Chapter 4

Testing Maintenance Draw-Down Alternatives

4.1 Draw-Downs for Dam Maintenance

Up to this point in the study, all model runs were made without considering the need to draw down the reservoir periodically to allow maintenance inspections. The remaining alternatives implement a draw-down scheme that lowers the water surface elevation to 1,100 feet to allow inspection and/or maintenance of Alamo Dam's outlet works. The BWRCTC tested alternatives for draw-down based on a fixed interval such as five, ten, or fifteen years. The draw-down scheme tested in the HEC-5 models started gradually lowering the water surface target in June, eventually reaching 1,100 feet in October or November to allow inspection and/or maintenance. The draw-down of the lake to 1,100 feet causes negative impacts on the evaluation criteria values. Based on the variability of inflows evident in the hydrologic record, a more flexible draw-down interval may have less negative impact on the evaluation criteria.

4.2 Proposed Flexible Draw-Down Strategy

For testing purposes, an assumption was made that would allow inspections to take place every three to eight years with a goal to achieve an average frequency of five years. Decisions for draw-down are tied to actual lake conditions and the time since the last inspection. Two different draw-down events are described: low-level draw-down and forced draw-down. If the water surface elevation is low following the historical rainy-season, then that year is a natural candidate for draw-down because storage in the lake is already low and the draw-down would have minimal incremental impact. If, however, an inspection has not been made for the last seven years, a draw-down will be made in the eighth year regardless of lake level.

The following strategy was used:

If the number of years since last inspection is >2 and < 8 then check for a low storage level in September.
If water surface elevation <= 1,105 feet between September 1 and September 15 then check average frequency of inspections updated for an inspection this year.
If average period between inspections updated for this year is > 4.8 then implement low level draw-down release rule.

Else if the number of years since last inspection is = 8 then implement forced draw-down release rule.

Details for the low level draw-down release rule and the forced draw-down release rule are presented in Appendix E. The forced draw-down release rule tries to utilize any surplus water to make the largest spring season pulse flow possible in April. The proposed draw-down scheme was tested for two different operating rules: Updated Base Condition - PFE and OBA 3G. The Updated Base Condition - PFE represents the BWRCTC recommended rule modified to sustain pulse flows greater than 1,000 cfs for at least 7 days, and OBA 3G represents the rule based on the optimization results.

4.3 Performance Improvements

The flexible interval draw-down release rule performs better than the fixed interval rule on many of the criteria. As expected, the alternatives with draw-down perform worse on many of the storage related criteria than the same alternatives without draw-down. Table 4.1 is a summary of the evaluation criteria values for the HEC-5 Base Case alternative with regular five year draw-downs (BWRCTC A1125D05) and the Updated Base Case - PFE and OBA 3G alternatives with and without draw-down. The performance index values in Figure 4.1 show that the flexible draw-down strategy performs better than the fixed interval draw-down on both storage and flow related evaluation criteria overall. Figure 4.2 compares evaluation criteria values for the HEC-5 Base with 5 year draw-down and the Updated Base Case - PFE with flexible draw-down. Figure 4.2 shows that the flexible draw-down performs better for recreation and shows a split for wildlife. The flexible draw-down alternative does better for lake fishery objectives, especially for F4 (maximum water surface drop, in feet, June through September). Results for stream fishery objectives are split between the alternatives. Figure 4.2 shows that the flexible draw-down strategy performs markedly better for riparian objectives, especially on pulse flows (RA6 and RA7).

The reservoir pool elevation time series for the HEC-5 Base with 5 year draw-down (A1125D05) and the Updated Base Case - PFE with flexible draw-down are compared in Figure 4.3. Eleven draw-downs were performed using the flexible draw-down strategy for an average period between draw-downs of 5.6 years. Table 4.2 contains a summary of the draw-down events for the Updated Base Case - PFE with flexible draw-down. The purpose of testing a flexible draw-down interval was to try and reduce the negative impacts of draw-down associated with the variable desert hydrology. If the water level in the reservoir can be used to help decide when to perform the draw-downs, overall reservoir performance should be improved. The evaluation criteria values discussed above confirm this is true, and the time series comparisons illustrate how this takes place. Conditions during 1968 to 1978 (Figure 4.3) dramatically show how scheduling draw-downs according to reservoir condition can provide benefits. Under the flexible draw-down strategy, almost ten years of extended periods of low storage levels experienced using the 5 year draw-down interval are avoided by not drawing down the reservoir at the beginning of drought periods.

Furthermore, under the flexible draw-down strategy, if a low storage level does not occur within the maximum allowable time between inspections, the water in the reservoir that must be

Table 4.1 Impacts from Draw-Down on Evaluation Criteria

	Alternative				
Criteria	HEC-5 Base Case with 5 yr Draw-Down	Updated Base - PFE without Draw-Down	Updated Base - PFE with Flex Draw-Down	OBA 3G without Draw-Down	OBA 3G with Flex Draw-Down
RE1 (%)	96.7	99.5	99.6	99.5	99.6
RE2 (%)	90.5	95.4	95.2	95.3	94.6
RE3 (%)	49.0	65.8	60.0	65.7	58.8
RE4.1 (%)	34.9	45.9	40.6	47.6	42.1
RE5 (%)	0.2	0.2	0.2	0.1	0.1
RE6 (%)	4.7	3.3	3.4	2.7	3.0
RE7.1 (%)	41.0	48.7	43.0	51.6	45.7
WC1 (af)	53,463	52,728	53,129	52,802	53,241
WC2 (af)	15,844	16,971	16,622	16,949	16,576
FC1 (#)	0	0	0	0	0
FC2 (%)	0.0	0.0	0.0	0.0	0.0
W1 (%)	69.2	80.4	77.8	80.4	77.5
W2 (#)	11	14	13	13	12
W3 (#)	11	13	12	12	11
F1.1 (%)	43.9	57.7	51.9	59.4	53.2
F2 (%)	4.6	4.5	5.4	3.2	4.2
F3 (%)	27.1	26.7	27.6	25.1	25.8
F4 (ft)	20.0	8.1	9.4	8.1	11.0
F5 (cfs)	72.0	56.0	58.0	56.0	59.0
F6 (cfs)	137.0	144.0	143.0	144.0	143.0
F7 (%)	19.0	15.5	15.9	14.8	15.2
RA1 (%)	51.3	50.4	49.6	49.5	48.7
RA2 (%)	69.5	80.4	77.8	80.4	77.5
RA3 (%)	59.6	78.0	73.3	78.0	73.1
RA4 (%)	70.3	81.8	79.6	81.7	79.4
RA5 (%)	61.2	80.6	78.7	80.6	78.1
RA6 (%)	12	22	21	22	21
RA7 (%)	16	22	25	23	26

Note: Gray cells indicate that lower values are preferred.

RE1 - % of time WSE at or above 1090'
RE2 - % of time WSE at or above 1094'
RE3 - % of time WSE at or above 1108'
RE4 - % of time WSE between 1115' and 1125'
RE4.1 - % of time WSE between 1115' and 1125.1'
RE5 - % of time WSE between 1144' and 1154'
RE6 - % of time Outflow between 300 and 7,000 cfs
RE7 - % of time in March thru May WSE between 1115' and 1125'
RE7.1 - % of time in March thru May WSE between 1115' and 1125.1'
WC1 - Avg annual delivery of water to Lake Havasu
WC2 - Avg. annual evaporation in ac-ft for simulation period
FC1 - No. of days WSE above 1171.3' during simulation period
FC2 - Max percent of flood control space used during simulation period
W1- % of time WSE at or above 1100'
W2- No. of times during the year that WSE exceeds 1135' two or more consecutive days
W3 - No. of times from 1 Dec thru 30 Jun that WSE exceeds 1135' two or more consecutive days

F1 - % of time WSE between 1110' and 1125'
F1.1 - % of time WSE between 1110' and 1125.1'
F2 - % of time in Mar thru May WSE fluctuates more than 2" per day
F3 - % of time in 15 Mar thru May WSE fluctuates more than 0.5" per day
F4 - Max WSE drop, in feet, in Jun thru Sep for simulation period
F5 - Avg. Daily release during Jun thru Sep
F6 - Avg. Daily release during Oct thru May
F7 - % of time stream flows at BW Refuge equal or exceed 25 cfs
RA1 - % of time stream flows at BW Refuge equal or exceed 18 cfs
RA2 - % of time WSE between 1100' and 1171.3'
RA3 - % of time Alamo releases >= 25 cfs in Nov thru Jan
RA4 - % of time Alamo releases >= 40 cfs in Feb thru Apr and Oct
RA5 - % of time Alamo releases >= 50 cfs in May thru Sep
RA6 - Total no. of occurrences that Alamo releases >= 1,000 cfs seven or more consecutive days in Nov thru Feb
RA7 - Total no. of occurrences that Alamo releases >= 1,000 cfs seven or more consecutive days in Mar thru Oct

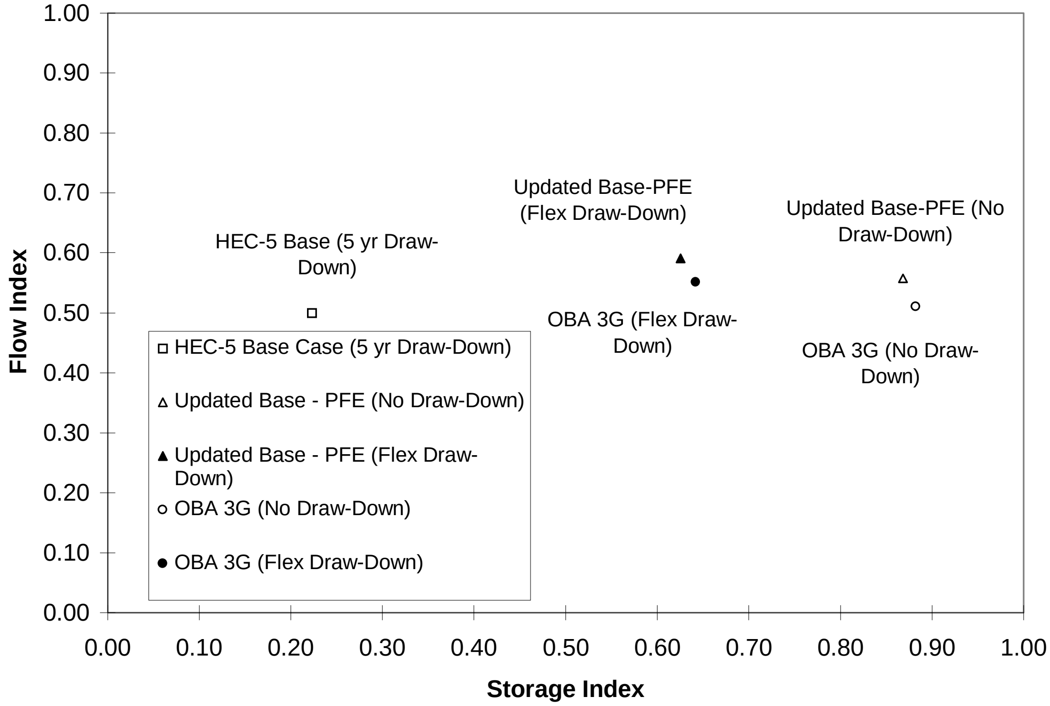

Figure 4.1 Performance Indexes for Alternatives with Draw-Down

evacuated is scheduled to provide spring flushing flows deemed to be important to long term vitality of the riparian corridor (BWRCTC 1994). Figure 4.4 shows releases during 1935 (one of the four years in which a forced draw-down was performed under the flexible draw-down strategy). Since a draw-down had not been performed within the last eight years of the simulation, the model forces a draw-down in 1935 even though the reservoir level is not low. Since there is surplus water, the model calculates how much water is available and makes a spring flushing flow release according to the guidelines in the *Proposed Water Management Plan* (BWRCTC 1994), retaining enough water to make desired releases from April to November. (See Appendix E for details.)

Comparing exceedance probabilities for reservoir pool elevation and Alamo Dam releases also show that the flexible draw-down scheme provides significant benefits. Figure 4.5 has exceedance curves for reservoir pool elevations for the fixed five year draw-down and the flexible draw-down strategy. At the 90% exceedance the water surface elevation for the five year interval alternative is 1,094 feet (meaning that the reservoir pool elevation is at or above 1,094 feet 90 percent of the days simulated). The flexible draw-down plan exceeds 1,096 feet 90% of the time, two feet higher than the fixed draw-down interval. Also, note that the fixed draw-down interval is below 1,100 feet 27% of the days simulated, and the flexible draw-down alternative is below 1,100 feet only 21% of the days simulated. This means that the flexible draw-down alternative is able to keep reservoir levels above the minimum level requested for bald eagle forage purposes (BWRCTC 1994) 6% more often (about 4 years more). At the 50% exceedance

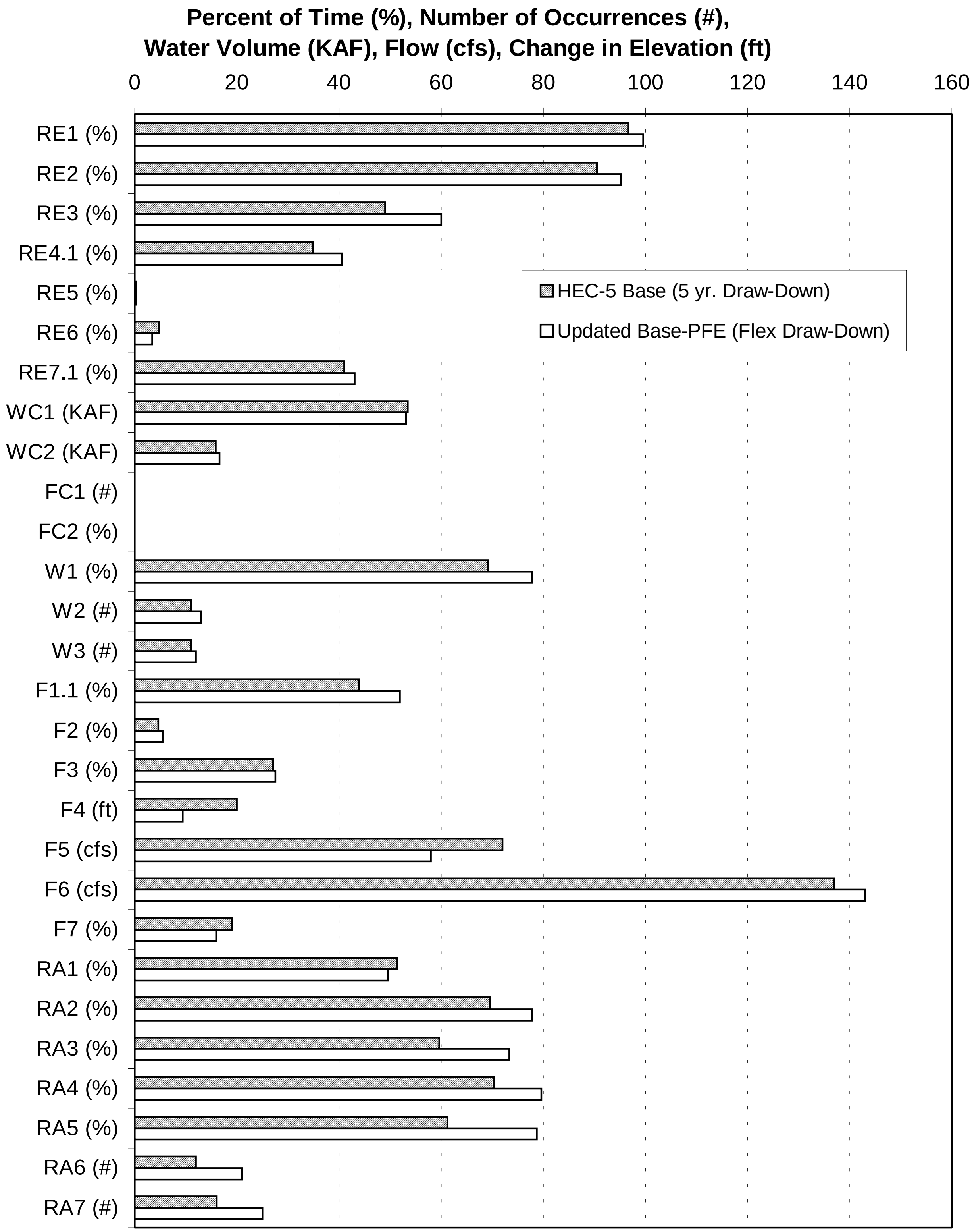

Figure 4.2 Evaluation Criteria: 5 Year vs Flexible Draw-Down

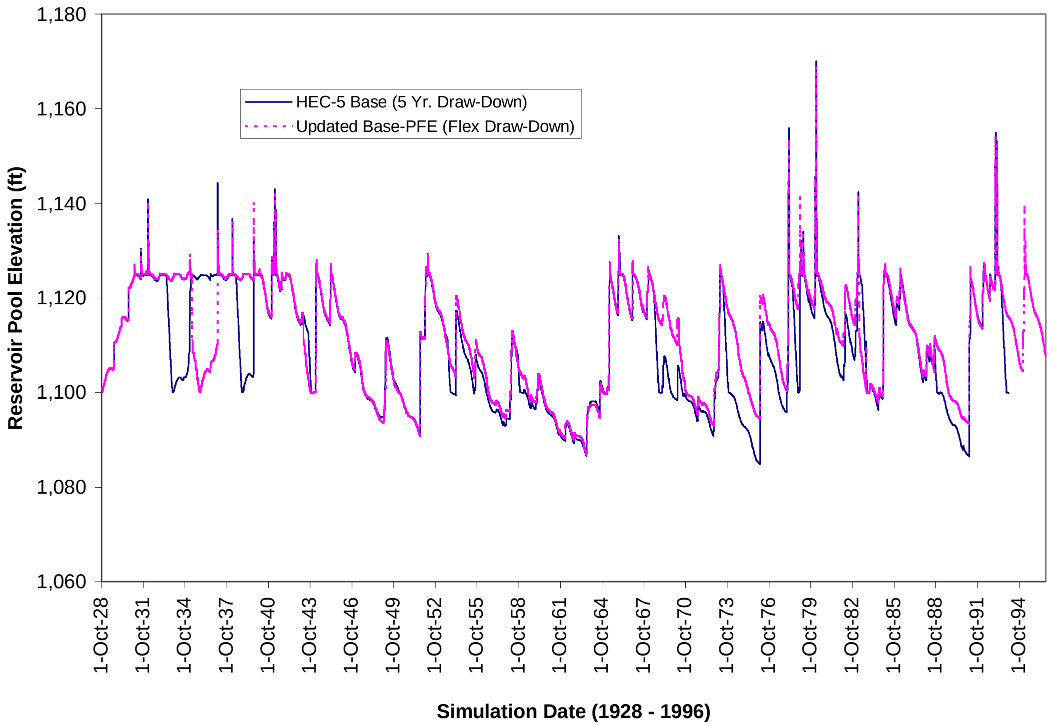

Figure 4.3 Reservoir Pool Elevation Time Series: 5 Yr. vs Flexible Draw-Down

Table 4.2 Summary of Draw-Downs for Updated Base Case-PFE (Flexible Draw-Down)

Draw-Down Type	Year	Number of Years Between Draw-Downs
Forced	1935	8
Forced	1943	8
Low level	1947	4
Low level	1950	3
Low level	1956	6
Low level	1959	3
Low level	1962	3
Forced	1970	8
Low level	1975	5
Forced	1983	8
Low level	1989	6

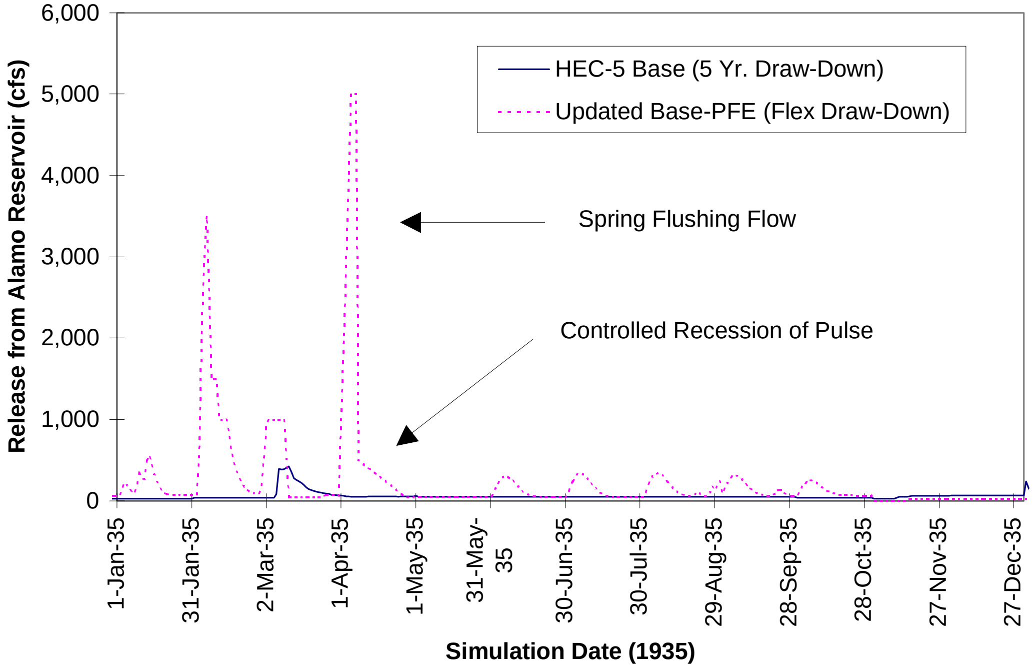

Figure 4.4 Spring Pulse Flow Resulting from Forced Draw-Down

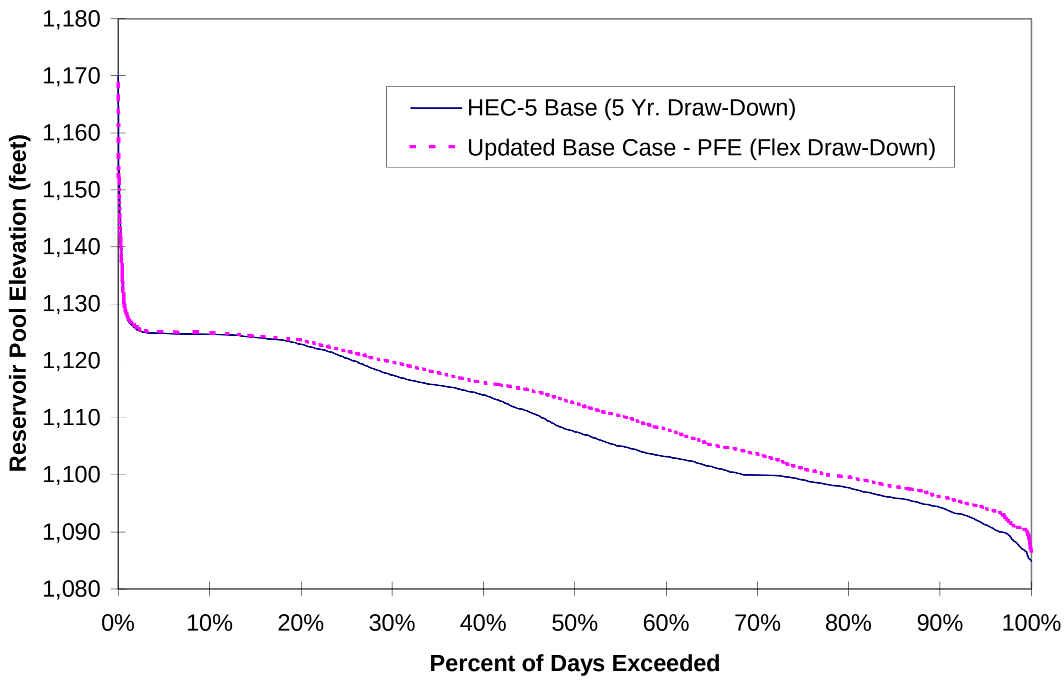

Figure 4.5 Elevation Exceedance Probabilities: 5 Year vs Flex Draw-Down

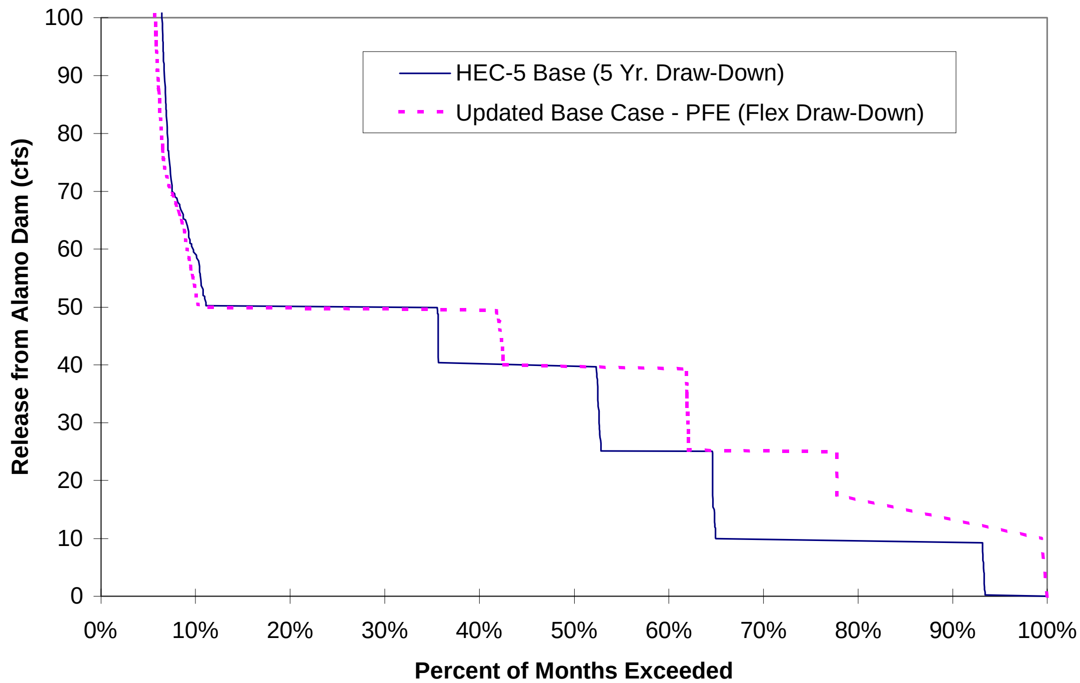

Figure 4.6 Release (< 100 cfs) Exceedance Probabilities: 5 Year vs Flex Draw-Down

level, the flexible draw-down scheme is at 1,113 feet and the fixed draw-down alternative is at 1,107 feet, six feet lower than the flexible draw-down alternative.

Exceedance probabilities for releases from Alamo Dam also help demonstrate the benefits of the flexible draw-down approach. Figure 4.6 compares the probability of exceeding releases below 100 cfs for the two draw-down alternatives. Note that under both alternatives, releases are below 100 cfs over 95% of the time. In general, the flexible draw-down strategy does significantly better maintaining desired flows for riparian objectives. The flexible draw-down alternative makes releases of 25 cfs or higher 78% of the time and 50 cfs 42% of the time whereas the fixed draw-down alternative can only meet or exceed these releases 65% and 36% of the time respectively.

The exceedance curves for releases below 25 cfs also are quite different. Statistics for releases below 25 cfs are not included in any of the evaluation criteria, but are likely to be important in comparing operational strategies. Observe that the flexible draw-down alternative is able to make releases at or above 10 cfs over 99 % of the time as compared to only 65 % of the time for the fixed draw-down alternative. The exceedance curves also suggest that the fixed interval draw-down makes no release (0 cfs) about 7% of the days whereas the flexible draw-down alternative makes no release less than 1% of the time. This large difference in the amount of time when no water is released from Alamo Dam between the alternatives appears to be due largely to the way draw-downs are implemented in the BWRCTC HEC-5 Alamo model. In the

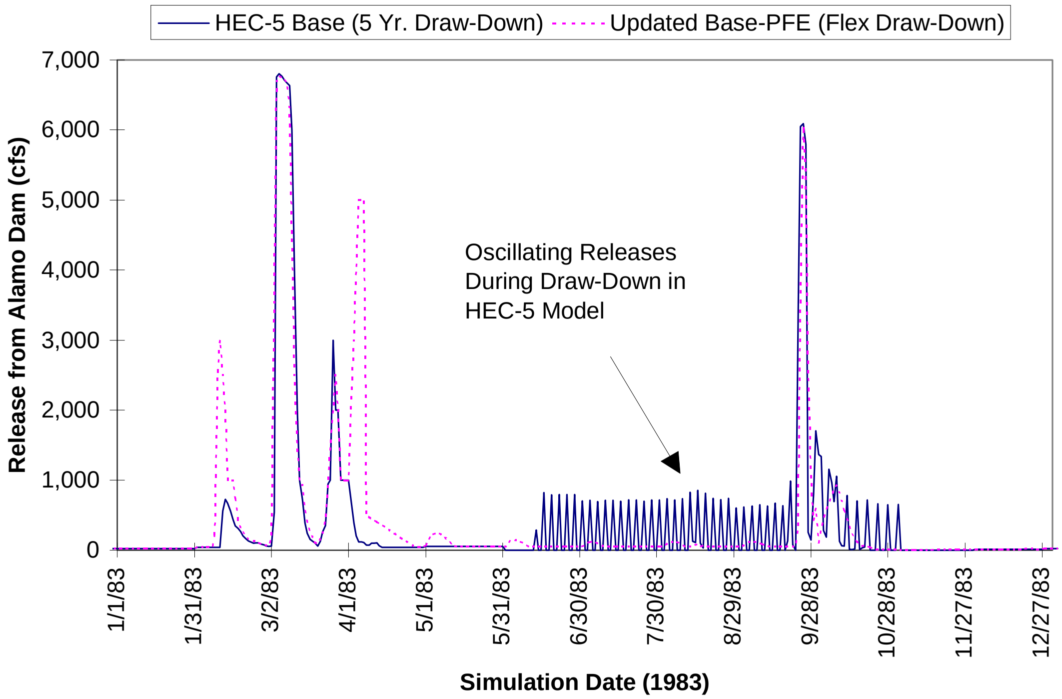

Figure 4.7 Oscillating Releases in HEC-5 Model During Draw-Down

HEC-5 model, draw-downs are made every five years. The draw-down is made over about five months, and during these five months the releases oscillate between values of 100 to 800 cfs for one day often followed by releases of 0 cfs for two or three days. Figure 4.7 illustrates this pattern for the HEC-5 draw-down event in 1983. This oscillation between relatively high releases and no release skews the release statistics and complicates direct comparison between the two different models. (This could be corrected by modifying the input configuration of the Alamo model in HEC-5.)

This unusual release pattern for the draw-down alternatives simulated with HEC-5 also may cause misleading values for some of the flow based evaluation criteria values. For instance, RE6 (Percent of time outflow is between 300 and 7,000 cfs) would likely have a higher value for alternatives simulated with the HEC-5 model due to the pattern of high flows (600 to 800 cfs) followed by 0 cfs flows. Figure 4.2 and Table 4.1 show that the HEC-5 modeled alternative does have the highest value for RE6. Figure 4.8 shows that flows between 100 and 800 cfs do occur more frequently in the HEC-5 modeled alternative. However, if the time series of releases are compared between the two models, flows in this range occur primarily during the HEC-5 draw-down events.

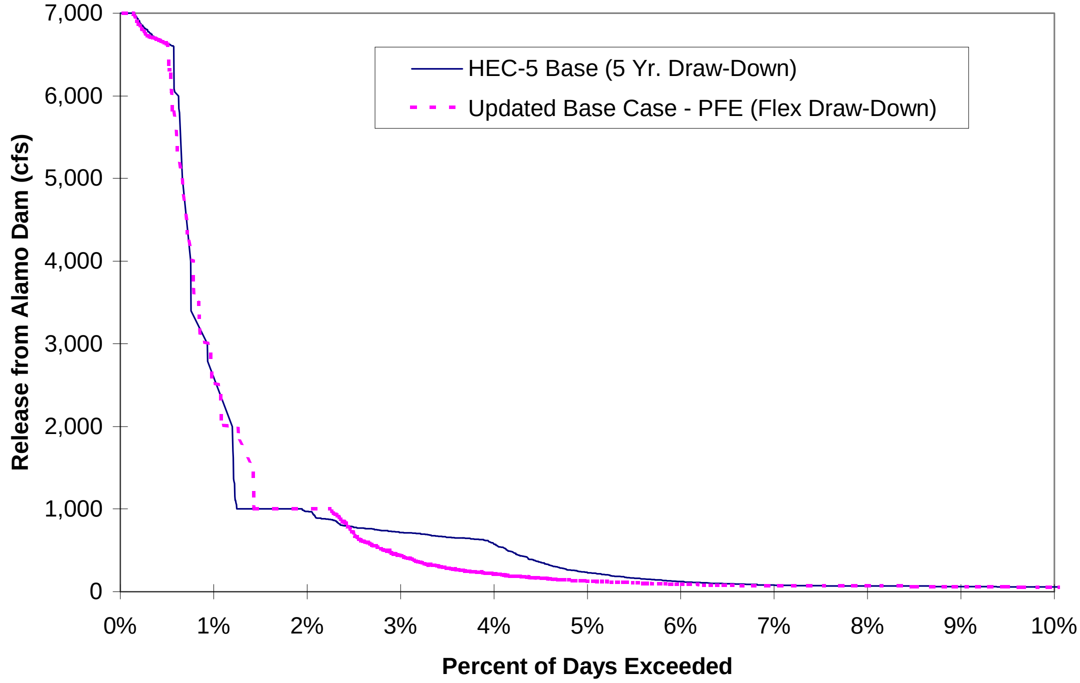

Figure 4.8 Release Exceedance Probabilities (0-10%): 5 Year vs Flex Draw-Down