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## Abstract

This study evaluates the effects of sediment retention in the Carraízo Reservoir and coastal erosion in Loíza, Puerto Rico. Since its construction in 1953, the reservoir has accumulated an approximated 11.74 million cubic meters (Mm<sup>3</sup>) of sediment, with Trap Efficiency (TE) values exceeding 89%, suggesting minimal sediment transport downstream. Historical shoreline data show that Loíza experienced an average retreat rate of -2.55 meters per year (m/yr) between 1951 and 1977, coinciding with the reservoir's early years of operation. To evaluate potential shoreline recovery, a theoretical scenario based on the Elwha River dam removal, which reversed erosion with the delivery of 13.3 Mm<sup>3</sup> of sediment was applied. Results indicate that, if Carraízo's sediment were fully delivered to the coast, Loíza could experience shoreline accretion of up to 17.6 m/yr. These findings suggest a correlation between sediment retention and coastal erosion in Loíza, Puerto Rico.

## Introduction

- Loíza, on Puerto Rico's northeastern coast, is experiencing long-term shoreline erosion.
- The Río Grande de Loíza flows through the region and into the Atlantic Ocean.
- In 1953, the Carraízo Reservoir was built along the river, altering sediment flow.
- The reservoir has significantly reduced the amount of sediment reaching the coast.
- This reduction may be contributing to Loíza's ongoing coastal erosion.
- The community is highly vulnerable to environmental hazards and shoreline retreat.
- This study investigates whether sediment retention is a key factor driving erosion in Loíza.

## Background

Rivers naturally transport sediment from upland areas to coastal zones, but dam construction disrupts this flow, trapping sediment upstream and reducing coastal supply (Ouillon, 2018). The Carraízo Reservoir, built in 1953 on the Río Grande de Loíza, has retained large amounts of sediment, decreasing its delivery to the Atlantic coast. As a result, the municipality of Loíza has experienced ongoing shoreline retreat, where the river flows. Similar global cases, such as the Elwha River dam removal, show that restoring sediment flow can help reverse coastal erosion, as shown by shoreline accretion rates of up to 20 meters per year—highlighting the relevance of this study.

## Problem

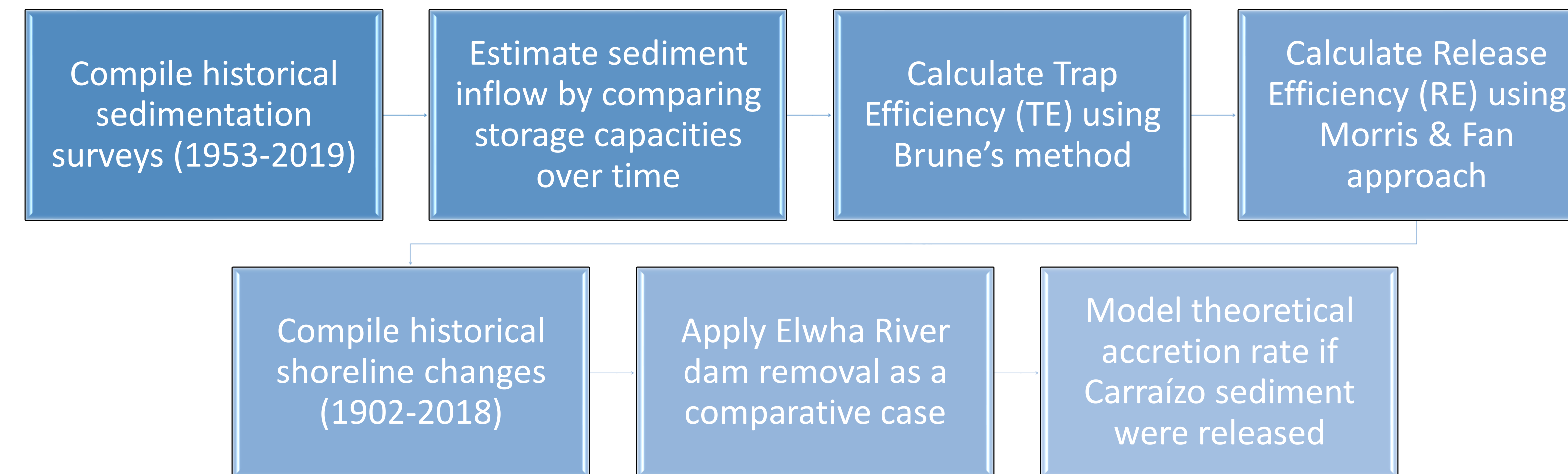
Loíza, one of Puerto Rico's most vulnerable coastal communities, has experienced severe shoreline retreat—averaging -2.55 meters per year between 1951 and 1977, during the early operation of the Carraízo Reservoir. This raises concern that sediment retention by the reservoir may be driving coastal erosion. Understanding this relationship is for informing future sediment management strategies, coastal resilience planning, and long-term environmental sustainability in the region.



Figure 1. Coastal Erosion observed in Parcelas Suárez

## Methodology

The purpose of this project is to evaluate the effects of sediment retention in the Carraízo Reservoir on the coastal erosion observed in the Loíza, Puerto Rico. The project aims examine the sediment trap capacity and accumulation of sediment within the reservoir since its construction, document historical shoreline retreat in Loíza's coast using existing data and imagery, and compare geomorphological impacts with global cases of sediment retention caused by dams with the Loíza coastal erosion situation.



## Results and Discussion

Year	Storage Capacity (Mm <sup>3</sup> )	Estimated Sediment Inflow (Mm <sup>3</sup> )
1953	26.8	0
1985	12.47	14.3
1994	14.2	12.6
1997	13.26	13.54
1999	19.35	7.45
2004	17.53	9.27
2009	16.42	10.38
2019	15.06	11.74

Table 1. Summary of sedimentation survey results for the Carraízo Reservoir, including storage capacity and estimated sediment inflow (in Mm<sup>3</sup>) from 1953 to 2019. Data compiled from multiple environmental assessments and surveys

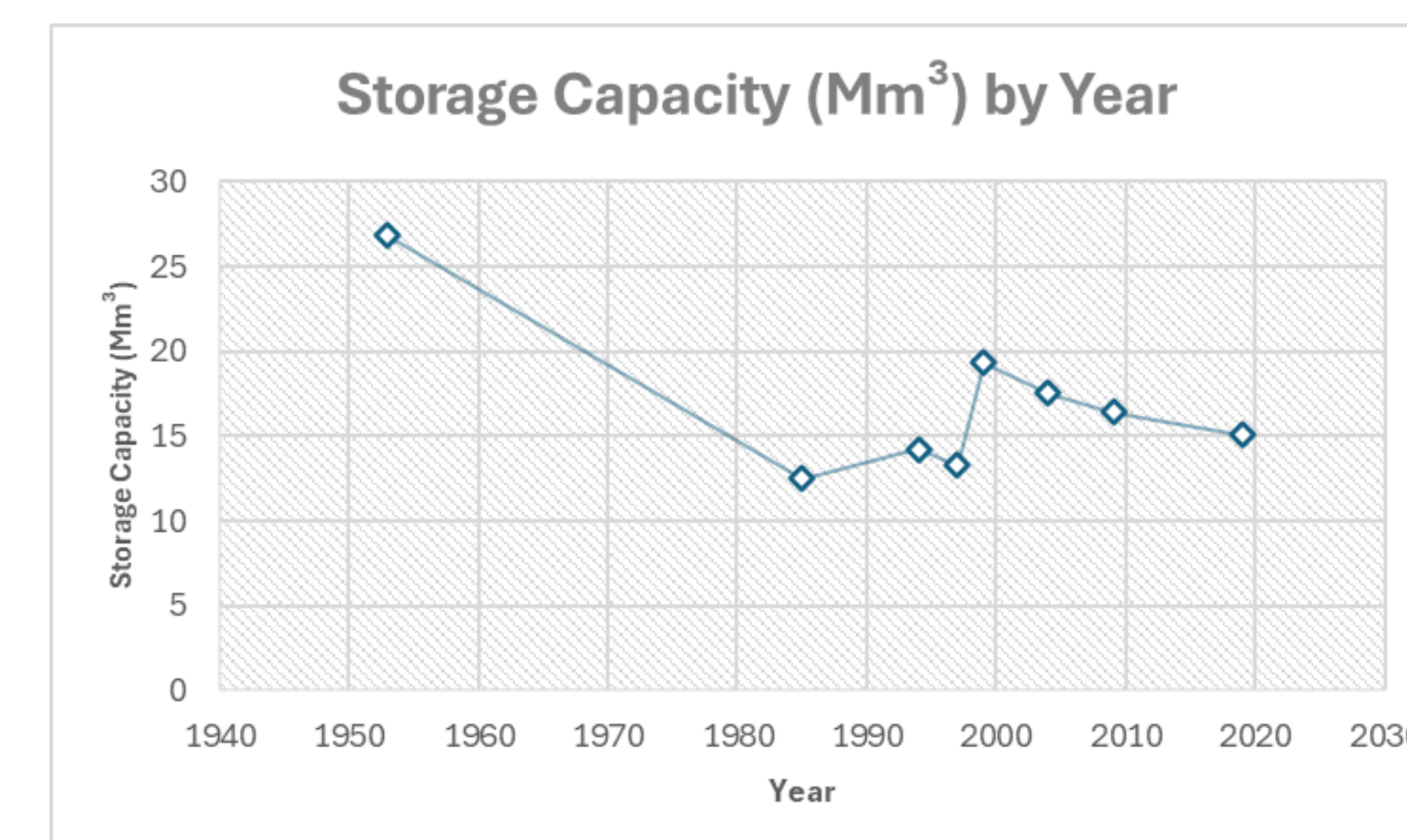


Figure 2. Storage Capacity (Mm<sup>3</sup>) chart of the Carraízo Reservoir based on the sedimentation surveys

$$TE = \frac{100 \left( \frac{C}{I} \right)}{a + \left( \frac{C}{I} \right)} \quad RE = 1 - TE \text{ or } 100\% - TE$$

where:  
TE = Trap Efficiency (%)  
C = Storage Capacity (Mm<sup>3</sup>)  
I = Sediment Inflow  
C/I = capacity-to-inflow ratio  
a = empirical constant, 0.1 for large reservoirs

where:  
RE = Release Efficiency  
TE = Trap Efficiency

Year	Trap Efficiency (TE)	Release Efficiency (RE)
1953	---	---
1985	89.70%	10.30%
1994	91.85%	8.15%
1997	90.73%	9.27%
1999	96.29%	3.71%
2004	94.98%	5.02%
2009	94.05%	5.95%
2019	92.77%	7.23%

Table 2. Results of TE using Brunes (1953) equations and RE using Morris and Fan (1998) approach.

Time Period	Trend	Average rate (m/year)
1902-1931	Accretion	+4.93
1931-1951	Accretion	Unknown
1951-1977	Erosion	-2.55
1977-1990	Erosion	Unknown
1990-2010	Erosion	Unknown
2010-2018	Accretion (localized)	+1.83

Table 3. Shoreline Change Trends and Average Rates between 1902-2018

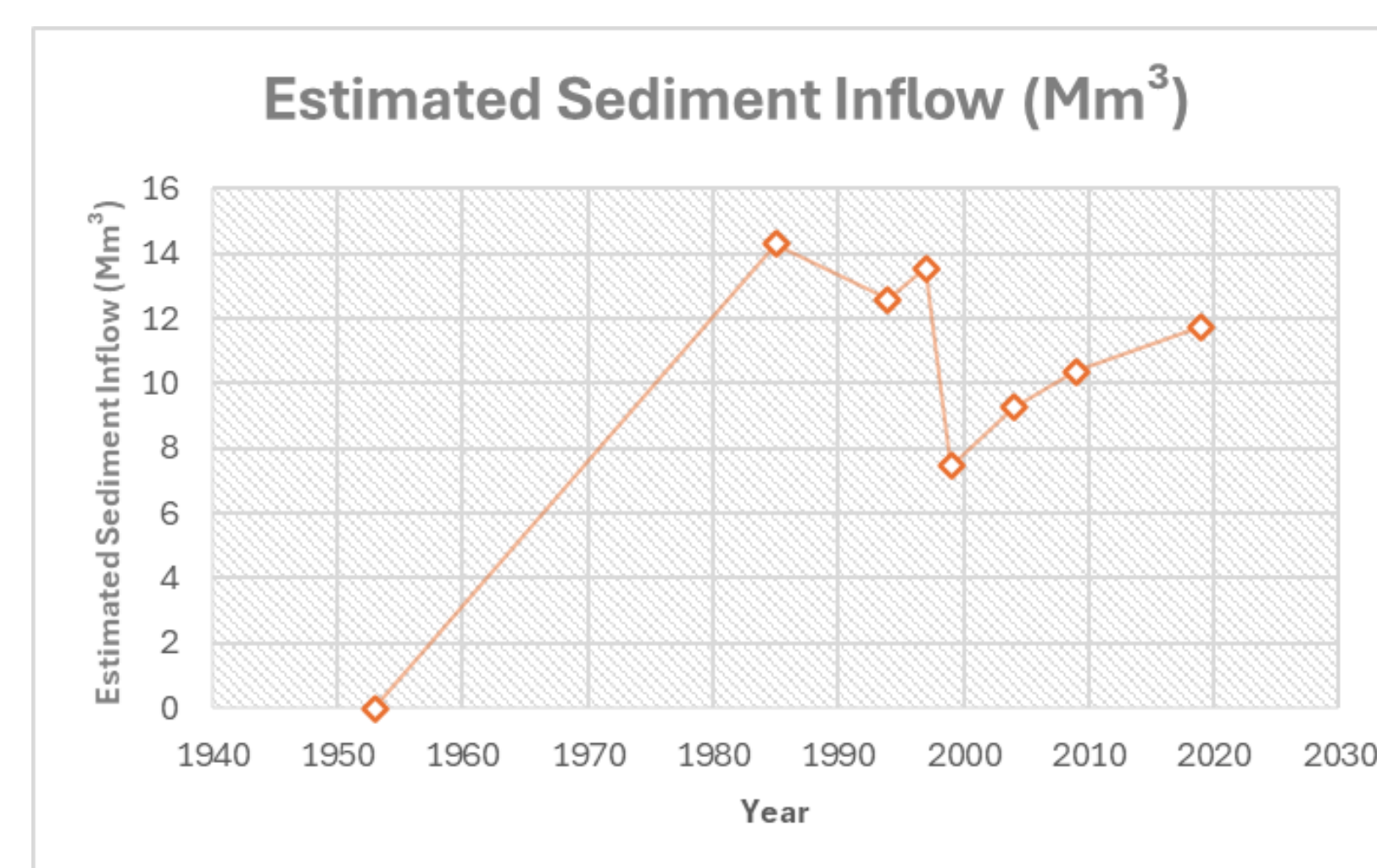


Figure 3. Estimated Sediment Inflow chart

### Theoretical Scenario: Carraízo Reservoir Removal

Sediment-to-accretion ratio derived from the Elwha River, using the 20 m/year of shoreline accretion resulting from 13.3 Mm<sup>3</sup> of sediment delivered to the coast:

$$\frac{20 \text{ m/yr}}{13.3 \text{ Mm}^3} \approx 1.50 \frac{\text{m}}{\text{yr}} / \text{Mm}^3$$

Using sediment-to-accretion ratio derived from the Elwha River and the estimated sediment inflow in the Carraízo Reservoir as of 2019, the theoretical potential shoreline accretion rate, if the Carraízo Reservoir were to be removed and all the sediment were to be delivered to the coast, it would result:

$$1.50 \frac{\text{m}}{\text{yr}} / \text{Mm}^3 \times 11.74 \text{ Mm}^3 \approx 17.6 \text{ m/yr}$$

## Conclusions

This study examined the impact of sediment retention in the Carraízo Reservoir on coastal erosion in Loíza, Puerto Rico. Results show that since its construction in 1953, the reservoir has retained over 89% of incoming sediment, while Loíza's shoreline has experienced consistent retreat. Using a theoretical model based on the Elwha River dam removal, it is estimated that fully releasing the trapped sediment could lead to shoreline accretion of up to 17.6 meters per year in Río Grande de Loíza's rivers mouth. While a strong correlation exists between sediment retention and coastal erosion at the Río Grande de Loíza's mouth, further evidence is needed to directly link this process to erosion in specific areas like Parcelas Suárez and Villa del Mar.

## Recommendations

To reduce future coastal erosion and support resilience in Loíza, agencies such as the Department of Natural and Environmental Resources (DNER) and the Puerto Rico Aqueduct and Sewer Authority (PRASA) should explore practical sediment management solutions. These may include dredging and the reintroduction of sediment downstream to restore the natural flow. Although, to better understand the relationship between sediment retention in the Carraízo Reservoir and Loíza's coast erosion, continued research is needed to evaluate and understand sediment transport patterns, coastal dynamics, and the environmental impacts of modifying the reservoir.

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