The economic case for sediment re-use from the Tuyamuyun Hydropower Complex
Using a profit and loss statement for sediment re-use

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Content

Context

Economics of reservoir management

Sedimentation - a global problem

Benefits of dredging and re-using sediments

Financial feasibility analysis of sediment re-use

The case for using recovered reservoir capacity efficiently

Conclusion
A reservoir is a resource.

A reservoir is economically viable if the Benefits > Costs

Cost Benefit Analysis is used to justify dam construction
Economics of reservoir management

• **Benefits**
  - Agricultural, Municipal & Industrial water supply, flood control benefits, hydropower benefits, recreational benefits

• **Costs**
  - Capital costs for construction & operation and maintenance
  - Known costs that have been planned for

• **Costs not considered**
  - Reservoir sediment management (left for the future)
  - Lost storage capacity over time (no direct cost associated with storage loss over time).
  - Upstream channel aggradation and downstream degradation
  - Dam decommissioning

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Economics of reservoir management

• **Cost Benefit Analysis is used to justify dam construction**

• CBAs for dams typically employ a 50-year economic lifetime (THC built 1969–1983).

• Any cost or benefit beyond 50-year is irrelevant (discounted to zero).
  
  • Sediment management should have been incorporated as an O&M cost from the beginning.

• The reservoir sediment plan was to make the dams big enough….
  
  • The problem is pushed to the future

• Dams are still being built this way.

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Economics of reservoir management

1st generation
- Conceives, plans, designs and constructs a dam and reservoir.

2nd & 3rd generation
- Starts receiving the benefits, paying back capital costs and pays O&M costs, but no sediment management cost.

4th generation
- Pays O&M costs, but not for sediment management.

5th generation
- Stuck with a retirement bill has to develop new water storage at a higher cost.

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Boyd and Randle (2018)
Sedimentation – a global problem

Sedimentation is steadily depleting reservoir capacity worldwide.

Global reservoir capacity is decreasing by 0.8% per year

(Annandale 2013)
The economic case for sustainable sediment management

1st best - trap the sediment

Reforestation upstream of Roghun/Nurek.

1 hectare of forestland restored = 9.6 m³ of reduced sediment
The economic case for sustainable sediment management

1st best - trap the sediment

2nd best
Keep it going. Routing sediment-laden flows

Last / most expensive option
Dredging, flushing, excavation, etc

Sumi et al., 2015
Another problem

26 APR 2022  |  PRESS RELEASE  |  EXTRACTIVES

Our use of sand brings us “up against the wall”, says UNEP report

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Supply and demand crisis of sand

• **Demand crisis**
  • Recent research projects a ~300% increase across lower & middle-income regions from 2020 to 2060 (Zhong et al., 2022)

• **Sand is extracted from environmentally sensitive habitats**
  • Extracting sand where it plays an active role, such as rivers, and coastal or marine ecosystems, can lead to erosion, salination of aquifers, loss of protection against storm surges, loss of breeding grounds, and wider impacts on biodiversity.
Sand mining is destroying Asia’s rivers

Uncontrolled and mostly illegal extraction of sand and rocks from riverbeds for construction is killing rivers across South Asia and China, and must be tightly controlled.

All UN member states adopted a new resolution, calling for actions on sustainable sand management, at the 5th UNEA (May 2022).
| Recommendation 1 | Recognise sand as a strategic resource that delivers critical ecosystem services and underpins the construction of vital infrastructure in expanding towns and cities globally. |
| Recommendation 2 | Include place-based perspectives for just sand transitions, ensuring the voices of all impacted people are part of decision-making, agenda-setting and action. |
| Recommendation 3 | Enable a paradigm shift to a regenerative and circular future. |
| Recommendation 4 | Adopt strategic and integrated policy and legal frameworks horizontally, vertically and intersectionally, in tune with local, national, and regional realities. |
| Recommendation 5 | Establish ownership and access to sand resources through mineral rights and consenting. |
| Recommendation 6 | Map, monitor and report sand resources for transparent, science-based and data-driven decision-making. |
| Recommendation 7 | Establish best practices and national standards, and a coherent international framework. |
| Recommendation 8 | Promote resource efficiency & circularity by reducing the use of sand, substituting with viable alternatives and recycling products made of sand when possible. |
| Recommendation 9 | Source responsibly by actively and consciously procuring sand in an ethical, sustainable, and socially conscious way. |
| Recommendation 10 | Restore ecosystems and compensate for remaining losses by advancing knowledge, mainstreaming the mitigation hierarchy, and promoting nature-based solutions. |
Sediment in the THC are valuable resources that are out of place.

The THC project can be used to demonstrate the value of reservoirs as a source of sand that have been sustainably supplied, whilst safeguarding food, water and energy security and promoting a circular economy in central Asia.
Financial feasibility assessment of sediment re-use from the THC
Use of coarse sediments in construction

- Concrete – the biggest driver of demand for sand
- A typical concrete mixture ratio is 1(cement):1.5 (sand): 3(gravel): 0.6 (Water)
- Sand and gravel from the THC can be readily used for construction
Reservoir sedimentation

- Sand and Gravel
- Silt and clay
<table>
<thead>
<tr>
<th>No.</th>
<th>Sample code (place of sampling)</th>
<th>Assessment according to Kaczynski</th>
<th>The content of fractions (mm) according to the US triangle, in%</th>
<th>FAO name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sand, 0.05-2.0</td>
<td>Silt, 0.002-0.005</td>
</tr>
<tr>
<td>1</td>
<td>PK-23 &quot;Uz&quot;</td>
<td>The sand is loose</td>
<td>91</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>TMGU Ave. coast of Uzb</td>
<td>Connected sand</td>
<td>29</td>
<td>69</td>
</tr>
<tr>
<td>3</td>
<td>№130®515 m Ave. Bank Ruslovaya ST-1</td>
<td>sandy loam</td>
<td>34</td>
<td>61</td>
</tr>
<tr>
<td>4</td>
<td>№130®515 m Ave. Bank Ruslovaya ST-1</td>
<td>sandy loam</td>
<td>39</td>
<td>56</td>
</tr>
<tr>
<td>5</td>
<td>PK-25 &quot;Uz&quot;</td>
<td>Medium loam</td>
<td>9</td>
<td>73</td>
</tr>
<tr>
<td>6</td>
<td>Military unit of TMGU Uzbek</td>
<td>Medium loam</td>
<td>12</td>
<td>71</td>
</tr>
<tr>
<td>7</td>
<td>ST 22 Uzb</td>
<td>Medium loam</td>
<td>5</td>
<td>79</td>
</tr>
<tr>
<td>8</td>
<td>TMGU Ave. beregTMGU</td>
<td>sandy loam</td>
<td>19</td>
<td>76</td>
</tr>
<tr>
<td>9</td>
<td>Etc. Bank No. 130 Run-of-river dam</td>
<td>light loam</td>
<td>9</td>
<td>81</td>
</tr>
<tr>
<td>10</td>
<td>Etc. Ruslovaya bank №130</td>
<td>light loam</td>
<td>7</td>
<td>81</td>
</tr>
<tr>
<td>11</td>
<td>ST 2® 436m Pr Bank Ruslova</td>
<td>Connected sand</td>
<td>33</td>
<td>63</td>
</tr>
<tr>
<td>12</td>
<td>Sultan Sanzhar Ave. Ruslovaya bank</td>
<td>Clay medium</td>
<td>3</td>
<td>66</td>
</tr>
<tr>
<td>13</td>
<td>Military unit of TMGU Uzbek</td>
<td>Medium loam</td>
<td>9</td>
<td>75</td>
</tr>
<tr>
<td>14</td>
<td>ST 2® 237m Pr Bank Ruslova</td>
<td>Medium loam</td>
<td>9</td>
<td>79</td>
</tr>
<tr>
<td>15</td>
<td>Pr shore® 65 Run-of-river ST 5</td>
<td>Clay medium</td>
<td>1</td>
<td>65</td>
</tr>
<tr>
<td>16</td>
<td>Pr shore® 436m Pr Bank Ruslova</td>
<td>Clay medium</td>
<td>33</td>
<td>63</td>
</tr>
</tbody>
</table>

16 samples from the THC from Shirokova Y. I. 2022

Some samples with pure sand,

And several with 30% sand content

Samples with 30% clay content
The ready sample product (bricks), made using the samples of the Channel reservoir sediment (Asian Institute for Ecological Research, 2022)
Clay sand is widely used in the Tashkent construction industry, for construction materials and a wide range of excavation works and landscaping. A characteristic feature of the material is the high content of clay particles (more than 30%), loam soil (10-30%), sandy soil (3 to 10%).
Use of fine particles in construction

- Always readily available demand for sand and gravel
- Harder to use silts and clays (considered unwanted by-products of quarrying operations).
- New research from France, shows that the finer particles (<0.06 mm) can be used to substitute cement in the order of 10% in concrete mixtures (Beddaa et al., 2022)
- Cement production: 7-8% of human produced CO2 emissions.
- An opportunity for achieving a significant environmental impact if finer sediment from THC is used as a supplement for cement in concrete production
- 1 ton cement = 1 ton CO2, roughly
OVERVIEW - BENEFITS FROM SEDIMENT RE-USE

**WEF**

PRODUCTIVE SERVICES

- Prolonged reservoir life-time, improved equipment operation
- Enhanced hydropower, freshwater, irrigation water → WEF Security

**DRR**

DISASTER RISK MITIGATION

- Reduced risk of flooding and sediment hazards
- Improved structural integrity of the dam

**E**

ENVIRONMENTAL BENEFITS

- Reduced pressures for sand extraction from sensitive habitats
- Circular economy
- Climate change mitigation

**M**

MARKETABLE BENEFITS

- Marketable value of sediment
The marketable value of sediment from THC?

- **Imminent action is needed to save the THC.** Start sooner, rather than later and be strategic by starting ‘small’

- **Recommend action point now:**
  - Maintenance dredging for the first 5 years, excavating 1-2 million m³ of sediment at strategic locations
    - Near the hydropower, canal intakes, spillways, and the intakes of the off-channel reservoirs. Upstream reservoir reach should also be dredged at regular intervals
  - Significant portions of sand (>30% to 85%) & clay sand (>30% clay content)

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The marketable value of sediment re-use

• Supply-side
  • Conservatively assume that 40% of the sediment can be re-used
    • 20% sand, and 20% clay-sand
    • 1-2 million m3 of sediment excavated → 200,000 to 400,000 m3 of sediment

Price of clay sand: **US$ 6 per m3**

Price of washed sand: **US$ 10.3 per m3**

(Internationally traded – US$ 30 per m3)
Revenue from the sale of sand and clay sand

Altus Impact
The marketable value of sediment re-use?

- **Demand-side**
- **1.5 units of sand per unit of cement**
- **Minimum annual demand of 20 million m³** in Uzbekistan and Turkmenistan combined.
- **Average annual growth rate** of the construction industry in Uzbekistan is >4%.
Costs - dredging

- **Inevitable costs**
- Dredging costs
- US$ 2 per m³ (Royal IHC) + Electricity costs

(Courtesy: Royal IHC)
Costs – confined disposal facilities

- A secure area where sediment is physically contained
- Compartments for sediment segregation
  - Clay ripening fields & sand separation
- Construction cost of 1.2 $/m³
- Yearly O&M cost of 0.06 $/m³

- With re-use of 40% of the sediment from the THC a 5 million m³ is needed (instead of 8 million m³)
## Costs – dredging and disposal

<table>
<thead>
<tr>
<th>YEAR</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantities dredged</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity of sediment dredged</td>
<td>1'000'000</td>
<td>1'500'000</td>
<td>1'500'000</td>
<td>2'000'000</td>
<td>2'000'000</td>
</tr>
<tr>
<td>Dredging cost - all cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dredging cost ($/m³)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total dredging cost - all sediments</td>
<td>-2'000'000</td>
<td>-3'000'000</td>
<td>-3'000'000</td>
<td>-4'000'000</td>
<td>-4'000'000</td>
</tr>
<tr>
<td>Confined disposal facility - all sediment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average cost per m³ capacity</td>
<td>1.18</td>
<td>1.18</td>
<td>1.18</td>
<td>1.18</td>
<td>1.18</td>
</tr>
<tr>
<td>Total construction cost for a 2 mil m³ facility (depreciated)</td>
<td>-113'503</td>
<td>-113'503</td>
<td>-113'503</td>
<td>-113'503</td>
<td>-113'503</td>
</tr>
<tr>
<td>Operation and maintenance cost ($/m³)</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Operation and maintenance cost ($)</td>
<td>-288'000</td>
<td>-288'000</td>
<td>-288'000</td>
<td>-288'000</td>
<td>-288'000</td>
</tr>
<tr>
<td>Total cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total dredging &amp; disposal cost</td>
<td>-2'401'503</td>
<td>-3'401'503</td>
<td>-3'401'503</td>
<td>-4'401'503</td>
<td>-4'401'503</td>
</tr>
</tbody>
</table>

= $2.4 to $4.4 million
Costs – Sand processing

• Estimates from WASH Construction engineers in Tajikistan and Uzbekistan

<table>
<thead>
<tr>
<th>Processing costs</th>
<th>Minimum (USD)</th>
<th>Maximum (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand and clay loam processing cost USD per m³</td>
<td>0.3 $/m³</td>
<td>0.6 $/m³</td>
</tr>
</tbody>
</table>

• Compared to estimates for the building of sand processing facilities

<table>
<thead>
<tr>
<th>Construction cost</th>
<th>Construction cost</th>
<th>Annual expense, depreciated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand processing plant in Australia</td>
<td>13 $/m³</td>
<td>0.26 $/m³</td>
</tr>
</tbody>
</table>
Costs – transportation costs

- According to country sources, these are $17 for a truckload of 8-9 m³ of sand transported 100 km from the sites (Davlatov 2022).

- Resulting in a cost of $0.02 per m³ per km transported by trucks.
- Image truck..
- Quickly limits the economic viability of re-use

<table>
<thead>
<tr>
<th>Transportation cost</th>
<th>USD/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuyamuyun - Urgench (100 km)</td>
<td>2 $/m³</td>
</tr>
<tr>
<td>Tuyamuyun - Bukhara / Navoie (350 km)</td>
<td>6.6 $/m³</td>
</tr>
</tbody>
</table>

Price of sand, Tashkent - $10/m³
Internationally traded – $30/m³
20 construction firms in Urgench alone

Figure 8: Google screenshot. Construction firms, including road construction firms, in Urgench.
Profit & Loss statement - illustrated

- Revenue, sand and clay sand
- Total dredging cost ($)
- CDF construction cost ($)
- CDF O&M cost ($)
- Sediment processing cost ($)
- Transport cost, urgench and surroundings (within 100 km of the site)
Sales revenues of **USD 3.3 to 6.6 million**

Can cover inevitable dredging and disposal costs of **USD 2.2 to 4.2 million**

...and reduce pressures on extraction from sensitive habitats
## Profit & Loss

<table>
<thead>
<tr>
<th>Operation</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Sales revenue</td>
<td>USD 3.3 to 6.6 million</td>
</tr>
<tr>
<td>-</td>
<td>Dredging and disposal costs</td>
<td>- USD 2.2 to USD 4.2 million</td>
</tr>
<tr>
<td>=</td>
<td>Gross profit</td>
<td>USD 2.3 to USD 4.2 million</td>
</tr>
<tr>
<td>-</td>
<td>Processing and transportation costs</td>
<td>- USD 1 to USD 2 million</td>
</tr>
<tr>
<td>=</td>
<td>Net profit</td>
<td>- USD 62,000 to 276,000 thousand</td>
</tr>
<tr>
<td>→</td>
<td>Recovery of dredging and disposal costs</td>
<td>97 – 106%</td>
</tr>
</tbody>
</table>
Sediment dredging and re-use should not be considered an option, but an imperative, to ensure proper functioning of the THC and make efficient use of resources that are currently trapped in the THC reservoir.
First phase maintenance dredging of 1-2 million m$^3$ per year, 2023-2028, may serve as an excellent pilot for a potentially much larger sediment re-use programme.

Under capital dredging, Giri (2022) proposes much larger volumes, for example 500 million m$^3$ of sediment from the channel reservoir over 5 years, to be compared with other options to be comprehensively studied...
Finally - back to the starting point

A reservoir is a resource

Dredging sediment from a silted reservoir, building an off-channel reservoir, etc. is economically viable if the

Benefits > Costs

Altus Impact
Benefits from irrigation?

- **Uzbekistan is the highest agricultural water consumer in Central Asia** (ADB, 2012)
  - Generally practiced methods of irrigation - furrow irrigation, basin and border
  - Waterlogging and salinization affect 50% of irrigated areas

- **The Karshi Steppe of Kashkadarya region, prime cotton producing area**
  - About 75% of this water is abstracted from Amu Darya River and raised up to 135 meters, using seven pumping stations to Karshi main canal.
Does furrow irrigation provide benefits?

Water Use Efficiency at the Karshi Steppe of Kashkadarya

+ 0.56 kg additional raw cotton for every m³ of water

+ 0.21 kg additional cotton lint for every m³ of water

<table>
<thead>
<tr>
<th>Cotton</th>
<th>Applied water (m³/ha)</th>
<th>Water use efficiency (kg cotton lint / m³)</th>
<th>Raw cotton yield - baseline (kg/ha)</th>
<th>Cotton lint yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional furrow Irrigation</td>
<td>6837</td>
<td>0.21 kg/m³</td>
<td>3487 kg/ha</td>
<td>1464 kg/ha</td>
</tr>
</tbody>
</table>

Djumaboev et al., (2019),
$ benefits from furrow and drip irrigation

Cotton lint sells at 2.05 $/kg & water pumping cost of 0.05 $/m³

<table>
<thead>
<tr>
<th>Cotton</th>
<th>Applied water (m³/ha)</th>
<th>Water use efficiency</th>
<th>Incremental revenue ($/m³)</th>
<th>Incremental profit ($/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional furrow Irrigation</td>
<td>6837 m³</td>
<td>0.21 kg/m³</td>
<td>0.4 $/m³</td>
<td>0.35 $/m³</td>
</tr>
<tr>
<td>Drip irrigation</td>
<td>3247 m³</td>
<td>0.6 kg/m³</td>
<td>1.2 $/m³</td>
<td>1.1 $/m³</td>
</tr>
</tbody>
</table>

Dredging at 2 $/m³ and not re-using sediment
But only getting 0.35 $/m³ of benefits
Inefficient
**Costs > Benefits**
.... And we have not even accounted for losses in the irrigation network!
Climate resilience and reaping more benefits

• **Long term outlook for our water storage supply is grim:** Droughts and more intense storm events.

• **Need to adopt climate smart farming**

• **Proven best management approaches** to conserving water resources whilst sustaining cotton production in semi-arid environments (DeLaune 2020).

  ➢ No-tillage with cover crops, increase yield and water use efficiency, compared to standard tillage.

  ➢ Use drip irrigation & applying irrigation water at a critical growth stage, more efficient than early season irrigation.
Conclusion

• There is an imminent global supply crisis of sand, whilst reservoirs are reaching their economic life-time due to sediment build-up.

• Sand extraction is associated with significant environmental impact. Policy moves towards a circular economy – e.g. banning landfilling of construction materials

• Sediments in reservoirs are resources that are out of place

• Opportune moment to capitalize on sediments from the THC!
Conclusion

• Construction materials sales revenues from can cover dredging, disposal and processing costs!

• Whilst helping safeguard Food, Water and Energy security from the THC

• Start sooner rather than later. Learn from the maintenance dredging base experience and build a bigger dredging operation.

• Let us not repeat the mistakes of the past and keep pushing sediment management problems to future generations

• Finally, recovered storage capacity from the Tuyamuyun should be used efficient.

• More efficient irrigation systems and climate smart farming is required to confront a challenging future.
THANK YOU VERY MUCH

Vanja Westerberg
Financing??

• For a campaign of this enormous scale it will require a consortium of financially stable major earth works companies that will also need to put in investment.

• Will the private developer give us the dredging equipment, the processing equipment, or the disposal facility that we want and need to ensure reliable and safe infrastructure to the public?

• Public private partnerships can help share project risks with the private entity that deliver the project. This can be done, for example, through a “design-build and maintain” project, which shifts the life-cycle of maintenance responsibility to the developer.

• It also includes a finance component, where the concessionaire provides private capital, for example, to procure dredging equipment, and build the disposal and sediment processing facility.

• This way, the developer is incentivized to provide the best infrastructure possibly (dredging equipment, disposal and sediment processing facility etc.) that will last as long as possible.

• Contractors or developers to come-in and suggest ideas, as the project is designed.