23692 Birtcher Drive
Lake Forest CA 92630

949.420.3030 phone
530.756.5991 fax
westyost.com

TECHNICAL MEMORANDUM

DATE: November 1, 2024

Project No.: 1123-80-24-01
SENT VIA: EMAIL

TO: Vina Groundwater Sustainability Agency

FROM: David A. Jaffe, PhD, PE, D.WRE

REVIEWED BY: DRAFT

SUBJECT: Ecological Flow Recommendation for Lindo Creek Diversion (DRAFT)

BACKGROUND AND OBJECTIVES

Goals:

1. Estimate volume of flow for in-stream recharge in Vina Creek/Lindo Channel.
2. Estimate the volume of water that needs to remain in Big Chico Creek for riparian habitat, fish passage and other environmental benefits.

Background

The California Environmental Flows Framework (CEFF) was developed by the California Water Quality Monitoring Council in partnership with UC Davis. The Environmental Flows Framework is based on Functional Flows, which are components of the hydrograph that perform specific ecologic or geomorphic functions at different times throughout the year. Function Flows are used to develop "scientifically defensible environmental flow recommendations that balance human and ecosystem needs for in-stream flows."[1]. CEFF calculations use stream gage data provided by the user.

In collaboration with the Environmental Flows Framework, USGS and the Nature Conservancy developed the Natural Flows Database (NFD). Natural Flows uses a state-wide statistical model that generates estimates of natural flows, which are defined for wet, dry, and moderate climatic conditions that output streamflow estimates for streams without anthropogenic modification. The Natural Flows database estimates functional flows based on the following flow predictor variables: watershed characteristics, rainfall and, temperature data. The relationship between flow predictor variables was established using machine learning models developed from reference stream gages.

Gao et al. (2018)[2] (hereafter, Gao) used separate calibrations of the Soil and Water Assessment Tool (SWAT) based on wet and dry years to improve simulation efficiency in a watershed with high interannual

[1] California Environmental Flows Framework. Accessed 9/1/2024. https://ceff.sf.ucdavis.edu/frameworkoverview

[2] Gao, X., X. Chen, T. Biggs, and H. Yao (2018) Separating Wet and Dry Years to Improve Calibration of SWAT in Barrett Watershed, Southern California. *Water* **2018**, *10*, 274; doi:10.3390/w10030274.

rainfall variability. The authors employed a relative deviation percentage method to separate the rainfall record into wet and dry years based on long-term annual runoff. To separate the annual runoff into wet and dry years, years that annual runoff was greater than the mean annual runoff were identified as wet years, while those that were less than the mean annual runoff were identified as dry years.

Setting

The Big Chico Creek watershed is in Tehama and Butte Counties, California, and has a total watershed area of approximately 235 square miles. The headwaters of the Creek are located near Colby Mountain and the total stream length is approximately 46 miles from the headwaters to the confluence with the Sacramento River. The Creek travels through the City of Chico upstream of Sacramento River. Big Chico Creek flow is partially diverted into Lindo Channel at Five-Mile Dam. Lindo Channel is a natural, ephemeral stream on the Chico alluvial fan. The Channel was modified above Manzanita Avenue, Chico, for flood control purposes in the early 1960's. The Channel runs east to west, parallel to Big Chico Creek, for approximately eight miles before it confluences with Big Chico Creek approximately 2.5 miles upstream of the Sacramento River.

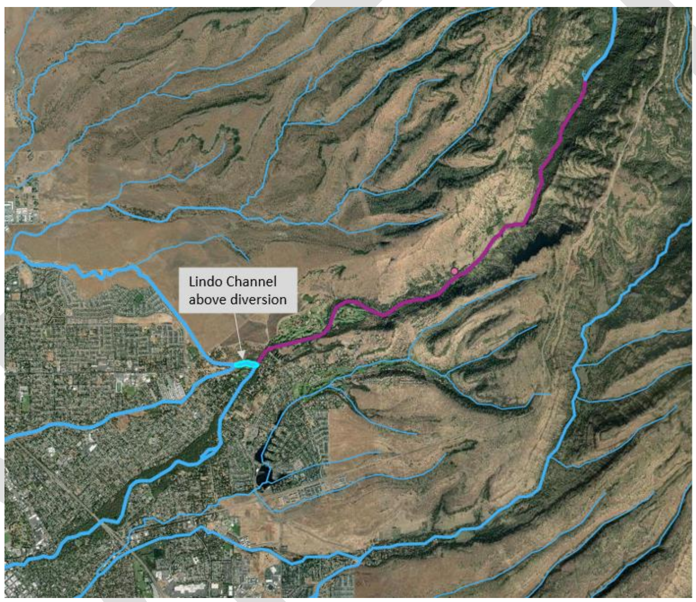

Figure 1. Location of Lindo Channel Diversion Below Big Chico Creek (Pink)

Approach

Environmental flow statistics are calculated using CEFF, NFD and Gao and results of the calculations are compared. CEFF and Gao use local gage data (CDEC gage BIC-20) for the period of the gage record (1997 to present). Examining older gage data near BIC-20 (Big Chico C NR Chico CA – 11384000, active 1960 – 1971) suggests that the historical data is statistically insufficiently like BIC-20. Therefore, it is not recommended to augment BIC-20 historical data with 11384000 data. The CEFF and Gao calculations provide a point of reference for achieving environmental flow targets in Big Chico Creek and as well as in Lindo Channel. The calculations also address environmental benefits on both channels while providing guidance for management of the Lindo Channel diversion. Finally, the calculations provide a baseline for potential recharge volume for a range of annual runoff conditions in the Channel.

BIC-20 gage data was input into the CEFF calculator, which output a broad spectrum of average functional flow values for each year of gage data. The gage data statistics were developed after Gao to separate each annual runoff volume into wet, average, or dry year categories. Finally, NFD statistics were generated for the reach of the Creek directly above the diversion.

Table 1 compares the environmental flow statistics for Big Chico Creek near Lindo Channel using CEFF and NFD. For most statistical categories NFD regional regression discharge values under-predict CEFF gage-based statistics by more than 10%. When NFD over predicts CEFF statistics the difference in values is greater than 10% for all categories. Despite the relatively short period of record (27 years) CEFF appears to be the preferable environmental flow statistical approach since it is based on flow data at the stream project reach instead of regional regression.

Table 1: Comparison of CEFF and NSD environmental flow statistics for Big Chico Creek at BIC-20.

CEFF Functional Flow Parameters	CEFF	NFD			
	Average All Years[i]	All Years	Wet Years	Moderate Years	Dry Years
Fall pulse magnitude	89 cfs	65 cfs	97 cfs	71 cfs	54 cfs
Fall pulse timing	27 cfs	10/23	10/20	10/25	10/25
Fall pulse duration	4 days	9 days	-	-	-
Wet-season low baseflow	63 cfs	70 cfs	94 cfs	71 cfs	42 cfs
Wet-season median baseflow	231 cfs	205 cfs	355 cfs	206 cfs	129 cfs
Wet-season timing	79 cfs	12/5	12/4	12/4	12/14
Wet-season duration	79 cfs	142 days	149 days	142 days	126 days
2-year flood magnitude	1906 cfs	2360 cfs	-	-	-
5-year flood magnitude	3159 cfs	-	-	-	-
10-year flood magnitude	3589 cfs	-	-	-	-
2-year flood duration	4 cfs	3 days	-	-	-
5-year flood duration	1 cfs	-	-	-	-
10-year flood duration	1 cfs	-	-	-	-
2-year flood frequency	2 cfs	2 occurrences	-	-	-
5-year flood frequency	1 cfs	-	-	-	-
10-year flood frequency	1 cfs	-	-	-	-
Spring recession magnitude	1364 cfs	551 cfs	858 cfs	549 cfs	341
Spring timing	158 cfs	4/20	4/19	4/27	4/18
Spring duration	88 cfs	51 cfs	50 cfs	51 cfs	53 cfs
Spring rate of change	0 cfs	6.6%	-	-	-
Dry-season median baseflow	28 cfs	18 cfs	25 cfs	19 cfs	13 cfs
Dry-season high baseflow	46 cfs	36 cfs	46 cfs	36 cfs	29 cfs
Dry-season timing	247 cfs	6/22	6/23	6/27	6/22
Dry-season duration	200 cfs	161 cfs	161 cfs	159 cfs	162 cfs

[i] CEFF Flows are not seasonally dependent, 50^{th} percentile annual flows are reported.

The environmental flow statistics for Big Chico Creek near Lindo Channel using CEFF and Gao methodologies are compared in **Table 2**. Discharges calculated using the two methodologies differed by an average of 8%. The difference between CEFF and Gao discharges (8%) is smaller than the difference between CEFF and NFD discharges (>10%). This is the expected outcome since the CEFF and Gao methods use the same BIC-20 gage data. Approximately two thirds of the years are statistically dry (20 of 28 years based on Gao deviation percentage), as shown in the 'Gao Water Year Type' column.

Table 2. CEFF and Gao flow statistics for Big Chico Creek near Lindo Channel

Water Year	CEFF Discharge (cfs)[ii]	Gao Discharge (cfs)	Gao Water Year Type
1997	0	5	DRY
1998	266	240	WET
1999	169	143	WET
2000	122	107	DRY
2001	74	65	DRY
2002	112	98	DRY
2003	287	269	WET
2004	141	129	DRY
2005	124	110	DRY
2006	348	331	WET
2007	62	62	DRY
2008	78	78	DRY
2009	112	100	DRY
2010	133	133	DRY
2011	209	196	WET
2012	76	64	DRY
2013	82	80	DRY
2014	42	40	DRY
2015	-	37	DRY
2016	-	113	DRY
2017	-	445	WET
2018	-	83	DRY
2019	-	296	WET
2020	61	61	DRY
2021	36	36	DRY
2022	77	77	DRY
2023	214	214	WET
2024	163	127	DRY

[ii] The CEFF calculator does not accept water year flow data with more than 7 total days of missing data and more than 1 consecutive day of missing data. Therefore, water years 2014 - 2018 have been excluded from the CEFF calculation table.

Rating Curve and Runoff Volume

Wet and dry years were determined based on volume of annual runoff using the Gao method. The Gao method calculates the average annual runoff for each year of the period of record (from volumetric rate gage data in cubic feet per second), then calculates the relative deviation percentage for each year from the annual average runoff. The relative deviation percentage shows how big of a positive or negative difference one year's value is from the average. Once found, the positive and negative relative deviation from the annual average signifies a wet or dry year, respectively, based on the sign. In other words, whether the annual runoff for a given year is below or above the annual average runoff of all years signifies whether it is a dry or wet year, respectively.

As shown in Table 3, the BIC-20 gage data indicates that a dry year occurs 71% of the time over the period of record. While the wet year median runoff is 62% higher than the annual average runoff, the dry year median runoff is 51% lower than the annual average runoff. The number of Below Rating Table (BRT) values that were recorded each year is also shown in Table 3. When the gage records BRT then the depth of flow at the gage is lower than the gage was set up to record. Years with higher BRT counts suggest dry periods because a longer duration of time low accounted for flows were not sufficient to be recorded by the gage. It is important to note that years with a high number of BRT values can still be statistically wet based on the total volume of runoff for the year. In such a year the total runoff volume can remain sufficiently high because of one or more high runoff-volume events during the year. During the 2011-2017 drought period in California the gage recorded the third highest BRT count in 2017 (the two highest annual BRT counts were also occurred during this period in 2015 and 2016) but was considered a wet year by total runoff volume. A similar high BRT count/high annual total runoff volume occurred again in 2019. This data suggests that the stream may be moving into a period with high total annual runoff with lower or more intermittent base flow.

Table 3. Wet And Dry Annual Runoff Volume By Relative Deviation Percent At Gauge Bic-20

Water Year	Annual Runoff (Acft)	Relative Deviation %	Wet Or Dry?	"Below Rating Table" Count Per Water Year
1997	3,408	-96.5	DRY	18
1998	173,421	79.4	WET	76
1999	103,500	7.1	WET	94
2000	77,594	-19.7	DRY	38
2001	46,710	-51.7	DRY	118
2002	71,098	-26.4	DRY	42
2003	195,074	101.8	WET	8
2004	93,713	-3.1	DRY	7
2005	79,598	-17.7	DRY	-
2006	239,575	147.8	WET	1
2007	44,607	-53.9	DRY	-
2008	56,410	-41.6	DRY	-
2009	72,207	-25.3	DRY	-
2010	96,088	-0.6	DRY	-
2011	141,925	46.8	WET	-
2012	46,577	-51.8	DRY	2
2013	57,853	-40.2	DRY	-
2014	28,932	-70.1	DRY	-
2015	26,866	-72.2	DRY	5994
2016	81,874	-15.3	DRY	7385
2017	322,262	233.4	WET	4117
2018	60,430	-37.5	DRY	7363
2019	214,062	121.4	WET	2981
2020	44,205	-54.3	DRY	-
2021	26,242	-72.9	DRY	-
2022	55,415	-42.7	DRY	-
2023	154,935	60.3	WET	-
2024	92,018	-4.8	DRY	-
Median	**74,900**		**% Dry**	**71%**
Average	**96,664**		**% Wet**	**29%**

A comparison of rating table values is shown in **Table 4**, where 12% of the values in the BIC-20 gage data reported as "below rating table", or "BRT". When the gage reads a BRT value, the streamflow is below a minimum threshold, and cannot be recorded by the gage. Years with higher "BRT" detection levels signify dry periods.

Table 4. Non-numerical values found in BIC-20 gage data

Count of specific values in "flow" column			
BRT	ART	BLANKS	Total Count
28244	12171	422	238,249
12%	5%	0.2%	

Recommendations

Both CEFF and Gao are based on stream gage data from BIC-20 and produce results that are similar. The NFD data, by contrast, is based on regional regression and produces statistics that are less similar than the gage-based methods. It is recommended to use CEFF and Gao results in lieu of NFD results for recharge calculations, environmental compliance, and operational decisions. Additionally, it is recommended to continue to exploit gage data for understanding drought and potential future conditions.