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STATE OF CALIFORNIA

Memorandum

Date: ~~Friday, May 22, 2020~~ Revised Thursday, July 02, 2020

Project: Lake Mendocino Forecast-Informed Reservoir Operations (FIRO) Full Viability Assessment (FVA) Water Control Plan (WCP) Alternative Analysis

To: Jay Jasperse, PE and Chris Delaney, PE

From: Michael Konieczki, PE, D.WRE (CA Lic. # 74357); Ric McCallan, PE; Megan Lionberger, PE; and Melissa Larsen, PE

Subject: WCP Alternative Analysis Results Metrics: 5-Day Deterministic Forecast Alternative

Background

In 2014, Sonoma Water (SW) undertook a study to confirm the agency could manage Lake Mendocino storage more efficiently for authorized project purposes by integrating reservoir inflow forecasts explicitly in release schedule decision making. That study—which was referred to as the preliminary viability assessment (PVA)—confirmed SW could increase water supply benefit without adversely affecting the flood risk reduction capability if forecast-informed reservoir operation (FIRO) procedures were used. The U.S. Army Corps of Engineers (USACE), which is responsible for flood operation of Lake Mendocino, agreed with the finding and subsequently approved SW's request for a major deviation from the Lake Mendocino water control plan (WCP). This temporary deviation permitted SW greater flexibility in managing Lake Mendocino storage, pending additional investigation that would support incorporation of FIRO procedures in a formal revision of the WCP.

The PVA evaluated candidate FIRO strategies in a reconnaissance-level technical study, confirming viability of FIRO in concept. However, the PVA did not recommend a single specific strategy for integrating FIRO into a future WCP. That task is to be completed in a subsequent planning study—the Full Viability Assessment (FVA).

The objective of the FVA is to identify, through appropriate detailed technical analyses and other considerations, the best FIRO strategy for Lake Mendocino, along with the manner in which the strategy can be implemented in real-time operation by Sonoma Water (SW) and USACE, and enable the Water Control Plan (WCP) changes necessary to permit that change permanently. The FVA will also evaluate potential adaptive strategies that would allow operators to utilize new technology and improved forecast skill as it becomes available in the future.

The FVA is managed by the Lake Mendocino FIRO steering committee (SC), who identified technical studies consistent with USACE guidance needed for FIRO strategy analysis. The SC prepared a hydrologic engineering management plan (HEMP) that is "a technical outline of the hydrologic engineering studies necessary to formulate a solution to a water resources problem" (FIRO SC 2019). The objective of the HEMP is to identify and evaluate Lake Mendocino FIRO alternatives in a systematic, defendable, repeatable manner, providing information to the SC so it may identify the best FIRO strategy.

The SC defined in the HEMP the set of 16 Metrics listed in Table 1 to evaluate the WCP alternatives consistently. In addition, the SC defined in the HEMP the 5 WCP alternatives listed in Table 2 to be evaluated for the FVA.

Table 1. Summary of metrics identified in the HEMP

Metric	Metric Description
M1	Annual maximum flow frequency function at Hopland, Cloverdale, Healdsburg, and Guerneville
M2	Annual maximum pool elevation frequency function of Lake Mendocino
M3	Annual maximum pool elevation frequency function of Lake Sonoma
M4	Annual maximum Lake Mendocino total release frequency function
M5	Annual maximum Lake Sonoma total release function
M6	Annual maximum uncontrolled spill frequency function for Lake Mendocino
M7	Annual maximum uncontrolled spill frequency function for Lake Mendocino
M8	Expected annual inundation damage at critical Russian River locations
M9	Expected annual potential (statistical) loss of life due to floodplain inundation, critical Russian River locations
M10	Reliability of water supply delivery, as measured by annual exceedance frequency of Lake Mendocino May 10 reservoir storage levels
M11	The ability to meet instream flows to support threatened and endangered fish during the summer rearing season, as measured by the annual exceedance of the number of days June through September flows exceed 125 cfs
M12	The ability to meet instream flows to support fall spawning migration, as measured by the annual exceedance of the number of days October 15 to January 1 flows exceed 105 cfs
M13	Impacts to the Bushay Campground during the rec season (Memorial Day through Labor Day), as measured by the annual exceedance of the number of days that Lake Mendocino water-surface elevation exceeds 750 ft
M14	Impacts to power production of the CVD powerhouse
M15	Lake Mendocino bank protection, as measured by annual frequency of exceeding elevation 758.8 ft
M16	Impacts to hours of operation

Table 2. Candidate FIRO alternatives to be evaluated

ID	WCP alternative	Description
1	Existing (Baseline) Conditions	This is the baseline condition (existing WCP operations) against which performance of all alternatives will be measured. It includes the seasonal rule curve and release selection rules from the 1986 USACE WCM and 2003 update to the flood control diagram (FCD).
2	Ensemble Forecast Operations (EFO)	Operates without a traditional rule curve and uses the 15-day ensemble streamflow forecasts to identify required flood releases.
3	Hybrid (Major Deviation #1)	A combination of the Baseline WCP and the EFO. This WCP was used for Major Deviation Operations in WY19 and WY20.
4	Modified Hybrid	Identical to Hybrid but with a “corner cutting” strategy that allows for greater storage to begin February 15th to aid with spring refill.
5	5-Day Deterministic Forecast	Defines alternative guide curves with 11,000 AF encroachment space and 10,000 draft space above and below the Baseline guide curve. Uses 5-day deterministic inflow (and Hopland) forecasts to choose the guide curve and make release decisions.

Task

Operation of each Lake Mendocino WCP alternative was simulated using an HEC-ResSim model of the Russian River. The reservoir releases were then routed hydraulically using an HEC-RAS model. We were tasked with processing the HEC-ResSim and HEC-RAS model results to evaluate the metrics defined in the HEMP for the 5-Day Deterministic Forecast WCP alternative.

Action

To evaluate the 5-Day Deterministic Forecast WCP alternative we:

1. Coordinated with SW and USACE Hydrologic Engineering Center (HEC) staff to develop procedures for computing each metric. These procedures are detailed in 2 technical memoranda titled *Proposed Procedure for Consequence Analysis* and *Procedures for computation of non-consequence metrics* provided on 4/24/2020.
2. Coordinated with SW and USACE Hydrologic Engineering Center (HEC) staff to obtain HEC-ResSim and HEC-RAS model results.
3. Evaluated the 16 metrics using the agreed procedures and documented our findings.

Study Area

Lake Mendocino, formed by the impoundment of the East Fork of the Russian River by the Coyote Valley Dam (CVD), is 3 miles east of the City of Ukiah, CA. Figure 1 shows its location. The 1,485-square mile Russian River watershed is a narrow valley between 2 adjacent northern coastal mountain ranges. The watershed is about 100 miles long and varies from 12 to 32 miles in width.

Inflows to Lake Mendocino include runoff from an approximately 105-square mile drainage area and diversions from the Eel River to the East Fork of the Russian River above CVD through the Potter Valley Project. Some streamflows on the East Fork of the Russian River are diverted for irrigation purposes. Water from Lake Mendocino flows generally south down the East Fork Russian River until its confluence with the Russian River mainstem. Flow continues south near the towns of Hopland, Cloverdale, and Healdsburg. Just south of Healdsburg, Dry Creek flows into the Russian River from the west. The Russian River continues west past Guerneville to the Pacific Ocean.

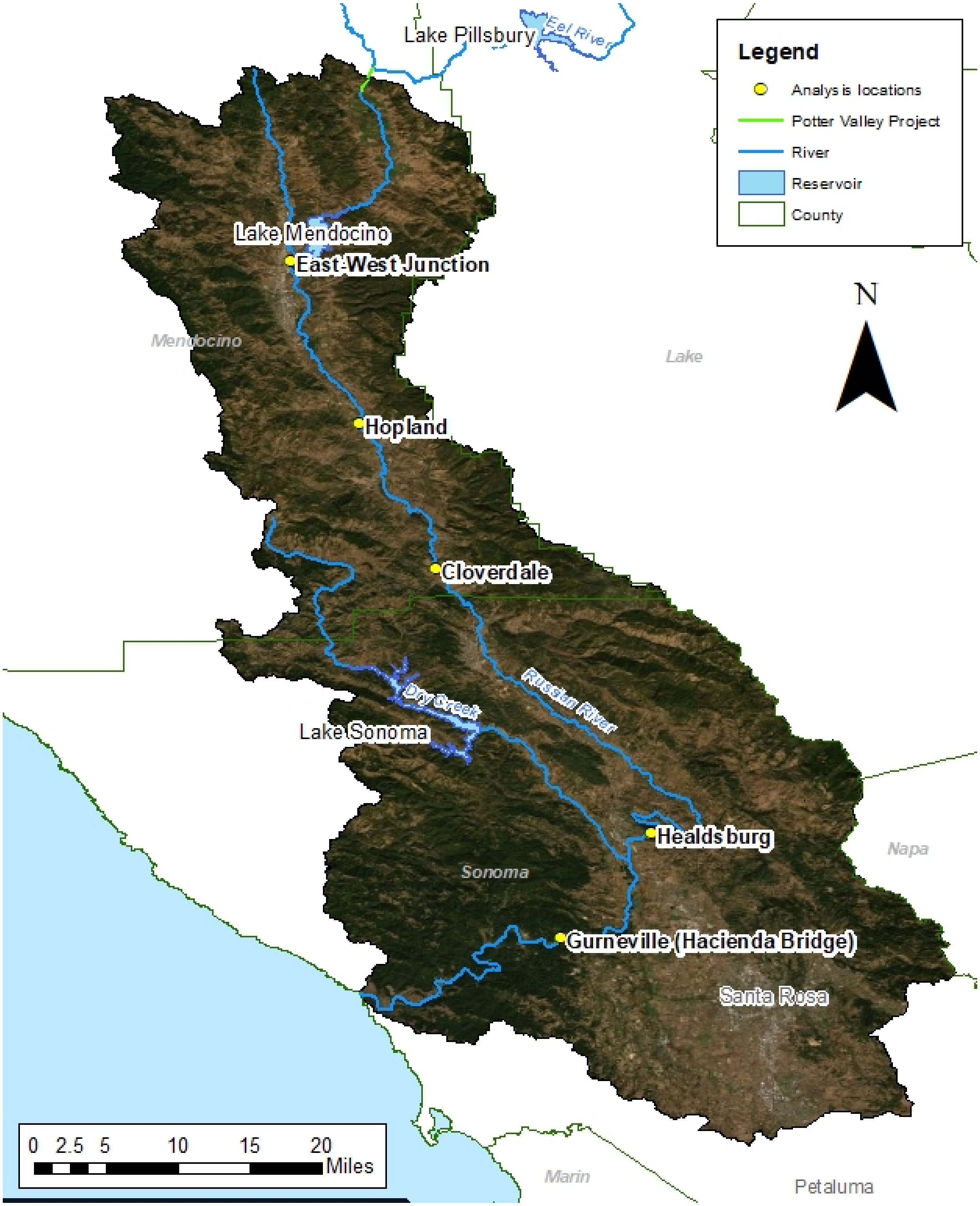

Figure 1. Map of Russian River watershed, including Lake Mendocino

Findings

According to the HEMP, the efficacy of WCP alternatives must be evaluated using a set of measurable statistics that assess each alternative objectively. The SC defined in the HEMP a set of 16 Metrics as listed in Table 1 above. The following sections of this memo summarize the modeling results in terms of these metrics for the 5-Day Deterministic Forecast WCP alternative.

Annual Maximum Flow-Frequency Functions (Metric 1)

M1 is calculated by post-processing HEC-ResSim output to determine the annual maximum flow for each water year in the period of record (POR) of 1/1/1985 through 9/30/2017 (water year [WY] 1985 to WY 2017), and the scaled 200-year and 500-year design floods (1986, 1995, 1997, and 2006). Figure 2 through Figure 5 show the annual exceedance probability (AEP) at Hopland, Cloverdale, Healdsburg, and Guerneville. Table 2 summarizes this information.

Table 3. Annual maximum regulated flow-frequency

Annual Exceedance Probability	1/AEP	Maximum Regulated Flow (cfs)			
		Hopland	Cloverdale	Healdsburg	Guerneville
0.5	2	10,677	15,237	25,364	39,849
0.2	5	16,753	26,818	42,861	61,199
0.1	10	25,128	37,797	61,066	85,212
0.05	20	32,307	45,744	75,985	100,291
0.02	50	35,153	51,726	84,438	116,733
0.01	100	39,258	59,163	97,652	135,332
0.005	200	43,014	65,968	109,745	152,354
0.002	500	50,473	77,115	127,159	179,162

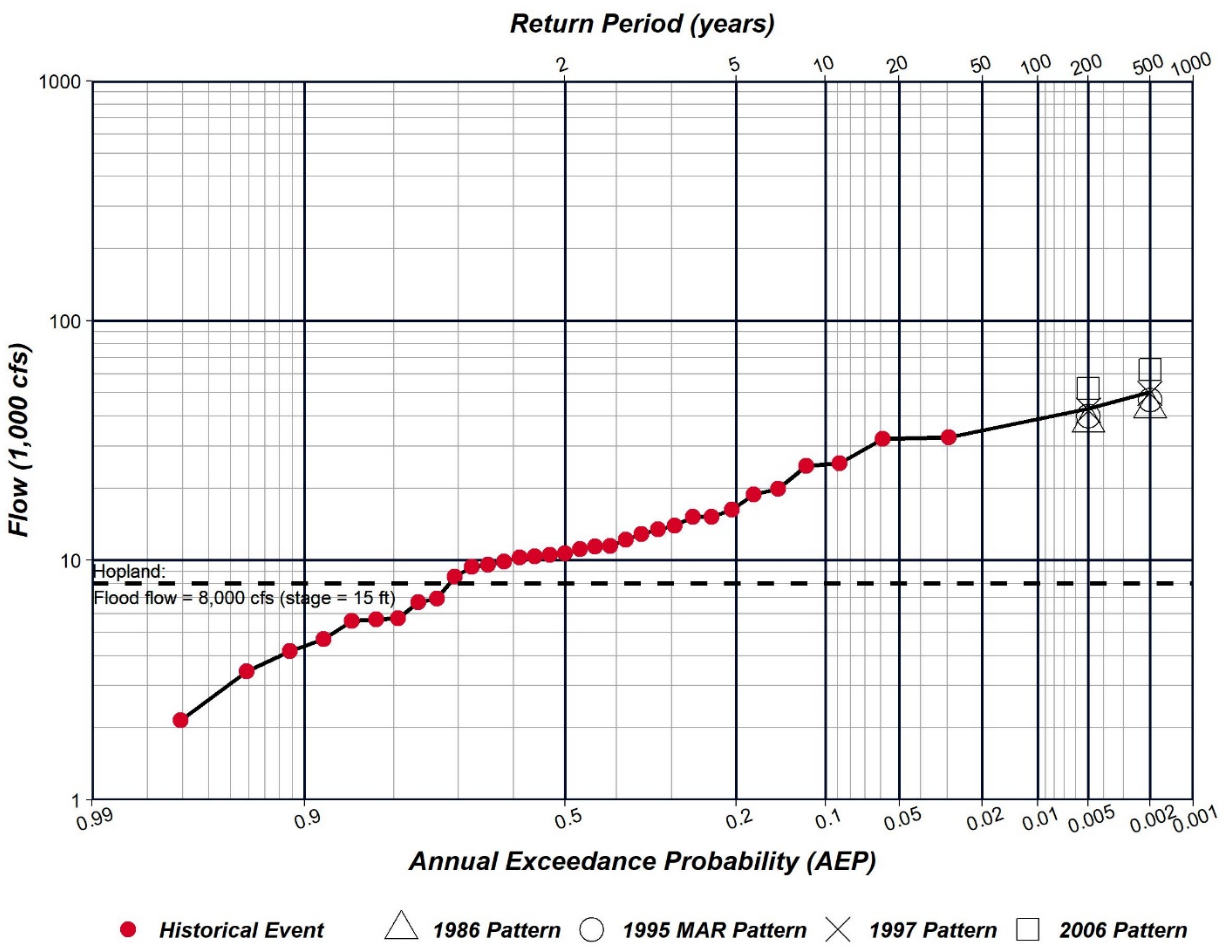

Figure 2. Annual exceedance probability at Hopland

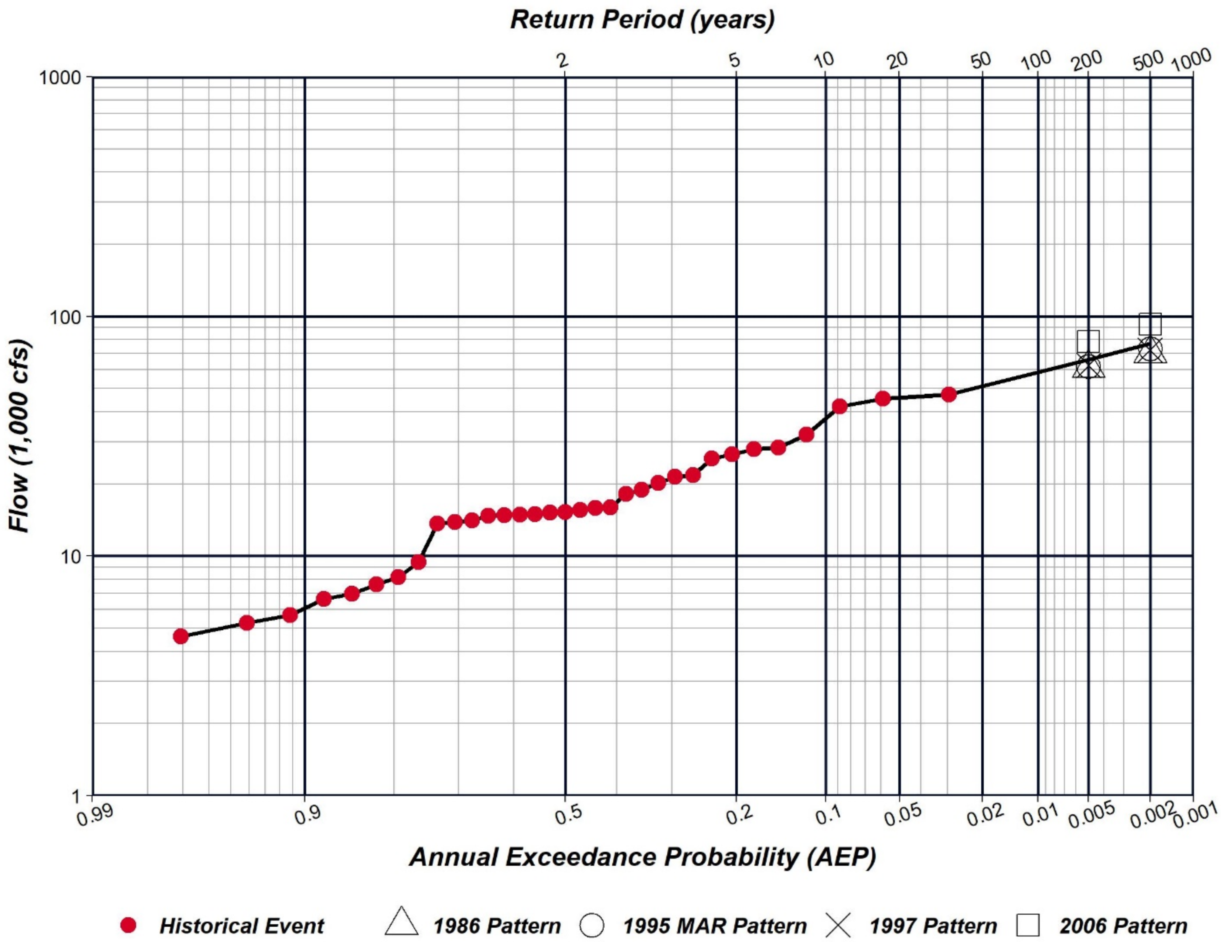

Figure 3. Annual exceedance probability at Cloverdale

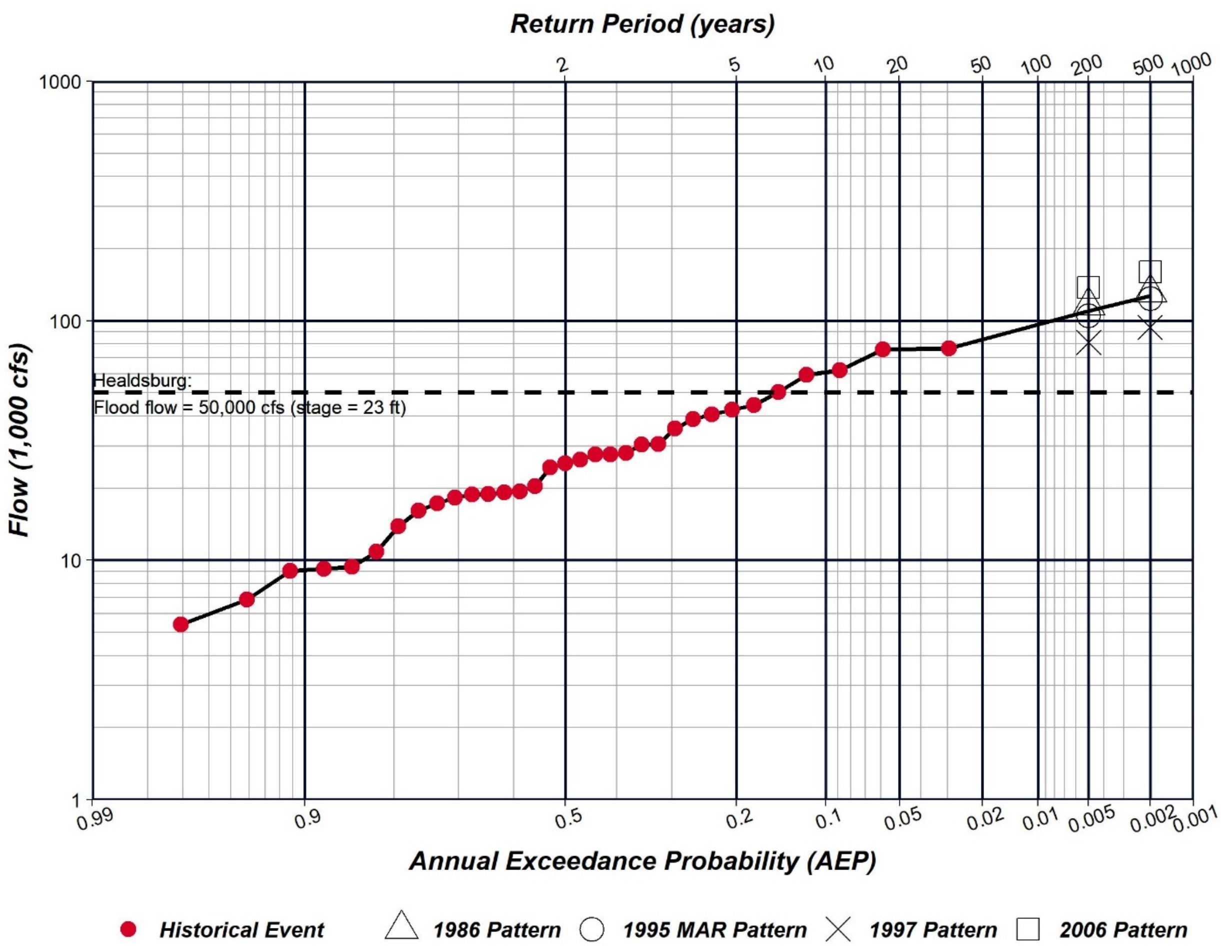

Figure 4. Annual exceedance probability at Healdsburg

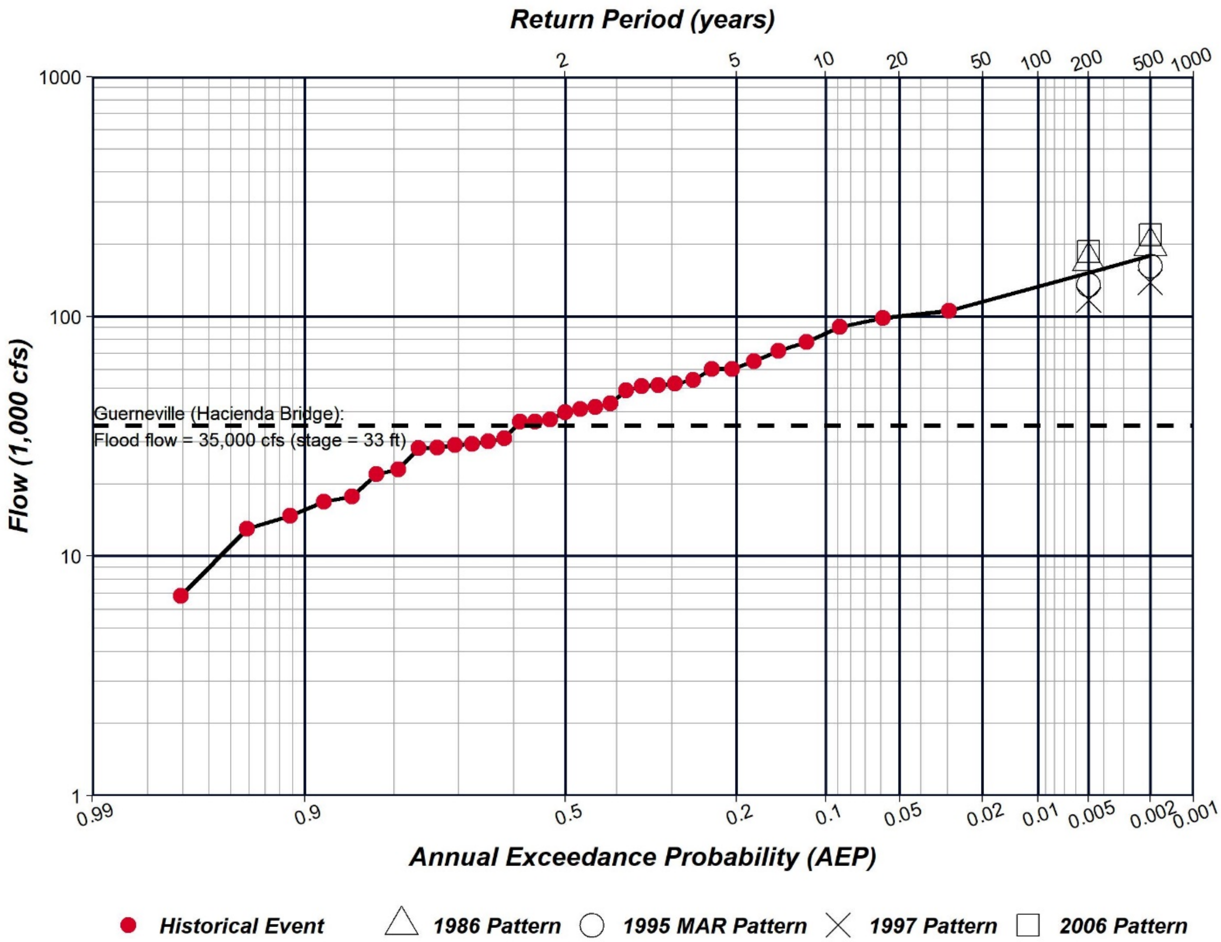

Figure 5. Annual exceedance probability at Guerneville (Hacienda Bridge)

Lake Mendocino Annual Maximum Frequency Functions (Metrics 2, 4, and 6)

M2, M4, and M6 describe the maximum pool elevation, maximum total release, and uncontrolled spill frequency functions at Lake Mendocino. Table 3 summarizes these functions and Figure 6 through Figure 8 show the functions graphically.

Table 4. Lake Mendocino annual maximum frequency functions

Annual Exceedance Probability	1/AEP	Maximum Pool Elevation (ft)	Maximum Total Release (cfs)	Uncontrolled Spill (cfs)
0.5	2	748.32	3,924	0
0.2	5	754.15	4,001	0
0.1	10	755.95	4,002	0
0.05	20	759.42	5,757	0
0.02	50	761.65	6,020	436
0.01	100	763.99	6,168	1,160
0.005	200	766.13	6,304	1,822
0.002	500	769.71	9,030	5,168

Note: Total release and flow are not always coincident

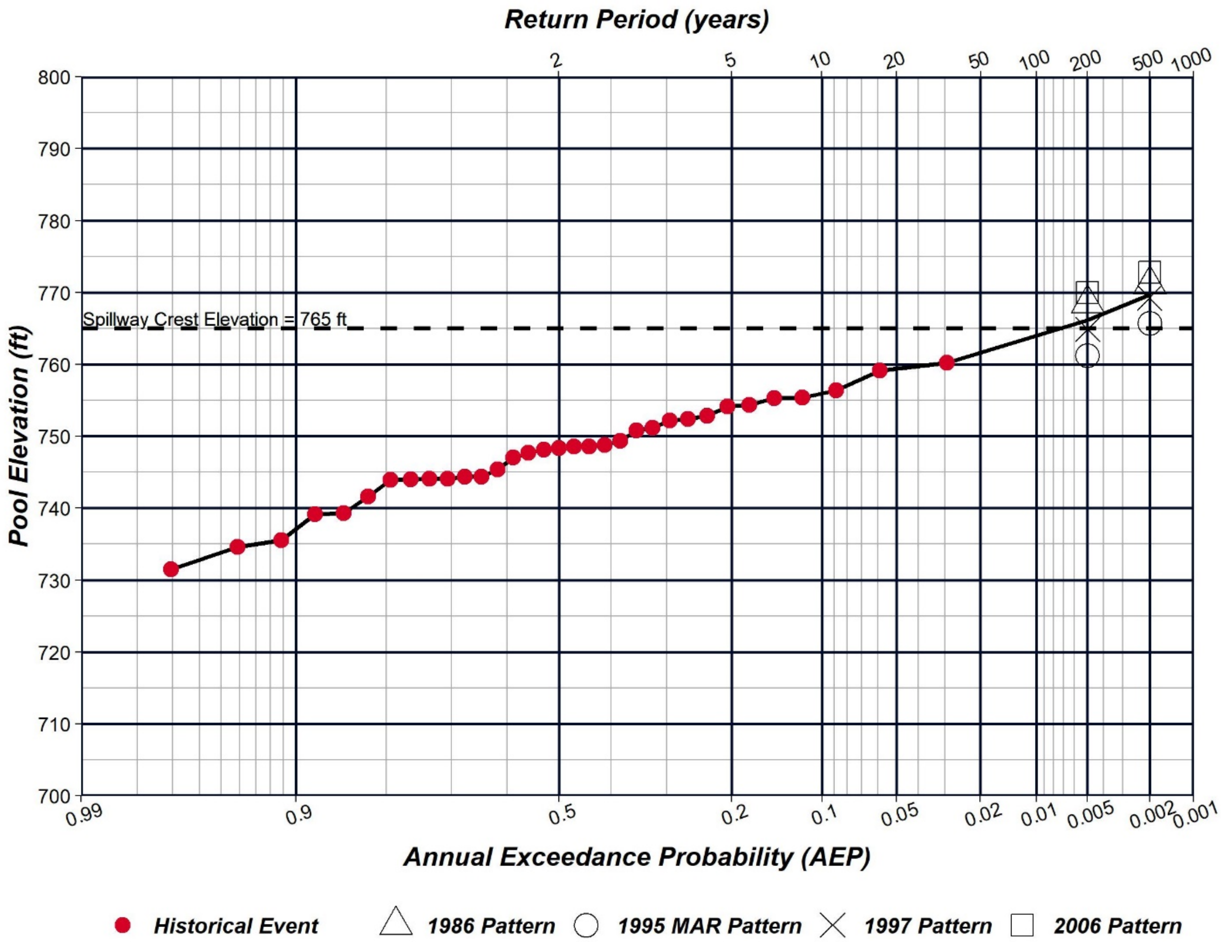

Figure 6. Lake Mendocino annual maximum pool elevation-frequency

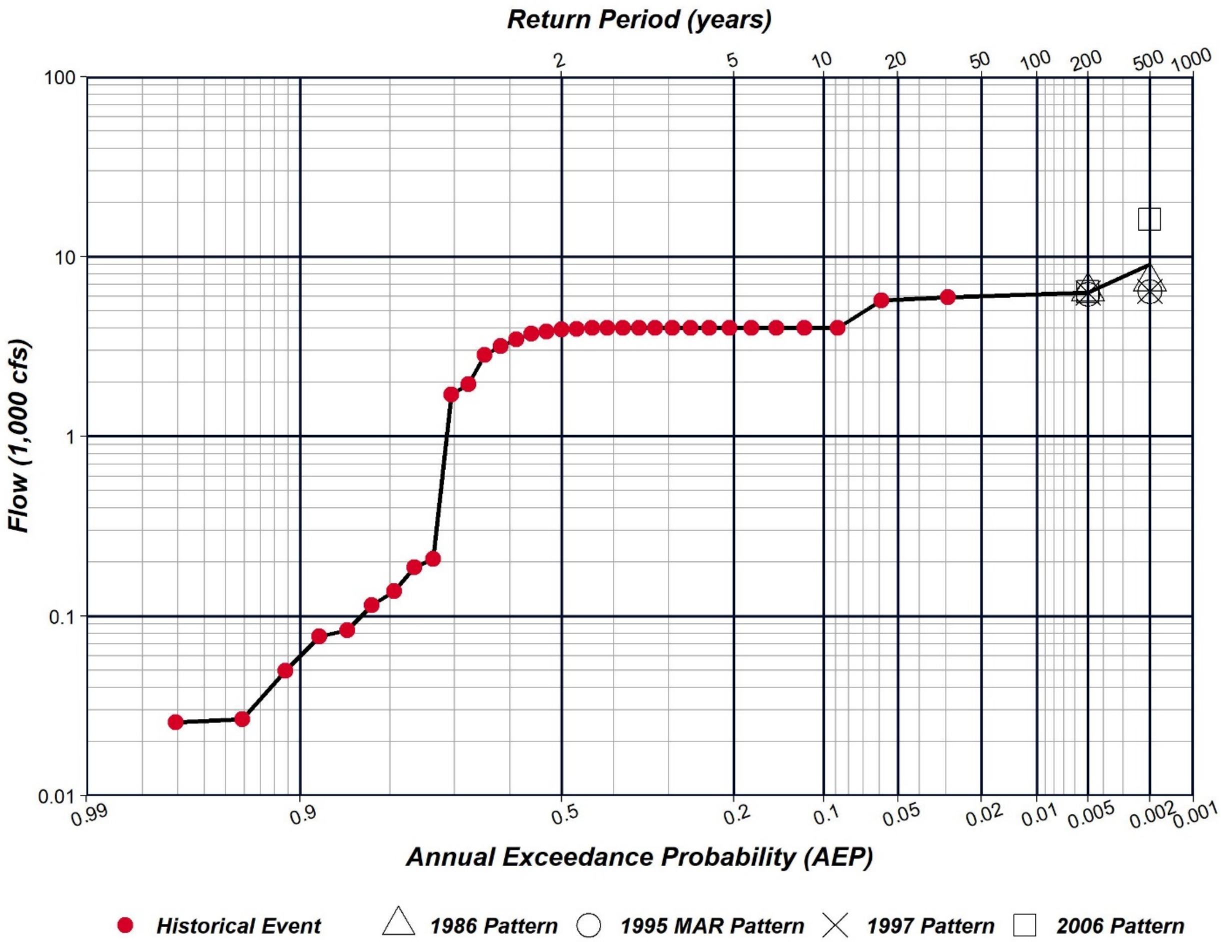

Figure 7. Lake Mendocino annual maximum total release-frequency

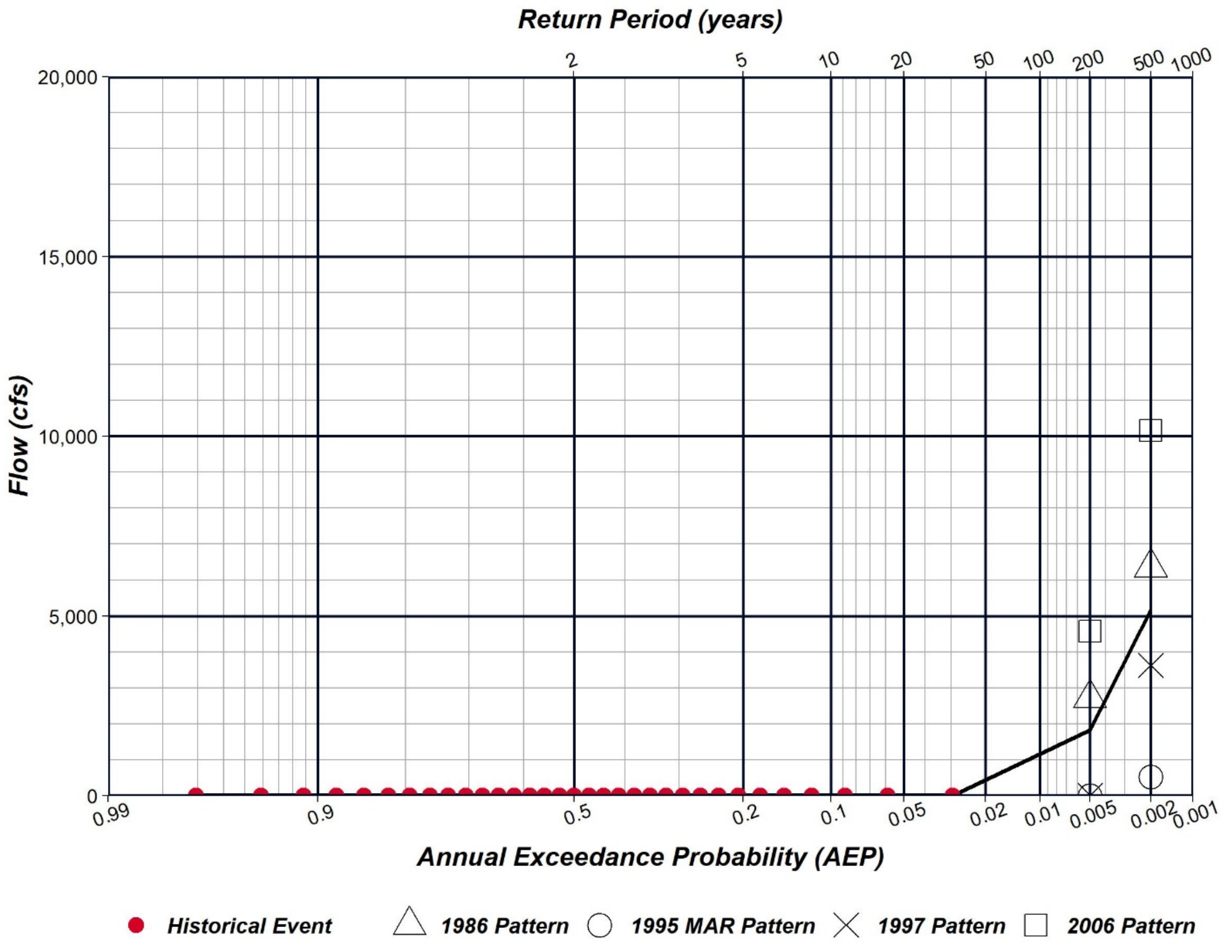

Figure 8. Lake Mendocino annual maximum uncontrolled spill-frequency

Lake Sonoma Annual Maximum Flow Frequency Functions (Metrics 3, 5, and 7)

M3, M5, and M7 describe the maximum pool elevation, maximum total release, and uncontrolled spill frequency functions at Lake Sonoma. Table 4 summarizes these functions and Figure 9 through Figure 11 show these functions graphically.

Table 5. Lake Sonoma annual maximum frequency functions

Annual Exceedance Probability	1/AEP	Maximum Pool Elevation (ft)	Maximum Total Release (cfs)	Uncontrolled Spill (cfs)
0.5	2	454.61	2,000	0
0.2	5	465.29	4,385	0
0.1	10	479.07	6,000	0
0.05	20	481.15	6,000	0
0.02	50	485.63	6,004	308
0.01	100	488.85	6,010	818
0.005	200	491.81	6,015	1,285
0.002	500	493.10	6,015	1,345

Note: Total release and flow are not always coincident

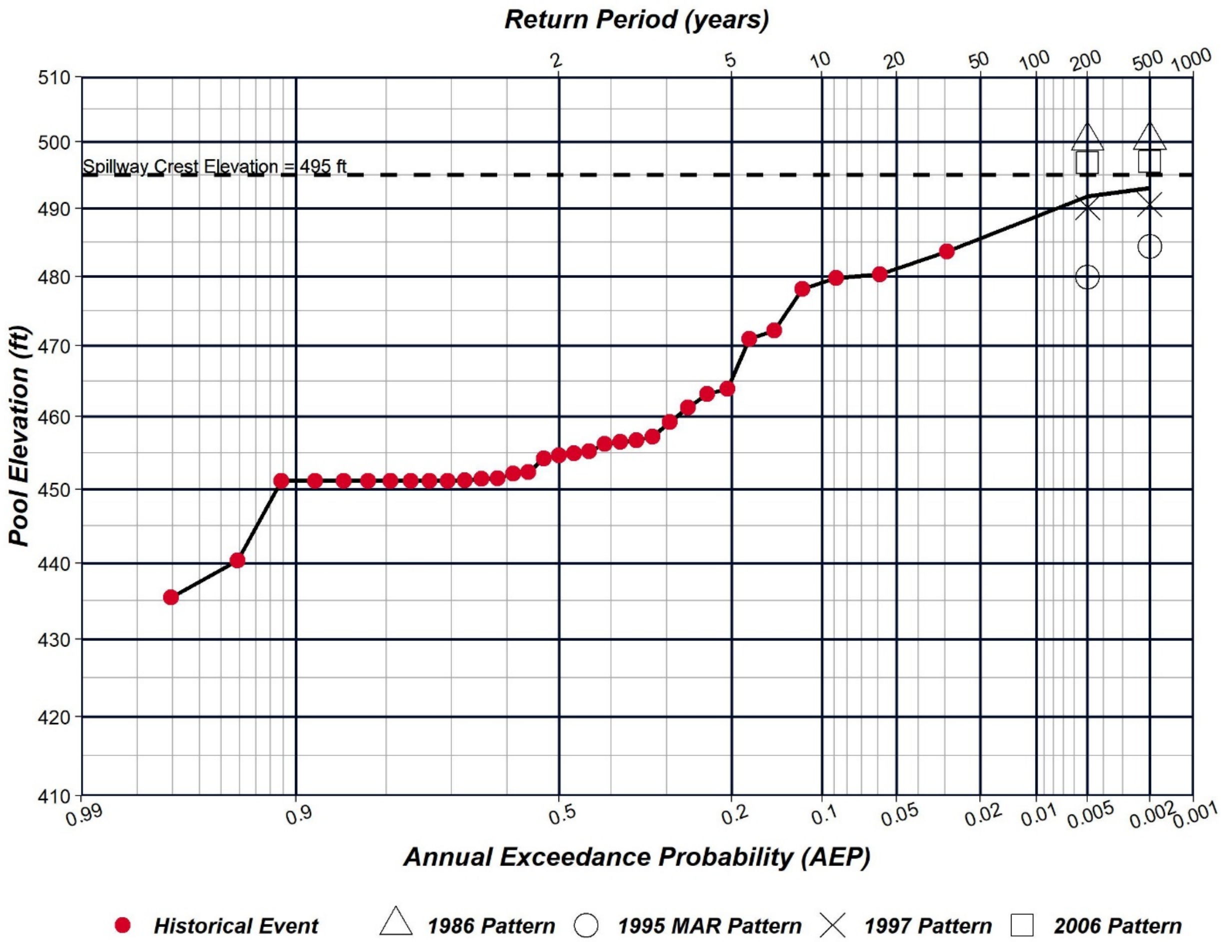

Figure 9. Lake Sonoma annual maximum pool elevation-frequency

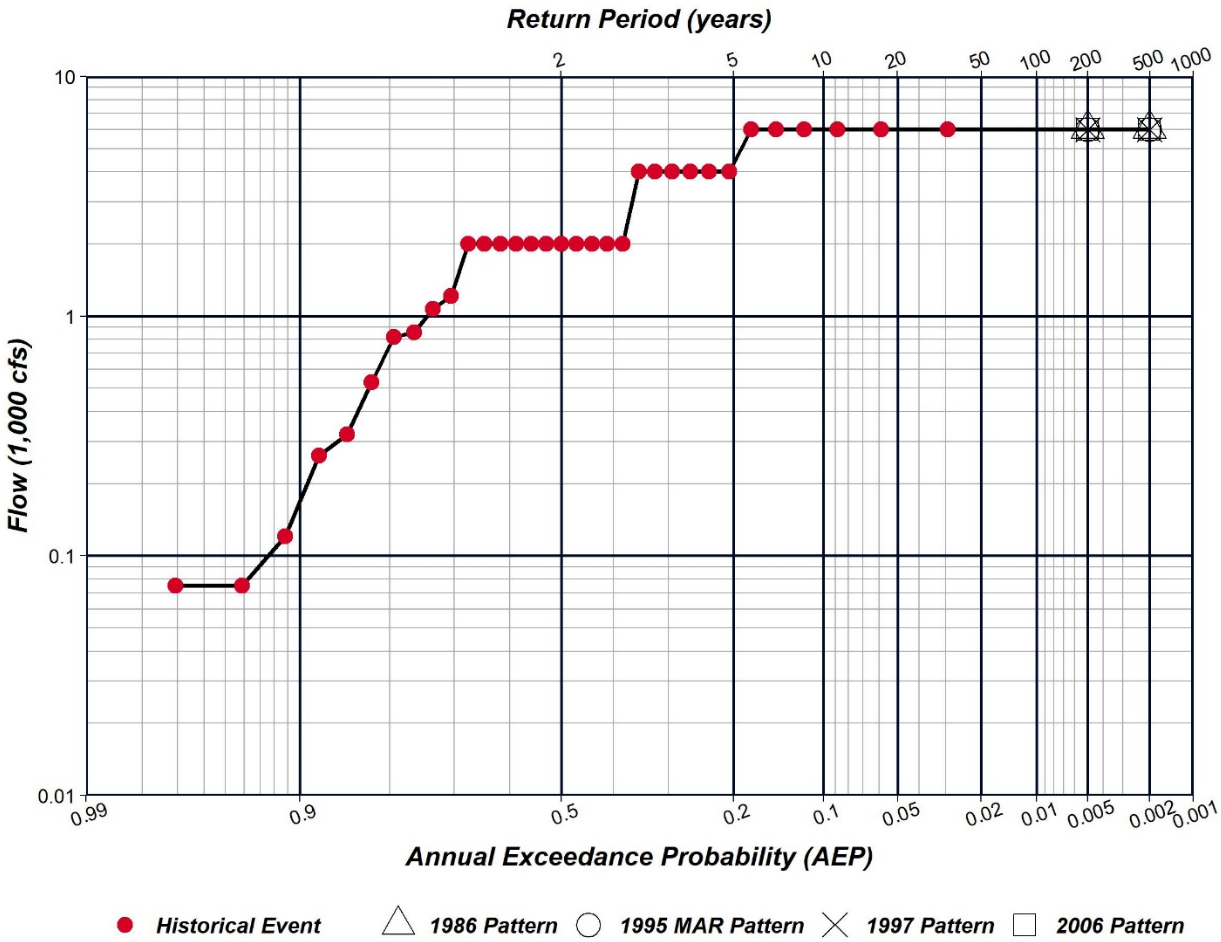

Figure 10. Lake Sonoma annual maximum total release-frequency

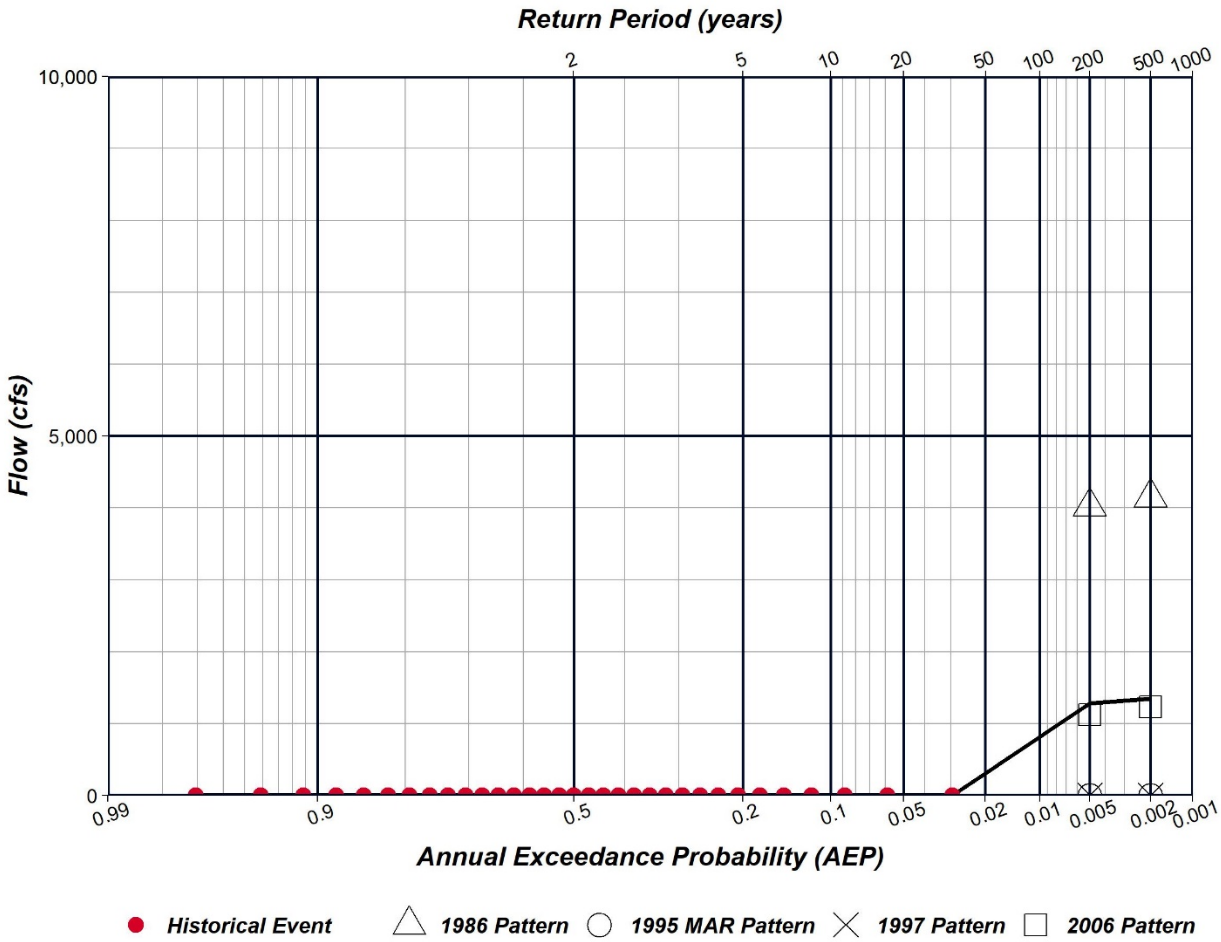

Figure 11. Lake Sonoma annual maximum uncontrolled spill-frequency

Expected Annual Damage (Metric 8)

Expected annual damage (EAD) is computed using an event-based approach that combines the hydrology from the historical period of record (POR) of Water Years (WY) 1986-2017 with design events representing hypothetical rare events not observed in the POR. The procedure for computing EAD is detailed in technical memorandum *Proposed Procedure for Consequence Analysis* provided 4/2/2020. Table 5 summarizes the EAD results by damage location.

Table 6. EAD Results by Damage Location

	EAD ($1,000) by event pattern used to define events rarer than those observed in the POR				
Location	**1986**	**1995**	**1997**	**2006**	**EAD**
Hopland	101.06	101.26	105.01	107.38	103.68
Cloverdale	664.57	689.38	700.82	770.79	706.39
Geyserville	175.36	175.71	160.36	246.17	189.40
Healdsburg	483.42	355.27	230.48	1,094.10	540.82
Dry Creek	2.68	1.75	0.14	6.14	2.68
Windsor	261.14	257.67	249.59	272.52	260.23
Santa Rosa	1,173.99	1,040.57	1,074.10	1,202.52	1,122.80
Green Valley Creek	598.85	642.30	672.22	600.65	628.51
Guerneville	11,222.01	11,145.16	11,459.49	11,270.04	11,274.18
Monte Rio	383.28	351.58	357.89	387.49	370.06
Total EAD	**15,066.36**	**14,760.65**	**15,010.10**	**15,957.80**	**15,198.73**

Expected Annual Loss of Life (Metric 9)

Expected annual potential (statistical) loss of life (EALL) is computed using an event-based approach that combines the hydrology from the historical period of record (POR) of Water Years (WY) 1986-2017 with design events representing hypothetical rare events not observed in the POR. The procedure for computing EALL is detailed in the technical memorandum *Proposed Procedure for Consequence Analysis* provided 4/2/2020. Computation of EALL is dependent on assumptions of population demographics, warning times, evacuation routes, and so on, some of which are interrelated with the forecast and decision horizon of a specific WCP. Here, we report the expected annual population exposed to flooding (EAP) as analog for EALL. EAP is a function of floodplain hydraulics and population location (i.e. structure inventory geodata) and therefore is a direct measure of WCP performance. Table 6 summarizes the EAP results by damage location.

Table 7. EAP results by damage location

	EAP (persons) by event pattern used to define events rarer than those observed in the POR				
Location	**1986**	**1995**	**1997**	**2006**	**EAP**
Hopland	13.9	14.0	15.7	16.0	14.9
Cloverdale	41.2	42.0	42.3	45.0	42.6
Geyserville	10.3	10.3	9.9	12.7	10.8
Healdsburg	49.5	41.1	29.6	73.8	48.5
Dry Creek	0.3	0.3	0.3	0.5	0.4
Windsor	40.4	40.0	39.8	40.5	40.2
Santa Rosa	106.0	96.7	96.4	107.0	101.5
Green Valley Creek	2.5	2.5	2.5	2.6	2.5
Guerneville	683.4	694.9	699.3	683.6	690.3
Monte Rio	20.8	21.2	21.8	20.9	21.2
Total EAD	**968.30**	**963.00**	**957.60**	**1,002.60**	**972.90**

Reliability of Water Supply Delivery (Metric 10)

The reliability of water supply delivery is represented by the May 10 storage in Lake Mendocino. The modeling results are extracted from HEC-ResSim output for each year in the POR of 1/1/1985 through 9/30/2017 (water year [WY] 1985 to WY 2017). Figure 12 shows the annual exceedance probability of Lake Mendocino storage on May 10 as a representation of annual water supply availability.

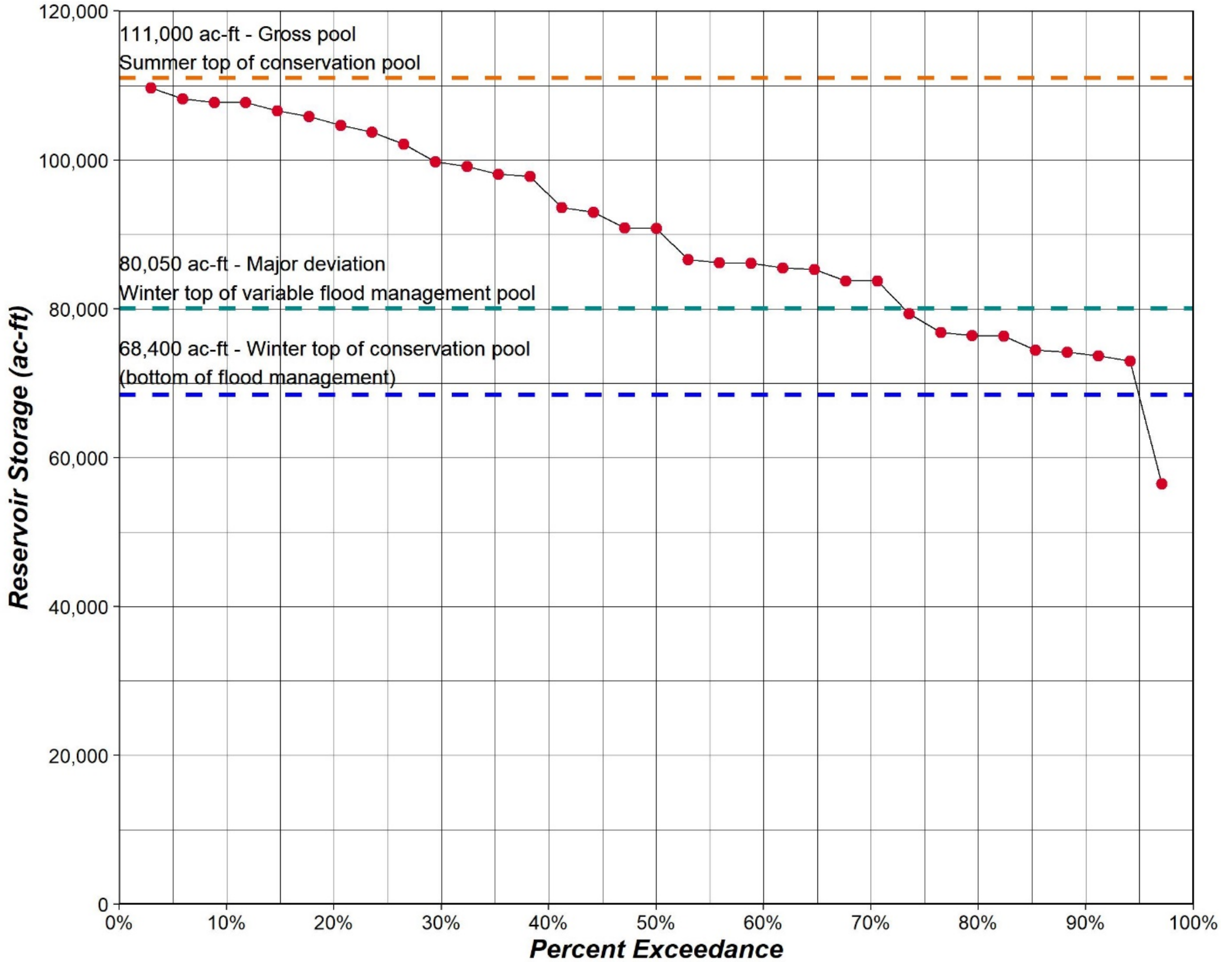

Figure 12. Annual exceedance probability of Lake Mendocino storage on May 10th

The Ability to Meet Instream Flows to Support Threatened and Endangered Fish during the Summer Rearing Season (Metric 11)

M11 evaluates the ability of the 5-Day Deterministic Forecast model run to meet environmental flow targets for critical life-stage periods for anadromous fish in the reach below Lake Mendocino to the Cloverdale gage. Specifically, this metric represents the percent of days per summer rearing season in which flows exceed a target threshold established by the 2008 Biological Opinion in the Upper Russian River, 125 cfs. Figure 13 through Figure 15 present the percent of days per season in which flows exceed 125 cfs.

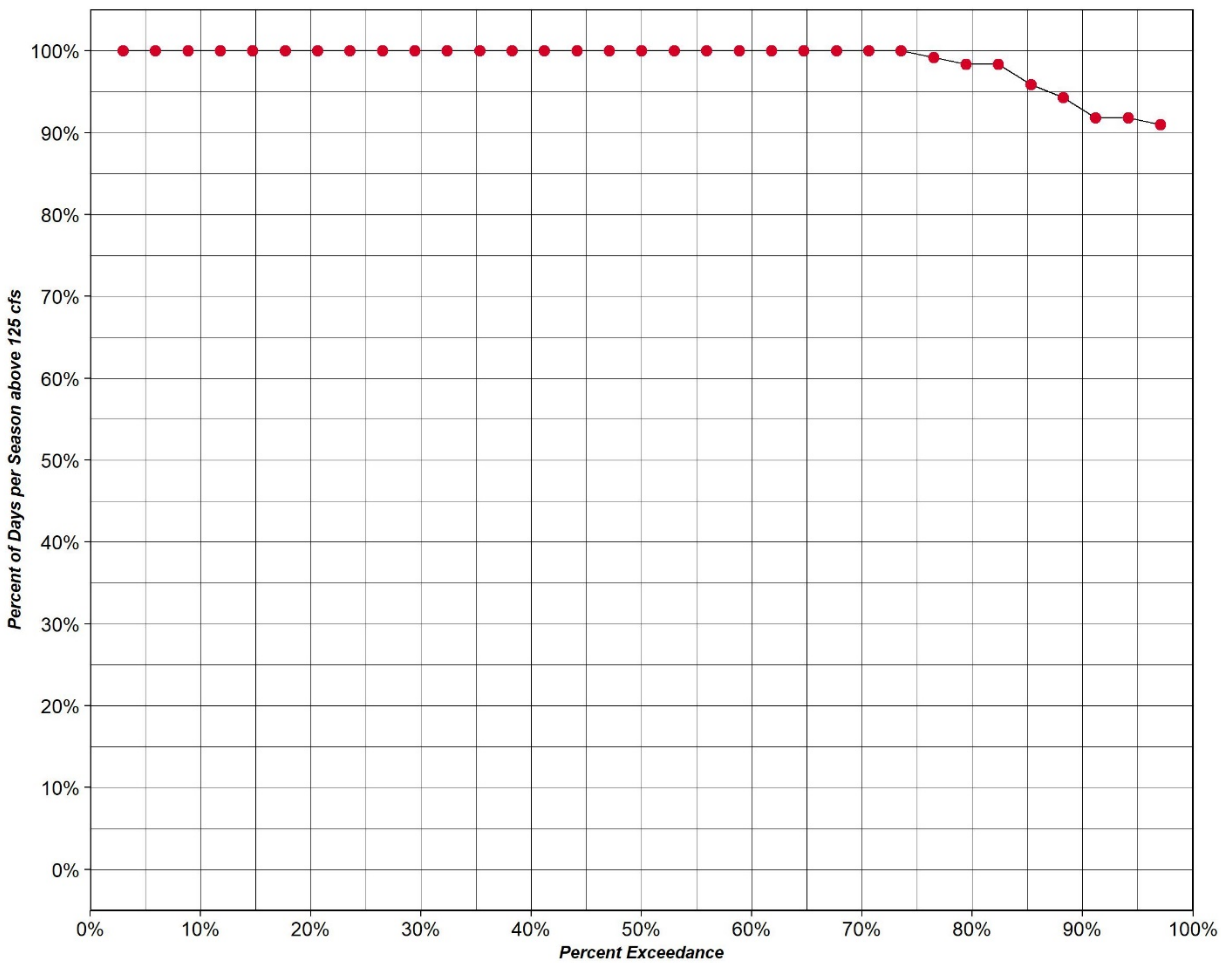

Figure 13. Percent of days per season, June through September, in which flows exceed 125 cfs at East-West Junction

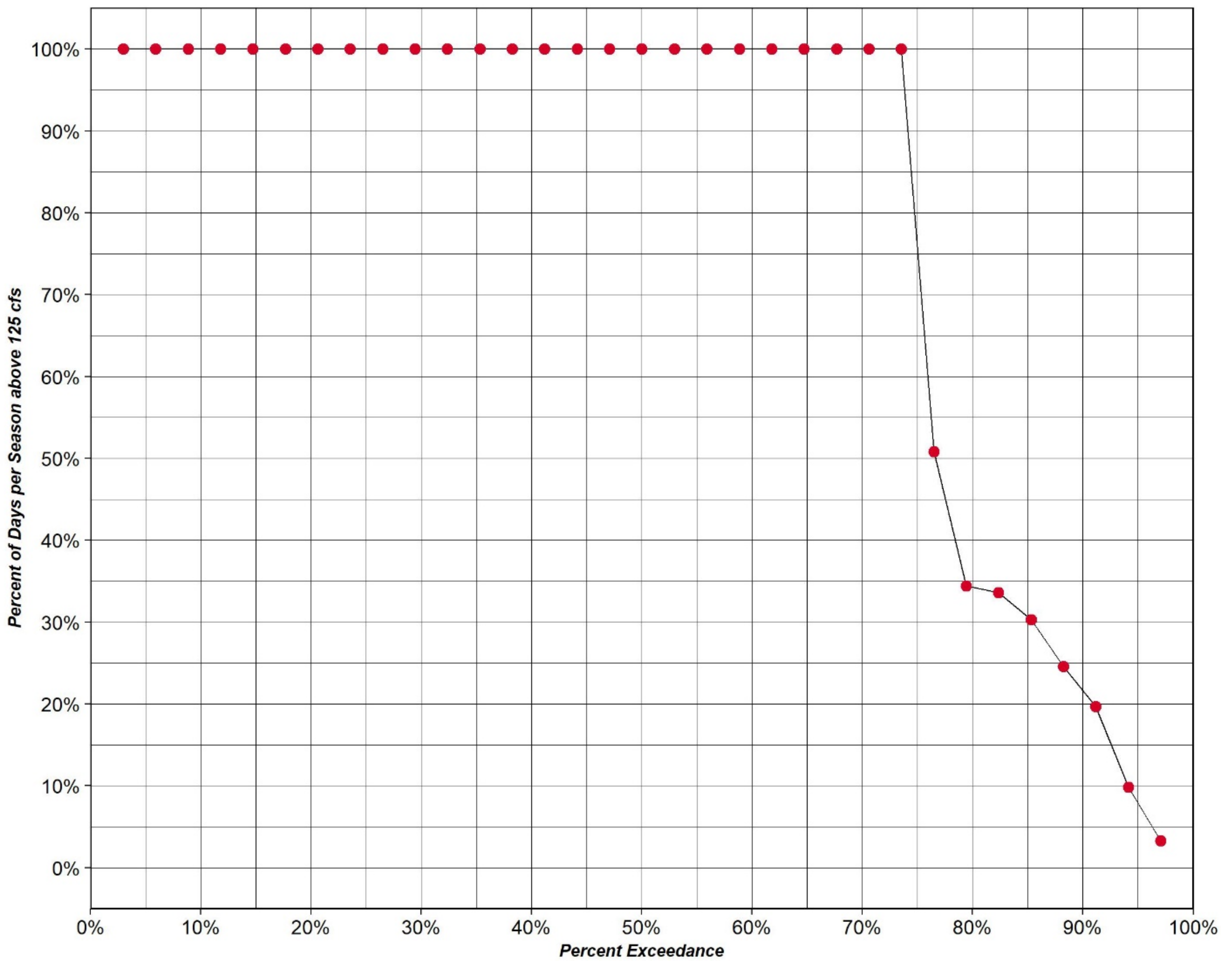

Figure 14. Percent of days per season, June through September, in which flows exceed 125 cfs at Hopland

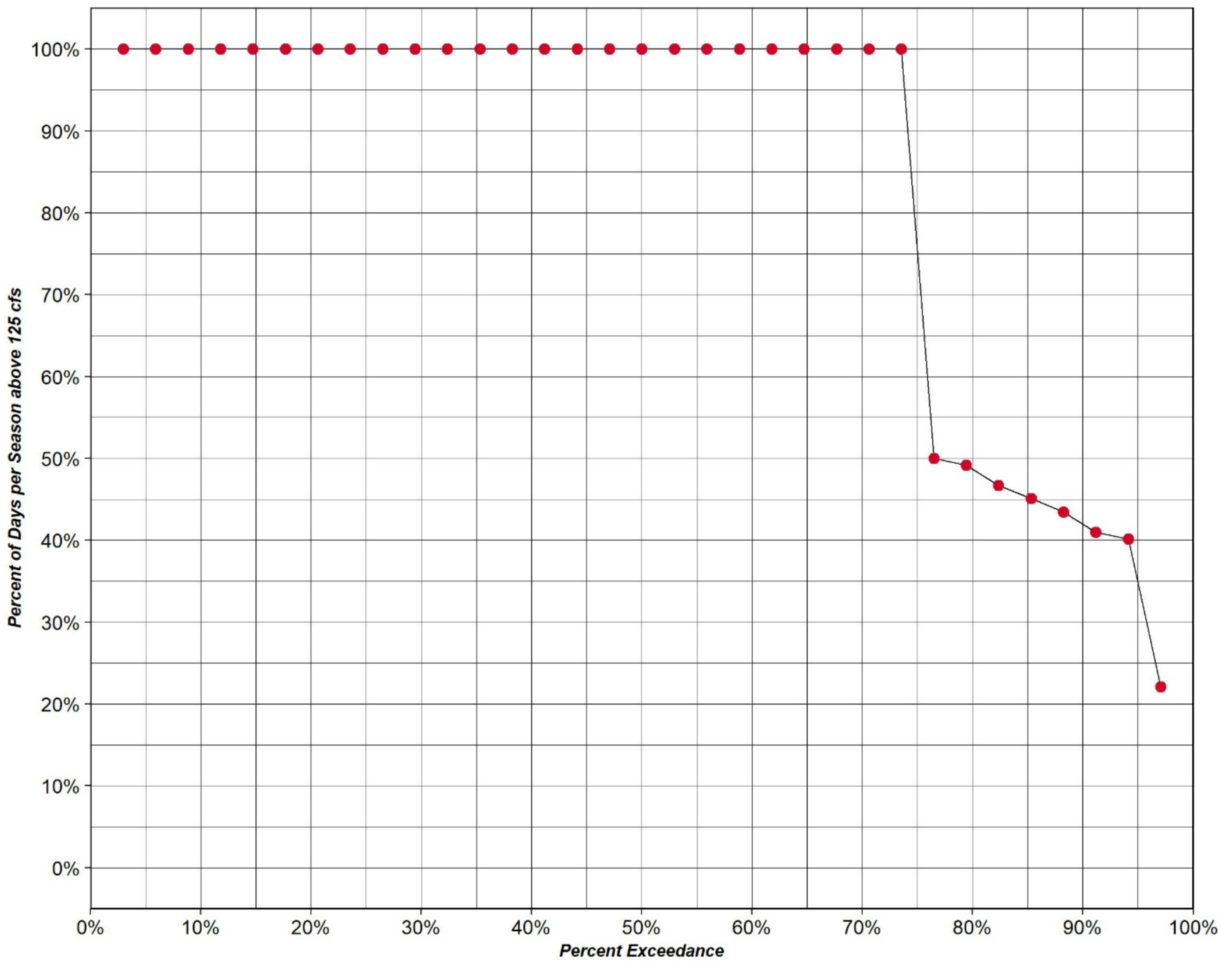

Figure 15. Percent of days per season, June through September, in which flows exceed 125 cfs at Cloverdale

The Ability to Meet Instream Flows to Support Fall Spawning Migration (Metric 12)

M12 evaluates the ability of the 5-Day Deterministic Forecast model run to meet environmental flow targets for critical life-stage periods for anadromous fish. This metric represents the percent of days per fall spawning season in which flows exceed a target threshold established by the 2008 Biological Opinion in the Upper Russian River, which is 105 cfs, except at the Hacienda Bridge gage downstream of Guerneville where it is 135 cfs. Figure 16 through Figure 21 present the percent of days per season in which flows exceed instream flow requirements.

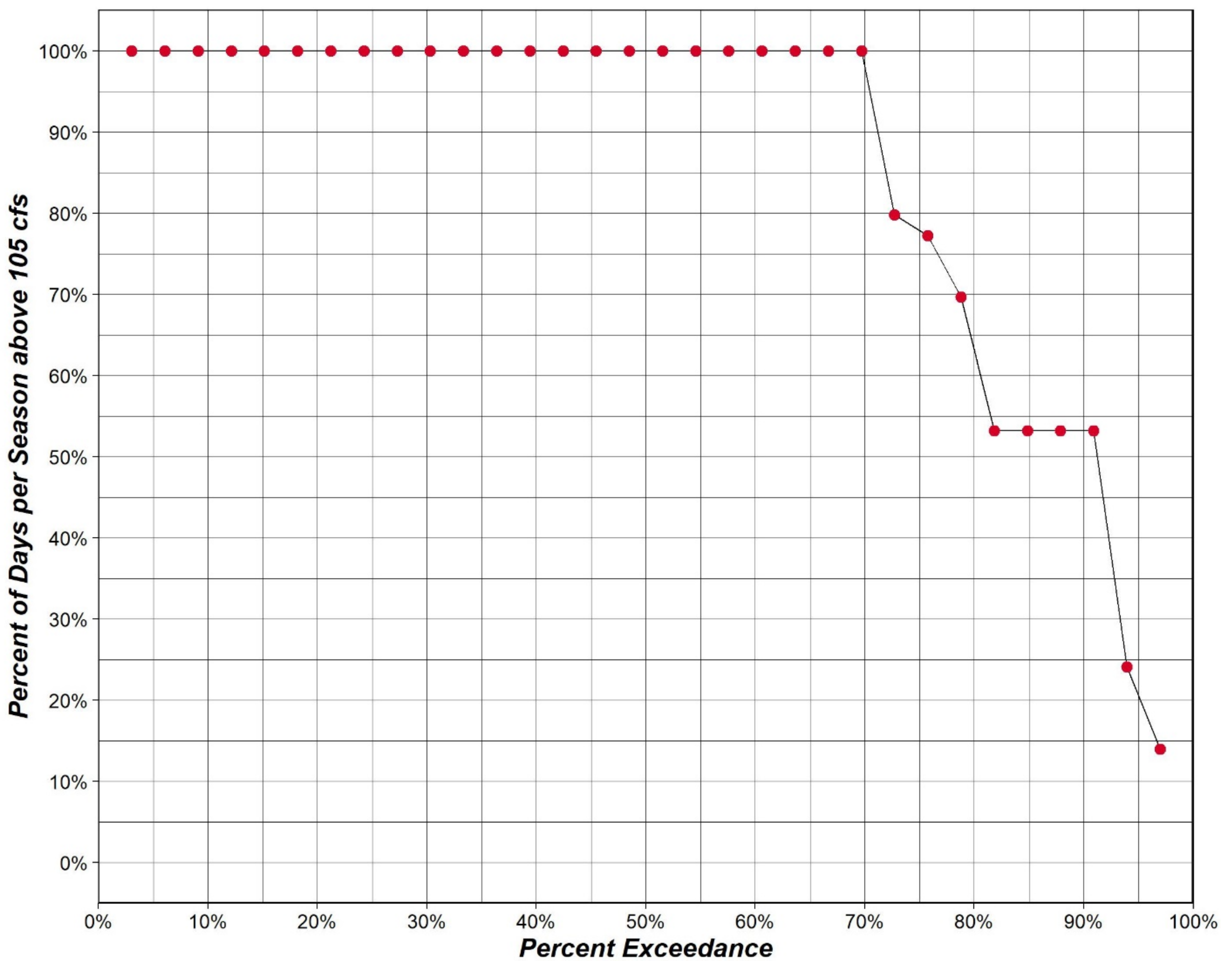

Figure 16. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at East-West Junction

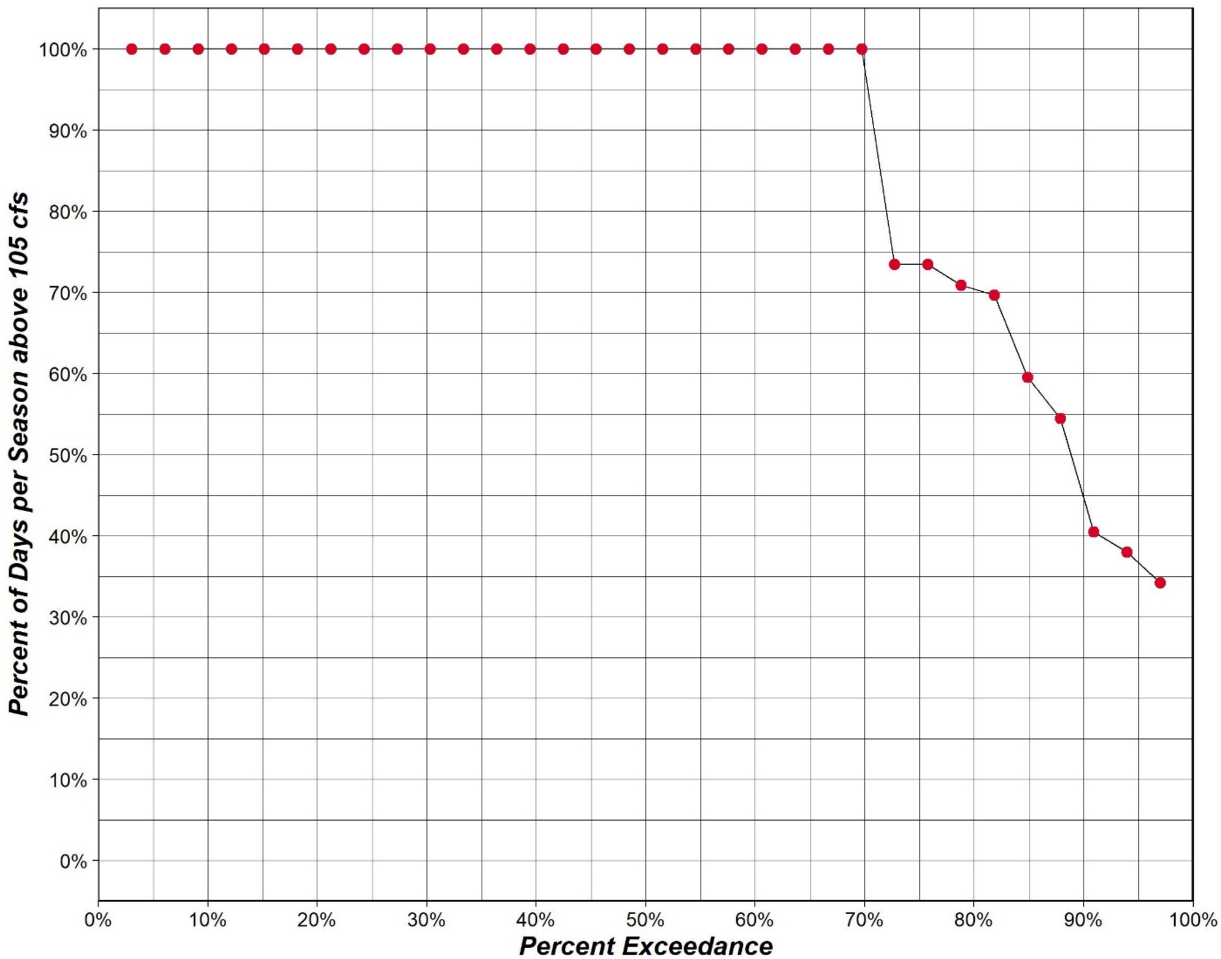

Figure 17. Percent of days per season, June through September, in which flows exceed 105 cfs at Hopland

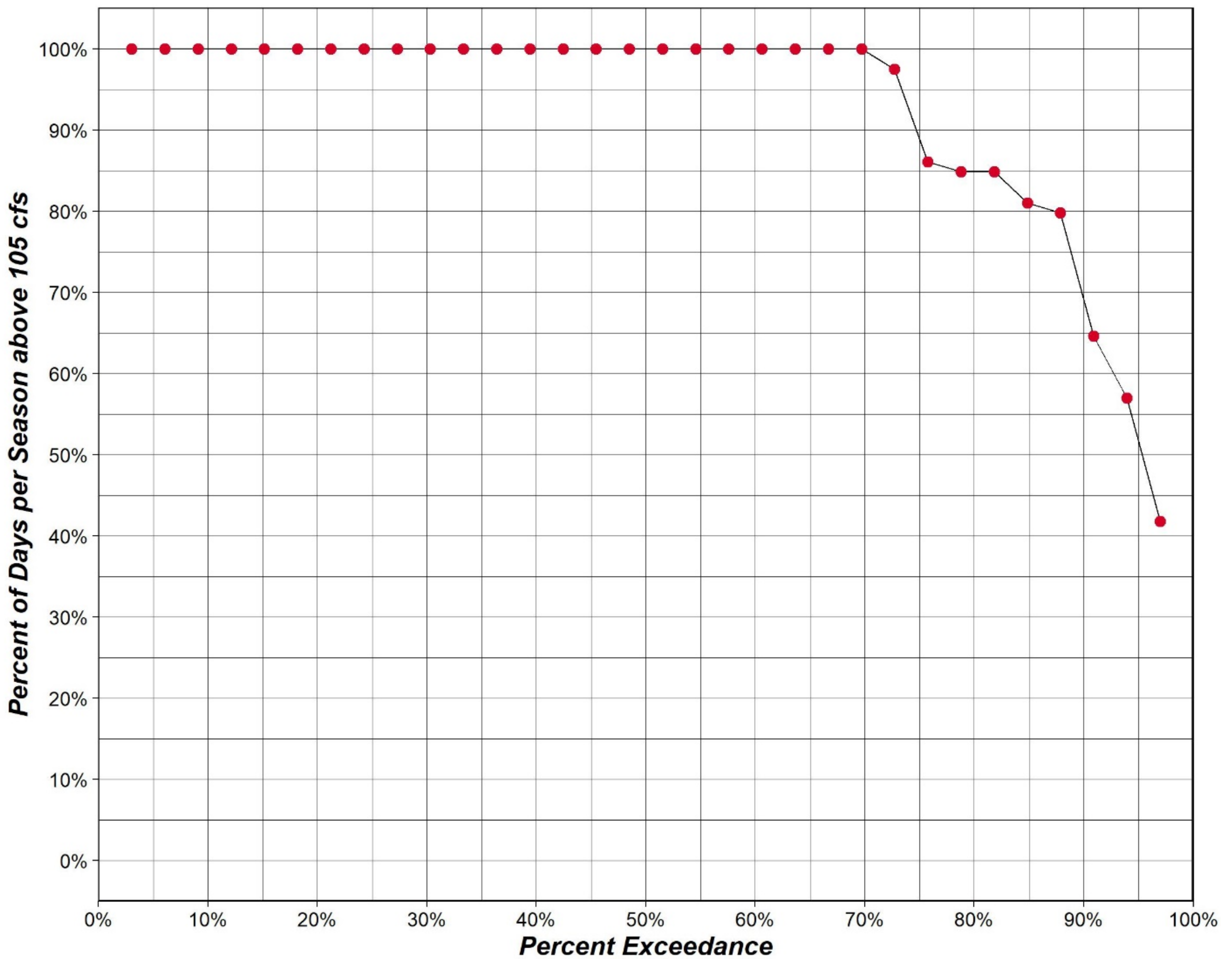

Figure 18. Percent of days per season, June through September, in which flows exceed 105 cfs at Cloverdale

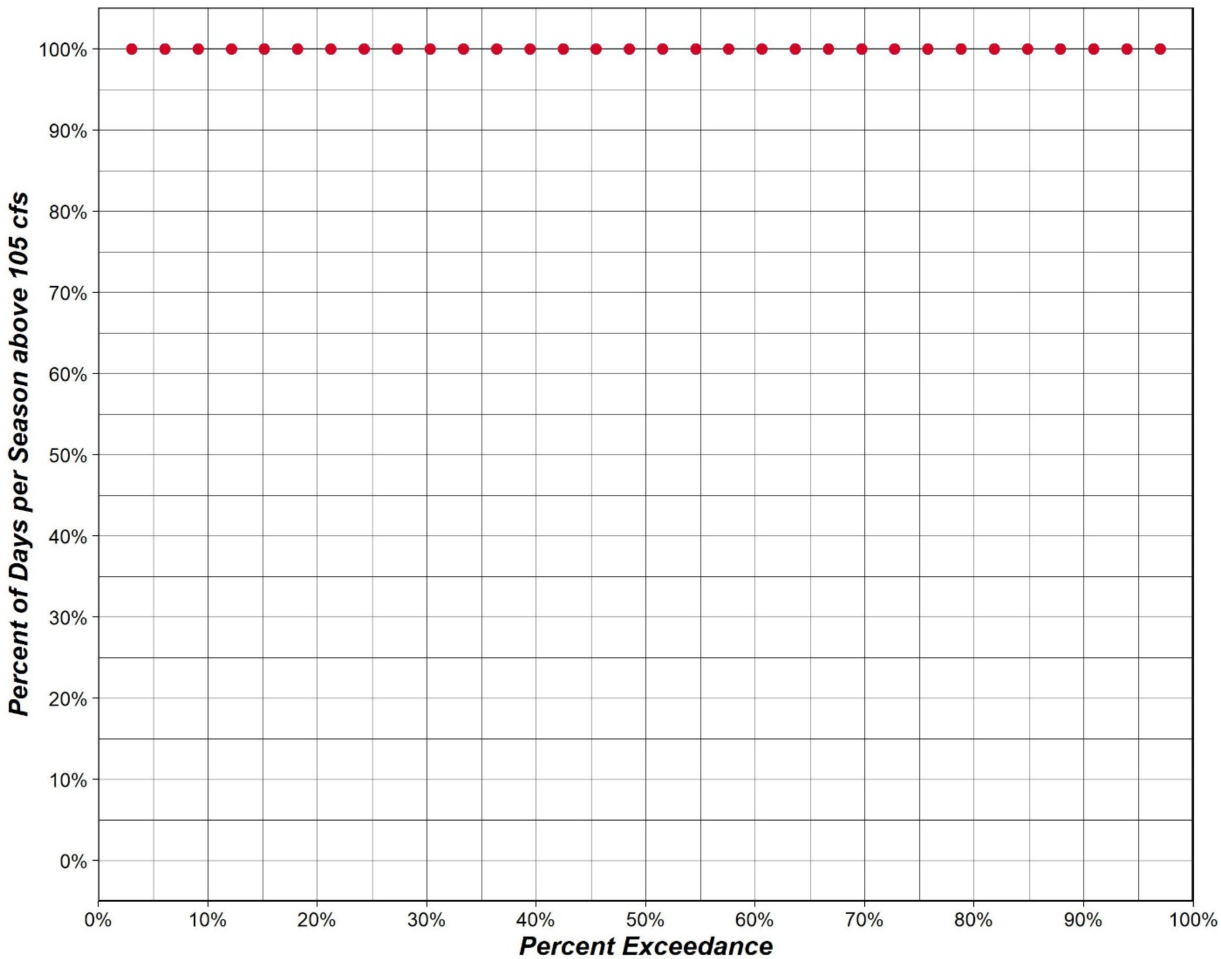

Figure 19. Percent of days per season, June through September, in which flows exceed 105 cfs at Dry Creek confluence

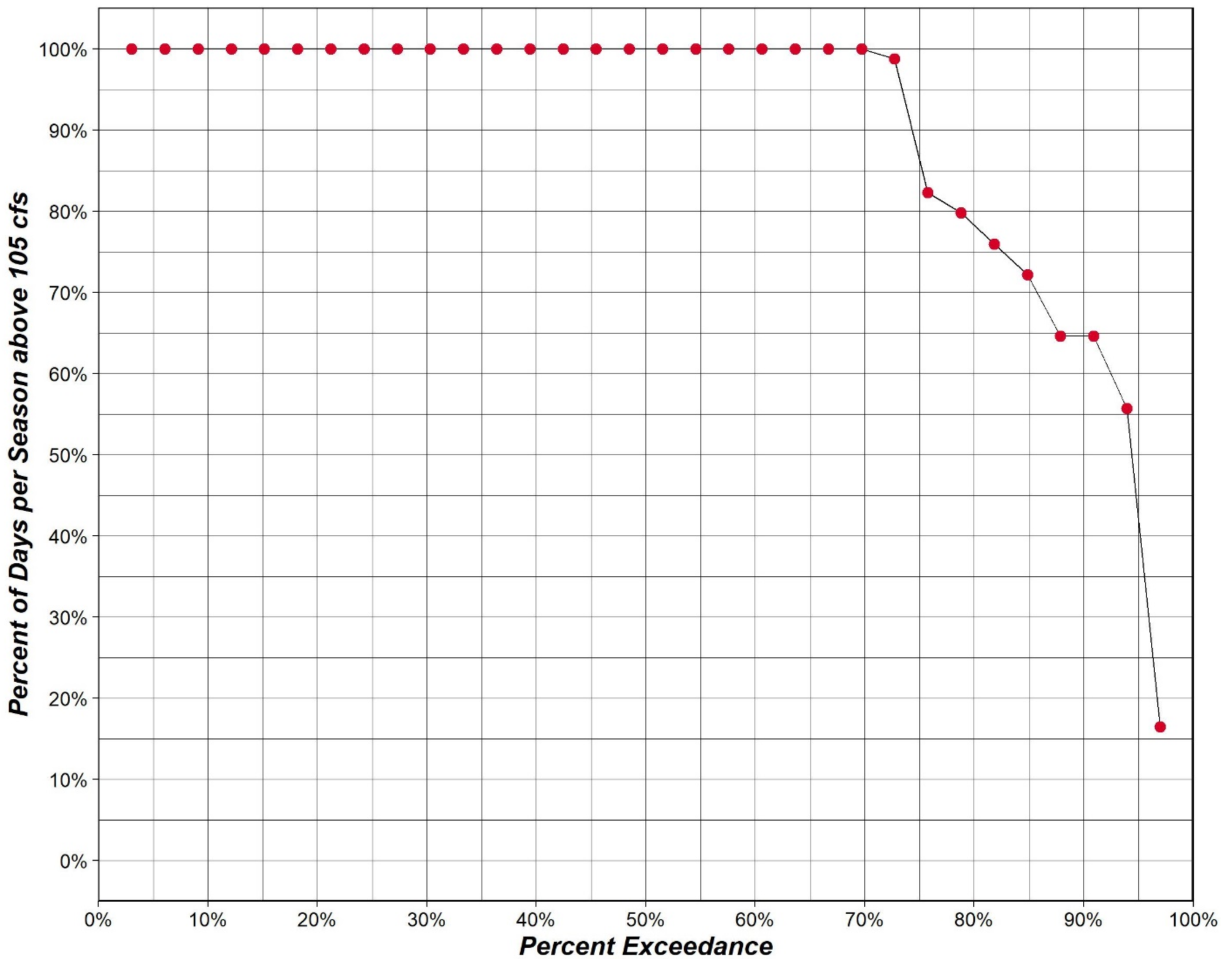

Figure 20. Percent of days per season, June through September, in which flows exceed 105 cfs at Healdsburg

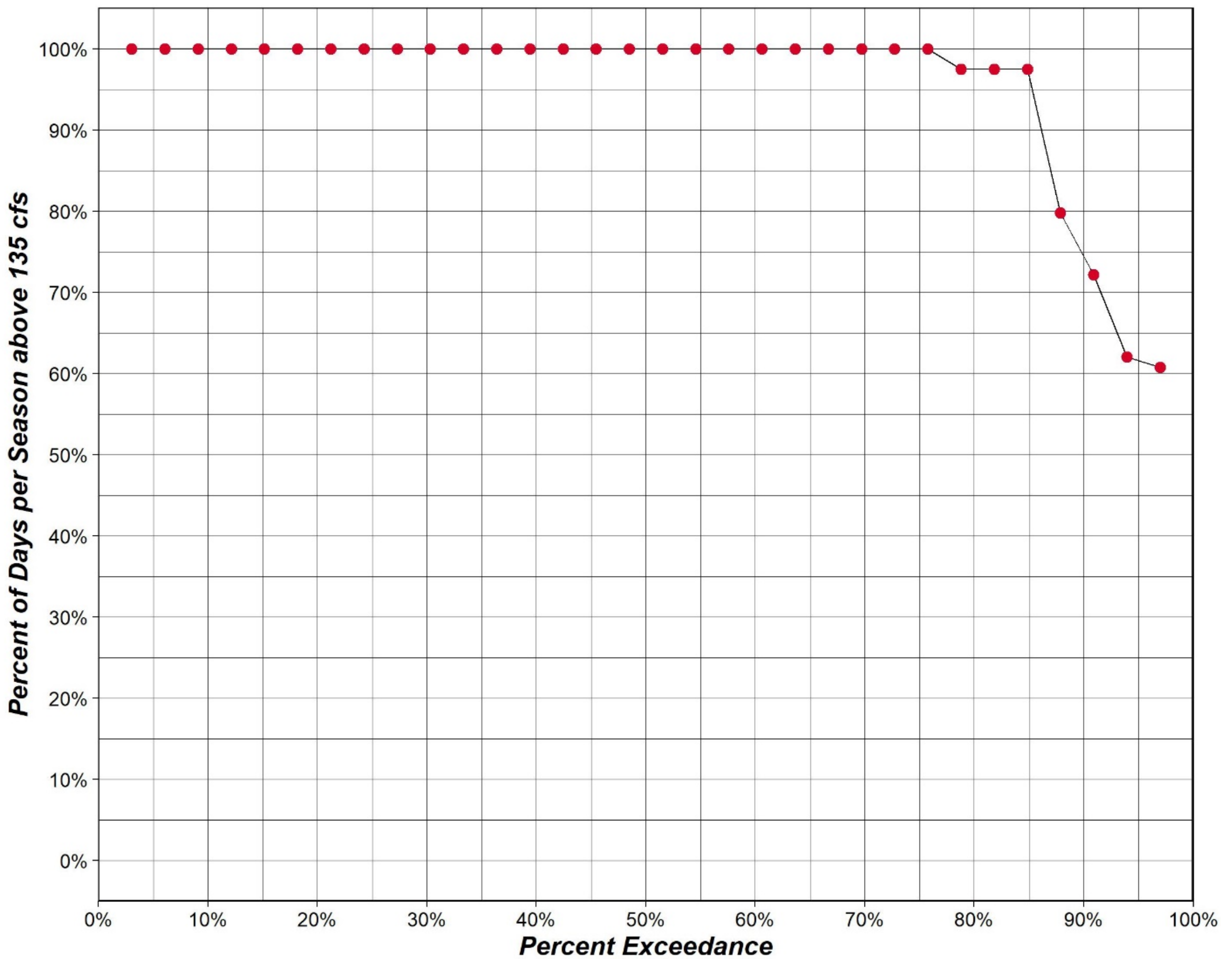

Figure 21. Percent of days per season, June through September, in which flows exceed 135 cfs at Guerneville (Hacienda Bridge).

Impacts to the Bushay Campground (Metric 13)

M13, presented in Figure 22, assesses the impacts to Bushay Campground. It is the inverse calculation of M11 and M12. It is the number of days a critical Lake Mendocino water-surface elevation exceeds a critical threshold during the recreation season: Memorial Day weekend through Labor Day weekend.

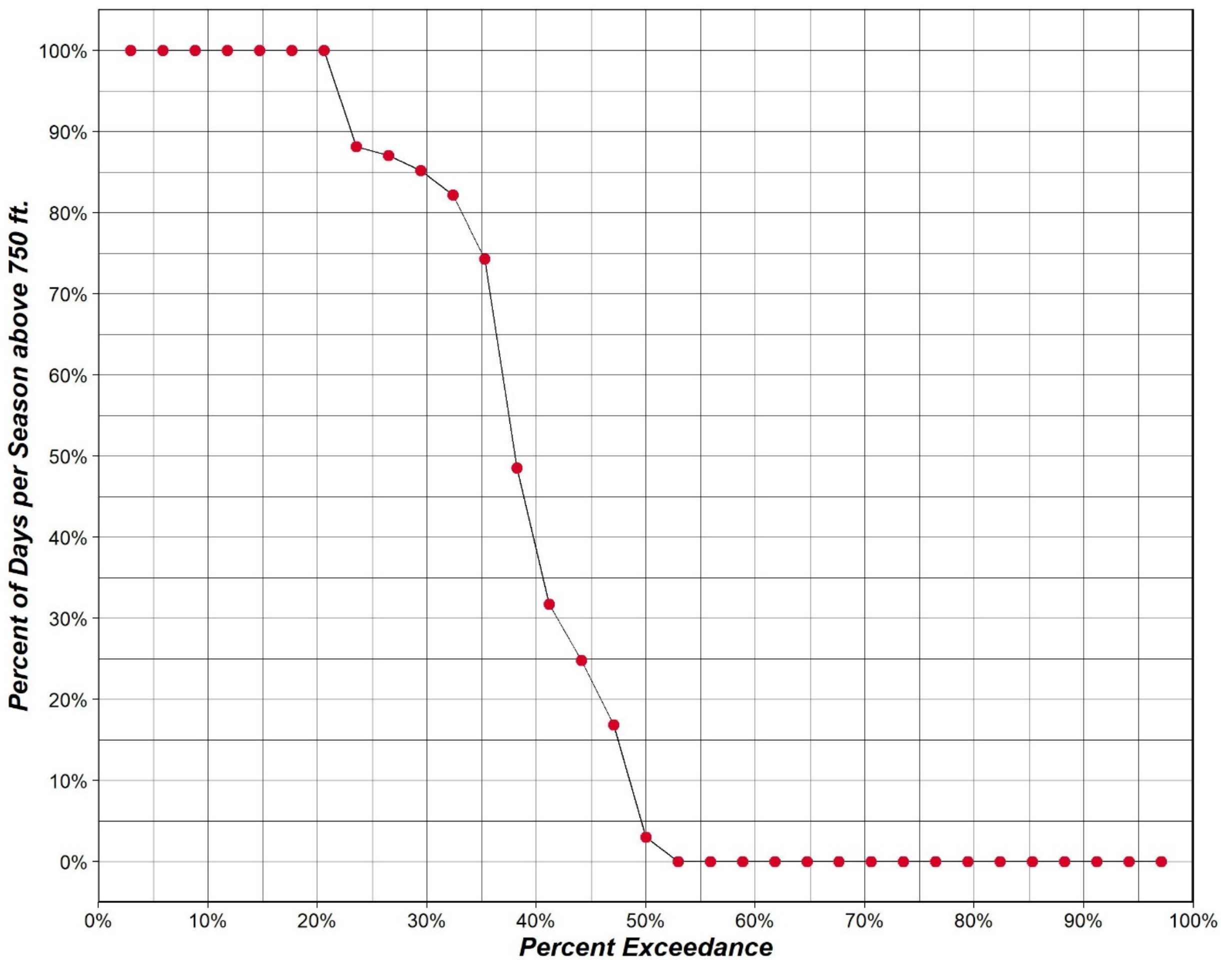

Figure 22. Percent of days per season that access to Bushay Campground is limited (pool elevation 750.0 feet is exceeded)

Impacts to Power Production of the CVD Powerhouse (Metric 14)

M14 evaluates the impact of the WCP on power production. To calculate M14, the HEC-ResSim results were post-processed to compute a timeseries of power production for the 33-year period of record. These results were used to compute statistics on annual power production and compute exceedance plots. The annual exceedance plots for power production for Lake Mendocino and Lake Sonoma are shown in Figure 23 and Figure 24, respectively.

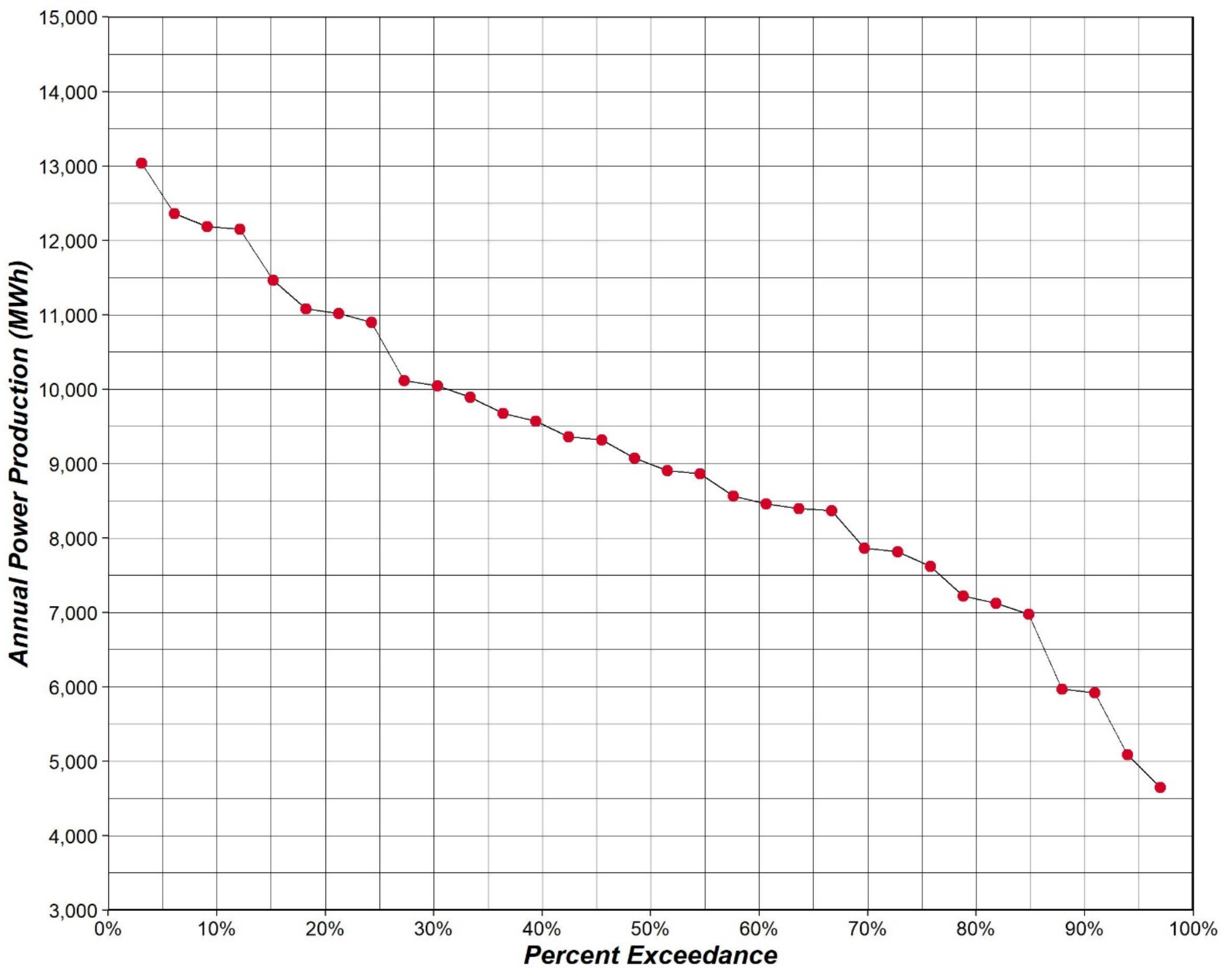

Figure 23. Power production exceedance plot for Lake Mendocino

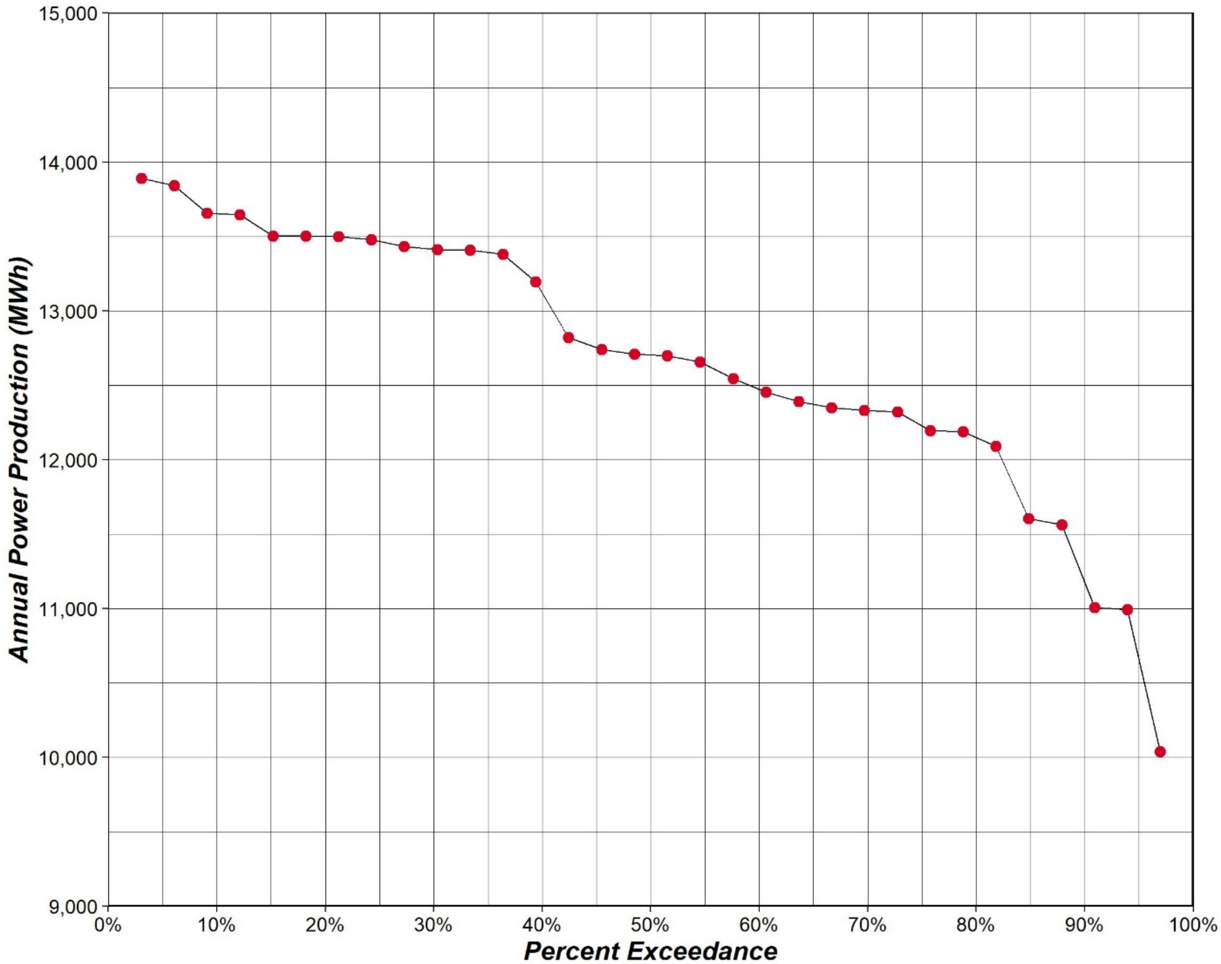

Figure 24. Power production exceedance plot for Lake Sonoma

Lake Mendocino Bank Protection (Metric 15)

M15, Lake Mendocino bank protection, is measured by the frequency that Lake Mendocino water surface elevation exceeds 758.8 ft on an annual basis (Figure 25). Above this elevation, riprap shore protection is limited. For existing conditions, the pool elevation will exceed 758.8 ft at an AEP = 0.062 (approximately a 16-year return period). The number of days per season in which an elevation of 758.8 ft is exceeded is also presented in Figure 26.

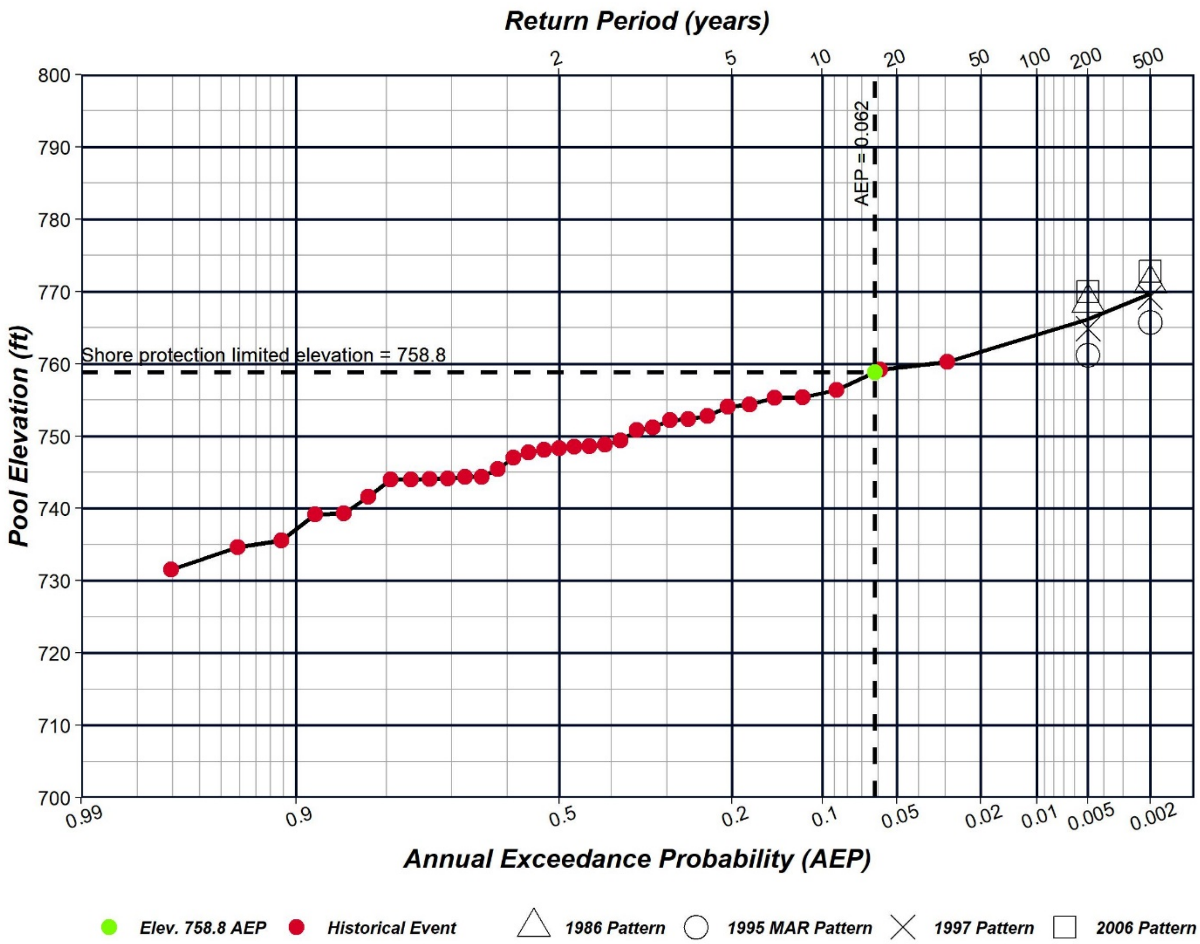

Figure 25. Annual frequency of exceeding elevation 758.8 ft in Lake Mendocino

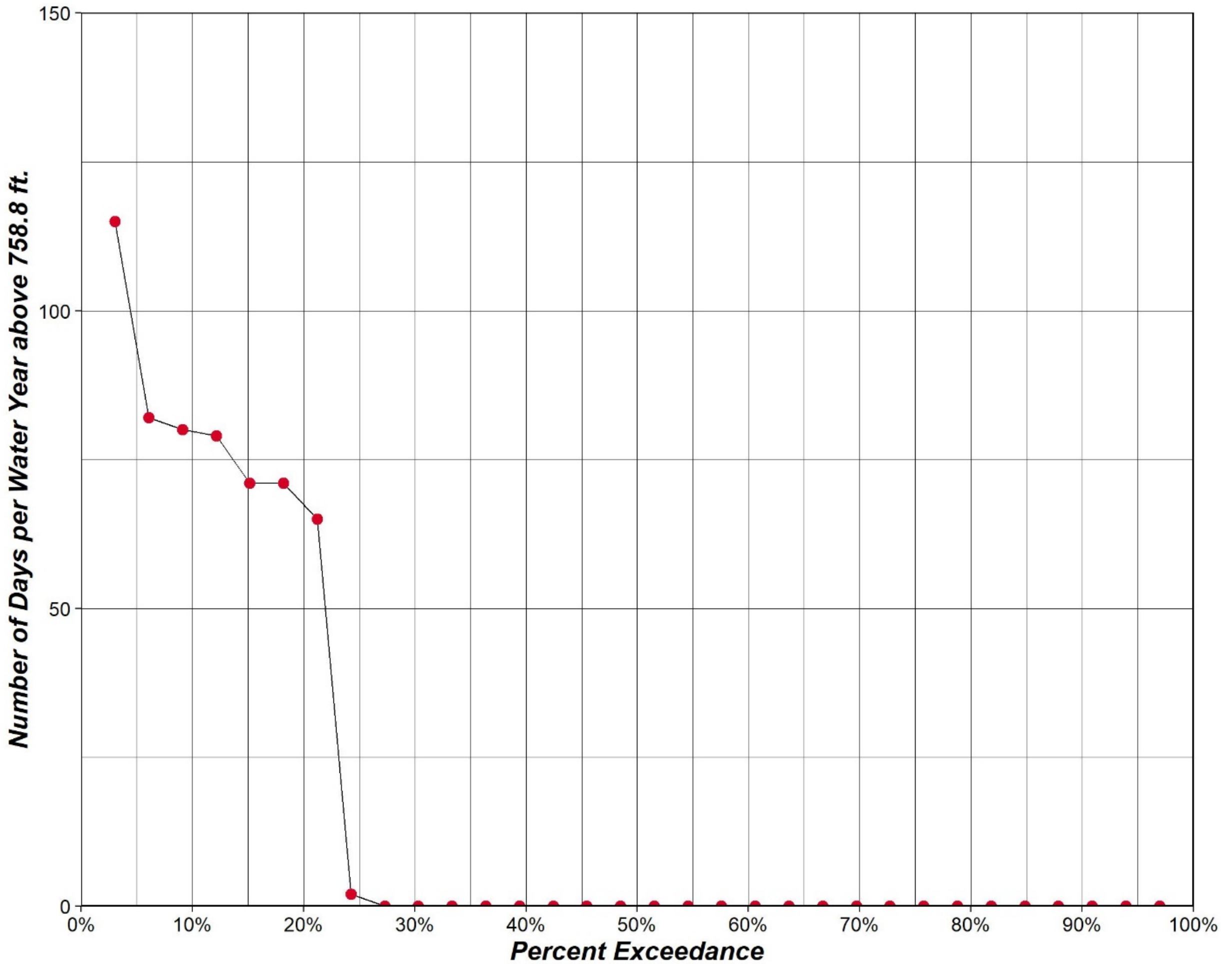

Figure 26. Number of days per season exceeding 758.8 ft. in Lake Mendocino

Impact to Hours of Operation (Metric 16)

The method in which HEC-ResSim makes flood releases from Lake Mendocino differs from the way that Sonoma Water releases flood waters in reality. There are a number of inconsistencies regarding operations assumptions in HEC-ResSim, including:

- The model contains flow ratings for both the gate and powerhouse, but since only one can be used at a time, the model's total capacity for the controlled outlets is generally too high.
- The model first allocates flow through powerhouse and uses the gate secondly. The model allows flow through both outlets simultaneously.
- Above 755 ft in elevation, the model constrains all controlled release to the gate. No powerhouse releases are allowed.

The total release simulated by the model is adequate, on a mass balance basis; however, the flow split between the two controlled outlets is not. To compensate for HEC-ResSim model shortcomings, HDR reallocates the releases based on the combined powerhouse and gate release output from the HEC-ResSim model assuming the following:

- Controlled releases are made through a single outlet, either the powerhouse or the controlled spillway, but not both simultaneously.
- Controlled releases less than 3,000 cfs are through the powerhouse, regardless of water-surface elevation.
- Controlled releases greater than 3,000 cfs are through the gate.

Each time flow through the gate goes up or down, it is counted as gate change, or a change operation. M16 quantifies the number of hourly gate changes for the period of record. The impacts to hours of operation, measured as the cumulative number of hourly gate changes throughout the period of record, is shown in Figure 27.

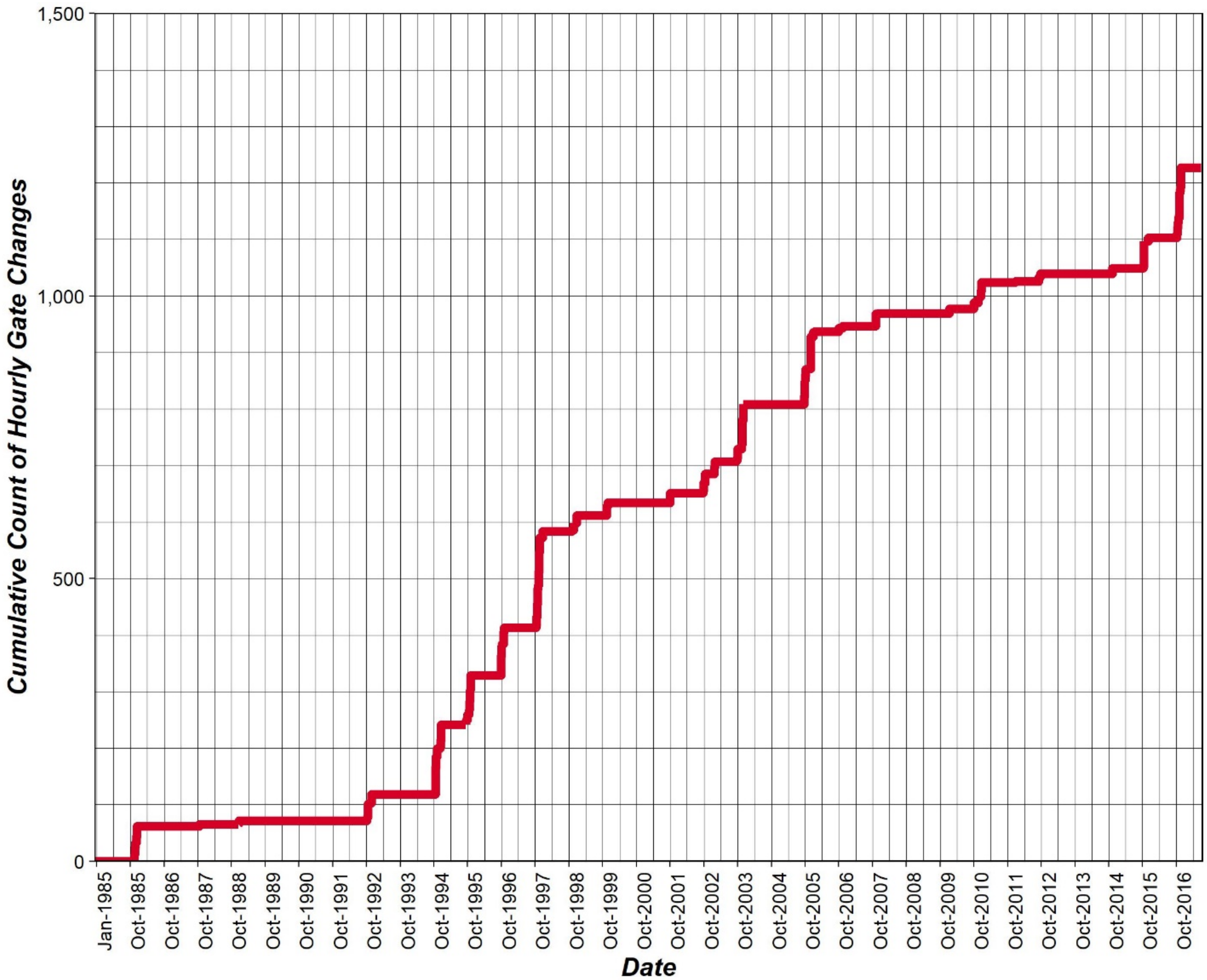

Figure 27. Count of cumulative gate changes

References

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