Attachment H-2:
Literature Search Overview Presentation

Lower Susquehanna River Watershed Assessment

Watershed/Reservoir Sediment Management Literature Search

Findings

Date of Presentation: September 24, 2012

US Army Corps of Engineers
BUILDING STRONG®

Purpose of the Literature Search

- Review, analyze, and synthesize literature on managing watershed/reservoir sedimentation.
- Findings and lessons learned will be incorporated into refining sediment/nutrient management strategies for LSRWA.
- Help us Brainstorm Ideas.

Methodology

- Reviewed Sediment Task Force Findings
- Conducted Database Literature Search
  - Findings
  - Trends
  - Conclusions

Sediment Task Force

Sediment Task Force
Who were they?

- ’99 - ’01
- Chaired by Susquehanna River Basin Commission
- Multi-agency, Multijurisdictional group
- Tasks:
  - *Review of existing studies*- Susquehanna sediment transport and storage;
  - Make *recommendations on management options* to address the issues;
  - *Symposium* of experts and policy makers; and
  - Recommend areas of *study, research, or demonstration*

Sediment Task Force

What did they do?

- ***Met for 18 months to bring together expertise on*:**
  - ***Sediment loads*** in the basin
  - Implications of sediment loading /reservoir capacity to ***Chesapeake Bay Program goals***;
  - Effectiveness of various *management technologies or practices*;
  - Analysis of ***reservoir***, ***riverine*** & ***upland*** *sediment management options;*
  - Susquehanna sediment management issues and their ***cumulative impacts to*** *Bay* watershed and restoration efforts; and
  - Recommended ***sediment monitoring*** *and* ***demonstration projects*****.**

Sediment Task Force
Findings (Dec, 2000)

1. Human influenced sediment loading is a problem.
2. Loads in early 1900’s were 2-3 times larger (land use, BMP’s, dams).
3. Benefits of dams will be lost once at steady state:
   - Increased loads
   - More scouring.
4. Steady State ~ 20 years???
5. Sediment transport is a natural process that has been aggravated by human activity. Management focus: reduce human impacts.

Sediment Task Force
Findings Cont'd (Dec, 2000)

6. Sediment transport is aggravated by catastrophic storm events.
7. Reducing loads to local streams, rivers and lakes has value.
8. Decreasing loads over time will restore Bay water quality and habitats; and
9. Need more knowledge of sediment and effectiveness of management options to support a comprehensive management strategy.

Sediment Task Force
Recommendations

Upland Management

- ▸ Agriculture Uplands: BMP's and clean water practices
- ▸ Urban Uplands: BMP's
- ▸ Transportation Systems: BMP's, ditch management
- ▸ Forestry Uplands: Expansion; harvesting BMPs
- ▸ Mining Uplands: Reclaim/reforest abandoned mine land

Sediment Task Force
Recommendations

Riverine Management

- Stream Restoration & Stabilization
- Sediment Trapping Structures (Impoundments/dams)
- Sediment Transport Assessments (Monitoring and Modeling)
- Stream Bank/Channel Stability Assessments (Monitoring and Modeling)
- Riparian Buffers
- Natural & Reconstructed Wetlands

Sediment Task Force
Recommendations (June, 2002)

Reservoir Management

- ***Sediment Bypassing:*** Would result in a base load condition that exceeds the current base load into the Bay. Counter to the currently accepted goal of reducing sediment input to the Bay.
- ***Sediment Fixing***: Would not mitigate scouring or change the amount of sediment passing through the system or add capacity.
- ***Modified Dam Operations***: Unclear if this would accomplish anything in the interest of sediment control other than as a form of bypassing.
- ***Dredging:*** Supports study to maintain/reduce trapping capacity.

Database Literature Search

Research Databases Used

- Google Scholar
- The Wall Street Journal
- ProQuest
- Academic Search Premier (EBSCO)
- ScienceDirect
- GreenFile (EBSCO)
- EnvironetBASE
- Agricola
- GEOBASE

Findings

- 100+ articles (National and International) were reviewed
- A sub-set were determined to be most relevant to sediment management and were summarized:
  - Studies/Modeling
  - Technology
  - Alternative Analysis
  - Recommendations
  - Implemented Actions

Domestic Results

Capital Lake Adaptive Management Plan

Location: Capital Lake/Deschutes River Olympia, Washington

Problem: Sediment is carried downstream from the Deschutes River and is trapped by the dam that forms Capital Lake. Flood risk, water quality issues.

Proposed work: Dredging, open water placement, beneficial re-use.

Cost: Infrastructure -$2-4 million

Maintenance -$39.8-$134.7 million (over 50 years)

Sediment Load: 875,000 cubic yards needs to be removed. Annual Rate is about 35,000 cubic yards

Year: 2009

Sixmile Creek and Watershed

Location: Six Mile Creek, Tompkins County, Brooktondale New York

Problem: High load of suspended sediment, a result of erosion along the main channel and tributaries, downstream to the dams and impacting water supply.

Proposed Work: use of hard engineering structures to control the channel location or channel erosion control using natural channel design, dam removal, dredging.

Cost: N/A

Sediment Load: Several hundred thousand cubic yards

Year: 2007

Russell Plant Dam

Location: Russell Plant Dam, Westfield River in Russell, Massachusetts

Problem: 1,200 cubic yards of sediment has built up over the past 8 years.

What Has Been Done: Dredging the dam by lowering the dam over 24 hours, then dredging the material. The goal after dredging is complete is to produce approximately 4.5 million kilowatts of energy .

Cost: N/A

Sediment Load: 1,200 cubic yards have accumulated over the past 8 years

Year: 2009

Lower Granite Dam

Location: Lower Granite Dam on the Lower Snake River

Problem: With approximately 611,680 cubic meters of sedimentation collecting annually, it has interfered with navigation and flood control operations

What Has Been Done: Dredging has taken place but the amount of dredging can be reduced by using several best management alternatives after finding the critical sediment producing watersheds from upstream.

Cost: N/A

Sediment Load: 611,680 cubic meters of sedimentation collecting annually

Year: 1995

Grove Lake

Location: Grove Lake, Northeastern Nebraska

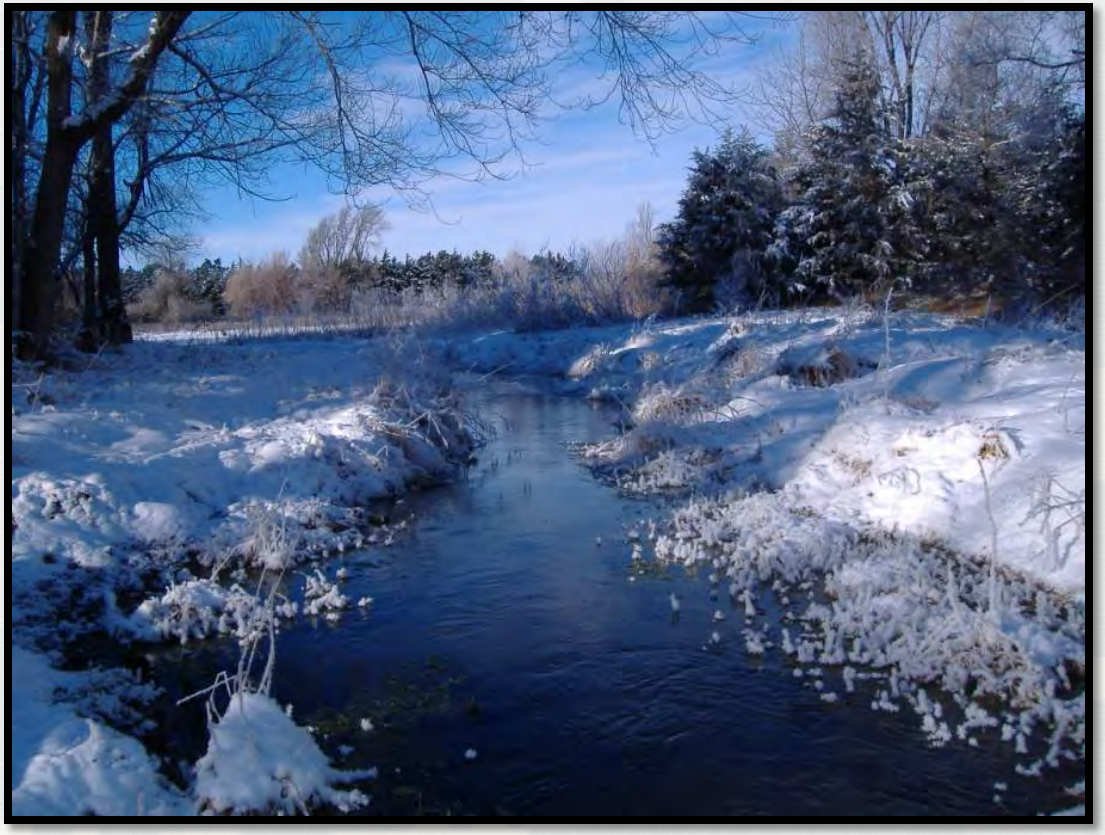
Problem: Large amounts of sediments have created a delta in the inlet of the lake due to large amounts of agricultural grazing in the Verdigre Creek Watershed above the lake, fisheries impacts

What Has Been Done:

--Install a siphon in the lake that would transport sediment and discharge it below the dam

-Currently siphon bypasses 50% of sediment entering lake.

-If remaining material is dredged in addition to being siphoned, it is predicted that the life of the lake will be 100+ years.



Cost: $42,000 (siphon option)

Sediment Load: 2466 cubic meters annually

Year: 2004

Louisiana Coastal Restoration

Location: Louisiana

Problem: N/A

Proposed Work: Application of Long Distance Conveyance (LDC) of Dredged Sediments to Louisiana Coastal Restoration. LDC projects are defined as involving hydraulic transport of slurry (mixture of sediment and water) through pipelines for distances of 16 km (10 miles) or greater. Long distance transport is a mature technology that has been used efficiently for applications like coal and iron ore transport.

Cost: N/A

Sediment Load: N/A

Year: 2011

Hydrosuction Sediment Removal System (HSRS)

Location: Woodside I & Woodside II Dams and Lake Atkinson, on the Elkhorn River, in Nebraska

Problem: Annual sediment load

What was Done: bypassing or dredging to move the annual sediment load.

Cost: Costs for pipeline and installation vary from about $160,000 for short dredging systems to about $865,000 for the longer bypassing systems

Sediment Load: 170 Tons/Day

Year: N/A

IVEX Dam

Location: IVEX Dam, Chagrin River, Northeastern Ohio

Problem: Failure of the dam occurred because of a combination of the following factors: inadequate spillway design, lack of emergency spillway, large loss of capacity from a large amount of sedimentation (86% over 152 years), and poor dam maintenance. The dam failure caused rapid incision of the stream bank and this changed the course of the river westward along the bedrock.

Proposed Work: N/A

Cost: $1-2.5 million

Sediment Load: 1,770 metric tons annually

Year: failure of the Dam occurred in 1994

Nebraska Valentine Mill Pond

Location: Nebraska

Problem: The capacity of the pond has decreased from 30 acres to 15 acres due to sedimentation

What Has Been Done:

-Mechanical excavation of sediment

-Hydrosuction sediment removal system which is a pipeline that catches the sediment as it enters the pond and travels around the dam and is discharged further down the creek

Cost: $1.6 million

Sediment Load: 60 tons of sediment daily

Year: 2003

Neosho Basin

Location: Neosho Basin, Kansas

Problem: Sedimentation and poor water quality are affecting reservoirs and have the potential to reduce their reliability as a source of water.

What Has Been Done: Dredging

Proposed Future Action:

-Sediment Removal

-Reallocation

-Structural Restoration (dams, diversion structures, treatment facilities)

-Flushing

Cost: N/A

Sediment Load: N/A

Year: 2008

Los Padres Dam

Location:

Problem: Dam's capacity has decreased from 3,030 acre-feet to 1,760 acre-feet which are due to sedimentation

Proposed Work

-Dredging

-Raising Reservoir Levels

-Increasing Capacity of the Dam

-Removing the Dam

-Building a New Dam

Cost: N/A

Sediment Load: N/A

Year: 2009

Regional Sediment Management (RSM)

- 1. To examine, apply and evaluate opportunities, practices, tools, benefits and impediments to applying regional approaches to sediment management.
- 2. Maintaining the navigability of ports and water
- 3. Dredged material, sediment, and watershed managers working together
- Protecting the environment;
- Conservation and restoration of estuaries and associated resources;
- Protecting water quality;
- Maintaining reservoir capacity ;
- Reducing flood and coastal storm damage;
- Managing watersheds;
- Managing coasts.

Reservoir Conservation RESCON
Volume I & Volume II (manual)

- **Managing Reservoir Sedimentation**
- **RESCON model: Technical and Economic Feasibility of various alternatives**
- **Alternatives Categories:**
  - **Reduce sediment inflows into the reservoir;**
  - **Manage sediments within the reservoir;**
  - **Evacuate sediments from the reservoir;**
  - **Replace lost storage**
- **Each Category has environmental and economic benefits and consequences.**

Year: 2003

Robles Diversion Dam

Location: Robles Diversion Dam, Ventura, California

Problem: the storage behind the dam has been significantly reduced by deposition of coarse sediment

Proposed Work:

-Hydraulic model study of the proposed High Flow Bypass spillway

-Froude-scale model was tested

-Improve upstream fish passage

Cost: N/A

Sediment Load: N/A

Year: 2008

San Clemente Dam

Location: San Clemente Dam on the Carmel River

Problem: The dam is 106 feet tall concrete arch and the reservoir it creates originally held 1,425 acre-feet of water but has now been reduced to 125 acre-feet due to sedimentation.

-Dam safety issue

Proposed Work:

-Dam Removal in January 2013

-Another alternative evaluated: Rerouting the river via bypass to avoid the accumulated sediment

-Reinforcing the current dam by adding support with rock or concrete structures

Cost: $84 million

Sediment Load: Today the reservoir has been filled by more than 2.5 million cubic yards of sediment, leaving a reservoir storage capacity of approximately 70 acre-feet as of 2008.

Year: 2009

Savage Rapids Dam

Location: Savage Rapids Dam, Southwestern Oregon, on the Rogue River

Problem: the dam has been diverting irrigation flows; fish ladders are old and do not meet the NMFS criteria

Proposed Work:

-Construction of two pumping plants to deliver irrigation water & removal of the dam

-Detailed sediment study

Cost: N/A

Sediment Load: 200,000 cubic yards

Year: N/A

Dillsboro Dam

Location: Dillsboro Dam

Problem: Sediment and sand behind the dam

Proposed Work:

-Dam Removal

-Dredging

Cost: N/A

Sediment Load: more than 100,000 cubic yards

Year: 2007

Saginaw River, Michigan

Location: Saginaw River, Michigan

Problem: Sediment Trap

Proposed Work:

-Theoretical Model to evaluate the efficiency of the sediment traps

Cost: N/A

Sediment Load: N/A

Year: 2001

Glen Canyon Dam

Location: Glen Canyon Dam on the Colorado River

Problem: sediment has now collected behind the dam and affects area beaches and wildlife both below the dam

Proposed Work:

-High flow releases

-Pipeline to transport sediment

Cost:

-Initial cost: $140-$430 million/yr

-Operations: $3.6-$17 million/yr

-Utilities: $89.1 million/yr

Sediment Load: N/A

Year: 2009

Utah's Reservoirs

Location: Various Reservoirs in Utah

Problem: Utah does not have any coordinated efforts to assess or manage reservoir sedimentation.

Proposed Work:

-Watershed Management

-Construction

-Mining

-Logging

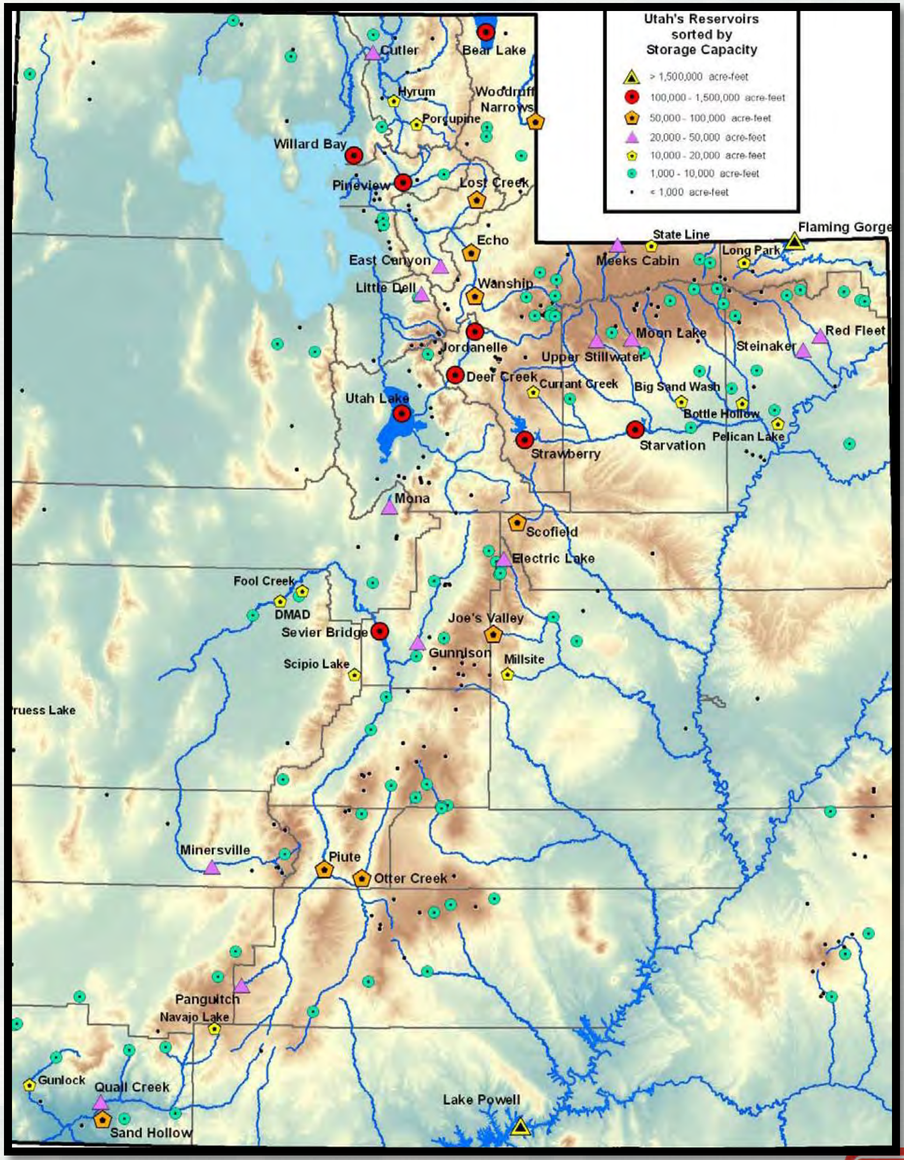
-Grazing

-Upstream Trapping

Cost: N/A

Sediment Load: Varies upon location

Year: 2010



International

Gezhouba & Three Gorges Dam

Location: Yangtze mainstem, China

Problem: The high sediment yields pose threats to the performance of the two dams

Proposed Work:

-Drawdown & Flushing

-Sluicing (Wash or rinse freely with a stream or shower of water)

-Releasing turbidity currents

-Dredging

Cost: N/A

Sediment Load: 100-150 million tons annually

Year: 2011

Going Full Circle (Discussion)

- **Practical Methods Recommended:**
  - Re-vegetation
  - Warping
  - Contour Farming
  - Check Dam
  - Bypassing (Implemented in **Switzerland** (5 bypass tunnel schemes) and **Japan** (4 bypass tunnel schemes))
  - Sluicing (Wash or rinse freely with a stream or shower of water)
  - Density Current Venting
  - Dredging
  - Dry Excavation
  - Hydro Suction
  - Drawdown Flushing
  - Pressure Flushing
- **Year:** 2011

Maithon Reservoir

Location: Maithon Reservoir, India

Problem: Sediment

Proposed Work:

-Rising of Reservoir Bed Levels
-Fill the dead storage zone with silt
-Siltation Trap

Cost: 2.8 mm^3/ year

Sediment Load: N/A

Year: 2006

Measures Against Reservoir Sedimentation (research study)

- **Location:** Switzerland
- **Problem:** The process of sedimentation is a severe threat to the artificial lakes serving as reservoirs for hydro-power production, drinking water supply or flood protection. It is a long-term problem with potential important economic consequences, which therefore requires a sustainable solution
- **Proposed Work:**
  - Release the sediments out of the reservoir in a continuous way in order to assimilate the natural conditions before the dam construction.
  - The momentum fluxes (jets or plumes) and the energy head of these water transfer tunnels can be used to create a rotational upward flow,
  - Define the upper limit of sediment concentration
- **Cost:** N/A
- **Sediment Load:** N/A
- **Year:** 2009

Yangtze River Basin

Location: Yangtze River Basin, China

Problem: The massive weight behind the Three Gorges Dam has begun to erode the Yangtze's steep shores at several spot, along with frequent fluctuations in water levels, has triggered a series of landslides and weakened the ground under Miaohe, village 10 miles up the reservoir. Additional dangers: as the dam blocks silt heading downstream, the Yangtze River estuary region is shrinking and sea water is coming further inland.

Work has been Done: New Dam

Cost: N/A

Sediment Load: 500 million metric tons of silt annually

Year: 2007

Reservoir Sedimentation and Sediment Management in Japan

- **Location:** Japan
- **Problem:** Rapid loss of sediment capacity, aging of reservoirs .
- **Work has been Done:**
  - Sediment Flushing
  - Sediment Bypassing
  - Excavating Turbid Water
  - Empty Dam
- **Cost:** N/A
- **Sediment Load:** 20 million m^3 annually
- **Year:** N/A

Naodehai Reservoir

- **Location:** Naodehai Reservoir, on the Liu River in China
- **Problem:** Reduce the sediment yield and deposition in the downstream channel
  Work has been Done:
  - -Reforestation
  - -Construction of Debris Dams
  - -Full Drawdown Flushing
- **Cost:** N/A
- **Sediment Load:** 261 million m^3 annually
- **Year:** 2004

Lower Ebro River

- **Location:** Spain
- **Problem:** The construction of dams has disrupted the sediment transport
- continuity, so the lower Ebro River and its delta are facing a sediment deficit
- **Proposed Work:**

  -Impounding the low-lying areas by means of defense structures

  -Restoring the sediment fluxes to the delta to stop coastal retreat and maintain land elevation
- **Cost:** Average cost of sediment dredging for wetland restoration is about US$ 40,000/ha, excluding additional activities such as construction of protective structures, planting, re-contouring, and monitoring
- **Sediment Load:** N/A
- **Year:** 2007

Sediment Management Round Table Discussion

- **<u>Danube River Basin, Europe</u>**
  - ► Need Sediment Flushing
- **<u>Elbe Basin, Central Europe</u>**
  - ► Maintenance and report of river-engineering works

Rhone River

Location: Rhone River, Switzerland

Problem: reservoir sedimentation resulting from bed and suspended load, endangers the safe and economic operation

Proposed Work:

-Flushing

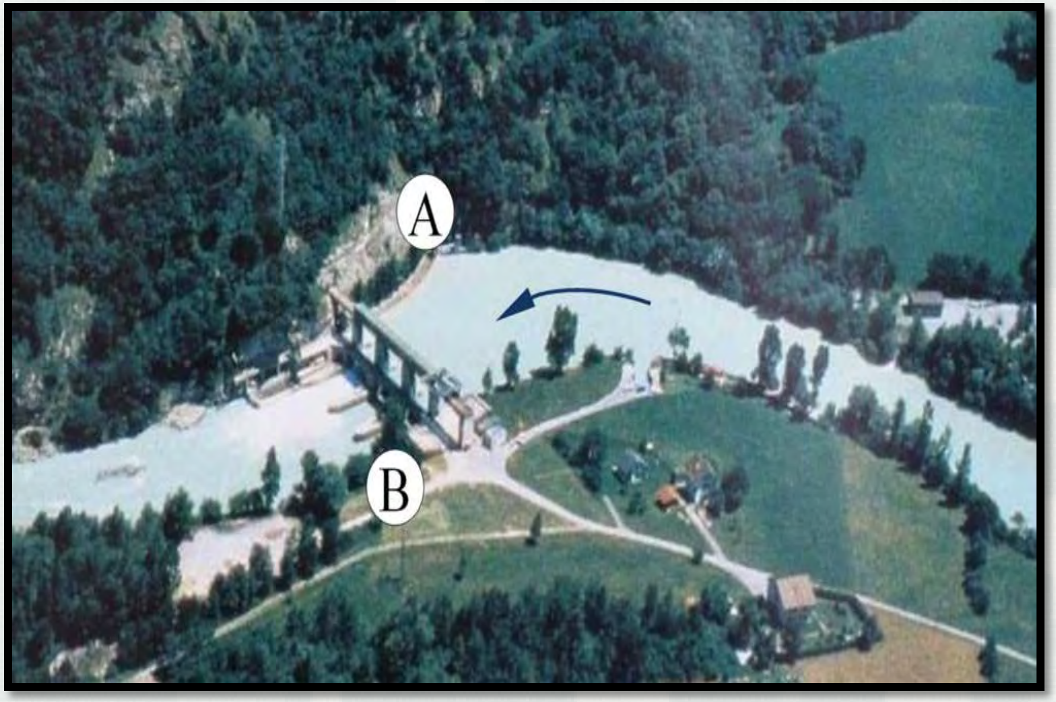
-Sluicing (Wash or rinse freely with a stream or shower of water)

-Hydraulic Model

Cost: N/A

Sediment Load: N/A

Year: 2012



Guanting Reservoir

Location: Guanting Reservoir on the Yongding River, China

Problem: reservoir storage capacity

What Has Been Done:

-Dredging

-Construction of hydraulic projects

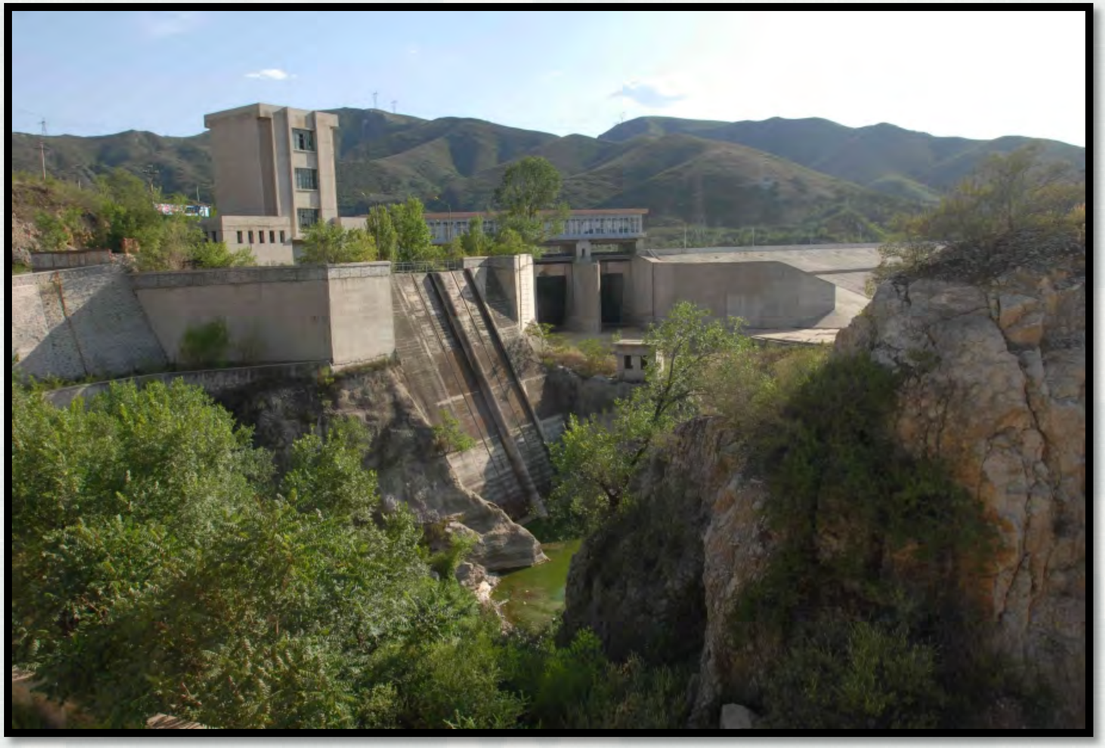
_building dams and reservoirs upstream

-Development of irrigation system

Cost: N/A

Sediment Load: N/A

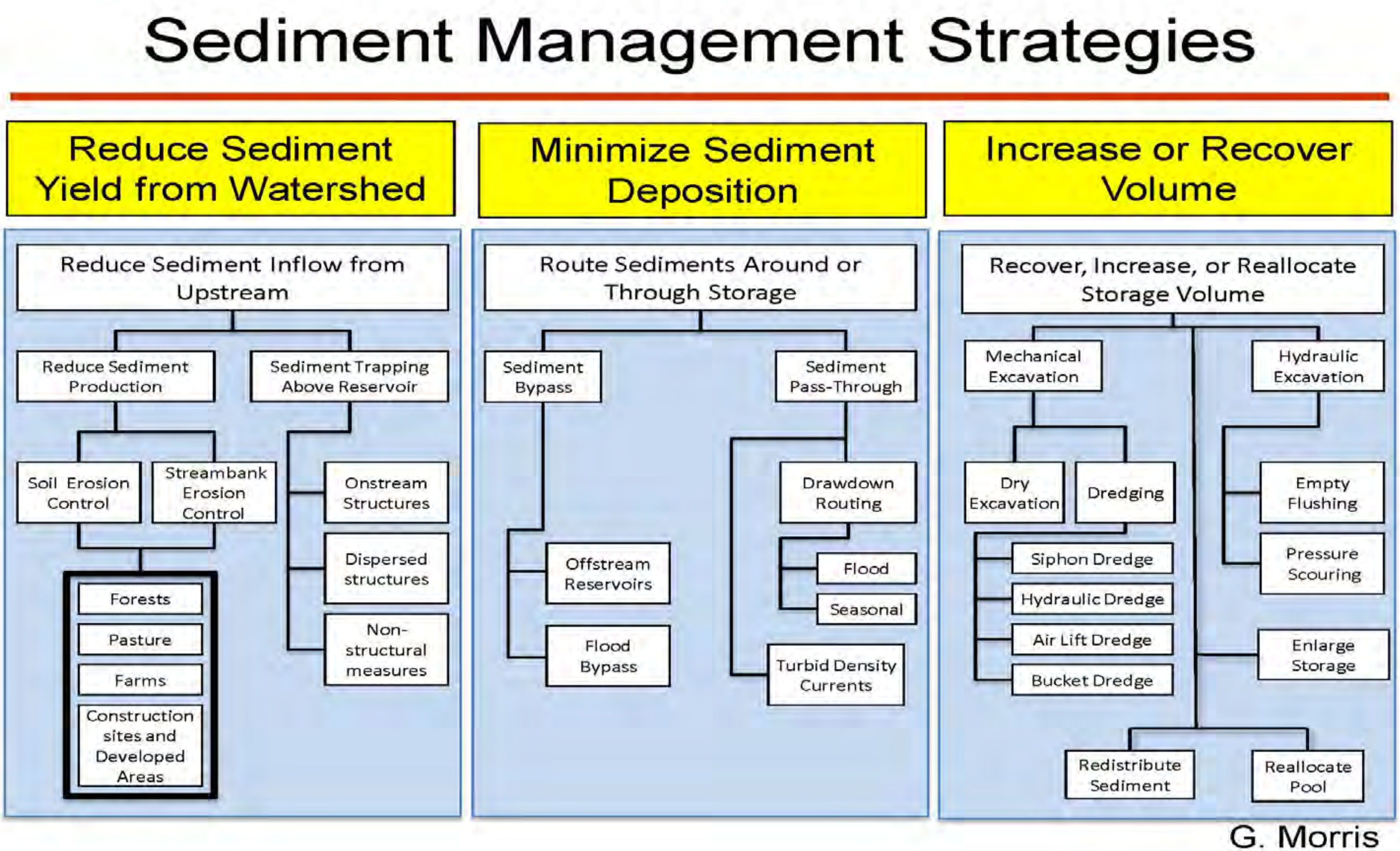
Year: 2004



Lit Search
Themes, Findings, Conclusions

- Reservoir sedimentation (declining storage) is a worldwide problem
- Trends like climate change and population growth are exacerbating problem
- Comprehensive, long-term sediment management is needed EVERYWHERE.
- New dams, have sediment management built in.

Lit Search
Themes, Findings, Conclusions



Lit Search
Themes, Findings, Conclusions

- **<u>Goals</u>** - What is driving the need for sediment management drives the solution:
  - Losing purpose/function of the dam (economics)?
  - Restoring natural sediment flow (environmental)?
- **<u>It's all about the sediment</u> -**
  - Where they are coming from?
  - Where they are depositing?
  - Sediment size and chemical characterization?
  - Contaminants; land-use history?
  - Particle size gradation and spatial distribution?
  - Erodability- Rate sediment would erode following dam removal? Transported downstream?
  - Location and magnitude of sediment deposition downstream?
  - Value of sediments behind the dam?
  - Precipitation patterns: when is sediment transported?

Lit Search
Themes, Findings, Conclusions

- **Effectiveness** - How effective is strategy at improving sedimentation?
- **Economic** -
  - Capital costs for strategy ?
  - Future operation and maintenance requirements?
- **Optimization/Adaptive Management** –
  - ✓ Modeling before implementation
  - ✓ Monitor effects of the implementation
  - ✓ Adjust activities to optimize effectiveness
  - ✓ Continuously improve system performance

Lit Search Themes, Findings, Conclusions

- **Environmental** -
  - Permitting requirements?
  - Impacts?
- **Schedule** -
  - How much time is required for solution to be implemented?
  - Long term problems often need long-term solutions.
  - Implementation sequence: long and short-term implementation?
- **Integrated sediment system management**-
  - Multi-faceted problem requires multi-faceted solution most have combinations.
- **Benefits** –
  - Costs incurred worthwhile?

Lit Search
Themes, Findings, Conclusions

- **Dredging (i.e. increasing or recovering volume)**

- ▸ O&M
- ▸ Contamination
- ▸ Dredging can be reduced by using BMP's and finding the critical sediment producing watersheds from upstream.
- ▸ Dredging is very expensive nomally is a last resort: often create new social and environmental problems .
- ▸ Tactical Dredging
- ▸ Beneficial re-use
  - Soil amendments (agriculture, mining etc.)
  - Habitat development/beach nourishment
  - Commercial (bricks, geotextile container fill groins, landfill capping, tiles, glass, cement blocks

Lit Search
Themes, Findings, Conclusions

By-passing - Routing sediments around or through storage

- **The technology to by-pass and transport sediments has been developed**
- **Long Distance Conveyance** hydraulic transport of through pipelines (>10 miles)
- **Hydrosuction sediment removal**
  - Dredging equipment with hydrostatic head over a dam to create suction at the upstream end.
  - Difference between water levels upstream and downstream of dam to remove sediment through a floating or submerged pipeline linked to an outlet or discharging over the dam.
  - **Hydrosuction dredging,** deposited sediment dredged and transported downstream or to a treatment basin.
  - **Hydrosuction bypassing**, incoming sediment is transported without deposition past the dam to the downstream receiving stream.

Lit Search
Themes, Findings, Conclusions

By-passing - Routing sediments around or through storage

- Pipeline diameter selection, and head size
- Environmental Impacts
  - Increased turbidity levels downstream?
  - Changes in water chemistry?
  - Impacts of sediment-removal upstream?
  - Regulatory agencies should be contacted early
- Ecological and operational aspects an upper limit of sediment concentration needs to be defined
- Out-flowing sediment concentration has to be regularly monitored and controlled.

LSRWA Goals and Objectives

1. **Evaluate strategies to manage sediment and associated nutrient delivery to the Chesapeake Bay.**
   - Strategies will incorporate input from Maryland, New York, and Pennsylvania Total Maximum Daily Load (TMDL) Watershed Implementation Plans.
   - Strategies will incorporate evaluations of sediment storage capacity at the three hydroelectric dams on the Lower Susquehanna River.
   - Strategies will evaluate types of sediment delivered and associated effects on the Chesapeake Bay.

2. **Evaluate strategies to manage sediment and associated nutrients available for transport during high flow storm events to reduce impacts to the Chesapeake Bay.**

3. **Determine the effects to the Chesapeake Bay due to the loss of sediment and nutrient storage behind the hydroelectric dams on the Lower Susquehanna River.**