Dams and Sediment in the Hudson
HUDSON RIVER
NATIONAL ESTUARINE RESEARCH RESERVE

IMPOUNDMENT SEDIMENT ESTIMATION TOOL FOR THE LOWER HUDSON RIVER VALLEY

Methods for assessing dam sediment inventories and a blue print for extension beyond the Hudson to the greater Northeast Region

This document is part of a series that captures the outcomes of Dams and Sediment on the Hudson (DaSH), a research project to assess how sediment released by dam removals in the Lower Hudson River watershed would affect the estuary. For more information, visit www.hrnerr.org/hrnerr-research/dams-and-sediment-in-the-hudson.

PURPOSE

This tool is designed to help dam owners and decision makers in the Lower Hudson River valley:

1. Compute a rough estimate of the total volume and mass of sediment stored behind a dam;
2. Compare the amount of trapped sediment to annual sediment loads from the watershed;
3. Classify the dam based on its current rate of sediment trapping;
4. Consider preliminary implications of sediment release from removing a dam.

Several examples are presented to demonstrate implementation of the tool for different types of dams.

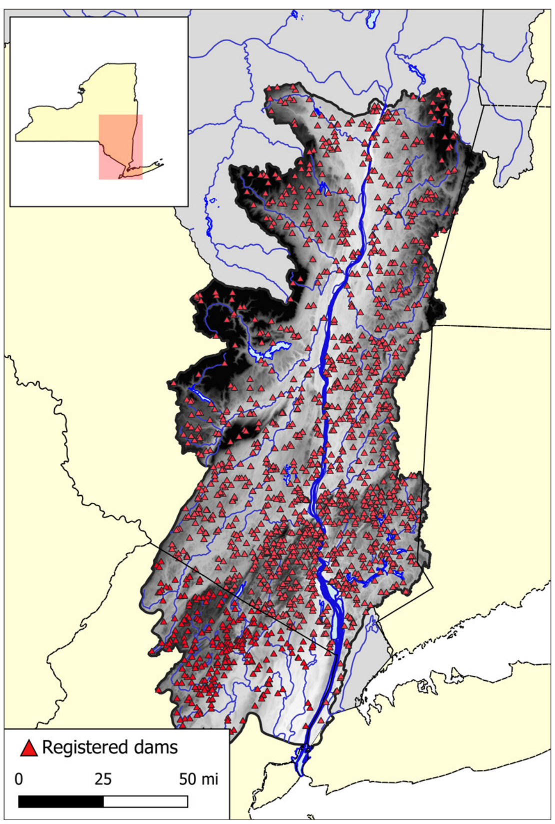

Figure 1 – All 1702 dams in the NID database within the Lower Hudson River watershed. The broader Hudson River watershed is shaded grey in both the inset map and larger map.

BACKGROUND

In recent years, diverse groups including state and federal regulators, environmental advocates, and dam owners have expressed increasing interest in removing relict dams that impede movement of aquatic organisms and pose flood risks to downstream communities. This tool was created to aid those considering dam management options as part of a NOAA-funded project for which the Consensus Building Institute facilitated collaboration between Hudson River stakeholders, the Hudson River National Estuarine Research Reserve, and scientists from the University of Massachusetts Amherst and Woods Hole Oceanographic Institution. One goal of the project was to assess how much sediment is stored behind the 1700 dams throughout the Lower Hudson River Valley (Figure 1), and assess potential impacts to the Hudson River estuary from sediment that would be released if dams were removed. The project collaborators found that most dams store relatively little sediment, and that the total amount of trapped sediment is modest compared to annual sediment load from the watershed. Thus, sediment released by dam removal is not expected to substantially change the amount of sediment delivered to the estuary. More information can be found at: www.hrnerr.org/hrnerr-research/dams-and-sediment-in-the-hudson

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New York State of Opportunity Department of Environmental Conservation
CBI CATALYZING COLLABORATION

BEFORE YOU BEGIN

1. Find the watershed area above the dam (W) in km^2. This can be done via USGS Streamstats application. For reference, 1 mi^2 = 2.62 km^2.
2. Find the surface area (***SA***) of the impounded pond/lake in m2. This can be done in Google Maps. In satellite view, right click anywhere on the pond's edge to start using the "measure" tool and click to outline the perimeter of the pond.
3. Measure the dam height (***H***) and estimate the average water depth. If measuring in feet, convert to meters by dividing by 3 ft/m.

PART I: DETERMINE WHAT TYPE OF DAM YOU ARE CONSIDERING

1. Is the depth of the water body more than the height of the dam? If so it's a **natural lake**. Even in the absence of a dam a lake would exist and trap sediment. *Proceed to PART II-A, "Non-source of Sediment".*
2. Find the watershed area (***W***) of the impoundment in square kilometers. The USGS maintains a web application Streamstats where you can do this.
3. Is the watershed area of the pond less than 1 km^2? If so, it's a **non-source of sediment** as dams impounding small watershed areas are generally spring-fed and have little upstream erosion to bring in sediment. *Proceed to PART II-A, "Non-source of Sediment".*
4. Multiply the pond surface area (***SA,*** m^2) by average water depth (m) to get capacity (***C***), or the volume of water in the pond in m^3.
5. Find the dam's capacity ratio (***C/W***) by dividing the capacity in units of m3 by watershed area in km^2. The capacity ratio comes from Brown (1943) and is used to estimate water residence time in the impoundment.
6. Read trapping efficiency (***TE***) off the Figure 2 (below) using the ***C/W*** value from step 5; note the log scale in Figure 2.
7. If ***TE*** is less than 10%, this is a dam does not significantly trap sediment. *Proceed to PART II-B, "Run-of-River."*
8. If ***TE*** is greater than 10%, this dam traps sediment. *Proceed to PART II-C, "Effective Sediment Trap.*

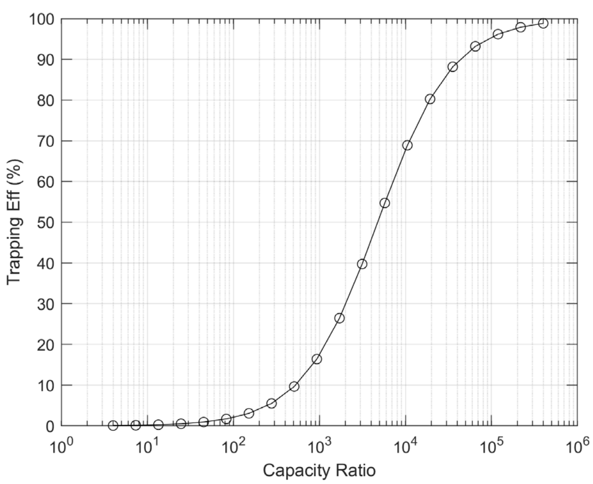


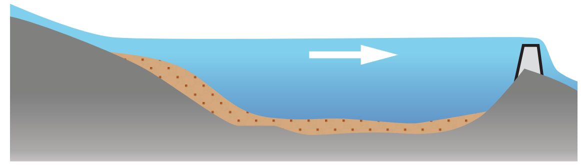
Figure 2 – Impoundment trapping efficiency (TE) for different capacity ratios (C/W) estimates the percentage of transported sediment that is trapped within an impoundment from Brown (1943). Capacity ratio is water volume or capacity in units of m^3 by watershed area in km^2.

PART II: TRAPPED SEDIMENT MASS AND CONSIDERATIONS

Here you will estimate the amount of sediment stored behind the dam of interest.

II-A. Non-Source of Sediment

- Dammed springs
- Natural lakes with dams

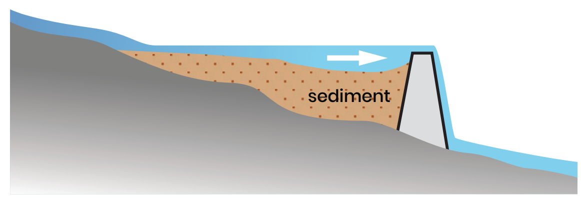


Considerations:

If your dam is classified as a non-source of sediment, the amount of sediment likely to be released by dam removal is small, and sediment is not likely to cause significant downstream impact with dam removal. Issues to consider if removing this type of dam include potential erosion at the new outlet and transition of wetland habitat due to lowering water levels. Removing a dam on a natural lake may impact recreation and strand docks due to lowering of the lake level.

II-B. Run of River Dam

- Accumulated sediment has filled the impoundment, typically soon after construction
- Additional sediment cannot deposit, so downstream sediment movement is minimally impeded



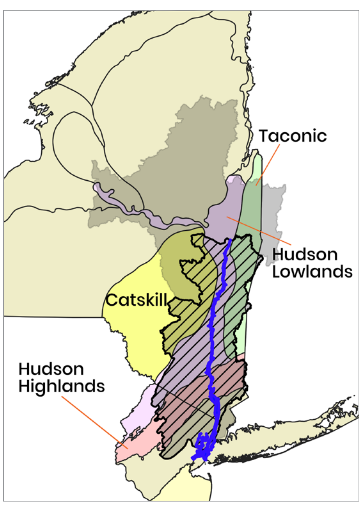


Figure 3 – Physiographic provinces of the Lower Hudson River watershed.

*To estimate **the mass of sediment trapped in the impoundment,** use the dam height (H, in m) and pond surface area (SA, in m²):*

$$Sed\ Mass(T)=0.2 \times H \times SA$$

The coefficient 0.2 is an empirical constant based on observations in Ralston et al., (2020) with units on T/m³. It is based on a dry bulk density of 0.5 T per cubic meter of sediment and average impoundment depth of 0.35*H*, where *H* is dam height. The product of sediment density and depth gives a value of roughly 0.2.

Note 1 T = 1000 kg = 2200 lbs

*To estimate **the upstream mass of sediment delivered from the watershed to the impoundment each year** (Q_S, in tons), combine the regional sediment yields (SY, table below from Ralston et al. 2020, see Fig. 3 for regions) and watershed area (W, in km²):*

$$Q\_S=SY*W$$

Regional sediment yields (SY)	
Region	**Sed Yield (T/km²/yr)**
Taconics	60
Hud. Lowlands	60
Catskills	100
Hud. Highlands	10

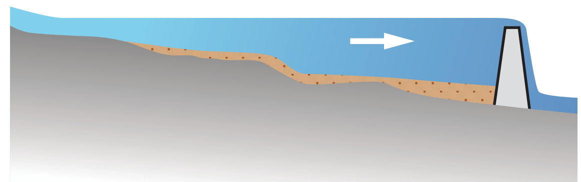
Considerations:

- How does the mass of trapped sediment behind the dam compare to the annual sediment load (SA)? This comparison can help to contextualize possible downstream impacts of released sediment following dam removal.
- Among considerations for downstream sediment mobilization, note
  - potential impacts to downstream structures, especially due to aggrading streambeds;
  - impoundment sediment quality (particle size, potential contaminants) relative to downstream sediment;
  - the portion of impounded sediment the stream can mobilize following dam removal.

II-C. Effective Sediment Trap

- These impoundments are large relative to the incoming stream flow so that they trap significant amounts of sediment and reduce conveyance of sediment to downstream habitats.

To estimate the mass of impounded sediment, use the trapping efficiency (***TE***) and watershed area (***W***) from PART I. Combine these with the number of years since the dam was constructed (***Y***) and the watershed sediment yield (***SY***, in T/km^2/yr) from the table in PART II-B.



$$\textit{Sed Mass}(T)=TE\% \times W \times SY \times Y$$

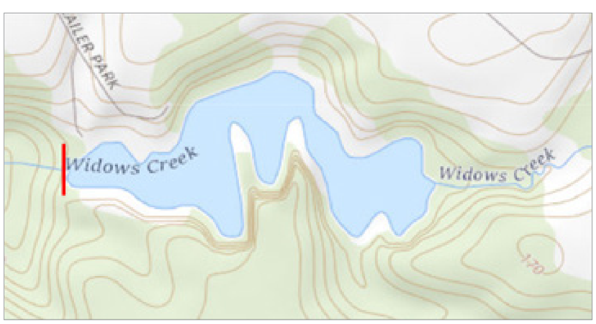
Considerations:

- The timing and portion of stored sediment that is mobilized by a dam removal depends on impoundment shape, sediment type, and the method used and time of year for dam removal.
- Phased dam removal and dewatering prior to removal can reduce downstream sediment loading.
- Downstream river reaches may be starved of sediment. Release of this impounded sediment may help to stabilize banks and streambeds. Differences in sediment characteristics between impounded material and the stream bed may also be a consideration in determining downstream impacts.

PART III: EXAMPLES

The figures below provide some examples of dams in the Hudson River Valley. The table on the next page provides guidance on how to apply the equations in this tool in order to help you navigate this tool.

Effective Trap
McCagg Pond; Stockport, NY
42.318, -73.725



Non-Source
Gilbert Boyd Pond; Craryville, NY
42.176, -73.702

Run-of-River
Beaver Mill Pond; Valatie, NY
42.413, -73.674

Site	McCagg Pond Stockport, NY	Gilbert Boyd Pond Craryville, NY	Beaver Mill Pond Valatie, NY
water depth (D, m)	1.8	3.3	1
dam height (H, m)	4	4	3
Watershed area (W, km^2)	9.2	0.4	707
Surface area (SA, m^2)	30,000	1,700	14,000
Year built	1967	1968	1925
Capacity (C=D*SA, m^3)	52,200	5,610	14,000
Cap. Ratio (CW, m^3/km^3)	$5.7*10^3$	$1.4*10^4$	$2.0*10^1$
Trapping Eff. (TE, %)	55	75	1
Site Classification	Eff. Sed. Trap	Non-Source	Run of River
Sed. Yield (SY, $T/km^2/yr$)	60	NA	60
Sed. Mass (T)	16,000	Negligible	8,000
Ann. sed. load (Q_S, T/yr)	60*9.2=550 T	NA	60*707=42,000 T
Equiv. sediment trapped	29 yr	NA	0.14 yr

MORE INFORMATION

To learn more, visit the project website for Dams and Sediment on the Hudson (https://www.hrnerr.org/hrnerr-research/dams-and-sediment-in-the-hudson).

REFERENCES

Brown, C. B. (1943), Discussion of sedimentation in reservoirs, by B. J. Witzig, Proc. Am. Soc. Civil Eng., 69, 1493–1500.

Ralston, D., Yellen, B., Woodruff, J., 2020. Watershed sediment supply and potential impacts of dam removals for an estuary [WWW Document]. Earth Space Sci. Open Arch. https://doi.org/10.1002/essoar.10502519.1