MANAGEMENT ALTERNATIVES FOR

SAVAGE RIVER RESERVOIR

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THE INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

SECTION FOR COOPERATIVE WATER SUPPLY OPERATIONS ON THE POTOMAC

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ABSTRACT

Savage River Reservoir is a multi-purpose reservoir which releases water at both constant release rates and as occasional high-flow releases. A computer model was developed to analyze reservoir management alternatives. Alternatives exist for maintaining a constant reservoir release rate as opposed to making occasional high-flow releases. The reservoir simulation model was operated for each of the three operating scenarios (no race release, early June release, late June release), for each of the different reservoir release rates (40, 50, 70, 90, and 110 cfs), and for each of the 62 years of inflow record. The model produced output for each of these model simulations which included the daily reservoir storages, releases, controlled drawdowns, and evaporation losses.

Considerable interest has also been expressed regarding the impact of downstream white water races on reservoir operations. Without white water releases, the reservoir's maximum sustainable release rate ranges from 66 to 174 cfs. The white water races reduce the amount of water available for both constant reservoir releases and high-flow releases. Holding the white water races in early June rather than late June increases the availability of water for other reservoir purposes. White water releases will frequently be replaced with water that would have been released in controlled drawdowns had the races not been held.

CHAPTER 1

INTRODUCTION

Savage River Dam is located on the Savage River, 4.5 miles upstream from its confluence with the North Branch Potomac River in western Maryland. The dam was completed in 1952 and impounds Savage River Reservoir, which has a storage capacity of 20,030 acre-feet at the spillway crest. The original project purposes were municipal water supply, flood control, low flow augmentation, and water quality management. The Savage River Reservoir operating rules allocate the first 2,000 acre-feet of storage to meeting the water supply needs of Westernport, MD. These rules also require the seasonal evacuation of a portion of the reservoir storage space in order to provide for flood control storage. Prior to 1981, the remainder of the reservoir water was primarily used to maintain a low flow requirement of 93 cfs on the North Branch Potomac River at Luke, Maryland (ACE, 1986).

In 1981, Jennings Randolph Dam was completed on the North Branch Potomac River upstream of its confluence with the Savage River. The low flow requirement at Luke is now met through coordinated releases from Jennings Randolph Lake and Savage River Reservoir. Most of the low flow requirement is met from Jennings Randolph releases; however, these releases are blended with smaller, higher-quality releases from Savage River Reservoir in order to maintain water quality. Recently, additional reservoir purposes have been suggested including fisheries enhancement, increased municipal water supply, white water races, and non-competitive recreational white water flow enhancement.

Water demands associated with particular water uses vary in both magnitude and timing. In addition, some uses require a high degree of certainty that the water will be available at a specific time, while other uses can more easily adjust their water demands to the uncertainties of the hydrologic system. In general, water quality management requires either fairly steady, long-term reservoir releases for purposes such as low flow augmentation, or large, short-term releases in order to flush accumulated sediments from the streambed. Fisheries require relatively steady streamflows, and are sensitive to the effects of large flows or thermal shocks. Municipal water suppliers require water in variable quantities in order to balance any shortfall between municipal supplies and demands. Municipal suppliers also require considerable certainty that the water will be available at the appropriate time. White water races require large daytime releases for a duration of approximately one week. Considerable flexibility is available in the scheduling of the races; however, a high degree of certainty is required that the water can be delivered at the scheduled dates and times. Non-competitive recreation (canoeing and rafting) requires large daytime releases, but it is quite flexible in the timing and frequency of releases, given sufficient notification that releases are scheduled to occur.

Savage River Reservoir's water yield is insufficient to meet the maximum potential demands of the different water users. However, the opportunity exists for the water users to develop a consensus for managing the reservoir, as an alternative to competing for limited water supplies. Progress in attaining four objectives would assist in the development of a mutually agreeable consensus for managing the reservoir. These objectives are:

1. Identify reservoir release scenarios which are detrimental to individual water users.

2. Maximize the opportunities for complementary water users to simultaneously utilize reservoir releases.

3. Maximize the use of water that would otherwise be released as controlled drawdowns from the reservoir.

4. Quantify the alternatives for satisfying the water needs of competing users.

This report presents alternatives for managing Savage River Reservoir in order to provide water for various reservoir purposes. It focuses primarily on the relationship between releasing water at a constant rate for purposes such as fisheries enhancement, municipal water supply, and low flow augmentation, and making large occasional high-flow releases for purposes such as white water races, non-competitive recreational white water flow enhancement, and for flushing accumulated sediments from the streambed. This trade-off between constant reservoir releases and occasional high-flow releases is affected by the natural variability in inflow to the reservoir. This report also focuses on the effects of the white water races on the management of Savage River Reservoir. There has been particular interest in recent years regarding the white water races' impact on the operations of Savage River Reservoir. This study's objectives are as follows:

1. Quantify the maximum sustainable reservoir release rates from Savage River Reservoir, and the associated exceedence probabilities.

2. Examine the effects that the white water races, and the timing of the races, have on the maximum sustainable reservoir release rates from Savage River Reservoir.

3. Determine the quantities of water remaining for other reservoir purposes, and the associated exceedence probabilities, given specific Savage River Reservoir release rates.

4. Examine the effects that the white water races, and the timing of the races, have on reducing controlled drawdowns from Savage River Reservoir.

5. Determine the amount of water that is used by the white water races, that can be recovered by reducing controlled drawdowns from Savage River Reservoir.

This study used a deterministic computer simulation model of Savage River Reservoir to simulate seasonal reservoir operations between June 1st and October 15th. The model simulated inflows into the reservoir based on a streamflow record of 62 years. Reservoir operations were constrained by operating rules used by the Corps of Engineers (ACE, 1986).

CHAPTER 2

RESERVOIR MODEL

Savage River Reservoir's operations were analyzed through the use of a computer model. The model consists of a spreadsheet which simulates the reservoir's daily operations from June 1st through October 15th. June 1st was selected as the starting date for the model simulations since Savage River Reservoir is usually full by this date, and demands for reservoir water generally commence at this time. October 15th was selected as the ending date for the model simulations since large reservoir releases after this date would interfere with fish spawning in the Savage River. The model operates on a daily time step and is based on the following form of the continuity equation:

$$S(t+1)=S(t)-R(t)-RA(t)-E(t)+I(t)-CD(t)$$

where:

$CD(t)$ = controlled drawdowns

$E(t)$ = reservoir evaporation

$I(t)$ = reservoir inflows

$R(t)$ = constant reservoir releases

$RA(t)$ = reservoir releases for the white water races

$S(t)$ = initial reservoir storage

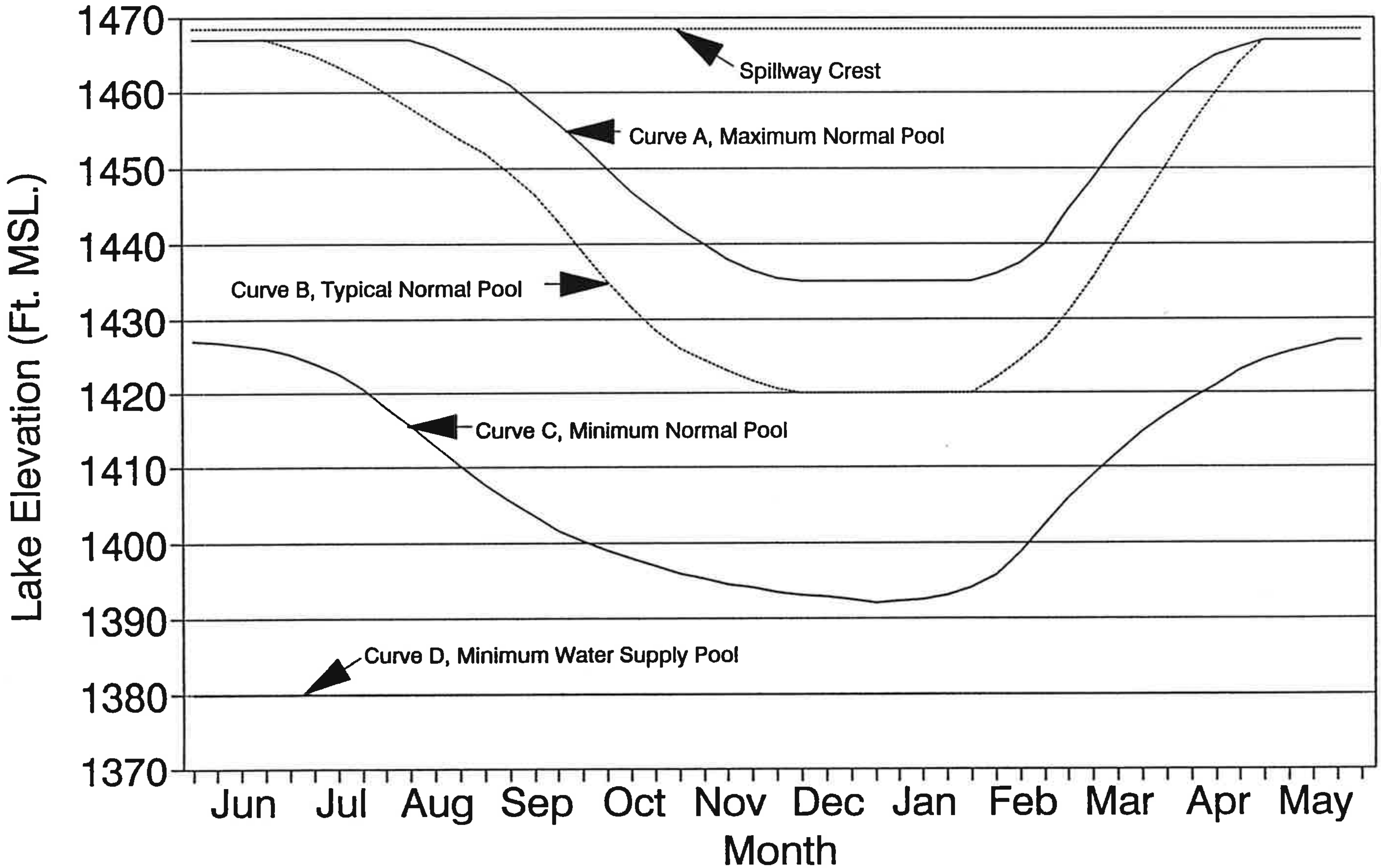
$S(t+1)$ = final reservoir storage

The model assumes that Savage River Reservoir has 19,500 acre-feet of water in storage on June 1st. On a daily basis, the model updates the reservoir storage to account for storage additions resulting from inflow, and storage reductions resulting from regulated releases, releases for the white water races, controlled drawdowns, and evaporation losses.

The model was operated for 62 seasons based on inflow data for 1926, 1927, and 1930-1989. The inflow into Savage River Reservoir was estimated based on the flow at various gages. Reservoir inflows for 1926, 1927 and 1930-1948 were based on the flow of the Savage River at Bloomington, MD. This site is downstream from Savage River Dam; therefore, the values were multiplied by 0.913 in order to estimate the inflow into Savage River Reservoir. This conversion factor represents the drainage area upstream of Savage River Reservoir relative to the drainage area upstream of the gage on the Savage River at Bloomington, MD. Savage River Reservoir was not yet in operation; therefore, the flow at Bloomington, MD was still unregulated. The reservoir inflow from 1949-1981 was based on the flow of the Savage River near Barton, MD, and the flow of Crabtree Creek near Swanton, MD. These gages are upstream of Savage River Reservoir, and they represent inflow from the two primary upstream sub-basins. The combined flow of these gages was multiplied by 1.60, based on differences in drainage area, in order to account for ungaged inflows into Savage River Reservoir. The inflow into Savage River Reservoir from 1982-1989 was based solely on the flow of the Savage River near Barton, MD, multiplied by an area correction factor of 2.14.

The U.S. Army Corps of Engineers uses the four reservoir guide curves shown in Graph 1, as reservoir rules for regulating Savage River Reservoir releases (ACE, 1986). These guide curves vary seasonally, and represent maximum and minimum reservoir operating levels. Curve A represents the maximum elevation at which the reservoir is generally operated. Available reservoir storage above this curve is reserved for the capture of potential flood inflows. As a result, if the level of Savage River Reservoir exceeds curve A, the Corps makes a controlled drawdown in order to lower the reservoir down to the elevation of curve A in a prompt and reasonable manner. Curve B shows the elevations at which the Corps typically operates the reservoir during the summer. Curve C represents the minimum reservoir operating level. If the elevation of Savage River Reservoir drops below curve C, the Corps is required to reduce reservoir releases to 20 cfs in order to maintain downstream water quality. Curve D represents the top of the water supply pool. The water below this elevation is reserved for the municipal needs of Westernport, Maryland. It is designed to compensate Westernport for a small reservoir which was inundated during construction of Savage River Reservoir. If the Savage River Reservoir's elevation drops below curve D, the Corps will only make releases for municipal water supply purposes.

Graph 1
Savage River Dam Reservoir Guide Curves



The Savage River Dam Reservoir guide curves constrained the manner in which the operations model could simulate reservoir operations. First, whenever the lake level exceeded the level specified by curve A, the amount of water in excess of curve A was released as a controlled drawdown during that particular one-day time period. Second, it was assumed that the only water that was available for purposes such as fisheries enhancement, increased municipal water supply, white water races, and noncompetitive white water flow enhancement, was that quantity of water above the level specified by curve C.

Separate reservoir simulations were made for each of the 62 years of available inflow data. For each year, different reservoir simulations were made using different reservoir release rates; however, the reservoir release rates remained constant throughout a given simulation. Simulations were made using two different types of reservoir release rates. First, for each year, a maximum sustainable release rate was calculated. This was defined to be the maximum release rate which could be maintained throughout the simulation period without causing the elevation of the reservoir to drop below the elevation specified by reservoir guide curve C. Second, for each year, simulations were made at reservoir release rates of 40, 50, 70, 90, and 110 cfs, but not at rates that exceeded the maximum sustainable release rate.

Reservoir model runs were also made which simulated the hydrologic effects of three different operating scenarios. The first scenario simulated Savage River Reservoir operations assuming that the white water races are not held. The second scenario simulated reservoir operations resulting from holding the races during the first seven days of June. The third scenario simulated reservoir operations resulting from holding the races during the final seven days of June. Reservoir releases for the white water races were modeled based on the actual releases for the 1988 races.

Reservoir storages were adjusted on a daily basis to account for lake evaporation losses. The model incorporated a linear area-capacity curve which specified the surface area of Savage River Reservoir based on the initial storage. The lake evaporation rates in inches per month were assumed to be 5.0 in June, 6.5 in July, 6.0 in August, 3.5 in September, and 2.0 in October.

The reservoir simulation model was operated for each of the three operating scenarios, for each of the different reservoir release rates, and for each of the 62 years of inflow record. The model produced output for each of these model simulations which included the daily reservoir storages, releases, controlled drawdowns, and evaporation losses.

CHAPTER 3

MODEL RESULTS

The computer model simulated the operations of Savage River Reservoir in order to quantify the maximum sustainable release rate which could be maintained throughout the season. The model was run for each of the 62 years of available inflow data. In each case, the model calculated the maximum release rate which could be maintained throughout the simulation period without causing the reservoir level to drop below the level specified by reservoir guide curve C. Model runs were made using each of the three different operating scenarios.

For each operating scenario, the resultant maximum sustainable release rates for each of the 62 years were then ranked from highest to lowest, and associated exceedence probabilities were assigned. The exceedence probability is the probability that in any year the maximum sustainable release rate will either meet or exceed a specific value. A high exceedence probability indicates that there is a high probability that the maximum sustainable release rate will meet or exceed a specific value, a low exceedence probability indicates that there is a low probability that the maximum sustainable release rate will meet or exceed a specific value.

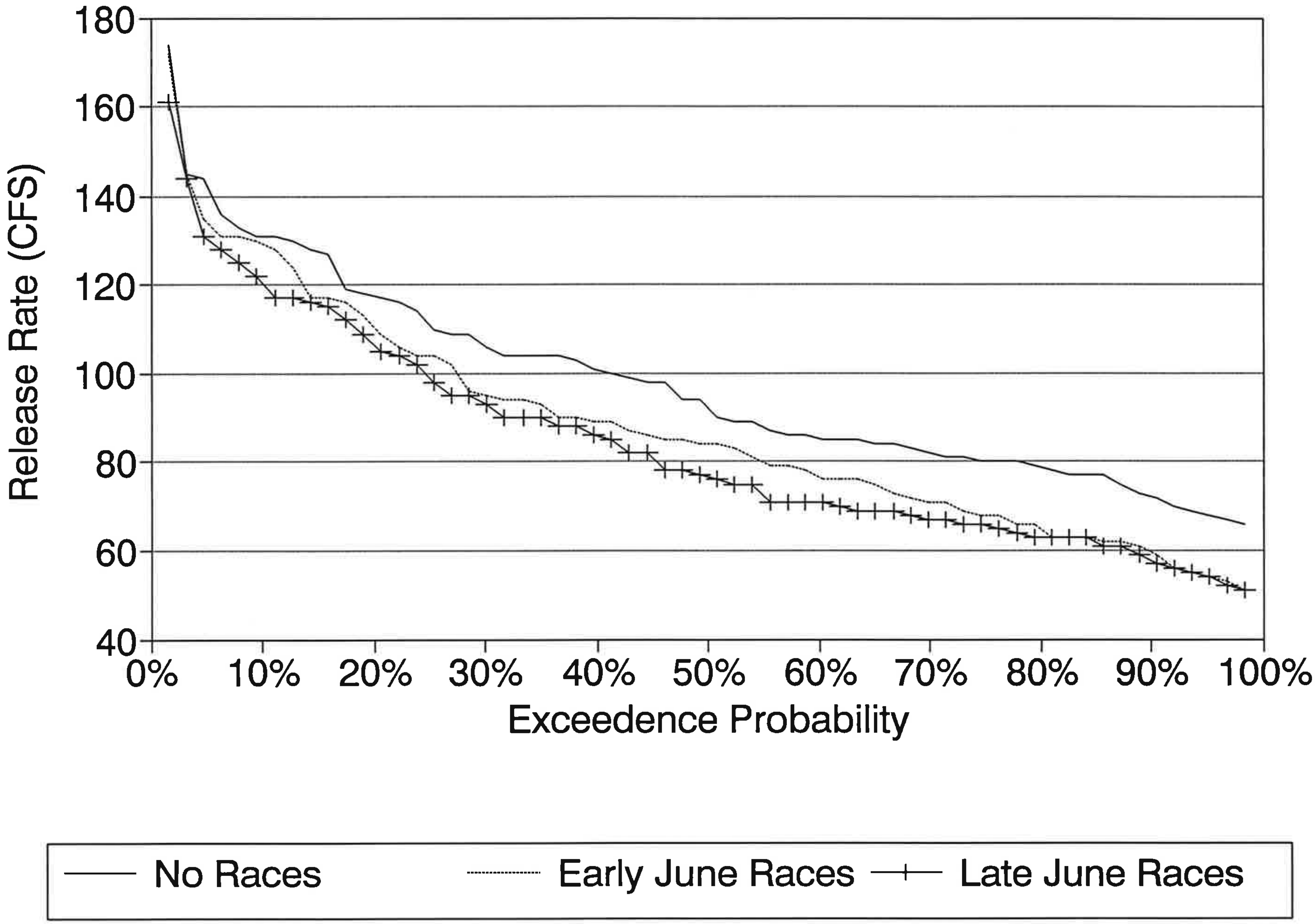
The model simulations retroactively calculate the maximum release rates which could have been sustained during the 62 years of record with the given inflow sequences that occurred during the years. The release rate which could be maintained would have a given exceedence probability (or reliability).

Graph 2 shows the exceedence probabilities associated with various reservoir release rates, for each of the operating scenarios. The first scenario assumed that the white water races were not held. In this case, the maximum sustainable release rate ranges from 66 cfs at an exceedence probability of 98% to 174 cfs at an exceedence probability of 2%. The second scenario assumed that the white water races were held during the first seven days of June. In this case, the maximum sustainable release rate ranges from 51 cfs at a 98% exceedence probability to 172 cfs at a 2% exceedence probability. The third scenario assumed that the white water races were held during the last seven days of June. In this case, the maximum sustainable release rate ranges from 51 cfs at a 98% exceedence probability to 161 cfs at a 2% exceedence probability.

Graph 2 shows that releasing water from Savage River Reservoir for the white water races reduces the maximum sustainable release rate. It also shows that holding the white water races in early June results in a higher maximum sustainable release rate than holding the races in late June. Early June white water race releases would result in an average decrease in the maximum sustainable release rate of 9.9 cfs. Late June races would result in an average decrease of 13.8 cfs. By holding the races in early June, a portion of Savage River Reservoir would be evacuated earlier than if the

Graph 2

Maximum Sustainable Release Rate



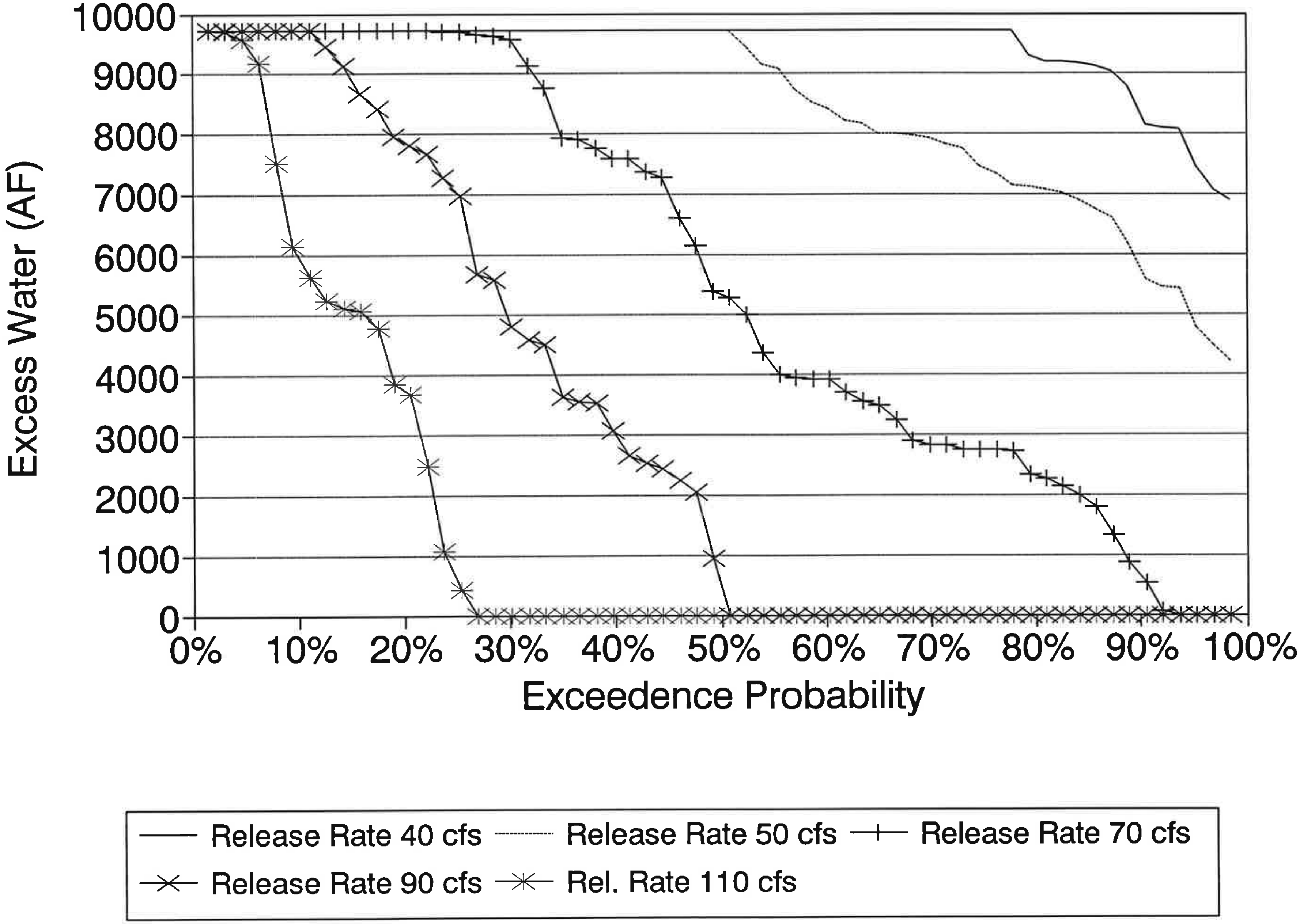
races were held in late June. This earlier evacuation of the reservoir allows additional time for the reservoir to refill with water that might have otherwise been released as controlled drawdowns had the reservoir been full in anticipation of late June races. The white water races reduce the maximum sustainable release rate more during dry years (years with high exceedence probabilities) than during wet years (years with low exceedence probabilities). The white water races result in vacant reservoir space which will refill less readily during dry years than during wet years. During the driest years, there is little advantage to holding the races in early June rather than in late June.

Operating simulations were also made to determine the quantities of water that would be available for other purposes, and the associated exceedence probabilities, given specific Savage River Reservoir release rates. For each operating scenario, and for each year, simulations were made at release rates of 40, 50, 70, 90 and 110 cfs, but not at rates that exceed the maximum sustainable release rate.

For each simulation, the computer model calculated the amount of excess water in storage on October 15th, which is the last day of the simulation period. Excess water is defined as the amount of water in storage above the lake elevation shown in reservoir guide curve C. The amount of excess water on October 15th approximates the quantity of water which would be available for increased municipal supply and for non-competitive recreational white water flow enhancement. This is water in excess of the amount necessary to meet the constant regulated reservoir release rate. While this water would be completely available on October 15th, the water would usually be available for periodic use throughout the summer. For each operating scenario, and at constant reservoir release rates, exceedence probabilities were calculated showing the amount of excess water on October 15th. These exceedence probabilities were calculated based on simulations using the 62 year inflow record.

Graph 3 shows the extent to which water in excess of reservoir guide curve C would be available on October 15th, if white water races were not held. The graph shows that as the reservoir release rate increases the amount of excess water in storage at a given exceedence probability decreases. A reservoir release rate of 40 cfs throughout the season would result in a 98% probability that the amount of excess water in storage on October 15th would be at least 6897 acre-feet. There would be a 78% probability that there would be 9726 acre-feet of excess water in storage. This represents the maximum amount of excess water that can be in storage on October 15th. It is the difference between the reservoir storages specified by reservoir guide curves A and C. On the other hand, a reservoir release rate of 110 cfs would result in only a 25% probability of there being any excess water in storage on October 15th. It would usually not be possible to maintain a reservoir release of 110 cfs throughout the simulation period. Graph 4 shows the results for the scenario

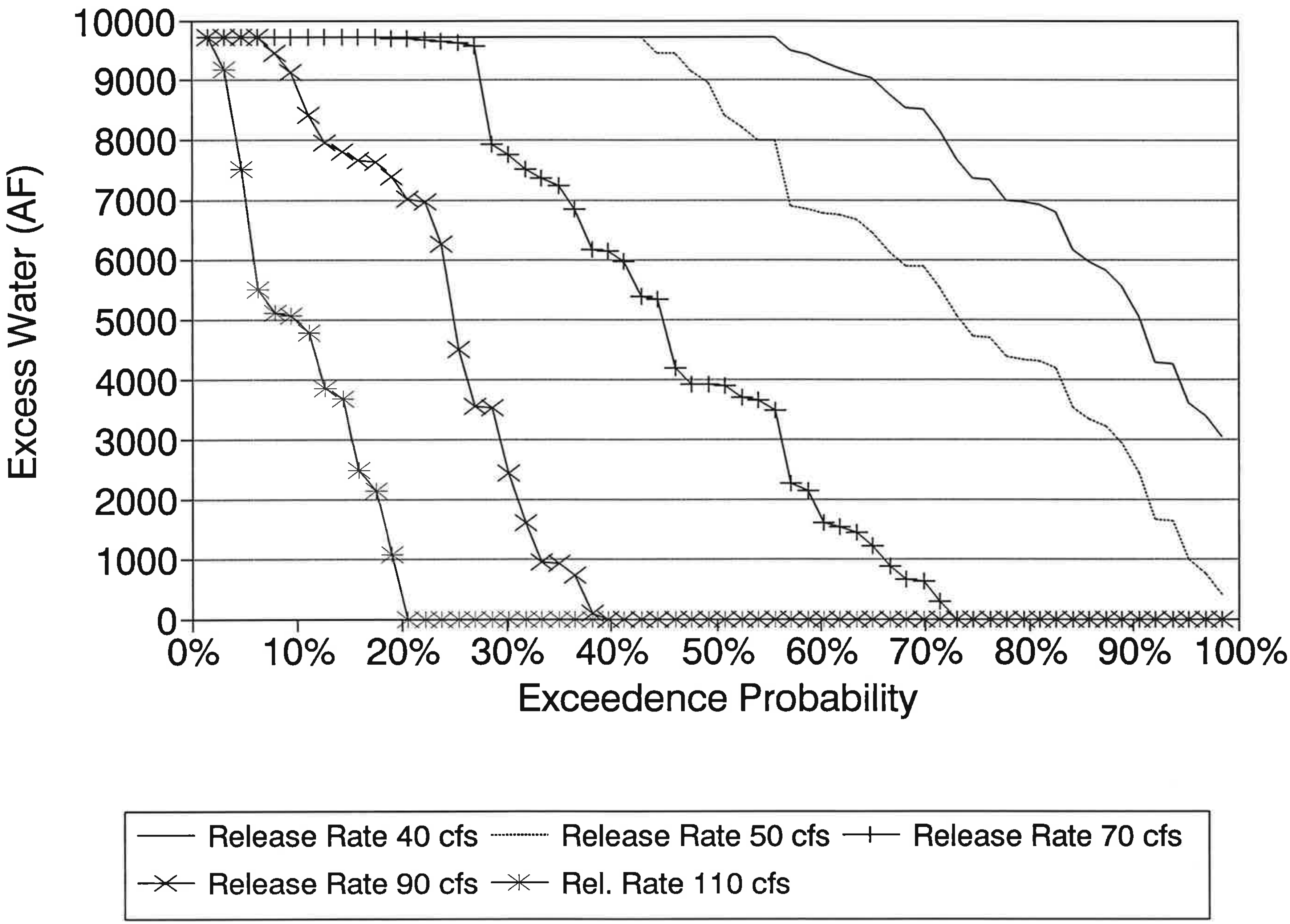
Graph 3
Excess Water on 10/15 - No Races



where the white water races are held in early June. Graph 5 shows the results for the scenario where the races are held in late June.

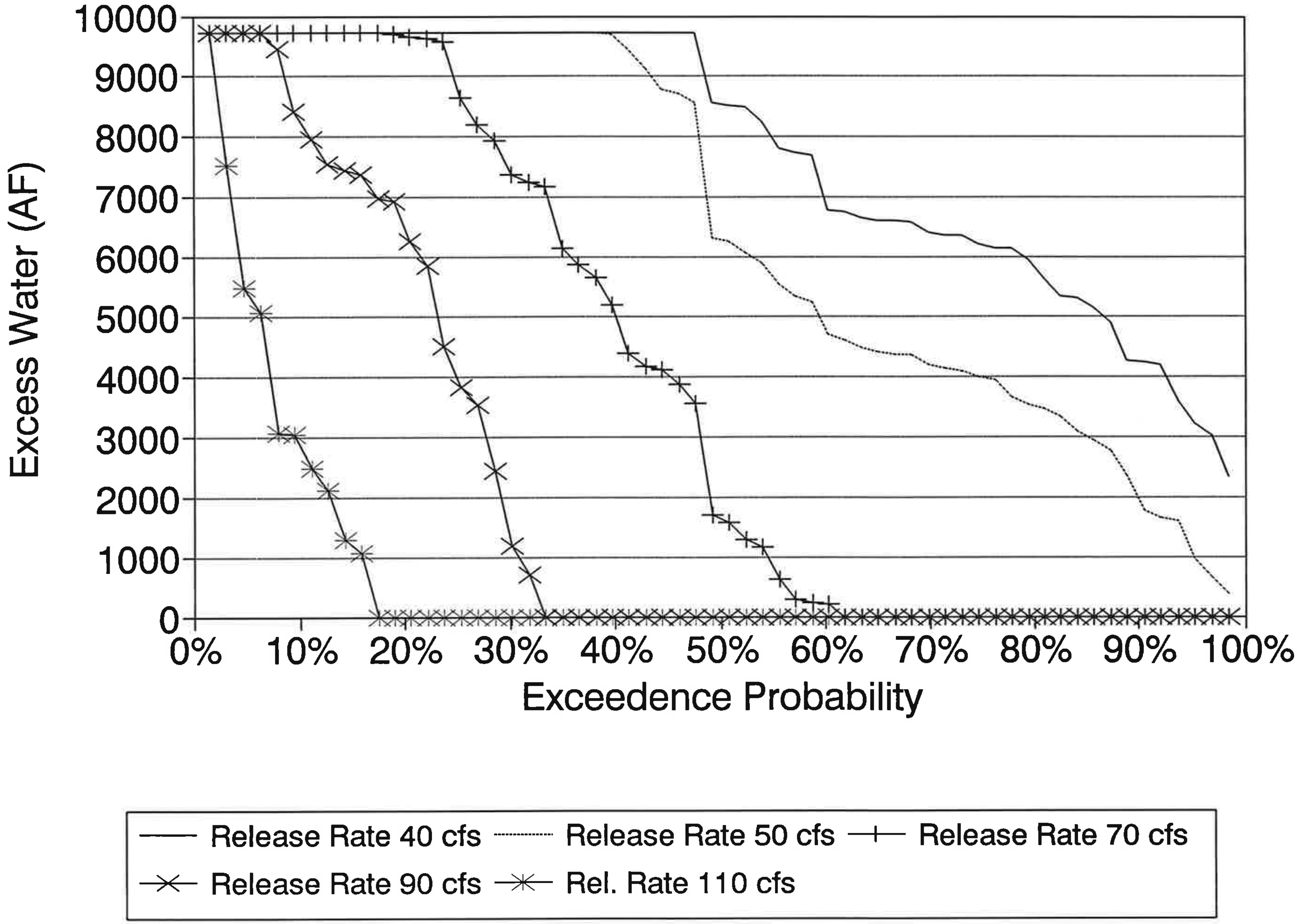
Graphs 3 through 5 illustrate possible operational trade-offs between maintaining higher constant reservoir release rates for the purpose of fisheries enhancement, and withholding greater quantities of reservoir water in storage for use in making occasional high-flow releases for non-competitive white water enhancement, and for increased municipal water supply. For example, graph 4 shows the resulting October 15th storages when the white water races are held in early June. The graph shows that there would be a 98% probability of maintaining a constant release rate of 50 cfs throughout the release period. In this case there would be a 98% probability of having 410 acre-feet of excess water in storage (which could be used for making occasional high-flow releases) and a 43% probability of having 9726 acre feet of excess water in storage. Therefore, you could almost always maintain the constant reservoir release rate. There would usually be a considerable amount of excess water available for making occasional high-flow releases; however, the availability of this water would be quite limited during dry years. On the other hand, there would be only a 71% probability of maintaining a constant reservoir release for 70 cfs and of having any excess water in storage. In this case, there would be a 17% probability of having 9726 acre-feet of excess water in storage. Therefore, during wet years the

Graph 4
Excess Water on 10/15-Early June Races



Graph 5

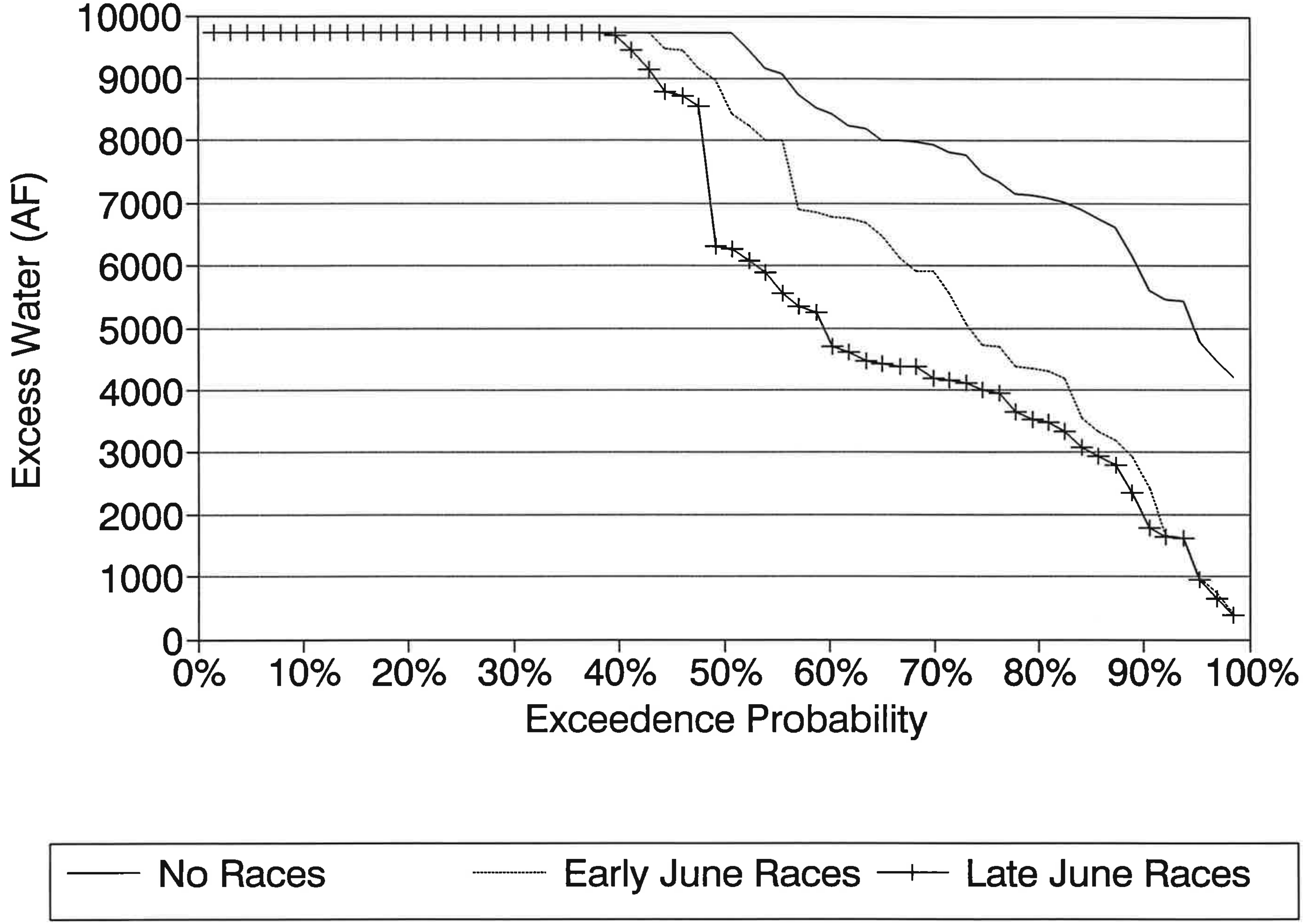
Excess Water on 10/15-Late June Races



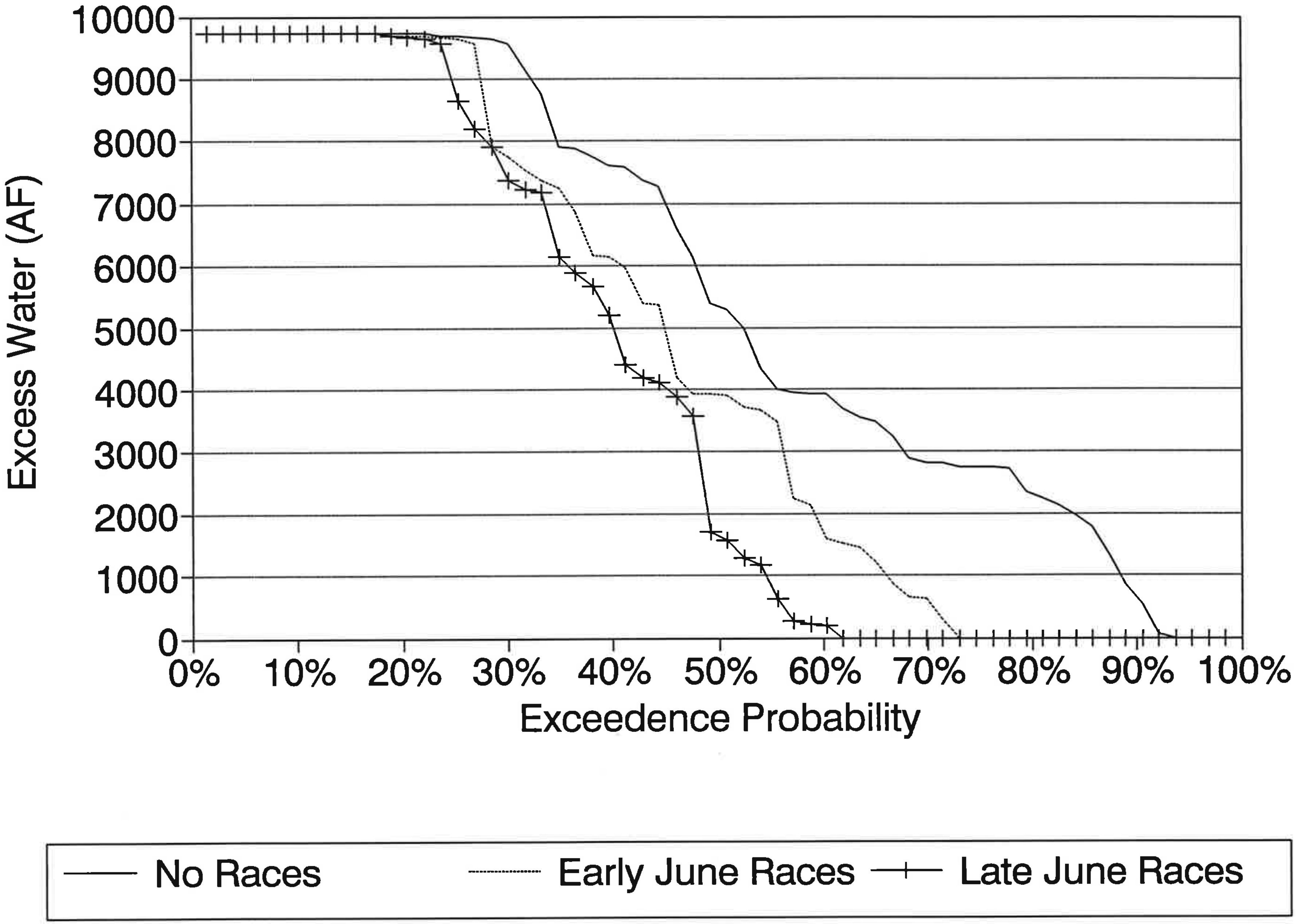
higher release rate of 70 cfs could be maintained and there would be excess water in storage. However, during dry years it would not be possible to maintain the 70 cfs reservoir release rate for the duration of the summer, nor would there be excess water in storage.

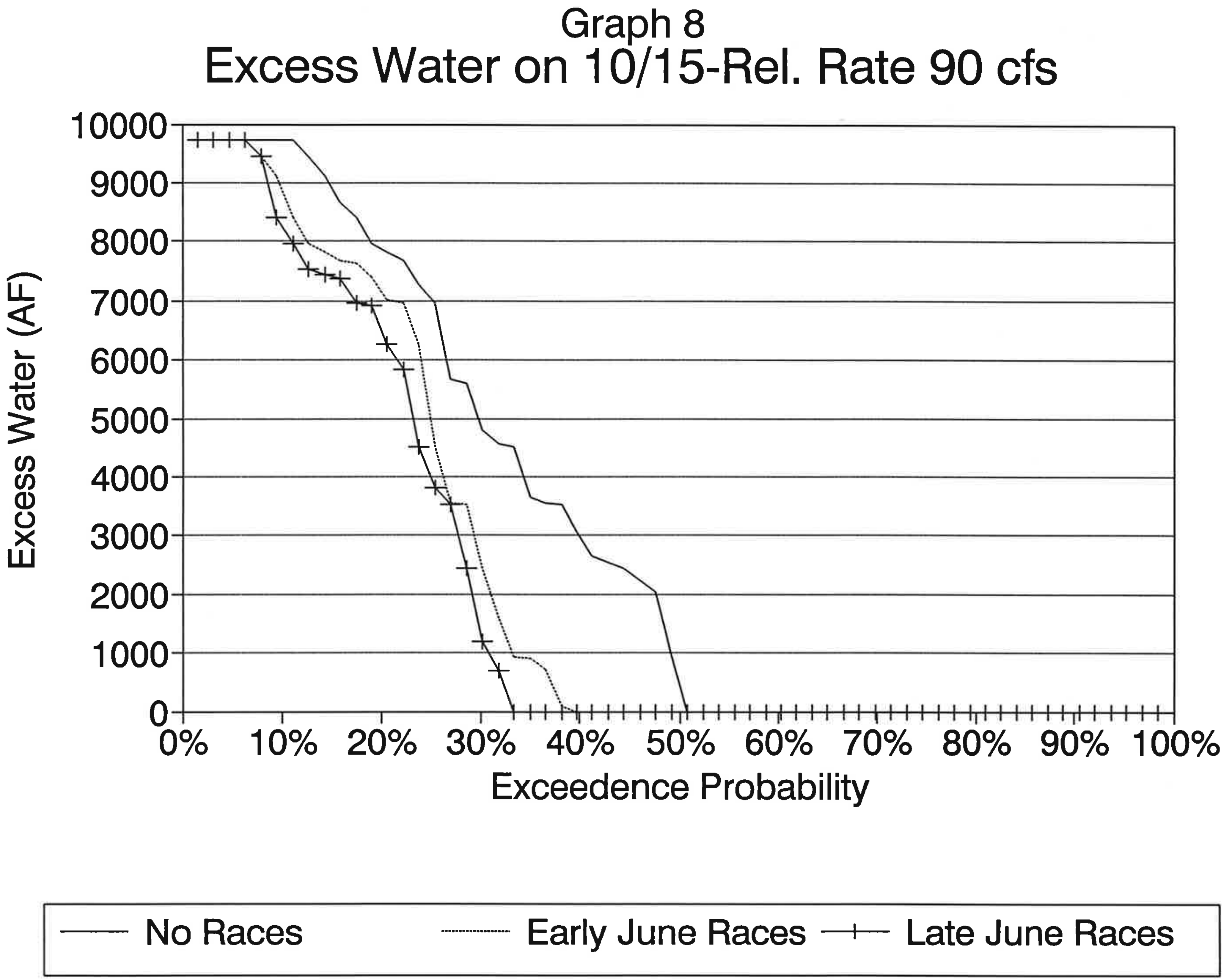
Graphs 6 through 8 compare the exceedence probabilities associated with specific amounts of excess water for the different operating scenarios, but at identical constant reservoir release rates. Graph 6 shows the results when the constant reservoir release rate is 50 cfs. Graphs 7 and 8 show the results associated with constant reservoir release rates of 70 cfs and 90 cfs respectively. These graphs show that at a given reservoir release rate, the white water races reduce the amount of water in excess of the amount specified by reservoir release curve C. Holding the races in late June also results in an overall greater reduction in the availability of excess water than does holding the races in early June. For example, graph 6 shows the results when the constant reservoir release rate is 50 cfs. At the 60% exceedence probability level, there would be 8420 acre-feet of excess water in storage on October 15th if the white water races are not held. On the other hand, at the same exceedence probability there would be 6789 acre-feet available if the races are held in early June, and 4710 acre-feet available if they are held in late June. Once again, holding the races in early June rather than late June provides additional time for the reservoir to refill.

Graph 6
Excess Water on 10/15-Rel. Rate 50 cfs



Graph 7
Excess Water on 10/15-Rel. Rate 70 cfs



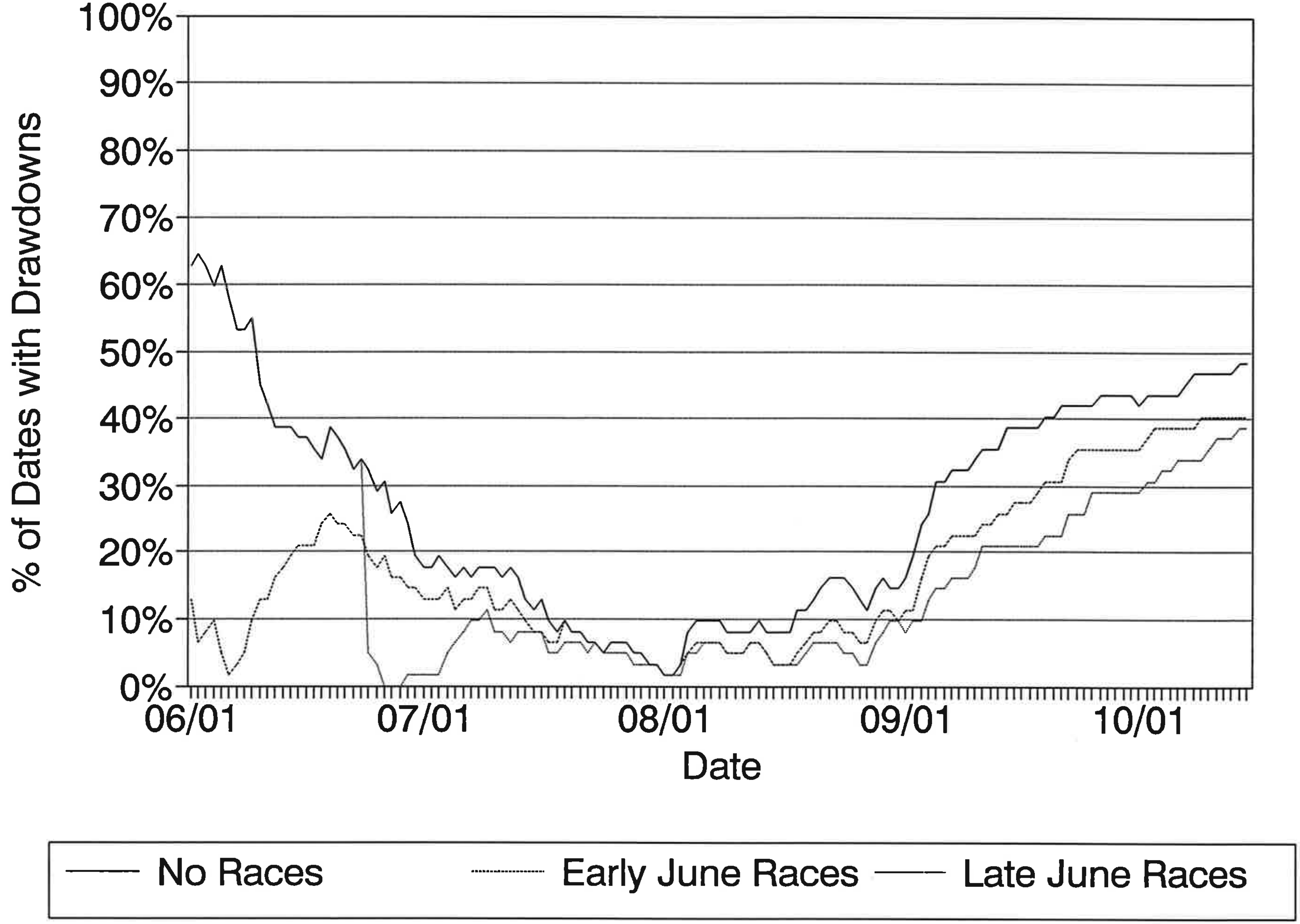

Graph 8
Excess Water on 10/15-Rel. Rate 90 cfs
Excess Water (AF)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Exceedence Probability
No Races
Early June Races
Late June Races

Graph 6 demonstrates two other relationships. First, if the white water races are held in very dry years, those with high exceedence probabilities, the amount of excess water in storage is almost identical regardless of the timing of the races. In dry years, the constant reservoir release provides enough reservoir storage to generally accommodate the inflows, even if the races are not held until late June. Second, in very wet years, those with low exceedence probabilities, the amount of excess water in storage is at a maximum regardless of the timing of the races. During these years the inflow is sufficient to refill the reservoir by October 15th to the level specified by reservoir guide curve A, even when the white water races are not held until late June.

The model assumed that whenever the reservoir level exceeded the level specified by reservoir guide curve A, a controlled drawdown would be made in order to lower the reservoir to the level specified by reservoir guide curve A. Holding the white water races in early June rather than late June provides additional opportunities for Savage River Reservoir to refill with water that would otherwise be released as controlled drawdowns if the races were held in late June. As a result, there is more water available for improved fisheries enhancement, and there is additional excess water available for non-competitive recreational white water flow enhancement, and for additional municipal water supply.

Graph 9 shows the seasonal pattern of controlled drawdowns from Savage River Reservoir under different

Graph 9
Frequency of Controlled Drawdowns



operating scenarios. Graph 9 is based on model runs with a constant reservoir release rate of 50 cfs. Based on the 62-year historical inflow record, it shows the frequency with which a controlled drawdown would have occurred on a given date.

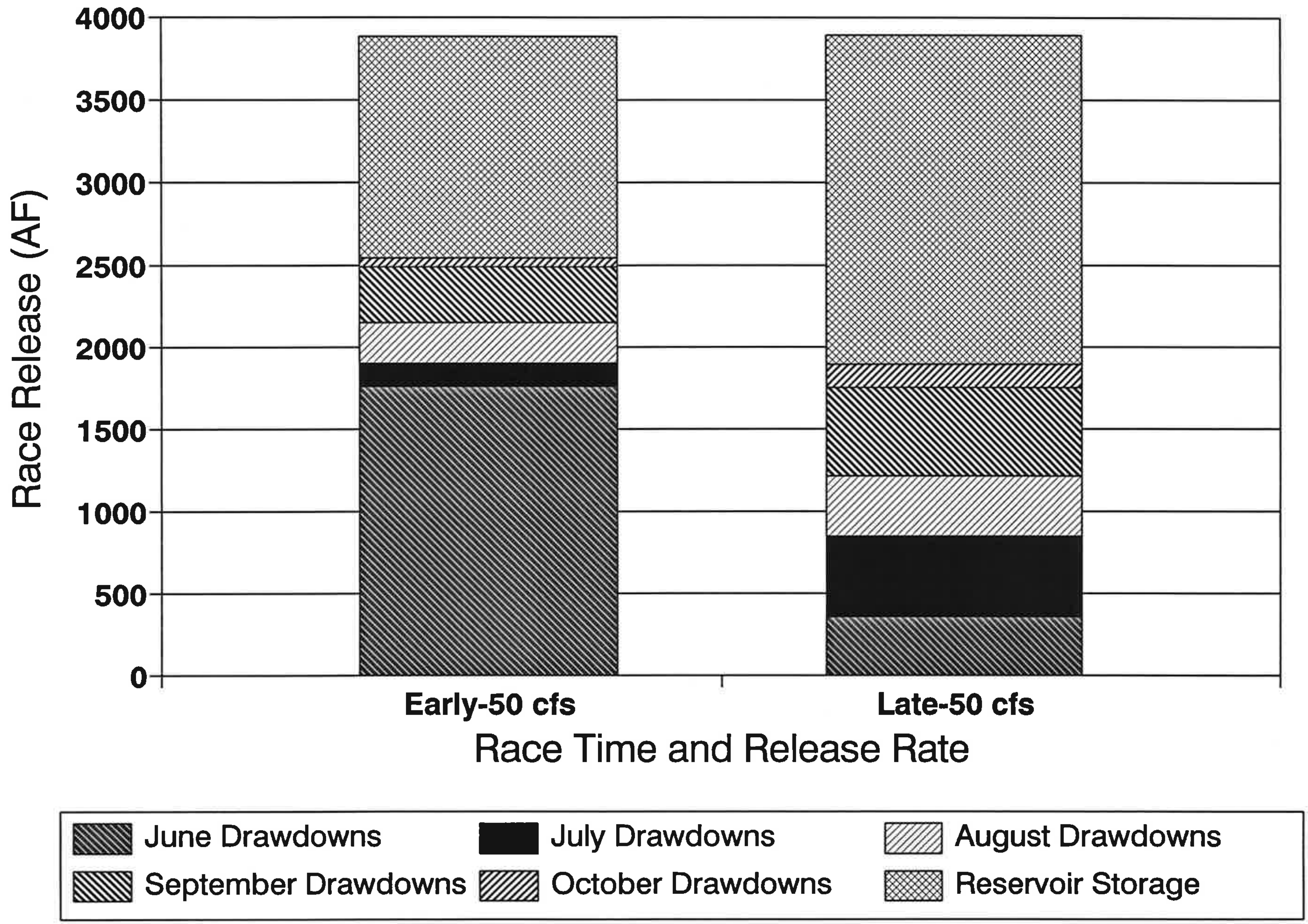
Graph 9 shows that if the white water races are not held, controlled drawdowns from Savage River Reservoir would have to be made 63% of the time on June 1st. The drawdown frequency would increase to 65% on June 2nd, before gradually tapering off to a low of 2% on August 1st. The drawdown frequency would then increase to a high of 48% on October 15th. The drawdown frequency increases in late summer and fall because the lake elevation specified by reservoir guide curve A decreases in order to evacuate additional space for flood control management. If the white water races are held in early June, the drawdown frequency is 13% on June 1st at the start of the races, and drops to 2% on June 6th near the end of the races. The drawdown frequency then increases to 26% on June 19th before again decreasing to 2% on August 1st. The drawdown frequency then increases to 40% at the end of the season. Holding the white water races in early June reduces the drawdown frequency throughout the season, this reduction is particularly pronounced during June.

Late June white water races result in a drawdown pattern that is identical to the no races scenario up until June 23rd. The races would start on June 24th, and the drawdown frequency would drop to 0% the following day. The drawdown frequency then gradually rises to 11% before dropping to 2% on August 1st. The drawdown frequency then reaches 39% at the end of the season. Holding the white water races in late June reduces the drawdown frequency throughout the remainder of the season from what it would have been had the races not been held. It also results in a reduced drawdown frequency starting in late June, compared to the drawdown frequency resulting from races in early June. The late June races reduce the chances of controlled drawdowns occurring as a result of Savage River Reservoir refilling following the races. However, holding the races in early June results in substantially greater benefits by reducing controlled drawdowns than does holding the races in late June.

The model results were also analyzed to determine the extent to which the white water races use water which otherwise would have been released from Savage River Reservoir as controlled drawdowns. This analysis was based on the model simulations with a constant reservoir release rate of 50 cfs. For each of the 62 years, the quantity of water which would have been released as controlled drawdowns under each of the three operating scenarios was determined. The quantity of race water obtained from reservoir drawdowns was calculated as the difference between the amount of water that would have been released as drawdowns if the white water races had taken place, and the quantity that would have been released as drawdowns had the races not been held. The analysis also determined the extent to which the white water races used water which otherwise would have been released as drawdowns during specific months. Separate calculations were made depending on whether the races were held in early or late June.

Graph 10 shows, on average, the extent to which water for the white water races would be replaced with water which would have otherwise been released from Savage River Reservoir as controlled drawdowns. The white water races used 3913 acre-feet of water. This does not include the constant reservoir release rate of 50 cfs which would be maintained throughout the races. If the races were held in early June, it could be expected that 2570 acre-feet, or 66% of the water used by the races, would on average be replaced with water which otherwise would have been released as drawdowns from Savage River Reservoir. Most of this water. 1756 acre-feet, would be obtained from reservoir drawdowns in June. If the races were held in late June, 1908 acre-feet or 49% of the race water, would be replaced with drawdown water. In this case, only 349 acre-feet of water would be replaced during June. Larger quantities of water would be replaced between July and October if the races were held in late June rather than early June. However, overall on average 662 acre-feet of additional water would be replaced with drawdown water if the races were held in early June rather than late June. In both cases, the white water races would still be consuming some reservoir storage water which could have been used for other purposes. If the races were held in early June, an average of 1343 acre-feet of

Graph 10
Potential Water Sources for Races

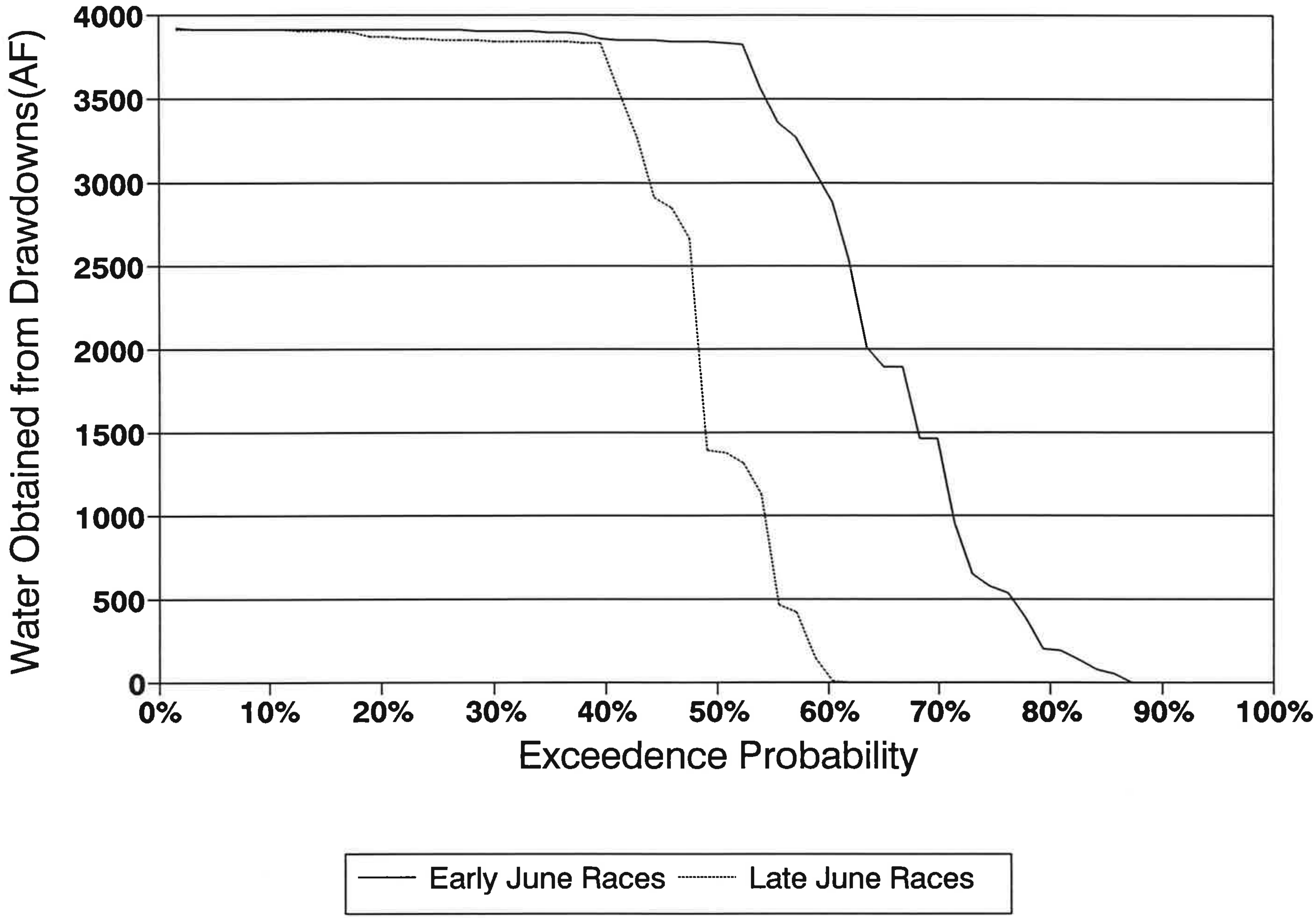


reservoir water would not be replaced with drawdown water. Late June races would result in an average of 2005 acre-feet of reservoir water not being replaced.

While most of the water used by the white water races would be replaced with water which otherwise would have been released as drawdowns, there is considerable variance in the extent to which drawdown water would replace race water. The exceedence probabilities showing the extent to which race water would be replaced with drawdown water are shown in Graph 11. These results are based on the 62-year historical inflow, and assume a constant reservoir release of 50 cfs. If the races are held in early June, there is an exceedence probability of 52% that at least 3818 acre-feet of the race water would be replaced with water that otherwise would have been released as drawdowns. This represents 98% of the 3913 acre-feet of water used by the races. However, the amount of race water that would be replaced with drawdown water drops off rapidly during dry years. There is an 86% probability that at least some of the race water will be replaced with water that otherwise would have been released as drawdowns. Therefore, there is a 14% probability that none of the race water will be replaced even if the races are held in early June.

If the races are held in late June there is a 40% exceedence probability that 3831 acre-feet, or 98% of the race water, will be replaced with water that otherwise would have been released as drawdowns. There is a 60% exceedence

Graph 11
Drawdowns as a Source of Race Water



probability that at least some race water will be replaced with drawdown water. Therefore, there is a 40% probability that none of the race water will be replaced with water that otherwise would have been released as drawdowns. These results indicate that although there is considerable uncertainty that water used for the white water races will be replaced, the probability of it being replaced increases considerably if the races are held in early June rather than late June.

CHAPTER 4

SUMMARY AND CONCLUSIONS

The original purposes for which Savage River Reservoir was constructed were municipal water supply, flood control, low flow augmentation, and water quality management. Additional reservoir purposes have recently been suggested including fisheries enhancement, increased municipal water supply, white water races, and non-competitive white water flow enhancement. The reservoir purposes can generally be classified into those which require constant reservoir releases throughout the release period, and those which require occasional high-flow releases.

This study used a computer model to simulate the hydrology of Savage River Reservoir, and to examine the effects of different reservoir management alternatives. An examination was made of the availability of water for constant reservoir releases, and for occasional high-flow releases. The potential impact of the white water races on other reservoir purposes was extensively examined.

Several conclusions can be reached regarding potential management alternatives for Savage River Reservoir:

1. The maximum sustainable release rate from Savage River Reservoir ranges from 66 cfs with a 98% exceedence probability to 174 cfs with a 2% exceedence probability.

2. Holding the white water races in early June reduces the maximum sustainable release rate by an average of 9.9 cfs, while holding the races in late June reduces the maximum sustainable release rate

by 13.8 cfs.

3. An increase in the constant reservoir release rate decreases the amount of water available for occasional high-flow releases. There are numerous options for altering the release patterns.

4. The white water races reduce the amount of water available for occasional high-flow releases. This negative impact is greater if the races are held in late June rather than in early June.

5. The white water races reduce the frequency with which Savage River Reservoir spills water. Holding the white water races in early June rather than late June provides greater opportunities for refilling Savage River Reservoir with water that otherwise would spill.

6. Water from Savage River Reservoir for the white water races will frequently be replaced with water that would have been spilled if the races had not been held. It is most likely that the race water will either be totally replaced or not replaced at all, rather than only partially replaced. Holding the white water races in early June as opposed to late June increases the probability of the race water being replaced.

7. The computer model and input date developed for this study could be used to examine the operational impacts of white water race releases held at any time during the period June 1 through October 15, or during a longer period.

ADDITIONAL RESEARCH

Additional research in the following areas might increase our understanding of the operational alternatives for managing Savage River Reservoir:

1. An examination of the effects of holding the white water races in the spring or fall rather than the summer.

2. An examination of the effects of varying the reservoir release rate throughout the release

period.

3. Development of a methodology for predicting inflows to Savage River Reservoir, in order to improve the reliability with which constant reservoir releases can be maintained.

LIST OF REFERENCES

U.S. Army Corps of Engineers, Baltimore District. 1986. "Master Manual for Reservoir Regulation in the North Branch Potomac River Basin."