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Don Saling
City of Sterling
421 N 4th Street
Sterling, CO 80751

RE: 2018 LIRF Credit Analysis

Dear Don:

In order to update the accounting for the City of Sterling's City-wide Augmentation Plan, we have completed the LIRF analysis[1] for 2018, and calculated the new LIRF and SWRSS recharge credits for the upcoming year, as shown in the attached Tables 1 through 5.

In 2018, the City produced a total of 3,110.5 acre-feet from the city-wide potable system wells, not including 405.4 acre-feet of concentrate from the City's reverse osmosis ("RO") water treatment plant (WTP) that was sent to the WTP's deep injection wells. Of the water pumped from the city-wide system wells, 1,017.9 acre-feet was used outdoors after accounting for base use and the RO concentrate sent to SWRSS. An additional 479.3 acre-feet was pumped from the irrigation-only wells, resulting in 3,995.2 acre-feet of total annual pumping.

For comparison, in 2017 the total pumping from the city-wide potable system wells was 3,081.5 acre-feet, not including 404.0 acre-feet of RO concentrate. Of the 2017 total pumping from potable system wells, the outdoor use was 752.0 acre-feet. Additionally, 456.4 acre-feet was pumped from the City's irrigation-only wells for a 2017 pumping total of 3,941.8 acre-feet. The total pumping in 2018 increased one percent from 2017, and the total outdoor use from the municipal system increased 35 percent from 2017. This large increase is likely due to the relatively low outdoor use calculated for 2017. RO concentrate deep injected in 2018 was 0.3 percent more than RO concentrate deep injected in 2017.

[1] Lawn Irrigation Return Flow (LIRF) analysis required per Paragraph 10.6.6.1 of the City of Sterling's Augmentation Plan Decree in Consolidated Case Nos. 98CW450 and 00CW253.

The total pumping numbers in 2017 and in 2018 do not include ethanol plant well production.

The potential consumptive use of lawn grass in the City was determined using 2018 daily temperature and precipitation data at the Northern Colorado Water Conservation District (NCWCD) Sterling weather station and is equal to 2.98 feet (see Table 1), which is five percent lower than the 2017 potential consumptive use calculated as 3.14 feet.

The total number of active equivalent taps for 2018 (9,145 equivalent taps) is within one percent of the number of taps estimated in 2017 (9,061 equivalent taps). A summary of the tap information is displayed in Table 2. The equivalent tap data is collected by the City on a monthly basis. For this analysis, we used the equivalent tap data from the month of June to represent the 2018 calendar year, because June is fairly representative of the City's water usage during the irrigation season. The 2018 combined estimated lawn area of 615.0 acres is slightly higher than the 2017 value (611.4 acres).

The net LIRF percentage for 2018 is equal to 16.0 percent including city-wide potable system and irrigation-only wells, as shown in Table 3. Based upon our analysis, 218.3 acre-feet of LIRF credits resulted from 2018 water use from the city-wide potable system and irrigation-only wells. The 2018 LIRF credit represents an increase of 44 percent over the 2017 credit, which was 151.8 acre-feet. The 2018 LIRF credit represents a return to a more typical LIRF credit level, closer to the 234.4 acre-feet of credit that was calculated in 2016 and the long term average of 296.9 acre-feet for the period 2000-2018. As described in our February 6, 2018 letter summarizing the 2017 analysis, the 2017 LIRF credit was unusually low due to a relatively high base water use rate coupled with a lower end-of-year irrigation application.

The 2018 LIRF credit was calculated using the five-year average (2012-2016) percent tree canopy that was established in a December 20, 2016 letter to the Division Engineer from our office. In 2018, the two percent surface runoff component, which is calculated in the Sterling accounting on a monthly basis, results in an additional 29.3 acre-feet of credit. However, the surface runoff is not included as part of the LIRF percentage because it is accounted for separately in the monthly accounting forms submitted by the City.

Table 4 summarizes the LIRF credits for the previous three years based on outdoor use from the city-wide system and irrigation-only wells. The three-year average credit that will be used for the 2019 accounting is 201.5 acre-feet. Table 4 also lists the 2019 monthly LIRF credits which range from 14.1 acre-feet in April to 19.7 acre-feet in October.

The total inflow to the Sterling Wastewater Recharge and Storage System (SWRSS) for the previous three-year period was 2,765.1 acre-feet as shown in Table 5. Inflow to recharge in 2018 was zero acre-feet because SWRSS was shut off on November 1, 2017 due to an order from the Colorado Department of Public Health and Environment (CDPHE). The average yearly inflow from 2016-2018 is equal to 921.7 acre-feet. Therefore, the average monthly credit for the 2019 calendar year will be 76.8 acre-feet. If

the City is unable to deliver water to the SWRSS moving forward, the monthly credit will drop to 33.8 acre-feet in 2020 and to 0 acre-feet in 2021.

Please give us a call if you have any questions.

Very truly yours,

BISHOP-BROGDEN ASSOCIATES, INC.

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TM/KW/JEB
Enclosure
7011.05

Table 1
Blaney-Criddle Analysis

City of Sterling

Project:	LIRF Analysis	**Crop:**	Cottonwood Bluegrass
Weather Station:	Sterling, CO (NCWCD)	**Depth (ft):**	1.0
Latitude (north):	40.6	**Kt override:**	No
Elevation (feet):	3938	**Year:**	2018
File name:	BC LIRF 18.xlsm	**Job #**	7011.05

	INPUT				OUTPUT				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Month	% Days In The Month	Mean Temperature (Fahrenheit)	Kc Growth Coefficient	Total Precipitation (Inches)	(Kt) Climate Coefficient	(P) Percent Daylight	Potential CU (Inches)	Effective Precipitation (Inches)	Consumptive Irrigation Requirement (Inches)
Nov		44.3			0.45				
Dec		39.5			0.37				
Jan		36.4			0.31				
Feb		39.6			0.37				
Mar		44.5	1.65		0.46				
Apr	76	49.4	1.65	0.89	0.54	6.77	2.99	0.89	2.10
May	100	61.6	1.30	4.33	0.75	10.05	6.04	3.61	2.43
Jun	100	71.7	1.10	1.23	0.93	10.13	7.40	1.23	6.17
Jul	100	74.4	0.95	2.45	0.97	10.26	7.06	2.45	4.61
Aug	100	69.4	0.95	1.06	0.89	9.57	5.59	1.06	4.53
Sep	100	64.6	1.10	0.38	0.80	8.40	4.79	0.38	4.41
Oct	73	50.2	1.20	0.74	0.55	5.62	1.88	0.74	1.13
Total				11.08			35.74	10.36	25.37
						Total (feet)	2.98		

References:

1) The percentage of the month contributing to the growing season, based upon a beginning and ending temperature of 45 degrees.
2) Obtained from the Northern Water Conservancy District, this value is adjusted based on % of days in
3) Based upon Pochop calibrated Kc values originally decreed in Cottonwood WSD decree (02CW184).
4) Obtained from Colorado Climate Center data, this value is adjusted based on % of days in the month. Annual total includes only the growing season.
5) Based on mean air temperature, Kt=0.0033*Temp+0.65 for bluegrass, based upon Pochop adjustment.
6) Valid for Latitudes between 35 to 45 degrees North, based on interpolation of SCS TR #21 data.
7) Blaney-Criddle Formula, Potential CU =Temp*P*Kt*Kc*e/100, where e = Pochop elevation adjustment .
8) Precipitation input for Cottonwood Curve analysis sets daily precipitation equal to <= 1"; therefore, Effective Precipitation equals Total Precipitation events less than or equal to 1" per day.
   Annual total includes only the growing season.
9) Consumptive Use Requirement = Potential CU - Effective Precipitation.

Table 2
City of Sterling
Number of Taps - 2018

Size	Equivalent Taps	Number of Taps			Equivalent Taps		
		Single-Family	Multi-Family	All-Others	Single-Family	Multi-Family	All-Others
5/8	1	66	15	6	66	15	6
3/4	1.5	3,106	252	336	4,659	378	504
1	2.5	482	85	156	1,205	213	390
1.5	5	8	33	37	40	165	185
2	8	3	4	57	24	32	456
3	16	0	4	25	0	64	400
4	27.5	0	2	7	0	55	193
6	50	0	0	0	0	0	0
10	95	0	0	1	0	0	95
Total					5,994	922	2,229

Based upon information provided by the City of Sterling. Number of taps are based upon June data as June is a representative month during the irrigation season.

Table 3
City of Sterling
LIRF Calculation 2018

Year:
2018

Line	Description	Source	Amount	Unit
[1]	Municipal Water System Production for Year of Record			
	[A] City-Wide System	City Records	3110.5	ac-ft
	[B] Irrigation-Only Wells	City Records	479.3	ac-ft
[2]	Average Monthly Base Use (City-Wide System Only)	Average from Previous Dec, Jan, and Feb	174.4	ac-ft
[3]	Outdoor Water Use (City-Wide System Only)	[1A] - [2] x 12 months	1017.9	ac-ft
[4]	Irrigation Water Use after 3% Reduction for Miscellaneous Outdoor Uses	[3] x 0.97	987.4	ac-ft
[5]	Amount of Water Applied to Lawns After 2% Reduction for Surface Runoff and 5% Reduction for Spray Loss	([4] + [1B]) x 0.93	1364.0	ac-ft
[6]	Number of Equivalent Taps for Each Type of Use Category (City-Wide System Only)			
	[A] Single Family	Note 1	5994	eq taps
	[B] Multi-Family	Note 1	922	eq taps
	[C] All Other	Note 1	2229	eq taps
	[E] Total	[A] + [B] + [C]	9145	eq taps
[7]	City-Wide Lawn Area			
	[A] Single Family (See Note 2)	2426	333.8	acres
	[B] Multi-Family (See Note 2)	2182	46.2	acres
	[C] All Other (See Note 2)	1734	88.7	acres
	[D] City-Owned Land Served by the Potable System	24 Acres Served by the City	24.0	acres
	[E] Parks, Cemetery, and Golf Course Served by Irrigation Only Wells	Note 2	122.3	acres
	[F] Total	[A] + [B] + [C] + [D] + [E]	615.0	acres
[8]	Irrigation Application Rate	[5] / [7F]	2.22	ft
[9]	Total Application + Precipitation (not including precipitation from events > 1")	[8] + Precipitation (< 1")	3.25	ft
[10]	Potential Lawngrass Evapotranspiration (ET), based upon crop coefficients from Cottonwood Curve	Blaney Criddle Analysis	2.98	ft
[11]	Total Application as a Percent of Potential ET	[9] / [10]	109.2%	%
[12]	Gross LIRF as a Percent of Total Application (Project Line [11] on X-Axis of Cottonwood Curve)	Y-Axis of Cottonwood Curve	19.3%	%
[13]	Net LIRF Percentage (adjust for Percent Tree Canopy, Note 3)	[12] x (100 - % Tree Canopy), Note 3	16.0%	%
[14]	Municipal Water System Net LIRF	[5] x [13]	218.3	ac-ft

Note 1 - Number of taps for each type of use determined annually from City records. Number of equivalent taps for each type of use calculated from total taps as follows:
5/8" tap = 1 equivalent tap 3/4" taps = 1.5 equivalent taps 1" taps = 2.5 equivalent taps 1.5" taps = 5 equivalent taps
2" taps = 8 equivalent taps 2.5" taps = 12 equivalent taps 3" taps = 16 equivalent taps 4" taps = 27.5 equivalent taps 6" taps = 50 equivalent taps 10" taps = 95 equiv. taps

Note 2 - Average lawn areas per equivalent tap for 2016-2020 as follows (to be recalculated every subsequent five year period as decribed in Paragraph 13.g.iv of decree):
Single Family = 2,426 sq. ft. Multi-Family = 2,182 sq. ft. All Others = 1,734 sq. ft.

Note 3 - Average percent tree canopy for 2016-2020 is 18.1% for City-Wide System and 15.4% for Irrigation-Only Wells (City-Wide value to be recalculated every subsequent five year period as decribed in Paragraph 10.6.6.3 of decree). Equals (0.180 x [4] + 0.154 x [1B]) / ([4] + [1B]. Weighted Canopy = 17.2%

Table 4
City of Sterling
Lawn Irrigation Return Flow (LIRF) Summary
(all values in acre-feet)

Annual LIRF Credit

Year	LIRF Credit
2016	234.4
2017	151.8
2018	218.3
Average	201.5

Monthly Distribution of Annual LIRF Credit

Month	Percentage	Monthly LIRF Credit
January	8.20%	16.5
February	7.70%	15.5
March	7.20%	14.5
April	7.00%	14.1
May	7.10%	14.3
June	7.70%	15.5
July	8.30%	16.7
August	9.20%	18.5
September	9.70%	19.5
October	9.80%	19.7
November	9.30%	18.7
December	8.80%	17.7
Total	100%	201.5

Table 5
City of Sterling
Three Year Recharge Summary

Year	Net Inflow to Recharge (ac-ft)
2016	1,547.3
2017	1,217.8
2018	0.0
Total	2,765.1
Average Yearly Inflow	921.7
Average Monthly Credit	76.8

Note(s):

- Water to recharge equals measured diversion to SWRSS less net evaporation.
- Pursuant to the decree entered in Case nos. 95CW137 and 00CW253, the average monthly credit which may be claimed in 2019 equals the average yearly inflow for the past three years divided by 12.