What can we learn from the removal of little dinky dams?

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Abstract

The topic of ‘dam removal’ has garnered national attention and been the focus of special sessions at numerous national scientific meetings; yet there remains a disparity between the need to understand and predict the effects of removing dams and the current state of the science. It has thus been argued that the removal of small dams should really be viewed as research opportunities. But why? And more importantly, how? While much has been written on dam removal, the majority of scientific literature published to date is based on anecdotal evidence and/or focused on broad contextual issues surrounding large dams. According to the 2002 Heinz Center report on Dam Removal; however, the vast majority of dams in this country, and almost all dams removed thus far, are small. Given the subtlety of their effects and the wide range of geomorphic contexts in which small dams are found, a consistent set of monitoring protocols are required if we are to develop a comprehensive understanding of dam removal effects. In this way, an empirical set of case lore can be built with which to test more rigorous dam removal models. Using insights gained from the removal of two small dam removals in Oregon; we offer the beginning of a national small dam removal monitoring protocol.

Introduction

Of the more than 77,000 dams listed in the U.S. National Inventory of Dams (NID) database (National Inventory of Dams, 2000), approximately 28% are beyond the average design life of 50 years; by the year 2020 that number will increase to more than 70% (Figure 1). While the structural life of a dam may be longer than 50 years, planning and economic studies rarely exceed 50 years and costs associated with maintenance and rehabilitation increase over time while accrued benefits decrease (Born et al., 1998).

American Rivers (2000) has identified more than 450 dams that have been removed from U.S. rivers since 1912; most were small and were removed because they were no longer performing the functions they were created for, posed environmental or safety concerns, and/or because the cost of dam rehabilitation was greater than the perceived benefits that dam provided. A recent study of small flood control dams in 22 States found that: 1) more than 22% of the 10,000 dams included in the study were in need of rehabilitation, 2) at least 650 of those dams posed a threat to public health and safety, and 3) the cost of rebuilding and upgrading just those 650 was nearly $400 million (Natural Resources Conservation Service, 2000).

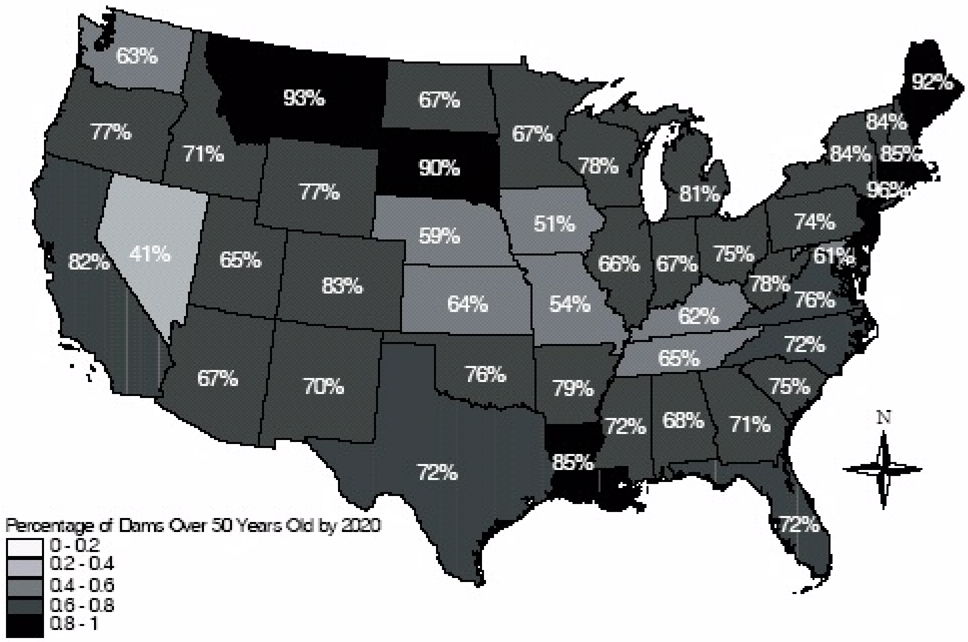

Figure 1: Percentage of dams over 50 years old by 2020 based on the National Inventory of Dams (2000).

As the average age of U.S. dams continues to grow, so will the number of cases in which cost-benefit analysis falls on the side of dam removal. This is especially true for small dams, which are less likely to serve their original purpose, and can be removed with relatively low cost and limited environmental impacts (Doyle, et al. 2003). Just as the effect of dams varies, so too will the effects of dam removal: some will have little or no effect yet others are likely to stimulate dramatic effects on river and ecosystem processes (Grant, 2001). It has been argued that the removal of these structures should be viewed as research opportunities (Doyle, et al. 2003), but how?

Given the subtlety of their effects, and the wide range of geomorphic contexts in which small dams are found, small dam removal research requires semi-quantitative documentation of dam removal processes over a wide variety of conditions based on a relatively consistent set of monitoring protocols (Pizzuto, 2002). In this way, an empirical set of case lore can be built with which to test more rigorous dam removal models.

In this paper we present a few of the techniques used in monitoring sediment dynamics associated with dam removal in Oregon. The purpose of these examples is to highlight the potential utility of a national small dam removal monitoring protocol, and to serve as a catalyst for its development.

Small Dam Removal Monitoring Protocol

Dam removal occurs within a geomorphic and ecological context that is particular to individual rivers and dams. Dams located in steep mountain streams carrying a range of grain sizes can be expected to erode and deposit sediment at different rates, and by different mechanisms, than those in low gradient rivers carrying only fine sediment. Thus aspects of national monitoring protocol will have to be tailored to regional conditions, yet must contain enough core similarities to allow inter-regional comparisons.

We focus on erosion and sedimentation associated with the removal of small dams whose reservoirs have filled with sediment (hereafter referred to as sediment filled dams). The release of stored reservoir sediment remains the most fundamental, yet poorly understood processes associated with dam removal (Heinz Center, 2002), especially in sediment filled reservoirs that have a limited ability to affect thermal and/or hydrologic regimes.

Reservoir Erosion

Monumented topographic and photographic surveys provide excellent means of recording the rates, timing, and magnitude of reservoir erosion (Table 1). Given their relatively simple geometries, topographic surveys of reservoirs can be collected with a modicum of effort and can be manipulated within GIS or CAD programs to provide quantitative estimates of reservoir erosion volumes between successive events (Figure 2). Channel geometries can be extracted from these topographic surveys as they change through time.

Because reservoir erosion is a function of discharge, the use of time-lapse photography with the sampling interval a function of discharge, can be extremely useful. Vertical knickpoints, for example, can migrate large distances over short time periods during periods of extremely inclement weather. During these periods, it may not be possible (or advisable) to collect field measurements, and the use of photography may help constrain the conditions and processes under which reservoir erosion occurs.

Water discharge and reservoir sediment properties offer first order controls on the rate, magnitude, and process by which reservoir erosion occurs. Reservoir sediment grain size measurements should be collected before and after dam removal. Pre-removal

Table 1: Small dam reservoir measurements

Physical Measurements	When to Collect	What they Inform
Monumented Photographs	Before, During, After	Process, volume, timing, geometry
Topographic Surveys	Before, During, After	Process, volume, timing
Discharge	During, After	Process controls
Surface and subsurface grainsize	Before, After	Process controls
Sediment properties (e.g cohesiveness)	After	Process controls

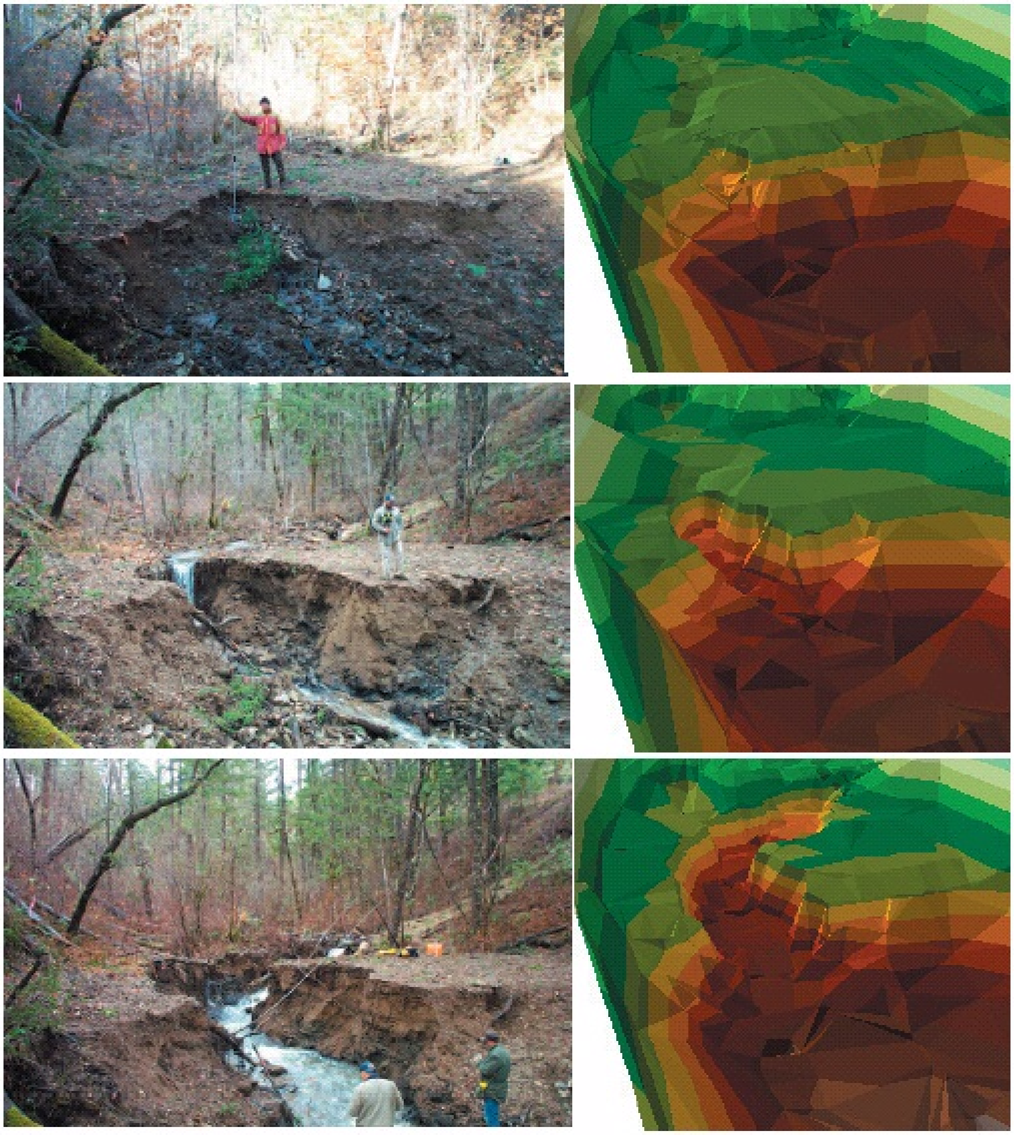

Figure 2: Example of the way monumented photographs (left) and modeled topography (right) can be used to illustrate erosion process, volume, timing, and geometry. Erosion is by vertical knickpoint migration and volume through time is calculated as the topographic difference between surveys.

grainsize data can be used for evaluating model development and testing a-priori hypotheses, while grain size measurements taken after reservoir incision may be necessary to correctly interpret why a reservoir eroded the way it did.

Downstream Deposition

At least three generic models of sediment transport following dam removal have been proposed in recent years: 1) dispersion, in which the accumulated sediment appears to decay in place; 2) translation, in which a sediment wave propagates downstream without a decrease in amplitude; or 3) a combination of both processes (Pizzuto, 2002).

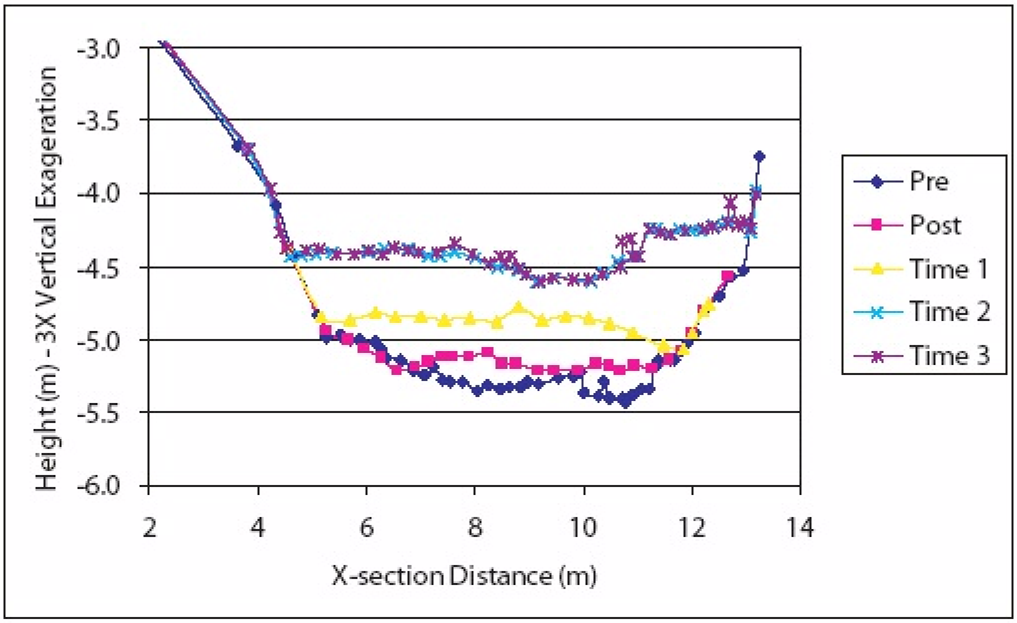

Figure 3: Cross-sectional measurements are well suited to rapid data collection and provide relatively detailed quantification of channel aggradation.

In the near dam region, a combination of topographic surveys, monumented photographs, channel cross-sections, and longitudinal profiles can be used to effectively quantify the proportion of reservoir sediment propagating by diffusion. Cross-section surveys are relatively easy to collect and provide detailed information on channel change for the area where they are collected (Figure 3). Where deposition is not uniform, however, cross-sections may be poorly suited to analysis of patterns or volumes of deposition. Volume estimates are likely to require detailed topographic surveys collected over a uniform grid or along topographic breaks in slope (Figure 4). Topographic and cross-sectional surveys are most useful when combined with repeat photography. Photographs have the potential to pointedly illustrate patterns and process associated with sedimentation that may not be obvious in survey data alone (Figure 5).

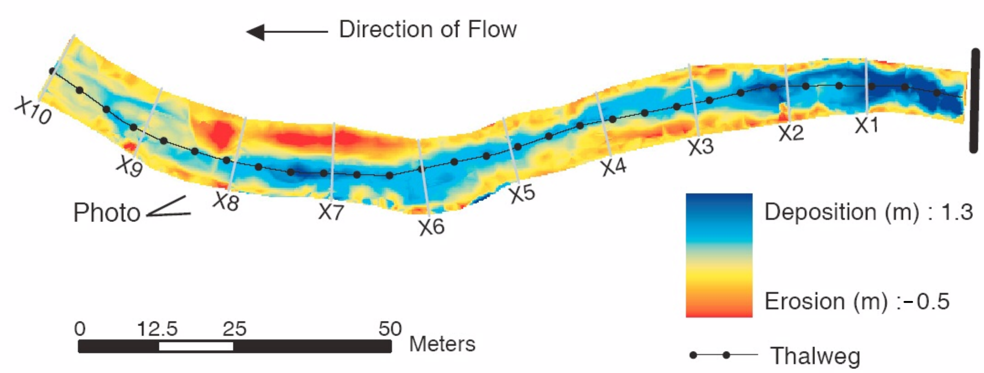

Figure 4: Topographic surveys collected between cross-sections allows for a more complete description of river sedimentation patterns. Photo point for Figure 5 shown.

Figure 5: When combined with topographic and cross-sectional surveys, repeat photography collected from monumented photo points can provide additional insight on channel change associated with dam removal. Top: Before dam removal. Bottom: 1-year after dam removal

Conclusions

We have presented the beginning outline of a monitoring protocol for evaluating the geomorphic implications of dam removal. These examples inform only a few of the geomorphic, and none of the ecological, questions related to dam removal; but we hope they will inspire a more complete dialog leading to the development of a national protocol for small dam removal monitoring. Few large dams have been removed to date, but several are slated for removal in coming years (e.g. Elwha and Glines Canyon Dams, Marmot Dam, and Matilija Dam). Meanwhile, small dams continue to be removed. If we are to learn the valuable lessons that little dinky dam removal offer us, we must develop a means for cataloging and differentiating small dam removal effects. Until we do, we are faced with contemplating the removal of large dams with greater uncertainty than warranted.

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