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WATER RESOURCES
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To: Mr. Jerrold Gregg, Area Manager, Snake River Area Office

From: Mr. Jim Fodrea, Manager, Water Resource Management, Pacific Northwest Regional Office

Subject: Revised winter flood control curves for Cascade and Deadwood Reservoirs

The Water Operations Group has concluded its review of current winter flood control rule curves for Cascade and Deadwood Reservoirs, as your office requested earlier this year. This memorandum will serve to relay the results of this review. The review can be briefly summarized as follows:

1. The current requirement of 280,000 acre feet (af) of winter flood control system space appears to be more than needed to control historic winter flood events.

2. A reduced space requirement of 190,000 af system space would be adequate to store all available reservoir inflows during two back to back historic winter floods of record (December 1964.)

3. Regulation of flood flows at Horseshoe Bend to 12,000 cfs is not always possible even when storing all reservoir inflows.

4. The additional carryover volume associated with the revised 190,000 af space requirement would have improved refill capabilities in Cascade Reservoir in only the four driest years since 1961 (assuming maximum carryover quantities were attainable on November 1 under actual operations.) Refill would have occurred in all other years under the existing or revised space requirements.

5. Flood control operations on the Payette are informal, and the rule curves serve as guidelines only. Actual operations may deviate based on current hydrological conditions, presumed risks, runoff projections, and operational flexibility and maintenance requirements.

**BACKGROUND INFORMATION**

Due to the amount of development along the Payette River, Reclamation has recognized that flood control operations are a necessary and prudent obligation of Cascade and Deadwood Reservoirs. Winter and spring flood events can occur on the Payette River drainage on any given year. The winter events are typically caused by a combination of unseasonably warm temperatures and rainfall on snow and/or frozen ground. These weather patterns are difficult to predict and can occur with relatively short notice. Spring snowmelt floods, on the other

hand, are more predictable. Runoff forecasts and snowpack data are available prior to the snowmelt period; total quantity and timing of runoff can be predicted to a much greater degree than in winter events.

Cascade and Deadwood Reservoirs can lessen the magnitude in either type of flood by storing water during times of high inflow. Ample time is usually available prior to spring snowmelt to evacuate space from the reservoirs, if necessary, in order to store inflow later. The unpredictability and short notice of winter events, however, requires space to be available at all times a flood is possible. Flood control rule curves serve as a guide to establish the amount of reservoir space necessary during the winter and spring periods to control flooding.

Current flood control rule curves call for a minimum November 1 to April 1 winter system space of 280,000 acre feet for Cascade and Deadwood Reservoirs, with this space split 80% and 20%, respectively, between the two reservoirs. This equates to a carryover volume of 429,000 af in Cascade and 106,000 af in Deadwood. The objective of the winter flood space is to provide sufficient room in the reservoirs to store all inflows during winter flood events, in order to regulate the flow at Horseshoe Bend to 12,000 cfs or less, if possible. The majority of the Payette basin is unregulated and it is possible to exceed 12,000 cfs even with complete reservoir shutoff. The largest winter flood on record occurred in late December, 1964, and resulted in a mean daily flow at Horseshoe Bend of 20,800 cfs. This flow would have been 29,280 cfs without storing inflows at the two reservoirs.

After April 1 the rule curves are based on forecasted runoff volume at Horseshoe Bend, with space requirements depending on forecasted runoff versus date of forecast. The current flood control rule curves are based on data through 1974. The primary purpose of this review is to assess the viability of the current minimum winter flood control requirements and propose new amounts if deemed appropriate.

## REVIEW OF MINIMUM WINTER FLOOD SPACE

The first step in determining a reasonable minimum winter flood space volume was an analysis of the maximum winter floods on record for the period 1920 to 1995. The three largest winter

floods at Horseshoe Bend and the associated 10-day storable volumes at the reservoirs are summarized as follows:

| Flood Event | 10 Day Storable Volume (Cascade + Deadwood) |
|---|---|
| December 22-31, 1964 | 89,300 af |
| December 20-29, 1956 | 77,500 af |
| January 15-29, 1974 | 86,600 af |

It is evident that although the 1964 flood was the largest on record, it was not necessarily a unique event. A frequency analysis was performed as part of the Probable Maximum Flood Study for Cascade Dam (dated April, 1987) and gives the following mean daily peak flows at Cascade (CSCI) and the respective return periods:

| Mean Daily Peak | Return Period |
|---|---|
| 6,554 cfs | 2 years |
| 8,167 cfs | 5 years |
| 9,125 cfs | 10 years |
| 10,234 cfs | 25 years |
| 11,041 cfs | 50 years |
| 11,797 cfs | 100 years |

The mean daily peak on December 22, 1964, at Cascade would have been 10,641 cfs without storing inflow. This indicates the 1964 event to have a recurrence interval of between 25 and 50 years. That is an event that can be expected to occur, on average, once every 25 to 50 years.

Some degree of subjectivity is required in deciding what level of flood protection is reasonable. For this study, it was decided that enough space should be provided to contain two back-to-back events approximately equal to the maximum event on record. The plausibility of such an occurrence can be supported by similar circumstances in California and Washington in the last several years. This would also serve to control a single event of greater intensity or longer duration.

Most of the storage space to be provided is in Cascade, therefore it was looked at individually to determine space requirements. Two back-to-back events similar to 1964 would require approximately 157,000 af of space (based on storing 10-day volumes.) This equates to a carryover in Cascade of roughly 500,000 af, with rounding. The 80/20 split in space between Cascade and Deadwood is based on the relative amount of runoff generated from each basin. Roughly 80% of the storable runoff volume on the Payette is derived from the Cascade drainage, with the other 20% coming in above Deadwood. This relationship was

determined to still be reasonable; therefore, the associated revised space requirement in Deadwood is 38,000 af, or a maximum carryover of approximately 124,000 af.

A reduction in minimum winter space requirements would also provide a smooth transition between the winter and spring portions of the rule curves. The amount of space required with an April 1 forecast of 100% of average runoff is about 182,000 af; this is very close to the 190,000 af being studied. Estimated April 1 space requirements are usually targeted in late winter/early spring when more is known about the hydrologic conditions, and this will still be the case. Less action, however, may be necessary to transition into spring rule curves in a near average year.

**CARRYOVER/REFILL COMPARISON**

A study was done to compare the relative effects on refill of carrying over the proposed 500,000 af maximum at Cascade versus the current maximum of 429,000 af. For the purpose of the study, it was assumed that the reservoir was at maximum carryover on November 1 for each year in the 1961-1995 period, and the actual runoff experienced in each year was applied to determine maximum fill in the following spring. Winter operations in each of the years were also changed where appropriate to reflect how the reservoir would be operated under the current operating scheme. The results of the study show that Cascade Reservoir would have refilled under either carryover option (429,000 af or 500,000 af) in all but four years in the 1961-1995 period, if maximum carryover had been attainable on November 1. Those four years are 1977, 1987, 1992, and 1994; refill would have occurred under the 500,000 af option in all but 1977. Enclosure 1 is a graph summarizing these results.

A similar refill study was conducted for Deadwood Reservoir for the two carryover options - the current 106,000 af carryover and the proposed 124,000 af level. Once again it was assumed that the reservoir was at maximum carryover on November 1 for each year in the 1961-1995 period. Refill capability in Deadwood is excellent and the reservoir would have filled under either option in all years except 1977, when it would have reached about 116,000 af content under the current plan, and about 134,000 af under the proposed new carryover limit.

**SPRING RULE CURVES**

The rule curves after April 1 are based on forecasted runoff at Horseshoe Bend. The spring rule curves are based on data from 1920 through 1974. The last 20 years of runoff records were examined for any potential impact on these curves. The curves were determined to still be adequate, and no changes are necessary in order to incorporate 1975-1995 data period.

With an accurate forecast, these curves will provide adequate flood control and assure reservoir refill. The forecast uses a multiple linear regression equation made up of precipitation, snowpack, and antecedent runoff variables. The coefficients for these variables are updated annually to include the latest year's data into the database. The forecasts are produced at the beginning of each month beginning January 1. Intensive efforts are made to assure the best possible forecast is used in operations, including (but not limited to) comparisons with other agencies' forecasts and with other hydrologically similar years. The development of an extensive system of remote sensing equipment (HYDROMET and SNOTEL) allows vigilant tracking of conditions on a real time basis, and provides a means of doing mid-month and 'earlybird' forecasts.

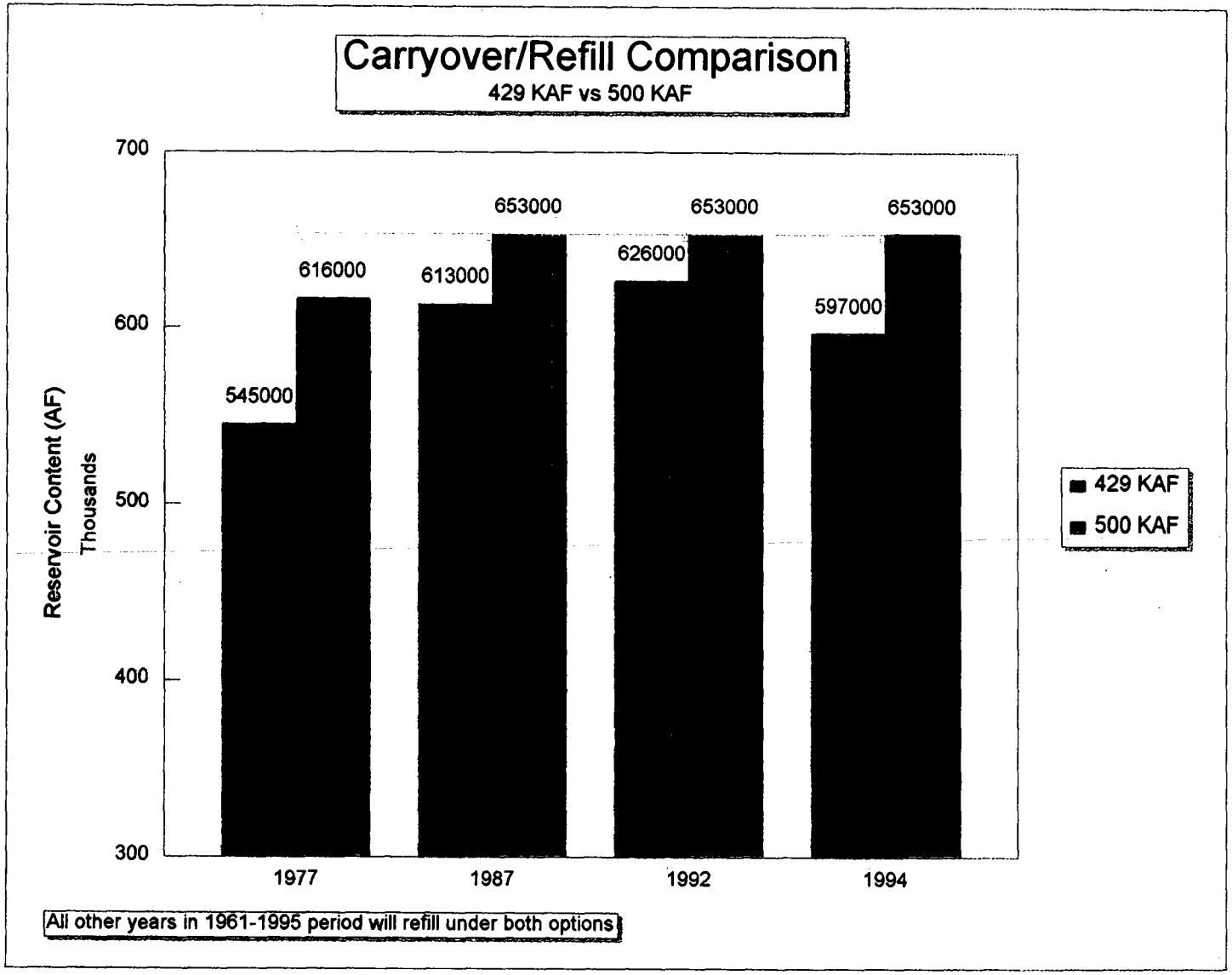
The accuracy of the Horseshoe Bend forecast was checked using a procedure known as a forecast generation. This procedure uses the current forecast equation (1995 equation) to recreate each month's forecast for every year of the forecast period, which is 1950 to 1995 for the Payette. The forecasts are prepared as if subsequent conditions are not known. For example, this recreates what the forecast would have actually been on January 1, 1950, using the current equation, and for February 1, 1950, etc. all the way up to the 1995 forecasts. These forecasts are then compared to the actual runoff observed for each respective period to determine relative errors and standard deviation in the forecast. The current forecast procedure for Horseshoe Bend has an average error of 8.6 percent on April 1 runoff forecasts, when applied to the 1950 to 1995 period. The forecast equation could predict runoff to within an average of 6.1% if all subsequent conditions were known at the time of the forecast. The forecast generation provides the statistical information necessary to establish confidence intervals to the runoff forecasts, allowing a range of probable outcomes to be considered when making actual flood control operations. The informal nature of the flood control operations allows flexibility to operate above or below curves if deemed appropriate.

**CONCLUSIONS AND RECOMMENDATIONS**

The current winter minimum flood control space of 280,000 af for the Payette system appears to be overly conservative when compared with actual historic winter flood events. A proposed new value of 190,000 af would provide adequate space to store all reservoir inflows during back to back events roughly equal to the maximum winter flood of record. Both dams can safely pass the probable maximum flood (a substantially larger event), starting at full pool, so safety of the structures is not an issue with either option. The proposed new value for minimum winter flood control space equates to maximum carryover amounts in Cascade and Deadwood Reservoirs of 500,000 af and 124,000 af, respectively. Attached as Enclosure 2 is a copy of the new rule curves reflecting this change.

The extra carryover allowed with a reduction of minimum winter space could potentially help refill capability in the driest of years, providing that the extra carryover is attainable going into such a year. In most years of near average or better runoff this extra November 1 carryover would most likely be released during spring flood control operations. Current operations on the Payette system for irrigation and flow augmentation obligate enough water from the reservoirs to preclude high mid-winter carryover amounts in most years.

Flood control operations on the Payette system are informal. Rule curves serve as an operational guideline, and actual operations can deviate from the curves according to hydrological conditions, presumed risks, runoff projections, operational flexibility needs, and maintenance requirements.


Carryover/Refill Comparison
429 KAF vs 500 KAF
700
600
500
400
300
Reservoir Content (AF)
Thousands
545000
616000
613000
653000
626000
653000
597000
653000
1977
1987
1992
1994
429 KAF
500 KAF
All other years in 1961-1995 period will refill under both options

***Enclosure 1***