SEDIMENT STUDY FOR RALSTON AFTERBAY RESERVOIR OPERATION FOR SEDIMENT PASS-THROUGH AND REDUCTION OF SEDIMENT DEPOSITION

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ABSTRACT

Ralston Afterbay Dam is located on the Middle Fork of the American River in Placer County, California, about 80 km North-east of Sacramento, California, and about 52 km upstream from Folsom Dam and reservoir. Ralston Afterbay serves as a re-regulating reservoir for Ralston Powerhouse, an 86 MW facility which is located on the Rubicon River at the head of Ralston Afterbay. The reservoir is a long, narrow, run of the river reservoir with a volume of about 3.4 million cubic meters.

Since Ralston Afterbay Dam was completed in 1966, the owner and operator, Placer County Water Agency, has experienced problems with sediment that have curtailed operation of the two powerhouses, and have required periodic dredging to keep the backwater from the reservoir from interfering with the operation of Ralston Powerhouse.

A sediment by-pass or Sediment Pass-Through (SPT) concept was developed for Ralston Afterbay Reservoir that will prolong the life of the reservoir and reduce the necessity for dredging the reservoir. Basically, the Sediment Pass-Through concept is a change in the way that the spillway gates and low-level outlet at Ralston Afterbay Dam are operated during floods, which will permit more sediment to pass through the reservoir than would be possible with the present operating procedures for the gates and low-level outlet. Thus, the concept is to change operating procedures so that more sediment passes through the reservoir, and less is deposited in the reservoir.

This concept was developed using HEC-6 for calculation of the deposition in the reservoir. Use of HEC-6 was complicated by the fact that the bed material consists of sands, gravels and cobbles, with a d_{50} in the upper reservoir deposits of 20 to 80 mm and a significant fraction of cobbles. The application of HEC-6 to analysis of the sediment deposition problem, the potential environmental impacts, and the recommendations for the changes in reservoir operating procedures are summarized in this paper.

Keywords: Reservoir operation, sediment deposition, sediment pass-through

INTRODUCTION

Ralston Afterbay Dam is located on the Middle Fork of the American River in Placer County, California, about 80 km North-east of Sacramento, California, and about 52 km upstream from Folsom Dam and reservoir. Ralston Afterbay serves as a re-regulating reservoir for Ralston Powerhouse, an 86 MW facility which is located on the Rubicon River at the head of Ralston Afterbay Reservoir as shown on Figure 1. The reservoir also impounds water for Oxbow Powerhouse, a 6 MW facility located near Ralston Afterbay Dam, as also indicated on Figure 1. The reservoir is a long, narrow, run of the river reservoir with a volume of about 3.4 million cubic meters. Ralston Afterbay Dam is a 27 m high concrete gravity structure equipped with five 9.1 m high by 12.2 m wide radial gates and one 1.8 m diameter low-level sluice.

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ANALYSIS OF THE PROBLEM

MOTIVATION FOR THE STUDY

Ralston Afterbay Powerhouse is located at the upper end of Ralston Afterbay Reservoir and contains one Pelton Turbine rated at 79 Mw and 382 meters head. The reservoir itself is long and narrow, with the result that deposition of sediment in the lower part of the reservoir caused excessive tailwater at the powerhouse. Since the unit was not equipped with a tailwater depression system, power generation had to be curtailed. The Placer County Water Agency dredged the reservoir several times following flooding in 1986, 1989 and 1994. Approximately 130,000 m^3 of deposition was removed in 1986, 30,000 m^3 in 1989, and about 53,000 m^3 in 1994. Because of the steep terrain, disposal of the dredged material presents problems both from space allocation and environmental viewpoints. The Placer County Water Agency therefore commissioned a study to ascertain if there was an economical way to solve the persistent and expensive problems caused by deposition of sediment in the Ralston Afterbay reservoir.

SEDIMENT MODEL AND CALIBRATION

The most critical aspect of an analysis of a reservoir sedimentation problem is the development and the calibration of the sediment rating curve for the reservoir inflow, irrespective of the detailed geomorphology in the upstream watershed. The HEC-6 model was developed by incorporating the channel geometry from a topographic survey of the reservoir, extending the river cross-sections about 900 meters upstream of Ralston Powerhouse, including the Ralston Powerhouse inflow, and including sediment data and reservoir operation rules.

As indicated by sediment sampling in the reservoir, about 30% of the total sediment deposition was expected to be coarse material with a median size larger than fine gravel. A literature review indicated that among the many published sediment transport equations, only equations from Parker (1982), Myer-Peter-Muller (1948), and Yang (1973) are among those few which are accepted by the sediment transport profession as suitable for application to coarse materials. The Parker equation is considered to be most suitable for use in the estimate of gravel transport. However, it was found that for application using HEC-6, Parker's (1982) method has the following disadvantages:

1. The format of his transport equation does not fit the pre-set format specified in the HEC-6 computer model.
2. It only computes the gross transport capacity for the gravel size and does not give the individual transport capacity by fraction for different sizes of coarse material.
3. It does not compute the transport capacity of sand sizes.

It was also found that the transport capacity given by the Myer-Peter-Muller (1948) equation is far too conservative and that both Parker (1982) and Yang's (1973) equations result in a similar transport capacity for the coarse materials. Since Yang's equation is one of the built-in equations in the HEC-6 model, Yang's method was therefore used in this study.

The measured bed profiles in the reservoir for 1966, 1987 and 1995 provided the means for calibrating the model. Using the 1966 bed profile as the baseline condition, the calibration process involves two important objectives: (1) the selection of a representative sediment gradation which would result in sediment deposition that matches the historical sediment profile data obtained in the reservoir, and (2) the development of a sediment supply rating curve, which after a 21-year sediment routing, would result in a deposition pattern and bed profile consistent with that surveyed in 1987.

With the fore-mentioned calibration objectives, a trial-and-error approach was then implemented to perform a sediment routing for the 1966-1987 period. It was determined that the average of the sediment data obtained in the lower, middle and upper reservoir constitutes a reasonable and representative set of sediment gradation data to simulate the sediment inflow from the watershed. Several combinations of gradation data from samples of the lower reach, the middle reach, and the upper reach of the reservoir were used for the calibration. For each combination of the assumed sediment gradation, the sediment transport capacities for different flow discharges were first computed for size fractions up to fine gravel and then extrapolated to material coarser than fine gravel. This computed sediment supply rating curve was used as the upper limit for the trial-and-error approach of HEC-6 runs. It was quickly found that the sediment supply is really governed by the sediment yield of the watershed. In other words, the river system is supply limited, just as field observations indicated. A revised sediment supply was then adjusted downward until the resulting sediment deposition volume and its corresponding gradations at various locations within the reservoir were reasonably similar to those surveyed in 1987.

The model was then validated by adjusting the sediment inflows to account for dredging operations between 1986 and 1995 and predicting the 1995 reservoir profile starting with the 1986 profile.

RESULTS

With the computer model successfully calibrated to simulate the past deposition in the reservoir, it was then used to predict future deposition for the following two cases:

1. The reservoir is operated just as it has been in the past (the “do nothing” option).
2. A Sediment Pass-Through concept is implemented.

The results showed that if present operating procedures continue (the “do nothing” approach) then deposition of sediment in Ralston Afterbay Reservoir will make it impossible to operate Ralston Powerhouse after about 15 years. If the SPT concept is implemented, then Ralston Powerhouse will continue to operate throughout the twenty five years of simulated deposition. Furthermore, the deposition at the end of the 25-year simulation period indicates that the powerhouse should continue to operate for considerably longer.

The SPT concept will not, however, completely solve the sediment problem because we cannot pass all of the material that comes into the reservoir through the reservoir. There is a large quantity of cobbles and boulders transported by the Rubicon River that cannot be passed through and will deposit in the reservoir. Consequently, the need for reservoir dredging can be delayed significantly, but inevitably, some dredging will be necessary. Our results thus show that the need for periodic dredging can be reduced significantly, and that this benefit can be achieved at relatively little cost to the Placer County Water Agency.

Several options were considered to supplement the SPT concept, including

1. Installation of a tailwater depression unit at Ralston Powerhouse
2. Construction of a sediment training wall at Ralston Powerhouse
3. Installation of a guard gate for the low-level outlet at Ralston Afterbay Dam

We concluded that if the SPT concept were implemented, the periods when the tailwater depression unit is needed would be so short that the cost of installation could not be justified. The training wall at Ralston Powerhouse also proved to be very costly. In addition, the recent installation of turbine pit gates at Ralston Powerhouse provides an additional method for controlling deposition in the turbine pit. We therefore concluded that operating experience with the SPT concept should be used to determine if a training wall warrants further consideration.

We also concluded that installation of a guard gate for the low-level outlet at Ralston Afterbay Dam was mandatory for implementation of the SPT concept. Past experience has shown that operation of the gate on the upstream side of the dam can result in debris jamming the gate. Since the operation of the low-level outlet is an essential part of the SPT concept, a guard gate must be installed to ensure that this outlet can remain operational and that it can be repaired easily should debris become lodged in the inlet.

THE SPT CONCEPT FOR RALSTON AFTERBAY RESERVOIR

The fundamental principle involved in the Sediment Pass-Through concept is to open the spillway gates and low-level outlet at the beginning of a flood event and to draw the reservoir down well before the peak flood flow occurs. This is in contrast to the present operating procedures, which keeps the reservoir level as high as possible throughout the flood event to maximize power production at Oxbow Powerhouse. Drawing the reservoir down increases the flow velocity through the reservoir and promotes transport of materials further down into the reservoir. It also provides for passage of suspended sediment in the inflow that under present operating procedures would have settled out and become trapped in the reservoir. This procedure reduces the deposition of material in the upper reaches of the reservoir which, in turn, causes a rise in tailwater and corresponding reduction in power generation at Ralston Powerhouse.

The Sediment Pass-Through concept is feasible at Ralston Afterbay for the following reasons:

1. The reservoir is essentially a run-of-the-river reservoir, is small, and can be readily drawn down at the beginning of a flood. Similarly, it can be refilled rapidly after the peak flood discharge has occurred.

2. The reservoir is long and narrow. Consequently, lowering the reservoir water level results in a significant increase in flow velocities through the reservoir, and increases the capability of transporting material further into the reservoir.

3. There is a low-level outlet that will reduce the accumulation of material directly in front of the dam by providing an outlet for sediment-laden flows

below the spillway crest during floods. The low-level outlet will remain operable as required for dam safety.

Thus, the configuration of the reservoir, the size of the reservoir, and the large spillway capacity all favor the use of a Sediment Pass-Through scheme.

There were some environmental concerns regarding material that was passed through the reservoir during the SPT operation. Analysis showed that this material would be fine sand or smaller, and would be transported downstream to Folsom Reservoir, just as it would have been prior to construction of Ralston Afterbay Dam.

CONCLUSION

The principal conclusion of this study is that implementation of the SPT concept at Ralston Afterbay Dam is a viable approach that can be used to significantly reduce the need for periodic dredging of Ralston Afterbay Reservoir. The changes in operating procedures required to implement this concept are not complicated. The concept will keep Ralston Powerhouse operational for a much longer period of time than under present operating procedures and will not result in adverse environmental impacts downstream from Ralston Afterbay Dam.

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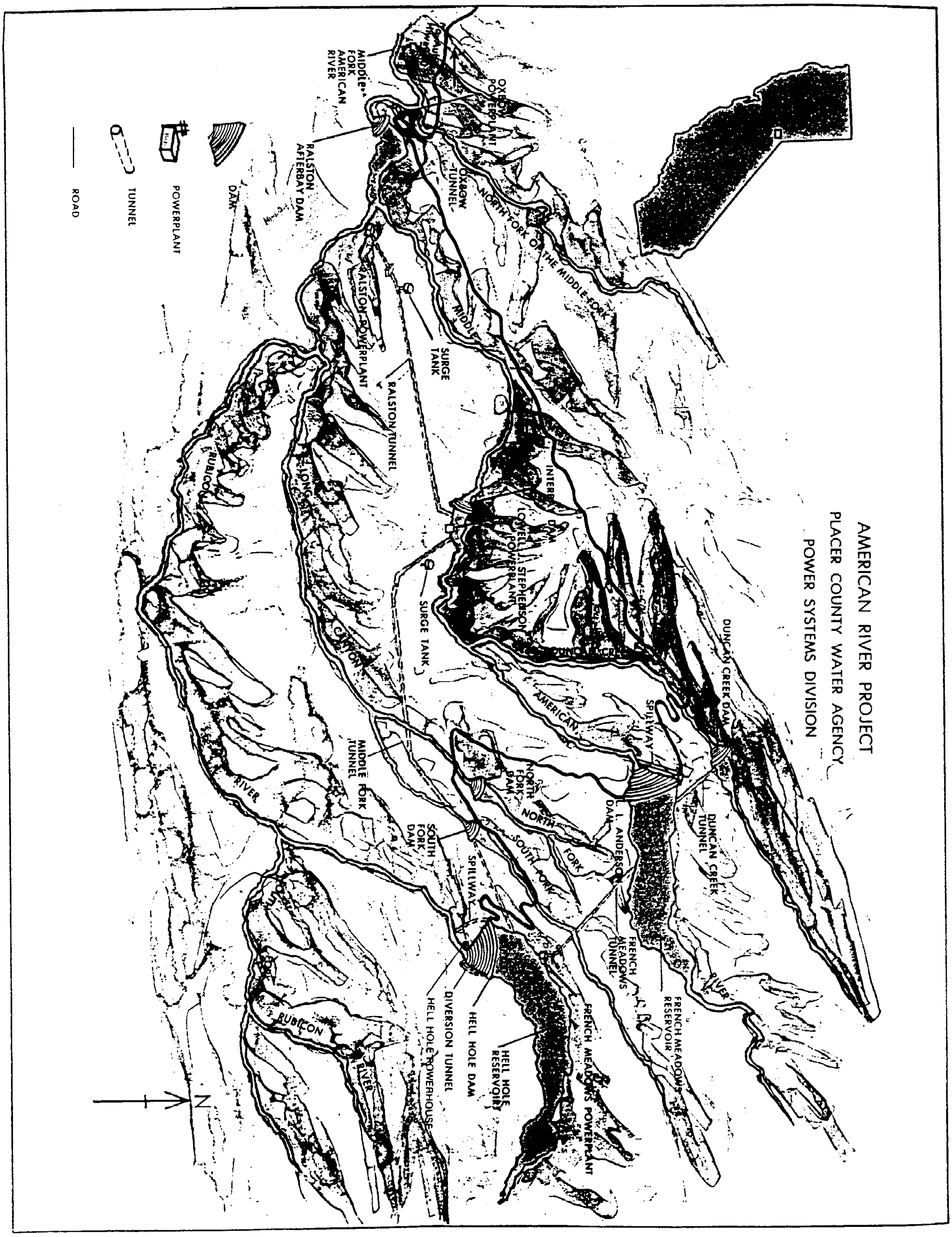

FIGURE 1. GENERAL LAYOUT OF RALSTON AFTERBAY DAM, POWERHOUSE AND AMERICAN RIVER PROJECT