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# Memorandum

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| Date: | ~~Friday, May 08, 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: Alternatives Comparison |

# 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.

# Action

To evaluate the 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 for each WCP alternative using the agreed procedures and documented our findings in a series of technical memoranda.
4. Compared, by metric, the results of each WCP to the existing (baseline) conditions and documented out 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.

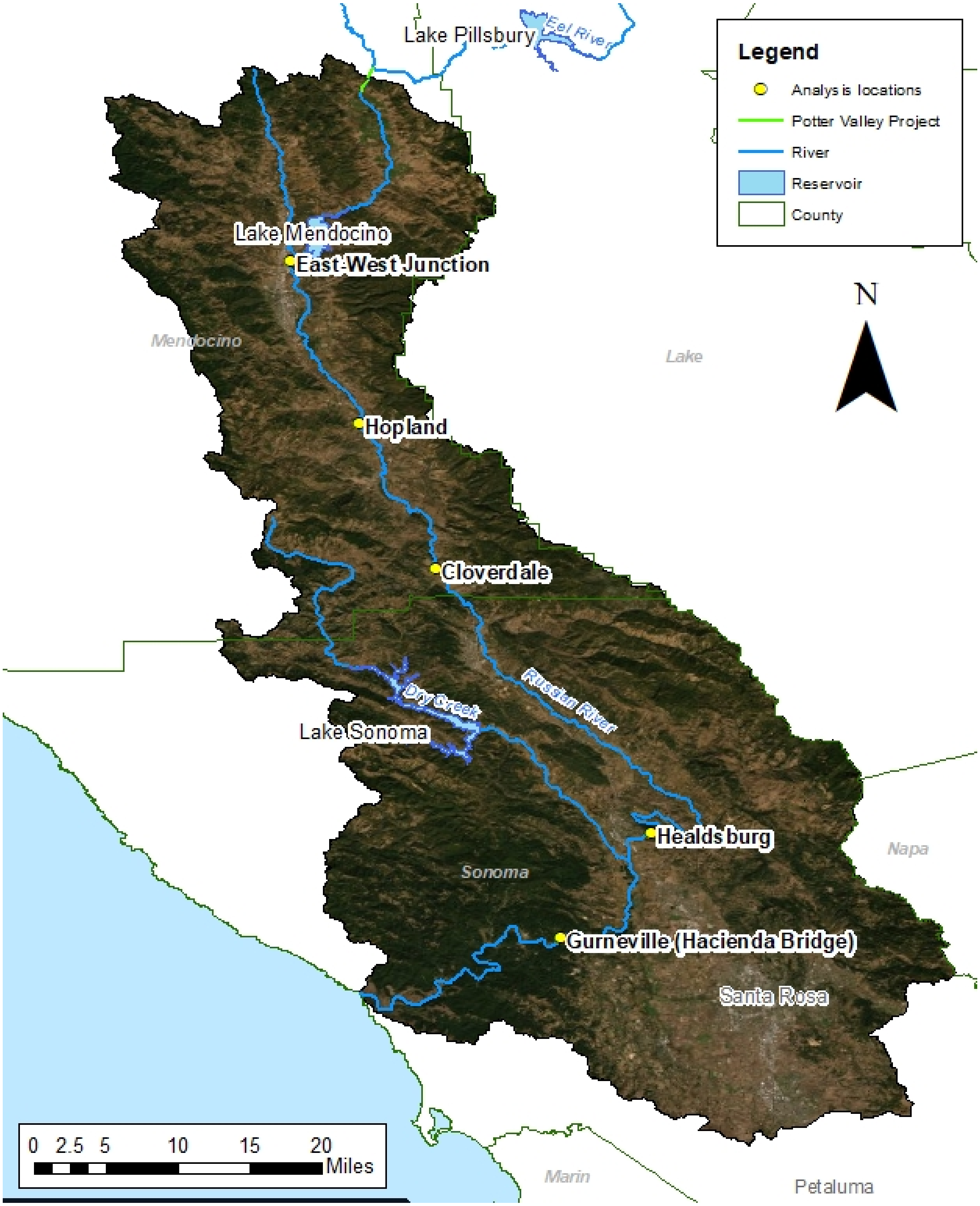


**Figure 1. Map of Russian River watershed, including Lake Mendocino**

# 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, and compare the performance of WCP alternatives to that of the existing (baseline) conditions.

## 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). Table 3 through Table 10 and Figure 2 through Figure 5 show the annual exceedance probability (AEP) at Hopland, Cloverdale, Healdsburg, and Guerneville.

### Table 3. Annual maximum regulated flow frequency at Hopland

| Annual Exceedance Probability | 1/AEP | Maximum Regulated Flow (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 11,143 | 10,677 | 11,143 | 10,972 | 10,677 |
| 0.2 | 5 | 16,770 | 16,875 | 16,843 | 16,842 | 16,753 |
| 0.1 | 10 | 25,502 | 25,100 | 25,099 | 25,098 | 25,128 |
| 0.05 | 20 | 32,287 | 32,272 | 32,273 | 32,291 | 32,307 |
| 0.02 | 50 | 35,118 | 34,991 | 35,043 | 35,123 | 35,153 |
| 0.01 | 100 | 39,301 | 39,114 | 39,245 | 39,284 | 39,258 |
| 0.005 | 200 | 43,129 | 42,886 | 43,091 | 43,091 | 43,014 |
| 0.002 | 500 | 53,302 | 51,967 | 50,498 | 50,498 | 50,473 |

### Table 4. Difference in annual maximum regulated flow frequency at Hopland

| Annual Exceedance Probability | 1/AEP | Difference in Annual Maximum Regulated Flow Quantile (cfs) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | -466 [-4%] | 0 [0%] | -171 [-2%] | -466 [-4%] |
| 0.2 | 5 | 105 [1%] | 73 [0%] | 72 [0%] | -17 [0%] |
| 0.1 | 10 | -402 [-2%] | -403 [-2%] | -404 [-2%] | -374 [-1%] |
| 0.05 | 20 | -15 [0%] | -14 [0%] | 4 [0%] | 20 [0%] |
| 0.02 | 50 | -127 [0%] | -75 [0%] | 5 [0%] | 35 [0%] |
| 0.01 | 100 | -187 [0%] | -56 [0%] | -17 [0%] | -43 [0%] |
| 0.005 | 200 | -243 [-1%] | -38 [0%] | -38 [0%] | -115 [0%] |
| 0.002 | 500 | -1335 [-3%] | -2804 [-5%] | -2804 [-5%] | -2829 [-5%] |

### Table 5. Annual maximum regulated flow frequency at Cloverdale

| Annual Exceedance Probability | 1/AEP | Maximum Regulated Flow (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 15,936 | 15,299 | 15,456 | 15,314 | 15,237 |
| 0.2 | 5 | 27,135 | 26,571 | 26,569 | 26,599 | 26,818 |
| 0.1 | 10 | 37,795 | 37,786 | 37,771 | 37,946 | 37,797 |
| 0.05 | 20 | 45,740 | 45,748 | 45,747 | 45,741 | 45,744 |
| 0.02 | 50 | 51,693 | 51,658 | 51,738 | 51,731 | 51,726 |
| 0.01 | 100 | 59,075 | 58,967 | 59,179 | 59,176 | 59,163 |
| 0.005 | 200 | 65,831 | 65,656 | 65,989 | 65,990 | 65,968 |
| 0.002 | 500 | 77,651 | 77,034 | 76,841 | 76,841 | 77,115 |

### Table 6. Difference in annual maximum regulated flow frequency at Cloverdale

| Annual Exceedance Probability | 1/AEP | Difference in Annual Maximum Regulated Flow Quantile (cfs) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | -637 [-4%] | -480 [-3%] | -622 [-4%] | -699 [-4%] |
| 0.2 | 5 | -564 [-2%] | -566 [-2%] | -536 [-2%] | -317 [-1%] |
| 0.1 | 10 | -9 [0%] | -24 [0%] | 151 [0%] | 2 [0%] |
| 0.05 | 20 | 8 [0%] | 7 [0%] | 1 [0%] | 4 [0%] |
| 0.02 | 50 | -35 [0%] | 45 [0%] | 38 [0%] | 33 [0%] |
| 0.01 | 100 | -108 [0%] | 104 [0%] | 101 [0%] | 88 [0%] |
| 0.005 | 200 | -175 [0%] | 158 [0%] | 159 [0%] | 137 [0%] |
| 0.002 | 500 | -617 [-1%] | -810 [-1%] | -810 [-1%] | -536 [-1%] |

### Table 7. Annual maximum regulated flow frequency at Healdsburg

| Annual Exceedance Probability | 1/AEP | Maximum Regulated Flow (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 25,448 | 25,150 | 25,325 | 25,147 | 25,364 |
| 0.2 | 5 | 43,105 | 42,271 | 42,528 | 42,704 | 42,861 |
| 0.1 | 10 | 60,843 | 60,450 | 60,451 | 60,707 | 61,066 |
| 0.05 | 20 | 75,949 | 75,980 | 75,981 | 75,973 | 75,985 |
| 0.02 | 50 | 84,436 | 84,404 | 84,476 | 84,475 | 84,438 |
| 0.01 | 100 | 97,646 | 97,550 | 97,743 | 97,751 | 97,652 |
| 0.005 | 200 | 109,736 | 109,581 | 109,885 | 109,902 | 109,745 |
| 0.002 | 500 | 127,529 | 127,222 | 127,099 | 127,099 | 127,159 |

### Table 8. Difference in annual maximum regulated flow frequency at Healdsburg

| Annual Exceedance Probability | 1/AEP | Difference in Annual Maximum Regulated Flow Quantile (cfs) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | -298 [-1%] | -123 [0%] | -301 [-1%] | -84 [0%] |
| 0.2 | 5 | -834 [-2%] | -577 [-1%] | -401 [-1%] | -244 [-1%] |
| 0.1 | 10 | -393 [-1%] | -392 [-1%] | -136 [0%] | 223 [0%] |
| 0.05 | 20 | 31 [0%] | 32 [0%] | 24 [0%] | 36 [0%] |
| 0.02 | 50 | -32 [0%] | 40 [0%] | 39 [0%] | 2 [0%] |
| 0.01 | 100 | -96 [0%] | 97 [0%] | 105 [0%] | 6 [0%] |
| 0.005 | 200 | -155 [0%] | 149 [0%] | 166 [0%] | 9 [0%] |
| 0.002 | 500 | -307 [0%] | -430 [0%] | -430 [0%] | -370 [0%] |

### Table 9. Annual maximum regulated flow frequency at Guerneville

| Annual Exceedance Probability | 1/AEP | Maximum Regulated Flow (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 39,946 | 39,535 | 39,525 | 39,539 | 39,849 |
| 0.2 | 5 | 61,252 | 61,061 | 61,130 | 61,164 | 61,199 |
| 0.1 | 10 | 85,090 | 84,823 | 84,824 | 84,821 | 85,212 |
| 0.05 | 20 | 100,176 | 99,785 | 99,786 | 100,143 | 100,291 |
| 0.02 | 50 | 116,759 | 116,700 | 116,767 | 116,772 | 116,733 |
| 0.01 | 100 | 135,402 | 135,245 | 135,426 | 135,440 | 135,332 |
| 0.005 | 200 | 152,464 | 152,218 | 152,503 | 152,524 | 152,354 |
| 0.002 | 500 | 179,745 | 179,248 | 179,063 | 179,061 | 179,162 |

### Table 10. Difference in annual maximum regulated flow frequency at Guerneville

| Annual Exceedance Probability | 1/AEP | Difference in Annual Maximum Regulated Flow Quantile (cfs) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | -411 [-1%] | -421 [-1%] | -407 [-1%] | -97 [0%] |
| 0.2 | 5 | -191 [0%] | -122 [0%] | -88 [0%] | -53 [0%] |
| 0.1 | 10 | -267 [0%] | -266 [0%] | -269 [0%] | 122 [0%] |
| 0.05 | 20 | -391 [0%] | -390 [0%] | -33 [0%] | 115 [0%] |
| 0.02 | 50 | -59 [0%] | 8 [0%] | 13 [0%] | -26 [0%] |
| 0.01 | 100 | -157 [0%] | 24 [0%] | 38 [0%] | -70 [0%] |
| 0.005 | 200 | -246 [0%] | 39 [0%] | 60 [0%] | -110 [0%] |
| 0.002 | 500 | -497 [0%] | -682 [0%] | -684 [0%] | -583 [0%] |

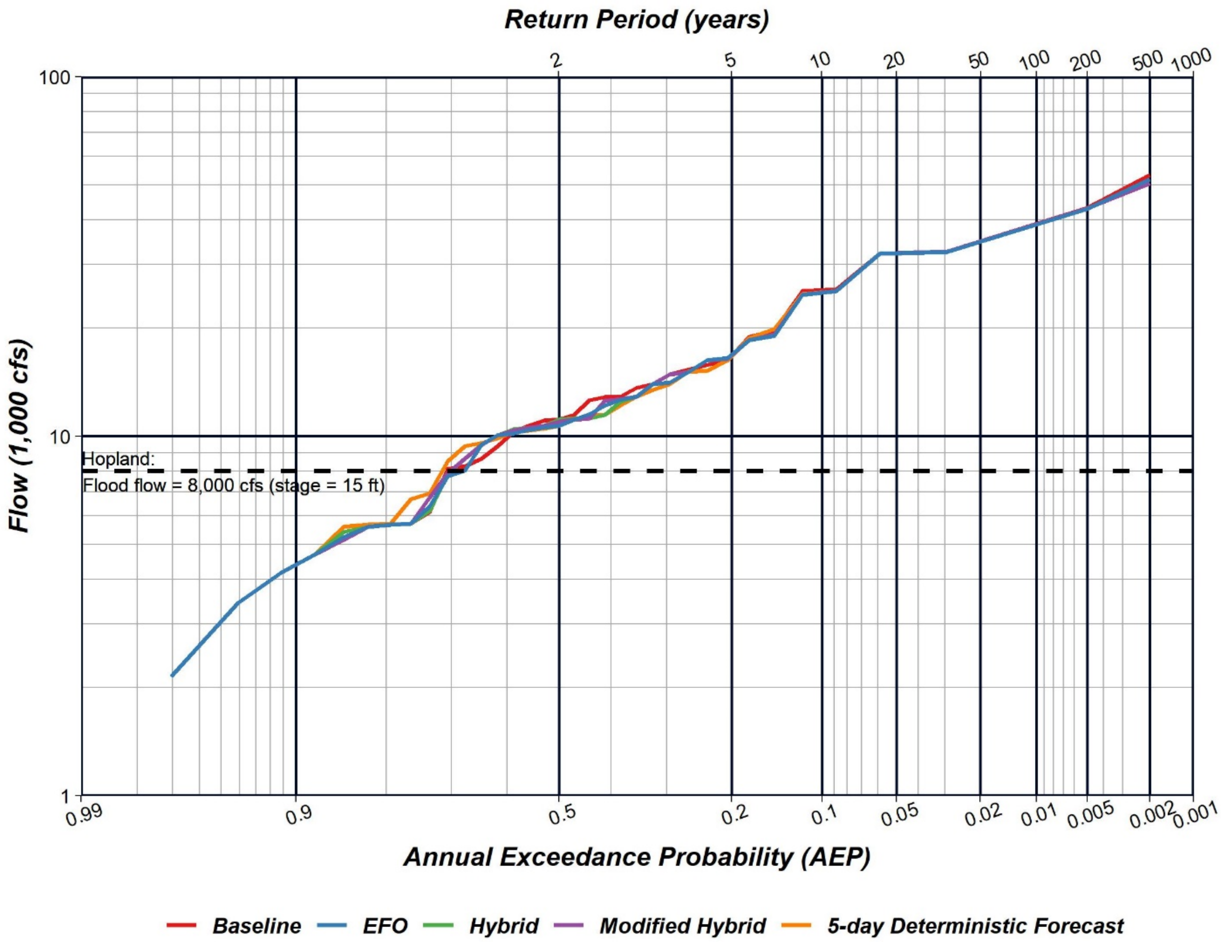


**Figure 2. Annual maximum flow exceedance probability at Hopland**

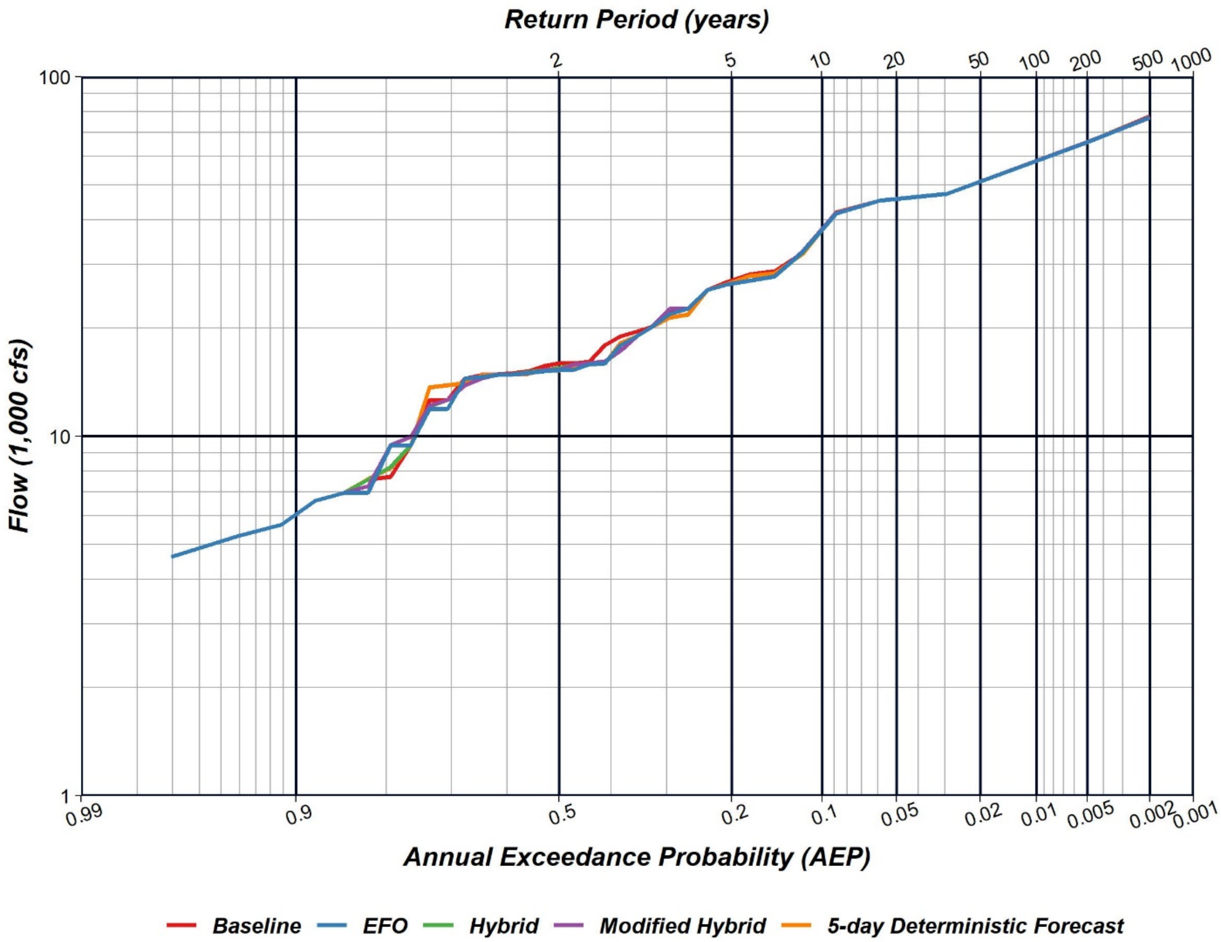


**Figure 3. Annual maximum flow exceedance probability at Cloverdale**

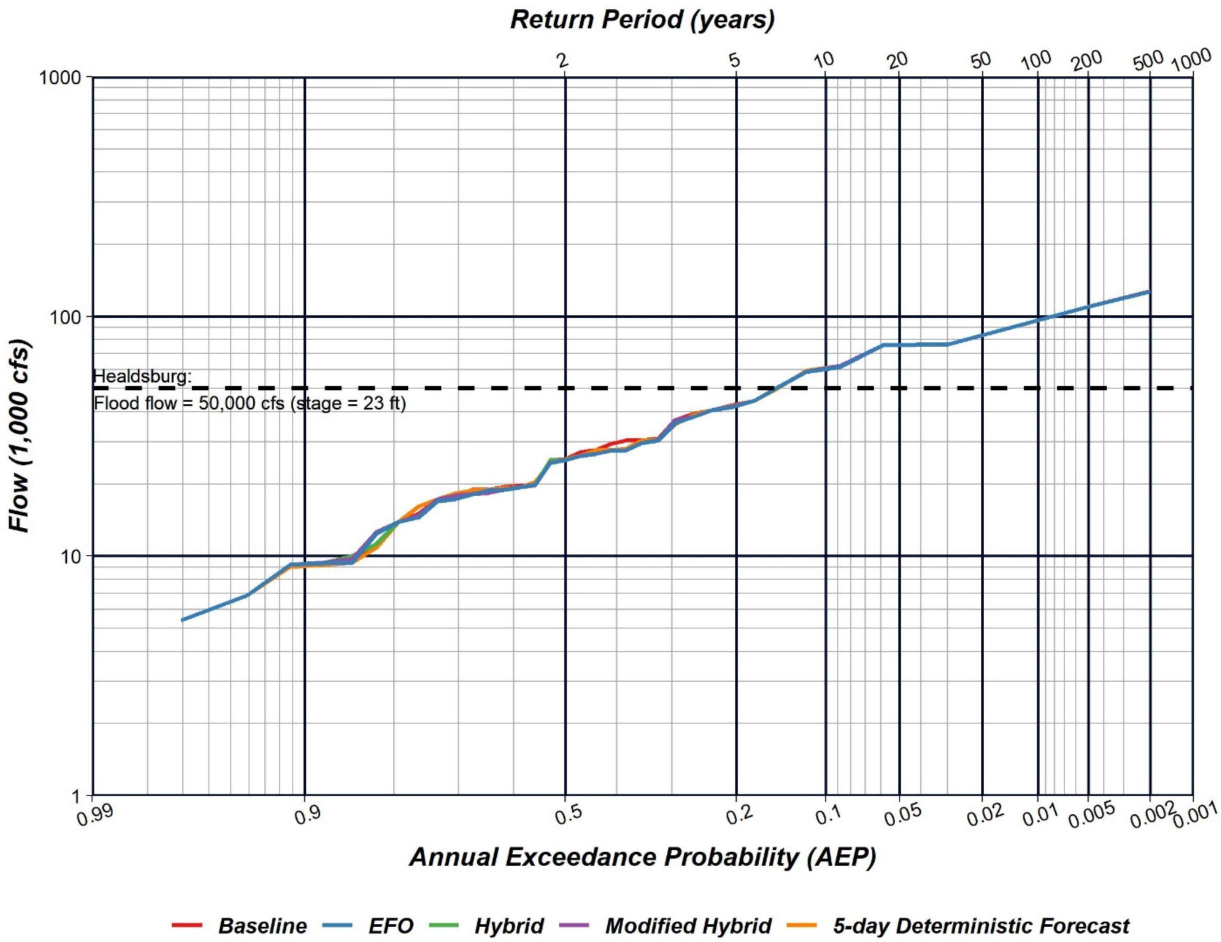


**Figure 4. Annual maximum flow exceedance probability at Healdsburg**

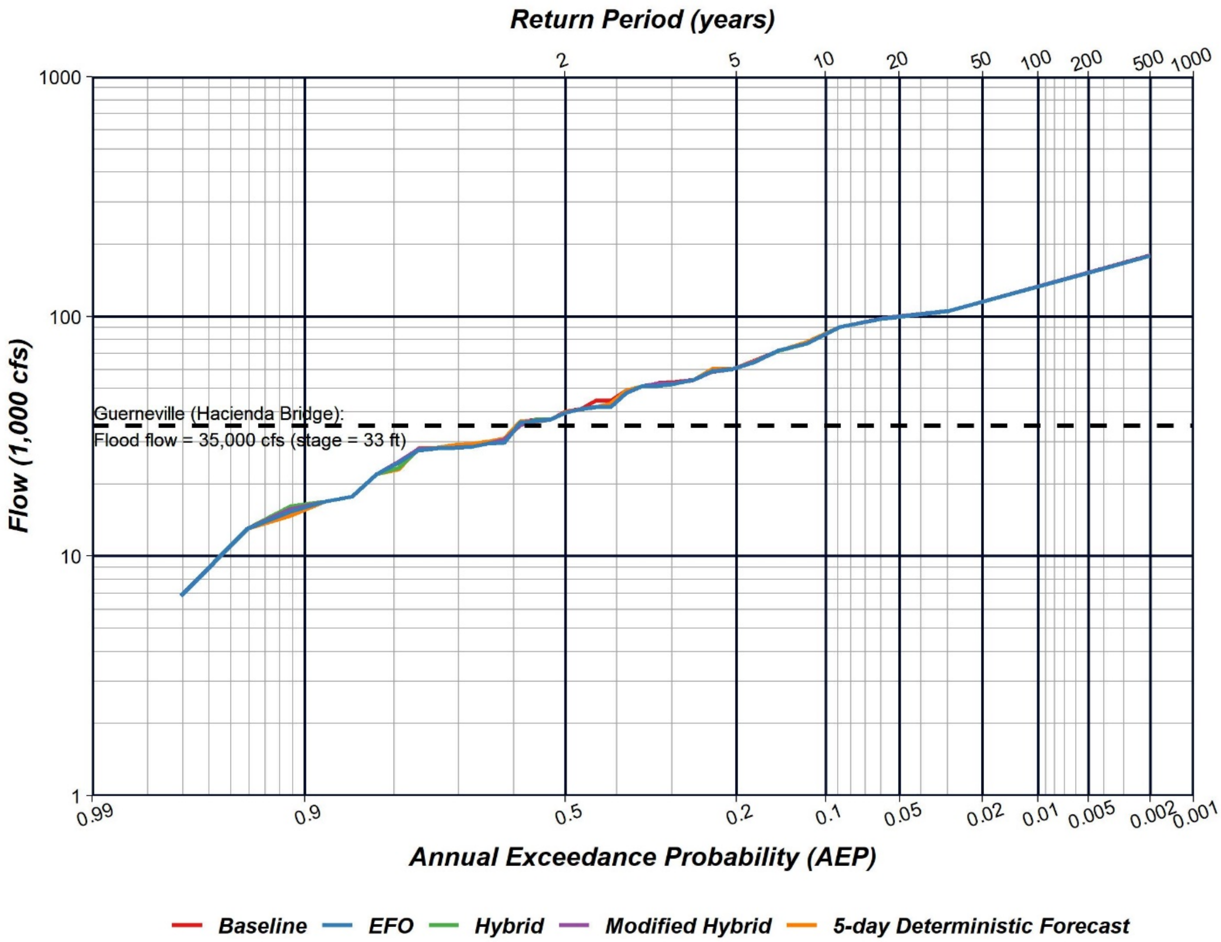


**Figure 5. Annual maximum flow exceedance probability at Guerneville (Hacienda Bridge)**

## 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 11 through Table 20 summarize these functions and Figure 6 through Figure 8 show the functions graphically.

### Table 11. Annual maximum pool elevation in Lake Mendocino

| Annual Exceedance Probability | 1/AEP | Maximum Pool Elevation (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 742.77 | 753.81 | 746.77 | 748.90 | 748.32 |
| 0.2 | 5 | 752.71 | 758.48 | 752.79 | 754.14 | 754.15 |
| 0.1 | 10 | 754.52 | 759.40 | 755.20 | 755.32 | 755.95 |
| 0.05 | 20 | 760.93 | 761.70 | 756.09 | 756.85 | 759.42 |
| 0.02 | 50 | 766.14 | 763.39 | 759.13 | 758.95 | 761.65 |
| 0.01 | 100 | 767.18 | 765.16 | 761.23 | 761.12 | 763.99 |
| 0.005 | 200 | 768.13 | 766.77 | 763.15 | 763.10 | 766.13 |
| 0.002 | 500 | 770.68 | 769.51 | 766.47 | 766.43 | 769.71 |

### Table 12. Difference in annual maximum pool elevation in Lake Mendocino

| Annual Exceedance Probability | 1/AEP | Difference in Annual Pool Elevation Frequency Quantile (ft) | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 11 [11%] | 4 [4%] | 6 [6%] | 6 [5%] |
| 0.2 | 5 | 6 [5%] | 0 [0%] | 1 [1%] | 1 [1%] |
| 0.1 | 10 | 5 [4%] | 1 [1%] | 1 [1%] | 1 [1%] |
| 0.05 | 20 | 1 [1%] | -5 [-4%] | -4 [-3%] | -2 [-1%] |
| 0.02 | 50 | -3 [-2%] | -7 [-6%] | -7 [-6%] | -4 [-4%] |
| 0.01 | 100 | -2 [-2%] | -6 [-5%] | -6 [-5%] | -3 [-3%] |
| 0.005 | 200 | -1 [-1%] | -5 [-4%] | -5 [-4%] | -2 [-2%] |
| 0.002 | 500 | -1 [-1%] | -4 [-3%] | -4 [-3%] | -1 [-1%] |

### Table 13. Annual maximum storage in Lake Mendocino

| Annual Exceedance Probability | 1/AEP | Maximum Storage (ac-ft) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 77,321 | 96,603 | 84,227 | 87,945 | 86,930 |
| 0.2 | 5 | 94,648 | 104,954 | 94,798 | 97,182 | 97,203 |
| 0.1 | 10 | 97,866 | 106,613 | 99,072 | 99,287 | 100,412 |
| 0.05 | 20 | 109,378 | 110,794 | 100,664 | 102,022 | 106,640 |
| 0.02 | 50 | 118,959 | 113,881 | 106,117 | 105,792 | 110,686 |
| 0.01 | 100 | 120,888 | 117,130 | 109,927 | 109,720 | 114,974 |
| 0.005 | 200 | 122,661 | 120,128 | 113,439 | 113,343 | 118,937 |
| 0.002 | 500 | 127,482 | 125,269 | 119,556 | 119,491 | 125,643 |

### Table 14. Difference in annual maximum storage in Lake Mendocino

| Annual Exceedance Probability | 1/AEP | Difference in Annual Storage Frequency Quantile (ac-ft) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 19,281 [25%] | 6,906 [9%] | 10,623 [14%] | 9,609 [12%] |
| 0.2 | 5 | 10,306 [11%] | 149 [0%] | 2,534 [3%] | 2,555 [3%] |
| 0.1 | 10 | 8,746 [9%] | 1,205 [1%] | 1,421 [1%] | 2,546 [3%] |
| 0.05 | 20 | 1,416 [1%] | -8,714 [-8%] | -7,356 [-7%] | -2,738 [-3%] |
| 0.02 | 50 | -5,078 [-4%] | -12,841 [-11%] | -13,166 [-11%] | -8,273 [-7%] |
| 0.01 | 100 | -3,757 [-3%] | -10,961 [-9%] | -11,167 [-9%] | -5,914 [-5%] |
| 0.005 | 200 | -2,533 [-2%] | -9,222 [-8%] | -9,318 [-8%] | -3,724 [-3%] |
| 0.002 | 500 | -2,213 [-2%] | -7,927 [-6%] | -7,992 [-6%] | -1,840 [-1%] |

### Table 15. Annual maximum total release in Lake Mendocino

| Annual Exceedance Probability | 1/AEP | Maximum Total Release (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 3,850 | 3,278 | 3,550 | 3,400 | 3,924 |
| 0.2 | 5 | 4,001 | 4,001 | 4,000 | 4,000 | 4,001 |
| 0.1 | 10 | 4,001 | 4,002 | 4,001 | 4,001 | 4,002 |
| 0.05 | 20 | 5,697 | 4,908 | 4,713 | 4,278 | 5,757 |
| 0.02 | 50 | 6,686 | 6,056 | 5,304 | 5,304 | 6,020 |
| 0.01 | 100 | 7,177 | 6,056 | 5,601 | 5,601 | 6,168 |
| 0.005 | 200 | 7,626 | 6,056 | 5,873 | 5,873 | 6,304 |
| 0.002 | 500 | 12,460 | 9,261 | 8,888 | 8,888 | 9,030 |

### Table 16. Difference in annual maximum total release in Lake Mendocino

| Annual Exceedance Probability | 1/AEP | Difference in Annual Total Release Frequency Quantile (ft) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | -572 [-15%] | -300 [-8%] | -450 [-12%] | 74 [2%] |
| 0.2 | 5 | 0 [0%] | -1 [0%] | -1 [0%] | 0 [0%] |
| 0.1 | 10 | 1 [0%] | 0 [0%] | [0%] | 1 [0%] |
| 0.05 | 20 | -789 [-14%] | -984 [-17%] | -1419 [-25%] | 60 [1%] |
| 0.02 | 50 | -630 [-9%] | -1382 [-21%] | -1382 [-21%] | -666 [-10%] |
| 0.01 | 100 | -1121 [-16%] | -1576 [-22%] | -1576 [-22%] | -1009 [-14%] |
| 0.005 | 200 | -1570 [-21%] | -1753 [-23%] | -1753 [-23%] | -1322 [-17%] |
| 0.002 | 500 | -3199 [-26%] | -3572 [-29%] | -3572 [-29%] | -3430 [-28%] |

### Table 17. Annual maximum uncontrolled spill in Lake Mendocino

| Annual Exceedance Probability | 1/AEP | Uncontrolled Spill (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0.2 | 5 | 0 | 0 | 0 | 0 | 0 |
| 0.1 | 10 | 0 | 0 | 0 | 0 | 0 |
| 0.05 | 20 | 94 | 0 | 0 | 0 | 0 |
| 0.02 | 50 | 1342 | 426 | 232 | 226 | 436 |
| 0.01 | 100 | 2940 | 1133 | 618 | 602 | 1160 |
| 0.005 | 200 | 4402 | 1781 | 971 | 946 | 1822 |
| 0.002 | 500 | 7342 | 5260 | 3278 | 3231 | 5168 |

### Table 18. Difference in annual uncontrolled spill frequency in Lake Mendocino

| Annual Exceedance Probability | 1/AEP | Difference in Annual Uncontrolled Spill Frequency Quantile (ft) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.2 | 5 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.1 | 10 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.05 | 20 | -94 [-100%] | -94 [-100%] | -94 [-100%] | -94 [-100%] |
| 0.02 | 50 | -916 [-68%] | -1110 [-83%] | -1116 [-83%] | -906 [-67%] |
| 0.01 | 100 | -1807 [-61%] | -2322 [-79%] | -2338 [-80%] | -1780 [-61%] |
| 0.005 | 200 | -2621 [-60%] | -3431 [-78%] | -3456 [-79%] | -2580 [-59%] |
| 0.002 | 500 | -2082 [-28%] | -4064 [-55%] | -4111 [-56%] | -2174 [-30%] |

### Table 19. Total hours of uncontrolled spill – 200-yr

| Scaled Event | Hours of Uncontrolled Spill | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 1986 | 101 | 97 | 61 | 53 | 94 |
| 1995 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 54 | 12 | 0 | 0 | 0 |
| 2006 | 78 | 85 | 68 | 68 | 72 |

### Table 20. Total hours of uncontrolled spill – 500-yr

| Scaled Event | Hours of Uncontrolled Spill | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 1986 | 108 | 111 | 95 | 92 | 102 |
| 1995 | 7 | 22 | 0 | 0 | 18 |
| 1997 | 65 | 64 | 0 | 0 | 53 |
| 2006 | 82 | 96 | 79 | 79 | 79 |

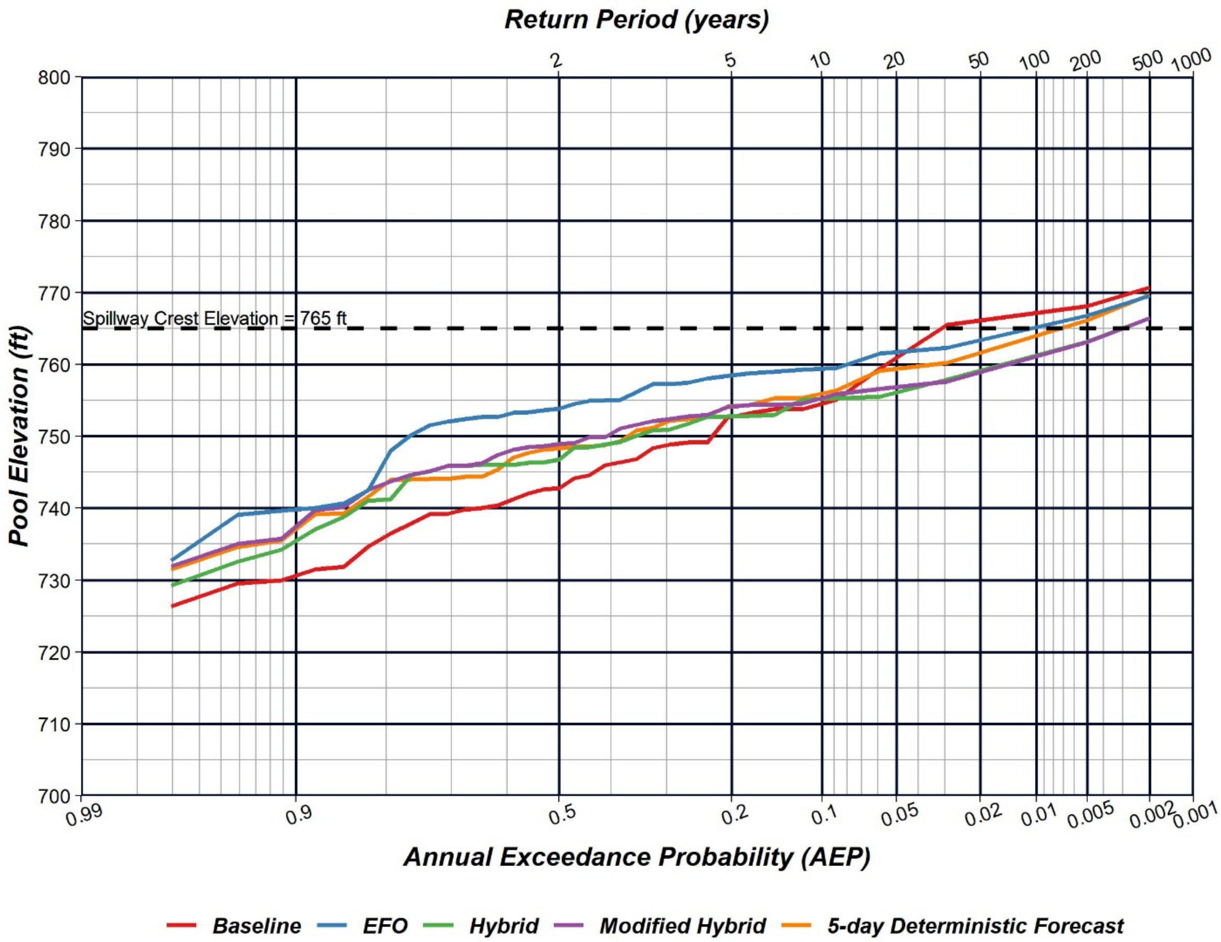


**Figure 6. Annual maximum pool elevation-frequency in Lake Mendocino**

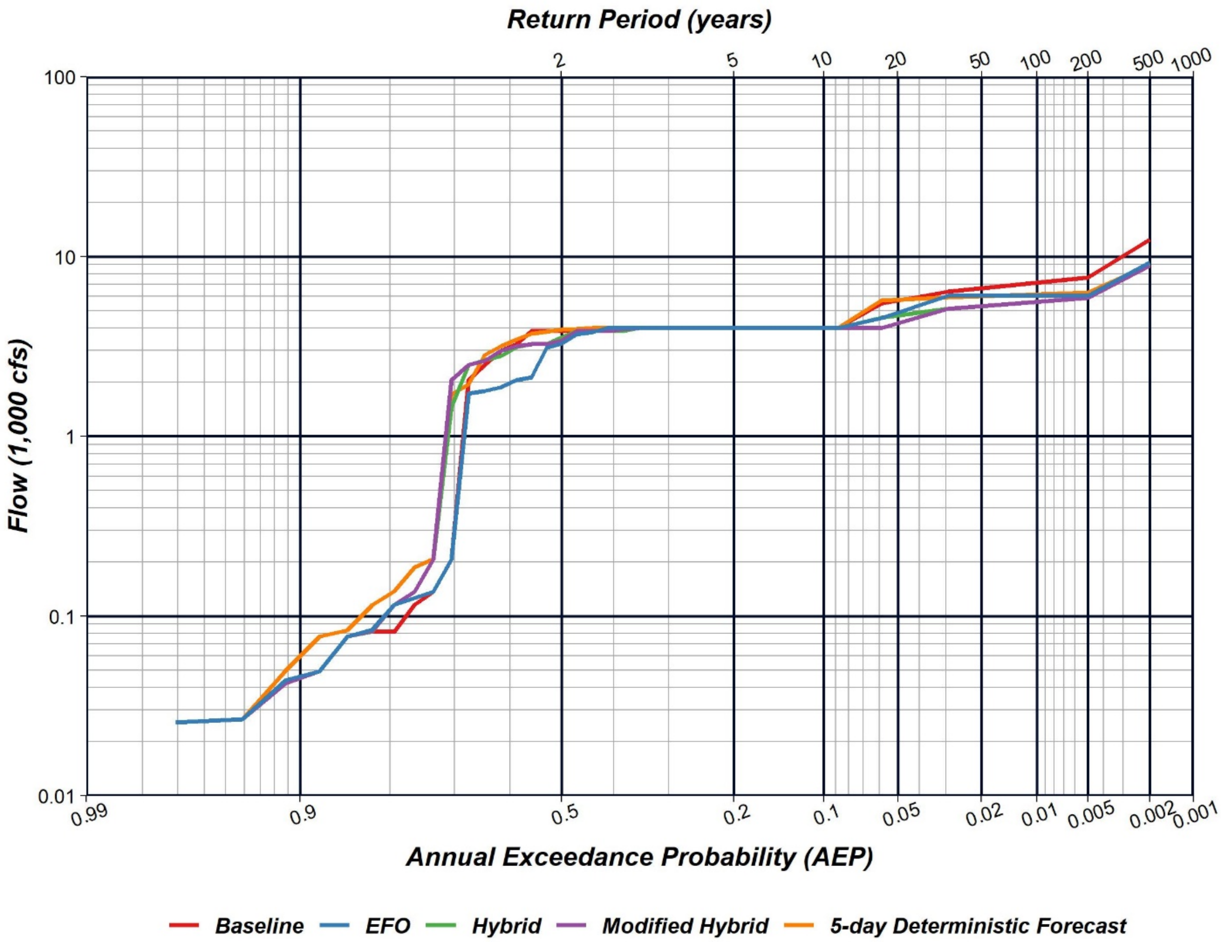


**Figure 7.Annual maximum total release-frequency in Lake Mendocino**

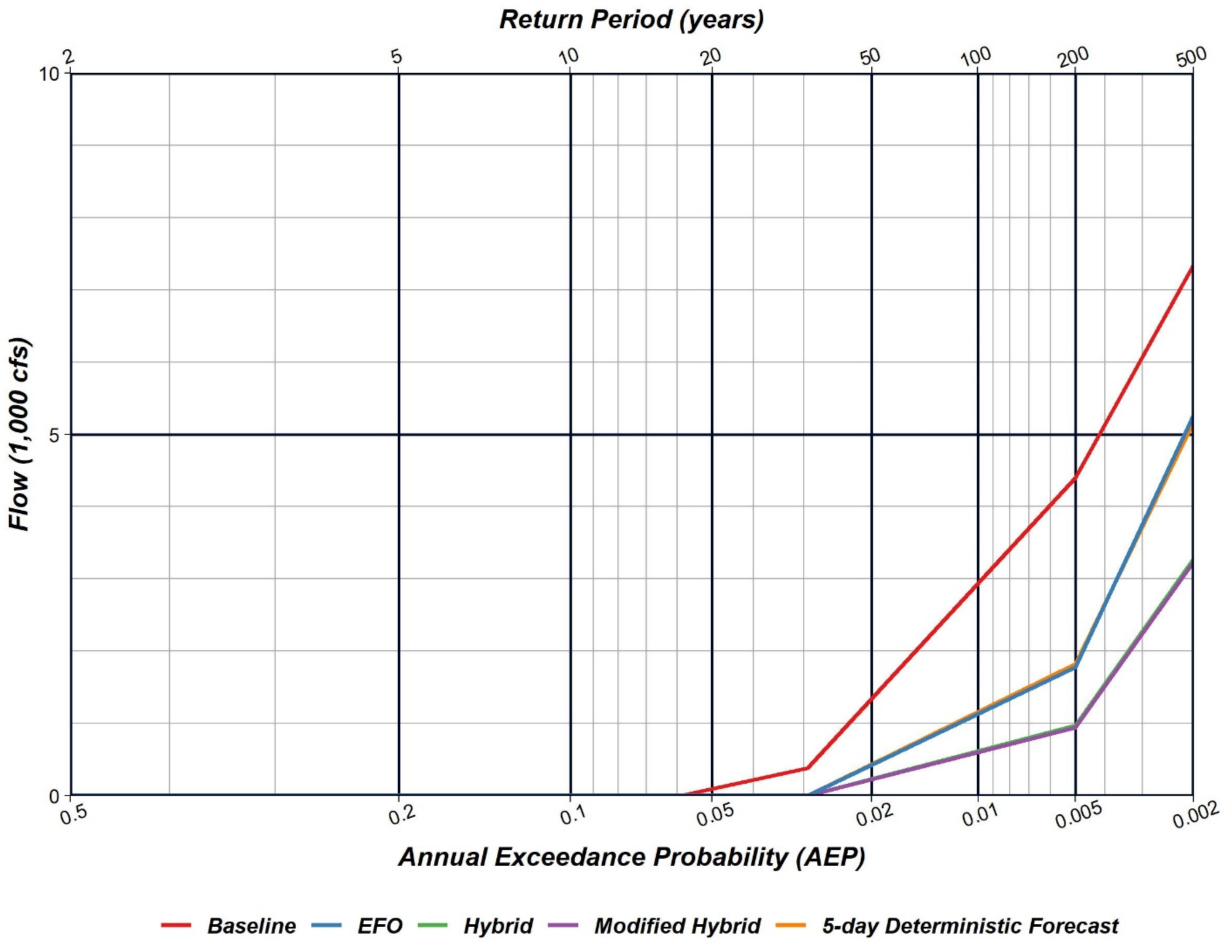


**Figure 8. Annual maximum uncontrolled spill-frequency in Lake Mendocino**

## 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 21 through Table 30 summarize these functions and Figure 9 through Figure 11 show these functions graphically.

### Table 21. Annual maximum pool elevation in Lake Sonoma

| Annual Exceedance Probability | 1/AEP | Maximum Pool Elevation (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 454.55 | 454.61 | 454.61 | 454.61 | 454.61 |
| 0.2 | 5 | 465.25 | 465.24 | 465.26 | 465.25 | 465.29 |
| 0.1 | 10 | 477.51 | 477.21 | 479.05 | 479.05 | 479.07 |
| 0.05 | 20 | 483.73 | 483.69 | 483.98 | 484.11 | 481.15 |
| 0.02 | 50 | 485.80 | 485.91 | 486.50 | 486.92 | 485.63 |
| 0.01 | 100 | 488.95 | 489.51 | 490.25 | 490.45 | 488.85 |
| 0.005 | 200 | 491.84 | 492.80 | 493.69 | 493.69 | 491.81 |
| 0.002 | 500 | 493.10 | 493.71 | 494.32 | 494.47 | 493.10 |

### Table 22. Difference in annual maximum pool elevation in Lake Sonoma

| Annual Exceedance Probability | 1/AEP | Difference in Annual Pool Elevation Frequency Quantile (ft) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 0.06 [0%] | 0.06 [0%] | 0.06 [0%] | 0.06 [0%] |
| 0.2 | 5 | -0.01 [0%] | 0.01 [0%] | 0.00 [0%] | 0.04 [0%] |
| 0.1 | 10 | -0.30 [0%] | 1.54 [1%] | 1.54 1%] | 1.56 [1%] |
| 0.05 | 20 | -0.04 [0%] | 0.25 [0%] | 0.38 [0%] | -2.58 [-1%] |
| 0.02 | 50 | 0.11 [0%] | 0.70 [0%] | 1.12 [0%] | -0.17 [0%] |
| 0.01 | 100 | 0.56 [0%] | 1.30 [0%] | 1.50 [1%] | -0.10 [0%] |
| 0.005 | 200 | 0.96 [0%] | 1.85 [1%] | 1.85 [1%] | -0.03 [0%] |
| 0.002 | 500 | 0.61 [0%] | 1.22 [0%] | 1.37 [1%] | 0.00 [0%] |

### Table 23. Annual maximum storage in Lake Sonoma

| Annual Exceedance Probability | 1/AEP | Maximum Storage (ac-ft) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 254,370 | 254,532 | 254,532 | 254,532 | 254,532 |
| 0.2 | 5 | 284,461 | 284,436 | 284,498 | 284,441 | 284,558 |
| 0.1 | 10 | 321,805 | 320,849 | 326,723 | 326,723 | 326,792 |
| 0.05 | 20 | 341,979 | 341,848 | 342,779 | 343,230 | 333,495 |
| 0.02 | 50 | 348,849 | 349,227 | 351,221 | 352,632 | 348,280 |
| 0.01 | 100 | 359,548 | 361,460 | 364,028 | 364,720 | 359,209 |
| 0.005 | 200 | 369,538 | 372,909 | 376,027 | 376,027 | 369,416 |
| 0.002 | 500 | 373,963 | 376,098 | 378,275 | 378,799 | 373,945 |

### Table 24. Difference in annual maximum storage in Lake Sonoma

| Annual Exceedance Probability | 1/AEP | Difference in Annual Storage Frequency Quantile (ac-ft) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 162 [0%] | 162 [0%] | 162 [0%] | 162 [0%] |
| 0.2 | 5 | -26 [0%] | 36 [0%] | -20 [0%] | 96 [0%] |
| 0.1 | 10 | -955 [0%] | 4,918 [2%] | 4,918 [2%] | 4,987 [2%] |
| 0.05 | 20 | -131 [0%] | 799 [0%] | 1,250 [0%] | -8,485 [-2%] |
| 0.02 | 50 | 378 [0%] | 2,372 [1%] | 3,782 [1%] | -569 [0%] |
| 0.01 | 100 | 1,912 [1%] | 4,479 [1%] | 5,171 [1%] | -340 [0%] |
| 0.005 | 200 | 3,371 [1%] | 6,489 [2%] | 6,489 [2%] | -122 [0%] |
| 0.002 | 500 | 2,135 [1%] | 4,312 [1%] | 4,836 [1%] | -18 [0%] |

### Table 25. Annual maximum total release in Lake Sonoma

| Annual Exceedance Probability | 1/AEP | Maximum Total Release (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| 0.2 | 5 | 4,385 | 4,385 | 4,385 | 4,385 | 4,385 |
| 0.1 | 10 | 6,000 | 6,000 | 6,000 | 6,000 | 6,000 |
| 0.05 | 20 | 6,000 | 6,000 | 6,000 | 6,000 | 6,000 |
| 0.02 | 50 | 6,004 | 6,004 | 6,004 | 6,004 | 6,004 |
| 0.01 | 100 | 6,010 | 6,010 | 6,010 | 6,010 | 6,010 |
| 0.005 | 200 | 6,015 | 6,015 | 6,015 | 6,015 | 6,015 |
| 0.002 | 500 | 6,015 | 6,015 | 6,015 | 6,015 | 6,015 |

### Table 26. Difference in annual maximum total release in Lake Sonoma

| Annual Exceedance Probability | 1/AEP | Difference in Annual Total Release Frequency Quantile (ft) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.2 | 5 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.1 | 10 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.05 | 20 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.02 | 50 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.01 | 100 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.005 | 200 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.002 | 500 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |

### Table 27. Annual maximum uncontrolled spill in Lake Sonoma

| Annual Exceedance Probability | 1/AEP | Uncontrolled Spill (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0.2 | 5 | 0 | 0 | 0 | 0 | 0 |
| 0.1 | 10 | 0 | 0 | 0 | 0 | 0 |
| 0.05 | 20 | 0 | 0 | 0 | 0 | 0 |
| 0.02 | 50 | 299 | 306 | 302 | 302 | 308 |
| 0.01 | 100 | 796 | 813 | 804 | 804 | 818 |
| 0.005 | 200 | 1,251 | 1,277 | 1,263 | 1,263 | 1,285 |
| 0.002 | 500 | 1,335 | 1,360 | 1,339 | 1,339 | 1,345 |

### Table 28. Difference in annual uncontrolled spill frequency in Lake Sonoma

| Annual Exceedance Probability | 1/AEP | Difference in Annual Uncontrolled Spill Frequency Quantile (ft) and [%] | | | |
|---|---|---|---|---|---|
| | | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.5 | 2 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.2 | 5 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.1 | 10 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.05 | 20 | 0 [0%] | 0 [0%] | 0 [0%] | 0 [0%] |
| 0.02 | 50 | 7 [2%] | 3 [1%] | 3 [1%] | 9 [3%] |
| 0.01 | 100 | 17 [2%] | 8 [1%] | 8 [1%] | 22 [3%] |
| 0.005 | 200 | 26 [2%] | 12 [1%] | 12 [1%] | 34 [3%] |
| 0.002 | 500 | 25 [2%] | 4 [0%] | 4 [0%] | 10 [1%] |

### Table 29. Total hours of uncontrolled spill – 200 year event

| Scaled Event | Hours of Uncontrolled Spill | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 1986 | 114 | 114 | 114 | 114 | 114 |
| 1995 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 39 | 41 | 40 | 40 | 41 |

### Table 30. Total hours of uncontrolled spill – 500 year event

| Scaled Event | Hours of Uncontrolled Spill | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 1986 | 115 | 115 | 115 | 115 | 115 |
| 1995 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 44 | 46 | 44 | 44 | 44 |

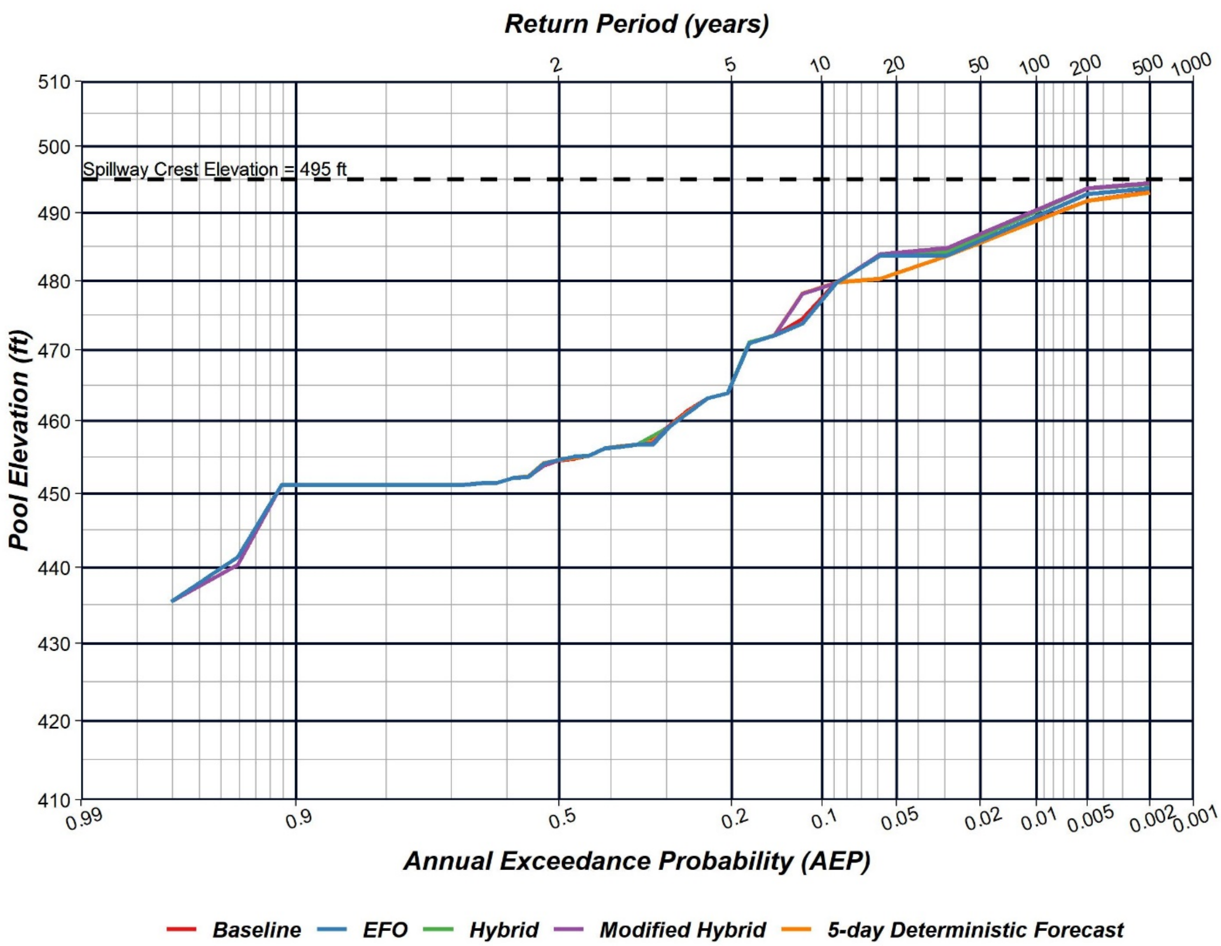


**Figure 9. Annual maximum pool elevation-frequency in Lake Sonoma**

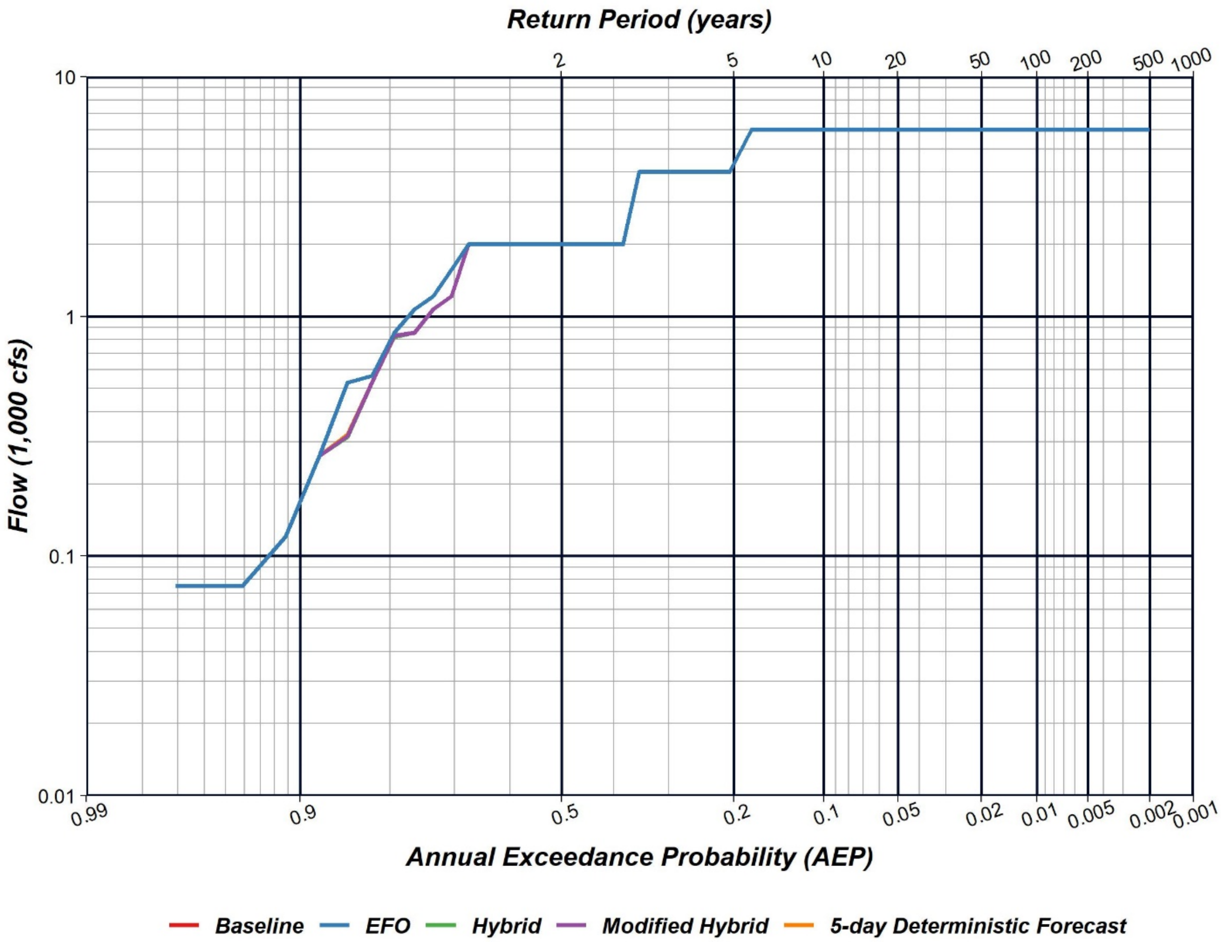


**Figure 10. Annual maximum total release-frequency in Lake Sonoma**

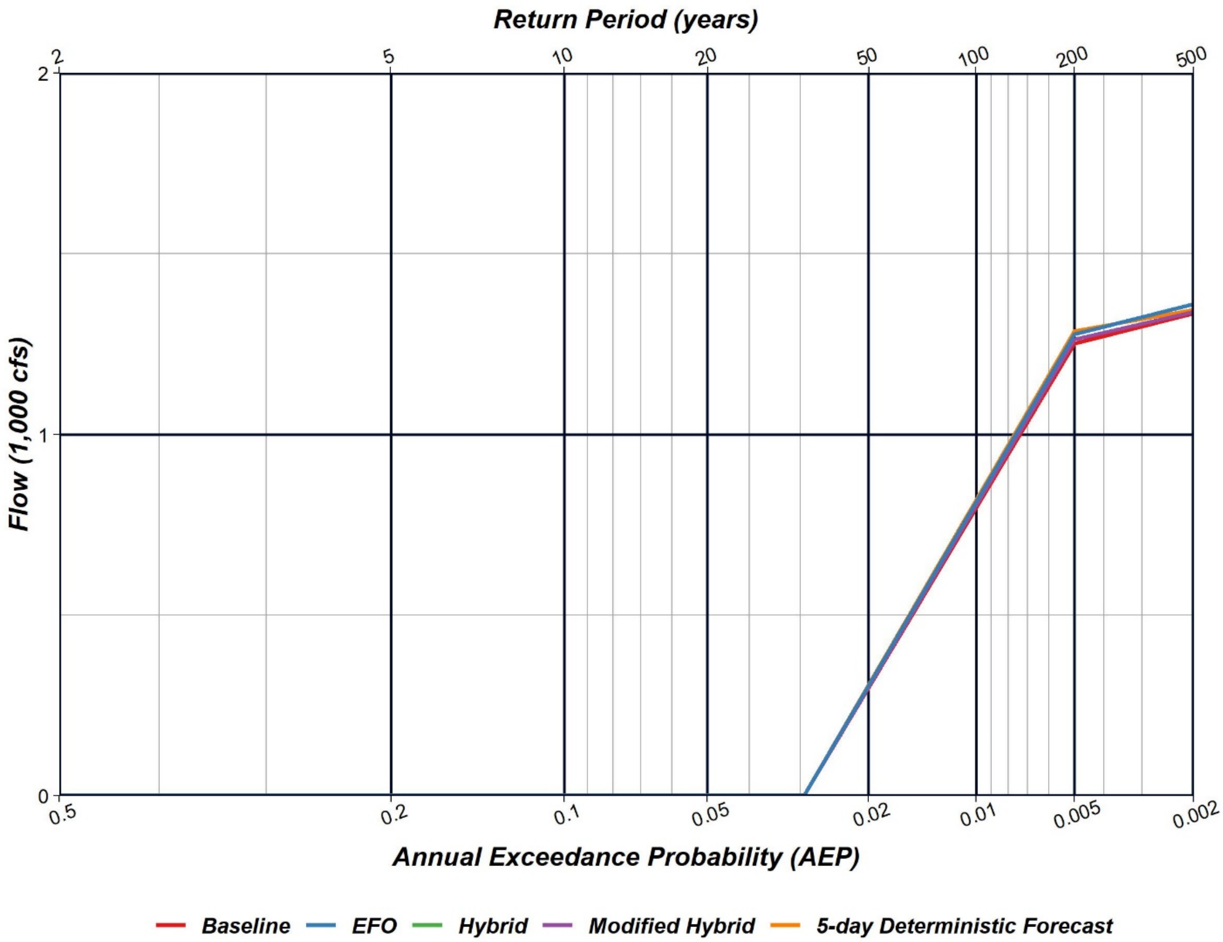


**Figure 11. Annual maximum uncontrolled spill-frequency in Lake Sonoma**

## 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 31 summarizes the EAD results by damage location.

**Table 31. Expected annual damage**

| | EAD ($1,000) by WCP Alternative | | | | |
|---|---|---|---|---|---|
| Location | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| Hopland | 104.09 | 101.10 | 98.50 | 100.60 | 103.68 |
| Cloverdale | 703.02 | 719.32 | 705.61 | 705.59 | 706.39 |
| Geyserville | 191.71 | 185.16 | 189.74 | 189.74 | 189.40 |
| Healdsburg | 542.20 | 532.17 | 533.05 | 535.03 | 540.82 |
| Dry Creek | 2.63 | 2.66 | 2.69 | 2.68 | 2.68 |
| Windsor | 265.56 | 259.56 | 258.48 | 258.48 | 260.23 |
| Santa Rosa | 1,121.14 | 1,119.92 | 1,104.01 | 1,100.50 | 1,122.80 |
| Green Valley Creek | 648.73 | 631.87 | 615.95 | 617.86 | 628.51 |
| Guerneville | 11,282.16 | 11,207.26 | 11,065.81 | 11,049.95 | 11,274.18 |
| Monte Rio | 369.84 | 366.74 | 364.47 | 363.75 | 370.06 |
| **Total EAD** | **15,231.08** | **15,125.73** | **14,938.30** | **14,924.16** | **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 32 summarizes the EAP results by damage location.

**Table 32. Annual population exposed to flooding**

| Location | EAP (persons) by WCP alternative | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| Hopland | 15.3 | 14.7 | 14.6 | 14.7 | 14.9 |
| Cloverdale | 42.8 | 42.7 | 42.4 | 42.4 | 42.6 |
| Geyserville | 10.9 | 10.5 | 10.8 | 10.8 | 10.8 |
| Healdsburg | 48.4 | 48.2 | 48.3 | 48.3 | 48.5 |
| Dry Creek | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| Windsor | 39.9 | 39.9 | 39.9 | 40.0 | 40.2 |
| Santa Rosa | 101.5 | 100.8 | 99.2 | 99.1 | 101.5 |
| Green Valley Creek | 2.6 | 2.5 | 2.5 | 2.5 | 2.5 |
| Guerneville | 697.0 | 688.1 | 683.2 | 683.2 | 690.3 |
| Monte Rio | 21.4 | 21.3 | 20.9 | 20.8 | 21.2 |
| **Total EAP** | **980.2** | **969.1** | **962.2** | **962.2** | **972.9** |

## 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.

**Table 33. Annual exceedance probability of Lake Mendocino storage on May 10th**

| Percent Exceedance | Annual Exceedance Probability of Lake Mendocino Storage on May 10th (ac-ft) | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 102,513 | 107,321 | 106,797 | 107,871 | 107,733 |
| 0.2 | 96,964 | 105,300 | 102,941 | 104,237 | 104,912 |
| 0.3 | 88,742 | 103,300 | 96,048 | 99,504 | 99,638 |
| 0.4 | 84,255 | 101,664 | 94,095 | 98,133 | 95,306 |
| 0.5 | 76,794 | 97,825 | 88,048 | 91,938 | 90,772 |
| 0.6 | 70,853 | 96,007 | 82,071 | 86,821 | 85,875 |
| 0.7 | 69,703 | 92,894 | 79,678 | 84,831 | 83,728 |
| 0.8 | 63,867 | 88,144 | 74,390 | 77,368 | 76,407 |
| 0.9 | 60,279 | 76,543 | 71,820 | 74,481 | 73,864 |

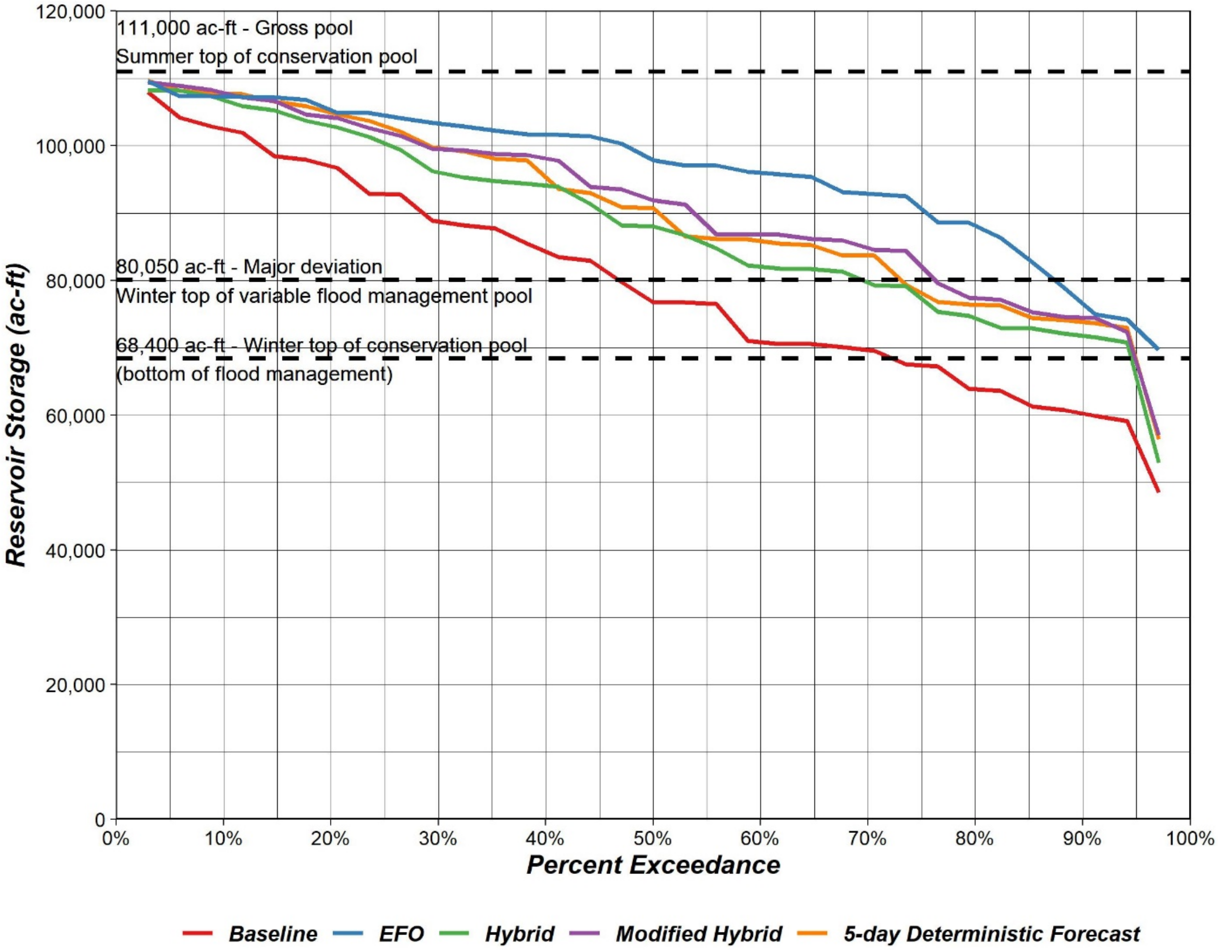


**Figure 12. Annual exceedance probability of Lake Mendocino storage on May 10th**

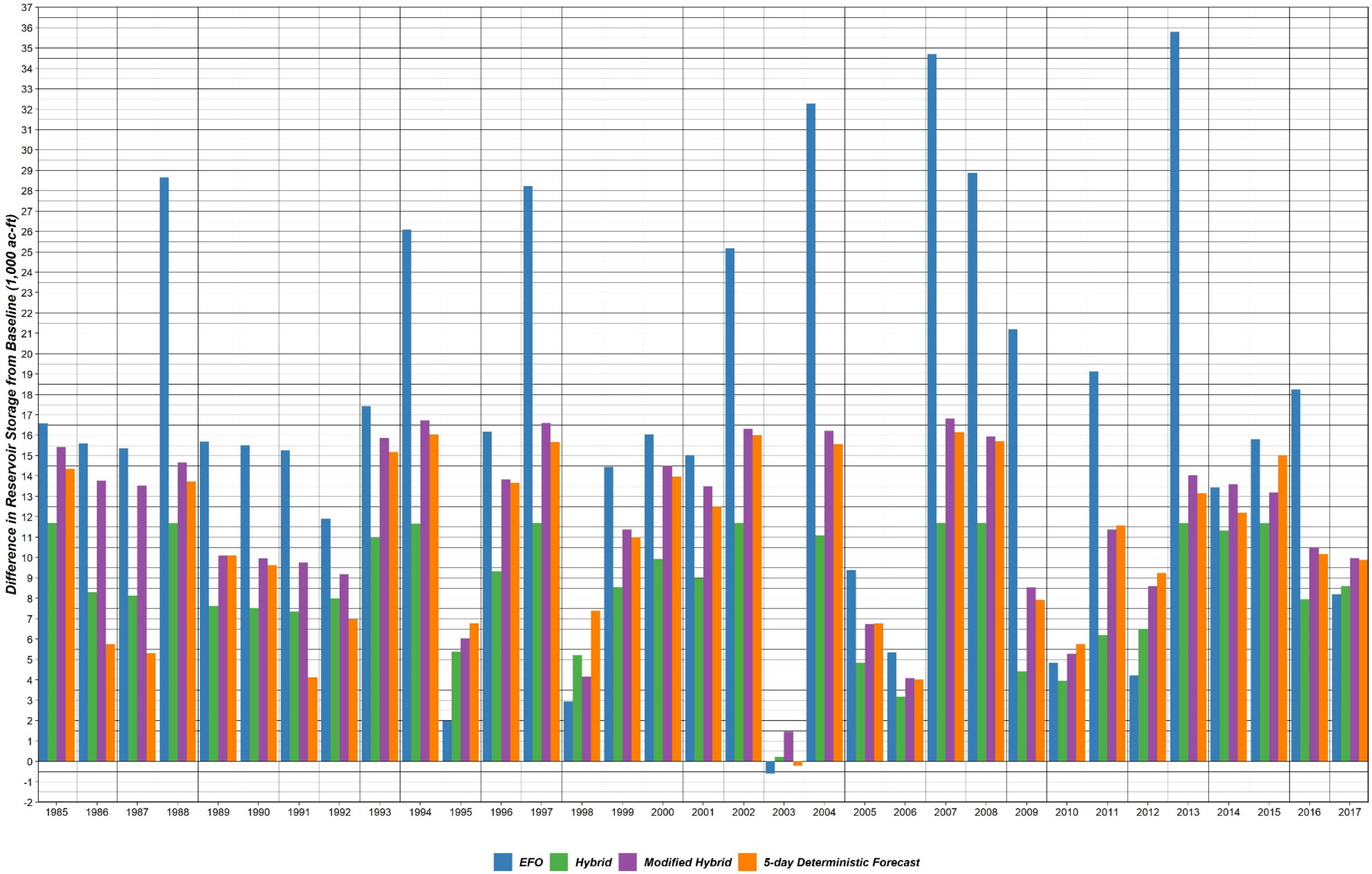


**Figure 13. Difference in Lake Mendocino storage on May 10th in comparison to Baseline**

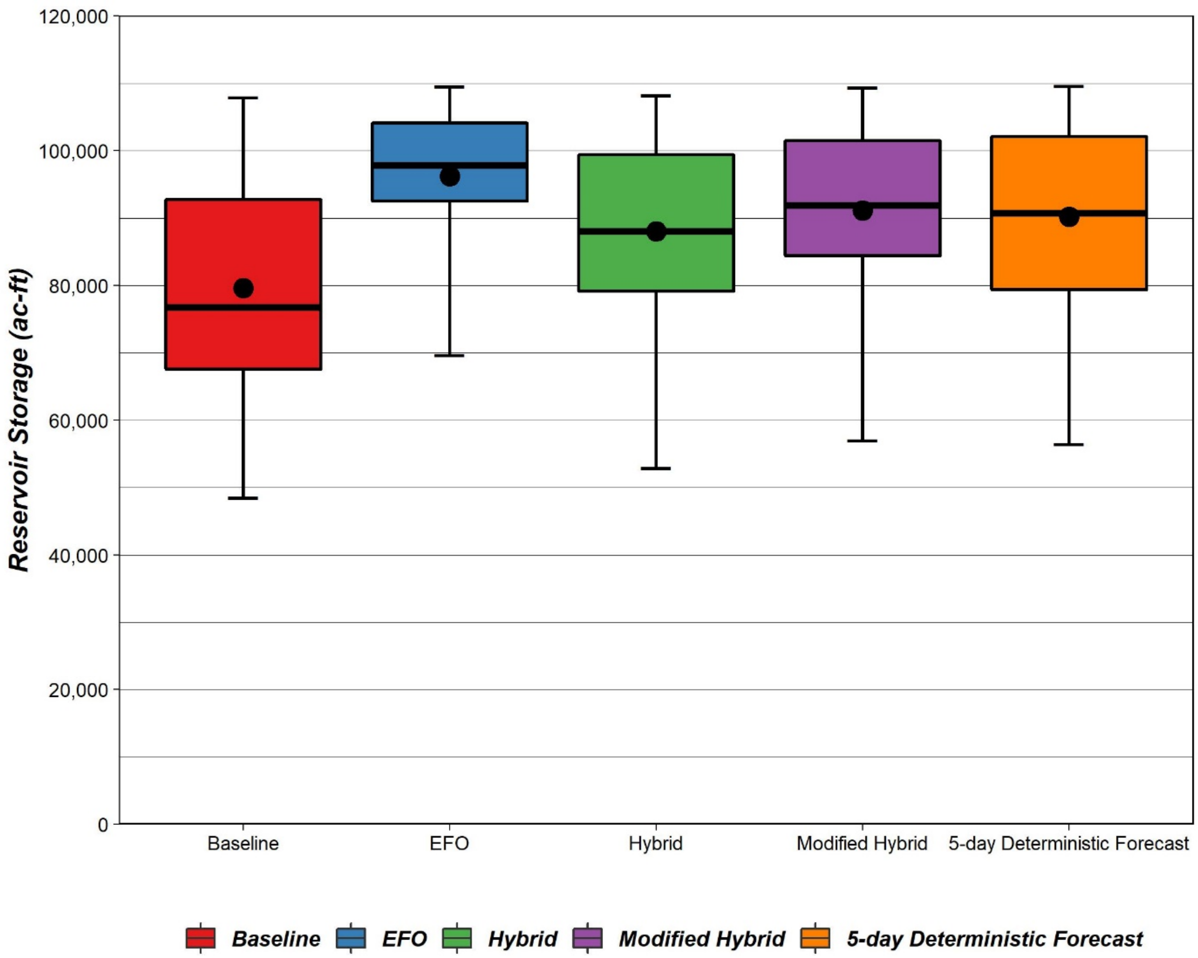


**Figure 14. Lake Mendocino storage on May 10th**

## 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 alternatives 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. Table 34 through Table 36 and Figure 15 through Figure 17 present the percent of days per season in which flows exceed 125 cfs at critical downstream gage locations.

**Table 34. Percent of days per season, June through September, in which flows exceed 125 cfs at East-West Junction**

| Percent Exceedance | East-West Junction | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 1 | 1 | 1 | 1 | 1 |
| 0.3 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 1 | 1 | 1 | 1 | 1 |
| 0.5 | 1 | 1 | 1 | 1 | 1 |
| 0.6 | 1 | 1 | 1 | 1 | 1 |
| 0.7 | 1 | 1 | 1 | 1 | 1 |
| 0.8 | 0.98 | 1 | 0.98 | 0.98 | 0.98 |
| 0.9 | 0.91 | 0.97 | 0.93 | 0.93 | 0.93 |

**Table 35. Percent of days per season, June through September, in which flows exceed 125 cfs at Hopland**

| Percent Exceedance | Hopland | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 1 | 1 | 1 | 1 | 1 |
| 0.3 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 1 | 1 | 1 | 1 | 1 |
| 0.5 | 1 | 1 | 1 | 1 | 1 |
| 0.6 | 1 | 1 | 1 | 1 | 1 |
| 0.7 | 0.61 | 1 | 1 | 1 | 1 |
| 0.8 | 0.28 | 1 | 0.34 | 0.35 | 0.34 |
| 0.9 | 0.14 | 0.31 | 0.22 | 0.22 | 0.22 |

**Table 36. Percent of days per season, June through September, in which flows exceed 125 cfs at Cloverdale**

| Percent Exceedance | Cloverdale | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 1 | 1 | 1 | 1 | 1 |
| 0.3 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 1 | 1 | 1 | 1 | 1 |
| 0.5 | 1 | 1 | 1 | 1 | 1 |
| 0.6 | 1 | 1 | 1 | 1 | 1 |
| 0.7 | 0.69 | 1 | 1 | 1 | 1 |
| 0.8 | 0.45 | 1 | 0.48 | 0.48 | 0.49 |
| 0.9 | 0.41 | 0.46 | 0.42 | 0.43 | 0.42 |

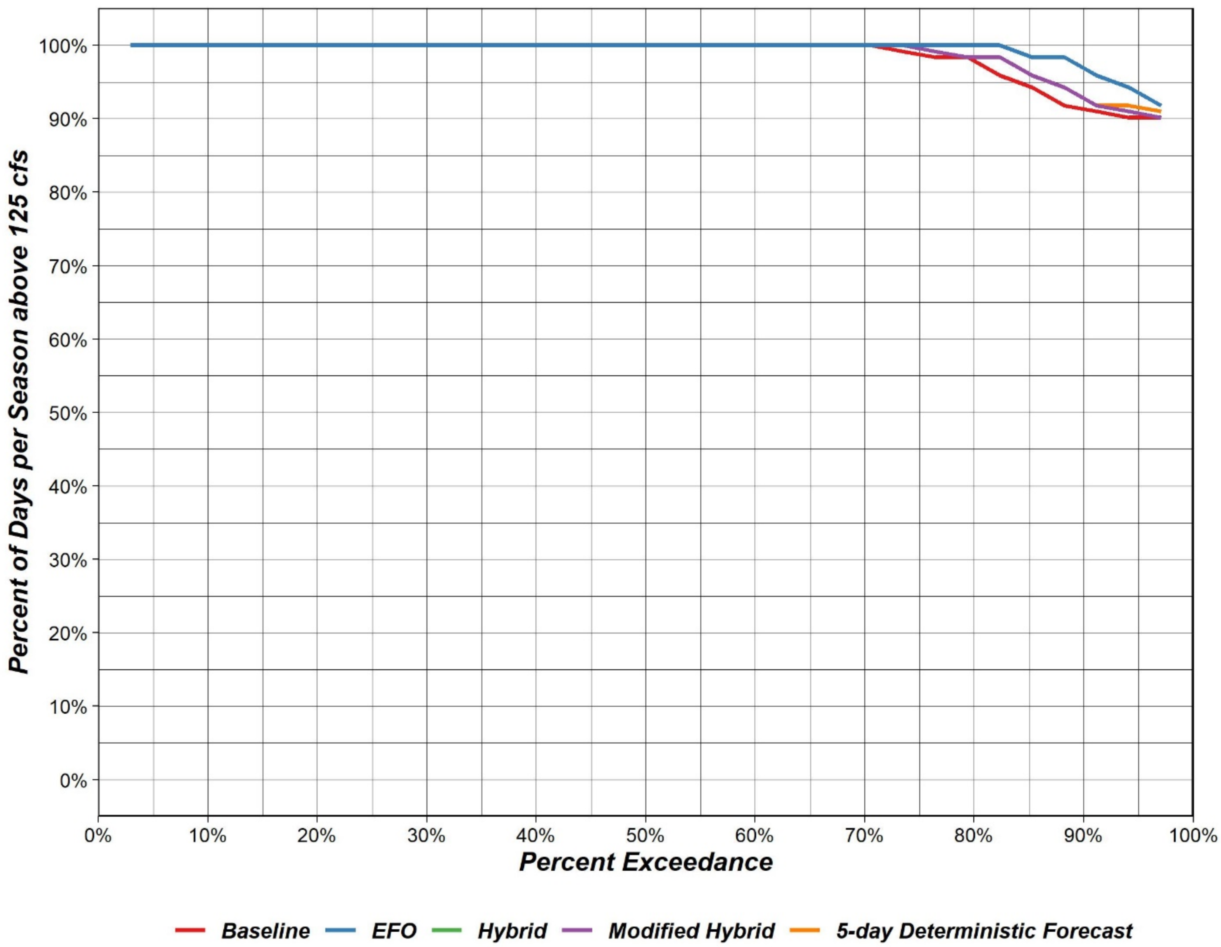


**Figure 15. Percent of days per season, June through September, in which flows exceed 125 cfs at East-West Junction**

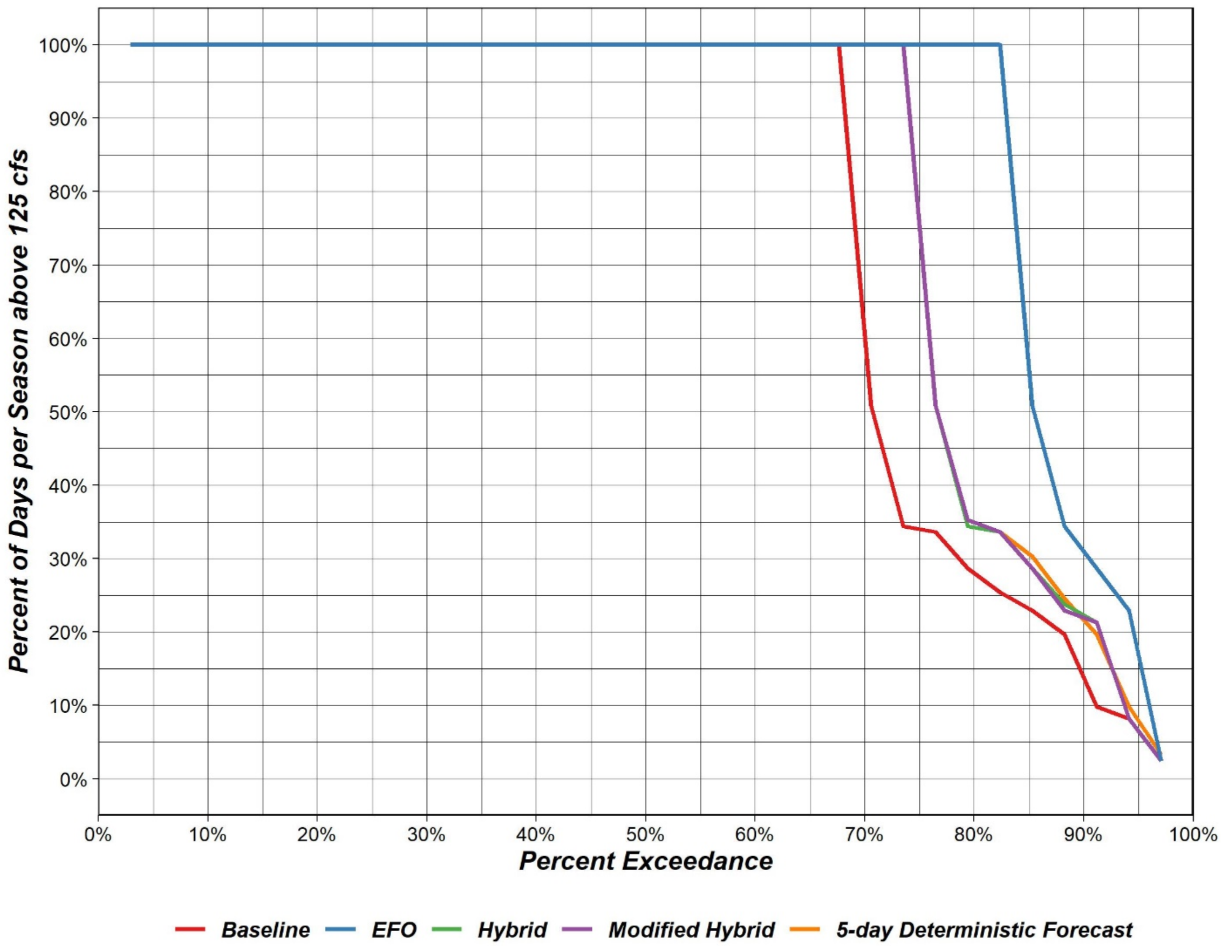


**Figure 16. Percent of days per season, June through September, in which flows exceed 125 cfs at Hopland**

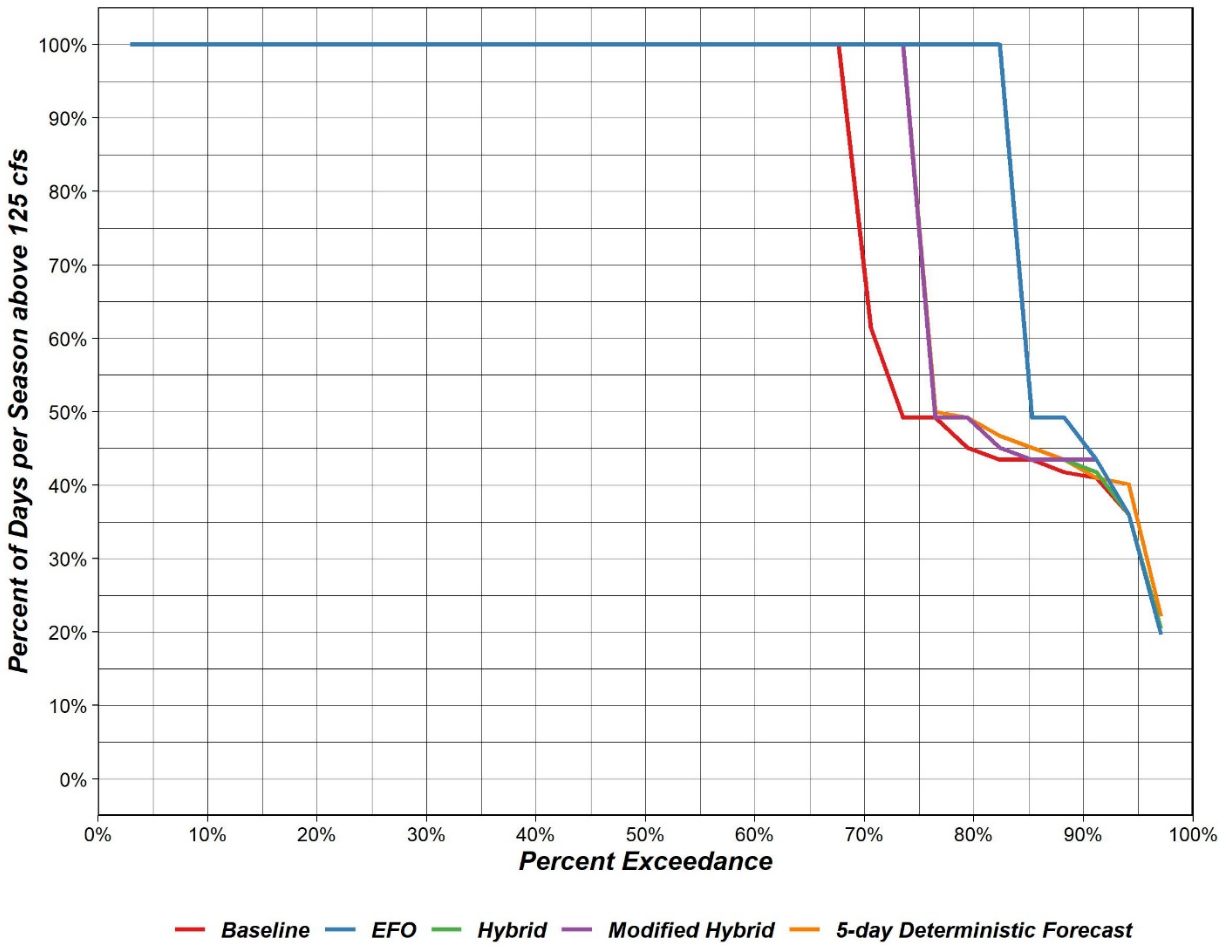


**Figure 17. Percent of days per season, June through September, in which flows exceed 125 cfs at Cloverdale**

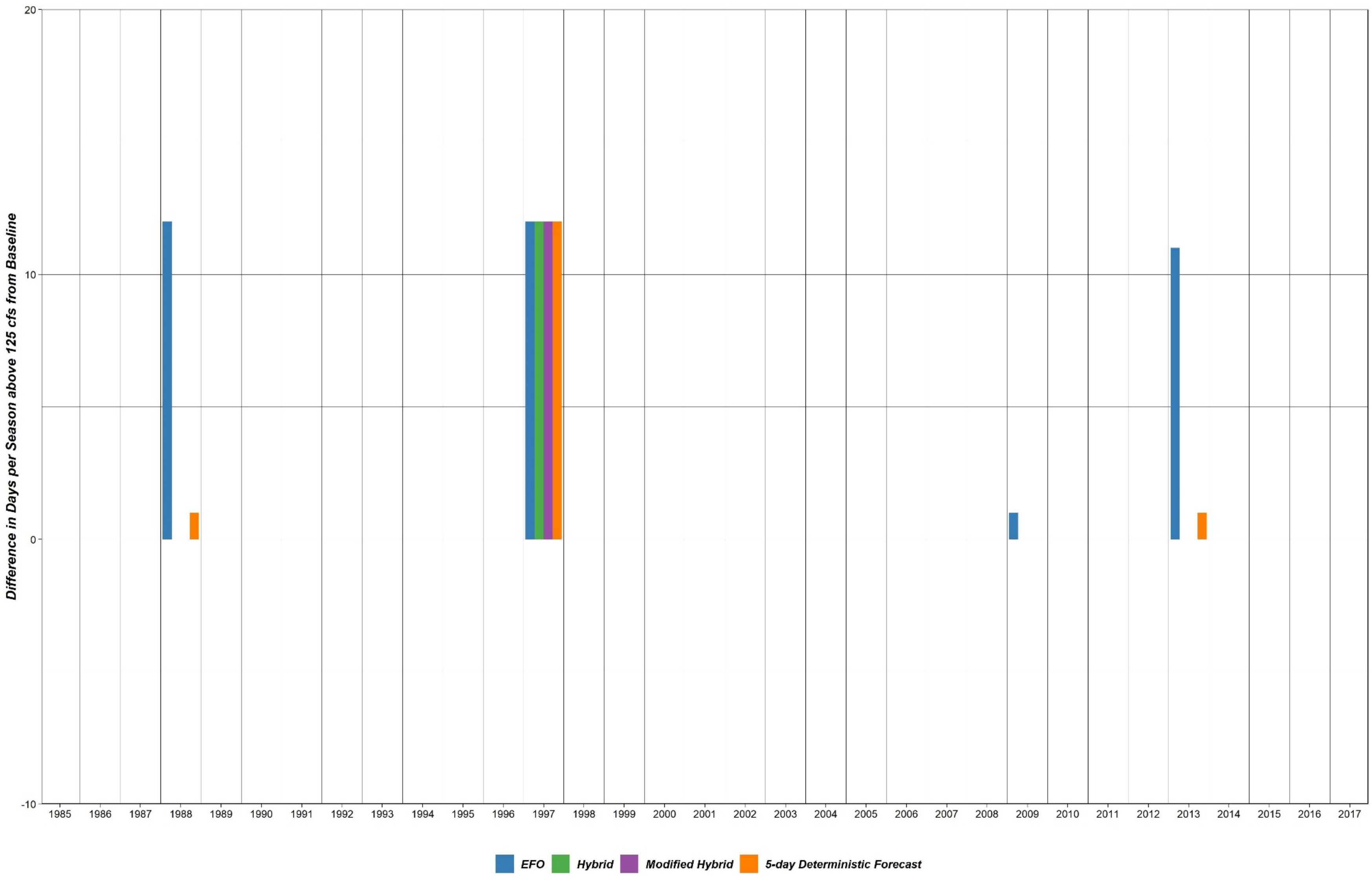


**Figure 18. Difference in days per season, June through September, in which flows exceed 125 cfs in comparison to Baseline at East-West Junction**

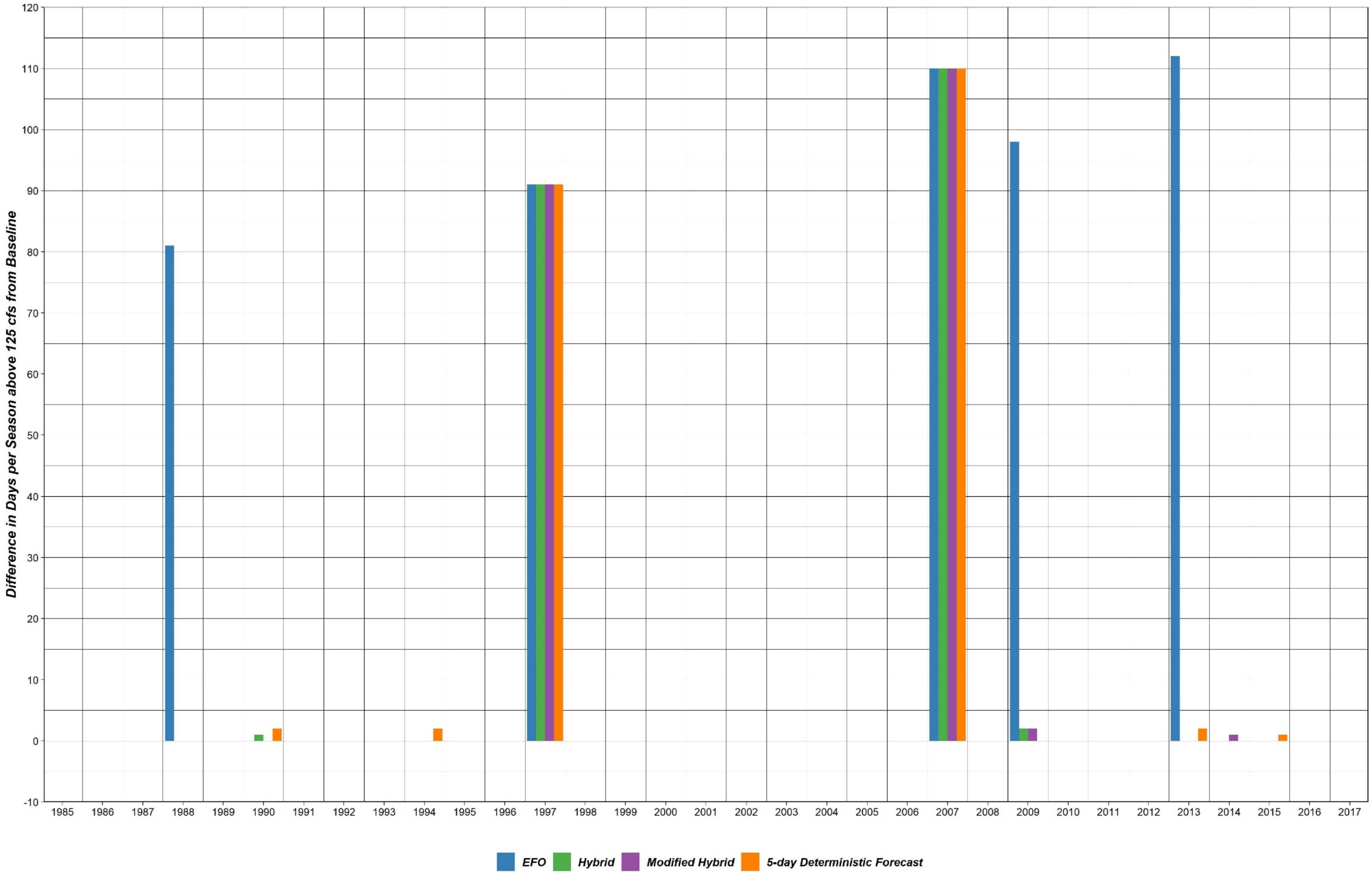


**Figure 19. Difference in days per season, June through September, in which flows exceed 125 cfs in comparison to baseline at Hopland**

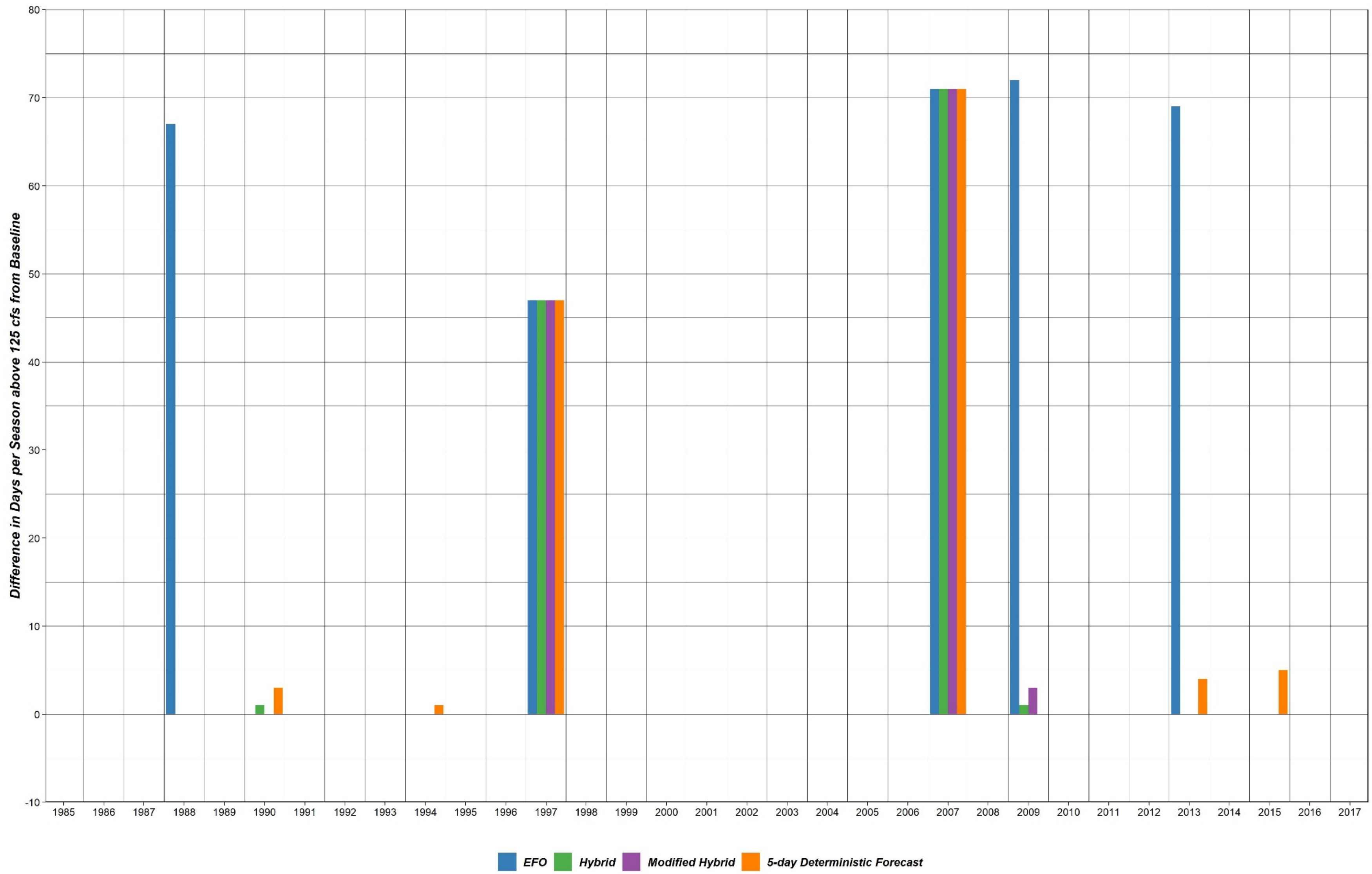


**Figure 20. Difference in days per season, June through September, in which flows exceed 125 cfs in comparison to baseline at Cloverdale**

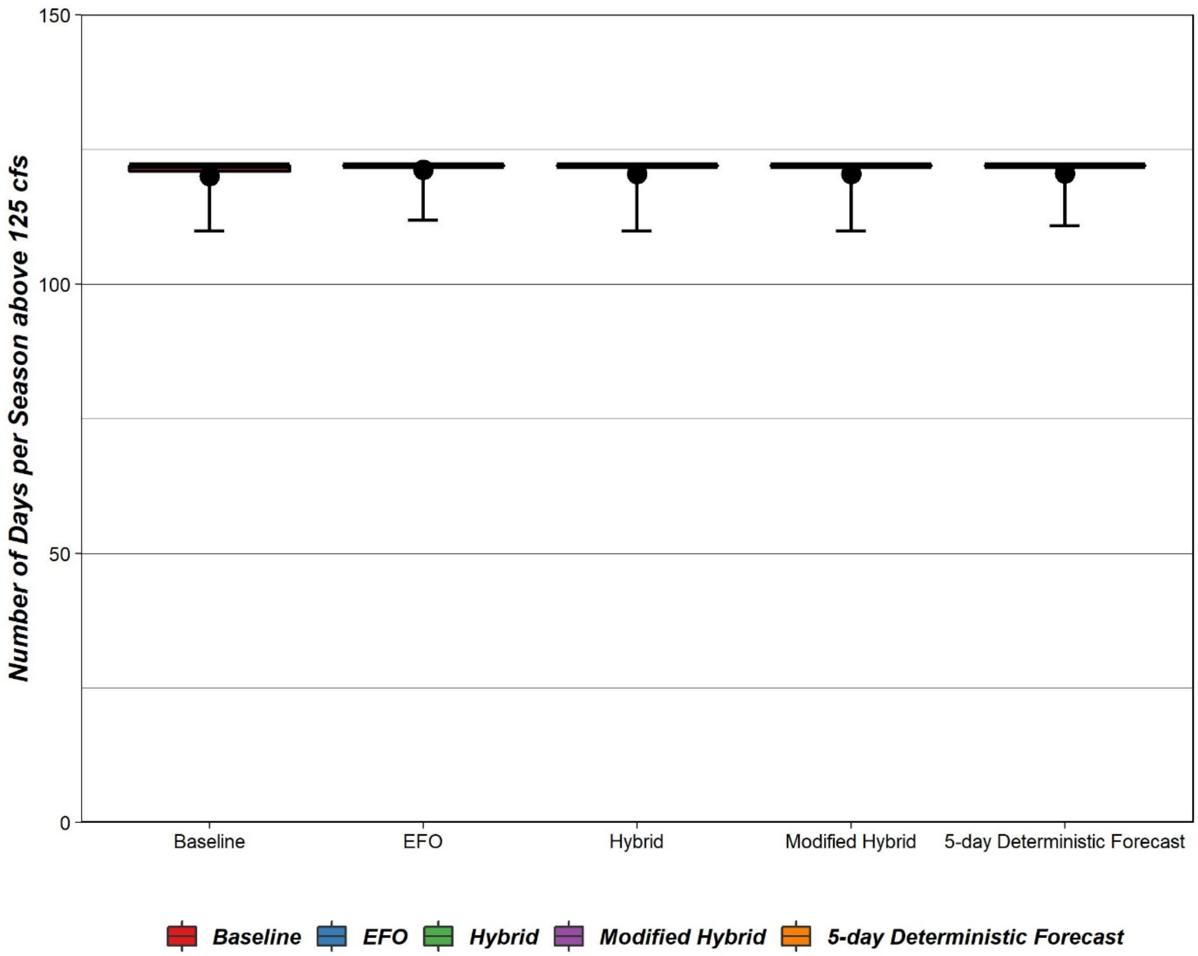


**Figure 21. Number of days per season, June through September, in which flows exceed 125 cfs at East-West Junction – box-and-whisker plot**

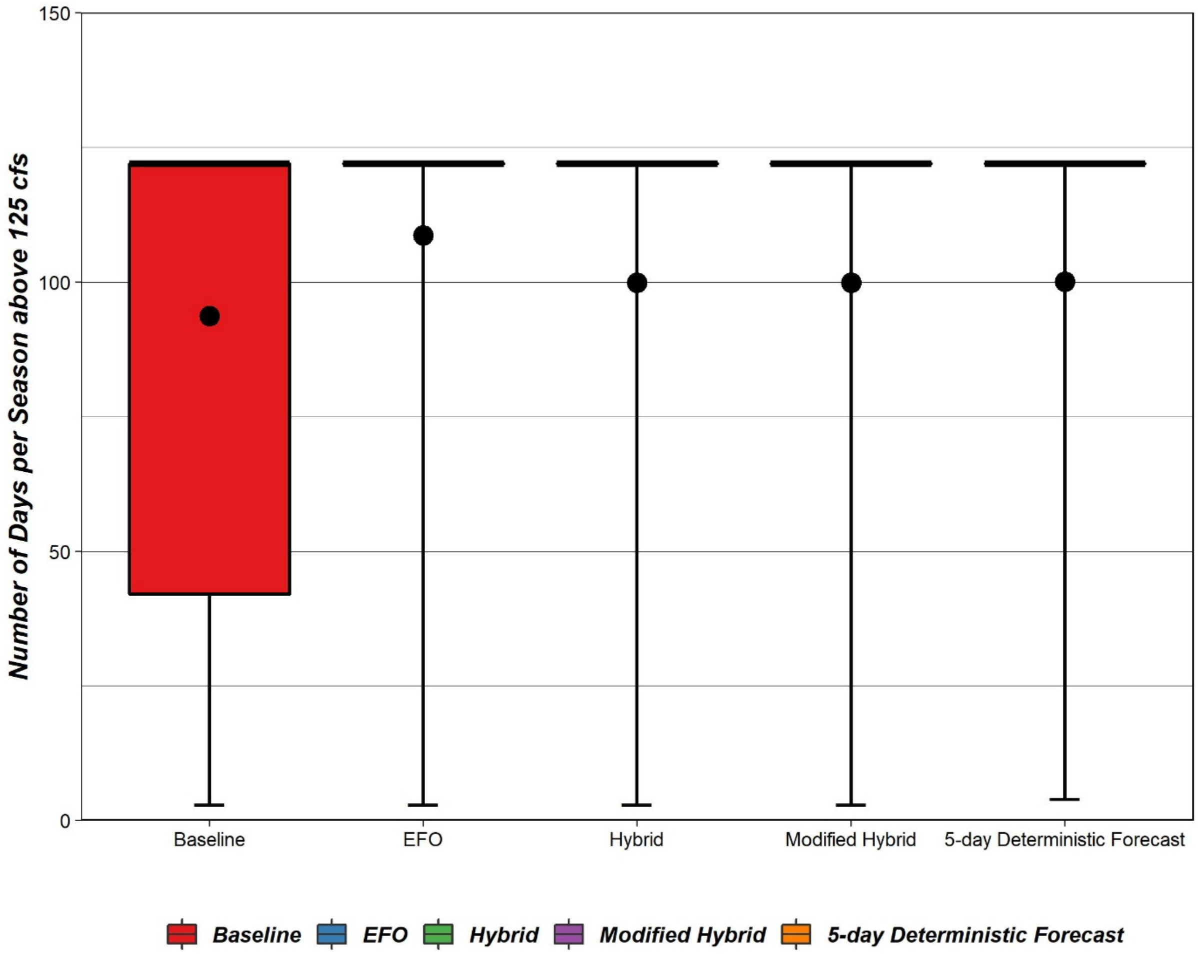


**Figure 22. Number of days per season, June through September, in which flows exceed 125 cfs at Hopland – box-and-whisker plot**

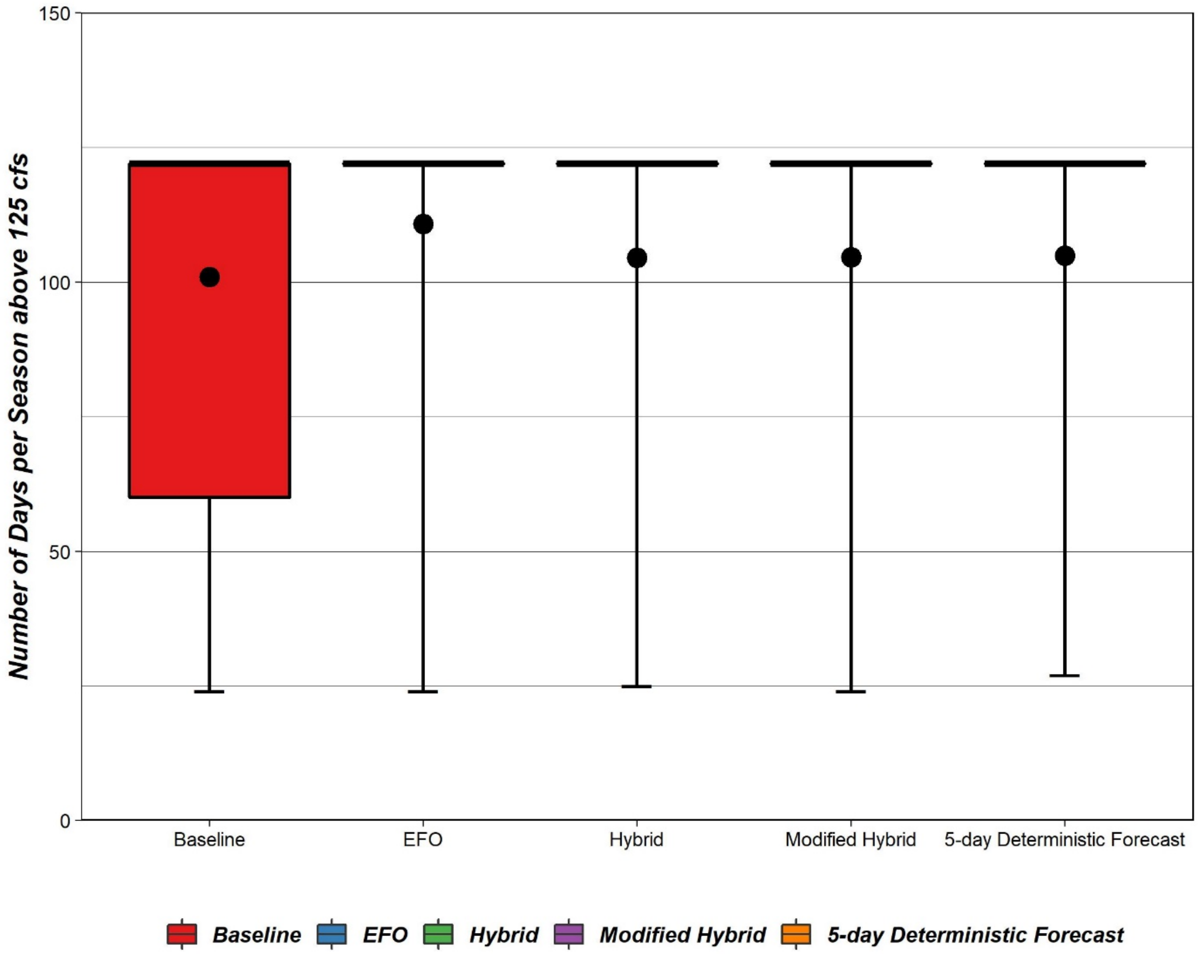


**Figure 23. Number of days per season, June through September, in which flows exceed 125 cfs at Cloverdale – box-and-whisker plot**

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

M12 evaluates the ability of the alternatives 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. Table 37 though Table 41 and Figure 24 through Figure 28 present the percent of days per season in which flows exceed instream flow requirements.

**Table 37. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at East-West Junction**

| Percent Exceedance | Flows Exceeding 105 cfs at East-West Junction | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 1 | 1 | 1 | 1 | 1 |
| 0.3 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 1 | 1 | 1 | 1 | 1 |
| 0.5 | 1 | 1 | 1 | 1 | 1 |
| 0.6 | 0.87 | 1 | 1 | 1 | 1 |
| 0.7 | 0.69 | 1 | 0.98 | 1 | 0.98 |
| 0.8 | 0.51 | 0.91 | 0.63 | 0.63 | 0.63 |
| 0.9 | 0.42 | 0.57 | 0.47 | 0.47 | 0.53 |

**Table 38. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at Hopland**

| Percent Exceedance | Flows Exceeding 105 cfs at Hopland | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 1 | 1 | 1 | 1 | 1 |
| 0.3 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 1 | 1 | 1 | 1 | 1 |
| 0.5 | 1 | 1 | 1 | 1 | 1 |
| 0.6 | 0.92 | 1 | 1 | 1 | 1 |
| 0.7 | 0.72 | 1 | 0.97 | 1.00 | 0.97 |
| 0.8 | 0.54 | 0.98 | 0.70 | 0.70 | 0.70 |
| 0.9 | 0.39 | 0.68 | 0.42 | 0.42 | 0.45 |

### Table 39. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at Cloverdale

| Percent Exceedance | Flows Exceeding 105 cfs at Cloverdale | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 1 | 1 | 1 | 1 | 1 |
| 0.3 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 1 | 1 | 1 | 1 | 1 |
| 0.5 | 1 | 1 | 1 | 1 | 1 |
| 0.6 | 1 | 1 | 1 | 1 | 1 |
| 0.7 | 0.86 | 1 | 0.99 | 1 | 1 |
| 0.8 | 0.79 | 0.99 | 0.84 | 0.86 | 0.85 |
| 0.9 | 0.67 | 0.85 | 0.70 | 0.70 | 0.69 |

### Table 40. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at Healdsburg

| Percent Exceedance | Flows Exceeding 105 cfs at Healdsburg | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 1 | 1 | 1 | 1 | 1 |
| 0.3 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 1 | 1 | 1 | 1 | 1 |
| 0.5 | 1 | 1 | 1 | 1 | 1 |
| 0.6 | 1 | 1 | 1 | 1 | 1 |
| 0.7 | 0.79 | 1 | 1 | 1 | 1 |
| 0.8 | 0.72 | 0.99 | 0.76 | 0.76 | 0.78 |
| 0.9 | 0.56 | 0.76 | 0.56 | 0.56 | 0.65 |

### Table 41. Percent of days per season, October 12 through January 1, in which flows exceed 135 cfs at Guerneville (Hacienda Bridge)

| Percent Exceedance | Flows Exceeding 135 cfs at Guerneville (Hacienda Bridge) | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 1 | 1 | 1 | 1 | 1 |
| 0.3 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 1 | 1 | 1 | 1 | 1 |
| 0.5 | 1 | 1 | 1 | 1 | 1 |
| 0.6 | 1 | 1 | 1 | 1 | 1 |
| 0.7 | 1 | 1 | 1 | 1 | 1 |
| 0.8 | 0.97 | 1 | 0.97 | 0.97 | 0.97 |
| 0.9 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 |

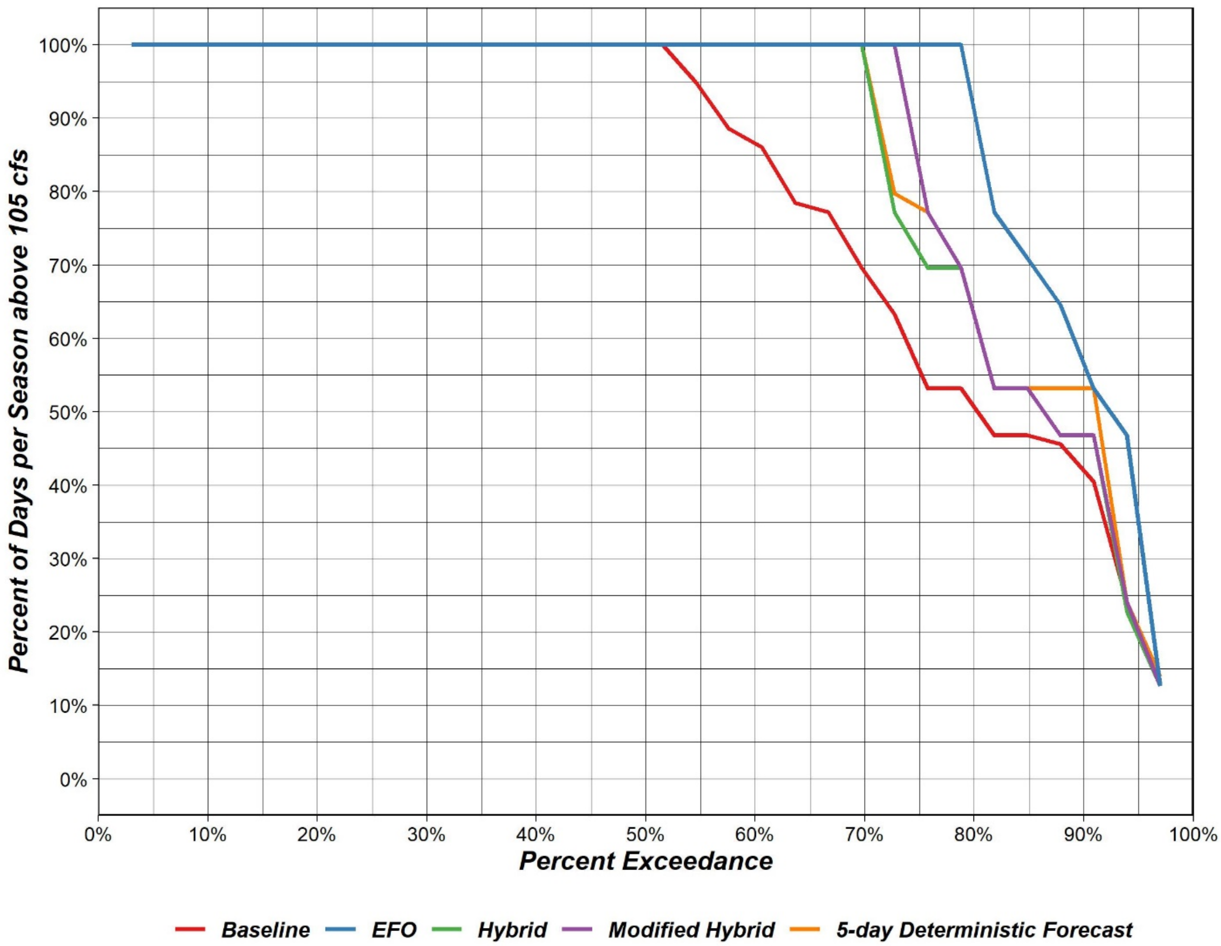


**Figure 24. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at East-West Junction**

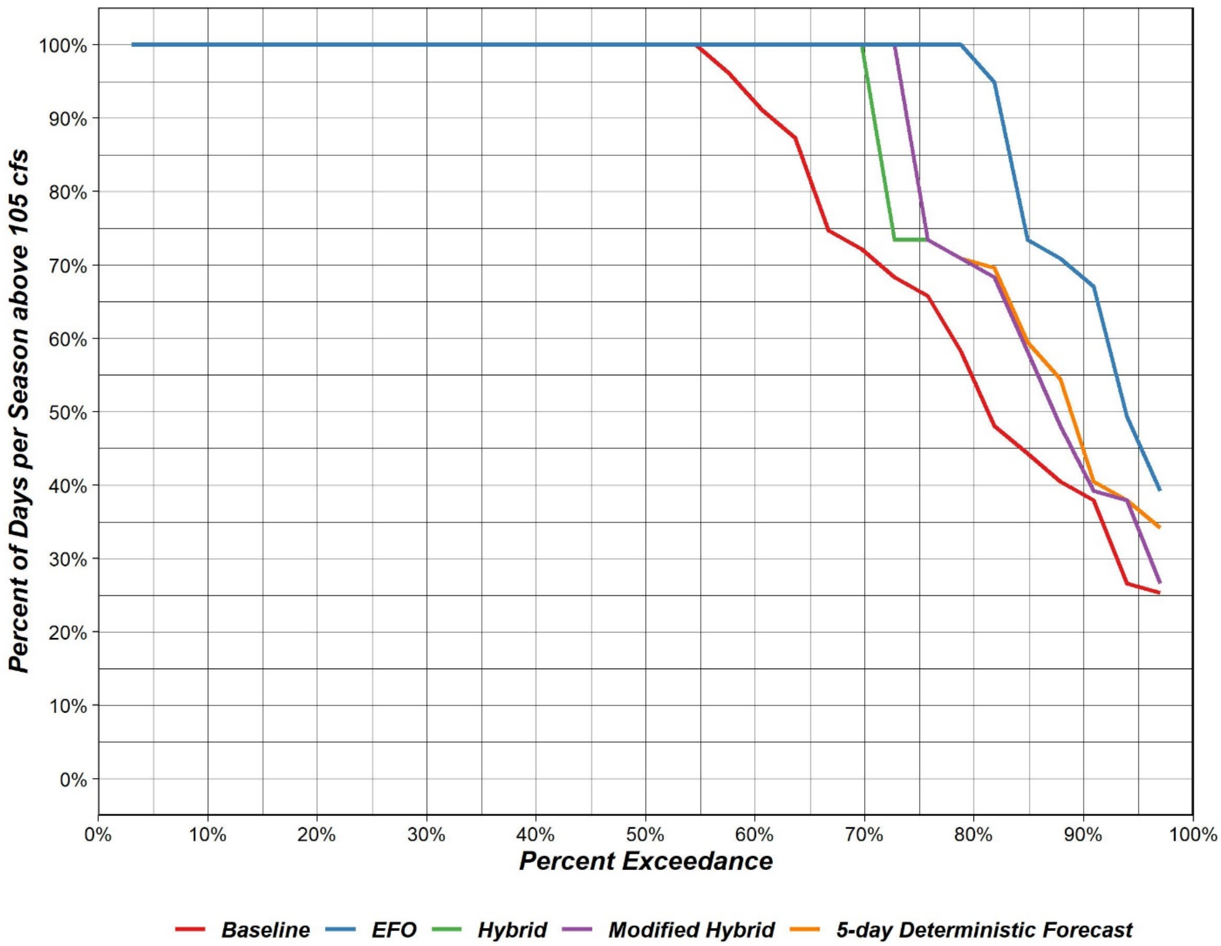


**Figure 25. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at Hopland**

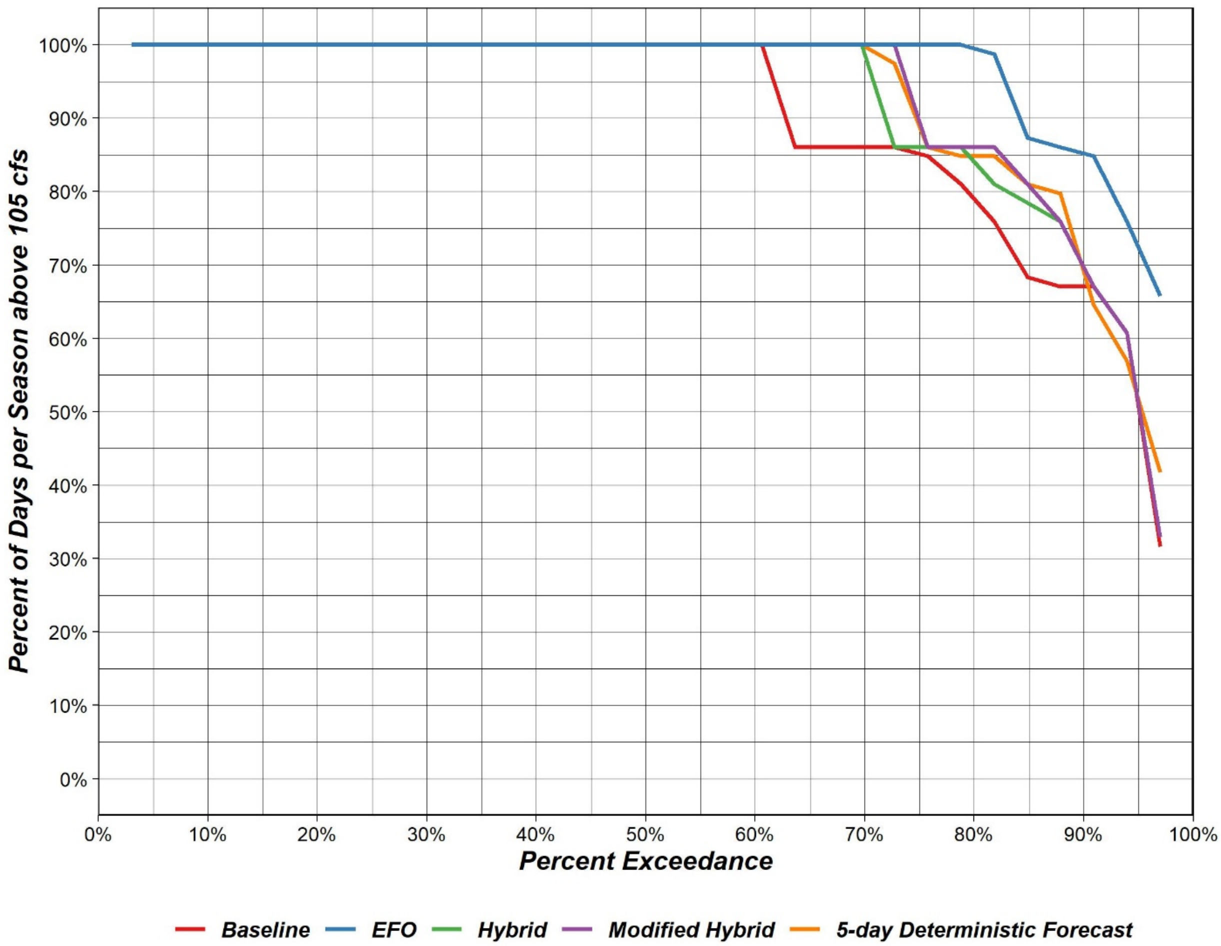


**Figure 26. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at Cloverdale**

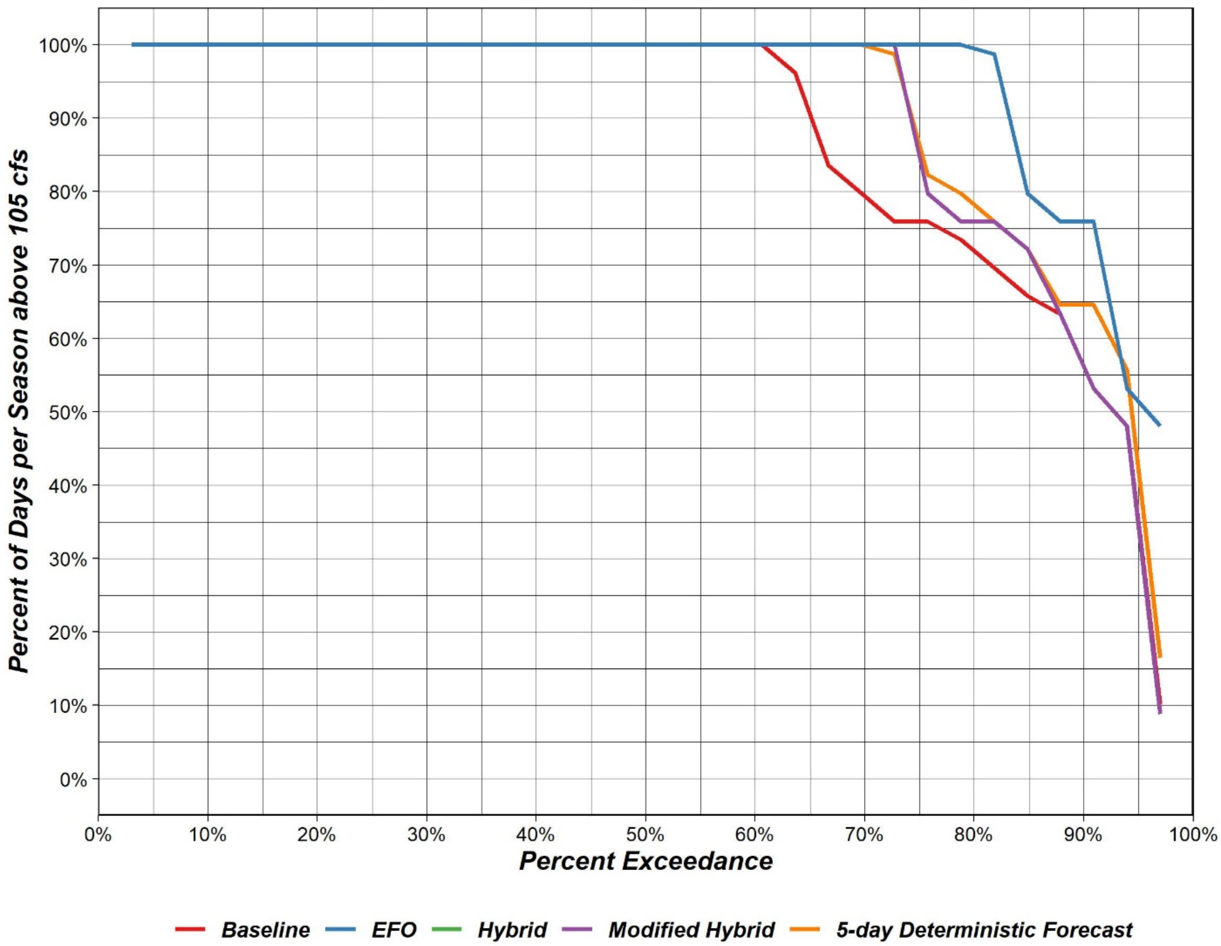


**Figure 27. Percent of days per season, October 12 through January 1, in which flows exceed 105 cfs at Healdsburg**

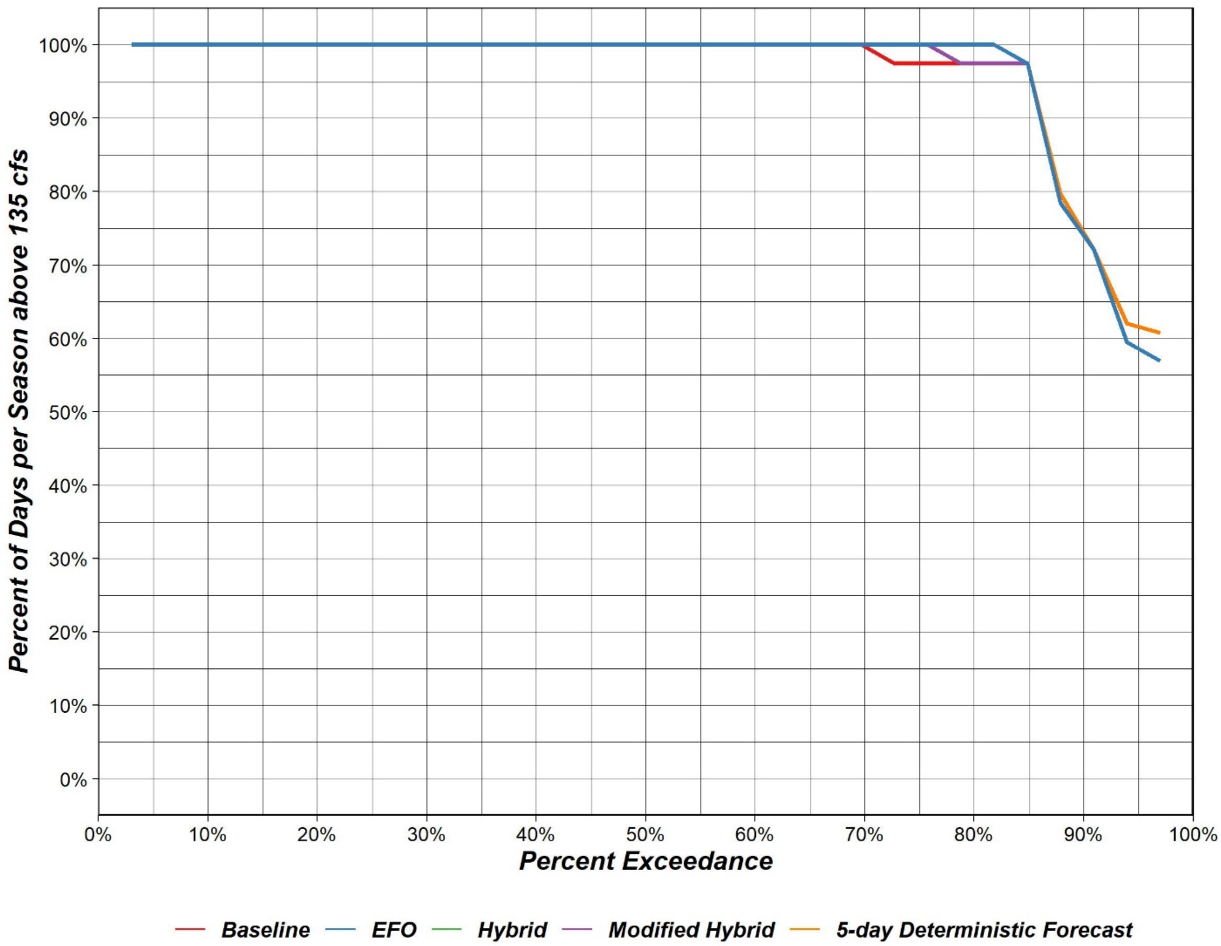


**Figure 28. Percent of days per season, October 12 through January 1, in which flows exceed 135 cfs at Guerneville (Hacienda Bridge)**

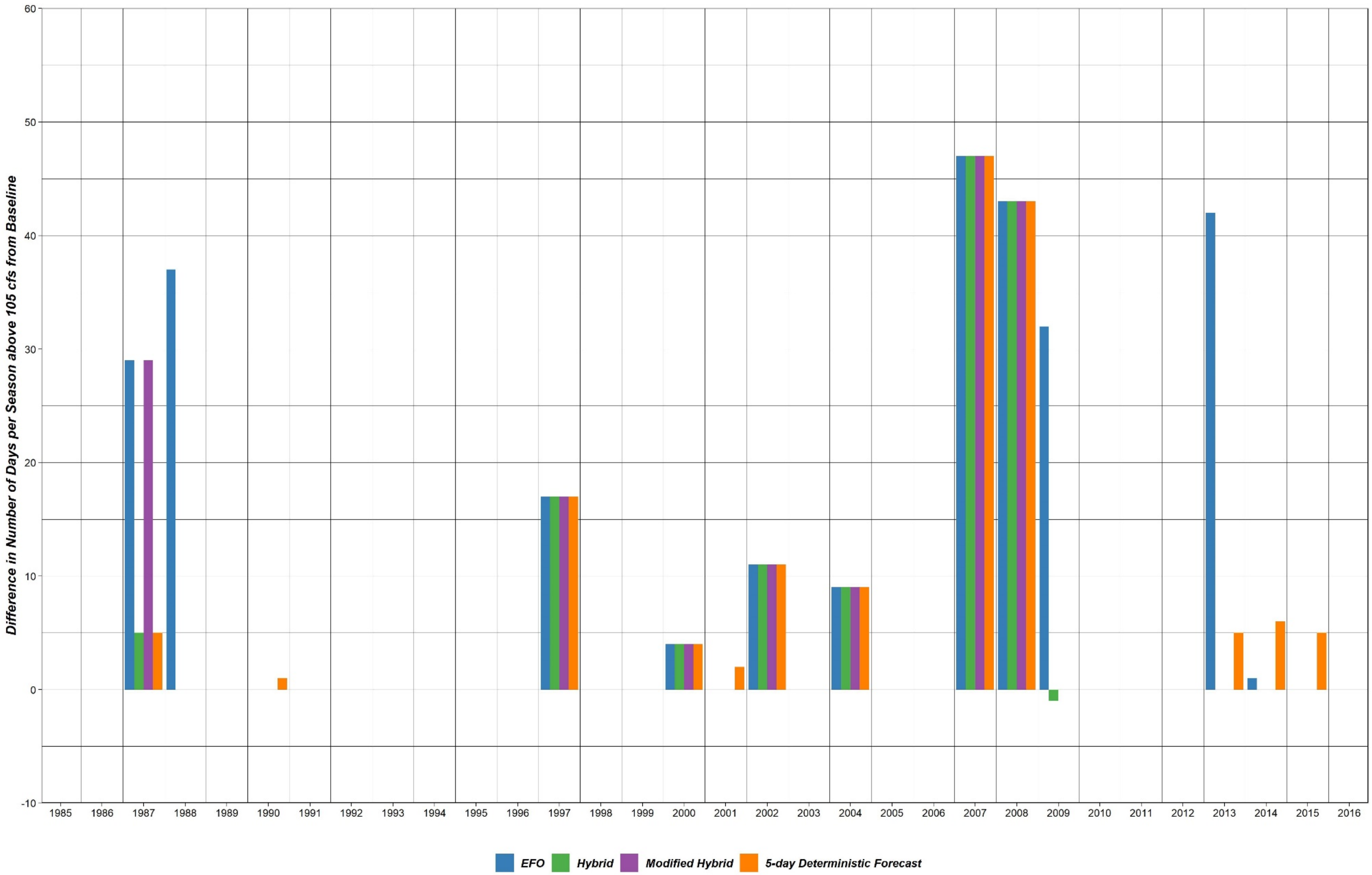


**Figure 29. Difference in number of days per season, October 12 through January 1, in which flows exceed 105 cfs in comparison to Baseline at East-West Junction**

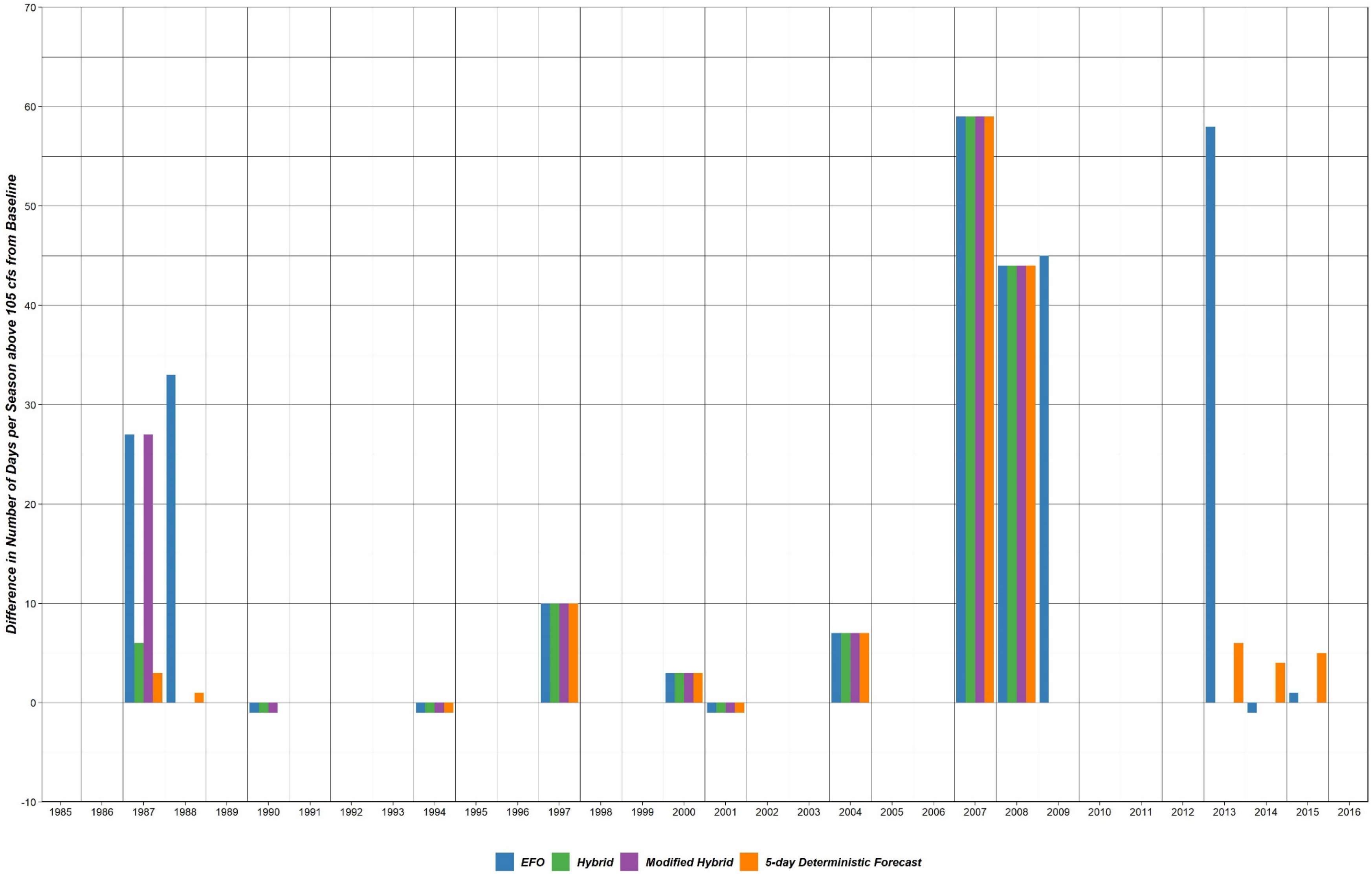


**Figure 30. Difference in number of days per season, October 12 through January 1, in which flows exceed 105 cfs in comparison to baseline at Hopland**

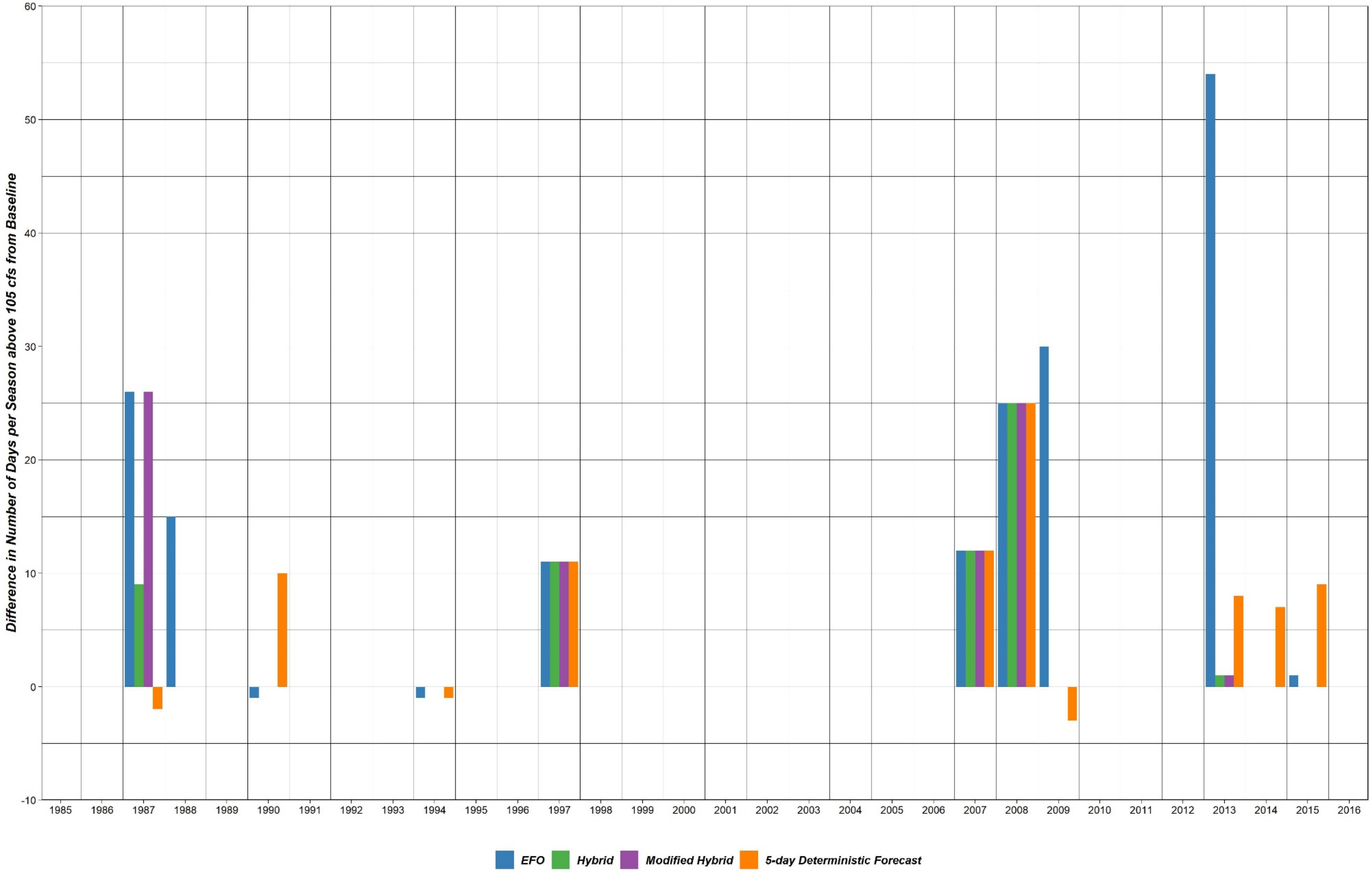


**Figure 31. Difference in number of days per season, October 12 through January 1, in which flows exceed 105 cfs in comparison to baseline at Cloverdale**

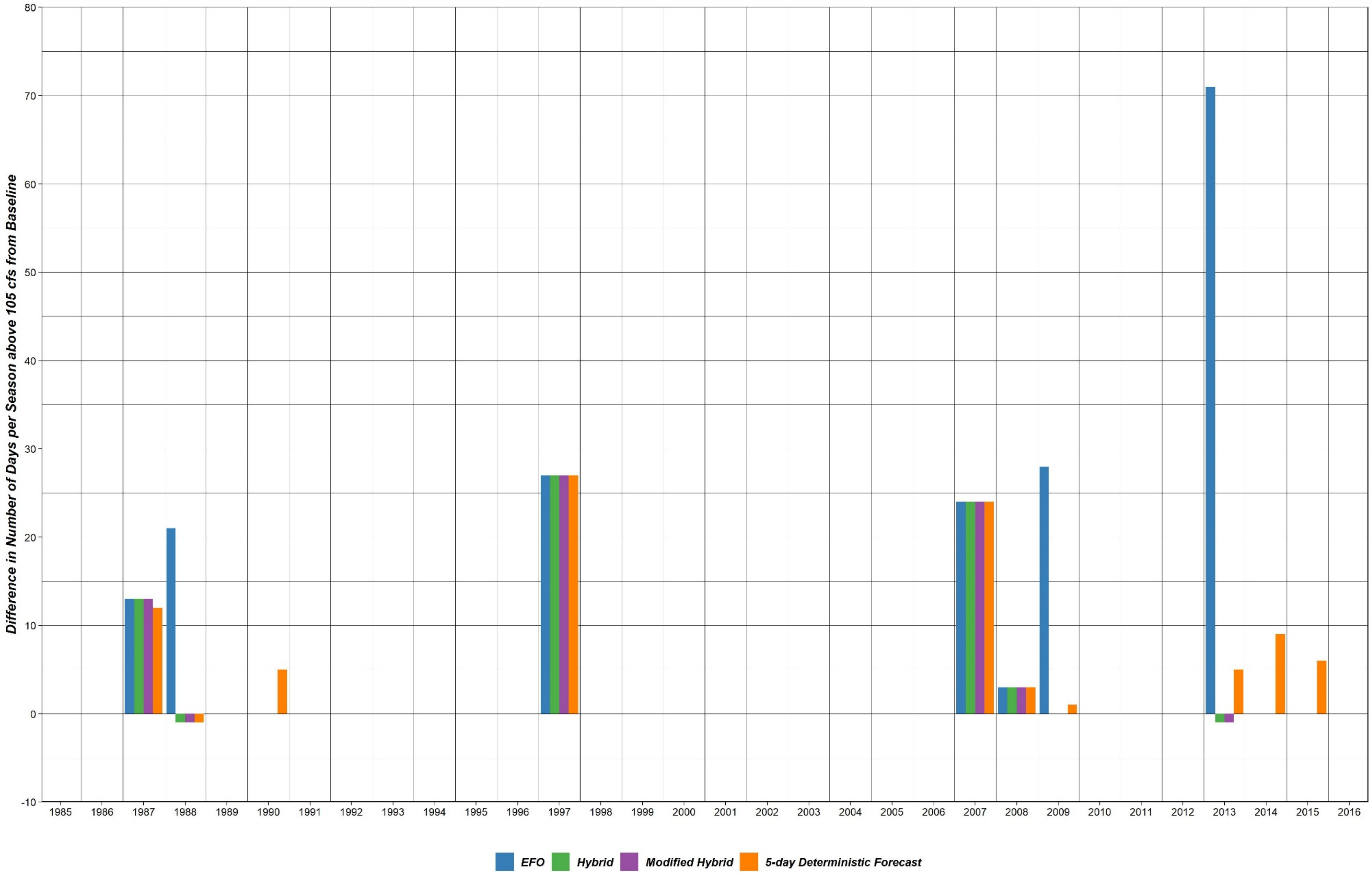


**Figure 32. Difference in number of days per season, October 12 through January 1, in which flows exceed 105 cfs in comparison to baseline at Healdsburg**

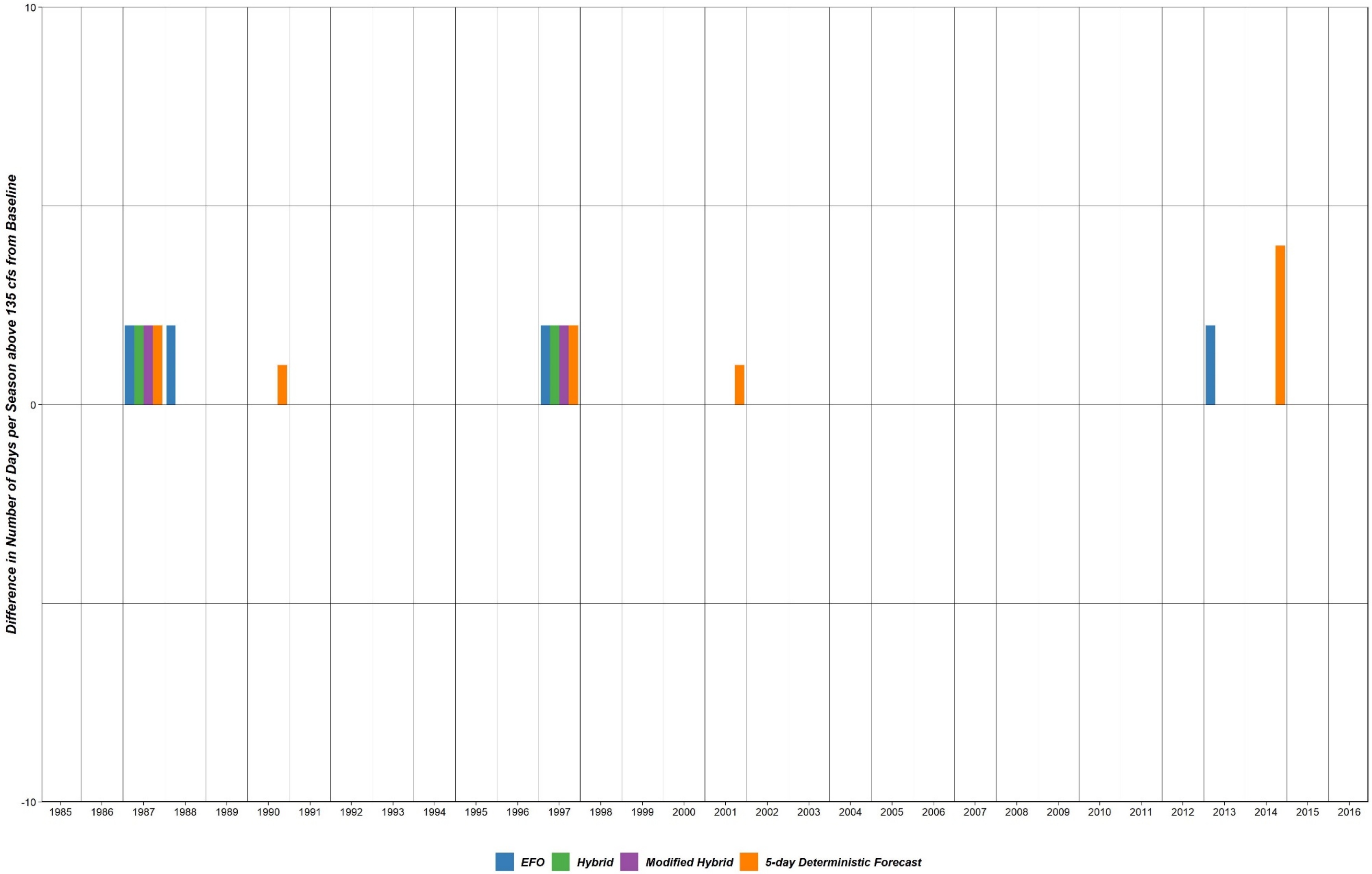


**Figure 33. Difference in number of days per season, October 12 through January 1, in which flows exceed 135 cfs in comparison to baseline at Guerneville (Hacienda Bridge)**

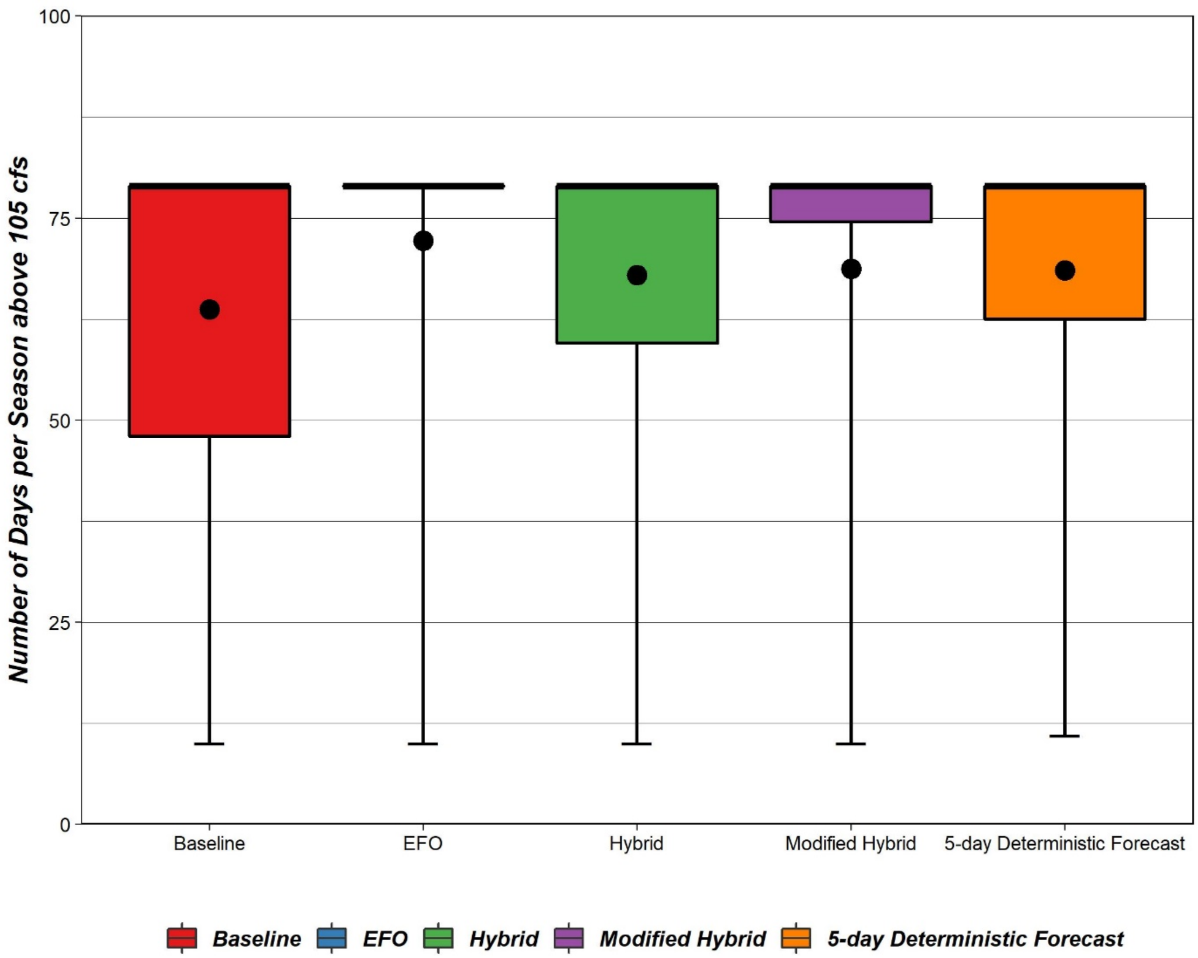


**Figure 34. Number of days per season, October 12 through January 1, in which flows exceed 105 cfs at East-West Junction – box-and-whisker plot**

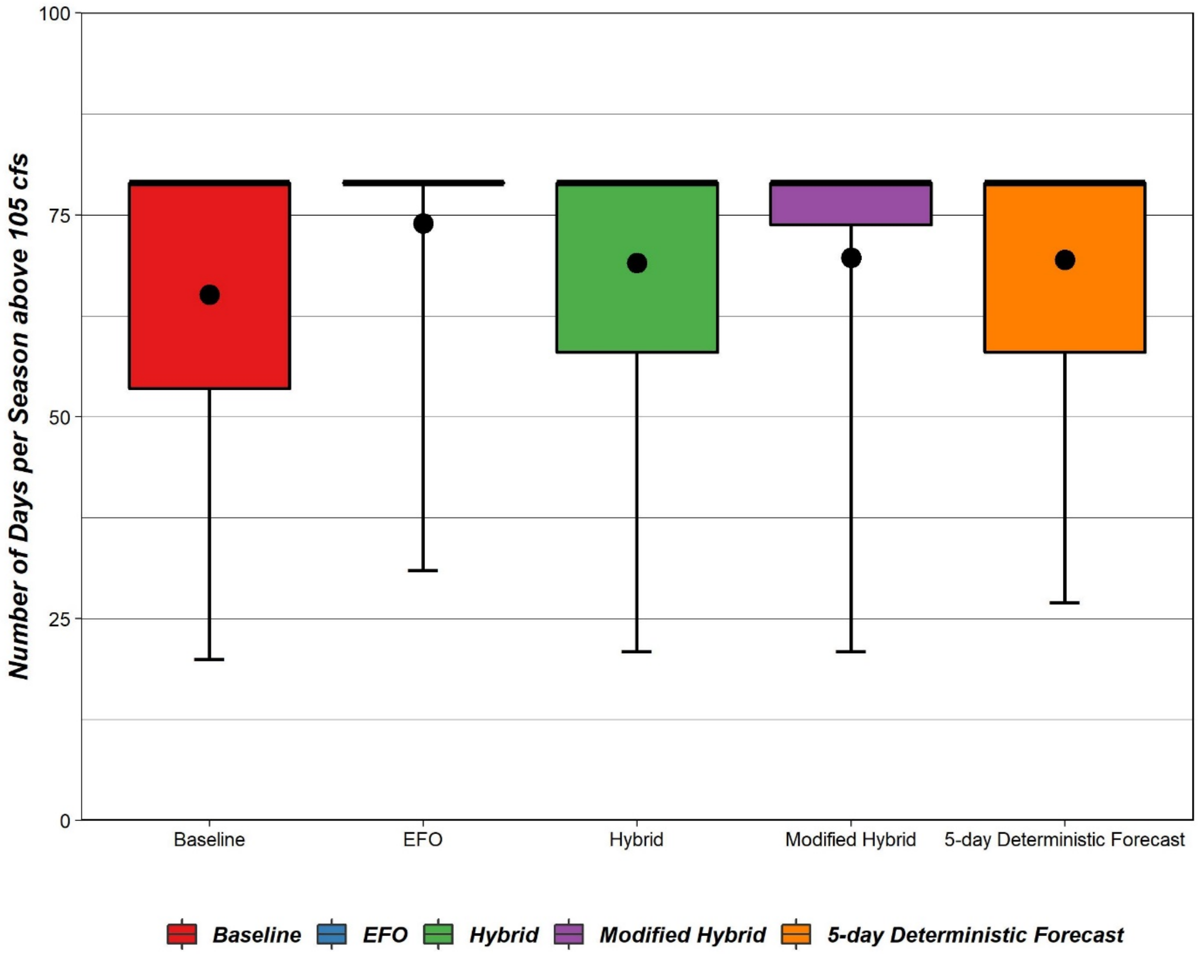


**Figure 35. Number of days per season, October 12 through January 1, in which flows exceed 105 cfs at Hopland – box-and-whisker plot**

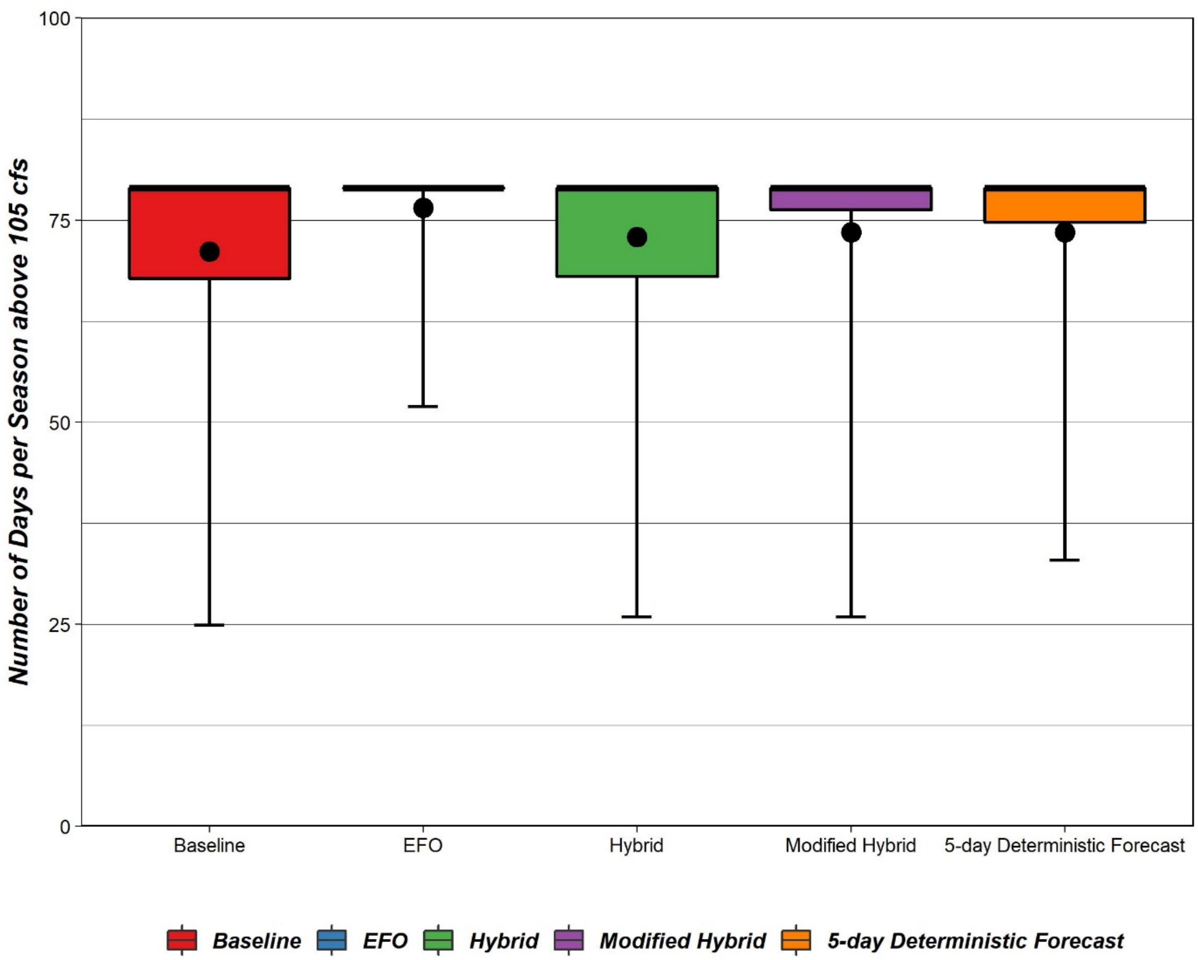


**Figure 36. Number of days per season, October 12 through January 1, in which flows exceed 105 cfs at Cloverdale – box-and-whisker plot**

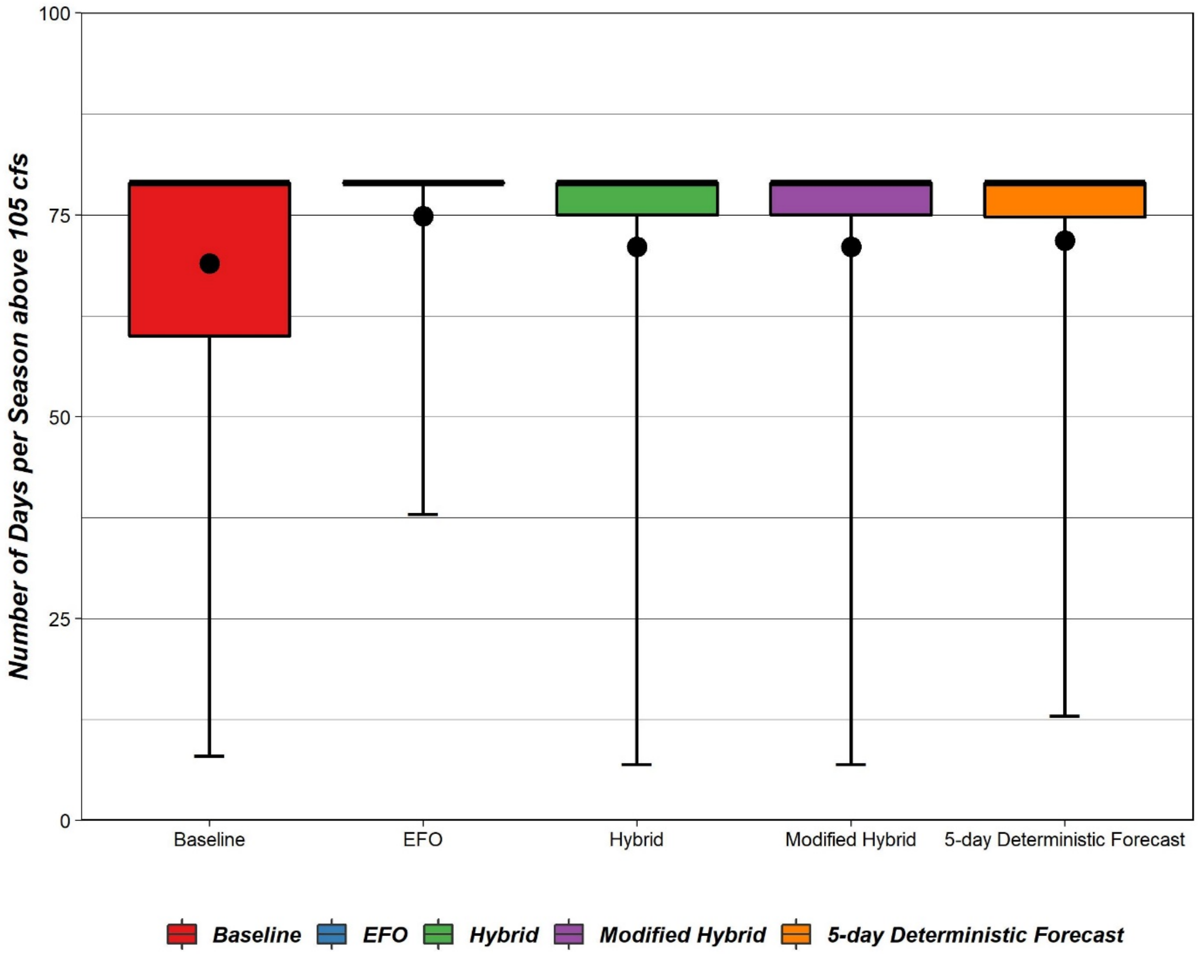


**Figure 37. Number of days per season, October 12 through January 1, in which flows exceed 105 cfs at Healdsburg – box-and-whisker plot**

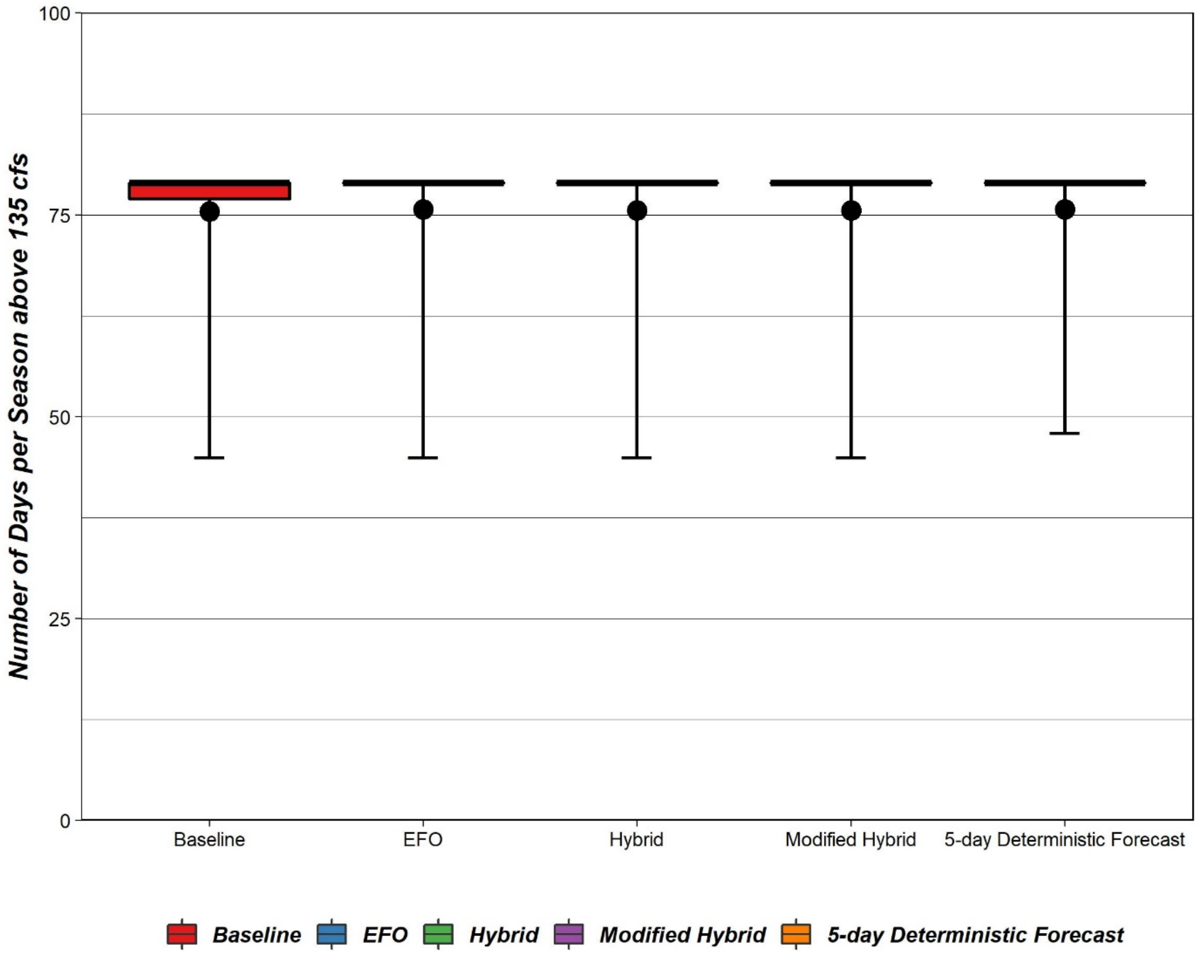


**Figure 38. Number of days per season, October 12 through January 1, in which flows exceed 135 cfs at Guerneville – box-and-whisker plot**

## Impacts to the Bushay Campground (Metric 13)

M13, presented in 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. Table 42 and Table 43 show the percent of days during which access is limited. Table 42 presents the data for a season while Table 43 presents the data for the whole calendar year. Figure 39, Figure 40 and Figure 41 show the percent of days and number of days in which the campground has limited access.

**Table 42. Percent of days per recreation season during which access to Bushay Campground is limited (pool elevation 750.0 feet is exceeded)**

| Percent Exceedance | Percent of Days per Season | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 0.68 | 1 | 0.95 | 1 | 1 |
| 0.3 | 0.25 | 0.92 | 0.68 | 0.86 | 0.85 |
| 0.4 | 0 | 0.67 | 0.33 | 0.43 | 0.38 |
| 0.5 | 0 | 0.54 | 0 | 0.29 | 0.03 |
| 0.6 | 0 | 0.41 | 0 | 0 | 0 |
| 0.7 | 0 | 0.21 | 0 | 0 | 0 |
| 0.8 | 0 | 0 | 0 | 0 | 0 |
| 0.9 | 0 | 0 | 0 | 0 | 0 |

**Table 43. Percent of days per year during which access to Bushay Campground is limited (pool elevation 750.0 feet is exceeded)**

| Percent Exceedance | Percent of Days per Year | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| 0.2 | 0.19 | 0.28 | 0.26 | 0.28 | 0.28 |
| 0.3 | 0.07 | 0.25 | 0.19 | 0.24 | 0.23 |
| 0.4 | 0 | 0.18 | 0.09 | 0.12 | 0.11 |
| 0.5 | 0 | 0.15 | 0 | 0.08 | 0.01 |
| 0.6 | 0 | 0.11 | 0 | 0 | 0 |
| 0.7 | 0 | 0.06 | 0 | 0 | 0 |
| 0.8 | 0 | 0 | 0 | 0 | 0 |
| 0.9 | 0 | 0 | 0 | 0 | 0 |

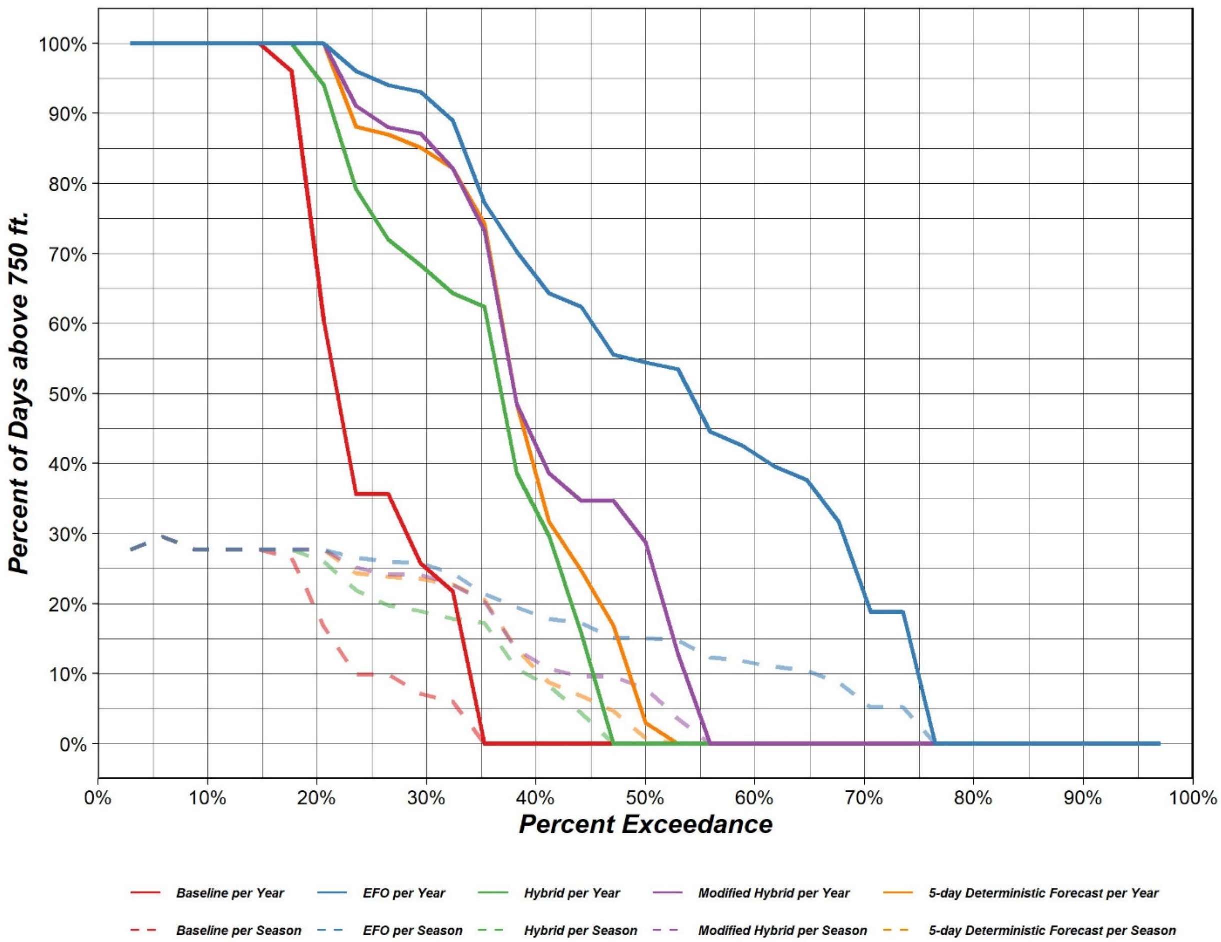


**Figure 39. Percent of days per recreation season and per year during which access to Bushay Campground is limited (pool elevation 750.0 feet is exceeded)**

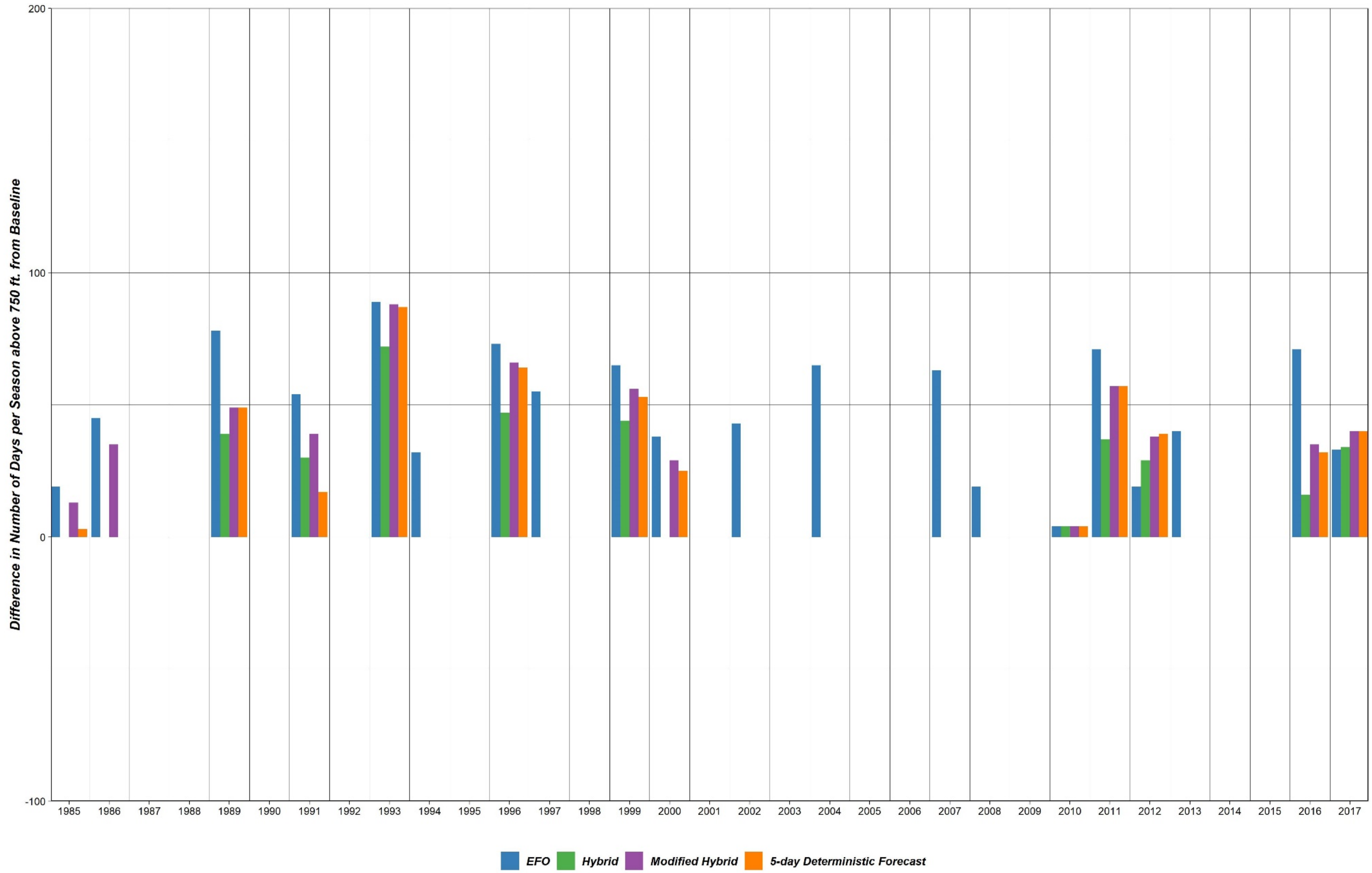


**Figure 40. Difference in number of days per recreation season during which access to Bushay Campground is limited (pool elevation 750.0 feet is exceeded) in comparison to Baseline**

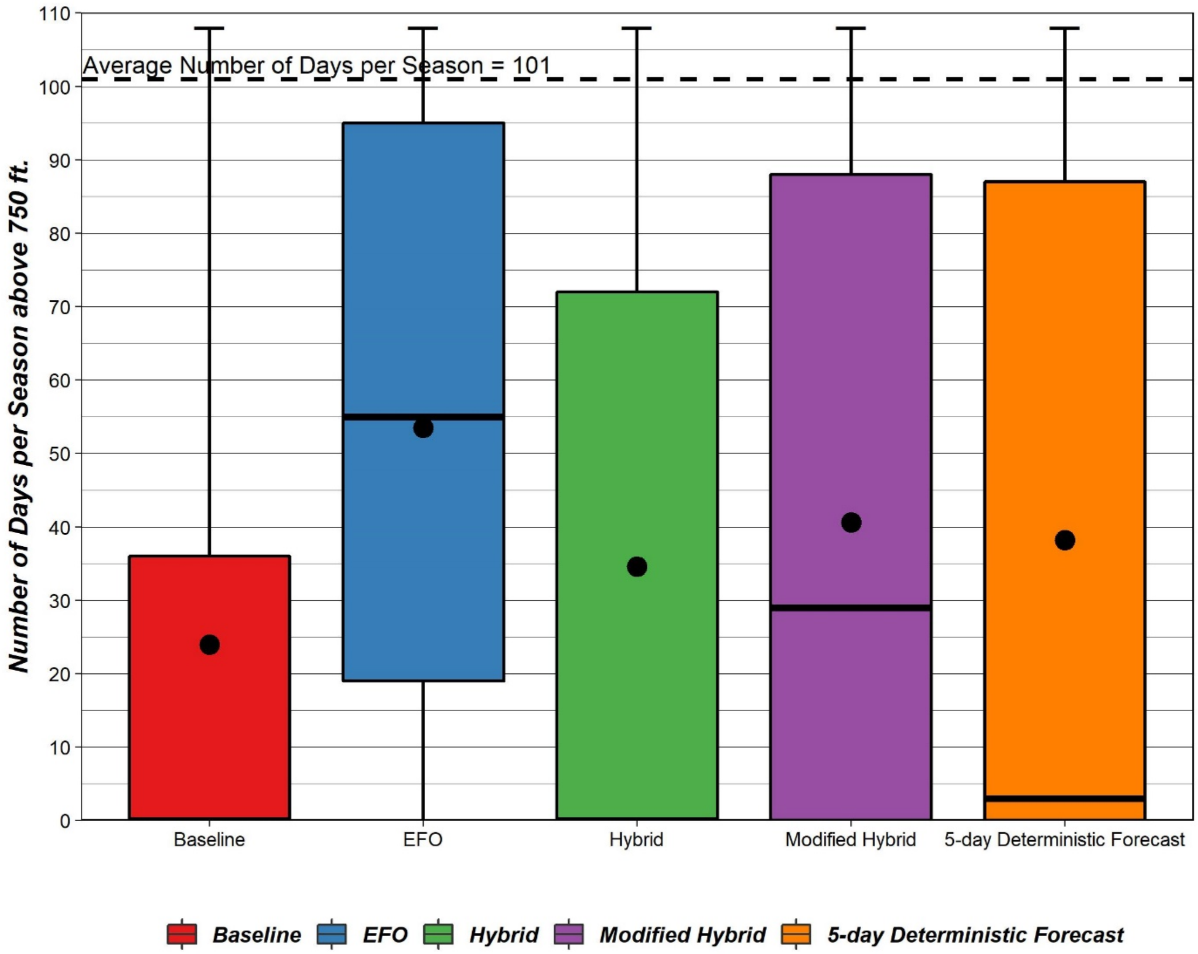


**Figure 41. Number of days per recreation season during which access to Bushay Campground is limited (pool elevation 750.0 feet is exceeded) – box-and-whisker plot**

## 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 and exceedance plots on annual power production during the calendar year, December through March, and April through November. The power production exceedance values for Lake Mendocino are shown in Table 44 through Table 46 and the exceedance plots are shown in Figure 42 through Figure 50.

**Table 44. Annual (calendar year) power production exceedance values**

| Percent Exceedance | Annual Power Production (MWh) | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 10,972 | 9,583 | 11,243 | 10,608 | 10,972 |
| 0.2 | 10,292 | 9,353 | 10,523 | 10,314 | 10,425 |
| 0.3 | 9,774 | 8,556 | 10,172 | 9,935 | 10,129 |
| 0.4 | 9,301 | 7,965 | 9,595 | 9,403 | 9,747 |
| 0.5 | 8,773 | 7,655 | 9,206 | 9,002 | 9,135 |
| 0.6 | 8,682 | 7,558 | 8,933 | 8,793 | 8,725 |
| 0.7 | 8,278 | 7,371 | 8,230 | 8,377 | 8,129 |
| 0.8 | 7,759 | 7,127 | 7,173 | 7,266 | 7,646 |
| 0.9 | 6,195 | 5,824 | 5,968 | 6,077 | 6,218 |

**Table 45. December through March power production exceedance values**

| Percent Exceedance | Power Production Dec-Mar (MWh) | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 4,480 | 3,222 | 4,650 | 4,634 | 5,163 |
| 0.2 | 3,966 | 2,994 | 4,294 | 4,175 | 4,508 |
| 0.3 | 3,765 | 2,729 | 3,867 | 3,602 | 4,117 |
| 0.4 | 3,514 | 2,621 | 3,398 | 3,222 | 3,509 |
| 0.5 | 3,310 | 1,954 | 3,246 | 3,062 | 3,216 |
| 0.6 | 2,957 | 1,840 | 2,604 | 2,563 | 2,774 |
| 0.7 | 1,910 | 1,604 | 2,071 | 2,161 | 1,993 |
| 0.8 | 1,615 | 1,436 | 1,635 | 1,691 | 1,504 |
| 0.9 | 1,131 | 1,234 | 1,284 | 1,363 | 1,447 |

### Table 46. April through November power production exceedance values

| Percent Exceedance | Power Production Apr-Nov (MWh) | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 7,320 | 7,836 | 7,636 | 7,742 | 7,611 |
| 0.2 | 7,200 | 7,605 | 7,428 | 7,563 | 7,503 |
| 0.3 | 6,932 | 7,138 | 7,149 | 7,318 | 7,226 |
| 0.4 | 6,710 | 5,922 | 6,953 | 6,406 | 6,313 |
| 0.5 | 5,669 | 5,618 | 6,278 | 5,650 | 5,744 |
| 0.6 | 5,316 | 5,219 | 5,531 | 5,556 | 5,558 |
| 0.7 | 5,097 | 4,781 | 4,885 | 4,957 | 4,967 |
| 0.8 | 4,858 | 4,298 | 4,710 | 4,739 | 4,718 |
| 0.9 | 4,365 | 3,991 | 4,439 | 4,411 | 4,360 |

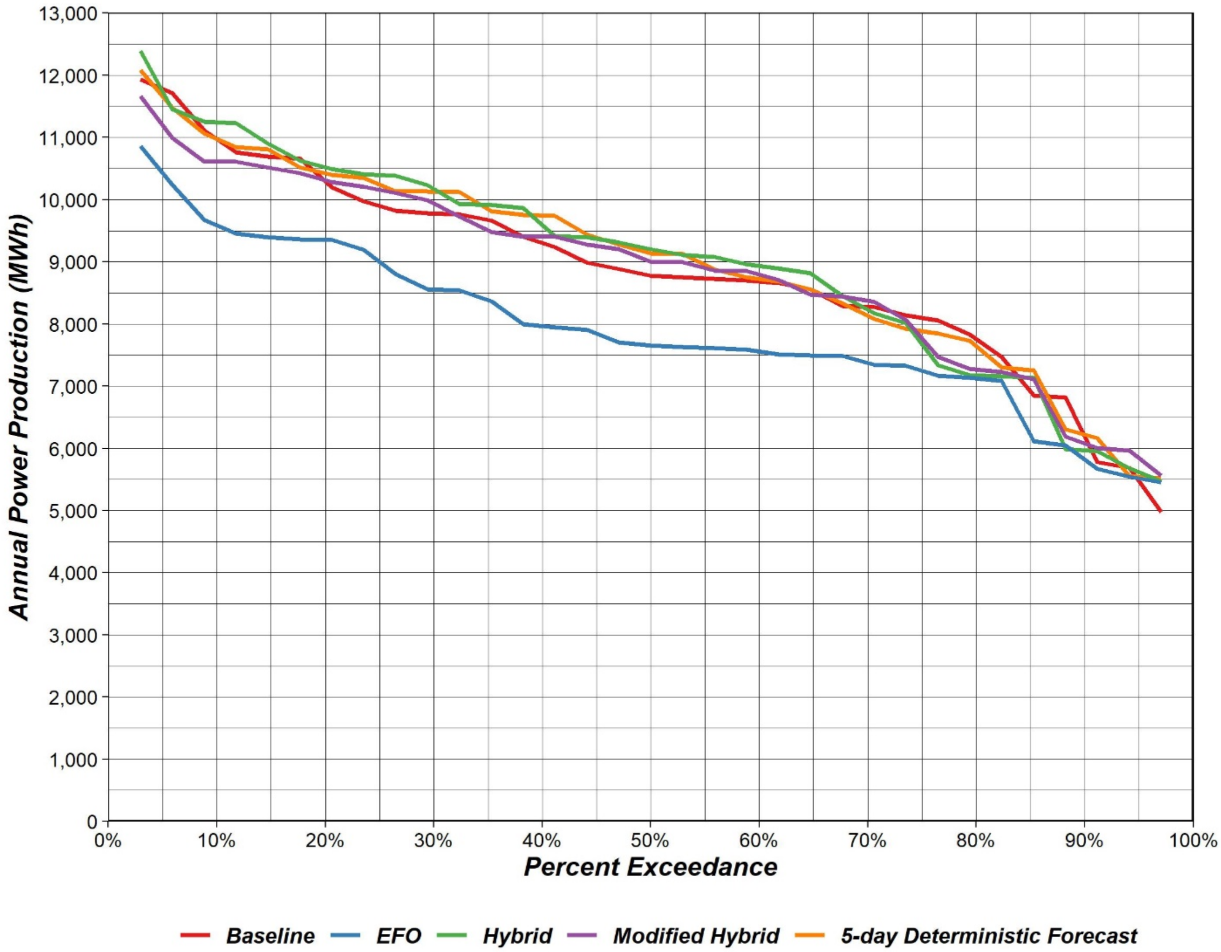


**Figure 42. Annual (calendar year) power production exceedance plot**

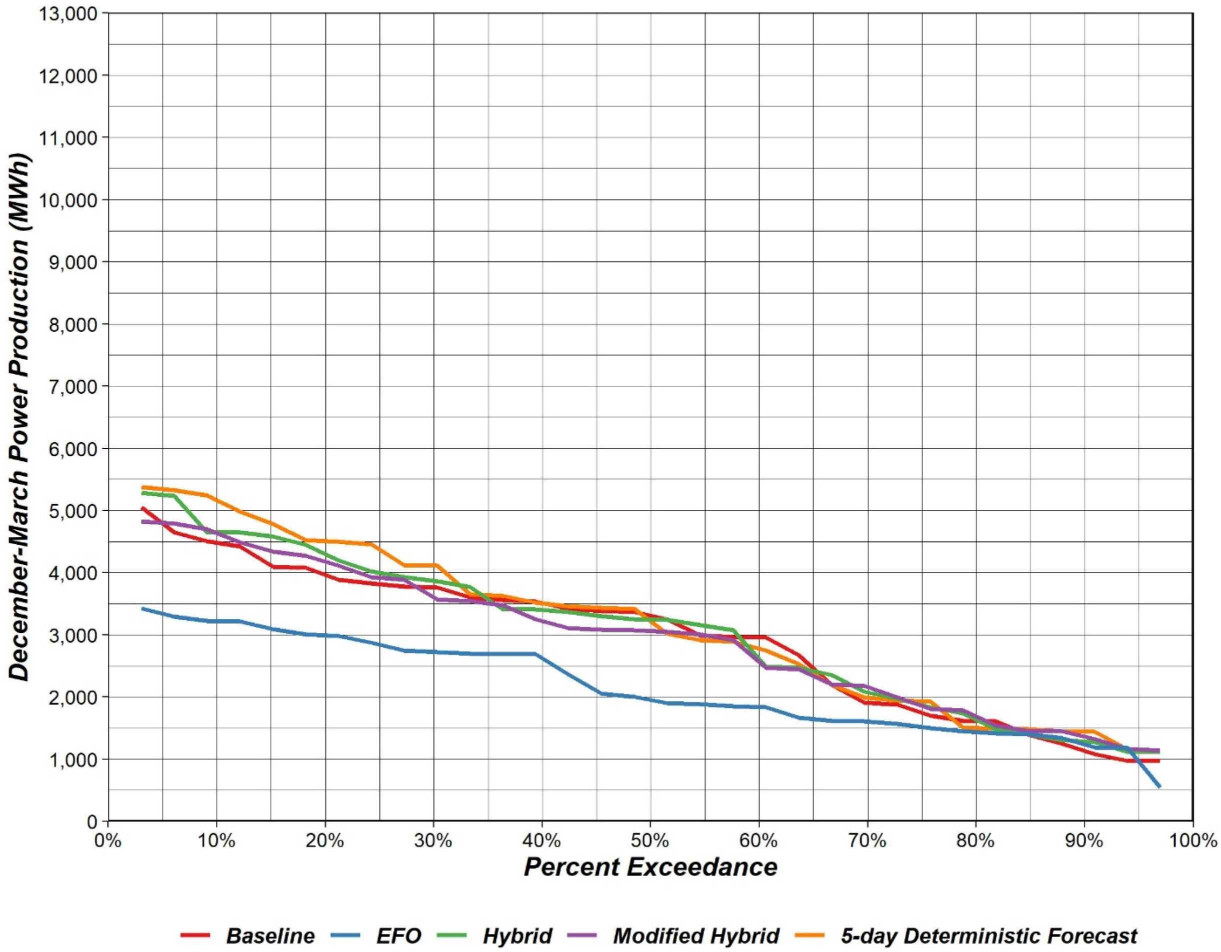


**Figure 43. December through March power production exceedance plot**

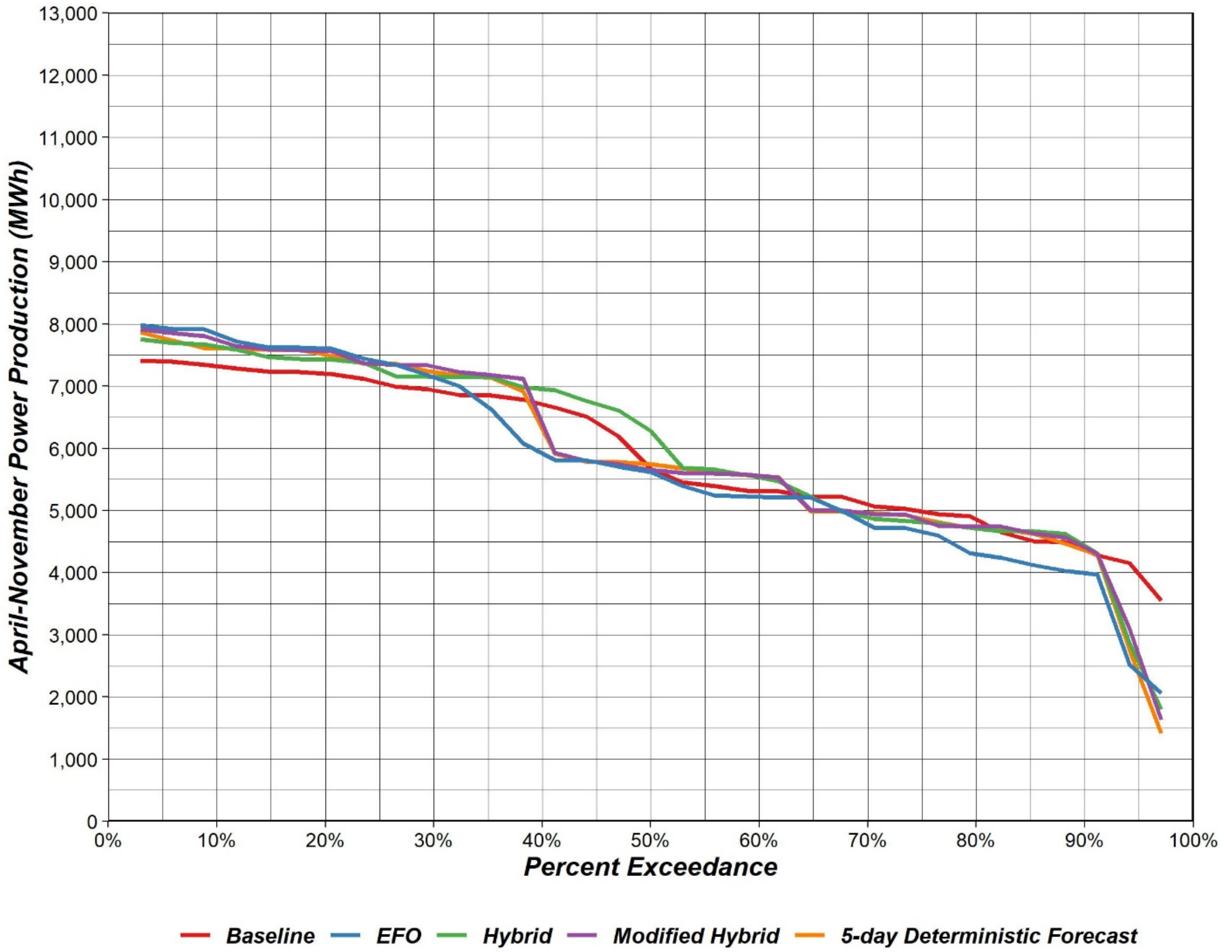


**Figure 44. April through November power production exceedance plot**

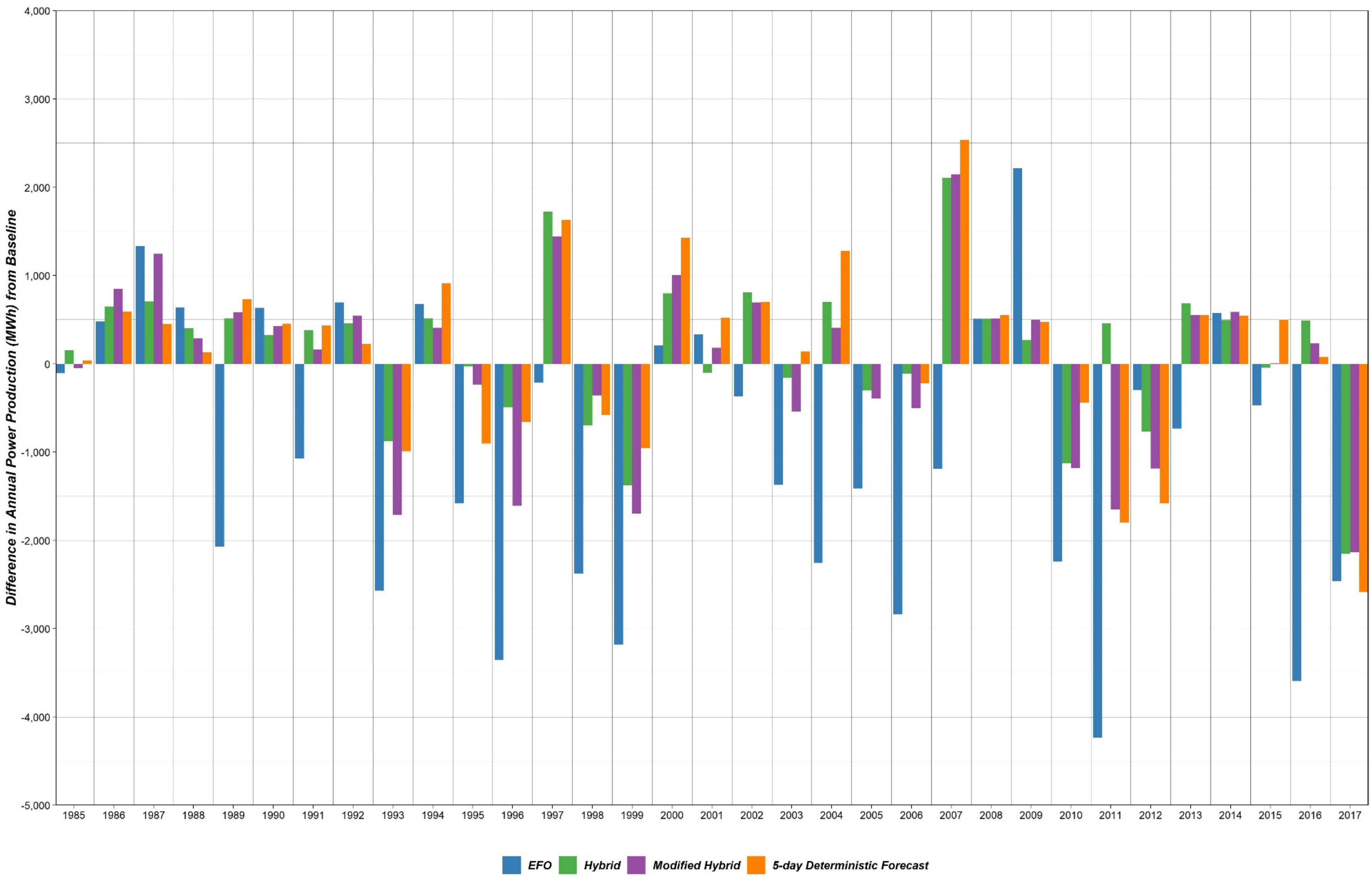


**Figure 45. Difference in annual power production in comparison to Baseline**

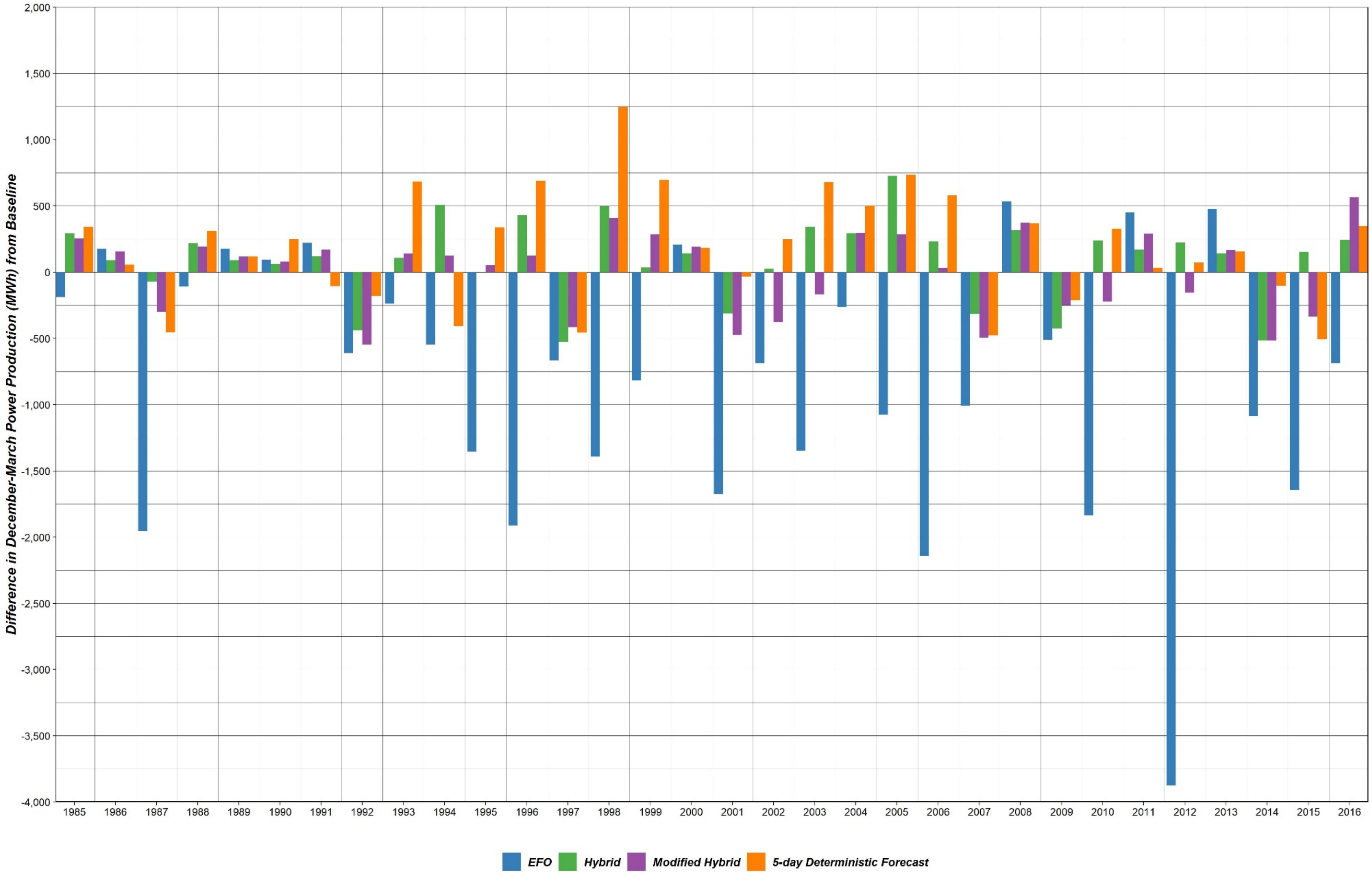


**Figure 46. Difference in December through March power production in comparison with baseline**

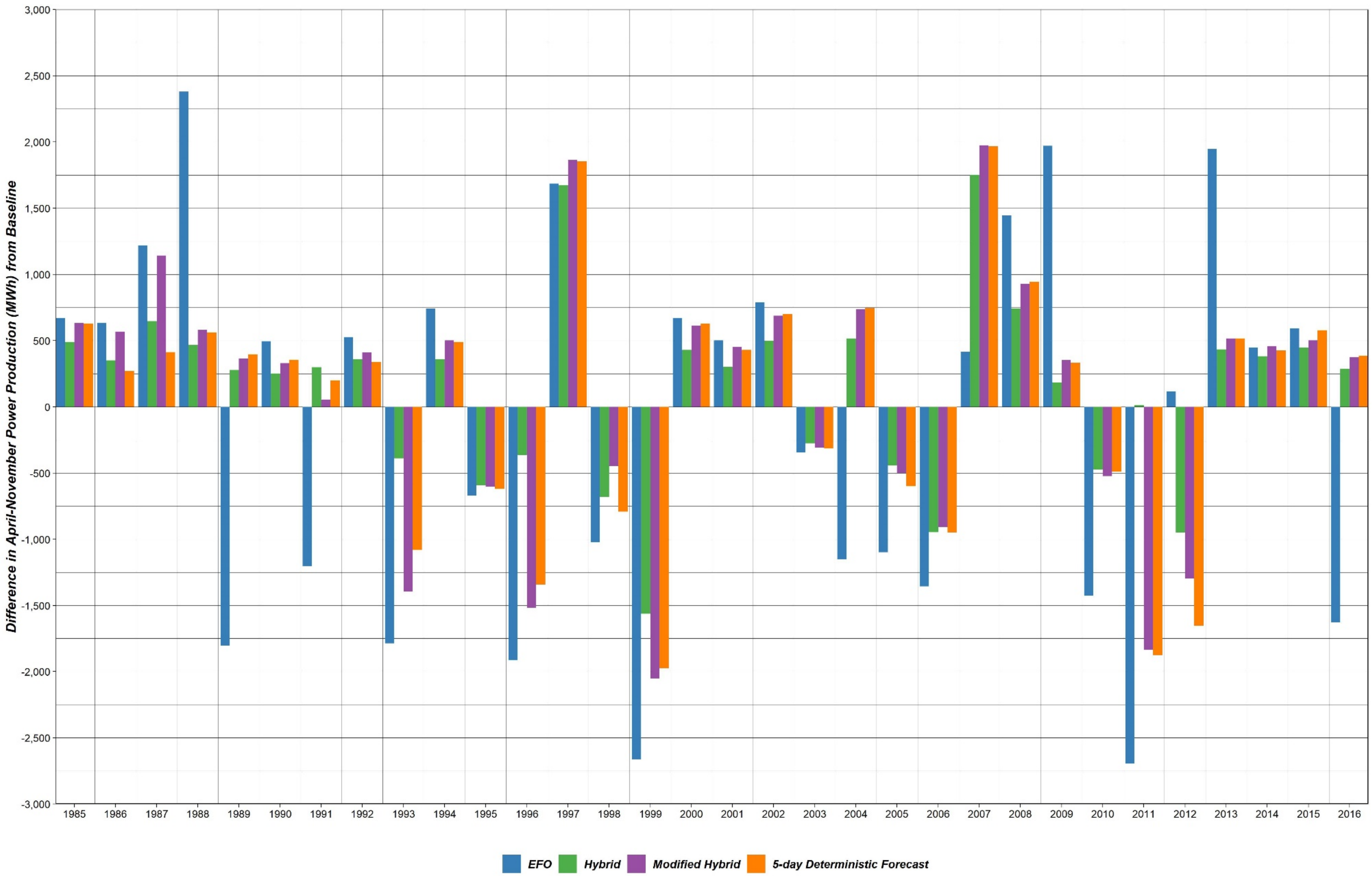


**Figure 47. Difference in April through November power production in comparison to Baseline**

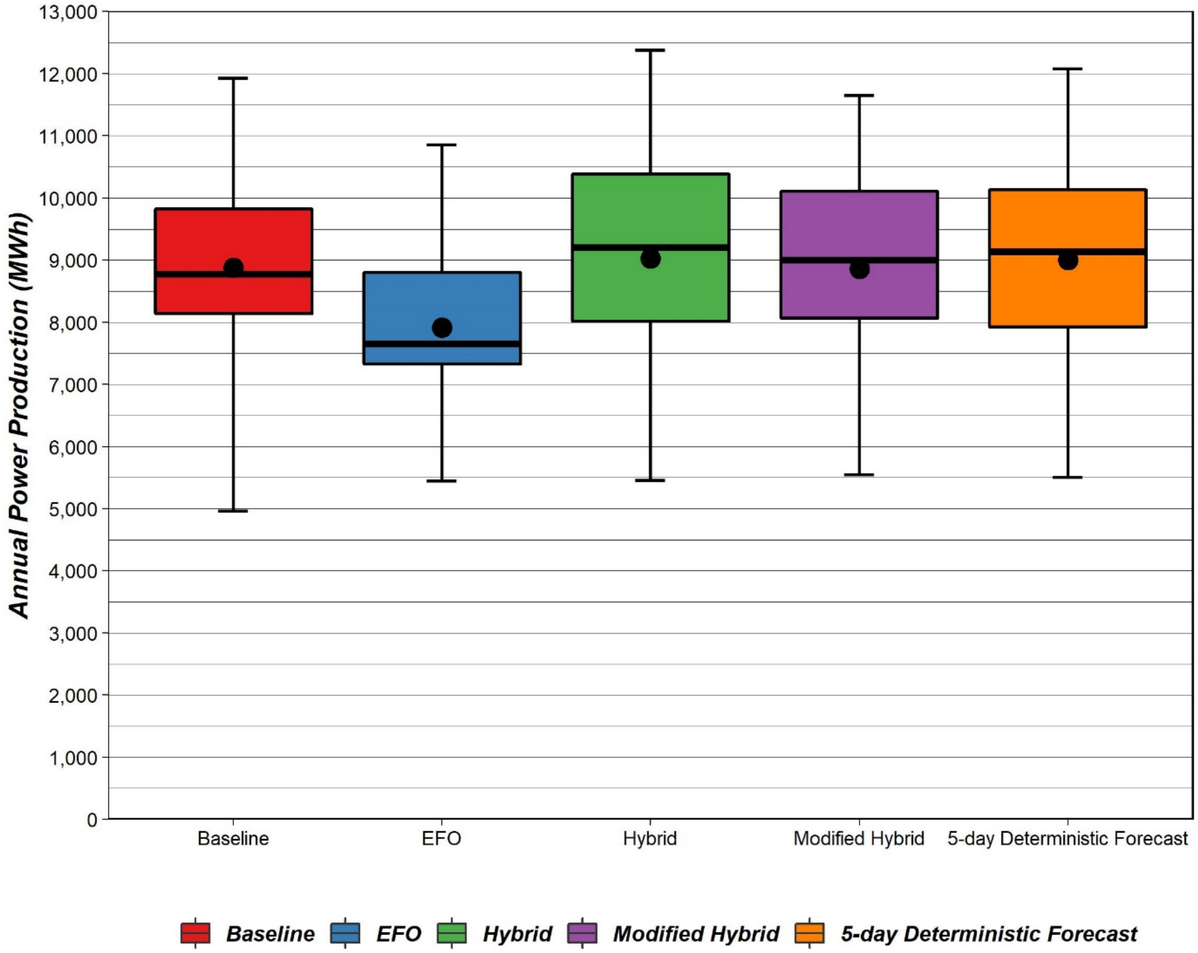


**Figure 48. Annual (calendar year) power production – box-and-whisker plot**

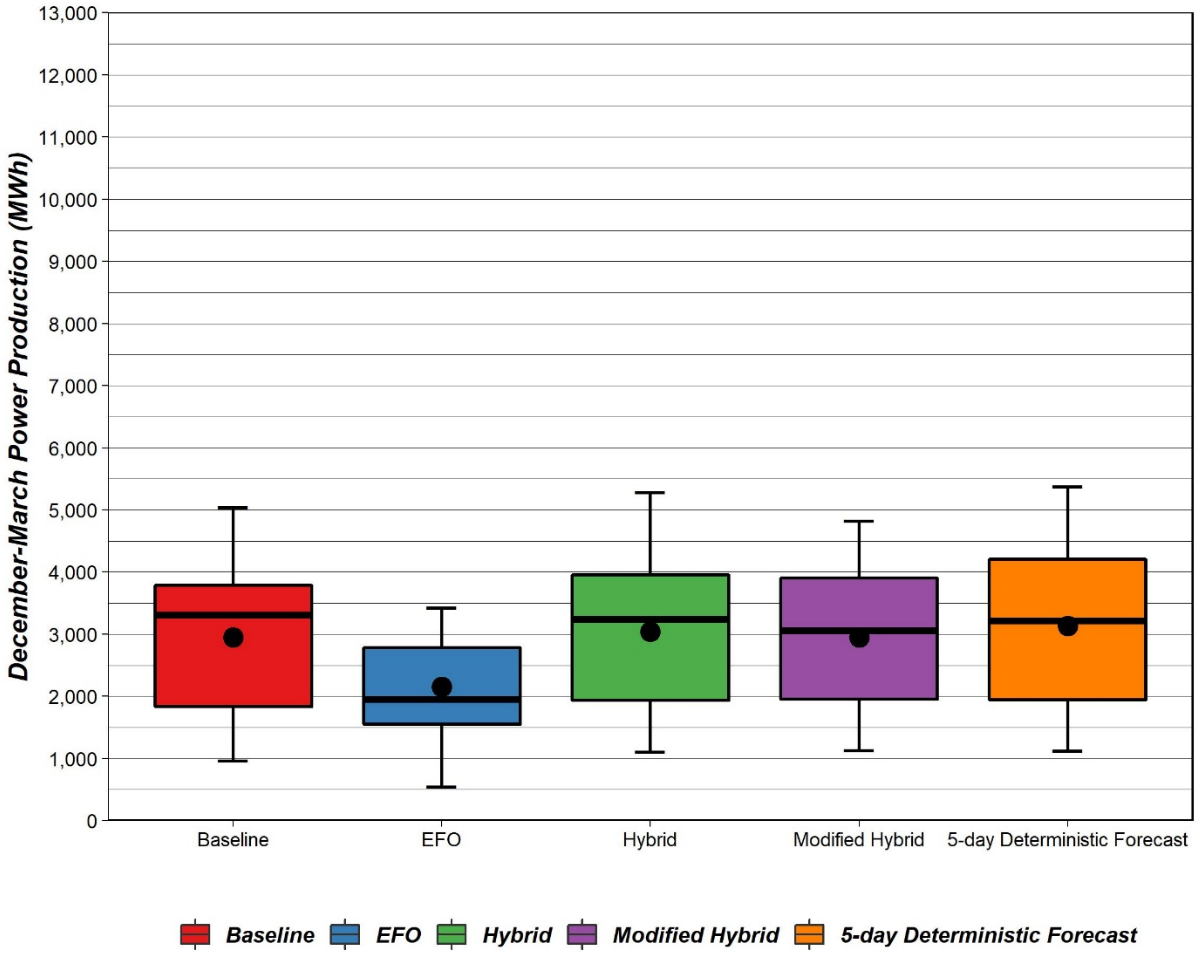


**Figure 49. December through March power production – box-and-whisker plot**

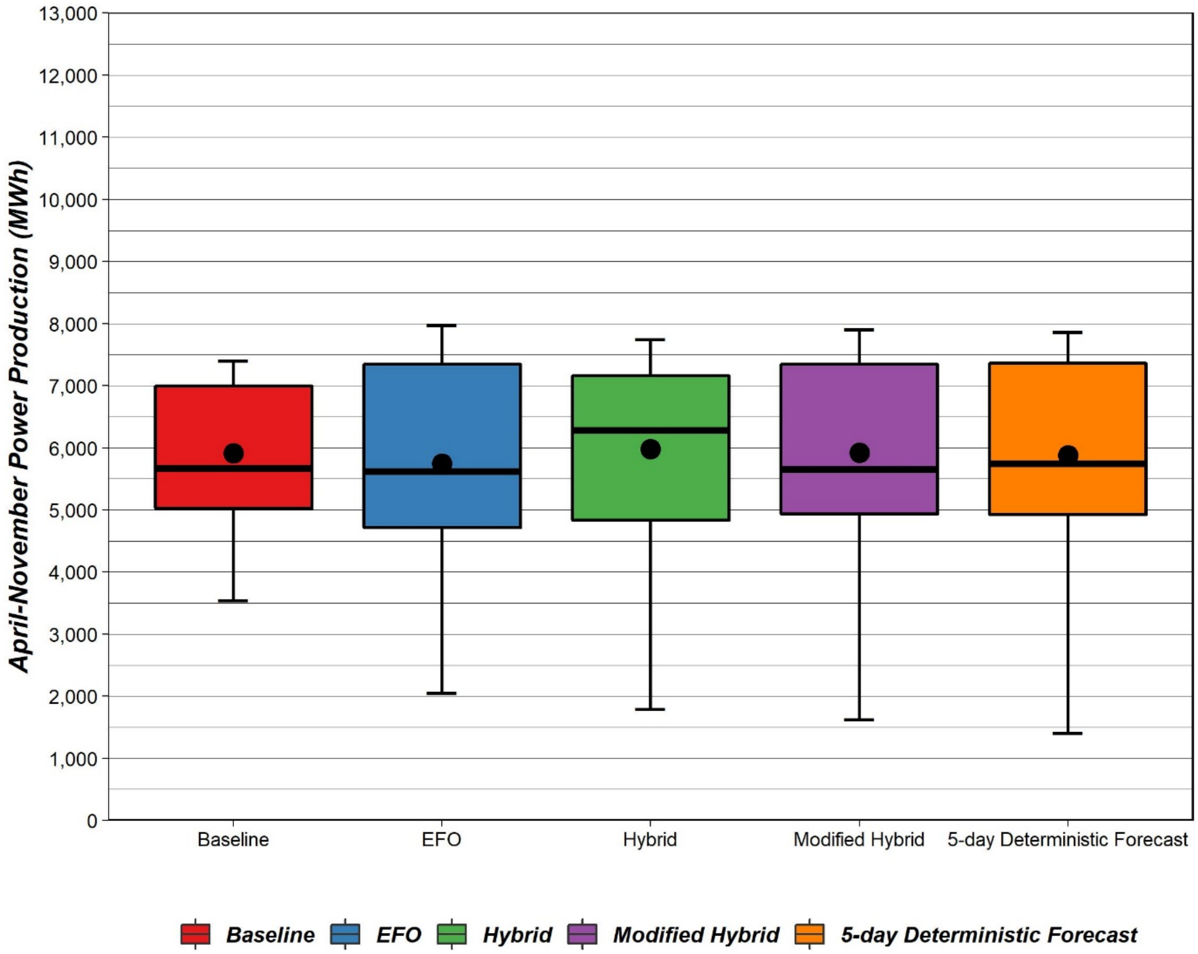


**Figure 50. April through November power production – box-and-whisker plot**

## 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 (Table 47). 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 presented in Table 48 and Figure 51.

### Table 47. Annual frequency of exceeding pool elevation 758.8 ft in Lake Mendocino

| WCP | AEP at 758.8 ft | 1/AEP |
|---|---|---|
| Baseline | 0.062 | 16 |
| EFO | 0.174 | 6 |
| Hybrid | 0.022 | 45 |
| Modified Hybrid | 0.021 | 48 |
| 5-Day Deterministic Forecast | 0.062 | 16 |

### Table 48. Annual number of days per water year exceeding pool elevation 758.8 ft in Lake Mendocino

| Percentile | Annual Number of Days per water year exceeding 758.8 ft in Lake Mendocino | | | | |
|---|---|---|---|---|---|
| | Baseline | EFO | Hybrid | Modified Hybrid | 5-Day Deterministic Forecast |
| 0.1 | 56 | 75 | 75 | 80 | 80 |
| 0.2 | 17 | 68 | 52 | 67 | 67 |
| 0.3 | 0 | 34 | 0 | 0 | 0 |
| 0.4 | 0 | 17 | 0 | 0 | 0 |
| 0.5 | 0 | 0 | 0 | 0 | 0 |
| 0.6 | 0 | 0 | 0 | 0 | 0 |
| 0.7 | 0 | 0 | 0 | 0 | 0 |
| 0.8 | 0 | 0 | 0 | 0 | 0 |
| 0.9 | 0 | 0 | 0 | 0 | 0 |

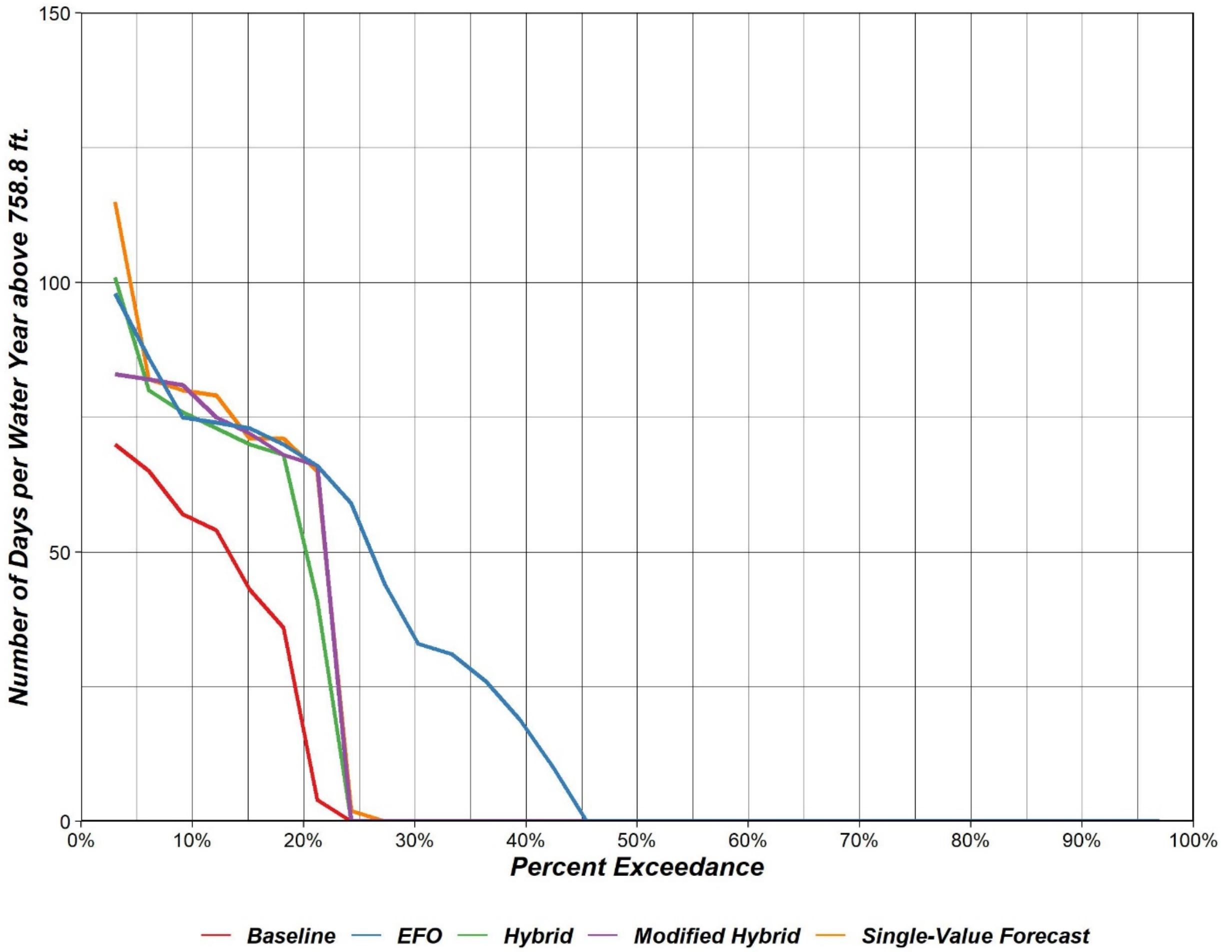


**Figure 51. Number of days per water year exceeding pool elevation 758.8 ft in Lake Mendocino**

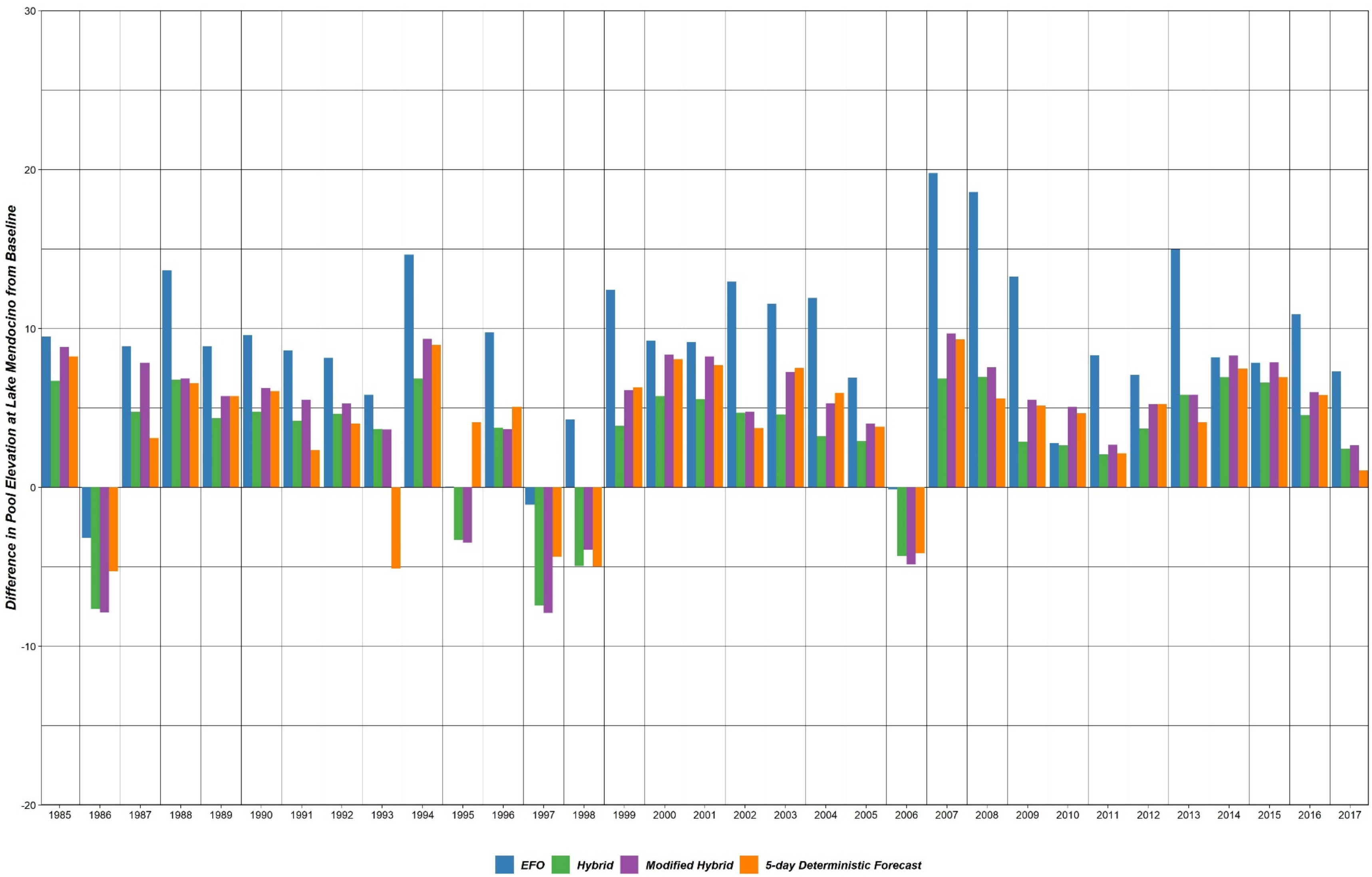


**Figure 52. Difference in Lake Mendocino pool elevation in comparison to Baseline**

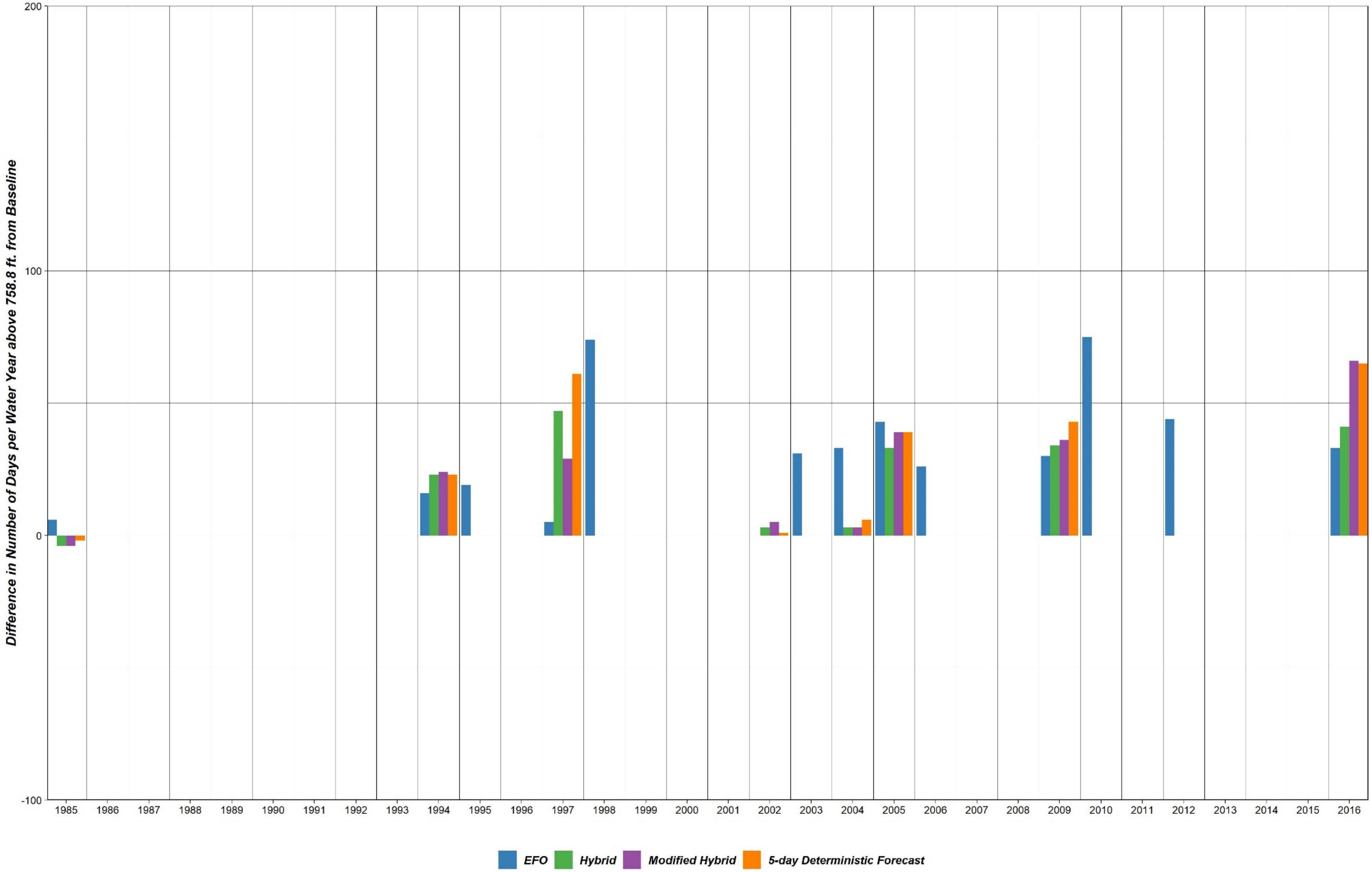


**Figure 53. Difference in number of days per water year above pool elevation 758.8 ft in comparison to Baseline**

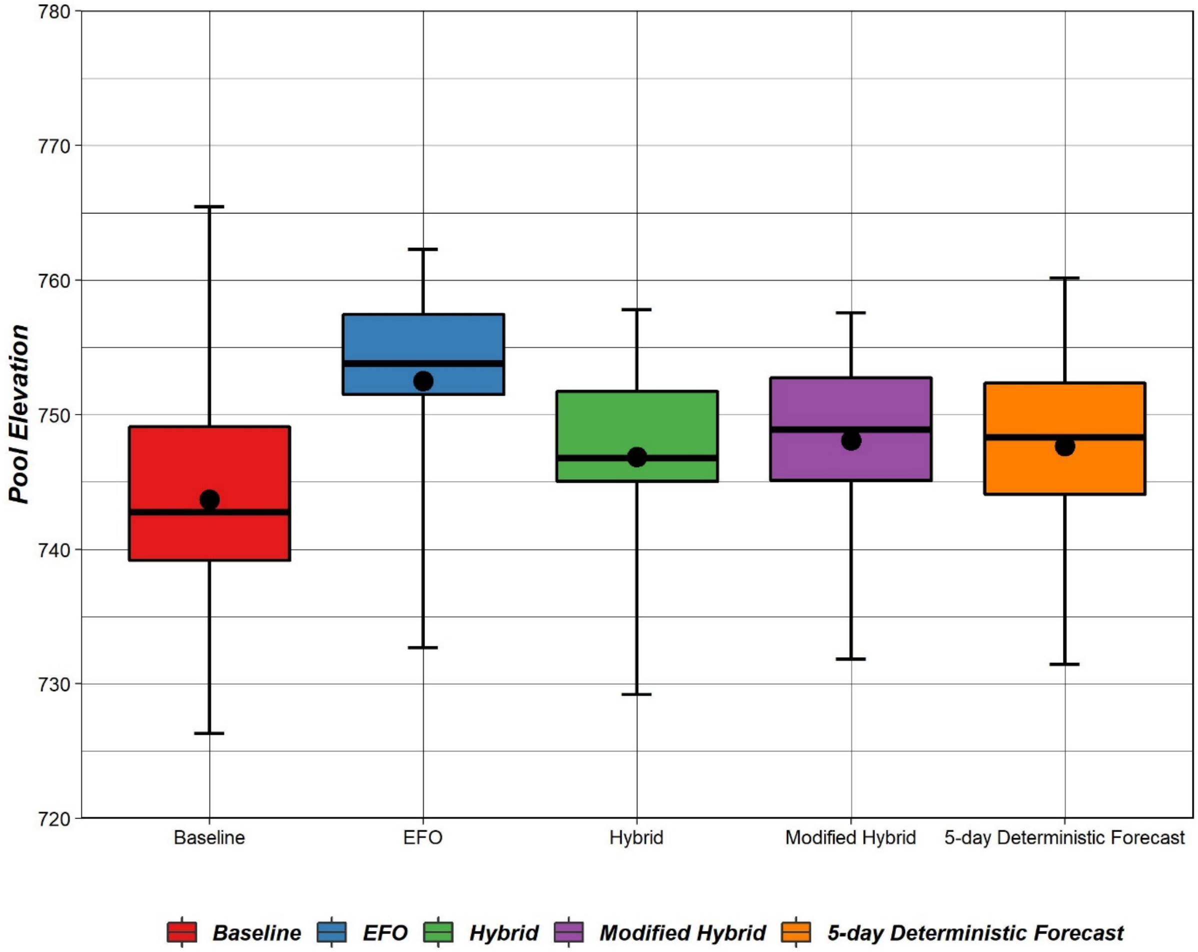


**Figure 54. Lake Mendocino pool elevation – box-and-whisker plot**

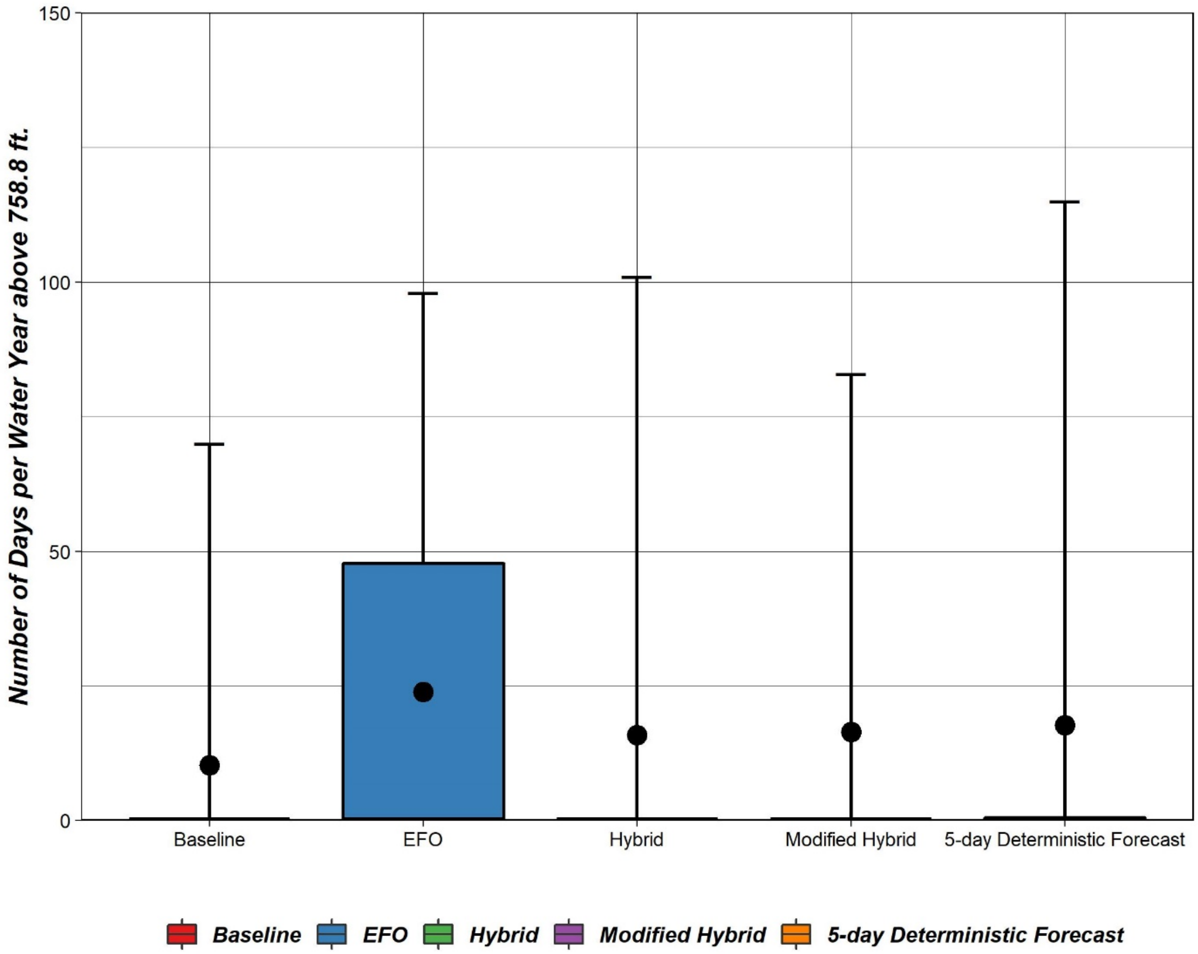


**Figure 55. Number of days per water year above pool elevation 758.8 ft**

## 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 56.

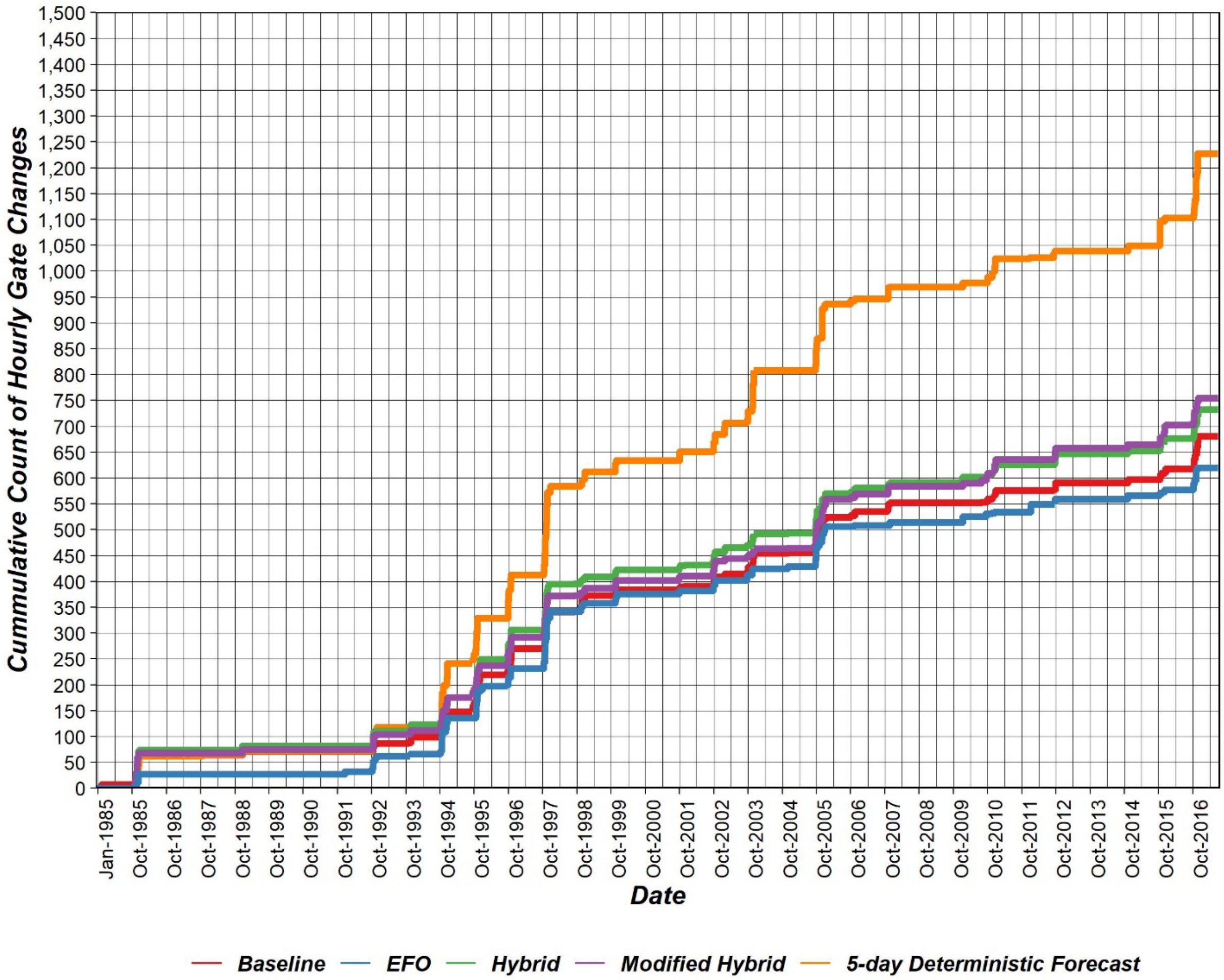


**Figure 56. Count of cumulative gate changes**

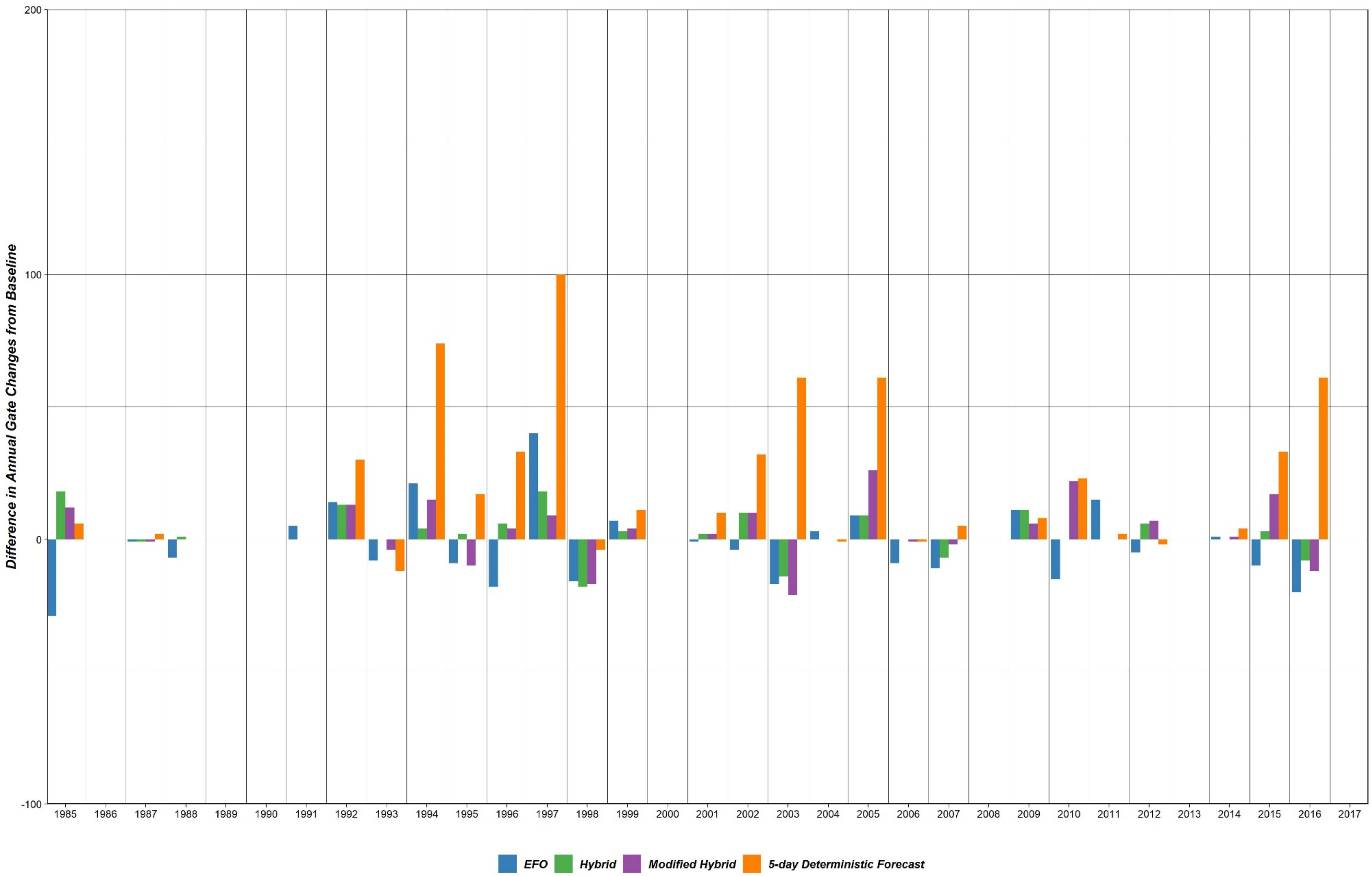


**Figure 57. Difference in annual count of hourly gate changes in comparison with Baseline**

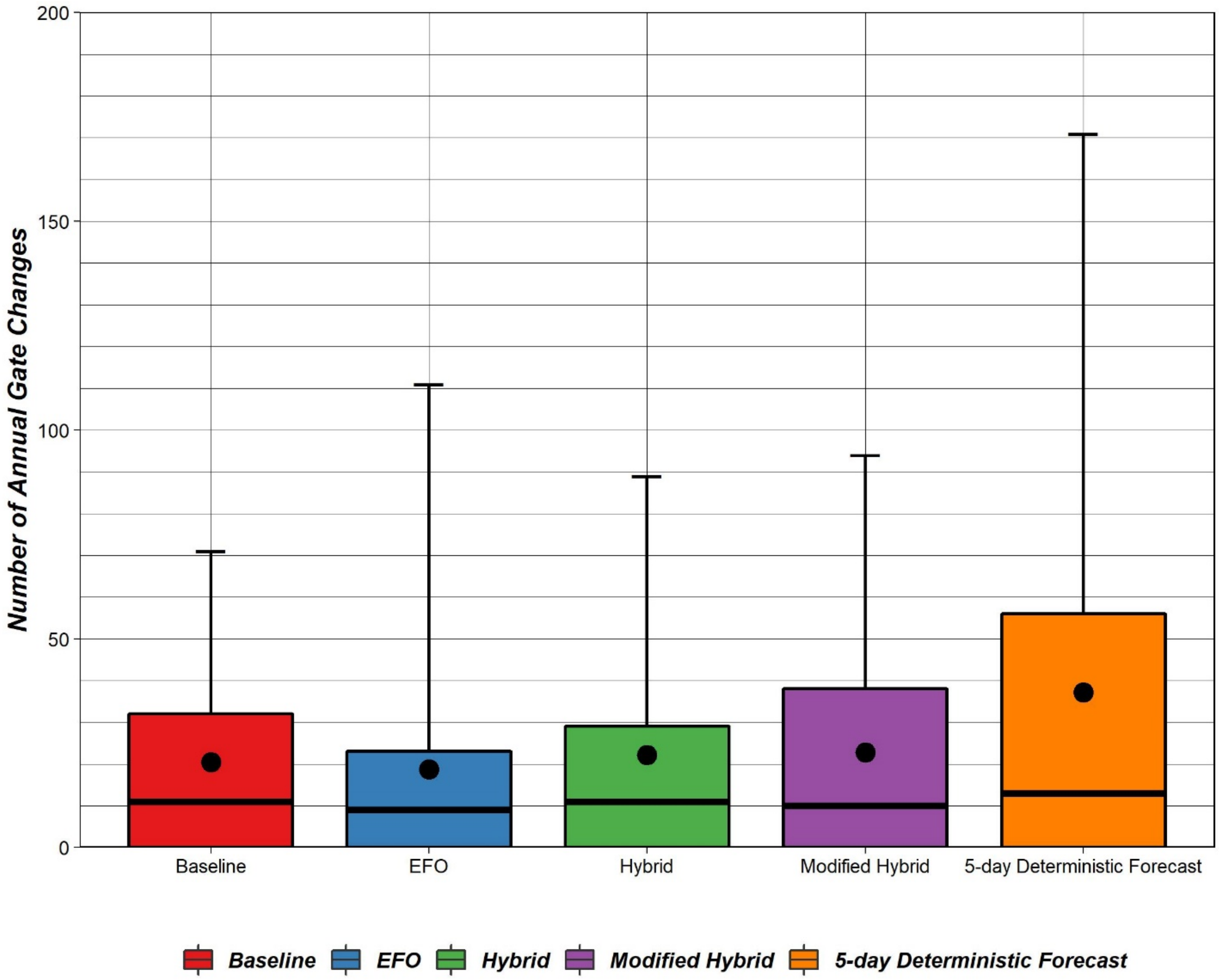


**Figure 58. Annual count of hourly gage changes**

# Key Findings

After reviewing the analysis results for these 16 metrics, we identified 8 key findings:

- The annual frequency and magnitude of uncontrolled spills at Lake Mendocino are reduced for all FIRO WCPs as shown in Figure 8 and Table 17.
- The annual flow frequency quantiles at Hopland for events less frequent than the p=0.5 (1/2-yr) event are generally the same (within 1% of baseline) and decrease by up to 5% from baseline for the p=0.002 (1/500-yr) event for all FIRO WCPs as shown in Figure 2 and Table 4.
- The total EAD and EAP values for the Russian River are generally the same (within 1% of baseline) and may decrease slightly for all FIRO WCPs as shown in Table 31 and Table 32 However, we did find that EAD values for all WCPs along the reach from Hopland to Cloverdale showed slight (within 2%) increases from baseline. This increase in total EAD is because of increased damages to non-residential structures for specific events simulated. EAP values for this reach are generally the same (within 1%). Similarly, the reach including Dry Creek shows slightly (within 4%) increased EAD values for this reason. In addition, the 5-day Deterministic Forecast alternative shows slight (less than 1%) increases in total EAD for the reaches of Santa Rosa and Monte Rio for the same reason.
- The water supply reliability—as measured by the median ($50^{th}$ percentile exceedance) of May 10 storage—increases for all FIRO WCPs as shown in Figure 12.
- The ability to meet instream flows for rearing or spawning habitat generally increases for all for all FIRO WCPs as exemplified in Figure 15 through Figure 38.
- All FIRO WCPs would negatively impact the ability to access Bushay Campground during the recreation season (Memorial Day to Labor Day) as shown in Figure 41.
- City of Ukiah hydropower generation increases slightly (~4%) for the Hybrid, Modified Hybrid, and 5-day Deterministic Forecast WCPs, and decreases by 13% for the EFO WCP as shown in Figure 48.
- There are no impacts on Lake Sonoma operations as shown in Figure 10.

# Performance summary

We ranked the performance of each WCP for the 16 metrics to understand better the information within the evaluated metrics. For several metrics, the process was complicated by multiple locations and WCP performance within the most important range of the frequency distributions. Table 49 lists the criteria we used to rank the metrics. Additionally, differences within 1% of each other were considered to be generally the same performance and thus given the same rank. In addition, we grouped the metrics into the following 4 categories (as listed in column 3 of Table 49):

- Flood risk management
- Water supply and environmental outcomes
- Recreation, power production, and staffing impacts

- Impacts to Lake Sonoma operations

Table 50 through Table 53 list the categorized rankings of each WCP by metric; color-coding them to display a "heat map" of performance.

**Table 49. Summary of methods to rank WCP by metric**

| Metric | Ranking method | Category |
|---|---|---|
| M1 | Average ranking of (1) flow quantiles in the tail of the distribution [p=0.01 through p=0.002), (2) the expected value [p=0.5], and (3) AEP of the flood flow at each location averaged across all locations. | Flood risk management |
| M2 | Average ranking of (1) flow quantiles in the tail of the distribution [p=0.01 through p=0.002) and (2) the expected value [p=0.5]. | Flood risk management |
| M3 | Average ranking of (1) flow quantiles in the tail of the distribution [p=0.01 through p=0.002) and (2) the expected value [p=0.5]. | Impacts to Lake Sonoma operations |
| M4 | Average ranking of (1) flow quantiles in the tail of the distribution [p=0.01 through p=0.002) and (2) the expected value [p=0.5]. | Flood risk management |
| M5 | Average ranking of (1) flow quantiles in the tail of the distribution [p=0.01 through p=0.002) and (2) the expected value [p=0.5]. | Impacts to Lake Sonoma operations |
| M6 | Average ranking of (1) flow quantiles in the tail of the distribution [p=0.01 through p=0.002) and (2) the expected value [p=0.5]. | Flood risk management |
| M7 | Average ranking of (1) flow quantiles in the tail of the distribution [p=0.01 through p=0.002) and (2) the expected value [p=0.5]. | Impacts to Lake Sonoma operations |
| M8 | Rank of difference in total EAD from baseline. | Flood risk management |
| M9 | Rank of difference in total EAP from baseline. | Flood risk management |
| M10 | Ranking of storage median (50%) exceedance values. | Water supply and environmental outcomes |
| M11 | Ranking of 75% of period exceedance values at each location averaged across all locations. | Water supply and environmental outcomes |
| M12 | Ranking of 75% of period exceedance values at each location averaged across all locations. | Water supply and environmental outcomes |
| M13 | Ranking of median (50%) number of days for which access to Bushay Campground is limited. | Recreation, power production, and staffing impacts |
| M14 | Ranking of median (50%) annual power production. | Recreation, power production, and staffing impacts |
| M15 | Ranking of mean number of days for which elevation 758.8 ft is exceeded annually. | Recreation, power production, and staffing impacts |
| M16 | Average ranking of the mean number of gate changes by water year from baseline. | Recreation, power production, and staffing impacts |

### Table 50. Summary of rankings: flood risk management metrics

| Rank of WCP alternative by flood risk management metrics | | | | | |
|---|---|---|---|---|---|
| Metric ID | Baseline | EFO | Hybrid | Modified Hybrid | 5-day deterministic forecast |
| M1 | 5 | 1 | 3 | 1 | 4 |
| M2 | 3 | 5 | 1 | 1 | 4 |
| M4 | 5 | 3 | 2 | 1 | 4 |
| M6 | 5 | 4 | 1 | 1 | 3 |
| M8 | 1 | 1 | 1 | 1 | 1 |
| M9 | 1 | 1 | 1 | 1 | 1 |
| **Average** | **3.3** | **2.5** | **1.5** | **1.0** | **2.8** |

### Table 51. Summary of rankings: Water supply and environmental outcomes metrics

| Rank of WCP alternative by water supply and environmental metrics | | | | | |
|---|---|---|---|---|---|
| Metric ID | Baseline | EFO | Hybrid | Modified Hybrid | 5-day deterministic forecast |
| M10 | 5 | 1 | 4 | 2 | 3 |
| M11 | 5 | 1 | 2 | 2 | 2 |
| M12 | 5 | 1 | 4 | 2 | 3 |
| **Average** | **5.0** | **1.0** | **3.3** | **2.0** | **2.7** |

### Table 52. Summary of rankings: Recreation, power production, and staffing impacts

| Rank of WCP alternative by recreation, power, dam safety, and operations metrics | | | | | |
|---|---|---|---|---|---|
| Metric ID | Baseline | EFO | Hybrid | Modified Hybrid | 5-day deterministic forecast |
| M13 | 1 | 5 | 1 | 4 | 3 |
| M14 | 4 | 5 | 1 | 1 | 1 |
| M15 | 1 | 5 | 2 | 2 | 4 |
| M16 | 2 | 1 | 3 | 4 | 5 |
| **Average** | **2.00** | **4.00** | **1.75** | **2.75** | **3.25** |

### Table 53. Summary of rankings: Impacts to Lake Sonoma operations

| Rank of WCP alternative by Lake Sonoma flood risk management metrics | | | | | |
|---|---|---|---|---|---|
| Metric ID | Baseline | EFO | Hybrid | Modified Hybrid | 5-day deterministic forecast |
| M3 | 1 | 1 | 1 | 1 | 1 |
| M5 | 1 | 1 | 1 | 1 | 1 |
| M7 | 1 | 1 | 1 | 1 | 1 |
| **Average** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** |

# References

United States Army Corps of Engineers (USACE 2013) HEC-ResSim Reservoir System Simulation User's Manual Version 3.1, May 2013.

United States Army Corps of Engineers (USACE 2016b) HEC-RAS River Analysis System User's Manual Version 5.0, February 2016.

FIRO Steering Committee (2019) Hydrologic engineering management plan (HEMP) for Lake Mendocino Forecast-informed Reservoir Operation (FIRO) evaluation of water control plan alternatives within the final viability assessment (FVA) Version 3.0, August 1,2019

FIRO Steering Committee (2017) Preliminary viability of Lake Mendocino forecast informed reservoir operations. June 25, 2017.