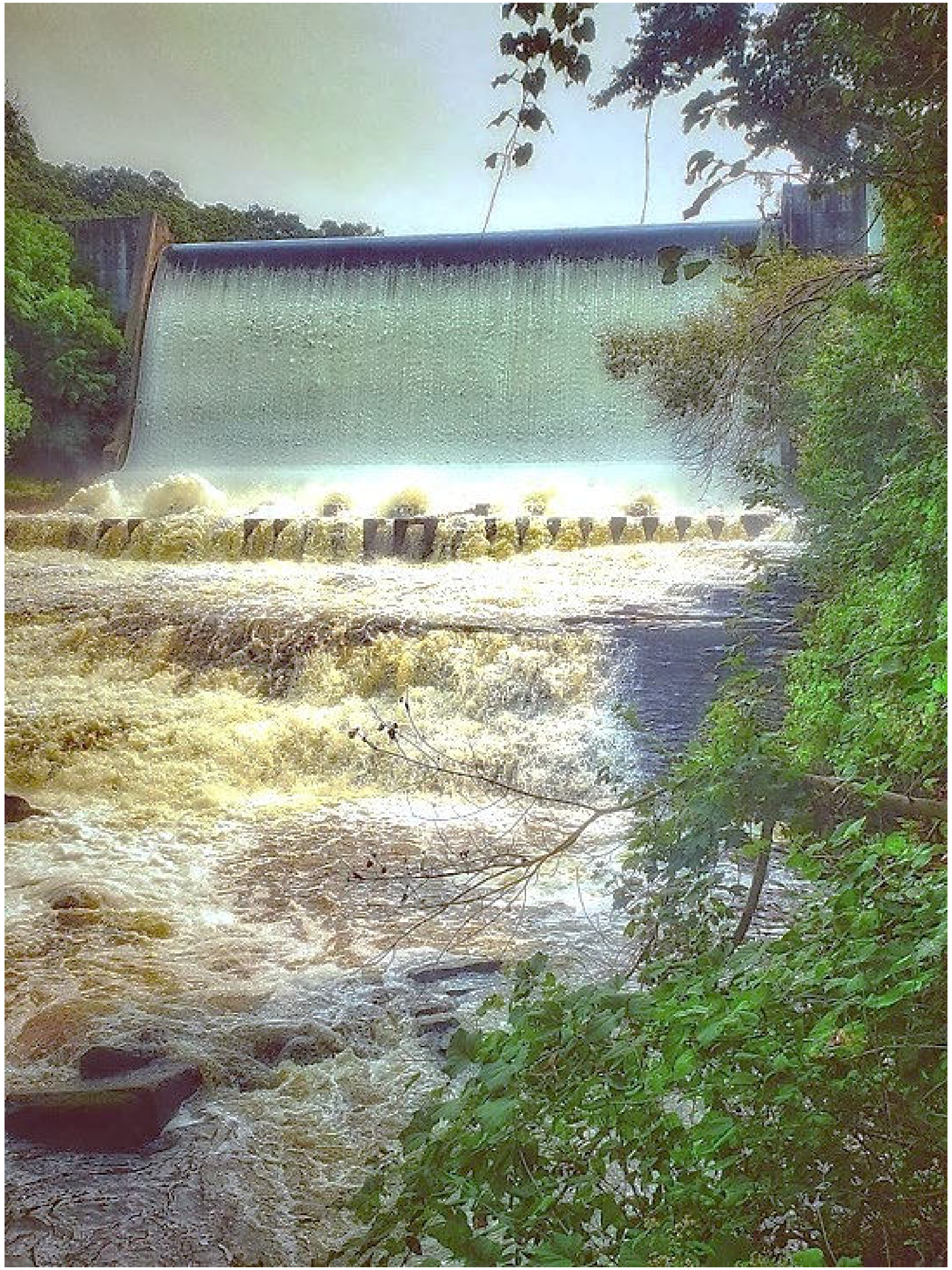

Mass Stabilization Processing of Impounded Sediments in Dam Removals - Promoting Ecological River Restoration and Upland Beneficial Use

12th International SedNet Conference (Virtual)
Sediment Challenges and Opportunities Due to Climate Change and Sustainable Development
29 June – 2 July 2021

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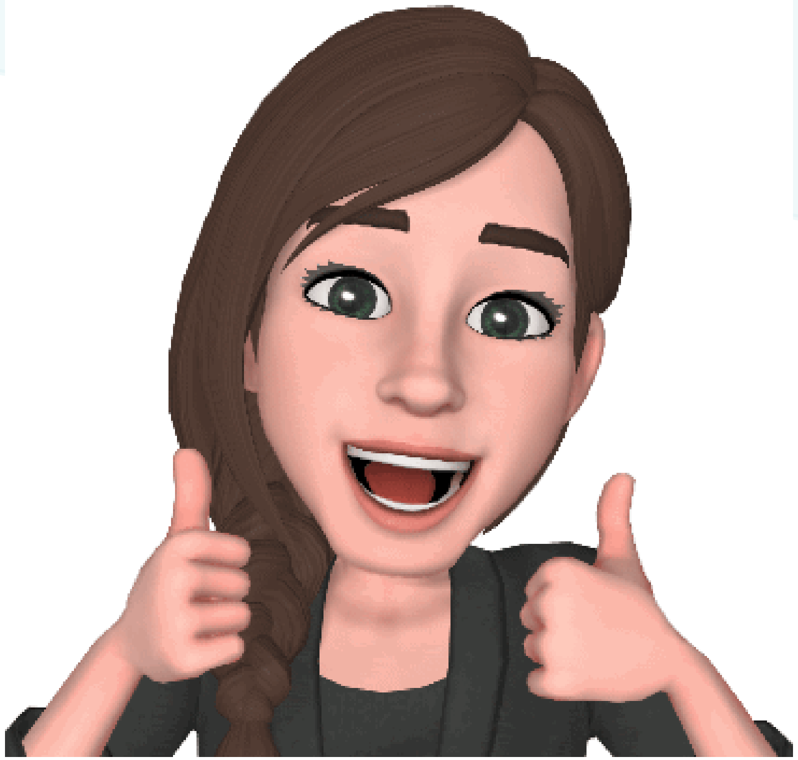


Lauren Iacobucci

Lead Project Engineer
Tipping Point Resources Group

Defining the Challenge: Sediments Behind Dams

“ **Billions of cubic yards of natural river-borne sediment are trapped behind the world’s 57,000 large dams** and countless small ones. This is material that otherwise would have been swept by river currents downstream and to the coast, where it **would help build up marshes and other wetlands to act as a buffer against rising seas**. Now, experts are searching for ways that this trapped sediment can be liberated and made available again to the rivers and estuaries to mitigate the loss of wetlands. ” *Source: Why the World’s Rivers Are Losing Sediment and Why It Matters – Jim Robbins, 2017*

Dam removal has become an **increasingly urgent global priority** due to:

- Aging infrastructure
- Flood safety issues (climate adaptation)
- Fluvial recreation demands
- Changing priorities in habitat/conservation management

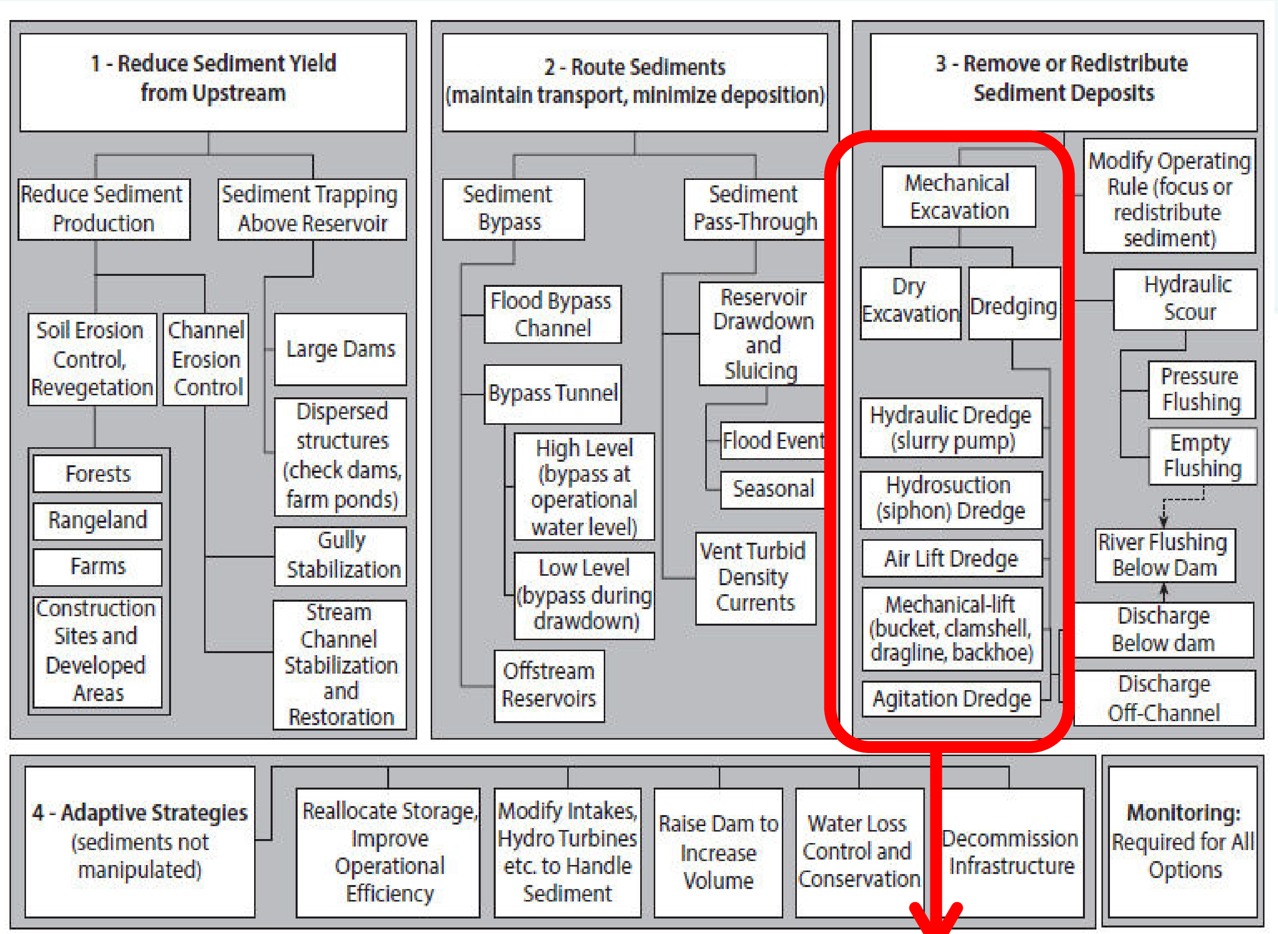
Thesis: Sustainable Sediment Management for Dams

Challenge: Removal of sediment from behind dams (dredging by mechanical means)

- High volumes
- Limited site access
- What to do with it?

Opportunity: Mass stabilization and beneficial use

- Stakeholder engagement
- Circular economy (sediment as a resource)



Circular Economy & Beneficial Use

Classification of Sediment Management Alternatives

Source: Extending the Life of Reservoirs – Sustainable Sediment Management for Dams and Run-of-River Hydropower (Annandale et al. 2016)

Sediments Behind Dams – Focus Areas & Examples

From the Mountains to the River to the Sea

Three common scenarios for sediment management from behind dams, with opportunities for mass stabilization and beneficial use:

	1) Sediment Transport	2) Reservoir Pool Capacity	3) Dam Removal
	Contaminated sediment accumulation behind dams: • Typical urban/industrial history and corresponding contamination profile • Must consider possibility of downstream transport/release	**Sediment volume at capacity behind dams:** • Increase in sediment transport accelerating buildup of loads behind dams • Design no longer sufficient to handle extreme weather events, etc.	**Removal of dams and impounded sediments:** • Promoting ecological/riverine restoration and recreation • Responding to aging infrastructure (dams at or approaching end-of-life)
Examples	Fort Edward Dam - Hudson River New York, USA	Conowingo Dam - Susquehanna River Pennsylvania/Maryland/Delaware/ New York, USA	Gorge Dam - Cuyahoga River Ohio, USA

Hudson River, New York – Fort Edward Dam

Example 1 - Contaminated Sediment Transport

1940s-1970s
General Electric uses PCBs in manufacturing of electrical capacitors at Fort Edward Plant, NY; 90,000-600,000 kg of mixed PCBs released into Hudson River

1973
NYS DEC permits derelict Fort Edward Dam to be demolished for river restoration, unknowingly releasing (rapidly) a great volume of PCBs trapped in sediments behind the dam

1975
Discover PCBs have affected much of upper Hudson

1987
GE Hudson Falls Plant declared US EPA Superfund Site – 321 km (to NYC)

2002
US EPA Record of Decision: dredging of 2.06M m^3 (65% of total PCB load)

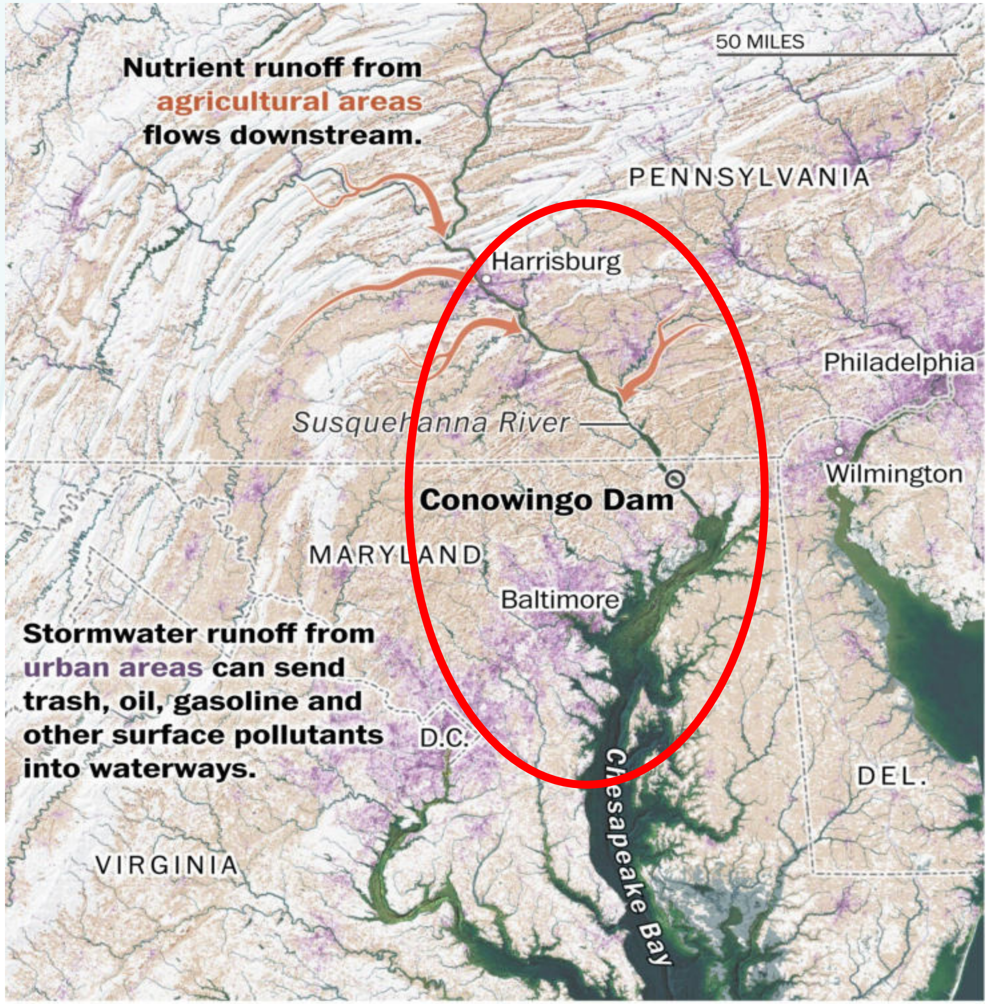
2009-2015
Mechanical dredging/dewatering and shipment to Texas

Today (2021)
Is it *really* done? Steady-state? Recovery? Lawsuits?

1940 1950 1960 1970 1980 1990 2000 2010 2020

Susquehanna River, PA/MD/DE/NY – Conowingo Dam

Example 2 - Dam Reservoir Pool Capacity



TIM MEKO/THE WASHINGTON POST

Mountains to the Bay to the Sea – A Story of Inescapable Sediment Volume

- Since the dam's construction in 1929, sediment and nutrients have been building up behind it and are released periodically into the Chesapeake Bay, especially during high flow events
  - Chesapeake Bay Program has spent at least $15 Billion USD in restoration over 30 years
- In 2014, State of MD and USACE announced the reservoir is in a state of "dynamic equilibrium" (point at which reservoir reaches full capacity and full volume of sediment/nutrients flowing downriver will go through the dam) – **at about 92% capacity** for sediment storage

Susquehanna River, PA/MD/DE/NY – Conowingo Dam

Example 2 - Dam Reservoir Pool Capacity

- USACE estimated 23M m^3 yards of sediment would need to be dredged (est. $3 Billion USD)
  - If flow of sediment coming down the river is not curtailed, the dam pond would gradually fill in again – 2.3M m^3/year would need to be dredged annually to avoid losing ground (est. $48 million to $267 million USD each year)
  - **4 states – who pays?** Maryland? Pennsylvania? Delaware? New York?

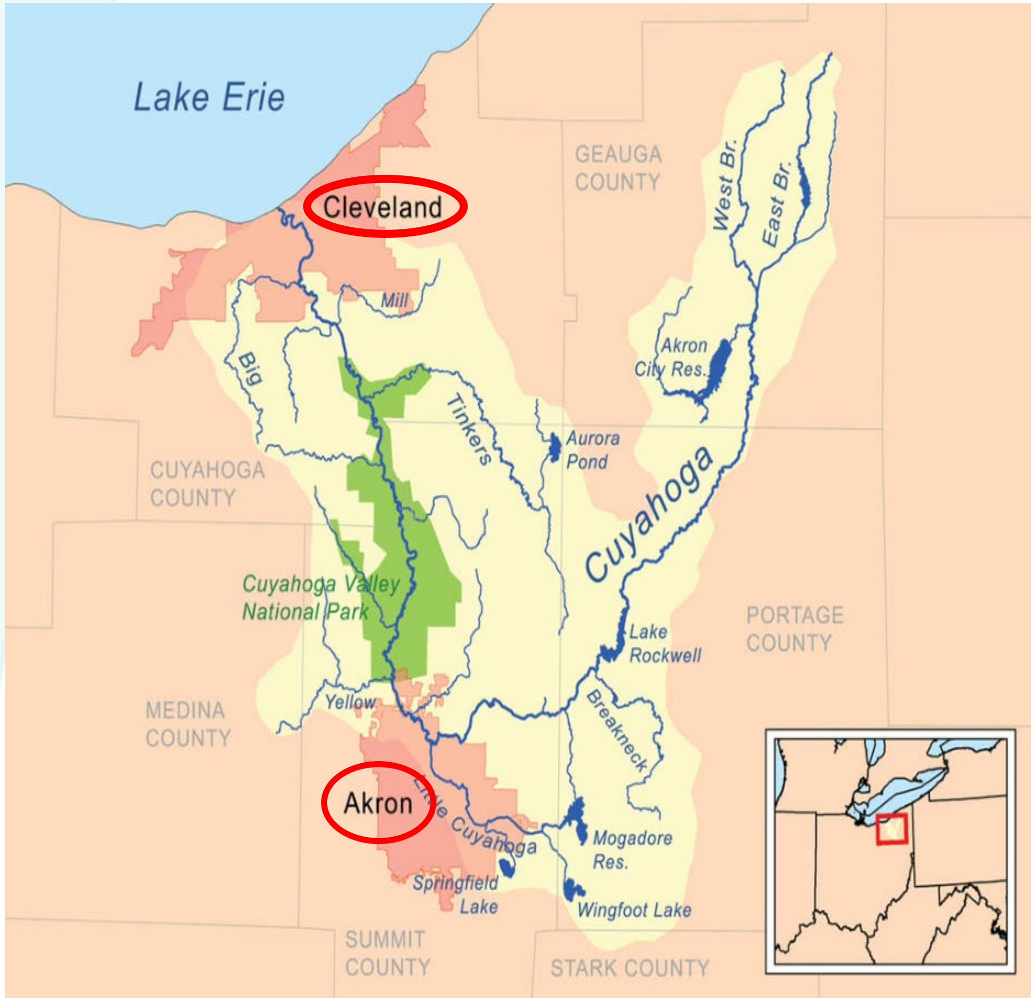
Aerial view of Conowingo Dam and surrounding States

Conowingo Dam overflow event

Conowingo Dam sediments contain significant coal deposits (photo from 2021 treatability study conducted by Rutgers and Tipping Point)

Cuyahoga River, Ohio – Gorge Dam

Example 3 - Dam Removal for River Restoration with Upland Beneficial Use



- Gorge Dam is the largest of 4 dams along the Cuyahoga River, constructed in 1914 for hydroelectric power and to provide cooling water for a coal power plant
- Cuyahoga River, Ohio has caught fire 14 times since 1868
  - **22 June 1969 fire helped spur the US Environmental Movement**
  - Launched H_2O pollution control activities & agencies:
    - USEPA (December 1970) and Ohio EPA (October 1972)
    - Clean H_2O Act
    - Great Lakes H_2O Quality Agreement
  - In popular culture:
    - ✓ Randy Newman – "Burn On"
    - ✓ REM – "Cuyahoga"
    - ✓ Great Lakes Brewing Co. – "Burning River Pale Ale"

Cuyahoga River, Ohio – Gorge Dam

Example 3 - Dam Removal for River Restoration with Upland Beneficial Use

- Designated in 1985 as an Area of Concern in Great Lakes Basin
- In 2010, the USEPA Great Lakes Legacy Act authorized assessment of sediments in Gorge Dam pool
- GLNPO Cost Share: 65% Federal USEPA / 35% Sponsors (Partners)
- Goal: Delist Beneficial Use Impairments (BUI)
- Action: **Dam removal with habitat restoration component (GLNPO requirement)**
    - Contaminated sediment load behind the dam pool needs to be dredged before dam is removed (organics/inorganics, oil, and grease exceed risk toxicity thresholds)

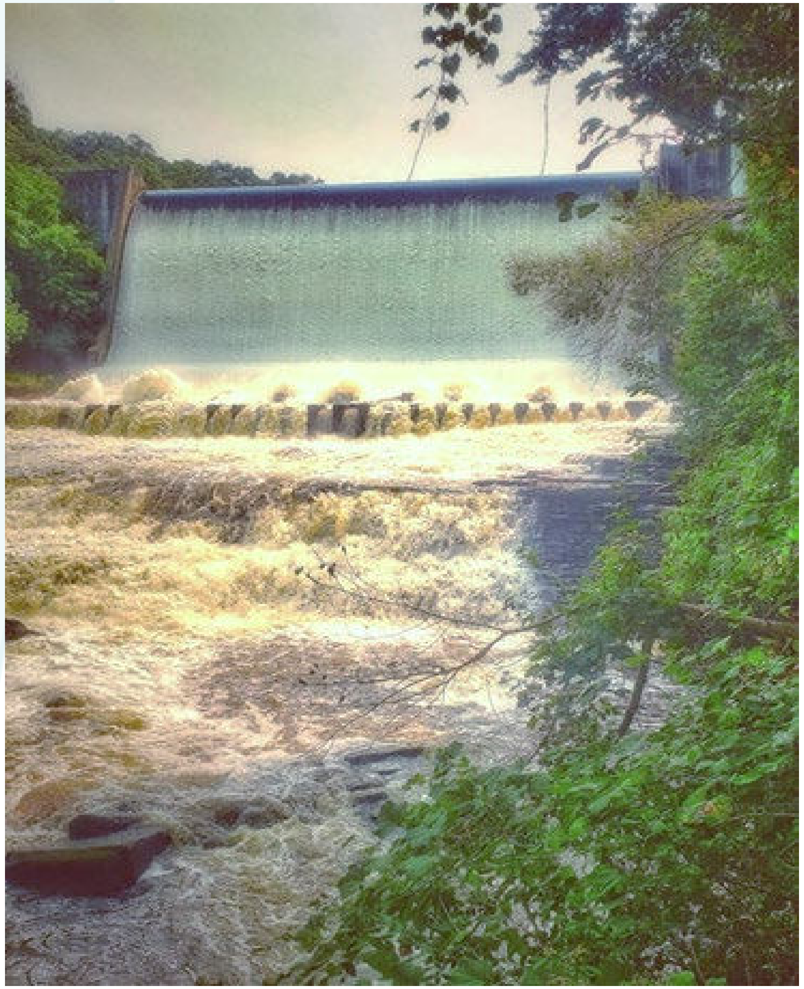
Cuyahoga River, Ohio – Gorge Dam

Example 3 - Dam Removal for River Restoration with Upland Beneficial Use

- Gorge Dam removal logic (BUI):
    - Habitat loss/impairment (fish migration) and benthos
    - Flow alteration/hydraulics
    - Excessive nutrients levels and low dissolved O_2
- To be conducted in parallel with City of Akron Combined Sewer Overflow long-term control plans
- Stakeholder/community interest: river recreation (white water kayaking)
- Sediment volume that needs to be dredged before dam removal – **671,000 m³**
    - That's easy… How do you do it? Where is it going? Limited site access and no CDF.
    - **Beneficial use?**

Aerial image of Gorge Dam reservoir pool (Source: Google Earth)

Case Study: Gorge Dam – Cuyahoga River, Ohio



Gorge Dam – Cuyahoga River, Ohio (Photo by Eric A. Stern)

Project Lead: USEPA Great Lakes National Program Office (GLNPO)

Project Cost-Share Sponsors: City of Akron, Gorge Dam Stakeholders Committee, First Energy, Summit Metro Park

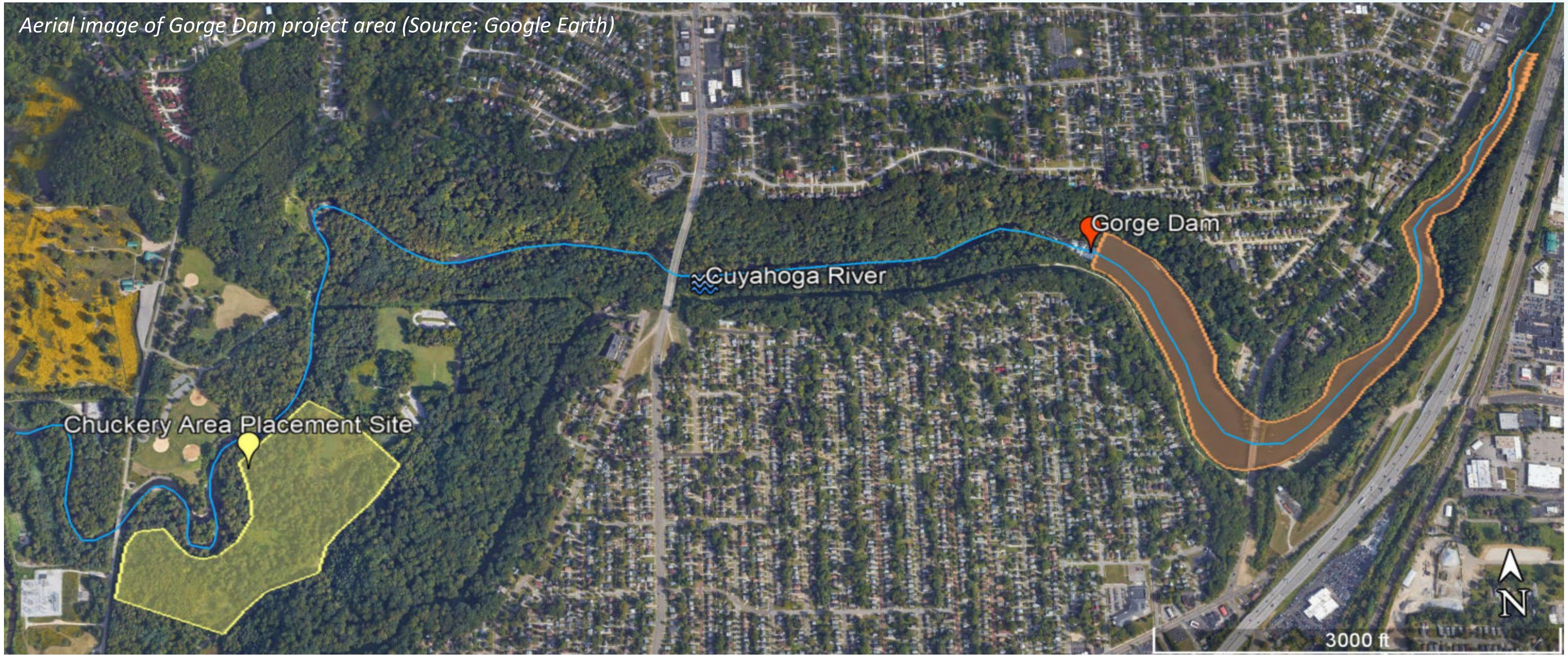
Design: Jacobs Engineering, Inc.

Treatability: Rutgers University and Tipping Point

Design Considerations -

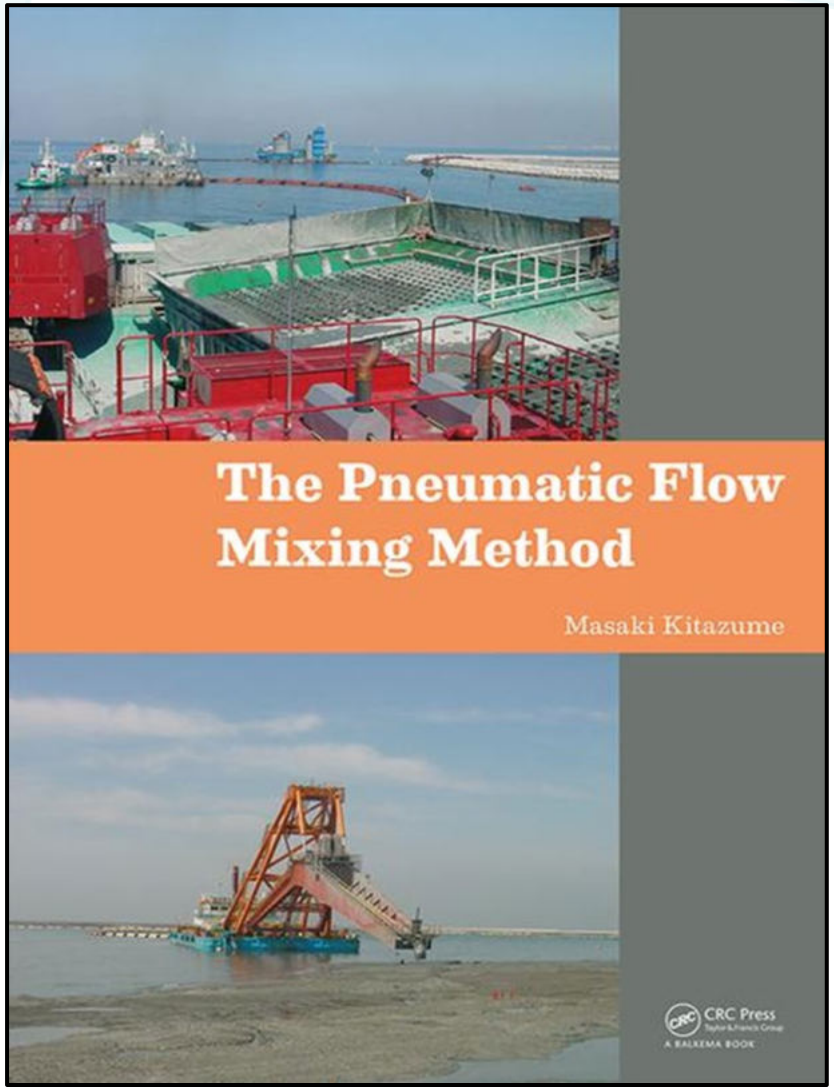
- Balance engineering cost-effective solution with high processing volume to meet dam removal schedule
- Dredging technique: **mechanical dredging**
- Sediment processing: **mass stabilization with pozzolanic binders**
- Beneficial use option: **community-supported habitat restoration**
- Selected based on removal efficiency, site limitations, scheduling of dam removal, and stakeholder engagement

Case Study: Gorge Dam – Cuyahoga River, Ohio



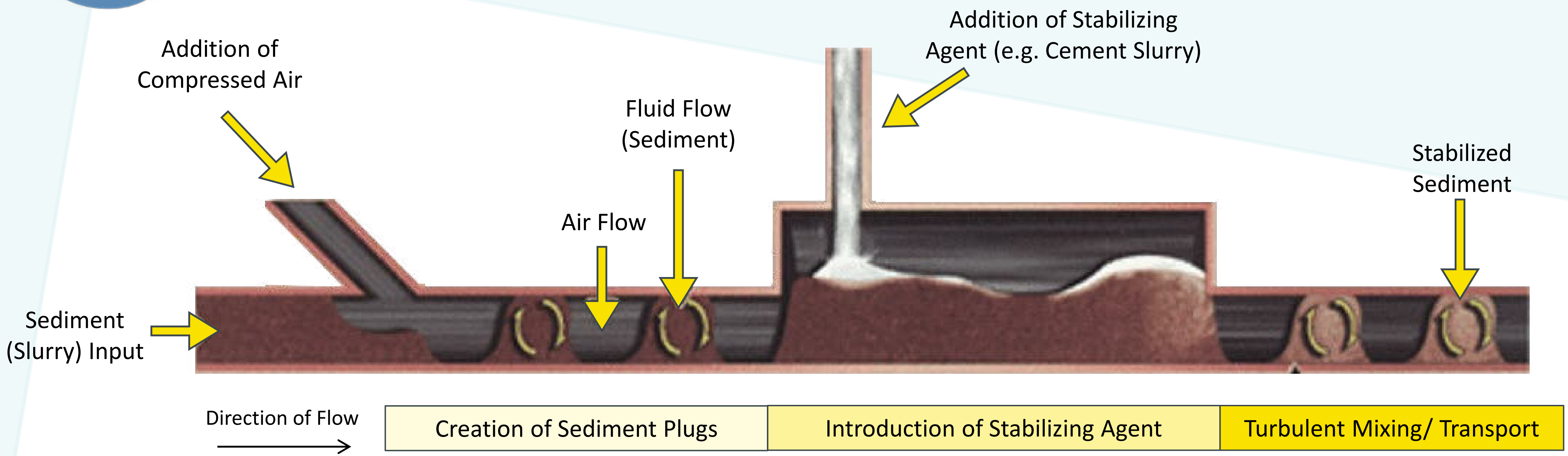
- Mass stabilization of sediments to produce an **<u>engineered structural fill: Pneumatic Flow Tube Mixing (PFTM)</u>**
- **<u>Upland placement of stabilized sediment</u>** at 35-acre former landfill (Chuckery Area Placement Site) adjacent to river, located 2.1 km from Gorge Dam pool
- Capping and revegetation with native grasses and trees

Pneumatic Flow Tube Mixing (PFTM)



- Developed in Japan in 1990s/early 2000s for large-scale land reclamation projects using fine silty clay sediments
- Many successful examples include land reclamation for Tokyo (Haneda – 2010) and Central Japan (Chubu – 2005) Airport projects

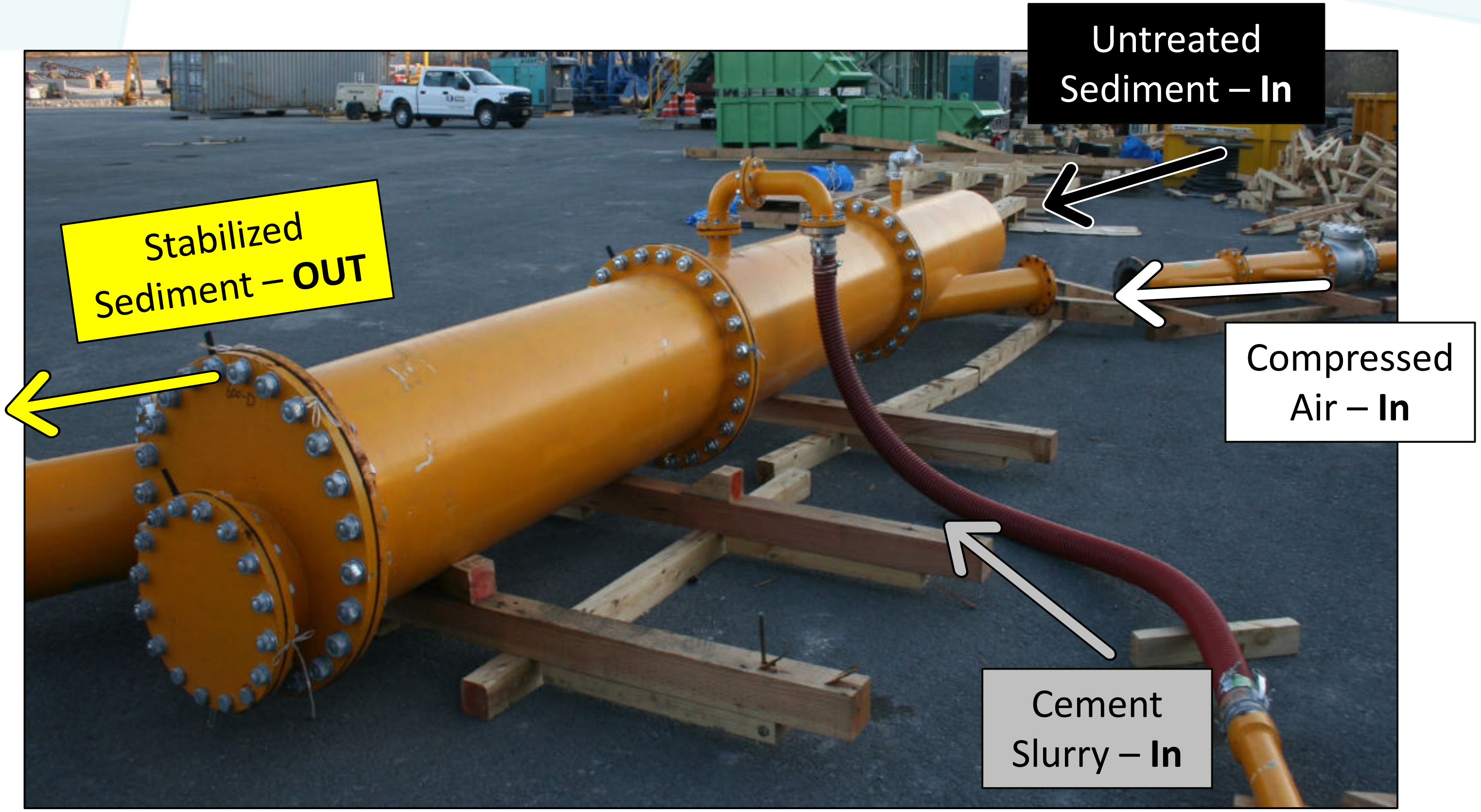
Pneumatic Flow Tube Mechanism



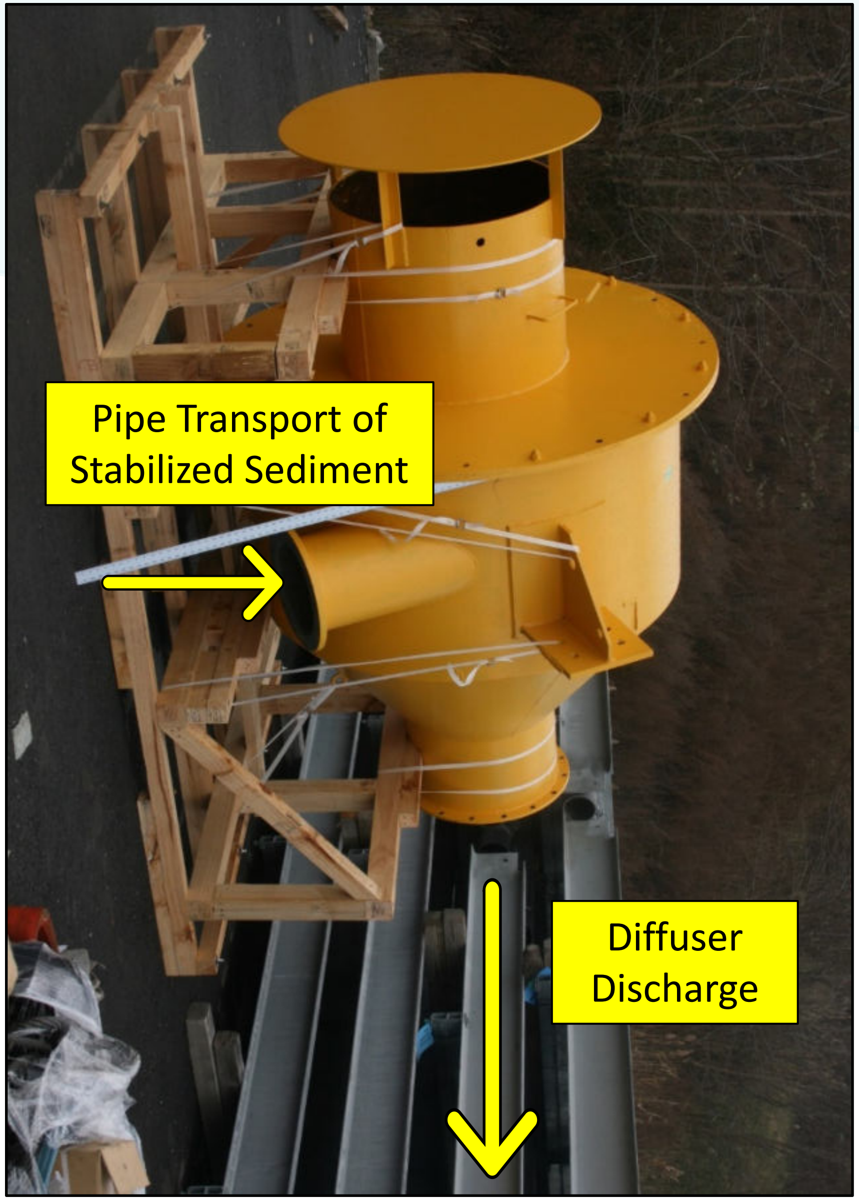
Soft sediment is broken into “plugs” by compressed air. Plugs reduce pipe surface friction, easing flow. **During transport, cement and sediments are <u>mixed by the turbulent flow within the “plug”.</u>**

(Kitazume 2002)

PFTM: Process Equipment



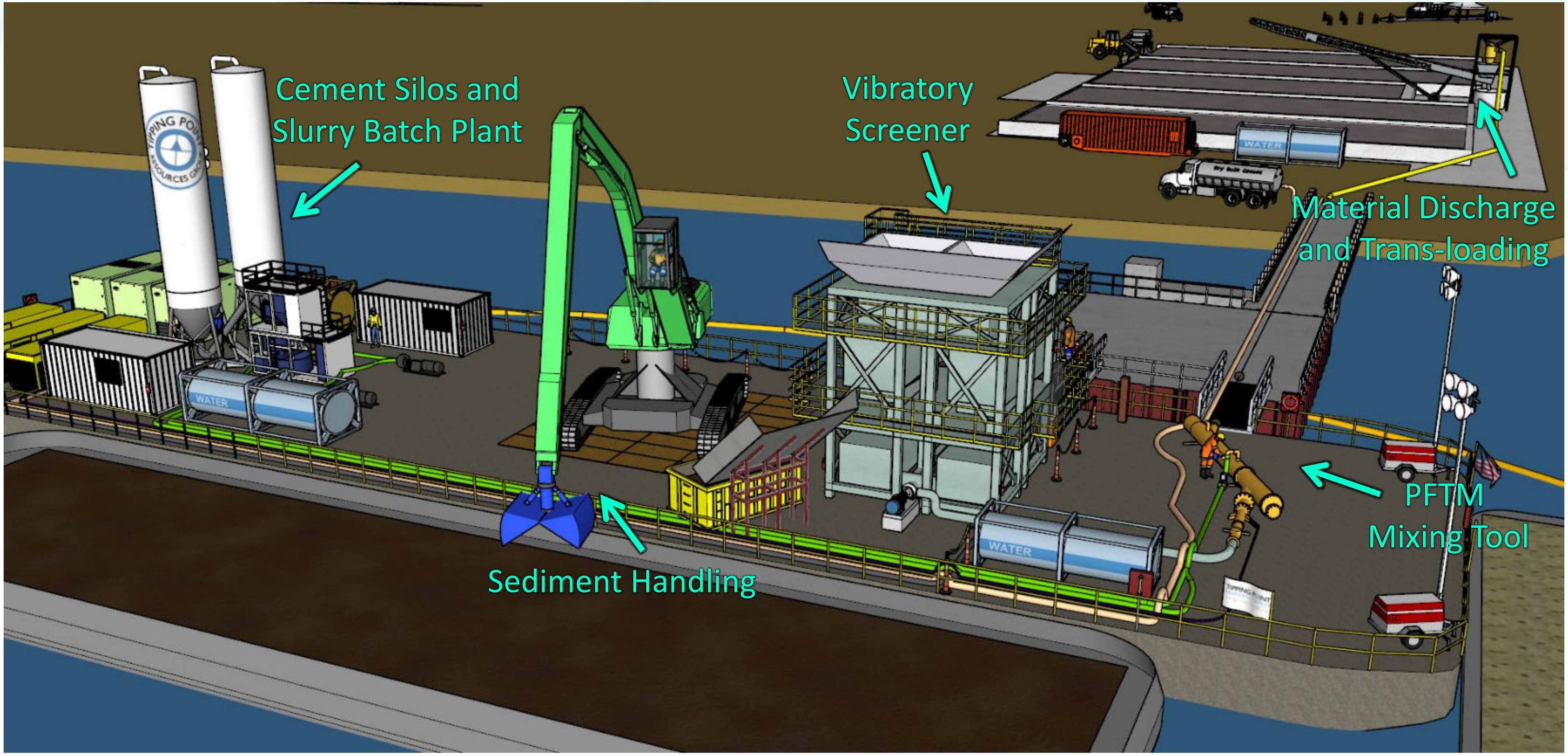
PFTM Mixing Tool - 1,530 m³/day (8-hr shift)



PFTM Cyclone Discharge Diffuser

Barge-mounted PFTM Operations

Mobile Operating Sediment Engineering System (MOSES)



PFTM: Processed Sediment

0 to 72 hours after placement

Dredged Sediment Prior to Stabilization

Freshly-placed PFTM Processed Sediment (8% Portland cement)

7.5% Portland cement
Immediately after mixing

7.5% Portland cement
After 24 hours

5% Portland cement
After 72 hours

Gorge Dam Bench-Scale Treatability Program

Site-specific treatability analysis is necessary to determine the suitable binder type/addition rate for the desired beneficial use (meeting environmental/geotechnical performance criteria).

Bench-scale laboratory treatability studies were conducted for the proposed upland placement of Gorge Dam sediments:

- Phase I – Proof-of-concept feasibility study (Dec 2019)
- Phase II – Geotechnical & material handling property assessment (Sept 2020 to March 2021)
- Phase III – Expanded characterization & alternative binder evaluation (Summer 2021)
- **Early & ongoing treatability program produced valuable support for project design.**

Sample preparation and curing procedures were designed to simulate the spectrum of material handling activities and curing conditions anticipated onsite – from bulk material placement to initial laydown period and construction of thin, compacted lifts.

- Motivation was to **understand the behavior of stabilized sediment throughout the dredging and upland placement cycle.**
- Results highlighted the tradeoff between laydown/curing time and binder dosage, enabling project decision-makers to **optimize design parameters to suit project needs.**

Gorge Dam Bench-Scale Treatability Program

Outline of Laboratory Geotechnical Testing Procedures

1

Material Characterization and Composite Preparation

2

Mixture Preparation and “Mellowing” Period

3

Mixture Homogenization Following ”Mellowing” Period

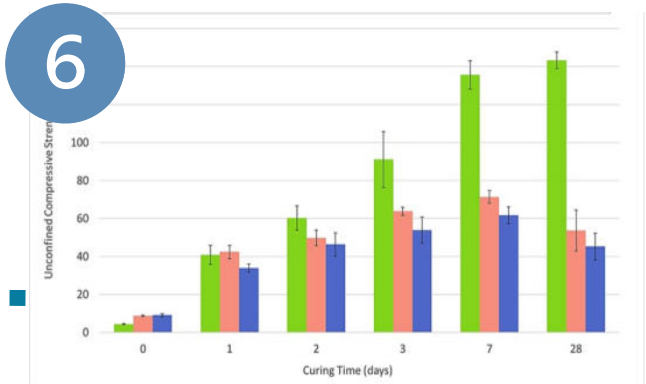
4

Sample Preparation (via modified Harvard Miniature Compaction) and Curing Period

5

Geotechnical Testing (UCS, CU Triaxial, Moisture Content, etc.)

6



Data Evaluation and Interpretation for Project Design

Presentation Summary

1. **Dam removal is an increasingly urgent national and global priority.**
    - Dams are being removed to promote riverine health/recreation, improve climate resilience, and respond to aging infrastructure.
    - Sediment quantity and quality behind a dam plays a complex role in determining engineering and environmental considerations for dam removal and subsequent downstream recovery.
    - Large volumes of contaminated impounded sediments are of particular concern and must be addressed prior to dam removal.
    - Rivers that flow through multiple jurisdictions present additional challenges to the management of sediments behind dams.

2. **PFTM is an innovative mass stabilization processing tool that allows greater project design flexibility, meeting dam removal challenges and creating opportunities for beneficial use.**
    - Pipeline transport and mass stabilization of impounded sediments presents unique opportunities for stakeholder engagement and creative beneficial use.

Presentation Summary (continued)

3. **Sustainable practices should be incorporated into dam removal projects for life-cycle sediment management:**
    - Pumping sediments for local beneficial use vs. vehicle and long-distance (or out-of-country) transport
    - Consideration of alternative (by-product) pozzolanic binders
    - Early and ongoing treatability assessment to support design and optimize design parameters
    - Innovative approaches, with public acceptance, to catalyze sustainable outcomes

4. **Beneficial use of stabilized sediment from behind dams fosters a circular economy by:**
    - Reducing open-water or land-based *disposal*
    - Providing opportunities for land improvement (e.g. Gorge Dam - Chuckery Area Placement Site)
    - Promoting both direct benefits (e.g. reduced over-land transport costs) and indirect benefits (e.g. stakeholder engagement, improved environmental health, and on-water/community recreation)

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