

The Importance of Overbank Deposition on a Floodplain Adjacent to a Filling Reservoir

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I Introduction

Sedimentation in reservoirs can lead to loss of water storage capacity, impairment of navigability, loss of downstream flood-control benefits, increased flooding upstream because of streambed aggradation in the deltaic region, and sediment entrainment in hydropower equipment (Fan and Morris, 1992). One aspect of reservoir sedimentation that has received little attention is deposition above the normal pool elevation, as shallow overbank flows during high flow periods spread across the alluvial surface of the sediment deposit. While this deposition does not directly result in storage capacity loss it has the potential to have a wide range of effects. Deposition within the reservoir (below normal-pool elevation), reservoir trap efficiency, and the sediment response to dam removal are all likely to be affected by above normal-pool deposition. The goal of this study is to use a combination of numerical modeling and field work to understand the magnitude of above-normal pool deposition relative to all reservoir sedimentation, as well the key drivers for the spatial variability of above normal-pool deposition. Our research site is Searsville Reservoir, located within Jasper Ridge Biological Preserve on the Stanford University campus in California, U.S.A.



Fig. 1. Location of Searsville Reservoir in San Francisco Bay Area (Google Earth, 2009)

II Methods

A combination of field work and numerical modeling is being used in this study. A sediment core sample taken from the shallow upstream end of Searsville Reservoir is being analyzed using gamma ray spectrometry for ¹³⁷Cs, ²¹⁰Pb and ⁷Be in order to estimate sediment deposition rates. Further coring will be done in the future if good results are obtained from the initial core. In addition, sediment traps have been deployed at various locations in the floodplain area upstream of the reservoir. The traps consist of filter paper placed in petri dishes and secured to the floodplain surface using wire staples, in a method similar to that of Reed (1989). Additionally, preliminary numerical simulations using the model Delft3d² are being conducted using idealized domains. Eventually, simulations will be done for the Searsville Reservoir area and compared to field results in order to gain a better understanding of the magnitude and spatial variability of the overbank deposition and its importance relative to deposition in the reservoir.

VII Summary

Background

- o Deposition above normal-pool elevation is an aspect of reservoir sedimentation that has received relatively little attention.
- o A combination of numerical modeling and field work based at Searsville Reservoir in the Jasper Ridge Biological Preserve is being used to study the above normal-pool deposition that occurs when the inflowing channel floods its banks after large winter rainfall events.

Modeling

- o Numerical Modeling is being used to simulate sediment deposition both in the reservoir and in the floodplain upstream of it.
- o Of interest is the spatial variability of the above normal pool deposition and its importance relative to deposition below normal-pool, and the dependence of these parameters to inputs such as sediment and water inflows and parameterization of vegetation.
- o The transition area between the inflowing channel and the surrounding floodplain is an important area to resolve, as the turbulence at this location likely drives transport away from the channel and out onto the floodplain.

Field Work

- o Radionuclide analysis of sediment cores for ⁷Be, ¹³⁷Cs and ²¹⁰Pb is being used to study sedimentation rates in the reservoir.
- o Sediment traps have been deployed to study the magnitude and spatial variability of floodplain deposition following a rainfall event.
- o These field data, as well as data from various bathymetric surveys of the reservoir will be used along with results from the numerical modeling to develop a better understanding of the importance of above normal-pool sediment deposition and how that importance changes overtime as the reservoir becomes full with sediments.

VIII References and Acknowledgements

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 Dr. Peter Swarzenski of the USGS Santa Cruz has been generous with time and labspace for the analysis of sediment cores. Prof. Oliver Fringer of Stanford continues to provide expertise in numerical modeling. David Hochstetler, Yacoub Rabehm, Spencer Searskaw, Yacoub Rabehm, Rae Brownshberger and Matt Le have helped with field work.

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III Field Site



Fig. 2. Searsville Dam is an old concrete structure whose construction by the Spring Valley Water Company was first completed in 1892. Downstream releases are exclusively via the broad-crested overflow spillway weir.



Fig. 4. Map of Searsville Reservoir and its surrounding area. The red outline indicates the approximate original extent of open water.



Fig. 6. Remaining ponded water on the floodplain upstream of Searsville Reservoir following the February 2009 flood event. Much of the floodplain was covered by a sheet of sediment-laden water and a new layer of sediment deposition was observed following the event.

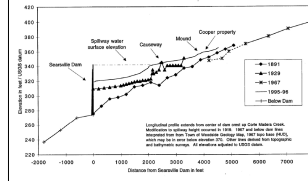


Fig. 3. This figure, taken from Balance Hydrologics (1996), Figure 14, shows the changes in the longitudinal profile from the dam crest up Corte Madera Creek over time. Note the substantial deposition above the spillway crest elevation.



Fig. 5. Corte Madera Creek, the main inflow to Searsville Reservoir, just after an overbank flooding event in February, 2009.



Fig. 7. Upstream end of Searsville Reservoir in February 2009. Much of the visible vegetation is growing on sediments deposited above the normal-pool elevation of the reservoir.

IV Radionuclide Analysis of Sediment Cores



Fig. 8. Collection of sediment core.

Radionuclide analysis of sediment cores has been widely used for decades both for coastal and lacustrine environments to determine rates of deposition and erosion of sediment over time scales on the order of years to decades. The use of the three isotopes chosen for this study has been well-established for analysis of sediment budgets over the time scales of interest—both within a year (⁷Be) and over decades (¹³⁷Cs and ²¹⁰Pb). Analysis is currently being conducted on an initial sediment core. If the method proves viable for this setting, more cores will be taken from the reservoir, and possibly from the floodplain as well. Beryllium-7 has a half life of 0.146 years and can be used in a method similar to ¹³⁷Cs and ²¹⁰Pb to measure shorter-term deposition rates, on the order of months as opposed to years and decades. This will allow for comparison with modeling results from single flood season simulations and data collected with sediment traps, whereas the ¹³⁷Cs- and ²¹⁰Pb-determined sedimentation rates over decades will be compared to estimates derived using bathymetric data, as well as modeling results from multi-year simulations. Searsville reservoir sediments are largely non-cohesive silts, with some clay and fine sand.

V Sediment Traps

- Sediment traps of various kinds (e.g. hardboard plates, astroturf) have been used in a number of studies.
- Using sediment traps allows for frequent sampling, and for collecting samples quickly after a significant flooding and sedimentation event (Reed, 1989).
- The Corte Madera Creek watershed is in an area of which includes very erodible rock formations, particularly the Purisima Formation.
- Sedimentation events at Searsville occur after seasonal flooding events.
- Sediment traps are being used in this study in order to understand the magnitude and variability of these overbank sedimentation events.
- The currently deployed traps are 9 cm diameter petri dishes with filter paper and secured with wire staples (similar to Reed, 1989).
- Vegetation likely plays an important role in determining the spatial pattern of deposition.

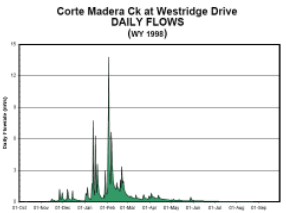


Fig. 9. Corte Madera Creek Daily Flows for 1998. Taken from Freyberg and Cohen (2001). Data from Balance Hydrologics (2000a).

VI Numerical Modeling

While custom models have been developed for dam removal and single turbidity currents, it appears that no models have been developed specifically to simulate a filling reservoir, or to include deposition above normal-pool elevation. Thus, this research fills an important need.

Modeling Considerations

- Past work on modeling overbank erosion and deposition has rarely used full Navier-Stokes equations.
- Need a model that couples sediment transport and morphological changes to hydrodynamics.
- The Transition between channel and floodplain is a key area. Will need to resolve the eddies in this area which play a key role in transporting sediment away from the channel.
- Interested in time scales from a single hydrograph to multiple years.
- The numerical modeling strategy for this research will be to use both idealized domains and a domain based on Searsville to simulate sediment deposition both on the floodplain and in the reservoir.
- Delft3d (Deltares, 2008) is being used in this study.

Input parameters of interest

- Inflow hydrograph
- Vegetation
- Magnitude and grain size distribution of sediment inflows

Output parameters of interest

- Relative magnitude of deposition on the floodplain vs. in the reservoir
- Spatial distribution of deposition on the floodplain

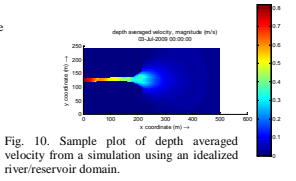


Fig. 10. Sample plot of depth averaged velocity from a simulation using an idealized river/reservoir domain.

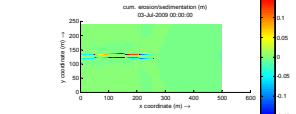


Fig. 11. Sample plot of cumulative erosion and sedimentation from a simulation using an idealized river/reservoir domain.