USU Ecosystem Restoration Consortium
Sediment Transport for Stream Assessment and Design
July 30, 2024

Logan River – Sediment Delivery to First Dam

Goals for learning and discussion:

A. Use simple hydraulic model to estimate gradually varied flow
B. Apply spatially variable stress to considerations of grain entrainment
C. Discuss sediment supply to First Dam Pond

Background

The city of Logan generates a small fraction (roughly 10%) of its electricity from two run-of-river hydroelectric plants. The lower plant takes water from Second Dam through a pressure penstock to the powerhouse at Ray Hugie Hydropower Park (Figure 1). The available head is about 60 m; the flow is limited by the need to deliver water to the diversion to the Logan, Hyde Park, and Smithfield Canal. The powerhouse discharges just upstream of First Dam, which has its own small hydro plant and also provides for diversion of water to the USU Water Research Lab just downstream.

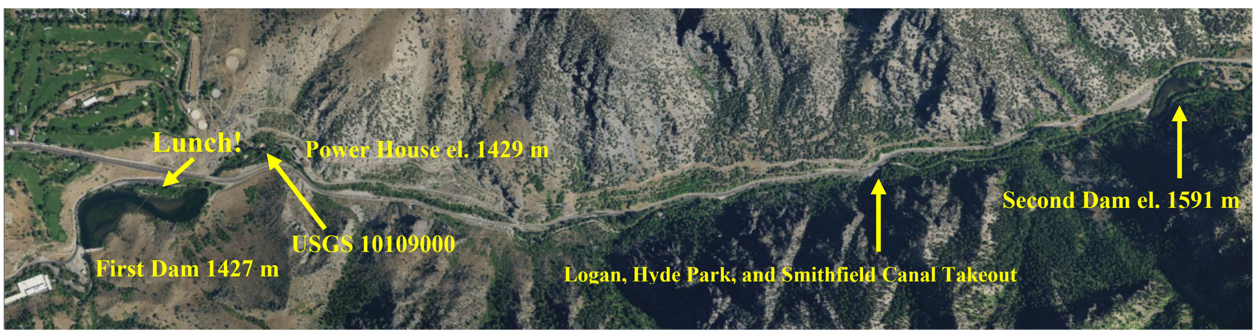

Figure1 1: Location and elevations, Lower Logan Canyon

Discharge is measured at USGS gage 10109000 just below the powerhouse return flow. It has an impressive 127-year record (there is an even older gage in Cache Valley). A record of annual maximum flows is given in Figure 2. Once spring runoff is over, there is little discharge between the canal diversion and First Dam during irrigation season. In roughly half of the years, the annual peak occurs before diversions begin. The diversion flow is also gaged by the USGS.

You have considered sediment supply and delivery through Logan Canyon. First dam traps sediment leaving the steep canyon and entering the Cache Valley floor. What is sediment supply to First Dam? Second Dam is mostly full of sediment and definitely passed all sizes in the 2023 flood. Does it pass sediment to First Dam? The reach below Second Dam does see high flows, whether the peak occurs before diversions begin or when the peak flow is much larger than the diversions at the time. The channel between the dams is very steep, with a coarse armored bed (Figure 3).

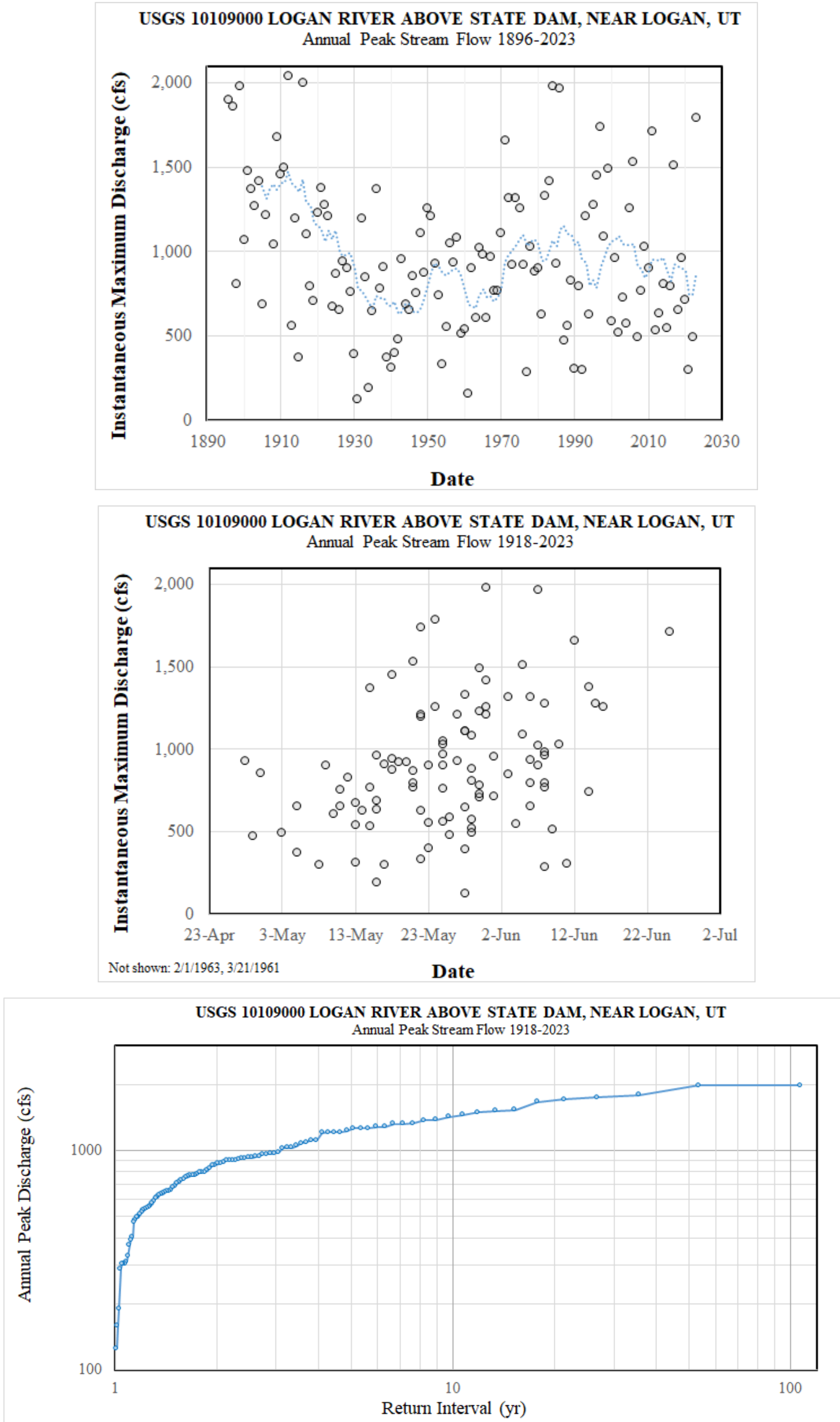

Figure 2. Annual maximum instantaneous flow, Logan R above State Dam. (a) Time series 1896-2023. (b) Date of peak flow (1918-2023). (c) Flood frequency curve (1918-2023)

Figure 3. Logan River at footbridge near Stokes Nature Center. 1.0 km above USGS 10109000

The reach below the powerhouse contains a prominent cobble bar (Figure 4). The USGS gage is near the upstream extent of the bar and flow over the bar crest acts as the control for the gage rating curve. Water level below the bar is generally very close to that of the First Dam pool. The bar appears to be a delta formed by sediment delivered from the upstream reach. Curiously, the bar appears to have been remarkably stable for decades. Is delivered sediment overpassing the bar? Is no sediment being delivered?

Exercise

In addition to enjoying a picnic and discussing flow measurement at the gage, we will consider the likelihood of grain entrainment on the bar and sediment delivery to First Dam pool.

Figures 5 and 6 give a long profile and cross-sections through the reach approaching the powerhouse and through to the First Dam pool. Elevations are from sub-m statewide lidar. The channel slope is very small approaching and passing the powerhouse, but this reach is also very narrow and engineered to give rapid flow that transports all sediment delivered to it. The slope on the cobble bar is steeper and the downstream end of the bar is close to pool elevation. Detailed long profiles over the bar are given in Figure 7 and a 2022 pebble count of the bar surface is given in Figure 8.

When considering flow over the bar, it is useful to remember that flow depth (hence, velocity and shear stress) vary alongstream. Assuming flow is critical over the bar crest (this is our ***flow control***), there will be a drawdown curve in the flow approaching the crest. The water surface elevation of First Dam pool will change with discharge and gate settings, introducing the possibility of a backwater curve over the bar.

You have been provided with a spreadsheet [**Logan R First Dam Approach Reach.xlsx**] that performs a direct-step backwater computation. Recall that the direct step approach requires that we know the channel geometry and elevation everywhere. We approximate the channel as a rectangle and you will need to assign a channel width and slope. Also, you will need to specify hydraulic roughness. You should consider how the flow behaves for different discharges. If you wish, you can mess with a backwater. Keep in mind the bar is no more than 70 m long – upstream of this the channel narrows into a high velocity engineered channel. Details on input are given in the spreadsheet

→ Evaluate whether the material in the bar is mobilized during floods. Is the bar static or mobile?
→ Evaluate whether you think the bed material in the bar is being delivered to the First Dam pool
→ What happened in the largest recent flood? In 2023, we had 1790 ft^3/s on May 24 which is about a 35 yr RI on Weibull plot.

The problem is somewhat open-ended. This is a chance to play with gradually varied flow in the context of sediment transport.

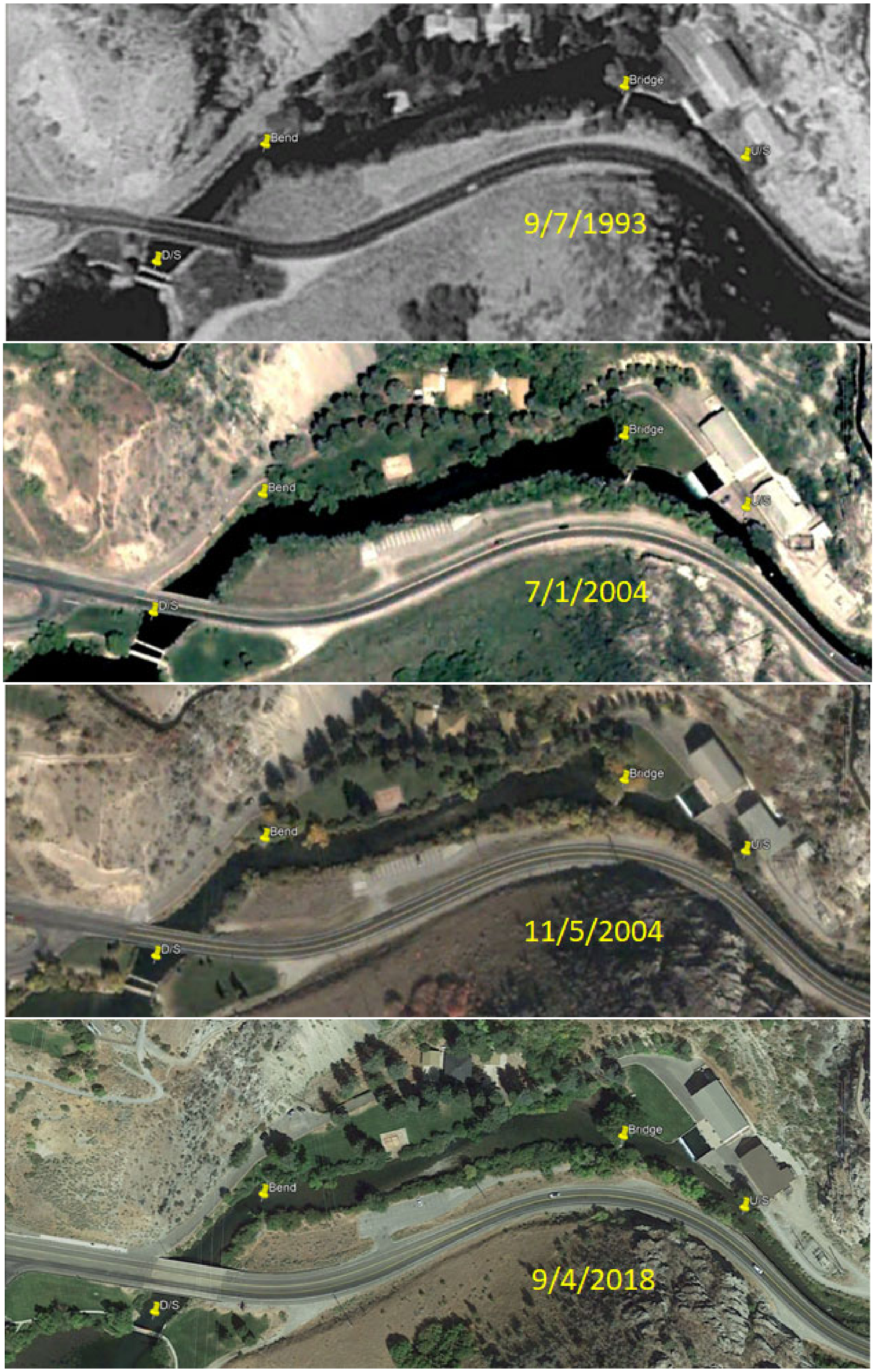

Figure 4. Logan River, over time, between the lower powerhouse and First Dam pool.

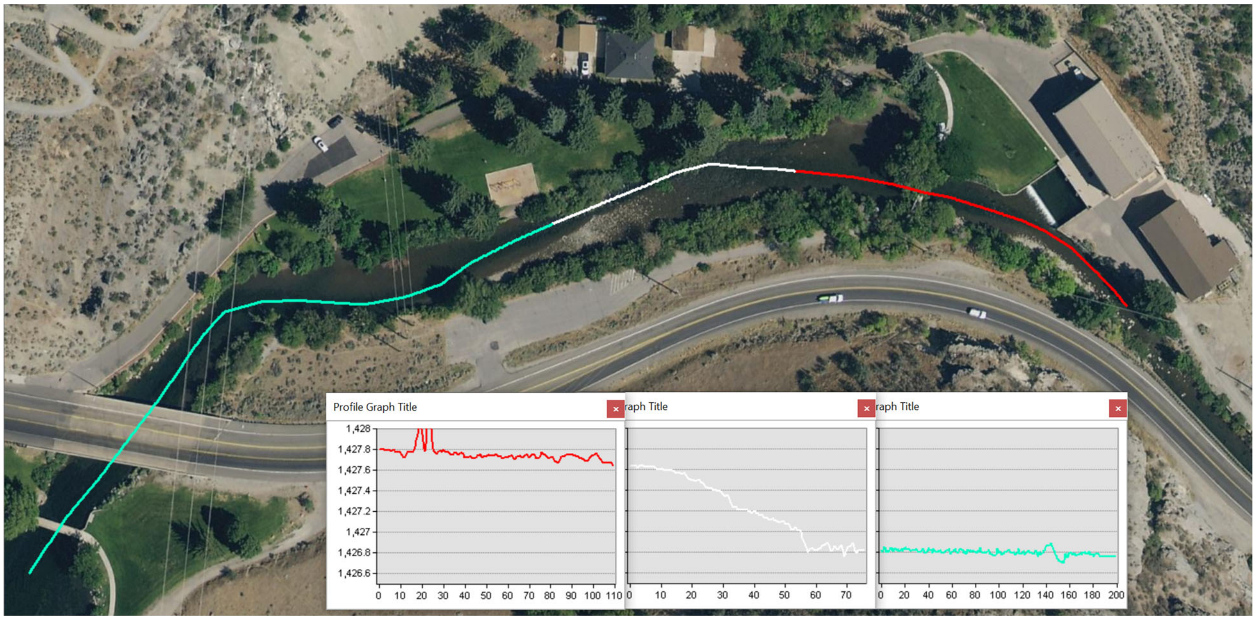

Figure 5. Long profile through reach approaching powerhouse and First Dam

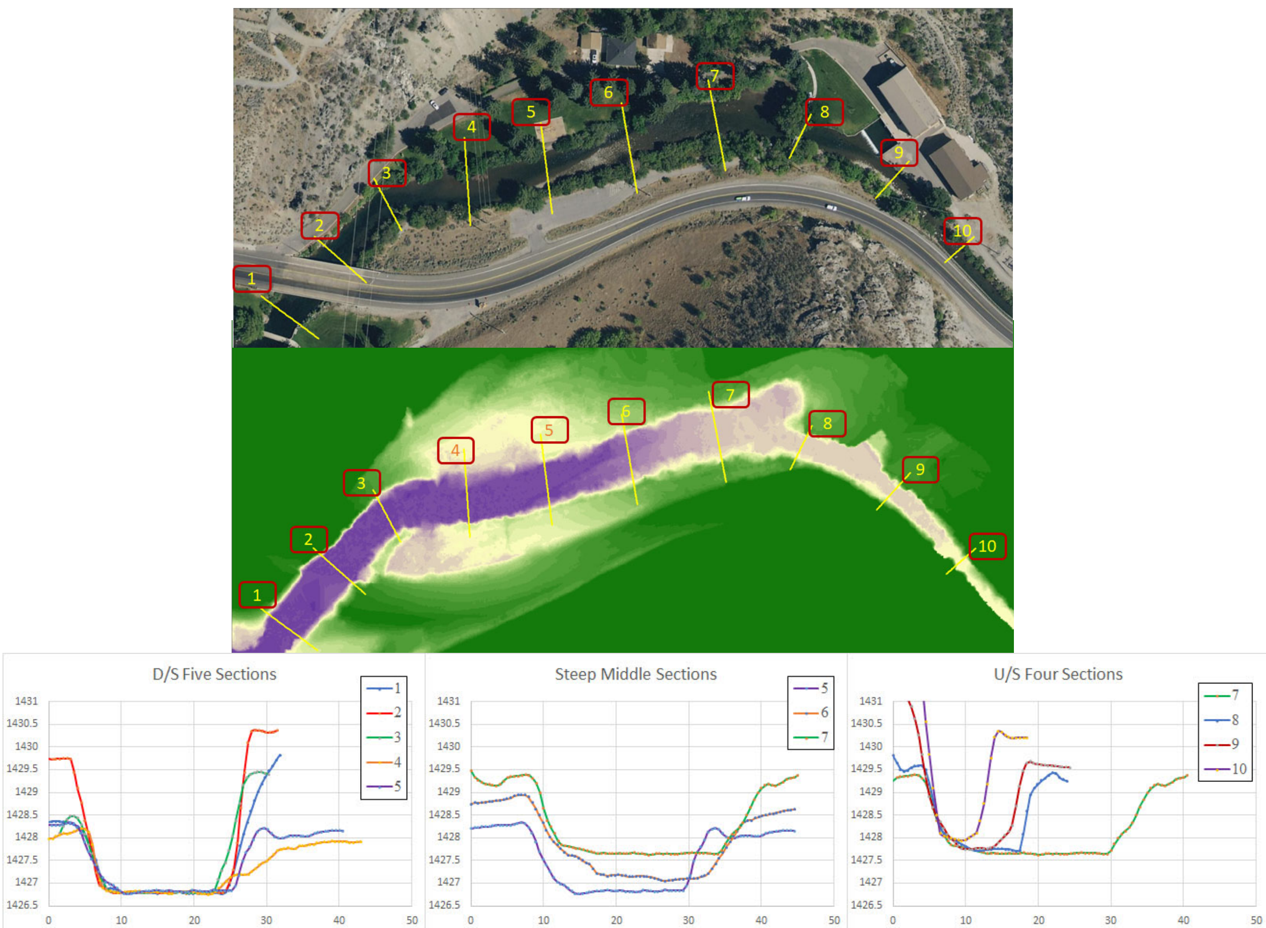

Figure 6. Cross-sections through reach approaching powerhouse and First Dam

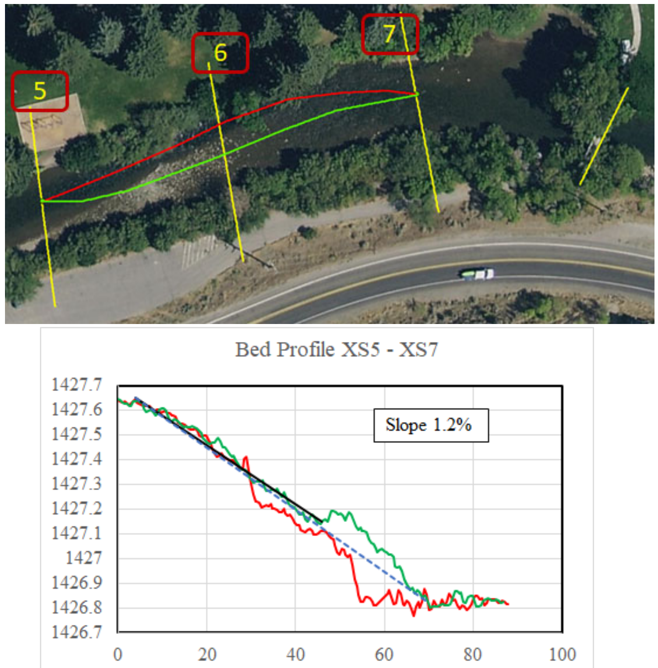

Figure 7. Long profiles over cobble bar.

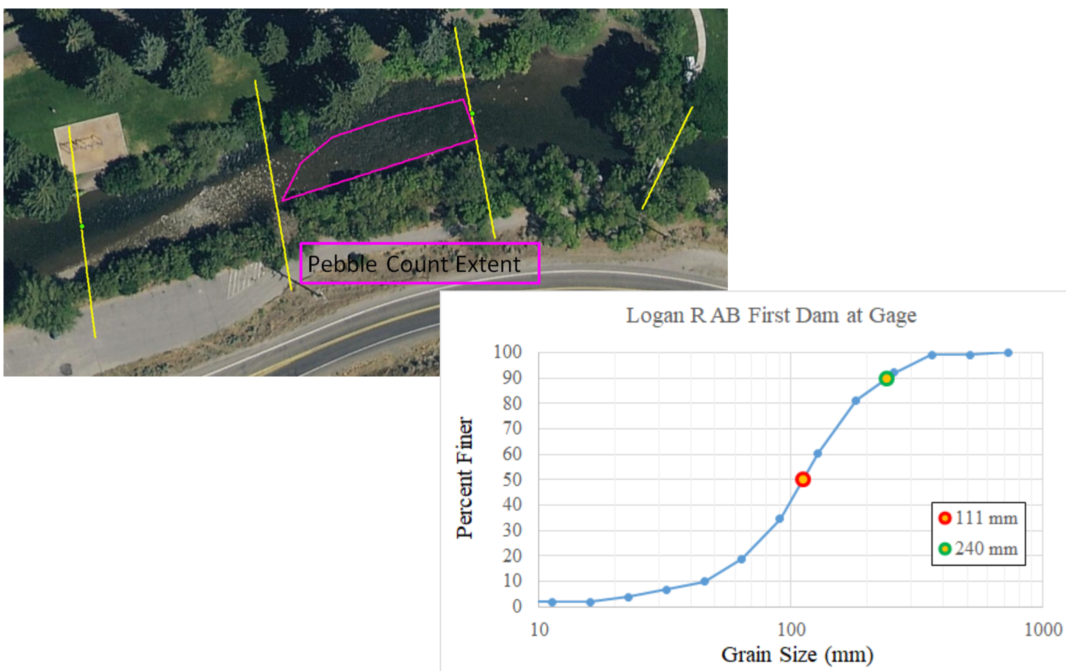

Figure 8. Pebble count (N = 101) of cobble bar

Is that ALL?

In addition to the delivery of coarse gravel and cobble bed material, what about the delivery of fine sediment? It turns out that there is sufficient delivery of fines that the small storage capacity of the reservoir quickly fills with mud and sand. The reservoir has been periodically drained to flush the sediment and for maintenance on the dam (Figure 9). In October 2001, the pool was drained in order to rehabilitate the dam. River flow was low and the sediment sluiced from the reservoir deposited along the river and killed much of the fish population. This was a major issue and a black eye for the university.

Figure 9. First Dam reservoir, drained. B&W from 1920s, roughly 10 years after dam completed in 1914. Color: October 2001, pool drained to reconstruct dam. Sediment sluicing during low river flow (100 cfs) produced extensive deposition and fish kills downstream.

Sediment is sluiced through two low level outlets (Figure 10). UWRL was retained to develop a sediment management plan. They determined that flow should be at least 400 cfs before the first outlet is opened and at least 500 cfs before opening the second outlet. Further, the gate above the outlet should be adjusted such that surface water cascades down on the slurry discharge.

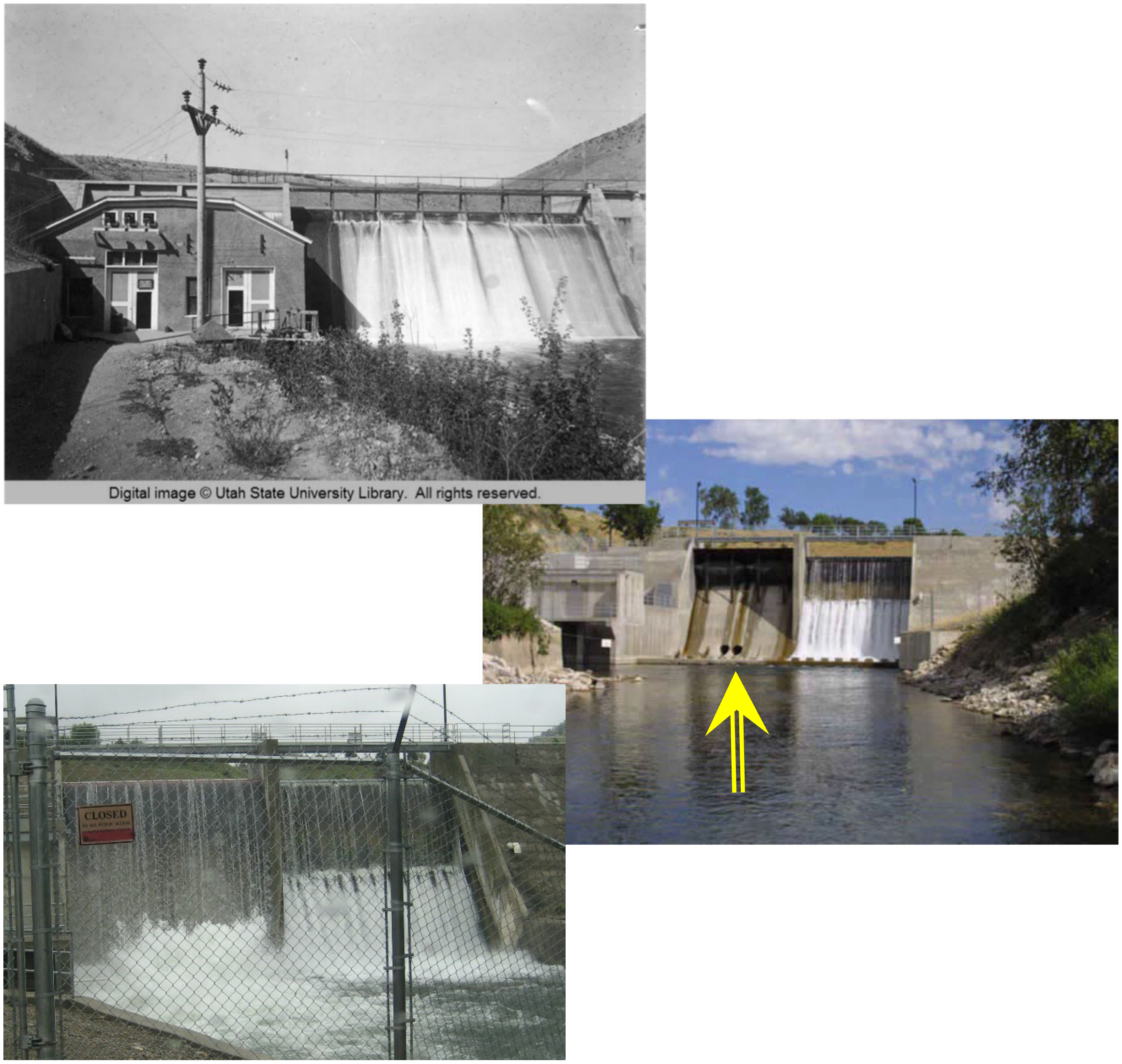

Figure 10. The original dam and powerhouse (B&W) and the rebuilt dam (color, 2002). Low level outlets are indicated and combined operation of the low level outlets and main gate shown.