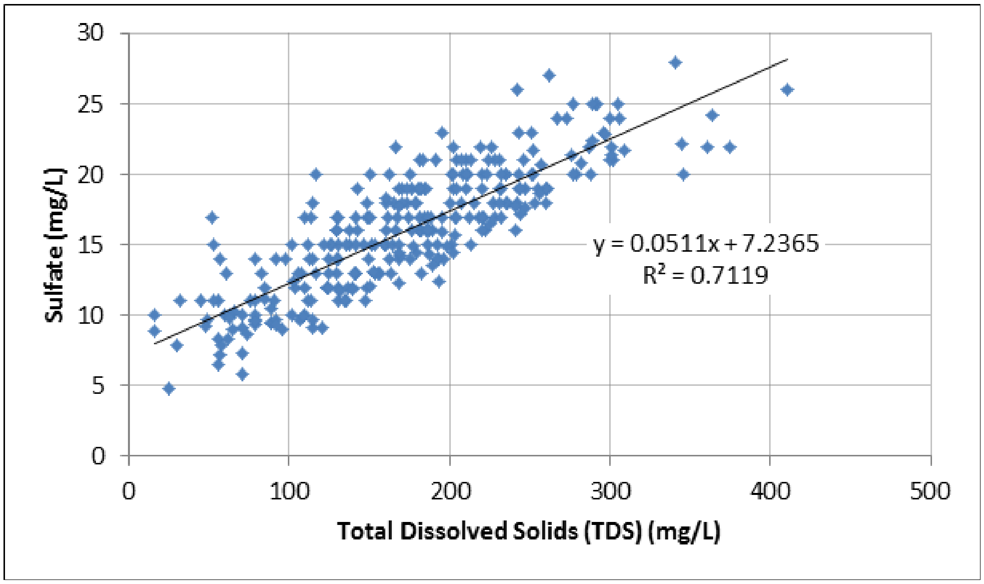


Figure 59. TDS and Sulfate Concentration Relationship for Fountain Creek near Colorado Springs Gage

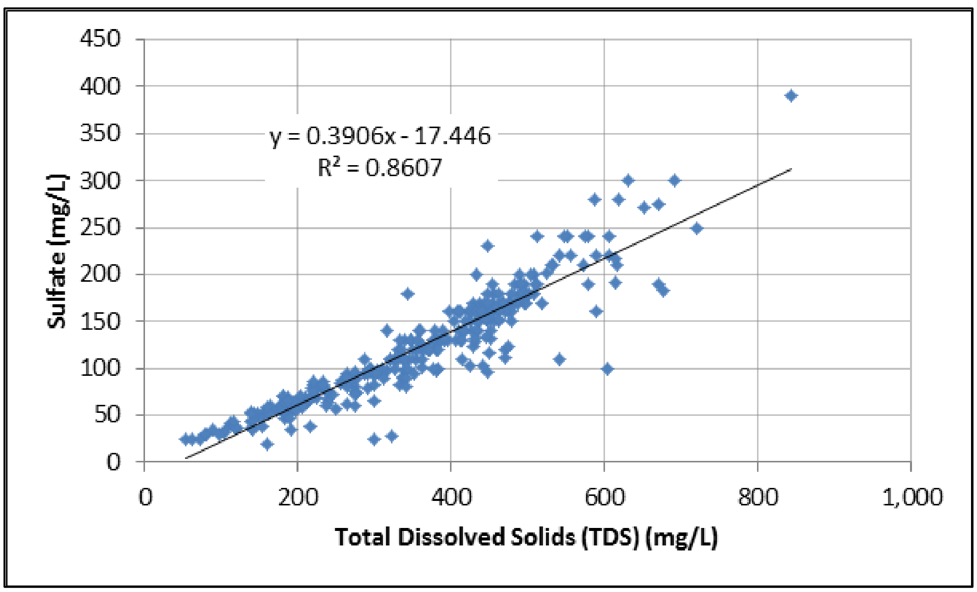


Figure 60. TDS and Sulfate Concentration Relationship for Fountain Creek at Colorado Springs Gage

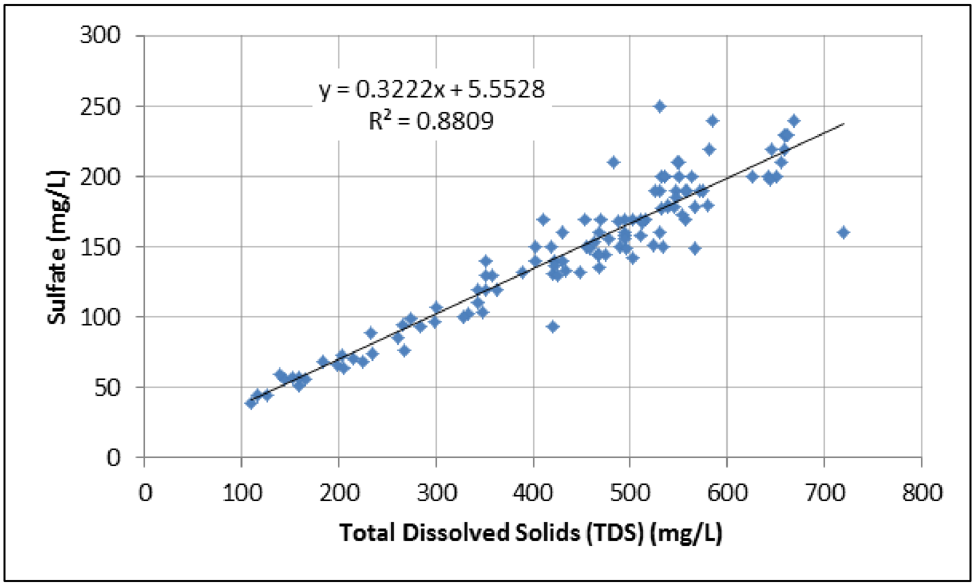


Figure 61. TDS and Sulfate Concentration Relationship for Fountain Creek at Security Gage

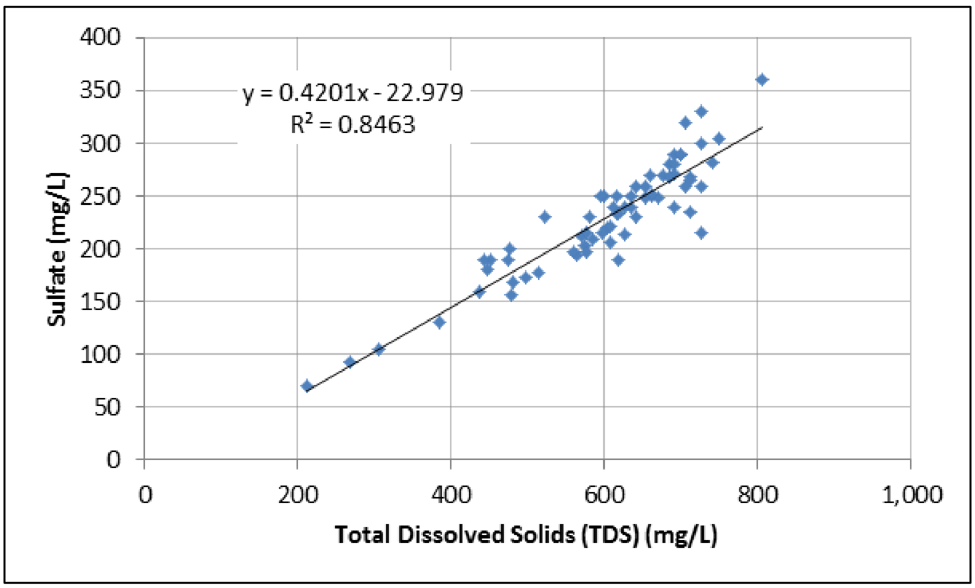


Figure 62. TDS and Sulfate Concentration Relationship for Fountain Creek near Fountain Gage

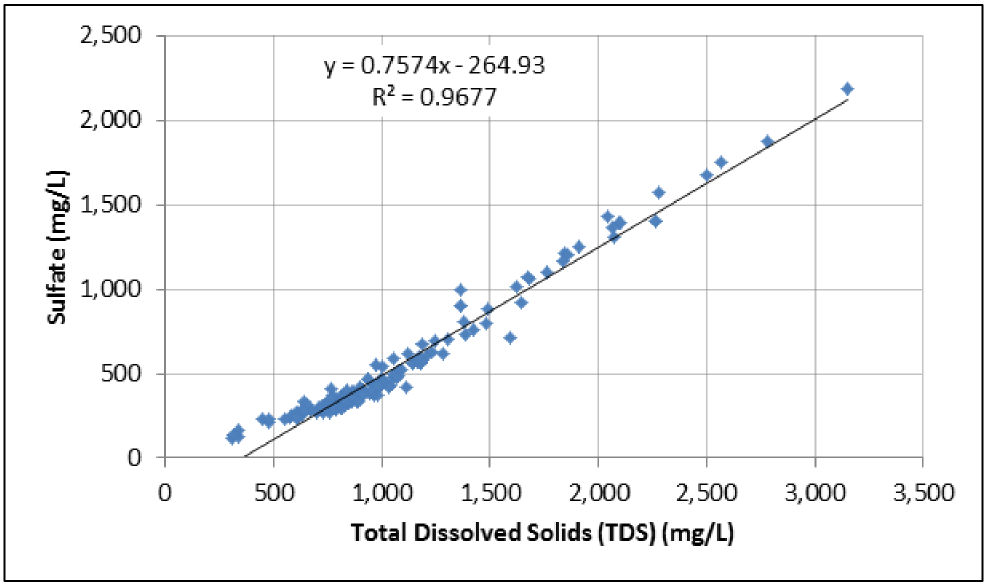


Figure 63. TDS and Sulfate Concentration Relationship for Fountain Creek at Pueblo Gage

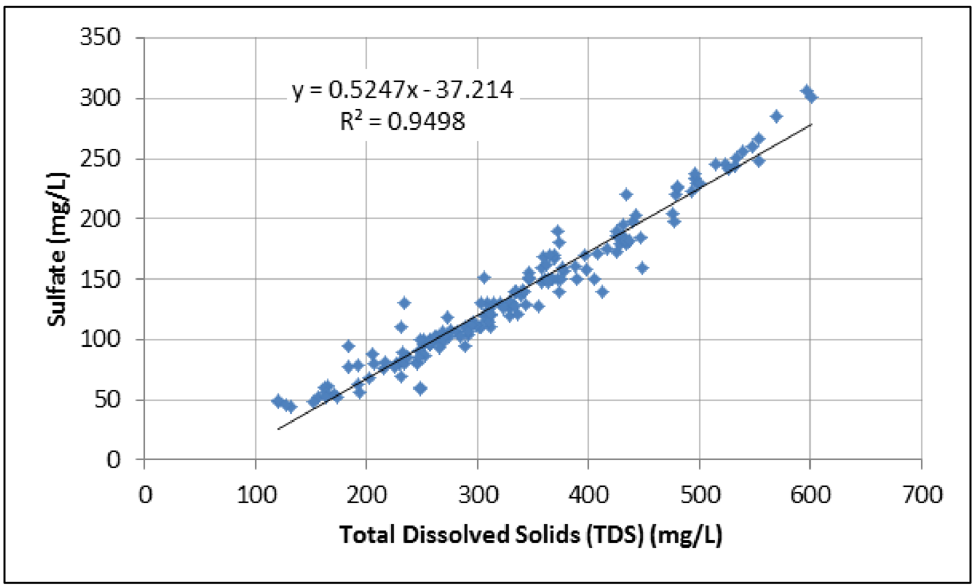


Figure 64. TDS and Sulfate Concentration Relationship for Arkansas River above Pueblo Gage

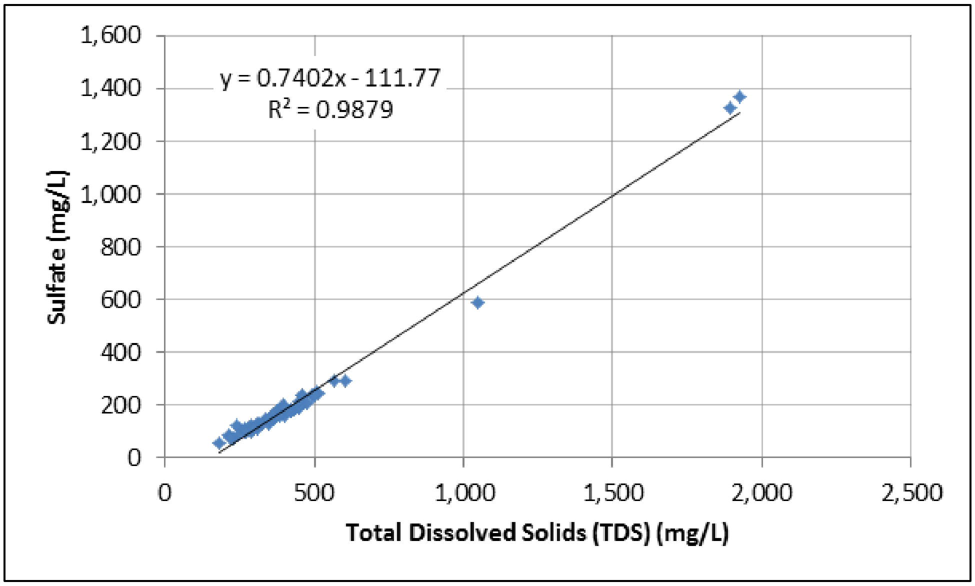


Figure 65. TDS and Sulfate Concentration Relationship for Arkansas River at Moffat St. Gage

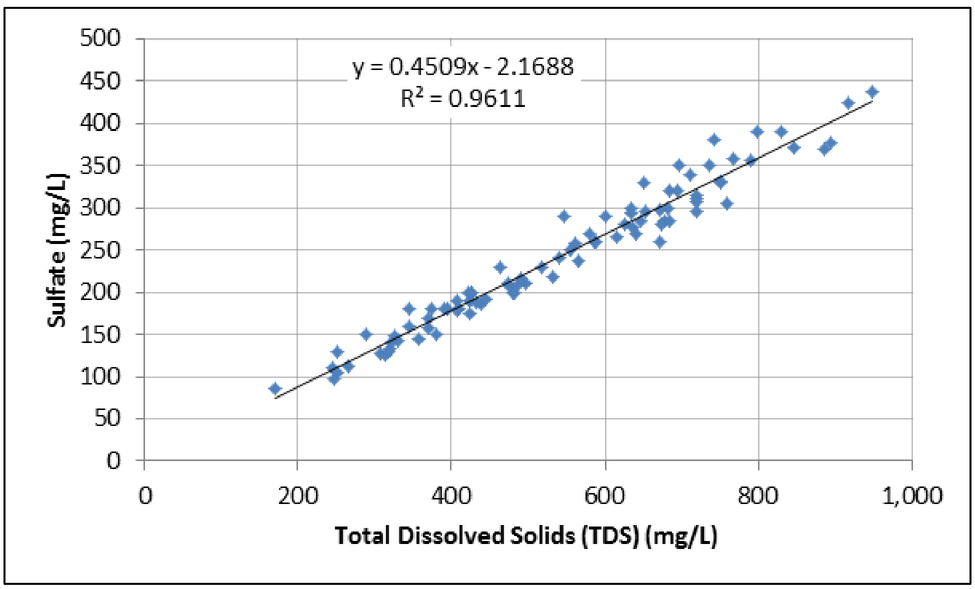


Figure 66. TDS and Sulfate Concentration Relationship for Arkansas River near Avondale Gage

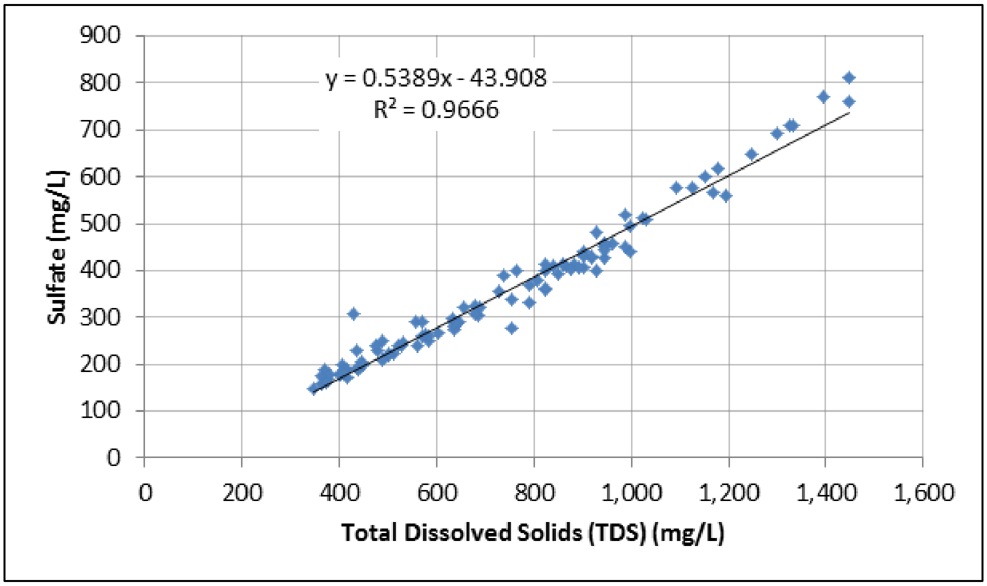


Figure 67. TDS and Sulfate Concentration Relationship for Arkansas River at Catlin Dam Gage

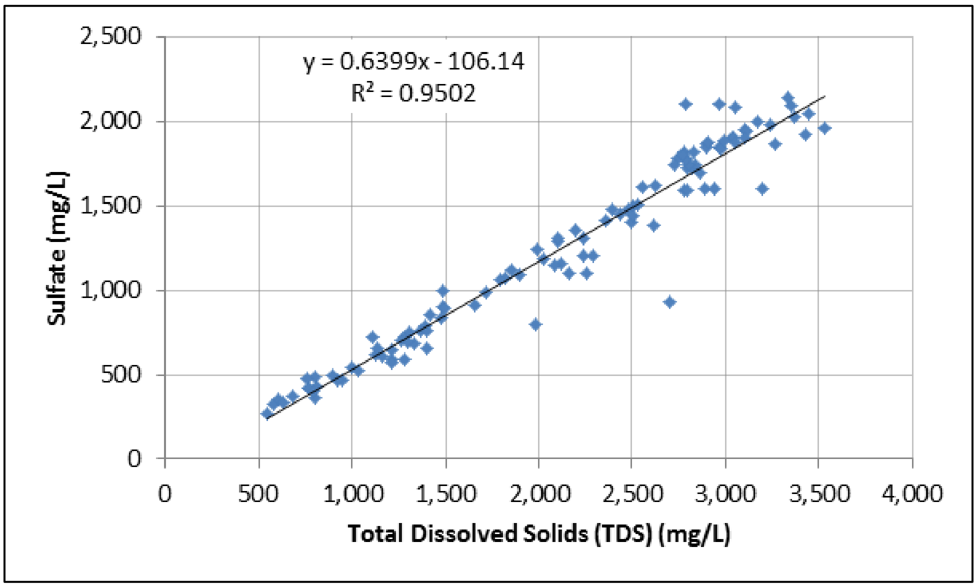


Figure 68. TDS and Sulfate Concentration Relationship for Arkansas River at Las Animas Gage

Uranium and Salinity Relationships

The estimated TDS dataset was also used to derive a relationship with measured sulfate. Measured uranium corresponds to the USGS published discrete sampling of uranium in µg/L.

Scatter plots were created to observe the relationship between uranium and the TDS. For each site, regression equations were developed to predict the concentration of uranium with TDS concentration as explanatory variable. TDS was derived from the measured specific conductance using USGS site-specific relationships (as previously described in Table 2).

Figure 69 to Figure 75 shows relationship between TDS and uranium at various USGS gaging stations located in the Arkansas River Basin. The coefficient of determination (R^2) values indicate a positive correlation between uranium and salinity concentrations.

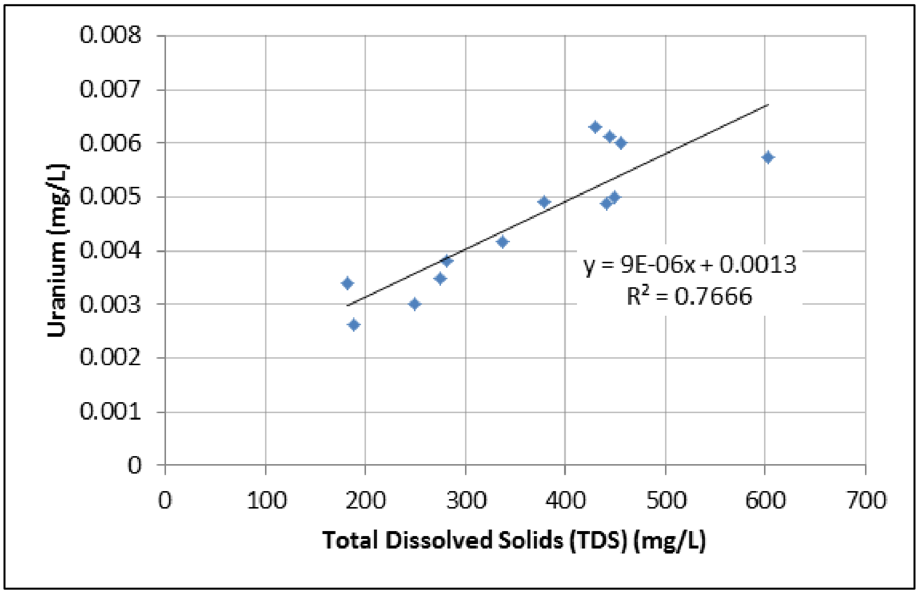


Figure 69. TDS and Uranium Concentration Relationship for Fountain Creek at Colorado Springs Gage

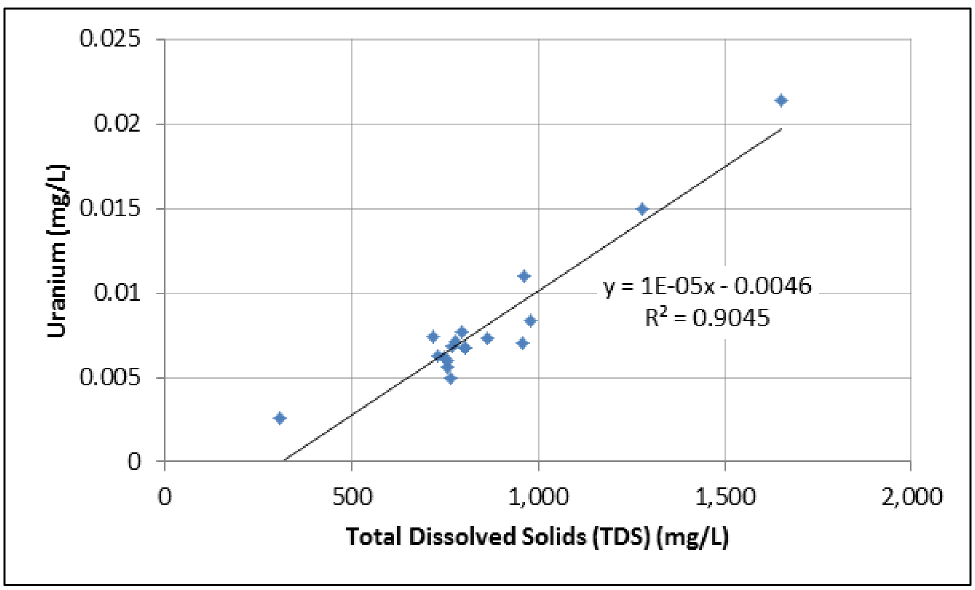


Figure 70. TDS and Uranium Concentration Relationship for Fountain Creek at Pueblo Gage

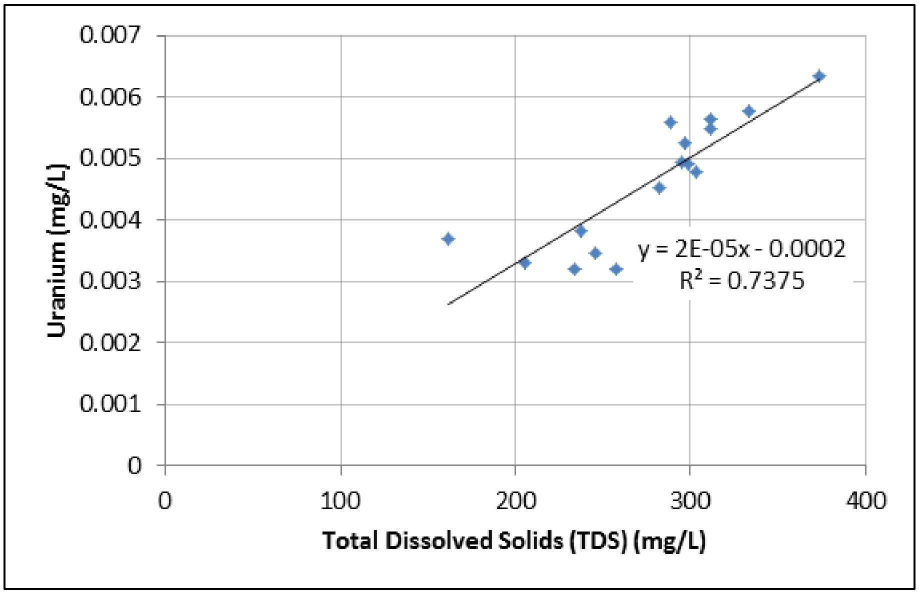


Figure 71. TDS and Uranium Concentration Relationship for Arkansas River above Pueblo Gage

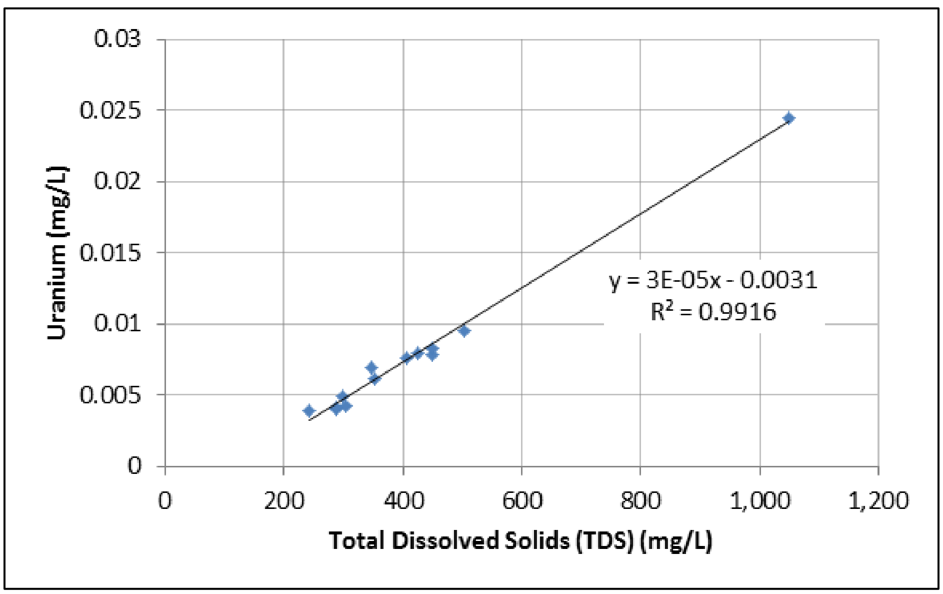


Figure 72. TDS and Uranium Concentration Relationship for Arkansas River at Moffat St. Gage

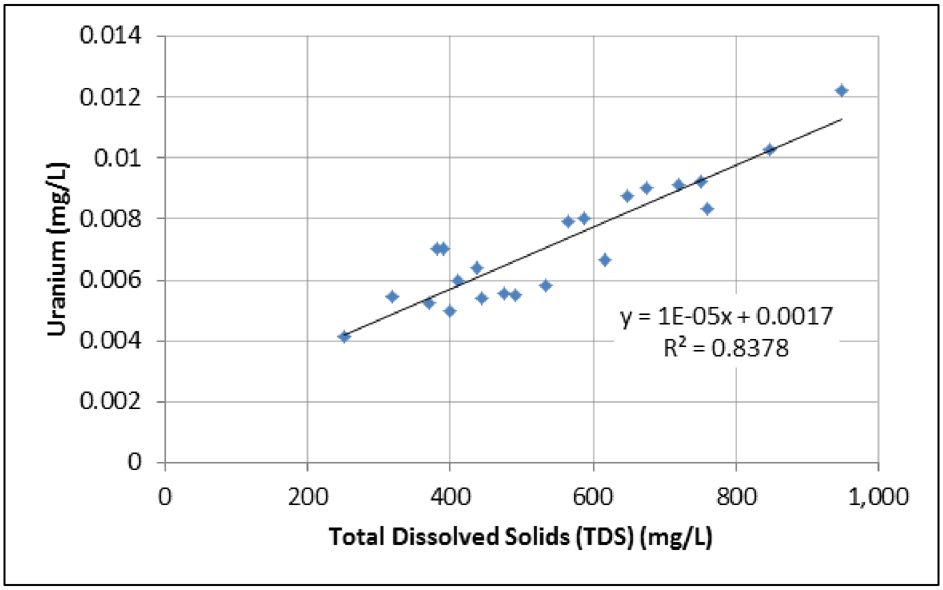


Figure 73. TDS and Uranium Concentration Relationship for Arkansas River near Avondale Gage

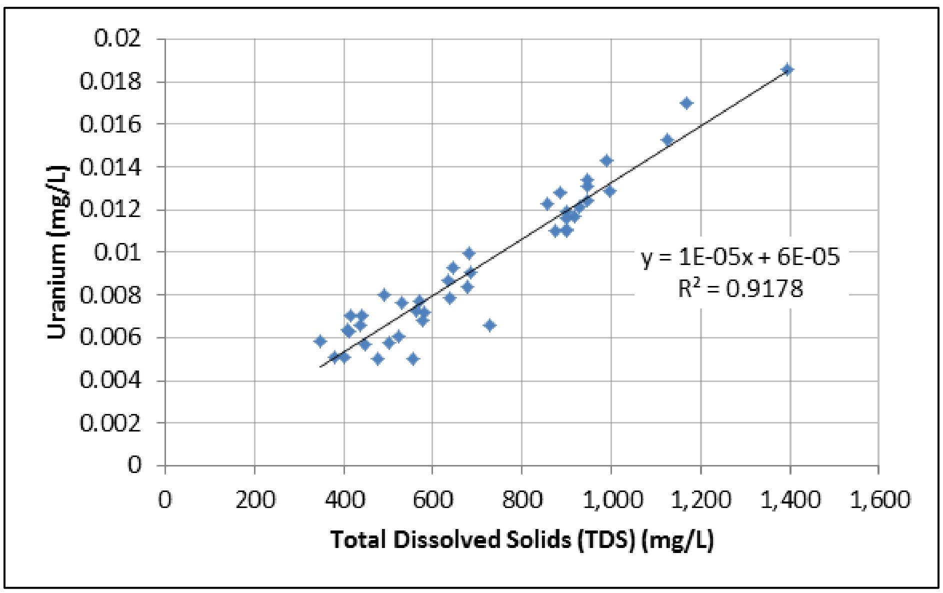


Figure 74. TDS and Uranium Concentration Relationship for Arkansas River at Catlin Dam Gage

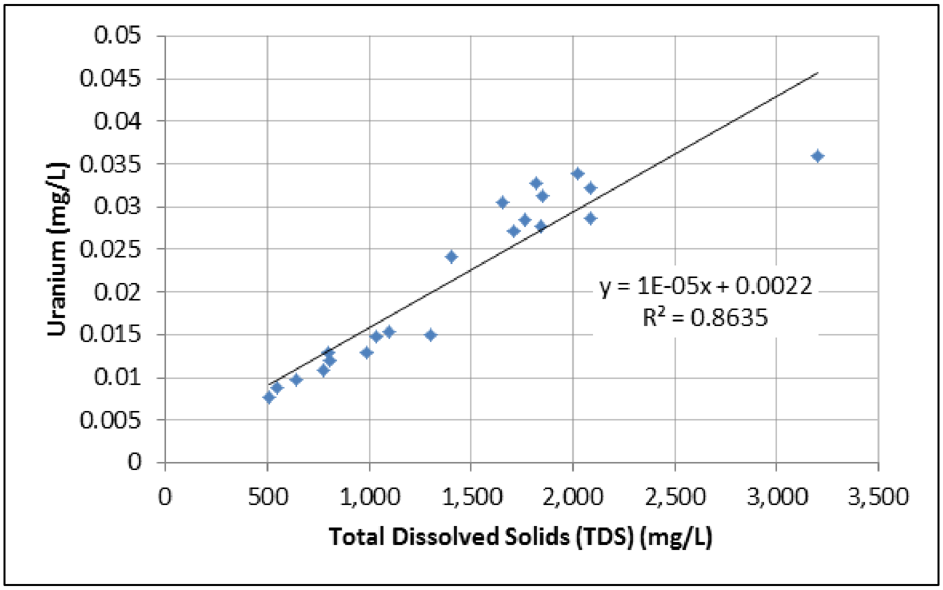


Figure 75. TDS and Uranium Concentration Relationship for Arkansas River at Las Animas Gage

Results

This section presents the direct, indirect, and cumulative effects for sulfate and uranium concentrations.

Direct and Indirect Effects

All alternatives would have negligible to minor adverse effects to sulfate and uranium concentrations, compared to No Action, at the Arkansas River at Moffat St. gage (Table 67 to Table 70) except River South and Master Contract Only. East of Pueblo municipal water supplies in the River South and Master Contract Only alternatives remain in the Arkansas River and flow past this gage, whereas the other alternatives deliver these supplies in the AVC, bypassing this gage. This bypass reduces flow and affects sulfate and uranium concentrations. The greatest increases occur in the fall and winter months.

Table 67. Direct Effects Simulated Sulfate Concentrations for Arkansas River at Moffat St. Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	178	189	199	199	198	199	176	190
15th percentile	84	86	86	86	86	86	82	86
25th percentile	110	113	113	113	113	113	112	113
50th percentile	158	166	173	173	170	173	160	169
75th percentile	198	212	223	223	222	223	208	213
85th percentile	219	242	261	263	257	259	238	243
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	10 (5.5)	11 (5.6)	9 (5.0)	10 (5.5)	-13 (-6.7)	1 (0.6)
15th percentile	---	---	0 (0.3)	0 (0.3)	0 (0.3)	0 (0.3)	-3 (-4.0)	0 (0.3)
25th percentile	---	---	1 (0.5)	1 (0.5)	1 (0.5)	1 (0.5)	-1 (-0.5)	0 (0.0)
50th percentile	---	---	7 (4.4)	7 (4.5)	5 (2.9)	7 (4.4)	-5 (-3.2)	3 (1.8)
75th percentile	---	---	11 (5.0)	11 (5.0)	10 (4.6)	10 (4.9)	-4 (-1.9)	1 (0.5)
85th percentile	---	---	20 (8.1)	21 (8.7)	15 (6.3)	18 (7.2)	-4 (-1.5)	1 (0.3)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	11 (6.0)	21 (11.8)	21 (11.9)	20 (11.3)	21 (11.8)	-2 (-1.1)	12 (6.6)
15th percentile	---	2 (2.1)	2 (2.4)	2 (2.4)	2 (2.4)	2 (2.4)	-2 (-2.0)	2 (2.4)
25th percentile	---	3 (2.8)	4 (3.4)	4 (3.4)	4 (3.3)	4 (3.4)	3 (2.3)	3 (2.9)
50th percentile	---	7 (4.7)	15 (9.3)	15 (9.4)	12 (7.7)	15 (9.3)	2 (1.3)	10 (6.6)
75th percentile	---	14 (7.0)	25 (12.4)	24 (12.3)	24 (12.0)	24 (12.2)	10 (5.0)	15 (7.5)
85th percentile	---	23 (10.6)	43 (19.5)	44 (20.2)	38 (17.6)	41 (18.6)	19 (8.9)	24 (11.0)

Table 68. Monthly Simulated Sulfate Concentration for Arkansas River at Moffat St. Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	238	246	264	265	261	264	231	249
Feb	270	285	307	308	308	307	247	286
Mar	179	189	204	204	203	203	176	192
Apr	160	168	175	175	176	174	166	169
May	148	150	152	151	151	152	150	151
Jun	93	95	95	95	95	95	94	95
Jul	85	89	91	91	91	91	84	89
Aug	135	144	152	152	152	151	125	144
Sep	190	203	218	219	216	219	185	203
Oct	187	209	225	224	217	225	204	214
Nov	223	239	247	247	248	247	220	236
Dec	246	266	279	279	277	279	248	267
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	18 (7.6)	19 (7.7)	15 (6.2)	18 (7.6)	-15 (-5.9)	3 (1.4)
Feb	---	---	22 (7.6)	23 (7.8)	23 (8.0)	22 (7.6)	-38 (-13.5)	1 (0.1)
Mar	---	---	15 (7.7)	15 (8.1)	14 (7.2)	14 (7.6)	-13 (-6.7)	3 (1.7)
Apr	---	---	7 (3.7)	7 (3.9)	8 (4.3)	6 (3.6)	-2 (-1.3)	1 (0.1)
May	---	---	2 (0.8)	1 (0.8)	1 (0.6)	2 (0.8)	0 (-0.2)	1 (0.4)
Jun	---	---	0 (0.7)	0 (0.8)	0 (0.7)	0 (0.7)	-1 (-0.9)	0 (0.0)
Jul	---	---	2 (2.7)	2 (2.6)	2 (2.1)	2 (2.7)	-5 (-5.4)	0 (0.0)
Aug	---	---	8 (5.5)	8 (5.4)	8 (5.8)	7 (5.3)	-19 (-13.0)	0 (0.5)
Sep	---	---	15 (7.5)	16 (7.8)	13 (6.6)	16 (7.7)	-18 (-8.7)	0 (-0.1)
Oct	---	---	16 (7.7)	15 (7.6)	8 (4.3)	16 (7.7)	-5 (-2.4)	5 (2.7)
Nov	---	---	8 (3.6)	8 (3.6)	9 (3.8)	8 (3.6)	-19 (-7.8)	-3 (-1.1)
Dec	---	---	13 (4.7)	13 (4.8)	11 (4.1)	13 (4.7)	-18 (-6.9)	1 (0.4)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	8 (3.3)	26 (11.1)	27 (11.2)	23 (9.6)	26 (11.2)	-7 (-2.8)	11 (4.7)
Feb	---	15 (5.6)	37 (13.6)	38 (13.8)	38 (14.0)	37 (13.6)	-23 (-8.6)	16 (5.7)
Mar	---	10 (5.7)	25 (13.8)	25 (14.3)	24 (13.4)	24 (13.7)	-3 (-1.3)	13 (7.6)
Apr	---	8 (5.1)	15 (8.9)	15 (9.1)	16 (9.6)	14 (8.9)	6 (3.7)	9 (5.2)
May	---	2 (1.7)	4 (2.6)	3 (2.5)	3 (2.3)	4 (2.6)	2 (1.5)	3 (2.2)
Jun	---	2 (1.6)	2 (2.4)	2 (2.4)	2 (2.3)	2 (2.3)	1 (0.7)	2 (1.7)
Jul	---	4 (5.3)	6 (8.1)	6 (8.0)	6 (7.6)	6 (8.1)	-1 (-0.4)	4 (5.3)
Aug	---	9 (6.6)	17 (12.5)	17 (12.4)	17 (12.8)	16 (12.3)	-10 (-7.2)	9 (7.2)
Sep	---	13 (7.1)	28 (15.1)	29 (15.5)	26 (14.1)	29 (15.3)	-5 (-2.3)	13 (6.9)
Oct	---	22 (11.4)	38 (20.0)	37 (19.9)	30 (16.2)	38 (20.0)	17 (8.7)	27 (14.4)
Nov	---	16 (7.0)	24 (10.9)	24 (10.9)	25 (11.2)	24 (10.9)	-3 (-1.3)	13 (5.9)
Dec	---	20 (8.1)	33 (13.1)	33 (13.2)	31 (12.6)	33 (13.1)	2 (0.6)	21 (8.6)

Table 69. Direct Effects Simulated Uranium Concentrations for Arkansas River at Moffat St. Gage

Statistic	Existing Conditions	No Action		Comanche South		Pueblo Dam South		JUP North		Pueblo Dam North		River South		Master Contract Only	
Simulated Concentration (µg/L)															
Mean	8.6	9.1		9.5		9.5		9.4		9.5		8.6		9.1	
15th percentile	4.8	4.9		4.9		4.9		4.9		4.9		4.8		4.9	
25th percentile	5.9	6.0		6.0		6.0		6.0		6.0		6.0		6.0	
50th percentile	7.8	8.1		8.4		8.4		8.3		8.4		7.9		8.3	
75th percentile	9.5	10.0		10.5		10.5		10.4		10.5		9.9		10.1	
85th percentile	10.3	11.2		12.0		12.1		11.8		11.9		11.1		11.3	
Change in Concentration Compared to No Action Alternative [µg/L (%)]															
Mean	---	---		0.4	(4.6)	0.4	(4.7)	0.4	(4.2)	0.4	(4.6)	-0.5	(-5.6)	0	(0.5)
15th percentile	---	---		0	(0.2)	0	(0.2)	0	(0.2)	0	(0.2)	-0.1	(-2.8)	0	(0.2)
25th percentile	---	---		0	(0.4)	0	(0.4)	0	(0.4)	0	(0.4)	0	(-0.4)	0	(0.0)
50th percentile	---	---		0.3	(3.6)	0.3	(3.7)	0.2	(2.4)	0.3	(3.6)	-0.2	(-2.7)	0.1	(1.5)
75th percentile	---	---		0.4	(4.3)	0.4	(4.3)	0.4	(4.0)	0.4	(4.2)	-0.2	(-1.6)	0	(0.4)
85th percentile	---	---		0.8	(7.0)	0.9	(7.6)	0.6	(5.5)	0.7	(6.3)	-0.2	(-1.3)	0	(0.3)
Change in Concentration Compared to Existing Conditions [µg/L (%)]															
Mean	---	0.4	(5.0)	0.9	(9.9)	0.9	(10.0)	0.8	(9.4)	0.9	(9.9)	-0.1	(-0.9)	0.5	(5.5)
15th percentile	---	0.1	(1.5)	0.1	(1.7)	0.1	(1.7)	0.1	(1.7)	0.1	(1.7)	-0.1	(-1.4)	0.1	(1.7)
25th percentile	---	0.1	(2.1)	0.1	(2.5)	0.1	(2.5)	0.1	(2.5)	0.1	(2.5)	0.1	(1.7)	0.1	(2.2)
50th percentile	---	0.3	(3.9)	0.6	(7.6)	0.6	(7.7)	0.5	(6.3)	0.6	(7.6)	0.1	(1.1)	0.4	(5.4)
75th percentile	---	0.6	(5.9)	1	(10.5)	1	(10.5)	1	(10.2)	1	(10.4)	0.4	(4.2)	0.6	(6.4)
85th percentile	---	0.9	(9.1)	1.7	(16.8)	1.8	(17.4)	1.6	(15.1)	1.6	(16.0)	0.8	(7.7)	1	(9.5)

Table 70. Monthly Simulated Uranium Concentration for Arkansas River at Moffat St. Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	11.1	11.4	12.1	12.2	12.0	12.1	10.8	11.5
Feb	12.4	13.0	13.9	13.9	13.9	13.9	11.4	13.0
Mar	8.7	9.1	9.7	9.7	9.6	9.7	8.6	9.2
Apr	7.9	8.3	8.5	8.5	8.5	8.5	8.2	8.3
May	7.4	7.5	7.6	7.6	7.6	7.6	7.5	7.5
Jun	5.2	5.3	5.3	5.3	5.3	5.3	5.2	5.3
Jul	4.9	5.0	5.1	5.1	5.1	5.1	4.8	5.0
Aug	6.9	7.3	7.6	7.6	7.6	7.6	6.5	7.3
Sep	9.1	9.7	10.3	10.3	10.2	10.3	8.9	9.6
Oct	9.0	9.9	10.5	10.5	10.2	10.5	9.7	10.1
Nov	10.5	11.1	11.4	11.4	11.5	11.5	10.3	11.0
Dec	11.4	12.2	12.7	12.7	12.7	12.7	11.5	12.3
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.7 (6.6)	0.8 (6.7)	0.6 (5.4)	0.7 (6.7)	-0.6 (-5.1)	0.1 (1.2)
Feb	---	---	0.9 (6.7)	0.9 (6.9)	0.9 (7.1)	0.9 (6.7)	-1.6 (-12.0)	0.0 (0.1)
Mar	---	---	0.6 (6.5)	0.6 (6.8)	0.5 (6.1)	0.6 (6.4)	-0.5 (-5.6)	0.1 (1.5)
Apr	---	---	0.2 (3.0)	0.2 (3.2)	0.2 (3.6)	0.2 (3.0)	-0.1 (-1.1)	0.0 (0.1)
May	---	---	0.1 (0.7)	0.1 (0.6)	0.1 (0.5)	0.1 (0.7)	0.0 (-0.1)	0.0 (0.4)
Jun	---	---	0.0 (0.5)	0.0 (0.5)	0.0 (0.5)	0.0 (0.5)	-0.1 (-0.7)	0.0 (0.0)
Jul	---	---	0.1 (1.9)	0.1 (1.8)	0.1 (1.5)	0.1 (1.9)	-0.2 (-3.9)	0.0 (0.0)
Aug	---	---	0.3 (4.4)	0.3 (4.4)	0.3 (4.6)	0.3 (4.2)	-0.8 (-10.5)	0.0 (0.4)
Sep	---	---	0.6 (6.4)	0.6 (6.7)	0.5 (5.6)	0.6 (6.5)	-0.8 (-7.4)	-0.1 (-0.1)
Oct	---	---	0.6 (6.6)	0.6 (6.5)	0.3 (3.7)	0.6 (6.6)	-0.2 (-2.0)	0.2 (2.3)
Nov	---	---	0.3 (3.1)	0.3 (3.1)	0.4 (3.3)	0.4 (3.2)	-0.8 (-6.8)	-0.1 (-0.9)
Dec	---	---	0.5 (4.1)	0.5 (4.2)	0.5 (3.7)	0.5 (4.1)	-0.7 (-6.1)	0.1 (0.4)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.3 (2.9)	1.0 (9.7)	1.1 (9.8)	0.9 (8.4)	1.0 (9.7)	-0.3 (-2.4)	0.4 (4.1)
Feb	---	0.6 (4.9)	1.5 (12.0)	1.5 (12.2)	1.5 (12.4)	1.5 (12.0)	-1.0 (-7.6)	0.6 (5.1)
Mar	---	0.4 (4.8)	1.0 (11.6)	1.0 (11.9)	0.9 (11.2)	1.0 (11.5)	-0.1 (-1.1)	0.5 (6.3)
Apr	---	0.4 (4.2)	0.6 (7.3)	0.6 (7.5)	0.6 (7.9)	0.6 (7.3)	0.3 (3.1)	0.4 (4.3)
May	---	0.1 (1.4)	0.2 (2.1)	0.2 (2.0)	0.2 (1.9)	0.2 (2.1)	0.1 (1.2)	0.1 (1.7)
Jun	---	0.1 (1.2)	0.1 (1.7)	0.1 (1.7)	0.1 (1.7)	0.1 (1.7)	0.0 (0.5)	0.1 (1.2)
Jul	---	0.1 (3.8)	0.2 (5.7)	0.2 (5.6)	0.2 (5.3)	0.2 (5.7)	-0.1 (-0.3)	0.1 (3.7)
Aug	---	0.4 (5.3)	0.7 (9.9)	0.7 (9.8)	0.7 (10.1)	0.7 (9.7)	-0.4 (-5.7)	0.4 (5.7)
Sep	---	0.6 (6.0)	1.2 (12.7)	1.2 (13.0)	1.1 (11.9)	1.2 (12.9)	-0.2 (-1.9)	0.5 (5.9)
Oct	---	0.9 (9.6)	1.5 (16.8)	1.5 (16.7)	1.2 (13.6)	1.5 (16.8)	0.7 (7.3)	1.1 (12.1)
Nov	---	0.6 (6.1)	0.9 (9.4)	0.9 (9.4)	1.0 (9.6)	1.0 (9.4)	-0.2 (-1.1)	0.5 (5.1)
Dec	---	0.8 (7.1)	1.3 (11.5)	1.3 (11.6)	1.3 (11.0)	1.3 (11.5)	0.1 (0.5)	0.9 (7.5)

All alternatives with both the AVC and a Master Contract would have negligible effects to sulfate and uranium concentrations at the Arkansas River near Avondale gage (Table 71 to Table 74). Alternatives without the AVC or a Master Contract would affect water quality less than alternatives that divert water in the AVC or exchange water into Pueblo Reservoir. Compared to existing conditions, sulfate and uranium concentrations would increase in all alternatives.

Table 71. Direct Effects Simulated Sulfate Concentrations for Arkansas River near Avondale Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	252	260	264	262	262	264	261	264
15th percentile	165	168	170	170	169	170	169	170
25th percentile	195	199	201	199	200	201	200	201
50th percentile	257	267	271	269	268	271	268	271
75th percentile	308	319	324	321	322	324	323	324
85th percentile	328	337	342	340	341	342	341	342
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	4 (1.5)	2 (0.8)	2 (0.7)	4 (1.5)	1 (0.3)	4 (1.5)
15th percentile	---	---	2 (1.0)	1 (0.8)	1 (0.5)	2 (1.1)	0 (0.2)	2 (1.0)
25th percentile	---	---	3 (1.3)	1 (0.4)	1 (0.5)	3 (1.3)	1 (0.5)	2 (1.2)
50th percentile	---	---	4 (1.6)	2 (0.7)	1 (0.4)	4 (1.6)	1 (0.2)	4 (1.3)
75th percentile	---	---	5 (1.6)	2 (0.7)	3 (1.0)	5 (1.6)	4 (1.1)	5 (1.5)
85th percentile	---	---	5 (1.5)	2 (0.7)	3 (1.0)	5 (1.5)	4 (1.0)	5 (1.6)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	8 (3.3)	12 (4.9)	10 (4.2)	10 (4.1)	12 (4.9)	9 (3.7)	12 (4.9)
15th percentile	---	3 (1.8)	5 (2.8)	4 (2.7)	4 (2.4)	5 (2.9)	3 (2.0)	5 (2.8)
25th percentile	---	4 (1.9)	6 (3.2)	5 (2.3)	5 (2.4)	6 (3.2)	5 (2.4)	6 (3.1)
50th percentile	---	10 (3.7)	14 (5.4)	12 (4.5)	11 (4.2)	14 (5.4)	10 (4.0)	13 (5.1)
75th percentile	---	12 (3.8)	17 (5.5)	14 (4.5)	15 (4.9)	17 (5.5)	15 (5.0)	16 (5.3)
85th percentile	---	9 (2.6)	14 (4.2)	11 (3.4)	12 (3.7)	14 (4.2)	12 (3.7)	14 (4.2)

Table 72. Monthly Simulated Sulfate Concentration for Arkansas River near Avondale Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	317	326	333	333	329	333	328	330
Feb	333	344	348	348	347	348	343	346
Mar	280	291	300	300	295	299	296	297
Apr	234	247	251	251	248	251	250	250
May	192	195	197	197	196	197	197	196
Jun	154	157	158	158	157	158	157	157
Jul	164	170	172	172	171	172	170	171
Aug	213	218	221	221	219	221	217	219
Sep	259	272	276	276	275	276	270	272
Oct	278	289	295	295	292	296	294	293
Nov	298	307	309	309	310	310	305	306
Dec	320	328	331	331	330	331	327	328
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	7 (2.1)	7 (2.1)	3 (0.9)	7 (2.1)	2 (0.4)	4 (1.2)
Feb	---	---	4 (1.2)	4 (1.3)	3 (0.9)	4 (1.2)	-1 (-0.2)	2 (0.5)
Mar	---	---	9 (3.0)	9 (3.1)	4 (1.5)	8 (2.8)	5 (1.6)	6 (1.9)
Apr	---	---	4 (1.7)	4 (1.7)	1 (0.6)	4 (1.7)	3 (1.5)	3 (1.4)
May	---	---	2 (0.8)	2 (0.8)	1 (0.3)	2 (0.8)	2 (0.7)	1 (0.6)
Jun	---	---	1 (0.5)	1 (0.6)	0 (0.4)	1 (0.5)	0 (0.1)	0 (0.2)
Jul	---	---	2 (1.3)	2 (1.1)	1 (0.7)	2 (1.3)	0 (0.0)	1 (0.6)
Aug	---	---	3 (1.3)	3 (1.3)	1 (0.4)	3 (1.3)	-1 (-0.4)	1 (0.3)
Sep	---	---	4 (1.3)	4 (1.2)	3 (0.8)	4 (1.3)	-2 (-0.9)	0 (-0.1)
Oct	---	---	6 (2.3)	6 (2.2)	3 (1.0)	7 (2.3)	5 (1.8)	4 (1.6)
Nov	---	---	2 (0.7)	2 (0.7)	3 (0.8)	3 (0.7)	-2 (-0.8)	-1 (-0.3)
Dec	---	---	3 (0.9)	3 (0.9)	2 (0.7)	3 (0.9)	-1 (-0.4)	0 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	9 (3.1)	16 (5.2)	16 (5.2)	12 (4.0)	16 (5.2)	11 (3.5)	13 (4.3)
Feb	---	11 (3.2)	15 (4.4)	15 (4.5)	14 (4.1)	15 (4.4)	10 (3.0)	13 (3.7)
Mar	---	11 (3.8)	20 (6.9)	20 (6.9)	15 (5.3)	19 (6.7)	16 (5.5)	17 (5.8)
Apr	---	13 (5.2)	17 (7.0)	17 (7.0)	14 (5.8)	17 (7.0)	16 (6.7)	16 (6.6)
May	---	3 (1.9)	5 (2.7)	5 (2.7)	4 (2.2)	5 (2.7)	5 (2.5)	4 (2.4)
Jun	---	3 (1.5)	4 (2.1)	4 (2.1)	3 (1.9)	4 (2.1)	3 (1.7)	3 (1.7)
Jul	---	6 (4.0)	8 (5.3)	8 (5.1)	7 (4.7)	8 (5.3)	6 (3.9)	7 (4.6)
Aug	---	5 (2.4)	8 (3.7)	8 (3.7)	6 (2.7)	8 (3.7)	4 (2.0)	6 (2.7)
Sep	---	13 (5.1)	17 (6.4)	17 (6.4)	16 (6.0)	17 (6.4)	11 (4.2)	13 (5.0)
Oct	---	11 (4.0)	17 (6.3)	17 (6.3)	14 (5.0)	18 (6.4)	16 (5.8)	15 (5.6)
Nov	---	9 (3.0)	11 (3.7)	11 (3.7)	12 (3.8)	12 (3.7)	7 (2.1)	8 (2.6)
Dec	---	8 (2.5)	11 (3.4)	11 (3.4)	10 (3.2)	11 (3.4)	7 (2.1)	8 (2.5)

Table 73. Direct Effects Simulated Uranium Concentrations for Arkansas River near Avondale Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	3.9	4.1	4.2	4.2	4.2	4.2	4.1	4.2
15th percentile	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1
25th percentile	2.7	2.8	2.8	2.8	2.8	2.8	2.8	2.8
50th percentile	4.1	4.3	4.4	4.3	4.3	4.4	4.3	4.3
75th percentile	5.2	5.4	5.5	5.5	5.5	5.5	5.5	5.5
85th percentile	5.6	5.8	5.9	5.9	5.9	5.9	5.9	5.9
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.1 (2.1)	0 (1.1)	0 (1.0)	0.1 (2.1)	0 (0.4)	0.1 (2.1)
15th percentile	---	---	0 (1.7)	0 (1.5)	0 (1.0)	0 (1.9)	0 (0.3)	0 (1.7)
25th percentile	---	---	0.1 (2.0)	0 (0.6)	0 (0.8)	0.1 (2.0)	0 (0.8)	0.1 (1.9)
50th percentile	---	---	0.1 (2.3)	0 (1.0)	0 (0.6)	0.1 (2.2)	0 (0.3)	0.1 (1.8)
75th percentile	---	---	0.1 (2.1)	0 (0.9)	0.1 (1.3)	0.1 (2.1)	0.1 (1.5)	0.1 (1.9)
85th percentile	---	---	0.1 (1.9)	0.1 (0.9)	0.1 (1.3)	0.1 (2.0)	0.1 (1.3)	0.1 (2.0)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.2 (4.8)	0.3 (6.9)	0.2 (5.9)	0.2 (5.8)	0.3 (6.9)	0.2 (5.2)	0.3 (6.9)
15th percentile	---	0.1 (3.4)	0.1 (5.2)	0.1 (4.9)	0.1 (4.4)	0.1 (5.4)	0.1 (3.7)	0.1 (5.1)
25th percentile	---	0.1 (3.1)	0.1 (5.2)	0.1 (3.7)	0.1 (3.9)	0.1 (5.2)	0.1 (3.9)	0.1 (5.1)
50th percentile	---	0.2 (5.3)	0.3 (7.7)	0.3 (6.3)	0.2 (5.9)	0.3 (7.6)	0.2 (5.6)	0.3 (7.2)
75th percentile	---	0.3 (5.0)	0.4 (7.2)	0.3 (5.9)	0.3 (6.4)	0.4 (7.2)	0.3 (6.6)	0.4 (7.0)
85th percentile	---	0.2 (3.4)	0.3 (5.4)	0.2 (4.4)	0.3 (4.8)	0.3 (5.5)	0.3 (4.8)	0.3 (5.5)

Table 74. Monthly Simulated Uranium Concentration for Arkansas River near Avondale Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	8.8	9.0	9.1	9.1	9.1	9.1	9.0	9.1
Feb	9.1	9.4	9.5	9.5	9.4	9.5	9.4	9.4
Mar	8.0	8.2	8.4	8.4	8.3	8.4	8.3	8.3
Apr	6.9	7.2	7.3	7.3	7.2	7.3	7.3	7.3
May	6.0	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Jun	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Jul	5.4	5.5	5.6	5.6	5.5	5.6	5.5	5.5
Aug	6.5	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Sep	7.5	7.8	7.9	7.9	7.8	7.9	7.7	7.8
Oct	7.9	8.2	8.3	8.3	8.2	8.3	8.3	8.3
Nov	8.4	8.6	8.6	8.6	8.6	8.6	8.5	8.5
Dec	8.9	9.0	9.1	9.1	9.1	9.1	9.0	9.0
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.1 (1.7)	0.1 (1.7)	0.1 (0.7)	0.1 (1.7)	0.0 (0.4)	0.1 (0.9)
Feb	---	---	0.1 (1.0)	0.1 (1.0)	0.0 (0.8)	0.1 (1.0)	0.0 (-0.1)	0.0 (0.4)
Mar	---	---	0.2 (2.4)	0.2 (2.4)	0.1 (1.1)	0.2 (2.2)	0.1 (1.3)	0.1 (1.5)
Apr	---	---	0.1 (1.3)	0.1 (1.3)	0.0 (0.4)	0.1 (1.3)	0.1 (1.1)	0.1 (1.1)
May	---	---	0.0 (0.6)	0.0 (0.6)	0.0 (0.2)	0.0 (0.6)	0.0 (0.5)	0.0 (0.4)
Jun	---	---	0.0 (0.4)	0.0 (0.4)	0.0 (0.3)	0.0 (0.4)	0.0 (0.1)	0.0 (0.1)
Jul	---	---	0.1 (0.9)	0.1 (0.7)	0.0 (0.5)	0.1 (0.9)	0.0 (0.0)	0.0 (0.4)
Aug	---	---	0.0 (0.9)	0.0 (1.0)	0.0 (0.3)	0.0 (1.0)	0.0 (-0.3)	0.0 (0.2)
Sep	---	---	0.1 (1.0)	0.1 (1.0)	0.0 (0.6)	0.1 (1.0)	-0.1 (-0.7)	0.0 (-0.1)
Oct	---	---	0.1 (1.8)	0.1 (1.8)	0.0 (0.8)	0.1 (1.8)	0.1 (1.4)	0.1 (1.2)
Nov	---	---	0.0 (0.5)	0.0 (0.5)	0.0 (0.6)	0.0 (0.5)	-0.1 (-0.7)	-0.1 (-0.3)
Dec	---	---	0.1 (0.7)	0.1 (0.7)	0.1 (0.6)	0.1 (0.7)	0.0 (-0.3)	0.0 (0.0)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.2 (2.4)	0.3 (4.1)	0.3 (4.2)	0.3 (3.2)	0.3 (4.1)	0.2 (2.8)	0.3 (3.4)
Feb	---	0.3 (2.6)	0.4 (3.6)	0.4 (3.6)	0.3 (3.3)	0.4 (3.6)	0.3 (2.4)	0.3 (3.0)
Mar	---	0.2 (2.9)	0.4 (5.4)	0.4 (5.4)	0.3 (4.1)	0.4 (5.2)	0.3 (4.3)	0.3 (4.5)
Apr	---	0.3 (3.9)	0.4 (5.2)	0.4 (5.2)	0.3 (4.3)	0.4 (5.2)	0.4 (5.0)	0.4 (5.0)
May	---	0.1 (1.3)	0.1 (1.9)	0.1 (1.9)	0.1 (1.6)	0.1 (1.9)	0.1 (1.8)	0.1 (1.7)
Jun	---	0.0 (1.0)	0.0 (1.4)	0.0 (1.4)	0.0 (1.3)	0.0 (1.4)	0.0 (1.1)	0.0 (1.1)
Jul	---	0.1 (2.7)	0.2 (3.6)	0.2 (3.4)	0.1 (3.2)	0.2 (3.6)	0.1 (2.7)	0.1 (3.1)
Aug	---	0.1 (1.7)	0.1 (2.7)	0.1 (2.7)	0.1 (2.0)	0.1 (2.7)	0.1 (1.5)	0.1 (2.0)
Sep	---	0.3 (3.9)	0.4 (4.9)	0.4 (4.9)	0.3 (4.6)	0.4 (4.9)	0.2 (3.2)	0.3 (3.9)
Oct	---	0.3 (3.1)	0.4 (4.9)	0.4 (4.9)	0.3 (3.9)	0.4 (5.0)	0.4 (4.5)	0.4 (4.4)
Nov	---	0.2 (2.4)	0.2 (2.9)	0.2 (2.9)	0.2 (3.0)	0.2 (2.9)	0.1 (1.7)	0.1 (2.1)
Dec	---	0.1 (2.0)	0.2 (2.7)	0.2 (2.7)	0.2 (2.6)	0.2 (2.7)	0.1 (1.6)	0.1 (2.0)

All alternatives except Master Contract Only would have negligible to minor adverse effects to sulfate and uranium concentrations at the Arkansas River at Catlin Dam gage (Table 75 to Table 78). The largest concentration increases occur during winter months at times of low flow. The Master Contract Only Alternative would affect water quality less than alternatives that divert water in the AVC. Compared to existing conditions, sulfate and uranium concentrations would increase because streamflow decreases in all alternatives.

Table 75. Direct Effects Simulated Sulfate Concentrations for Arkansas River at Catlin Dam Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	376	382	389	389	389	389	387	383
15th percentile	208	209	211	211	211	211	210	209
25th percentile	246	256	262	262	261	262	262	260
50th percentile	385	397	402	403	402	402	399	398
75th percentile	478	482	491	489	488	490	488	481
85th percentile	528	525	545	542	537	544	540	527
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	7 (1.8)	7 (1.9)	7 (1.9)	7 (1.9)	4 (1.2)	1 (0.2)
15th percentile	---	---	2 (1.0)	2 (1.0)	2 (1.1)	2 (1.0)	1 (0.4)	0 (0.1)
25th percentile	---	---	6 (2.3)	6 (2.3)	5 (1.9)	6 (2.3)	5 (2.0)	4 (1.5)
50th percentile	---	---	5 (1.4)	6 (1.6)	5 (1.3)	5 (1.3)	2 (0.6)	1 (0.3)
75th percentile	---	---	9 (1.9)	7 (1.5)	6 (1.3)	8 (1.7)	7 (1.4)	0 (-0.1)
85th percentile	---	---	20 (3.9)	17 (3.2)	12 (2.3)	19 (3.7)	14 (2.8)	2 (0.5)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	6 (1.5)	13 (3.4)	13 (3.4)	13 (3.4)	13 (3.4)	10 (2.7)	7 (1.8)
15th percentile	---	1 (0.3)	3 (1.3)	3 (1.3)	3 (1.4)	3 (1.3)	2 (0.7)	1 (0.4)
25th percentile	---	10 (4.2)	16 (6.6)	16 (6.6)	15 (6.2)	16 (6.6)	16 (6.3)	14 (5.8)
50th percentile	---	12 (3.2)	18 (4.6)	19 (4.8)	18 (4.6)	17 (4.5)	15 (3.8)	14 (3.5)
75th percentile	---	4 (0.8)	13 (2.8)	11 (2.3)	10 (2.2)	12 (2.6)	11 (2.3)	3 (0.7)
85th percentile	---	-3 (-0.6)	17 (3.2)	14 (2.6)	9 (1.7)	16 (3.1)	11 (2.1)	-1 (-0.2)

Table 76. Monthly Simulated Sulfate Concentration for Arkansas River at Catlin Dam Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	500	505	519	520	519	519	515	508
Feb	539	534	552	552	544	552	547	539
Mar	441	449	460	459	455	460	459	456
Apr	342	351	359	360	360	359	359	355
May	247	253	256	255	255	256	255	254
Jun	188	192	194	194	194	194	193	191
Jul	224	231	235	234	233	235	233	235
Aug	296	300	302	303	302	303	300	298
Sep	407	418	424	425	426	425	421	416
Oct	421	437	442	442	444	442	440	436
Nov	451	455	454	454	464	454	449	445
Dec	493	492	504	504	506	504	497	493
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	14 (2.7)	15 (2.9)	14 (2.7)	14 (2.7)	10 (1.9)	3 (0.5)
Feb	---	---	18 (3.4)	18 (3.4)	10 (2.0)	18 (3.4)	13 (2.5)	5 (1.1)
Mar	---	---	11 (2.3)	10 (2.2)	6 (1.3)	11 (2.3)	10 (2.1)	7 (1.4)
Apr	---	---	8 (2.0)	9 (2.4)	9 (2.3)	8 (2.1)	8 (2.3)	4 (1.1)
May	---	---	3 (1.2)	2 (1.1)	2 (1.1)	3 (1.3)	2 (1.0)	1 (0.6)
Jun	---	---	2 (0.8)	2 (0.9)	2 (0.9)	2 (0.8)	1 (0.4)	-1 (-0.3)
Jul	---	---	4 (1.9)	3 (1.3)	2 (1.1)	4 (2.0)	2 (1.1)	4 (1.8)
Aug	---	---	2 (0.9)	3 (1.0)	2 (0.9)	3 (1.0)	0 (0.1)	-2 (-0.4)
Sep	---	---	6 (1.6)	7 (1.7)	8 (2.0)	7 (1.7)	3 (0.8)	-2 (-0.4)
Oct	---	---	5 (1.2)	5 (1.2)	7 (1.6)	5 (1.2)	3 (0.9)	-1 (-0.1)
Nov	---	---	-1 (-0.2)	-1 (-0.1)	9 (2.1)	-1 (-0.1)	-6 (-1.2)	-10 (-2.1)
Dec	---	---	12 (2.3)	12 (2.4)	14 (2.7)	12 (2.3)	5 (0.8)	1 (0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	5 (0.9)	19 (3.7)	20 (3.8)	19 (3.6)	19 (3.7)	15 (2.9)	8 (1.4)
Feb	---	-5 (-1.0)	13 (2.4)	13 (2.4)	5 (1.0)	13 (2.4)	8 (1.5)	0 (0.1)
Mar	---	8 (1.9)	19 (4.3)	18 (4.1)	14 (3.3)	19 (4.3)	18 (4.1)	15 (3.4)
Apr	---	9 (2.7)	17 (4.8)	18 (5.2)	18 (5.1)	17 (4.9)	17 (5.1)	13 (3.8)
May	---	6 (2.3)	9 (3.6)	8 (3.4)	8 (3.4)	9 (3.6)	8 (3.3)	7 (3.0)
Jun	---	4 (2.0)	6 (2.8)	6 (2.9)	6 (2.9)	6 (2.8)	5 (2.4)	3 (1.7)
Jul	---	7 (3.2)	11 (5.1)	10 (4.5)	9 (4.3)	11 (5.3)	9 (4.3)	11 (5.0)
Aug	---	4 (1.2)	6 (2.1)	7 (2.3)	6 (2.1)	7 (2.2)	4 (1.3)	2 (0.8)
Sep	---	11 (2.7)	17 (4.4)	18 (4.5)	19 (4.8)	18 (4.5)	14 (3.5)	9 (2.3)
Oct	---	16 (3.6)	21 (4.9)	21 (4.9)	23 (5.3)	21 (4.9)	19 (4.5)	15 (3.5)
Nov	---	4 (0.8)	3 (0.6)	3 (0.7)	13 (2.9)	3 (0.7)	-2 (-0.4)	-6 (-1.3)
Dec	---	-1 (-0.1)	11 (2.2)	11 (2.3)	13 (2.5)	11 (2.2)	4 (0.7)	0 (0.0)

Table 77. Direct Effects Simulated Uranium Concentrations for Arkansas River at Catlin Dam Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	7.7	7.8	8.0	8.0	8.0	8.0	7.9	7.9
15th percentile	4.6	4.6	4.7	4.7	4.7	4.7	4.6	4.6
25th percentile	5.3	5.5	5.6	5.6	5.6	5.6	5.6	5.6
50th percentile	7.9	8.1	8.2	8.2	8.2	8.2	8.2	8.1
75th percentile	9.6	9.7	9.9	9.8	9.8	9.8	9.8	9.7
85th percentile	10.6	10.5	10.9	10.8	10.7	10.9	10.8	10.5
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.1 (1.6)	0.1 (1.7)	0.1 (1.7)	0.1 (1.7)	0.1 (1.0)	0 (0.2)
15th percentile	---	---	0 (0.8)	0 (0.8)	0 (0.9)	0 (0.8)	0 (0.4)	0 (0.1)
25th percentile	---	---	0.1 (2.0)	0.1 (2.0)	0.1 (1.7)	0.1 (2.0)	0.1 (1.7)	0.1 (1.3)
50th percentile	---	---	0.1 (1.2)	0.1 (1.4)	0.1 (1.2)	0.1 (1.2)	0 (0.6)	0 (0.3)
75th percentile	---	---	0.2 (1.8)	0.1 (1.4)	0.1 (1.2)	0.2 (1.6)	0.1 (1.3)	0 (-0.1)
85th percentile	---	---	0.4 (3.6)	0.3 (3.0)	0.2 (2.1)	0.4 (3.4)	0.3 (2.6)	0 (0.4)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.1 (1.4)	0.2 (3.0)	0.2 (3.1)	0.2 (3.1)	0.2 (3.1)	0.2 (2.4)	0.1 (1.6)
15th percentile	---	0 (0.3)	0 (1.1)	0 (1.1)	0.1 (1.2)	0.1 (1.1)	0 (0.6)	0 (0.4)
25th percentile	---	0.2 (3.6)	0.3 (5.7)	0.3 (5.7)	0.3 (5.4)	0.3 (5.7)	0.3 (5.4)	0.3 (5.0)
50th percentile	---	0.2 (2.9)	0.3 (4.2)	0.3 (4.4)	0.3 (4.1)	0.3 (4.1)	0.3 (3.5)	0.3 (3.2)
75th percentile	---	0.1 (0.8)	0.2 (2.6)	0.2 (2.1)	0.2 (2.0)	0.2 (2.4)	0.2 (2.1)	0.1 (0.7)
85th percentile	---	-0.1 (-0.6)	0.3 (3.0)	0.3 (2.4)	0.2 (1.6)	0.3 (2.8)	0.2 (2.0)	0 (-0.1)

Table 78. Monthly Simulated Uranium Concentration for Arkansas River at Catlin Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	10.2	10.2	10.5	10.5	10.5	10.5	10.4	10.3
Feb	10.9	10.8	11.1	11.1	11.0	11.1	11.0	10.9
Mar	9.1	9.2	9.4	9.4	9.3	9.4	9.4	9.3
Apr	7.2	7.4	7.5	7.6	7.5	7.5	7.5	7.5
May	5.5	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Jun	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.4
Jul	5.0	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Aug	6.4	6.4	6.5	6.5	6.5	6.5	6.4	6.4
Sep	8.4	8.6	8.8	8.8	8.8	8.8	8.7	8.6
Oct	8.7	9.0	9.1	9.1	9.1	9.1	9.0	9.0
Nov	9.2	9.3	9.3	9.3	9.5	9.3	9.2	9.1
Dec	10.0	10.0	10.2	10.2	10.3	10.2	10.1	10.0
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.3 (2.5)	0.3 (2.6)	0.3 (2.4)	0.3 (2.5)	0.2 (1.8)	0.1 (0.4)
Feb	---	---	0.3 (3.1)	0.3 (3.2)	0.2 (1.8)	0.3 (3.1)	0.2 (2.3)	0.1 (1.0)
Mar	---	---	0.2 (2.1)	0.2 (2.0)	0.1 (1.2)	0.2 (2.1)	0.2 (1.9)	0.1 (1.3)
Apr	---	---	0.1 (1.8)	0.2 (2.1)	0.1 (2.1)	0.1 (1.8)	0.1 (2.0)	0.1 (0.9)
May	---	---	0.0 (1.0)	0.0 (0.9)	0.0 (0.9)	0.0 (1.1)	0.0 (0.8)	0.0 (0.5)
Jun	---	---	0.1 (0.6)	0.1 (0.7)	0.1 (0.7)	0.1 (0.6)	0.1 (0.3)	0.0 (-0.2)
Jul	---	---	0.0 (1.6)	0.0 (1.0)	0.0 (0.9)	0.0 (1.7)	0.0 (0.9)	0.0 (1.5)
Aug	---	---	0.1 (0.8)	0.1 (0.9)	0.1 (0.8)	0.1 (0.8)	0.0 (0.0)	0.0 (-0.4)
Sep	---	---	0.2 (1.5)	0.2 (1.6)	0.2 (1.8)	0.2 (1.5)	0.1 (0.7)	0.0 (-0.4)
Oct	---	---	0.1 (1.1)	0.1 (1.1)	0.1 (1.4)	0.1 (1.1)	0.0 (0.8)	0.0 (-0.1)
Nov	---	---	0.0 (-0.2)	0.0 (-0.1)	0.2 (1.9)	0.0 (-0.1)	-0.1 (-1.1)	-0.2 (-1.9)
Dec	---	---	0.2 (2.1)	0.2 (2.2)	0.3 (2.4)	0.2 (2.1)	0.1 (0.8)	0.0 (0.1)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.0 (0.9)	0.3 (3.3)	0.3 (3.5)	0.3 (3.3)	0.3 (3.3)	0.2 (2.6)	0.1 (1.3)
Feb	---	-0.1 (-0.9)	0.2 (2.2)	0.2 (2.3)	0.1 (0.9)	0.2 (2.2)	0.1 (1.4)	0.0 (0.1)
Mar	---	0.1 (1.8)	0.3 (3.9)	0.3 (3.7)	0.2 (3.0)	0.3 (3.9)	0.3 (3.7)	0.2 (3.1)
Apr	---	0.2 (2.4)	0.3 (4.2)	0.4 (4.6)	0.3 (4.5)	0.3 (4.3)	0.3 (4.4)	0.3 (3.4)
May	---	0.1 (2.0)	0.1 (3.0)	0.1 (2.9)	0.1 (2.9)	0.1 (3.0)	0.1 (2.8)	0.1 (2.5)
Jun	---	0.0 (1.6)	0.1 (2.2)	0.1 (2.3)	0.1 (2.3)	0.1 (2.2)	0.1 (1.9)	0.0 (1.3)
Jul	---	0.2 (2.6)	0.2 (4.2)	0.2 (3.7)	0.2 (3.5)	0.2 (4.4)	0.2 (3.6)	0.2 (4.2)
Aug	---	0.0 (1.0)	0.1 (1.8)	0.1 (1.9)	0.1 (1.8)	0.1 (1.9)	0.0 (1.1)	0.0 (0.7)
Sep	---	0.2 (2.5)	0.4 (4.0)	0.4 (4.0)	0.4 (4.3)	0.4 (4.0)	0.3 (3.2)	0.2 (2.1)
Oct	---	0.3 (3.3)	0.4 (4.4)	0.4 (4.4)	0.4 (4.8)	0.4 (4.4)	0.3 (4.1)	0.3 (3.2)
Nov	---	0.1 (0.7)	0.1 (0.6)	0.1 (0.6)	0.3 (2.6)	0.1 (0.6)	0.0 (-0.4)	-0.1 (-1.2)
Dec	---	0.0 (-0.1)	0.2 (2.0)	0.2 (2.1)	0.3 (2.3)	0.2 (2.0)	0.1 (0.7)	0.0 (0.0)

All alternatives would have predominately negligible sulfate and uranium effects at the Arkansas River at Las Animas gage, though occasional minor sulfate increases would occur (Table 79 to Table 82). Concentration compared to existing conditions would typically decrease for all alternatives because of increases in streamflow.

Table 79. Direct Effects Simulated Sulfate Concentrations for Arkansas River at Las Animas Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	972	933	932	934	938	932	931	928
15th percentile	454	449	453	452	447	453	448	443
25th percentile	649	634	631	633	637	631	632	630
50th percentile	1,016	986	989	992	1,001	990	991	987
75th percentile	1,198	1,147	1,144	1,150	1,151	1,143	1,149	1,144
85th percentile	1,380	1,282	1,292	1,292	1,306	1,286	1,292	1,284
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	-1 (-0.1)	1 (0.1)	5 (0.6)	-1 (-0.1)	-2 (-0.2)	-5 (-0.5)
15th percentile	---	---	4 (0.8)	3 (0.8)	-2 (-0.5)	4 (1.0)	-1 (-0.3)	-6 (-1.2)
25th percentile	---	---	-3 (-0.5)	-1 (-0.1)	3 (0.5)	-3 (-0.5)	-2 (-0.3)	-5 (-0.7)
50th percentile	---	---	3 (0.3)	6 (0.6)	15 (1.5)	3 (0.4)	5 (0.5)	1 (0.1)
75th percentile	---	---	-3 (-0.3)	3 (0.2)	4 (0.3)	-5 (-0.4)	1 (0.1)	-3 (-0.3)
85th percentile	---	---	10 (0.7)	10 (0.8)	23 (1.8)	3 (0.2)	10 (0.8)	1 (0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	-39 (-4.0)	-39 (-4.1)	-38 (-3.9)	-33 (-3.4)	-39 (-4.1)	-41 (-4.2)	-44 (-4.5)
15th percentile	---	-5 (-1.1)	-1 (-0.3)	-2 (-0.3)	-7 (-1.6)	-1 (-0.1)	-6 (-1.4)	-11 (-2.3)
25th percentile	---	-15 (-2.3)	-18 (-2.8)	-16 (-2.5)	-12 (-1.8)	-18 (-2.8)	-17 (-2.6)	-20 (-3.1)
50th percentile	---	-30 (-2.9)	-27 (-2.6)	-23 (-2.3)	-15 (-1.4)	-26 (-2.6)	-25 (-2.5)	-29 (-2.8)
75th percentile	---	-50 (-4.2)	-53 (-4.4)	-48 (-4.0)	-47 (-3.9)	-55 (-4.6)	-49 (-4.1)	-53 (-4.5)
85th percentile	---	-98 (-7.1)	-88 (-6.4)	-88 (-6.4)	-75 (-5.4)	-95 (-6.9)	-88 (-6.4)	-97 (-7.0)

Table 80. Monthly Simulated Sulfate Concentration for Arkansas River at Las Animas Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	1,046	1,044	1,061	1,062	1,056	1,061	1,060	1,051
Feb	1,002	986	1,003	1,003	981	1,004	1,003	997
Mar	1,170	1,084	1,030	1,033	1,080	1,030	1,034	1,022
Apr	1,311	1,229	1,195	1,202	1,241	1,192	1,189	1,194
May	775	723	730	731	730	730	732	732
Jun	561	536	537	538	539	537	538	535
Jul	695	650	659	660	657	658	656	650
Aug	783	728	735	738	739	739	730	728
Sep	1,090	1,053	1,045	1,044	1,050	1,041	1,048	1,055
Oct	1,111	1,064	1,100	1,100	1,070	1,102	1,098	1,088
Nov	1,066	1,057	1,037	1,039	1,062	1,038	1,032	1,040
Dec	1,076	1,073	1,082	1,082	1,084	1,082	1,079	1,073
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	17 (1.6)	18 (1.7)	12 (1.1)	17 (1.6)	16 (1.5)	7 (0.6)
Feb	---	---	17 (1.7)	17 (1.6)	-5 (-0.5)	18 (1.8)	17 (1.7)	11 (1.1)
Mar	---	---	-54 (-5.0)	-51 (-4.7)	-4 (-0.4)	-54 (-5.0)	-50 (-4.7)	-62 (-5.7)
Apr	---	---	-34 (-2.8)	-27 (-2.1)	12 (1.0)	-37 (-3.0)	-40 (-3.2)	-35 (-2.8)
May	---	---	7 (1.0)	8 (1.1)	7 (0.9)	7 (1.0)	9 (1.2)	9 (1.2)
Jun	---	---	1 (0.3)	2 (0.3)	3 (0.5)	1 (0.3)	2 (0.3)	-1 (-0.1)
Jul	---	---	9 (1.4)	10 (1.5)	7 (1.1)	8 (1.2)	6 (1.0)	0 (0.0)
Aug	---	---	7 (0.9)	10 (1.3)	11 (1.4)	11 (1.4)	2 (0.2)	0 (0.0)
Sep	---	---	-8 (-0.7)	-9 (-0.9)	-3 (-0.3)	-12 (-1.2)	-5 (-0.5)	2 (0.2)
Oct	---	---	36 (3.3)	36 (3.4)	6 (0.6)	38 (3.5)	34 (3.2)	24 (2.3)
Nov	---	---	-20 (-1.9)	-18 (-1.8)	5 (0.5)	-19 (-1.8)	-25 (-2.4)	-17 (-1.7)
Dec	---	---	9 (0.9)	9 (0.9)	11 (1.1)	9 (0.9)	6 (0.6)	0 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-2 (-0.2)	15 (1.4)	16 (1.5)	10 (0.9)	15 (1.4)	14 (1.3)	5 (0.4)
Feb	---	-16 (-1.6)	1 (0.1)	1 (0.1)	-21 (-2.1)	2 (0.2)	1 (0.1)	-5 (-0.5)
Mar	---	-86 (-7.3)	-140 (-12.0)	-137 (-11.7)	-90 (-7.7)	-140 (-12.0)	-136 (-11.7)	-148 (-12.6)
Apr	---	-82 (-6.3)	-116 (-8.9)	-109 (-8.3)	-70 (-5.4)	-119 (-9.1)	-122 (-9.4)	-117 (-8.9)
May	---	-52 (-6.7)	-45 (-5.7)	-44 (-5.7)	-45 (-5.8)	-45 (-5.7)	-43 (-5.5)	-43 (-5.5)
Jun	---	-25 (-4.5)	-24 (-4.3)	-23 (-4.2)	-22 (-4.0)	-24 (-4.3)	-23 (-4.2)	-26 (-4.6)
Jul	---	-45 (-6.5)	-36 (-5.2)	-35 (-5.1)	-38 (-5.5)	-37 (-5.4)	-39 (-5.6)	-45 (-6.5)
Aug	---	-55 (-6.9)	-48 (-6.1)	-45 (-5.7)	-44 (-5.6)	-44 (-5.6)	-53 (-6.7)	-55 (-6.9)
Sep	---	-37 (-3.4)	-45 (-4.1)	-46 (-4.3)	-40 (-3.7)	-49 (-4.5)	-42 (-3.9)	-35 (-3.2)
Oct	---	-47 (-4.2)	-11 (-1.0)	-11 (-0.9)	-41 (-3.6)	-9 (-0.8)	-13 (-1.2)	-23 (-2.0)
Nov	---	-9 (-0.8)	-29 (-2.7)	-27 (-2.6)	-4 (-0.4)	-28 (-2.6)	-34 (-3.2)	-26 (-2.5)
Dec	---	-3 (-0.3)	6 (0.5)	6 (0.6)	8 (0.8)	6 (0.5)	3 (0.3)	-3 (-0.3)

Table 81. Direct Effects Simulated Uranium Concentrations for Arkansas River at Las Animas Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	14.6	14.0	14.0	14.1	14.1	14.0	14.0	14.0
15th percentile	6.6	6.5	6.5	6.5	6.4	6.5	6.5	6.4
25th percentile	9.6	9.4	9.3	9.4	9.4	9.3	9.3	9.3
50th percentile	15.3	14.9	14.9	15.0	15.1	14.9	14.9	14.9
75th percentile	18.2	17.4	17.3	17.4	17.4	17.3	17.4	17.3
85th percentile	21.0	19.5	19.6	19.7	19.9	19.5	19.7	19.5
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0 (-0.1)	0 (0.1)	0.1 (0.6)	0 (-0.1)	0 (-0.2)	-0.1 (-0.5)
15th percentile	---	---	0.1 (0.9)	0.1 (0.8)	0 (-0.6)	0.1 (1.1)	0 (-0.3)	-0.1 (-1.3)
25th percentile	---	---	0 (-0.5)	0 (-0.2)	0 (0.5)	0 (-0.5)	0 (-0.3)	-0.1 (-0.8)
50th percentile	---	---	0 (0.3)	0.1 (0.7)	0.2 (1.6)	0.1 (0.4)	0.1 (0.5)	0 (0.1)
75th percentile	---	---	0 (-0.3)	0 (0.3)	0.1 (0.3)	-0.1 (-0.4)	0 (0.1)	0 (-0.3)
85th percentile	---	---	0.1 (0.8)	0.2 (0.8)	0.4 (1.8)	0 (0.3)	0.2 (0.8)	0 (0.1)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	-0.6 (-4.1)	-0.6 (-4.2)	-0.6 (-4.0)	-0.5 (-3.6)	-0.6 (-4.2)	-0.6 (-4.3)	-0.7 (-4.6)
15th percentile	---	-0.1 (-1.2)	0 (-0.3)	0 (-0.4)	-0.1 (-1.8)	0 (-0.2)	-0.1 (-1.5)	-0.2 (-2.5)
25th percentile	---	-0.2 (-2.5)	-0.3 (-3.0)	-0.3 (-2.6)	-0.2 (-2.0)	-0.3 (-3.0)	-0.3 (-2.8)	-0.3 (-3.2)
50th percentile	---	-0.5 (-3.0)	-0.4 (-2.7)	-0.4 (-2.4)	-0.2 (-1.5)	-0.4 (-2.7)	-0.4 (-2.5)	-0.4 (-2.9)
75th percentile	---	-0.8 (-4.3)	-0.8 (-4.6)	-0.7 (-4.1)	-0.7 (-4.0)	-0.9 (-4.7)	-0.8 (-4.2)	-0.8 (-4.6)
85th percentile	---	-1.5 (-7.3)	-1.4 (-6.6)	-1.4 (-6.5)	-1.2 (-5.6)	-1.5 (-7.0)	-1.4 (-6.6)	-1.5 (-7.2)

Table 82. Monthly Simulated Uranium Concentration for Arkansas River at Las Animas - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	20.2	20.2	20.4	20.5	20.4	20.4	20.4	20.3
Feb	19.5	19.3	19.5	19.5	19.2	19.5	19.5	19.4
Mar	22.1	20.8	20.0	20.0	20.7	20.0	20.0	19.8
Apr	24.4	23.1	22.5	22.6	23.3	22.5	22.4	22.5
May	16.0	15.2	15.3	15.3	15.3	15.3	15.3	15.3
Jun	12.6	12.2	12.3	12.3	12.3	12.3	12.3	12.2
Jul	14.7	14.0	14.2	14.2	14.1	14.1	14.1	14.0
Aug	16.1	15.2	15.3	15.4	15.4	15.4	15.3	15.2
Sep	20.9	20.3	20.2	20.2	20.3	20.1	20.2	20.3
Oct	21.2	20.5	21.0	21.1	20.6	21.1	21.0	20.9
Nov	20.5	20.4	20.1	20.1	20.5	20.1	20.0	20.1
Dec	20.7	20.6	20.8	20.8	20.8	20.8	20.7	20.6
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.2 (1.3)	0.3 (1.4)	0.2 (0.9)	0.2 (1.3)	0.2 (1.2)	0.1 (0.5)
Feb	---	---	0.2 (1.4)	0.2 (1.3)	-0.1 (-0.4)	0.2 (1.4)	0.2 (1.4)	0.1 (0.9)
Mar	---	---	-0.8 (-4.1)	-0.8 (-3.8)	-0.1 (-0.3)	-0.8 (-4.1)	-0.8 (-3.8)	-1.0 (-4.7)
Apr	---	---	-0.6 (-2.3)	-0.5 (-1.8)	0.2 (0.8)	-0.6 (-2.5)	-0.7 (-2.7)	-0.6 (-2.3)
May	---	---	0.1 (0.8)	0.1 (0.8)	0.1 (0.7)	0.1 (0.8)	0.1 (0.9)	0.1 (0.9)
Jun	---	---	0.1 (0.2)	0.1 (0.2)	0.1 (0.4)	0.1 (0.2)	0.1 (0.2)	0.0 (-0.1)
Jul	---	---	0.2 (1.0)	0.2 (1.1)	0.1 (0.8)	0.1 (0.9)	0.1 (0.7)	0.0 (0.0)
Aug	---	---	0.1 (0.7)	0.2 (1.0)	0.2 (1.1)	0.2 (1.1)	0.1 (0.2)	0.0 (0.0)
Sep	---	---	-0.1 (-0.6)	-0.1 (-0.7)	0.0 (-0.2)	-0.2 (-0.9)	-0.1 (-0.4)	0.0 (0.2)
Oct	---	---	0.5 (2.7)	0.6 (2.8)	0.1 (0.5)	0.6 (2.9)	0.5 (2.6)	0.4 (1.8)
Nov	---	---	-0.3 (-1.6)	-0.3 (-1.4)	0.1 (0.4)	-0.3 (-1.5)	-0.4 (-1.9)	-0.3 (-1.4)
Dec	---	---	0.2 (0.7)	0.2 (0.7)	0.2 (0.9)	0.2 (0.7)	0.1 (0.5)	0.0 (0.0)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.0 (-0.1)	0.2 (1.1)	0.3 (1.2)	0.2 (0.7)	0.2 (1.2)	0.2 (1.1)	0.1 (0.4)
Feb	---	-0.2 (-1.2)	0.0 (0.1)	0.0 (0.1)	-0.3 (-1.7)	0.0 (0.1)	0.0 (0.1)	-0.1 (-0.4)
Mar	---	-1.3 (-6.1)	-2.1 (-9.9)	-2.1 (-9.7)	-1.4 (-6.3)	-2.1 (-9.9)	-2.1 (-9.6)	-2.3 (-10.4)
Apr	---	-1.3 (-5.3)	-1.9 (-7.5)	-1.8 (-7.0)	-1.1 (-4.5)	-1.9 (-7.7)	-2.0 (-7.9)	-1.9 (-7.5)
May	---	-0.8 (-5.0)	-0.7 (-4.3)	-0.7 (-4.3)	-0.7 (-4.4)	-0.7 (-4.3)	-0.7 (-4.2)	-0.7 (-4.2)
Jun	---	-0.4 (-3.1)	-0.3 (-3.0)	-0.3 (-2.9)	-0.3 (-2.8)	-0.3 (-3.0)	-0.3 (-2.9)	-0.4 (-3.2)
Jul	---	-0.7 (-4.8)	-0.5 (-3.9)	-0.5 (-3.7)	-0.6 (-4.0)	-0.6 (-4.0)	-0.6 (-4.1)	-0.7 (-4.8)
Aug	---	-0.9 (-5.3)	-0.8 (-4.6)	-0.7 (-4.3)	-0.7 (-4.3)	-0.7 (-4.3)	-0.8 (-5.1)	-0.9 (-5.3)
Sep	---	-0.6 (-2.8)	-0.7 (-3.4)	-0.7 (-3.5)	-0.6 (-3.0)	-0.8 (-3.7)	-0.7 (-3.2)	-0.6 (-2.6)
Oct	---	-0.7 (-3.4)	-0.2 (-0.8)	-0.1 (-0.8)	-0.6 (-3.0)	-0.1 (-0.7)	-0.2 (-0.9)	-0.3 (-1.7)
Nov	---	-0.1 (-0.7)	-0.4 (-2.2)	-0.4 (-2.1)	0.0 (-0.3)	-0.4 (-2.1)	-0.5 (-2.6)	-0.4 (-2.0)
Dec	---	-0.1 (-0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.6)	0.1 (0.4)	0.0 (0.3)	-0.1 (-0.2)

All alternatives would have negligible effects to sulfate concentrations at the Fountain Creek near Fountain gage (Table 83 to Table 84). Sulfate concentrations would increase for all alternatives compared to existing conditions. Uranium effects were not assessed at this gage because data were not available to develop a relationship to salinity concentrations.

Table 83. Direct Effects Simulated Sulfate Concentrations for Fountain Creek near Fountain Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	227	253	255	255	253	255	255	256
15th percentile	156	193	194	194	193	194	193	194
25th percentile	186	217	217	217	217	217	215	218
50th percentile	235	256	258	258	255	257	258	258
75th percentile	270	289	294	294	289	294	294	295
85th percentile	285	314	314	314	313	314	314	314
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	2 (0.7)	2 (0.6)	0 (0.0)	2 (0.6)	1 (0.6)	2 (0.9)
15th percentile	---	---	2 (0.9)	1 (0.7)	0 (0.0)	1 (0.7)	0 (0.0)	2 (0.9)
25th percentile	---	---	0 (0.1)	0 (0.0)	0 (0.2)	0 (0.0)	-2 (-0.8)	1 (0.3)
50th percentile	---	---	1 (0.4)	1 (0.4)	-2 (-0.7)	1 (0.4)	1 (0.4)	1 (0.5)
75th percentile	---	---	6 (2.0)	6 (2.0)	0 (0.0)	6 (2.0)	6 (2.0)	6 (2.1)
85th percentile	---	---	0 (0.1)	0 (0.1)	-1 (-0.3)	0 (0.1)	0 (0.1)	0 (0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	26 (11.4)	28 (12.2)	28 (12.1)	26 (11.4)	28 (12.1)	27 (12.0)	28 (12.4)
15th percentile	---	36 (23.2)	38 (24.3)	38 (24.1)	36 (23.2)	38 (24.1)	36 (23.2)	38 (24.3)
25th percentile	---	31 (16.7)	31 (16.8)	31 (16.7)	31 (16.9)	31 (16.7)	29 (15.7)	32 (17.0)
50th percentile	---	21 (8.9)	22 (9.3)	22 (9.4)	19 (8.1)	22 (9.3)	22 (9.4)	22 (9.4)
75th percentile	---	19 (6.9)	24 (9.0)	24 (9.0)	19 (6.9)	24 (9.0)	24 (9.0)	25 (9.1)
85th percentile	---	29 (10.1)	29 (10.2)	29 (10.2)	28 (9.8)	29 (10.2)	29 (10.2)	29 (10.2)

Table 84. Monthly Simulated Sulfate Concentration for Fountain Creek near Fountain Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	245	272	276	276	272	276	272	276
Feb	242	266	271	271	266	271	271	272
Mar	233	255	262	260	256	260	261	261
Apr	203	250	250	250	249	250	253	254
May	191	223	227	227	225	227	227	226
Jun	201	227	228	228	227	228	228	228
Jul	196	234	234	234	234	234	234	234
Aug	208	218	217	217	217	217	217	218
Sep	232	275	272	272	272	272	269	274
Oct	269	282	285	285	285	285	285	285
Nov	256	271	271	271	271	271	271	271
Dec	262	273	272	272	272	272	272	272
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	4 (1.3)	4 (1.3)	0 (-0.2)	4 (1.3)	0 (0.0)	4 (1.5)
Feb	---	---	5 (1.9)	5 (1.9)	0 (0.2)	5 (2.0)	5 (2.0)	6 (2.2)
Mar	---	---	7 (2.7)	5 (2.1)	1 (0.5)	5 (2.0)	6 (2.4)	6 (2.5)
Apr	---	---	0 (0.2)	0 (0.1)	-1 (-0.2)	0 (0.2)	3 (1.4)	4 (1.4)
May	---	---	4 (1.7)	4 (1.7)	2 (0.7)	4 (1.8)	4 (1.8)	3 (1.2)
Jun	---	---	1 (0.3)	1 (0.4)	0 (0.0)	1 (0.3)	1 (0.4)	1 (0.3)
Jul	---	---	0 (0.1)	0 (0.1)	0 (0.0)	0 (0.1)	0 (0.1)	0 (0.1)
Aug	---	---	-1 (-0.2)	-1 (-0.2)	-1 (-0.4)	-1 (-0.2)	-1 (-0.2)	0 (-0.1)
Sep	---	---	-3 (-1.1)	-3 (-1.1)	-3 (-1.0)	-3 (-1.1)	-6 (-2.1)	-1 (-0.3)
Oct	---	---	3 (1.1)	3 (1.0)	3 (1.1)	3 (1.0)	3 (1.1)	3 (1.1)
Nov	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dec	---	---	-1 (-0.4)	-1 (-0.4)	-1 (-0.5)	-1 (-0.4)	-1 (-0.4)	-1 (-0.4)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	27 (11.2)	31 (12.7)	31 (12.7)	27 (11.0)	31 (12.7)	27 (11.2)	31 (12.9)
Feb	---	24 (10.0)	29 (12.1)	29 (12.2)	24 (10.2)	29 (12.2)	29 (12.2)	30 (12.4)
Mar	---	22 (9.4)	29 (12.3)	27 (11.7)	23 (9.9)	27 (11.6)	28 (12.0)	28 (12.2)
Apr	---	47 (23.2)	47 (23.4)	47 (23.4)	46 (23.0)	47 (23.4)	50 (24.9)	51 (25.0)
May	---	32 (17.0)	36 (19.0)	36 (19.0)	34 (17.8)	36 (19.1)	36 (19.0)	35 (18.4)
Jun	---	26 (13.4)	27 (13.8)	27 (13.8)	26 (13.4)	27 (13.7)	27 (13.8)	27 (13.7)
Jul	---	38 (19.1)	38 (19.2)	38 (19.2)	38 (19.1)	38 (19.2)	38 (19.2)	38 (19.2)
Aug	---	10 (4.4)	9 (4.2)	9 (4.2)	9 (4.0)	9 (4.2)	9 (4.2)	10 (4.3)
Sep	---	43 (18.4)	40 (17.2)	40 (17.2)	40 (17.2)	40 (17.2)	37 (15.9)	42 (18.1)
Oct	---	13 (4.9)	16 (6.0)	16 (6.0)	16 (6.0)	16 (6.0)	16 (6.0)	16 (6.0)
Nov	---	15 (5.8)	15 (5.8)	15 (5.8)	15 (5.8)	15 (5.8)	15 (5.8)	15 (5.8)
Dec	---	11 (4.5)	10 (4.1)	10 (4.1)	10 (4.0)	10 (4.1)	10 (4.1)	10 (4.1)

All alternatives would have negligible effects to sulfate concentrations at the Fountain Creek at Pueblo gage (Table 85 to Table 86) as changes are around 2 percent or less. Sulfate concentrations would increase for all alternatives compared to existing conditions.

Uranium effects would be predominately negligible, compared to the No Action Alternative, and concentrations would increase for all alternatives compared to existing conditions (Table 87 and Table 88).

Table 85. Direct Effects Simulated Sulfate Concentrations for Fountain Creek at Pueblo Gage.

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	264	300	300	300	300	300	300	301
15th percentile	131	163	162	161	167	162	162	162
25th percentile	176	214	221	218	213	218	216	222
50th percentile	270	308	312	311	308	310	308	313
75th percentile	358	384	383	383	383	383	382	384
85th percentile	394	421	420	420	421	420	420	420
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	0 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (-0.1)	1 (0.4)
15th percentile	---	---	-1 (-0.8)	-2 (-1.0)	4 (2.7)	-2 (-0.9)	-1 (-0.8)	-1 (-0.5)
25th percentile	---	---	7 (3.2)	4 (2.0)	0 (-0.2)	4 (2.1)	2 (1.0)	8 (3.9)
50th percentile	---	---	4 (1.2)	2 (0.8)	0 (-0.1)	2 (0.7)	0 (-0.1)	4 (1.4)
75th percentile	---	---	-1 (-0.3)	-1 (-0.3)	-2 (-0.4)	-1 (-0.3)	-3 (-0.7)	0 (0.0)
85th percentile	---	---	-1 (-0.2)	-1 (-0.2)	-1 (-0.1)	-1 (-0.2)	-1 (-0.2)	-1 (-0.2)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	36 (13.7)	36 (13.8)	36 (13.7)	36 (13.7)	36 (13.7)	36 (13.6)	37 (14.1)
15th percentile	---	32 (24.8)	31 (23.8)	31 (23.5)	37 (28.1)	31 (23.6)	31 (23.8)	32 (24.1)
25th percentile	---	38 (21.7)	45 (25.6)	42 (24.1)	38 (21.4)	43 (24.2)	40 (22.9)	46 (26.3)
50th percentile	---	38 (14.2)	42 (15.6)	41 (15.1)	38 (14.1)	40 (15.0)	38 (14.2)	43 (15.8)
75th percentile	---	26 (7.4)	25 (7.0)	25 (7.0)	25 (6.9)	25 (7.0)	24 (6.7)	26 (7.4)
85th percentile	---	27 (6.9)	26 (6.6)	26 (6.6)	27 (6.7)	26 (6.6)	26 (6.6)	26 (6.7)

Table 86. Monthly Simulated Sulfate Concentration for Fountain Creek at Pueblo Gage - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	294	333	332	332	331	332	326	333
Feb	302	336	339	339	337	339	339	340
Mar	273	304	311	309	306	309	311	312
Apr	242	311	305	305	310	305	309	309
May	190	240	243	244	243	243	244	242
Jun	205	248	249	249	248	249	249	249
Jul	197	255	255	255	255	255	255	255
Aug	220	231	230	230	230	230	230	231
Sep	229	299	294	293	294	293	288	297
Oct	361	366	371	371	371	371	371	371
Nov	319	333	332	332	333	332	332	332
Dec	345	351	346	346	349	346	346	346
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	-1 (-0.1)	-1 (-0.1)	-2 (-0.4)	-1 (-0.1)	-7 (-2.0)	0 (0.1)
Feb	---	---	3 (0.7)	3 (0.6)	1 (0.1)	3 (0.7)	3 (0.7)	4 (1.0)
Mar	---	---	7 (2.4)	5 (1.7)	2 (0.7)	5 (1.7)	7 (2.2)	8 (2.5)
Apr	---	---	-6 (-1.7)	-6 (-1.8)	-1 (-0.3)	-6 (-1.8)	-2 (-0.6)	-2 (-0.5)
May	---	---	3 (1.5)	4 (1.5)	3 (1.3)	3 (1.5)	4 (1.8)	2 (1.0)
Jun	---	---	1 (0.4)	1 (0.5)	0 (0.0)	1 (0.4)	1 (0.6)	1 (0.6)
Jul	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Aug	---	---	-1 (-0.5)	-1 (-0.5)	-1 (-0.6)	-1 (-0.5)	-1 (-0.4)	0 (-0.2)
Sep	---	---	-5 (-1.8)	-6 (-1.8)	-5 (-1.5)	-6 (-1.8)	-11 (-3.6)	-2 (-0.6)
Oct	---	---	5 (1.4)	5 (1.4)	5 (1.4)	5 (1.4)	5 (1.4)	5 (1.4)
Nov	---	---	-1 (-0.2)	-1 (-0.1)	0 (0.0)	-1 (-0.2)	-1 (-0.2)	-1 (-0.1)
Dec	---	---	-5 (-1.4)	-5 (-1.4)	-2 (-0.7)	-5 (-1.4)	-5 (-1.4)	-5 (-1.3)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	39 (13.1)	38 (13.0)	38 (13.0)	37 (12.6)	38 (13.0)	32 (10.8)	39 (13.2)
Feb	---	34 (11.2)	37 (12.0)	37 (11.9)	35 (11.4)	37 (12.0)	37 (12.0)	38 (12.3)
Mar	---	31 (11.3)	38 (14.0)	36 (13.2)	33 (12.1)	36 (13.1)	38 (13.7)	39 (14.1)
Apr	---	69 (28.4)	63 (26.2)	63 (26.0)	68 (28.0)	63 (26.1)	67 (27.6)	67 (27.7)
May	---	50 (26.2)	53 (28.1)	54 (28.1)	53 (27.8)	53 (28.1)	54 (28.5)	52 (27.4)
Jun	---	43 (21.1)	44 (21.6)	44 (21.6)	43 (21.1)	44 (21.5)	44 (21.8)	44 (21.8)
Jul	---	58 (29.6)	58 (29.6)	58 (29.6)	58 (29.6)	58 (29.6)	58 (29.6)	58 (29.6)
Aug	---	11 (5.1)	10 (4.6)	10 (4.6)	10 (4.4)	10 (4.6)	10 (4.6)	11 (4.9)
Sep	---	70 (30.8)	65 (28.4)	64 (28.4)	65 (28.9)	64 (28.4)	59 (26.2)	68 (30.1)
Oct	---	5 (1.3)	10 (2.7)	10 (2.7)	10 (2.7)	10 (2.7)	10 (2.7)	10 (2.7)
Nov	---	14 (4.5)	13 (4.3)	13 (4.3)	14 (4.4)	13 (4.3)	13 (4.3)	13 (4.3)
Dec	---	6 (1.8)	1 (0.4)	1 (0.4)	4 (1.2)	1 (0.5)	1 (0.4)	1 (0.5)

Table 87. Direct Effects Simulated Uranium Concentrations for Fountain Creek at Pueblo Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	2.4	2.9	2.9	2.9	2.9	2.9	2.9	2.9
15th percentile	0.6	1.1	1.0	1.0	1.1	1.0	1.0	1.0
25th percentile	1.2	1.7	1.8	1.8	1.7	1.8	1.8	1.8
50th percentile	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
75th percentile	3.6	4.0	4.0	4.0	4.0	4.0	3.9	4.0
85th percentile	4.1	4.5	4.4	4.4	4.5	4.4	4.4	4.4
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (-0.1)	0 (0.5)
15th percentile	---	---	0 (-1.7)	0 (-2.1)	0.1 (5.5)	0 (-1.9)	0 (-1.6)	0 (-1.1)
25th percentile	---	---	0.1 (5.3)	0.1 (3.3)	0 (-0.4)	0.1 (3.4)	0 (1.7)	0.1 (6.3)
50th percentile	---	---	0 (1.6)	0 (1.1)	0 (-0.1)	0 (0.9)	0 (-0.1)	0.1 (1.9)
75th percentile	---	---	0 (-0.4)	0 (-0.4)	0 (-0.5)	0 (-0.4)	0 (-0.8)	0 (0.0)
85th percentile	---	---	0 (-0.3)	0 (-0.3)	0 (-0.1)	0 (-0.3)	0 (-0.3)	0 (-0.2)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.5 (20.0)	0.5 (20.2)	0.5 (20.1)	0.5 (20.0)	0.5 (20.1)	0.5 (19.9)	0.5 (20.6)
15th percentile	---	0.4 (68.6)	0.4 (65.8)	0.4 (65.0)	0.5 (77.9)	0.4 (65.4)	0.4 (65.9)	0.4 (66.8)
25th percentile	---	0.5 (41.2)	0.6 (48.7)	0.6 (45.9)	0.5 (40.7)	0.6 (46.0)	0.5 (43.6)	0.6 (50.2)
50th percentile	---	0.5 (20.6)	0.6 (22.5)	0.5 (21.9)	0.5 (20.5)	0.5 (21.7)	0.5 (20.5)	0.6 (22.9)
75th percentile	---	0.3 (9.6)	0.3 (9.1)	0.3 (9.1)	0.3 (9.1)	0.3 (9.1)	0.3 (8.7)	0.3 (9.7)
85th percentile	---	0.4 (8.7)	0.3 (8.4)	0.3 (8.4)	0.4 (8.5)	0.3 (8.4)	0.3 (8.4)	0.3 (8.5)

Table 88. Monthly Simulated Uranium Concentration for Fountain Creek at Pueblo - Direct and Indirect Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	2.8	3.3	3.3	3.3	3.3	3.3	3.2	3.3
Feb	2.9	3.3	3.4	3.4	3.3	3.4	3.4	3.4
Mar	2.5	2.9	3.0	3.0	2.9	3.0	3.0	3.0
Apr	2.1	3.0	2.9	2.9	3.0	2.9	3.0	3.0
May	1.4	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Jun	1.6	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Jul	1.5	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Aug	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Sep	1.9	2.8	2.8	2.8	2.8	2.8	2.7	2.8
Oct	3.7	3.7	3.8	3.8	3.8	3.8	3.8	3.8
Nov	3.1	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Dec	3.4	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.0 (-0.1)	0.0 (-0.1)	0.0 (-0.5)	0.0 (-0.1)	-0.1 (-2.7)	0.0 (0.1)
Feb	---	---	0.1 (0.9)	0.1 (0.9)	0.0 (0.2)	0.1 (1.0)	0.1 (0.9)	0.1 (1.3)
Mar	---	---	0.1 (3.4)	0.1 (2.3)	0.0 (1.0)	0.1 (2.3)	0.1 (3.1)	0.1 (3.5)
Apr	---	---	-0.1 (-2.3)	-0.1 (-2.5)	0.0 (-0.4)	-0.1 (-2.4)	0.0 (-0.8)	0.0 (-0.7)
May	---	---	0.0 (2.3)	0.0 (2.4)	0.0 (1.9)	0.0 (2.3)	0.0 (2.8)	0.0 (1.5)
Jun	---	---	0.0 (0.6)	0.0 (0.7)	0.0 (0.0)	0.0 (0.5)	0.0 (0.8)	0.0 (0.8)
Jul	---	---	0.0 (0.0)	0.0 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Aug	---	---	0.0 (-0.7)	0.0 (-0.7)	0.0 (-1.0)	0.0 (-0.7)	0.0 (-0.7)	0.0 (-0.3)
Sep	---	---	0.0 (-2.5)	0.0 (-2.6)	0.0 (-2.1)	0.0 (-2.6)	-0.1 (-4.9)	0.0 (-0.8)
Oct	---	---	0.1 (1.8)	0.1 (1.8)	0.1 (1.9)	0.1 (1.8)	0.1 (1.9)	0.1 (1.8)
Nov	---	---	0.0 (-0.2)	0.0 (-0.2)	0.0 (0.0)	0.0 (-0.2)	0.0 (-0.2)	0.0 (-0.2)
Dec	---	---	0.0 (-1.8)	0.0 (-1.8)	0.0 (-0.9)	0.0 (-1.8)	0.0 (-1.8)	0.0 (-1.7)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.5 (18.3)	0.5 (18.1)	0.5 (18.1)	0.5 (17.7)	0.5 (18.1)	0.4 (15.1)	0.5 (18.4)
Feb	---	0.4 (15.5)	0.5 (16.5)	0.5 (16.5)	0.4 (15.7)	0.5 (16.6)	0.5 (16.6)	0.5 (17.0)
Mar	---	0.4 (16.2)	0.5 (20.1)	0.5 (18.9)	0.4 (17.4)	0.5 (18.9)	0.5 (19.8)	0.5 (20.3)
Apr	---	0.9 (43.3)	0.8 (40.0)	0.8 (39.7)	0.9 (42.7)	0.8 (39.9)	0.9 (42.2)	0.9 (42.2)
May	---	0.7 (46.7)	0.7 (50.0)	0.7 (50.2)	0.7 (49.5)	0.7 (50.1)	0.7 (50.7)	0.7 (48.9)
Jun	---	0.6 (35.6)	0.6 (36.4)	0.6 (36.5)	0.6 (35.6)	0.6 (36.3)	0.6 (36.7)	0.6 (36.7)
Jul	---	0.8 (51.4)	0.8 (51.4)	0.8 (51.5)	0.8 (51.4)	0.8 (51.4)	0.8 (51.3)	0.8 (51.4)
Aug	---	0.1 (8.2)	0.1 (7.4)	0.1 (7.4)	0.1 (7.1)	0.1 (7.4)	0.1 (7.4)	0.1 (7.9)
Sep	---	0.9 (48.6)	0.9 (44.8)	0.9 (44.8)	0.9 (45.5)	0.9 (44.8)	0.8 (41.3)	0.9 (47.4)
Oct	---	0.0 (1.6)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)	0.1 (3.5)
Nov	---	0.2 (6.1)	0.2 (5.8)	0.2 (5.9)	0.2 (6.0)	0.2 (5.8)	0.2 (5.8)	0.2 (5.9)
Dec	---	0.1 (2.4)	0.1 (0.6)	0.1 (0.6)	0.1 (1.5)	0.1 (0.6)	0.1 (0.6)	0.1 (0.6)

Cumulative Effects

All alternatives would have negligible to minor adverse cumulative effects to sulfate and uranium concentrations, compared to No Action, at the Arkansas River at Moffat St. gage (Table 89 to Table 92) except River South and Master Contract Only. The largest increases would occur in drier months in the fall and winter. All alternatives would increase sulfate and uranium concentrations compared to existing conditions.

Table 89. Cumulative Effects Simulated Sulfate Concentrations for Arkansas River at Moffat St. Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	178	213	224	224	224	224	198	214
15th percentile	84	92	96	95	95	95	90	92
25th percentile	110	128	131	131	130	131	127	128
50th percentile	158	192	201	201	201	201	179	191
75th percentile	198	241	253	254	254	254	231	242
85th percentile	219	277	288	289	286	288	268	278
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	11 (5.1)	11 (5.1)	10 (4.8)	11 (5.2)	-15 (-7.0)	1 (0.3)
15th percentile	---	---	4 (4.0)	3 (3.4)	3 (3.5)	3 (3.5)	-3 (-2.8)	0 (0.2)
25th percentile	---	---	3 (2.4)	3 (2.1)	2 (1.9)	3 (2.5)	-1 (-1.0)	0 (0.3)
50th percentile	---	---	9 (4.7)	9 (4.6)	9 (4.5)	9 (4.8)	-13 (-6.7)	-1 (-0.4)
75th percentile	---	---	13 (5.3)	14 (5.7)	13 (5.4)	14 (5.7)	-9 (-3.9)	1 (0.4)
85th percentile	---	---	12 (4.2)	12 (4.3)	10 (3.5)	11 (4.1)	-9 (-3.3)	1 (0.4)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	36 (20.0)	46 (26.1)	46 (26.1)	46 (25.7)	47 (26.2)	21 (11.5)	36 (20.3)
15th percentile	---	8 (9.9)	12 (14.3)	11 (13.6)	11 (13.7)	12 (13.8)	6 (6.9)	8 (10.1)
25th percentile	---	18 (16.6)	21 (19.4)	21 (19.0)	21 (18.8)	21 (19.5)	17 (15.5)	19 (16.9)
50th percentile	---	34 (21.5)	43 (27.3)	43 (27.1)	43 (27.0)	43 (27.3)	21 (13.3)	33 (21.0)
75th percentile	---	42 (21.3)	55 (27.7)	56 (28.2)	55 (27.8)	56 (28.2)	33 (16.6)	43 (21.8)
85th percentile	---	58 (26.6)	70 (31.9)	70 (32.1)	68 (31.0)	70 (31.8)	49 (22.4)	59 (27.1)

Table 90. Monthly Simulated Sulfate Concentration for Arkansas River at Moffat St. Gage - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	238	261	276	277	276	277	242	261
Feb	270	275	298	298	297	298	240	276
Mar	179	204	214	215	215	215	184	203
Apr	160	191	198	198	197	198	186	192
May	148	180	183	183	185	184	175	182
Jun	93	104	105	105	105	105	102	103
Jul	85	103	107	107	108	107	97	104
Aug	135	178	189	189	188	190	157	179
Sep	190	260	277	277	276	277	240	260
Oct	187	268	288	288	281	288	257	272
Nov	223	270	279	279	281	279	252	270
Dec	246	289	299	299	299	299	268	288
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	15 (6.0)	16 (6.1)	15 (5.7)	16 (6.1)	-19 (-7.2)	0 (0.2)
Feb	---	---	23 (8.4)	23 (8.4)	22 (8.1)	23 (8.4)	-35 (-12.8)	1 (0.2)
Mar	---	---	10 (5.2)	11 (5.6)	11 (5.5)	11 (5.3)	-20 (-9.5)	-1 (-0.4)
Apr	---	---	7 (3.8)	7 (3.7)	6 (3.3)	7 (3.8)	-5 (-2.6)	1 (0.4)
May	---	---	3 (1.8)	3 (1.8)	5 (2.7)	4 (2.0)	-5 (-2.6)	2 (1.2)
Jun	---	---	1 (0.9)	1 (1.2)	1 (1.2)	1 (1.2)	-2 (-1.3)	-1 (-0.5)
Jul	---	---	4 (3.9)	4 (3.8)	5 (4.8)	4 (4.2)	-6 (-5.4)	1 (1.3)
Aug	---	---	11 (5.9)	11 (6.2)	10 (5.3)	12 (6.4)	-21 (-11.9)	1 (0.2)
Sep	---	---	17 (6.6)	17 (6.6)	16 (6.1)	17 (6.6)	-20 (-7.7)	0 (0.1)
Oct	---	---	20 (7.3)	20 (7.4)	13 (4.7)	20 (7.6)	-11 (-4.0)	4 (1.4)
Nov	---	---	9 (3.1)	9 (3.1)	11 (3.9)	9 (3.2)	-18 (-6.8)	0 (0.0)
Dec	---	---	10 (3.6)	10 (3.6)	10 (3.6)	10 (3.6)	-21 (-7.2)	-1 (-0.2)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	23 (9.6)	38 (16.2)	39 (16.3)	38 (15.9)	39 (16.3)	4 (1.7)	23 (9.8)
Feb	---	5 (1.8)	28 (10.3)	28 (10.3)	27 (10.0)	28 (10.3)	-30 (-11.3)	6 (2.0)
Mar	---	25 (14.0)	35 (20.0)	36 (20.4)	36 (20.3)	36 (20.1)	5 (3.2)	24 (13.5)
Apr	---	31 (19.3)	38 (23.8)	38 (23.7)	37 (23.2)	38 (23.7)	26 (16.1)	32 (19.7)
May	---	32 (21.9)	35 (24.1)	35 (24.0)	37 (25.1)	36 (24.2)	27 (18.7)	34 (23.3)
Jun	---	11 (11.2)	12 (12.2)	12 (12.5)	12 (12.5)	12 (12.5)	9 (9.7)	10 (10.6)
Jul	---	18 (21.7)	22 (26.4)	22 (26.3)	23 (27.5)	22 (26.7)	12 (15.1)	19 (23.2)
Aug	---	43 (32.2)	54 (40.0)	54 (40.3)	53 (39.2)	55 (40.7)	22 (16.5)	44 (32.5)
Sep	---	70 (37.2)	87 (46.3)	87 (46.2)	86 (45.5)	87 (46.3)	50 (26.6)	70 (37.4)
Oct	---	81 (43.1)	101 (53.6)	101 (53.7)	94 (49.9)	101 (54.0)	70 (37.4)	85 (45.0)
Nov	---	47 (21.2)	56 (25.0)	56 (25.0)	58 (26.0)	56 (25.1)	29 (13.0)	47 (21.2)
Dec	---	43 (17.3)	53 (21.6)	53 (21.5)	53 (21.5)	53 (21.5)	22 (8.9)	42 (17.1)

Table 91. Cumulative Effects Simulated Uranium Concentrations for Arkansas River at Moffat St. Gage.

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	8.6	10.1	10.5	10.5	10.5	10.5	9.5	10.1
15th percentile	4.8	5.2	5.3	5.3	5.3	5.3	5.1	5.2
25th percentile	5.9	6.6	6.7	6.7	6.7	6.7	6.6	6.6
50th percentile	7.8	9.2	9.6	9.6	9.6	9.6	8.7	9.2
75th percentile	9.5	11.2	11.7	11.7	11.7	11.7	10.8	11.2
85th percentile	10.3	12.6	13.1	13.1	13.0	13.1	12.3	12.7
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.4 (4.4)	0.4 (4.4)	0.4 (4.1)	0.4 (4.4)	-0.6 (-6.0)	0 (0.2)
15th percentile	---	---	0.1 (2.9)	0.1 (2.5)	0.1 (2.5)	0.1 (2.5)	-0.1 (-2.0)	0 (0.1)
25th percentile	---	---	0.1 (1.9)	0.1 (1.7)	0.1 (1.5)	0.1 (2.0)	-0.1 (-0.8)	0 (0.2)
50th percentile	---	---	0.4 (4.0)	0.4 (3.9)	0.4 (3.8)	0.4 (4.1)	-0.5 (-5.7)	0 (-0.4)
75th percentile	---	---	0.5 (4.6)	0.6 (5.0)	0.5 (4.7)	0.6 (4.9)	-0.4 (-3.4)	0 (0.4)
85th percentile	---	---	0.5 (3.7)	0.5 (3.9)	0.4 (3.1)	0.5 (3.7)	-0.4 (-2.9)	0 (0.4)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	1.4 (16.7)	1.9 (21.8)	1.9 (21.8)	1.9 (21.5)	1.9 (21.9)	0.8 (9.6)	1.5 (17.0)
15th percentile	---	0.3 (7.0)	0.5 (10.0)	0.5 (9.6)	0.5 (9.7)	0.5 (9.7)	0.2 (4.8)	0.3 (7.1)
25th percentile	---	0.7 (12.5)	0.9 (14.7)	0.8 (14.4)	0.8 (14.2)	0.9 (14.8)	0.7 (11.7)	0.8 (12.8)
50th percentile	---	1.4 (17.6)	1.7 (22.3)	1.7 (22.2)	1.7 (22.1)	1.8 (22.3)	0.9 (10.9)	1.3 (17.1)
75th percentile	---	1.7 (18.1)	2.2 (23.5)	2.3 (23.9)	2.2 (23.6)	2.3 (23.9)	1.3 (14.1)	1.8 (18.5)
85th percentile	---	2.4 (22.9)	2.8 (27.5)	2.8 (27.6)	2.7 (26.7)	2.8 (27.4)	2 (19.3)	2.4 (23.4)

Table 92. Monthly Simulated Uranium Concentration for Arkansas River at Moffat St. Gage - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	11.1	12.0	12.6	12.6	12.6	12.6	11.2	12.0
Feb	12.4	12.6	13.5	13.5	13.5	13.5	11.2	12.6
Mar	8.7	9.7	10.1	10.2	10.1	10.1	8.9	9.7
Apr	7.9	9.2	9.5	9.5	9.4	9.5	9.0	9.2
May	7.4	8.7	8.9	8.9	8.9	8.9	8.5	8.8
Jun	5.2	5.6	5.7	5.7	5.7	5.7	5.6	5.6
Jul	4.9	5.6	5.8	5.8	5.8	5.8	5.4	5.7
Aug	6.9	8.7	9.1	9.1	9.0	9.1	7.8	8.7
Sep	9.1	12.0	12.7	12.7	12.6	12.7	11.2	12.0
Oct	9.0	12.3	13.1	13.1	12.8	13.1	11.9	12.4
Nov	10.5	12.4	12.7	12.7	12.8	12.7	11.6	12.4
Dec	11.4	13.1	13.6	13.6	13.6	13.6	12.3	13.1
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.6 (5.3)	0.6 (5.4)	0.6 (5.0)	0.6 (5.4)	-0.8 (-6.4)	0.0 (0.2)
Feb	---	---	0.9 (7.4)	0.9 (7.4)	0.9 (7.1)	0.9 (7.4)	-1.4 (-11.4)	0.0 (0.2)
Mar	---	---	0.4 (4.5)	0.5 (4.8)	0.4 (4.7)	0.4 (4.6)	-0.8 (-8.1)	0.0 (-0.3)
Apr	---	---	0.3 (3.2)	0.3 (3.1)	0.2 (2.8)	0.3 (3.2)	-0.2 (-2.2)	0.0 (0.3)
May	---	---	0.2 (1.5)	0.2 (1.5)	0.2 (2.3)	0.2 (1.6)	-0.2 (-2.2)	0.1 (1.0)
Jun	---	---	0.1 (0.7)	0.1 (0.9)	0.1 (0.9)	0.1 (0.9)	0.0 (-1.0)	0.0 (-0.4)
Jul	---	---	0.2 (2.9)	0.2 (2.9)	0.2 (3.6)	0.2 (3.1)	-0.2 (-4.0)	0.1 (0.9)
Aug	---	---	0.4 (4.9)	0.4 (5.1)	0.3 (4.4)	0.4 (5.3)	-0.9 (-9.9)	0.0 (0.2)
Sep	---	---	0.7 (5.9)	0.7 (5.8)	0.6 (5.3)	0.7 (5.8)	-0.8 (-6.8)	0.0 (0.1)
Oct	---	---	0.8 (6.5)	0.8 (6.6)	0.5 (4.2)	0.8 (6.7)	-0.4 (-3.5)	0.1 (1.2)
Nov	---	---	0.3 (2.8)	0.3 (2.7)	0.4 (3.4)	0.3 (2.8)	-0.8 (-6.0)	0.0 (0.0)
Dec	---	---	0.5 (3.2)	0.5 (3.2)	0.5 (3.2)	0.5 (3.2)	-0.8 (-6.4)	0.0 (-0.2)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.9 (8.4)	1.5 (14.1)	1.5 (14.2)	1.5 (13.8)	1.5 (14.2)	0.1 (1.5)	0.9 (8.6)
Feb	---	0.2 (1.6)	1.1 (9.1)	1.1 (9.1)	1.1 (8.9)	1.1 (9.1)	-1.2 (-10.0)	0.2 (1.8)
Mar	---	1.0 (11.7)	1.4 (16.7)	1.5 (17.0)	1.4 (17.0)	1.4 (16.8)	0.2 (2.7)	1.0 (11.3)
Apr	---	1.3 (15.8)	1.6 (19.5)	1.6 (19.4)	1.5 (19.1)	1.6 (19.5)	1.1 (13.2)	1.3 (16.1)
May	---	1.3 (17.6)	1.5 (19.4)	1.5 (19.4)	1.5 (20.3)	1.5 (19.6)	1.1 (15.1)	1.4 (18.8)
Jun	---	0.4 (8.1)	0.5 (8.8)	0.5 (9.1)	0.5 (9.1)	0.5 (9.1)	0.4 (7.0)	0.4 (7.7)
Jul	---	0.7 (15.3)	0.9 (18.6)	0.9 (18.6)	0.9 (19.4)	0.9 (18.9)	0.5 (10.7)	0.8 (16.4)
Aug	---	1.8 (25.5)	2.2 (31.7)	2.2 (32.0)	2.1 (31.1)	2.2 (32.2)	0.9 (13.1)	1.8 (25.7)
Sep	---	2.9 (31.4)	3.6 (39.0)	3.6 (38.9)	3.5 (38.4)	3.6 (39.0)	2.1 (22.4)	2.9 (31.5)
Oct	---	3.3 (36.3)	4.1 (45.1)	4.1 (45.2)	3.8 (42.0)	4.1 (45.4)	2.9 (31.5)	3.4 (37.9)
Nov	---	1.9 (18.3)	2.2 (21.6)	2.2 (21.6)	2.3 (22.4)	2.2 (21.7)	1.1 (11.2)	1.9 (18.3)
Dec	---	1.7 (15.2)	2.2 (18.9)	2.2 (18.8)	2.2 (18.8)	2.2 (18.8)	0.9 (7.8)	1.7 (15.0)

All alternatives would have predominately negligible effects to sulfate and uranium concentrations at the Arkansas River near Avondale gage (Table 93 to Table 96). Compared to existing conditions, sulfate and uranium concentrations would increase in drier months.

Table 93. Cumulative Effects Simulated Sulfate Concentrations for Arkansas River near Avondale Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	264	271	273	272	273	272	271	271
15th percentile	170	190	192	192	192	192	189	189
25th percentile	201	229	230	229	228	230	230	232
50th percentile	271	283	286	285	285	285	282	284
75th percentile	324	317	318	318	318	317	319	317
85th percentile	342	334	335	334	334	333	333	332
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	2 (0.7)	1 (0.5)	2 (0.6)	1 (0.4)	0 (-0.1)	0 (0.0)
15th percentile	---	---	3 (1.5)	2 (1.1)	2 (1.3)	2 (1.1)	-1 (-0.3)	-1 (-0.3)
25th percentile	---	---	1 (0.3)	0 (0.1)	-1 (-0.3)	1 (0.3)	1 (0.4)	3 (1.3)
50th percentile	---	---	3 (1.0)	2 (0.7)	2 (0.8)	2 (0.6)	-1 (-0.2)	1 (0.4)
75th percentile	---	---	2 (0.6)	1 (0.3)	2 (0.5)	1 (0.3)	2 (0.6)	0 (0.0)
85th percentile	---	---	1 (0.4)	0 (0.0)	1 (0.2)	0 (-0.1)	-1 (-0.2)	-2 (-0.5)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	7 (2.6)	9 (3.3)	8 (3.1)	9 (3.2)	8 (3.0)	7 (2.5)	7 (2.7)
15th percentile	---	20 (11.6)	22 (13.2)	22 (12.8)	22 (13.0)	22 (12.8)	19 (11.2)	19 (11.2)
25th percentile	---	28 (13.9)	29 (14.2)	28 (14.0)	27 (13.5)	29 (14.2)	29 (14.3)	31 (15.3)
50th percentile	---	12 (4.3)	14 (5.3)	14 (5.0)	14 (5.2)	13 (5.0)	11 (4.1)	13 (4.7)
75th percentile	---	-8 (-2.4)	-6 (-1.8)	-7 (-2.1)	-6 (-1.9)	-7 (-2.1)	-6 (-1.8)	-8 (-2.4)
85th percentile	---	-9 (-2.5)	-7 (-2.1)	-9 (-2.5)	-8 (-2.3)	-9 (-2.6)	-9 (-2.7)	-10 (-3.0)

Table 94. Monthly Simulated Sulfate Concentration for Arkansas River near Avondale Gage - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	333	317	319	319	319	319	316	317
Feb	348	319	321	321	322	321	318	319
Mar	300	297	296	296	298	296	295	295
Apr	251	268	269	269	268	270	268	269
May	197	235	235	230	234	230	234	233
Jun	158	197	198	198	196	197	198	197
Jul	172	187	191	190	190	191	186	189
Aug	221	235	241	241	242	237	234	236
Sep	276	290	292	292	291	291	294	290
Oct	295	296	298	298	297	298	298	297
Nov	309	307	308	308	308	308	306	307
Dec	331	321	321	321	322	321	319	320
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	2 (0.6)	2 (0.6)	2 (0.5)	2 (0.6)	-1 (-0.4)	0 (-0.1)
Feb	---	---	2 (0.6)	2 (0.7)	3 (0.8)	2 (0.7)	-1 (-0.5)	0 (0.0)
Mar	---	---	-1 (-0.4)	-1 (-0.4)	1 (0.2)	-1 (-0.4)	-2 (-0.7)	-2 (-0.7)
Apr	---	---	1 (0.4)	1 (0.4)	0 (0.1)	2 (1.1)	0 (0.3)	1 (0.7)
May	---	---	0 (0.3)	-5 (-2.1)	-1 (-0.1)	-5 (-2.0)	-1 (-0.2)	-2 (-0.7)
Jun	---	---	1 (0.6)	1 (0.6)	-1 (-0.1)	0 (0.3)	1 (0.5)	0 (0.3)
Jul	---	---	4 (1.9)	3 (1.8)	3 (1.6)	4 (1.9)	-1 (-0.8)	2 (1.0)
Aug	---	---	6 (2.8)	6 (2.7)	7 (3.2)	2 (0.8)	-1 (-0.3)	1 (0.4)
Sep	---	---	2 (0.5)	2 (0.4)	1 (0.3)	1 (0.4)	4 (1.3)	0 (0.0)
Oct	---	---	2 (0.7)	2 (0.8)	1 (0.3)	2 (0.7)	2 (0.5)	1 (0.3)
Nov	---	---	1 (0.5)	1 (0.4)	1 (0.5)	1 (0.5)	-1 (-0.2)	0 (0.0)
Dec	---	---	0 (0.3)	0 (0.2)	1 (0.4)	0 (0.3)	-2 (-0.4)	-1 (-0.1)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-16 (-4.8)	-14 (-4.2)	-14 (-4.2)	-14 (-4.3)	-14 (-4.2)	-17 (-5.1)	-16 (-4.9)
Feb	---	-29 (-8.3)	-27 (-7.7)	-27 (-7.7)	-26 (-7.6)	-27 (-7.7)	-30 (-8.7)	-29 (-8.4)
Mar	---	-3 (-0.9)	-4 (-1.3)	-4 (-1.3)	-2 (-0.7)	-4 (-1.3)	-5 (-1.6)	-5 (-1.6)
Apr	---	17 (6.7)	18 (7.1)	18 (7.1)	17 (6.8)	19 (7.8)	17 (7.0)	18 (7.4)
May	---	38 (19.1)	38 (19.5)	33 (16.7)	37 (19.0)	33 (16.7)	37 (18.9)	36 (18.3)
Jun	---	39 (24.7)	40 (25.5)	40 (25.5)	38 (24.6)	39 (25.0)	40 (25.4)	39 (25.1)
Jul	---	15 (8.5)	19 (10.6)	18 (10.5)	18 (10.3)	19 (10.6)	14 (7.7)	17 (9.6)
Aug	---	14 (6.4)	20 (9.4)	20 (9.3)	21 (9.8)	16 (7.3)	13 (6.2)	15 (6.8)
Sep	---	14 (5.3)	16 (5.8)	16 (5.8)	15 (5.6)	15 (5.7)	18 (6.7)	14 (5.3)
Oct	---	1 (0.2)	3 (0.9)	3 (0.9)	2 (0.5)	3 (0.9)	3 (0.7)	2 (0.5)
Nov	---	-2 (-0.9)	-1 (-0.4)	-1 (-0.4)	-1 (-0.3)	-1 (-0.3)	-3 (-1.1)	-2 (-0.8)
Dec	---	-10 (-3.2)	-10 (-2.9)	-10 (-2.9)	-9 (-2.8)	-10 (-2.9)	-12 (-3.6)	-11 (-3.3)

Table 95. Cumulative Effects Simulated Uranium Concentrations for Arkansas River near Avondale Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	4.2	4.4	4.4	4.4	4.4	4.4	4.4	4.4
15th percentile	2.1	2.6	2.6	2.6	2.6	2.6	2.5	2.5
25th percentile	2.8	3.4	3.4	3.4	3.4	3.4	3.4	3.5
50th percentile	4.4	4.6	4.7	4.7	4.7	4.7	4.6	4.6
75th percentile	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.4
85th percentile	5.9	5.7	5.8	5.7	5.8	5.7	5.7	5.7
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0 (0.9)	0 (0.6)	0 (0.8)	0 (0.5)	0 (-0.1)	0 (0.0)
15th percentile	---	---	0.1 (2.4)	0 (1.9)	0.1 (2.1)	0 (1.9)	0 (-0.5)	0 (-0.5)
25th percentile	---	---	0 (0.4)	0 (0.1)	0 (-0.4)	0 (0.5)	0 (0.6)	0.1 (1.9)
50th percentile	---	---	0.1 (1.3)	0 (0.9)	0.1 (1.2)	0 (0.9)	0 (-0.3)	0 (0.5)
75th percentile	---	---	0 (0.7)	0 (0.4)	0 (0.7)	0 (0.3)	0 (0.8)	0 (0.0)
85th percentile	---	---	0 (0.5)	0 (0.0)	0 (0.3)	0 (-0.1)	0 (-0.3)	0 (-0.6)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.2 (3.7)	0.2 (4.6)	0.2 (4.3)	0.2 (4.5)	0.2 (4.2)	0.1 (3.5)	0.2 (3.7)
15th percentile	---	0.4 (20.6)	0.5 (23.5)	0.5 (22.8)	0.5 (23.1)	0.5 (22.8)	0.4 (19.9)	0.4 (19.9)
25th percentile	---	0.6 (22.0)	0.6 (22.5)	0.6 (22.2)	0.6 (21.5)	0.6 (22.6)	0.6 (22.8)	0.7 (24.3)
50th percentile	---	0.3 (5.9)	0.3 (7.3)	0.3 (6.9)	0.3 (7.1)	0.3 (6.8)	0.2 (5.6)	0.3 (6.4)
75th percentile	---	-0.2 (-3.1)	-0.1 (-2.4)	-0.1 (-2.7)	-0.1 (-2.4)	-0.2 (-2.8)	-0.1 (-2.4)	-0.2 (-3.1)
85th percentile	---	-0.2 (-3.2)	-0.2 (-2.7)	-0.2 (-3.2)	-0.2 (-2.9)	-0.2 (-3.3)	-0.2 (-3.5)	-0.2 (-3.8)

Table 96. Monthly Simulated Uranium Concentration for Arkansas River near Avondale Gage - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	9.1	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Feb	9.5	8.8	8.9	8.9	8.9	8.9	8.8	8.8
Mar	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Apr	7.3	7.7	7.7	7.7	7.7	7.7	7.7	7.7
May	6.1	7.0	7.0	6.8	6.9	6.8	6.9	6.9
Jun	5.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Jul	5.6	5.9	6.0	6.0	6.0	6.0	5.9	5.9
Aug	6.6	7.0	7.1	7.1	7.1	7.0	6.9	7.0
Sep	7.9	8.2	8.2	8.2	8.2	8.2	8.3	8.2
Oct	8.3	8.3	8.4	8.4	8.3	8.4	8.3	8.3
Nov	8.6	8.6	8.6	8.6	8.6	8.6	8.5	8.6
Dec	9.1	8.9	8.9	8.9	8.9	8.9	8.8	8.8
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.0 (0.5)	0.0 (0.5)	0.0 (0.4)	0.0 (0.5)	0.0 (-0.3)	0.0 (-0.1)
Feb	---	---	0.1 (0.5)	0.1 (0.5)	0.1 (0.6)	0.1 (0.5)	0.0 (-0.4)	0.0 (0.0)
Mar	---	---	0.0 (-0.3)	0.0 (-0.3)	0.0 (0.1)	0.0 (-0.3)	0.0 (-0.6)	0.0 (-0.5)
Apr	---	---	0.0 (0.3)	0.0 (0.3)	0.0 (0.1)	0.0 (0.8)	0.0 (0.3)	0.0 (0.5)
May	---	---	0.0 (0.2)	-0.2 (-1.5)	-0.1 (-0.1)	-0.2 (-1.5)	-0.1 (-0.1)	-0.1 (-0.5)
Jun	---	---	0.0 (0.5)	0.0 (0.4)	0.0 (0.0)	0.0 (0.2)	0.0 (0.4)	0.0 (0.2)
Jul	---	---	0.1 (1.4)	0.1 (1.3)	0.1 (1.1)	0.1 (1.4)	0.0 (-0.5)	0.0 (0.7)
Aug	---	---	0.1 (2.1)	0.1 (2.0)	0.1 (2.4)	0.0 (0.6)	-0.1 (-0.2)	0.0 (0.3)
Sep	---	---	0.0 (0.4)	0.0 (0.3)	0.0 (0.2)	0.0 (0.3)	0.1 (1.0)	0.0 (0.0)
Oct	---	---	0.1 (0.6)	0.1 (0.6)	0.0 (0.2)	0.1 (0.5)	0.0 (0.4)	0.0 (0.3)
Nov	---	---	0.0 (0.4)	0.0 (0.3)	0.0 (0.4)	0.0 (0.4)	-0.1 (-0.2)	0.0 (0.0)
Dec	---	---	0.0 (0.2)	0.0 (0.2)	0.0 (0.3)	0.0 (0.2)	-0.1 (-0.3)	-0.1 (-0.1)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.3 (-3.9)	-0.3 (-3.4)	-0.3 (-3.4)	-0.3 (-3.5)	-0.3 (-3.4)	-0.3 (-4.2)	-0.3 (-4.0)
Feb	---	-0.7 (-6.8)	-0.6 (-6.3)	-0.6 (-6.3)	-0.6 (-6.2)	-0.6 (-6.3)	-0.7 (-7.1)	-0.7 (-6.8)
Mar	---	-0.1 (-0.7)	-0.1 (-1.0)	-0.1 (-1.0)	-0.1 (-0.6)	-0.1 (-1.0)	-0.1 (-1.3)	-0.1 (-1.2)
Apr	---	0.4 (5.1)	0.4 (5.4)	0.4 (5.4)	0.4 (5.1)	0.4 (6.0)	0.4 (5.3)	0.4 (5.6)
May	---	0.9 (13.6)	0.9 (13.9)	0.7 (11.9)	0.8 (13.5)	0.7 (12.0)	0.8 (13.5)	0.8 (13.1)
Jun	---	0.9 (16.5)	0.9 (17.0)	0.9 (17.0)	0.9 (16.4)	0.9 (16.7)	0.9 (16.9)	0.9 (16.7)
Jul	---	0.3 (5.9)	0.4 (7.3)	0.4 (7.2)	0.4 (7.1)	0.4 (7.3)	0.3 (5.3)	0.3 (6.6)
Aug	---	0.4 (4.7)	0.5 (7.0)	0.5 (6.8)	0.5 (7.2)	0.4 (5.4)	0.3 (4.5)	0.4 (5.0)
Sep	---	0.3 (4.1)	0.3 (4.5)	0.3 (4.5)	0.3 (4.3)	0.3 (4.4)	0.4 (5.2)	0.3 (4.1)
Oct	---	0.0 (0.2)	0.1 (0.7)	0.1 (0.7)	0.0 (0.4)	0.1 (0.7)	0.0 (0.6)	0.0 (0.4)
Nov	---	0.0 (-0.7)	0.0 (-0.3)	0.0 (-0.4)	0.0 (-0.3)	0.0 (-0.3)	-0.1 (-0.9)	0.0 (-0.7)
Dec	---	-0.2 (-2.6)	-0.2 (-2.4)	-0.2 (-2.4)	-0.2 (-2.2)	-0.2 (-2.4)	-0.3 (-2.9)	-0.3 (-2.7)

All alternatives would have predominately negligible effects to sulfate and uranium concentrations at the Arkansas River at Catlin Dam gage (Table 97 to Table 100), though some minor increases occur late summer and early fall months. Compared to existing conditions, sulfate and uranium concentrations would increase.

Table 97. Cumulative Effects Simulated Sulfate Concentrations for Arkansas River at Catlin Dam Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	376	398	402	402	402	401	403	398
15th percentile	208	235	245	247	243	243	238	240
25th percentile	246	296	302	298	306	303	299	304
50th percentile	385	427	427	424	426	424	426	425
75th percentile	478	482	485	487	486	485	491	482
85th percentile	528	527	532	532	532	531	539	522
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	4 (1.0)	4 (0.9)	4 (0.9)	3 (0.8)	5 (1.3)	0 (-0.1)
15th percentile	---	---	10 (4.1)	12 (4.9)	7 (3.1)	8 (3.4)	2 (1.0)	5 (2.0)
25th percentile	---	---	6 (2.0)	1 (0.5)	9 (3.2)	6 (2.1)	3 (0.9)	8 (2.6)
50th percentile	---	---	0 (0.1)	-2 (-0.5)	-1 (-0.2)	-3 (-0.7)	-1 (-0.2)	-1 (-0.3)
75th percentile	---	---	3 (0.5)	5 (1.0)	4 (0.8)	3 (0.6)	8 (1.7)	0 (-0.1)
85th percentile	---	---	5 (1.0)	6 (1.1)	5 (1.0)	5 (0.9)	12 (2.2)	-5 (-0.9)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	22 (5.7)	26 (6.8)	25 (6.7)	25 (6.7)	25 (6.6)	27 (7.0)	21 (5.6)
15th percentile	---	27 (13.0)	37 (17.6)	39 (18.6)	34 (16.5)	35 (16.8)	30 (14.2)	32 (15.2)
25th percentile	---	50 (20.5)	56 (22.9)	52 (21.1)	60 (24.3)	57 (23.0)	53 (21.6)	58 (23.6)
50th percentile	---	42 (10.9)	42 (10.9)	40 (10.3)	41 (10.7)	39 (10.1)	41 (10.6)	40 (10.5)
75th percentile	---	5 (1.0)	7 (1.5)	10 (2.0)	8 (1.8)	8 (1.6)	13 (2.7)	4 (0.9)
85th percentile	---	-2 (-0.3)	4 (0.7)	4 (0.8)	4 (0.7)	3 (0.6)	10 (1.9)	-7 (-1.2)

Table 98. Monthly Simulated Sulfate Concentration for Arkansas River at Catlin Dam Gage -umulative Effects.

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	500	506	510	512	510	511	512	504
Feb	539	482	477	477	479	478	495	483
Mar	441	444	445	443	445	443	444	444
Apr	342	401	404	404	402	404	404	400
May	247	306	315	309	308	306	315	307
Jun	188	236	238	238	236	237	237	237
Jul	224	246	254	253	255	254	249	251
Aug	296	321	329	328	331	326	325	321
Sep	407	436	445	445	442	444	454	439
Oct	421	467	473	473	473	474	469	465
Nov	451	462	465	466	468	465	463	458
Dec	493	484	489	489	490	489	490	482
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	4 (0.9)	6 (1.1)	4 (0.8)	5 (1.0)	6 (1.1)	-2 (-0.3)
Feb	---	---	-5 (-1.0)	-5 (-1.0)	-3 (-0.7)	-4 (-0.8)	13 (2.6)	1 (0.2)
Mar	---	---	1 (0.0)	-1 (-0.4)	1 (0.2)	-1 (-0.4)	0 (-0.1)	0 (-0.1)
Apr	---	---	3 (0.6)	3 (0.7)	1 (0.2)	3 (0.8)	3 (0.8)	-1 (-0.4)
May	---	---	9 (2.8)	3 (1.0)	2 (0.5)	0 (0.0)	9 (2.8)	1 (0.1)
Jun	---	---	2 (0.7)	2 (0.7)	0 (-0.1)	1 (0.5)	1 (0.5)	1 (0.4)
Jul	---	---	8 (3.0)	7 (2.5)	9 (3.4)	8 (3.2)	3 (0.9)	5 (1.9)
Aug	---	---	8 (2.5)	7 (2.2)	10 (3.0)	5 (1.7)	4 (1.1)	0 (-0.1)
Sep	---	---	9 (1.9)	9 (2.0)	6 (1.3)	8 (1.6)	18 (4.1)	3 (0.7)
Oct	---	---	6 (1.3)	6 (1.2)	6 (1.3)	7 (1.4)	2 (0.4)	-2 (-0.5)
Nov	---	---	3 (0.7)	4 (0.8)	6 (1.4)	3 (0.7)	1 (0.3)	-4 (-0.7)
Dec	---	---	5 (0.9)	5 (1.0)	6 (1.2)	5 (0.9)	6 (1.1)	-2 (-0.5)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	6 (1.1)	10 (2.0)	12 (2.2)	10 (1.9)	11 (2.1)	12 (2.2)	4 (0.8)
Feb	---	-57 (-10.5)	-62 (-11.4)	-62 (-11.4)	-60 (-11.2)	-61 (-11.3)	-44 (-8.2)	-56 (-10.4)
Mar	---	3 (0.8)	4 (0.9)	2 (0.4)	4 (1.0)	2 (0.4)	3 (0.8)	3 (0.7)
Apr	---	59 (17.4)	62 (18.0)	62 (18.1)	60 (17.6)	62 (18.3)	62 (18.3)	58 (16.9)
May	---	59 (24.0)	68 (27.4)	62 (25.2)	61 (24.6)	59 (24.1)	68 (27.5)	60 (24.2)
Jun	---	48 (25.3)	50 (26.2)	50 (26.2)	48 (25.2)	49 (26.0)	49 (26.0)	49 (25.9)
Jul	---	22 (10.2)	30 (13.5)	29 (13.0)	31 (13.9)	30 (13.8)	25 (11.2)	27 (12.3)
Aug	---	25 (8.4)	33 (11.1)	32 (10.9)	35 (11.6)	30 (10.2)	29 (9.6)	25 (8.4)
Sep	---	29 (7.3)	38 (9.4)	38 (9.5)	35 (8.7)	37 (9.1)	47 (11.7)	32 (8.1)
Oct	---	46 (10.8)	52 (12.2)	52 (12.2)	52 (12.2)	53 (12.4)	48 (11.3)	44 (10.3)
Nov	---	11 (2.4)	14 (3.2)	15 (3.2)	17 (3.9)	14 (3.2)	12 (2.7)	7 (1.7)
Dec	---	-9 (-1.8)	-4 (-0.9)	-4 (-0.8)	-3 (-0.5)	-4 (-0.9)	-3 (-0.7)	-11 (-2.2)

Table 99. Cumulative Effects Simulated Uranium Concentrations for Arkansas River at Catlin Dam Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	7.7	8.1	8.2	8.2	8.2	8.2	8.2	8.1
15th percentile	4.6	5.1	5.3	5.3	5.3	5.3	5.2	5.2
25th percentile	5.3	6.3	6.4	6.3	6.4	6.4	6.3	6.4
50th percentile	7.9	8.7	8.7	8.6	8.7	8.6	8.7	8.6
75th percentile	9.6	9.7	9.8	9.8	9.8	9.8	9.9	9.7
85th percentile	10.6	10.5	10.6	10.6	10.6	10.6	10.7	10.4
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0.1 (0.9)	0.1 (0.8)	0.1 (0.9)	0.1 (0.7)	0.1 (1.1)	0 (-0.1)
15th percentile	---	---	0.2 (3.5)	0.2 (4.2)	0.1 (2.6)	0.1 (2.9)	0 (0.9)	0.1 (1.7)
25th percentile	---	---	0.1 (1.7)	0 (0.4)	0.2 (2.8)	0.1 (1.8)	0 (0.8)	0.1 (2.3)
50th percentile	---	---	0 (0.0)	0 (-0.5)	0 (-0.2)	-0.1 (-0.6)	0 (-0.2)	0 (-0.3)
75th percentile	---	---	0 (0.5)	0.1 (0.9)	0.1 (0.7)	0.1 (0.5)	0.2 (1.6)	0 (-0.1)
85th percentile	---	---	0.1 (0.9)	0.1 (1.0)	0.1 (0.9)	0.1 (0.8)	0.2 (2.1)	-0.1 (-0.9)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	0.4 (5.2)	0.5 (6.1)	0.5 (6.0)	0.5 (6.1)	0.5 (5.9)	0.5 (6.4)	0.4 (5.1)
15th percentile	---	0.5 (10.9)	0.7 (14.7)	0.7 (15.6)	0.6 (13.8)	0.7 (14.1)	0.5 (11.9)	0.6 (12.8)
25th percentile	---	0.9 (17.6)	1 (19.6)	1 (18.1)	1.1 (20.8)	1.1 (19.8)	1 (18.5)	1.1 (20.2)
50th percentile	---	0.8 (9.8)	0.8 (9.9)	0.7 (9.3)	0.8 (9.6)	0.7 (9.2)	0.8 (9.6)	0.8 (9.5)
75th percentile	---	0.1 (0.9)	0.1 (1.4)	0.2 (1.9)	0.2 (1.6)	0.1 (1.5)	0.2 (2.5)	0.1 (0.9)
85th percentile	---	0 (-0.3)	0.1 (0.6)	0.1 (0.7)	0.1 (0.7)	0.1 (0.6)	0.2 (1.8)	-0.1 (-1.1)

Table 100. Monthly Simulated Uranium Concentration for Arkansas River at Catlin Gage - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	10.2	10.3	10.3	10.4	10.3	10.4	10.4	10.2
Feb	10.9	9.8	9.7	9.7	9.8	9.7	10.1	9.8
Mar	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Apr	7.2	8.3	8.4	8.4	8.3	8.4	8.4	8.3
May	5.5	6.6	6.7	6.6	6.6	6.6	6.7	6.6
Jun	4.4	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Jul	5.0	5.4	5.6	5.6	5.6	5.6	5.5	5.5
Aug	6.4	6.8	7.0	7.0	7.0	6.9	6.9	6.8
Sep	8.4	9.0	9.1	9.1	9.1	9.1	9.3	9.0
Oct	8.7	9.5	9.6	9.6	9.6	9.7	9.6	9.5
Nov	9.2	9.4	9.5	9.5	9.6	9.5	9.5	9.4
Dec	10.0	9.9	9.9	10.0	10.0	9.9	10.0	9.8
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.0 (0.8)	0.1 (1.0)	0.0 (0.7)	0.1 (0.9)	0.1 (1.0)	-0.1 (-0.3)
Feb	---	---	-0.1 (-0.9)	-0.1 (-0.9)	0.0 (-0.6)	-0.1 (-0.8)	0.3 (2.4)	0.0 (0.1)
Mar	---	---	0.0 (0.0)	0.0 (-0.3)	0.0 (0.1)	0.0 (-0.4)	0.0 (-0.1)	0.0 (-0.1)
Apr	---	---	0.1 (0.5)	0.1 (0.6)	0.0 (0.2)	0.1 (0.7)	0.1 (0.7)	0.0 (-0.4)
May	---	---	0.1 (2.4)	0.0 (0.9)	0.0 (0.4)	0.0 (0.0)	0.1 (2.4)	0.0 (0.1)
Jun	---	---	0.0 (0.6)	0.0 (0.6)	0.0 (-0.1)	0.0 (0.4)	0.0 (0.4)	0.0 (0.4)
Jul	---	---	0.2 (2.5)	0.2 (2.1)	0.2 (2.8)	0.2 (2.7)	0.1 (0.7)	0.1 (1.6)
Aug	---	---	0.2 (2.2)	0.2 (2.0)	0.2 (2.6)	0.1 (1.5)	0.1 (1.0)	0.0 (0.0)
Sep	---	---	0.1 (1.8)	0.1 (1.8)	0.1 (1.1)	0.1 (1.5)	0.3 (3.7)	0.0 (0.6)
Oct	---	---	0.1 (1.1)	0.1 (1.1)	0.1 (1.1)	0.2 (1.3)	0.1 (0.3)	0.0 (-0.4)
Nov	---	---	0.1 (0.7)	0.1 (0.7)	0.2 (1.3)	0.1 (0.7)	0.1 (0.3)	0.0 (-0.7)
Dec	---	---	0.0 (0.8)	0.1 (0.9)	0.1 (1.1)	0.0 (0.8)	0.1 (1.0)	-0.1 (-0.4)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	0.1 (1.0)	0.1 (1.8)	0.2 (2.1)	0.1 (1.7)	0.2 (2.0)	0.2 (2.0)	0.0 (0.7)
Feb	---	-1.1 (-9.7)	-1.2 (-10.5)	-1.2 (-10.5)	-1.1 (-10.3)	-1.2 (-10.4)	-0.8 (-7.6)	-1.1 (-9.6)
Mar	---	0.0 (0.8)	0.0 (0.8)	0.0 (0.4)	0.0 (0.9)	0.0 (0.4)	0.0 (0.7)	0.0 (0.7)
Apr	---	1.1 (15.2)	1.2 (15.9)	1.2 (15.9)	1.1 (15.5)	1.2 (16.1)	1.2 (16.0)	1.1 (14.8)
May	---	1.1 (20.2)	1.2 (23.0)	1.1 (21.2)	1.1 (20.7)	1.1 (20.2)	1.2 (23.1)	1.1 (20.3)
Jun	---	0.9 (20.3)	0.9 (20.9)	0.9 (21.0)	0.9 (20.2)	0.9 (20.8)	0.9 (20.8)	0.9 (20.7)
Jul	---	0.4 (8.4)	0.6 (11.2)	0.6 (10.7)	0.6 (11.5)	0.6 (11.4)	0.5 (9.2)	0.5 (10.2)
Aug	---	0.4 (7.3)	0.6 (9.6)	0.6 (9.4)	0.6 (10.0)	0.5 (8.8)	0.5 (8.3)	0.4 (7.2)
Sep	---	0.6 (6.6)	0.7 (8.5)	0.7 (8.5)	0.7 (7.8)	0.7 (8.2)	0.9 (10.5)	0.6 (7.2)
Oct	---	0.8 (9.7)	0.9 (11.0)	0.9 (11.0)	0.9 (11.0)	1.0 (11.2)	0.9 (10.1)	0.8 (9.3)
Nov	---	0.2 (2.2)	0.3 (2.9)	0.3 (2.9)	0.4 (3.5)	0.3 (2.9)	0.3 (2.5)	0.2 (1.5)
Dec	---	-0.1 (-1.6)	-0.1 (-0.8)	0.0 (-0.7)	0.0 (-0.5)	-0.1 (-0.8)	0.0 (-0.6)	-0.2 (-2.0)

All alternatives would have predominately negligible effects to sulfate and uranium concentrations at the Arkansas River at Las Animas gage (Table 101 to Table 104). Compared to existing conditions, sulfate concentrations would decrease. Uranium concentration for the alternatives would decrease in some months, compared to existing conditions.

Table 101. Cumulative Effects Simulated Sulfate Concentrations for Arkansas River at Las Animas Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	972	920	919	918	918	920	919	918
15th percentile	454	464	450	451	460	451	460	459
25th percentile	649	630	628	627	632	628	637	632
50th percentile	1,016	975	961	958	969	958	972	971
75th percentile	1,198	1,126	1,123	1,123	1,125	1,123	1,126	1,122
85th percentile	1,380	1,271	1,272	1,272	1,271	1,278	1,263	1,264
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	-1 (-0.1)	-2 (-0.2)	-2 (-0.2)	0 (-0.1)	-1 (-0.2)	-2 (-0.2)
15th percentile	---	---	-13 (-2.9)	-13 (-2.8)	-4 (-0.9)	-13 (-2.9)	-4 (-0.8)	-5 (-1.1)
25th percentile	---	---	-2 (-0.3)	-3 (-0.4)	2 (0.3)	-2 (-0.4)	7 (1.2)	3 (0.4)
50th percentile	---	---	-14 (-1.5)	-17 (-1.7)	-6 (-0.6)	-17 (-1.7)	-4 (-0.4)	-4 (-0.4)
75th percentile	---	---	-3 (-0.3)	-3 (-0.3)	-1 (-0.1)	-3 (-0.3)	0 (0.0)	-5 (-0.4)
85th percentile	---	---	1 (0.0)	1 (0.0)	0 (0.0)	7 (0.6)	-8 (-0.7)	-7 (-0.5)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	-52 (-5.3)	-52 (-5.4)	-53 (-5.5)	-54 (-5.5)	-52 (-5.4)	-53 (-5.4)	-53 (-5.5)
15th percentile	---	10 (2.2)	-4 (-0.8)	-3 (-0.7)	6 (1.3)	-3 (-0.8)	6 (1.4)	5 (1.1)
25th percentile	---	-20 (-3.0)	-22 (-3.4)	-22 (-3.4)	-18 (-2.7)	-22 (-3.4)	-12 (-1.9)	-17 (-2.6)
50th percentile	---	-41 (-4.0)	-55 (-5.4)	-57 (-5.7)	-47 (-4.6)	-58 (-5.7)	-44 (-4.4)	-45 (-4.4)
75th percentile	---	-72 (-6.0)	-75 (-6.2)	-75 (-6.3)	-73 (-6.1)	-74 (-6.2)	-72 (-6.0)	-76 (-6.4)
85th percentile	---	-109 (-7.9)	-109 (-7.9)	-109 (-7.9)	-109 (-7.9)	-102 (-7.4)	-118 (-8.5)	-116 (-8.4)

Table 102. Monthly Simulated Sulfate Concentration for Arkansas River at Las Animas Gage - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	1,046	1,041	1,049	1,048	1,048	1,048	1,048	1,040
Feb	1,002	905	872	871	875	874	927	905
Mar	1,170	1,021	1,010	1,014	1,030	1,013	1,008	1,008
Apr	1,311	1,178	1,185	1,175	1,175	1,179	1,160	1,162
May	775	704	710	707	713	709	704	702
Jun	561	514	509	509	512	508	511	516
Jul	695	687	687	688	678	695	671	697
Aug	783	746	750	749	750	749	750	748
Sep	1,090	1,053	1,046	1,047	1,047	1,046	1,035	1,050
Oct	1,111	1,105	1,116	1,115	1,100	1,116	1,111	1,109
Nov	1,066	1,060	1,066	1,066	1,051	1,065	1,064	1,057
Dec	1,076	1,062	1,068	1,068	1,069	1,068	1,069	1,062
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	8 (0.8)	7 (0.7)	7 (0.7)	7 (0.8)	7 (0.7)	-1 (-0.1)
Feb	---	---	-33 (-3.7)	-34 (-3.7)	-30 (-3.2)	-31 (-3.4)	22 (2.5)	0 (0.0)
Mar	---	---	-11 (-1.1)	-7 (-0.7)	9 (0.9)	-8 (-0.8)	-13 (-1.3)	-13 (-1.3)
Apr	---	---	7 (0.6)	-3 (-0.3)	-3 (-0.2)	1 (0.1)	-18 (-1.6)	-16 (-1.4)
May	---	---	6 (0.9)	3 (0.4)	9 (1.3)	5 (0.8)	0 (0.0)	-2 (-0.3)
Jun	---	---	-5 (-1.0)	-5 (-1.1)	-2 (-0.5)	-6 (-1.2)	-3 (-0.6)	2 (0.4)
Jul	---	---	0 (0.0)	1 (0.2)	-9 (-1.3)	8 (1.2)	-16 (-2.3)	10 (1.4)
Aug	---	---	4 (0.5)	3 (0.4)	4 (0.5)	3 (0.3)	4 (0.5)	2 (0.2)
Sep	---	---	-7 (-0.6)	-6 (-0.6)	-6 (-0.6)	-7 (-0.6)	-18 (-1.7)	-3 (-0.3)
Oct	---	---	11 (0.9)	10 (0.9)	-5 (-0.5)	11 (1.0)	6 (0.5)	4 (0.3)
Nov	---	---	6 (0.7)	6 (0.6)	-9 (-0.8)	5 (0.6)	4 (0.4)	-3 (-0.3)
Dec	---	---	6 (0.5)	6 (0.5)	7 (0.6)	6 (0.5)	7 (0.7)	0 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-5 (-0.5)	3 (0.3)	2 (0.1)	2 (0.2)	2 (0.2)	2 (0.2)	-6 (-0.6)
Feb	---	-97 (-9.7)	-130 (-13.0)	-131 (-13.0)	-127 (-12.6)	-128 (-12.8)	-75 (-7.5)	-97 (-9.6)
Mar	---	-149 (-12.8)	-160 (-13.7)	-156 (-13.4)	-140 (-12.0)	-157 (-13.4)	-162 (-13.9)	-162 (-13.9)
Apr	---	-133 (-10.2)	-126 (-9.7)	-136 (-10.4)	-136 (-10.4)	-132 (-10.1)	-151 (-11.6)	-149 (-11.4)
May	---	-71 (-9.1)	-65 (-8.3)	-68 (-8.8)	-62 (-7.9)	-66 (-8.4)	-71 (-9.1)	-73 (-9.4)
Jun	---	-47 (-8.4)	-52 (-9.3)	-52 (-9.4)	-49 (-8.8)	-53 (-9.5)	-50 (-8.9)	-45 (-8.0)
Jul	---	-8 (-1.1)	-8 (-1.2)	-7 (-0.9)	-17 (-2.4)	0 (0.0)	-24 (-3.4)	2 (0.3)
Aug	---	-37 (-4.7)	-33 (-4.2)	-34 (-4.3)	-33 (-4.1)	-34 (-4.4)	-33 (-4.2)	-35 (-4.5)
Sep	---	-37 (-3.4)	-44 (-4.0)	-43 (-4.0)	-43 (-4.0)	-44 (-4.0)	-55 (-5.0)	-40 (-3.7)
Oct	---	-6 (-0.5)	5 (0.5)	4 (0.4)	-11 (-0.9)	5 (0.5)	0 (0.0)	-2 (-0.1)
Nov	---	-6 (-0.6)	0 (0.0)	0 (0.0)	-15 (-1.4)	-1 (-0.1)	-2 (-0.2)	-9 (-0.9)
Dec	---	-14 (-1.3)	-8 (-0.8)	-8 (-0.8)	-7 (-0.7)	-8 (-0.8)	-7 (-0.6)	-14 (-1.3)

Table 103. Cumulative Effects Simulated Uranium Concentrations for Arkansas River at Las Animas Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	14.6	13.8	13.8	13.8	13.8	13.8	13.8	13.8
15th percentile	6.6	6.7	6.5	6.5	6.6	6.5	6.7	6.6
25th percentile	9.6	9.3	9.3	9.3	9.3	9.3	9.4	9.3
50th percentile	15.3	14.7	14.5	14.4	14.6	14.4	14.6	14.6
75th percentile	18.2	17.1	17.0	17.0	17.0	17.0	17.1	17.0
85th percentile	21.0	19.3	19.3	19.3	19.3	19.4	19.2	19.2
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0 (-0.1)	0 (-0.2)	0 (-0.2)	0 (-0.1)	0 (-0.2)	0 (-0.2)
15th percentile	---	---	-0.2 (-3.1)	-0.2 (-3.0)	-0.1 (-0.9)	-0.2 (-3.1)	-0.1 (-0.9)	-0.1 (-1.2)
25th percentile	---	---	0 (-0.4)	0 (-0.4)	0 (0.3)	0 (-0.4)	0.1 (1.2)	0 (0.4)
50th percentile	---	---	-0.2 (-1.5)	-0.3 (-1.8)	-0.1 (-0.6)	-0.3 (-1.8)	-0.1 (-0.4)	-0.1 (-0.4)
75th percentile	---	---	0 (-0.3)	-0.1 (-0.3)	0 (-0.1)	0 (-0.3)	0 (0.0)	-0.1 (-0.4)
85th percentile	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0.1 (0.6)	-0.1 (-0.7)	-0.1 (-0.6)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	-0.8 (-5.5)	-0.8 (-5.6)	-0.8 (-5.7)	-0.8 (-5.7)	-0.8 (-5.5)	-0.8 (-5.7)	-0.8 (-5.7)
15th percentile	---	0.2 (2.4)	-0.1 (-0.8)	0 (-0.7)	0.1 (1.4)	-0.1 (-0.8)	0.1 (1.5)	0.1 (1.2)
25th percentile	---	-0.3 (-3.2)	-0.3 (-3.6)	-0.3 (-3.6)	-0.3 (-2.9)	-0.3 (-3.6)	-0.2 (-2.0)	-0.3 (-2.8)
50th percentile	---	-0.6 (-4.1)	-0.9 (-5.6)	-0.9 (-5.9)	-0.7 (-4.7)	-0.9 (-5.9)	-0.7 (-4.5)	-0.7 (-4.6)
75th percentile	---	-1.1 (-6.2)	-1.2 (-6.4)	-1.2 (-6.4)	-1.1 (-6.3)	-1.2 (-6.4)	-1.1 (-6.1)	-1.2 (-6.6)
85th percentile	---	-1.7 (-8.1)	-1.7 (-8.1)	-1.7 (-8.1)	-1.7 (-8.1)	-1.6 (-7.6)	-1.8 (-8.7)	-1.8 (-8.6)

Table 104. Monthly Simulated Uranium Concentration for Arkansas River at Las Animas - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	20.2	20.1	20.2	20.2	20.2	20.2	20.2	20.1
Feb	19.5	18.0	17.5	17.5	17.5	17.5	18.3	18.0
Mar	22.1	19.8	19.6	19.7	19.9	19.7	19.6	19.6
Apr	24.4	22.3	22.4	22.2	22.2	22.3	22.0	22.0
May	16.0	14.9	15.0	14.9	15.0	14.9	14.9	14.8
Jun	12.6	11.9	11.8	11.8	11.9	11.8	11.8	11.9
Jul	14.7	14.6	14.6	14.6	14.5	14.7	14.3	14.7
Aug	16.1	15.5	15.6	15.6	15.6	15.6	15.6	15.5
Sep	20.9	20.3	20.2	20.2	20.2	20.2	20.0	20.3
Oct	21.2	21.1	21.3	21.3	21.1	21.3	21.2	21.2
Nov	20.5	20.4	20.5	20.5	20.3	20.5	20.5	20.4
Dec	20.7	20.5	20.5	20.5	20.6	20.5	20.6	20.5
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.1 (0.6)	0.1 (0.5)	0.1 (0.6)	0.1 (0.6)	0.1 (0.6)	0.0 (-0.1)
Feb	---	---	-0.5 (-2.9)	-0.5 (-2.9)	-0.5 (-2.5)	-0.5 (-2.7)	0.3 (1.9)	0.0 (0.0)
Mar	---	---	-0.2 (-0.9)	-0.1 (-0.6)	0.1 (0.7)	-0.1 (-0.6)	-0.2 (-1.0)	-0.2 (-1.0)
Apr	---	---	0.1 (0.5)	-0.1 (-0.2)	-0.1 (-0.2)	0.0 (0.1)	-0.3 (-1.3)	-0.3 (-1.1)
May	---	---	0.1 (0.7)	0.0 (0.3)	0.1 (1.0)	0.0 (0.6)	0.0 (0.0)	-0.1 (-0.2)
Jun	---	---	-0.1 (-0.6)	-0.1 (-0.7)	0.0 (-0.3)	-0.1 (-0.8)	-0.1 (-0.4)	0.0 (0.3)
Jul	---	---	0.0 (0.0)	0.0 (0.1)	-0.1 (-1.0)	0.1 (0.9)	-0.3 (-1.7)	0.1 (1.1)
Aug	---	---	0.1 (0.3)	0.1 (0.3)	0.1 (0.4)	0.1 (0.2)	0.1 (0.4)	0.0 (0.1)
Sep	---	---	-0.1 (-0.5)	-0.1 (-0.5)	-0.1 (-0.5)	-0.1 (-0.5)	-0.3 (-1.4)	0.0 (-0.2)
Oct	---	---	0.2 (0.8)	0.2 (0.7)	0.0 (-0.4)	0.2 (0.8)	0.1 (0.4)	0.1 (0.3)
Nov	---	---	0.1 (0.5)	0.1 (0.5)	-0.1 (-0.7)	0.1 (0.5)	0.1 (0.4)	0.0 (-0.2)
Dec	---	---	0.0 (0.4)	0.0 (0.4)	0.1 (0.5)	0.0 (0.4)	0.1 (0.5)	0.0 (0.0)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.1 (-0.4)	0.0 (0.2)	0.0 (0.1)	0.0 (0.1)	0.0 (0.2)	0.0 (0.2)	-0.1 (-0.5)
Feb	---	-1.5 (-7.8)	-2.0 (-10.4)	-2.0 (-10.5)	-2.0 (-10.1)	-2.0 (-10.3)	-1.2 (-6.0)	-1.5 (-7.7)
Mar	---	-2.3 (-10.5)	-2.5 (-11.3)	-2.4 (-11.0)	-2.2 (-9.9)	-2.4 (-11.1)	-2.5 (-11.5)	-2.5 (-11.5)
Apr	---	-2.1 (-8.6)	-2.0 (-8.1)	-2.2 (-8.8)	-2.2 (-8.7)	-2.1 (-8.5)	-2.4 (-9.7)	-2.4 (-9.6)
May	---	-1.1 (-6.9)	-1.0 (-6.3)	-1.1 (-6.6)	-1.0 (-6.0)	-1.1 (-6.4)	-1.1 (-6.9)	-1.2 (-7.1)
Jun	---	-0.7 (-5.8)	-0.8 (-6.4)	-0.8 (-6.5)	-0.7 (-6.1)	-0.8 (-6.6)	-0.8 (-6.2)	-0.7 (-5.6)
Jul	---	-0.1 (-0.8)	-0.1 (-0.9)	-0.1 (-0.7)	-0.2 (-1.8)	0.0 (0.0)	-0.4 (-2.5)	0.0 (0.2)
Aug	---	-0.6 (-3.5)	-0.5 (-3.2)	-0.5 (-3.2)	-0.5 (-3.1)	-0.5 (-3.3)	-0.5 (-3.2)	-0.6 (-3.4)
Sep	---	-0.6 (-2.8)	-0.7 (-3.3)	-0.7 (-3.2)	-0.7 (-3.2)	-0.7 (-3.3)	-0.9 (-4.1)	-0.6 (-3.0)
Oct	---	-0.1 (-0.4)	0.1 (0.4)	0.1 (0.3)	-0.1 (-0.8)	0.1 (0.4)	0.0 (0.0)	0.0 (-0.1)
Nov	---	-0.1 (-0.5)	0.0 (0.0)	0.0 (0.0)	-0.2 (-1.2)	0.0 (0.0)	0.0 (-0.1)	-0.1 (-0.7)
Dec	---	-0.2 (-1.0)	-0.2 (-0.6)	-0.2 (-0.6)	-0.1 (-0.5)	-0.2 (-0.6)	-0.1 (-0.5)	-0.2 (-1.1)

All alternatives would have predominately negligible cumulative effects to sulfate concentrations at the Fountain Creek near Fountain gage, though minor beneficial decrease also would occur (Table 105 to Table 106). Sulfate concentrations would increase and decrease for all alternatives compared to existing conditions, depending on the time of year. Uranium effects were not assessed at this gage because data was not available to develop a relationship to salinity concentrations.

Table 105. Cumulative Effects Simulated Sulfate Concentrations for Fountain Creek near Fountain Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	227	233	233	232	233	231	233	233
15th percentile	156	184	181	181	182	180	182	184
25th percentile	186	200	200	199	199	199	200	200
50th percentile	235	223	224	223	223	223	224	223
75th percentile	270	247	247	247	247	247	249	248
85th percentile	285	264	264	263	264	263	265	264
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	0 (0.2)	-1 (-0.3)	0 (-0.1)	-1 (-0.5)	0 (-0.1)	0 (0.1)
15th percentile	---	---	-3 (-1.8)	-3 (-1.8)	-2 (-1.2)	-4 (-1.9)	-2 (-1.2)	0 (0.0)
25th percentile	---	---	0 (0.1)	-1 (-0.3)	0 (-0.1)	-1 (-0.3)	1 (0.3)	1 (0.4)
50th percentile	---	---	1 (0.3)	0 (0.2)	0 (0.1)	1 (0.2)	1 (0.3)	1 (0.3)
75th percentile	---	---	1 (0.3)	0 (0.1)	0 (0.0)	0 (0.2)	2 (0.9)	1 (0.4)
85th percentile	---	---	0 (0.0)	-1 (-0.4)	0 (0.0)	-1 (-0.3)	1 (0.5)	0 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	5 (2.3)	6 (2.5)	5 (2.0)	5 (2.2)	4 (1.8)	5 (2.2)	5 (2.4)
15th percentile	---	28 (17.6)	24 (15.5)	24 (15.5)	25 (16.2)	24 (15.3)	25 (16.2)	28 (17.7)
25th percentile	---	14 (7.4)	14 (7.4)	13 (7.0)	13 (7.2)	13 (7.0)	14 (7.7)	14 (7.8)
50th percentile	---	-13 (-5.4)	-12 (-5.1)	-12 (-5.2)	-12 (-5.3)	-12 (-5.2)	-12 (-5.1)	-12 (-5.1)
75th percentile	---	-23 (-8.6)	-23 (-8.4)	-23 (-8.5)	-23 (-8.6)	-23 (-8.4)	-21 (-7.8)	-22 (-8.3)
85th percentile	---	-21 (-7.4)	-21 (-7.4)	-22 (-7.7)	-21 (-7.4)	-22 (-7.7)	-20 (-7.0)	-21 (-7.4)

Table 106. Monthly Simulated Sulfate Concentration for Fountain Creek near Fountain Gage - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	245	234	234	234	234	234	233	233
Feb	242	224	226	226	225	226	224	224
Mar	233	232	230	229	230	229	230	231
Apr	203	223	223	223	223	228	224	228
May	191	250	246	233	246	234	245	243
Jun	201	263	263	263	261	262	265	264
Jul	196	220	222	222	218	222	217	222
Aug	208	208	218	218	219	208	210	209
Sep	232	233	234	234	233	233	237	235
Oct	269	231	228	228	229	227	232	231
Nov	256	231	231	230	231	231	231	231
Dec	262	238	238	238	238	238	238	238
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	0 (0.2)	0 (0.1)	0 (0.1)	0 (0.0)	-1 (-0.3)	-1 (-0.3)
Feb	---	---	2 (0.9)	2 (0.9)	1 (0.5)	2 (0.9)	0 (0.2)	0 (0.3)
Mar	---	---	-2 (-0.8)	-3 (-1.2)	-2 (-0.8)	-3 (-1.1)	-2 (-0.6)	-1 (-0.5)
Apr	---	---	0 (0.0)	0 (0.2)	0 (-0.1)	5 (2.5)	1 (0.4)	5 (2.3)
May	---	---	-4 (-1.5)	-17 (-6.7)	-4 (-1.5)	-16 (-6.6)	-5 (-2.2)	-7 (-2.7)
Jun	---	---	0 (0.1)	0 (0.1)	-2 (-0.7)	-1 (-0.3)	2 (0.7)	1 (0.6)
Jul	---	---	2 (1.0)	2 (1.1)	-2 (-0.9)	2 (1.1)	-3 (-1.6)	2 (0.7)
Aug	---	---	10 (4.7)	10 (4.7)	11 (5.0)	0 (0.0)	2 (0.6)	1 (0.6)
Sep	---	---	1 (0.2)	1 (0.2)	0 (-0.2)	0 (0.0)	4 (1.6)	2 (0.9)
Oct	---	---	-3 (-1.5)	-3 (-1.5)	-2 (-1.0)	-4 (-1.9)	1 (0.4)	0 (-0.3)
Nov	---	---	0 (-0.1)	-1 (-0.2)	0 (-0.1)	0 (0.1)	0 (0.2)	0 (0.1)
Dec	---	---	0 (0.0)	0 (0.0)	0 (-0.1)	0 (0.0)	0 (-0.1)	0 (0.0)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-11 (-4.6)	-11 (-4.4)	-11 (-4.5)	-11 (-4.5)	-11 (-4.6)	-12 (-4.8)	-12 (-4.9)
Feb	---	-18 (-7.4)	-16 (-6.5)	-16 (-6.6)	-17 (-7.0)	-16 (-6.6)	-18 (-7.2)	-18 (-7.2)
Mar	---	-1 (-0.6)	-3 (-1.4)	-4 (-1.8)	-3 (-1.4)	-4 (-1.6)	-3 (-1.2)	-2 (-1.0)
Apr	---	20 (9.9)	20 (9.9)	20 (10.0)	20 (9.8)	25 (12.6)	21 (10.3)	25 (12.3)
May	---	59 (30.9)	55 (28.9)	42 (22.2)	55 (28.9)	43 (22.3)	54 (28.1)	52 (27.4)
Jun	---	62 (31.0)	62 (31.1)	62 (31.1)	60 (30.1)	61 (30.6)	64 (31.9)	63 (31.8)
Jul	---	24 (12.2)	26 (13.4)	26 (13.4)	22 (11.2)	26 (13.4)	21 (10.4)	26 (13.0)
Aug	---	0 (-0.1)	10 (4.6)	10 (4.6)	11 (4.9)	0 (-0.1)	2 (0.5)	1 (0.5)
Sep	---	1 (0.5)	2 (0.7)	2 (0.7)	1 (0.4)	1 (0.5)	5 (2.1)	3 (1.4)
Oct	---	-38 (-14.0)	-41 (-15.3)	-41 (-15.3)	-40 (-14.8)	-42 (-15.6)	-37 (-13.6)	-38 (-14.2)
Nov	---	-25 (-10.0)	-25 (-10.1)	-26 (-10.1)	-25 (-10.1)	-25 (-9.8)	-25 (-9.7)	-25 (-9.9)
Dec	---	-24 (-9.1)	-24 (-9.2)	-24 (-9.2)	-24 (-9.2)	-24 (-9.2)	-24 (-9.2)	-24 (-9.1)

All alternatives would have predominately negligible effects to sulfate concentrations at the Fountain Creek at Pueblo gage, though occasional minor increases would occur (Table 107 to Table 108). Sulfate concentrations would increase and decrease for all alternatives compared to existing conditions, depending on the time of year.

Uranium effects would be predominately negligible, compared to the No Action Alternative, though moderate cumulative increases would occur in the Comanche South, Pueblo Dam South, and JUP North alternatives (Table 109 and Table 110).

Table 107. Cumulative Effects Simulated Sulfate Concentrations for Fountain Creek at Pueblo Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Mean	264	236	237	235	236	234	236	236
15th percentile	131	124	124	122	124	124	126	126
25th percentile	176	159	159	159	159	159	160	161
50th percentile	270	223	225	225	221	225	225	225
75th percentile	358	279	280	278	279	278	282	279
85th percentile	394	314	317	315	317	314	311	315
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Mean	---	---	1 (0.5)	-1 (-0.5)	0 (0.0)	-2 (-0.9)	-1 (-0.3)	0 (0.0)
15th percentile	---	---	0 (0.1)	-1 (-1.2)	0 (-0.2)	0 (-0.2)	3 (2.1)	3 (2.1)
25th percentile	---	---	0 (-0.2)	-1 (-0.4)	0 (0.0)	-1 (-0.5)	1 (0.3)	2 (1.1)
50th percentile	---	---	2 (1.0)	2 (0.8)	-2 (-1.1)	2 (0.9)	2 (0.9)	2 (0.7)
75th percentile	---	---	1 (0.4)	-1 (-0.2)	0 (0.1)	-1 (-0.2)	3 (1.2)	0 (-0.1)
85th percentile	---	---	3 (1.0)	1 (0.4)	4 (1.1)	0 (0.1)	-3 (-0.8)	1 (0.4)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Mean	---	-27 (-10.4)	-26 (-10.0)	-29 (-10.8)	-28 (-10.4)	-30 (-11.2)	-28 (-10.7)	-28 (-10.4)
15th percentile	---	-7 (-5.2)	-7 (-5.1)	-8 (-6.3)	-7 (-5.4)	-7 (-5.4)	-4 (-3.2)	-4 (-3.2)
25th percentile	---	-16 (-9.3)	-17 (-9.5)	-17 (-9.6)	-16 (-9.3)	-17 (-9.7)	-16 (-9.0)	-15 (-8.3)
50th percentile	---	-47 (-17.4)	-45 (-16.6)	-45 (-16.8)	-49 (-18.3)	-45 (-16.7)	-45 (-16.7)	-45 (-16.8)
75th percentile	---	-79 (-22.0)	-78 (-21.7)	-80 (-22.2)	-79 (-22.0)	-79 (-22.2)	-76 (-21.1)	-79 (-22.1)
85th percentile	---	-80 (-20.4)	-77 (-19.6)	-79 (-20.1)	-77 (-19.5)	-80 (-20.3)	-83 (-21.0)	-79 (-20.0)

Table 108. Monthly Simulated Sulfate Concentration for Fountain Creek at Pueblo Gage - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (mg/L)								
Jan	294	246	247	247	247	246	243	244
Feb	302	235	236	236	237	236	235	234
Mar	273	234	230	229	231	230	232	233
Apr	242	220	218	219	218	227	221	227
May	190	239	232	209	232	210	230	228
Jun	205	265	266	265	263	264	268	268
Jul	197	203	208	208	200	208	197	207
Aug	220	189	207	207	207	190	191	191
Sep	229	216	220	220	217	219	224	220
Oct	361	254	253	252	252	251	257	255
Nov	319	251	253	252	252	253	251	251
Dec	345	272	270	270	273	270	271	271
Change in Concentration Compared to No Action Alternative [mg/L (%)]								
Jan	---	---	1 (0.2)	1 (0.1)	1 (0.3)	0 (-0.2)	-3 (-1.1)	-2 (-1.0)
Feb	---	---	1 (0.5)	1 (0.6)	2 (0.7)	1 (0.5)	0 (-0.1)	-1 (-0.5)
Mar	---	---	-4 (-1.7)	-5 (-2.2)	-3 (-1.7)	-4 (-2.0)	-2 (-1.2)	-1 (-0.8)
Apr	---	---	-2 (-1.0)	-1 (-0.8)	-2 (-1.0)	7 (3.2)	1 (0.2)	7 (2.9)
May	---	---	-7 (-2.8)	-30 (-12.4)	-7 (-2.8)	-29 (-12.3)	-9 (-3.9)	-11 (-4.8)
Jun	---	---	1 (0.3)	0 (0.1)	-2 (-0.8)	-1 (-0.4)	3 (1.0)	3 (1.1)
Jul	---	---	5 (2.6)	5 (2.6)	-3 (-1.4)	5 (2.4)	-6 (-3.0)	4 (2.1)
Aug	---	---	18 (9.4)	18 (9.2)	18 (9.6)	1 (0.4)	2 (0.9)	2 (0.9)
Sep	---	---	4 (1.7)	4 (1.6)	1 (0.3)	3 (1.3)	8 (3.7)	4 (1.8)
Oct	---	---	-1 (-0.5)	-2 (-0.7)	-2 (-0.8)	-3 (-1.2)	3 (0.9)	1 (0.2)
Nov	---	---	2 (0.7)	1 (0.7)	1 (0.4)	2 (1.0)	0 (0.2)	0 (0.3)
Dec	---	---	-2 (-0.6)	-2 (-0.6)	1 (0.3)	-2 (-0.6)	-1 (-0.3)	-1 (-0.4)
Change in Concentration Compared to Existing Conditions [mg/L (%)]								
Jan	---	-48 (-16.3)	-47 (-16.1)	-47 (-16.2)	-47 (-16.0)	-48 (-16.4)	-51 (-17.2)	-50 (-17.1)
Feb	---	-67 (-22.3)	-66 (-21.9)	-66 (-21.8)	-65 (-21.7)	-66 (-21.9)	-67 (-22.4)	-68 (-22.6)
Mar	---	-39 (-14.2)	-43 (-15.7)	-44 (-16.1)	-42 (-15.6)	-43 (-15.9)	-41 (-15.2)	-40 (-14.9)
Apr	---	-22 (-8.9)	-24 (-9.8)	-23 (-9.6)	-24 (-9.8)	-15 (-6.0)	-21 (-8.7)	-15 (-6.2)
May	---	49 (25.7)	42 (22.2)	19 (10.1)	42 (22.2)	20 (10.3)	40 (20.9)	38 (19.7)
Jun	---	60 (29.4)	61 (29.8)	60 (29.6)	58 (28.4)	59 (28.9)	63 (30.6)	63 (30.8)
Jul	---	6 (3.3)	11 (6.0)	11 (6.0)	3 (1.8)	11 (5.7)	0 (0.2)	10 (5.4)
Aug	---	-31 (-13.9)	-13 (-5.8)	-13 (-6.0)	-13 (-5.7)	-30 (-13.6)	-29 (-13.1)	-29 (-13.1)
Sep	---	-13 (-5.3)	-9 (-3.7)	-9 (-3.8)	-12 (-5.0)	-10 (-4.1)	-5 (-1.8)	-9 (-3.6)
Oct	---	-107 (-29.6)	-108 (-30.0)	-109 (-30.1)	-109 (-30.2)	-110 (-30.5)	-104 (-29.0)	-106 (-29.5)
Nov	---	-68 (-21.3)	-66 (-20.7)	-67 (-20.8)	-67 (-21.0)	-66 (-20.5)	-68 (-21.1)	-68 (-21.1)
Dec	---	-73 (-21.2)	-75 (-21.7)	-75 (-21.7)	-72 (-20.9)	-75 (-21.7)	-74 (-21.4)	-74 (-21.5)

Table 109. Cumulative Effects Simulated Uranium Concentrations for Fountain Creek at Pueblo Gage

Statistic	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Mean	2.4	2.0	2.0	2.0	2.0	2.0	2.0	2.0
15th percentile	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.6
25th percentile	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
50th percentile	2.5	1.8	1.9	1.9	1.8	1.9	1.9	1.9
75th percentile	3.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
85th percentile	4.1	3.0	3.1	3.1	3.1	3.0	3.0	3.1
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Mean	---	---	0 (0.7)	0 (-0.7)	0 (0.0)	0 (-1.3)	0 (-0.5)	0 (0.0)
15th percentile	---	---	0 (0.2)	0 (-3.7)	0 (-0.7)	0 (-0.7)	0 (6.4)	0 (6.4)
25th percentile	---	---	0 (-0.3)	0 (-0.8)	0 (0.0)	0 (-1.0)	0 (0.7)	0 (2.3)
50th percentile	---	---	0 (1.5)	0 (1.2)	0 (-1.7)	0 (1.5)	0 (1.4)	0 (1.1)
75th percentile	---	---	0 (0.5)	0 (-0.3)	0 (0.1)	0 (-0.3)	0 (1.6)	0 (-0.1)
85th percentile	---	---	0 (1.4)	0 (0.5)	0 (1.6)	0 (0.1)	0 (-1.1)	0 (0.6)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Mean	---	-0.4 (-15.2)	-0.3 (-14.6)	-0.4 (-15.9)	-0.4 (-15.3)	-0.4 (-16.4)	-0.4 (-15.7)	-0.4 (-15.3)
15th percentile	---	-0.1 (-14.3)	-0.1 (-14.2)	-0.1 (-17.5)	-0.1 (-14.9)	-0.1 (-14.9)	-0.1 (-8.8)	-0.1 (-8.8)
25th percentile	---	-0.2 (-17.7)	-0.2 (-18.0)	-0.2 (-18.3)	-0.2 (-17.8)	-0.2 (-18.5)	-0.2 (-17.2)	-0.2 (-15.8)
50th percentile	---	-0.6 (-25.2)	-0.6 (-24.0)	-0.6 (-24.3)	-0.7 (-26.5)	-0.6 (-24.1)	-0.6 (-24.2)	-0.6 (-24.4)
75th percentile	---	-1 (-28.7)	-1 (-28.4)	-1 (-29.0)	-1 (-28.7)	-1 (-29.0)	-1 (-27.6)	-1 (-28.8)
85th percentile	---	-1.1 (-25.9)	-1 (-24.8)	-1 (-25.5)	-1 (-24.7)	-1.1 (-25.8)	-1.1 (-26.7)	-1 (-25.4)

Table 110. Monthly Simulated Uranium Concentration for Fountain Creek at Pueblo - Cumulative Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Concentration (µg/L)								
Jan	2.8	2.1	2.2	2.2	2.2	2.1	2.1	2.1
Feb	2.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Mar	2.5	2.0	1.9	1.9	1.9	1.9	2.0	2.0
Apr	2.1	1.8	1.8	1.8	1.8	1.9	1.8	1.9
May	1.4	2.1	2.0	1.7	2.0	1.7	1.9	1.9
Jun	1.6	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Jul	1.5	1.6	1.7	1.7	1.5	1.6	1.5	1.6
Aug	1.8	1.4	1.6	1.6	1.6	1.4	1.4	1.4
Sep	1.9	1.8	1.8	1.8	1.8	1.8	1.9	1.8
Oct	3.7	2.3	2.2	2.2	2.2	2.2	2.3	2.3
Nov	3.1	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Dec	3.4	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Change in Concentration Compared to No Action Alternative [µg/L (%)]								
Jan	---	---	0.1 (0.3)	0.1 (0.2)	0.1 (0.5)	0.0 (-0.3)	0.0 (-1.7)	0.0 (-1.4)
Feb	---	---	0.0 (0.7)	0.0 (0.9)	0.0 (1.1)	0.0 (0.8)	0.0 (-0.1)	0.0 (-0.7)
Mar	---	---	-0.1 (-2.6)	-0.1 (-3.4)	-0.1 (-2.6)	-0.1 (-3.1)	0.0 (-1.8)	0.0 (-1.2)
Apr	---	---	0.0 (-1.6)	0.0 (-1.3)	0.0 (-1.7)	0.1 (5.1)	0.0 (0.4)	0.1 (4.7)
May	---	---	-0.1 (-4.2)	-0.4 (-19.0)	-0.1 (-4.3)	-0.4 (-18.8)	-0.2 (-5.9)	-0.2 (-7.3)
Jun	---	---	0.0 (0.5)	0.0 (0.2)	0.0 (-1.1)	0.0 (-0.6)	0.0 (1.4)	0.0 (1.6)
Jul	---	---	0.1 (4.5)	0.1 (4.5)	-0.1 (-2.4)	0.0 (4.1)	-0.1 (-5.0)	0.0 (3.5)
Aug	---	---	0.2 (16.9)	0.2 (16.5)	0.2 (17.2)	0.0 (0.7)	0.0 (1.6)	0.0 (1.7)
Sep	---	---	0.0 (2.7)	0.0 (2.6)	0.0 (0.5)	0.0 (2.0)	0.1 (6.1)	0.0 (2.9)
Oct	---	---	-0.1 (-0.7)	-0.1 (-1.1)	-0.1 (-1.2)	-0.1 (-1.8)	0.0 (1.3)	0.0 (0.3)
Nov	---	---	0.0 (1.1)	0.0 (1.0)	0.0 (0.6)	0.0 (1.5)	0.0 (0.3)	0.0 (0.4)
Dec	---	---	0.0 (-0.8)	0.0 (-0.9)	0.0 (0.5)	0.0 (-0.9)	0.0 (-0.4)	0.0 (-0.5)
Change in Concentration Compared to Existing Conditions [µg/L (%)]								
Jan	---	-0.7 (-22.7)	-0.6 (-22.5)	-0.6 (-22.6)	-0.6 (-22.3)	-0.7 (-22.9)	-0.7 (-24.1)	-0.7 (-23.8)
Feb	---	-0.9 (-30.8)	-0.9 (-30.3)	-0.9 (-30.2)	-0.9 (-30.0)	-0.9 (-30.2)	-0.9 (-30.9)	-0.9 (-31.3)
Mar	---	-0.5 (-20.4)	-0.6 (-22.5)	-0.6 (-23.1)	-0.6 (-22.5)	-0.6 (-22.9)	-0.5 (-21.9)	-0.5 (-21.4)
Apr	---	-0.3 (-13.5)	-0.3 (-14.9)	-0.3 (-14.7)	-0.3 (-15.0)	-0.2 (-9.1)	-0.3 (-13.2)	-0.2 (-9.5)
May	---	0.7 (45.9)	0.6 (39.7)	0.3 (18.1)	0.6 (39.6)	0.3 (18.4)	0.5 (37.2)	0.5 (35.2)
Jun	---	0.8 (49.6)	0.8 (50.3)	0.8 (49.9)	0.8 (47.9)	0.8 (48.7)	0.8 (51.7)	0.8 (51.9)
Jul	---	0.1 (5.7)	0.2 (10.4)	0.2 (10.4)	0.0 (3.1)	0.1 (10.0)	0.0 (0.3)	0.1 (9.4)
Aug	---	-0.4 (-22.4)	-0.2 (-9.4)	-0.2 (-9.6)	-0.2 (-9.1)	-0.4 (-21.9)	-0.4 (-21.2)	-0.4 (-21.1)
Sep	---	-0.1 (-8.4)	-0.1 (-5.9)	-0.1 (-6.0)	-0.1 (-7.9)	-0.1 (-6.5)	0.0 (-2.8)	-0.1 (-5.7)
Oct	---	-1.4 (-38.5)	-1.5 (-39.0)	-1.5 (-39.2)	-1.5 (-39.3)	-1.5 (-39.6)	-1.4 (-37.7)	-1.4 (-38.3)
Nov	---	-0.9 (-28.9)	-0.9 (-28.1)	-0.9 (-28.1)	-0.9 (-28.5)	-0.9 (-27.8)	-0.9 (-28.6)	-0.9 (-28.5)
Dec	---	-0.9 (-28.0)	-0.9 (-28.6)	-0.9 (-28.6)	-0.9 (-27.6)	-0.9 (-28.6)	-0.9 (-28.3)	-0.9 (-28.4)

Chronic Low Flows and Water Quality Assessments

Changes in streamflow could affect effluent limitations and treatment requirements for permitted discharges such as those from WWTFs. Of principal concern to WWTFs would be a reduction in receiving water streamflows, which dilute effluent concentrations. Reduced dilution would increase the stringency of those effluent limitations that are calculated using dilution in the receiving water. Effluent limits that typically consider dilution flow include ammonia, whole effluent toxicity, some metals, and some other inorganic parameters.

Methods

Chronic low flow and water quality assessment methods are described in this section. The results of chronic low flow analyses are inputs to water quality assessment methods.

Chronic Low Flow

The chronic low flow analysis used the Health Department's method for determining low flows for discharge permits. Chronic low flows were evaluated using the biologically-based design flow method to determine the minimum low flow over a 30-day averaging period occurring every 3 years. The biologically-based method examines all low flow events within a period of record even if several occur in one year. The period of record for determining chronic low flows should be a minimum of 10 years (Health Department 2012). The Health Department's version of the U.S. Environmental Protection Agency's DFLOW program (Oppelt 2004) was used with Daily Model streamflow output to evaluate chronic low flows. Simulated daily streamflow data for the last 10 years of the hydrologic model study period (1999 to 2009) were used to calculate chronic low flows.

Chronic low flows were estimated for major WWTFs (1 million gallons per day capacity or greater) in the Daily Model study area. The WWTF evaluated are summarized in Table 111. The approximate Daily Model links are located just upstream from the respective treatment plant discharges.

Table 111. Summary of WWTFs, Permitted Flow, and Hydrologic Model Links Upstream of WWTFs Evaluated Using DFLOW

WWTF	Permitted Flow (mgd)	Hydrologic Model Link
Buena Vista Sanitation District	1.5	LNODE200
City of Salida	2.1	LNODE240
Fremont Sanitation District Rainbow Park	8	LNODE360 – PenInL - FloInL
Pueblo West Metropolitan District	0.8	LNODE530
City of Pueblo	19	LNODE620
City of Rocky Ford	1.2	DSRF
City of La Junta	2.3	LNODE870
Security Sanitation District	2.4	LNODE6670
Widefield Water and Sanitation District and U.S. Department of Army Fort Carson	2.5 (Widefield) 4 (Fort Carson)	DSFCSEC
Fountain Sanitation District	1.9	DSJCC

Source: WWTF Discharge Permits

Potential effects of AVC alternatives on chronic low flows were evaluated using the following sequential process.

- Chronic low flow decreases of less than 10 percent compared to the No Action Alternative were not evaluated further, as these differences were within the range of Daily Model accuracy for low streamflows (Appendix D.3).
- Dilution flow was evaluated for chronic low flow decreases that exceeded 10 percent. Dilution flow is the percentage of streamflow at the discharge point that originates upstream from the discharge. The Colorado Mixing Zone Implementation Guidance (Health Department 2002) and Colorado Biomonitoring Guidance Document (Health Department 2006) indicate that discharges with greater that 90 percent dilution would not typically have discharge limits based on streamflow.
- Chronic low flows and discharge dilutions exceeding the above limits were further evaluated by applying chronic low flow percent differences between the No Action and action alternatives to chronic low flows in current permit water quality assessments. The existing discharge permits were evaluated to determine if chronic low flow effects would affect permitted discharge limits. The significance criteria in Table 7 were used to guide this evaluation.

Acute Low Flow

Acute low flows, those that occur over a 1-day period, were not analyzed due to limitations in the Daily Model that could cause rare, short-term anomalies in simulated streamflows. The anomalies found in Daily Model output are unlikely to occur in reality, as flow management programs would typically prevent operations of the alternatives that would cause decreases in acute low flows, even in reaches that are not covered by a flow management programs. Daily Model acute low flow anomalies likely result from one of two causes:

- Complex exchanges occurring simultaneously occasionally cannot be solved by the program (i.e., non-convergence error), resulting in an erroneous streamflow value.
- Simulated exchanges in the Daily Model occur instantaneously, whereas in reality, travel time of a transfer between the lower basin and the upper basin could take a day or two. The overall amount of water delivered is not different between actual operations and simulated operations, but because travel time is not in the model, improbable simulated flows or major differences between alternatives can be simulated for a day.

These two factors could have slight effects on flows on individual days, but there is typically no net effect on flows summarized over a time step larger than a day. Because these statistically-based 1-day low flows cannot be directly compared, the effects analysis includes a short discussion of the flow management programs and binding minimum low flow agreements that limit exchanges by participants (see Appendix D.3 and Appendix D.4).

Water Quality Assessments

Adverse chronic low flow effects greater than 10 percent for WWTFs without 90 percent dilution flows were further evaluated using a water quality assessment. Water quality assessments are typically used to prepare and issue Colorado discharge permits. An assessment evaluates the assimilative capacities of various constituents available to a permittee, and guides development of permit discharge limits that would prevent stream water quality violations.

The water quality assessments in this EIS follow the Health Department's standard analysis of using steady-state, mass-balance calculations to calculate chronic (30-day average) water quality based effluent limits, or the maximum allowable effluent concentrations. The mass-balance equation accounts for the existing upstream pollutant concentration, annual low flow, discharge rate, and the water quality standard. The mass-balance equation is expressed as:

Equation 3

Where Q_1 = Upstream chronic low flow (lowest of monthly chronic low flows)
Q_2 = Average daily effluent flow (design hydraulic capacity)
Q_3 = Downstream flow ($Q_1 + Q_2$)
M_1 = In-stream background pollutant concentrations at the existing quality (ambient water quality)
M_2 = Calculated water quality based effluent limitations (assimilative capacity)
M_3 = Maximum allowable in-stream pollutant concentration (water quality standards)

WWTFs in streams not designated as Use Protected also use an antidegradation review to determine and assess discharge limits. Antidegradation reviews assessed in the EIS used methodology outlined in *The Basic Standards and Methodologies for Surface Water* (Health Department 2012).

Because future permitted discharge limits, ambient water quality, and water quality standards are unknown, the water quality assessments in this EIS used water quality information from current discharge permits to evaluate effects. The chronic low flow percent changes of the alternatives compared to the No Action and existing conditions were applied to the current discharge permit chronic low flow, and then used in Equation 3 to evaluate effects to assimilative capacities. Changes in calculated assimilative capacities were compared with current permit capacities, discharge limits, and discharge limit rationales to evaluate effects of decreased low flow.

Results

Chronic low flow and dilution results are presented in this section for the Arkansas River and Fountain Creek basins. Water quality assessment results are then presented for WWTFs with chronic low flow effects.

Chronic Low Flow Effects

Major WWTFs in the Upper Arkansas River Basin are operated by the Buena Vista Sanitation District, the City of Salida, and the Fremont Sanitation District. The Lower Arkansas River Basin WWTFs include the Pueblo West Metropolitan District and the cities of Pueblo, Rocky

Ford, La Junta, and Lamar. Fountain Creek Basin WWTFs are operated by the Security Sanitation District, the Widefield Water and Sanitation District, the U.S. Department of Army Fort Carson, and the Fountain Sanitation District.

Upper Arkansas River Basin Major WWTF. Effects to chronic low flows in the Upper Arkansas River would be negligible for all action alternatives. Changes to streamflow in the Upper Arkansas River would be minimal, and would not affect permitted discharges (see Appendix D.4).

The Buena Vista Sanitation District WWTF discharges to the Arkansas River south of the City of Buena Vista. Link LNode200 of the hydrologic model was used to evaluate potential effects on chronic low flow. Decreases in chronic low flow for all alternatives compared to either the No Action or existing conditions would be less than 10 percent (Table 112 and Table 113).

The City of Salida WWTF discharges to the Arkansas River downstream from town. Link LNode240 of the hydrologic model was used to evaluate potential effects on chronic low flow. Decreases in chronic low flow for all alternatives compared to either the No Action or existing conditions would be less than 10 percent (Table 114 and Table 115).

The Fremont Sanitation District Rainbow Park Regional WWTF discharges to the Arkansas River east of the Town of Florence. Link number 3367 of the hydrologic model was used to evaluate potential effects on chronic low flow. Decreases in direct effects chronic low flow for all alternatives compared to the No Action would be less than 10 percent (Table 116). Compared to existing conditions, decreases in direct effects chronic low flow would be greater than 10 percent for the No Action and action alternatives. Decrease in cumulative effects chronic low flow, compared to either the No Action Alternative or existing conditions, would be greater than 10 percent for the Pueblo Dam South and River South alternatives (Table 117).

The permitted flow of this WWTF is 8 MGD or about 12.4 cfs. Projected permitted flow in 2060 would be 16.1 MGD (using projected demand growth of 100 percent), or 24.9 cfs. Dilution flows for direct and cumulative effects would be about 80 percent.

Table 112. Direct Effects Chronic Low Flow for Buena Vista Sanitation District

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	125	126	121	122	126	121	126	121
Feb	125	126	121	122	126	121	126	121
Mar	125	126	121	122	126	121	126	121
Apr	139	139	140	140	141	140	139	140
May	179	181	181	181	182	181	182	181
Jun	205	220	209	209	218	209	209	209
Jul	185	190	190	190	190	190	190	190
Aug	180	183	183	183	183	183	183	183
Sep	156	156	157	157	156	157	157	157
Oct	139	139	139	139	140	139	139	139
Nov	129	130	130	130	130	130	130	130
Dec	125	126	121	122	126	121	126	121
Annual	125	126	121	122	126	121	126	121
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	-5 (-4.0)	-4 (-3.2)	0 (0.0)	-5 (-4.0)	0 (0.0)	-5 (-4.0)
Feb	---	---	-5 (-4.0)	-4 (-3.2)	0 (0.0)	-5 (-4.0)	0 (0.0)	-5 (-4.0)
Mar	---	---	-5 (-4.0)	-4 (-3.2)	0 (0.0)	-5 (-4.0)	0 (0.0)	-5 (-4.0)
Apr	---	---	1 (0.7)	1 (0.7)	2 (1.4)	1 (0.7)	0 (0.0)	1 (0.7)
May	---	---	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	1 (0.6)	0 (0.0)
Jun	---	---	-11 (-5.0)	-11 (-5.0)	-2 (-0.9)	-11 (-5.0)	-11 (-5.0)	-11 (-5.0)
Jul	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Aug	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sep	---	---	1 (0.6)	1 (0.6)	0 (0.0)	1 (0.6)	1 (0.6)	1 (0.6)
Oct	---	---	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)
Nov	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dec	---	---	-5 (-4.0)	-4 (-3.2)	0 (0.0)	-5 (-4.0)	0 (0.0)	-5 (-4.0)
Annual	---	---	-5 (-4.0)	-4 (-3.2)	0 (0.0)	-5 (-4.0)	0 (0.0)	-5 (-4.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	1 (0.8)	-4 (-3.2)	-3 (-2.4)	1 (0.8)	-4 (-3.2)	1 (0.8)	-4 (-3.2)
Feb	---	1 (0.8)	-4 (-3.2)	-3 (-2.4)	1 (0.8)	-4 (-3.2)	1 (0.8)	-4 (-3.2)
Mar	---	1 (0.8)	-4 (-3.2)	-3 (-2.4)	1 (0.8)	-4 (-3.2)	1 (0.8)	-4 (-3.2)
Apr	---	0 (0.0)	1 (0.7)	1 (0.7)	2 (1.4)	1 (0.7)	0 (0.0)	1 (0.7)
May	---	2 (1.1)	2 (1.1)	2 (1.1)	3 (1.7)	2 (1.1)	3 (1.7)	2 (1.1)
Jun	---	15 (7.3)	4 (2.0)	4 (2.0)	13 (6.3)	4 (2.0)	4 (2.0)	4 (2.0)
Jul	---	5 (2.7)	5 (2.7)	5 (2.7)	5 (2.7)	5 (2.7)	5 (2.7)	5 (2.7)
Aug	---	3 (1.7)	3 (1.7)	3 (1.7)	3 (1.7)	3 (1.7)	3 (1.7)	3 (1.7)
Sep	---	0 (0.0)	1 (0.6)	1 (0.6)	0 (0.0)	1 (0.6)	1 (0.6)	1 (0.6)
Oct	---	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)
Nov	---	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)
Dec	---	1 (0.8)	-4 (-3.2)	-3 (-2.4)	1 (0.8)	-4 (-3.2)	1 (0.8)	-4 (-3.2)
Annual	---	1 (0.8)	-4 (-3.2)	-3 (-2.4)	1 (0.8)	-4 (-3.2)	1 (0.8)	-4 (-3.2)

Table 113. Cumulative Effects Chronic Low Flow for Buena Vista Sanitation District WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	125	118	119	118	118	119	119	118
Feb	125	118	119	118	118	119	119	118
Mar	125	118	119	118	118	119	119	118
Apr	139	139	140	141	139	140	136	140
May	179	183	183	183	184	182	184	184
Jun	205	189	204	205	189	203	193	194
Jul	185	189	204	205	189	203	189	194
Aug	180	178	180	180	177	180	184	179
Sep	156	158	160	160	158	160	161	160
Oct	139	139	139	139	140	139	139	139
Nov	129	130	130	130	130	130	130	130
Dec	125	118	119	119	118	119	119	119
Annual	125	118	119	118	118	119	119	118
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	1 (0.8)	0 (0.0)	0 (0.0)	1 (0.8)	1 (0.8)	0 (0.0)
Feb	---	---	1 (0.8)	0 (0.0)	0 (0.0)	1 (0.8)	1 (0.8)	0 (0.0)
Mar	---	---	1 (0.8)	0 (0.0)	0 (0.0)	1 (0.8)	1 (0.8)	0 (0.0)
Apr	---	---	1 (0.7)	2 (1.4)	0 (0.0)	1 (0.7)	-3 (-2.2)	1 (0.7)
May	---	---	0 (0.0)	0 (0.0)	1 (0.5)	-1 (-0.5)	1 (0.5)	1 (0.5)
Jun	---	---	15 (7.9)	16 (8.5)	0 (0.0)	14 (7.4)	4 (2.1)	5 (2.6)
Jul	---	---	15 (7.9)	16 (8.5)	0 (0.0)	14 (7.4)	0 (0.0)	5 (2.6)
Aug	---	---	2 (1.1)	2 (1.1)	-1 (-0.6)	2 (1.1)	6 (3.4)	1 (0.6)
Sep	---	---	2 (1.3)	2 (1.3)	0 (0.0)	2 (1.3)	3 (1.9)	2 (1.3)
Oct	---	---	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)
Nov	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dec	---	---	1 (0.8)	1 (0.8)	0 (0.0)	1 (0.8)	1 (0.8)	1 (0.8)
Annual	---	---	1 (0.8)	0 (0.0)	0 (0.0)	1 (0.8)	1 (0.8)	0 (0.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	-7 (-5.6)	-6 (-4.8)	-7 (-5.6)	-7 (-5.6)	-6 (-4.8)	-6 (-4.8)	-7 (-5.6)
Feb	---	-7 (-5.6)	-6 (-4.8)	-7 (-5.6)	-7 (-5.6)	-6 (-4.8)	-6 (-4.8)	-7 (-5.6)
Mar	---	-7 (-5.6)	-6 (-4.8)	-7 (-5.6)	-7 (-5.6)	-6 (-4.8)	-6 (-4.8)	-7 (-5.6)
Apr	---	0 (0.0)	1 (0.7)	2 (1.4)	0 (0.0)	1 (0.7)	-3 (-2.2)	1 (0.7)
May	---	4 (2.2)	4 (2.2)	4 (2.2)	5 (2.8)	3 (1.7)	5 (2.8)	5 (2.8)
Jun	---	-16 (-7.8)	-1 (-0.5)	0 (0.0)	-16 (-7.8)	-2 (-1.0)	-12 (-5.9)	-11 (-5.4)
Jul	---	4 (2.2)	19 (10.3)	20 (10.8)	4 (2.2)	18 (9.7)	4 (2.2)	9 (4.9)
Aug	---	-2 (-1.1)	0 (0.0)	0 (0.0)	-3 (-1.7)	0 (0.0)	4 (2.2)	-1 (-0.6)
Sep	---	2 (1.3)	4 (2.6)	4 (2.6)	2 (1.3)	4 (2.6)	5 (3.2)	4 (2.6)
Oct	---	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)
Nov	---	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)
Dec	---	-7 (-5.6)	-6 (-4.8)	-6 (-4.8)	-7 (-5.6)	-6 (-4.8)	-6 (-4.8)	-6 (-4.8)
Annual	---	-7 (-5.6)	-6 (-4.8)	-7 (-5.6)	-7 (-5.6)	-6 (-4.8)	-6 (-4.8)	-7 (-5.6)

Table 114. Direct Effects Chronic Low Flow for City of Salida

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	201	201	203	201	201	201	201	201
Feb	200	200	203	200	200	200	200	200
Mar	200	200	203	200	200	200	200	200
Apr	200	200	203	200	200	200	200	200
May	203	206	211	203	205	203	204	202
Jun	253	263	254	253	261	253	253	253
Jul	235	234	233	235	234	234	234	234
Aug	225	225	228	225	225	225	224	225
Sep	205	205	211	205	205	205	205	204
Oct	200	200	204	200	200	200	200	200
Nov	200	200	204	200	200	200	200	200
Dec	202	202	203	202	202	202	202	202
Annual	200	200	203	200	200	200	200	200
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	2 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Feb	---	---	3 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Mar	---	---	3 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Apr	---	---	3 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
May	---	---	5 (2.4)	-3 (-1.5)	-1 (-0.5)	-3 (-1.5)	-2 (-1.0)	-4 (-1.9)
Jun	---	---	-9 (-3.4)	-10 (-3.8)	-2 (-0.8)	-10 (-3.8)	-10 (-3.8)	-10 (-3.8)
Jul	---	---	-1 (-0.4)	1 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Aug	---	---	3 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	-1 (-0.4)	0 (0.0)
Sep	---	---	6 (2.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	-1 (-0.5)
Oct	---	---	4 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Nov	---	---	4 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dec	---	---	1 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Annual	---	---	3 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	0 (0.0)	2 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Feb	---	0 (0.0)	3 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Mar	---	0 (0.0)	3 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Apr	---	0 (0.0)	3 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
May	---	3 (1.5)	8 (3.9)	0 (0.0)	2 (1.0)	0 (0.0)	1 (0.5)	-1 (-0.5)
Jun	---	10 (4.0)	1 (0.4)	0 (0.0)	8 (3.2)	0 (0.0)	0 (0.0)	0 (0.0)
Jul	---	-1 (-0.4)	-2 (-0.9)	0 (0.0)	-1 (-0.4)	-1 (-0.4)	-1 (-0.4)	-1 (-0.4)
Aug	---	0 (0.0)	3 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	-1 (-0.4)	0 (0.0)
Sep	---	0 (0.0)	6 (2.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	-1 (-0.5)
Oct	---	0 (0.0)	4 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Nov	---	0 (0.0)	4 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dec	---	0 (0.0)	1 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Annual	---	0 (0.0)	3 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Table 115. Cumulative Effects Chronic Low Flow for City of Salida

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	201	201	201	201	201	201	201	201
Feb	200	200	201	201	200	201	201	201
Mar	200	200	201	201	200	201	201	201
Apr	200	200	201	201	200	201	201	201
May	203	208	204	204	204	204	201	202
Jun	253	237	252	254	237	252	240	240
Jul	235	236	252	254	236	252	231	240
Aug	225	222	223	223	222	223	227	221
Sep	205	208	210	210	208	210	210	209
Oct	200	201	203	203	201	203	202	202
Nov	200	201	203	203	201	203	202	202
Dec	202	202	202	202	202	202	202	202
Annual	200	200	201	201	200	201	201	201
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Feb	---	---	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	1 (0.5)	1 (0.5)
Mar	---	---	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	1 (0.5)	1 (0.5)
Apr	---	---	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	1 (0.5)	1 (0.5)
May	---	---	-4 (-1.9)	-4 (-1.9)	-4 (-1.9)	-4 (-1.9)	-7 (-3.4)	-6 (-2.9)
Jun	---	---	15 (6.3)	17 (7.2)	0 (0.0)	15 (6.3)	3 (1.3)	3 (1.3)
Jul	---	---	16 (6.8)	18 (7.6)	0 (0.0)	16 (6.8)	-5 (-2.1)	4 (1.7)
Aug	---	---	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	5 (2.3)	-1 (-0.5)
Sep	---	---	2 (1.0)	2 (1.0)	0 (0.0)	2 (1.0)	2 (1.0)	1 (0.5)
Oct	---	---	2 (1.0)	2 (1.0)	0 (0.0)	2 (1.0)	1 (0.5)	1 (0.5)
Nov	---	---	2 (1.0)	2 (1.0)	0 (0.0)	2 (1.0)	1 (0.5)	1 (0.5)
Dec	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Annual	---	---	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	1 (0.5)	1 (0.5)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Feb	---	0 (0.0)	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	1 (0.5)	1 (0.5)
Mar	---	0 (0.0)	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	1 (0.5)	1 (0.5)
Apr	---	0 (0.0)	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	1 (0.5)	1 (0.5)
May	---	5 (2.5)	1 (0.5)	1 (0.5)	1 (0.5)	1 (0.5)	-2 (-1.0)	-1 (-0.5)
Jun	---	-16 (-6.3)	-1 (-0.4)	1 (0.4)	-16 (-6.3)	-1 (-0.4)	-13 (-5.1)	-13 (-5.1)
Jul	---	1 (0.4)	17 (7.2)	19 (8.1)	1 (0.4)	17 (7.2)	-4 (-1.7)	5 (2.1)
Aug	---	-3 (-1.3)	-2 (-0.9)	-2 (-0.9)	-3 (-1.3)	-2 (-0.9)	2 (0.9)	-4 (-1.8)
Sep	---	3 (1.5)	5 (2.4)	5 (2.4)	3 (1.5)	5 (2.4)	5 (2.4)	4 (2.0)
Oct	---	1 (0.5)	3 (1.5)	3 (1.5)	1 (0.5)	3 (1.5)	2 (1.0)	2 (1.0)
Nov	---	1 (0.5)	3 (1.5)	3 (1.5)	1 (0.5)	3 (1.5)	2 (1.0)	2 (1.0)
Dec	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Annual	---	0 (0.0)	1 (0.5)	1 (0.5)	0 (0.0)	1 (0.5)	1 (0.5)	1 (0.5)

Table 116. Direct Effects Chronic Low Flow for Fremont Sanitation District Rainbow Park

Month	Existing Conditions	No Action		Comanche South		Pueblo Dam South		JUP North		Pueblo Dam North		River South		Master Contract Only	
Simulated Streamflow (cfs)															
Jan	169	169		167		167		167		167		167		167	
Feb	169	169		167		167		167		167		167		167	
Mar	131	114		109		110		117		110		111		110	
Apr	104	91		87		88		92		88		88		87	
May	104	91		87		88		92		88		88		87	
Jun	173	162		165		163		158		168		171		161	
Jul	103	91		87		88		91		88		88		87	
Aug	103	91		87		88		91		88		88		87	
Sep	103	91		87		88		91		88		88		87	
Oct	103	91		87		88		91		88		88		87	
Nov	108	105		106		106		103		106		105		105	
Dec	161	159		159		159		159		159		159		159	
Annual	103	91		87		88		91		88		88		87	
Change in Streamflow Compared to No Action [cfs (%)]															
Jan	---	---		-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)
Feb	---	---		-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)
Mar	---	---		-5	(-4.4)	-4	(-3.5)	3	(2.6)	-4	(-3.5)	-3	(-2.6)	-4	(-3.5)
Apr	---	---		-4	(-4.4)	-3	(-3.3)	1	(1.1)	-3	(-3.3)	-3	(-3.3)	-4	(-4.4)
May	---	---		-4	(-4.4)	-3	(-3.3)	1	(1.1)	-3	(-3.3)	-3	(-3.3)	-4	(-4.4)
Jun	---	---		3	(1.9)	1	(0.6)	-4	(-2.5)	6	(3.7)	9	(5.6)	-1	(-0.6)
Jul	---	---		-4	(-4.4)	-3	(-3.3)	0	(0.0)	-3	(-3.3)	-3	(-3.3)	-4	(-4.4)
Aug	---	---		-4	(-4.4)	-3	(-3.3)	0	(0.0)	-3	(-3.3)	-3	(-3.3)	-4	(-4.4)
Sep	---	---		-4	(-4.4)	-3	(-3.3)	0	(0.0)	-3	(-3.3)	-3	(-3.3)	-4	(-4.4)
Oct	---	---		-4	(-4.4)	-3	(-3.3)	0	(0.0)	-3	(-3.3)	-3	(-3.3)	-4	(-4.4)
Nov	---	---		1	(1.0)	1	(1.0)	-2	(-1.9)	1	(1.0)	0	(0.0)	0	(0.0)
Dec	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Annual	---	---		-4	(-4.4)	-3	(-3.3)	0	(0.0)	-3	(-3.3)	-3	(-3.3)	-4	(-4.4)
Change in Streamflow Compared to Existing Conditions [cfs (%)]															
Jan	---	0	(0.0)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)
Feb	---	0	(0.0)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)
Mar	---	-17	(-13.0)	-22	(-16.8)	-21	(-16.0)	-14	(-10.7)	-21	(-16.0)	-20	(-15.3)	-21	(-16.0)
Apr	---	-13	(-12.5)	-17	(-16.3)	-16	(-15.4)	-12	(-11.5)	-16	(-15.4)	-16	(-15.4)	-17	(-16.3)
May	---	-13	(-12.5)	-17	(-16.3)	-16	(-15.4)	-12	(-11.5)	-16	(-15.4)	-16	(-15.4)	-17	(-16.3)
Jun	---	-11	(-6.4)	-8	(-4.6)	-10	(-5.8)	-15	(-8.7)	-5	(-2.9)	-2	(-1.2)	-12	(-6.9)
Jul	---	-12	(-11.7)	-16	(-15.5)	-15	(-14.6)	-12	(-11.7)	-15	(-14.6)	-15	(-14.6)	-16	(-15.5)
Aug	---	-12	(-11.7)	-16	(-15.5)	-15	(-14.6)	-12	(-11.7)	-15	(-14.6)	-15	(-14.6)	-16	(-15.5)
Sep	---	-12	(-11.7)	-16	(-15.5)	-15	(-14.6)	-12	(-11.7)	-15	(-14.6)	-15	(-14.6)	-16	(-15.5)
Oct	---	-12	(-11.7)	-16	(-15.5)	-15	(-14.6)	-12	(-11.7)	-15	(-14.6)	-15	(-14.6)	-16	(-15.5)
Nov	---	-3	(-2.8)	-2	(-1.9)	-2	(-1.9)	-5	(-4.6)	-2	(-1.9)	-3	(-2.8)	-3	(-2.8)
Dec	---	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)	-2	(-1.2)
Annual	---	-12	(-11.7)	-16	(-15.5)	-15	(-14.6)	-12	(-11.7)	-15	(-14.6)	-15	(-14.6)	-16	(-15.5)

Table 117. Cumulative Effects Chronic Low Flow for Fremont Sanitation District Rainbow Park

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	169	169	167	167	169	167	167	167
Feb	169	169	167	167	169	167	167	167
Mar	131	112	118	109	119	121	91	112
Apr	104	106	103	91	107	102	91	105
May	104	106	103	91	107	102	91	105
Jun	173	173	182	184	179	182	163	147
Jul	103	105	102	101	130	126	102	116
Aug	103	105	102	91	107	102	91	104
Sep	103	105	102	91	107	102	91	104
Oct	103	105	102	91	107	102	91	104
Nov	108	106	108	108	107	108	107	109
Dec	161	161	160	160	161	160	162	160
Annual	103	105	102	91	107	102	91	104
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	-2 (-1.2)	-2 (-1.2)	0 (0.0)	-2 (-1.2)	-2 (-1.2)	-2 (-1.2)
Feb	---	---	-2 (-1.2)	-2 (-1.2)	0 (0.0)	-2 (-1.2)	-2 (-1.2)	-2 (-1.2)
Mar	---	---	6 (5.4)	-3 (-2.7)	7 (6.3)	9 (8.0)	-21 (-18.8)	0 (0.0)
Apr	---	---	-3 (-2.8)	-15 (-14.2)	1 (0.9)	-4 (-3.8)	-15 (-14.2)	-1 (-0.9)
May	---	---	-3 (-2.8)	-15 (-14.2)	1 (0.9)	-4 (-3.8)	-15 (-14.2)	-1 (-0.9)
Jun	---	---	9 (5.2)	11 (6.4)	6 (3.5)	9 (5.2)	-10 (-5.8)	-26 (-15.0)
Jul	---	---	-3 (-2.9)	-4 (-3.8)	25 (23.8)	21 (20.0)	-3 (-2.9)	11 (10.5)
Aug	---	---	-3 (-2.9)	-14 (-13.3)	2 (1.9)	-3 (-2.9)	-14 (-13.3)	-1 (-1.0)
Sep	---	---	-3 (-2.9)	-14 (-13.3)	2 (1.9)	-3 (-2.9)	-14 (-13.3)	-1 (-1.0)
Oct	---	---	-3 (-2.9)	-14 (-13.3)	2 (1.9)	-3 (-2.9)	-14 (-13.3)	-1 (-1.0)
Nov	---	---	2 (1.9)	2 (1.9)	1 (0.9)	2 (1.9)	1 (0.9)	3 (2.8)
Dec	---	---	-1 (-0.6)	-1 (-0.6)	0 (0.0)	-1 (-0.6)	1 (0.6)	-1 (-0.6)
Annual	---	---	-3 (-2.9)	-14 (-13.3)	2 (1.9)	-3 (-2.9)	-14 (-13.3)	-1 (-1.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	0 (0.0)	-2 (-1.2)	-2 (-1.2)	0 (0.0)	-2 (-1.2)	-2 (-1.2)	-2 (-1.2)
Feb	---	0 (0.0)	-2 (-1.2)	-2 (-1.2)	0 (0.0)	-2 (-1.2)	-2 (-1.2)	-2 (-1.2)
Mar	---	-19 (-14.5)	-13 (-9.9)	-22 (-16.8)	-12 (-9.2)	-10 (-7.6)	-40 (-30.5)	-19 (-14.5)
Apr	---	2 (1.9)	-1 (-1.0)	-13 (-12.5)	3 (2.9)	-2 (-1.9)	-13 (-12.5)	1 (1.0)
May	---	2 (1.9)	-1 (-1.0)	-13 (-12.5)	3 (2.9)	-2 (-1.9)	-13 (-12.5)	1 (1.0)
Jun	---	0 (0.0)	9 (5.2)	11 (6.4)	6 (3.5)	9 (5.2)	-10 (-5.8)	-26 (-15.0)
Jul	---	2 (1.9)	-1 (-1.0)	-2 (-1.9)	27 (26.2)	23 (22.3)	-1 (-1.0)	13 (12.6)
Aug	---	2 (1.9)	-1 (-1.0)	-12 (-11.7)	4 (3.9)	-1 (-1.0)	-12 (-11.7)	1 (1.0)
Sep	---	2 (1.9)	-1 (-1.0)	-12 (-11.7)	4 (3.9)	-1 (-1.0)	-12 (-11.7)	1 (1.0)
Oct	---	2 (1.9)	-1 (-1.0)	-12 (-11.7)	4 (3.9)	-1 (-1.0)	-12 (-11.7)	1 (1.0)
Nov	---	-2 (-1.9)	0 (0.0)	0 (0.0)	-1 (-0.9)	0 (0.0)	-1 (-0.9)	1 (0.9)
Dec	---	0 (0.0)	-1 (-0.6)	-1 (-0.6)	0 (0.0)	-1 (-0.6)	1 (0.6)	-1 (-0.6)
Annual	---	2 (1.9)	-1 (-1.0)	-12 (-11.7)	4 (3.9)	-1 (-1.0)	-12 (-11.7)	1 (1.0)

Lower Arkansas River Basin Major WWTFs. The Pueblo West WWTF discharges to the Pesthouse Gulch, a tributary to Wildhorse Creek, which itself is a tributary to the Arkansas River. These streams are not explicitly simulated in the Daily Model. Link LNODE530 of the hydrologic model was used to evaluate potential effects on Pueblo West chronic low flows in the

Arkansas River. Chronic low flows for direct and cumulative effects, are in Table 118 and Table 119, respectively.

Under direct effects and cumulative effects, all alternatives would have annual chronic low flow reductions in the Arkansas River of less than 10 percent, compared to the No Action, which would be negligible. Both direct and cumulative effects would increase Arkansas River flows under River South. Compared to existing conditions, most alternatives would have reduced annual chronic low flow, up to 30 percent for cumulative effects.

The current 2011 permitted flow of Pueblo West WWTF is 1.8 MGD. Projected permitted flow in 2070 is 2.5 MGD (using projected demand growth of 41 percent), or 3.9 cfs. Direct effects Arkansas River dilution flows for all alternatives would be greater than 90 percent. Cumulative effects dilution flows for alternatives with the AVC would be about 88 percent, and greater than 90 percent for remaining alternatives.

The City of Pueblo WWTF discharges to the Arkansas River downstream from Pueblo. Link LNODE620 of the hydrologic model was used to evaluate potential effects on chronic low flows. Table 120 presents chronic low flows for direct effects and Table 121 presents chronic low flows for cumulative effects.

Direct and cumulative effects would not decrease flows more than 10 percent for any of the alternatives, as compared to either the No Action Alternative or existing conditions, and would be negligible. The current permitted flow of City of Pueblo WWTF is 19.0 MGD. Projected permitted flow in 2070 is 30.8 MGD (using projected demand growth of 62 percent), or 47.6 cfs. Direct effects dilution flows for all alternatives would be greater than 86 percent. Cumulative effects dilution for all alternatives would be about 80 percent.

Table 118. Direct Effects Chronic Low Flow for Pueblo West WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	43	42	43	42	42	43	49	43
Feb	43	41	38	38	38	38	49	38
Mar	43	41	38	38	38	38	49	38
Apr	73	66	59	59	56	59	68	61
May	96	82	68	68	74	68	79	72
Jun	135	136	115	115	122	115	139	121
Jul	48	45	40	40	39	40	58	43
Aug	43	41	37	37	37	37	51	38
Sep	43	41	37	37	37	37	50	38
Oct	43	41	37	37	37	37	49	38
Nov	56	45	37	37	42	37	49	40
Dec	74	66	55	55	69	55	63	61
Annual	43	41	37	37	37	37	49	38
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	1 (2.4)	0 (0.0)	0 (0.0)	1 (2.4)	7 (16.7)	1 (2.4)
Feb	---	---	-3 (-7.3)	-3 (-7.3)	-3 (-7.3)	-3 (-7.3)	8 (19.5)	-3 (-7.3)
Mar	---	---	-3 (-7.3)	-3 (-7.3)	-3 (-7.3)	-3 (-7.3)	8 (19.5)	-3 (-7.3)
Apr	---	---	-7 (-10.6)	-7 (-10.6)	-10 (-15.2)	-7 (-10.6)	2 (3.0)	-5 (-7.6)
May	---	---	-14 (-17.1)	-14 (-17.1)	-8 (-9.8)	-14 (-17.1)	-3 (-3.7)	-10 (-12.2)
Jun	---	---	-21 (-15.4)	-21 (-15.4)	-14 (-10.3)	-21 (-15.4)	3 (2.2)	-15 (-11.0)
Jul	---	---	-5 (-11.1)	-5 (-11.1)	-6 (-13.3)	-5 (-11.1)	13 (28.9)	-2 (-4.4)
Aug	---	---	-4 (-9.8)	-4 (-9.8)	-4 (-9.8)	-4 (-9.8)	10 (24.4)	-3 (-7.3)
Sep	---	---	-4 (-9.8)	-4 (-9.8)	-4 (-9.8)	-4 (-9.8)	9 (22.0)	-3 (-7.3)
Oct	---	---	-4 (-9.8)	-4 (-9.8)	-4 (-9.8)	-4 (-9.8)	8 (19.5)	-3 (-7.3)
Nov	---	---	-8 (-17.8)	-8 (-17.8)	-3 (-6.7)	-8 (-17.8)	4 (8.9)	-5 (-11.1)
Dec	---	---	-11 (-16.7)	-11 (-16.7)	3 (4.5)	-11 (-16.7)	-3 (-4.5)	-5 (-7.6)
Annual	---	---	-4 (-9.8)	-4 (-9.8)	-4 (-9.8)	-4 (-9.8)	8 (19.5)	-3 (-7.3)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	-1 (-2.3)	0 (0.0)	-1 (-2.3)	-1 (-2.3)	0 (0.0)	6 (14.0)	0 (0.0)
Feb	---	-2 (-4.7)	-5 (-11.6)	-5 (-11.6)	-5 (-11.6)	-5 (-11.6)	6 (14.0)	-5 (-11.6)
Mar	---	-2 (-4.7)	-5 (-11.6)	-5 (-11.6)	-5 (-11.6)	-5 (-11.6)	6 (14.0)	-5 (-11.6)
Apr	---	-7 (-9.6)	-14 (-19.2)	-14 (-19.2)	-17 (-23.3)	-14 (-19.2)	-5 (-6.8)	-12 (-16.4)
May	---	-14 (-14.6)	-28 (-29.2)	-28 (-29.2)	-22 (-22.9)	-28 (-29.2)	-17 (-17.7)	-24 (-25.0)
Jun	---	1 (0.7)	-20 (-14.8)	-20 (-14.8)	-13 (-9.6)	-20 (-14.8)	4 (3.0)	-14 (-10.4)
Jul	---	-3 (-6.3)	-8 (-16.7)	-8 (-16.7)	-9 (-18.8)	-8 (-16.7)	10 (20.8)	-5 (-10.4)
Aug	---	-2 (-4.7)	-6 (-14.0)	-6 (-14.0)	-6 (-14.0)	-6 (-14.0)	8 (18.6)	-5 (-11.6)
Sep	---	-2 (-4.7)	-6 (-14.0)	-6 (-14.0)	-6 (-14.0)	-6 (-14.0)	7 (16.3)	-5 (-11.6)
Oct	---	-2 (-4.7)	-6 (-14.0)	-6 (-14.0)	-6 (-14.0)	-6 (-14.0)	6 (14.0)	-5 (-11.6)
Nov	---	-11 (-19.6)	-19 (-33.9)	-19 (-33.9)	-14 (-25.0)	-19 (-33.9)	-7 (-12.5)	-16 (-28.6)
Dec	---	-8 (-10.8)	-19 (-25.7)	-19 (-25.7)	-5 (-6.8)	-19 (-25.7)	-11 (-14.9)	-13 (-17.6)
Annual	---	-2 (-4.7)	-6 (-14.0)	-6 (-14.0)	-6 (-14.0)	-6 (-14.0)	6 (14.0)	-5 (-11.6)

Table 119. Cumulative Effects Chronic Low Flow for Pueblo West WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	43	70	65	65	67	65	73	69
Feb	43	49	45	45	45	46	53	47
Mar	43	46	39	40	43	40	50	44
Apr	73	46	39	40	43	40	50	44
May	96	62	56	56	58	57	73	62
Jun	135	69	71	72	71	69	73	72
Jul	48	33	30	30	30	30	44	35
Aug	43	33	30	30	30	30	44	35
Sep	43	33	30	30	30	30	44	35
Oct	43	33	30	30	30	30	44	35
Nov	56	35	34	34	31	34	44	38
Dec	74	56	62	62	52	62	66	63
Annual	43	33	30	30	30	30	44	35
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	-5 (-7.1)	-5 (-7.1)	-3 (-4.3)	-5 (-7.1)	3 (4.3)	-1 (-1.4)
Feb	---	---	-4 (-8.2)	-4 (-8.2)	-4 (-8.2)	-3 (-6.1)	4 (8.2)	-2 (-4.1)
Mar	---	---	-7 (-15.2)	-6 (-13.0)	-3 (-6.5)	-6 (-13.0)	4 (8.7)	-2 (-4.3)
Apr	---	---	-7 (-15.2)	-6 (-13.0)	-3 (-6.5)	-6 (-13.0)	4 (8.7)	-2 (-4.3)
May	---	---	-6 (-9.7)	-6 (-9.7)	-4 (-6.5)	-5 (-8.1)	11 (17.7)	0 (0.0)
Jun	---	---	2 (2.9)	3 (4.3)	2 (2.9)	0 (0.0)	4 (5.8)	3 (4.3)
Jul	---	---	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	11 (33.3)	2 (6.1)
Aug	---	---	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	11 (33.3)	2 (6.1)
Sep	---	---	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	11 (33.3)	2 (6.1)
Oct	---	---	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	11 (33.3)	2 (6.1)
Nov	---	---	-1 (-2.9)	-1 (-2.9)	-4 (-11.4)	-1 (-2.9)	9 (25.7)	3 (8.6)
Dec	---	---	6 (10.7)	6 (10.7)	-4 (-7.1)	6 (10.7)	10 (17.9)	7 (12.5)
Annual	---	---	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	-3 (-9.1)	11 (33.3)	2 (6.1)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	27 (62.8)	22 (51.2)	22 (51.2)	24 (55.8)	22 (51.2)	30 (69.8)	26 (60.5)
Feb	---	6 (14.0)	2 (4.7)	2 (4.7)	2 (4.7)	3 (7.0)	10 (23.3)	4 (9.3)
Mar	---	3 (7.0)	-4 (-9.3)	-3 (-7.0)	0 (0.0)	-3 (-7.0)	7 (16.3)	1 (2.3)
Apr	---	-27 (-37.0)	-34 (-46.6)	-33 (-45.2)	-30 (-41.1)	-33 (-45.2)	-23 (-31.5)	-29 (-39.7)
May	---	-34 (-35.4)	-40 (-41.7)	-40 (-41.7)	-38 (-39.6)	-39 (-40.6)	-23 (-24.0)	-34 (-35.4)
Jun	---	-66 (-48.9)	-64 (-47.4)	-63 (-46.7)	-64 (-47.4)	-66 (-48.9)	-62 (-45.9)	-63 (-46.7)
Jul	---	-15 (-31.3)	-18 (-37.5)	-18 (-37.5)	-18 (-37.5)	-18 (-37.5)	-4 (-8.3)	-13 (-27.1)
Aug	---	-10 (-23.3)	-13 (-30.2)	-13 (-30.2)	-13 (-30.2)	-13 (-30.2)	1 (2.3)	-8 (-18.6)
Sep	---	-10 (-23.3)	-13 (-30.2)	-13 (-30.2)	-13 (-30.2)	-13 (-30.2)	1 (2.3)	-8 (-18.6)
Oct	---	-10 (-23.3)	-13 (-30.2)	-13 (-30.2)	-13 (-30.2)	-13 (-30.2)	1 (2.3)	-8 (-18.6)
Nov	---	-21 (-37.5)	-22 (-39.3)	-22 (-39.3)	-25 (-44.6)	-22 (-39.3)	-12 (-21.4)	-18 (-32.1)
Dec	---	-18 (-24.3)	-12 (-16.2)	-12 (-16.2)	-22 (-29.7)	-12 (-16.2)	-8 (-10.8)	-11 (-14.9)
Annual	---	-10 (-23.3)	-13 (-30.2)	-13 (-30.2)	-13 (-30.2)	-13 (-30.2)	1 (2.3)	-8 (-18.6)

Table 120. Direct Effects Chronic Low Flow for Pueblo WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	182	184	193	193	187	193	187	195
Feb	181	178	180	180	179	180	178	184
Mar	181	178	180	180	179	180	178	184
Apr	200	193	198	198	190	198	190	198
May	200	193	198	198	190	198	190	198
Jun	271	284	280	280	283	281	280	286
Jul	186	185	183	183	182	184	181	186
Aug	181	178	180	180	179	180	178	184
Sep	181	178	180	180	179	180	178	184
Oct	183	181	180	180	181	180	180	185
Nov	182	192	194	194	193	194	188	194
Dec	182	192	193	193	193	193	188	194
Annual	181	178	180	180	179	180	178	184
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	9 (4.9)	9 (4.9)	3 (1.6)	9 (4.9)	3 (1.6)	11 (6.0)
Feb	---	---	2 (1.1)	2 (1.1)	1 (0.6)	2 (1.1)	0 (0.0)	6 (3.4)
Mar	---	---	2 (1.1)	2 (1.1)	1 (0.6)	2 (1.1)	0 (0.0)	6 (3.4)
Apr	---	---	5 (2.6)	5 (2.6)	-3 (-1.6)	5 (2.6)	-3 (-1.6)	5 (2.6)
May	---	---	5 (2.6)	5 (2.6)	-3 (-1.6)	5 (2.6)	-3 (-1.6)	5 (2.6)
Jun	---	---	-4 (-1.4)	-4 (-1.4)	-1 (-0.4)	-3 (-1.1)	-4 (-1.4)	2 (0.7)
Jul	---	---	-2 (-1.1)	-2 (-1.1)	-3 (-1.6)	-1 (-0.5)	-4 (-2.2)	1 (0.5)
Aug	---	---	2 (1.1)	2 (1.1)	1 (0.6)	2 (1.1)	0 (0.0)	6 (3.4)
Sep	---	---	2 (1.1)	2 (1.1)	1 (0.6)	2 (1.1)	0 (0.0)	6 (3.4)
Oct	---	---	-1 (-0.6)	-1 (-0.6)	0 (0.0)	-1 (-0.6)	-1 (-0.6)	4 (2.2)
Nov	---	---	2 (1.0)	2 (1.0)	1 (0.5)	2 (1.0)	-4 (-2.1)	2 (1.0)
Dec	---	---	1 (0.5)	1 (0.5)	1 (0.5)	1 (0.5)	-4 (-2.1)	2 (1.0)
Annual	---	---	2 (1.1)	2 (1.1)	1 (0.6)	2 (1.1)	0 (0.0)	6 (3.4)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	2 (1.1)	11 (6.0)	11 (6.0)	5 (2.7)	11 (6.0)	5 (2.7)	13 (7.1)
Feb	---	-3 (-1.7)	-1 (-0.6)	-1 (-0.6)	-2 (-1.1)	-1 (-0.6)	-3 (-1.7)	3 (1.7)
Mar	---	-3 (-1.7)	-1 (-0.6)	-1 (-0.6)	-2 (-1.1)	-1 (-0.6)	-3 (-1.7)	3 (1.7)
Apr	---	-7 (-3.5)	-2 (-1.0)	-2 (-1.0)	-10 (-5.0)	-2 (-1.0)	-10 (-5.0)	-2 (-1.0)
May	---	-7 (-3.5)	-2 (-1.0)	-2 (-1.0)	-10 (-5.0)	-2 (-1.0)	-10 (-5.0)	-2 (-1.0)
Jun	---	13 (4.8)	9 (3.3)	9 (3.3)	12 (4.4)	10 (3.7)	9 (3.3)	15 (5.5)
Jul	---	-1 (-0.5)	-3 (-1.6)	-3 (-1.6)	-4 (-2.2)	-2 (-1.1)	-5 (-2.7)	0 (0.0)
Aug	---	-3 (-1.7)	-1 (-0.6)	-1 (-0.6)	-2 (-1.1)	-1 (-0.6)	-3 (-1.7)	3 (1.7)
Sep	---	-3 (-1.7)	-1 (-0.6)	-1 (-0.6)	-2 (-1.1)	-1 (-0.6)	-3 (-1.7)	3 (1.7)
Oct	---	-2 (-1.1)	-3 (-1.6)	-3 (-1.6)	-2 (-1.1)	-3 (-1.6)	-3 (-1.6)	2 (1.1)
Nov	---	10 (5.5)	12 (6.6)	12 (6.6)	11 (6.0)	12 (6.6)	6 (3.3)	12 (6.6)
Dec	---	10 (5.5)	11 (6.0)	11 (6.0)	11 (6.0)	11 (6.0)	6 (3.3)	12 (6.6)
Annual	---	-3 (-1.7)	-1 (-0.6)	-1 (-0.6)	-2 (-1.1)	-1 (-0.6)	-3 (-1.7)	3 (1.7)

Table 121. Cumulative Effects Chronic Low Flow for Pueblo WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	182	201	202	202	202	202	195	201
Feb	181	220	222	222	221	222	217	222
Mar	181	241	256	259	242	256	237	245
Apr	200	227	249	252	235	249	223	239
May	200	227	249	252	235	249	223	239
Jun	271	276	250	251	258	254	257	264
Jul	186	192	187	188	191	186	183	188
Aug	181	192	187	188	191	186	183	188
Sep	181	192	187	188	191	186	183	188
Oct	183	192	187	188	197	186	183	189
Nov	182	193	187	188	192	186	188	193
Dec	182	193	191	192	192	192	188	193
Annual	181	192	187	188	191	186	183	188
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	1 (0.5)	1 (0.5)	1 (0.5)	1 (0.5)	-6 (-3.0)	0 (0.0)
Feb	---	---	2 (0.9)	2 (0.9)	1 (0.5)	2 (0.9)	-3 (-1.4)	2 (0.9)
Mar	---	---	15 (6.2)	18 (7.5)	1 (0.4)	15 (6.2)	-4 (-1.7)	4 (1.7)
Apr	---	---	22 (9.7)	25 (11.0)	8 (3.5)	22 (9.7)	-4 (-1.8)	12 (5.3)
May	---	---	22 (9.7)	25 (11.0)	8 (3.5)	22 (9.7)	-4 (-1.8)	12 (5.3)
Jun	---	---	-26 (-9.4)	-25 (-9.1)	-18 (-6.5)	-22 (-8.0)	-19 (-6.9)	-12 (-4.3)
Jul	---	---	-5 (-2.6)	-4 (-2.1)	-1 (-0.5)	-6 (-3.1)	-9 (-4.7)	-4 (-2.1)
Aug	---	---	-5 (-2.6)	-4 (-2.1)	-1 (-0.5)	-6 (-3.1)	-9 (-4.7)	-4 (-2.1)
Sep	---	---	-5 (-2.6)	-4 (-2.1)	-1 (-0.5)	-6 (-3.1)	-9 (-4.7)	-4 (-2.1)
Oct	---	---	-5 (-2.6)	-4 (-2.1)	5 (2.6)	-6 (-3.1)	-9 (-4.7)	-3 (-1.6)
Nov	---	---	-6 (-3.1)	-5 (-2.6)	-1 (-0.5)	-7 (-3.6)	-5 (-2.6)	0 (0.0)
Dec	---	---	-2 (-1.0)	-1 (-0.5)	-1 (-0.5)	-1 (-0.5)	-5 (-2.6)	0 (0.0)
Annual	---	---	-5 (-2.6)	-4 (-2.1)	-1 (-0.5)	-6 (-3.1)	-9 (-4.7)	-4 (-2.1)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	19 (10.4)	20 (11.0)	20 (11.0)	20 (11.0)	20 (11.0)	13 (7.1)	19 (10.4)
Feb	---	39 (21.5)	41 (22.7)	41 (22.7)	40 (22.1)	41 (22.7)	36 (19.9)	41 (22.7)
Mar	---	60 (33.1)	75 (41.4)	78 (43.1)	61 (33.7)	75 (41.4)	56 (30.9)	64 (35.4)
Apr	---	27 (13.5)	49 (24.5)	52 (26.0)	35 (17.5)	49 (24.5)	23 (11.5)	39 (19.5)
May	---	27 (13.5)	49 (24.5)	52 (26.0)	35 (17.5)	49 (24.5)	23 (11.5)	39 (19.5)
Jun	---	5 (1.8)	-21 (-7.7)	-20 (-7.4)	-13 (-4.8)	-17 (-6.3)	-14 (-5.2)	-7 (-2.6)
Jul	---	6 (3.2)	1 (0.5)	2 (1.1)	5 (2.7)	0 (0.0)	-3 (-1.6)	2 (1.1)
Aug	---	11 (6.1)	6 (3.3)	7 (3.9)	10 (5.5)	5 (2.8)	2 (1.1)	7 (3.9)
Sep	---	11 (6.1)	6 (3.3)	7 (3.9)	10 (5.5)	5 (2.8)	2 (1.1)	7 (3.9)
Oct	---	9 (4.9)	4 (2.2)	5 (2.7)	14 (7.7)	3 (1.6)	0 (0.0)	6 (3.3)
Nov	---	11 (6.0)	5 (2.7)	6 (3.3)	10 (5.5)	4 (2.2)	6 (3.3)	11 (6.0)
Dec	---	11 (6.0)	9 (4.9)	10 (5.5)	10 (5.5)	10 (5.5)	6 (3.3)	11 (6.0)
Annual	---	11 (6.1)	6 (3.3)	7 (3.9)	10 (5.5)	5 (2.8)	2 (1.1)	7 (3.9)

The City of Rocky Ford WWTF discharges to the Arkansas River northeast of Rocky Ford. Link DSRF of the hydrologic model was used to evaluate potential effects on chronic low flows. Table 122 presents chronic monthly low flows for direct effects, and Table 123 shows flows for cumulative effects.

The direct effects annual chronic low flows increase for all alternatives compared to the No Action, up to 47 percent. The cumulative effects annual chronic low flow would not change for all alternatives, except for Master Contact Only which would increase flow by 12 percent. Compared to existing conditions, cumulative chronic low flow decreases more than 10 percent in for all alternatives except Master Contract Only.

The permitted flow of the Rocky Ford WWTF is 1.2 MGD or about 1.9 cfs. Projected permitted flow in 2070 would be 1.4 MGD (using projected demand growth of 16 percent), or 2.2 cfs. Direct effects dilution flows for all alternatives would be greater than 90 percent. Cumulative effects dilution flows for all alternatives would be about 88 percent.

The City of La Junta WWTF discharges to King Arroyo, a tributary to the Arkansas River downstream of La Junta. Link DSLJ of the hydrologic model, on the Arkansas River downstream of King Arroyo, was used to evaluate potential effects on chronic low flows. Table 124 lists chronic low flows for direct effects, and Table 125 presents flows for cumulative effects.

Under direct effects, all alternatives except Master Contract Only would reduce annual chronic low flows up to 73 percent, relative to the No Action, which would have a minor adverse effect. Under cumulative effects, the JUP North and River South alternatives would decrease annual chronic low flows more than 10 percent. Compared to existing conditions, all alternatives decrease annual chronic low in direct effects.

The permitted flow of this WWTF is 2.3 MGD or about 3.6 cfs. Projected permitted flow in 2070 would be 2.7 MGD (using projected demand growth of 19 percent), or 4.2 cfs. Direct effects dilution flows for all alternatives range between 49 and 77 percent. Cumulative effects dilution flows for all alternatives would range between 72 and 85 percent.

Table 122. Direct Effects Chronic Low Flow for Rocky Ford WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	20	17	23	23	22	23	23	25
Feb	20	24	23	23	22	23	23	26
Mar	23	28	24	24	26	24	23	26
Apr	58	69	67	66	69	67	67	64
May	81	75	73	71	67	73	72	73
Jun	39	48	49	48	47	50	50	48
Jul	19	18	25	28	24	28	29	25
Aug	19	17	23	23	22	23	23	25
Sep	19	17	23	23	22	23	23	25
Oct	27	22	23	23	23	24	24	25
Nov	21	17	25	25	23	25	25	26
Dec	20	17	24	23	22	23	24	25
Annual	19	17	23	23	22	23	23	25
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	6 (35.3)	6 (35.3)	5 (29.4)	6 (35.3)	6 (35.3)	8 (47.1)
Feb	---	---	-1 (-4.2)	-1 (-4.2)	-2 (-8.3)	-1 (-4.2)	-1 (-4.2)	2 (8.3)
Mar	---	---	-4 (-14.3)	-4 (-14.3)	-2 (-7.1)	-4 (-14.3)	-5 (-17.9)	-2 (-7.1)
Apr	---	---	-2 (-2.9)	-3 (-4.3)	0 (0.0)	-2 (-2.9)	-2 (-2.9)	-5 (-7.2)
May	---	---	-2 (-2.7)	-4 (-5.3)	-8 (-10.7)	-2 (-2.7)	-3 (-4.0)	-2 (-2.7)
Jun	---	---	1 (2.1)	0 (0.0)	-1 (-2.1)	2 (4.2)	2 (4.2)	0 (0.0)
Jul	---	---	7 (38.9)	10 (55.6)	6 (33.3)	10 (55.6)	11 (61.1)	7 (38.9)
Aug	---	---	6 (35.3)	6 (35.3)	5 (29.4)	6 (35.3)	6 (35.3)	8 (47.1)
Sep	---	---	6 (35.3)	6 (35.3)	5 (29.4)	6 (35.3)	6 (35.3)	8 (47.1)
Oct	---	---	1 (4.5)	1 (4.5)	1 (4.5)	2 (9.1)	2 (9.1)	3 (13.6)
Nov	---	---	8 (47.1)	8 (47.1)	6 (35.3)	8 (47.1)	8 (47.1)	9 (52.9)
Dec	---	---	7 (41.2)	6 (35.3)	5 (29.4)	6 (35.3)	7 (41.2)	8 (47.1)
Annual	---	---	6 (35.3)	6 (35.3)	5 (29.4)	6 (35.3)	6 (35.3)	8 (47.1)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	-3 (-15.0)	3 (15.0)	3 (15.0)	2 (10.0)	3 (15.0)	3 (15.0)	5 (25.0)
Feb	---	4 (20.0)	3 (15.0)	3 (15.0)	2 (10.0)	3 (15.0)	3 (15.0)	6 (30.0)
Mar	---	5 (21.7)	1 (4.3)	1 (4.3)	3 (13.0)	1 (4.3)	0 (0.0)	3 (13.0)
Apr	---	11 (19.0)	9 (15.5)	8 (13.8)	11 (19.0)	9 (15.5)	9 (15.5)	6 (10.3)
May	---	-6 (-7.4)	-8 (-9.9)	-10 (-12.3)	-14 (-17.3)	-8 (-9.9)	-9 (-11.1)	-8 (-9.9)
Jun	---	9 (23.1)	10 (25.6)	9 (23.1)	8 (20.5)	11 (28.2)	11 (28.2)	9 (23.1)
Jul	---	-1 (-5.3)	6 (31.6)	9 (47.4)	5 (26.3)	9 (47.4)	10 (52.6)	6 (31.6)
Aug	---	-2 (-10.5)	4 (21.1)	4 (21.1)	3 (15.8)	4 (21.1)	4 (21.1)	6 (31.6)
Sep	---	-2 (-10.5)	4 (21.1)	4 (21.1)	3 (15.8)	4 (21.1)	4 (21.1)	6 (31.6)
Oct	---	-5 (-18.5)	-4 (-14.8)	-4 (-14.8)	-4 (-14.8)	-3 (-11.1)	-3 (-11.1)	-2 (-7.4)
Nov	---	-4 (-19.0)	4 (19.0)	4 (19.0)	2 (9.5)	4 (19.0)	4 (19.0)	5 (23.8)
Dec	---	-3 (-15.0)	4 (20.0)	3 (15.0)	2 (10.0)	3 (15.0)	4 (20.0)	5 (25.0)
Annual	---	-2 (-10.5)	4 (21.1)	4 (21.1)	3 (15.8)	4 (21.1)	4 (21.1)	6 (31.6)

Table 123. Cumulative Effects Chronic Low Flow for Rocky Ford WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	20	16	16	16	16	16	16	18
Feb	20	19	22	22	22	22	21	20
Mar	23	25	23	23	23	23	23	25
Apr	58	63	51	51	67	50	65	61
May	81	126	136	136	136	136	137	109
Jun	39	27	38	34	40	26	45	27
Jul	19	17	16	16	16	16	16	18
Aug	19	16	16	16	16	16	16	18
Sep	19	16	16	16	16	16	16	18
Oct	27	23	18	17	17	18	17	30
Nov	21	16	18	18	18	18	18	18
Dec	20	16	16	16	16	16	16	18
Annual	19	16	16	16	16	16	16	18
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (12.5)
Feb	---	---	3 (15.8)	3 (15.8)	3 (15.8)	3 (15.8)	2 (10.5)	1 (5.3)
Mar	---	---	-2 (-8.0)	-2 (-8.0)	-2 (-8.0)	-2 (-8.0)	-2 (-8.0)	0 (0.0)
Apr	---	---	-12 (-19.0)	-12 (-19.0)	4 (6.3)	-13 (-20.6)	2 (3.2)	-2 (-3.2)
May	---	---	10 (7.9)	10 (7.9)	10 (7.9)	10 (7.9)	11 (8.7)	-17 (-13.5)
Jun	---	---	11 (40.7)	7 (25.9)	13 (48.1)	-1 (-3.7)	18 (66.7)	0 (0.0)
Jul	---	---	-1 (-5.9)	-1 (-5.9)	-1 (-5.9)	-1 (-5.9)	-1 (-5.9)	1 (5.9)
Aug	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (12.5)
Sep	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (12.5)
Oct	---	---	-5 (-21.7)	-6 (-26.1)	-6 (-26.1)	-5 (-21.7)	-6 (-26.1)	7 (30.4)
Nov	---	---	2 (12.5)	2 (12.5)	2 (12.5)	2 (12.5)	2 (12.5)	2 (12.5)
Dec	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (12.5)
Annual	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (12.5)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	-4 (-20.0)	-4 (-20.0)	-4 (-20.0)	-4 (-20.0)	-4 (-20.0)	-4 (-20.0)	-2 (-10.0)
Feb	---	-1 (-5.0)	2 (10.0)	2 (10.0)	2 (10.0)	2 (10.0)	1 (5.0)	0 (0.0)
Mar	---	2 (8.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (8.7)
Apr	---	5 (8.6)	-7 (-12.1)	-7 (-12.1)	9 (15.5)	-8 (-13.8)	7 (12.1)	3 (5.2)
May	---	45 (55.6)	55 (67.9)	55 (67.9)	55 (67.9)	55 (67.9)	56 (69.1)	28 (34.6)
Jun	---	-12 (-30.8)	-1 (-2.6)	-5 (-12.8)	1 (2.6)	-13 (-33.3)	6 (15.4)	-12 (-30.8)
Jul	---	-2 (-10.5)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-1 (-5.3)
Aug	---	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-1 (-5.3)
Sep	---	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-1 (-5.3)
Oct	---	-4 (-14.8)	-9 (-33.3)	-10 (-37.0)	-10 (-37.0)	-9 (-33.3)	-10 (-37.0)	3 (11.1)
Nov	---	-5 (-23.8)	-3 (-14.3)	-3 (-14.3)	-3 (-14.3)	-3 (-14.3)	-3 (-14.3)	-3 (-14.3)
Dec	---	-4 (-20.0)	-4 (-20.0)	-4 (-20.0)	-4 (-20.0)	-4 (-20.0)	-4 (-20.0)	-2 (-10.0)
Annual	---	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-3 (-15.8)	-1 (-5.3)

Table 124. Direct Effects Chronic Low Flow for La Junta WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	54	54	55	55	54	55	55	54
Feb	28	35	7	8	4	7	7	14
Mar	22	24	7	8	4	7	7	14
Apr	22	23	7	8	4	7	7	14
May	22	15	24	24	23	24	25	14
Jun	22	15	25	24	25	25	25	14
Jul	31	29	34	33	34	34	33	29
Aug	39	28	38	38	41	39	41	27
Sep	37	15	36	36	19	35	31	27
Oct	28	15	7	8	4	7	7	24
Nov	28	15	7	8	4	7	7	24
Dec	38	37	7	8	13	7	7	39
Annual	22	15	7	8	4	7	7	14
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	1 (1.9)	1 (1.9)	0 (0.0)	1 (1.9)	1 (1.9)	0 (0.0)
Feb	---	---	-28 (-80.0)	-27 (-77.1)	-31 (-88.6)	-28 (-80.0)	-28 (-80.0)	-21 (-60.0)
Mar	---	---	-17 (-70.8)	-16 (-66.7)	-20 (-83.3)	-17 (-70.8)	-17 (-70.8)	-10 (-41.7)
Apr	---	---	-16 (-69.6)	-15 (-65.2)	-19 (-82.6)	-16 (-69.6)	-16 (-69.6)	-9 (-39.1)
May	---	---	9 (60.0)	9 (60.0)	8 (53.3)	9 (60.0)	10 (66.7)	-1 (-6.7)
Jun	---	---	10 (66.7)	9 (60.0)	10 (66.7)	10 (66.7)	10 (66.7)	-1 (-6.7)
Jul	---	---	5 (17.2)	4 (13.8)	5 (17.2)	5 (17.2)	4 (13.8)	0 (0.0)
Aug	---	---	10 (35.7)	10 (35.7)	13 (46.4)	11 (39.3)	13 (46.4)	-1 (-3.6)
Sep	---	---	21 (140.0)	21 (140.0)	4 (26.7)	20 (133.3)	16 (106.7)	12 (80.0)
Oct	---	---	-8 (-53.3)	-7 (-46.7)	-11 (-73.3)	-8 (-53.3)	-8 (-53.3)	9 (60.0)
Nov	---	---	-8 (-53.3)	-7 (-46.7)	-11 (-73.3)	-8 (-53.3)	-8 (-53.3)	9 (60.0)
Dec	---	---	-30 (-81.1)	-29 (-78.4)	-24 (-64.9)	-30 (-81.1)	-30 (-81.1)	2 (5.4)
Annual	---	---	-8 (-53.3)	-7 (-46.7)	-11 (-73.3)	-8 (-53.3)	-8 (-53.3)	-1 (-6.7)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	0 (0.0)	1 (1.9)	1 (1.9)	0 (0.0)	1 (1.9)	1 (1.9)	0 (0.0)
Feb	---	7 (25.0)	-21 (-75.0)	-20 (-71.4)	-24 (-85.7)	-21 (-75.0)	-21 (-75.0)	-14 (-50.0)
Mar	---	2 (9.1)	-15 (-68.2)	-14 (-63.6)	-18 (-81.8)	-15 (-68.2)	-15 (-68.2)	-8 (-36.4)
Apr	---	1 (4.5)	-15 (-68.2)	-14 (-63.6)	-18 (-81.8)	-15 (-68.2)	-15 (-68.2)	-8 (-36.4)
May	---	-7 (-31.8)	2 (9.1)	2 (9.1)	1 (4.5)	2 (9.1)	3 (13.6)	-8 (-36.4)
Jun	---	-7 (-31.8)	3 (13.6)	2 (9.1)	3 (13.6)	3 (13.6)	3 (13.6)	-8 (-36.4)
Jul	---	-2 (-6.5)	3 (9.7)	2 (6.5)	3 (9.7)	3 (9.7)	2 (6.5)	-2 (-6.5)
Aug	---	-11 (-28.2)	-1 (-2.6)	-1 (-2.6)	2 (5.1)	0 (0.0)	2 (5.1)	-12 (-30.8)
Sep	---	-22 (-59.5)	-1 (-2.7)	-1 (-2.7)	-18 (-48.6)	-2 (-5.4)	-6 (-16.2)	-10 (-27.0)
Oct	---	-13 (-46.4)	-21 (-75.0)	-20 (-71.4)	-24 (-85.7)	-21 (-75.0)	-21 (-75.0)	-4 (-14.3)
Nov	---	-13 (-46.4)	-21 (-75.0)	-20 (-71.4)	-24 (-85.7)	-21 (-75.0)	-21 (-75.0)	-4 (-14.3)
Dec	---	-1 (-2.6)	-31 (-81.6)	-30 (-78.9)	-25 (-65.8)	-31 (-81.6)	-31 (-81.6)	1 (2.6)
Annual	---	-7 (-31.8)	-15 (-68.2)	-14 (-63.6)	-18 (-81.8)	-15 (-68.2)	-15 (-68.2)	-8 (-36.4)

Table 125. Cumulative Effects Chronic Low Flow for La Junta WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	54	61	61	61	61	61	61	61
Feb	28	20	18	20	12	18	12	24
Mar	22	20	18	20	11	18	11	24
Apr	22	20	18	20	11	18	11	24
May	22	21	22	20	23	22	21	24
Jun	22	28	41	41	44	40	43	27
Jul	31	28	34	34	34	34	34	27
Aug	39	27	30	30	30	30	30	28
Sep	37	23	18	22	24	18	24	28
Oct	28	20	18	22	11	18	11	26
Nov	28	20	19	24	11	19	11	26
Dec	38	37	40	40	11	40	11	41
Annual	22	20	18	20	11	18	11	24
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Feb	---	---	-2 (-10.0)	0 (0.0)	-8 (-40.0)	-2 (-10.0)	-8 (-40.0)	4 (20.0)
Mar	---	---	-2 (-10.0)	0 (0.0)	-9 (-45.0)	-2 (-10.0)	-9 (-45.0)	4 (20.0)
Apr	---	---	-2 (-10.0)	0 (0.0)	-9 (-45.0)	-2 (-10.0)	-9 (-45.0)	4 (20.0)
May	---	---	1 (4.8)	-1 (-4.8)	2 (9.5)	1 (4.8)	0 (0.0)	3 (14.3)
Jun	---	---	13 (46.4)	13 (46.4)	16 (57.1)	12 (42.9)	15 (53.6)	-1 (-3.6)
Jul	---	---	6 (21.4)	6 (21.4)	6 (21.4)	6 (21.4)	6 (21.4)	-1 (-3.6)
Aug	---	---	3 (11.1)	3 (11.1)	3 (11.1)	3 (11.1)	3 (11.1)	1 (3.7)
Sep	---	---	-5 (-21.7)	-1 (-4.3)	1 (4.3)	-5 (-21.7)	1 (4.3)	5 (21.7)
Oct	---	---	-2 (-10.0)	2 (10.0)	-9 (-45.0)	-2 (-10.0)	-9 (-45.0)	6 (30.0)
Nov	---	---	-1 (-5.0)	4 (20.0)	-9 (-45.0)	-1 (-5.0)	-9 (-45.0)	6 (30.0)
Dec	---	---	3 (8.1)	3 (8.1)	-26 (-70.3)	3 (8.1)	-26 (-70.3)	4 (10.8)
Annual	---	---	-2 (-10.0)	0 (0.0)	-9 (-45.0)	-2 (-10.0)	-9 (-45.0)	4 (20.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	7 (13.0)	7 (13.0)	7 (13.0)	7 (13.0)	7 (13.0)	7 (13.0)	7 (13.0)
Feb	---	-8 (-28.6)	-10 (-35.7)	-8 (-28.6)	-16 (-57.1)	-10 (-35.7)	-16 (-57.1)	-4 (-14.3)
Mar	---	-2 (-9.1)	-4 (-18.2)	-2 (-9.1)	-11 (-50.0)	-4 (-18.2)	-11 (-50.0)	2 (9.1)
Apr	---	-2 (-9.1)	-4 (-18.2)	-2 (-9.1)	-11 (-50.0)	-4 (-18.2)	-11 (-50.0)	2 (9.1)
May	---	-1 (-4.5)	0 (0.0)	-2 (-9.1)	1 (4.5)	0 (0.0)	-1 (-4.5)	2 (9.1)
Jun	---	6 (27.3)	19 (86.4)	19 (86.4)	22 (100.0)	18 (81.8)	21 (95.5)	5 (22.7)
Jul	---	-3 (-9.7)	3 (9.7)	3 (9.7)	3 (9.7)	3 (9.7)	3 (9.7)	-4 (-12.9)
Aug	---	-12 (-30.8)	-9 (-23.1)	-9 (-23.1)	-9 (-23.1)	-9 (-23.1)	-9 (-23.1)	-11 (-28.2)
Sep	---	-14 (-37.8)	-19 (-51.4)	-15 (-40.5)	-13 (-35.1)	-19 (-51.4)	-13 (-35.1)	-9 (-24.3)
Oct	---	-8 (-28.6)	-10 (-35.7)	-6 (-21.4)	-17 (-60.7)	-10 (-35.7)	-17 (-60.7)	-2 (-7.1)
Nov	---	-8 (-28.6)	-9 (-32.1)	-4 (-14.3)	-17 (-60.7)	-9 (-32.1)	-17 (-60.7)	-2 (-7.1)
Dec	---	-1 (-2.6)	2 (5.3)	2 (5.3)	-27 (-71.1)	2 (5.3)	-27 (-71.1)	3 (7.9)
Annual	---	-2 (-9.1)	-4 (-18.2)	-2 (-9.1)	-11 (-50.0)	-4 (-18.2)	-11 (-50.0)	2 (9.1)

Fountain Creek Basin Major WWTF. The Security Sanitation District WWTF discharges to Fountain Creek southwest of the community of Security. Link LNODE6670 of the hydrologic model was used to evaluate potential effects on chronic low flows. Table 126 presents chronic low flows for direct effects and Table 127 presents flows for cumulative effects.

None of the alternatives would have direct or cumulative effects that would cause a reduction in flow of ten percent or more compared to the No Action Alternative or existing conditions.

Effects would be negligible. Under cumulative effects, there would be a substantial increase in chronic low flow.

The permitted flow of this WWTF is 2.4 mgd or about 3.7 cfs. Projected permitted flow in 2060 is 3.2 MGD (using projected demand growth of 35 percent), or 5 cfs. Dilution flow for all alternatives in direct and cumulative effects would be greater than 90 percent.

The Widefield Water and Sanitation District and U.S. Department of the Army – Fort Carson WWTFs discharge to Fountain Creek southwest of the community of Widefield. Link DFSCSEC of the hydrologic model was used to evaluate potential effects on chronic low flows. Table 128 displays chronic low flows for direct effects, and Table 129 presents flows for cumulative effects.

None of the alternatives would have direct or cumulative effects that would cause a reduction in flow of ten percent or more compared to the No Action Alternative or existing conditions. Effects would be negligible. Under cumulative effects, there would be a substantial increase in chronic low flow.

The permitted flow of the Widefield WWTF is 2.5 mgd or about 3.9 cfs. The permitted flow for the Fort Carson WWTF is 4.0 MGD or about 6.2 cfs. Projected permitted flow in 2060 for the combined facilities is 9.2 MGD (using projected demand growth of 109 percent), or 14.3 cfs. Dilution flow for all alternatives would be 78 percent for direct effects, and 91 percent for cumulative effects.

The Fountain Sanitation District WWTF discharges to Fountain Creek south of the City of Fountain. Link DSJCC of the hydrologic model was used to evaluate potential effects on chronic low flows. Table 130 addresses chronic low flows for direct effects, and Table 131 presents flows for cumulative effects.

None of the alternatives would have direct or cumulative effects that would cause a reduction in flow of ten percent or more compared to the No Action Alternative or existing conditions. Effects would be negligible. Under cumulative effects, there would be a substantial increase in chronic low flow.

The permitted flow of this WWTF is 1.9 mgd or about 2.9 cfs. Projected permitted flow in 2060 is 5.7 MGD (using projected demand growth of 201 percent), or 8.9 cfs. Dilution flow for all alternatives in direct and cumulative effects would be 88 percent.

Table 126. Direct Effects Chronic Low Flow for Security WWTF

Month	Existing Conditions	No Action		Comanche South		Pueblo Dam South		JUP North		Pueblo Dam North		River South		Master Contract Only	
Simulated Streamflow (cfs)															
Jan	42	43		43		43		43		43		43		43	
Feb	43	46		46		46		46		46		46		46	
Mar	63	63		63		63		63		63		63		63	
Apr	68	71		71		71		71		71		71		71	
May	68	71		71		71		71		71		71		71	
Jun	59	62		62		62		62		62		62		62	
Jul	56	58		58		58		58		58		58		58	
Aug	56	58		58		58		58		58		58		58	
Sep	64	65		66		66		66		66		65		65	
Oct	55	57		57		57		57		57		57		57	
Nov	42	43		43		43		43		43		43		43	
Dec	42	43		43		43		43		43		43		43	
Annual	42	43		43		43		43		43		43		43	
Change in Streamflow Compared to No Action [cfs (%)]															
Jan	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Feb	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Mar	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Apr	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
May	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Jun	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Jul	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Aug	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Sep	---	---		1	(1.5)	1	(1.5)	1	(1.5)	1	(1.5)	0	(0.0)	0	(0.0)
Oct	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Nov	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Dec	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Annual	---	---		0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]															
Jan	---	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)
Feb	---	3	(7.0)	3	(7.0)	3	(7.0)	3	(7.0)	3	(7.0)	3	(7.0)	3	(7.0)
Mar	---	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Apr	---	3	(4.4)	3	(4.4)	3	(4.4)	3	(4.4)	3	(4.4)	3	(4.4)	3	(4.4)
May	---	3	(4.4)	3	(4.4)	3	(4.4)	3	(4.4)	3	(4.4)	3	(4.4)	3	(4.4)
Jun	---	3	(5.1)	3	(5.1)	3	(5.1)	3	(5.1)	3	(5.1)	3	(5.1)	3	(5.1)
Jul	---	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)
Aug	---	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)
Sep	---	1	(1.6)	2	(3.1)	2	(3.1)	2	(3.1)	2	(3.1)	1	(1.6)	1	(1.6)
Oct	---	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)	2	(3.6)
Nov	---	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)
Dec	---	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)
Annual	---	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)	1	(2.4)

Table 127. Cumulative Effects Chronic Low Flow for Security WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	42	134	134	134	134	134	135	134
Feb	43	140	140	140	140	140	142	140
Mar	63	162	162	162	162	162	162	162
Apr	68	162	162	162	162	162	162	162
May	68	164	164	164	164	164	164	164
Jun	59	166	166	166	166	166	166	166
Jul	56	161	161	161	161	161	161	161
Aug	56	161	161	161	161	161	161	161
Sep	64	154	154	154	155	154	155	155
Oct	55	153	152	152	153	152	153	153
Nov	42	134	134	134	134	134	135	134
Dec	42	134	134	134	134	134	135	134
Annual	42	134	134	134	134	134	135	134
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)
Feb	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.4)	0 (0.0)
Mar	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Apr	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
May	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Jun	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Jul	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Aug	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sep	---	---	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	1 (0.6)	1 (0.6)
Oct	---	---	-1 (-0.7)	-1 (-0.7)	0 (0.0)	-1 (-0.7)	0 (0.0)	0 (0.0)
Nov	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)
Dec	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)
Annual	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	92 (219.0)	92 (219.0)	92 (219.0)	92 (219.0)	92 (219.0)	93 (221.4)	92 (219.0)
Feb	---	97 (225.6)	97 (225.6)	97 (225.6)	97 (225.6)	97 (225.6)	99 (230.2)	97 (225.6)
Mar	---	99 (157.1)	99 (157.1)	99 (157.1)	99 (157.1)	99 (157.1)	99 (157.1)	99 (157.1)
Apr	---	94 (138.2)	94 (138.2)	94 (138.2)	94 (138.2)	94 (138.2)	94 (138.2)	94 (138.2)
May	---	96 (141.2)	96 (141.2)	96 (141.2)	96 (141.2)	96 (141.2)	96 (141.2)	96 (141.2)
Jun	---	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)
Jul	---	105 (187.5)	105 (187.5)	105 (187.5)	105 (187.5)	105 (187.5)	105 (187.5)	105 (187.5)
Aug	---	105 (187.5)	105 (187.5)	105 (187.5)	105 (187.5)	105 (187.5)	105 (187.5)	105 (187.5)
Sep	---	90 (140.6)	90 (140.6)	90 (140.6)	91 (142.2)	90 (140.6)	91 (142.2)	91 (142.2)
Oct	---	98 (178.2)	97 (176.4)	97 (176.4)	98 (178.2)	97 (176.4)	98 (178.2)	98 (178.2)
Nov	---	92 (219.0)	92 (219.0)	92 (219.0)	92 (219.0)	92 (219.0)	93 (221.4)	92 (219.0)
Dec	---	92 (219.0)	92 (219.0)	92 (219.0)	92 (219.0)	92 (219.0)	93 (221.4)	92 (219.0)
Annual	---	92 (219.0)	92 (219.0)	92 (219.0)	92 (219.0)	92 (219.0)	93 (221.4)	92 (219.0)

Table 128. Direct Effects Chronic Low Flow for Widefield and Fort Carson WWTFs

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	50	52	52	52	52	52	52	52
Feb	50	55	55	55	55	55	55	55
Mar	73	73	74	74	73	74	74	74
Apr	72	72	73	73	72	73	74	73
May	72	72	73	73	72	73	74	73
Jun	63	68	68	68	68	68	68	68
Jul	59	63	63	63	63	63	63	63
Aug	59	63	63	63	63	63	63	63
Sep	68	70	71	71	70	71	70	70
Oct	65	68	68	68	68	68	68	68
Nov	50	52	52	52	52	52	52	52
Dec	50	52	52	52	52	52	52	52
Annual	50	52	52	52	52	52	52	52
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Feb	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Mar	---	---	1 (1.4)	1 (1.4)	0 (0.0)	1 (1.4)	1 (1.4)	1 (1.4)
Apr	---	---	1 (1.4)	1 (1.4)	0 (0.0)	1 (1.4)	2 (2.8)	1 (1.4)
May	---	---	1 (1.4)	1 (1.4)	0 (0.0)	1 (1.4)	2 (2.8)	1 (1.4)
Jun	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Jul	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Aug	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sep	---	---	1 (1.4)	1 (1.4)	0 (0.0)	1 (1.4)	0 (0.0)	0 (0.0)
Oct	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Nov	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dec	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Annual	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)
Feb	---	5 (10.0)	5 (10.0)	5 (10.0)	5 (10.0)	5 (10.0)	5 (10.0)	5 (10.0)
Mar	---	0 (0.0)	1 (1.4)	1 (1.4)	0 (0.0)	1 (1.4)	1 (1.4)	1 (1.4)
Apr	---	0 (0.0)	1 (1.4)	1 (1.4)	0 (0.0)	1 (1.4)	2 (2.8)	1 (1.4)
May	---	0 (0.0)	1 (1.4)	1 (1.4)	0 (0.0)	1 (1.4)	2 (2.8)	1 (1.4)
Jun	---	5 (7.9)	5 (7.9)	5 (7.9)	5 (7.9)	5 (7.9)	5 (7.9)	5 (7.9)
Jul	---	4 (6.8)	4 (6.8)	4 (6.8)	4 (6.8)	4 (6.8)	4 (6.8)	4 (6.8)
Aug	---	4 (6.8)	4 (6.8)	4 (6.8)	4 (6.8)	4 (6.8)	4 (6.8)	4 (6.8)
Sep	---	2 (2.9)	3 (4.4)	3 (4.4)	2 (2.9)	3 (4.4)	2 (2.9)	2 (2.9)
Oct	---	3 (4.6)	3 (4.6)	3 (4.6)	3 (4.6)	3 (4.6)	3 (4.6)	3 (4.6)
Nov	---	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)
Dec	---	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)
Annual	---	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)	2 (4.0)

Table 129. Cumulative Effects Chronic Low Flow for Widefield and Fort Carson WWTFs

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	50	143	144	143	144	144	143	144
Feb	50	147	150	150	148	150	152	150
Mar	73	164	165	165	164	165	165	165
Apr	72	164	165	165	164	165	165	165
May	72	165	165	165	164	165	165	165
Jun	63	171	171	171	171	171	171	171
Jul	59	166	166	166	166	166	166	166
Aug	59	166	166	166	166	166	166	166
Sep	68	159	158	158	159	158	159	159
Oct	65	158	157	157	158	157	158	158
Nov	50	143	144	143	144	144	143	144
Dec	50	143	144	143	144	144	143	144
Annual	50	143	144	143	144	144	143	144
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	1 (0.7)	0 (0.0)	1 (0.7)	1 (0.7)	0 (0.0)	1 (0.7)
Feb	---	---	3 (2.0)	3 (2.0)	1 (0.7)	3 (2.0)	5 (3.4)	3 (2.0)
Mar	---	---	1 (0.6)	1 (0.6)	0 (0.0)	1 (0.6)	1 (0.6)	1 (0.6)
Apr	---	---	1 (0.6)	1 (0.6)	0 (0.0)	1 (0.6)	1 (0.6)	1 (0.6)
May	---	---	0 (0.0)	0 (0.0)	-1 (-0.6)	0 (0.0)	0 (0.0)	0 (0.0)
Jun	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Jul	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Aug	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sep	---	---	-1 (-0.6)	-1 (-0.6)	0 (0.0)	-1 (-0.6)	0 (0.0)	0 (0.0)
Oct	---	---	-1 (-0.6)	-1 (-0.6)	0 (0.0)	-1 (-0.6)	0 (0.0)	0 (0.0)
Nov	---	---	1 (0.7)	0 (0.0)	1 (0.7)	1 (0.7)	0 (0.0)	1 (0.7)
Dec	---	---	1 (0.7)	0 (0.0)	1 (0.7)	1 (0.7)	0 (0.0)	1 (0.7)
Annual	---	---	1 (0.7)	0 (0.0)	1 (0.7)	1 (0.7)	0 (0.0)	1 (0.7)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	93 (186.0)	94 (188.0)	93 (186.0)	94 (188.0)	94 (188.0)	93 (186.0)	94 (188.0)
Feb	---	97 (194.0)	100 (200.0)	100 (200.0)	98 (196.0)	100 (200.0)	102 (204.0)	100 (200.0)
Mar	---	91 (124.7)	92 (126.0)	92 (126.0)	91 (124.7)	92 (126.0)	92 (126.0)	92 (126.0)
Apr	---	92 (127.8)	93 (129.2)	93 (129.2)	92 (127.8)	93 (129.2)	93 (129.2)	93 (129.2)
May	---	93 (129.2)	93 (129.2)	93 (129.2)	92 (127.8)	93 (129.2)	93 (129.2)	93 (129.2)
Jun	---	108 (171.4)	108 (171.4)	108 (171.4)	108 (171.4)	108 (171.4)	108 (171.4)	108 (171.4)
Jul	---	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)
Aug	---	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)	107 (181.4)
Sep	---	91 (133.8)	90 (132.4)	90 (132.4)	91 (133.8)	90 (132.4)	91 (133.8)	91 (133.8)
Oct	---	93 (143.1)	92 (141.5)	92 (141.5)	93 (143.1)	92 (141.5)	93 (143.1)	93 (143.1)
Nov	---	93 (186.0)	94 (188.0)	93 (186.0)	94 (188.0)	94 (188.0)	93 (186.0)	94 (188.0)
Dec	---	93 (186.0)	94 (188.0)	93 (186.0)	94 (188.0)	94 (188.0)	93 (186.0)	94 (188.0)
Annual	---	93 (186.0)	94 (188.0)	93 (186.0)	94 (188.0)	94 (188.0)	93 (186.0)	94 (188.0)

Table 130. Direct Effects Chronic Low Flow for Fountain Sanitation District WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	58	64	64	64	64	64	64	64
Feb	58	66	66	66	66	66	66	66
Mar	72	78	79	79	78	79	79	79
Apr	70	77	78	78	77	78	78	78
May	70	77	78	78	77	78	78	78
Jun	66	74	74	74	74	74	74	74
Jul	63	70	70	70	70	70	70	70
Aug	63	70	70	70	70	70	70	70
Sep	71	77	77	77	77	77	77	77
Oct	70	76	77	77	76	77	77	76
Nov	58	64	64	64	64	64	64	64
Dec	58	64	64	64	64	64	64	64
Annual	58	64	64	64	64	64	64	64
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Feb	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Mar	---	---	1 (1.3)	1 (1.3)	0 (0.0)	1 (1.3)	1 (1.3)	1 (1.3)
Apr	---	---	1 (1.3)	1 (1.3)	0 (0.0)	1 (1.3)	1 (1.3)	1 (1.3)
May	---	---	1 (1.3)	1 (1.3)	0 (0.0)	1 (1.3)	1 (1.3)	1 (1.3)
Jun	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Jul	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Aug	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sep	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Oct	---	---	1 (1.3)	1 (1.3)	0 (0.0)	1 (1.3)	1 (1.3)	0 (0.0)
Nov	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dec	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Annual	---	---	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)
Feb	---	8 (13.8)	8 (13.8)	8 (13.8)	8 (13.8)	8 (13.8)	8 (13.8)	8 (13.8)
Mar	---	6 (8.3)	7 (9.7)	7 (9.7)	6 (8.3)	7 (9.7)	7 (9.7)	7 (9.7)
Apr	---	7 (10.0)	8 (11.4)	8 (11.4)	7 (10.0)	8 (11.4)	8 (11.4)	8 (11.4)
May	---	7 (10.0)	8 (11.4)	8 (11.4)	7 (10.0)	8 (11.4)	8 (11.4)	8 (11.4)
Jun	---	8 (12.1)	8 (12.1)	8 (12.1)	8 (12.1)	8 (12.1)	8 (12.1)	8 (12.1)
Jul	---	7 (11.1)	7 (11.1)	7 (11.1)	7 (11.1)	7 (11.1)	7 (11.1)	7 (11.1)
Aug	---	7 (11.1)	7 (11.1)	7 (11.1)	7 (11.1)	7 (11.1)	7 (11.1)	7 (11.1)
Sep	---	6 (8.5)	6 (8.5)	6 (8.5)	6 (8.5)	6 (8.5)	6 (8.5)	6 (8.5)
Oct	---	6 (8.6)	7 (10.0)	7 (10.0)	6 (8.6)	7 (10.0)	7 (10.0)	6 (8.6)
Nov	---	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)
Dec	---	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)
Annual	---	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)	6 (10.3)

Table 131. Cumulative Effects Chronic Low Flow for Fountain Sanitation District WWTF

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	58	64	63	63	64	63	64	66
Feb	58	64	66	66	64	66	66	66
Mar	72	111	105	105	102	106	112	111
Apr	70	109	115	118	108	116	112	111
May	70	109	128	131	114	129	112	118
Jun	66	146	135	137	137	138	149	144
Jul	63	91	91	91	90	91	92	90
Aug	63	88	91	91	87	89	89	88
Sep	71	83	79	79	79	78	83	83
Oct	70	78	78	78	79	77	79	79
Nov	58	64	63	63	64	63	64	66
Dec	58	64	63	63	64	63	64	66
Annual	58	64	63	63	64	63	64	66
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	-1 (-1.6)	-1 (-1.6)	0 (0.0)	-1 (-1.6)	0 (0.0)	2 (3.1)
Feb	---	---	2 (3.1)	2 (3.1)	0 (0.0)	2 (3.1)	2 (3.1)	2 (3.1)
Mar	---	---	-6 (-5.4)	-6 (-5.4)	-9 (-8.1)	-5 (-4.5)	1 (0.9)	0 (0.0)
Apr	---	---	6 (5.5)	9 (8.3)	-1 (-0.9)	7 (6.4)	3 (2.8)	2 (1.8)
May	---	---	19 (17.4)	22 (20.2)	5 (4.6)	20 (18.3)	3 (2.8)	9 (8.3)
Jun	---	---	-11 (-7.5)	-9 (-6.2)	-9 (-6.2)	-8 (-5.5)	3 (2.1)	-2 (-1.4)
Jul	---	---	0 (0.0)	0 (0.0)	-1 (-1.1)	0 (0.0)	1 (1.1)	-1 (-1.1)
Aug	---	---	3 (3.4)	3 (3.4)	-1 (-1.1)	1 (1.1)	1 (1.1)	0 (0.0)
Sep	---	---	-4 (-4.8)	-4 (-4.8)	-4 (-4.8)	-5 (-6.0)	0 (0.0)	0 (0.0)
Oct	---	---	0 (0.0)	0 (0.0)	1 (1.3)	-1 (-1.3)	1 (1.3)	1 (1.3)
Nov	---	---	-1 (-1.6)	-1 (-1.6)	0 (0.0)	-1 (-1.6)	0 (0.0)	2 (3.1)
Dec	---	---	-1 (-1.6)	-1 (-1.6)	0 (0.0)	-1 (-1.6)	0 (0.0)	2 (3.1)
Annual	---	---	-1 (-1.6)	-1 (-1.6)	0 (0.0)	-1 (-1.6)	0 (0.0)	2 (3.1)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	6 (10.3)	5 (8.6)	5 (8.6)	6 (10.3)	5 (8.6)	6 (10.3)	8 (13.8)
Feb	---	6 (10.3)	8 (13.8)	8 (13.8)	6 (10.3)	8 (13.8)	8 (13.8)	8 (13.8)
Mar	---	39 (54.2)	33 (45.8)	33 (45.8)	30 (41.7)	34 (47.2)	40 (55.6)	39 (54.2)
Apr	---	39 (55.7)	45 (64.3)	48 (68.6)	38 (54.3)	46 (65.7)	42 (60.0)	41 (58.6)
May	---	39 (55.7)	58 (82.9)	61 (87.1)	44 (62.9)	59 (84.3)	42 (60.0)	48 (68.6)
Jun	---	80 (121.2)	69 (104.5)	71 (107.6)	71 (107.6)	72 (109.1)	83 (125.8)	78 (118.2)
Jul	---	28 (44.4)	28 (44.4)	28 (44.4)	27 (42.9)	28 (44.4)	29 (46.0)	27 (42.9)
Aug	---	25 (39.7)	28 (44.4)	28 (44.4)	24 (38.1)	26 (41.3)	26 (41.3)	25 (39.7)
Sep	---	12 (16.9)	8 (11.3)	8 (11.3)	8 (11.3)	7 (9.9)	12 (16.9)	12 (16.9)
Oct	---	8 (11.4)	8 (11.4)	8 (11.4)	9 (12.9)	7 (10.0)	9 (12.9)	9 (12.9)
Nov	---	6 (10.3)	5 (8.6)	5 (8.6)	6 (10.3)	5 (8.6)	6 (10.3)	8 (13.8)
Dec	---	6 (10.3)	5 (8.6)	5 (8.6)	6 (10.3)	5 (8.6)	6 (10.3)	8 (13.8)
Annual	---	6 (10.3)	5 (8.6)	5 (8.6)	6 (10.3)	5 (8.6)	6 (10.3)	8 (13.8)

Water Quality Assessment of Permitted Dischargers

WWTFs with potential adverse chronic low flow effects greater than 10 percent that would not have greater than 90 percent dilution flows were evaluated using a water quality assessment. The City of La Junta WWTF chronic low flow direct effects and the Fremont Sanitation District Rainbow Park WWTF chronic low flow cumulative effects were the only facilities meeting this criterion. Chapter 4 – *Water Quality* describes the significance of these effects.

City of La Junta WWTF. Direct effects chronic low flow for the City of La Junta WWTF would decrease more than 10 percent for most alternatives compared to the No Action Alternative and existing conditions (Table 124), and the dilution of La Junta's WWTF discharge in the Arkansas River would be below 90 percent. The chronic low flow effects were applied to the current discharge permit chronic low flow to evaluate effects to La Junta's current discharge limits (Table 132 and Table 133). An antidegradation review was not necessary in the current permit and was not assessed in this analysis, as both King's Arroyo and the Arkansas River at La Junta are designated Use Protected.

The assimilative capacities of all alternatives compared to the No Action and existing conditions are in Table 134 and Table 135, respectively. La Junta's current residual chlorine discharge limit equals the assimilative capacity of the current permit (0.029 mg/L, Health Department 2004). The alternatives would decrease this capacity, compared to the No Action, but would not affect La Junta's discharge permit as the method detection limit identified in the permit exceeds the assimilative capacity. The No Action Alternative, compared to existing conditions, would also decrease the assimilative capacity of residual chlorine.

The alternatives would increase the assimilative capacity of fecal coliform, compared to the No Action, and would not affect La Junta's current discharge permit. The upstream fecal coliform concentration exceeds the water quality standard in the current discharge permit. The alternatives would decrease the upstream flow, thereby decreasing upstream loading and increasing the assimilative capacity for La Junta's discharge. The No Action Alternative, compared to existing conditions, would also increase the assimilative capacity of fecal coliform.

The alternatives would decrease the selenium assimilative capacity, compared to the No Action, but capacities would be higher than the current discharge limit and would not affect La Junta's current permit. La Junta's current selenium discharge limit equals the water quality standard (27.1 µg/L, Health Department 2004). The No Action Alternative, compared to existing conditions, would also decrease the selenium assimilative capacity.

La Junta's current permit does not have set limits for remaining metals, rather La Junta is required to monitor discharge concentrations. Upon examining the current permit's water quality assessment and discharge monitoring data, the Health Department concluded that "[La Junta's] discharge does not present a reasonable potential to cause or contribute to an exceedence of stream standards for [these] metals" (Health Department 2004). The No Action and Master Contract Only alternatives assume a zero liquid discharge for La Junta's reverse osmosis water treatment plant, and the remaining alternatives provide AVC water supply. Both of these actions would further decrease La Junta's discharge metal concentrations because of lower source water concentration. Lower assimilative capacities for these metals for all alternatives would not affect La Junta's current permit.

Current ammonia discharge limits for the months of February through October are set the assimilative capacities in the water quality assessment. The assimilative capacities were calculated in the current permit using chronic low flow values in King's Arroyo, degradation of ammonia to the confluence, and chronic low flows in the Arkansas River. All alternatives may decrease the ammonia assimilative capacity because of changes in Arkansas River chronic low flows, though chronic low flows in King's Arroyo would not be affected. Effects to the discharge permit would be minor.

Table 132. City of La Junta WWTF Adjusted Chronic Low Flows of Alternatives Compared to No Action

Chronic Low Flow	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Daily Model Chronic Low Flow (cfs)	15	7	8	4	7	7	14
Change Compared to No Action (%)	0	-53	-47	-73	-53	-53	-7
Adjusted Chronic Low Flow (cfs) used in Water Quality Assessment Effects Analysis	12(1)	6	6	3	6	6	11

Notes:
(1) The No Action Alternative chronic low flow is assumed equal to the current discharge permit chronic low flow (12 cfs, Health Department 2004) to evaluate action alternatives.

Table 133. City of La Junta WWTF Adjusted Chronic Low Flows of Alternatives Compared to Existing Conditions

Chronic Low Flow	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Modeled Chronic Low Flow (cfs)	22	15	7	8	4	7	7	14
Change Compared to No Action (%)	0	-32	-68	-64	-82	-68	-68	-36
Adjusted Chronic Low Flow (cfs) used in Water Quality Assessment Effects Analysis	12(1)	8	4	4	2	4	4	8

Notes:
(1) The existing conditions chronic low flow is assumed equal to the current discharge permit chronic low flow (12 cfs, Health Department 2004) to evaluate all alternatives.

Table 134. City of La Junta Water Quality Assessment for Alternatives Compared to the No Action

Constituent	Water Quality Standards	Permit Limits	No Action[(1)]	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
			Assimilative Capacities[(2)]						
Chlorine (mg/L)	0.011	0.029	0.029	0.019	0.021	0.016	0.019	0.019	0.028
Fecal Coliform (#/100 mL)	200	194	194	197	197	198	197	197	194
Cd, Dis (µg/L)	6	Report	16	11	12	9	11	11	16
Cr^{+6}, Dis (µg/L)	11	Report	29	19	21	16	19	19	28
Cu, Dis (µg/L)	29	Report	55	41	43	36	41	41	53
Fe, Dis (µg/L)	369	Report	369	369	369	369	369	369	369
Fe, Trec (µg/L)	2,000	Report	-	-	-	664	-	-	-
Pb, Dis (µg/L)	11	Report	14	13	13	12	13	13	14
Mn, Dis (µg/L)	74	Report	93	83	84	79	83	83	92
Hg, Tot (µg/L)	0.010	Report	0.026	0.018	0.019	0.014	0.018	0.018	0.025
Ni, Dis (µg/L)	168	Report	435	293	310	239	293	293	417
Se, Dis (µg/L)	27.1	27.1	41.9	34.0	35.0	31.0	34.0	34.0	40.9
Ag, Dis (µg/L)	3.50	Report	8.67	5.91	6.26	4.88	5.91	5.91	8.33
Zn, Dis (µg/L)	382	Report	979	660	700	541	660	660	939

Notes:
(1) The No Action Alternative chronic low flow and assimilative capacities are assumed equal to the current discharge permit (Health Department 2004).
(2) Assimilative capacities greater than the permit limits would not adversely affect the WWTF.

Table 135. City of La Junta Water Quality Assessment for Alternatives Compared to Existing Conditions

Constituent	Water Quality Standards	Permit Limits	Existing Conditions [1]	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
			Assimilative Capacities[2]							
Chlorine (mg/L)	0.011	0.029	0.029	0.023	0.017	0.017	0.014	0.017	0.017	0.022
Fecal Coliform (#/100 mL)	200	194	194	196	198	198	199	198	198	196
Cd, Dis (µg/L)	6	Report	16	13	9	10	8	9	9	13
Cr^{+6}, Dis (µg/L)	11	Report	29	23	17	17	14	17	17	22
Cu, Dis (µg/L)	29	Report	55	47	37	38	34	37	37	46
Fe, Dis (µg/L)	369	Report	369	369	369	369	369	369	369	369
Fe, Trec (µg/L)	2,000	Report	-	-	406	178	1,089	406	406	-
Pb, Dis (µg/L)	11	Report	14	13	12	12	12	12	12	13
Mn, Dis (µg/L)	74	Report	93	87	80	81	78	80	80	86
Hg, Tot (µg/L)	0.010	Report	0.026	0.021	0.015	0.016	0.013	0.015	0.015	0.020
Ni, Dis (µg/L)	168	Report	435	350	253	265	217	253	253	338
Se, Dis (µg/L)	27.1	27.1	41.9	37.2	31.8	32.5	29.8	31.8	31.8	36.5
Ag, Dis (µg/L)	3.50	Report	8.67	7.03	5.15	5.38	4.44	5.15	5.15	6.79
Zn, Dis (µg/L)	382	Report	979	789	572	599	491	572	572	762

Notes:
(1) The existing conditions chronic low flow and assimilative capacities are assumed equal to the current discharge permit (Health Department 2004).
(2) Assimilative capacities greater than the permit limits would not adversely affect the WWTF.

Fremont Sanitation District Rainbow Park WWTF. Cumulative effects chronic low flow for the Fremont Sanitation District Rainbow Park WWTF would decrease more than 10 percent for the Pueblo Dam South and River South alternatives compared to the No Action Alternative and existing conditions (Table 136 and Table 137), and dilution of the WWTF discharge in the Arkansas River would be below 90 percent. The chronic low flow effects were applied to the current discharge permit chronic low flow to evaluate effects to Rainbow Park's current discharge limits (Table 136 and Table 137). The antidegradation review in the current permit's water quality assessment was evaluated because this reach of the river is not designated Use Protected.

The antidegradation-based average concentrations (ADBAC) of all alternatives compared to the No Action and existing conditions are in Table 138 and Table 139, respectively. Rainbow Park currently disinfects effluent using UV treatment, and the current residual chlorine discharge limit has been retained from previous permits. Effects to the residual chlorine discharge would be negligible.

All alternatives except JUP North would decrease the fecal coliform ADBAC, compared to the No Action. Fremont Sanitation District elected to retain their prior fecal coliform discharge limit (2,073 counts/100 mL) rather than adopt the more stringent ADBAC (534 counts/100 mL) (Health Department 2003). Though the alternatives affect the ADBAC level, effects to the discharge limit would be negligible. The Comanche South, Pueblo Dam South, Pueblo Dam North, and River South alternatives would decrease the fecal coliform ADBAC, compared to existing conditions, but would not affect the discharge limit.

Several alternatives would decrease the lead and zinc ADBACs, compared to the No Action or existing conditions, but the ADBACs would be above the current discharge limit, which equals the table value standard. Effects would be negligible. No alternatives would affect the mercury ADBAC, compared to No Action or existing conditions. The current mercury discharge limit has also been retained from the previous permit. Effects to the mercury discharge limit would be negligible. Rainbow Park's current permit does not have set limits for remaining metals, rather they are required to monitor discharge concentrations.

All alternatives would decrease ammonia ADBACs by less than 10 percent, compared to the No Action and existing conditions. Fremont Sanitation District elected to retain their prior ammonia monthly limits rather than adopt the more stringent ADBAC limits (Health Department 2003). Effects would be negligible.

Table 136. Fremont Sanitation District Rainbow Park WWTF Adjusted Chronic Low Flows of Alternatives Compared to No Action

Chronic Low Flow	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Daily Model Chronic Low Flow (cfs)	105	102	91	107	102	91	104
Change Compared to No Action (%)	0	-3	-13	2	-3	-13	-1
Adjusted Chronic Low Flow (cfs) used in Water Quality Assessment Effects Analysis	234[(1)]	227	203	238	227	203	232

Notes:
(1) The No Action Alternative chronic low flow is assumed equal to the current discharge permit chronic low flow (234 cfs, Health Department 2003) to evaluate action alternatives.

Table 137. Fremont Sanitation District Rainbow Park WWTF Adjusted Chronic Low Flows of Alternatives Compared to Existing Conditions

Chronic Low Flow	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Modeled Chronic Low Flow (cfs)	103	105	102	91	107	102	91	104
Change Compared to No Action (%)	0	2	-1	-12	4	-1	-12	1
Adjusted Chronic Low Flow (cfs) used in Water Quality Assessment Effects Analysis	234[(1)]	239	232	207	243	232	207	236

Notes:
(1) The existing conditions chronic low flow is assumed equal to the current discharge permit chronic low flow (234 cfs, Health Department 2003) to evaluate all alternatives.

Table 138. Fremont Sanitation District Rainbow Park Water Quality Assessment for Alternatives Compared to the No Action

Constituent	Water Quality Standards	Permit Limits	No Action[1]	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
			Antidegradation-Based Average Concentrations[2][3]						
Chlorine (mg/L)	0.011	0.035	0.040	0.039	0.035	0.040	0.039	0.035	0.039
Fecal Coliform (#/100 mL)	200	2,073	534	521	473	542	521	473	529
Cd, Dis (µg/L)	4.1	Report	12	12	11	13	12	11	12
Cr^{+6}, Dis (µg/L)	11	Report	26	25	23	26	25	23	26
Cu, Dis (µg/L)	18	Report	52	51	47	53	51	47	52
Fe, Dis (µg/L)	300	Report	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fe, Trec (µg/L)	1,000	Report	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pb, Dis (µg/L)	6	6	17	17	15	17	17	15	17
Mn, Dis (µg/L)	50	Report	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg, Tot (µg/L)	0.01	0.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ni, Dis (µg/L)	103	Report	316	308	277	322	308	277	314
Se, Dis (µg/L)	4.6	Report	22.9	22.6	21.5	23.1	22.6	21.5	22.8
Ag, Dis (µg/L)	0.3	Report	0.9	0.9	0.8	0.9	0.9	0.8	0.9
Zn, Dis (µg/L)	234	234	712	694	626	724	694	626	706
NH3, Jan (mg/L)	0.7	8.6	3.4	3.4	3.4	3.4	3.4	3.3	3.4
NH3, Feb(mg/L)	0.6	6.6	2.2	2.2	2.1	2.3	2.3	2.1	2.1
NH3, Mar (mg/L)	0.4	4.1	3.4	3.4	3.4	3.4	3.4	3.3	3.4
NH3, Apr (mg/L)	0.4	4.2	2.2	2.2	2.1	2.3	2.3	2.1	2.1
NH3, May (mg/L)	0.3	2.9	0.9	0.9	0.8	0.9	0.9	0.8	0.9
NH3, Jun (mg/L)	0.3	3.5	2.2	2.2	2.1	2.3	2.3	2.1	2.1
NH3, Jul (mg/L)	0.3	3.6	2.2	2.2	2.1	2.3	2.3	2.1	2.1
NH3, Aug (mg/L)	0.3	3.3	0.9	0.9	0.8	0.9	0.9	0.8	0.9
NH3, Sep (mg/L)	0.3	2.8	0.9	0.9	0.8	0.9	0.9	0.8	0.9
NH3, Oct (mg/L)	0.3	3.1	0.9	0.9	0.8	0.9	0.9	0.8	0.9
NH3, Nov (mg/L)	0.3	3.3	0.9	0.9	0.8	0.9	0.9	0.8	0.9
NH3, Dec (mg/L)	0.5	3.5	2.2	2.2	2.1	2.3	2.3	2.1	2.1

Key: N/A = not available, effluent data was not available for calculation

Notes:

(1) The No Action Alternative chronic low flow and assimilative capacities are assumed equal to the current discharge permit (Health Department 2003).

(2) Permit limits greater than the No Action Alternative antidegradation-based average concentrations were retained from previous permit. The alternatives would not adversely affect the WWTF.

(3) Antidegradation-based average concentrations greater than the permit limits would not adversely affect the WWTF.

Table 139. Fremont Sanitation District Rainbow Park Water Quality Assessment for Alternatives Compared to Existing Conditions

Constituent	Water Quality Standards	Permit Limits	Existing Conditions (1)	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
			Antidegradation-Based Average Concentrations (2)(3)							
Chlorine (mg/L)	0.011	0.035	0.040	0.040	0.039	0.036	0.041	0.039	0.036	0.040
Fecal Coliform (#/100 mL)	200	2,073	534	543	529	480	552	529	480	538
Cd, Dis (µg/L)	4.1	Report	12	13	12	11	13	12	11	13
Cr^{+6}, Dis (µg/L)	11	Report	26	26	26	23	27	26	23	26
Cu, Dis (µg/L)	18	Report	52	53	52	47	54	52	47	52
Fe, Dis (µg/L)	300	Report	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fe, Trec (µg/L)	1,000	Report	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pb, Dis (µg/L)	6	6	17	17	17	15	18	17	15	17
Mn, Dis (µg/L)	50	Report	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg, Tot (µg/L)	0.01	0.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ni, Dis (µg/L)	103	Report	316	322	314	282	328	314	282	319
Se, Dis (µg/L)	4.6	Report	22.9	23.1	22.8	21.7	23.3	22.8	21.7	23.0
Ag, Dis (µg/L)	0.3	Report	0.9	0.9	0.9	0.8	1.0	0.9	0.8	0.9
Zn, Dis (µg/L)	234	234	712	725	706	637	737	706	637	718
NH3, Jan (mg/L)	0.7	8.6	3.4	3.3	3.3	3.3	3.3	3.3	3.2	3.3
NH3, Feb(mg/L)	0.6	6.6	2.2	2.2	2.2	2.2	2.3	2.3	2.1	2.1
NH3, Mar (mg/L)	0.4	4.1	3.4	3.3	3.3	3.3	3.3	3.3	3.2	3.3
NH3, Apr (mg/L)	0.4	4.2	2.2	2.2	2.2	2.2	2.3	2.3	2.1	2.1
NH3, May (mg/L)	0.3	2.9	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9
NH3, Jun (mg/L)	0.3	3.5	2.2	2.2	2.2	2.2	2.3	2.3	2.1	2.1
NH3, Jul (mg/L)	0.3	3.6	2.2	2.2	2.2	2.2	2.3	2.3	2.1	2.1
NH3, Aug (mg/L)	0.3	3.3	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9
NH3, Sep (mg/L)	0.3	2.8	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9
NH3, Oct (mg/L)	0.3	3.1	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9
NH3, Nov (mg/L)	0.3	3.3	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9
NH3, Dec (mg/L)	0.5	3.5	2.2	2.2	2.2	2.2	2.3	2.3	2.1	2.1

Key: N/A = not available, effluent data was not available for calculation

Notes:

(1) The existing conditions chronic low flow and assimilative capacities are assumed equal to the current discharge permit (Health Department 2003).

(2) Permit limits greater than the antidegradation-based average concentrations were retained from previous permit. Changes in concentrations would not adversely affect the WWTF.

(3) Antidegradation-based average concentrations greater than the permit limits would not adversely affect the WWTF.

Total Maximum Daily Loads

Changes in streamflow could affect constituent load allocations assigned to permitted and non-permitted point dischargers, and to non-point sources. Allocations have been assigned in approved Total Maximum Daily Loads (TMDL).

Methods

Several TMDLs have been approved in the Upper Arkansas River Basin (Table 140). These TMDLs are further described in Appendix F.1.

Table 140. Upper Arkansas River Basin Approved Total Maximum Daily Loads in Daily Model Analysis Area

River Segment	Constituent
Arkansas River between Lake Fork Creek and Lake Creek (COARUA2c)	Cadmium, zinc
Arkansas River between Lake Creek and Pueblo Reservoir (COARUA3)	Cadmium, zinc, lead
Lake Creek (COARUA10)	Copper

Source: Health Department 2009, 2010

The TMDL for the Arkansas River between Lake Fork Creek and Lake Creek was not assessed in this EIS because streamflow and water quality at the Arkansas River below Leadville gage was used to quantify the TMDL and allocations (Health Department 2009). This gage is an input of the Daily Model and is not simulated (i.e. outside the analysis area) (see Appendix D.3). Streamflow effects at this gage would not occur.

The TMDL for Lake Creek was not assessed in this EIS because streamflow and water quality at the Lake Creek above Twin Lakes gage was used to quantify the TMDL and allocations (Health Department 2010). This gage is outside the Daily Model analysis area (see Appendix D.3). Streamflow effects at this gage would not occur.

The TMDL for the Arkansas River between Lake Creek and Pueblo Reservoir used streamflow and water quality data at the Arkansas River near Wellsville gage to quantify the TMDL and allocations (Health Department 2009). Median monthly flows and 95th percentile concentrations of cadmium, zinc, and lead were used to quantify the existing stream load. Median monthly flows and the water quality standard were used to quantify the TMDL.

Because future permitted discharge limits, ambient water quality, and water quality standards are unknown, the TMDL assessments in this EIS used water quality information from current TMDL documentation to evaluate effects. The median streamflow percent changes of the alternatives compared to the No Action Alternative were applied to historical median streamflow used to quantify the TMDL. These adjusted median streamflows were then used to calculate effects to existing stream load, the TMDL, and load reductions required to meet the TMDL.

Critical conditions periods in the Upper Arkansas River Basin, or periods when water quality exceedences are most likely to occur, are typically during high streamflow and dry periods

(Health Department 2009). Chronic low flow periods for the Arkansas River between Lake Creek and Pueblo Reservoir were evaluated in a previous section of this Appendix. Wet and dry periods were further assessed by examining the percent changes in streamflow during these critical periods.

Results

Changes in median streamflow at the Arkansas River near Wellsville gage are in Table 141. Changes for all alternatives would typically be less than 2 percent, though occasional monthly decreases or increases of up to 4 percent would occur, especially in spring months.

The No Action and action alternatives' effects on cadmium load reductions to meeting TMDLs in the Arkansas River between Lake Creek and Pueblo Reservoir are in Table 142 through Table 148. These results indicate that the negligible effects on streamflow in this reach wouldn't substantially affect existing load and TMDLs, and would not affect the required cadmium load reductions and associated allocations. Results would be similar for lead and zinc.

Changes in critical conditions (wet and dry periods) for the Arkansas River TMDL between Lake Creek and Pueblo Reservoir are in Figure 77 and Figure 76. The percent changes in streamflow are in Table 149. Maximum increases in wet period flows would change less than 9 percent for all alternatives compared to No Action. Wet period flows would increase less than about 2 percent most of the time. Maximum decreases in dry period flows would change less than 2 percent for all alternatives compared to No Action.

Table 141. Median Streamflow at Arkansas River near Wellsville Gage – Direct Effects

Month	Existing Conditions	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Streamflow (cfs)								
Jan	258	255	252	253	257	253	252	249
Feb	168	164	164	165	164	166	164	161
Mar	141	137	138	138	143	138	137	135
Apr	173	179	174	175	184	175	174	174
May	626	628	624	624	630	624	624	624
Jun	1,419	1,396	1,399	1,402	1,397	1,404	1,397	1,403
Jul	774	777	775	776	780	775	775	776
Aug	532	537	537	537	540	536	536	538
Sep	186	193	192	192	193	192	192	192
Oct	154	156	155	155	155	155	155	155
Nov	186	185	184	184	185	184	184	183
Dec	207	204	205	204	204	205	205	204
Change in Streamflow Compared to No Action [cfs (%)]								
Jan	---	---	-3 (-1.2)	-2 (-0.8)	2 (0.8)	-2 (-0.8)	-3 (-1.2)	-6 (-2.4)
Feb	---	---	0 (0.0)	1 (0.6)	0 (0.0)	2 (1.2)	0 (0.0)	-3 (-1.8)
Mar	---	---	1 (0.7)	1 (0.7)	6 (4.4)	1 (0.7)	0 (0.0)	-2 (-1.5)
Apr	---	---	-5 (-2.8)	-4 (-2.2)	5 (2.8)	-4 (-2.2)	-5 (-2.8)	-5 (-2.8)
May	---	---	-4 (-0.6)	-4 (-0.6)	2 (0.3)	-4 (-0.6)	-4 (-0.6)	-4 (-0.6)
Jun	---	---	3 (0.2)	6 (0.4)	1 (0.1)	8 (0.6)	1 (0.1)	7 (0.5)
Jul	---	---	-2 (-0.3)	-1 (-0.1)	3 (0.4)	-2 (-0.3)	-2 (-0.3)	-1 (-0.1)
Aug	---	---	0 (0.0)	0 (0.0)	3 (0.6)	-1 (-0.2)	-1 (-0.2)	1 (0.2)
Sep	---	---	-1 (-0.5)	-1 (-0.5)	0 (0.0)	-1 (-0.5)	-1 (-0.5)	-1 (-0.5)
Oct	---	---	-1 (-0.6)	-1 (-0.6)	-1 (-0.6)	-1 (-0.6)	-1 (-0.6)	-1 (-0.6)
Nov	---	---	-1 (-0.5)	-1 (-0.5)	0 (0.0)	-1 (-0.5)	-1 (-0.5)	-2 (-1.1)
Dec	---	---	1 (0.5)	0 (0.0)	0 (0.0)	1 (0.5)	1 (0.5)	0 (0.0)
Change in Streamflow Compared to Existing Conditions [cfs (%)]								
Jan	---	-3 (-1.2)	-6 (-2.3)	-5 (-1.9)	-1 (-0.4)	-5 (-1.9)	-6 (-2.3)	-9 (-3.5)
Feb	---	-4 (-2.4)	-4 (-2.4)	-3 (-1.8)	-4 (-2.4)	-2 (-1.2)	-4 (-2.4)	-7 (-4.2)
Mar	---	-4 (-2.8)	-3 (-2.1)	-3 (-2.1)	2 (1.4)	-3 (-2.1)	-4 (-2.8)	-6 (-4.3)
Apr	---	6 (3.5)	1 (0.6)	2 (1.2)	11 (6.4)	2 (1.2)	1 (0.6)	1 (0.6)
May	---	2 (0.3)	-2 (-0.3)	-2 (-0.3)	4 (0.6)	-2 (-0.3)	-2 (-0.3)	-2 (-0.3)
Jun	---	-23 (-1.6)	-20 (-1.4)	-17 (-1.2)	-22 (-1.6)	-15 (-1.1)	-22 (-1.6)	-16 (-1.1)
Jul	---	3 (0.4)	1 (0.1)	2 (0.3)	6 (0.8)	1 (0.1)	1 (0.1)	2 (0.3)
Aug	---	5 (0.9)	5 (0.9)	5 (0.9)	8 (1.5)	4 (0.8)	4 (0.8)	6 (1.1)
Sep	---	7 (3.8)	6 (3.2)	6 (3.2)	7 (3.8)	6 (3.2)	6 (3.2)	6 (3.2)
Oct	---	2 (1.3)	1 (0.6)	1 (0.6)	1 (0.6)	1 (0.6)	1 (0.6)	1 (0.6)
Nov	---	-1 (-0.5)	-2 (-1.1)	-2 (-1.1)	-1 (-0.5)	-2 (-1.1)	-2 (-1.1)	-3 (-1.6)
Dec	---	-3 (-1.4)	-2 (-1.0)	-3 (-1.4)	-3 (-1.4)	-2 (-1)	-2 (-1.0)	-3 (-1.4)

Table 142. No Action Alternative Direct Effects on Upper Arkansas River Basin Segment 3 Cadmium TMDL

Month	Current TMDL - Cadmium					No Action Alternative [1]				
	Median Flow (cfs)	Existing Load (lbs/day)	TMDL (lbs/day	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)	Median Flow [2] (cfs)	Existing Load (lbs/day)	TMDL (lbs/day)	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)
Jan	386	1.08	0.83	0.25	23	381	1.06	0.82	0.24	23
Feb	364	2.06	0.75	1.31	64	355	2.01	0.73	1.28	64
Mar	318	1.53	0.67	0.86	56	307	1.48	0.65	0.83	56
Apr	299	1.12	0.60	0.52	47	309	1.16	0.62	0.54	47
May	706	4.20	1.03	3.17	76	708	4.21	1.03	3.18	76
Jun	1645	3.56	2.13	1.43	40	1,619	3.50	2.10	1.41	40
Jul	888	1.19	1.29	0.00	0	892	1.20	1.30	0.00	0
Aug	657	1.23	1.24	0.00	0	664	1.24	1.25	0.00	0
Sep	338	0.68	0.77	0.00	0	352	0.71	0.80	0.00	0
Oct	356	0.95	0.79	0.16	17	359	0.96	0.79	0.16	17
Nov	403	0.69	0.85	0.00	0	401	0.69	0.84	0.00	0
Dec	392	1.97	0.91	1.06	54	387	1.94	0.90	1.05	54

Notes:
(1) Compared to existing conditions.
(2) Adjusted median flow calculated by applying percent change in flow to TMDL median streamflow.

Table 143. Comanche South Alternative Direct Effects on Upper Arkansas River Basin Segment 3 Cadmium TMDL

Month	Current TMDL - Cadmium					Comanche South Alternative [1]				
	Median Flow (cfs)	Existing Load (lbs/day)	TMDL (lbs/day	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)	Median Flow [2] (cfs)	Existing Load (lbs/day)	TMDL (lbs/day)	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)
Jan	386	1.08	0.83	0.25	23	381	1.07	0.82	0.24	23
Feb	364	2.06	0.75	1.31	64	364	2.06	0.75	1.31	64
Mar	318	1.53	0.67	0.86	56	320	1.54	0.67	0.87	56
Apr	299	1.12	0.60	0.52	47	291	1.09	0.58	0.51	47
May	706	4.20	1.03	3.17	76	702	4.17	1.02	3.15	76
Jun	1645	3.56	2.13	1.43	40	1,649	3.57	2.13	1.43	40
Jul	888	1.19	1.29	0.00	0	886	1.19	1.29	0.00	0
Aug	657	1.23	1.24	0.00	0	657	1.23	1.24	0.00	0
Sep	338	0.68	0.77	0.00	0	336	0.68	0.76	0.00	0
Oct	356	0.95	0.79	0.16	17	354	0.94	0.78	0.16	17
Nov	403	0.69	0.85	0.00	0	401	0.69	0.84	0.00	0
Dec	392	1.97	0.91	1.06	54	394	1.98	0.91	1.07	54

Notes:
(1) Compared to existing conditions.
(2) Adjusted median flow calculated by applying percent change in flow to TMDL median streamflow.

Table 144. Pueblo Dam South Alternative Direct Effects on Upper Arkansas River Basin Segment 3 Cadmium TMDL

Month	Current TMDL - Cadmium					Pueblo Dam South Alternative [1]				
	Median Flow (cfs)	Existing Load (lbs/day)	TMDL (lbs/day	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)	Median Flow [2] (cfs)	Existing Load (lbs/day)	TMDL (lbs/day)	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)
Jan	386	1.08	0.83	0.25	23	383	1.07	0.83	0.25	23
Feb	364	2.06	0.75	1.31	64	366	2.07	0.75	1.32	64
Mar	318	1.53	0.67	0.86	56	320	1.54	0.67	0.87	56
Apr	299	1.12	0.60	0.52	47	292	1.09	0.58	0.51	47
May	706	4.20	1.03	3.17	76	702	4.17	1.02	3.15	76
Jun	1645	3.56	2.13	1.43	40	1,652	3.58	2.14	1.44	40
Jul	888	1.19	1.29	0.00	0	887	1.19	1.29	0.00	0
Aug	657	1.23	1.24	0.00	0	657	1.23	1.24	0.00	0
Sep	338	0.68	0.77	0.00	0	336	0.68	0.76	0.00	0
Oct	356	0.95	0.79	0.16	17	354	0.94	0.78	0.16	17
Nov	403	0.69	0.85	0.00	0	401	0.69	0.84	0.00	0
Dec	392	1.97	0.91	1.06	54	392	1.97	0.91	1.06	54

Notes:
(1) Compared to existing conditions.
(2) Adjusted median flow calculated by applying percent change in flow to TMDL median streamflow.

Table 145. JUP North Alternative Direct Effects on Upper Arkansas River Basin Segment 3 Cadmium TMDL

Month	Current TMDL - Cadmium					JUP North Alternative [1]				
	Median Flow (cfs)	Existing Load (lbs/day)	TMDL (lbs/day	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)	Median Flow [2] (cfs)	Existing Load (lbs/day)	TMDL (lbs/day)	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)
Jan	386	1.08	0.83	0.25	23	389	1.09	0.84	0.25	23
Feb	364	2.06	0.75	1.31	64	364	2.06	0.75	1.31	64
Mar	318	1.53	0.67	0.86	56	332	1.60	0.70	0.90	56
Apr	299	1.12	0.60	0.52	47	307	1.15	0.61	0.54	47
May	706	4.20	1.03	3.17	76	708	4.21	1.03	3.18	76
Jun	1645	3.56	2.13	1.43	40	1,646	3.56	2.13	1.43	40
Jul	888	1.19	1.29	0.00	0	891	1.19	1.30	0.00	0
Aug	657	1.23	1.24	0.00	0	661	1.24	1.25	0.00	0
Sep	338	0.68	0.77	0.00	0	338	0.68	0.77	0.00	0
Oct	356	0.95	0.79	0.16	17	354	0.94	0.78	0.16	17
Nov	403	0.69	0.85	0.00	0	403	0.69	0.85	0.00	0
Dec	392	1.97	0.91	1.06	54	392	1.97	0.91	1.06	54

Notes:
(1) Compared to existing conditions.
(2) Adjusted median flow calculated by applying percent change in flow to TMDL median streamflow.

Table 146. Pueblo Dam North Alternative Direct Effects on Upper Arkansas River Basin Segment 3 Cadmium TMDL

Month	Current TMDL - Cadmium					Pueblo Dam North Alternative [1]				
	Median Flow (cfs)	Existing Load (lbs/day)	TMDL (lbs/day	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)	Median Flow [2] (cfs)	Existing Load (lbs/day)	TMDL (lbs/day)	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)
Jan	386	1.08	0.83	0.25	23	383	1.07	0.83	0.25	23
Feb	364	2.06	0.75	1.31	64	368	2.09	0.76	1.33	64
Mar	318	1.53	0.67	0.86	56	320	1.54	0.67	0.87	56
Apr	299	1.12	0.60	0.52	47	292	1.09	0.58	0.51	47
May	706	4.20	1.03	3.17	76	702	4.17	1.02	3.15	76
Jun	1645	3.56	2.13	1.43	40	1,654	3.58	2.14	1.44	40
Jul	888	1.19	1.29	0.00	0	886	1.19	1.29	0.00	0
Aug	657	1.23	1.24	0.00	0	656	1.23	1.24	0.00	0
Sep	338	0.68	0.77	0.00	0	336	0.68	0.76	0.00	0
Oct	356	0.95	0.79	0.16	17	354	0.94	0.78	0.16	17
Nov	403	0.69	0.85	0.00	0	401	0.69	0.84	0.00	0
Dec	392	1.97	0.91	1.06	54	394	1.98	0.91	1.07	54

Notes:
(1) Compared to existing conditions.
(2) Adjusted median flow calculated by applying percent change in flow to TMDL median streamflow.

Table 147. River South Alternative Direct Effects on Upper Arkansas River Basin Segment 3 Cadmium TMDL

Month	Current TMDL - Cadmium					River South Alternative [1]				
	Median Flow (cfs)	Existing Load (lbs/day)	TMDL (lbs/day	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)	Median Flow [2] (cfs)	Existing Load (lbs/day)	TMDL (lbs/day)	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)
Jan	386	1.08	0.83	0.25	23	381	1.07	0.82	0.24	23
Feb	364	2.06	0.75	1.31	64	364	2.06	0.75	1.31	64
Mar	318	1.53	0.67	0.86	56	318	1.53	0.67	0.86	56
Apr	299	1.12	0.60	0.52	47	291	1.09	0.58	0.51	47
May	706	4.20	1.03	3.17	76	702	4.17	1.02	3.15	76
Jun	1645	3.56	2.13	1.43	40	1,646	3.56	2.13	1.43	40
Jul	888	1.19	1.29	0.00	0	886	1.19	1.29	0.00	0
Aug	657	1.23	1.24	0.00	0	656	1.23	1.24	0.00	0
Sep	338	0.68	0.77	0.00	0	336	0.68	0.76	0.00	0
Oct	356	0.95	0.79	0.16	17	354	0.94	0.78	0.16	17
Nov	403	0.69	0.85	0.00	0	401	0.69	0.84	0.00	0
Dec	392	1.97	0.91	1.06	54	394	1.98	0.91	1.07	54

Notes:
(1) Compared to existing conditions.
(2) Adjusted median flow calculated by applying percent change in flow to TMDL median streamflow.

Table 148. Master Contract Only Alternative Direct Effects on Upper Arkansas River Basin Segment 3 Cadmium TMDL

Month	Current TMDL - Cadmium					Master Contract Only Alternative [1]				
	Median Flow (cfs)	Existing Load (lbs/day)	TMDL (lbs/day)	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)	Median Flow [2] (cfs)	Existing Load (lbs/day)	TMDL (lbs/day)	Reduction to Meet TMDL (lbs/day)	Reduction to Meet TMDL (%)
Jan	386	1.08	0.83	0.25	23	377	1.05	0.81	0.24	23
Feb	364	2.06	0.75	1.31	64	357	2.02	0.73	1.29	64
Mar	318	1.53	0.67	0.86	56	313	1.51	0.66	0.85	56
Apr	299	1.12	0.60	0.52	47	291	1.09	0.58	0.51	47
May	706	4.20	1.03	3.17	76	702	4.17	1.02	3.15	76
Jun	1645	3.56	2.13	1.43	40	1,653	3.58	2.14	1.44	40
Jul	888	1.19	1.29	0.00	0	887	1.19	1.29	0.00	0
Aug	657	1.23	1.24	0.00	0	658	1.23	1.24	0.00	0
Sep	338	0.68	0.77	0.00	0	336	0.68	0.76	0.00	0
Oct	356	0.95	0.79	0.16	17	354	0.94	0.78	0.16	17
Nov	403	0.69	0.85	0.00	0	399	0.68	0.84	0.00	0
Dec	392	1.97	0.91	1.06	54	392	1.97	0.91	1.06	54

Notes:
(1) Compared to existing conditions.
(2) Adjusted median flow calculated by applying percent change in flow to TMDL median streamflow.

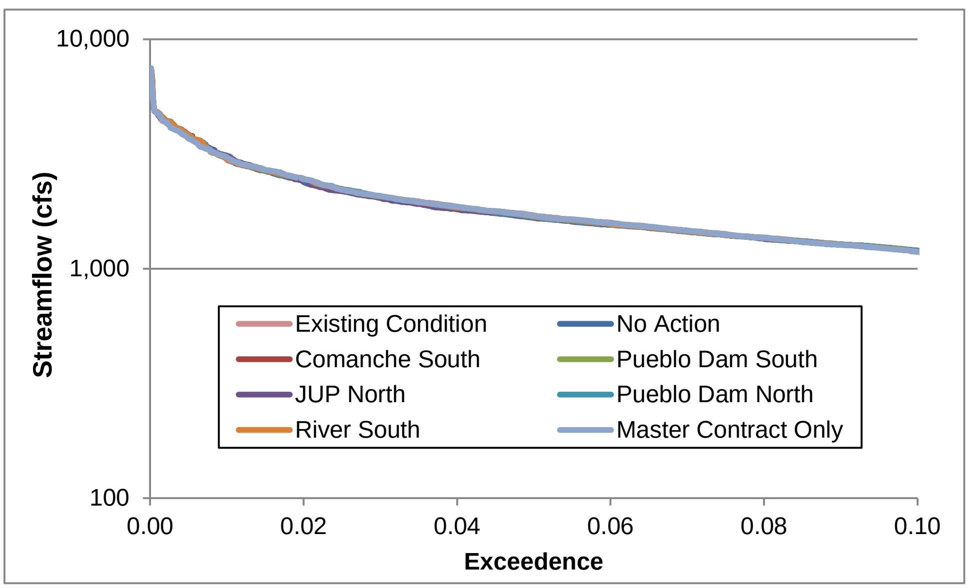


Figure 76. Wet Period Flows at Arkansas River near Wellsville Gage

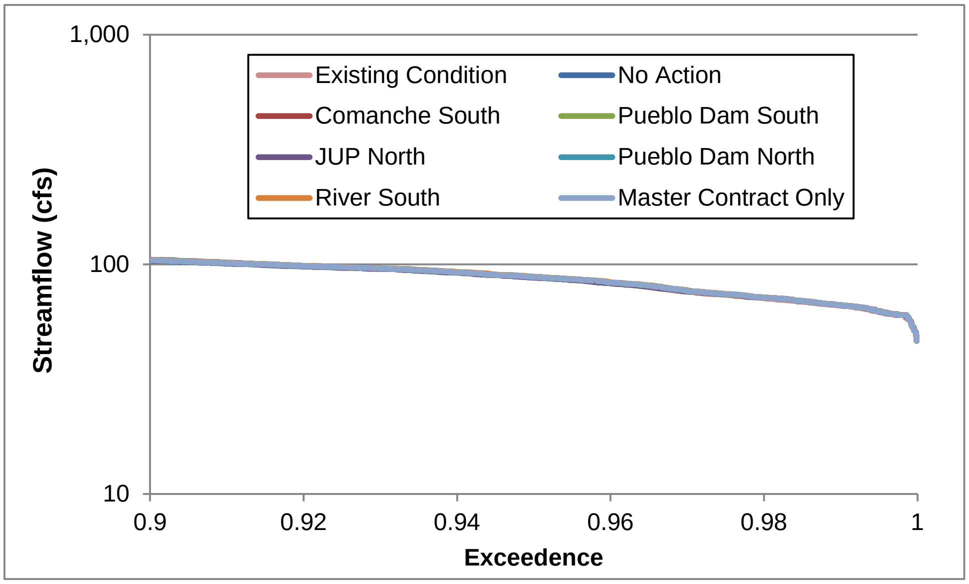


Figure 77. Dry Period Flows at Arkansas River near Wellsville Gage

Table 149. Changes in Critical Condition Flows at Arkansas River near Wellsville Gage

Percent Changes in Flow	No Action (1)	Comanche South (2)	Pueblo Dam South	JUP North (2)	Pueblo Dam North (2)	River South (2)	Master Contract Only (2)
Wet Period Flows (< 10 % exceedence)							
Mean	-0.77	0.43	0.41	-0.26	0.45	0.53	0.62
Maximum decrease in flow	-7.63	-2.55	-3.02	-6.49	-3.05	-3.05	-5.32
5th Percentile	-2.24	-0.57	-0.61	-1.76	-0.46	-0.45	-2.30
25th Percentile	-1.37	-0.02	0.01	-0.96	-0.05	0.15	0.27
Median	-0.93	0.34	0.36	-0.20	0.36	0.43	0.81
75th Percentile	-0.48	0.73	0.72	0.33	0.72	0.82	1.17
95th Percentile	1.87	1.64	1.54	1.49	1.86	1.75	2.26
Maximum increase in flow	4.40	8.32	8.26	3.15	8.32	8.32	4.67
Dry Period Flows (> 90 % exceedence)							
Mean	-0.02	0.56	0.24	0.07	0.64	0.67	0.46
Maximum decrease in flow	-1.50	-1.44	-1.44	-1.44	-1.44	-1.44	-1.44
5th Percentile	-0.86	-0.02	-0.19	-0.16	-0.01	0.00	0.00
25th Percentile	-0.42	0.21	0.00	0.00	0.29	0.33	0.20
Median	-0.19	0.66	0.21	0.03	0.74	0.74	0.47
75th Percentile	0.49	0.87	0.45	0.15	0.97	0.95	0.68
95th Percentile	1.01	1.03	0.74	0.44	1.17	1.36	1.05
Maximum increase in flow	3.22	1.30	0.99	2.30	1.69	1.78	1.51

Notes:
(1) Compared to existing conditions.
(2) Compared to No Action Alternative.

References

Bossong, C.R. 2001. Summary of water-quality data October 1987 through September 1998 for Fountain and Monument Creeks, El Paso and Pueblo Counties, Colorado. Denver: Prepared in Cooperation with Colorado Springs Utilities. USGS Water Resources Investigations, 2000-4263.

Cohn, T.A., D.L. Caulder, E.J. Gilroy, L.D. Zynjuk, and R.M. Summers. 1992. The validity of a simple statistical model for estimating fluvial constituent loads: An empirical study involving nutrient loads entering Chesapeake Bay. Water Resources Research 28(9), 2353-2363.

Colorado Department of Public Health and Environment (Health Department). 2002. Colorado Mixing Zone Implementation Guidance. Water Quality Control Division. April.

Colorado Department of Public Health and Environment (Health Department). 2003. Colorado Discharge Permit System, Fremont Sanitation District Rainbow Park Regional Wastewater Treatment Plan. Permit No. CO-0039748. Water Quality Control Division. February 1.

Colorado Department of Public Health and Environment (Health Department). 2004. Colorado Discharge Permit System, City of La Junta. Permit No. CO-0021261. Water Quality Control Division. October 28.

Colorado Department of Public Health and Environment (Health Department). 2005. Final section 303(d) listing methodology, 2006 listing cycle.

Colorado Department of Public Health and Environment (Health Department). 2006. Biomonitoring Guidance Document. Water Quality Control Division. May.

Colorado Department of Public Health and Environment (Health Department). 2009. Total Maximum Daily Load Assessment, Arkansas River/Lake Creek/Chalk Creek/Evans Gulch, Lake/Chaffee County, Colorado. June.

Colorado Department of Public Health and the Environment (Health Department). 2010. Total Maximum Daily Load (TMDL) Assessment, Lake Creek, Lake County, Colorado. June 2010.

Colorado Department of Public Health and the Environment (Health Department). 2012. The Basic Standards and Methodologies for Surface Water. Water Quality Control Commission, Regulation No. 31, 5 CCR 1002-31. January 1.

Galloway, J.M., and W. R. Green. 2002. Simulation of Hydrodynamics, Temperature, and Dissolved Oxygen in Norfork Lake, Arkansas, 1994-1995. USGS Water-Resources Investigations Report 02-42-50.

Labadie, J.W. 2006. MODSIM: River Basin Management Decision Support System. In Watershed Models, by V P Singh, & D K Frevert, Chapter 23 . Boca Raton, FL: CRC/Taylor & Francis.

Oppelt, E. 2004. Personal communication by E. Oppelt, Colorado Water Quality Control Division, with Tracy Wilcox, MWH. June 29, 2004.

Ortiz, R.F. 2012. Simulated Effects of Proposed Arkansas Valley Conduit on Hydrodynamics and Water Quality for Projected Demands through 2070, Pueblo Reservoir, Southeastern Colorado. U.S. Geological Survey Scientific Investigations Report, In Press.

Seiler, R.L., J.P. Skorupa, D.L. Naftz, and B.T. Nolan. 2003. Irrigation-induced contamination of water, sediment, and biota in the Western United States – synthesis of data from the National Irrigation Water Quality Program. USGS Professional Paper 1655.

Triana, E., J.W. Labadie, and T.K. Gates. 2010. River GeoDSS for Agro-environmental Enhancement of Colorado’s Lower Arkansas River Basin. I: Model Development and Calibration. Journal of Water Resources Planning and Management. 135(2), 177-189.

U.S. Bureau of Reclamation (Reclamation). 2008. Southern Delivery System Final Environmental Impact Statement. Denver.

U.S. Geological Survey (USGS). 2004. Methods to identify changes in background water quality conditions using dissolved solids concentrations and loads as indicators, Arkansas River and Fountain Creek, in the Vicinity of Pueblo, Colorado. Roderick F. Ortiz. Scientific Investigations Report 2004-5024.

U.S. Geological Survey (USGS). 2010. Occurrence and Distribution of Dissolved Solids, Selenium, and Uranium in Groundwater and Surface Water in the Arkansas River Basin from the Headwaters to Coolidge. Scientific Investigations Report 2010–5069.

U.S. Geological Survey (USGS). 2011. USGS Water quality samples for USA. 10 15. <http://nwis.waterdata.usgs.gov/usa/nwis/qwdata>.

Appendix G.1 - Geomorphology Effects

Introduction

Appendix G supplements the Chapter 4 – *Geomorphology* section in the EIS. This appendix contains further information on methodology and quantitative effects of alternatives on Lower Arkansas River and Fountain Creek geomorphology.

Geomorphology is the study of landforms and the processes that shape them. In this analysis, geomorphology is specific to stream channels where changes in discharge may affect sediment transport, erosion, sedimentation, and other processes that affect stream channel characteristics and stability. Geomorphic effects could potentially occur at any location in the study area where there is a change in hydrology, sediment inflow, or channel geometry. Geomorphic effects would include bank and channel bed erosion (collectively called erosion or degradation) and sediment deposition (also referred to as sedimentation or aggradation). Changes in discharge from the alternatives could affect sediment transport, erosion, sedimentation, and other processes potentially altering channel characteristics and stability resulting in erosion/sedimentation, changes in stream meander patterns, or reduced water quality.

Although there are no specific geomorphic related regulatory requirements, related regulatory requirements discussed in other sections of this EIS may indirectly apply to geomorphology (e.g., changes in sediment concentrations or channel stability could affect water quality regulated under the Clean Water Act or habitat for species regulated under the Endangered Species Act).

Study Area

The analysis area for geomorphology generally encompasses the stream systems identified in the surface water hydrology study area (Appendix D.3 and Appendix D.5), with the following exceptions:

Aggradation is the accumulation of sediment in a stream channel resulting in reduced channel capacity.

Channel form is the shape and pattern of the path of the stream channel and its cross section.

Degradation is the erosion of sediment from the channel.

Discharge is the streamflow in a stream channel.

Entrenchment is the ratio of the stream width at flood conditions to the width at bankfull flow.

Sediment load is the sediment discharge or concentration of sediment within the flowing water.

Sediment transport capacity is the amount of potential sediment that can be transported by flowing water given adequate sediment supply.

Stream power is a measure of the energy of the flow of water in a stream, and is commonly used to estimate the magnitude of sediment transport capacity of flowing water.

Stream sinuosity is the length of a stream segment (following the path of water through stream meanders) divided by the length of the valley that the stream flows through. Higher sinuosity indicates a twisted or curvy channel form.

- Reservoirs identified in the surface water hydrology study area are not included in the geomorphology study area.
- The Arkansas River between Pueblo Reservoir and Fountain Creek was not included because the channel is predominantly lined or otherwise stabilized and would not be affected by changes in discharge (U.S. Army Corps of Engineers 2001).
- The Arkansas River downstream from John Martin Reservoir is not included in the analysis area because changes in hydrology downstream from John Martin Reservoir would be predominately negligible (Appendix D.5).
- West Slope stream geomorphology was not evaluated because West Slope streams are steeply sloped, cobble-bed streams with limited mobile sediment and would be generally unaffected by small hydrology effects reported in this Chapter 4 – *Surface Water Hydrology* (Reclamation 2008).

The study area streams were divided into geographical reaches as described below.

Arkansas River Upstream from Pueblo Reservoir

The perennial streams composing the Arkansas River headwaters are supplied by snow melting in mountains surrounding the area of Leadville, Colorado (Abbott 1985). Upstream from Pueblo Reservoir the Arkansas River is a single channel stream with moderate entrenchment characterized by steep gradient, high-velocity flows confined to a relatively narrow rock and cobble stream bed and abundant riparian vegetation. East of Cañon City, river gradient decreases as it flows out of the mountains to Pueblo Reservoir. This geographical reach also includes Lake Creek between Twin Lakes and the confluence with the Arkansas River, which varies from a sand bed, slightly entrenched stream upstream, to a gravel/boulder, moderately entrenched stream in the lower portion. The transition from a sand bed stream to a gravel and boulder stream is likely a result of an increase in stream slope from upstream to downstream.

Arkansas River Downstream from Fountain Creek

The Arkansas River, downstream from its confluence with Fountain Creek, is primarily an alluvial sand-bed stream with notable meandering and slight entrenchment. The bottom width varies from 100 to 250 feet (U.S. Army Corps of Engineers 2009). Photo 1 shows the Arkansas River at the USGS Rocky Ford Gaging Station. Riparian vegetation plays a significant role in geomorphic stability for sand bed streams within the analysis area (i.e., Fountain Creek and the Arkansas River downstream from Fountain Creek).

Source: Livingston 2011

Photo 1. Arkansas River at Gaging Station ARKROCCO, Arkansas River at Rocky Ford, Colorado

Fountain Creek

Fountain Creek is primarily an alluvial sandbed stream with notable meandering and bank storage with slight to moderate entrenchment. The width of Fountain Creek varies from 100 to 250 feet with side slopes of 3H:1V (horizontal to vertical distance ratio). The Fountain Creek Watershed Study noted historical changes in channel form for Fountain Creek and the Arkansas River downstream from Fountain Creek. The changes in channel form are likely a result of channel migration over time, indicating the susceptibility of these reaches for geomorphic change as a result of changes in discharge.

Methods and Analysis

Fluvial geomorphology is a complex science based on the interaction between streamflow and sediment transport. Detailed geomorphic analyses typically involve comprehensive sediment transport modeling that can be data and time intensive. A calibrated sediment transport model would produce more detailed predictions of long-term effects, but was not completed for this analysis because adequate sediment transport data were not available to develop and calibrate such a model and because uncertainty with the model results would still exist from the complex nature of geomorphic interactions. Because the extensive data required for detailed sediment transport analysis were not available to for this analysis, indirect methods were selected to evaluate potential geomorphic effects (i.e., approximate differences in geomorphic properties were estimated among alternatives).

The objective of this analysis is to evaluate the potential geomorphic effects (erosion and deposition) on study area streams caused by hydrologic effects. Potential changes in geomorphology were evaluated using:

- Rosgen Stream Classification System
- Changes in mobile grain size during baseflow conditions.

The sediment transport capacity and loadings at peak flows were not evaluated because the alternatives' effects on flood hydrology and floodplains would be negligible (Reclamation 2011). Potential change in flood flow would vary from a 0.1 percent increase to a 1.4 percent decrease for the Q_2, Q_{10}, and Q_{100} peak flows, which would cause a potential maximum change in flow depth of less than ½ inch for all gage locations, with the largest effects immediately downstream from Pueblo Dam. These amounts could be considered within the margin of error for determining flood hydrology and floodplains. Since anticipated changes in flood hydrology are negligible, there would be no measurable effect on floodplain width or stage caused by changes in peak flows.

Rosgen Stream Classification System

The Rosgen Stream Classification Method (Rosgen 1996) is the most widely used stream classification system in the United States. Figure 1 shows the Rosgen Classification Key for Natural Streams. Streams are grouped into categories A though G based upon the water surface slope, entrenchment, width/depth ratio, and sinuosity. Using dominate stream bed particle size, each category is further refined into six sub-classes, 1 (bedrock) to 6 (silt/clay). Rosgen Stream Classifications for study area streams were obtained from both the Southern Delivery System EIS (Reclamation 2008) and Fountain Creek Watershed Study (U.S. Army Corps of Engineers 2009), and are in Figure 2.

The Rosgen Stream Classification System, along with pebble count and stream cross sections data (Reclamation 2008), were used to perform an initial screening of study area stream segments to identify segments that may be geomorphically sensitive to changes in discharge associated with the alternatives. In general, geomorphically sensitive segments have low to moderate entrenchment and/or sand or gravel bed material. These segments have the capability of being eroded and changing meander patterns as a result of changes in hydrology. Based upon this initial screening, the potential geomorphically sensitive segments comprising the analysis include: the Arkansas River from Highway 115 to the inlet to Pueblo Reservoir; Fountain Creek from the City of Fountain to the Arkansas River confluence; and the Arkansas River from the Fountain Creek mouth to the Avondale Gage. The characteristics of these potential geomorphic sensitive stream segments are listed in Table 1 and the locations are shown in Figure 3. The remainder of the analysis will be limited to these potentially geomorphically sensitive segments.

Table 1. Characteristics of Potential Geomorphic Sensitive Arkansas River Basin Area Streams

	Geomorphic Parameter		
Stream Segment	Channel Material	Entrenchment	Riparian Vegetation Affects Stability
Arkansas River from Colorado 115 to Pueblo Reservoir	Gravel	Moderate	No
Fountain Creek from City of Fountain to Arkansas River	Sand	Slight/Moderate	Yes
Arkansas River from Fountain Creek to Avondale Gage	Sand	Slight	Yes

Upon identifying potential geomorphically sensitive streams, the Rosgen Stream Classification System parameters (width to depth ratio, sinuosity, channel slope, and channel bed material) were further analyzed using cross sectional survey data (LDC 2006) and satellite imagery and are summarized in Table 2, along with the recommended Rosgen classification ranges for each parameter and stream type. Although the Rosgen Stream Classification System uses channel forming discharge (effective discharge, approximately equal to the two-year flood event), the results from this analysis were further defined to determine if any of the stream segments were close to a potential geomorphic threshold, indicating a potential change from one Rosgen stream type to another under changing discharge conditions.

As presented in Table 2, no parameters used to classify the stream segments would be close to the outside of their respective ranges, therefore, existing Rosgen Stream Classifications would not likely change from one classification to another as a result of minor changes in discharge associated with the alternatives. In addition, as mentioned previously, changes in discharge associated with the alternatives would not affect the flood hydrology, which confirms that the Rosgen classifications should not change as a result of minor changes in discharge for study area streams.

Table 2. Summary of Estimated Rosgen Stream Classification Parameters for Study Area

Stream Segment	Rosgen Stream Type	Sinuosity		Slope		Width / Depth	
		Estimated	Rosgen Range [1]	Estimated	Rosgen Range [1]	Estimated	Rosgen Range [1]
Fountain Creek from Fountain to Pinion Gage	C4	1.47	> 1.2	0.0045	0.001 – 0.02	33	> 12
Fountain Creek from Pinion to Pueblo Gage	C4	1.30	> 1.2	0.0039	0.001 – 0.02	40	> 12
Arkansas River – Colorado 115 to Pueblo Reservoir	B4c	1.30	> 1.2	0.00507	< 0.02	21	> 12
Arkansas River - Fountain Creek to Avondale Gage	D5	1.36	n/a	0.00192	0.001 – 0.02	75	> 40

Notes:
[1] From Applied River Morphology (Rosgen).

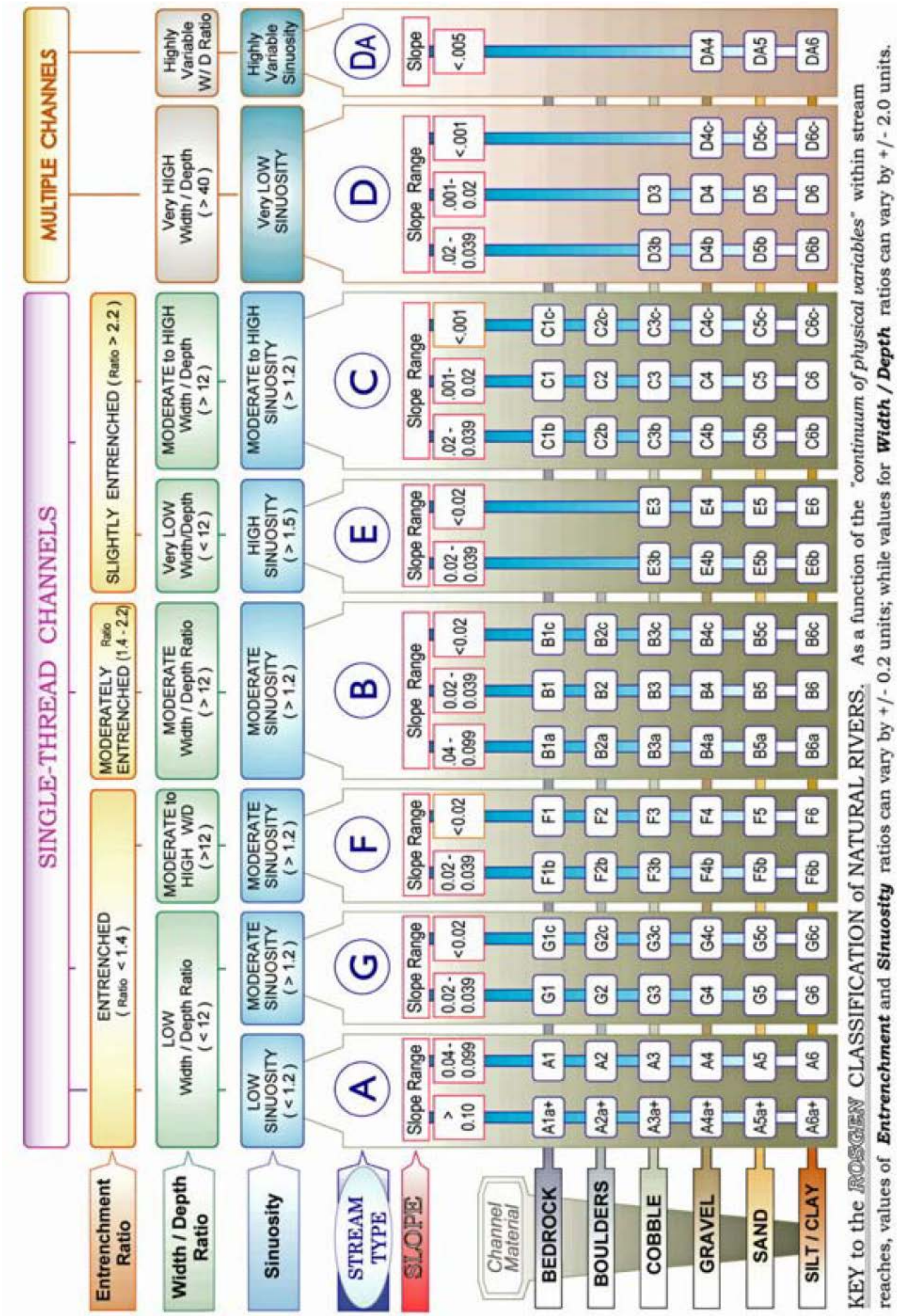


Figure 1. Rosgen Classification Key for Natural Streams

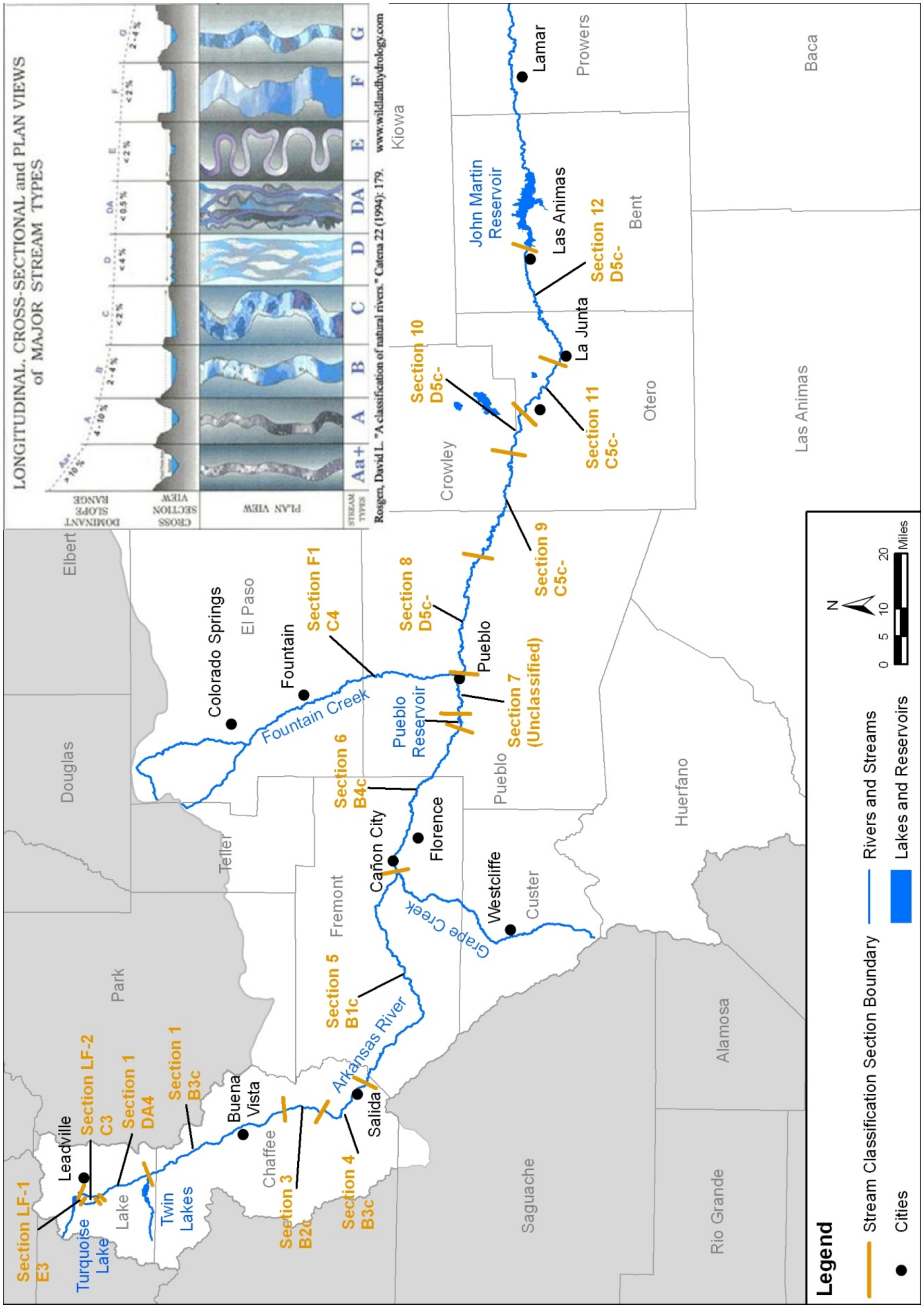


Figure 2. Arkansas River Basin Stream Segment Classifications

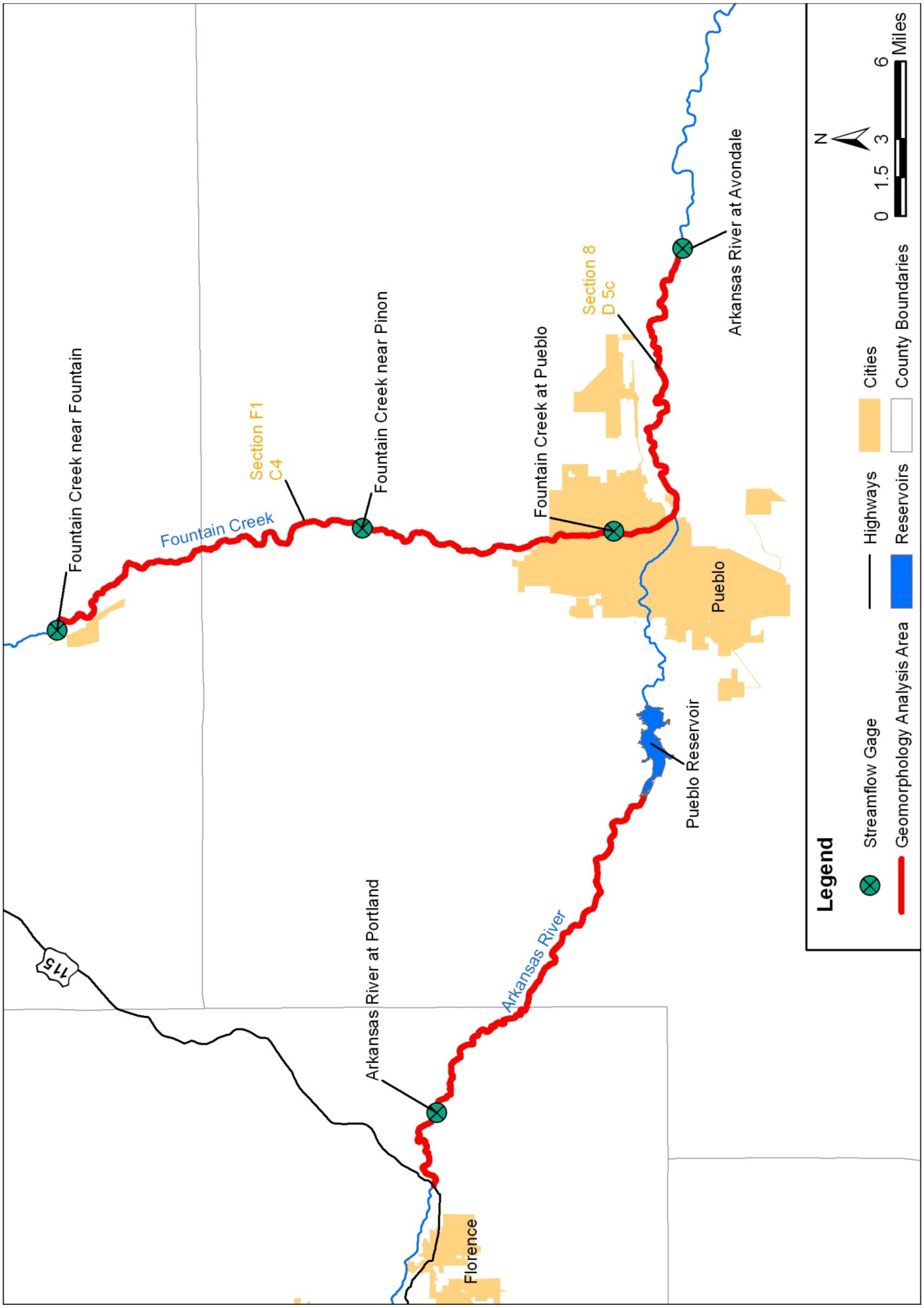


Figure 3. Geomorphic Effects Analysis Area

Mobile Grain Size Analysis

Changes in the sizes of sediment particles that can be transported at baseflows could cause a gradual, long-term geomorphic change. Baseflow is streamflow that occurs at low flow conditions as a result of soil moisture, ground water inflow, and wastewater effluent. Baseflow was estimated as the average daily flow from December through February (the winter period represents baseflows not associated with storm water runoff) for calculations of baseflow mobile grain size. Baseflow is considered to be a primary influence on long-term gradual transport of sediment on Fountain Creek, especially the finer portion of the sediment (e.g., suspended load and the finer material in the bed load) (Stogner 2000). Mobile grain size was evaluated using the critical Shields Parameter (Meyer-Peter and Muller 1948; Gessler 1965), which uses Equation 1 to calculate the largest sediment particle that would move at any given streamflow.

Equation 1

$$\theta = \left[\frac{\tau}{g \cdot \rho \left(\frac{\rho_s}{\rho} - 1 \right) \cdot D_{50}} \right]$$

Where,

θ = Shields parameter
g = gravity
ρ_s = sediment density
ρ = fluid density
D_{50} = median particle diameter
τ = shear stress.

The Shields parameter was developed by Shields (1936) as a function of shear stress, fluid density, sediment density, and sediment size (D_{50}). Critical shear stress for incipient motion (the point at which sediment is mobilized) occurs when the Shields parameter reaches the value 0.047. Shear stress was calculated using the Equation 2.

Equation 2

$$\tau = \gamma \cdot R \cdot S$$

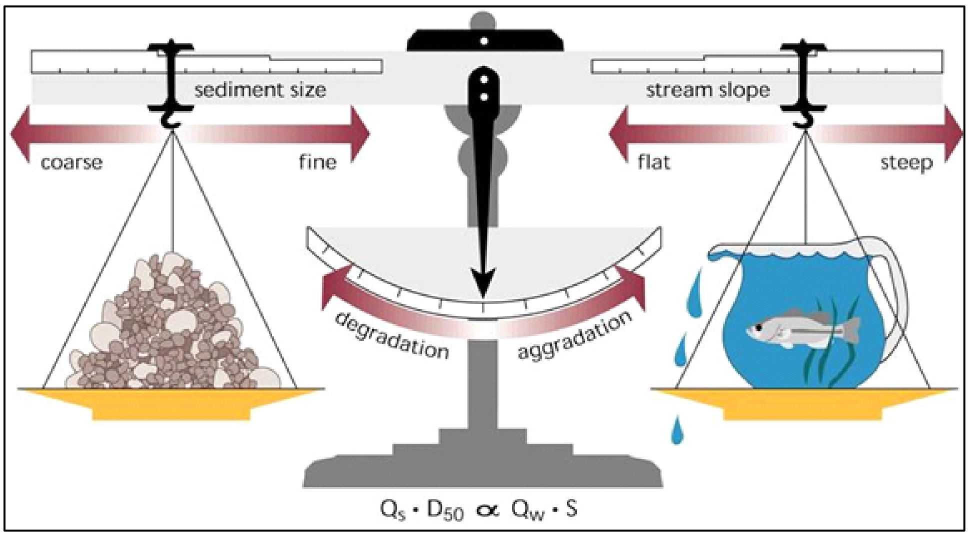
Where,

τ = wall shear stress
γ = specific weight of water
R = hydraulic radius
S = channel slope.

In order to calculate the grain size transported at incipient motion (mobile grain size) for the baseflow condition, Equation 1 was rearranged to solve for D_{50}. The hydraulic radius was calculated by utilizing a stage discharge relationship developed from the Flowmaster at each cross section.

Evaluation of Results

Several uncertainties are associated with the geomorphic effects analysis. The effects described in this analysis are large-scale effects averaged for a stream segment. It is not possible to evaluate effects at an exact location using the methods for this analysis. Determination of effects for a given location would require a calibrated sediment transport model and a large amount of sediment transport data that were not available for this analysis. Additionally, long-term dynamic changes that would occur as streams attempt to adjust to a new geomorphic equilibrium were estimated with the conceptual model in Figure 4. Results of the short-term geomorphic analyses (i.e., predictions of erosion or sedimentation) were considered in the context of the conceptual model to predict long-term geomorphic adjustments. These long-term effects should be considered as approximations of gross-scale effects that would occur, and specific long-term effects may vary from segment to segment.



Source: Natural Resources Conservation Service 1998
Figure 4. Lanes Balance for Sediment Transport

Criteria for Determining Significance of Effects

Linear relationships between the percent change in baseflow mobile grain size and the classification of geomorphic effects were assumed in developing the effects significance in Table 3.The intensity of geomorphic effects (e.g., minor versus major) was based on professional judgment using knowledge of study area streams.

Table 3. Intensity of Geomorphology Effects Based on Changes in Baseflow Mobile Grain Size

Effect Intensity [(1)]	Intensity Description
Negligible	The alternative would change geomorphic conditions, but the change would be so small that it would be immeasurable or imperceptible. The change would be within accuracies of calculation methods used to estimate sediment transport and other geomorphic characteristics. Effects to baseflow mobile grain size would less than 5 percent.
Minor	The alternative would cause a measureable change to geomorphic conditions, but the change would be small, localized, and of little consequence. The geomorphic condition would not affect other downstream reaches - any changes in sediment transport capacity or other geomorphic characteristics would be limited to a single reach. Effects to baseflow mobile grain size would be between 5 and 10 percent.
Moderate	The alternative would cause a measureable and consequential change to geomorphic conditions, but would be limited to existing areas of geomorphic instability and would not affect other downstream locations. Changes in sediment transport capacity or other geomorphic characteristics would be limited to existing locations of geomorphic instabilities. These areas of geomorphic instabilities would be covered under existing plans to improve geomorphic conditions within study area streams. Effects to baseflow mobile grain size would be between 10 and 15 percent.
Major	The alternative would cause a large, measurable, consequential change to geomorphic conditions. Changes in sediment transport capacity or other geomorphic characteristics would occur consistently at locations outside of existing locations of geomorphic instabilities. Geomorphic conditions would be exacerbated over a wide area and introduce new reaches of streams to geomorphic instabilities (erosion or sediment deposition) that were previously considered stable and not covered under existing plans to improve geomorphic conditions within study area streams. Effects to baseflow mobile grain size would be between greater than 15 percent.

Notes:
(1) Effects are relative to the No Action Alternative.

Results

Direct, indirect, and cumulative effects of alternatives on geomorphology, along with actions to minimize effects, are presented in this section. AVC and Master Contract operations would directly and indirectly affect geomorphology because of streamflow changes in sensitive stream segments. These same operations, along with other reasonably foreseeable actions, would cumulatively affect geomorphology.

As previously described, the analysis focused on large-scale geomorphic processes for stream reaches, but does not predict effects at point locations where local controls would play an important part in determining thresholds for estimating the degree of geomorphic effects.

Effects on geomorphic stability associated with changes to riparian vegetation were qualitatively considered. Erosion of channel banks could occur as a result of reduced riparian vegetation, especially in streams with sand and gravel bed material (e.g., Fountain Creek and the Arkansas River downstream from Fountain Creek). Riparian vegetation would not have a substantial effect on geomorphic stability in stream segments with more cohesive bed material such as bedrock. Overall effects on riparian vegetation would be negligible.

Direct and Indirect Effects

Differences in hydrology among the alternatives generally would result in effects on geomorphology when compared to the No Action Alternative and existing conditions. Effects to baseflow for all alternatives relative to both the No Action Alternative and existing conditions are in Table 4 and geomorphic effects of changes in mobile grain size relative to the No Action Alternative and existing conditions are in Table 5.

Arkansas River Upstream from Pueblo Reservoir

There would be negligible effects for the alternatives relative to the No Action Alternative along the Arkansas River from Highway 115 to Pueblo Reservoir, with estimated changes in mobile grain size ranging from -0.4 to 0.0 percent.

The estimated changes in mobile grain size compared to existing conditions would range from -0.8 to -0.1 percent, which would correspond to a decrease in mobile grain size of -0.2 to -0.1 mm. The alternatives would not affect sedimentation or aggradation for baseflow conditions along this reach when compared to existing conditions.

Arkansas River Downstream From Fountain Creek

Geomorphic effects of changes in mobile grain size would be negligible relative to both the No Action Alternative and existing conditions along the Arkansas River from the Fountain Creek mouth to the Avondale Gage. When comparing the alternatives to the No Action Alternative, the estimated change in mobile grain size would range from -1.1 to 1.4 percent, which would represent a change in mobile grain of -1.0 to 1.3 mm. The JUP North Alternative is the only alternative that would decrease mobile grain size, but effects would be negligible.

When comparing the alternatives to existing conditions, the estimated change in mobile grain size would range from 0.3 to 2.8 percent, which would increase the mobile grain size 0.3 to 2.6 mm and could cause minimal increased erosion at baseflow conditions.

Fountain Creek

Although some alternatives would affect baseflow more than 5 percent along Fountain Creek, compared to the No Action, effects to mobile grain size would be negligible. Mobile grain size would increase up to 0.2 mm or a 2.4 percent increase, which would be negligible.

The No Action Alternative would not adversely affect geomorphology compared to existing conditions. Although there would be minor effects to baseflow along Fountain Creek from Fountain to its confluence with the Arkansas River, this change in baseflow would result in a negligible effect on mobile grain size. The estimated changes in mobile grain size of the alternatives compared to existing conditions would range from 2.4 to 4.8 percent, which would change mobile grain size less than 0.5 mm, and would indicate negligible erosion along this reach as a result of changes in baseflow.

Although geomorphic effects on Fountain Creek would be predominately negligible, Fountain Creek historically has been a geomorphically unstable stream. Erosion typically occurs in the upper part of Fountain Creek leading to sedimentation in Lower Fountain Creek and the confluence with the Arkansas River as a result of decreased stream power. This leads to changes in channel form as a result of natural changes in streamflow from year to year. These existing erosion/sedimentation processes would still occur; however, from the results presented above, changes to the existing stream processes as a result of the alternatives would be negligible.

As previously stated, the Rosgen Stream Classification of the study area streams would not change as a result of the minor changes in baseflow associated with the alternatives.

Cumulative Effects

Cumulative effects to baseflow and mobile grain size for all alternatives relative to the No Action Alternative are summarized in Table 6 and Table 7. Geomorphic effects caused by changes in mobile grain size for all alternatives relative to the No Action Alternative would be negligible.

The No Action Alternative would increase baseflow and mobile grain size in Fountain Creek, compared to existing conditions. Reasonably foreseeable urban and suburban development in the Fountain Creek watershed would increase baseflow because of increased water use and associated return flows, and could lead to increased erosion. The increase in mobile grain size would range from 1.9 mm to 2.5 mm, which would represent an increase of about 1/16 of an inch.

Similarly, baseflow and mobile grain size would increase in the No Action Alternative relative to existing conditions along the Arkansas River between Fountain Creek and the Arkansas River Near Avondale Gage. The increase in mobile grain size would be about 1/2 of an inch (13 mm). The Southern Delivery System EIS (Reclamation 2008) found that cumulative flood flows would increase in the No Action Alternative, compared to existing conditions, and would affect Fountain Creek geomorphology.

Table 4. Direct and Indirect Geomorphic Effects – Baseflow

Aquifer	Existing Condition	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Baseflow (cfs)								
Arkansas River from CO 115 to the Pueblo Res.	401.3	397.3	396.7	396.3	399.7	396.7	396.3	396.0
Fountain Creek from Fountain to Pinion Gage	111.0	117.7	124.3	124.3	118.0	124.3	124.3	124.3
Fountain Creek from Pinion Gage to Pueblo Gage	122.7	129.3	135.3	135.3	129.3	135.3	135.3	135.3
Arkansas River from the Fountain Creek to Avondale Gage	253.6	257.7	260.3	260.0	254.7	260.3	257.7	261.7
Effects – Change in Baseflow [(1)] [cfs (%)] (No Action Baseline)								
Arkansas River from CO 115 to the Pueblo Res.	---	---	-0.6 (-0.2)	-1.0 (-0.3)	2.4 (0.6)	-0.6 (-0.2)	-1.0 (-0.3)	-1.3 (-0.3)
Fountain Creek from Fountain to Pinion Gage	---	---	6.6 (5.6)	6.6 (5.6)	0.3 (0.3)	6.6 (5.6)	6.6 (5.6)	6.6 (5.6)
Fountain Creek from Pinion Gage to Pueblo Gage	---	---	6.0 (4.6)	6.0 (4.6)	0.0 (0.0)	6.0 (4.6)	6.0 (4.6)	6.0 (4.6)
Arkansas River from the Fountain Creek to Avondale Gage	---	---	2.6 (1.0)	2.3 (0.9)	-3.0 (-1.2)	2.6 (1.0)	0.0 (0.0)	4.0 (1.6)
Effects – Change in Baseflow [(1)] [cfs (%)] (Existing Conditions Baseline)								
Arkansas River from CO 115 to the Pueblo Res.	---	-4.0 (-1.0)	-4.6 (-1.1)	-5.0 (-1.2)	-1.6 (-0.4)	-4.6 (-1.1)	-5.0 (-1.2)	-5.3 (-1.3)
Fountain Creek from Fountain to Pinion Gage	---	6.7 (6.0)	13.3 (11.9)	13.3 (11.9)	7.0 (6.3)	13.3 (11.9)	13.3 (11.9)	13.3 (11.9)
Fountain Creek from Pinion Gage to Pueblo Gage	---	6.6 (5.4)	12.6 (10.3)	12.6 (10.3)	6.6 (5.4)	12.6 (10.3)	12.6 (10.3)	12.6 (10.3)
Arkansas River from the Fountain Creek to Avondale Gage	---	4.1 (1.6)	6.7 (2.6)	6.4 (2.5)	1.1 (0.4)	6.7 (2.6)	4.1 (1.6)	8.1 (3.2)

Notes:
(1) Positive changes represent trends toward increased erosion or decreased aggradation; negative changes represent trends toward increased aggradation or decreased erosion.

Table 5. Direct and Indirect Geomorphic Effects – Mobile Grain Size

Aquifer	Existing Condition	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Mobile Grain Size (mm)								
Arkansas River from CO 115 to the Pueblo Res.	26.2	26.1	26.1	26.1	26.1	26.1	26.1	26.0
Fountain Creek from Fountain to Pinion Gage	8.3	8.5	8.7	8.7	8.5	8.7	8.7	8.7
Fountain Creek from Pinion Gage to Pueblo Gage	10.3	10.6	10.8	10.8	10.6	10.8	10.8	10.8
Arkansas River from the Fountain Creek to Avondale Gage	92.0	93.3	94.2	94.1	92.3	94.2	93.3	94.6
Effects – Change in Mobile Grain Size [(1)] [mm (%)] (No Action Baseline)								
Arkansas River from CO 115 to the Pueblo Res.	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	-0.1 (-0.4)
Fountain Creek from Fountain to Pinion Gage	---	---	0.2 (2.4)	0.2 (2.4)	0.0 (0.0)	0.2 (2.4)	0.2 (2.4)	0.2 (2.4)
Fountain Creek from Pinion Gage to Pueblo Gage	---	---	0.2 (1.9)	0.2 (1.9)	0.0 (0.0)	0.2 (1.9)	0.2 (1.9)	0.2 (1.9)
Arkansas River from the Fountain Creek to Avondale Gage	---	---	0.9 (1.0)	0.8 (0.9)	-1.0 (-1.1)	0.9 (1.0)	0.0 (0.0)	1.3 (1.4)
Effects – Change in Mobile Grain Size [(1)] [mm (%)] (Existing Conditions Baseline)								
Arkansas River from CO 115 to the Pueblo Res.	---	-0.1 (-0.4)	-0.1 (-0.4)	-0.1 (-0.4)	-0.1 (-0.4)	-0.1 (-0.4)	-0.1 (-0.4)	-0.2 (-0.8)
Fountain Creek from Fountain to Pinion Gage	---	0.2 (2.4)	0.4 (4.8)	0.4 (4.8)	0.2 (2.4)	0.4 (4.8)	0.4 (4.8)	0.4 (4.8)
Fountain Creek from Pinion Gage to Pueblo Gage	---	0.3 (2.6)	0.5 (4.5)	0.5 (4.5)	0.3 (2.6)	0.5 (4.5)	0.5 (4.5)	0.5 (4.5)
Arkansas River from the Fountain Creek to Avondale Gage	---	1.3 (1.4)	2.2 (2.4)	2.1 (2.3)	0.3 (0.3)	2.2 (2.4)	1.3 (1.4)	2.6 (2.8)

Notes:
[(1)] Positive changes represent trends toward increased erosion or decreased aggradation; negative changes represent trends toward increased aggradation or decreased erosion.

Table 6. Cumulative Geomorphic Effects – Baseflow

Aquifer	Existing Condition	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Simulated Baseflow (cfs)								
Arkansas River from CO 115 to the Pueblo Res.	401.4	420.3	423.0	423.0	423.7	423.0	421.3	419.0
Fountain Creek from Fountain to Pinion Gage	111.0	183.7	185.7	185.7	183.0	185.3	185.7	186.0
Fountain Creek from Pinion Gage to Pueblo Gage	122.6	191.7	193.3	193.0	191.0	193.3	193.7	194.0
Arkansas River from the Fountain Creek to Avondale Gage	253.7	295.3	296.3	295.7	293.7	296.0	292.7	297.3
Effects – Change in Baseflow [(1)] [cfs (%)] (No Action Baseline)								
Arkansas River from CO 115 to the Pueblo Res.	---	---	2.7 (0.6)	2.7 (0.6)	3.4 (0.8)	2.7 (0.6)	1.0 (0.2)	-1.3 (-0.3)
Fountain Creek from Fountain to Pinion Gage	---	---	2.0 (1.1)	2.0 (1.1)	-0.7 (-0.4)	1.6 (0.9)	2.0 (1.1)	2.3 (1.3)
Fountain Creek from Pinion Gage to Pueblo Gage	---	---	1.6 (0.8)	1.3 (0.7)	-0.7 (-0.4)	1.6 (0.8)	2.0 (1.0)	2.3 (1.2)
Arkansas River from the Fountain Creek to Avondale Gage	---	---	1.0 (0.3)	0.4 (0.1)	-1.6 (-0.5)	0.7 (0.2)	-2.6 (-0.9)	2.0 (0.7)
Effects – Change in Baseflow [(1)] [cfs (%)] (Existing Conditions Baseline)								
Arkansas River from CO 115 to the Pueblo Res.	---	18.9 (4.7)	21.6 (5.4)	21.6 (5.4)	22.3 (5.5)	21.6 (5.4)	19.9 (4.9)	17.6 (4.4)
Fountain Creek from Fountain to Pinion Gage	---	72.7 (65.5)	74.7 (67.3)	74.7 (67.3)	72.0 (64.9)	74.3 (66.9)	74.7 (67.3)	75.0 (67.6)
Fountain Creek from Pinion Gage to Pueblo Gage	---	69.1 (56.3)	70.7 (57.6)	70.4 (57.4)	68.4 (55.7)	70.7 (57.6)	71.1 (57.9)	71.4 (58.2)
Arkansas River from the Fountain Creek to Avondale Gage	---	41.6 (16.4)	42.6 (16.8)	42.0 (16.6)	40.0 (15.8)	42.3 (16.7)	39.0 (15.4)	43.6 (17.2)

Notes:
[(1)] Positive changes represent trends toward increased erosion or decreased aggradation; negative changes represent trends toward increased aggradation or decreased erosion.

Table 7. Cumulative Geomorphic Effects – Mobile Grain Size

Aquifer	Existing Condition	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Mobile Grain Size (mm)								
Arkansas River from CO 115 to the Pueblo Res.	26.2	26.6	26.7	26.7	26.7	26.7	26.7	26.6
Fountain Creek from Fountain to Pinion Gage	8.3	10.2	10.2	10.2	10.2	10.2	10.2	10.2
Fountain Creek from Pinion Gage to Pueblo Gage	10.3	12.8	12.9	12.9	12.8	12.9	12.9	12.9
Arkansas River from the Fountain Creek to Avondale Gage	92.0	105.6	105.9	105.7	105.1	105.8	104.7	106.2
Effects – Change in Mobile Grain Size [(1)] [mm (%)] (No Action Baseline)								
Arkansas River from CO 115 to the Pueblo Res.	---	---	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.0 (0.0)
Fountain Creek from Fountain to Pinion Gage	---	---	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Fountain Creek from Pinion Gage to Pueblo Gage	---	---	0.1 (0.8)	0.1 (0.8)	0.0 (0.0)	0.1 (0.8)	0.1 (0.8)	0.1 (0.8)
Arkansas River from the Fountain Creek to Avondale Gage	---	---	0.3 (0.3)	0.1 (0.1)	-0.5 (-0.5)	0.2 (0.2)	-0.9 (-0.9)	0.6 (0.6)
Effects – Change in Mobile Grain Size [(1)] [mm (%)] (Existing Conditions Baseline)								
Arkansas River from CO 115 to the Pueblo Res.	---	0.4 (1.7)	0.5 (2.1)	0.5 (2.1)	0.5 (2.1)	0.5 (2.1)	0.5 (2.1)	0.4 (1.7)
Fountain Creek from Fountain to Pinion Gage	---	1.9 (22.2)	1.9 (22.2)	1.9 (22.2)	1.9 (22.2)	1.9 (22.2)	1.9 (22.2)	1.9 (22.2)
Fountain Creek from Pinion Gage to Pueblo Gage	---	2.5 (24.6)	2.6 (25.6)	2.6 (25.6)	2.5 (24.6)	2.6 (25.6)	2.6 (25.6)	2.6 (25.6)
Arkansas River from the Fountain Creek to Avondale Gage	---	13.6 (14.8)	13.9 (15.1)	13.7 (14.9)	13.1 (14.3)	13.8 (15.0)	12.7 (13.8)	14.2 (15.5)

Notes:
[(1)] Positive changes represent trends toward increased erosion or decreased aggradation; negative changes represent trends toward increased aggradation or decreased erosion.

References

Abbott, P.O. 1985. Description of Water-Systems Operations in the Arkansas River Basin, Colorado: U.S. Geological Survey Water-Resources Investigations Report 85- 4092. Lakewood, CO.

Gessler, J. 1965. The Beginning of Bedload Movement of Mixtures Investigated as Natural Armoring in Channels. Report No. 69 of the Laboratory of Hydraulic Research and Soil Mechanics of the Swiss Federal Institute of Technology. Zurich, Switzerland (translation by W. M. Keck Laboratory of Hydraulics and Water Resources, California Inst. Technology).

Land Development Consultants (LDC). 2006. Channel cross-section topography for the Southern Delivery System Environmental Impact Statement. May.

Meyer-Peter, E. and R. Muller. 1948. Formulas for Bed-Load Transport. Second Meeting of the International Association for Hydraulics Research. Stockholm, Sweden, Appendix 2.

Natural Resources Conservation Service. 1998. Stream Corridor Restoration: Principles, Processes, and Practices. Federal Interagency Stream Restoration Working Group.

Rosgen, D. 1996. Applied River Morphology. Pagosa Springs, Colorado: Wildland Hydrology.

Stogner, R.W. 2000. Trends in Precipitation and Streamflow and Changes in Stream Morphology in the Fountain Creek Watershed, Colorado, 1939-99. USGS Water-Resources Investigations Report 00- 4130. Denver, CO: U.S. Geological Survey.

U.S. Army Corps of Engineers. 2001. Draft Ecosystem Restoration Report and Environmental Assessment, Arkansas River Fisheries Habitat Restoration, Pueblo, CO.

U.S. Army Corps of Engineers. 2009. U.S. Fountain Creek Watershed Study. Watershed Management Plan. January.

U.S. Bureau of Reclamation (Reclamation). 2008. Southern Delivery System Final Environmental Impact Statement. Filing Number: FES 08-63. Great Plains Region, Eastern Colorado Area Office, Loveland. December.

U.S. Bureau of Reclamation (Reclamation) 2011. AVC Flood Hydrology and Floodplains Memorandum dated April 13, 2011

Appendix H.1 – Aquatic Resources – Common and Scientific Names

Introduction

This appendix includes a table on fish species and hybrids discussed in the EIS and Appendix H, as well as their status as native (N) or introduced (I) to the Arkansas River Basin (Nesler 1997), and their status as a federally threatened (FT), state threatened (ST), state endangered (SE), state species of special concern (SC), extirpated, or extinct species.

Table 1. Common and Scientific Names of Fish Species and Hybrids and their Status

Common Name	Scientific Name	Native/Introduced	Status
American eel	*Anguilla rostrata*	N	Extirpated
Arkansas darter	*Etheostoma cragini*	N	ST
Arkansas River Shiner	*Notropis girardi*	N	(1)
Black bullhead	*Ameiurus melas*	N	--
Black crappie	*Pomoxis nigromaculatus*	I	--
Blue catfish	*Ictalurus furcatus*	I	--
Bluegill	*Lepomis macrochirus*	I	--
Brook stickleback	*Culaea inconstans*	I	--
Brook trout	*Salvelinus fontinalis*	I	--
Brown trout	*Salmo trutta*	I	--
Central stoneroller	*Campostoma anomalum*	N	--
Channel catfish	*Ictalurus punctatus*	N	--
Common carp	*Cyprinus carpio*	I	--
Creek chub	*Semotilus atromaculatus*	I	--
Cutbow trout (hybrid)	*Oncorhynchus mykiss x O. clarkii*	I	--
Cutthroat trout	*Oncorhynchus clarkii*	N and I strains	--
European Rudd	*Scardinius erythrophthalmus*	I	--
Fathead minnow	*Pimephales promelas*	N	--
Flathead catfish	*Pylodictis olivaris*	I	--
Flathead chub	*Platygobio gracilis*	N	SC
Freshwater drum	*Aplodinotus grunniens*	I	--
Gizzard shad	*Dorosoma cepedianum*	N	--
Golden Shiner	*Notemigonus crysoleucas*	I	--
Grass carp	*Ctenopharyngodon idella*	I	--
Greenback cutthroat	*Oncorhynchus clarkii stomias*	N	FT/ST
Green sunfish	*Lepomis cyanellus*	N	--
Hybrid bluegill	*Lepomis macrochirus x L. cyanellus*	I	--
Kokanee (sockeye)	*Oncorhynchus nerka*	I	--
Lake trout	*Salvelinus namaycush*	I	--
Largemouth bass	*Micropterus salmoides*	I	--
Longnose dace	*Rhinichthys cataractae*	N	--
Longnose sucker	*Catostomus catostomus*	I	--
Orangespotted sunfish	*Lepomis humilis*	N	--

Common Name	Scientific Name	Native/Introduced	Status
Plains killifish	*Fundulus zebrinus*	N	--
Plains minnow	*Hybognathus placitus*	N	SE
Rainbow trout	*Oncorhynchus mykiss*	I	--
Red shiner	*Cyprinella lutrensis*	N	--
Sand shiner	*Notropis stramineus*	N	--
Saugeye (hybrid)	*Stizostedion canadense* x *S. vitreum*	I	--
Smallmouth bass	*Micropterus dolomieu*	I	--
Southern redbelly dace	*Phoxinus erythrogaster*	N	SE
Speckled chub	*Macrhybopsis aestivalis*	N	Extirpated
Spotted bass	*Micropterus punctulatus*	I	--
Striped bass	*Morone saxatilis*	I	--
Suckermouth minnow	*Phenacobius mirabilis*	N	SE
Tiger muskie (hybrid)	*Esox masquinongy x E. lucius*	I	--
Walleye	*Stizostedion vitreum*	I	--
Western mosquitofish	*Gambusia affinis*	I	--
White bass	*Morone chrysops*	I	--
White crappie	*Pomoxis annularis*	I	--
White sucker	*Catostomus commersonii*	N	--
Wiper (hybrid)	*Morone chrysops* x *M. saxatilis*	I	--
Yellow bullhead	*Ameiurus natalis*	N	--
Yellowfin cutthroat	*Oncorhynchus clarkii macdonaldi*	N	Extinct
Yellow perch	*Perca flavescens*	I	--

Key:
FT = federally threatened
I = introduced
N = native
SC = state species of special concern
SE = state endangered
ST =state threatened

Notes:
(1) Never been collected in Colorado.

References

Nesler, T.P. 1997. Native and introduced fish species by major river basins in Colorado. Nongame and Endangered Aquatic Wildlife Program. Colorado Division of Wildlife.

Appendix H.2 – Aquatic Resources – Affected Environment

Introduction

The primary purpose of this Aquatic Resources Affected Environment Appendix is to present data on the existing aquatic resources that may be affected by the proposed alternatives. This information is used in the preparation of an Environmental Impact Statement (EIS) evaluating the proposed alternatives. The information in this appendix is used as the basis for the Affected Environment section of the EIS (Chapter 3) and is intended to provide sufficient data to support the determination of potential impacts in the Environmental Consequences section of the EIS (Chapter 4). The aquatic resources that the alternatives could potentially affect include fish and invertebrate populations and their habitat in the study area described below. The alternatives could potentially affect the aquatic environment through changes in streamflow, storage patterns in reservoirs, water quality, flooding, channel geomorphology, or riparian vegetation in the water bodies in the study area.

The primary assumption for the AVC EIS is that fish, benthic invertebrates, and their habitat represent the components of the aquatic environment of interest to agencies and to the public. Based on public comments received during scoping and discussions with the state and federal agencies, this assumption is appropriate.

This appendix includes the assumption that the alternatives could potentially affect aquatic resources through changes in flow in streams, storage patterns in reservoirs, and/or changes to water quality in the study area. The impact assessment in the EIS focuses on changes in fish and invertebrate species composition and abundance parameters. Therefore, the data presented in this appendix focuses on these aspects of the aquatic community.

The specific objectives of this appendix are to document methods used in obtaining data on aquatic resources, and to describe the fish, invertebrate, and habitat resources of the study area. We collected information primarily by reviewing literature from past studies by state and federal agencies. We collected supplemental data for fish and habitat in one stream section where data gaps had been identified during the agency scoping process. Aquatic resources not expected to be affected by the proposed alternatives are not described in this appendix.

Study Area

For the purposes of this description of aquatic resources, the spatial scope of the alternatives includes water bodies potentially affected by the alternatives, either because of modified hydrology or changes to water quality. Streams potentially affected by altered flow regimes include Lake Fork downstream from Turquoise Lake, Lake Creek downstream from Twin Lakes, the Arkansas River downstream from Lake Fork to the Kansas State line, Grape Creek both upstream and downstream from DeWeese Reservoir, and Fountain Creek from the Security Gage downstream to its confluence with the Arkansas River in Pueblo. Eight reservoirs could be affected by the proposed alternatives, including Turquoise, Twin Lakes, DeWeese, Pueblo, Lake Henry, Lake Meredith, Holbrook, and John Martin reservoirs. These streams and reservoirs are collectively referred to as the study area.

Historical Influences

The present status of the aquatic biological communities in the study area is a result of historical and current activities and differs from the natural ecosystem that existed prior to settlement. Activities that have influenced the aquatic ecosystem have caused changes in hydrology, water quality, and channel morphology. Changes in hydrology are due to the development of water resources for agriculture, municipal and industrial water supply, and other uses. This includes previous construction of the reservoirs in the study area. Changes in water quality are due to activities such as mining, urbanization, and changes in land use. Changes in channel morphology and habitat are directly due to activities, such as reservoir construction and channelization, or indirectly due to changes in hydrology and urbanization.

The Arkansas River is one of the most highly managed rivers in the western United States, with transmountain diversions and construction of reservoirs beginning in the early 1900s (Gierard et al. 2000). Impacts from placer mining were noted on the Arkansas River in the Granite and Leadville areas as early as 1889 (Jordan 1891). Also, some fish populations are managed for recreational fishing. These activities have changed species composition, species distribution, and habitat from pre-settlement conditions.

There is limited historical information to document changes from pre-settlement condition. However, reconstructions by Fausch and Bestgen (1997) and Nesler (1997) of the historic native fish assemblage of the Arkansas River Basin resulted in 20 and 21 species, respectively being considered native and present prior to settlement. Eighteen of the species are common between the two studies. Of these species, the American eel and speckled chub have been extirpated (i.e., are no longer present locally) from the Arkansas River Basin (Nesler 1997) and the yellowfin cutthroat trout, which was present only in Twin Lakes as recently as 1889, is extinct (Behnke 2002).

The native coldwater fish assemblage in the Arkansas River Basin, with the exception of Twin Lakes consisted of greenback cutthroat trout, longnose dace, and white sucker. The greenback cutthroat trout has been displaced by non-native trout. Longnose dace and white sucker still persist, but the non-native longnose sucker is also now prevalent in coldwater reaches of the Arkansas River.

Most of the native warmwater fish species are still present in the Arkansas River Basin and have been collected recently in the study area in at least low numbers. Exceptions include speckled chub and American eel, which have been extirpated from the basin in Colorado (Nesler 1997), Arkansas River shiners which have never been collected in the state (Fausch and Bestgen 1997), and plains minnow, which were described as not rare in 1889 (Jordan 1891), but have not been documented recently.

This appendix focuses on existing conditions in the streams and reservoirs in the study area. However, changes from pre-settlement conditions are described when appropriate.

Methods

Much of the information in this appendix is available from existing agency sources. During agency scoping and initial study plan development, several data gaps were identified that required supplemental data collection specifically for this EIS.

The data presented in this appendix concentrate on the aspects of the aquatic resources that are relevant for assessing potential impacts in the EIS for fish and benthic invertebrate communities. This report uses a "top-down" approach to data presentation; with fish data presented first, followed by data for benthic invertebrates and habitat.

The best available data for aquatic resources are both quantitative and qualitative. Quantitative data are collected over a known area, such as a known length and width of stream for fish or a known section of the stream bottom for benthic invertebrates. An attempt is made to collect all, or nearly all, of the fish or invertebrates in the sampled area. Quantitative data are generally comparable between sites, dates, and different studies. Quantitative data were collected for fish usually with electrofishing over a length of stream several hundred feet long with the intent of collecting all or a large portion of the fish at the site. Quantitative data were collected for benthic invertebrates with a Hess or Surber sampler which is a cylinder or square with a known area of approximately one square foot with the intent of collecting nearly all of the organisms in the sampling area.

Qualitative data are collected over an unspecified area or time, with differing levels of effort, and only a portion of the fish or invertebrates are collected. Qualitative data are usually not comparable between sites and studies, especially in terms of abundance parameters, such as the number of fish or invertebrates collected. Qualitative data can usually be compared in terms of the relative abundance of the different species and the number of species collected, assuming that sampling effort was relatively similar and sufficient to collect a representative number of the species present. For fish, qualitative data were usually collected with electrofishing in only a small portion of a stream or reservoir or with a gill net in a reservoir with the expectation that only a small portion of the total fish in the stream or reservoir are being collected. For benthic macroinvertebrates, qualitative data were collected with a kick net, which is a simple long-handled net that samples an undetermined area of the stream bottom and an unknown portion of the total invertebrate population.

For fish, the relevant parameters focus on species composition and distribution, and measures of abundance. In coldwater streams, the measures of abundance are usually quantitative, such as density (number per acre) and biomass (pounds per acre). In warmwater streams and reservoirs, the abundance measurements are generally qualitative, such as number collected and relative abundance. Both quantitative and qualitative data on fish provide information on species composition and distribution.

For benthic invertebrates, the relevant parameters focus on species composition and distribution, measures of abundance, and species tolerance values. In coldwater streams, there is usually quantitative information with abundance parameters, such as density (traditionally expressed as number per square meter ($\#/m^2$)). In warmwater streams, much of the information is qualitative.

Both quantitative and qualitative data on benthic invertebrates provide information on species composition and distribution. In reservoirs, benthic invertebrate data are not routinely collected in the study area, thus benthic invertebrate data are generally not presented for the reservoirs in this appendix.

Existing Data Sources Review

In order to gather appropriate information to describe the existing conditions of the aquatic biological resources for the study area, requests for available aquatic biological data were sent to the State of Colorado, United States Geological Survey (USGS), Dr. Scott Herrmann of Colorado State University (CSU)-Pueblo, and Dr. Kevin Bestgen of CSU-Fort Collins. We also searched the available scientific literature. Data were returned through these requests from Colorado Parks and Wildlife (CPW), Colorado Department of Public Health and Environment (Health Department), USGS, Dr. Herrmann, and Dr. Bestgen. The United States Department of the Interior, Bureau of Reclamation (Reclamation) also provided information from past reports. In addition, we searched our internal files at GEI Consultants, Inc. (GEI), formerly (Chadwick Ecological Consultants, Inc. [CEC]) for data from past and current studies we conducted for the City of Colorado Springs and the City of Pueblo.

Existing data are available from as far back as 1979 for some portions of the study area and as recently as 2010 for others. None of the segments of the study area have continuous data over this entire period. For most stream segments, the available data are the result of one or more short-term studies. In a few cases, the data from 1979 and the early 1980s represent a substantial portion of the data available for the stream segment.

Much of the existing data are available from four studies. The first is a joint, long-term monitoring program between the CPW and Resurrection Mining Company (through CEC, their consultant) in the streams in the Leadville area, including Lake Fork and the Upper Arkansas River. This is part of monitoring of the California Gulch Superfund Site. The second study is a long-term monitoring project by Colorado Springs Utilities and by Jim Bruce of the USGS on Fountain Creek. The CPW also assisted with fish data collection as part of this project. Both studies provide multiple years of fish, benthic invertebrate, and habitat data for their respective study areas. The third study is by CPW (Loeffler et al. 1982) for most of the streams in the study area. They sampled fish in 1979 through 1981 to document the status and distribution of the Arkansas darter and the speckled chub in the lower Arkansas River drainage. The data also provided the first systematic survey of fish present in the lower Arkansas River drainage. Lastly, CEC and CPW collected data in 2003 and 2004 to address gaps in the existing information for fish, benthic invertebrates, and habitat for the Southern Delivery System (SDS) EIS (CEC 2006). The CPW also provided data collected as part of their routine sampling programs within the Arkansas River Basin.

Existing Data

This section identifies the available aquatic resources data and is organized into the different sections of streams and reservoirs that comprise the study area. It provides the source of the data, the years the data were collected and brief comments concerning the collection methods.

Lake Fork

Fish community data for Lake Fork are available for fall 1991 from Aquatics Associates, and for spring 1994 (Roy F. Weston, 1995) and fall 1996 from CEC. The CPW sampled the same site in fall 1994. CPW and CEC jointly sampled this site in late summer 1997, 1999, 2001 through 2006, and 2008 (Table 1). Quantitative data were collected using bank-shocking equipment with two pass electrofishing methods.

Table 1: Existing Fish, Benthic Invertebrate, and Habitat Data for Lake Fork from Turquoise Lake Downstream to the Arkansas River Confluence

Agency/Source	Sample Year	Method
Fish Data		
Aquatics Associates (1993)	1991	Quantitative (electrofishing)
CPW (Policky 1994, 1999, 2001, 2002, 2003, 2004a, 2005b, 2006, 2008)	1994, 1997-2006, 2008	Quantitative (electrofishing)
CEC (1994, 1998a, 2001, 2002, 2003, 2004a, 2005), GEI (2006, 2007a, 2008b), Roy F. Weston (1995)	1994, 1996-2006, 2008	Quantitative (electrofishing)
Benthic Invertebrate Data		
Engineering Science (1986)	1985	Quantitative (Hess samples)
Aquatics Associates (1993)	1991	Qualitative (kick samples)
CEC (1994, 1998a, 1999a, 2001, 2002, 2003, 2004a, 2005), EPA (2008), GEI (2006, 2007a, 2008a, b), Roy F. Weston (1995)	1995-2008	Quantitative (Hess samples) Qualitative (sweep samples)
Reclamation (Nelson 2000, Nelson and Roline 1996a, 2003)	1993, 1997-2000	Quantitative (Surber and hyporheic samples) Qualitative (kick samples)
Habitat Data		
CEC (1999a, 2001, 2002, 2003, 2004a, 2005), GEI (2006, 2007a, 2008a)	1998-2007	Quantitative (multiple parameters) Qualitative (RBP)

Benthic macroinvertebrate data are available for the Lake Fork from the monitoring of the California Gulch Superfund Site from Engineering Science for 1985, Aquatics Associates for spring and fall 1991, Reclamation for 1993 and 1997 through 2000, CEC in spring and fall from 1995 through 2007 and spring 2008, and EPA (collected by CEC) in fall 2008 (Table 1). Engineering Science used a Hess sampler to collect quantitative samples. Aquatics Associates data from 1991 were qualitative kick samples collected in riffle habitat. CEC collected quantitative data using a Hess sampler by taking three replicate samples from riffle habitats. The quantitative data were supplemented by a qualitative sweep sample using a kick net in habitats other than riffles. Reclamation collected quantitative data with a Surber sampler and qualitative data with a kick net. Reclamation also collected quantitative hyporheic samples of invertebrates that live below the surface of the stream bottom.

Habitat data are available from CEC and GEI for 1998 through 2007 for Lake Fork from the California Gulch monitoring study (Table 1). This includes collection of quantitative parameters, such as width and depth, as well as a qualitative rating using the United States Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBP) habitat assessment procedure described in Barbour et al. (1999).

Arkansas River, Lake Fork Downstream to the Inlet of Pueblo Reservoir

Recent quantitative fish community data are available from 1994 and 1996-2009 from CPW and/or CEC at several sites upstream from Granite. These sites were sampled at least once in spring and late summer or fall each year. The data were collected by multiple-pass bank electrofishing. The CPW also has quantitative data available for sites between Salida and Coaldale for 1994-2009 (Table 2). This information was collected by electrofishing from a raft and using mark-recapture methods.

Various CPW studies provided data for this section of the Arkansas River from 1979 through the early 1990s (Table 2). Several consultants sampled fish at a few sites in the Leadville area in 1985, 1987, and 1991 using quantitative electrofishing.

Qualitative fish community data for the Arkansas River, from Lake Fork downstream to Pueblo Reservoir, are available from CPW for 1979 through 1981, and 1994 through 1996 (Table 2). Data were collected using various methods. Loeffler et al. (1982) collected data at a few sites just upstream from Pueblo Reservoir in 1979-1981. Nesler et al. (1999) collected data in this reach to update the status of Arkansas River native fishes in Colorado. Both studies have limited data from the lower part of this reach near Pueblo Reservoir.

Table 2: Existing Fish, Benthic Invertebrate, and Habitat Data for the Arkansas River from Lake Fork Downstream to Pueblo Reservoir

Agency/Source	Sample Year	Method
Fish Data		
CPW (Loeffler et al. 1982)	1979, 1980, 1981	Qualitative (seining, electrofishing)
CPW (Nehring and Anderson 1982)	1981, 1982	Quantitative (electrofishing)
CPW (Nehring 1986)	1985	Quantitative (electrofishing)
Engineering Science (1986)	1985	Quantitative (electrofishing)
ENSR (1989)	1985,1987	Quantitative (electrofishing)
CPW (Anderson and Krieger 1994)	1981-1986, 1988, 1990-1991	Quantitative (electrofishing)
Aquatics Associates (1993)	1991	Quantitative (electrofishing)
CPW (Nesler et al. 1999)	1994, 1995, 1996	Qualitative (seining, electrofishing)
CPW (Policky 1994, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005b, 2006, 2007, 2008, 2009)	1994-2009	Quantitative (electrofishing)
CEC (1994, 1998a, 2001, 2002, 2003, 2004a, 2005), GEI (2006, 2007a, 2008a,b), Roy F. Weston (1995)	1994, 1996-2008	Quantitative (electrofishing)
Benthic Invertebrate Data		
Reclamation (LaBounty et al. 1975)	1974	Quantitative (Surber samples)
Reclamation (Roline and Boehmke 1981)	1979, 1980	Quantitative (Surber samples)
Winters (1988)	1982	Quantitative (Surber samples)
Ruse, et al. (2000), Ruse and Herrmann (2000)	1984-1985	Qualitative (multiple methods)
Engineering Science (1986)	1985	Quantitative (Hess samples)
Kiffney and Clements (1993), Clements (1994), Clements and Kiffney (1994, 1995)	1989-1992	Quantitative (Hess samples)
Aquatics Associates (1993)	1991	Qualitative (kick samples)
Pueblo Science Associates (1991)	1991	Qualitative (unspecified methods)
Reclamation (Nelson and Roline 1995, 1996b)	1992-1994	Quantitative (Surber and Hess samples)
Decker (1998)	1994-1995	Qualitative (multiple methods)
CEC (1994, 1998a, 1998c, 1999a, 2001, 2002, 2003, 2004a, 2005, 2006), GEI (2006, 2007a, 2008a, b), Roy F. Weston (1995)	1994-2008	Quantitative (Hess samples) and Qualitative (sweep samples)
Health Department (2000)	2000	Qualitative (unspecified)
EPA (2008)	2008	Quantitative (Hess samples and Qualitative (sweep samples)
Habitat Data		
CPW (Bridges et al. 2000; Smith and Hill 2000)	2000	Quantitative (PHABSIM)
CEC (1999a, 2001, 2002, 2003, 2004a, 2005), GEI (2006, 2007a, 2008a)	1999-2007	Quantitative (multiple parameters) Qualitative (RBP)

Several groups collected benthic invertebrate data from the Upper Arkansas River between 1974 and 1994 (Table 2). Much of the data are quantitative and were collected in the Arkansas River between Leadville and Buena Vista, including the studies by Reclamation in the 1970s and 1980s, and by Ruse et al. (2000), Ruse and Herrmann (2000), Engineering Science (1986), Kiffney and Clements (1993), Clements (1994), Clements and Kiffney (1994, 1995), Aquatics Associates (1993), and Pueblo Science Associates (1991). In 1992 through 1994, Reclamation collected samples along much of this section of the Arkansas River (Nelson and Roline 1995, 1996b). The Health Department collected qualitative data in 2000; the method of collection was unspecified. CEC collected quantitative data annually in spring and fall from 1994 through 2008 in the California Gulch area. Quantitative data consist of three replicate Hess samples, and a supplemental qualitative sweep sample. Decker (1998) collected qualitative data on species composition at a site just upstream of Pueblo Reservoir in 1994 and 1995. CEC (2006) also collected supplemental qualitative samples (multihabitat kick sample) in 2003 and 2004 at five sites in this reach for the SDS EIS.

CPW modeled trout habitat at six locations in this reach of the Arkansas River with the Physical Habitat Simulation Model (PHABSIM). This model simulates a relationship between flow level and fish habitat, and was used to manage flow and fishery issues in the Upper Arkansas River. CEC also collected habitat data in 1999 through 2007 (Table 2).

Arkansas River, Outlet of Pueblo Reservoir to the Inlet of John Martin Reservoir

Qualitative fish community data for the section of the Arkansas River from downstream from Pueblo Reservoir to the inlet of John Martin Reservoir are available from 1979 through 1981, 1990, 1994 through 1996, 2002, 2004-2006, 2009, and 2011 (Table 3). Data were collected using various methods. Loeffler et al. (1982) collected data from multiple sites in 1979, 1980 and 1981. Bennett et al. (1990) used boat electrofishing gear to sample the Arkansas River in Pueblo in 1990. These data were used to evaluate future management of this reach of the river. Nesler et al. (1999) collected data in this reach to update the status of Arkansas River native fishes in Colorado. No information is available on the methods used for the single site sampled in 1995 by CPW habitat biologists (Woodling 1999).

Bestgen et al. (2003) collected data in 2002 related to the status and distribution of the suckermouth minnow in eastern plains streams of Colorado. Dr. Bestgen collected similar data in February and March 2005 (Krieger 2005; Ramsay 2004). In both studies, he used seining as the primary method of collecting fish. GEI (formerly CEC) collected fish for a selenium study for the City of Pueblo in 2003 through 2006 (CEC 2004b, 2006; GEI 2007b). GEI used backpack electrofishing and seining to collect fish and compiled a list of the species encountered during the collection.

CPW and CEC sampled the Arkansas River downstream from Pueblo Reservoir in April 2004 (Melby 2010; CPW 2011a). Approximately three miles of the river from near Pueblo dam to Wildhorse Creek were sampled with a raft-mounted electrofishing unit. CPW and CEC sampled two sites in the City of Pueblo in late April 2004. The first site was immediately downstream from the 4th Street Bridge and the second site was adjacent to the Runyon Wildlife Area downstream from the Moffat Street Bridge. One-pass electrofishing was conducted at both sites with a bank electrofishing unit and five hand-held electrodes. The upper two segments were resampled by CPW in 2009 (Melby 2010). Six sites in this reach, arranged from just downstream from Pueblo Reservoir to just upstream from John Martin Reservoir were sampled at least once during 2011 by GEI Consultants to validate habitat suitability curves used for PHABSIM modeling. The sampling was conducted using a backpack electrofisher and random and nonrandom techniques to identify habitat conditions where fish were present and absent. The sampling in 2011 results in qualitative fish presence data.

CEC collected quantitative macroinvertebrate data for this river segment in 1994, 1996, and 1998 (Table 3). The collection method consisted of three replicate Hess samples taken from riffle habitat. The data were collected for a study for the City of Pueblo.

Table 3: Existing Fish and Benthic Invertebrate Data for the Arkansas River from Pueblo Reservoir Downstream to the Inlet of John Martin Reservoir

Agency/Source	Sample Year	Method
Fish Data		
CPW (Loeffler et al. 1982)	1979, 1980, 1981	Qualitative (seining, electrofishing)
CPW (Bennett et al. 1990)	1990	Qualitative (boat electrofishing)
CPW (Nesler et al. 1999)	1994, 1995, 1996	Qualitative (seining, electrofishing)
CPW (Woodling 1999)	1995	Qualitative (unspecified methods)
Bestgen et al. (2003) ; CPW (Ramsay 2004)	2002	Qualitative (seining, electrofishing)
CEC (2004b, 2006)	2003, 2004	Qualitative (electrofishing)
Bestgen (Krieger to Conklin 2005)	2005	Qualitative (seining)
GEI 2007b	2005, 2006	Qualitative (seining and electrofishing)
CPW (Melby 2010), CPW (2011a)	2004, 2009	Qualitative (boat electrofishing)
GEI (2011)	2011	Qualitative (backpack electrofishing)
Benthic Invertebrate Data		
Ruse et al. (2000), Ruse and Herrmann (2000)	1984-1985	Qualitative (multiple methods)
Health Department (2000, 2002)	2000, 2002	Qualitative (kick sample)
Decker (1998)	1994-1995	Qualitative (multiple methods)
CEC (1995, 1998b 1999b)	1994, 1996, 1998	Quantitative (Hess sample)
CEC (2006)	2003, 2004	Qualitative (kick sample)
Kleinert (2008), Powell (2008)	2004, 2006	Qualitative (multiple methods)
Benthic Invertebrate Data		
CEC (2006)	2004	Quantitative (PHABSIM)

Qualitative macroinvertebrate data for the Arkansas River downstream from Pueblo Reservoir to the inlet of John Martin Reservoir are available for 2000 and 2002 from the Health Department (Table 3). Additional qualitative samples were collected by CEC in 2003 and 2004 at eight sites in this segment for the SDS EIS (CEC 2006). The method of collection was a kick sample. Students from CSU-Pueblo studied macroinvertebrates in the segment of the Arkansas River just downstream of Pueblo Reservoir in the mid 1990's and 2000's (Decker 1998; Kleinert 2008; Powell 2008). These studies provided qualitative data on species composition.

CEC collected PHABSIM habitat data in this segment in 2004 and modeled habitat availability for rainbow trout adults and juveniles and brown trout adults for the SDS EIS (CEC 2006).

Arkansas River, Outlet of John Martin Reservoir to the Kansas State Line

Qualitative fish community data were available for the Arkansas River, downstream from John Martin Reservoir from several sources (Table 4). Loeffler et al. (1982) collected data from multiple sites in 1979, 1980 and 1981. Dr. Bestgen collected data at nine sites in this segment in 2005 (Krieger to Conklin 2005) using seining techniques. CPW also sampled fish in this segment at various sites in 2003, 2004, 2006, and 2009 (Ramsay 2004; CPW 2011a). The fish data were collected by seining in 2004 (Ramsay 2004) and the sampling technique was not specified during the remaining years. Benthic invertebrate and habitat data were not available for this reach.

Table 4: Existing Fish Data for the Arkansas River from the Outlet of John Martin Reservoir Downstream to the Kansas State Line

Agency/Source	Sample Year	Method
Fish Data		
CPW (Loeffler et al. 1982)	1979, 1980, 1981	Qualitative (seining, electrofishing)
CPW (Ramsay 2004)	2004	Qualitative (seining)
Bestgen (Krieger to Conklin 2005); CPW (Ramsay 2004)	2005	Qualitative (seining)
CPW (2011a)	2003, 2006, 2009	Qualitative (unknown)

Grape Creek

Qualitative and quantitative fish data for Grape Creek are available for a number of years from 1981 through 2010 (Table 5). Loeffler et al. (1982) collected fish data in 1981 at a site located three miles downstream from DeWeese Reservoir. CPW biologists collected data in Grape Creek upstream and downstream from DeWeese Reservoir at several locations during several years from 2000 through 2010 using qualitative and quantitative methods. Additional qualitative presence/ absence sampling was conducted upstream from DeWeese Reservoir in 1995, 1996, and 2004.

Table 5: Existing Fish Data for Grape Creek, Upstream and Downstream of De Weese Reservoir

Agency/Source	Sample Year	Method
Fish Data		
CPW (Loeffler et al. 1982)	1981	Qualitative (seining, electrofishing)
CPW (CPW 2011a)	2000, 2003, 2004, 2006, 2010	Quantitative and Qualitative (electrofishing)
Other Agencies (CPW 2011a)	1995, 1996, 2004	Qualitative (electrofishing)

Fountain Creek

Qualitative fish community data for Fountain Creek are available for many years from 1979 through 2010 (Table 6). Various collection methods were used. Data collected for Colorado Springs Wastewater Division (CSWD) in 1979, 1980 and 1989 were used to assess potential effects of wastewater discharges into Fountain Creek. Loeffler et al. (1982) collected data in Fountain Creek in 1979 and 1981. Nesler et al. (1999) collected data in Fountain Creek in 1994-1995. Two separate CPW area biologists collected data in Fountain Creek in 2001 as part of native plains fish inventories. CPW and USGS jointly sampled Fountain Creek in 2003 through 2010 as part of a long-term monitoring study, with qualitative methods.

Several groups collected quantitative macroinvertebrate data from Fountain Creek including CSWD in 1979 and 1980, USGS from 1985 through 1988, CEC for CSWD in 1989, Colorado Springs Utilities from 1994 through 2000, URS/CDM in 2000, and USGS from 2001 through 2010. The method of collection by CSWD was a coring device, while CEC, Colorado Springs Utilities, and USGS collected samples using a Surber or Hess sampler. Colorado Springs Utilities also collected qualitative samples using a kick net in conjunction with the quantitative samples in all years (1994-2000) and URS/CDM collected qualitative kick net samples in 2000.

Colorado Springs Utilities measured habitat variables in 1998 through 2000. Habitat data were collected by USGS from 2001 through 2010 (Table 6). They measured numerous habitat variables as well as qualitatively rated the habitat with the RBP method. URS/CDM rated the habitat in 2000 with RBP and an alternative, similar method (URS and CDM 2002).

Table 6: Existing Fish, Benthic Invertebrate, and Habitat Data for Fountain Creek from Security Gage Downstream to the Arkansas River Confluence

Agency/Source	Sample Year	Method
Fish Data		
CSWD (1980)	1979, 1980	Qualitative (seining, electrofishing)
CPW (Loeffler et al. 1982)	1979, 1981	Qualitative (seining, electrofishing)
CSWD (1989)	1989	Quantitative (electrofishing)
CPW (Nesler et al.1999)	1994, 1995	Qualitative (seining, electrofishing)
CPW (Melby 2001)	2001	Qualitative (seining, electrofishing)
CPW (Dowler 2001)	1994, 2001	Qualitative (seining, electrofishing)
CPW/USGS (USGS 2003-2010; Dowler 2004b)	2003-2010	Qualitative (seining, electrofishing)
Benthic Invertebrate Data		
CSWD (1980)	1979, 1980	Quantitative (coring device)
USGS (von Guerard 1989)	1985-1988	Quantitative (Surber sample)
CSWD (1989)	1989	Quantitative (Hess sample)
Colorado Springs Utilities (1994, 1995, 1996, 1997, 1998, 1999, 2000)	1994-2000	Quantitative (Hess sample) Qualitative (kick sample)
URS and CDM (2002)	2000	Qualitative (kick sample)
USGS (2001a, 2002, 2003-2010)	2001-2010	Quantitative (Hess sample)
Habitat Data		
Colorado Springs Utilities (1998, 1999, 2000)	1998-2000	Quantitative (multiple parameters) Qualitative (RBP)
URS and CDM (2002)	2000	Qualitative (RBP)
USGS (2001a, 2002, 2003-2010)	2001-2010	Quantitative (multiple parameters) Qualitative (RBP)

Turquoise Lake

Nesler (1981) of CPW prepared a report for Reclamation that summarizes limnological and biological data for Turquoise Lake. This includes fish sampling information from 1978 and 1980 (Table 7). Currently, CPW samples Turquoise Lake every other year with gill nets. Current data are available for 1999, 2001, 2003, 2005, 2007, and 2009. The annual reports prepared by CPW (Policky 1999, 2001, 2003, 2005, 2007, and 2009) also contain stocking data back to 1985 and limited fish collection data back to 1984.

Table 7: Existing Fish Data for Turquoise Lake

Agency/Source	Sample Year	Method
Fish Data		
CPW (Nesler 1981)	1978, 1980	Qualitative (gill net)
CPW (Policky 1999, 2001, 2003, 2005, 2007, 2009)	1984-1999, 2001, 2003, 2005, 2007, 2009	Qualitative (gill net)

Twin Lakes

Reclamation and CPW have studied many aspects of Twin Lakes since the 1970s relative to potential effects of the Mt. Elbert hydroelectric plant. This includes data on fish, plankton, benthic invertebrates, and other aspects of the lakes. Reclamation (1993) summarizes and evaluates the information from 1971 through 1986. This includes fish sampling data for almost all years between 1973 and 1984 (Table 8).

Table 8: Existing Fish Data for Twin Lakes

Agency/Source	Sample Year	Method
Fish Data		
Reclamation (1993)	1973-1984	Qualitative (gill net)
CPW (Policky 1999, 2001, 2003, 2005, 2007, 2009)	1999, 2001, 2003, 2005, 2007, 2009	Qualitative (gill net)
Mueller et al. (2004)	2001, 2002	Quantitative (acoustical survey)

CPW currently samples Twin Lakes with gill nets every other year. Current data are available for 1999, 2001, 2003, 2005, 2007, and 2009. The annual reports (Policky 1999, 2001, 2003, 2005, 2007, 2009) also contain stocking and limited fish sampling data back to 1984. Mueller et al. (2004) sampled Twin Lakes with acoustical equipment in 2001 and 2002.

De Weese Reservoir

CPW collected qualitative fish data for DeWeese Reservoir in most years from 2000 through 2009 using gill nets and/or by electrofishing (Table 9).

Table 9: Existing Fish Data for DeWeese Reservoir

Agency/Source	Sample Year	Method
Fish Data		
CPW (Melby 2001-2003, 2004a, 2005-2010; CPW 2011a)	2000-2001, 2003-2009	Qualitative (gill net)
CPW (Melby 2001, 2004a, 2006, 2008)	2000, 2003, 2005, 2007	Qualitative (electrofishing)

Pueblo Reservoir

CPW collected qualitative fish data for Pueblo Reservoir from 1999 through 2009 (Table 10) using gill nets. Data collected by electrofishing are also available from 1999 through 2001, 2003, and 2006 through 2008.

Table 10: Existing Fish Data for Pueblo Reservoir

Agency/Source	Sample Year	Method
Fish Data		
CPW (Melby 2000, 2001, 2002, 2003,2004a, 2005, 2006, 2007, 2008, 2009, 2010)	1999-2009	Qualitative (gill net)
CPW (Melby 2000, 2001, 2002, 2004a, 2007, 2008, 2009)	1999-2001, 2003, 2006-2008	Qualitative (electrofishing)

Lake Henry

CPW collected qualitative fish data for Lake Henry in 2000, 2001, 2004, and 2006 through 2009 (Table 11). Data were collected using gill nets.

Table 11: Existing Fish Data for Lake Henry

Agency/Source	Sample Year	Method
Fish Data		
CPW (Bennett 2001, 2002; Ramsay 2004)	2000, 2001, 2004	Qualitative (gill net)
CPW (2011a)	2006, 2007, 2008, 2009	Qualitative (gill net)

Lake Meredith

CPW collected qualitative data for Lake Meredith in 1999, 2000, 2007, and 2008 (Table 12). Data were collected using gill nets.

Table 12: Existing Fish Data for Lake Meredith

Agency/Source	Sample Year	Method
Fish Data		
CPW (Bennett 2000, 2001)	1999, 2000	Qualitative (gill net)
CPW (2011a)	2007, 2008	Qualitative (gill net)

Holbrook Reservoir

No sampling data were available for Holbrook Reservoir for the 1999 through 2012 time-period as sampling was not conducted by CPW during this time (Ramsay 2012).

John Martin Reservoir

CPW collected qualitative data for John Martin Reservoir in 1999 through 2001, 2004, and 2006 through 2009 (Table 13). Data were collected using gill nets.

Table 13: Existing Fish Data for John Martin Reservoir

Agency/Source	Sample Year	Method
Fish Data		
CPW (Bennett 2000, 2001, 2002; Ramsay 2004)	1999, 2000, 2001, 2004	Qualitative (gill net)
CPW (2011a)	2006, 2007, 2008, 2009	Qualitative (gill net)

Supplemental Data Collection

GEI and CPW collected supplemental data in 2011 to address gaps in the existing information for fish and habitat. The following sections describe the rationale, locations, and methods for collecting supplemental data.

Fish

During meetings with CPW, fish population data gaps were identified for the Arkansas River between Fountain Creek and John Martin Reservoir. Additional fish community data were collected jointly by CPW and CEC for this river segment in spring 2011 during high flows and in summer 2011 during base flows. All supplemental data collected were qualitative and were collected in a manner to allow verification of habitat suitability curves.

Habitat

During coordination meetings with CPW, it was agreed to use the PHABSIM component of the Instream Flow Incremental Methodology (IFIM) (Bovee 1982) as the habitat evaluation tool in certain segments of the study area. GEI collected supplemental PHABSIM data in 2011 for the Arkansas River between Fountain Creek and John Martin Reservoir.

GEI collected PHABSIM field data in the Arkansas River at transects at a site established near Nyberg Road in Pueblo County. GEI and CPW jointly discussed the general locations of the PHABSIM transects at the site and the habitat types that were modeled. GEI established the exact transect locations that were used for data collection for the PHABSIM sites established in 2011. Measurements were taken at these transects in spring and summer 2011. Habitat modeling at these transects represents the Arkansas River from Fountain Creek downstream to John Martin Reservoir.

GEI collected PHABSIM field data based on the habitat mapping approach developed by Bovee (1989). With this approach, general habitat types were identified for each stream segment (e.g., riffle, open channel, and island habitats). One or two transects were placed in each habitat type in the stream segment. Eight transects were established to represent the habitat in Segment 3. Transects were located in a wide shallow run, wide deep thalweg, riffle, bank snag, vegetated island, backwater, cobble bar, and sand bar with bank snag. The percentage of each habitat type was determined by estimating the length of habitat units in the entire segment using available satellite imagery taken mostly in 2005 and 2011 to identify the percentage of open channel and island habitats to estimate the overall percentage of habitat for each transect type. Wide shallow runs comprised the greatest percentage of habitat (45 percent), followed by vegetated islands (22 percent) and wide deep thalweg (16 percent). The remaining transects represented 5 percent or less of the habitat.

At points across each transect, data collected included water surface elevation, velocity, cross-section profile, substrate, and cover. Water surface elevations were collected on three occasions, during low, medium, and high flows for model calibration. Data were then analyzed with the Physical Habitat Simulation System Model (PHABSIM) (USGS 2001b; Hardy 2005) of IFIM to represent the habitat at each transect.

PHABSIM simulates a relationship between flow level and hydraulic properties (i.e., depth, velocity, substrate, and cover) for each habitat type. The habitat types are weighted according to the proportions determined during habitat mapping. The link between hydraulic portions of PHABSIM and habitat for fish is habitat suitability curves for different fish species. Suitability curves present the relative use value over a range of depth, velocity, substrate, and cover conditions that may be present in a stream as modeled by PHABSIM. PHABSIM and suitability curves for a species of fish simulate the fish habitat available (weighted useable area, or "WUA") over a range of flows, producing a WUA versus discharge relationship for each modeled fish species and life stage. This relationship was used to predict the potential effects of changes in flow resulting from the proposed alternatives to fish habitat and populations.

The fish population in Segment 2 of the Arkansas River between Fountain Creek and John Martin Reservoir is largely comprised of native non-game species. Appropriate suitability curves were available for the most common large-bodied species in this segment of the Arkansas River, the white sucker (Twomey et al. 1984). These curves were used to model habitat for adult, fry, and spawning life stages of white suckers. Suitability curves were also available for sand shiner, red shiner, plains killifish, and juvenile channel catfish (Conklin et al. 1996), all native species. Habitat availability was modeled for the adult life stages of these species (except channel catfish), but suitability curves were not available for other life stages of these species. Habitat suitability was also modeled for adult, spawning, and fry flathead chub, another native species and a state species of concern, using curves developed by a consensus discussion of experts for suitability in the Central Platte River in Nebraska (Fannin and Nelson 1986).

The fish population in Fountain Creek is similar to in Segment 2 of the Arkansas River. Thus, habitat suitability was modeled for a similar group of species; white sucker, sand shiner, red shiner, and flathead chub based on the relationships developed for the SDS EIS.

Data Analysis

The existing and supplemental data available for the aquatic biological resources in the study area were collected and presented in various ways by the different authors. Our data analysis focuses on the relevant parameters that describe the existing environment, and parameters that will be used for assessing potential effects on fish and invertebrates in the EIS. These parameters and the approach to data analysis are described below for the available fish, benthic invertebrate, and habitat data.

All information available since 1979 was reviewed during the preparation of this appendix. For some of the water bodies in the study area, there is not much recent information, and the data from 1979 and the 1980s represent a substantial portion of the data. For other water bodies, such as reservoirs, CPW periodically collects data, and the data from the most recent period (usually 1999-2009) are sufficient to describe existing aquatic resources. For these waters, data prior to 1999 are not summarized in this report.

Segmentation

In some reaches of the Arkansas River and in Fountain Creek, some of the potential effects of the alternatives were evaluated in the EIS with PHABSIM. This incorporates habitat data with hydrologic data to estimate habitat availability (WUA) for fish under the different flow scenarios. The PHABSIM portion of IFIM simulates and represents habitat for specific segments of river. In order to provide fish population information that is compatible with effects analysis with PHABSIM in the EIS, the fish population data are summarized with respect to the appropriate segments. Therefore, the fish population data and the corresponding benthic invertebrate and habitat data in the Arkansas River and Fountain Creek are summarized in this report with respect to PHABSIM segmentation.

In the Arkansas River between Lake Fork and Pueblo Reservoir, there are seven segments, six of which are evaluated with PHABSIM. In the Arkansas River downstream from Pueblo Reservoir, there are four segments and two of these segments are evaluated with PHABSIM. In Fountain Creek, PHABSIM is used for each of the two total segments. In all other streams and reservoirs in the study area, PHABSIM information is not available and there are no corresponding PHABSIM segments. These water bodies will have data summarized for the reach as a whole.

Fish

All of the available fish data for the different water bodies in the study area include a list of species collected. This represents the most basic level of information about fish populations, and allows descriptions of the presence and distribution of fish species in the study area.

Estimates of abundance vary widely for the available data. Much of the data for the Upper Arkansas River were collected with quantitative methods and include estimates of density (number per acre) and biomass (pounds per acre). These standard parameters allow an accurate description of the existing environment, and will be used as a basis for predictions of potential effects in the future. For the reservoirs and warmwater streams in the study area, the available data are usually semi-quantitative (number collected per unit of effort) or qualitative (number collected). These parameters allow a less accurate description of the existing environment, and only qualitative predictions of potential effects.

Other parameters are also available for some of the data sets, such as measures of fish condition and length-frequency data. However, data on these parameters are available for only a small portion of the data sets, and are not proposed to be used for the assessment of effects. Therefore, data on these parameters are not presented in this report.

Benthic Invertebrates

Existing and/or supplemental benthic invertebrate information is available for all of the stream segments in the study area, upstream from John Martin Reservoir. No benthic invertebrate data is available for the Arkansas River downstream from John Martin Reservoir; however, the benthic invertebrate community is likely similar to that in the Arkansas River from Fountain Creek downstream to John Martin Reservoir. Effects to benthic invertebrates in streams will be evaluated in the EIS for the alternatives. For most lakes and reservoirs in the study area, benthic invertebrate data are not available, except for studies in Twin Lakes. Effects to invertebrates in reservoirs are not evaluated in the EIS, and the data are not presented in this report.

The wide variety of stream benthic invertebrate collection methods resulted in data that were presented in many different ways in the original sources. However, common parameters are used in this report to summarize and evaluate the data. Benthic invertebrate parameters used in this evaluation and presentation of the data include density, number of taxa, number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, diversity, and the Hilsenhoff Biotic Index (HBI), when available. These parameters are explained below.

Density is the number of benthic invertebrates found, normalized to a unit area, typically number per square meter. Quantitative sampling allows calculation of density, but qualitative sampling does not. Streams with good water quality generally have higher density of invertebrates than streams with poor water quality. However, density can also be very high in situations where the water is highly productive due to organic enrichment with high levels of nitrogen and phosphorus, and anthropogenic or naturally disturbed streams which can allow for tolerant organisms to dominate.

The number of taxa (typically species) is usually available for both quantitative and qualitative samples. This parameter is also sometimes referred to as taxa richness. Higher numbers of taxa are usually found in streams with good water quality compared to streams with poor water quality.

Most of the available data include a list of the taxa present in a sample. However, a typical sample will have dozens of individual species of benthic invertebrates with names that are unfamiliar to most readers of this report. In order to summarize this information into more meaningful terms, the number of EPT taxa, a diversity index, and a biotic index are used and are described below.

The presence of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) species (collectively referred to as the EPT taxa) can be used as an indicator of water quality (Lydy et al. 2000). These insect groups are considered sensitive to a wide range of pollutants (Plafkin et al. 1989; Wiederholm 1989; Klemm et al. 1990; Lenat and Penrose 1996; Wallace et al. 1996). Higher values for EPT taxa generally indicate better water quality.

The Shannon-Weaver Diversity Index (H') is recommended by the EPA as a measure of the effects of stress on macroinvertebrate communities (Klemm et al. 1990) and measures the extent to which total density is evenly distributed among the component taxa. Values generally range from 0 to over 4, with values greater than 2.50 considered indicative of a benthic invertebrate community with little or no stress (Wilhm 1970; Bukantis 1998). Stressed sites often have communities strongly dominated by one or a few taxa because conditions favor only those taxa (Allan 1995); therefore, H' values less than 1.0 typically indicate a stream community under severe stress (Wilhm 1970; Klemm et al. 1990; Bukantis 1998).

The HBI is a single score for each set of samples, either quantitative replicates or qualitative sweep and kick samples. The HBI method multiplies the abundance of a species by its tolerance value, and calculates a weighted average for each sample. Scores from 0 to 3.5 represent invertebrate populations comprised of intolerant species and indicate very good to excellent water quality; scores from 7.5 to 10 represent populations comprised of many pollution tolerant species and indicate significant to severe pollution. Scores between 3.5 and 7.5 represent invertebrate communities that are comprised of a mix of tolerant and intolerant species and indicate moderate water quality impairment (Hilsenhoff 1987). Hilsenhoff (1977) originally developed the HBI to detect organic pollution and nutrient enrichment. Since that time, taxa tolerance values have been adjusted to account for other stressor types (Grafe 2002). CEC calculated the HBI for all supplemental benthic macroinvertebrate data collected for the SDS EIS (CEC 2006). However, apparently none of the other sources of benthic macroinvertebrate data used in this report include HBI scores. Calculating HBI scores for past data would require a substantial effort, especially with much of the data only available in hard copy (paper) format. Therefore, HBI was not calculated for these data sets.

All of the benthic invertebrate parameters described above can be sensitive to inherent differences in major habitat types. Parameter values tend to be substantially "better" in high gradient, mountain streams than in lower-gradient plains or transition zone streams. Consequently, parameter values are suitable for comparing sites only within a common major habitat type.

Habitat

PHABSIM habitat availability relationships for the Arkansas River and Fountain Creek are used to assess the effects of the proposed alternatives. The simulated relationship between flow and habitat availability (WUA) is presented in this report for the available data from GEI and CPW.

Much of the remainder of the habitat data available for the streams in the study area are in the form of a wide variety of descriptive parameters, such as width, depth, substrate composition, and bank stability. Habitat data of this type have only limited value in assessing the potential effects of the proposed alternatives and are not presented in detail in this report. We present a brief summary of habitat parameters that are common to much of the available data, including proportion of pool habitat, typical width and depth at low flow, and general substrate composition.

Habitat at some sites in the study area was also evaluated by the EPA's RBP habitat assessment procedure (Barbour et al. 1999). CEC collected RBP data from sites on Lake Fork and Upper Arkansas River in 1998 through 2007; Colorado Springs Utilities collected RBP data from Monument and Fountain creeks in 1994 through 2001; Jim Bruce of USGS collected RBP data from Fountain Creeks in 2001 through 2010; and URS/CDM collected RBP data from Fountain Creek in 2000. However, RBP assessments require that data from a stream site be compared to a reference condition in order to rate the quality of the habitat (Barbour et al. 1999). The RBP score for a site has little value in describing habitat conditions without the comparison to a reference site. The issue of the availability of reference sites for the streams in the study area, and the resulting comparisons are beyond the scope of this report, and RBP information is not presented.

Habitat data were not collected in the lakes and reservoirs in the study area. Measurements of basic features of reservoirs, such as surface area and maximum depth, are presented as available.

Nuisance Species

The Arkansas River Basin has tested positive for *Myxobolus cerebralis*, the causative agent of whirling disease, from the upper reaches of the Arkansas River mainstem as far downstream as John Martin Reservoir (Schisler 2000). Whirling disease limits natural reproduction of rainbow trout. In 2009, a whirling disease resistant strain of rainbow trout was stocked in the upper Arkansas River, with the intent to increase survival and reproduction in the future (Policky 2009). While brown trout populations have persisted with the onset of whirling disease in the Arkansas River, *M. cerebralis* spore counts from brown trout samples in the upper Arkansas River in 2008, may be high enough to result in decreased brown trout recruitment (Policky 2009).

New Zealand mud snails, zebra mussels, and Quagga mussels are invasive molluscs that each has the potential for detrimental ecological and economic effects. These species can invade a wide variety of aquatic habitats and are usually introduced into new waters by transfer from boats or anglers. They have recently begun invading western waters especially the Pacific coast states and are currently more common in the Great Lakes states and along the Mississippi River. According to the USGS's nonindigenous aquatic species website (http://nas.er.usgs.gov), New Zealand mud snails have not been detected from the Arkansas River basin watershed (Benson 2011). Zebra and quagga mussels have not been found in Turquoise Reservoir and Twin Lakes and these reservoirs likely provide poor conditions for these invasive species due to low calcium levels (Claudi and Prescott 2009b).

Zebra mussels including two adults, one juvenile, and one veliger (larva), were collected in 2007 and veligers were detected in 2008 and 2009. Quagga mussel veligers were collected in 2008 and 2011 from Pueblo Reservoir (http://nas.er.usgs.gov). These mussels have not yet established extensive populations in Pueblo Reservoir likely due to water quality conditions that do not allow these species to survive well (Claudi and Prescott 2009a).

Didymosphenia geminata, commonly known as didymo or “rock snot” is a stalked diatom that can form thick blooms and affect the ecological function and aesthetic appeal of rivers (Spaulding and Elwell 2007). Didymo has been reported in the western US for over 100 years, but expansive nuisance blooms have become more common recently (Kumar et al. 2009). Didymo has not been documented in the Arkansas River, according to the most recent and extensive published dataset by Kumar et al. (2009); however, modeling conducted by the authors suggest a high probability of didymo presence in the Arkansas River basin (Kumar et al. 2009).

The Asiatic clam (*Corbicula fluminea*) was first introduced purposely on the west coast of North America in the 1900s (Vaughn and Spooner 2006) and has been documented in Colorado in the Arkansas, Colorado, Platte, and San Juan drainages (Cordeiro et al. 2007). In the study area, the Asiatic Clam has been found in the Arkansas River mainstem near Pueblo, Lamar, and Caddoa, and in Pueblo Reservoir, John Martin Reservoir, and Lake Meredith (Chadwick Ecological Consultants 2006, Cordeiro et al. 2007). The impact of Asiatic clams on native mussels in Colorado is not known; however, some studies suggest the species may compete for space and food (Cordeiro et al. 2007; Strayer 1999). These organisms are aggressive filter feeders that can reduce the amount of phytoplankton needed as food by native organisms. They also have the potential to increase ammonia levels (Cordeiro et al. 2007), which can be detrimental to native organisms.

Results

The following sections describe the existing conditions and results of the data collections for the study area.

Lake Fork Downstream from Turquoise Lake

Fish and benthic macroinvertebrate populations have been sampled in Lake Fork just upstream from the confluence with the Arkansas River near the Halfmoon Creek Road crossing during several studies of the Upper Arkansas River. This site is used as a reference site for the California Gulch Superfund Site Project near Leadville. Data are available from the late 1980s through 2008. Since spring 1994, CPW and/or CEC have sampled fish nearly every year; benthic invertebrates have been sampled every year in both spring and fall from 1994 through 2008 by CEC. This information represents consistent, long-term data collected with the same methods each year. This information is the basis for the description of the existing environment for Lake Fork downstream from Turquoise Lake.

Fish

CEC sampled fish populations at the site on Lake Fork in spring 1994 (Roy F. Weston 1995; CEC 1994) and fall 1996 (CEC 1998a). CPW collected data in fall 1994 (Policky 1994). CPW and CEC jointly collected data yearly in late summer from 1997 through 2006, and in 2008 (Policky 1999, 2001, 2002, 2003, 2004a, 2005b, 2006, 2008; CEC 1998a, 2001, 2002, 2003, 2004a, 2005; GEI 2006, 2007a, 2008b). All data were collected by quantitative multiple-pass electrofishing on a similar length of stream each year.

Brown trout dominate the species composition and biomass at this site (Table 14). Brook, cutthroat, and rainbow trout are also present in low numbers. No fish are stocked in Lake Fork by CPW; however, brown trout, cutthroat trout, and rainbow trout are stocked in Turquoise Lake and/or the Arkansas River by CPW and some may have migrated to Lake Fork and been present during sampling.

None of the trout species collected from 1994 through 2008 are native to Lake Fork, including the strains of cutthroat trout stocked by CPW. Historically, greenback cutthroat trout are native to the Upper Arkansas River Basin, but they have been extirpated from the study reach and replaced by non-native trout. Greenback cutthroat trout currently persist in only a few small tributary streams, isolated from contact with non-native trout (Behnke 2002).

Table 14: Summary of Lake Fork Fish Species Composition and Biomass (Pounds per Acre), Spring 1994 and Late Summer and Fall 1994 through 2008

Species/Date	Spring 1994	Late Summer – Fall 1994-2008	
		Mean	***Range***
Brook trout	1.6	2.4	0.6-5.8
Brown trout	54.6	114.3	52.0-167.4
Cutthroat trout	3.6	1.4	0-6.8
Rainbow trout	0	0.5	0-2.0
Longnose sucker	3.0	1.3	0-9.8
White sucker	0	0.1	0-0.6

Data Source: Appendix H.4, Table 1

White suckers are native to the Upper Arkansas River (Nesler 1997), and probably Lake Fork. Longnose suckers are an introduced species that are native to other basins in Colorado (Nesler 1997). These two species have been collected in low numbers at the Lake Fork site (Table 14).

The size range of the brook and brown trout collected in Lake Fork each year commonly includes young of the year (YOY) fish (Policky 1994, 1999, 2001, 2002, 2003, 2004a, 2005b, 2006, 2008; CEC 1994, 1998a, 2001, 2002, 2003, 2004a, 2005; GEI 2006, 2007a, 2008b). This indicates that natural reproduction is occurring and is sustaining the populations of these species. All of the cutthroat trout and all but a few of the rainbow trout collected over the years have been much larger than YOY fish, indicating the natural reproduction for these species is limited or absent. The sucker species collected are not stocked in the drainage and are the result of natural reproduction.

Brown trout biomass varies considerably from year to year (Table 14 and Appendix H.4, Table 1). Biomass in late-summer and fall in almost every year was higher than the spring 1994 level. Biomass for the other five species collected in Lake Fork also varied considerably from year to year and averages just a few pounds per acre or less for these species (Table 14).

Aquatics Associates sampled fish in Lake Fork in August 1991 (Aquatics Associates 1993). They collected brook and brown trout over a wide range of sizes for both species. Brown trout biomass was comparable to that in Table 14; brook trout biomass in 1991 was much higher than for later samples by CPW and CEC.

Benthic Invertebrates

CEC sampled benthic macroinvertebrates at the site on Lake Fork in spring and fall, 1994 through 2007 and spring 2008 (Roy F. Weston 1995; CEC 1994, 1998a, 1999a, 2001, 2002, 2003, 2004a, 2005; GEI 2006, 2007a, 2008a,b). GEI collected benthic invertebrate data at the Lake Fork site in fall 2008 and this data was provided by EPA (EPA 2008). Sampling was quantitative with three Hess samples in riffle habitat supplemented by a qualitative sweep sample in other habitats.

Samples from Lake Fork contained a wide variety of invertebrates including numerous species of mayflies, stoneflies, and caddisflies (the EPT taxa) as well as beetles, many species of flies, and a few crustaceans, worms, clams, and snails. The density of benthic macroinvertebrates varied substantially from year to year in both seasons (Table 15 and Appendix H.4, Table 2). Mean density was similar in both spring and fall (Table 15).

Number of taxa, number of EPT taxa and diversity varied less than density (Table 15 and Appendix H.4, Table 2). Values for all three parameters were similar in spring and fall. EPT taxa comprised nearly half of the species collected, and mean diversity was greater than 2.5 in both spring and fall. These parameters indicate that water quality and habitat in Lake Fork are sufficient to sustain sensitive species and a balanced community of invertebrates.

Table 15: Summary of Lake Fork Benthic Invertebrate Parameters, Spring and Fall 1994 through 2008

Parameter/Date	Spring 1994-2008		Fall 1994-2008	
	Mean	Range	Mean	Range
Density (#/m^2)	48,608	12,718-141,776	45,713	5,885-122,065
Number of Taxa	46	28-58	43	19-55
Number of EPT taxa	19	12-23	18	11-25
Diversity (H')	3.12	2.64-3.75	3.35	2.53-3.87

Data Source: Appendix H.4, Table 2

Engineering Science (1986) sampled benthic macroinvertebrates in September and October 1985 at a site on Lake Fork. The sampling in 1985 was quantitative, with three Hess samples. However, the invertebrates were identified to the family level, and the data are not comparable to the CEC species level data in terms of number of taxa, number of EPT taxa, and diversity. Density of the 1985 samples was substantially less, approximately 1,000 per square meter. EPT taxa comprised a high proportion of the density, suggesting good water quality and habitat. Aquatics Associates (1993) sampled invertebrates in May and September 1991. The samples were qualitative kick samples and density data are not available. However, the species composition indicated that just under half of the taxa collected were EPT taxa, similar to that for the CEC data (Table 15). Diversity of these samples was somewhat lower, although this may be due to the differences in sampling methods.

Reclamation (Nelson 2000; Nelson and Roline 1996a, 2003) sampled invertebrates in fall 1993, 1998, 1999 and spring 2000 at sites on Lake Fork just downstream from Turquoise Lake. The samples included quantitative Surber samples and qualitative kick samples. In 1997 through 2000, they also collected quantitative hyporheic samples, which collect invertebrates from the substrate below the stream bottom. Their data presentation is not directly comparable to that for the CEC data. However, their results indicate similar species composition, including numerous EPT taxa.

Habitat

CEC evaluated habitat at the site on Lake Fork in each year from 1998 through 2007 (CEC 1999a, 2001, 2002, 2003, 2004a, 2005; GEI 2006, 2007a, 2008a). Habitat parameters varied little between years (Appendix H.4, Table 3). Pools were absent from the sampling site in all years (Table 16). Substrate is a mix of sand, gravel, and cobble in near equal amounts. There is some variability from year to year (Appendix H.4, Table 3), with gravel slightly more abundant overall (Table 16).

Table 16: Summary of Lake Fork Habitat Data, Fall 1998 through 2007

Pool Area (%)	Mean Bank Width (ft)	Mean Wetted Width (ft)	Predominant Substrate	Mean Depth (ft)
0	45	36	Gravel	0.9

Data Source: Appendix H.4, Table 3

Lake Creek Downstream from Twin Lakes

Lake Creek consists of approximately 1.7 miles of mostly private stream from the outlet of Twin Lakes to the Arkansas River. This stream segment consists of mostly high gradient habitat. Fish and benthic invertebrate data are not available for this stream segment; however, the fish and benthic invertebrate communities are likely similar to those present in Lake Fork. The fish community is likely comprised of mostly brown trout with some other trout present at low abundances. EPT taxa likely comprise a similar large percentage of the benthic invertebrate community in Lake Creek as in Lake Fork. No habitat data are available for Lake Creek.

Upper Arkansas River, Lake Fork Downstream to Pueblo Reservoir

The Upper Arkansas River between the confluence with Lake Fork and Pueblo Reservoir is divided into seven segments for the purposes of this technical report. The seven segments roughly correspond to segments established by CPW in their collection and interpretation of PHABSIM data (Bridges et al. 2000). The potential effects of the alternatives are evaluated in the EIS using the PHABSIM habitat relationships from CPW. This report summarizes the aquatic biological data with respect to the seven segments to provide the data in a form that are compatible with effects analysis.

CPW stocks fish in the Upper Arkansas River and the data are separated with respect to CPW management segments, which do not correspond to PHABSIM segments. Therefore, we provide the available stocking data from 1999 through 2009 for the entire reach of the river (Table 17) prior to the discussion of the individual segments. CPW currently stocks only rainbow trout in the Arkansas River from Lake Fork downstream to Temple Creek near Cañon City. The trout are usually stocked in late summer and from 1999 through 2005 were small, approximately 3 to 5 inches in length (Policky 2004b). In the past, CPW also stocked larger (> 8 inches) rainbow trout, brown trout, and several strains of cutthroat trout (Policky 1999), but this was discontinued in the mid 1990s. Beginning in 2006, the average size of the stocked rainbow trout was approximately 6 inches or larger, to alleviate predation by brown trout. The increased size of the rainbow trout being stocked has appeared to increase recruitment and survival to subsequent years (Policky 2009). A whirling disease-resistant Hofer/Colorado River hybrid strain rainbow trout was stocked in 2009, which should increase rainbow trout survival and reproduction in the Arkansas River (Policky 2009).

Limited stocking has occurred from Temple Creek downstream to Pueblo Reservoir during the 1999 through 2009 time-period. In 2002, rainbow trout (30,046) were stocked in this reach. Two rare native species, southern redbelly dace (1,207) and Arkansas darters (500), were stocked off-channel to the main river in suitable habitat at tributary confluences (Policky 2009; Krieger and Lovell 2011). Southern redbelly dace (2,231) were stocked again in 2006 (Policky 2009).

Table 17: Rainbow Trout Stocking Data (Number Stocked per Year) for the Upper Arkansas River, 1999 through 2009

Section/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009 [(1)]
Lake Fork to Nathrop	34,497	42,367	33,000	34,133	34,019	43,180	34,000	0	7,946	18,169	42,001
Nathrop to Browns Canyon	14,999	16,020	16,080	17,980	18,006	17,999	18,000	0	0	11,564	22,003
Browns Canyon to S. ARk. River	20,002	20,640	22,080	24,021	24,005	23,999	24,000	5,299	0	15,561	30,000
S. Ark. River to Parkdale	31,503	32,560	36,120	87,477	42,012	41,993	42,000	5,202	0	27,698	40,002
Parkdale to Temple Creek	0	0	0	25,066	0	0	0	0	0	0	0

Data Source: Policky 2004a, 2009

Note:

[(1)] The Rainbow Trout Stocked in 2009 were a Whirling Disease Resistant Hofer/Colorado River Hybrid Strain

Segment 1, Lake Fork to Granite

Fish and benthic macroinvertebrates have been sampled at several sites in this segment of the Upper Arkansas River for the California Gulch Superfund Site Project. Data are available from the late 1980s through 2009. Many different groups have collected data, primarily at a site on the Smith Ranch (usually referred to as Site AR-4, just downstream from the confluence with Lake Fork) and at a site near the confluence with Empire Gulch downstream from Highway 24 (Site AR-5). Other sites between Empire Gulch and Granite have been sampled less frequently.

CPW and/or CEC have sampled fish nearly every year from 1994 through 2009 and benthic invertebrates have been sampled every year in both spring and fall from 1994 through 2008 by CEC for the California Gulch project. This information represents consistent, long-term, recent data collected with the same methods each year. This information is the basis for the description of the existing environment for Segment 1 of the Upper Arkansas River. All of this information was collected after the Yak Tunnel treatment facility began operation in 1992 (Roy F. Weston 1995).

All of the other available fish and benthic macroinvertebrate data for Segment 1 of the Upper Arkansas River were collected prior to 1992. This information may not represent present conditions due to water quality changes since 1992. This information is presented as appropriate but is not summarized.

Fish

CPW and/or CEC collected fish population data at sites in Segment 1 in all years since 1994, except for 1995 (Appendix H.4, Tables 4 through 8). Sites included the Smith Ranch (AR-4), near Empire Gulch (AR-5), Panark (AR-6A), Kobe (AR-6), and Granite (AR-7) (Policky 1994, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005b, 2006, 2008, 2009; Roy F. Weston 1995; CEC 1994, 1998a, 2001, 2002, 2003, 2004a, 2005; GEI 2006, 2007a, 2008a,b). All data were collected by quantitative, multiple-pass electrofishing over a similar known length of stream each year.

The Upper Arkansas River from the confluence with Lake Fork downstream to Pueblo Reservoir is managed by CPW as a coldwater brown trout and rainbow trout fishery. The fish assemblage in Segment 1 consists primarily of brown trout, with rainbow trout, brook trout, cutthroat trout, lake trout, longnose sucker, and white sucker also present in low numbers (Table 18). CPW management objectives are to optimize production of self-reproducing brown trout populations and encourage development of a self-reproducing rainbow trout population (Bridges et al. 2000).

Table 18: Summary of Upper Arkansas River Segment 1 Fish Species Composition and Biomass (Pounds per Acre), Spring 1994 through 2000 and Late Summer and Fall 1994 through 2009

Species/Date	Spring 1994-2000		Late Summer – Fall 1994-2009	
	Mean	*Range*	*Mean*	*Range*
Brook trout	0.1	0-0.5	0.4	0-3.9
Brown trout	42.2	20.6-64.6	102.2	27.5-254.4
Cutthroat trout	0.1	0-1.0	1.1	0-27.6
Lake trout	0	0	<0.1	0-1.1
Rainbow trout	0.2	0-2.7	1.1	0-7.1
Longnose sucker	2.6	0-33.7	0.8	0-14.1
White sucker	0.2	0-3.6	0.6	0-21.1

Data Source: Appendix H.4, Tables 4 through 8

Brown trout collected during sampling since 1994 includes a wide size range including YOY fish (Policky 1994, 1998, 1999, 2000, 2001, 2002, 2003, 2004; CEC 1994, 1998a, 2001, 2002, 2003, 2004a, 2005b, 2006, 2008, 2009). No brown trout are currently stocked in the Upper Arkansas River; thus, natural reproduction is sustaining the brown trout population.

Few rainbow trout were collected (Table 18 and Appendix H.4, Tables 4 through 8) despite annual stocking of subcatchable sized fish by CPW (Table 17), indicating that natural reproduction of rainbow trout in the Upper Arkansas River is very limited (Policky 2003). However, the stocking of larger rainbow trout and whirling disease resistant rainbow trout in recent years should increase survival and recruitment in the future (Policky 2009). No other species are currently stocked in this section of the Arkansas River.

Brook trout, longnose sucker, and white sucker probably also maintain populations through natural reproduction and appear only in low numbers. The few cutthroat and lake trout collected over the years were probably stocked in Turquoise Lake or in private ponds (Policky 2005a).

Brown trout biomass varies substantially from year to year and from site to site (Table 18 and Appendix H.4, Tables 4 through 8). Biomass in late-summer and fall samples average over twice that of spring samples (Table 18). Biomass for all other species of fish is low and varies considerably from year to year and site to site.

Several groups have sampled fish at or near the Smith Ranch and Empire Gulch Sites from 1979 to 1991. Brown trout were the dominant fish species collected in all samples. The biomass of trout collected was somewhat lower than the mean biomass calculated for 1994-2009 (Table 18). However, methods and capture efficiency were somewhat different for many of these studies (Roline and Boehmke 1981; Nehring 1986; Engineering Science 1986; ENSR 1989; Aquatics Associates 1993). CPW also sampled sites in Segment 1 prior to 1985 and this information is not reviewed.

Benthic Invertebrates

CEC sampled benthic macroinvertebrates at the Smith Ranch and Empire Gulch sites in spring and fall, 1994 through spring 2008 (Roy F. Weston 1995; CEC 1994, 1998a, 1999a, 2001, 2002, 2003, 2004a, 2005; GEI 2006, 2007a, 2008a,b). GEI sampled benthic invertebrates in fall 2008 and these data are provided by the EPA (EPA 2008). Sampling was quantitative with three Hess samples in riffles and a supplemental sweep sample in other habitats. CEC also collected samples at the Kobe and Granite sites in spring 1998 using the same methods (CEC 1998c).

Samples from this segment of the Arkansas River contained a wide variety of invertebrates including numerous species of mayflies, stoneflies, caddisflies and flies as well as a few beetles, crustaceans, worms, clams, and snails. Density of macroinvertebrates in Segment 1 of the Upper Arkansas River varied by an order of magnitude among sites and seasons (Table 19 and Appendix H.4, Tables 9 through 11). The mean density and range of values was similar for both spring and fall data (Table 19).

The other parameters varied over a more narrow range than did density (Table 19). All parameters were very similar between spring and fall. The number of taxa was comprised of approximately half EPT taxa in both seasons. Mean diversity and most of the values at the individual sites/seasons were much greater than 2.50, indicating that water quality and habitat since 1994 were suitable to support balanced communities.

Table 19: Summary of Upper Arkansas River Segment 1 Benthic Invertebrate Parameters, Spring and Fall 1994 through 2008

Parameter/Date	Spring 1994-2008		Fall 1994-2008	
	Mean	*Range*	*Mean*	*Range*
Density (#/m^2)	11,647	2,333-27,952	12,029	2,048-26,501
Number of Taxa	46	30-60	45	22-60
Number of EPT taxa	23	16-29	21	14-28
Diversity (H’)	3.58	2.04-4.40	3.74	3.01-4.34

Data Source: Appendix H.4, Tables 9 through 11

Prior to 1994, several other organizations sampled benthic invertebrates in Segment 1 of the Upper Arkansas River. All of these studies investigated benthic macroinvertebrate communities relative to the input of water from California Gulch. Roline and Boehmke (1981), Engineering Science (1986), Clements (1994) and Clements and Kiffney (1994) all collected quantitative data with Hess or Surber samplers in the 1980s and early 1990s. All of these studies reported invertebrate communities similar to those present after 1994, including the presence of numerous EPT taxa. Ruse et al. (2000) and Ruse and Herrmann (2000) collected adult aquatic insects at several sites in Segment 1 of the Upper Arkansas River in 1984 through 1985. They collected many Plecoptera and Trichoptera species, but few Ephemeroptera.

Nelson and Roline (1995) collected samples from 1992 through 1994 to evaluate the effects of increased flows on benthic invertebrates. The report does not present the raw data; however, the authors apparently collected numerous species, including several EPT species at a site in Segment 1. The macroinvertebrate density of their samples was approximately 900 per square meter, lower than the mean density for the CEC samples from Segment 1 (Table 19).

LaBounty et al. (1975) collected samples in 1974 with artificial substrates. Aquatics Associates (1993) and Pueblo Science Associates (1991) used qualitative kick net methods in 1991. These studies generally reported low numbers of organisms, low number of taxa, and few EPT taxa.

Habitat

CPW developed habitat versus flow relationships for brown and rainbow trout (Figure 1 and Appendix H.4, Table 12) at their "Leadville" site. These PHABSIM curves were used in the Upper Arkansas River Water Needs Assessment (Bridges et al. 2000; Smith and Hill 2000) and represent the habitat in the Arkansas River in Segment 1.

Brown trout populations are self-sustaining in the Arkansas River. PHABSIM relationships were simulated for four different life stages of brown trout – spawning, fry, juvenile, and adult. Rainbow trout populations are maintained by CPW stocking; there is very limited natural reproduction and any young rainbow trout fry that do hatch are exposed to whirling disease and have had little chance for long-term survival (Policky 2004b). In 2009, stocking of a whirling disease resistant rainbow trout strain began and larger individuals are currently being stocked, which is expected to increase survival (Policky 2009). As a result, all four life stages simulated for brown trout were also simulated for rainbow trout with PHABSIM.

For both brown and rainbow trout, highest habitat levels occur at relatively low flows, near 100 cfs (Figure 1). For most life-stages of trout, habitat levels decrease at flows higher than 100 cfs. For brown trout fry, habitat levels are relatively low at all flows, but tend to increase up to 500 cfs.

CEC measured habitat variables at the Smith Ranch and Empire Gulch Sites in 1998 through 2007 (CEC 1999a, 2001, 2002, 2003, 2004a, 2005; GEI 2006, 2007a, 2008a). At these two sites, mean pool area was low (Table 20) but varied among years at the Smith Ranch Site; there were no pools at the Empire Gulch Site. The dominant substrate was cobble at both sites in all years. Mean depth varied little over time, but was greatest in 2007 (Appendix H.4, Table 13).

Table 20: Summary of Upper Arkansas River Segment 1 Habitat Data, Fall 1999 through 2007

Pool Area (%)	Mean Bank Width (ft)	Mean Wetted Width (ft)	Predominant Substrate	Mean Depth (ft)
8	94	47	Cobble	1.4

Data Source: Appendix H.4, Table 13

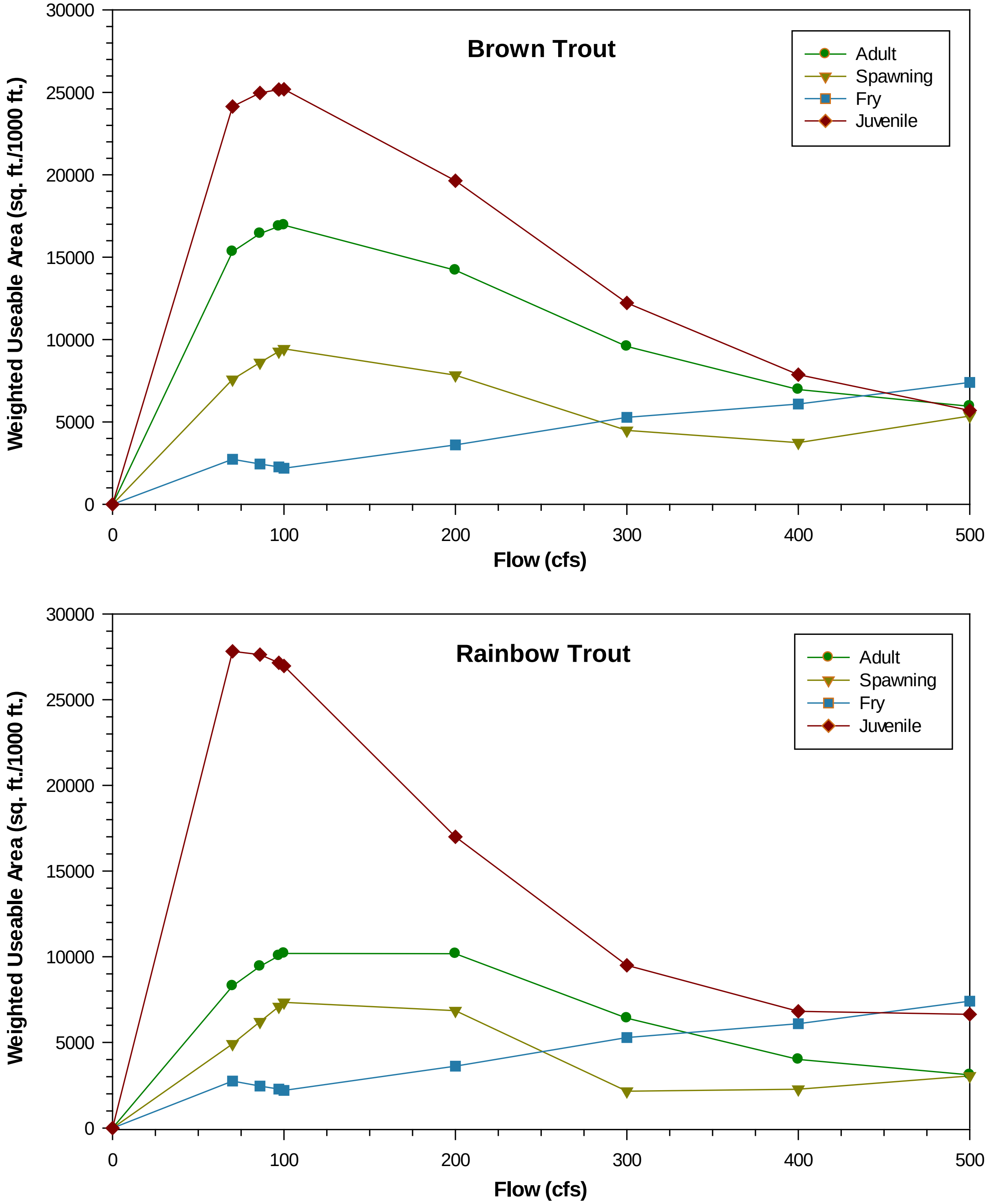


Figure 1: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Brown and Rainbow Trout in Upper Arkansas River Segment 1 (Smith and Hill 2000)

Segment 2, Granite to Buena Vista

There has been very little sampling of fish or benthic macroinvertebrates in Segment 2 of the Upper Arkansas River, from Granite to Buena Vista. We could find no available fish data for this segment. A few studies associated with the California Gulch project included benthic macroinvertebrate sampling sites just downstream from Granite . CPW developed a PHABSIM habitat versus flow relationship for this segment of the Upper Arkansas River.

Fish

No fish data are available for Segment 2 of the Upper Arkansas River. Based on the fish community at the Granite Site at the downstream end of Segment 1 (Appendix H.4, Table 8), the species composition in Segment 2 is probably comprised predominately of brown trout, with low numbers of stocked rainbow trout. Other species that are present probably include low numbers of longnose and white sucker.

Benthic Invertebrates

Colorado State University has conducted several studies of invertebrates in the Upper Arkansas River with respect to concentrations of metals in water and tissues. One of the sample sites (Site AR-8) is just upstream from Buena Vista in Segment 2.

Clements (1994) quantitatively sampled this site with a Hess sampler in 1989 to 1991. He presented his data graphically, and actual values for community parameters are not available. Density over the sampling period ranged from approximately 3,500 to 7,500 per square meter. Mean number of taxa per sample at this site was approximately 17, although he did not present total number of taxa for all of the samples combined. The relative abundance of EPT taxa varied from approximately 40 to 50 percent of the total density. These parameters suggest that water quality conditions in the late 1980s and early 1990s were sufficient to support sensitive EPT taxa in Segment 2. Nelson and Roline (1995) collected quantitative samples in 1992 through 1994. Density at two sites in Segment 2 ranged from approximately 1,400 to 1,900 per square meter, somewhat less than that from Clements (1994).

Kiffney and Clements (1993) and Clements and Kiffney (1994) also sampled Site AR-8 in 1990 and 1991 and Clements and Kiffney (1995) sampled Site AR-8 in 1992. They do not present much information on benthic macroinvertebrate community parameters as their work was focused on metals levels in water and tissues. They did collect several EPT species for metals analysis and the information presented was consistent with that in Clements (1994). Ruse et al. (2000) and Ruse and Herrmann (2000) collected adult aquatic insects (terrestrial phase) at one site in Segment 2. They found numerous Plecoptera and Trichoptera species, but few Ephemeroptera in 1984 and 1985.

Habitat

The CPW developed habitat versus flow relationships for brown trout and rainbow trout for Segment 2 of the Upper Arkansas River (Appendix H.4, Table 14). The PHABSIM data were collected at their "Numbers" site between Granite and Buena Vista (Bridges et al. 2000; Smith and Hill 2000). For most life stages of both species, highest habitat levels occur over the range of flows from 200 cfs to approximately 600 cfs (Figure 2). Habitat levels do not vary much over the modeled range of flows above 200 cfs.

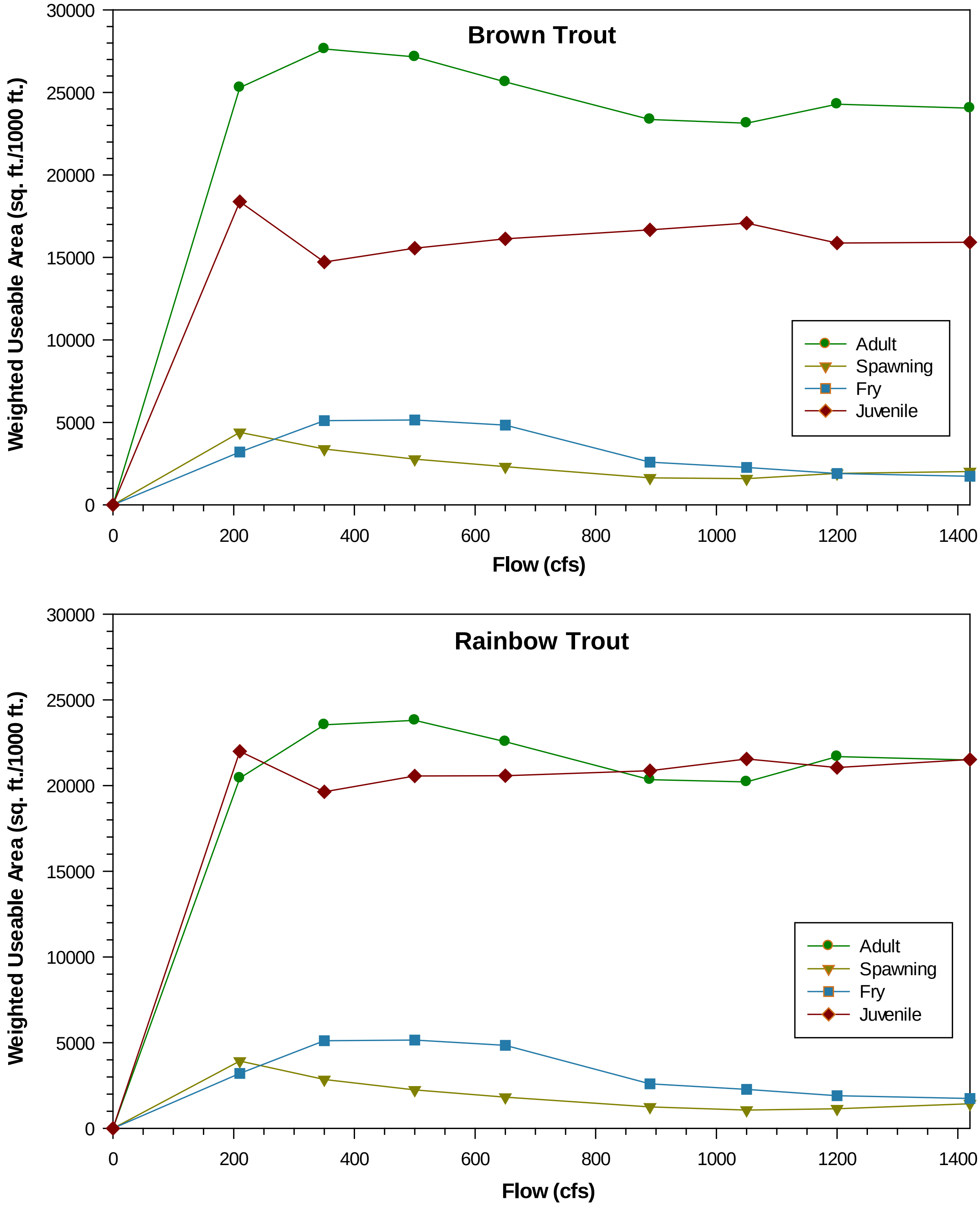


Figure 2: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Brown and Rainbow Trout in Upper Arkansas River Segment 2 (Smith and Hill 2000)

Segment 3, Buena Vista through Browns Canyon

There is little information available for fish or benthic macroinvertebrates in Segment 3 of the Upper Arkansas River. Fish have not been sampled in this segment since 1985. Benthic invertebrate samples were collected in 2003 and 2004 as part of the SDS EIS. CPW developed PHABSIM habitat versus flow relationships for this segment for brown and rainbow trout.

Fish

No recent fish data are available for Segment 3 of the Upper Arkansas River. However, CPW annually stocks rainbow trout in Segment 3 (Table 17). The presence of brown trout fisheries in Segment 1 and Segment 4 suggests that brown trout are the dominant fish species in Segment 3 as well. The other trout and sucker species that are also present in Segments 1 and 4 are probably also present in Segment 3 in low numbers. CPW (Nehring 1986) sampled a site near Nathrop in 1985 and collected brown trout with a biomass of 37 pounds per acre.

Benthic Invertebrates

CEC collected benthic invertebrate samples during supplemental data collection for the SDS EIS at a site just upstream from Nathrop, (Site UAR-1) in fall 2003 and spring 2004. Sampling during both seasons resulted in the collection of a wide variety of species and abundant invertebrates, with numerous taxa (Table 21 and Appendix H.4, Table 15) including mayflies, stoneflies, caddisflies, beetles, flies, and a few worms, clams, and a dragonfly. Approximately 40 percent of the taxa in both seasons were EPT taxa. Diversity in both seasons was well above 2.5, and the HBI indicates that the community was comprised of a mix of tolerant and intolerant species, with proportionally more intolerant species. The data indicate that water quality and habitat are suitable to support a balanced community with numerous, sensitive EPT taxa.

Table 21: Summary of Upper Arkansas River Segment 3 Benthic Invertebrate Parameters

Parameter/Date	Fall 2003[(1)]	Spring 2004[(1)]
Abundance (#/sample)	7,777	5,274
Number of Taxa	33	47
Number of EPT Taxa	14	17
Diversity (H’)	3.67	3.85
Biotic Index (HBI)	4.55	4.52

Data Source: Appendix H.4, Table 15
Note:
(1) Data for Fall 2003 and Spring 2004 were collected for the SDS EIS (CEC 2006).

The Health Department collected numerous taxa, including EPT taxa and tolerant taxa with a kick net from a site near Salida in April 2000 (Health Department 2000). Their sample results are consistent with those from the data collected in 2003 and 2004 by CEC. Nelson and Roline (1995) collected Surber samples at one site on the Arkansas River south of Buena Vista from 1992 through 1993. Most of the invertebrates collected were EPT species with density of approximately 1,400 per square meter. Ruse and Herrmann (2000) found several species of Plecoptera and Trichoptera at one site in Segment 3 in 1984 and 1985. They found few species of Ephemeroptera.

Habitat

The CPW developed PHABSIM habitat versus flow relationships for brown and rainbow trout (Figure 3 and Appendix H.4, Table 16) that were used in the upper Arkansas Water Needs

Assessment (Bridges et al. 2000; Smith and Hill 2000). CPW collected the data at the "Browns Canyon" site. For both brown and rainbow trout, highest habitat levels for most life stages occur at a flow of approximately 200 to 400 cfs (Figure 3).

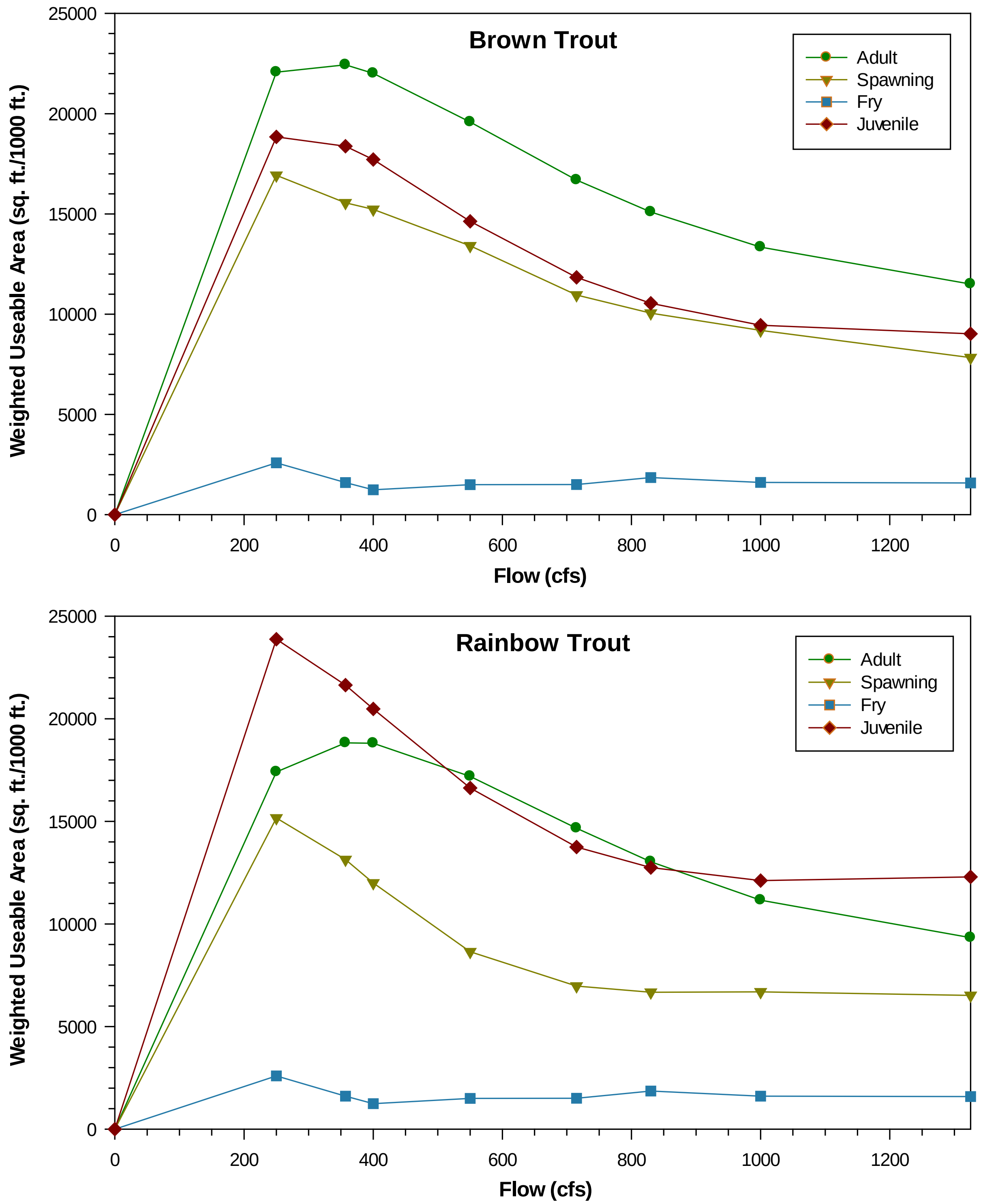


Figure 3: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Brown and Rainbow Trout in Upper Arkansas River Segment 3 (Smith and Hill 2000)

Segment 4, Browns Canyon to Coaldale

Recent fish sampling data are available for Segment 4 of the Upper Arkansas River. CEC collected benthic macroinvertebrate data in 2003 and 2004 to update the limited data available from the 1990s and 1980s. CPW developed PHABSIM relationships for trout in this segment.

Fish

CPW collected quantitative fish community data using a mark-recapture method at the Big Bend (between Browns Canyon and Salida), Wellsville, and Coaldale sites (Policky 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2006, 2007, 2008, 2009). CPW sampled in spring from 1994 through 2000 and more recently in fall from 1998 through 2009. Both spring and fall data are summarized (Table 22).

Table 22: Summary of Upper Arkansas River Segment 4 Fish Species Composition and Biomass (Pounds per Acre), Spring 1994 through 2000 and Fall 1998 through 2009

Species/Date	Spring 1994-2000		Fall 1998-2009	
	Mean	*Range*	*Mean*	*Range*
Brook trout	0	0	<0.1	N/A
Brown trout	78.6	19.6-119.2	108.1	37.8-223.9
Cutthroat trout	<0.1	0-0.3	<0.1	0-0.1
Rainbow trout	11.5	0-32.6	11.2	2.1-32.0
Cutbow trout	0	0	<0.1	N/A
Longnose dace	<0.1	N/A	<0.1	N/A
Longnose sucker	4.2	0-31.1	17.8	0-36.6
White sucker	0.9	0-3.6	13.2	12.0-14.3

Data Source: Appendix H.4, Tables 17 through 19

Brown trout are the most abundant species in Segment 4 of the Upper Arkansas River (Table 22). Brook trout, cutthroat trout, rainbow trout, cutbow hybrids, two species of sucker, and longnose dace are also present in low numbers. Rainbow trout are stocked by CPW in this segment (Table 17). No other species are currently stocked, and populations of most species other than rainbow trout are maintained by natural reproduction. The few cutthroat trout and cutbow hybrids collected in Segment 4 may have been fish originally stocked in Turquoise Lake or Twin Lakes by CPW.

Brown trout biomass varies substantially from year to year and from site to site (Table 22 and Appendix H.4, Tables 17 through 19), with biomass generally higher in fall than in spring. Biomass of most other species is much lower than that of brown trout. However, the CPW data do not always present biomass numbers for these species. Rainbow trout biomass is consistently low, despite stocking by CPW.

CPW sampled several sites in Segment 4 of the Upper Arkansas River in the 1980s and early 1990s and summarized the data in Policky (1999) and Anderson and Krieger (1994). Population parameters for brown and rainbow trout were within the range presented for data collected since 1994. These reports do not present data for other trout or non-game species.

Benthic Invertebrates

CEC sampled invertebrates at a site upstream from Salida (Site UAR-2) and at a site near Vallie (Site UAR-3) in fall 2003 and spring 2004 as part of the SDS EIS (CEC 2006). Sampling during both seasons resulted in the collection of numerous taxa, with approximately one-third comprised of EPT taxa (Table 23 and Appendix H4, Table 20). The samples contained a wide variety of invertebrates including numerous species of mayflies, stoneflies, caddisflies, and flies as well as beetles and a few crustaceans, worms, clams, and snails. Mean diversity was above 2.5 during both seasons. The HBI was higher in fall than in spring and values indicate a mixture of intolerant and tolerant species during both seasons.

Table 23: Summary of Upper Arkansas River Segment 4 Benthic Invertebrate Parameters

Parameter/Date	Fall 2003[1]		Spring 2004[1]	
	Mean	*Range*	*Mean*	*Range*
Abundance (#/sample)	10,753	7,046-14,460	6,610	2,202-11,018
Number of Taxa	35	34-35	40	38-41
Number of EPT Taxa	13	12-14	14	14
Diversity (H')	3.13	3.03-3.23	2.88	2.36-3.40
Biotic Index (HBI)	5.45	5.41-5.48	4.59	4.45-4.72

Data Source: Appendix H.4, Table 20
Note:
(1) Data for Fall 2003 and Spring 2004 were collected for the SDS EIS (CEC 2006).

Nelson and Roline (1995) quantitatively sampled three sites in Segment 4 in 1992 through 1993 with a Surber sampler. Density ranged from 500 to 3,700 per square meter. Approximately half of the density was comprised of EPT taxa. Ruse and Herrmann (2000) sampled two sites in Segment 4 of the Upper Arkansas River in 1984 and 1985. They collected 20 species of adult Plecoptera and Trichoptera.

Habitat

CPW used data from its "Independent Whitewater" PHABSIM site to develop habitat versus flow relationships for Segment 4 of the Upper Arkansas River (Bridges et al. 2000). For brown and rainbow trout, highest habitat levels occur at approximately 200 to 400 cfs (Figure 4 and Appendix H.4, Table 21), with declining habitat levels at higher flows. Anderson and Krieger (1994) focused on habitat for juvenile brown trout over the summer growing season. They concluded that flows of 700 cfs or higher in August reduce the growth rate of young brown trout in the Arkansas River near Wellsville.

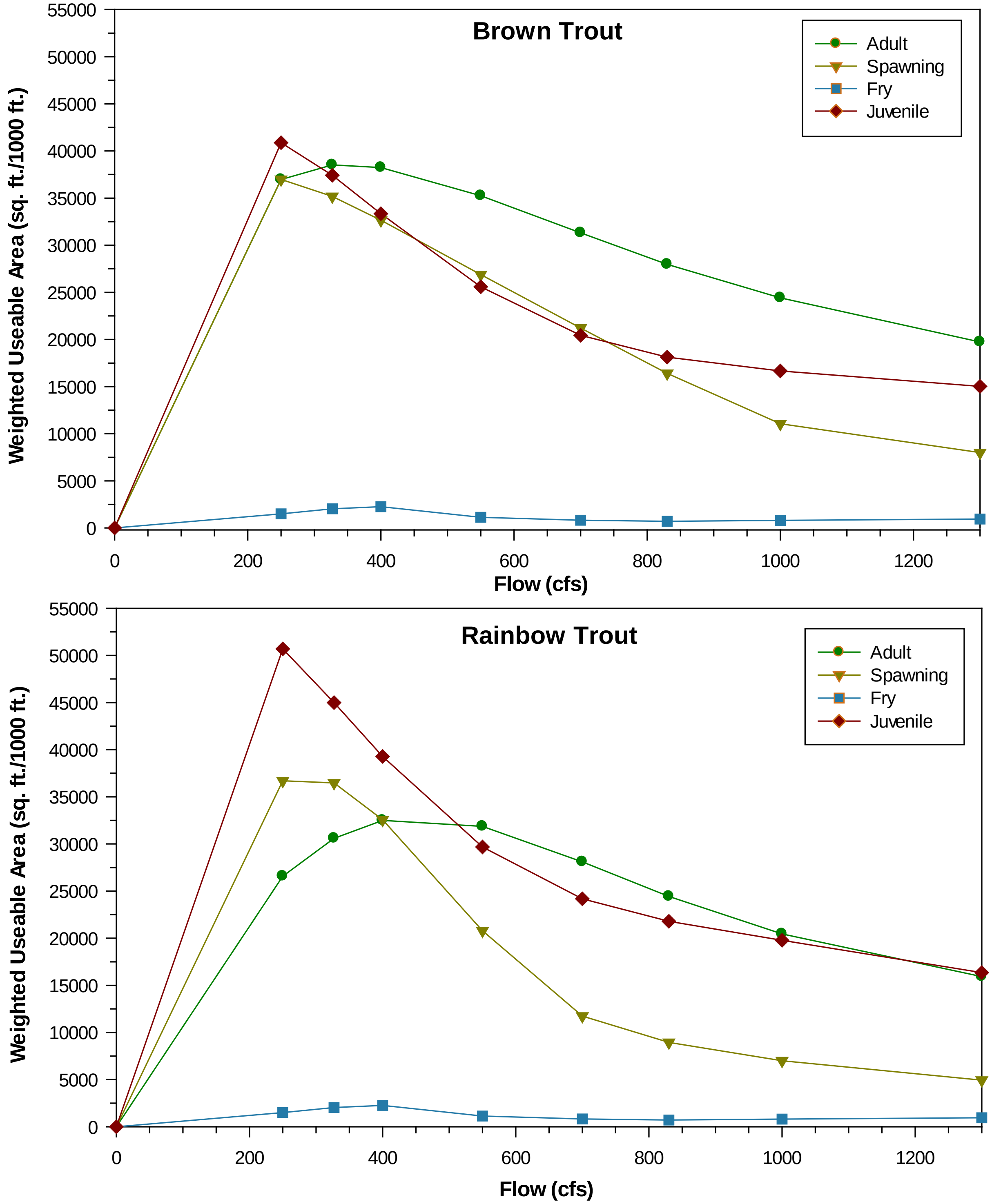


Figure 4: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Brown and Rainbow Trout in Upper Arkansas River Segment 4 (Smith and Hill 2000)

Segment 5, Coaldale to Texas Creek

Segment 5 of the Upper Arkansas River includes the short section of stream between Coaldale and Texas Creek. Fish and invertebrates have been sampled sporadically in the past. CPW states that PHABSIM data from another site on the Arkansas River also represents the habitat in Segment 5. No other habitat data are available.

Fish

The CPW does not currently sample fish in Segment 5 of the Upper Arkansas River, and no recent data are available. The CPW annually stocks rainbow trout in this segment of the Arkansas River (Table 17).

CPW sampled a site between Cotopaxi and Texas Creek in this segment in the early 1980s and mid 1990s (Nehring and Anderson 1982; Policky 1999). They collected brown trout and a few stocked cutthroat trout and rainbow trout. Brown trout biomass was approximately 70 to 100 pounds per acre. CPW did not present data on other species of fish in this segment, but mentioned that deep pools and runs contained many suckers (Nehring and Anderson 1982). The presence of longnose sucker, white suckers and longnose dace in segments both upstream and downstream from Segment 5 of the Upper Arkansas River suggests that these species are present in Segment 5 as well.

Benthic Invertebrates

No recent benthic macroinvertebrate data are available for Segment 5 of the Upper Arkansas River. Nelson and Roline (1995) collected quantitative samples from one site in Segment 5 in 1992 through 1993. Density over the years ranged from 1,900 to 4,600 per square meter. Most of these invertebrates were EPT taxa. Winters (1988) collected quantitative samples of invertebrates several times in 1982 and 1983 at a site in Segment 5. The data indicate the presence of numerous species with over half of them being EPT taxa, on average (Table 24 and Appendix H4, Table 22). Ruse et al. (2000) and Ruse and Herrmann (2000) collected 15 species of adult Plecoptera and Trichoptera in 1984 and 1985 at one site in Segment 5.

Table 24: Summary of Upper Arkansas River Segment 5 Benthic Invertebrate Parameters, 1982 and 1983

Parameter/Date	1982-1983	
	Mean	***Range***
Density (#/m^2)	2,796	1,080-7,328
Number of Taxa	25	20-30
Number of EPT Taxa	13	8-17

Data Source: Appendix H.4, Table 22

Habitat

The CPW states that PHABSIM data collected at the “Stockyard Bridge” PHABSIM site near Salida represents the habitat in Segment 5 of the Upper Arkansas River (Bridges et al. 2000; Smith and Hill 2000). Habitat for most life stages of brown and rainbow trout is highest at approximately 200 to 600 cfs (Figure 5 and Appendix H.4, Table 23).

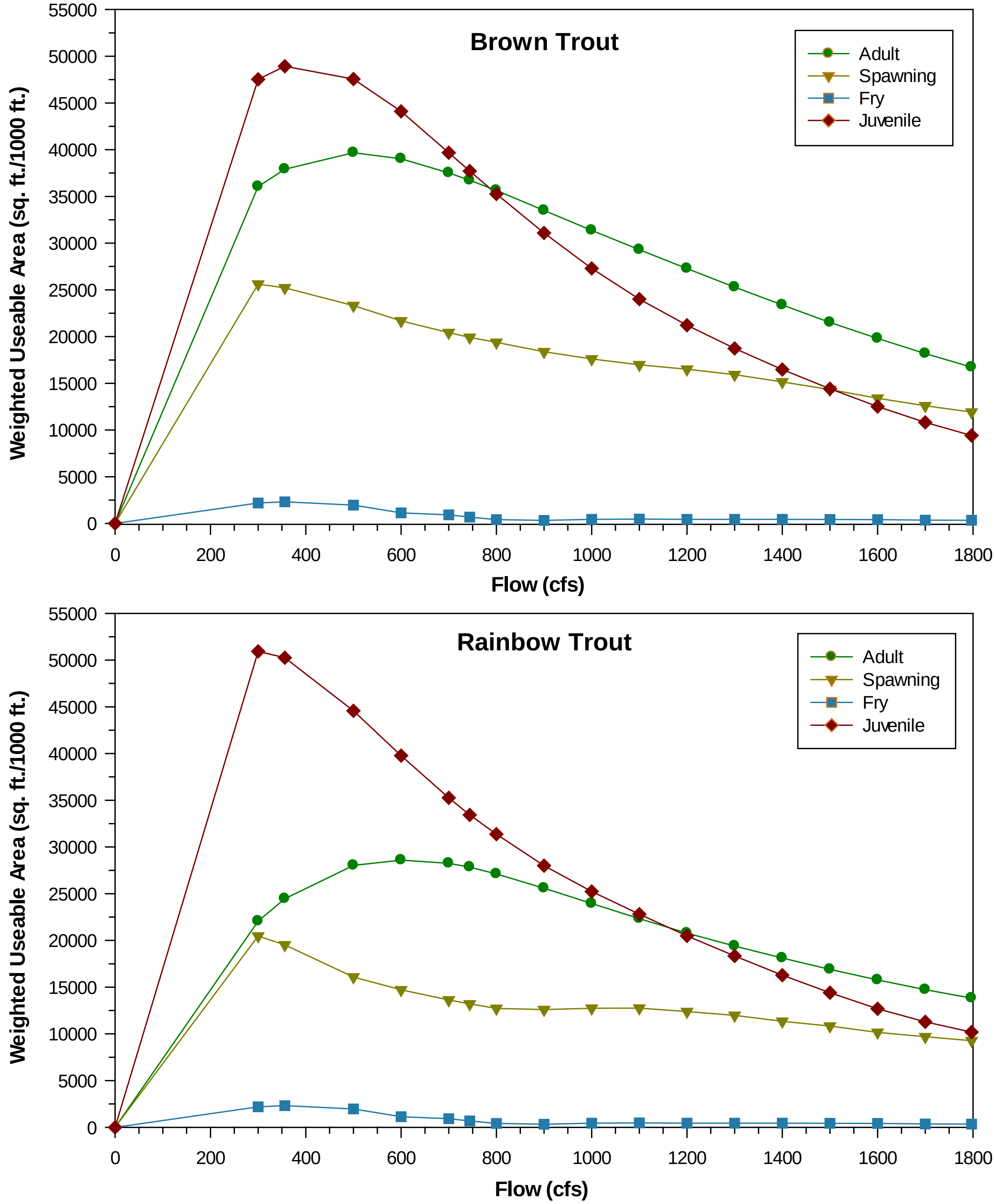


Figure 5: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Brown and Rainbow Trout in Upper Arkansas River Segment 5 (Smith and Hill 2000)

Segment 6, Texas Creek to Cañon City

Segment 6 of the Upper Arkansas River is not routinely sampled for fish or invertebrates. Limited data are available from the 1980s and 1990s. No habitat measurements have been taken in this segment.

Fish

No recent fish data are available for Segment 6 of the Upper Arkansas River. CPW sampled fish in the Arkansas River near the Loma Linda campground just downstream from Texas Creek for several years between 1981 and 1990 (Nehring and Anderson 1982; Policky 1999). Brown trout biomass was in the range of 50 to 100 pounds per acre. A few stocked cutthroat trout were also collected. CPW does not mention other species in this segment; however, suckers and longnose dace are probably present, based on their presence in nearby segments of the river. The CPW annually stocks this segment of the river with rainbow trout (Table 17).

Benthic Invertebrates

Recent benthic macroinvertebrate data are not available for Segment 6 of the Upper Arkansas River. The invertebrate community is probably similar to that of the adjacent segments. Nelson and Roline (1995) quantitatively sampled one site in 1992 through 1993. Their results indicate density from 1,200 to 2,900 per square meter. The majority of the density was comprised of EPT taxa. Ruse et al. (2000) and Ruse and Herrmann (2000) collected 18 species of adult Plecoptera and Trichoptera at two sites in Segment 6 of the Upper Arkansas River in 1984 and 1985.

Habitat

The CPW data collected at the “Floodplain” PHABSIM site represent the habitat in Segment 6 of the Upper Arkansas River (Bridges et al. 2000; Smith and Hill 2000). Habitat for most life stages of brown and rainbow trout is highest at flows of approximately 300 to 600 cfs (Figure 6 and Appendix H.4, Table 24). Habitat levels are relatively consistent from 600 to 2,000 cfs.

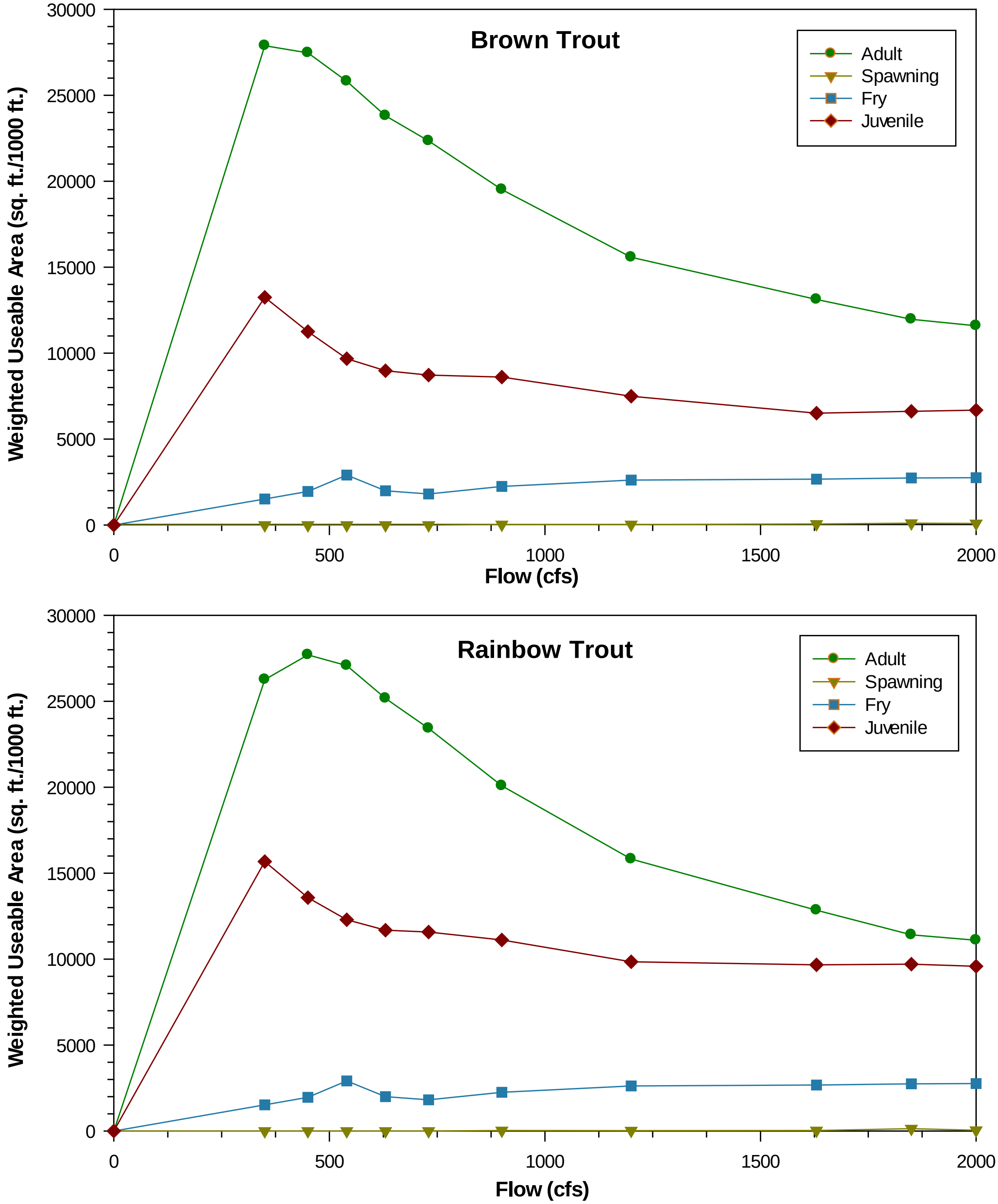


Figure 6: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Brown and Rainbow Trout in Upper Arkansas River Segment 6 (Smith and Hill 2000)

Segment 7, Cañon City to Pueblo Reservoir

Segment 7 of the Upper Arkansas River is not routinely sampled for fish and macroinvertebrates. Limited fish data from the late 1970s through 2007 are available for a few sites. Benthic invertebrate data were collected in 2003 and 2004 as part of the SDS EIS (CEC 2006). No data on habitat measurements are available for this segment.

Fish

No sites in Segment 7 of the Upper Arkansas River are routinely monitored by the CPW. However, the CPW recently sampled this segment in Canon City and has periodically sampled this segment further downstream in the past during surveys for rare and endangered species. The CPW last stocked rainbow trout in this reach in 2002 (Policky 2009). Southern redbelly dace and Arkansas darters were also stocked in off-channel habitats to the Arkansas River in this reach at tributary confluences in 2002 and southern redbelly dace were stocked again in 2006 (Policky 2009; Krieger and Lovell 2011).

Fish community data collected by CPW in 2005 and 2007 demonstrate that a brown trout fishery is present in Canon City (Table 25 and Appendix H4, Table 25). Brown trout were reported as the most abundant species present and a few rainbow trout were collected in 2005. However, the fish community is indicative of a transitional zone community between coldwater and warmwater with abundant suckers. Sucker abundance was reported as less than the number of brown trout present during 2005 and 2007, but CPW notes that numerous suckers were observed and not collected during sampling. Longnose dace were also present and relatively abundant, while two warmwater species, fathead minnow and green sunfish were present at low abundances.

Table 25: Summary of Upper Arkansas River Segment 7 Fish Species Composition (# Collected) at a Site near Canon City, 2005 and 2007

Species/Date	Fall	
	2005	2007
Brown trout	889 (38.9)[1]	346 (26.0)[1]
Rainbow trout	12	0
Fathead minnow	2	1
Green sunfish	1	0
Longnose dace	101	54
Longnose sucker [2]	438	163
White sucker [2]	133	38

Data Source: Appendix H.4, Table 25

Notes:

(1) Values in parentheses represent biomass (pounds per acre)

(2) CPW noted that numerous suckers were observed that were not collected.

Loeffler et al. (1982) of CPW sampled fish at several sites in the Arkansas River between Cañon City and Pueblo Reservoir in 1979, 1980, and 1981 (Appendix H4, Table 26). They collected eleven species with the native white sucker, longnose dace, and central stoneroller being most abundant (Table 26). Nesler et al. (1999) of CPW sampled the Arkansas River from Cañon City to Pueblo Reservoir in 1993 through 1996. They found many of the same species as the earlier study (Table 26) including flathead chub, a species of special concern in Colorado. Many of the species collected in both studies are transition zone species (Nesler et al. 1999) or warmwater species; few brown trout were collected by Loeffler et al. (1982) and none by Nesler et al. (1999). The data indicate that downstream from Cañon City, Segment 7 of the Upper Arkansas River is in the transition zone between a coldwater and warmwater stream.

Table 26: Upper Arkansas River Segment 7 Fish Species Composition, 1979 through 1996

Species/Date	1979-1981 (Total # Collected)	1993-1996 (Present)
Black bullhead	2	0
Brown trout	24	0
Central stoneroller	91	X[(1)]
Fathead minnow	58	X[(1)]
Flathead chub	31	X[(1)]
Green sunfish	34	X[(1)]
Longnose dace	183	X[(1)]
Longnose sucker	82	X[(1)]
Red shiner	19	0
Sand shiner	48	X[(1)]
White sucker	262	X[(1)]

Data Source: Appendix H.4, Table 26 and Nesler et al. (1999)
Note:
[(1)] "X" represents present, but numbers are unavailable

Several species of fish apparently migrate upstream into Segment 7 of the Upper Arkansas River from Pueblo Reservoir. CPW has information from sampling near the inlet of Pueblo Reservoir and from angler reports indicating that fish seasonally move into the Arkansas River in spring (Krieger to Van Derveer 2005). The river is accessible to fish from the reservoir upstream nearly to Portland, approximately 18 miles. Rainbow trout migrate during spawning, probably in late February through March. Walleye also migrate during spawning, probably in March through mid-April. Wiper is a sterile hybrid between striped bass and white bass. However, they apparently move into the river during spawning season in April and May, according to angler reports. Channel catfish also apparently migrate into the river in spring and summer for spawning or for other reasons (Krieger to Van Derveer 2005).

Benthic Invertebrates

Decker (1998) studied the species composition of mayflies, stoneflies, caddisflies, and true flies (Diptera) at a site just upstream of Pueblo Reservoir in 1994 and 1995. She found a wide variety of species of each group.

CEC collected benthic invertebrate data in the Arkansas River at two sites in fall 2003 and spring 2004 as part of the SDS EIS (CEC 2006) (Appendix H.4, Table 27). One site was located just upstream from Cañon City (Site UAR-4) and the second site was just upstream from Pueblo Reservoir near Swallows (Site UAR-5). These data indicate the presence of an abundant and diverse invertebrate community. A wide variety of invertebrates were collected including numerous species of mayflies, flies, and caddisflies as well as a few stoneflies, beetles, and a few crustaceans, worms, clams, and snails. Approximately one-third of the taxa collected were EPT taxa and diversity was higher than the threshold of 2.50 (Table 27). The HBI indicates a mix of tolerant and intolerant species. During each season, the number of taxa and number of EPT taxa was greater at the upstream site, near Canon City than at the downstream site near Pueblo

Reservoir. The data indicate that water quality and habitat in Segment 7 of the Upper Arkansas River are sufficient to support numerous species of invertebrates, including sensitive EPT species. However, the benthic invertebrate community appears to shift to a slightly more tolerant community at the downstream site near Pueblo Reservoir than at the upstream site, based on the smaller percentage of EPT taxa present.

Table 27: Summary of Upper Arkansas River Segment 7 Benthic Invertebrate Parameters

Parameter/Date	Fall 2003[1]		Spring 2004[1]	
	Mean	***Range***	***Mean***	***Range***
Abundance (#/sample)	7,316	4,710-9,922	6,872	1,771-12,572
Number of Taxa	33	26-39	38	34-42
Number of EPT taxa	13	9-16	12	9-15
Diversity (H')	3.65	3.53-3.76	3.08	2.65-3.51
Biotic Index (HBI)	5.04	4.93-5.14	4.89	4.44-5.33

Data Source: Appendix H.4, Table 27
Note:
(1) Data for Fall 2003 and Spring 2004 were collected for the SDS EIS (CEC 2006).

Ruse et al. (2000) and Ruse and Herrmann (2000) had two collection sites in Segment 7 of the Upper Arkansas River in 1984 and 1985. They collected a total of 24 species of Plecoptera and Trichoptera and 35 species of midges (Diptera, Chironomidae) at the two sites, combined.

Habitat

No PHABSIM site was established in Segment 7. The CPW suggests that the habitat in Segment 7 of the Upper Arkansas River would be represented by the PHABSIM data collected in Browns Canyon (Bridges et al. 2000). However, they modeled habitat for brown and rainbow trout, which are rare or absent from much of Segment 7. They did not provide habitat relationships for the transition zone species and warmwater species that are present in Segment 7. Therefore, habitat relationships are not presented for PHABSIM modeling in this segment.

Lower Arkansas River, Pueblo Reservoir Downstream to Kansas State Line

The lower Arkansas River from Pueblo Reservoir downstream to the Kansas State Line is divided into four segments for the purposes of this appendix. The first segment is from Pueblo Reservoir to the confluence of Wildhorse Creek. The potential effects of flow changes in this segment are evaluated in the EIS using PHABSIM data collected in 2004 by CEC (CEC 2006). The second segment is a short mostly channelized segment that extends from Wildhorse Creek to Fountain Creek. The third segment extends from Fountain Creek downstream to John Martin Reservoir. The potential effects of flow changes in this segment are evaluated using PHABSIM data collected by GEI in 2011. The fourth segment extends from the outlet of John Martin Reservoir downstream to the Kansas state line. No PHABSIM data are available for lower Arkansas River segments 2 and 4.

Segments 1 and 2, Pueblo Reservoir to Fountain Creek

Segment 1 includes the reach from Pueblo Reservoir downstream to Wildhorse Creek and Segment 2 includes the short channelized reach from Wildhorse Creek to Fountain Creek. For the purposes of describing the aquatic environment, segments 1 and 2 are combined in this appendix. CPW crews have sampled fish several times in the past in Segments 1 and 2 of the lower Arkansas River. CPW and CEC collected data in 2004 in this reach of the river as part of the SDS EIS (CEC 2006). Additional fish sampling was conducted by CPW in 2005, 2006, and 2009. GEI and CPW collected qualitative fish presence data in 2011 for habitat suitability curve validation studies (GEI 2011). CEC also collected benthic invertebrate samples at four sites in this reach to update the limited data available prior to 2003 (CEC 2006).

Fish

The Arkansas River downstream from Pueblo Reservoir to Wildhorse Creek is currently managed as a coldwater sport fishery by CPW. Downstream of Wildhorse Creek, the channel is confined between concrete banks, and the fish community shifts from stocked coldwater species to predominantly native warmwater species.

The CPW stocks brown, rainbow, cutthroat, and cutbow trout downstream from Pueblo Dam to maintain the "put-grow-and-take" fishery (Table 28). The number of fish stocked has varied considerably since 1999. Stocked trout populations are sustained through coldwater releases from Pueblo Reservoir. Saugeye, a hybrid between sauger and walleye, were also stocked in 2005 and 2009.

Table 28: Fish Stocking Data (Number Stocked per Year) for the Lower Arkansas River Downstream from Pueblo Reservoir, 1999 through 2009

Species/Date	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Brown trout	62,000	6,031	12,008	6,899	8,008	14,000	18,986	17,876	12,000	11,999	8,000
Cutbow trout	0	5,573	2,666	8,100	0	0	0	0	0	0	0
Cutthroat trout	0	3,376	6,673	8,140	0	2,600	0	98	1,023	3,025	44
Rainbow trout	434,169	40,517	21,762	0	48,230	55,800	31,402	34,822	34,801	30,696	28,632
Saugeye	0	0	0	0	0	0	20,000	0	0	0	10,000

Data Source: Melby (2004b, 2010)

Limited recent data are available on the fish community of Segments 1 and 2 of the lower Arkansas River. CPW and CEC jointly collected fish population data in spring 2004 at four sites in Segments 1 and 2 (Appendix H.4, Table 28). Two of the sites sampled were upstream from Wildhorse Creek and two sites were downstream from Wildhorse Creek. A total of 20 species of fish and three hybrids were collected (Table 29). White sucker, longnose dace, and longnose sucker were the most common species collected. Upstream of Wildhorse Creek, a mixture of warmwater, coldwater, game and non-game species were collected. Downstream of Wildhorse Creek, the species present was similar except no trout species were collected and flathead chub, a species of special concern in Colorado, was also collected. These data indicate that the lower Arkansas River transitions from coldwater habitat below the dam to warmwater habitat downstream from Wildhorse Creek. Several of the fish taxa, such as saugeye, spotted bass, walleye, wiper, and yellow perch were probably introduced to Segments 1 and 2 by releases from Pueblo Reservoir.

The two uppermost sites sampled in spring 2004, upstream from Wildhorse Creek, were sampled again by CPW in 2009 (Melby 2010) (Appendix H.4, Table 28). The fish species composition was similar with abundant suckers and few brown trout present again in 2009. However, rainbow trout were much more abundant in 2009 than in 2004 and smallmouth bass were also more abundant. One three-inch brown trout and five three-inch rainbow trout were collected in 2009, which would seem to indicate natural recruitment (Melby 2010). However, these fish were all collected near the hatchery outflow, which contained both of these species at these sizes, suggesting they may not be the product of natural recruitment. Brown trout abundance has remained low despite stocking hundreds of thousands of brown trout over the last 25 years. CPW notes that rainbow trout presence appears directly related to stocking in this reach (Melby 2010).

Additional sampling was conducted in September and October 2009 by CPW and CSU-Pueblo at a site located near I-25 (CPW 2011a). Nine species were collected and longnose dace were the most abundant species. Central stoneroller, longnose dace, rainbow trout, and white suckers were collected at one site in this reach during 2011 by GEI Consultants (2011).

Table 29: Fish Population Data (Total Number Collected) for the Lower Arkansas River Segments 1 and 2, 1979 through 2004

Species/Date	1979-1981	1990	1993-1996	1995	2004	2004	2005-2006	2009	2009
Black bullhead	2	1	0	0	0	0	0	0	0
Black crappie	0	0	0	0	2	0	0	0	0
Bluegill	0	0	0	0	0	X(1)	16	0	1
Brown trout	0	5	0	0	20	0	0	26	0
Carp	0	0	0	0	5	0	0	5	15
Central stoneroller	31	3	X(1)	0	163	X(1)	9	0	8
Channel catfish	70	0	0	0	1	0	0	0	0
Cutbow	0	0	0	0	23	0	0	0	0
Fathead minnow	32	0	0	0	3	0	0	0	0
Flathead chub	18	3	X(1)	0	12	0	203	0	0
Green sunfish	215	0	0	0	1	X(1)	26	0	5
Largemouth bass	0	0	0	0	7	X(1)	24	7	0
Longnose dace	412	0	X(1)	23	77	0	6	21	1,215
Longnose sucker	4	534	X(1)	7	103	X(1)	13	22 (2)	20
Mosquitofish	0	0	0	0	0	0	0	0	4
Orangespotted sunfish	0	0	0	0	4	X(1)	24	0	0
Plains killifish	0	0	0	0	0	X(1)	0	0	0
Rainbow trout	0	1	0	0	35	X(1)	0	307	1
Red shiner	26	0	0	0	4	X(1)	0	0	0
Sand shiner	50	0	0	0	3	X(1)	11	0	0
Saugeye	0	0	0	0	1	0	0	0	0
Smallmouth bass	0	0	0	0	10	0	27	37	5
Spotted bass	0	0	0	0	1	0	0	1	0
Walleye	0	14	0	0	2	0	0	0	0
White crappie	2	0	0	0	0	0	1	0	0
White sucker	33	270	X(1)	0	841	X(1)	35	286 (2)	26
Wiper	0	0	0	0	2	0	0	0	0
Yellow perch	0	3	0	0	2	0	0	2	0

Data Source: Appendix H.4, Tables 28 and 29, Bennett et al. (1990), Woodling (1999), Nesler et al. (1999), CEC (2004b, 2006), Melby (2010), and CPW (2011a)

Notes:

(1) "X" represents present, but numbers are unavailable.

(2) CPW noted that numerous suckers were observed that were not collected.

In December 2004, CEC collected fish for tissue analysis for the City of Pueblo (CEC 2004b). During this collection, 11 species were collected at one site just upstream from Fountain Creek (Table 29 and Appendix H4, Table 28). Two of these species, bluegill and plains killifish, were not present during earlier samples from this segment of the river. Additional sampling was conducted at a site at Moffat Street in 2005 and 2006 and 12 species were collected over the two years (GEI 2007b).

Various CPW crews sampled sites in Segments 1 and 2 between 1979 and 1990 (Table 29). Species composition varied considerably between sampling. Loeffler et al. (1982) sampled three sites in 1979 and 1981 and collected 12 species (Appendix H.4, Table 29). Bennett et al. (1990) collected nine species in 1990; almost all of the fish were white and longnose suckers (Table 29). Nesler et al. (1999) collected four species at two sites in 1993 through 1996. Woodling (1999) collected two species at one site in Lake Pueblo State Park in 1995. Combined, the studies from 1979 through 2009 collected 28 fish taxa in Segments 1 and 2 of the lower Arkansas River.

Benthic Invertebrates

Students from CSU-Pueblo examined species composition of mayflies, stoneflies, caddisflies, and true flies at sites just downstream of Pueblo Reservoir in 1994 and 1995 (Decker 1998) and in 2004 and 2006 (Kleinert 2008; Powell 2008). Using several collection methods, they found a wide variety of species of midges and caddisflies. There were fewer species of mayflies and only one species of stonefly. They concluded the species composition was typical of that found downstream of reservoirs.

CEC collected benthic macroinvertebrate data in fall 2003 and spring 2004 at four sites in Segments 1 and 2 of the lower Arkansas River (CEC 2006) (Appendix H.4, Table 30). The sites were located just downstream from Pueblo Dam (Site MAR-1), at the Greenway and Nature Center of Pueblo (Site MAR-2), just downstream from Wildhorse Creek (Site MAR-3), and just upstream from Fountain Creek (Site MAR-4). The data indicate the presence of abundant and diverse populations of invertebrates (Table 30). The species composition was somewhat different than in the segments in the upper Arkansas River, partially due to the transition from a coldwater to a warmwater river. Downstream of Pueblo Dam, there were only a few species of mayflies and caddisflies although they were sometimes very abundant. There were no stoneflies but there were dragonflies, damselflies, beetles, moths, true bugs, some crustaceans, worms, snails, clams, and abundant flies. The number of taxa was slightly higher in spring than in fall and the mean number of EPT taxa was the same in both seasons with similar ranges at the four sites (Appendix H.4, Table 30). The number of taxa and number of EPT taxa were lowest at the upstream (downstream from Pueblo Reservoir) and downstream (just upstream from Fountain Creek) sites in each season. Diversity followed this same trend in fall and in spring the second lowest value was at the site downstream from Pueblo Reservoir. The reduced number of taxa and diversity at the site immediately downstream from Pueblo Reservoir is a common characteristic of tailwater benthic invertebrate communities (Allan 1995). The changes in the invertebrate communities in tailwater reaches, immediately downstream from dams are due the altered chemical and physical environment, including reduced habitat complexity and reduced flow variability (Allan 1995).

EPT taxa accounted for approximately 25 percent or less of the total number of taxa. Although the mean and range of diversity was well above the threshold level of 2.50 at all sites in both seasons, the HBI was above 5.0 for every sample. This indicates that the mixture of species included more tolerant species than intolerant species. The relatively low number of EPT taxa and the relatively high HBI, as compared to upstream sites, indicate that the benthic macroinvertebrate community in Segments 1 and 2 of the lower Arkansas River is impaired to some degree by water quality, water quantity, and/or habitat. HBI values were highest at the downstream-most site during each season.

Table 30: Summary of Lower Arkansas River Segments 1 and 2 Benthic Invertebrate Parameters

Parameter/Date	Fall 2003		Spring 2004	
	Mean	***Range***	***Mean***	***Spring***
Abundance (#/sample)	8,933	2,189-14,508	3,363	550-6,548
Number of Taxa	27	21-33	31	26-36
Number of EPT Taxa	7	4-9	7	4-10
Diversity (H')	3.22	2.78-3.64	3.67	3.18-4.00
Biotic Index (HBI)	5.84	5.09-7.58	6.06	5.32-7.15

Data Source: Appendix H.4, Table 30
Note:
(1) Data for Fall 2003 and Spring 2004 were collected for the SDS EIS (CEC 2006).

The Health Department also sampled benthic macroinvertebrates at two sites in December 2000 and June 2002 (Health Department 2000, 2002). The data are not in a form to compare to the data collected by CEC for the SDS EIS. However, the Health Department results indicate that their samples included abundant, tolerant species at both sites with only a few EPT taxa present. The data are generally consistent with the data collected by CEC in 2003 and 2004.

Ruse et al. (2000) and Ruse and Herrmann (2000) collected adult aquatic insects at two sites in this reach of the lower Arkansas River in 1984 and 1985. They collected 14 species of Trichoptera, but no Plecoptera. They do not report the number of Ephemeroptera species collected, but state that few were found at any site. The absence of Plecoptera in this section of the Arkansas River is consistent with the data collected by CEC (2006); however, the samples collected by CEC contained several species of Ephemeroptera.

Habitat

CEC collected PHABSIM data for Segment 1 (from Pueblo Reservoir downstream to Wildhorse Creek) of the lower Arkansas River in 2004, and developed habitat versus flow relationships for the two trout species managed by CPW, brown trout and rainbow trout for the SDS EIS (CEC 2006) (Figure 7 and Appendix H.4, Table 31). Both brown and rainbow trout populations in Segment 1 are maintained by stocking of fish by CPW. Successful spawning of trout is limited or absent. Therefore, CEC simulated habitat relationships for the life stages of trout present in this segment of the Arkansas River. For brown trout, the CPW stocks juvenile fish (a few inches long) that grow to adult size and these two life stages were simulated. For rainbow trout, adult fish (usually greater than nine inches long) are stocked by CPW, and this life stage was simulated. For brown trout juveniles and adults, habitat levels change little above 200 cfs. For rainbow trout adults, habitat levels are highest from 100 to 350 cfs.

No PHABSIM site was established in Segment 2 of the Lower Arkansas River. This segment of the river is short and channelized with little habitat for fish and macroinvertebrates.

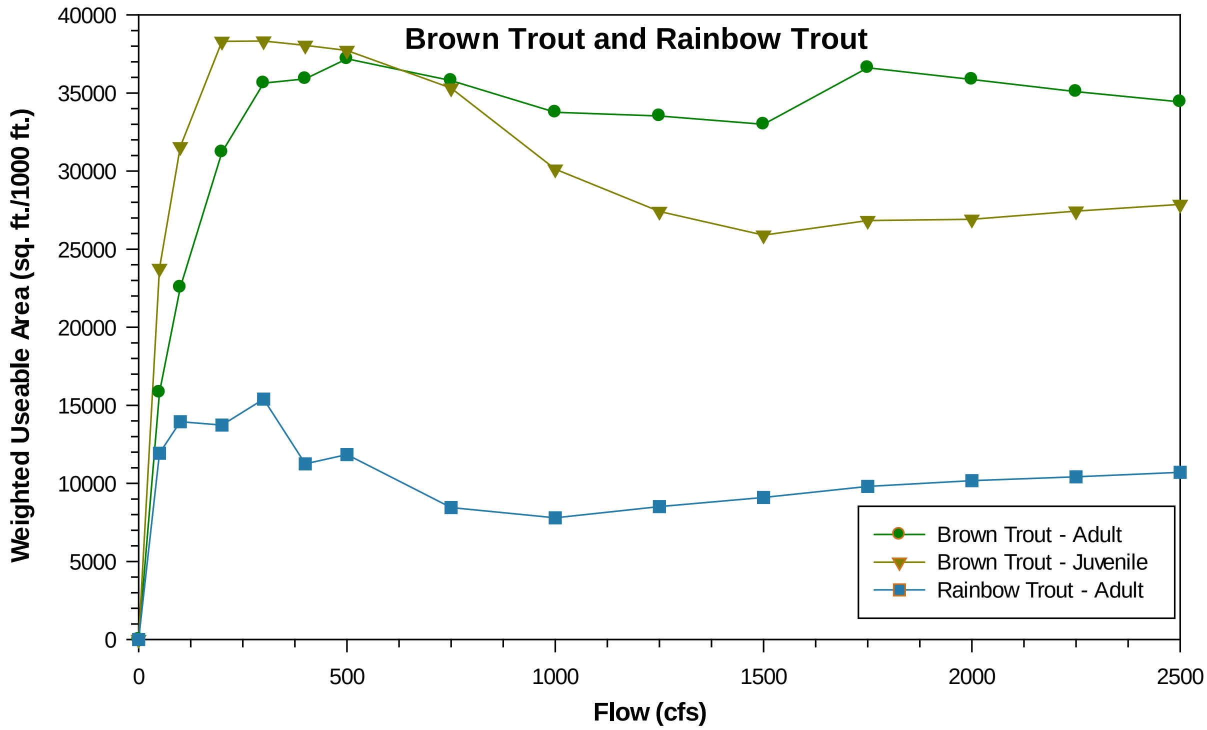


Figure 7: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Brown and Rainbow Trout in Lower Arkansas River Segment 1

Segment 3, Fountain Creek to John Martin Reservoir

Downstream of Fountain Creek, Segment 3 of the lower Arkansas River is a plains stream. Fish have not been routinely sampled, but several sampling events of varying degrees of effort have been conducted over the last 30 years. Very little benthic invertebrate data are available other than data collected by CEC in 2003 and 2004 (CEC 2006). Supplemental PHABSIM data were collected for Segment 3 of the lower Arkansas River in 2011.

Fish

CPW collected fish data from Segment 3 of the lower Arkansas River several times since 1979 (Table 31). The earliest collection was by Loeffler et al. (1982), who sampled several sites in 1979, 1980, and 1981 (Appendix H.4, Table 32). Seventeen species were collected with fathead minnow, red shiner and sand shiner, three native minnow species, most abundant.

Nesler et al. (1999) sampled sites in Segment 3 in 1993 through 1996 as part of the CPW Arkansas River native fish inventory. The data are not listed by collection site or year, so only presence of the species is reported (Table 31). They collected 19 species, many of which were previously collected by Loeffler et al. (1982). Woodling (1999) provided data collected by CPW from 1995 through 1999 at six sites (Appendix H.4, Table 33). Over this period, 16 species were collected, with considerable overlap of species with the previous studies. Native minnows were most abundant (Table 31). Bestgen et al. (2003) collected data at two sites during sampling in 2002 to evaluate the status of suckermouth minnow in the river. The number of fish collected is not included in the report and they report only five species at the two sites.

During sampling to collect fish for tissue analysis, CEC collected ten fish species in December 2004 at one site downstream from Pueblo (CEC 2004b). In spring 2005, Dr. Bestgen sampled 13 sites in Segment 3 of the lower Arkansas River (Krieger to Conklin 2005). He collected 24 species, including nearly all of the species that had previously been collected in this segment of the river. Nineteen Arkansas darters (a Colorado threatened species) were collected during this survey at one site, 12 suckermouth minnow (a Colorado endangered species) at four sites, and 354 flathead chub (a Colorado species of special concern) at eleven sites (Appendix H.4, Table 34).

Table 31: Fish Population Data (Number Collected) for the Lower Arkansas River Segment 3, 1979 through 2011

Species/Date	1979-1981	1993-1996	1995-1999	2002	2004	2005	2005-2006	2011
Arkansas darter	0	0	0	0	0	19	0	0
Black bullhead	7	X	4	0	X	3	1	X
Black crappie	0	X	0	0	0	2	0	0
Bluegill	0	X	0	0	0	4	2	X
Brook stickleback	0	X	2	0	0	77	0	0
Brown trout	0	0	0	0	0	1	0	0
Carp	10	X	30	0	X	36	9	X
Central stoneroller	32	X	18	0	0	70	36	0
Creek chub	0	0	0	0	0	0	0	X
Channel catfish	4	X	45	X	0	13	2	X
Fathead minnow	1,110	X	27	X	X	305	34	X
Flathead catfish	0	0	3	0	0	0	0	0
Flathead chub	167	X	173	X	0	354	107	X
Gizzard shad	0	0	0	0	0	0	0	X
Green sunfish	184	X	8	0	X	14	3	X
Largemouth bass	2	0	0	0	X	7	25	X
Longnose dace	122	X	9	0	0	18	6	X
Longnose sucker	10	X	5	0	0	18	3	X
Mosquitofish	3	X	0	0	0	30	5	X
Orangespotted sunfish	4	X	1	0	0	2	0	0
Plains killifish	229	X	0	0	X	76	4	X
Rainbow trout	0	0	0	0	0	2	0	0
Red shiner	2,229	X	511	X	X	1,307	124	X
Sand shiner	742	X	214	X	X	2,422	82	X
Saugeye	0	0	0	0	0	0	3	0
Smallmouth bass	0	0	0	0	0	11	15	0
Suckermouth minnow	0	0	0	0	0	12	0	X
White crappie	8	0	0	0	X	0	2	0
White sucker	44	X	6	0	X	90	73	X
Yellow bullhead	0	0	0	0	0	0	1	X
Yellow perch	0	X	1	0	0	0	0	0

Data Source: Appendix H.4, Tables 32 through 35, Nesler et al. (1999), Bestgen et al. (2003), and GEI (2011)
Note:
(1) "X" represents present, but numbers are unavailable.

Three sites were sampled by backpack electrofishing and seining in this reach in 2005 and 2006 as part of a selenium study for the City of Pueblo by GEI Consultants (2007b) (Appendix H.4, Table 35). Twenty species were collected, most of which had been collected during the previous sampling events. Flathead chub, red shiner, sand shiner, and white suckers were the most abundant species (Table 31).

Five sites in this reach located near Nyberg Road in Pueblo County, Fowler, Rocky Ford State Wildlife Area, Oxbow State Wildlife Area in Otero County, and the John Martin State Wildlife Area in Bent County were sampled one to three times from June through October 2011 to collect fish and habitat use data to validate habitat suitability curves (GEI 2011). The resulting sampling collected 19 species, including two state listed species, the flathead chub and suckermouth minnow (Table 31).

The studies together reported a total of 30 fish species and one hybrid in Segment 3 of the lower Arkansas River (Table 31). The four studies that reported numbers of fish collected both indicate that red shiner or sand shiner were most abundant. Several other native species, including fathead minnow, flathead chub, and plains killifish, were also abundant in one or more of the studies.

In 2011, CPW stocked plains minnows (a Colorado endangered species) and suckermouth minnows into the Arkansas River in this reach (CPW 2011b). Approximately 38,000 plains minnow and 4,000 suckermouth minnows between one and two inches long, were stocked in the Arkansas River near Rocky Ford and Oxbow State Wildlife Areas. Efforts to spawn and rear these species in hatchery conditions had previously been unsuccessful. Prior to these stocking efforts, the plains minnow had not been documented in the Arkansas River since the 1960s (CPW 2011b).

Benthic Invertebrates

CEC collected benthic macroinvertebrate data at four sites in Segment 3 of the lower Arkansas River in fall 2003 and spring 2004 as part of the SDS EIS (CEC 2006) (Appendix H.4, Table 36). The sites were located near Baxter (LAR-1), upstream from Fowler (LAR-2), upstream from Rocky Ford (LAR-3), and at Las Animas (LAR-4). The invertebrates were more abundant and diverse in the fall samples than in spring (Table 32). The species collected was dominated by a few species of mayflies and midges (flies) and there were several other species of insects, worms, crustaceans, clams, and snails. EPT taxa were present in both seasons, but comprised a smaller percentage in spring. In both seasons, the HBI indicates a mix of tolerant and intolerant species, with tolerant species being more abundant. The low proportion of EPT species and modest HBI level indicate that invertebrate populations in Segment 3 are impaired to some degree by water quality/quantity and/or habitat.

Table 32: Summary of Lower Arkansas River Segment 3 Benthic Invertebrate Parameters

Parameter/Date	Fall 2003[1]		Spring 2004[1]	
	Mean	***Range***	***Mean***	***Range***
Abundance (#/sample)	2,661	1,290-3,248	885	669-1,052
Number of Taxa	29	24-41	23	19-25
Number of EPT Taxa	8	6-12	4	3-4
Diversity (H’)	3.24	1.79-4.06	2.70	1.32-3.51
Biotic Index (HBI)	5.96	5.21-6.67	6.07	5.69-6.62

Data Source: Appendix H.4, Table 36
Note:
(1) Data for Fall 2003 and Spring 2004 were collected for the SDS EIS (CEC 2006).

CEC collected quantitative benthic macroinvertebrate data in 1994, 1996 and 1998 at four sites downstream from the Pueblo Wastewater Treatment Plant (WWTP) for the City of Pueblo (CEC 1995, 1998b, 1999b). These samples resulted in a wide range of data for the parameters among the sites and dates (Table 33 and Appendix H4, Table 37). The mean values for number of taxa and number of EPT taxa are lower than for sites upstream on the Arkansas River between Fountain Creek and the WWTP. Mean diversity is at the threshold of 2.50, with many values ranging below this level. The data from these sites are consistent with the data collected by CEC in 2003 and 2004 (CEC 2006). Both data sets indicate some impairment of the benthic invertebrate community in Segment 3 of the lower Arkansas River.

Table 33: Summary of Lower Arkansas River Segment 3 Benthic Invertebrate Parameters, Fall 1994, 1996 and 1998

Parameter	Mean	Range
Density (#/m^2)	658	9-2,487
Number of Taxa	12	3-25
Number of EPT Taxa	3	0-6
Diversity (H')	2.50	1.17-3.46

Data Source: Appendix H.4, Table 37

The Health Department collected samples at two sites in lower Arkansas River Segment 3 in 2000 and 2002 (Health Department 2000, 2002). The data indicate the presence of numerous tolerant invertebrate species. One of the sites had a few EPT species while the other site had none. The data are generally consistent with the data collected by CEC in 2003 and 2004.

Habitat

PHABSIM data were collected for the lower Arkansas River Segment 3 in 2011. Habitat suitability (WUA) relationships with flow were developed for adult sand shiners, red shiners, and plains killifish, juvenile/fry channel catfish, and for adult, spawning, and fry white suckers and flathead chub (Figures 8 and 9; Appendix H.4, Table 38).

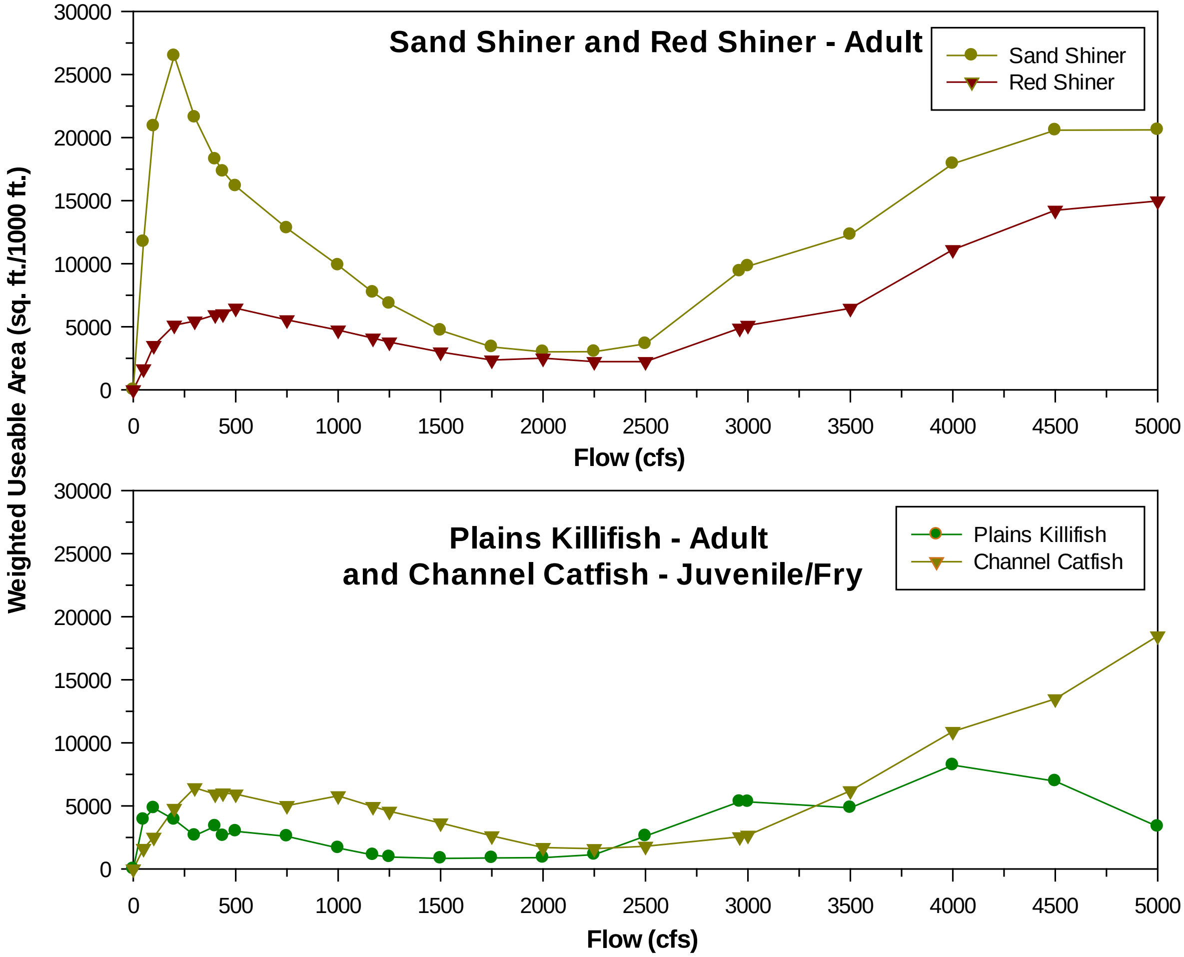


Figure 8: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationship for Adult Sand Shiners, Adult Red Shiners, and Juvenile/Fry Channel Catfish in Lower Arkansas River Segment 3

Habitat availability is consistently low for most flows for adult red shiners, adult plains killifish, juvenile/fry channel catfish, adult and fry white suckers, and spawning flathead chub (Figures 8 and 9). The habitat suitability versus flow curves indicates relatively high habitat availability up to approximately 1,000 cfs for most species and life stages. Habitat then decreases for most species and life stages at flows greater than 1,000 cfs up to approximately 3,000 cfs, and then increases at flows greater than 3,000 cfs as islands and bank vegetation is inundated.

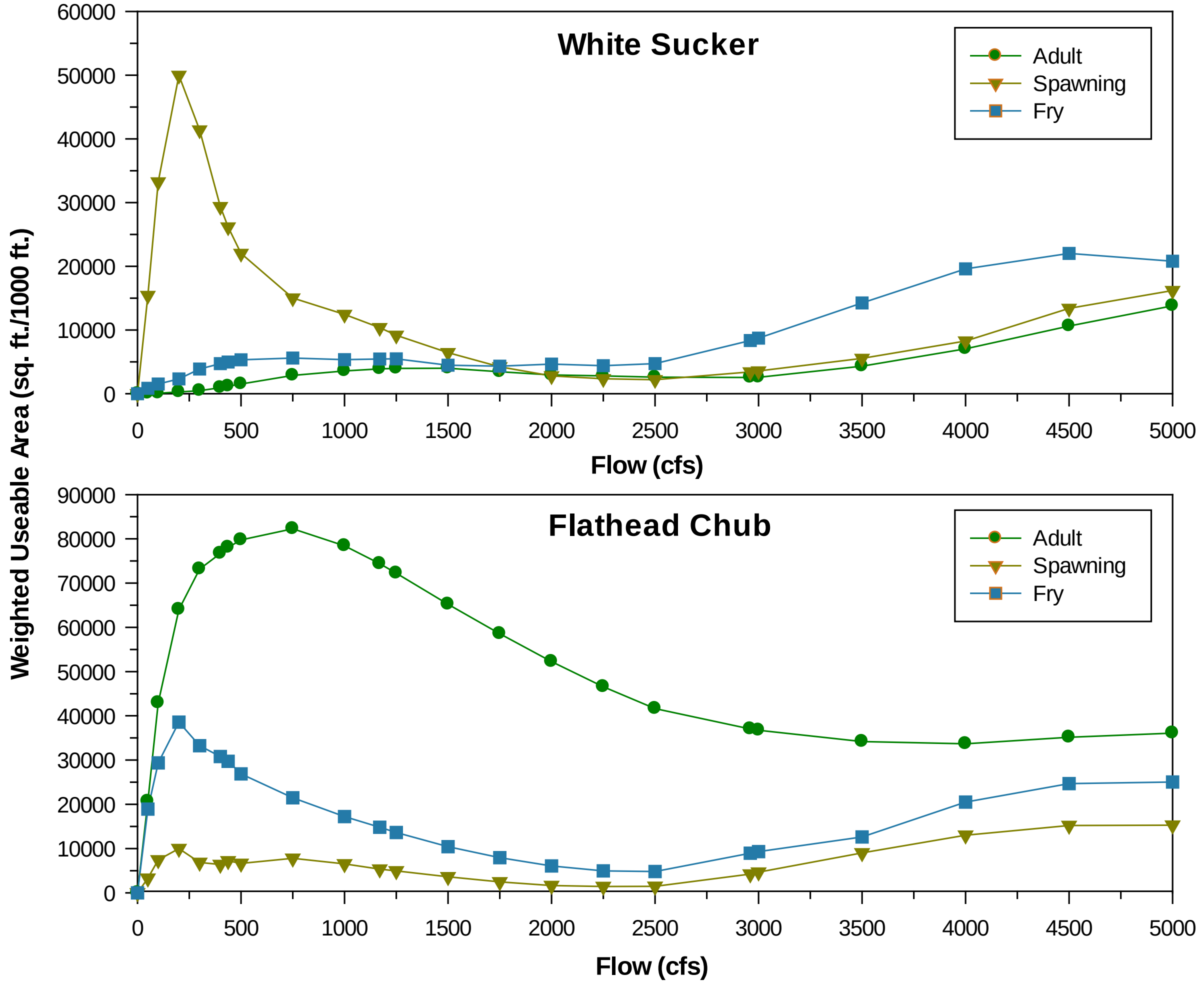


Figure 9: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Adult, Spawning, and Fry White Suckers and Flathead Chub in Lower Arkansas River Segment 3 [(1)]

[(1)] Note that the y-axis differs between the top and bottom panel and from Figure 8.

Segment 4, John Martin Reservoir to Kansas State Line

Segment 4 extends from the outlet of John Martin Reservoir, downstream to the Kansas State Line. Recent fish data are available for this reach from 2003 through 2006, and 2009, which includes native plains fish surveys conducted by CPW (2011a) and data collected in 2005 by Dr. Bestgen. Fish data are also available from 1979 through 1981 from an Arkansas River threatened fish survey (Loeffler 1982) and fish data are provided from a subsequent native fish survey published by Nesler et al. (1999). No benthic invertebrate or habitat data are available for this reach. However, the benthic invertebrate community and habitat is likely similar to in the Lower Arkansas River Segment 3. No PHABSIM fish habitat relationships are available for Segment 4 of the Lower Arkansas River. The fish habitat relationships are likely similar to those in Segment 3.

Fish

Sampling was conducted in 2006 and 2009 by CPW (2011a) at four sites in this reach and 20 species were collected (Table 34 and Appendix H.4, Table 39). The non-native mosquitofish was the most abundant species during the 2009 sampling event, followed by the native sand shiner and red shiner. One Arkansas darter, a state threatened species, was collected in 2009. In 2006, sand shiners, plains killifish, and red shiners were the most abundant species.

Nine sites were sampled in 2005 by Dr. Bestgen arranged throughout the reach and downstream to the Kansas State Line. Twelve species were collected, most of which are native to the Arkansas River drainage in Colorado (Table 34). The native sand shiner, red shiner, and plains killifish were the most abundant species (Appendix H.4, Table 40). Central stoneroller, fathead minnow, plains killifish, red shiner, sand shiner, and suckermouth minnow were collected at eight or all nine of the sites sampled, while the remaining species were collected less frequently.

Table 34: Fish Population Data (Number Collected) for the Lower Arkansas River Segment 4, 1979-1981, 2003, 2004, 2005, 2006, and 2009

Species/Site	1979-1981	2003	2004	2005	2006	2009
Arkansas darter	0	0	0	0	0	1
Black bullhead	234	0	0	1	0	0
Black crappie	0	0	0	0	12	1
Carp	290 (1)	0	0	36	0	2
Central stoneroller	176	30	32	142	44	15
Channel catfish	26	7	0	17	14	6
Fathead minnow	619	4	17	84	13	0
Flathead chub	76	0	0	0	1	0
Freshwater drum	0	0	0	0	0	2
Gizzard shad	210	0	0	0	8	8
Green sunfish	261	1	1	10	3	8
Largemouth bass	1	0	0	0	0	0
Longnose dace	4	0	0	0	0	0
Longnose sucker	2	0	0	0	0	17
Mosquitofish	0	6	16	194	52	1,564
Orangespotted sunfish	43	0	0	0	0	0
Plains killifish	1,003	43	122	1,437	193	34
Red shiner	754	336	26	2,208	143	202
Sand shiner	6,047	539	328	5,974	351	209
Saugeye	0	0	0	0	11	0
Suckermouth minnow	767	11	101	95	86	9
Walleye	11	0	0	0	0	1
White crappie	49	0	0	0	0	0
White sucker	15	4	15	21	8	35
Wiper	0	0	0	0	0	1

Data Source: Appendix H.4, Tables 39 through 43

Note:

(1) Does not include all fish, at one site carp were too numerous to count.

Three sites were sampled in 2003 and two sites were sampled in 2004 on the Arkansas River. The sites were east of Granada, near Lamar, and near Holly (Table 34) (Ramsay 2004; CPW 2011a). Most of the species collected are native to the Arkansas River drainage. A total of ten species were collected during the surveys (Table 34 and Appendix H4, Tables 41 and 42). Sand shiners were most abundant at each site. Suckermouth minnow, a Colorado endangered species, were collected at each site.

An inventory and status of Arkansas River native fishes in 1999, suggested an increased abundance of nonnative mosquitofish in this reach of the Arkansas River, downstream from John Martin Reservoir (Nesler et al. 1999). This reach is thought to provide much of the available habitat for plains minnow and suckermouth minnows in the Arkansas River drainage. Plains minnow are a state endangered fish, native to the Arkansas River, but not collected in any of the surveys in this report. One Arkansas darter was collected from the mainstem Arkansas River near May Valley Ditch during this inventory (Nesler et al. 1999).

Extensive sampling was conducted from 1979 through 1981 at eleven sites as part of an Arkansas River drainage threatened fishes survey (Loeffler 1982). Nineteen species were collected, many of which are native to the Arkansas River drainage. Sand shiner, plains killifish, red shiner, and suckermouth minnow were the most abundant species (Appendix H4, Table 43). Flathead chub, a state species of special concern was also collected. The most abundant species sampled were similar to the most abundant species collected during the more recent surveys, except suckermouth minnow were less abundant in the more recent sampling events and mosquitofish were not collected during the earlier sampling event. The fish communities were overall similar among the sampling events, except a few additional species were collected during the 1979 through 1981 sampling.

Grape Creek

The Grape Creek study area includes Grape Creek upstream and downstream from DeWeese Reservoir in Custer County. Quantitative and qualitative fish data were available for a number of years and sites from 1981 through 2010 and were provided by CPW (2011a). Benthic invertebrate and habitat data were not available for Grape Creek.

Fish

Most fish data, including all of the quantitative fish data, available since 1982 were provided by CPW (Appendix H.4, Tables 44 and 45). Quantitative fish data includes one site sampled upstream from DeWeese Reservoir in 2003, one site downstream from DeWeese Reservoir in 2004 and 2006, and two additional sites downstream from DeWeese Reservoir in 2010 (Table 35; Appendix H.4, Table 44). Qualitative presence/absence fish data (Appendix H.4, Table 45) were collected by Loeffler et al. (1982), CPW, and other agencies at various sites upstream and downstream from DeWeese Reservoir in a number of years from 1981 through 2010 (CPW 2011a).

The quantitative fish data indicate that a mix of warm and coldwater fish species inhabit Grape Creek, upstream and downstream from DeWeese Reservoir (Table 35; Appendix H.4, Table 44). Upstream of DeWeese Reservoir, the fish community in 2003 was dominated by warmwater species and species tolerant of both warm and coldwater, including white suckers and longnose dace (Table 35; Appendix H.4, Table 44). However, brown trout were also relatively abundant. Downstream of DeWeese Reservoir, brown trout were the dominant species present, comprising the greatest percentage of the density and biomass at each site. Rainbow trout were collected at each site and cutthroat and cutbow trout were each collected at one of the four sites sampled. Longnose suckers and white suckers were also relatively abundant at the sites sampled downstream from DeWeese Reservoir.

Table 35: Summary of Grape Creek Fish Species Composition, Density (Number per Acre), and Biomass (Pounds per Acre) Data, Upstream and Downstream of DeWeese Reservoir, 2003, 2004, 2006, and 2010

Species/Date	Upstream of DeWeese – 2003	Downstream of DeWeese – 2004, 2006, 2010[1]			
	Density	*Density*		*Biomass*	
		Mean	*Range*	*Mean*	*Range*
Brown trout	120	691	512-1,114	130.7	82-213
Cutthroat trout	--	62	0-249	6.9	0-28
Cutbow trout	--	1	0-5	--	--
Fathead minnow	33	--	--	--	--
Longnose dace	272	19	0-74	--	--
Longnose sucker	--	168	0-417	43.7	0-114
Rainbow trout	--	48	5-131	5.6	--
Sand shiner	316	--	--	--	--
Smallmouth bass	54	--	--	--	--
White sucker	185	139	25-239	30.9	19-43

Data Source: Appendix H.4, Table 44 and CPW 2011a
Note:
(1) Two sites were sampled downstream from DeWeese Reservoir in 2010

Qualitative presence/absence sampling in 1995, 2000, and 2003 in Grape Creek at three sites within one kilometer upstream from DeWeese Reservoir, confirms a mixture of cold and warmwater species immediately upstream from DeWeese Reservoir (Appendix H.4, Table 45). During presence/absence sampling in 1995 brook trout and white suckers were collected further upstream at the above Hermit Road and below Baldy Road sites. Overall, quantitative and qualitative fish data indicate a mixture of warm and coldwater species upstream from DeWeese Reservoir and a fish community dominated by brown trout and an abundant sucker population downstream from DeWeese Reservoir.

Fountain Creek

The study area on Fountain Creek was previously divided into four segments from Colorado Springs downstream to the Arkansas River for analysis during the SDS EIS (CEC 2006). The segments corresponded to PHABSIM segments jointly established between the study team and CPW. CEC collected PHABSIM data in 2004 and 2005 in these segments (CEC 2006). These data will be used to model and evaluate the potential effects of the alternatives. This report summarizes the aquatic biological data with respect to the two lower segments (Segments 3 and 4) on Fountain Creek that are included in the study area.

Several different agencies have sampled Fountain Creek since the 1980s. Although the data were collected by different agencies, using different techniques, many of the sampling site locations have remained consistent, or were at least located around a common access point, which facilitates organization of the data.

Fish populations were sampled sporadically until recently. Since 2003, annual fish population surveys have been conducted by USGS (USGS 2003-2010). All fish data available since 1979 on Fountain Creek are included in the discussions in this report. More data are available on benthic macroinvertebrate populations, especially since 1994. Colorado Springs Utilities and USGS have been collecting data at least annually, and in some cases, seasonally, at consistent sites since 1994. This information is the basis for describing existing benthic macroinvertebrate communities in this report. The Las Vegas Street WWTP was upgraded in 1996, resulting in improvements to effluent water quality. Therefore, this report focuses on benthic macroinvertebrate data collected from 1996 through 2009. Data collected prior to 1996 may not represent existing conditions, and are not presented. Colorado Springs Utilities and USGS consistently measured habitat variables in Fountain Creek since 1998 and this information is presented to represent current habitat conditions. The relationships between habitat including urban-related environmental variables with fish and benthic invertebrate populations over time were discussed in a series of papers by USGS (Bruce 2002; Zuellig et al. 2008; Zuellig et al. 2010). No supplemental fish, invertebrate, or habitat data were collected by GEI in Fountain Creek for this study.

Segment 3, Security to County Line

Segment 3 of Fountain Creek extends from Security downstream to the border between El Paso and Pueblo counties. Much of the sampling of fish, benthic invertebrates, and habitat in this segment was on the Clear Spring Ranch. USGS currently monitors invertebrates and habitat; USGS and CPW together sample fish annually in this segment. CEC developed PHABSIM relationships for this segment (CEC 2006).

Fish

Several agencies sampled sites in Segment 3 of Fountain Creek since 1979 (Table 36). The USGS and CPW sampled from 2003 through 2010 at a site near Fountain on the Clear Spring Ranch owned by Colorado Springs Utilities (USGS Site 6000) (USGS 2003-2009, 2010). Fifteen species of fish were collected (Table 36) with similar results among years (Appendix H.4, Table 46). The native flathead chub comprised most of the fish collected in each year. Sand shiners and white suckers, which are also native, were also abundant during some years. The relative abundance of the remaining species was lower during most years.

Several agencies sampled between 1979 and 2001 at multiple sites in Segment 3. The sites were clustered around the city of Fountain and near the Clear Spring Ranch. All of these previous studies collected fewer species of fish than the recent USGS/CPW study (Table 36). However, Arkansas darters and smallmouth bass were collected at low abundances from at least one of the earlier studies and were not collected during the 2003 through 2010 sampling.

Almost all of the species listed in Table 36 were either collected in multiple years or were collected recently by USGS/CPW (Table 36). The state threatened Arkansas darter has not been observed since 1995. Fountain Creek does not provide optimum habitat for this species “which is normally found in small, shallow, clear, usually spring-fed streams” (Krieger et al. 2001). Fountain Creek may not support self-sustaining populations of darters but may act as a route for migration between populations in tributary streams or in off-channel areas of Fountain Creek. Flathead chub, a species of special concern in Colorado, was collected in all of the past studies and was the most abundant species from 2003 through 2010 (Appendix H.4, Table 46). Only a few black bullhead, common carp, and smallmouth bass have been collected during the surveys since 1979, thus these species probably do not maintain resident populations in Fountain Creek. The remaining species collected over the years probably maintain resident, self-sustaining populations in Segment 3.

Table 36: Fountain Creek Segment 3 Fish Population Data (Number Collected), 1979 through 2010

Species/Date	1979-1980	1979, 1981	1989	1994-1995	2001	2003-2010
Arkansas darter	0	1	0	1	0	0
Black bullhead	0	0	0	0	0	1
Brook stickleback	10	1	0	4	5	5
Central stoneroller	1	0	0	0	15	145
Common carp	0	0	0	0	0	3
Creek chub	4	0	0	0	0	40
Fathead minnow	27	101	0	47	19	110
Flathead chub	9	62	141	865	25	2,592
Green sunfish	3	15	1	4	0	3
Longnose dace	0	0	33	65	5	118
Longnose sucker	0	0	0	0	0	44
Minnow, unidentified	0	0	0	0	0	6
Plains killifish	8	3	0	0	0	2
Red shiner	0	0	0	0	0	11
Sand shiner	0	9	0	2	26	427
Smallmouth bass	0	1	0	0	0	0
White sucker	0	2	0	8	0	364
Young of the year, unidentified	0	0	0	0	0	7

Data Source: Appendix H.4, Table 46

Benthic Invertebrates

Colorado Springs Utilities collected benthic macroinvertebrate data at a site near Fountain on the Clear Spring Ranch in 1994 through 2000 (Colorado Springs Utilities 1994, 1995, 1996, 1997, 1998, 1999, 2000). The data were collected primarily in spring and fall with summer samples collected in 1995 through 1997. USGS collected samples at a similar site (USGS Site 6000) in 2001 through 2009 (USGS 2001a, 2002, 2003-2009). Both agencies used quantitative collection methods, with a supplemental sweep sample. The information collected since the upgrade of the Las Vegas Street WWTP in 1996 represents the most current data available. CSWD (1980) collected samples in 1979 and 1980 and USGS (von Guerard 1989) collected samples in the 1980s at a similar site. The data from the 1970s and 1980s are not presented in this report.

In Segment 3 of Fountain Creek, the benthic macroinvertebrate data collected since 1996 demonstrate higher values in the fall than in spring (Table 37). As noted previously, this is a result of the fall data collection extending through 2009 and spring data collection ceasing after 2000 (Appendix H.4, Table 47). The trend is for higher values for parameters in the more recent samples, which results in higher mean values for the fall samples.

Table 37: Summary of Fountain Creek Segment 3 Benthic Invertebrate Parameters, 1996 through 2009

Parameter/Date	Spring 1996-2000		Fall 1996-2009	
	Mean	*Range*	*Mean*	*Range*
Density (#/m^2)	1,232	196-2,963	2,129	30-8,851
Number of Taxa	11	5-22	34	4-56
Number of EPT Taxa	1	0-5	6	0-9
Diversity (H’)	1.60	0.86-2.04	2.39	0.63-3.38

Data Source: Appendix H.4, Table 47

Both the spring and fall samples indicate invertebrate populations with low density, number of taxa, and number of EPT taxa and diversity below the threshold of 2.50 (Table 37). The benthic macroinvertebrate populations in Segment 3 of Fountain Creek continue to exhibit signs of water quality and/or habitat impairment. The more recent data collected by USGS suggest that conditions may be improving, with a trend towards higher values for population parameters since 2000 (Appendix H.4, Table 47).

Habitat

CEC developed habitat availability versus flow relationships for red shiner, sand shiner, flathead chub, and white sucker as part of the SDS EIS (CEC 2006) (Figure 10). The PHABSIM WUA versus flow curves indicate that habitat for all species is relatively high up to approximately 500 cfs. Habitat decreases for red and sand shiner and the spawning life stage of white sucker at flows higher than 500 cfs. Flathead chub habitat availability doesn’t begin decreasing until approximately 800 cfs. For adult and fry white sucker, habitat is consistently low at all flows (Appendix H.4, Table 48).

USGS (2001a, 2002, 2003-2009, 2010) collected data on habitat variables at the Fountain site on the Clear Spring Ranch in 2001 through 2010. The data indicate that Segment 3 of Fountain Creek is wide and shallow, with predominantly gravel substrate (Table 38). Sand is also a very common substrate material (Appendix H.4, Table 49).

Table 38: Summary of Fountain Creek Segment 3 habitat data from 1998 through 2010

Pool Length (%)	Mean Bank Width (ft)	Mean Wetted Width (ft)	Predominant Substrate	Mean Depth (ft)
0	194	93	Gravel	0.8

Data Source: Appendix H.4, Table 49

CEC measured the extent of different habitat types during PHABSIM data collection in 2004 (CEC 2006). The habitat in Segment 3 of Fountain Creek predominantly consists of braided, open channel habitat. This habitat type has very shallow water and flows through multiple channels between and around sand bars and islands. Deeper areas, found on bends in the channel, account for approximately 13 percent of the habitat. Riffles are slightly less common, comprising approximately 11 percent of the habitat. A smaller portion of the habitat in Segment 3 was comprised of a single channel confined between two sand bars. This single channel habitat type was usually deeper, with a higher current velocity than the majority of the channel with the braided habitat type.

CEC collected data on habitat variables for CSWD in 1988 at a site near the Clear Spring Ranch (CSWD 1989). The data were collected with different methods than the recent USGS data and are not presented in this report. The data from 1988 are generally consistent with the recent data, indicating that the channel is wide and shallow with a gravel and sand substrates predominant. However, the channel width in 1988 was approximately 100 feet, approximately one-half of the channel width measured by USGS (Table 38).

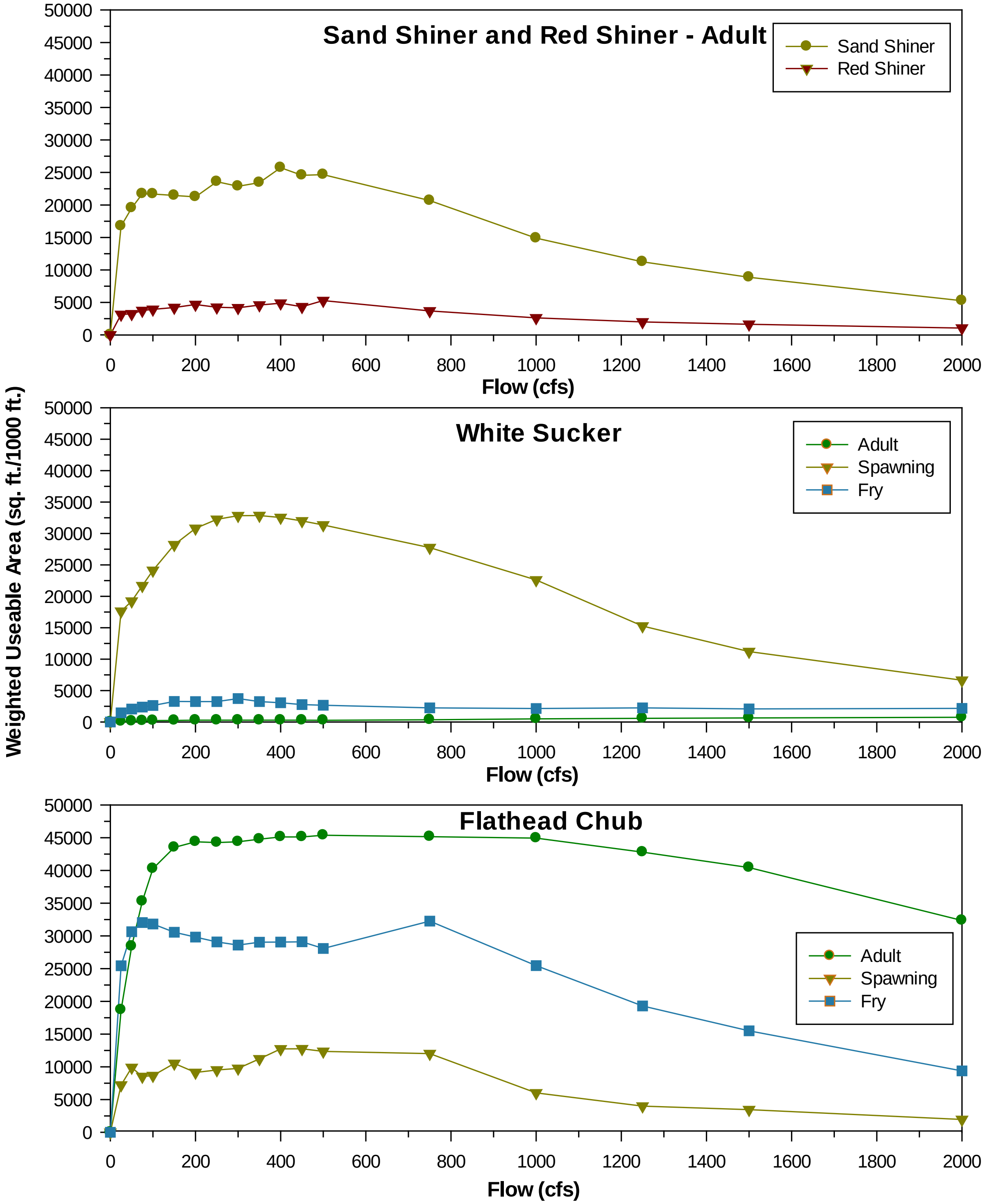


Figure 10: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Red Shiner, Sand Shiner, White Sucker, and Flathead Chub in Fountain Creek Segment 3

Segment 4, County Line to Arkansas River

CPW and USGS have collected fish data annually in Segment 4 of Fountain Creek from 2003 through 2010. Prior to 2003, CPW crews collected fish data in several years since 1981. Benthic invertebrates have been sampled by Colorado Springs Utilities and by USGS since the mid-1990s. CEC developed PHABSIM relationships for Segment 4 of Fountain Creek (CEC 2006). Much of the data collection in this segment was focused around sites near Piñon and in Pueblo.

Fish

USGS and CPW (USGS 2003-2009, 2010) sampled two sites in Segment 4 of Fountain Creek from 2003 through 2010. One site was near Piñon (USGS Site 6300) and one site was near Pueblo (USGS Site 6500). Fifteen species of fish were collected from 2003 through 2010 and ten of these species were present at both sites during at least one of the years (Appendix H.4, Table 50). Flathead chub was the most abundant species collected at both sites in all but one year. Central stonerollers were also frequently abundant and plains killifish, red shiners, sand shiners, and white suckers were occasionally abundant. CEC sampled a site near Piñon and a site downstream from 4th Street in Pueblo to collect fish for tissue analysis in December 2004 and ten species were collected (Table 39).

Table 39: Fountain Creek Segment 4 Fish Population Data (Number Collected), 1981 through 2010

Species/Date	1981	1989	1994	2001	2004	2003-2010
Arkansas darter	0	0	1	0	0	9
Black bullhead	1	0	0	0	0	0
Bluegill	0	0	1	0	0	0
Brook stickleback	1	5	5	0	X(1)	49 (2)
Brown trout	0	0	0	0	0	2
Common Carp	0	0	0	0	0	4
Central stoneroller	0	15	1	6	X(1)	997 (2)
Creek chub	0	0	0	0	0	5
Fathead minnow	2	0	2	4	X(1)	45
Flathead chub	12	192	826	74	X(1)	2,604 (2)
Green sunfish	0	0	2	0	0	3
Longnose dace	7	29	54	1	X(1)	215
Longnose sucker	0	2	0	0	X(1)	21
Minnow, unidentified	0	0	0	0	0	19
Plains killifish	4	1	0	1	X(1)	177
Red shiner	1	0	0	0	X(1)	128
Sand shiner	4	15	5	42	X(1)	501
White sucker	5	2	13	0	X(1)	326
Young of the year, unidentified	0	0	0	0	0	1

Data Source: Appendix H.4, Table 50

Notes:

(1) "X" represents present, but numbers are unavailable.

(2) Does not include an unspecified number collected in 2003 by USGS (Bruce to Dowler 2003).

The USGS also sampled the "Piñon Gallery" in 2003, which functions as a side channel to Fountain Creek near Piñon (Bruce 2005), where they were searching for Arkansas darters. They collected five Arkansas darters and also collected brook stickleback, central stoneroller, and flathead chub, but did not count them (Bruce to Dowler 2003).

Loeffler et al. (1982), CSWD (1989), Nesler et al. (1999), and Melby (2001) also sampled sites near Piñon and Pueblo in 1981-2001 (Table 39). These collections resulted in fewer total species than the more recent collections. However, nearly all of the species collected by USGS/CPW in 2003 and 2004 had been previously collected at least once in the other studies (Table 39). Flathead chub, a species of special concern in Colorado, was the most abundant species collected during all five sampling periods.

A total of 17 species have been collected by one or more agencies over the years (Table 39). The most abundant species are the native minnow species, and the native white sucker and plains killifish. As noted above for Segment 3 of Fountain Creek, the single Arkansas darter collected in 1994, the five collected in 2003, and the three collected in 2010 may not represent a resident population in the main channel of Fountain Creek itself. The fish from 2003 came from a side channel population of darters.

Only one black bullhead, one bluegill, and two brown trout have been collected since 1981, thus these three species do not appear be maintaining resident populations. Only four carp and five creek chubs were collected from 2003 through 2010. Given the low abundances and infrequent collections over the eight year period, these introduced species do not appear to be maintaining resident populations in this segment of Fountain Creek. However, creek chub are becoming more abundant in the upstream segments of Fountain Creek. Two green sunfish were collected by Nesler et al. (1999) in 1994, and 3 were collected from 2003 through 2010. This native species was also collected sporadically in Segment 3 and in the lower Arkansas River, thus they may be maintaining limited populations in Segment 4 of Fountain Creek as well.

Of the 17 species collected to date in Segment 4 of Fountain Creek, 10 are probably maintaining resident populations. Green sunfish may also be maintaining populations at very low levels. The state threatened Arkansas darter is probably a transient species in the main channel of Segment 4 of Fountain Creek, as they have been documented in off-channel areas.

Benthic Invertebrates

Colorado Springs Utilities (1995, 1996, 1997, 1998, 1999, 2000) sampled three sites in Segment 4 of Fountain Creek between 1995 and 2000. The three sites were at Piñon, above Pueblo, and at Pueblo. USGS (2001a, 2002, 2003-2009) has sampled the Piñon (USGS Site 6300) and Pueblo (USGS Site 6500) sites since 2001. The USGS consistently collected samples in the fall at these two sites. The Colorado Springs Utilities sampling was not consistent as in some years they collected samples in spring, summer, and fall, and in other years they collected samples in only one or two seasons (Appendix H.4, Table 51). Data from 1996 through 2009 are used to characterize existing conditions.

As in other segments of Fountain Creek, the data from Segment 4 indicate a wide range of values for parameters over the years (Table 40 and Appendix H.4, Table 51). Samples from spring indicate low abundance, low number of taxa, low number of EPT taxa, and low diversity. Samples from fall indicate higher levels of parameters than for spring (Table 40). This is at least partially due to the spring samples being collected prior to 2001, while the fall samples were collected through 2009, including higher population levels in the more recent years. Data for both spring and fall indicate benthic macroinvertebrate populations that are impaired by water quality or habitat, as was true for Segment 3 on Fountain Creek.

Table 40: Summary of Fountain Creek Segment 4 Benthic Invertebrate Population Parameters, 1996 through 2009

Parameter/Date	Spring 1996-2000		Fall 1996-2009	
	Mean	*Range*	*Mean*	*Range*
Density (#/m^2)	692	3-2,660	1,915	3-9,423
Number of Taxa	9	1-22	36	1-67
Number of EPT Taxa	1	0-4	6	0-13
Diversity (H')	0.96	0.00-1.91	2.63	0.00-4.03

Data Source: Appendix H.4, Table 51

Habitat

CEC developed habitat versus flow relationships for red shiner, sand shiner, flathead chub, and white sucker as part of the SDS EIS (CEC 2006) (Figure 11). The PHABSIM WUA versus flow curves indicate that habitat for sand shiner adults and the spawning life stage of white sucker is highest at 50 to 350 cfs and declines at higher flows. For red shiner and the fry life stage of white sucker, habitat is relatively low at all flows, with slightly higher habitat levels at flows less than 350 cfs (Appendix H.4, Table 52). For adult white sucker, habitat levels are low across the range of flows. Flathead chub habitat availability is high from about 100 to 500 cfs (Figure 11).

The USGS (2001a, 2002, 2003-2009, 2010) collected data on habitat at the Piñon and Pueblo sites in 2001 through 2010. The data indicate that Fountain Creek in Segment 4 is wide and shallow. The substrate was predominantly gravel at the Piñon site and was predominantly sand at the Pueblo site (Table 41 and Appendix H.4, Table 53).

Table 41: Summary of Fountain Creek Segment 4 Habitat Data from 2001 through 2010

Pool Length (%)	Mean Bank Width (ft)	Mean Wetted Width (ft)	Predominant Substrate	Mean Depth (ft)
0.1	185	96	Sand/Gravel	0.8

Data Source: Appendix H.4, Table 53

CEC measured the extent of different habitat types during PHABSIM data collection in 2004 (CEC 2006). In Segment 4 of Fountain Creek, only two habitat types were present. The open-channel, braided habitat type accounted for over 80 percent of the habitat. The remainder of the habitat was the single channel habitat that was also found in Segment 3.

CEC collected data on habitat for CSWD in 1988 at two sites in Segment 4 of Fountain Creek (CSWD 1989). The data are not presented in this report. The data are generally consistent with the data collected by USGS, except that the channel width in 1988, approximately 90 feet, was much less than that measured by USGS (Table 41).

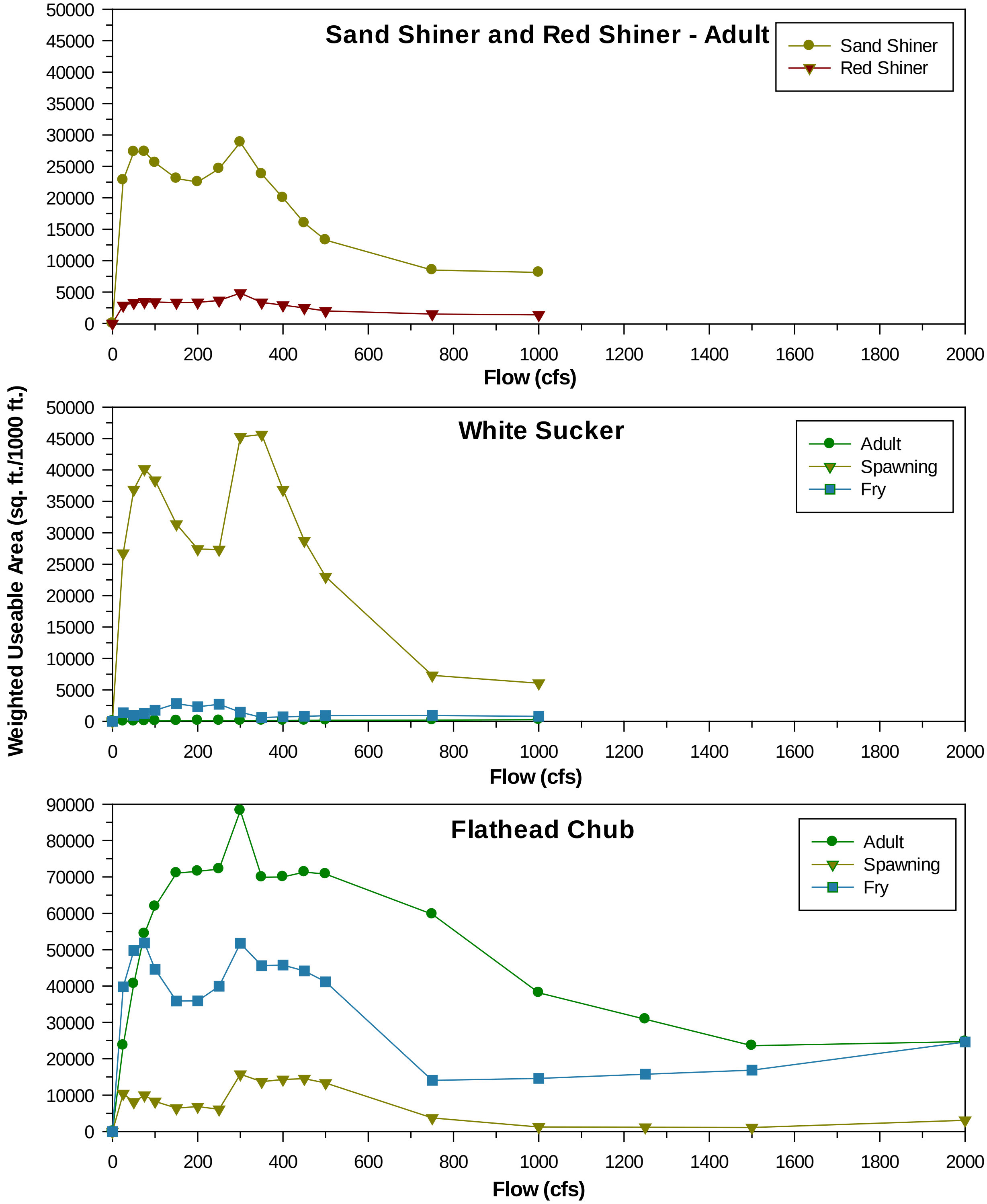


Figure 11: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Red Shiner, Sand Shiner, White Sucker, and Flathead Chub in Fountain Creek Segment 4[(1)]

[(1)] Note That the Y-Axis Changes for Flathead Chub.

Turquoise Lake

Turquoise Lake is an impoundment on Lake Fork of the Arkansas River. CPW manages the recreational fishery in the reservoir and samples fish every other year, in odd-numbered years. They do not currently collect data on benthic macroinvertebrates or plankton. Habitat features of the reservoir are not routinely monitored, and the existing data are limited to physical descriptions of the size of the reservoir. The reservoir has a maximum depth of 128 feet and a surface area at full capacity of approximately 1,700 acres, based on various estimates in Policky (2003), Bridges et al. (2000), and Nesler (1981).

Nesler (1981) summarizes limnological and biological data for Turquoise Lake. However, the management and operation of the reservoir has changed since that time. The recent data from CPW (Policky 1999, 2001, 2003, 2005, 2007, 2009) are used to describe existing conditions in Turquoise Lake.

Fish

CPW qualitatively sampled fish in Turquoise Lake in 1999, 2001 2003, 2005, 2007, and 2009 with gill nets (Table 42) (Policky 1999, 2001, 2003, 2005, 2007, 2009). They collected five species of trout and two species of sucker. All species, except for brook trout and cutthroat trout have been collected during all or most of the recent samples. In the past, CPW has also collected kokanee salmon in the reservoir (Nesler 1981), but this species has not been collected recently.

Table 42: Fish Population Data (Number Collected) for Turquoise Lake

Species/Year	1999	2001	2003	2005	2007	2009
Brook trout	0	0	0	1	0	0
Brown trout	18	14	12	26	36	15
Cutthroat trout	0	0	0	0	10	10
Lake trout	55	81	47	97	42	73
Rainbow trout	0	20	74	1	50	42
Longnose sucker	218	283	420	381	369	336
White sucker	34	58	96	36	50	27

Data Source: Policky (1999, 2001, 2003, 2005, 2007, 2009)

The white and longnose suckers are not stocked, and maintain resident, self-sustaining populations. They are commonly the most abundant species in the reservoir (Table 42). Lake trout populations are maintained primarily through stocking by CPW. However, some natural reproduction also occurs for this species in Turquoise Lake (Policky 2003). Lake trout are often the second or third most abundant species sampled, but many of the lake trout are small, less than 18 inches (Policky 2009). Brown trout are also stocked by CPW (Table 43), which maintains this species in the reservoir. Limited reproduction of brown trout may occur in Lake Fork upstream from the reservoir (Policky 2005a). Brook trout are present in Lake Fork upstream from the reservoir and could drift downstream. However, only one brook trout has been collected in the reservoir during gill net sampling since 1999. Cutthroat trout are also stocked and were collected in 2007 and 2009 (Table 42) after a substantial number were stocked in 2006 (Table 43).

Table 43: Fish Stocking Data (Number Stocked per Year) for Turquoise Lake

Species/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Brown trout	58,418	42,194	81,694	0	16,120	25,985	0	40,000	40,000	40,000	21,250
Cutthroat trout	200,375	0	0	0	0	0	0	11,518	6,780	48,569	16,243
Cutbow trout	0	0	0	0	0	0	0	48,045	0	0	0
Greenback trout	0	0	0	0	2,000	0	0	0	0	0	0
Lake trout	8,140	0	0	0	0	0	15,000	15,000	18,500	21,633	15,213
Rainbow trout	134,646	113,089	126,379	389,664	209,830	247,177	33,156	79,698	63,404	17,955	54,636

Data Source: Policky (2001, 2003, 2009) and CPW (2004, 2005)

Stocked catchable size rainbow trout were the basis for the recreational fishery in Turquoise Lake through 1996 (Policky 2003). However, Turquoise Lake is whirling disease negative, and only whirling disease-free fish can be stocked, according to CPW policy. Catchable sized rainbow trout that are whirling disease free were not available for stocking in Turquoise Lake from 1996 through 2006 (Policky 2009). Therefore, smaller size trout (a few inches long) were stocked by CPW during these years (Policky 2003, 2009). These smaller fish have lower survival, and rainbow trout populations have declined since the mid 1990s. Catchable size whirling disease free rainbow trout and cutthroat trout have been available and been stocked in Turquoise Lake since 2007 and the continued stocking of these catchable size trout should improve angler catch and satisfaction (Policky 2009). The U.S. Fish and Wildlife Service (USFWS) also contributed to the stocking of rainbow trout in Turquoise Lake in 1995 through 2002 (Martinez to Garrett 2005) and these fish are included in the numbers in Table 43.

Turquoise Lake is oligotrophic, and has low productivity for supporting fish (Bridges et al. 2000; Policky 2003, 2009). Furthermore, the time of year and depth of water withdrawals can affect lake productivity and the resulting fishery (Policky 2009). These factors contribute to limiting the fish populations in the reservoir.

Invertebrates

No data are available on the benthic invertebrate community of Turquoise Lake; however, the community is likely similar to the benthic invertebrate communities of Twin Lakes, which are dominated by midges, worms, and clams (U.S. Bureau of Reclamation [USBR] 1993). Dragonflies, damselflies, beetles, and true bugs are also probably common in littoral zone (shallow) areas. An established population of *Mysis relicta* (opossum shrimp), which are not native, also exists in Turquoise Lake (Martinez and Bergersen 1989).

Twin Lakes

Twin Lakes is an impoundment of two natural lakes on Lake Creek. The total area of the lakes is approximately 2,700 acres, based on estimates by Bridges et al. (2000) and Policky (2003, 2009). CPW manages the fishery for recreational fishing and samples the lake every other year, in odd-numbered years. The CPW data represent the most current data for Twin Lakes. No data on benthic macroinvertebrates, plankton, or habitat are currently collected by CPW.

Reclamation (1993) reviews much of the historical data collected from Twin Lakes through 1986. The report contains historic data on fish as well as data on benthic macroinvertebrates, plankton, water chemistry, and other aspects of the reservoir. The benthic invertebrate data from this report is used to describe the invertebrate communities in Twin Lakes. The recent fish data collected by CPW are used to describe the existing conditions in Twin Lakes.

Fish

CPW has collected seven species of fish in Twin Lakes since 1999 in qualitative gill net samples (Table 44) (Policky 1999, 2001, 2003, 2005, 2007, 2009). The majority of the catch in most of the recent years was white sucker (Table 44). Rainbow trout were most abundant in 2009, cutthroat trout were also abundant in 2007, and longnose sucker abundance was high in 1999 (Table 44). The catch of rainbow and cutthroat trout has varied considerably from year to year, in contrast to the similar abundance of lake trout collected during gill net samples since 1999. Few brook and brown trout were collected during any of the past sampling events since 1999.

Mueller et al. (2004) surveyed Twin Lakes with acoustical equipment in 2001 and 2002. They found that upper Twin Lake had a higher density of fish than lower Twin Lake. They estimated a population size of 40,505 fish in 2001 and 56,427 fish in 2002 in the upper and lower lakes, combined.

Table 44: Fish Population Data (Number Collected) for Twin Lakes, Upper and Lower Basins Combined

Species/Year	1999	2001	2003	2005	2007	2009
Brook trout	0	1	0	0	0	0
Brown trout	6	2	8	1	8	2
Cutthroat trout	17	67	0	27	149	6
Lake trout	61	44	78	57	63	56
Rainbow trout	97	11	36	79	79	192
Longnose sucker	135	72	13	21	15	12
White sucker	383	504	312	180	273	163

Data Source: Policky (1999, 2001, 2003, 2005, 2007, 2009)

CPW stocks rainbow trout annually in Twin Lakes. The USFWS also stocked rainbow trout in Twin Lakes in 1999 through 2002 (Martinez to Garrett 2005) and these fish are included in the numbers in Table 45. This maintains population levels for this species; there is little or no natural reproduction of rainbow trout (Policky 2005a). Lake trout were stocked on a nearly annual basis during the mid- 1980's through 1999 (Policky 2009). Lake trout were not stocked from 2000 through 2004, but stocking resumed in 2005 through 2009 (Table 45). Annual plants are needed to maintain the lake trout fishery as limited natural reproduction is believed to occur in Twin Lakes (Policky 2009). Cutthroat trout and hybrid cutbow trout are also stocked in some years (Table 45).

Brook and brown trout are not stocked by CPW and are collected in low numbers. Nesler et al. (1993) reports that most of the brook and brown trout collected historically have been near the inlet of Lake Creek, indicating that reproduction in Lake Creek maintains low numbers of these species in Twin Lakes. White and longnose suckers also are not stocked by CPW. Spawning for these species apparently occurs in Twin Lakes and not in Lake Creek (Krieger 1980; Nesler et al. 1993.

Table 45: Fish Stocking Data (Number Stocked per Year) for Twin Lakes

Species/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cutbow trout	0	5,127	0	21,378	0	0	0	0	0	0	0
Cutthroat trout	0	3,126	70,837	99,433	0	0	5,211	0	62,838	40,196	27,279
Lake trout	11,984	0	0	0	0	0	15,000	15,000	20,185	21,633	15,358
Rainbow trout	172,475	16,757	59,999	238,975	173,160	287,653	31,511	70,413	40,566	60,196	54,301

Data Source: Policky (2003, 2009) and CPW (2004, 2005)

Invertebrates

The invertebrate communities of Twin Lakes are dominated by midges, worms, and clams (USBR 1993). Dragonflies, damselflies, beetles, and true bugs are also probably common in littoral zone (shallow) areas. *Mysis relicta* were stocked into Twin Lakes in 1957 (USBR 1993). The *Mysis* shrimp population was abundant by 1970 and serves as an important part of the diet of lake trout in Twin Lakes.

De Weese Reservoir

De Weese Reservoir is an impoundment on Grape Creek and is managed by CPW for recreational fishing. The reservoir size is 352 acres and has a maximum depth of 42 feet (Reclamation 2009). CPW qualitatively samples the reservoir with gill nets in most years and by electrofishing in some years. CPW stocks a variety of species of fish into the reservoir annually.

Fish

CPW has collected ten species of fish and one hybrid from De Weese Reservoir since 2000 (Table 46) (Melby 2001-2003, 2004a, 2005-2010; CPW 2011a). The majority of the species collected are game species, providing recreational fishing opportunities. The CPW manages the reservoir mainly for coldwater trout fishing; however, smallmouth bass and tiger muskie are also part of the fishery (Table 46).

During sampling from 2000 through 2005 (except for 2002 when sampling was not conducted), white suckers were the most abundant species sampled, whereas from 2006 through 2009 either cutbow trout or rainbow trout were the most abundant species sampled (Table 46). Management efforts by CPW through the 1990s and 2000s have mainly focused on decreasing the percentage of white suckers and increasing the trout population (Melby 2001-2003, 2004a, 2005-2010). By 2009, the management efforts on the reservoir had nearly completed the reduction of the sucker population in the reservoir (Melby 2010). The percentage of suckers was less than 5 percent of the catch in 2009 compared to 85 percent of the population in 1989 (Melby 2010). The reduction in white suckers was largely achieved by stocking tiger muskie (Melby 2001-2003, 2004a, 2005-2010), which is an aggressive predator. Electrofishing efforts were conducted less frequently than gill netting surveys, but document the presence and sometimes relatively abundant populations of other species, such as fathead minnow, green sunfish, and smallmouth bass.

Most of the species present during sampling efforts correspond to the species stocked by the CPW (Tables 46 and 47) (Melby 2001-2003, 2004a, 2005-2010). Rainbow trout have been stocked in all 11 years from 1999 through 2009, brown trout and cutbow trout have been stocked in 10 of the 11 years, and cutthroat trout have been stocked in 4 of the 11 years. Smallmouth bass were last stocked in 2000 and tiger muskie were stocked each year, except 2007 and 2009, when none were available to stock. Kokanee salmon were stocked in 2007 through 2009.

Table 46: Fish Population Data (Number Collected) for De Weese Reservoir

Species/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gilnetting										
Brown trout	4	4	NS(1)	1	6	9	6	1	1	0
Cutbow trout	0	0	NS(1)	0	0	4	51	11	38	100
Cutthroat trout	0	15	NS(1)	0	0	1	0	0	0	0
Green sunfish	0	0	NS(1)	0	0	1	1	1	1	1
Kokanee	0	0	NS(1)	0	0	0	0	1	1	0
Rainbow trout	72	63	NS(1)	44	84	23	63	34	85	11
Smallmouth bass	1	0	NS(1)	2	1	4	3	7	5	2
Tiger muskie	1	2	NS(1)	0	1	1	0	0	3	1
White sucker	271	266	NS(1)	169	131	58	30	13	13	5
Electrofishing										
Brown trout	5	NS(1)	NS(1)	27	NS(1)	4	NS(1)	1	NS(1)	NS(1)
Cutbow trout	0	NS(1)	NS(1)	0	NS(1)	0	NS(1)	15	NS(1)	NS(1)
Cutthroat	7	NS(1)	NS(1)	0	NS(1)	0	NS(1)	0	NS(1)	NS(1)
Fathead minnow	0	NS(1)	NS(1)	0	NS(1)	69	NS(1)	299	NS(1)	NS(1)
Green sunfish	0	NS(1)	NS(1)	1	NS(1)	7	NS(1)	20	NS(1)	NS(1)
Rainbow trout	7	NS(1)	NS(1)	23	NS(1)	35	NS(1)	18	NS(1)	NS(1)
Smallmouth bass	128	NS(1)	NS(1)	62	NS(1)	128	NS(1)	128	NS(1)	NS(1)
Tiger muskie	0	NS(1)	NS(1)	1	NS(1)	0	NS(1)	2	NS(1)	NS(1)
White sucker	63	NS(1)	NS(1)	97	NS(1)	54	NS(1)	16	NS(1)	NS(1)

Data Source: Melby (2001- 2003, 2004a, 2005- 2010) and CPW (2011a)
Note:
(1) "NS" represents not sampled.

Table 47: Fish Stocking Data (Number Stocked per Year) for De Weese Reservoir

Species/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Brown trout	0	10,020	13,034	23,734	10,010	15,052	15,000	27,093	15,000	15,000	8,000
Cutbow trout	0	6,274	10,269	21,302	2,722	3,139	3,789	8,000	4,500	18,466	18,984
Cutthroat	0	1,803	5,200	12,435	0	18,988	0	0	0	0	0
Kokanee	0	0	0	0	0	0	0	0	99,998	19,920	3,5570
Rainbow trout	49,709	30,423	36,637	17,500	44,258	30,807	41,207	35,448	51,586	35,734	13,048
Smallmouth bass	2,000	2,000	0	0	0	0	0	0	0	0	0
Tiger muskie	3,000	2,460	6,000	6,000	3,000	3,000	1,221	3,000	0	1,313	0

Data Source: Melby (2004a, 2005-2010)

Invertebrates

The invertebrate community of De Weese Reservoir is likely dominated by midges, worms, and clams, which is typical of reservoirs. Dragonflies, damselflies, beetles, and true bugs are also probably common in littoral zone (shallow) areas.

Pueblo Reservoir

Pueblo Reservoir is an impoundment on the Arkansas River and is managed by CPW for recreational fishing. The reservoir size is 4,611 acres and has a maximum depth of greater than 118 feet when full (Bridges et al. 2000). CPW qualitatively samples the reservoir annually with gill nets and in some years by electrofishing. CPW stocks a variety of species of fish into the reservoir annually.

Fish

CPW has collected 18 species of fish and four hybrids in Pueblo Reservoir since 1999 (Table 48) (Melby 2000, 2001, 2002, 2003, 2004a, 2005). The majority of these species are game fish, providing opportunities for recreational fishing. Gizzard shad is the predominant forage fish species and the most common species in electrofishing samples. CPW manages Pueblo Reservoir for warm, cool, and coldwater fishing (Bridges et al. 2000), and fish species from all three of these categories are collected in the reservoir.

Table 48: Fish Population Data (Number Collected) for Pueblo Reservoir

Species/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gillnetting											
Black crappie	0	0	0	0	0	5	0	3	1	3	0
Bluegill	0	0	0	0	1	1	1	2	4	1	3
Carp	5	9	10	8	12	16	14	13	16	27	11
Channel catfish	7	6	22	5	6	18	6	11	11	10	15
Cutbow trout	0	0	0	0	0	0	2	2	0	0	0
European rudd	0	2	0	0	0	0	1	0	0	0	0
Flathead catfish	0	0	0	0	0	0	2	1	1	1	2
Gizzard shad	65	115	71	103	105	88	98	106	56	50	28
Rainbow trout	0	3	1	0	2	9	0	1	0	1	2
Smallmouth bass	25	39	29	3	1	5	0	2	17	20	17
Spotted bass	7	1	4	1	3	6	17	8	24	8	23
Tiger muskie	0	0	0	0	0	1	0	0	0	0	0
Walleye	213	169	179	125	99	114	72	125	133	188	160
White crappie	2	2	8	10	5	0	2	0	3	12	5
White sucker	2	16	42	5	19	24	30	41	40	36	21
Wiper	66	129	109	114	58	60	82	73	52	25	37
Yellow perch	0	0	0	1	0	0	2	1	3	0	0
Electrofishing											
Black crappie	0	0	0	NS(1)	0	NS(1)	NS(1)	1	0	14	NS(1)
Bluegill	75	186	173	NS(1)	77	NS(1)	NS(1)	340	44	302	NS(1)
Carp	42	3	27	NS(1)	13	NS(1)	NS(1)	13	5	14	NS(1)
Channel catfish	1	0	0	NS(1)	0	NS(1)	NS(1)	1	0	1	NS(1)
Crappie spp.	20	8	0	NS(1)	0	NS(1)	NS(1)	0	0	0	NS(1)
Fathead minnow	7	0	0	NS(1)	0	NS(1)	NS(1)	0	0	0	NS(1)
Gizzard shad	7,049	238	262	NS(1)	218	NS(1)	NS(1)	247	660	530	NS(1)
Golden shiner	0	0	0	NS(1)	0	0	NS(1)	1	0	0	NS(1)
Green sunfish	2	0	7	NS(1)	4	NS(1)	NS(1)	19	3	45	NS(1)
Hybrid bluegill	0	1	0	NS(1)	0	NS(1)	NS(1)	0	0	0	NS(1)
Largemouth bass	49	16	11	NS(1)	31	NS(1)	NS(1)	12	13	51	NS(1)
Rainbow trout	0	0	0	NS(1)	1	NS(1)	NS(1)	3	0	0	NS(1)
Smallmouth bass	7	257	171	NS(1)	169	NS(1)	NS(1)	249	205	365	NS(1)
Spotted bass	2	47	42	NS(1)	74	NS(1)	NS(1)	153	22	129	NS(1)
Walleye	27	0	30	NS(1)	23	NS(1)	NS(1)	20	19	9	NS(1)
White crappie	0	0	0	NS(1)	1	NS(1)	NS(1)	2	0	0	NS(1)
White sucker	0	0	2	NS(1)	2	NS(1)	NS(1)	5	0	9	NS(1)
Wiper	2	0	64	NS(1)	0	NS(1)	NS(1)	5	0	1	NS(1)
Yellow perch	4	1	0	NS(1)	1	NS(1)	NS(1)	92	9	19	NS(1)

Data Source: Melby (2000, 2001, 2002, 2003, 2004a, 2005, 2006, 2007, 2008, 2009, 2010)

Note:

(1) "NS" represents not sampled

CPW annually stocks the reservoir with a variety of game fish species and hybrids (Table 49). Since 1999, CPW has stocked nine different species and three hybrids. All but one species were stocked in multiple years. Stocking by CPW supports the coldwater fishery, comprised of rainbow trout, and occasional stocking of cutbow hybrid trout and cutthroat trout (Bridges et al. 2000). Apparently, there is little or no reproduction by rainbow and cutthroat trout to sustain populations of these coldwater species in the reservoir.

Table 49: Fish Stocking Data (Number Stocked per Year) for Pueblo Reservoir

Species/ Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Black crappie	0	0	0	0	88,358	0	0	0	0	0	0
Blue catfish	18,240	10,400	25,246	20,000	20,000	0	0	0	0	0	0
Channel catfish	53,440	60,002	47,316	4,200	136,306	90,547	111,225	79,999	46.000	72,000	22,400
Cutbow trout	0	15,504	0	0	9,207	0	0	8,000	0	6,458	9,668
Cutthroat trout	0	8,160	142,779	0	0	4,750	0	45,727	0	0	0
Flathead catfish	0	0	10,893	24,000	17,000	2,205	0	37,994	48,000	0	72,000
Largemouth bass	8,840	11,550	10,000	10,000	10,000	15,203	5,550	10,000	7,725	2,000	0
Rainbow trout	26,998	396,503	36,492	93,186	110,194	302,465	67,954	51,650	103,213	418,717	263,984
Smallmouth bass	22,165	20,000	6,400	20,000	9,759	0	20,000	0	30,182	0	0
Tiger muskie	0	0	10,215	1,800	0	0	0	0	0	0	0
Walleye (1)	11.8	12.5	16.5	12.1	12.1	13.2	12.3	13.8	14.2	13.2	13.4
Wiper	400,000	40,181	235,010	200,000	200,000	200,000	400,074	405,259	400,000	532,125	394,000

Data Source: Melby (2004a, 2005, 2006, 2007, 2008, 2009, 2010)

Note:

(1) Represented in millions.

A few of the species and hybrids are maintained entirely by stocking. The hybrid tiger muskie and wiper do not spawn successfully and are maintained entirely by stocking. Flathead catfish are also stocked frequently since 1999, and were not collected until 2005 through 2009 when one or two individuals were sampled in gillnets during each year. This species may also be maintained only by stocking.

Three species, the native fathead minnow and the introduced European rudd and golden shiner, are not stocked by CPW, but are common baitfish species. These species have only been collected in low numbers during only one or two years. They may have entered the lake from a bait-bucket transfer and do not appear to have established resident, self-sustaining populations.

Other species are probably maintained by a combination of stocking and natural reproduction. Channel catfish, largemouth bass, smallmouth bass, and walleye are stocked every year or nearly every year (Table 49) and are also present in CPW collections every year (Table 48). The habitat in Pueblo Reservoir is suitable for spawning by these species.

The remaining taxa have not been stocked at least since 1999, and still are present in CPW collections. This includes the abundant gizzard shad and bluegill, carp, green sunfish, hybrid bluegill, spotted bass, white crappie, white sucker, and yellow perch.
According to Bridges et al. (2000), largemouth bass, smallmouth bass, and crappie use submerged bank vegetation as spawning areas from March through June in Pueblo Reservoir. The majority of warmwater species, including forage fish, use the littoral zone as their preferred habitat. This area also serves as a nursery for younger fish.

The most abundant species in Pueblo Reservoir is gizzard shad. CPW collects this species by both gillnetting and electrofishing. Walleye are also abundant in gillnet samples, but are less common in electrofishing catches (Table 48). Electrofishing is focused on littoral habitat, which is suitable for the sunfish species (e.g., largemouth bass, smallmouth bass, spotted bass, and bluegill) that are commonly caught during electrofishing as well as carp (Table 48). Gillnetting results in collecting a higher proportion of white sucker and wiper than electrofishing. The remaining species are collected in relatively low numbers by both methods.

Invertebrates

No data were available on the benthic invertebrate community of Pueblo Reservoir. The community is probably dominated by midges, worms, and clams typical of reservoirs. Dragonflies, damselflies, beetles, and true bugs are also probably common in littoral zone areas.

Lake Henry

Lake Henry is a 1,120-acre reservoir (Bennett 2002) that is on the Colorado Canal. Lake Henry is shallow, with a maximum depth of 10 feet and has a high flow through or exchange rate (Bennett 2002). CPW has sampled the lake sporadically over the past 10 years. Low water levels precluded sampling in 2002 and 2003 (Krieger 2004). Sampling in 2000 may have been affected by poor weather conditions; sampling in 2001 was affected by very low water (three feet or less over much of the lake) (Bennett 2001, 2002).

Fish

CPW manages Lake Henry as a warmwater fishery. The fish collected from 2000 through 2009 in qualitative gillnet samples represent warmwater species and one coolwater species (yellow perch) (Table 50). Seven game fish species and hybrids have been stocked in the reservoir since 1999, with channel catfish, saugeye, and wiper each stocked in all but one year (Table 51).

From 2000 through 2009, a total of 12 species and two hybrids have been collected from the reservoir (Table 50). Five of these 14 taxa of fish are also regularly stocked by CPW. The remaining nine taxa are probably maintaining populations through natural reproduction or are being periodically introduced to the reservoir by the canal.

According to Bennett (2002), the physical and operational characteristics of the reservoir limit effective fisheries management. The shallow, homogenous structure of the lake limits production of fish. The high exchange rate and an outlet structure that allows passage of fish into the canal lead to high loss of fish out of the reservoir. Lake Henry “acts as a nursery to Meredith Reservoir” (Bennett 2002) which is the next reservoir downstream along the canal. In addition, the low water levels in 2002 and 2003 reduced the abundance of fish in the reservoir.

Table 50: Fish Population Data (Number Collected by Gillnet) for Lake Henry

Species/Year	2000	2001	2004	2006	2007	2008	2009
Black bullhead	46	32	19	50	37	73	14
Black crappie	2	1	2	22	24	25	19
Blue catfish	0	0	1	0	0	0	0
Carp	8	2	38	40	18	18	9
Channel catfish	45	35	44	63	51	42	16
European rudd	5	4	5	0	0	0	1
Flathead catfish	0	0	0	0	1	0	0
Gizzard shad	91	87	502	410	46	289	114
Largemouth bass	0	5	0	0	0	3	2
Saugeye	11	12	18	126	5	4	0
Striped bass	0	0	0	0	0	13	0
White sucker	0	7	0	0	0	5	12
Wiper	8	22	1	8	1	10	4
Yellow perch	8	2	0	0	0	0	0

Data Source: Bennett (2001, 2002), Ramsay (2004), and CPW (2011a)

Sampling data since 2000 indicates a few general patterns of relative abundance that probably represent long-term conditions. The most abundant species during each sampling period was gizzard shad (Table 50). This species is not stocked and is probably maintained through natural reproduction. Black bullhead and carp are also not stocked, but have been common in some or all of the samples. Channel catfish are typically the most abundant stocked species; however, black crappie and saugeye have periodically been the most abundant taxa sampled.

Table 51: Fish Stocking Data (Number Stocked per Year) for Lake Henry

Species/ Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Black crappie	30,000	0	45,000	30,000	35,000	0	30,406	15,461	20,000	0	0
Blue catfish	23,695	13,520	35,729	0	20,000	10,000	0	0	0	0	7,500
Channel catfish	9,750	37,500	35,000	0	50,000	53,349	50,000	50,000	37,900	45,000	14,000
Saugeye (1)	1.0	1.0	1.2	1.1	1.6	0.8	1.1	1.0	0	1.1	1.0
Striped bass	0	0	0	0	0	0	0	0	6,933	0	0
Walleye (1)	0	0	0	0	0	0	0	0.6	1.0	0	0
Wiper	200,000	2,000	110,251	0	100,000	200,000	300,000	205,000	200,000	500,000	211,568

Data Source: Ramsay (2004, 2011)
Note:
(1) Represented in millions

Invertebrates
No data were available on the benthic invertebrate community of Henry Lake. The community is probably dominated by midges, worms, and clams typical of reservoirs. Dragonflies, damselflies, beetles, and true bugs are also probably common in littoral zone areas.

Lake Meredith
Lake Meredith is a reservoir on the Colorado Canal downstream from Lake Henry. The CPW collected fish samples from the reservoir in 1999, 2000, 2007, and 2008. The reservoir is 3,300

acres in size and has a maximum depth of 9 feet (Bennett 2001). The reservoir was dewatered in 2002 resulting in the loss of all fish. No data were available from 2001 through 2006, or 2009 (CPW 2011a). Like Lake Henry, Lake Meredith is shallow, with a high exchange rate and no barrier to fish movements into the canal (Bennett 2001).

Fish

CPW manages Lake Meredith for warmwater game fish. CPW collected a total of 11 fish species and two hybrids in the reservoir since 1999 (Table 52). A few of these taxa are also stocked (Table 53), although stocking rates in 2002 and 2003 were lower than in other years, probably due to low water levels, and no fish were stocked in 2004 (Ramsay 2004). Stocking was resumed from 2005 through 2009 (Table 53) (Ramsay 2011).

Table 52: Fish Population Data (Number Collected by Gillnet) for Lake Meredith

Species/Year	1999	2000	2007	2008
Black bullhead	140	101	58	86
Black crappie	5	4	92	92
Carp	43	12	167	56
Channel catfish	14	31	1	15
Gizzard shad	51	71	526	553
Green sunfish	1	0	5	1
Largemouth bass	2	7	12	2
Saugeye	43	11	5	24
Smallmouth bass	0	0	3	0
Striped bass	0	0	0	1
White sucker	6	2	1	5
Wiper	30	117	0	3
Yellow perch	1	2	0	0

Data Source: Bennett (2000, 2001) and CPW (2011a)

Table 53: Fish Stocking Data (Number Stocked per Year) for Lake Meredith

Species/ Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Black crappie	30,000	25,763	45,000	0	35,000	0	30,000	0	10,000	0	0
Channel catfish	50,100	53,985	52,500	0	0	0	0	25,000	39,300	67,500	21,000
Grass Carp	0	0	0	0	0	0	0	0	500	0	0
Saugeye [(1)]	2.3	2.1	3.4	3.1	2.1	0	3.1	1.5	0	3.1	3.1
Striped bass	0	0	0	0	0	0	0	0	8,763	0	0
Tiger muskie	0	0	7,608	0	0	0	0	0	0	0	0
Walleye	0	0	0	0	0	0	0	0	3.0[1]	0	10,001
Wiper	400,000	300,000	475,000	200,000	100,000	0	500,000	400,000	500,000	929,999	411,568

Data Source: Bennett (2001) and Ramsay (2004, 2011)

Note:

(1) Represented in millions.

The fish community composition was similar between the years prior to dewatering (1999 and 2000) and the years after dewatering (2007 and 2008). Gizzard shad were the most abundant species sampled in recent years and were the second most abundant species prior to dewatering.

Black bullhead, black crappie, and common carp were abundant in the recent sampling events and black bullhead were also abundant in the earlier sampling events. A number of the species were collected at low abundances during both sampling periods.

Many of the species collected in Lake Meredith were not stocked. Natural reproduction may be maintaining these species. However, the species collected in Lake Meredith are nearly identical to those from Lake Henry, upstream on the canal. Some of the fish in Lake Meredith could have originated in Lake Henry and migrated downstream through the canal.

Stocking maintains the abundance of several other species and hybrids in the reservoir. Channel catfish, saugeye, and wipers were also relatively abundant in 1999 and 2000. All three of these taxa were stocked in these years (Table 53) and most years from 1990 and 1998 (Bennett 2000).

Invertebrates

No data were available on the benthic invertebrate community of Lake Meredith. The community is probably dominated by midges, worms, and clams typical of reservoirs. Dragonflies, damselflies, beetles, and true bugs are also probably common in littoral zone areas.

Holbrook Reservoir

Holbrook Reservoir has a surface area of 660 acres, a maximum depth of 20 feet, and capacity of nearly 6,200 ac-ft (GEI 2008c). Holbrook Reservoir is managed for warmwater game fish and catchable trout by the CPW. Holbrook Reservoir has had low water levels or been dry at times during the drought period prior to the completion of the SDS EIS in 2008, disrupting the normal cycle of sampling and fish stocking by CPW (GEI 2008c). When there is water in the reservoir, it is regularly stocked with several species of fish by CPW.

Fish

Five species and three hybrids have been stocked by CPW from 1999 through 2012 (Table 54) (Ramsay 2012). Warmwater fish were stocked as young of the year or juveniles and coldwater fish were stocked as catchable sized trout. The stocking density was reduced or no fish were stocked during some years from 2006 through 2010, compared to years prior and after this time-period. No fish population sampling has been conducted since prior to 1999 (Ramsay 2012).

Table 54: Fish Stocking Data (Number Stocked per Year) for Holbrook Reservoir

Species/ Year	1999	2000	2001	2002	2003	2006	2008	2009	2010	2011	2012
Black crappie	30,000	0	0	24,867	35,000	14,999	0	0	0	30,081	0
Channel catfish	10,688	12,000	16,000	0	16,000	0	14,400	8,050	16,000	11,200	0
Cutbow trout	0	5,712	376	500	0	0	0	0	0	517	0
Cutthroat trout	0	4,608	0	0	0	0	0	0	0	0	0
Rainbow trout	4,629	9,139	0	0	1,000	0	0	0	0	546	4,979
Saugeye	50,000	30,000	10,000	12,625	21,770	0	0	0	0	0	0
Walleye	0	0	0	0	20,000	0	0	0	0	0	500,000
Wiper	10,690	0	10,352	0	10,000	0	0	0	0	0	0

Data Source: Ramsay (2012)
Note:
(1) No fish were stocked in 2004, 2005, and 2007.

Invertebrates
No data were available on the benthic invertebrate community of Holbrook Reservoir. The community is probably dominated by midges, worms, and clams typical of reservoirs. Dragonflies, damselflies, beetles, and true bugs are also probably common in littoral zone areas.

John Martin Reservoir
John Martin Reservoir is located on the Arkansas River, just upstream from the Town of Lamar. The CPW collected fish samples from the reservoir in 1999, 2000, 2001, 2004 (Bennett 2000, 2001, 2002; Ramsay 2004), and 2006 through 2009 (CPW 2011a). The reservoir ranges from 2,000 to 17,000 acres in size and has a maximum depth from 34 to 80 feet deep depending on water fluctuations (Bennett 2001).

Fish
CPW manages John Martin Reservoir for warmwater game fish. Seventeen species of fish and two hybrids have been collected since 1999 (Table 55). Gizzard shad have been the most abundant species sampled during most years. White bass were the most abundant species sampled in 2006 and 2007, and saugeye were most abundant in 2009. Channel catfish and wiper have also been abundant periodically. The percentage of gizzard shad from 1999 through 2004 ranged from 27 to 80 percent, which is considered higher than desired and not conducive to sport fishing (Bennett 2001, 2002; Ramsay 2004). Gizzard shad have made up a smaller proportion of the catch during sampling in recent years, comprising less than 20 percent of the catch in three of the four years from 2006 through 2009.

Table 55: Fish Population Data (Number Collected by Gillnet) for John Martin Reservoir

Species/Year	1999	2000	2001	2004	2006	2007	2008	2009
Black bullhead	5	0	0	0	0	0	2	1
Blue catfish	0	0	0	0	0	1	0	1
Black crappie	3	8	15	1	10	8	85	8
Bluegill	0	2	0	0	0	0	0	0
Carp	19	17	14	32	21	111	140	26
Channel catfish	51	79	109	51	26	38	92	27
Drum	1	2	5	6	0	0	58	14
European rudd	0	1	0	0	0	0	0	0
Freshwater drum	0	0	0	0	23	40	0	0
Gizzard shad	284	324	142	453	79	128	242	78
Green sunfish	0	0	0	0	0	0	2	0
Largemouth bass	1	0	0	0	0	1	0	4
Rainbow trout	0	10	0	0	0	0	0	0
Saugeye	37	27	142	12	66	244	165	181
Smallmouth bass	1	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	1	2
Walleye	0	0	0	0	0	0	0	46
White bass	65	53	27	9	240	324	54	74
Wiper	124	52	64	2	3	11	26	14

Data Source: Bennett (2000, 2001, 2002), Ramsay (2004), and CPW (2011a)

Ten species of fish and three hybrids have been stocked since 1999 (Table 56). Channel catfish, saugeye, smallmouth bass, and wiper have been stocked in all or most years, while the remaining species have been stocked only periodically. Saugeye and wiper have been stocked at the greatest abundances and are stocked as fry. Extreme fluctuations in reservoir water levels can adversely affect the fish populations in John Martin Reservoir by flushing the stocked fry downstream out of the reservoir as was the case in 2004 when they were observed in the river and canals downstream to the Kansas State Line (Ramsay 2004).

Table 56: Fish Stocking Data (Number Stocked per Year) for John Martin Reservoir

Species/ Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Black crappie	0	0	0	0	54,288	0	0	0	25,000	0	0
Blue catfish	27,365	32,640	57,248	25,000	75,571	75,000	0	0	0	19,125	36,790
Channel catfish	59,300	62,730	37,500	0	105,200	77,000	66,560	25,000	56,666	81,750	37,158
Cutbow trout	0	6,188	0	0	0	0	0	0	0	0	0
Cutthroat trout	0	10,208	0	0	0	0	0	0	0	0	0
Flathead catfish	0	0	10,893	0	20,000	2,047	0	34,998	32,000	0	30,000
Largemouth bass	15,001	14	0	0	323,900	0	661,899	0	0	0	0
Rainbow trout	0	46,360	0	0	0	0	0	7,784	0	0	0
Saugeye [(1)]	5.7	10.3	6.5	5.7	3.4	5.3	6.2	6.6	0	6.7	5.2
Smallmouth bass	30,000	15,269	15,000	0	15,000	3,675	28,093	0	41,065	30,000	2,603
Striped bass	0	0	0	0	0	0	0	0	0	100,000	0
Walleye	0	0	0	0	882,855	0	0	1.0[1]	6.1[1]	0	691,000
Wiper	500,000	345,764	710,000	400,000	200,000	900,000	1.0[1]	600,000	800,000	1.7[1]	811,570

Data Source: Ramsay (2004, 2011)

Note:

(1) Represented in millions.

Invertebrates

No data were available on the benthic invertebrate community of John Martin Reservoir. The community is probably dominated by midges, worms, and clams typical of reservoirs. Dragonflies, damselflies, beetles, and true bugs are also probably common in littoral zone areas.

References

Allan, J.D. 1995. Stream Ecology. London: Chapman & Hall Publishers, London, UK.

Anderson, R.M., and D. A. Krieger. 1994. Impact analysis of a flow augmentation program on the brown trout fishery of the Arkansas River, Colorado. Special Report Number 70. Colorado Division of Wildlife.

Aquatics Associates. 1993. Aquatic sampling program results, California Gulch Site, Leadville, Colorado, 1991. Report prepared for Res-ASARCO Joint Venture, California Gulch CERCLA project.

Barbour, M.T., J. Gerritson, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish, 2nd Edition. EPA 841-B-99-002. Washington, D. C.: U.S. Environmental Protection Agency.

Behnke, R. J. 2002. Trout and salmon of North America. The Free Press, New York.

Bennett, C.D. 2000. 1999 Fisheries inventories, Lower Arkansas River Basin. Colorado Division of Wildlife.

Bennett, C.D. 2001. 2000 Fisheries inventories, Lower Arkansas River Basin. Colorado Division of Wildlife.

Bennett, C.D. 2002. 2001 Fisheries inventories, Lower Arkansas River Basin. Colorado Division of Wildlife.

Bennett, C.D., J.L. Melby, and R. M. Anderson. 1990. Colorado Division of Wildlife, Southeast region, 1990 fisheries inventories. Colorado Division of Wildlife.

Benson, A. J. 2011. New Zealand mudsnail sightings distribution. Available: newzealandmudsnaildistribution.aspx. Accessed 3/16/2011.

Bestgen, K.R., K. Zelasko, and R. Compton. 2003. Environmental factors limiting suckermouth minnow *Phenacobius mirabilis* populations in Colorado. Colorado Division of Wildlife.

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Insream Flow Information Paper: No. 12. FWS/OBS-82/26. U.S. Department of the Interior, Fish and Wildlife Service.

Bovee, K.D. 1989. Determination of reach lengths and weight factors using “habitat mapping” data. PHABSIM Technical Note 48. U.S. Department of the Interior, Fish and Wildlife Service.

Bridges C., M. Elkins, D. Gilbert, and G. Policky. 2000. Natural resource assessment. In Arkansas River water needs assessment. Smith, R.E., and L.M. Hill, eds. USDI Bureau of Land Management, USDI Bureau of Reclamation, USDA Forest Service, and Colorado Department of Natural Resources.

Bruce, J.F. 2002. Characterization and analysis of temporal and spatial variations in habitat and macroinvertebrate community structure, Fountain Creek, Basin, Colorado Springs and vicinity, Colorado, 1998-2001. U.S. Geological Survey, Denver. Water-Resources Investigations Report 02-4093.

Bruce, Jim (USGS). E-mail to Gary Dowler (CPW) "Arkansas darters sampled 9-24-03." Sept. 25, 2003.

Bruce, Jim (USGS) 2005. Personal communication with Don Conklin (CEC). Littleton, Colorado. June 10, 2005.

Bukantis, R. 1998. Rapid bioassessment macroinvertebrate protocols: sampling and sample analysis SOPs. Working Draft. Montana Department of Environmental Quality, Planning, Prevention, and Assistance Division. Helena, MT.

Chadwick Ecological Consultants, Inc. 1988. Brown and rainbow trout habitat suitability curves. (Unpublished data).

Chadwick Ecological Consultants, Inc. 1994. 1994 Arkansas River and Lake Fork fish and benthic invertebrate sampling data. (Unpublished data sheets).

Chadwick Ecological Consultants, Inc. 1995. Aquatic biological survey of the Arkansas River in the vicinity of the city of Pueblo wastewater reclamation facility. Prepared for City of Pueblo, CO.

Chadwick Ecological Consultants, Inc. 1998a. Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado (1995-1998). Prepared for Resurrection Mining Company.

Chadwick Ecological Consultants, Inc. 1998b. Survey of the benthic invertebrates in the Arkansas River in the vicinity of the City of Pueblo wastewater reclamation facility October 1996. Prepared for City of Pueblo, CO.

Chadwick Ecological Consultants, Inc. 1998c. 1998 Arkansas River benthic invertebrate sampling data at Kobe and Granite sites. (Unpublished data sheets).

Chadwick Ecological Consultants, Inc. 1999a. 1998 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, CO. Prepared for Resurrection Mining Company.

Chadwick Ecological Consultants, Inc. 1999b. Survey of the benthic invertebrates in the Arkansas River in the vicinity of the City of Pueblo wastewater reclamation facility November 1998. Prepared for City of Pueblo, CO.

Chadwick Ecological Consultants, Inc. 2001. 1999-2000 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado. Prepared for Resurrection Mining Company, Denver, CO.

Chadwick Ecological Consultants, Inc. 2002. 2001 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado. Prepared for Resurrection Mining Company, Denver, CO.

Chadwick Ecological Consultants, Inc. 2003. 2002 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado Prepared for Resurrection Mining Company, Denver, CO.

Chadwick Ecological Consultants, Inc. 2004a. 2003 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado. Prepared for Resurrection Mining Company, Denver, CO.

Chadwick Ecological Consultants, Inc. 2004b. December 2004 fish collection data for the Arkansas River and Fountain Creek (Unpublished field notes).

Chadwick Ecological Consultants, Inc. 2005. 2004 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado (Draft). Prepared for Resurrection Mining Company, Denver, CO.

Chadwick Ecological Consultants, Inc. 2006. Aquatic Resources Technical Report, Southern Delivery System Environmental Impact Statement. Prepared for Bureau of Reclamation

Claudi, R., and T. Prescott. 2009a. Assessment of the Potential Impact of Invasive Mussels on Water System Facilities and Structures and Recommendations for Control-Pueblo Reservoir, Fryingpan-Arkansas Project. Prepared for Eastern Colorado Area Office, Bureau of Reclamation. RNT Consulting, Inc., Ontario, Canada.

Claudi, R., and T. Prescott. 2009b. Assessment of the Potential Impact of Invasive Mussels on the Following Fryingpan-Arkansas Project Facilities and Structures: Turquoise Reservoir, Mt. Elbert Forebay and Powerplant, Twin Lakes, and Reudi Reservoir. Prepared for Eastern Colorado Area Office, Bureau of Reclamation. RNT Consulting, Inc., Ontario, Canada.

Clements, W.H. 1994. Benthic invertebrate community responses to heavy metals in the Upper Arkansas River Basin, Colorado. *Journal of the North American Benthological Society* 13(1):30-44.

Clements, W.H., and P.M. Kiffney. 1994. Integrated laboratory and field approach for assessing impacts of heavy metals at the Arkansas River, Colorado. *Environmental Toxicology and Chemistry* 13(1):397-404.

Clements, W.H., and P.M. Kiffney. 1995. The influence of elevation on benthic community responses to heavy metals in Rocky Mountain streams. *Canadian Journal of Fisheries and Aquatic Sciences* 52(9):166-177.

Colorado Department of Public Health and Environment. 2000. 2000 Arkansas River benthic invertebrate sampling data. (Unpublished data sheets).

Colorado Department of Public Health and Environment. 2002. 2002 Arkansas River benthic invertebrate sampling data. (Unpublished data sheets).

CPW (Colorado Parks and Wildlife). 2004. Turquoise Reservoir and Twin Lakes fish stocking data. (Unpublished data sheets).

CPW (Colorado Parks and Wildlife). 2005. Turquoise Reservoir and Twin Lakes fish stocking data. (Unpublished data sheets).

CPW (Colorado Parks and Wildlife. 2011a. Unpublished fish survey data through 2009 for the Arkansas River, Fountain Creek, Pueblo Reservoir, Henry Lake, Lake Meredith, and John Martin Reservoir and through 2010 for Grape Creek and DeWeese Reservoir.

CPW (Colorado Parks and Wildlife. 2011b. E-mail from Colorado Parks and Wildlife Insider. Rare minnows restored to Arkansas River. December 12, 2011.

Colorado Springs Utilities. 1994. 1994 Fountain Creek benthic invertebrate sampling data at Colorado Springs, below Janitell Road, at Stratmoor and near Fountain, (Unpublished data sheets).

Colorado Springs Utilities. 1995. 1995 Fountain Creek benthic invertebrate sampling data at Colorado Springs, below Janitell Road, at Security, near Fountain, at Piñon, and above Pueblo. (Unpublished data sheets).

Colorado Springs Utilities. 1996. 1996 Fountain Creek benthic invertebrate sampling data at Colorado Springs, below Janitell Road, at Security, near Fountain, at Piñon, and above Pueblo. (Unpublished data sheets).

Colorado Springs Utilities. 1997. 1997 Fountain Creek benthic invertebrate sampling data at Colorado Springs, below Janitell Road, at Security, near Fountain, at Piñon, and above Pueblo. (Unpublished data sheets).

Colorado Springs Utilities. 1998. 1998 Fountain Creek benthic invertebrate sampling data at Colorado Springs, below Janitell Road, at Stratmoor, near Fountain, at Pueblo and Monument Creek at Bijou Street. (Unpublished data sheets).

Colorado Springs Utilities. 1999. 1999 Fountain Creek benthic invertebrate sampling data at Colorado Springs, below Janitell Road, at Stratmoor, near Fountain, at Pueblo and Monument Creek at Bijou Street. (Unpublished data sheets).

Colorado Springs Utilities. 2000. 2000 Fountain Creek benthic invertebrate sampling data at Colorado Springs, below Janitell Road, at Stratmoor, at Security, near Fountain, at Pueblo and Monument Creek at Bijou Street. (Unpublished data sheets).

Colorado Springs Wastewater Division. 1980. Stream study, October 1980.

Colorado Springs Wastewater Division. 1989. Fountain Creek Segment 2: 1989 use attainability analysis update. November 1989.

Conklin, D.J., S.P. Canton, J.W. Chadwick, and W.J. Miller. 1996. Habitat suitability curves for selected fish species in the Central Platte River, Nebraska. *Rivers* 5(4):250-266.

Cordeiro, J.R., A.P. Olivero, and J. Sovell. 2007. Corbicula fluminea (Bivalvia: Sphaeriacea: Corbiculidae) in Colorado. The Southwestern Naturalist 52 (3): 424-430.

CSWD (see Colorado Springs Wastewater Division)

Decker, J. 1998. Effects of Pueblo Reservoir, an impoundment of the Arkansas River, Colorado, on the abundance and diversity of Diptera, Ephemeroptera, Plecoptera, and Trichoptera (Insecta). Masters Thesis. Colorado State University-Pueblo.

Dowler, G. 2001. 2001 Fisheries inventories Front Range East and South Republican Drainage. Colorado Division of Wildlife.

Dowler, G. (CPW). 2004a. Personal communication with Don Conklin (CEC) during fish sampling. Fountain, Colorado. April 16, 2004.

Dowler, G. 2004b. 2004 Fisheries inventories Front Range East and South Republican Drainage. Colorado Division of Wildlife.

Engineering Science, Inc. 1986. Chapter 7. Aquatic biota investigation. In Yak tunnel/California Gulch Remedial Investigation. Denver.

ENSR Consulting and Engineering. 1989. An evaluation of metal standards in the Upper Arkansas River and their relationship to the survival and growth of brown trout. Report prepared for Bradley, Campbell and Carney. Ft. Collins, CO.

EPA (see U.S. Environmental Protection Agency)

Fausch, K. D., and K. R. Bestgen. 1997. Ecology of fishes indigenous to the central and southwestern Great Plains. Pages 131-166 in F. L. Knopf and F. B. Samson, eds. Ecology and Conservation of Great Plains Vertebrates. Ecological Studies 125. Springer-Verlag, New York.

GEI Consultants, Inc. 2006. 2005 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado. Prepared for Resurrection Mining Company, Denver, CO.

GEI Consultants, Inc. 2007a. 2006 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado. Prepared for Resurrection Mining Company, Denver, CO.

GEI Consultants, Inc. 2007b. Aquatic biological monitoring and selenium investigation of the Arkansas River, Fountain Creek, Wildhorse Creek, and the St. Charles River. Prepared for City of Pueblo WRP, Pueblo, CO.

GEI Consultants, Inc. 2008a. 2007 Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado. Prepared for Resurrection Mining Company, Denver, CO.

GEI Consultants, Inc. 2008b. 2008 Arkansas River and Lake Fork fish and spring benthic invertebrate sampling data. (Unpublished data sheets).

GEI Consultants, Inc. 2008c. Aquatic Resources Effects Analysis for the Southern Delivery Environmental Impact Statement. Prepared for Bureau of Reclamation.

GEI Consultants, Inc. 2011. 2011 Unpublished Habitat Suitability Curve Validation Fish Sampling Data – June, August, and October 2011.

Gierard, J., D. Gilbert, D. Krieger, G. Policky, R. Smith, S. Swanson, D. Taliaferro. 2000. Executive Summary *in* Arkansas River water needs. Smith, R. E., and L. M. Hill, eds. USDI Bureau of Land Management, USDI Bureau of Reclamation, USDA Forest Service, and Colorado Department of Natural Resources.

Grafe, C.S., ed. 2002. Idaho small stream ecological assessment framework: an integrated approach. Idaho Department of Environmental Quality. Boise.

Hardy, T. 2005. PHABWin-2005. Primary software developed by Bridger Tech, Inc. Additional Support by Utah State University.

Health Department (see Colorado Department of Public Health and Environment)

Hilsenhoff, W.L. 1977. Use of arthropods to evaluate water quality of streams. Technical Bulletin 100, Wisconsin Department of Natural Resources.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. *Great Lakes Entomologist* 20:31-39.

Jordan, D. S. 1891. Report of explorations in Colorado and Utah during the summer of 1889, with an account of the fishes found in each of the river basins examined. U. S. Fish Commission Bulletin 9:1-40.

Kiffney, P.M., and W.H. Clements. 1993. Bioaccumulation of heavy metals by benthic invertebrates at the Arkansas River, Colorado. *Environmental Toxicology and Chemistry* 12:1507-1517.

Kleinert, C. E. 2008. A qualitative study of Ephemeroptera, Plecoptera, Trichoptera and Chironomidae in the Arkansas River, Colorado, below Pueblo Dam 2004-2006. Masters Thesis. Colorado State University-Pueblo.

Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA/600/4-90/030. U.S. Environmental Protection Agency.

Krieger, Doug 1980. Ecology of Catostomids in Twin Lakes, Colorado, in relation to a pumped-storage powerplant. Report No. REC-ERC-80-2. U.S. Bureau of Reclamation.

Krieger, Doug (CPW). 2004. Telephone conversation with Chris Garrett (CEC). May 2004.

Krieger, Doug (CPW). E-mail to Don Conklin (CEC). Arkansas River fish sampling data collected by Dr. K. Bestgen, CSU. October 17, 2005.

Krieger, Doug. (CPW). E-mail to Bill Van Deveer (MWH). SDS-EIS fish runs out of Pueblo Reservoir. November 23, 2005.

Krieger, D. and D Lovell (CPW). 2011. Comments on Draft Chapter 3 – Affected Environment. Submitted to Reclamation.

Krieger, D., T. Nesler, C. Bennett, G. Dowler, and J. Melby. 2001. Arkansas darter *Etheostoma cragini* recovery plan. Colorado Division of Wildlife.

Kumar, S., Spaulding, S. A., Stohlgren, T., Hermann, K., Schmidt, T. and Bahls, L. 2009. Potential habitat distribution for the freshwater diatom *Didymosphenia geminata* in the continental US. Frontiers in Ecology and the Environment 7(8): 415-420.

LaBounty, J.F., J.J. Sartoris, L.D. Klein, E F. Monk, and H.A. Salman. 1975. Assessment of heavy metals pollution in the Upper Arkansas River of Colorado. Report No. REC-ERC-75-7. U.S. Bureau of Reclamation.

Lenat, D.R., and D.L. Penrose. 1996. History of the EPT taxa richness metric. *Bulletin of the North American Benthological Society* 13:305-307.

Loeffler, C., D. Miller, R. Shuman, D. Winters, and P. Nelson. 1982. Arkansas River threatened fishes survey. Performance Report, Federal Aid Project SE-8-1-2. Colorado Division of Wildlife.

Lydy, M.J., C.G. Crawford, and J. W. Frey. 2000. A comparison of selected diversity, similarity, and biotic indices for detecting changes in benthic-invertebrate community structure and stream quality. *Archives of Environmental Contamination and Toxicology* 39:469-479.

Martinez, Carlos (USFWS). E-mail to Chris Garrett (CEC). “Unpublished fish stocking data from Leadville National Fish Hatchery.” Jul. 18, 2005.

Martinez, P. J. and E. P. Bergersen. 1989. Proposed biological management of *Mysis relicta* in Colorado lakes and reservoirs. North American Journal of Fisheries Management 9:1-11.

Melby, J.L. 2000. 1999 Fisheries inventories Middle Arkansas River Basin and Front Range. Colorado Division of Wildlife.

Melby, J.L. 2001. 2000 Fisheries inventories Middle Arkansas River Basin and Front Range. Colorado Division of Wildlife.

Melby, J.L. 2002. 2001 Fisheries inventories Middle Arkansas River Basin and Front Range. Colorado Division of Wildlife.

Melby, J.L. 2003. 2002 Fisheries inventories Middle Arkansas River Basin and Front Range. Colorado Division of Wildlife.

Melby, J.L. 2004a. 2003 Fisheries inventories Middle Arkansas River Basin and Front Range. Colorado Division of Wildlife.

Melby, J.L. 2004b. Arkansas River 3B fish stocking report. Colorado Division of Wildlife. (Unpublished data sheets).

Melby, J.L. 2005. 2004 Fisheries inventories Middle Arkansas River Basin. State of Colorado, Colorado Division of Wildlife.

Melby, J.L. 2006. 2005 Fisheries inventories Middle Arkansas River Basin and Front Range. State of Colorado, Colorado Division of Wildlife.

Melby, J.L. 2007. 2006 Fisheries inventories Middle Arkansas River Basin and Front Range. State of Colorado, Colorado Division of Wildlife.

Melby, J.L. 2008. 2007 Fisheries inventories Middle Arkansas River Basin and Front Range. State of Colorado, Colorado Division of Wildlife.

Melby, J.L. 2009. 2008 Fisheries inventories Middle Arkansas River Basin and Front Range. State of Colorado, Colorado Division of Wildlife.

Melby, J.L. 2010. 2009 Fisheries inventories Middle Arkansas River Basin and Front Range. State of Colorado, Colorado Division of Wildlife.

Mueller, G.A., A.M. Montaño, R. Roline, and R. Wydoski. 2004. Acoustical fish surveys of Twin Lakes and the Mt. Elbert Pumping Plant Forebay, August 2001 and 2002. Bureau of Reclamation Report, Denver, CO.

Nehring, R.B. 1986. Stream fisheries investigations. Job Progress Report. Project F-51-R. Colorado Division of Wildlife.

Nehring, R.B., and R. Anderson. 1982. Stream fisheries investigations. Job Progress Report. Project F-51-R-7. Colorado Division of Wildlife.

Nelson, S.M. 2000. Comparison of two methods for measuring the impact of metals on benthic communities in a regulated river. Technical Memorandum No. 8220-00-3. U.S. Bureau of Reclamation. Denver.

Nelson, S.M., and R.A. Roline. 1995. Aquatic macroinvertebrate communities and probable impacts of various discharges: Upper Arkansas River. Technical Memorandum No. 8220-95-4. U.S. Bureau of Reclamation. Denver.

Nelson, S.M., and R.A. Roline. 1996a. Results of macroinvertebrate sampling on Lake Fork and some recommendations for monitoring Dinero Tunnel impacts on Lake Fork. Technical Memorandum No. 8220-96-17. U.S. Bureau of Reclamation. Denver.

Nelson, S.M., and R.A. Roline. 1996b. Distribution of aquatic macroinvertebrates in relation to stream flow characteristics in the Arkansas River. Technical Memorandum No. 8220-96-19. U.S. Bureau of Reclamation. Denver.

Nelson, S.M., and R.A. Roline. 2003. Effects of multiple stressors on hyporheic invertebrates in a lake system. Ecological Indicators 3, 65-79.

Nesler, T.P. 1981. Studies of the limnology, fish populations, and fishery of Turquoise Lake, Colorado - 1979-1980. U.S. Bureau of Reclamation Report No. REC-ERC-82-5. Denver.

Nesler, T.P. 1997. Native and introduced fish species by major river basins in Colorado. Nongame and Endangered Aquatic Wildlife Program. Colorado Division of Wildlife.

Nesler, T., L. Finnell,., E. P. Bergersen, L. Walch, J. Griest, D. Krieger, and K. Hamilton. 1993. Chapter 12: Fish populations. In Aquatic ecology studies of Twin Lakes, Colorado 1971-86. Denver: U.S. Government Printing Office.

Nesler, T.P., C. Bennett, J. Melby, G. Dowler, and M. Jones. 1999. Inventory and status of Arkansas River native fishes in Colorado. Final report. Colorado Division of Wildlife.

Plafkin, J.L., M.T. Barbour, K .D. Porter, S .K. Gross, and R .M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA 44/4-89-001. U.S. Environmental Protection Agency.

Policky, G. 1994. 1994 Sampling on Lake Fork between Turquoise Reservoir and Arkansas River confluence, and Arkansas River from Lake Fork downstream to Pueblo Reservoir. (Unpublished fish data from September 1994).

Policky, G. 1998. 1998 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 1999. 1999 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2000. 2000 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2001. 2001 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2002. 2002 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2003. 2003 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2004a. 2004 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. (CPW). 2004b. Personal communication with Don Conklin (CEC) during fish sampling. Leadville, Colorado. August 2004.

Policky, G. (CPW). 2005a. Personal communication with Don Conklin (CEC). May 2005.

Policky, G. 2005b. 2005 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2006. 2006 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2007. 2007 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2008. 2008 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Policky, G. 2009. 2009 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Powell, R. J. 2008. A comparison of species richness of Ephemeroptera, Plecoptera, Trichoptera and Chironomidae in the Arkansas River above and below Pueblo Reservoir after completion of the Arkansas River Fisheries Habitat Restoration (Legacy) Project. Masters Thesis. Colorado State University-Pueblo.

Pueblo Science Associates. 1991. Project report to Roy F. Weston, Inc, Managers, Designers/Consultants. Pueblo, CO.

Ramsay, J.W. 2004. 2004 Fisheries inventories, Lower Arkansas River Basin. Colorado Division of Wildlife.

Ramsay, J.W. 2011. E-mail to Morriah Cowden (GEI Consultants). Unpublished fish stocking data for Lake Henry, Lake Meredith, and John Martin Reservoir. Colorado Division of Wildlife.

Ramsay, J.W. 2012. E-mail to Morriah Cowden (GEI Consultants). Unpublished fish stocking data for Holbrook Reservoir. Colorado Division of Wildlife.

Reclamation (see U.S. Bureau of Reclamation)

Roline, R.A., and J.R. Boehmke. 1981. Heavy metals pollution of the Upper Arkansas River, Colorado, and its effects on the distribution of the aquatic macrofauna. Report No. REC-ERC-81-15. U.S. Bureau of Reclamation. Denver.

Roy F. Weston, Inc. 1995. Final baseline aquatic ecological risk assessment California Gulch NPL site. Report prepared for U.S. Environmental Protection Agency.

Ruse, L.P. and S.J. Herrmann. 2000. Plecoptera and Trichoptera species distribution related to environmental characteristics of the metal-polluted Arkansas River, Colorado. *Western North American Naturalist.* 60:57-65

Ruse, L.P., S.J. Herrmann, and J.E. Sublette. 2000. Chironomidae (Diptera) species distribution related to environmental characteristics of the metal-polluted Arkansas River, Colorado. *Western North American Naturalist.* 60:34-56.

Schisler, G. S. 2000. Whirling disease investigations. Federal Aid Project F-237-R. Colorado Division of Wildlife.

Smith, R.E., and L.M. Hill., eds. 2000. Appendix D. Arkansas River water needs assessment. USDI Bureau of Land Management, USDI Bureau of Reclamation, USDA Forest Service, and Colorado Department of Natural Resources.

Spaulding, S. and L. Elwell. 2007. Increase in nuisance blooms and geographic expansion of the freshwater diatom Didymosphenia geminata: Recommendations for response. U.S. Environmental Protection Agency White Paper, 33 p.

Strayer, D. L. 1999. Effects of alien species of freshwater mollusks in North America. Journal of the North American Benthological Society 18:74-98.

Twomey, K.A., K.L. Williamson, and P. C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: white sucker. FWS/OBS-82/10.64. U.S. Fish and Wildlife Service.

URS Corporation and CDM Inc. 2002. Arid west water quality research project. Habitat characterization study final report. Phoenix.

U.S. Bureau of Reclamation. 1993. Aquatic ecology studies of Twin Lakes, Colorado 1971-86. Effects of a pumped-storage hydroelectric project on a pair of montane lakes. Engineering and Science monograph No. 43. Denver: U.S. Government Printing Office.

U.S. Bureau of Reclamation. 2009. 2009 Upper Arkansas Water Conservancy District temporary excess capacity contract, Fryingpan-Arkansas Project. Environmental Assessment, No. EC-1300-09-02.

U.S. Environmental Protection Agency (EPA). 2008. Arkansas River and Lake Fork fall benthic invertebrate sampling data. (Unpublished data sheets).

USGS (see U.S. Geological Survey)

U.S. Geological Survey. 2001a. 2001 Fountain Creek benthic invertebrate and habitat data (Unpublished data sheets).

U.S. Geological Survey. 2001b. PHABSIM for Windows. Users manual and exercises. Open File Report 01-340.

U.S. Geological Survey. 2002. 2002 Fountain Creek benthic invertebrate and habitat data (Unpublished data sheets).

U.S. Geological Survey. 2003-2009. 2003 through 2009 Fountain Creek fish, benthic invertebrate, and habitat data. (Unpublished data sheets).

U.S. Geological Survey. 2010. 2010 Fountain Creek fish and habitat data. (Unpublished data sheets).

Vaughn, C. C. and D. E. Spooner. 2006. Scale-dependent associations between native freshwater mussels and invasive Corbicula. Hydrobiologia 568:331-339.

von Guerard, P. 1989. Sediment-transport characteristics and effects of sediment transport on benthic invertebrates in the Fountain Creek Drainage Basin upstream from Widefield, Southeastern Colorado, 1985-88. Water-Resources Investigations Report 89-4161. U.S. Geological Survey. Denver.

Wallace, J.B., J.W. Grubaugh, and M. R. Whiles. 1996. Biotic indices and stream ecosystem processes: results from an experimental study. *Ecological Applications* 6:140-151.

Wiederholm. T. 1989. Responses of aquatic insects to environmental pollution. The ecology of aquatic insects, Resh, V. H., and D. M. Rosenberg, eds. New York: Praeger Scientific.

Wilhm, J.L. 1970. Range of diversity index in benthic macroinvertebrate populations. *Journal of Water Pollution Control Federation* 42:R227-R224.

Winters, D.S. 1988. Seasonal relationships between the benthos, invertebrate drift and brown trout predation. Masters Thesis. Colorado State University.

Woodling, J. 1999. 1995, 1998, and 1999 fish sampling data from Arkansas River sites below Pueblo Reservoir. (Unpublished data sheets).

Zuellig, R. E., J. F. Bruce, E. E Evins, and R. W. Stogner. 2008. Urban-related environmental variables and their relation with patterns in biological community structure in the Fountain Creek basin, Colorado, 2003-2005. U.S. Geological Survey Scientific Investigations Report 2007-5225, 24 p.

Zuellig, R. E., J. F. Bruce, and R. W. Stogner. 2010. Temporal change in biological community structure in the Fountain Creek basin, Colorado, 2001-2008. U.S. Geological Survey Scientific Investigations Report 2010-5103, 19 p.

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Appendix H.3 – Aquatic Resources – Environmental Consequences

Introduction

This Draft Environmental Impact Statement (EIS) documents analyses of potential environmental consequences associated with constructing and operating the proposed Arkansas Valley Conduit (AVC), a conveyance contract for the Pueblo Dam north-south outlet works interconnect (Interconnect), and a long-term excess capacity master contract (Master Contract). These facilities and contract are needed to deliver higher quality water, meet existing and future water demands, and provide system redundancy for water deliveries. All alternatives would be part of, or use features of, the Fryingpan-Arkansas Project (Fry-Ark), which is owned by the United States, and operated by the Department of the Interior, Bureau of Reclamation (Reclamation). Because of this, Reclamation is the lead federal agency for the proposed federal actions and preparation of this EIS.

The proposed alternatives would change hydrologic and other conditions in the streams and reservoirs in the Arkansas River Basin and could have effects on aquatic resources. Aquatic resources including fish and invertebrate communities and their habitat are being evaluated as part of the AVC EIS. Modified hydrology or changes to water quality, flood hydrology, channel geomorphology, or riparian vegetation could affect aquatic resources within the analysis area. This Aquatic Resources Environmental Consequences Appendix (Appendix H) was prepared as part of the AVC EIS technical analysis to present the results of the evaluation of potential changes to aquatic resources and to compare results among alternatives. A description of the aquatic resources currently present in the streams and reservoirs in the analysis area is presented in the Aquatic Resources Affected Environment Appendix (Appendix H.2).

Proposed Alternatives

The proposed alternatives would be located in the Lower Arkansas River Basin extending eastward from the Arkansas River at Pueblo Reservoir. As required under NEPA regulations, a Proposed Action and a range of alternatives are being considered in the AVC EIS. The alternatives are No Action, Comanche South, Pueblo Dam South, JUP North, Pueblo Dam North, River South, and Master Contract Only. Alternatives are described in detail in Chapter 2 of the EIS.

Purpose of This Document

The primary purpose of this Aquatic Resources Environmental Consequences analysis is to present the details of the direct, indirect, and cumulative effects on aquatic resources for the alternatives. The information in this environmental consequences appendix is intended to provide sufficient data to support the determination of potential effects in the Affected Environment and Environmental Consequences section of the AVC EIS. The aquatic resources that the alternatives could potentially affect include fish and invertebrate populations and their habitat in the analysis area described below. The alternatives could potentially affect the aquatic environment primarily through changes to hydrologic regimes in the water bodies in the analysis area.

The primary assumption in the Aquatic Resources Environmental Consequences analysis is that fish, benthic invertebrates, and their habitat represent the components of the aquatic environment of interest for the alternatives. Based on public comments received during scoping and discussions with the state and federal agencies, this assumption is appropriate.

This environmental consequences appendix includes the assumption that the alternatives could potentially affect aquatic resources through changes in flow in streams, storage patterns in reservoirs, and/or changes to water quality, flood hydrology, channel geomorphology, or riparian vegetation in the analysis area. The environmental consequences assessment in the EIS for the alternatives focuses on changes in fish and invertebrate species composition and abundance parameters. Therefore, the data presented in this effects analysis focused on these aspects of the aquatic community.

Analysis Area

The analysis area for the Aquatic Resources Environmental Consequences analysis includes water bodies potentially affected by the alternatives because of modified hydrology. Streams potentially affected by altered flow regimes include Lake Fork downstream from Turquoise Lake, Lake Creek downstream from Twin Lakes, the Arkansas River downstream from Lake Fork to the Kansas State Line, and Fountain Creek from Security downstream to its confluence with the Arkansas River in Pueblo (Appendix D.4). Grape Creek, a small tributary to the Arkansas River is also included in the study area. Seven reservoirs could be potentially affected by the proposed project including Turquoise Lake, Twin Lakes, Pueblo, Lake Henry, Lake Meredith, Holbrook, and John Martin reservoirs. These streams and reservoirs are collectively referred to as the analysis area and were described in the Aquatic Resources Affected Environment Appendix (Appendix H.2).

The water bodies in the analysis area were grouped into four general categories: coldwater streams, warmwater streams, coldwater reservoirs, and warmwater reservoirs. Briefly, coldwater streams have water temperatures low enough throughout the year to support trout. In the analysis area this included Lake Fork, Lake Creek, and the Arkansas River upstream from Wildhorse Creek in Pueblo. Warmwater streams have higher water temperatures and include the Lower Arkansas River downstream from Wildhorse Creek and Fountain Creek. Some sections of streams represent transition zones from cold to warmwater fisheries. The Arkansas River from Canon City to Pueblo Reservoir and the Arkansas River from Wildhorse Creek to Fountain Creek represent transition zones. Turquoise and Twin Lakes reservoirs are coldwater reservoirs and support trout, Pueblo Reservoir supports both coldwater and warmwater species, and Lake Henry, Lake Meredith and John Martin reservoirs support warmwater fish communities.

Some portions of the analysis area had extensive data available, resulting from the periodic collection of quantitative samples over a number of years, as summarized in the Aquatic Resources Affected Environment Appendix (Appendix H.2). Other portions of the analysis area had only a few qualitative samples available for the characterization of the fish and invertebrate communities. All portions of the analysis area had adequate data available for describing the aquatic resources of the existing environment (Appendix H.2).

Methods

This analysis evaluated the potential for direct, indirect, and cumulative effects on fish and invertebrate communities in the analysis area. Fish and invertebrate communities are collectively referred to as aquatic resources in this report. The alternatives could have direct and indirect effects on aquatic resources. Most of the effects to aquatic resources would be indirect and long-term, through changes in stream flow or reservoir operation, or the suitability of the stream to support aquatic resources. Direct effects would be temporary and limited to disturbances of short sections of streams during construction.

Biological Evaluation Parameters

An array of commonly accepted parameters was used to characterize the existing conditions of fish and invertebrate communities (Table 1). The parameters used in coldwater streams, warmwater streams, and reservoirs are described below. Assessing the effects of the alternatives, such as changes to species composition, was limited to some extent by the amount and type of data available for the portions of the analysis area with qualitative data on the presence and abundance of species.

Fish Parameters

In coldwater streams, the parameters used in the analysis for fish were the number of species and the density and biomass of self–sustaining and stocked species (Table 1). For most sections of coldwater streams in the analysis area, quantitative sampling provided data on the density and biomass of fish at a sampling site, measured as number or pounds of fish in an acre of stream (#/ac, lbs/ac). Self-sustaining species are fish species that maintain populations through natural reproduction, not through stocking. Self-sustaining fish species can be directly affected by changes in habitat availability and water quality and are the primary focus of this evaluation. Habitat availability can be affected by changes in hydrology, riparian vegetation, channel morphology, etc.

Table 1: Fish and Benthic Invertebrate Parameters Used as Indicators to Characterize Existing Conditions and Evaluate Effects

Water Body Type	Community Parameters	
	Fish	Benthic Invertebrate
Coldwater Streams	• Number of self-sustaining and stocked species • Density and biomass of self-sustaining and stocked species	• Number of species • Density
Warmwater Streams	• Number of self-sustaining and stocked species • Abundance of self-sustaining and stocked species	• Number of species • Abundance
Cold and Warmwater Reservoirs	• Number of self-sustaining and stocked species • Abundance of self-sustaining and stocked species	• Qualitative effects

Stocked fish species are also affected by these factors, but their numbers and population levels are also controlled by decisions on the numbers, size, frequency, timing, and species of fish stocked by the management agencies, such as the Colorado Parks and Wildlife (CPW) and by harvest by recreational anglers. Stocked trout provide the basis for the recreational fishing opportunity in the Arkansas River from Pueblo Reservoir downstream to Wildhorse Creek, thus stocked trout are the primary focus in this segment. In the coldwater streams in the analysis area, the dominant fish species is brown trout (Appendix H.2). A few other species of trout and suckers are also present in lower numbers. CPW stocks rainbow trout in some years in the Upper Arkansas River. The species composition of these streams is stable, with few other species that could potentially become part of the community. Therefore, differences in the number of species, either gains or losses, would be limited to only a few species with any scenario.

In warmwater streams, the parameters used in the analysis for fish were the number and abundance of self-sustaining species (Table 1). For the warmwater streams in the analysis area, qualitative sampling provided data on the relative abundance of fish present at a site; the number of fish per area or length of stream is typically not known. This evaluation focused on potential effects of the alternatives on the number and abundance of self-sustaining fish species. Warmwater streams in the analysis area generally have more fish species than coldwater streams, with a few abundant species and many less common species (Appendix H.2). In addition, CPW has programs to enhance populations of native minnow species in the Lower Arkansas River Basin that include stocking of warmwater species such as suckermouth minnow and plains minnow. Different conditions among alternatives could result in differences of several species.

In reservoirs, the parameters used in the analysis for fish were the same as for warmwater streams - number and abundance of species (Table 1). Fish data from reservoir sampling included qualitative data on the number and kind of fish species collected. All of the existing reservoirs in the analysis area are stocked with fish to support recreational fishing and contain a mixture of a few abundant and many less common self-sustaining and stocked species. In some of the reservoirs, such as Pueblo Reservoir, the species composition is already very diverse with multiple species of self-sustaining and stocked species. It would be difficult to add to the species composition of Pueblo Reservoir because there would not be many new candidate species available. This evaluation focused on the potential effects of the alternatives on the suitability of the reservoirs to support self-sustaining and stocked species of fish.

Benthic Invertebrate Parameters

In coldwater and warmwater streams, the parameters used in the analysis for benthic invertebrates were the number of species present and the abundance of invertebrates (Table 1). The benthic invertebrate data available for the analysis area were collected by a wide variety of methods and included both quantitative and qualitative data (Appendix H.2). Invertebrate communities in streams typically consist of a few abundant species and many less common species.

The abundance of invertebrates is the number of invertebrates that is supported in a given stream reach. For quantitative data in coldwater streams and Fountain Creek, this is usually expressed as density, the number of invertebrates per unit area (usually number per square meter of stream bottom). For qualitative data in warmwater streams, abundance is usually expressed as the number collected per sample. The number of taxa (roughly the number of different species) is available for both quantitative and qualitative data. This parameter is also sometimes referred to as taxa richness.

For the coldwater and warmwater streams in this analysis area, these two benthic invertebrate community parameters are sensitive to changes in habitat availability and water quality. In this analysis, effects on these benthic invertebrate community parameters were evaluated based on the available hydrology and water quality information. There were little or no current benthic invertebrate community data available for most reservoirs in the analysis area, although some historical data were available for Turquoise Lake and Twin Lakes. The environmental consequences analysis qualitatively evaluated potential changes in the invertebrate communities of all the reservoirs in the analysis area.

Simulation Methods

The Physical Habitat Simulation System (PHABSIM) is a component of the Instream Flow Incremental Methodology (IFIM) (Bovee 1982) and was used for evaluating the effects of changes in flow with the alternatives on fish habitat availability in streams in the analysis area. This method along with the best available scientific information and professional judgment was used to evaluate how hydrologic characteristics of the alternatives may affect fish and benthic invertebrate communities in streams. In reservoirs, the effects of changes in reservoir storage patterns over time on aquatic resources were evaluated using the best available scientific information and professional judgment.

PHABSIM and its use were described in greater detail in Appendix H.2. The output of PHABSIM used in this environmental consequences analysis was the simulated habitat versus flow relationships for different species and life stages of fish. This relationship provides habitat availability, expressed as square feet of WUA (weighted useable area of habitat) per 1,000 feet of stream (ft^2/1,000 ft) available over a range of flows. Combining this relationship with simulated flow data for a section of stream, fish habitat availability for existing conditions and the seven alternatives was calculated and evaluated.

PHABSIM data were available from CPW for sections of the Arkansas River between Lake Fork and Cañon City (Bridges et al. 2000) and these relationships were used in the environmental consequences analysis. PHABSIM habitat availability versus flow relationships were developed for the Southern Delivery System (SDS) EIS for the Arkansas River from Pueblo Reservoir downstream to Wildhorse Creek and for several segments in Fountain Creek (Reclamation 2008). These relationships developed for the SDS EIS were also used in the AVC environmental consequences analysis.

GEI Consultants collected supplemental data for developing PHABSIM habitat availability versus flow relationships on the Arkansas River near Nyberg Road in Pueblo County in 2011 to represent the Arkansas River from Fountain Creek downstream from John Martin Reservoir. Based on the species composition present, habitat suitability curves available, and discussions with CPW, sand shiners, red shiners, plains killifish, channel catfish (Conklin et al. 1996), flathead chub (Fannin and Nelson 1986), and white sucker (Twomey et al. 1984) were modeled. Supplemental fish sampling was conducted in 2011 to validate that the habitat suitability curves for these species were appropriate for use in the Lower Arkansas River. Results from this study are included in Appendix H.7.

Segmentation

PHABSIM simulates habitat for specific segments of stream. To provide fish community information that was compatible with effects analysis using PHABSIM, the fish data were organized with respect to PHABSIM segments. Therefore, the fish and benthic invertebrate data in the Arkansas River and Fountain Creek were organized in this report with respect to PHABSIM segmentation. The segmentation used for the Environmental Consequences analysis is the same as that described in the Affected Environment Section of this Appendix (Appendix H.2) (Table 2 and Figure 1) and follows that previously used in the SDS EIS (Reclamation 2008).

Table 2. Summary of PHABSIM Modeling for Streams in the Analysis Area

Stream Segment	Species Simulated	Life Stages Simulated	Basis for Selection
Upper Arkansas River			
Segment 1 – Lake Fork to Granite	Brown and Rainbow Trout	Brown Trout • Adult • Spawning • Fry • Juvenile	Brown trout are the dominant, self-sustaining, resident species with all life stages present.
Segment 2 – Granite to Buena Vista			
Segment 3 – Buena Vista through Browns Canyon			
Segment 4 – Browns Canyon to Coaldale		Rainbow Trout • Adult • Spawning • Fry • Juvenile	Rainbow trout are stocked as juveniles or adults, and are not self-sustaining; the spawning and fry life stages are not present.
Segment 5 – Coaldale to Texas Creek			
Segment 6 – Texas Creek to Cañon City			
Segment 7 Cañon City to Pueblo Reservoir	No PHABSIM Habitat Simulation Available		
Lower Arkansas River			
Segment 1 – Pueblo Reservoir to Wildhorse Creek	Brown and Rainbow Trout	Brown Trout • Adult • Juvenile Rainbow Trout • Adult	Brown and rainbow trout are recreationally important species stocked as juveniles and/or adults, and are not self-sustaining; other life stages are not present.
Segment 2 Wildhorse Creek to Fountain Creek	No PHABSIM Habitat Simulation Available		
Segment 3 – Fountain Creek to John Martin Reservoir	Red Shiner, Sand Shiner, Plains Killifish, Flathead chub, White Sucker, and Channel Catfish	Red Shiner, Sand Shiner, Plains Killifish • Adult	These species and life stages are present in the Arkansas River, have PHABSIM habitat relationships available, and represent the habitat requirements for much of the fish community in this reach.
		Flathead Chub and White Sucker • Adult/Juvenile • Spawning • Fry	
		Channel Catfish • Juvenile/Fry	
Segment 4 John Martin Reservoir to Kansas State Line	No PHABSIM Habitat Simulation Available		
Fountain Creek			
Segment 3 – Security to El Paso-Pueblo County Line	Red Shiner, Sand Shiner, Flathead chub, and White Sucker	Red and Sand Shiner • Adult	These species and life stages are present in the Arkansas River, have PHABSIM habitat relationships available, and represent the habitat requirements for much of the fish community in this reach.
Segment 4 – El Paso-Pueblo County Line to Arkansas River		Flathead Chub and White Sucker • Adult • Spawning • Juvenile/Fry	

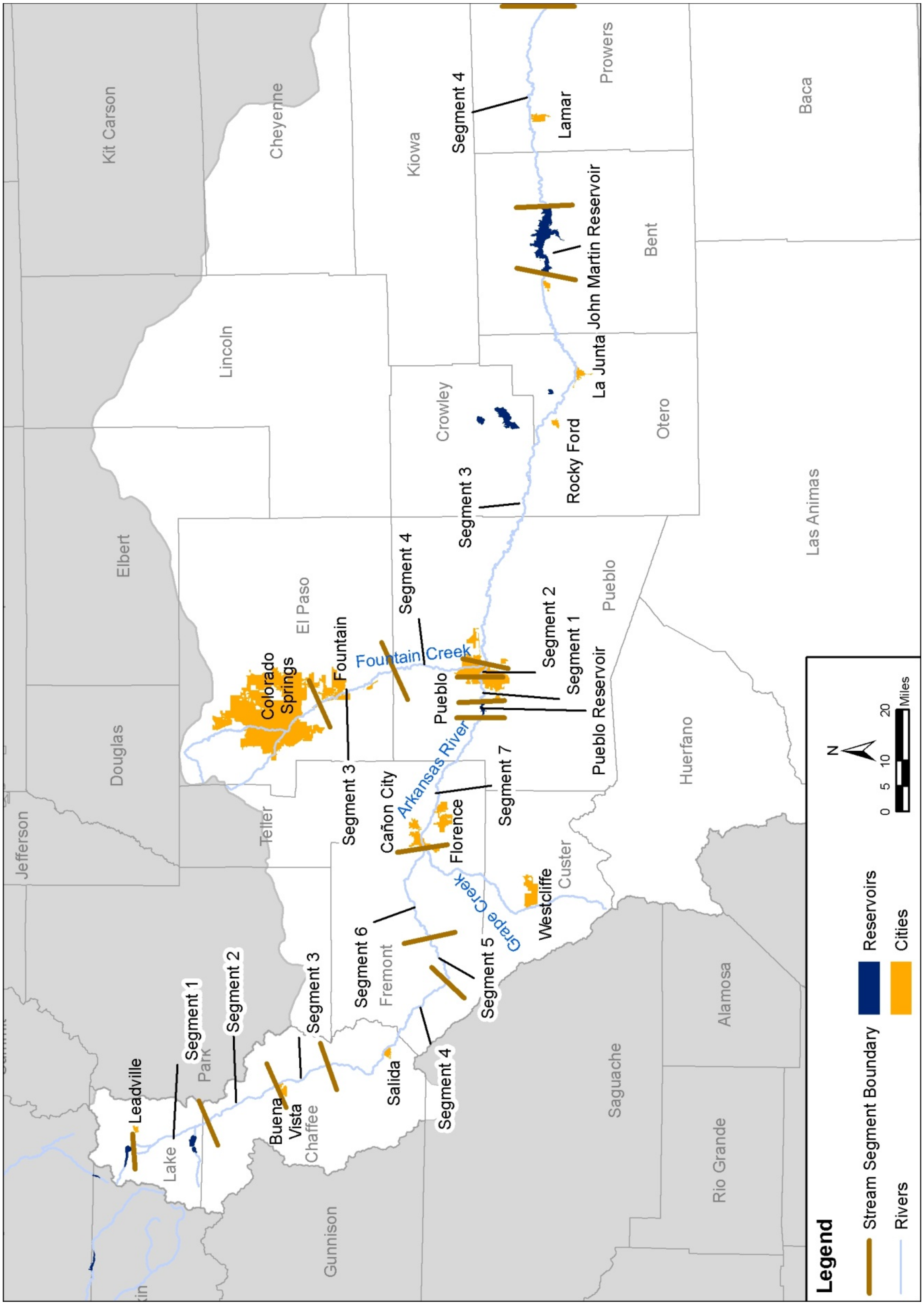

Figure 1. Map of Aquatic Life Analysis Area

Three segments in the analysis area have no PHABSIM habitat simulations available (Table 2). In Upper Arkansas River Segment 7, CPW did not collect PHABSIM data in this portion of the river when the evaluated upstream sections. This segment mostly flows through private property and much of it is inaccessible. Segment 2 of the Lower Arkansas River is short and channelized with limited, degraded habitat for fish and macroinvertebrates and no PHABSIM data were collected in this segment. In the Lower Arkansas River Segment 4, downstream from John Martin Reservoir, flow changes with the alternatives were expected to be minor and it was agreed during agency scoping that a PHABSIM site was not necessary in this segment. These segments are all adjacent to modeled segments and the habitat relationships in the adjacent segments are used to help evaluate project effects.

Life Stages and Periodicity

Fish pass through several life stages during their lives from egg to adult. Habitat simulation information is available for several of these life stages. For example, for brown trout and rainbow trout habitat information is available for spawning, fry, juvenile, and adults. For some of the warmwater fish, habitat information is commonly only available for the adult life stage (Table 2).

Periodicity refers to the time of the year when a life stage is present, and habitat simulations are appropriate. For example, brown trout spawn in fall, and habitat simulations for the spawning life stage are only appropriate for October and November. Simulating habitat for spawning brown trout in spring would be inappropriate and irrelevant to the effects analysis. In Segments 1 through 6 of the Upper Arkansas River, brown trout are self-sustaining and are the dominant species of fish. All life stages of brown trout are present. Juvenile and adult brown trout are present throughout the year, and the periodicity for these two life stages is the entire year. Brown trout eggs hatch into fry in spring and fry are present through the summer. The periodicity for brown trout fry is March through September. For rainbow trout, the populations in Segments 1 through 6 of the Upper Arkansas River are maintained by CPW stocking. However, CPW now stocks a whirling disease resistant strain of rainbow trout at larger sizes and thus expect increased natural reproduction (Policky 2009) (Appendix H.2). Accordingly, adult, spawning, fry, and juvenile life stages of rainbow trout were simulated (Table 2). Adult and juvenile rainbow trout habitat availability was simulated for the entire year, spawning habitat was simulated from March through April, and fry habitat was simulated from May through September.

In Lower Arkansas River Segment 1, from Pueblo Reservoir to Wildhorse Creek, brown and rainbow trout are maintained by stocking. Brown trout are stocked as fingerlings (juveniles) and grow to adults. Habitat for these two life stages was simulated throughout the year. CPW currently stocks cacheable-size (adult) rainbow trout in this section of the Arkansas River. Therefore, habitat was simulated for adult rainbow trout throughout the year (Table 2).

In the Lower Arkansas River Segment 3, from Fountain Creek downstream to John Martin Reservoir, sand shiner, red shiner, plains killifish, channel catfish, flathead chub, and white sucker maintain self-sustaining populations (Table 2). These species are not stocked. Only information for the adult life stage of sand shiner, red shiner, and plains killifish and the juvenile/fry life stage of channel catfish was available for habitat simulation. Simulations for these species were run throughout the year. Flathead chub information was available for spawning and fry life stages and a combined juvenile/adult life stage (Fannin and Nelson 1986). Flathead chub spawn in late spring, thus, habitat was simulated for May 15 through June. The fry life stage was simulated for June through October. The juvenile/adult life stage is present throughout the year and habitat was simulated for the entire year. For white sucker, information was available for spawning, fry, and adult life stages. Suckers spawn in spring, thus, habitat for the spawning life stage was simulated for March, April, and May. The fry life stage was simulated for May through September. Habitat for the adult life stage of white suckers was simulated throughout the year.

In Fountain Creek, habitat availability versus flow relationships for sand shiner, red shiner, flathead chub, and white sucker developed for the SDS EIS were modeled for the alternatives (Table 2). The same periodicity was used in Fountain Creek as for the Lower Arkansas River Segment 3.

Relevant Parameters

Habitat was simulated for normal (2005), dry (2004), and wet (1997) years using daily flow as the time step for each species and life stage, given the periodicity described above. Fish populations are generally influenced by extremes in flow and habitat conditions, which can act as a bottleneck to limit population size. The timing and magnitude of minimum habitat periods are important factors in regulating fish population size (Bovee et al. 1994). Therefore, the change in minimum habitat availability for each species and life stage for each year type (normal, dry, or wet) for alternatives compared to the No Action Alternative was evaluated (Appendix H.5). With PHABSIM, the minimum habitat availability is usually a function of the 1-day maximum or 1-day minimum flow in a year. The changes in median habitat availability were also evaluated as a measure of the overall change in habitat availability. Sufficient flows are needed to support both cold and warmwater fisheries. Thus, when appropriate, the number of low flow days among alternatives and existing conditions were evaluated. Results are also presented for the change in minimum and median habitat availability for alternatives compared to existing conditions (Appendix H.6).

Limitations of PHABSIM

PHABSIM was developed in the late 1970's and early 1980's as a method for evaluating the consequences of water withdrawal and storage on fish populations in streams (Bovee et al. 1994). It is widely used in the U. S. (Reiser et al 1989), but there are many concerns about its use (Orth and Maughan 1982; Mathur et al. 1985; Orth and Maughan 1986; Mathur et al. 1986; Scott and Shirvell 1987; Armour and Taylor 1991; Bovee et al. 1994). The use of PHABSIM assumes that the size of a fish population in a stream is directly related to habitat availability as simulated by PHABSIM. A basic criticism of PHABSIM is that direct relationships between modeled habitat availability (WUA) and fish density or biomass have been demonstrated only rarely. Other factors, such as food availability, water quality, species interactions, instream cover, different habitat use between day and night or between seasons, etc. may also be affecting fish populations and are not usually accounted for with PHABSIM.

There are also two factors to consider with the specific use of PHABSIM for this project. The first is that the habitat relationships developed by the CPW for the Upper Arkansas River simulated habitat in some segments up to 1,300 to 1,400 cfs while the hydrology data indicate that peak flows reach over 2,000 cfs in some segments. Similar scenarios occur in the Lower

Arkansas River where some daily peak flows exceed the flows simulated for habitat availability. In order to simulate habitat availability at the higher flows, habitat relationships were extrapolated. However, because the high flow periods often represent low habitat availability, and may represent the minimum habitat availability in a year, the analysis is based on extrapolated information in these cases. However, the minimum habitat availability may also occur during periods of low flow, which can provide useful information. Furthermore, evaluation of median habitat availability incorporates the habitat availability over the entire year, limiting the influence of the extrapolated data on this metric. The second factor is that data collection for PHABSIM in Fountain Creek and in the Lower Arkansas River Segment 3 was complicated by the unstable nature of the stream. PHABSIM data collection and habitat simulation is most reliable for stream channels that are stable over a wide range of flows. The shifting sand substrate and unstable banks were a limitation on the data collection and overall quality of the PHABSIM simulations for these stream segments.

Despite these limitations, the use of PHABSIM for effects evaluation for this project is appropriate for several reasons. The differences among alternatives for aquatic resources are differences in flow, which can be easily modeled with PHABSIM, and all alternatives were evaluated with the same tool. Also, variability in fish populations in most cases is related to variability in habitat; with other factors such as food and interactions between species being important in fewer cases (Hall and Knight 1981). Finally, these other factors, such as food, species interactions, and seasonal habitat differences, would not be directly influenced by the differences in hydrology among alternatives, although they may be indirectly influenced and this was noted when appropriate.

Simulated Hydrology

For the purposes of evaluating the relative effects of the seven alternatives with PHABSIM, simulated hydrology for direct effects and cumulative effects as described in the Surface Water Daily Hydrologic Model Results (Appendix D.4) was used. Fish habitat availability was simulated with PHABSIM for normal (2005), dry (2004), and wet (1997) years using daily flow as the time step. Normal, dry, and wet years are explained in more detail in the Surface Water Daily Hydrologic Model Results (Appendix D.4).

The hydrology in the streams and reservoirs in the analysis area is regulated for a number of different uses and is described in Chapter 3 – *Surface Water Hydrology*. Thus, the hydrology has been altered and does not always follow the seasonal patterns in the streams and natural lakes that were present prior to settlement.

Approach to Environmental Consequences Analysis

Using the simulated hydrology for alternatives as described in the Surface Water Daily Model Results (Appendix D.4), differences in hydrology and the effects to fish habitat availability among the alternatives were evaluated with PHABSIM. Tables were produced for each species, life stage, year type, and segment evaluating the percent change in minimum and median habitat availability for the alternatives compared to the No Action Alternative (Appendix H.5). The daily habitat availability and hydrology for each year type for all streams in the analysis area were also plotted as a qualitative evaluation technique to further assess the biological significance of the differences in hydrology among the alternatives.

Corresponding analyses depicting the change in habitat availability and hydrology compared to existing conditions were conducted and are presented in Appendix H.6. Evaluations of changes in hydrology and habitat availability of the No Action Alternative compared to existing conditions are included in the cumulative effects section of this appendix when relevant to further characterize the magnitude of effects.

For minimum and median percent change calculations, the percent change was calculated as the value of the difference of the parameter for any alternative compared to the No Action Alternative, divided by the value for the No Action Alternative. A difference in any parameter of 10 percent or greater was used to indicate that aquatic resources may be potentially affected and warranted further analysis. Differences in parameters of less than 10 percent would be unlikely to result in adverse or beneficial effects on aquatic biota due to the natural variability in the hydrological and biological data, which would result in differences less than 10 percent being undetectable. Consequently, changes in parameters of less than 10 percent were considered to have a negligible effect on aquatic resources and were not discussed further. Differences in parameters of 10 percent or greater were further evaluated in the direct effects and cumulative effects sections of this appendix. These changes may or may not result in effects on aquatic biota, depending upon the specific circumstances in each stream segment or reservoir and each hydrologic scenario as discussed in our evaluation.

Fish and benthic invertebrate communities naturally fluctuate from year to year from the influences of factors such as weather and flow conditions. Fluctuations in trout populations can be as much as 100 percent between years, and even in relatively stable populations can be 50 percent of the average (Hall and Knight 1981). The fluctuations in population parameters for fish and invertebrates in the analysis area are substantial under existing conditions (Appendix H.2). For example, at the Empire Gulch Site on the Upper Arkansas River near Leadville, brown trout biomass during fall sampling varied from 37 to 119 lbs/ac from 1994 to 2009 (Appendix H.2). At the Smith Ranch Site near Leadville, biomass varied from 51 to 254 lbs/ac over this period (Appendix H.2). Benthic macroinvertebrate density in Segment 3 of Fountain Creek varied from 30 to 8,851 invertebrates per square meter and the number of species varied from 4 to 56 in fall samples from 1996 to 2009. This variability should be taken into account in impact studies (Hall and Knight 1981). Therefore, it is unlikely that a change of less than 10 percent in any single parameter would result in a change in fish or invertebrate communities that can be distinguished from the natural background variability.

Specific responses of aquatic resources to changes in fish habitat availability parameters have not been developed in general and not for this analysis area in particular. However, the general, anticipated responses to these variables, either beneficial or adverse, are described in the results. Trends of several parameters for several species, life stages, and year types all indicating a consistent direction of effect (beneficial or adverse) were given more weight than conflicting parameters. These factors were considered when evaluating the effects of the alternatives on fish and invertebrate communities in the analysis area. This environmental consequences analysis focuses on fish communities as a whole. Some of the warmwater streams are used by special status fish species, including Arkansas darter (State Threatened), southern redbelly dace (State Endangered), suckermouth minnow (State Endangered), plains minnow (State Endangered), and flathead chub (state species of special concern). Any effects to special status species that would be different than effects to the community as a whole were noted as appropriate.

The environmental consequences analysis focuses on changes in fish habitat availability using PHABSIM results. Relationships between flow changes and changes to macroinvertebrate communities are difficult to quantify. Macroinvertebrate communities usually contain several dozen species with a wide range of habitat preferences making modeling (such as with PHABSIM) difficult. There can be both beneficial and adverse changes to macroinvertebrates from changes in flow (Dewson, et al 2007). Therefore, effects to macroinvertebrates were evaluated using professional judgment based on the best available scientific information.

Other Resources

The suitability of a stream to support aquatic resources is also influenced by other aspects of habitat and water quality. Flooding, channel geomorphology, sediment transport, water quality and riparian vegetation have an influence on fish and macroinvertebrate habitat suitability. Therefore, the results of the Chapter 4 – *Surface Water Hydrology, Water Quality, Geomorphology,* and *Vegetation and Wetlands* sections of the EIS were also incorporated into the evaluation of effects on aquatic resources using professional judgment. However, direct, indirect, and cumulative effects to vegetation and wetlands, and geomorphology are expected to be negligible to minor for all alternatives and thus are not discussed further in this section. Some direct and cumulative effects to water quality were identified in Chapter 4 – *Water Quality* section of the EIS and these effects were incorporated into the environmental consequences evaluation for aquatic resources when appropriate.

Interpretation of Effects

Effects to aquatic resources could be negligible, beneficial, or adverse. A negligible effect would result in no detectable differences between alternatives in the number and abundance of fish and invertebrate species (Table 3). Differences in habitat availability and hydrologic parameters of less than 10 percent would be unlikely to result in adverse or beneficial effects on aquatic biota, because natural variability in hydrologic and biological data renders a change of less than 10 percent undetectable. If a difference in the parameters was more than 10 percent, the change was graded as minor, moderate, or major according to professional judgment.

Beneficial and adverse effects could vary in intensity from minor to moderate or major (Table 3). The intensity of effects was evaluated on a case-by-case basis for each stream segment and reservoir using professional judgment, given the PHABSIM output, hydrology, storage contents, other resources, and the status of the existing environment. For the PHABSIM output and hydrology, daily, monthly, wet, dry and normal year types, as well as overall annual and monthly changes were considered. As a result, changes in some individual days, months, or individual year types may warrant a greater or lesser effect intensity designation than the effect based solely on the overall average. Guidelines for determining minor, moderate, and major effects are described in detail in Table 3.

Table 3. Aquatic Resources Effect and Intensity Description

Effect Intensity	Intensity Description
Negligible	Changes in fish habitat availability and hydrologic parameters would be mostly less than 10%. The alternative would result in a slight change to a fish and benthic macroinvertebrate community, but the change would not be of measurable or perceptible consequence, and would be well within natural variability.
Minor	Changes in fish habitat availability and hydrologic parameters would be more than 10%. The alternative would result in a change to a fish and benthic macroinvertebrate community. The change would be measurable, but small and not outside the range of natural variability. There would be no change in species composition for fish and little change in species composition for benthic macroinvertebrates.
Moderate	Effects on the abundance of fish and benthic macroinvertebrates, their habitat, or the natural processes sustaining them would be detectable and readily apparent and sometimes out of the historic range of natural variability. In coldwater streams and reservoirs there likely would be no change in fish species composition. In warmwater streams and reservoirs there likely would be changes in the number of less common fish species. For benthic macroinvertebrates there would be changes in the number of species.
Major	The alternative would result in a substantial and readily apparent effect to abundance and species composition of the fish and benthic macroinvertebrate communities outside of the range of natural variability.

Results

The direct, indirect, and cumulative effects of alternatives on aquatic resources are compared in this section for various geographic locations.

Direct and Indirect Effects

As mentioned, most effects to aquatic resources would be indirect and long-term, through changes in streamflow or reservoir operation, or suitability of streams to support aquatic resources. Direct effects would be short-term and limited to disturbances of short sections of streams during construction.

Upper Arkansas River Basin – Arkansas River Segments 1 through 7, Lake Fork, Lake Creek, and Grape Creek

In Lake Fork and Lake Creek, changes in the overall average streamflow would result in an increase or decrease of 1 cfs depending on the alternative, which corresponds to a percent change of -0.5 to 5.6 percent (Appendix D.4, Tables 38 and 46). The simulated mean monthly streamflow result in little to no change for most months and most alternatives compared to the No Action Alternative in Lake Fork and Lake Creek (Appendix H.5, Figures 1 and 2). The greatest changes in hydrology from the No Action Alternative would occur during May and June in Lake Fork and changes would be more variable in Lake Creek (Appendix D.4, Tables 38 and 46). Overall, these changes in hydrology from the No Action Alternative would result in negligible changes to aquatic resources in Lake Fork and Lake Creek for all alternatives.

The effects of the alternatives on average monthly streamflow at Upper Arkansas River gages would be negligible for most months and minor for remaining months (Chapter 4 – *Surface Water Hydrology*). Furthermore, changes to daily hydrology would be minimal in the Upper

Arkansas River in most stream segments during most times of the year (Appendix H.5, Figures 3 through 8). Effects to water quality, geomorphology, and riparian vegetation would be negligible for all alternatives (Chapter 4 – *Water Quality*, *Geomorphology*, and *Vegetation and Wetlands*).

In segments 1 through 6 of the Upper Arkansas River, direct effects to changes in hydrology would be small compared to the No Action Alternative, resulting in similar habitat availability for all brown trout and rainbow trout life stages among alternatives (Table 4; Appendix H.5, Figures 9 through 44). Changes in daily flow from the No Action Alternative generally would be less than 10 percent for all alternatives in segments 1 through 6 (Appendix H.5, Figures 3 through 8). Several exceptions would occur for some alternatives, including increases and decreases in flow from the No Action Alternative up to approximately 60 percent in January and April of wet years in most Upper Arkansas River stream segments. These changes would be short in duration and the decreases result in similar low flows to those observed during other times during the pre-runoff period, such as in February.

Overall, the changes in minimum and median habitat availability for brown trout and rainbow trout life stages, as well as the changes to habitat availability on a daily basis (Appendix H.5, Figures 9 through 44), including during the most important pre- and post runoff periods for evaluating trout habitat availability identified by CPW, would be minimal. The average change in the minimum and median habitat availability for all life stages of brown trout and rainbow trout for Upper Arkansas River Segments 1 through 6 would be within 2 percent for each year type (Table 4). The range (minimum to maximum) of the percent changes in minimum trout habitat availability was between a 12 percent decrease for spawning brown trout and a 5 percent increase for spawning rainbow trout. The percent change in the minimum habitat availability for brown trout and rainbow trout life stages would be generally less than 5 percent and often less than 2 percent (Table 4; Appendix H.5, Tables 1, 3, 5, 7, 9, and 11). The range of the percent change in median trout habitat availability for segments 1 through 6 was between a 6 percent decrease in habitat availability for spawning rainbow trout in Segment 4 and a 5 percent increase in habitat availability for adult rainbow trout in Segment 5 (Table 4; Appendix H.5, Tables 2, 4, 6, 8, 10, and 12).

For macroinvertebrates, the minimal changes to hydrology indicate that the area of the stream bottom (wetted perimeter) available to support these species would not change substantially with the alternatives. The negligible effects to water quality and geomorphology indicate that these components would not affect the suitability of the streams to support macroinvertebrates.

The small changes to habitat availability and the negligible effects to water quality, geomorphology, and riparian vegetation indicate that effects to aquatic resources in the Upper Arkansas River Segments 1 through 6 would be negligible compared to the No Action Alternative.

Table 4. Effects Summary for the Upper Arkansas River Segments 1 through 6 of the Percent Change in Minimum and Median Habitat Availability for All Alternatives Compared to the No Action Alternative for Normal, Dry, and Wet Years

Species/ Life Stage	Percent Change in Minimum WUA						Percent Change in Median WUA					
	Normal		Dry		Wet		Normal		Dry		Wet	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Brown trout												
adult	-0.5	-9 to 1	0.3	-1 to 1	-1.5	-11 to 2	-0.4	-1 to 1	0.3	-1 to 1	-1.0	-5 to 1
spawn	-0.3	-1 to 0	-1.8	-12 to 2	-1.1	-4 to 1	-0.2	-1 to 1	0.0	-1 to 1	0.0	-1 to 1
fry	0.4	-1 to 2	0.8	-1 to 4	-1.5	-11 to 2	0.2	-1 to 2	0.5	-1 to 3	-0.1	-4 to 2
juvenile	-0.5	-9 to 1	0.3	-1 to 1	-1.5	-11 to 2	-0.4	-2 to 1	0.3	-1 to 1	-0.3	-1 to 1
Rainbow trout												
adult	-0.5	-9 to 1	0.3	-1 to 1	-1.5	-11 to 2	-0.1	-2 to 2	0.4	-1 to 1	-1.1	-5 to 5
spawn	1.0	0 to 3	0.4	-1 to 3	1.1	-1 to 5	0.7	-1 to 4	0.5	-1 to 4	0.1	-6 to 2
fry	0.4	-1 to 2	0.9	-1 to 4	-1.5	-11 to 2	-0.2	-2 to 2	0.1	-1 to 1	0.1	-1 to 2
juvenile	-0.5	-9 to 1	0.5	-1 to 3	-1.5	-11 to 2	-0.5	-2 to 1	0.1	-1 to 1	-0.3	-1 to 1

No PHABSIM relationships are available for Segment 7; however, evaluation of daily flow data for the alternatives at the Arkansas River at Portland gage demonstrate similar flows among alternatives and similar changes in hydrology to upstream segments (Appendix H.5, Figures 3 through 8). The percent change in flow from the No Action Alternative generally would be less than 10 percent. Several exceptions occurred for multiple alternatives, including decreases in flow from the No Action Alternative up to 40 percent in January and April of wet years. These decreases would be short in duration and result in similar low flow values to those observed during other times during the pre-runoff period, such as in February. Overall, the similar changes in hydrology from the No Action Alternative as the changes in hydrology in segments 1 through 6 indicate that changes to aquatic resources would be negligible in Segment 7.

The effects on the hydrology of Grape Creek from agricultural dry-up associated with the alternatives would be negligible (Chapter 4 – *Surface Water Hydrology*). No change in hydrology would occur between the alternatives with the No Action Alternative, because all alternatives including the No Action Alternative simulate the transfer of water from the agricultural dry-up (Appendix D.5). Accordingly, the alternatives would result in negligible changes to the aquatic resources in Grape Creek compared to the No Action Alternative.

The No Action Alternative would result in similar hydrology (Appendix D.4) and habitat availability (Appendix H.6, Figures 3 through 8) in the Upper Arkansas River Basin as for existing conditions. Habitat availability in segments 1 through 6 of the Upper Arkansas River would change less than 10 percent for most species, life stages, and year types for the No Action Alternative compared to existing conditions (Appendix H.6, Tables 1 through 12). Habitat availability was not simulated for Lake Fork, Lake Creek, or Segment 7 of the Arkansas River; however, given the small changes in flow, similar changes in habitat of less than 10 percent would be expected between the No Action Alternative and existing conditions. These changes in hydrology for the No Action Alternative would result in a negligible effect to aquatic resources compared to existing conditions for Lake Fork, Lake Creek, and the Upper Arkansas River.

In Grape Creek, increases in flow up to 7 cfs (up to 52 percent increase during dry years) would occur during summer months for the No Action Alternative compared to existing conditions (Appendix D.5), which would likely result in a minor beneficial effect to aquatic resources in Grape Creek.

Lower Arkansas River – Segment 1, Pueblo Reservoir to Wildhorse Creek

Changes to average monthly streamflow in the Lower Arkansas River Segment 1 for the alternatives compared to the No Action Alternative would be negligible to minor, with minor effects occurring especially between August and March (Chapter 4 – *Surface Water Hydrology*). Moderate effects to hydrology (reductions greater than 10 percent) were simulated in January and March of normal years and February through April of dry years for most alternatives. In dry years, flows of approximately 50 cfs during the typical low flow period in early March would be extended from just a few days to more than a week (Appendix H.5, Figure 45) but the single-day minimum flow during this period would change by less than 3 cfs for most alternatives, resulting in similar minimum habitat availability.

The effects of the alternatives to fish habitat availability would vary depending on the species, life stage, and year type assessed. However, for most of the year, the simulated changes in habitat availability among the alternatives would be small (Appendix H.5, Figures 46 to 48). Percent changes in brown trout minimum and median habitat availability would be greatest in magnitude during normal years (Table 5). Minimum adult and juvenile brown trout habitat availability would increase during normal years between 14 and 28 percent for all alternatives except Master Contract Only (Table 5; Appendix H.5, Table 13), because of an increase in flow from 39 cfs to between 44 and 50 cfs. This increase in the minimum flow would occur for only one day and likely would not have a noticeable effect on aquatic resources. Median adult habitat availability would decrease between 4 and 9 percent for all alternatives during normal years (Table 5; Appendix H.5, Table 14). Changes to habitat availability for adult and juvenile brown trout would be less than 8 percent in dry and wet years (Table 5; Appendix H.5, Tables 13 and 14). Rainbow trout minimum and median adult habitat availability would vary less than 1 percent for all alternatives and year types (Table 5; Appendix H.5, Tables 13 and 14).

Similar to the habitat availability for fish, minimum habitat availability for macroinvertebrates is not expected to change substantially. The low flow period likely represents the minimum amount of stream bottom to support macroinvertebrates. Although the length of the minimum flow period would be extended for a few more days, the absolute minimum flow would not change and there likely would be no change in the minimum habitat on the stream bottom for macroinvertebrates.

All alternatives except River South and Master Contract Only would result in negligible to minor adverse effects to water quality through the City of Pueblo (Chapter 4 – *Water Quality*) with occasional moderate effects in dry years as a result of increases in salinity and selenium in this stream reach. The River South and Master Contract Only alternatives would have no effect on water quality.

Table 5. Effects Summary of the Percent Change in Minimum and Median Habitat Availability in Normal, Dry, and Wet Years For All Alternatives Compared to the No Action Alternative for Brown and Rainbow Trout, Lower Arkansas River Segment 1

Species/Life Stage	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Percent Change in Minimum Habitat Availability Compared to No Action Alternative							
Normal year							
Brown trout							
adult	--	15	15	28	14	23	3
juvenile	--	15	15	28	14	23	3
Rainbow trout							
adult	--	-<1	-<1	-<1	-<1	<1	<1
Dry Year							
Brown trout							
adult	--	-5	-5	-6	-5	8	7
juvenile	--	-5	-5	-6	-5	8	7
Rainbow trout							
adult	--	-<1	-<1	-<1	-<1	<1	-<1
Wet Year							
Brown trout							
adult	--	0	0	0	0	0	0
juvenile	--	-<1	-<1	-<1	-<1	-1	-1
Rainbow trout							
adult	--	-<1	-<1	-<1	-<1	-1	-1
Percent Change in Median Habitat Availability Compared to No Action Alternative							
Normal Year							
Brown trout							
adult	--	-9	-8	-4	-8	-5	-5
juvenile	--	-2	-1	-1	-2	<1	-<1
Rainbow trout							
adult	--	<1	<1	<1	<1	-<1	<1
Dry Year							
Brown trout							
adult	--	-5	-5	-3	-5	-1	-3
juvenile	--	-2	-2	-<1	-2	-<1	-<1
Rainbow trout							
adult	--	<1	<1	<1	<1	<1	<1
Wet Year							
Brown trout							
adult	--	-<1	-<1	<1	-<1	-<1	-<1
juvenile	--	<1	-<1	<1	-<1	-<1	-<1
Rainbow trout							
adult	--	<1	<1	<1	<1	-<1	-<1

Salinity levels in this segment of the Arkansas River are well below levels that would have harmful effects to fish and macroinvertebrates. The macroinvertebrate species present in this segment of the river include many tolerant midges, mayflies, and caddis flies with salinity toxicity thresholds several times higher than now exist in the river (EPA 2011). The minor changes in salinity would not affect the fish and macroinvertebrate communities. Selenium concentrations in water are a poor predictor of toxicity to aquatic organisms as sediment and food chain effects are more important (Canton and Van Derveer 1997). This segment of the river and the existing fish and macroinvertebrate populations already experience naturally high selenium concentrations with occasional exceedences of the selenium standard and substantial seasonal variations with existing conditions. Other nearby streams in the Arkansas Basin support native fish and macroinvertebrate communities with considerably higher selenium concentrations than those in this segment of the Arkansas River (Van Derveer and Canton 1997). Additional occasional exceedences in dry years are not likely to affect aquatic resources in this segment. Overall, the small changes to hydrology, habitat availability, and water quality would likely result in negligible effects to fish and macroinvertebrates in this segment for all alternatives.

Changes to hydrology for the No Action Alternative compared to existing conditions in the Lower Arkansas River Segment 1, would result in a 22 percent decrease in minimum habitat availability for adult and juvenile brown trout in normal years and an 11 and 10 percent decrease in minimum habitat availability during dry years (Appendix H.6, Table 13), due to decreases in the minimum flow. The remaining comparisons between the No Action Alternative and existing conditions for minimum and median brown trout and rainbow trout habitat availability would result in changes of less than 10 percent (Appendix H.6, Table 14). The number of low flow days (less than or equal to 10 cfs) would be similar between the No Action Alternative and existing conditions. The minimum flow was 50 cfs for existing conditions and occurred on 35 days during normal years. For each of these days, the simulated flow for the No Action Alternative was equal to 50 cfs or greater. The decreases in minimum habitat availability would occur because of decreases in flow for one day (March 17th), from 100 to 39 cfs during normal years and 117 to 47 cfs for dry years. Given that the low flow would occur on only one day and the 35 days of low flow conditions for existing conditions would remain similar (and in some cases flows increase) under the No Action Alternative, the decrease in minimum habitat availability for both fish and macroinvertebrates would not likely affect the aquatic resources. Thus, a negligible effect to aquatic resources would occur for the No Action Alternative compared to existing conditions.

Lower Arkansas River – Segment 2, Wildhorse Creek to Fountain Creek

Habitat availability was not simulated for this short, channelized section of the Lower Arkansas River, Segment 2. The fish community present is largely comprised of warmwater species. The water quality effects in this section of river would be similar to those described upstream from Wildhorse Creek (Chapter 4 – *Water Quality*). Simulated flows in this section of the Lower Arkansas River would be similar among alternatives, including compared to the No Action Alternative during most times of the year (Appendix H.5, Figure 49). Sufficient flows are needed to support the warmwater fish and macroinvertebrate communities present in this reach. All alternatives would result in one additional low flow day (<10 cfs) compared to the No Action Alternative in either normal (from 1 to 2 days) or dry years (from 3 to 4 days) during the typical low flow period in late winter and early spring. The addition of one low flow day in this segment, which is already dewatered for at least one day during normal and dry years for existing conditions would likely result in negligible effects for all alternatives compared to the No Action Alternative.

Changes to hydrology for the No Action Alternative compared to existing conditions, in the Lower Arkansas River Segment 2 would result in similar hydrology during most times of the year (Appendix H.6, Figure 49). Two additional low flow days (<10 cfs) are simulated during dry years for the No Action Alternative. The number of low flow days would be one for both existing conditions and the No Action Alternative during normal years and zero low flow days occur during dry years. The two additional low flow days during dry years would likely result in a negligible effect to aquatic resources in Segment 2 of the Lower Arkansas River for the No Action Alternative.

Lower Arkansas River – Segment 3, Fountain Creek to John Martin Reservoir

Direct effects to mean monthly streamflow would result in negligible to minor decreases for most months for all alternatives compared to the No Action Alternative at the Arkansas River near Avondale gage (Appendix D.4). Changes to daily flow would be similar for all alternatives compared to the No Action Alternative during most times of the year (Appendix H.5, Figure 50).

The negligible to minor changes in flow at the Arkansas River near Avondale gage, would result in similar macroinvertebrate habitat availability and fish habitat availability among all alternatives for most species, life stages, and year types (Appendix H.5, Figures 51 to 59). The effects of changes in minimum and median fish habitat availability in Segment 3 of the Lower Arkansas River would be generally less than or equal to 5 percent and were often less than 1 percent (Table 6). The only exceptions would occur for white suckers for most alternatives and year types and for flathead chub for the JUP North Alternative during wet years, where minimum and median habitat availability increase 16 and 6 percent, respectively (Table 6; Appendix H.5, Tables 15 and 16). Reductions in minimum habitat availability during dry years range from 9 to 13 percent for white sucker adults and from less than 1 to 6 percent for white sucker fry for all alternatives. During wet years, white sucker minimum habitat availability would increase from 6 to 19 percent for all alternatives.

Similar but smaller reductions in median habitat availability were simulated for white sucker adults during normal and dry years (Table 6; Appendix H.5, Tables 15 and 16). Habitat availability for white sucker adults would be low in the Lower Arkansas River Segment 3 for all flows, compared to most species. Thus, small changes in habitat availability would result in a larger percent change for white suckers compared to species with more available habitat.

All alternatives would have negligible to minor adverse effects to salinity, selenium, sulfate, and uranium concentrations in this segment of the Arkansas River near Avondale gage with moderate increases in salinity and selenium in a few normal and dry year months (Chapter 4 – *Water Quality*). Salinity, sulfate, and uranium effects would decrease downstream. Overall, the effects from changes to hydrology would result in only small changes to water quality and to habitat availability for macroinvertebrates and most fish species, life stages, and year types, which would result in negligible changes to aquatic resources.

Table 6. Effects Summary of the Percent Change in Minimum and Median Habitat Availability For All Alternatives Compared to the No Action Alternative for White Sucker, Flathead Chub, Sand Shiner (Adult), Red Shiner (Adult), Plains Killifish (Adult), and Channel Catfish (Juvenile/Fry), Lower Arkansas River, Segment 3. Values Represent the Minimum and Maximum Values for Normal, Dry, and Wet Years

Species/ Life Stage	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Percent Change in Minimum WUA							
Normal, Dry, and Wet Years (Min, Max)							
White sucker							
adult/juvenile	--	-12, 19	-11, 11	-11, 6	-11, 11	-9, 11	-13, 9
spawning	--	<1, 3	<1, 3	<1, <1	<1, 3	<1, 3	-<1, 3
fry	--	-6, <1	-6, <1	-6, <1	-5, <1	-4, <1	-2, -<1
Flathead chub							
adult/juvenile	--	-5, <1	-5, <1	<1, 16	-5, <1	-5, <1	-5, <1
spawning	--	-<1, 3	-<1, 2	-<1, 3	-<1, 3	-<1, 3	-<1, 1
fry	--	<1, 2	<1, 2	<1, 2	<1, 2	<1, 2	<1, 1
Sand shiner	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1
Red shiner	--	<1, <1	<1, <1	<1, <1	<1, <1	<1, <1	-<1, <1
Plains killifish	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1
Channel catfish	--	-2, 3	-2, 2	-<1, 3	-2, 3	-2, 3	-1, 1
Percent Change in Median WUA							
Normal, Dry, and Wet Years (Min, Max)							
White sucker							
adult/juvenile	--	-8, <1	-8, <1	-9, -<1	-8, <1	-8, <1	-7, <1
spawning	--	-<1, 2	<1, 2	-<1, 1	-<1, 3	-<1, 2	-<1, 1
fry	--	-<1, 1	-<1, 2	<1, 2	-<1, 2	-<1, 2	-<1, <1
Flathead chub							
adult/juvenile	--	-<1, -<1	-<1, -<1	-<1, -<1	-<1, -<1	-<1, -<1	-<1, <1
spawning	--	-3, 4	-3, 4	2, 6	-3, 4	-3, 4	-2, <1
fry	--	<1, 5	<1, 5	-<1, 2	<1, 4	<1, 2	-<1, <1
Sand shiner	--	<1, 2	<1, 2	<1, 3	<1, 2	<1, 2	<1, 2
Red shiner	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1
Plains killifish	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, -<1
Channel catfish	--	<1, 1	<1, 1	-<1, <1	<1, 1	-<1, <1	<1, 1

Changes to hydrology for the No Action Alternative compared to existing conditions in the Lower Arkansas River Segment 3, generally would result in changes in habitat availability less than 10 percent for most fish species (Appendix H.6, Tables 15 and 16). The lone exception is a 38 percent reduction in minimum habitat availability simulated for white sucker adults during wet years as a result of the low flow changing from 303 to 220 cfs for one day of the year. The large percent reduction in habitat availability is in part a product of the change in a low amount of habitat availability (480 to 296 ft^2/1,000 ft) compared to other species. The changes to hydrology for the No Action Alternative would result in a negligible effect to aquatic resources compared to existing conditions.

Lower Arkansas River – Segment 4, John Martin Reservoir to Kansas State Line

Effects on aquatic life in the Arkansas River downstream from John Martin Reservoir would be negligible for all alternatives. Changes in average monthly streamflow at the Arkansas River near Granada gage would be less than 5 percent (negligible to minor) for all alternatives (see Chapter 4 – *Surface Water Hydrology*). These changes in streamflow would cause negligible changes in habitat availability for aquatic life.

Changes to mean monthly streamflow for the No Action Alternative compared to existing conditions would be negligible during normal, wet, and dry years, except for small increases in flow during August and September of normal years (Appendix D.5 and Appendix H.6, Figure 60). These small changes in hydrology for the No Action Alternative would result in a negligible effect to aquatic resources compared to existing conditions.

Fountain Creek – Segments 3 and 4, Security Gage to Arkansas River

Changes to flow patterns in segments 3 and 4 of Fountain Creek generally would result in negligible to minor increases in flow, especially from January through March for all alternatives except JUP North (Chapter 4 – *Surface Water Hydrology*; Appendix D.4) (Appendix H.5, Figures 61 and 71). These increases in flow from January through March (up to 13 percent mean monthly increase at the Fountain Creek at Pueblo gage in January of dry years) generally would result in small increases in habitat availability for white sucker adults and fry and flathead chub adults, and small reductions in habitat availability for red shiners and sand shiners (Appendix H.5, Figures 62 to 70 and 72 to 80). The increased flows result in both increases and decreases in habitat availability for flathead chub fry. The JUP North Alternative would result in very little change in flow from the No Action Alternative and results in almost no changes in habitat availability for all year types (Table 7; Appendix H.5, Figures 62 to 70 and 72 to 80). Habitat for macroinvertebrates would likely increase with the increased flows and increased wetted stream bottom.

Changes in minimum habitat availability for segments 3 and 4 for all species and life stages vary from a decrease of less than 1 percent to an increase of 7 percent compared to the No Action Alternative (Table 7; Appendix H.5, Tables 17 and 19). Changes in median habitat availability for segments 3 and 4 for all species and life stages vary from a 3 percent decrease to a 14 percent increase (Table 7; Appendix H.5, Tables 18 and 20). The larger increases in habitat availability occurred for white suckers in Segment 4; however, these increases are the result of a change in very low amounts of habitat availability (from 44 to 50 ft^2/1,000 ft) (Appendix H.5, Table 20).

Effects to water quality would be mostly negligible in Fountain Creek for all alternatives except for selenium (Chapter 4 – *Water Quality*). Minor adverse effects to selenium would occur for all alternatives, except the JUP North Alternative, which would have a negligible effect. Overall, the changes to hydrology from all alternatives result in only small changes to water quality and habitat availability compared to the No Action Alternative and thus negligible effects to aquatic resources would occur for Fountain Creek.

Table 7. Effects Summary of the Percent Change in Minimum and Median Habitat Availability For All Alternatives Compared to the No Action Alternative for White Sucker, Flathead Chub, Sand Shiner (Adult), and Red Shiner (Adult), Fountain Creek, Segments 3 and 4. Values Represent the Minimum and Maximum Values for Normal, Dry, and Wet Years

Species/ Life Stage	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Percent Change in Minimum WUA							
Normal, Dry, and Wet Years (Min, Max)							
White sucker							
adult/juvenile	--	0, 5	0, 5	0, 0	0, 5	0, 7	0, 5
spawning	--	-<1, 2	-<1, 2	0, <1	-<1, 2	-<1, 2	-<1, 2
fry	--	-<1, <1	-<1, <1	0, 0	-<1, <1	-<1, <1	-<1, <1
Flathead chub							
adult/juvenile	--	-<1, 3	-<1, 3	0, 0	-<1, 3	-<1, 3	-<1, 3
spawning	--	-<1, <1	-<1, <1	0, 0	-<1, <1	-<1, <1	-<1, <1
fry	--	-<1, <1	-<1, <1	0, 0	-<1, <1	-<1, <1	-<1, <1
Sand shiner	--	-<1, <1	-<1, <1	0, 0	-<1, <1	-<1, <1	-<1, <1
Red shiner	--	-<1, <1	-<1, <1	0, 0	-<1, <1	-<1, <1	-<1, <1
Percent Change in Median WUA							
Normal, Dry, and Wet Years (Min, Max)							
White sucker							
adult/juvenile	--	<1, 13	<1, 14	0, <1	<1, 13	<1, 13	<1, 10
spawning	--	-3, 4	-3, 4	0, 0	-3, 4	-3, 3	-3, 3
fry	--	-2, 8	-2, 8	-<1, 0	-2, 8	-<1, 8	-<1, 9
Flathead chub							
adult/juvenile	--	<1, 2	<1, 2	0, <1	<1, 2	<1, 2	<1, 2
spawning	--	-1, 2	-1, 2	0, 0	-1, 2	-1, 2	-1, 2
fry	--	-<1, <1	-<1, <1	0, 0	-<1, <1	-<1, <1	-<1, <1
Sand shiner	--	-<1, -<1	-<1, -1	0, <1	-<1, -<1	-<1, -<1	-<1, -<1
Red shiner	--	-<1, <1	-<1, <1	0, <1	-<1, <1	-<1, <1	-<1, <1

Habitat simulations result in increases in minimum habitat availability (up to 37 percent) for adult, spawning, and fry white suckers, adult and spawning flathead chub, adult red shiners, and adult sand shiners during normal and wet years in Fountain Creek for the No Action Alternative compared to existing conditions (Appendix H.6, Tables 17 and 19). Increases in fish habitat availability would be largely associated with short-term increases in minimum flows, including an increase in flow during normal years in Segment 4 from 0 to 4 cfs. Changes in median habitat availability would be generally less than 5 percent, except for increases up to 16 percent for white sucker adult and fry in Segment 4 of Fountain Creek. Habitat for macroinvertebrates also would likely increase with the increased flows and increased wetted stream bottom. These increases in minimum and median habitat availability from changes to hydrology would result in a minor beneficial effect to aquatic resources in Fountain Creek for the No Action Alternative compared to existing conditions.

Lakes and Reservoirs

The effects to changes in the mean monthly storage contents, reservoir elevation, and surface area for all alternatives compared to the No Action Alternative for Turquoise and Twin Lakes reservoirs would be negligible (Appendix D.4). Furthermore, changes would be negligible between the No Action Alternative and existing conditions (Appendix D.4). The effects to changes in the aquatic resources of Turquoise and Twin Lakes reservoirs would be negligible for all alternatives, based on the negligible changes in storage contents, elevation, and surface area.

Overall effects to storage, elevation, and surface area in Pueblo Reservoir on an annual basis would be negligible for the Comanche South, Pueblo Dam South, and Pueblo Dam North alternatives, minor for JUP North from decreases in storage, negligible to minor for River South from increases in storage, and minor for Master Contract Only from increases in storage (Appendix D.4). These effects to overall annual storage in Pueblo Reservoir would result in less than or equal to 2 percent changes for the Comanche South, Pueblo Dam South, Pueblo Dam North, and River South alternatives compared to the No Action Alternative (Appendix D.4, Table 161). The changes in the overall mean monthly storage, elevation, and area of Pueblo Reservoir would be less than 3 percent for the Comanche South, Pueblo Dam South, Pueblo Dam North, and River South alternatives compared to the No Action Alternative (Appendix D.4, Tables 161, 169, and 177). Changes in the mean monthly storage, elevation, and area of Pueblo Reservoir would be less than 8 percent for these alternatives, when considering individual normal, wet, and dry year types. The changes in storage would occur throughout the year and would not change the existing seasonal pattern of increasing reservoir storage in winter with maximum reservoir storage in early spring and drawdown through the summer irrigation season. The alternatives also would not change the long-term pattern of wet and dry periods; they would occur similarly as for the No Action Alternative and existing conditions (Appendix D.4, Figure 32). An overall annual 8 percent decrease and 5 percent increase in storage would occur for the JUP North and Master Contract Only alternatives, respectively. Mean monthly storage would be changed throughout the year with the changes larger in fall than in spring. The percent change in the overall mean monthly storage, elevation, and surface area for the JUP North Alternative varies from a 4 to 10 percent decrease and for the Master Contract Only Alternative varies from a 2 to 6 percent increase. Additionally, the JUP North Alternative would result in decreases in storage from 19 to 27 percent throughout the year in average and dry years which would make the dry periods more severe in the long-term pattern of reservoir storage (Appendix D.4, Figure 32). Elevation and surface area would decrease between 9 and 14 percent throughout the year in average and dry years for this alternative.

Changes to water quality parameters in Pueblo Reservoir would be negligible to minor (Chapter 4 – *Water Quality*) and would not be expected to affect aquatic resources. Overall, the effects of alternatives the Comanche South, Pueblo Dam South, Pueblo Dam North, River South, and Master Contract Only alternatives to storage contents, elevation, and area would be small and would result in negligible effects to the aquatic resources of Pueblo Reservoir. The effects of changes in overall storage contents, elevation, and surface area vary up to 10 percent in some months for the JUP North Alternative with greater decreases in average and dry years, which would result in moderate adverse effects to the aquatic resources of Pueblo Reservoir compared to the No Action Alternative. The decrease in storage contents, elevation, and surface area occurs throughout the year, which would be expected to decrease habitat for spawning fish and overall fish habitat for survival and growth.

The No Action Alternative would result in slightly lower storage contents, elevation, and surface area in Pueblo Reservoir than existing conditions (Appendix D.4). Mean monthly changes in these components of reservoir operation in Pueblo Reservoir would usually be 2 to 6 percent and thus, effects on aquatic resources would likely be negligible for the No Action Alternative compared to existing conditions.

Lake Meredith and Lake Henry are both part of the Colorado Canal system and the operation of the two reservoirs are intertwined, thus differences among alternatives are similar between reservoirs (Appendix D.4). The effects to mean monthly storage contents, elevation, and surface area of Lake Meredith and Lake Henry would be negligible to minor (Appendix D.4). The greatest difference for the alternatives compared to the No Action Alternative is a 3 percent decrease in the overall storage for all alternatives except JUP North during November for Lake Meredith and an approximate 5 percent decrease in overall storage for the same alternatives in November and December for Lake Henry. Both reservoirs would have monthly changes in elevation and surface area of 2 percent or less in most months. The alternatives would not change the long-term pattern of wet and dry periods; they would occur similar to the No Action alternative and existing conditions (Appendix D.4). Lake Meredith and Lake Henry would have minor adverse salinity and selenium effects for all alternatives. The negligible to minor changes in storage contents and water quality of Lake Meredith and Lake Henry would result in negligible changes to aquatic resources in these reservoirs.

Compared to existing conditions, changes in mean monthly storage contents for Lake Meredith would be greatest in dry years, decreasing for the No Action Alternative by 10 to 12 percent during July through November with associated reductions in elevation up to 8 percent and in surface area up to 6 percent (Appendix D.4). This decrease in storage for the No Action Alternative would have a minor adverse effect on aquatic resources compared to existing conditions. Changes in mean monthly storage, elevation, and area for Lake Henry would be less than 10 percent for the No Action Alternative compared to existing conditions (Appendix D.4) and thus, effects to aquatic resources would be negligible.

The average annual effects to changes in storage contents, elevation, and surface area of Holbrook Reservoir would be negligible for all alternatives compared to the No Action Alternative (Appendix D.4). However, some months show minor effects to storage and moderate effects would also occur during some months in normal and dry years (Appendix D.4). Changes to overall mean monthly storage contents, elevation, and surface area would result in increases or decreases less than 8 percent during all months for all alternatives compared to the No Action Alternative. However, mean monthly changes in storage contents would decrease for all alternatives except the JUP North Alternative, during June through November from 17 to 67 percent during normal years and from 8 to 33 percent during wet years. Elevation and surface area would also decrease during these months for normal and dry years, up to 36 and 42 percent during dry years for elevation and surface area, respectively. Changes in mean monthly storage contents, elevation, and surface area would be less than 5 percent and often zero during wet years for all alternatives. Overall changes in mean monthly storage contents, elevation, and surface area would be negligible for the JUP North Alternative. These changes in reservoir operations would result in a moderate adverse effect to the aquatic resources of Holbrook Reservoir for the Comanche South, Pueblo Dam South, Pueblo Dam North, River South, and Master Contract

Only alternatives. Effects to aquatic resources for the JUP North Alternative would be negligible.

Compared to existing conditions, changes in the overall annual storage contents, elevation, and surface area of Holbrook Reservoir would result in decreases of less than 10 percent during all months, except for an 11 percent decrease in storage contents in September. However, decreases in mean monthly storage contents during normal years from May through December, ranged from 31 to 83 percent for the No Action Alternative compared to existing conditions. During dry years, storage contents increased by as much as 79 percent from January through April and decreased by 36 percent in May for the No Action Alternative compared to existing conditions. Changes in storage contents were negligible for all months during wet years. Percent changes in mean monthly elevation and surface area were similar to the percent changes in the mean monthly storage contents, but were smaller in magnitude. The decreases in storage for the No Action Alternative compared to existing conditions from May through December of average years would result in an overall moderate adverse effect to aquatic resources in Holbrook Reservoir.

The effects to changes in storage contents of John Martin Reservoir would result in negligible to minor increases in storage depending on the year type and alternative compared to the No Action Alternative (Appendix D.5). Overall changes in storage contents of John Martin Reservoir would be less than or equal to 2 percent for all months and alternatives. The maximum mean monthly change in storage contents during normal, dry, and wet years would be an 8 percent increase in storage for the Master Contract Only Alternative during May of wet years (Appendix D.5, Tables 71-73). These negligible to minor increases in storage in John Martin Reservoir would result in negligible effects to the aquatic resources in John Martin Reservoir compared to the No Action Alternative.

Compared to existing conditions, the No Action Alternative would result in an increase in storage in John Martin Reservoir during all months for each year type (Appendix D.5, Tables 71 and 73). Increases in mean monthly storage would be largest during normal and dry years, with increases between 6 and 23 percent in normal years and between 11 and 36 percent in dry years (Appendix D.5, Tables 71 and 73). Increases in storage in John Martin Reservoir for the No Action Alternative compared to existing conditions would result in a moderate beneficial effect to aquatic resources as the increased storage would likely increase habitat for spawning fish and overall fish habitat for survival and growth.

Nuisance Species

Two nuisance species, didymo and New Zealand mud snails, are not currently found in the waters of the study area and are not expected to be introduced by project activities. Whirling disease is currently present throughout the study area and the project would have no effect on its distribution. Similarly, Asiatic clams are currently present in Pueblo Reservoir and in the lower Arkansas River and the project would have no effect on the distribution of this species.

Zebra and Quagga mussels have been detected in Pueblo Reservoir but have not established extensive populations, possibly due to water quality factors in the reservoir (Claudi and Prescott 2009). The project is not expected to appreciably change water quality conditions in the reservoir and it is likely that the project would have no effect on the establishment of these mussels. If these mussels become established in the future, they may enter the water distribution system associated with the project and could require additional maintenance.

Summary of Direct and Indirect Effects

Direct and indirect effects to aquatic resources would be negligible for most alternatives for most stream segments and water bodies in the study area (Table 8). Moderate adverse effects would occur for the JUP North Alternative for Pueblo Reservoir and moderate adverse effects would occur for the remaining alternatives for Holbrook Reservoir.

Table 8. Direct and Indirect Effects Summary for All Alternatives Compared to the No Action Alternative for the Arkansas Valley Conduit Study Area.

Major	Moderate	Minor	Negligible	Minor	Moderate	Major
⊙	◐	⦶	=	⊖	◒	●
Beneficial ↔ Adverse						
Increase ↔ Decrease (SW Only)						

	Comanche South	**Pueblo Dam South**	**JUP North**	**Pueblo Dam North**	**River South**	**Master Contract Only**
Upper Arkansas River Basin						
Lake Fork, Lake Creek, Upper Arkansas River, Grape Creek	=	=	=	=	=	=
Lower Arkansas River						
Pueblo Reservoir to Wildhorse Creek	=	=	=	=	=	=
Wildhorse Creek to Fountain Creek	=	=	=	=	=	=
Fountain Creek to John Martin Reservoir	=	=	=	=	=	=
John Martin Reservoir to State Line	=	=	=	=	=	=
Fountain Creek						
Security to Arkansas River	=	=	=	=	=	=
Reservoirs						
Turquoise and Twin Lakes	=	=	=	=	=	=
Pueblo Reservoir	=	=	◒	=	=	=
Lake Henry and Lake Meredith	=	=	=	=	=	=
Holbrook Reservoir	◒	◒	=	◒	◒	◒
John Martin Reservoir	=	=	=	=	=	=

Cumulative Effects

The cumulative effects of the alternatives and the reasonably foreseeable actions (Appendix B.4) are discussed in this section for various geographical locations in the Arkansas River and Fountain Creek basins.

Upper Arkansas River Basin – Arkansas River Segments 1 through 7, Lake Fork, Lake Creek, and Grape Creek

Cumulative effects on water quality in the Upper Arkansas River Basin would be negligible (Chapter 4 – *Water Quality*). The cumulative effects of changes in hydrology from alternatives would generally demonstrate the same effects as the direct effects compared to the No Action Alternative in Lake Fork (Appendix D.4; Appendix H.5, Figure 81). Most changes in the overall monthly flow would be less than 5 percent, but exceptions include an overall 10 percent decrease in flow in June for the JUP North Alternative, a 6 percent decrease in flow in June for the River South Alternative, and a 10 percent increase in flow in June for the Master Contract Only Alternative (Appendix D.4, Table 42). Overall, these cumulative changes in hydrology compared to the No Action Alternative would result in negligible changes to aquatic resources for all alternatives in Lake Fork, similar to direct effects.

Cumulative effects to hydrology in Lake Fork would result in a decrease in the overall monthly flow during the runoff season of May through July, up to 51 percent in June (a reduction from 103to 51 cfs) for the No Action Alternative compared to existing conditions (Appendix D.4 and Appendix H.6, Figure 81). This decrease in the mean monthly flow may have an adverse effect on flushing flows, sediment transport, and channel maintenance, and thus would likely have a moderate adverse effect on aquatic resources for the No Action Alternative compared to the existing conditions.

The cumulative effects of changes in overall monthly flow in Lake Creek would result in a maximum decrease in flow of 7 percent in April for the Master Contract Only Alternative and a maximum increase in flow of 15 percent in October for the Comanche-South and Pueblo Dam North alternatives (Appendix D.4, Table 50; Appendix H.5, Figure 82). The overall average change in hydrology in Lake Creek ranges from 0 to 1.1 percent for all alternatives (Appendix D.4, Table 50). The cumulative effects of changes in hydrology to Lake Creek compared to the No Action Alternative would result in negligible changes to aquatic resources.

In Lake Creek, cumulative effects of changes to hydrology for the No Action Alternative would result in increases in overall mean monthly flow in October through January of up to 63 percent compared to existing conditions and decreases in mean monthly flow the rest of the year up to 43 percent in September (Appendix D.4, Table 50; and Appendix H.6, Figure 82). PHABSIM habitat availability relationships are not available in Lake Creek and a geomorphology analysis was not conducted in this stream. Decreases in overall mean monthly flow during the runoff period often would be near 20 percent, which may have an adverse effect on sediment transport and channel maintenance and thus a long-term adverse effect on aquatic resources. However, increased flows during winter and decreased flows during fall would likely have a beneficial effect on habitat availability, resulting in a corresponding minor beneficial effect on aquatic resources.

In segments 1 through 6 of the Upper Arkansas River, cumulative effects to changes in hydrology would be small compared to the No Action Alternative (Appendix H.5, Figures 83 to 87), resulting in similar habitat availability for all brown trout and rainbow trout life stages among alternatives during most times of the year (Table 9) (Appendix H.5, Figures 89 to 124 and Tables 21 to 32). The averages and ranges of the percent change in minimum and median habitat availability from the cumulative effects of alternatives are similar in magnitude to the changes observed for direct effects (Tables 4 and 9). The average percent change in the minimum and median habitat availability for all life stages of brown trout and rainbow trout in segments 1 through 6 is between a 1 percent decrease and a 2 percent increase (Table 9). The range of the percent change in minimum trout habitat availability for segments 1 through 6 is between an 8 percent decrease for spawning rainbow trout and a 19 percent increase for rainbow trout fry

(Table 9). The range of the percent change in median trout habitat availability for segments 1 through 6 varies less than minimum habitat availability and is between a 4 percent decrease for adult brown trout and a 10 percent increase for rainbow trout fry (Table 9).

Overall, the small changes in minimum and median habitat availability for all alternatives except Master Contract Only compared to the No Action Alternative, along with the similar habitat and flows among alternatives on a daily basis (Appendix H.5, Figures 83 to 124), indicate that negligible changes in aquatic resources would occur for Segments 1 through 6 of the Upper Arkansas River.

No PHABSIM relationships are available for Segment 7 of the Upper Arkansas River; however, cumulative changes in hydrology for the alternatives from the No Action Alternative in Segment 7 would be similar to the changes observed in Segment 6, near Canyon City (Appendix H.5, Figures 83 to 88). The percent change in flow is generally less than 10 percent. Several exceptions occur for multiple alternatives, including decreases in flow from the No Action Alternative up to 35 percent in January of wet years and up to approximately 50 percent for one day in May of dry years for the River South Alternative (Appendix H.5, Figure 88). The decreases in flow are short in duration and would result in similar flow values to those observed during other times of the year. These changes to hydrology indicate that cumulative effects to aquatic resources would be negligible in Segment 7 of the Upper Arkansas River as in Segments 1 through 6.

Table 9. Cumulative Effects Summary for the Upper Arkansas River Segments 1 through 6 of the Percent Change in Minimum and Median Habitat Availability for All Alternatives Compared to the No Action Alternative for Normal, Dry, and Wet Years

Species/ Life Stage	Percent Change in Minimum WUA						Percent Change in Median WUA					
	Normal		Dry		Wet		Normal		Dry		Wet	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Brown trout												
adult	0.4	-2 to 1	0.1	-1 to 3	0.5	-1 to 1	0.4	-2 to 2	-0.1	-1 to 1	-0.5	-4 to 1
spawn	-0.6	-4 to 1	0.2	-1 to 1	-0.6	-3 to 1	-0.4	-2 to 1	-0.3	-1 to 1	-0.2	-3 to 1
fry	-0.5	-5 to 1	1.3	-1 to 8	0.4	0 to 1	0.3	-2 to 2	-0.2	-2 to 1	0.0	-1 to 1
juvenile	0.4	-2 to 1	0.1	-2 to 4	0.5	-1 to 1	0.4	-1 to 3	0.2	-1 to 1	-0.3	-2 to 1
Rainbow trout												
adult	0.4	-2 to 1	0.1	-1 to 3	0.5	-1 to 1	0.3	-1 to 1	-0.1	-1 to 1	-0.7	-1 to 0
spawn	-0.4	-8 to 1	0.1	-4 to 1	-0.3	-6 to 8	0.3	-1 to 2	1.0	-1 to 5	0.7	-1 to 4
fry	1.3	-5 to 13	1.7	-1 to 19	0.4	0 to 1	0.4	-1 to 10	-0.2	-3 to 1	0.2	-1 to 1
juvenile	0.4	-2 to 1	0.6	-2 to 5	0.5	-1 to 1	0.1	-1 to 1	0.2	-1 to 1	-0.2	-2 to 1

In the Upper Arkansas River, there would be some large increases in minimum fish habitat availability for the No Action Alternative compared to existing conditions for most life stages of brown trout and rainbow trout as a result of a reduction in peak flows (Appendix H.6, Tables 21, 23, 25, 27, 29, and 31). Minimum spawning habitat availability and median habitat availability would both increase and decrease from existing conditions, depending on the year type, species, life stage, and segment. Overall, the increases in minimum habitat availability would be short-term. No consistent pattern of changes in median habitat availability are identified (Appendix H.6, Tables 22, 24, 26, 28, 30, and 32), thus cumulative effects for the No Action

Alternative compared to existing conditions would likely be negligible in the Upper Arkansas River.

The cumulative effects of the alternatives on the hydrology of Grape Creek are the same as for the direct effects. Thus, cumulative effects of the alternatives would result in negligible effects to the aquatic resources in Grape Creek compared to the No Action Alternative. A minor beneficial cumulative effect to aquatic resources would occur for the No Action Alternative compared to existing conditions, as was the case for direct effects.

Lower Arkansas River – Segment 1, Pueblo Reservoir to Wildhorse Creek

Cumulative effects to changes in hydrology would result in negligible to minor decreases in flow for all months and alternatives compared to the No Action Alternative (Appendix D.4). The greatest change in the simulated mean monthly flow would be a 7 percent decrease in flow during October for the Comanche South, Pueblo Dam South, and the Pueblo Dam North alternatives compared to the No Action Alternative (Appendix D.4). Simulated daily flows are similar among all alternatives and with the No Action Alternative during most times of the year (Appendix H.5, Figure 125). As a result, habitat availability is similar among alternatives and with the No Action Alternative for brown trout adults, brown trout juveniles, and rainbow trout adults during most times of the year (Appendix H.5, Figures 126 to 128) and likely for macroinvertebrates as well.

The only changes in minimum or median habitat availability greater than 10 percent would occur for adult and juvenile brown trout, where a 22 percent increase in minimum habitat availability is simulated for all alternatives except the JUP North Alternative during normal years and a 14 percent increase in minimum habitat availability for brown trout adults is simulated for the Master Contract Only Alternative in wet years (Table 10; Appendix H.5, Tables 33). Most changes in the minimum and median habitat availability from the No Action Alternative would be less than 1 percent (Table 10). Overall, the changes to hydrology compared to the No Action Alternative, indicate that negligible cumulative effects to the aquatic resources would occur for all alternatives, similar to direct effects.

Decreases in median habitat availability of 26 and 19 percent are simulated for brown trout adults during normal and dry years, respectively for the No Action Alternative compared to existing conditions (Appendix H.6, Table 34). A 17 percent increase in median habitat availability is simulated for rainbow trout adults during wet years. Changes in minimum habitat availability would be less than 10 percent for all species and life stages, except for an 18 percent decrease in minimum habitat availability for brown trout adult and juveniles in normal years (Appendix H.6, Table 33). This decrease in habitat availability is the result of a decrease in flow from 50 to 41 cfs; however, this occurs on only one day whereas an increase in flow above the existing conditions low flow of 50 cfs occurs on several days. Overall, the decreases in median habitat availability for brown trout would result in a minor negative effect on aquatic resources for the No Action Alternative compared to existing conditions for the Lower Arkansas River Segment 1.

Table 10. Cumulative Effects Summary of the Percent Change in Minimum and Median Habitat Availability in Normal, Dry, and Wet Years For All Alternatives Compared to the No Action Alternative for Brown and Rainbow Trout, Lower Arkansas River Segment 1

Species/Life Stage	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Percent Change in Minimum Habitat Availability Compared to No Action Alternative							
Normal Year							
Brown trout							
adult	--	22	22	-2	22	22	22
juvenile	--	22	22	-2	22	22	22
Rainbow trout							
adult	--	<1	-<1	-<1	-<1	-<1	<1
Dry Year							
Brown trout							
adult	--	1	1	-<1	1	-3	-<1
juvenile	--	1	1	-<1	1	-3	-<1
Rainbow trout							
adult	--	<1	<1	-<1	<1	<1	<1
Wet Year							
Brown trout							
adult	--	-<1	-2	-<1	-2	8	14
juvenile	--	<1	<1	<1	<1	-<1	<1
Rainbow trout							
adult	--	<1	<1	<1	<1	-<1	<1
Percent Change in Median Habitat Availability Compared to No Action Alternative							
Normal Year							
Brown trout							
adult	--	-<1	-1	-<1	-<1	-<1	1
juvenile	--	<1	<1	-<1	<1	-<1	<1
Rainbow trout							
adult	--	-<1	-<1	-<1	-<1	<1	-<1
Dry Year							
Brown trout							
adult	--	-1	-1	-1	-<1	-1	-<1
juvenile	--	-<1	-<1	-<1	-<1	-<1	-<1
Rainbow trout							
adult	--	-<1	-<1	-<1	-<1	<1	<1
Wet Year							
Brown trout							
adult	--	-<1	-<1	-<1	-<1	-<1	-<1
juvenile	--	-<1	-<1	-<1	-<1	-<1	<1
Rainbow trout							
adult	--	<1	<1	-<1	<1	1	<1

Lower Arkansas River – Segment 2, Wildhorse Creek to Fountain Creek

Changes to hydrology in the Lower Arkansas River Segment 2 compared to the No Action Alternative would result in one additional day of low flows for all alternatives, except the River South Alternative, which has five additional low flow days during dry years and one additional low flow day during normal years. Otherwise, the daily hydrology is similar among all alternatives, including the No Action Alternative during most times of the year in normal, dry, and wet years (Appendix H.5, Figure 129). The increased number of low flow days for the River South Alternative compared to the No Action Alternative would result in a minor adverse cumulative effect on aquatic resources. A negligible cumulative effect on aquatic resources would occur for the remaining alternatives compared to the No Action Alternative in Segment 2 of the Lower Arkansas River.

In wet years there would be similar flows for the Arkansas River from Wildhorse Creek to Fountain Creek for the No Action Alternative compared to existing conditions during most times of the year (Appendix H.6, Figure 129). During normal and dry years flows would often be reduced during the non-runoff times of the year for the No Action Alternative compared to existing conditions, which would likely reduce habitat availability. Eleven additional days of low flow less than 10 cfs are simulated for dry years at the Arkansas River at Moffat St. gage for the No Action Alternative. The more frequent low flow periods would be short in duration, with the longest period lasting three days. The overall lower flows during normal and dry years and the additional days of flow less than 10 cfs during dry years would result in moderate adverse cumulative effects to aquatic resources for the No Action Alternative compared to existing conditions.

Lower Arkansas River – Segment 3, Fountain Creek to John Martin Reservoir

Cumulative effects to mean monthly streamflow would result in negligible to minor decreases for most months for all alternatives compared to the No Action Alternative at the Arkansas River near Avondale gage (Appendix D.4). Simulated daily flows are similar among all alternatives and with the No Action Alternative during most times of the year (Appendix H.5, Figure 130). As a result, habitat availability is similar among alternatives and with the No Action Alternative for all species and life stages during most times of the year (Appendix H.5, Figures 131 to 139).

The cumulative effects of the alternatives to changes in minimum and median fish habitat availability in the Lower Arkansas River Segment 3 would be similar to the direct and indirect effects and generally result in changes less than or equal to 10 percent (Table 11; Appendix H.5, Tables 35 and 36). The only exceptions occur with changes in minimum habitat availability for white suckers and flathead chub (Table 11). For white suckers, minimum adult habitat availability for the River South Alternative increase 33 percent for the Master Contract Only Alternative compared to the No Action Alternative during wet years (Table 11; Appendix H.5, Table 35). The large increase is the product of a change in low overall adult white sucker habitat availability from 324 to 433 ft^2/1,000 ft. Flathead chub minimum spawning habitat availability for the River South Alternative decreased 15 percent for the JUP North Alternative during dry years as a result of an increased flow from 1,685 to 1,788 cfs during the spawning season (Table 11; Appendix H.5, Table 35). This increased flow would occur on only one day and overall would not likely have a measurable effect on flathead chub spawning success. Cumulative effects to water quality are expected to be negligible for this stream segment (Chapter 4, Water Quality Section). Overall, the effects from changes to the hydrology result in only small changes in habitat availability for most species, life stages, and year types, which would result in negligible changes to aquatic resources compared to the No Action Alternative.

Table 11. Cumulative Effects Summary of the Percent Change in Minimum and Median Habitat Availability For All Alternatives Compared to the No Action Alternative for White Sucker, Flathead Chub, Sand Shiner (Adult), Red Shiner (Adult), Plains Killifish (Adult), and Channel Catfish (Juvenile/Fry), Lower Arkansas River, Segment 3. Values Represent the Minimum and Maximum Values for Normal, Dry, and Wet Years

Species/ Life Stage	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Percent Change in Minimum WUA							
Normal, Dry, and Wet Years (Min, Max)							
White sucker							
adult/juvenile	--	-2, 9	<1, 8	<1, 7	3, 9	-6, <1	3, 33
spawning	--	-5, -2	-7, -2	-<1, <1	-7, -2	-8, 2	-3, <1
fry	--	-<1, 4	<1, 3	-<1, 3	<1, 5	-3, <1	<1, 3
Flathead chub							
adult/juvenile	--	<1, 1	<1, 1	<1, <1	<1, 1	<1, 1	-<1, <1
spawning	--	-<1, 10	-<1, 9	-15, <1	-<1, 10	-<1, 10	-<1, 8
fry	--	-2, <1	-2, <1	-1, <1	-2, <1	-7, <1	-<1, <1
Sand shiner	--	-<1, 1	-<1, 1	-1, -<1	-<1, 1	-<1, <1	-2, <1
Red shiner	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1
Plains killifish	--	-<1, -<1	-<1, -<1	-<1, -<1	-<1, -<1	-<1, -<1	-<1, -<1
Channel catfish	--	-1, <1	-1, <1	-<1, <1	-1, <1	-4, <1	-<1, <1
Percent Change in Median WUA							
Normal, Dry, and Wet Years (Min, Max)							
White sucker							
adult/juvenile	--	-<1, 7	-<1, 2	<1, 5	-1, 5	-5, <1	-<1, 5
spawning	--	-1, <1	-<1, <1	-<1, <1	-1, <1	-<1, 2	-2, 2
fry	--	-<1, -<1	-<1, <1	-<1, -<1	-<1, <1	-<1, <1	-<1, <1
Flathead chub							
adult/juvenile	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, -<1	-<1, <1
spawning	--	-3, 4	-1, 4	-<1, <1	-1, 3	-4, <1	-1, 3
fry	--	<1, 1	-<1, 2	-2, <1	<1, <1	-2, <1	-1, -<1
Sand shiner	--	-2, <1	-<1, <1	-1, <1	-1, 1	-<1, 1	-1, <1
Red shiner	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, -<1	-<1, <1
Plains killifish	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	<1, <1	-<1, <1
Channel catfish	--	-<1, -<1	-<1, <1	-<1, <1	-<1, 0	-<1, -<1	-<1, <1

Increases in minimum habitat availability from 12 to 65 percent would occur for spawning white sucker, spawning flathead chub, adult sand shiner, and young channel catfish during dry and/or normal years for the No Action Alternative compared to existing conditions (Appendix H.6, Table 35). Minimum white sucker adult habitat would decrease 32 percent in wet years. Median habitat availability would increase 24 percent for spawning flathead chub and would increase or decrease up to 16 percent for white suckers, depending on the life stage and year type (Appendix H.6, Table 36). Overall, the increases in habitat availability would likely outweigh the few decreases and would result in a minor beneficial cumulative effect on aquatic resources for the No Action Alternative compared to existing conditions for the Lower Arkansas River from Fountain Creek to John Martin Reservoir.

Lower Arkansas River – Segment 4, John Martin Reservoir to Kansas State Line

The cumulative effects to streamflow downstream from John Martin Reservoir would be similar to the observed changes in streamflow for the direct effects (Chapter 4 – *Surface Water Hydrology*). Mean monthly changes in streamflow at the Arkansas River near Granada gage would be less than 5 percent for all months, alternatives, and year types, except during normal years in September, when a decrease of 1 to 2 cfs results in a 5 to 11 percent decrease in flow (Appendix D.5; Appendix H.5, Figure 140). Overall, the cumulative effects of these changes in streamflow would result in negligible changes to aquatic resources for all alternatives.

Changes to the overall mean monthly streamflow for the Arkansas River downstream from John Martin Reservoir for the No Action Alternative compared to existing conditions would generally be less than 10 percent (Appendix D.5). These changes in hydrology would result in a negligible cumulative effect on aquatic resources for the No Action Alternative compared to existing conditions.

Fountain Creek – Segments 3 and 4, Security Gage to Arkansas River

Cumulative changes in streamflow in Fountain Creek would generally result in increased flow compared to direct effects, because of increased return flows from Colorado Springs (Chapter 4 – *Surface Water Hydrology*). Average annual effects of changes in the simulated streamflow at the Fountain Creek at Security and Fountain Creek at Pueblo gages are negligible for all alternatives compared to the No Action Alternative (Appendix D.4). The daily hydrology is similar among all alternatives, including the No Action Alternative during most times of the year at the Fountain Creek at Security and Fountain Creek at Pueblo gages (Appendix H.5, Figures 141 and 151). As a result, habitat availability is similar among most alternatives, including similar to the No Action Alternative during most times of the year (Appendix H.5 Figures 142 to 150 and 152 to 160).

In Fountain Creek segments 3 and 4, minimum and median habitat availability would vary by less than 1 percent for red shiners and sand shiners for all alternatives and year types; however, the cumulative effect of the alternatives would result in substantial variation in the change in habitat availability for white sucker and flathead chub (Table 12; Appendix H.5, Tables 37 through 40). While minimum habitat availability would increase by 15 percent for white sucker and flathead chub adults for most alternatives, these increases are the result of changes in very low levels of habitat for white suckers (approximately 0.4 ft^2/1,000ft) and an increase in flow from 20 to 23 cfs on only one day of the year for flathead chubs. Reductions in the median habitat availability for white sucker fry are between 15 and 23 percent for all alternatives except River South and Master Contract Only for segment 4 during normal years, in part from increases in flow in spring and reductions in fall flows (Table 12; Appendix H.5, Tables 38 and 40). Reductions of median flathead chub spawning habitat availability in wet years of 7, 6, and 16 percent are simulated for the Comanche South, Pueblo Dam South, and Pueblo Dam North alternatives, respectively for Segment 4, because of increases in flow (Table 12; Appendix H.5, Tables 38 and 40). Cumulative effects to salinity and selenium would be negligible to minor for all alternatives (Chapter 4 – *Water Quality*). Overall, the reductions in median habitat for both white sucker fry and spawning flathead chub indicate that minor adverse cumulative effects to aquatic resources would occur for the Comanche South, Pueblo Dam South, and Pueblo Dam North alternatives in Fountain Creek. Cumulative effects of the JUP North, River South, and Master Contract Only alternatives to aquatic resources would be negligible compared to the No Action Alternative, similar to direct effects.

Table 12. Cumulative Effects Summary of the Percent Change in Minimum and Median Habitat Availability For All Alternatives Compared to the No Action Alternative for White Sucker, Flathead Chub, Sand Shiner (Adult), and Red Shiner (Adult), Fountain Creek, Segments 3 and 4. Values Represent the Minimum and Maximum Values for Normal, Dry, and Wet Years

Species/ Life Stage	No Action	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Percent Change in Minimum WUA							
Normal, Dry, and Wet Years (Min, Max)							
White sucker							
adult/juvenile	--	0, 15	0, 15	0, 0	0, 15	0, 15	0, 15
spawning	--	-3, 1	-3, 1	0, 1	-3, 1	-4, 2	-4, 2
fry	--	-<1, 8	-<1, 10	-<1, 11	-<1, 4	-<1, 1	-<1, 7
Flathead chub							
adult/juvenile	--	<1, 15	-<1, 15	0, 0	<1, 15	-<1, 15	<1, 15
spawning	--	-<1, <1	-<1, <1	-<1, 0	-<1, <1	-<1, 4	-<1, <1
fry	--	-<1, <1	-<1, <1	-<1, 0	-<1, <1	-<1, <1	-<1, <1
Sand shiner	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, 1	-<1, <1
Red shiner	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, 1	-<1, <1
Percent Change in Median WUA							
Normal, Dry, and Wet Years (Min, Max)							
White sucker							
adult/juvenile	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1
spawning	--	-4, <1	-4, <1	-4, <1	-4, <1	-4, <1	-4, <1
fry	--	-23, <1	-15, -<1	-18, <1	-19, <1	-3, 2	-12, 3
Flathead chub							
adult/juvenile	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1
spawning	--	-7, 3	-6, 3	-<1, 1	-16, 3	-<1, <1	-<1, <1
fry	--	-2, <1	-2, 1	-<1, 2	-2, 1	-2, <1	-<1, <1
Sand shiner	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1
Red shiner	--	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1	-<1, <1

Changes in hydrology for the No Action Alternative compared to existing conditions would result in small increases and decreases in minimum and median habitat suitability, depending on the species, life stage, segment, and year type (Appendix H.6, Tables 37 through 40). Overall, cumulative effects to aquatic resources from the changes in hydrology for the No Action Alternative would be negligible for Fountain Creek, compared to existing conditions.

Lakes and Reservoirs

Differences among alternatives in the mean monthly overall storage contents, elevation, and surface area of Turquoise Lake for cumulative effects would be similar to the direct effects, except minor decreases in storage contents would occur for some months for the JUP North Alternative and minor increases for the Master Contract Only Alternative (Appendix D.4). The minor changes would be less than 3 percent (Appendix D.4). The differences in the storage contents, elevation, and surface area of Twin Lakes for cumulative effects would be similar to direct effects and less than 1 percent (Appendix D.4). These negligible to minor changes in storage content levels, elevation, and surface area would result in negligible changes to aquatic resources in Turquoise and Twin Lakes reservoirs for all alternatives compared to the No Action Alternative.

Decreases in storage, elevation, and surface area for the No Action Alternative compared to existing conditions would occur for all months for Turquoise and Twin Lakes reservoirs (Appendix D.4). Decreases would be greatest from January through May for both reservoirs with decreases in overall monthly storage between 14 and 19 percent for this time-period for Turquoise Lake and between 11 and 13 percent for Twin Lakes. Changes to elevation and surface area were similar, but smaller in magnitude than the changes in storage. These changes in storage, elevation, and surface area would result in minor adverse cumulative effects to aquatic resources in both reservoirs for the No Action Alternative compared to existing conditions.

Cumulative effects to overall annual storage, elevation, and surface area of Pueblo Reservoir would result in similar changes from the No Action Alternative for all alternatives as for direct and indirect effects (Appendix D.4). Cumulative effects to water quality are negligible for all alternatives with minor increases or decreases in temperature depending on water depth and year type (Chapter 4, Water Quality Section). The cumulative effects for all alternatives except JUP North would result in negligible effects to the aquatic resources of Pueblo Reservoir. The cumulative effects of the JUP North Alternative would result in a 7 percent decrease in overall annual storage (Appendix D.4, Table 165) and would include reductions throughout the year. Overall annual changes to elevation and surface area for this alternative would be less than the changes for storage. Additionally, the JUP North Alternative would make the dry periods more severe in the long-term pattern of reservoir storage (Appendix D.4, Figure 33). The JUP North Alternative would result in minor adverse effects to the aquatic resources of Pueblo Reservoir, as was the case for direct and indirect effects.

Decreases in overall monthly storage would vary from 19 to 28 percent for all months for the No Action Alternative compared to existing conditions for Pueblo Reservoir (Appendix D.4). Overall annual changes to elevation and surface area would follow the reductions in storage, but would be smaller in magnitude. These decreases in storage, elevation, and surface area would likely decrease habitat for spawning fish and overall fish habitat for survival and growth, which would result in moderate adverse cumulative effects to the aquatic resources of Pueblo Reservoir for the No Action Alternative compared to existing conditions.

Cumulative effects to overall monthly storage contents, elevation, and surface area of Lake Meredith and Lake Henry would be similar to direct effects and would be negligible to minor (Appendix D.4). Differences for the alternatives compared to the No Action Alternative range from a 3 percent decrease to a 3 percent increase in overall monthly storage contents for Lake Meredith and a 7 percent decrease to a 5 percent increase for Lake Henry (Appendix D.4, Tables

189 and 213). Percent changes to overall monthly elevation and surface area compared to the No Action Alternative would be similar to or less than the changes for storage contents for Lake Meredith and Lake Henry. The greatest decreases in storage for Lake Henry occur for the Master Contract Only Alternative during winter months. Cumulative effects to water quality would be similar to the direct and indirect effects on water quality (Chapter 4 – *Water Quality*). Overall, the negligible to minor changes in storage contents, elevation, and surface area of Lake Meredith and Lake Henry would result in negligible cumulative effects to aquatic resources in these reservoirs.

Changes in overall monthly storage in Lake Meredith and Lake Henry for the No Action Alternative compared to existing conditions would result in decreases in storage during all months, up to 30 and 44 percent for each reservoir, respectively (Appendix D.4, Tables 189 and 213). Percent changes to overall monthly elevation and surface area for the No Action Alternative compared to existing conditions would be similar to or less than the changes for storage contents for Lake Meredith and Lake Henry. During dry years, storage contents would be reduced by up to 86 percent in October in Lake Meredith. In Lake Henry, reductions in storage would occur throughout the year and would be as large as 82, 79, and 82 percent during fall and winter months of normal, wet, and dry years, respectively. The reservoirs would become nearly dry during late summer in most years. This would substantially limit the ability of fish and macroinvertebrates to survive and grow from year to year. These changes in storage, elevation, and surface area would result in major adverse cumulative effects for aquatic resources in Lake Meredith and Lake Henry for the No Action Alternative compared to existing conditions, because of a reduction in habitat.

Cumulative effects to hydrology for Holbrook Reservoir would typically be negligible, with moderate effects during a few months of normal and dry years (Appendix D.4). Cumulative effects to Holbrook Reservoir would typically be less than direct effects (Appendix D.4). Changes to the overall monthly storage contents, elevation, and surface area would be less than 7 percent during each month for all alternatives and were often zero. The negligible and occasionally moderate effects to storage contents, elevation, and surface area would result in negligible cumulative effects to aquatic resources in Holbrook Reservoir for all alternatives.

Compared to existing conditions, the No Action Alternative would result in decreases in overall storage during all months, ranging from 4 to 21 percent. Decreases in storage would be greatest from June through December of normal years, ranging from 71 to 94 percent. During dry years, both increases and decreases in storage would occur and during wet years, decreases in storage would occur, although generally less than 10 percent. Percent changes to elevation and surface area for the No Action Alternative compared to existing conditions would be similar to or less than the changes for storage contents. The large decreases in storage, elevation, and surface area for the No Action Alternative during normal years, would result in an overall major adverse effect to aquatic resources of Holbrook Reservoir, compared to existing conditions.

The overall cumulative effects on monthly average storage contents of John Martin Reservoir would be negligible for all alternatives when compared to the No Action Alternative (Appendix D.5). Cumulative effects in normal, wet, and dry years would be minor decreases or minor increases in storage contents (Appendix D.5). In normal and dry years storage contents would increase up to 9 percent depending on the month for alternatives 2 through 6 and decrease from 1 to 5 percent for the Master Contract Only Alternative (Appendix D.5, Tables 75 and 77). In wet years, storage contents would increase less than 5 percent in all months for alternatives 2, 3, 5, and 7 and decrease up to 2 percent for alternatives 4 and 6 (Appendix D.5, Table 76). These negligible to minor increases and decreases in storage in John Martin Reservoir would result in negligible changes to the aquatic resources.

Changes in storage in John Martin Reservoir for the No Action Alternative compared to existing conditions would result in the overall mean monthly storage contents increasing from between 2 and 4 percent depending on the month (Appendix D.5). However, the long-term pattern of wet and dry years would change somewhat with less severe drought periods (Appendix D.5, Figure 24). Mean monthly storage would increase for all months in normal and dry years, up to 30 percent in normal years and 74 percent in dry years (Appendix D.5). Mean monthly storage would decrease in all months for wet years between 2 and 5 percent (Appendix D.5). Overall, the increases in storage would result in increased habitat availability in normal and dry years, and would result in moderate beneficial effects to aquatic resources in John Martin Reservoir for the No Action Alternative compared to existing conditions.

Climate Change

Climate change may decrease spring runoff flows and may result in earlier runoff and earlier low flows in summer. In the Upper Arkansas River, this may have short-term benefits to habitat availability for trout but may have long-term adverse effects to the timing of biological processes in the spring, to channel morphology, and to sediment transport that could make the river less suitable to support fish. These effects would occur in all alternatives, including the No Action. In the Lower Arkansas River and in Fountain Creek, the cumulative effects may be negligible because high flows are related more to storm events than to snowmelt runoff.

Summary of Cumulative Effects

Cumulative effects to aquatic resources would be negligible for most alternatives and for most stream segments and water bodies in the study area (Table 13). In the Lower Arkansas River from Wildhorse Creek to Fountain Creek, a minor adverse effect would occur for the River South Alternative. Minor adverse effects would also occur in Fountain Creek for the Comanche South, Pueblo Dam South, and Pueblo Dam North alternatives and in Pueblo Reservoir for the JUP North Alternative.

Table 13. Cumulative Effects Summary for All Alternatives Compared to the No Action Alternative for the Arkansas Valley Conduit Study Area.

Major	Moderate	Minor	Negligible	Minor	Moderate	Major
⦿	◐	⦶	=	⊖	◒	●
Beneficial ↔ Adverse						
Increase ↔ Decrease (SW Only)						

	Comanche South	Pueblo Dam South	JUP North	Pueblo Dam North	River South	Master Contract Only
Upper Arkansas River Basin						
Lake Fork, Lake Creek, Upper Arkansas River, Grape Creek	=	=	=	=	=	=
Lower Arkansas River						
Pueblo Reservoir to Wildhorse Creek	=	=	=	=	=	=
Wildhorse Creek to Fountain Creek	=	=	=	=	⊖	=
Fountain Creek to John Martin Reservoir	=	=	=	=	=	=
John Martin Reservoir to State Line	=	=	=	=	=	=
Fountain Creek						
Security to Arkansas River	⊖	⊖	=	⊖	=	=
Reservoirs						
Turquoise and Twin Lakes	=	=	=	=	=	=
Pueblo Reservoir	=	=	⊖	=	=	=
Lake Henry and Lake Meredith	=	=	=	=	=	=
John Martin Reservoir	=	=	=	=	=	=

References

Armour, C.L., and J. G. Taylor. 1991. Evaluation of the Instream Flow Incremental Methodology by U.S. Fish and Wildlife users. Fisheries 16(5):36-43.

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper: No. 12. FWS/OBS-82/26. U.S. Department of the Interior, Fish and Wildlife Service.

Bovee, K.D., T.J. Newcomb, and T. G. Coon. 1994. Relations between habitat variability and population dynamics of bass in the Huron River, Michigan. U.S. Department of the Interior, National Biological Survey. Biological Report 21. Washington D.C.

Bridges C., M. Elkins, D. Gilbert, and G. Policky. 2000. Natural resource assessment. In Arkansas River water needs assessment. Smith, R.E., and L.M. Hill, eds. USDI Bureau of Land Management, USDI Bureau of Reclamation, USDA Forest Service, and Colorado Department of Natural Resources.

Canton, S. P. and W. D. Van Derveer. 1997. Selenium toxicity to aquatic life: an argument for sediment-based water quality criteria. *Environmental Toxicology and Chemistry* 16(6): 1255-1259.

Conklin, D. J., S. P. Canton, J. W. Chadwick, and W. J. Miller. 1996. Habitat suitability curves for selected fish species in the Central Platte River, Nebraska. Rivers 5(4):250-266.

Dewson, Z. S., A. B. W. James, and R. G. Death. 2007. A review of the consequences of decreased flow for instream habitat and macroinvertebrates. *Journal of the North American Benthological Society* 26: 401-415.

Fannin, T. E., and P. Nelson. 1986. Habitat suitability index curves for channel catfish, common carp, sand shiner, plains killifish, and flathead chub developed by consensus discussion for use in the Instream Flow Incremental Methodology on the Central Platte River. Final Report No. 14-16-0009-1542, Research Work Order No. 55, Modification No. 2. U.S. Fish and Wildlife Service, Wyoming Fish and Wildlife Cooperative Research Unit, University of Wyoming, Laramie.

Hall, J.D., and N. J. Knight. 1981. Natural variation in abundance of salmonid population densities in streams and its implication for design of impact studies, a review. U.S. Environmental Protection Agency, EPA 600/3-81-021. National Technical Information Service, Springfield, Va.

Mathur, D., W. H Bason, E. J. Purdy, Jr., and C. A. Silver. 1985. A critique of the Instream Flow Incremental Methodology. Canadian Journal of Fisheries and Aquatic Sciences 42(4):825-831.

Mathur, D., W. H Bason, and E. J. Purdy, Jr. 1986. Reply to In Defense of the Instream Flow Incremental Methodology by D. J. Orth and O. E. Maughan. Canadian Journal of Fisheries and Aquatic Sciences 43(5):1093-1094.

Orth, D. J., and O. E. Maughan. 1982. Evaluation of the Instream Flow Incremental Methodology for recommending instream flows for fishes. Transactions of the American Fisheries Society. 111(4):413-445.

Orth, D. J., and O. E. Maughan. 1986. In Defense of the Instream Flow Incremental Methodology. Canadian Journal of Fisheries and Aquatic Sciences 43(5):1092.

Policky, G. 2009. 2009 Fisheries inventories Upper Arkansas River Basin. Colorado Division of Wildlife.

Reiser, D. W., T. A. Wesche, and C. Estes. 1989. Status of instream flow legislation and practices in North America. Fisheries 14(2):22-29.

Scott, D., and C. J. Shirvell. 1987. A critique of the Instream Flow Incremental Methodology and observations of flow determination in New Zealand. J. F. Craig and J. B. Kemper, eds. New York: Regulated Streams, Advances in Ecology.

Twomey, K. A., K. L. Williamson, and P. C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: white sucker. U.S Fish and Wildlife Service. FWS/OBS-82/10.64. 56 pp.

U.S. Bureau of Reclamation (Reclamation). 2008. Southern Delivery System Final Environmental Impact Statement, FES 08-63. Reclamation, Eastern Colorado Area Office, Loveland, CO.

U.S. Environmental Protection Agency (EPA). 2011. A field-based aquatic life benchmark for conductivity in central Appalachian streams. EPA/600/R-10/023F, USEPA, Cincinnati, OH.

Van Derveer, W. D., and S. P. Canton. 1997. Selenium sediment toxicity thresholds and derivation of water quality criteria for freshwater biota of western streams. *Environmental Toxicology and Chemistry* 16(6): 1260-1268.

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Appendix H.4 – Aquatic Resources – Affected Environment – Supplemental Tables and Figures

Table 1. Fish Population Data for Lake Fork between Turquoise Lake and the Arkansas River Confluence (Site LF-1). Data from CEC (1994, 1998a, 2001, 2002, 2003, 2004a, 2005), GEI (2006, 2007, 2008b), Roy F. Weston (1995), and Policky (1994, 1999, 2001, 2002, 2003, 2004a, 2005b, 2006, 2008)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Spring 1994			
Brook trout	3	7	1.6
Brown trout	66	172	54.6
Cutthroat trout	4	9	3.6
Longnose sucker	1	2	3.0
Fall 1994			
Brook trout	11	20	3.6
Brown trout	461	881	93.3
Cutthroat trout	3	6	4.9
Longnose sucker	2	4	0.3
Rainbow trout	3	6	1.3
Fall 1996			
Brook trout	1	2	0.6
Brown trout	169	309	52.0
Cutthroat trout	2	3	1.0
Longnose sucker	2	3	0.4
Rainbow trout	4	7	2.0
Late Summer 1997			
Brook trout	16	33	3.8
Brown trout	182	391	63.3
Cutthroat trout	10	20	6.8
Longnose sucker	13	27	9.8
Rainbow trout	1	2	0.8
Late Summer 1999			
Brook trout	14	24	N/A
Brown trout	386	741	N/A
Cutthroat trout	1	2	1.3
Longnose sucker	4	7	N/A
White sucker	1	2	0.6
Late Summer 2001			
Brook trout	11	23	3.8
Brown trout	352	790	113.8
Rainbow trout	1	2	<0.1
Longnose sucker	1	2	0.2
Late Summer 2002			
Brook trout	30	73	5.8
Brown trout	917	2,231	143.6
Longnose sucker	1	2	<0.1

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Late Summer 2003			
Brook trout	10	21	1.9
Brown trout	1,030	2,360	160.8
Cutthroat trout	1	2	0.8
Longnose sucker	1	2	0.1
White sucker	1	2	0.5
Late Summer 2004			
Brook trout	5	8	0.8
Brown trout	323	641	82.3
Longnose sucker	1	2	<0.1
Late Summer 2005			
Brook trout	3	7	0.7
Brown trout	483	1,151	135.5
Late Summer 2006			
Brook trout	7	13	1.5
Brown trout	471	982	130.5
Rainbow trout	1	2	1.6
Late Summer 2008			
Brook trout	9	18	1.4
Brown trout	320	675	167.4
Cutthroat trout	1	2	0.7
Longnose sucker	2	4	1.5

Table 2. Benthic Invertebrate Population Data for Lake Fork between Turquoise Lake and the Arkansas River Confluence (Site LF-1). Data from CEC (1994, 1998a, 1999a, 2001, 2002, 2003, 2004a, 2005), EPA (2008), GEI (2006, 2007a, 2008a, b), and Roy F. Weston (1995)

Year	Density (#/m^2)	Number of Taxa	Number of EPT Taxa	Diversity (H')
Spring				
1994	24,723	32	12	3.02
1995	32,183	43	18	3.35
1996	28,183	41	19	3.22
1997	64,299	42	20	2.67
1998	69,181	48	20	3.08
1999	12,718	28	15	2.95
2000	25,628	39	18	2.64
2001	66,170	47	21	3.10
2002	48,470	45	23	2.77
2003	27,293	51	19	3.59
2004	141,776	52	18	3.21
2005	89,399	54	17	2.70
2006	33,003	57	21	3.01
2007	29,705	58	18	3.67
2008	36,389	55	20	3.75
Fall				
1994	5,885	19	11	2.53
1995	12,546	29	13	3.05
1996	11,493	31	14	3.37
1997	29,895	39	18	3.40
1998	13,536	40	25	3.70
1999	11,421	42	22	3.53
2000	103,328	55	24	2.88
2001	52,316	49	20	3.80
2002	18,267	46	18	3.73
2003	122,065	46	15	2.61
2004	82,164	51	18	3.52
2005	94,093	51	17	2.98
2006	63,132	49	20	3.59
2007	51,175	50	13	3.87
2008	14,384	44	19	3.62

Table 3. Habitat Data for Lake Fork between Turquoise Lake and the Arkansas River Confluence (Site LF-1). Data from CEC (1999a, 2001, 2002, 2003, 2004a, 2005) and GEI (2006, 2007a, 2008a)

Year	% pools	Mean Bank Width (ft)	Mean Wetted Width (ft)	Dominant Substrate	Mean Depth (ft)
1998	0	48.2	41.5	Cobble	0.9
1999	0	46.7	38.4	Cobble	0.8
2000	0	42.7	34.5	Gravel	1.0
2001	0	43.9	35.8	Sand	0.9
2002	0	45.3	35.1	Gravel	0.8
2003	0	41.9	31.9	Gravel	0.8
2004	0	45.0	34.3	Gravel	0.8
2005	0	47.7	38.8	Gravel	0.9
2006	0	41.1	36.0	Gravel	1.0
2007	0	51.8	38.5	Cobble	1.1

Table 4. Fish Population Data for Upper Arkansas River Segment 1, Smith Ranch Site (Site AR-4). Data from CEC (1994, 1998a, 2001, 2002, 2003, 2004a, 2005), GEI (2006, 2007a, 2008a, b), Roy F. Weston (1995), and Policky (1994, 1998, 1999, 2000, 2001, 2003, 2004a, 2005b, 2006, 2008, 2009)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Spring 1994			
Brown trout	44	108	41.4
Spring 1998			
Brook trout	5	7	0.3
Brown trout	62	103	52.2
Cutthroat trout	1	1	0.6
Spring 1999			
Brown trout	70	N/A	N/A
Spring 2000			
Brook trout	2	3	0.1
Brown trout	80	125	41.8
Cutthroat trout	1	1	1.0
Fall 1994			
Brook trout	1	2	<0.1
Brown trout	249	552	109.5
Cutthroat trout	1	2	1.4
Rainbow trout	1	2	1.9
Fall 1996			
Brook trout	4	6	0.1
Brown trout	88	153	50.8
Late Summer 1997			
Brook trout	8	11	0.5
Brown trout	113	252	62.5
Cutthroat trout	1	1	0.4
Rainbow trout	1	1	0.8
Late Summer 1999			
Brook trout	9	13	1.3
Brown trout	145	233	72.5
Cutthroat trout	2	3	3.7
Late Summer 2001			
Brook trout	10	14	1.4
Brown trout	235	361	147.4
Rainbow trout	1	1	1.3
Late Summer 2002			
Brook trout	13	21	3.9
Brown trout	869	1,446	254.4
Rainbow trout	1	2	3.2
Longnose sucker	1	2	<0.1
Late Summer 2003			
Brook trout	5	7	1.3
Brown trout	392	621	148.1
Cutthroat trout	1	1	2.1
Lake trout	1	1	1.1
Rainbow trout	1	1	1.8

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Late Summer 2004			
Brook trout	7	10	1.1
Brown trout	497	818	198.9
Rainbow trout	1	1	1.2
Late Summer 2005			
Brook trout	1	2	0.8
Brown trout	578	963	231.0
Rainbow trout	1	2	2.4
Late Summer 2006			
Brook trout	3	4	1.6
Brown trout	689	958	234.9
Late Summer 2007			
Brown trout	112	141	55.4
Late Summer 2008			
Brook trout	7	8	0.5
Brown trout	361	456	192.6
Cutthroat trout	1	1	0.3
Late Summer 2009			
Brook trout	2	2	N/A
Brown trout	434	529	235
Rainbow trout	1	1	N/A

Table 5. Fish Population Data for Upper Arkansas River Segment 1, Empire Gulch Site (Site AR-5). Data from CEC (1994, 1998a, 2001, 2002, 2003, 2004a, 2005), GEI (2006, 2007, 2008a, b), Roy F. Weston (1995), and Policky (1994, 1998, 1999, 2000, 2001, 2003, 2004a, 2005b, 2006, 2008, 2009)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Spring 1994			
Brook trout	1	2	0.5
Brown trout	36	72	33.4
Spring 1998			
Brook trout	1	1	0.3
Brown trout	50	66	36.2
Cutthroat trout	1	1	0.1
Spring 1999			
Brown trout	71	N/A	N/A
Rainbow trout	1	N/A	N/A
Longnose sucker	1	N/A	N/A
Spring 2000			
Brown trout	54	74	35.7
Fall 1994			
Brook trout	7	9	2.4
Brown trout	96	128	43.8
Rainbow trout	1	1	<0.1
Late Summer 1997			
Brown trout	81	119	53.0
Cutthroat trout	5	6	2.8
Rainbow trout	1	1	1.5
Late Summer 1998			
Brown trout	81	109	57.8
Rainbow trout	1	1	2.3
Late Summer 1999			
Brown trout	77	121	50.1
Rainbow trout	1	1	1.8
Longnose sucker	1	1	0.1
Late Summer 2001			
Brook trout	1	2	<0.1
Brown trout	135	234	74.4
Rainbow trout	3	5	4.8
Longnose sucker	3	3	0.1
Late Summer 2002			
Brown trout	123	225	60.4
Cutthroat trout	2	4	1.4
Rainbow trout	2	4	0.7
Longnose sucker	1	2	0.1
Late Summer 2003			
Brown trout	99	253	66.3
Late Summer 2004			
Brown trout	100	245	96.3
Longnose sucker	1	2	0.2
Late Summer 2005			
Brown trout	182	357	119.2
Longnose sucker	1	1	<0.1

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Late Summer 2006			
Brown trout	227	330	94.6
Late Summer 2007			
Brown trout	58	90	37.1
Longnose sucker	1	1	0.3
Late Summer 2008			
Brown trout	130	180	74.4
Late Summer 2009			
Brown trout	169	267	80
Rainbow trout	4	6	2

Table 6. Fish Population Data for Upper Arkansas River Segment 1, Pan Ark Site (Site AR-6A). Data from Policky (1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005b, 2006, 2008, 2009)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Spring 1999			
Brown trout	92	N/A	N/A
Spring 2000			
Brown trout	87	115	51.0
Rainbow trout	2	2	<0.1
Fall 1998			
Brown trout	147	187	104.3
Rainbow trout	1	1	0.6
Late Summer 1999			
Brown trout	112	141	62.7
Cutthroat trout	2	2	1.1
Rainbow trout	1	1	0.6
White sucker	1	1	0.4
Late Summer 2001			
Brook trout	1	1	0.6
Brown trout	207	612	81.9
Cutthroat trout	2	2	2.3
Rainbow trout	1	1	0.5
Longnose sucker	3	3	<0.1
Late Summer 2002			
Brook trout	1	2	1.4
Brown trout	195	395	133.8
Cutthroat trout	3	6	1.7
Rainbow trout	4	8	1.5
Longnose sucker	20	42	0.9
Late Summer 2003			
Brown trout	309	390	106.7
Cutthroat trout	2	2	0.9
Rainbow trout	3	4	1.8
Longnose sucker	9	11	0.4
White sucker	1	1	<0.1
Late Summer 2004			
Brown trout	348	446	137.8
Cutthroat trout	4	5	4.2
Rainbow trout	5	6	3.1
Longnose sucker	57	74	7.2
White sucker	11	13	1.7
Late Summer 2005			
Brown trout	435	453	184.9
Cutthroat trout	5	7	27.6
Rainbow trout	5	7	7.1
Longnose sucker	166	167	14.1
White sucker	44	23	3.4

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Late Summer 2006			
Brook trout	1	1	N/A
Brown trout	202	258	109
Rainbow trout	1	1	N/A
Longnose sucker	17	78	6
White sucker	15	61	6
Late Summer 2008			
Brook trout	3	1	N/A
Brown trout	142	195	108
Cutthroat trout	2	N/A	N/A
Rainbow trout	1	N/A	N/A
Longnose sucker	4	5	N/A
Late Summer 2009			
Brook trout	3	4	N/A
Brown trout	184	257	105
Rainbow trout	1	1	N/A
Longnose sucker	1	1	N/A

Table 7. Fish Population Data for Upper Arkansas River Segment 1, Kobe Site (Site AR-6). Data from Policky (1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005b, 2006, 2008, 2009)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Spring 1998			
Brook trout	1	3	0.5
Brown trout	24	63	20.6
Longnose sucker	10	26	33.7
White sucker	1	3	3.6
Spring 1999			
Brook trout	1	N/A	N/A
Brown trout	38	N/A	N/A
Longnose sucker	6	N/A	N/A
Spring 2000			
Brown trout	45	148	34.0
Rainbow trout	8	21	2.7
Fall 1998			
Brown trout	39	152	38.8
Longnose sucker	1	3	3.1
Late Summer 1999			
Brown trout	31	82	27.5
Late Summer 2001			
Brook trout	1	2	0.2
Brown trout	63	132	41.2
Rainbow trout	9	17	4.3
Longnose sucker	1	2	0.4
Late Summer 2002			
Brown trout	201	486	97.5
Cutthroat trout	1	2	0.7
Rainbow trout	9	21	3.3
Longnose sucker	4	9	0.2
Late Summer 2003			
Brown trout	166	372	87.3
Rainbow trout	3	6	1.6
Longnose sucker	1	2	3.2
Late Summer 2004			
Brown trout	81	197	52.3
Rainbow trout	2	4	0.7
Late Summer 2005			
Brown trout	147	302	105.6
Cutthroat trout	2	4	3.2
Late Summer 2006			
Brown trout	106	290	116.1
Late Summer 2008			
Brown trout	66	162	86.0
Late Summer 2009			
Brown trout	92	309	143
Rainbow trout	2	N/A	N/A

Table 8. Fish Population Data for Upper Arkansas River Segment 1, Granite Site (Site AR-7). Data from Policky (1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2006, 2008)

Species	Number Collected	Density (#/ha)	Biomass (lbs/ac)
Spring 1998			
Brown trout	81	144	64.6
Rainbow trout	2	2	<0.1
Spring 1999			
Brown trout	75	N/A	N/A
Longnose sucker	1	N/A	N/A
Spring 2000			
Brown trout	108	153	53.3
Rainbow trout	2	2	<0.1
Longnose sucker	1	1	<0.1
Fall 1994			
Brown trout	206	243	67.5
Cutthroat trout	2	2	1.1
Rainbow trout	2	2	0.7
Longnose sucker	8	9	6.4
White sucker	13	15	21.1
Fall 1998			
Brown trout	94	109	54.1
Rainbow trout	1	1	0.1
Late Summer 2001			
Brown trout	160	266	70.0
Late Summer 2002			
Brown trout	163	230	55.1
Rainbow trout	1	1	0.1
Late Summer 2003			
Brown trout	138	210	69.4
Rainbow trout	1	1	0.2
Late Summer 2004			
Brown trout	167	236	80.7
Rainbow trout	1	1	< 0.1
Longnose sucker	2	2	< 0.1
Late Summer 2006			
Brown trout	144	226	104
Late Summer 2008			
Brown trout	255	369	143

Table 9. Benthic Invertebrate Population Data for Upper Arkansas River Segment 1, Smith Ranch Site (Site AR-4). Data from CEC (1994, 1998a, 1999a, 2001, 2002, 2003, 2004a, 2005), EPA (2008), GEI (2006, 2007a, 2008a, b), and Roy F. Weston (1995)

Year	Density (#/m^2)	Number of Taxa	Number of EPT Taxa	Diversity (H')
Spring				
1994	9,803	40	19	3.53
1995	18,677	38	22	3.79
1996	15,578	39	21	3.76
1997	27,952	50	29	3.77
1998	6,625	45	26	3.89
1999	10,984	43	25	3.29
2000	14,658	47	23	4.02
2001	27,899	40	23	3.46
2002	25,655	40	20	3.36
2003	18,192	58	28	3.96
2004	26,886	58	28	4.33
2005	8,467	60	25	4.40
2006	10,287	57	28	4.16
2007	7,009	52	22	4.06
2008	13,513	48	25	3.73
Fall				
1994	9,478	36	23	3.66
1995	4,934	33	17	3.56
1996	14,514	47	23	4.15
1997	5,738	38	21	3.79
1998	15,140	44	26	3.80
1999	9,198	34	20	3.70
2000	26,501	60	28	3.95
2001	12,972	45	23	4.18
2002	16,927	54	21	4.08
2003	18,183	53	22	4.26
2004	23,728	49	23	3.64
2005	14,060	51	21	3.39
2006	16,804	59	26	4.34
2007	22,177	50	20	4.05
2008	9,312	45	22	4.27

Table 10. Benthic Invertebrate Population Data for Upper Arkansas River Segment 1, Empire Gulch Site (Site AR-5). Data from CEC (1994, 1998a, 1999a, 2001, 2002, 2003, 2004a, 2005), EPA (2008), GEI (2006, 2007a, 2008a, b), and Roy F. Weston (1995)

Year	Density (#/m^2)	Number of Taxa	Number of EPT Taxa	Diversity (H')
Spring				
1994	5,504	30	16	2.04
1995	6,042	44	25	2.99
1996	6,711	36	19	3.84
1997	14,943	45	23	3.61
1998	4,998	37	20	3.04
1999	4,231	38	20	3.83
2000	8,650	39	20	3.67
2001	11,009	43	25	3.46
2002	10,187	48	22	3.23
2003	8,007	54	25	2.85
2004	9,377	53	23	3.95
2005	8,331	54	22	3.50
2006	10,356	55	21	3.58
2007	4,553	45	18	3.57
2008	8,985	53	26	3.37
Fall				
1994	3,492	22	14	3.01
1995	2,048	31	17	3.76
1996	13,870	43	21	3.39
1997	7,448	42	22	3.14
1998	6,523	41	26	3.85
1999	15,334	35	20	3.39
2000	12,758	43	21	3.39
2001	8,506	54	26	3.25
2002	9,173	41	17	3.56
2003	16,970	45	18	3.96
2004	6,463	57	25	3.74
2005	9,177	45	17	3.62
2006	7,104	47	19	3.81
2007	14,625	47	19	4.02
2008	7,708	49	26	3.54

Table 11. Benthic Invertebrate Data for Upper Arkansas River Segment 1, Kobe and Granite Sites (Sites AR-6 and AR-7), for Spring 1998. Data from CEC (1998c)

Density (#/m^2)	Number of Taxa	Number of EPT Taxa	Diversity (H')
Spring 1998 – Kobe Site			
2,333	35	19	3.63
Spring 1998 – Granite Site			
6,305	33	17	2.87

Table 12. PHABSIM Habitat (WUA in ft²/1,000 ft of Stream) Versus Flow (cfs) Relationships for Upper Arkansas River Segment 1. Data from Smith and Hill (2000)

Flow (cfs)	Life Stage			
	Spawning	Fry	Juvenile	Adult
Brown Trout				
70	7,588	2,739	24,140	15,334
86	8,611	2,452	24,968	16,434
97	9,285	2,272	25,172	16,868
100	9,444	2,195	25,190	16,944
200	7,843	3,613	19,642	14,212
300	4,488	5,280	12,227	9,587
400	3,747	6,089	7,875	6,968
500	5,360	7,406	5,695	5,951
Rainbow Trout				
70	4,909	2,739	27,820	8,288
86	6,202	2,452	27,624	9,432
97	7,086	2,272	27,149	10,048
100	7,336	2,195	26,963	10,192
200	6,847	3,613	16,996	10,176
300	2,150	5,280	9,496	6,410
400	2,265	6,089	6,814	4,003
500	3,041	7,406	6,635	3,106

Table 13. Habitat Data for Upper Arkansas River Segment 1 (Sites AR-4 and AR-5). Data from CEC (1999a, 2001, 2002, 2003, 2004a, 2005) and GEI (2006, 2007a, 2008a)

Year	% Pools	Mean Bank Width (ft)	Mean Wetted Width (ft)	Dominant Substrate	Mean Depth (ft)
AR-4					
1998	6.0	104.6	51.9	Cobble	1.4
1999	6.9	106.2	52.3	Cobble	1.4
2000	6.6	117.3	57.7	Cobble	1.6
2001	6.6	117.3	57.7	Cobble	1.6
2002	12.4	119.1	42.9	Cobble	1.6
2003	22.5	115.1	42.6	Cobble	1.8
2004	19.0	111.7	42.0	Cobble	1.8
2005	20.1	110.8	37.2	Cobble	1.5
2006	19.7	106.7	42.8	Cobble	1.7
2007	36.6	118.0	43.4	Cobble	2.1
AR-5					
1998	0	71.6	48.8	Cobble	1.2
1999	0	70.8	48.5	Cobble	1.2
2000	0	70.4	48.5	Cobble	1.5
2001	0	76.9	44.3	Cobble	1.1
2002	0	76.5	45.0	Cobble	1.0
2003	0	65.6	42.4	Cobble	1.2
2004	0	68.8	45.4	Cobble	1.1
2005	0	67.9	46.6	Cobble	1.2
2006	0	94.3	45.5	Cobble	1.3
2007	0	93.2	46.9	Cobble	1.5

Table 14. PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Upper Arkansas River Segment 2. Data from Smith and Hill (2000)

Flow (cfs)	Life Stage			
	Spawning	Fry	Juvenile	Adult
Brown Trout				
210	4,396	3,206	18,383	25,295
350	3,390	5,108	14,726	27,640
500	2,781	5,147	15,566	27,159
650	2,320	4,839	16,128	25,642
890	1,646	2,594	16,675	23,362
1050	1,594	2,275	17,078	23,143
1200	1,914	1,904	15,877	24,287
1420	2,024	1,739	15,925	24,048
Rainbow Trout				
210	3,928	3,206	21,994	20,438
350	2,849	5,108	19,634	23,542
500	2,240	5,147	20,555	23,806
650	1,823	4,839	20,573	22,556
890	1,250	2,594	20,864	20,341
1050	1,064	2,275	21,548	20,209
1200	1,145	1,904	21,047	21,691
1420	1,437	1,739	21,517	21,486

Table 15. Summary of Upper Arkansas River Segment 3 Benthic Invertebrate Parameters for a Site near Nathrop (Site UAR-1). Data Were Collected in Fall 2003 and Spring 2004 for the SDS EIS (CEC 2006)

Parameter/Date	Fall 2003	Spring 2004
Abundance (#/sample)	7,777	5,274
Number of Taxa	33	47
Number of EPT Taxa	14	17
Diversity (H')	3.67	3.85
Biotic Index (HBI)	4.55	4.52

Table 16. PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Upper Arkansas River Segment 3. Data from Smith and Hill (2000)

Flow (cfs)	Life Stage			
	Spawning	Fry	Juvenile	Adult
Brown Trout				
250	16,930	2,590	18,845	22,069
357	15,560	1,604	18,375	22,438
400	15,229	1,241	17,717	22,012
550	13,409	1,500	14,629	19,583
715	10,959	1,506	11,838	16,692
830	10,055	1,855	10,547	15,101
1,000	9,195	1,608	9,449	13,344
1,325	7,839	1,584	9,026	11,505
Rainbow Trout				
250	15,163	2,590	23,873	17,409
357	13,140	1,604	21,635	18,825
400	11,998	1,241	20,475	18,805
550	8,644	1,500	16,622	17,191
715	6,969	1,506	13,746	14,664
830	6,672	1,855	12,744	13,029
1,000	6,686	1,608	12,111	11,156
1,325	6,514	1,584	12,290	9,333

Table 17. Fish Population Data for Upper Arkansas River Segment 4, Big Bend Site. Data from Policky (1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2006, 2008)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Spring 1994			
Brown trout	N/A	35	19.6
Rainbow trout	N/A	6	4.3
Spring 1996			
Brown trout	N/A	47	21.3
Rainbow trout	N/A	5	4.5
Spring 1998			
Brown trout	915	61	35.2
Cutthroat trout	2	< 1	0.1
Rainbow trout	19	1	0.8
Longnose sucker	90	1	31.1
White sucker	35	2	3.0
Fall 2000			
Brown trout	1,531	102	37.8
Cutthroat trout	4	<0.1	<0.1
Rainbow trout	45	3	2.5
Longnose sucker	108	22	21.8
White sucker	46	N/A	N/A
Fall 2002			
Brown trout	1,197	142	91.5
Cutbow trout	5	N/A	N/A
Cutthroat trout	6	N/A	N/A
Rainbow trout	46	14	19.0
Longnose sucker	89	18	20.0
White sucker	45	12	14.3
Fall 2004			
Brown trout	979	112	61.1
Cutthroat trout	3	NA	NA
Rainbow trout	61	9	3.4
Longnose sucker	77	NA	NA
White sucker	6	NA	NA
Fall 2006			
Brown trout	1,577	151	105.0
Cutthroat trout	3	N/A	N/A
Rainbow trout	114	13	12.8
Longnose dace	25	5	N/A
Longnose sucker	44	8	10.0
White sucker	32	9	12.0
Fall 2008			
Brown trout	755	54	39.2
Cutthroat trout	1	N/A	N/A
Rainbow trout	53	3	3.1
Longnose sucker	14	2	N/A
White sucker	24	5	N/A

Table 18. Fish Population Data for Upper Arkansas River Segment 4, Wellsville Site. Data from Policky (1994, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2006, 2007, 2008, 2009)

Species	Number Collected	Density(#/ac)	Biomass (lb/ac)
Spring 1994			
Brown trout	N/A	188	100.9
Rainbow trout	N/A	12	12.9
Spring 1995			
Brown trout	N/A	193	78.0
Rainbow trout	N/A	35	25.7
Spring 1996			
Brown trout	N/A	274	105.4
Rainbow trout	N/A	26	23.8
Spring 1997			
Brown trout	N/A	180	97.6
Rainbow trout	N/A	20	32.6
Spring 1998			
Brown trout	NA	193	85.9
Longnose dace	13	N/A	N/A
Rainbow trout	NA	13	19.8
Spring 1999			
Brown trout	2,627	217	104.6
Rainbow trout	177	18	10.3
Cutthroat trout	1	<0.1	0.1
Longnose dace	8	N/A	N/A
Longnose sucker	39	N/A	4.4
White sucker	29	N/A	2.9
Spring 2000			
Brown trout	2,676	198	64.1
Rainbow trout	126	9.1	5.0
Cutthroat trout	10	0.6	0.3
Longnose dace	5	N/A	N/A
Longnose sucker	48	N/A	3.1
White sucker	39	N/A	2.2
Fall 1999			
Brown trout	2,495	282	114.0
Rainbow trout	102	14	10.3
Longnose sucker	61	12	12.5
White sucker	35	N/A	N/A
Fall 2000			
Brown trout	1,735	205	62.3
Cutthroat trout	3	< 1	0.1
Rainbow trout	50	22	11.4
Longnose sucker	11	N/A	N/A
White sucker	10	N/A	N/A
Fall 2001			
Brown trout	2,213	230	91.4
Rainbow trout	48	8	8.1
Longnose sucker	18	N/A	N/A
White sucker	3	N/A	N/A

Species	Number Collected	Density(#/ac)	Biomass (lb/ac)
Fall 2002			
Brown trout	2,521	392	223.9
Rainbow trout	49	3	2.8
Longnose sucker	81	42	36.6
White sucker	28	N/A	N/A
Fall 2003			
Brown trout	2,575	451	146.2
Rainbow trout	56	6	2.1
Longnose sucker	55	26	23.5
White sucker	17	N/A	N/A
Fall 2004			
Brown trout	2,315	310	139.4
Rainbow trout	64	33	32.0
Longnose sucker	30	NA	NA
White sucker	2	NA	NA
Fall 2006			
Brown trout	1,149	314	172.6
Rainbow trout	111	32	16.7
Longnose dace	2	N/A	N/A
Longnose sucker	14	4	N/A
White sucker	17	5	N/A
Fall 2007			
Brown trout	1,303	222	116.5
Rainbow trout	125	19	13.2
Longnose sucker	19	6	N/A
White sucker	28	11	N/A
Fall 2008			
Brown trout	796	141	89.7
Rainbow trout	142	20	13.8
Longnose sucker	8	2	N/A
White sucker	23	8	N/A
Fall 2009			
Brown trout	735	154	100.5
Rainbow trout	221	22	19.5
White sucker	16	3	N/A

Table 19. Fish Population Data for Upper Arkansas River Segment 4, Coaldale Site. Data from Policky (1994, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2008)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Spring 1994			
Brown trout	N/A	157	78.6
Spring 1996			
Brown trout	N/A	283	111.7
Rainbow trout	N/A	12	6.2
Spring 1998			
Brown trout	1,978	214	119.2
Rainbow trout	24	4	3.4
Longnose sucker	125	N/A	16.3
White sucker	27	N/A	3.6
Fall 2000			
Brown trout	3,202	269	87.0
Brook trout	1	N/A	N/A
Cutthroat trout	1	N/A	N/A
Rainbow trout	104	18	N/A
Longnose sucker	174	72	N/A
White sucker	32	10	N/A
Fall 2002			
Brown trout	2,288	252	146.2
Rainbow trout	45	5	2.6
Longnose sucker	122	N/A	N/A
White sucker	12	N/A	N/A
Fall 2004			
Brown trout	1,981	234	109.2
Rainbow trout	103	18	12.9
Longnose sucker	128	NA	NA
White sucker	26	NA	NA
Fall 2008			
Brown trout	987	180	121.1
Rainbow trout	155	17	15.1
Longnose sucker	76	93	N/A
White sucker	26	10	N/A

Table 20. Benthic Invertebrate Data for Upper Arkansas River Segment 4 at a Site Upstream of Salida (Site UAR-2) and at a Site near Vallie (Site UAR-3) in Fall 2003 and Spring 2004, sampled as part of the SDS EIS (CEC 2006)

Site	Density (#/m^2)	Number of Taxa	Number of EPT Taxa	Diversity (H')
Fall 2003				
UAR-2	7,046	35	12	3.23
UAR-3	14,460	34	14	3.03
Spring 2004				
UAR-2	2,202	38	14	3.40
UAR-3	11,018	41	14	2.36

Table 21. PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Upper Arkansas River Segment 4. Data from Smith and Hill (2000)

Flow (cfs)	Life Stage			
	Spawning	Fry	Juvenile	Adult
Brown Trout				
250	36,979	1,505	40,880	36,970
327	35,182	2,034	37,422	38,520
400	32,660	2,260	33,350	38,241
550	26,892	1,132	25,587	35,244
700	21,217	824	20,444	31,320
830	16,404	711	18,127	27,979
1,000	11,062	808	16,661	24,425
1,300	8,007	954	15,028	19,734
Rainbow Trout				
250	36,695	1,505	50,690	26,581
327	36,474	2,034	44,988	30,602
400	32,573	2,260	39,277	32,502
550	20,793	1,132	29,679	31,865
700	11,744	824	24,172	28,093
830	8,945	711	21,796	24,437
1,000	6,995	808	19,779	20,452
1,300	4,938	954	16,353	15,928

Table 22. Benthic Invertebrate Population Data for Upper Arkansas River Segment 5. Data from Winters (1988)

Date	Density (#/m^2)	Number of Taxa	Number of EPT Taxa
July 1982	1,080	22	8
September 1982	2,869	22	11
October 1982	4,603	30	17
November 1982	1,179	22	13
December 1982	1,879	24	15
January 1983	3,272	20	11
February 1983	2,083	22	12
March 1983	1,640	26	16
April 1983	2,710	28	14
March 1983	2,109	30	16
August 1983	7,328	25	14

Table 23: PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Upper Arkansas River Segment 5. Data from Smith and Hill (2000)

Flow (cfs)	Life Stage			
	Spawning	Fry	Juvenile	Adult
Brown Trout				
300	25,621	2,190	47,533	36,049
356	25,218	2,326	48,923	37,915
500	23,318	1,968	47,558	39,678
600	21,683	1,135	44,099	39,031
700	20,421	918	39,677	37,518
744	19,915	689	37,722	36,733
800	19,384	414	35,270	35,646
900	18,388	334	31,094	33,497
1,000	17,605	449	27,292	31,368
1,100	16,992	468	24,015	29,305
1,200	16,501	438	21,219	27,276
1,300	15,928	448	18,737	25,299
1,400	15,157	447	16,484	23,385
1,500	14,336	427	14,422	21,514
1,600	13,406	423	12,512	19,802
1,700	12,602	356	10,826	18,180
1,797	11,924	352	9,417	16,730
Rainbow Trout				
300	20,476	2,190	50,932	22,058
356	19,526	2,326	50,248	24,467
500	16,086	1,968	44,574	28,026
600	14,711	1,135	39,782	28,590
700	13,625	918	35,258	28,250
744	13,214	689	33,427	27,844
800	12,721	414	31,375	27,115
900	12,607	334	28,005	25,585
1,000	12,747	449	25,241	23,955
1,100	12,756	468	22,810	22,334
1,200	12,395	438	20,490	20,783
Rainbow Trout				
1,300	11,979	448	18,346	19,401
1,400	11,345	447	16,283	18,108
1,500	10,843	427	14,400	16,895
1,600	10,160	423	12,692	15,772
1,700	9,695	356	11,294	14,730
1,797	9,274	352	10,194	13,823

Table 24. PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Upper Arkansas River Segment 6. Data from Smith and Hill (2000)

Flow (cfs)	Life Stage			
	Spawning	Fry	Juvenile	Adult
Brown Trout				
350	0	1,517	13,251	27,890
450	0	1,954	11,254	27,474
540	0	2,909	9,677	25,816
630	0	1,995	8,981	23,808
730	5	1,808	8,728	22,352
900	37	2,251	8,613	19,517
1,200	38	2,621	7,496	15,578
1,630	64	2,670	6,512	13,130
1,850	109	2,744	6,621	11,973
2,000	96	2,760	6,690	11,598
Rainbow Trout				
350	0	1,517	15,670	26,254
450	0	1,954	13,571	27,694
540	0	2,909	12,286	27,074
630	0	1,995	11,678	25,165
730	0	1,808	11,571	23,419
900	29	2,251	11,114	20,083
1,200	19	2,621	9,843	15,821
1,630	30	2,670	9,667	12,842
1,850	134	2,744	9,706	11,414
2,000	43	2,760	9,581	11,096

Table 25. Fish Population Data for Upper Arkansas River Segment 7, Canon City Site. Data from Policky (2005b and 2007)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Fall 2005			
Brown trout	889	80	38.9
Rainbow trout	12	N/A	N/A
Fathead minnow	2	N/A	N/A
Longnose dace	101	N/A	N/A
Longnose sucker[1]	438	N/A	N/A
White sucker[1]	133	N/A	N/A
Green sunfish	1	N/A	N/A
Fall 2007			
Brown trout	346	49	26.0
Fathead minnow	1	N/A	N/A
Longnose dace	54	N/A	N/A
Longnose sucker[1]	163	9	N/A
White sucker[1]	38	2	N/A

Note:
(1) Colorado Parks and Wildlife (CPW) noted that numerous suckers were seen but not collected.

Table 26. Fish Population Data (Number Collected) for Upper Arkansas River Segment 7. Data from Loeffler et al. (1982)

Date	1979	1980		1981		
Species/Site #	***18***	***2***	***30***	***16***	***17***	***19***
Black bullhead	0	0	2	0	0	0
Brown trout	0	0	6	2	16	0
Central stoneroller	0	0	0	91	0	0
Fathead minnow	0	2	47	8	0	1
Flathead chub	0	17	9	5	0	0
Green sunfish	0	0	22	12	0	0
Longnose dace	20	38	84	15	24	2
Longnose sucker	0	5	8	2	67	0
Red shiner	0	0	0	18	0	1
Sand shiner	0	3	0	45	0	0
White sucker	16	4	108	90	10	34

Table 27. Benthic Invertebrate Data for Upper Arkansas River Segment 7 at a Site just Upstream of Canon City (Site UAR-4) and at a Site just Upstream of Pueblo Reservoir (Site UAR-5) in Fall 2003 and Spring 2004, sampled as part of the SDS EIS (CEC 2006)

Site	Density (#/m^2)	Number of Taxa	Number of EPT Taxa	Diversity (H')	HBI
Fall 2003					
UAR-4	4,710	39	16	3.53	4.93
UAR-5	9,922	26	9	3.76	5.14
Spring 2004					
UAR-4	12,572	42	15	2.65	5.33
UAR-5	1,771	34	9	3.51	4.44

Table 28. Fish Population Data (Number Collected) for Lower Arkansas River Segments 1 and 2 collected in April 2004 (CEC 2006), 2005 and 2006 (GEI 2007b), and 2009 (Melby 2010)

Species/Site	Pueblo Reservoir to Pueblo Blvd.		Pueblo Blvd. to Wildhorse Creek		Downstream of 4th Street Bridge	Runyon Wildlife Area	At Moffat St.	
	2004	2009[1]	2004	2009	2004	2004	2005	2006
Black crappie	1	0	1	0	0	0	0	0
Bluegill	0	0	0	0	0	0	16	0
Brown trout	17	14	3	12	0	0	0	0
Carp	1	1	4	4	0	0	0	0
Central stoneroller	0	0	1	0	20	142	0	9
Channel catfish	1	0	0	0	0	0	0	0
Cutbow trout	2	0	21	0	0	0	0	0
Fathead minnow	0	0	0	0	0	3	0	0
Flathead chub	0	0	0	0	11	1	0	203
Green sunfish	1	0	0	0	0	0	26	0
Largemouth bass	5	4	2	3	0	0	24	0
Longnose dace	21	16	8	5	38	10	1	5
Longnose sucker	16	13	14	9	72	1	13	0
Orangespotted sunfish	0	0	0	0	0	4	24	0
Rainbow trout	19	191	16	116	0	0	0	0
Red shiner	0	0	0	0	0	4	0	0
Sand shiner	0	0	0	0	0	3	0	11
Saugeye	0	0	1	0	0	0	0	0
Smallmouth bass	8	28	0	9	2	0	27	0
Spotted bass	1	1	0	0	0	0	0	0
Walleye	2	0	0	0	0	0	0	0
White crappie	0	0	0	0	0	0	1	0
White sucker	223	135	297	151	309	12	22	13
Wiper	0	0	2	0	0	0	0	0
Yellow perch	0	2	2	0	0	0	0	0

Note:
(1) The site in 2009 extended downstream to the old Valco cement bridge, upstream of Pueblo Boulevard.

Table 29. Fish Population Data (Number Collected) for Lower Arkansas River Segments 1 and 2 at Sites sampled in Pueblo. Data from Loeffler et al. (1982). Sites sampled in 1979 and 1980 were upstream of Wildhorse Creek and the site sampled in 1981 was downstream of Wildhorse Creek

Date	1979		1980	1981
Species/Site #	***17***	***26***	***12***	***12***
Black bullhead	0	0	0	2
Channel catfish	0	0	70	0
Fathead minnow	1	22	1	8
Flathead chub	0	2	15	1
Green sunfish	0	23	118	74
Longnose dace	30	0	266	116
Longnose sucker	0	0	0	4
Red shiner	0	10	16	0
Sand shiner	0	4	46	0
Stoneroller	0	7	0	24
White crappie	0	0	0	2
White sucker	0	4	16	13

Table 30. Benthic Invertebrate Data for Lower Arkansas River Segments 1 and 2 at Sites Downstream of Pueblo Reservoir (Site MAR-1), at the Nature Center (Site MAR-2), downstream of Wildhorse Creek (Site MAR-3), and Upstream of Fountain Creek (Site MAR-4) in Fall 2003 and Spring 2004, Sampled as Part of the SDS EIS (CEC 2006)

Site	Density (#/m^2)	Number of Taxa	Number of EPT Taxa	Diversity (H')	HBI
Fall 2003					
MAR-1	14,508	27	6	3.00	5.18
MAR-2	12,300	33	9	3.47	5.09
MAR-3	6,736	27	9	3.64	5.51
MAR-4	2,189	21	4	2.78	7.58
Spring 2004					
MAR-1	2,635	26	5	3.64	6.21
MAR-2	6,548	36	10	4.00	5.32
MAR-3	3,717	31	7	3.18	5.57
MAR-4	550	31	4	3.84	7.15

Table 31. PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Lower Arkansas River Segment 1. Data Collected in 2004 as Part of the SDS EIS (CEC 2006)

Flow (cfs)	Life Stage		
	Juvenile	Adult	Adult
	Brown Trout		*Rainbow Trout*
50	23,767	15,830	11,937
100	31,561	22,557	13,958
200	38,309	31,220	13,739
300	38,329	35,631	15,403
400	38,054	35,914	11,260
500	37,731	37,199	11,855
750	35,315	35,802	8,460
1,000	30,125	33,773	7,804
1,250	27,423	33,536	8,517
1,500	25,904	33,001	9,100
1,750	26,835	36,622	9,809
2,000	26,921	35,869	10,179
2,250	27,445	35,090	10,424
2,500	27,872	34,440	10,710

Table 32. Fish Population Data (Number Collected) for Lower Arkansas River Segment 3. Data from Loeffler et al. (1982)

Date	1979						1980				1981			
Species/Site #	*11*	*24*	*27*	*29*	*34*	*43*	*14*	*17*	*24*	*26*	*7*	*8*	*35*	*36*
Black bullhead	0	0	0	0	0	2	0	2	0	0	1	0	0	29
Carp	0	0	0	1	1	0	0	3	2	0	3	0	0	29
Central stoneroller	0	5	0	0	1	0	0	0	0	0	0	0	0	6
Channel catfish	0	0	0	0	0	0	1	3	0	0	0	0	0	0
Fathead minnow	1	3	0	0	0	6	843	132	11	28	15	17	16	7
Flathead chub	19	61	0	50	4	8	22	3	6	13	19	12	7	7
Green sunfish	0	2	0	0	0	2	46	12	7	5	4	2	3	22
Largemouth bass	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longnose dace	0	0	0	0	4	0	2	0	0	1	0	0	0	0
Longnose sucker	0	0	0	0	0	0	3	1	0	2	0	0	0	0
Mosquitofish	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Orangespotted sunfish	0	0	0	0	0	0	0	3	0	0	0	0	1	0
Plains killifish	0	7	1	0	0	0	30	0	4	124	21	46	3	11
Red shiner	0	165	0	127	5	31	391	1,479	13	16	24	108	9	16
Sand shiner	3	249	54	11	8	41	64	54	24	29	262	136	3	330
White crappie	0	0	0	0	0	1	4	0	0	0	0	1	0	0
White sucker	1	1	0	0	1	8	1	0	2	3	0	7	2	0

Table 33. Fish Population Data (Number Collected) for Lower Arkansas River Segment 3. Data from Woodling (1999)

Date	1995	1995	1995	1998	1998	1999
Species/Site	***Las Animas***	***Old Bent's Fort***	***La Junta***	***Rocky Ford SWA***	***Ft Lyons Headgate***	***Co. Canal Headgate***
Black bullhead	4	0	0	0	0	0
Brook stickleback	0	0	0	0	2	0
Carp	10	16	3	0	1	0
Central stoneroller	0	0	0	0	18	0
Channel catfish	13	18	10	4	0	0
Fathead minnow	18	0	0	0	8	1
Flathead catfish	0	0	0	3	0	0
Flathead chub	75	8	10	0	70	10
Green sunfish	4	3	0	1	0	0
Longnose dace	2	0	0	0	0	7
Longnose sucker	3	2	0	0	0	0
Orangespotted sunfish	0	0	0	0	1	0
Red shiner	234	31	5	9	221	11
Sand shiner	10	0	0	1	84	119
Suckermouth minnow	0	0	0	0	4	0
White sucker	0	0	4	0	2	0
Yellow perch	0	0	1	0	0	0

Table 34. Fish Population Data (Number Collected) for Lower Arkansas River Segment 3. Data from CPW (Krieger to Conklin 2005) and Melby 2006 based on collections in February and March, 2005 by Dr. Bestgen of CSU–Fort Collins

Species/Site #	01	02	03	05	06	07	08	09	10	11	12	13	14
Arkansas darter	0	0	0	0	0	0	19	0	0	0	0	0	0
Black bullhead	0	0	0	0	0	0	0	2	0	1	0	0	0
Black crappie	0	0	0	0	0	0	2	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	3	0	0	1	0	0	0
Brook stickleback	0	0	0	0	0	0	22	27	8	20	0	0	0
Brown trout	0	0	0	0	0	0	0	0	0	1	0	0	0
Carp	1	0	1	0	0	1	1	25	1	4	0	0	2
Central stoneroller	0	0	0	0	0	0	0	1	3	42	23	0	1
Channel catfish	7	0	0	3	0	1	0	0	1	1	0	0	0
Fathead minnow	11	0	76	50	14	0	54	5	0	2	3	15	75
Flathead chub	0	0	2	4	1	53	14	6	5	1	54	8	206
Green sunfish	0	0	1	2	0	1	8	0	0	2	0	0	0
Largemouth bass	0	0	0	0	0	0	4	0	0	2	0	1	0
Longnose dace	3	0	0	0	0	2	0	8	2	1	1	0	1
Longnose sucker	0	0	0	0	0	2	0	9	1	2	4	0	0
Mosquitofish	0	0	0	10	0	0	3	0	0	0	0	1	16
Orangespotted sunfish	0	0	0	0	0	0	1	1	0	0	0	0	0
Plains killifish	0	0	1	3	0	1	29	2	5	3	0	0	32
Rainbow trout	0	0	0	0	0	1	0	0	0	1	0	0	0
Red shiner	8	15	116	33	23	78	239	120	205	82	66	84	238
Sand shiner	821	5	173	173	17	22	285	54	59	31	82	38	662
Smallmouth bass	0	0	0	0	0	1	0	0	0	10	0	0	0
Suckermouth minnow	4	0	3	3	0	0	0	0	0	0	0	0	2
White sucker	0	0	0	0	0	40	0	28	6	12	2	1	1

Table 35. Fish Population Data (Number Collected) for Lower Arkansas River Segment 3 collected from three sites in 2005 and 2006 as part of the Pueblo Selenium Study (GEI Consultants 2007b)

Date	2005			2006		
Species/Site #	***Near Neilson St.***	***Near Baxter***	***Near Nyberg***	***Near Neilson St.***	***Near Baxter***	***Near Nyberg***
Black bullhead	0	0	0	1	0	0
Bluegill	0	0	0	0	2	0
Carp	0	4	2	0	0	3
Central stoneroller	2	21	1	0	12	0
Channel catfish	0	1	0	1	0	0
Fathead minnow	5	19	4	6	0	0
Flathead chub	34	2	4	46	20	1
Green sunfish	1	0	1	0	1	0
Largemouth bass	3	0	6	5	6	5
Longnose dace	0	3	0	1	2	0
Longnose sucker	0	1	1	0	0	1
Mosquitofish	0	0	2	0	1	2
Plains killifish	0	3	0	1	0	0
Red shiner	5	7	45	42	12	13
Sand shiner	50	8	16	0	7	1
Saugeye	0	0	0	1	0	2
Smallmouth bass	7	3	5	0	0	0
White crappie	0	0	2	0	0	0
White sucker	32	16	10	5	5	5
Yellow bullhead	0	0	1	0	0	0

Table 36. Benthic Invertebrate Data for Lower Arkansas River Segment 3 at Sites near Baxter (Site LAR-1), Upstream of Fowler (Site LAR-2), Upstream of Rocky Ford (Site LAR-3), and at Las Animas (Site LAR-4) in Fall 2003 and Spring 2004, sampled as part of the SDS EIS (CEC 2006)

Site	Density (#/m^2)	Number of Taxa	Number of EPT Taxa	Diversity (H')	HBI
Fall 2003					
LAR-1	1,209	24	6	1.79	5.21
LAR-2	3,248	27	8	3.48	5.83
LAR-3	2,915	41	12	4.06	6.67
LAR-4	3,190	25	7	3.62	6.14
Spring 2004					
LAR-1	893	19	3	2.74	5.92
LAR-2	1,052	23	4	3.24	5.69
LAR-3	669	23	4	1.32	6.04
LAR-4	924	25	3	3.51	6.62

Table 37. Benthic Invertebrate Population Data for Lower Arkansas River Segment 3. Data from CEC (1995, 1998b, 1999b)

Year	Density #/m^2	Number of Taxa	Number of EPT Taxa	Diversity
Site: 60m Upstream of WWTP North Bank				
1994	466	14	4	2.85
1996	342	19	4	3.39
1998	56	6	3	1.96
Site: 60m Upstream of WWTP Middle Channel				
1994	676	15	5	2.99
1996	32	6	0	2.09
1998	292	14	3	2.76
Site: 60 m Upstream of WWTP South Bank				
1994	1,913	9	4	2.21
1996	199	16	5	3.03
1998	110	12	1	2.97
Site: 900 m Downstream of WWTP North Bank				
1994	875	10	4	2.54
1996	652	25	4	3.46
Site: 900 m Downstream of WWTP Middle Channel				
1994	1,148	10	4	2.50
1996	306	13	2	2.35
1998	138	12	1	2.78
Site: 900m Downstream of WWTP South Bank				
1994	2,384	10	4	1.97
1996	760	19	4	2.65
1998	1,100	8	2	1.63
Site: 1,700m Downstream of WWTP North Bank				
1994	1,131	11	4	2.33
1996	91	8	2	1.66
1998	9	3	0	1.17
Site: 1,700m Downstream of WWTP Middle Channel				
1998	43	6	0	2.19
Site: 1,700m Downstream of WWTP South Bank				
1994	965	13	4	2.63
1996	991	21	6	3.37
Site: 4,000m Downstream of WWTP North Channel				
1994	928	8	4	2.58
1996	147	8	2	2.19
1998	74	6	1	2.32
Site: 4,000m Downstream of WWTP Middle Channel				
1994	763	9	3	2.51
1998	154	13	4	2.67
Site: 4,000m on Center of WWTP South Bank				
1994	2,487	14	4	2.34
1996	504	18	4	2.92

Table 38. PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Lower Arkansas River Segment 3. Data Collected as Supplemental Data in 2011

Flow (cfs)	Species/Life Stage									
	Red shiner	*Sand shiner*	*Plains killifish*	*Channel catfish*	*White sucker*			*Flathead chub*		
	Adult	Adult	Adult	Juv/Fry	Adult	Fry	Spawning	Adult	Fry	Spawning
50	1,672	11,745	3,909	1,619	43	831	15,423	20,647	18,923	3,308
100	3,518	20,908	4,814	2,501	52	1,500	33,264	42,917	29,348	7,426
200	5,135	26,486	3,909	4,791	253	2,306	49,986	64,009	38,591	10,003
300	5,461	21,602	2,649	6,437	464	3,857	41,414	73,155	33,231	6,857
400	5,951	18,280	3,380	5,930	944	4,725	29,378	76,711	30,795	6,375
437	6,030	17,314	2,615	6,018	1,169	4,957	26,183	78,079	29,733	7,232
500	6,486	16,156	2,987	5,931	1,514	5,324	22,042	79,748	26,860	6,656
750	5,555	12,823	2,578	5,017	2,857	5,582	15,021	82,291	21,491	7,796
1,000	4,738	9,885	1,654	5,791	3,561	5,346	12,434	78,417	17,225	6,529
1,170	4,101	7,735	1,109	4,939	3,880	5,425	10,364	74,395	14,800	5,339
1,250	3,789	6,845	940	4,571	3,955	5,456	9,163	72,217	13,618	4,959
1,500	3,011	4,724	833	3,647	3,979	4,460	6,436	65,230	10,431	3,612
1,750	2,369	3,412	869	2,622	3,440	4,316	4,203	58,545	7,932	2,454
2,000	2,521	3,021	892	1,688	2,934	4,644	2,793	52,244	6,059	1,641
2,250	2,250	3,031	1,132	1,607	2,783	4,397	2,342	46,556	4,940	1,440
2,500	2,247	3,658	2,609	1,796	2,597	4,718	2,184	41,630	4,801	1,463
2,960	4,892	9,407	5,329	2,545	2,549	8,344	3,401	37,012	8,941	4,246
3,000	5,119	9,803	5,315	2,667	2,575	8,721	3,558	36,741	9,307	4,673
3,500	6,468	12,301	4,846	6,193	4,305	14,240	5,548	34,197	12,619	9,010
4,000	11,123	17,937	8,237	10,912	7,037	19,610	8,272	33,660	20,514	13,032
4,500	14,243	20,599	6,962	13,491	10,609	22,035	13,393	35,139	24,667	15,205
5,000	14,983	20,619	3,352	18,476	13,798	20,814	16,188	36,074	25,034	15,267

Table 39. Fish Population Data (Number Collected) for Lower Arkansas River Segment 4, collected in 2006 and 2009.Data from CPW (2011)

Species/Site	Above Hwy. 50 near Lamar - 2006	Below Hwy. 50 near Lamar - 2006	Below Hwy. 385 - 2006	Below Big Sandy Creek - 2009
Arkansas darter	0	0	0	1
Black crappie	0	0	12	1
Central stoneroller	28	0	16	15
Channel catfish	0	6	8	6
Common carp	0	0	0	2
Fathead minnow	5	8	0	0
Flathead chub	0	0	1	0
Freshwater drum	0	0	0	2
Gizzard shad	0	8	0	8
Green sunfish	3	0	0	8
Longnose sucker	0	0	0	17
Mosquitofish	12	40	0	1,564
Plains killifish	58	72	63	34
Red shiner	11	90	42	202
Sand shiner	122	211	18	209
Saugeye	0	0	11	0
Suckermouth minnow	62	24	0	9
Walleye	0	0	0	1
White sucker	8	0	0	35
Wiper	0	0	0	1

Table 40. Fish Population Data (Number Collected) for Lower Arkansas River Segment 4. Data from CPW (Krieger to Conklin 2005) and Melby 2006 based on collections in February and March, 2005 by Dr. Bestgen of CSU–Fort Collins

Species/Site #	15	16	17	18	19	20	21	22	23
Black bullhead	0	0	1	0	0	0	0	0	0
Carp	23	0	0	2	0	1	4	3	3
Central stoneroller	0	50	12	2	6	22	7	4	39
Channel catfish	0	12	0	0	0	0	1	4	0
Fathead minnow	2	2	4	1	17	1	1	3	53
Green sunfish	1	0	8	0	0	0	0	1	0
Mosquitofish	93	3	0	0	21	0	7	53	17
Plains killifish	0	74	247	233	452	158	187	19	67
Red shiner	4	109	18	128	83	55	21	590	1,200
Sand shiner	1	482	921	411	745	516	285	1,071	1,542
Suckermouth minnow	1	30	12	2	2	7	0	8	33
White sucker	0	1	8	0	0	0	0	6	6

Table 41. Fish Population Data (Number Collected) for Lower Arkansas River Segment 4, collected in 2003. Data from CPW (2011)

Species/Site	Above Hwy. 50 near Lamar	Below Hwy. 50 near Lamar	Above Hwy. 89 near Holly
Central stoneroller	27	3	0
Channel catfish	0	7	0
Fathead minnow	0	3	1
Green sunfish	0	1	0
Mosquitofish	6	0	0
Plains killifish	11	30	2
Red shiner	23	214	99
Sand shiner	127	300	112
Suckermouth minnow	8	2	1
White sucker	1	2	1

Table 42. Fish Population Data (Number Collected) for Lower Arkansas River Segment 4, collected in 2004. Data from Ramsay (2004)

Species/Site	Lamar Bridge	Hwy. 50 Crossing E. of Granada
Central stoneroller	32	0
Fathead minnow	1	16
Green sunfish	1	0
Mosquitofish	6	10
Plains killifish	71	51
Red shiner	4	22
Sand shiner	250	78
Suckermouth minnow	87	14
White sucker	15	0

Table 43. Fish Population Data (Number Collected) for Lower Arkansas River Segment 4. Data from Loeffler et al. (1982)

Date	1979	1980				1981					
Species/Site #	***35***	***4***	***6***	***7***	***11***	***9***	***26***	***27***	***29***	***32***	***34***
Black bullhead	0	67	80	14	3	2	34	0	4	8	22
Carp	1	22	76	17	10	0	11	0	80	73	TNTC[1]
Central stoneroller	14	13	6	27	0	11	0	60	45	0	0
Channel catfish	0	11	2	1	0	0	10	0	0	0	2
Fathead minnow	4	105	79	149	62	128	15	71	5	0	1
Flathead chub	18	2	0	4	6	0	0	0	2	13	31
Gizzard shad	0	28	87	72	0	0	0	0	0	2	21
Green sunfish	4	13	16	4	47	14	9	27	28	54	45
Largemouth bass	0	1	0	0	0	0	0	0	0	0	0
Longnose dace	4	0	0	0	0	0	0	0	0	0	0
Longnose sucker	0	0	0	0	0	0	0	0	0	2	0
Orangespotted sunfish	0	10	2	9	1	0	0	0	0	19	2
Plains killifish	1	68	76	234	4	54	165	383	15	0	3
Red shiner	15	178	187	146	34	37	35	52	43	13	14
Sand shiner	80	1,627	690	510	41	945	704	1,214	215	4	17
Suckermouth minnow	0	110	92	90	5	180	39	206	44	0	1
Walleye	0	0	0	1	0	0	0	0	0	3	7
White crappie	0	2	34	13	0	0	0	0	0	0	0
White sucker	2	0	0	0	0	0	0	0	11	0	2

Note:
(1) Too numerous to count.

Table 44. Quantitative Fish Population Data for Grape Creek, Upstream and Downstream of DeWeese Reservoir. Data from CPW (2011)

Species	Number Collected	Density (#/ac)	Biomass (lbs/ac)
Upstream of DeWeese Reservoir			
175 m Above DeWeese Reservoir – August 2003			
Brown trout	8	120	--
Fathead minnow	3	33	--
Longnose dace	22	272	--
Sand shiner	29	316	--
Smallmouth bass	5	54	--
White sucker	17	185	--
Downstream of DeWeese Reservoir			
0.3 miles Above Grape Creek Drive- November 2004			
Brown trout	91	559	81.9
Cutthroat trout	39	249	27.7
Rainbow trout	21	131	--
Longnose sucker	27	185	31.7
White sucker	29	178	43.2
0.3 miles Above Grape Creek Drive- November 2006			
Brown trout	181	1,114	213.3
Rainbow trout	3	18	--
Longnose dace	12	74	--
Longnose sucker	66	417	114.2
White sucker	39	239	--
Above Temple Canyon Road – May 2010			
Brown trout	162	580	134.9
Rainbow trout	8	39	5.6
Longnose sucker	19	71	28.8
White sucker	7	25	--
Above Dead Mule Gulch Access– May 2010			
Brown trout	81	512	92.7
Cutbow trout	1	5	--
Rainbow trout	1	5	--
White sucker	12	112	18.5

Table 45. Qualitative Fish Population Data (Number Collected) for Grape Creek, Upstream and Downstream of DeWeese Reservoir. The Data from 1981 is from Loeffler et al. (1982) and the Remaining was Collected by CPW Biologist and Other Agencies CPW (2011). The Above Swift Creek, Above Hemenway Road, and Above Hermit Road Sites were Each Sampled Four Times in 2004

Species	Site/Date					
	175 m Above DeWeese		500 m Above DeWeese	825 m Above DeWeese	Above Hermit Road	Below Baldy Road
	Upstream of DeWeese Reservoir					
	9/12/95	7/24/00	8/12/03	8/12/03	9/13/95	9/13/95
Brook trout	--	--	--	--	8	14
Brown trout	6	4	14	14	--	--
Cutthroat trout	5	1	--	--	--	--
Rainbow trout	7	22	2	2	--	--
Fathead minnow	--	--	7	11	--	--
Longnose dace	--	10	25	80	--	--
Minnows	2	--	--	--	--	--
Sand shiner	--	1	--	2	--	--
Smallmouth bass	--	1	4	3	--	--
White sucker	20	27	18	37	43	81
	Downstream of DeWeese Reservoir					
	Above Bear Gulch Parking Lot			3 miles below DeWeese		
	11/19/04	11/20/06	5/17/2010	9/25/1981	11/19/2004	11/21/2006
Brown trout	--	5	41	3	--	8
Cutthroat trout	--	--	--	--	3	--
Rainbow trout	24	6	4	3	1	2
Fathead minnow	--	--	--	10	--	--
Longnose dace	--	115	--	6	--	--
Longnose sucker	--	1	--	--	--	--
White sucker	106	70	32	295	119	43

Table 46. Fish Population Data (Number Collected) for Fountain Creek, Segment 3. Data from CSWD (1980), Loeffler et al. (1982), CSWD (1989), Nesler et al. (1999), Dowler (2001), and USGS (2003-2010)

Species	Agency/Site/Date				
	CSWD (1980)				
Site: 7, Downstream of 85/87 bridge					
	Feb. 1979	*Feb. 1980*	*Mar. 1980*	*Apr. 1980*	*June 1980*
Fathead minnow	No Fish	No Fish	2	9	No Fish
Site: 8, South of Fountain					
	Feb. 1979	*Feb. 1980*	*Mar. 1980*	*Apr. 1980*	*June 1980*
Brook stickleback	No Fish	2	4	2	2
Central stoneroller		1	0	0	0
Creek chub		0	0	0	4
Fathead minnow		1	6	5	4
Flathead chub		3	1	5	0
Green sunfish		0	1	0	2
Plains killifish		4	2	1	1

	Loeffler et al. (1982)		CSWD (1989)	
	North of Co. Springs Wildlife Area (Clear Spring Ranch)	Old Pueblo Road	F-3, Hanna Ranch (Clear Spring Ranch)	
	1979	*1981*	*June 1989*	*Aug. 1989*
Arkansas darter	1	0	0	0
Brook stickleback	1	0	0	0
Fathead minnow	1	100	0	0
Flathead chub	1	61	17	124
Green sunfish	1	14	0	1
Longnose dace	0	0	10	23
Plains killifish	1	2	0	0
Sand shiner	0	9	0	0
Smallmouth bass	0	1	0	0
White sucker	1	1	0	0

	Nesler et al. (1999)					
	USGS 6000	Fountain	Hanson Park	KOA Camp-ground	Clear Spring Ranch (dam)	Hanna Ranch
	1994	*1994*	*1995*	*1995*	*1995*	*1995*
Arkansas darter	0	0	0	No fish	0	1
Brook stickleback	1	0	0		0	3
Fathead minnow	11	0	0		24	12
Flathead chub	564	21	3		260	17
Green sunfish	0	0	0		4	0
Longnose dace	19	0	0		23	23
Sand shiner	2	0	0		0	0
White sucker	4	0	0		4	0

Species	Agency/Site/Date		
	Dowler (2001)		
	Clear Spring Ranch	Irrigation Overflow	Wetland discharge
	2001	***2001***	***2001***
Brook stickleback	0	0	5
Central stoneroller	3	5	7
Fathead minnow	0	12	7
Flathead chub	13	12	0
Longnose dace	5	0	0
Sand shiner	0	26	0

	USGS (2003-2010)							
Site: USGS 6000, near Fountain (Clear Spring Ranch)								
	2003	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***
Black bullhead	0	1	0	0	0	0	0	0
Brook stickleback	2	0	0	1	0	2	0	0
Central stoneroller	10	11	0	5	9	57	28	25
Common carp	0	0	0	0	0	0	1	2
Creek chub	1	4	0	1	5	6	9	14
Fathead minnow	19	7	0	9	19	33	10	13
Flathead chub	284	214	235	214	397	514	230	504
Green sunfish	0	0	0	0	0	0	0	3
Longnose dace	0	13	22	4	20	23	21	15
Longnose sucker	7	5	5	1	4	11	8	3
Minnow, unidentified	6	0	0	0	0	0	0	0
Plains killifish	0	0	0	1	1	0	0	0
Red shiner	3	3	1	0	1	1	1	1
Sand shiner	93	192	9	41	15	29	36	12
White sucker	14	21	9	30	44	147	32	67
Young of the year, unidentified	0	0	0	7	0	0	0	0

Table 47. Benthic Invertebrate Population Data for Fountain Creek Segment 3. Data from Colorado Springs Utilities (1996, 1997, 1998, 1999, 2000) and USGS (2001a, 2002, 2003, 2004)

Year	Density #/m^2	Number of Taxa	Number of EPT Taxa	Diversity
Site: USGS 6000, near Fountain (Clear Spring Ranch)				
Spring				
1996	2,564	8	0	1.93
1997	2,963	8	0	1.68
1998	490	13	0	1.04
1999	884	22	5	2.04
2000	196	12	4	2.03
2000	293	5	0	0.86
Summer				
1996	216	3	0	1.17
1997	30	3	0	1.15
Fall				
1996	105	8	0	0.63
1998	4,306	30	9	1.85
1999	76	23	8	1.45
1999	30	4	0	1.88
2000	537	37	6	2.61
2001	1,749	40	4	3.38
2002	4,214	43	7	3.22
2003	8,851	56	7	3.17
2004	1,071	44	8	2.54
2004	3,026	25	5	3.13
2005	191	30	4	1.43
2006	281	40	6	2.76
2007	4,274	53	7	2.43
2008	1,193	40	9	2.81
2009	2,034	33	5	2.57

Table 48. PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Fountain Creek Segment 3. Data Collected in 2004 as Part of the SDS EIS (CEC 2006)

Flow (cfs)	Species/Life Stage							
	Red shiner	*Sand shiner*	*White sucker*			*Flathead chub*		
	Adult	Adult	Adult	Fry	Spawning	Adult	Fry	Spawning
25	3,160	16,751	69	1,439	17,628	18,696	25,433	7,210
50	3,246	19,525	128	2,049	19,234	28,403	30,630	9,891
75	3,756	21,707	181	2,373	21,697	35,267	32,040	8,503
100	3,936	21,691	212	2,611	24,143	40,276	31,819	8,646
150	4,228	21,467	232	3,254	28,217	43,516	30,553	10,519
200	4,684	21,239	286	3,245	30,830	44,369	29,809	9,137
250	4,264	23,575	272	3,236	32,252	44,246	29,078	9,518
300	4,186	22,866	286	3,724	32,835	44,377	28,593	9,749
350	4,596	23,429	290	3,230	32,867	44,763	29,032	11,211
400	4,887	25,745	286	3,050	32,549	45,106	29,049	12,723
450	4,340	24,557	277	2,755	32,016	45,110	29,088	12,759
500	5,283	24,658	269	2,653	31,360	45,360	28,070	12,359
750	3,696	20,685	354	2,242	27,756	45,145	32,255	12,015
1,000	2,624	14,905	493	2,131	22,623	44,930	25,450	6,003
1,250	2,012	11,245	575	2,242	15,289	42,782	19,283	3,991
1,500	1,632	8,879	625	2,078	11,192	40,437	15,500	3,449
2,000	1,049	5,267	747	2,158	6,645	32,344	9,371	1,952

Table 49. Habitat Data for Fountain Creek Segment 3. Data from USGS (2001a, 2002, 2003-2010)

Date	% Pool by Length	Mean Bank Width (ft)	Mean Wetted Width (ft)	Dominant Substrate	Mean Depth (ft)
Site: USGS 6000, near Fountain (Clear Spring Ranch)					
Fall 2001	0	468.5	86.3	Sand	0.9
Fall 2002	0	458.7	86.6	Gravel	0.7
Fall 2003	0	126.0	94.2	Gravel	0.7
Fall 2004	0	122.7	99.7	Sand	0.8
Fall 2005	0	126.6	91.5	Sand	0.8
Fall 2006	0	128.0	98.1	Gravel	0.7
Fall 2007	0	122.4	107.6	Gravel	0.7
Fall 2008	0	131.2	85.3	Gravel	0.7
Fall 2009	0	126.3	86.9	Sand	0.8
Fall 2010	0	125.7	91.2	Gravel	0.7

Table 50. Fish Population Data (Number Collected) for Fountain Creek Segment 4. Data from Loeffler et al. (1982), CSWD (1989), Nesler et al. (1999), Melby (2001), CEC (2004b), and USGS (2003-2010). X = Present, but Number Not Available

Species	Agency/Site/Date				
	Loeffler et al. (1982)	CSWD (1989)			
	Site: Pueblo	Site: F-4, Piñon USGS 6300		Site: F-5, near Pueblo USGS 6500	
	1981	*June 1989*	*Aug. 1989*	*June 1989*	*Aug. 1989*
Black bullhead	1	0	0	0	0
Brook stickleback	1	0	2	3	0
Central stoneroller	0	1	4	9	1
Fathead minnow	2	0	0	0	0
Flathead chub	12	0	8	96	88
Longnose dace	7	3	0	11	15
Longnose sucker	0	0	0	2	0
Plains killifish	4	0	0	0	1
Red shiner	1	0	0	0	0
Sand shiner	4	0	8	0	7
White sucker	5	0	0	0	2

	Nesler et al. (1999)		
	Site: Piñon	Site: I-25, Eden	Site: 4th Street Bridge
	1994	*1994*	*1994*
Arkansas darter	0	1	0
Bluegill	1	0	0
Brook stickleback	5	0	0
Central stoneroller	1	0	0
Fathead minnow	1	1	0
Flathead chub	587	125	114
Green sunfish	0	2	0
Longnose dace	52	1	1
Sand shiner	2	3	0
White sucker	2	9	2

	Melby (2001)	
	Site: North of Wal-Mart	Site: 4th Street Bridge
	2001	*2001*
Central stoneroller	0	6
Fathead minnow	3	1
Flathead chub	20	54
Longnose dace	1	0
Plains killifish	0	1
Sand shiner	9	33

Species	Agency/Site/Date	
	CEC (2004b)	
	Site: Near Piñon	Site: 4th Street Bridge
Brook stickleback	X	0
Central stoneroller	X	X
Fathead minnow	X	X
Flathead chub	X	X
Longnose dace	X	0
Longnose sucker	X	X
Plains killifish	0	X
Red shiner	X	X
Sand shiner	X	X
White sucker	X	X

Species	USGS (2003-2010)								
	Site: "Piñon Gallery"	Site: USGS 6300, Near Piñon							
	2003	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***
Arkansas darter	5	0	0	1	0	0	0	0	3
Brook stickleback	X	1	4	21	5	6	0	4	6
Brown trout	0	0	0	0	0	0	0	1	1
Carp	0	2	0	0	2	0	0	0	0
Central stoneroller	X	34	47	84	33	12	286	230	69
Creek chub	0	1	3	0	0	0	0	0	1
Fathead minnow	0	11	0	3	7	3	4	2	2
Flathead chub	X	70	137	114	150	21	87	264	221
Green sunfish	0	0	0	0	1	0	2	0	0
Longnose dace	0	12	1	4	13	11	28	42	27
Longnose sucker	0	4	0	4	3	0	1	2	6
Minnow, unidentified	0	2	3	0	0	0	0	0	0
Plains killifish	0	1	0	0	0	0	1	2	0
Red shiner	0	57	0	11	0	0	0	1	0
Sand shiner	0	55	22	12	18	1	11	29	10
White sucker	0	6	2	31	29	6	59	75	26
Young of the year, unidentified	0	0	0	1	0	0	0	0	0

Species	Site: USGS 6500, Near Pueblo							
	2003	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***
Brook stickleback	0	0	1	0	0	1	0	0
Central stoneroller	1	39	7	24	13	59	22	37
Fathead minnow	3	1	3	3	0	2	1	0
Flathead chub	97	304	89	221	162	320	88	259
Longnose dace	0	6	2	16	10	9	16	18
Longnose sucker	0	0	0	0	0	1	0	0
Minnow, unidentified	14	0	0	0	0	0	0	0
Plains killifish	93	39	16	5	0	3	10	7
Red shiner	2	32	6	0	18	0	1	0
Sand shiner	33	123	22	49	39	27	32	18
White sucker	0	4	5	7	4	51	12	9

Table 51. Benthic Invertebrate Population Data for Fountain Creek Segment 4. Data from Colorado Springs Utilities (1996, 1997, 1998, 1999, 2000), and USGS (2001a, 2002, 2003, 2004)

Year	Density #/m^2	Number of Taxa	Number of EPT Taxa	Diversity
Site: USGS 6300, Near Piñon				
Spring				
1996	2,405	8	0	1.64
1997	54	7	0	1.17
Summer				
1996	426	4	0	0.00
1997	70	2	0	0.03
Fall				
1996	67	4	0	1.15
2001	3,168	41	6	3.03
2002	2,164	35	8	3.48
2002	3,220	45	8	3.39
2003	5,008	67	12	4.03
2004	6,062	47	9	3.87
2004	1,703	34	7	3.79
2005	1,031	43	8	2.14
2006	505	44	6	2.77
2007	1,530	49	13	3.90
2008	3,006	49	9	3.20
2009	1,740	40	10	2.36
Site: Above Pueblo				
Spring				
1996	2,660	5	0	0.51
1997	329	5	0	1.91
Summer				
1996	108	6	0	0.00
1997	74	1	0	0.03
Fall				
1996	47	5	0	1.07
Site: USGS 6500, Near Pueblo				
Spring				
1998	10	1	0	0.00
1998	10	8	0	0.62
1999	62	16	4	1.54
2000	3	22	4	0.31
Fall				
1998	3	1	0	0.00
1998	3	20	0	0.00
1999	16	11	3	1.09
2000	68	35	6	2.62
2001	372	32	3	1.25
2002	336	38	5	3.90
2003	9,423	58	10	3.36
2003	1,084	25	5	3.28
2004	4,215	51	7	3.42
2005	861	41	6	2.51
2006	67	43	6	2.03
2007	902	45	9	3.98
2008	3,732	44	9	2.73
2009	1,365	31	7	2.78

Table 52. PHABSIM Habitat (WUA in ft^2/1,000 ft of Stream) Versus Flow (cfs) Relationships for Fountain Creek Segment 4. Data Collected in 2004 as Part of the SDS EIS (CEC 2006)

Flow (cfs)	Species/Life Stage							
	Red shiner	*Sand shiner*	*White sucker*			*Flathead chub*		
	Adult	Adult	Adult	Fry	Spawning	Adult	Fry	Spawning
25	2,881	22,832	0	1,341	26,751	23,685	39,761	10,439
50	3,319	27,315	1	921	36,897	40,644	49,785	8,118
75	3,454	27,341	22	1,230	40,164	54,362	51,842	9,990
100	3,435	25,584	43	1,748	38,355	61,875	44,631	8,269
150	3,346	23,080	81	2,807	31,383	71,041	35,857	6,437
200	3,356	22,529	84	2,303	27,419	71,546	35,917	6,841
250	3,677	24,642	88	2,707	27,341	72,172	39,957	6,098
300	4,837	28,848	93	1,441	45,290	88,259	51,734	15,737
350	3,369	23,790	108	592	45,653	69,914	45,589	13,692
400	2,918	20,008	124	693	36,885	70,004	45,765	14,315
450	2,483	15,998	138	784	28,759	71,325	44,145	14,539
500	2,011	13,281	147	876	23,029	70,804	41,174	13,324
750	1,509	8,512	170	910	7,293	59,758	14,048	3,743
1,000	1,377	8,129	233	783	6,048	38,137	14,600	1,237
1,250	--	--	--	--	--	30,870	15,738	1,167
1,500	--	--	--	--	--	23,603	16,876	1,096
2,000	--	--	--	--	--	24,731	24,591	3,084

Table 53. Habitat Data for Fountain Creek Segment 4. Data from USGS (2001a, 2002, 2003-2010)

Date	% Pool by Length	Mean Bank Width (ft)	Mean Wetted Width (ft)	Dominant Substrate	Mean Depth (ft)
Site: USGS 6300, near Piñon					
Fall 2001	0	670.3	77.1	Gravel	0.8
Fall 2002	0	184.7	60.0	Gravel	0.7
Fall 2003	0	130.6	60.0	Sand	0.9
Fall 2004	0	167.3	86.6	Gravel	1.0
Fall 2005	0	163.7	87.9	Sand	0.9
Fall 2006	0	163.4	74.1	Gravel	0.9
Fall 2007	0	129.9	101.7	Gravel	0.8
Fall 2008	0	143.4	65.6	Gravel	0.9
Fall 2009	0	145.3	95.8	Sand	0.7
Fall 2010	1.7	146.7	73.8	Gravel	0.8
Site: USGS 6500, near Pueblo					
Fall 2001	0	192.9	127.6	Gravel	0.6
Fall 2002	0	201.1	133.2	Sand	0.7
Fall 2003	0	161.1	132.9	Sand	0.6
Fall 2004	0	161.7	103.7	Sand	0.8
Fall 2005	0	164.4	120.4	Sand	0.8
Fall 2006	0	154.2	99.7	Sand	0.8
Fall 2007	0	153.9	121.7	Sand	0.8
Fall 2008	0	165.7	96.8	Gravel	0.6
Fall 2009	0	156.5	86.0	Sand	0.7
Fall 2010	0	147.6	108.9	Gravel	0.6