Extended Abstract: An Upcoming Pilot Project for Reservoir Sediment Removal via Water Injection Dredging

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Abstract

Reservoir sedimentation is a serious problem impacting reservoirs worldwide. At Tuttle Creek Lake in north-central Kansas, the multipurpose pool has filled in at a rate of 6.1 million cubic yards per year and the flood pool and a rate of 2 million cubic yards per year. Traditional dredging with land storage would cost over $57 million per year, just to maintain current storage.

Starting in the Spring of 2024, a sediment removal demonstration project using water injection dredging will take place at Tuttle Creek Lake. This will be the first time water injection dredging has been used in a lake, anywhere in the world. This presentation explains the basics of water injection dredging, discusses the parameters under which this technology can be successful, and presents baseline data, operational, and monitoring plans for the upcoming demonstration.

Water Injection Dredging

Sediment deposits and accumulates in reservoirs in the United States and across the world. In the United States, only a handful of reservoirs manage sediment for sustainability of the lake volume (Shelley et al. 2022). Traditional hydraulic dredging methods include loosening, suctioning, transporting via pipeline, and disposing of sediment into a confined disposal facility or beneficial reuse location. Due to the large quantities involved, these traditional methods have proven cost prohibitive at many reservoirs in the United States.

Water Injection Dredging (WID) is a relatively niche dredging mode that has been applied in harbors, ports, and navigation channels but not yet in lakes. Welp et al. (2017) explains:

> "WID is a dredging technique in which a dredge vessel pumps water into channel bottom sediments at low pressure and relatively high-volume flow rates. This dilutes and fluidizes the sediments, creating a near-bottom layer (density current) with higher density than the surrounding water. This layer is transported downslope by gravity to deeper water."

Density currents form naturally in some lakes as heavier, sediment-laden water plunges and travels along the bottom of a lake due to the difference in density. Water injection dredging induces the density current by creating heavier, sediment-laden water near the lake bottom. The heavier water then flows downslope.

Where it works, WID is often the least expensive way to remove sediment, because it works with rather than against gravity. Instead of pumping a sediment slurry up from the reservoir bed and

then thousands of feet through a pipeline, the dredge pumps only clear water tens of feet down to the reservoir bed.

Figure 1. The jet bar on a water injection dredge used by the port of North Carolina.

Tuttle Creek Lake

Tuttle Creek Lake impounds the Big Blue River in north-central Kansas. It had an original multipurpose pool size of 424 kac-ft, but sedimentation had shrunk the lake to 257 kac-ft in 2009. Projections indicate that by 2074, the multipurpose pool will be 75% full of sediment which endangers water sustainability for millions of people in Kansas.

Figure 2. Tuttle Creek Lake (from Shelley and Wells, 2019)

The bed of Tuttle Creek Lake is comprised of predominantly clay and silt with very little sand. Shelley and Wells (2019) found the material very erodible, with critical shear stresses ranging from 0.1 to 1.6 Pa.

Most importantly, the gates through which Tuttle Creek Lake releases water are situated on the lake bottom. Thus, a turbidity current that travels to the inlet will be able to free flow through the conduit to the downstream channel.

Pilot Project

Congress provided initial funding for a Tuttle Creek lake water injection dredging demonstration project in the 2022 Energy and Water Development Appropriations Bill. As currently planned, the dredge will operate for 1 to 2 weeks in the Spring, Summer, and Fall of 2024. The time between dredging events will allow for updating the operation to increase effectiveness and/or decrease impacts. Moreover, it will allow a study of the effects of sediment releases in the downstream channel over a range of seasons.

In-lake Monitoring

This demonstration project presents a unique opportunity to gain insight into density current processes and water injection dredging specifically. Major questions we hope to answer include:

How much sediment does a single pass of the WID remove?

How deep is the sediment excavation?

How far and quickly does the turbidity current transport?

How does the turbidity current spread out or deposit as it travels?

What are the optimal dredging parameters (dredge speed, water jetting rate, jetting angle, etc.)

What would the cost per cubic yard of removal be for continuous, long-term implementation?

Downstream Channel Monitoring

Tuttle Creek Lake discharges to the Big Blue River, which free flows through the Kansas, Missouri, and Mississippi Rivers to the Gulf of Mexico without any major impoundments. A very significant monitoring effort is planned for the downstream channel to (1) estimate the sediment concentrations and loads released by the WID, (2) comply with the water quality and environmental requirements of the Environmental Assessment, and (3) study the effects of sediment releases from reservoirs on aquatic organisms.

Collaborators

The Water Injection Dredging project is being led by the Army Corps of Engineers, Kansas City District, with project stakeholders and research collaborators from multiple agencies including the Kansas Water Office, USACE Engineering Research and Development Center, Kansas State University, Kansas Department of Health and Environment, US Geological Survey, Bureau of Reclamation and University of Kansas.

Conclusion

Reservoir sedimentation is a growing problem across the United States. The Water Injection Dredging demonstration project at Tuttle Creek Lake will offer a unique opportunity to understand how water injection dredging

References

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