Assessing Ecological Effects of Sediment Release from Reservoirs

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Unclassified

Overview

1. **Conceptualizing the Downstream Ecological Effects of Reservoir Sediment Release** Tech Report

2. **Hydraulic Analysis for Sediment Release Scenarios** Tech Report

3. **Sediment Web Application Tool** Demonstration

4. Q&A

Conceptualizing the Downstream Ecological Effects of Reservoir Sediment Release TR

Authors:

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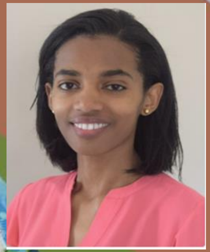
- Interests: ecosystem restoration, ecological modeling, evaluating environmental effects of USACE projects

Glorimar Franqui-Rivera, MSc, PhD student – ERDC-UPR intern

- Interests: marine sciences, biodiversity, ecological dynamics

Dr. Kyle McKay, MSc, PhD – Research Civil Engineer

§Interests: effects of water source mgmt., ecosystem restoration, modeling



Dr. Liya Abera, PhD – Civil Engineer ERDC-ORISE fellow

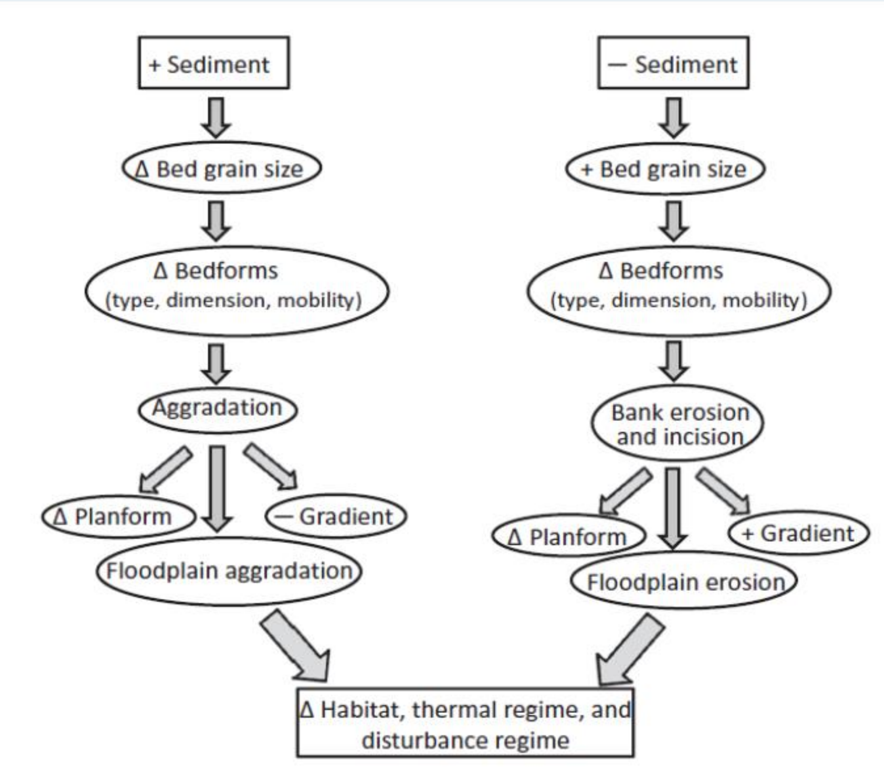
§Interests: Nature Based Solutions, stormwater engineering, life-cycle cost

Conceptualizing the Downstream Ecological Effects of Reservoir Sediment Release TR

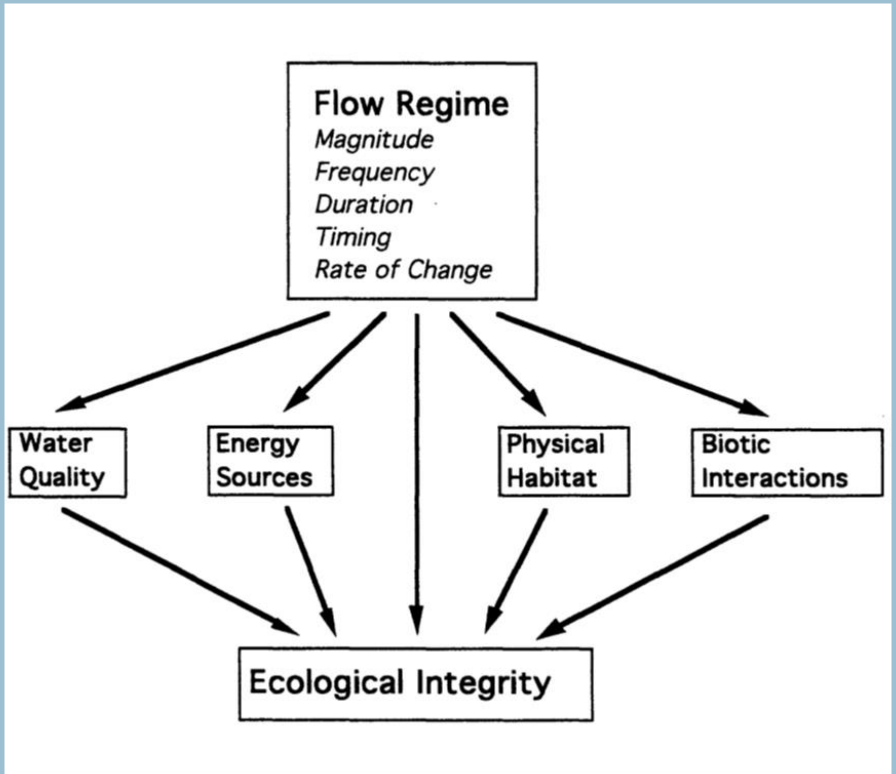
Report content:

Intro	• Hydrological and sediment regimes • Up, down, in-reservoir effects • Need for sustainable practices
Geomorphic Effects	• CWA Sec 404 • Physical effects • Effects on habitat
Water Quality Effects	• CWA Sec 401 • Effects on WQ • Effects on habitat
Aquatic Organism Effects	• ESA Sec 7 and 9 • Effects of WQ and fluvial geomorph
R&D Gaps & Recommendations	• Workshop findings • Lit review findings

Introduction: Hydrological & sediment regimes

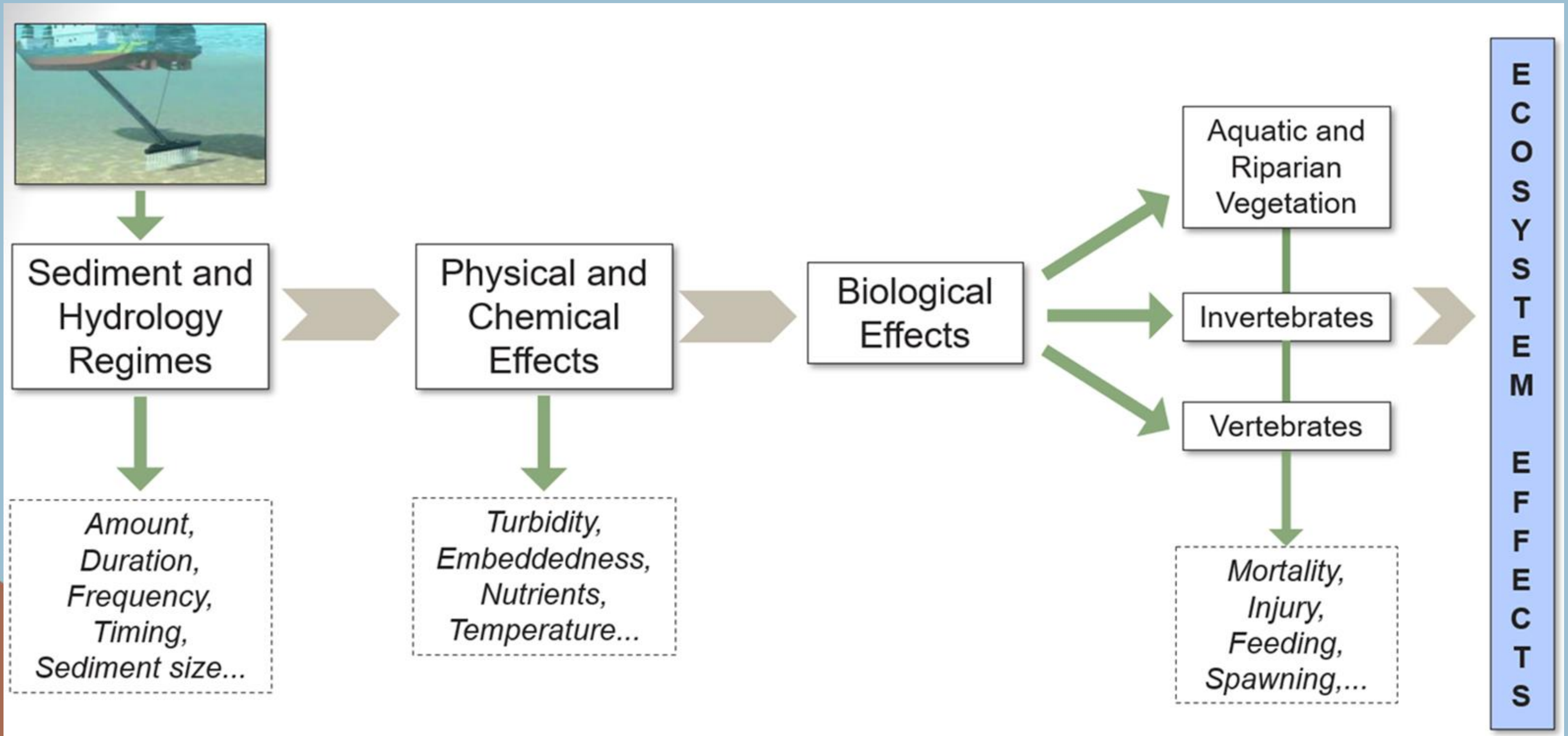


Wohl et al. (2015

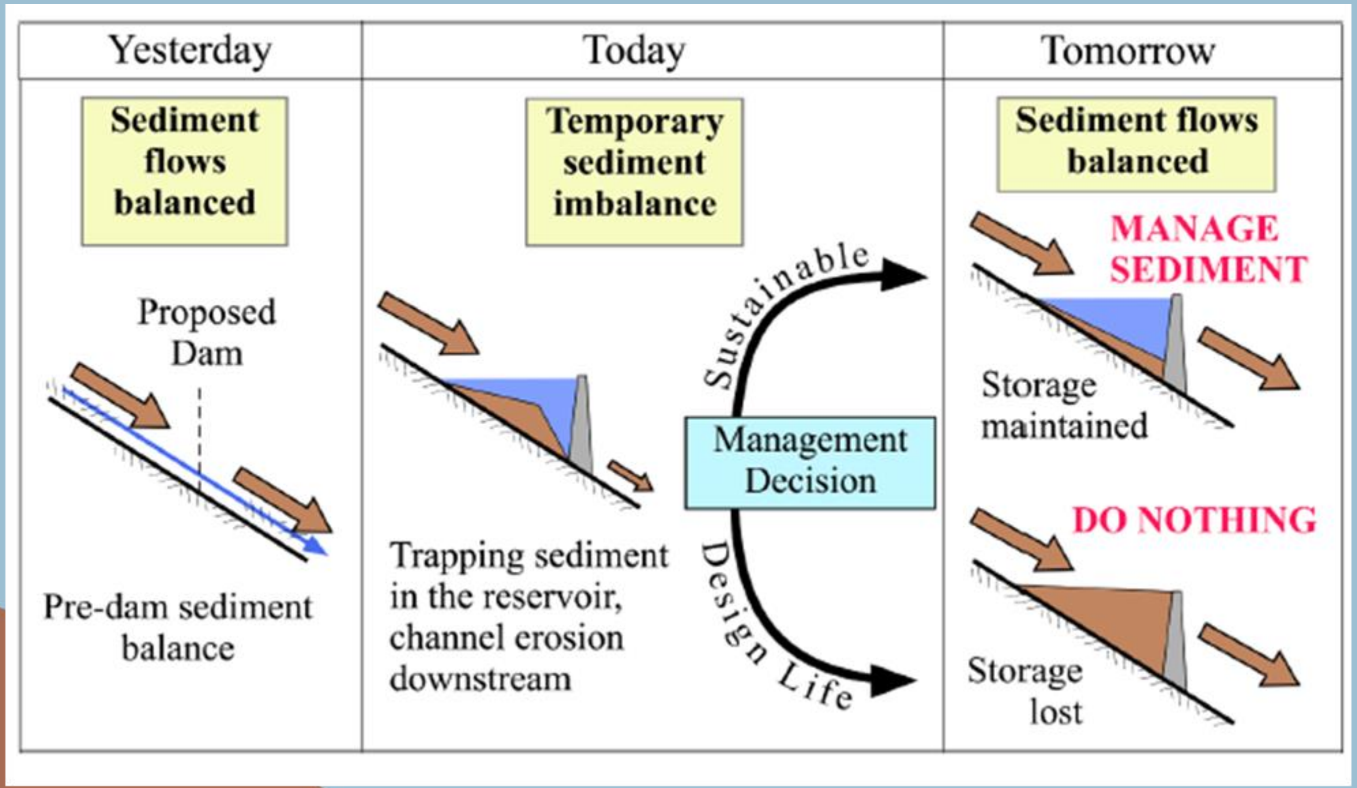


Poff et al. (1997)

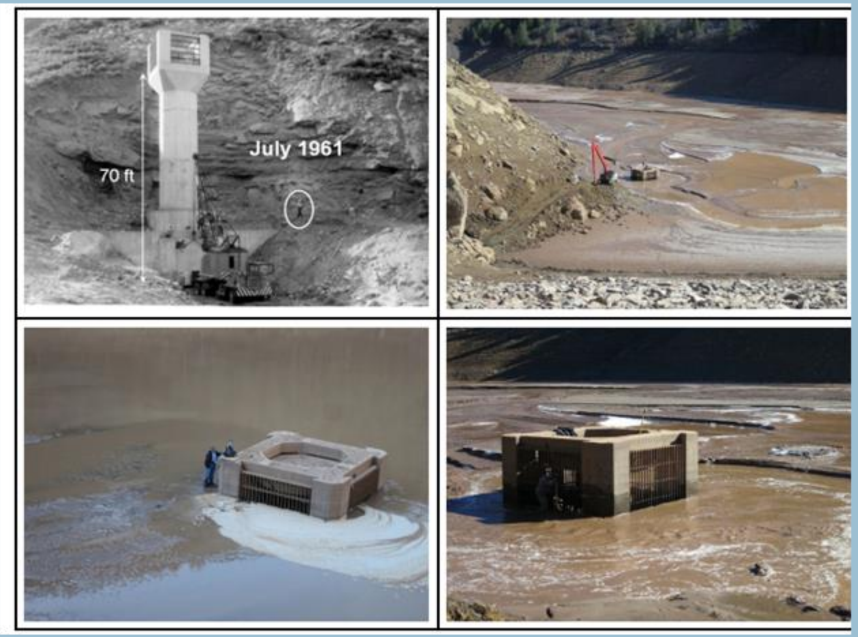
Introduction: Impoundment effects



Introduction: Need for sustainable practices



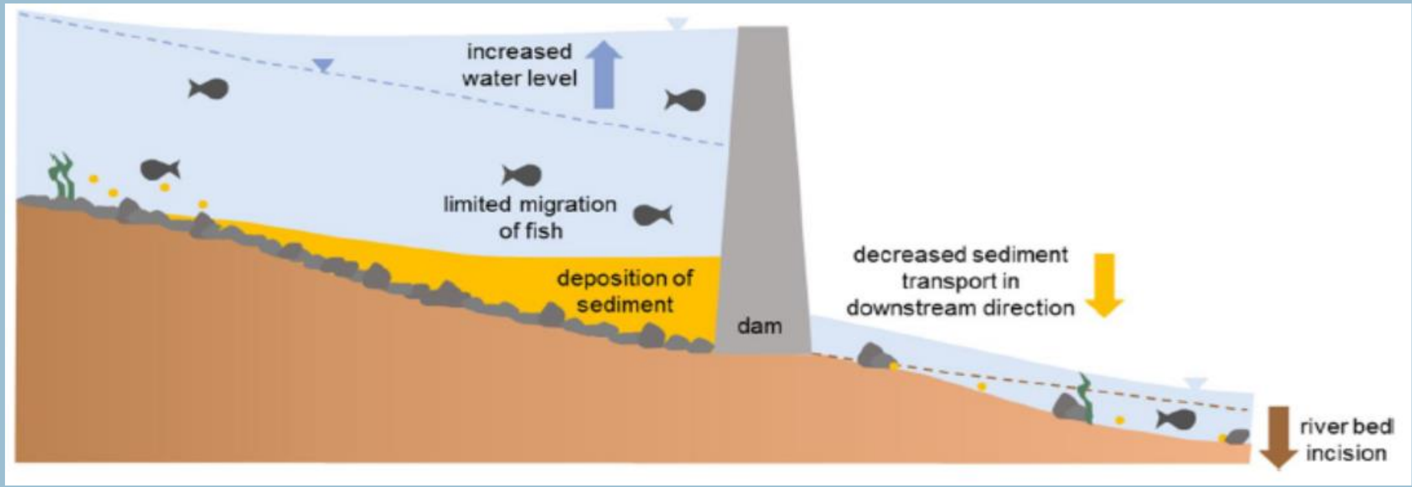
Morris (2020)



Paonia Reservoir, Colorado (Randle et al. 2019)

Geomorphic Effects: CWA Sec 404

- Sect 404 - requires a permit for discharges of dredged or fill material into the waters of the United States, including wetlands
- Regulates activities resulting in sediment altering aquatic ecosystem integrity (e.g., excessive sediment released into water)
- Information needed for least damaging practice alternative analysis, avoidance, minimization, mitigation plan, monitoring, etc.



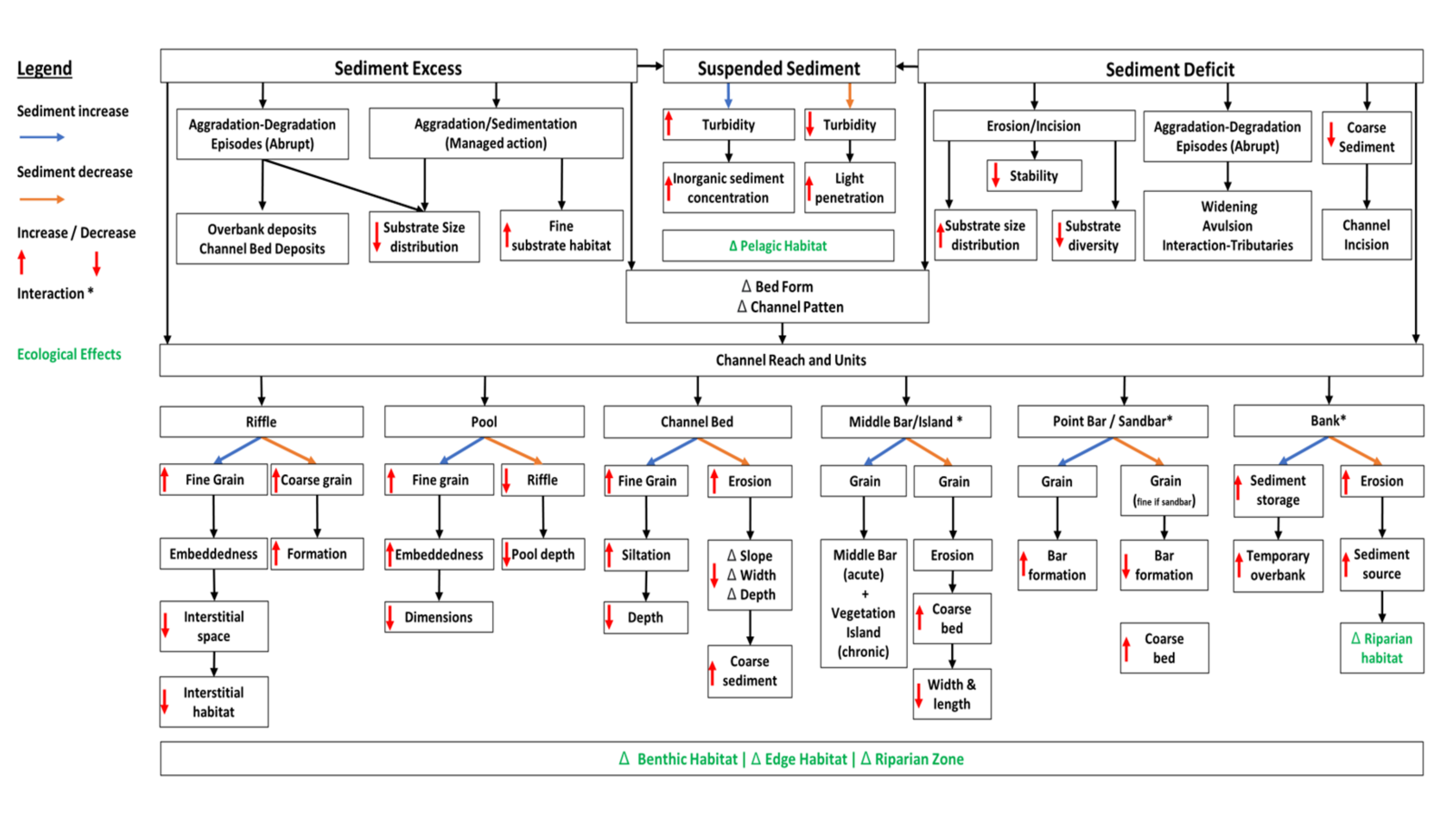
MaaB et al. 2021

Geomorphic Effects: physical

Case (post)	Terrace	Riffle	Pool	Bed	Width	Depth	Grain (D50)	Notes
Q=, L<K	Formation	Erosion	Erosion	D	↓	↑	↑	Clear-water scour; armoring
Q↓, L<K	Formation	Erosion	Eros./Dep.	0/D	↓	±	±	**Parallel ↓**: direction depends on material, bank cohesion/veg., and thresholds
Q↑, L<K	Disintegration	Eros./Dep.	Erosion	D	±	↑	↑	Incision vs widening (bank strength/confinement)
Q=, L>K	Erosion	Deposition	Deposition	A	↑	↓	↓	Aggradation; braiding risk
Q↓, L>K	Formation	Deposition	Deposition	A	±	↓	↓	Aggradation; width conditional (cohesive banks → narrowing; weak banks → widening)
Q=, L=K	0	0	0	0	0	0	0	Equilibrium
Q↓, L=K	0	Erosion	Deposition	0	↓	↓	↓	Deposition in low-velocity zones (pools)
Q↑, L=K	Disintegration	Deposition	Erosion	0	↑	↑	↑	Higher energy; instability ↑
Q↑, L>K	Disintegration	Deposition	Eros./Dep.	A	↑	±	±	Unstable; fines → shoaling, coarse pulses → deep scour; braiding risk

Legend: A = aggradation, **D** = degradation, **0** = little/no net change; **↑/↓** = increase/decrease; **±** = conditional/uncertain. Table modified from Brandt (2000) and Bledsoe et al. (2008)

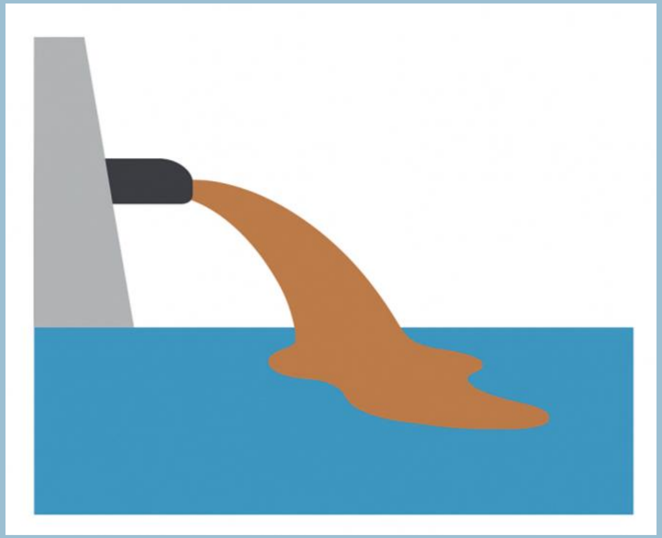
Geomorphic Effects: habitat



Water Quality Effects: CWA Sec 401

•Pollutant discharge permits into navigable waters to ensure sediment discharge meets local water quality requirements.

•Certification includes monitoring, limits, and other conditions to ensure compliance with the CWA and local laws.



Water Quality Effects: physical

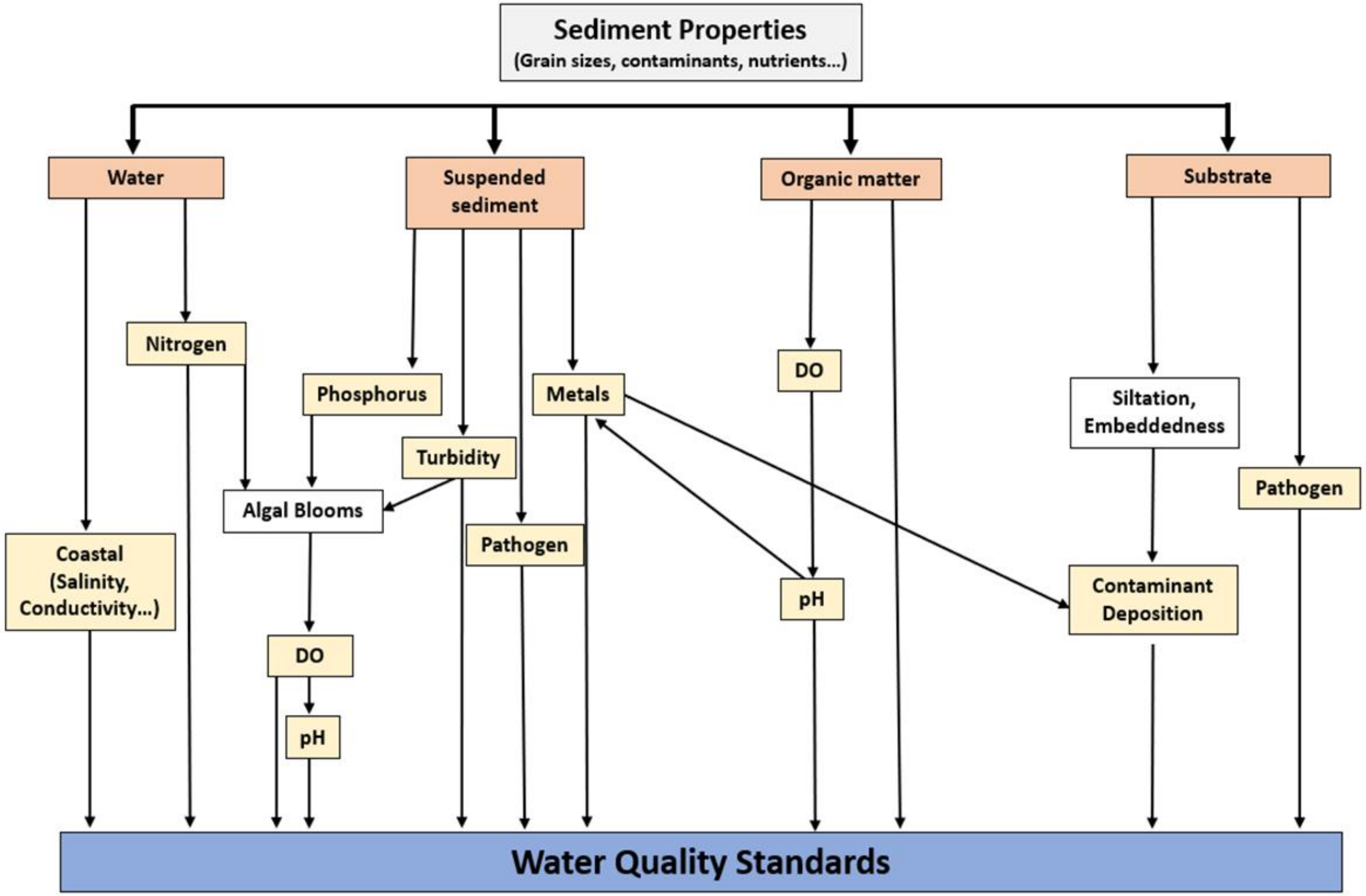
Legend:
- Sediment Characteristics
- Water Quality Component
- Water Quality Monitoring

Table. Example General Surface Water Quality criteria; Classification EPA: FW2;NJ.

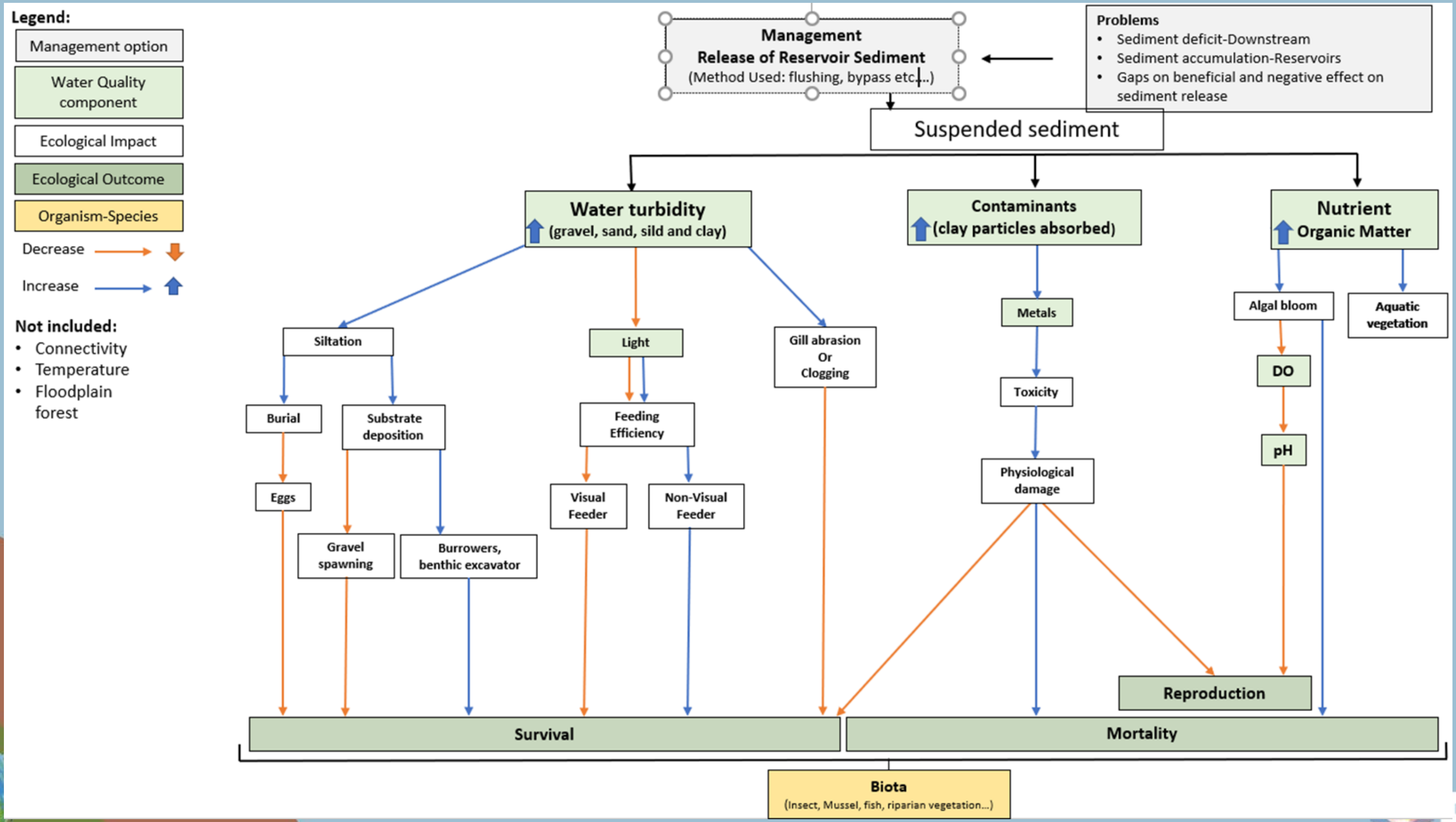
Constituent	Concentration (mg/l)
Dissolved Oxygen (DO)	7.0 – FW2-TP
Phosphorus (P)	Non tidal stream-0.1 Lake-0.05
pH	6.5 – 8.5
Sulfate	250
Copper	0.908
Nickel	0.846
Zinc	0.950
Nitrato (N)	2 – FW1
Pathogen (*E. coli*)	single sample maximum of 235/100 ml

FW2-Fresh Water classification with man-made water discharge

Ref. Ref. (Effective July 29, 2020) Surface water classifications, designated uses, quality criteria and policies and procedures for the waters of the State of New Jersey



Water Quality Effects: habitat



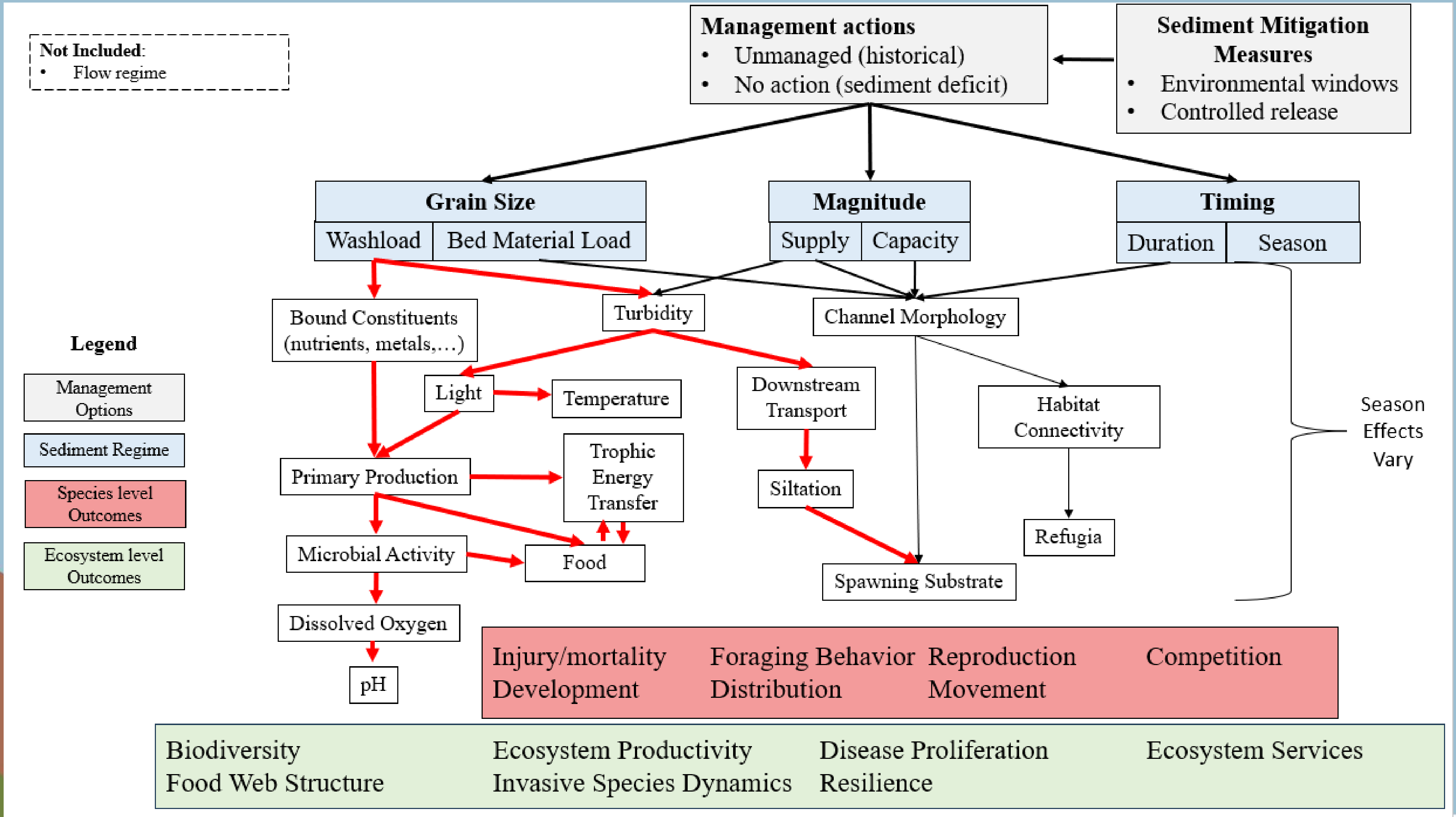
Aquatic Organism Effects: ESA Sec 7 & Sec 10

- Protects endangered species and their habitats

- **ESA Section 7** mandates that federal agencies ensure their actions do not jeopardize endangered species or habitats
  - Requires a multi-step consultation process with USFWS and NMFS, potentially including a Biological Assessment and formal consultation

- **ESA Section 10** governs non-federal activities that may affect endangered species
  - Requires an Incidental Take Permit and a Habitat Conservation Plan to minimize impacts on species and habitats

Aquatic Organism Effects



Gaps and Recs: Workshop Findings

- **Conduct baseline surveys** (sediment, bathymetry, ecological benchmarks) for reservoirs slated for management.
- **Design and pilot standardized release-specific monitoring protocols** (BACI + event triggers) at 3–5 representative sites.
- **Develop a coupled, regionally parameterized modeling suite** (sediment → water quality → habitat → taxa) with uncertainty quantification.
- **Operational clarity and management objectives.** Participants noted that uncertain or shifting management goals undermine good monitoring and create conflicting expectations about acceptable impacts.
- **Run targeted field experiments** to derive taxa- and life-stage thresholds for turbidity, burial, dissolved metals, and hypoxia.
- **Launch funded pilot release experiments** under adaptive management frameworks, with mandatory data sharing and practitioner training.

Gaps and Recs: Literature Review

- **Case study access:** documented studies from different management alternatives, reservoir design, or geographic variability difficult to find or access

- **Focus on Salmonids and downstream effects**: Most research centers on salmonids, with limited studies on other endangered aquatic species or other aquatic organisms. Upstream and in-reservoir effects rarely published.

- **Lack of Species-Specific Data**: Few studies address sediment effects on species adapted to low-visual or sediment-rich environments.

- **Unclear Sediment Release Thresholds**: The optimal sediment release volumes that balance ecological benefits and species safety are not well defined.

- **Long-Term Impact Gaps**: Insufficient data on long-term effects and species recovery after sediment disturbances.

- **Compound Effects:** Insufficient information on compound effects (e.g., extreme weather events, reservoirs in series).

Hydraulic Modeling of Environmental Effects of Sediment Release TR

- Co-authors: Logan Rowley, Sam Wiest, Keith Gido
- Collaborators:
  - CENWK, particularly J. Shelley, M. Boyer, K. Bingham and M. Mansfield in technical expertise regarding sediment release and study design; J. Albrecht, D. Wansing, in data collection and monitoring; and L. Totten for WID project management.
- (Editing, soon to be published)

Scope of Analysis: Scenarios

- Confluence of Big Blue River and Kansas River.
- Comparison of current or "existing" conditions relative to sediment release.
- Designed to inform management decisions based on environmental context.

Streamflow (4)
- Backwater effects
- Mesohabitat

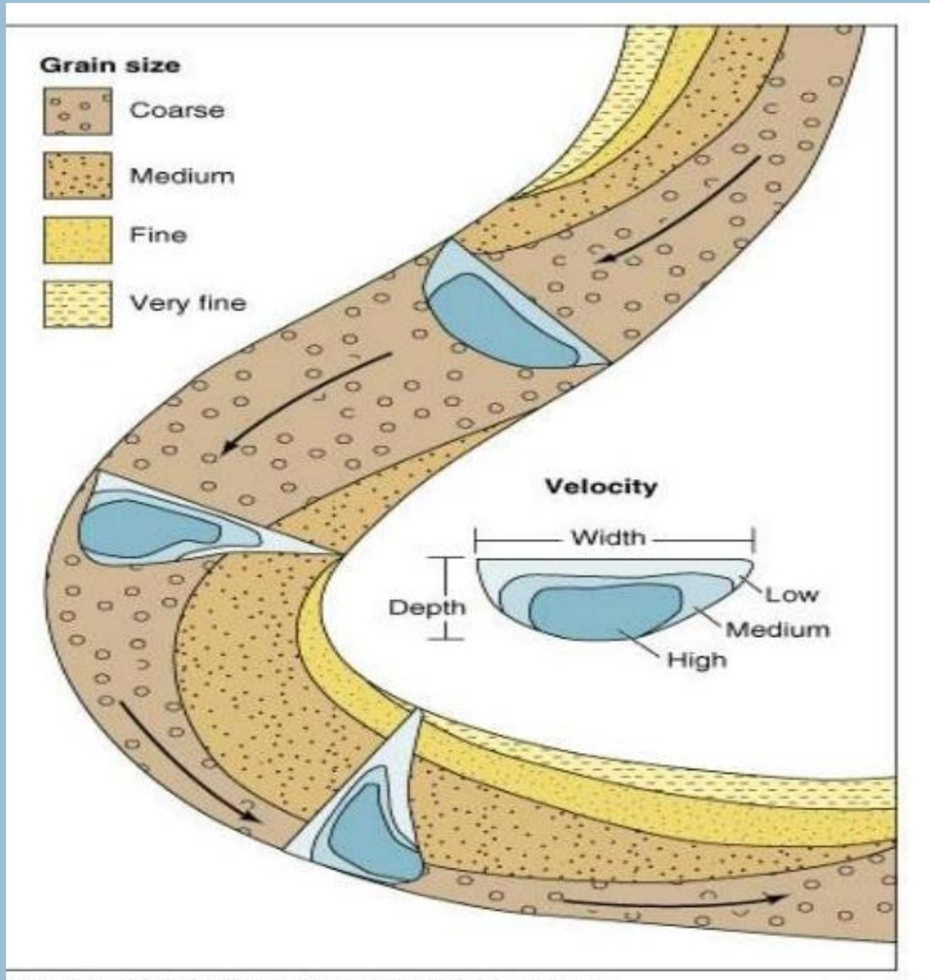
Sediment Gradation (3)
- Concentration
- Deposition

Drawdown (2)
- Concentration after flushing

Literature Review : Geomorphic Outcomes

Focused on "Fine Sediment Release" on Geomorphology and Ecology:

- Every river has its own responses: Balance of sediment-transport-limit and flux.
- Deposition in slow-moving areas: filling of pools, channel edges.
- Deposition of fine sediment may support vegetation recruitment.
- Coarser materials are more slowly flushed and contribute to more significant geomorphic change.



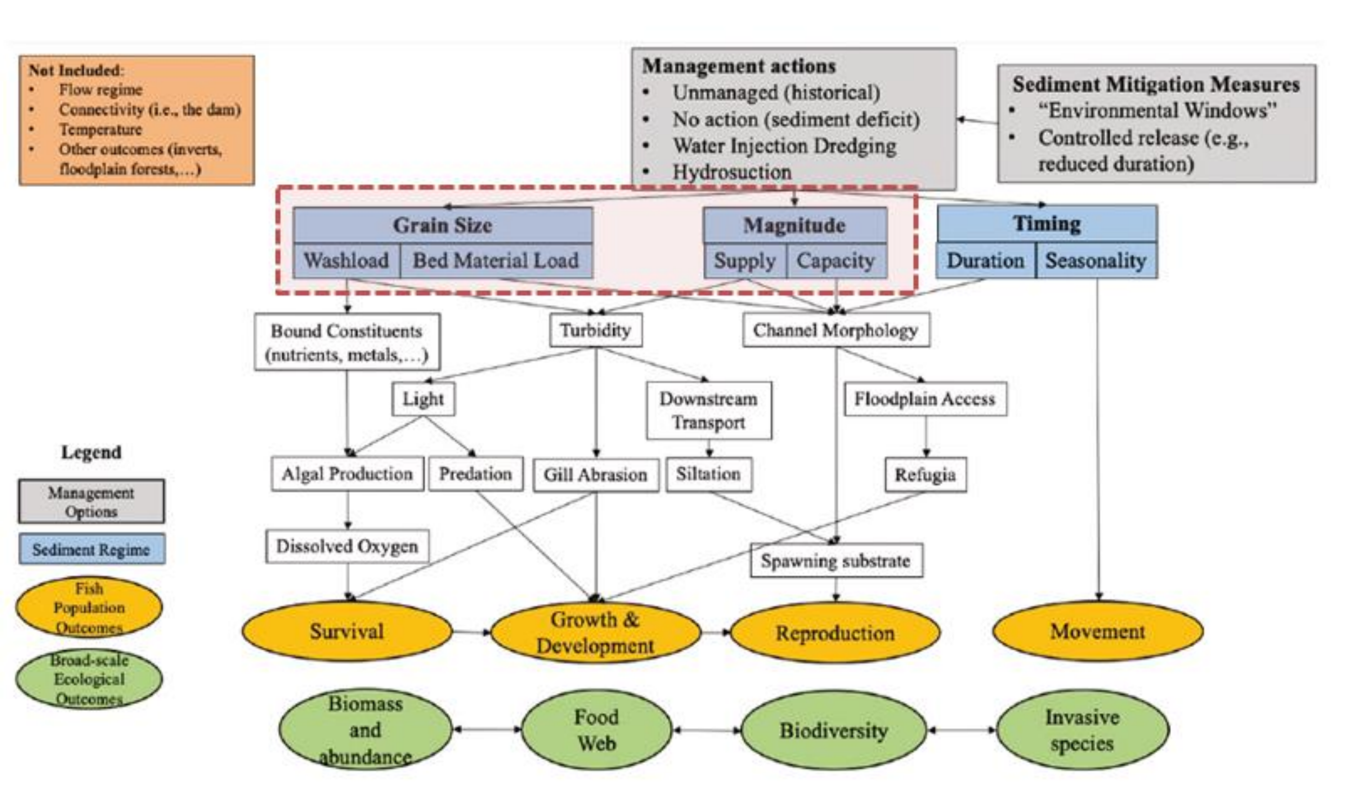
www.usd.edu/esci/figures/158401.JPG

Literature Review: Managing for Ecology

- Negative effects of flushing may be short-lived; depends on life history of affected species.
- Duration and frequency of flushing strongly affects ecological outcomes.
- Flushing during high flows will emulate historic event conditions.
- Clearwater flushing after release is recommended.

Conceptual Model

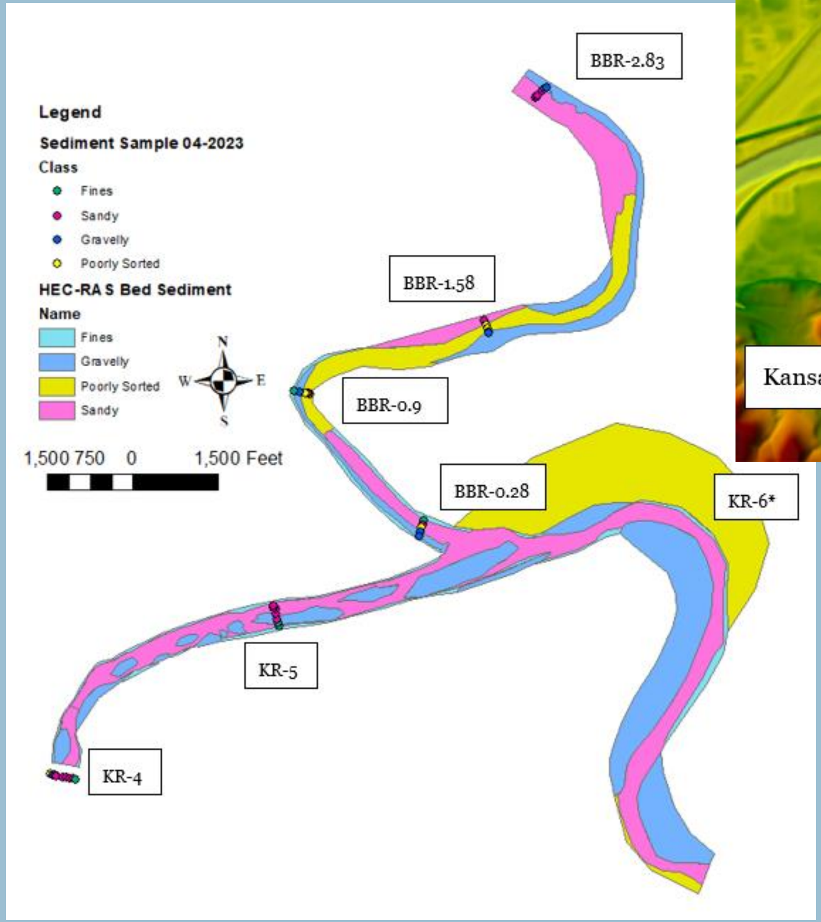
- Link physical habitat change, magnitude of disturbance, with potential changes in fish populations.
- (ERDC-TN EMRRP-EI-6)

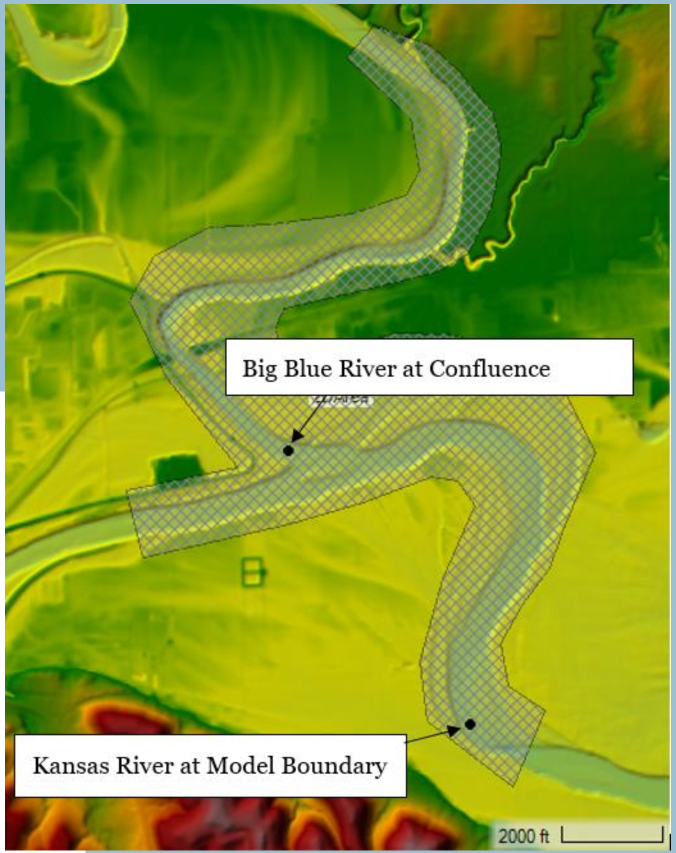


Hernandez-Abrams, D. D., Bailey, S. E., & McKay, S. K. (2022). *Environmental Effects of Sediment Release from Dams : Conceptual Model and Literature Review for the Kansas River Basin* (Report). Engineer Research and Development Center (U.S.). Retrieved from https://erdc-library.erdc.dren.mil/jspui/handle/11681/44880

Sediment Transport Model: Geometry

- Bathymetric cross-sections from April 2023; included sediment samples.
- 1D Cross-sections converted to a 2D terrain; published as a clear-water HEC-RAS model in Wiest et al., 2024.

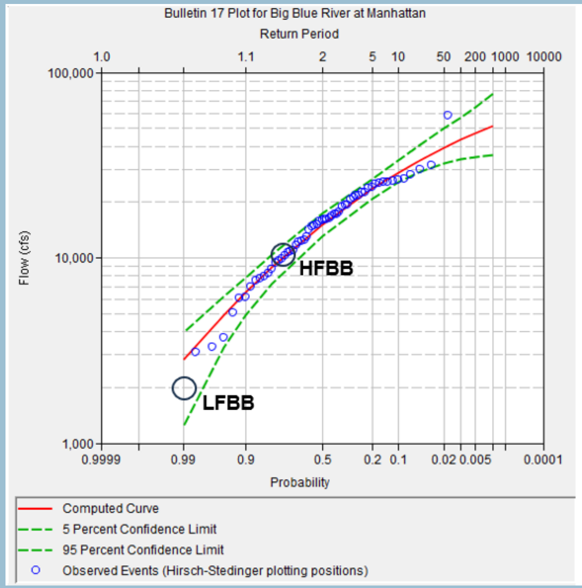


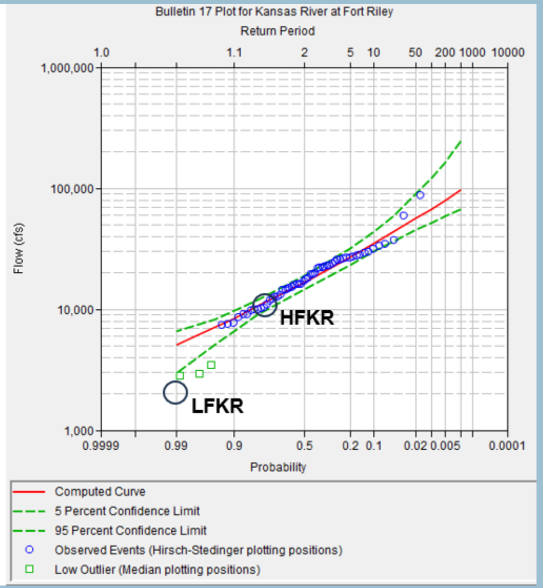


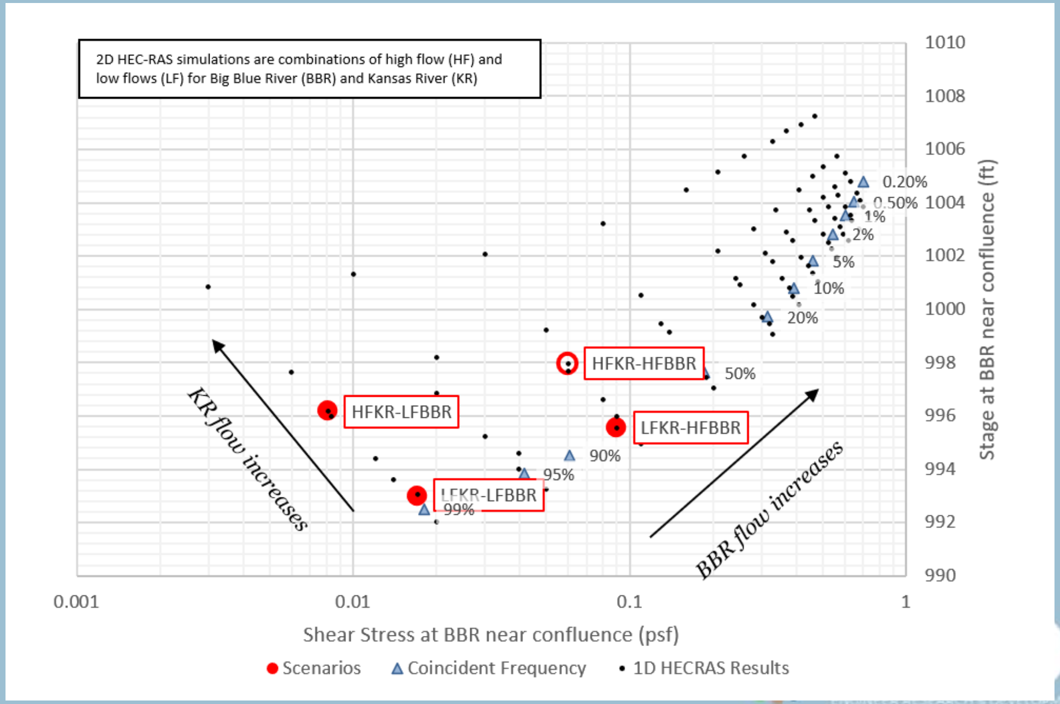
https://doi.org/10.5061/dryad.k3j9kd5gr

Modeling Hydrologic Scenarios

- "Low Flow" (2000 cfs) and "High Flow" (10k cfs) for both KR and BBR.
- Provides a possible "operating window" of effects.

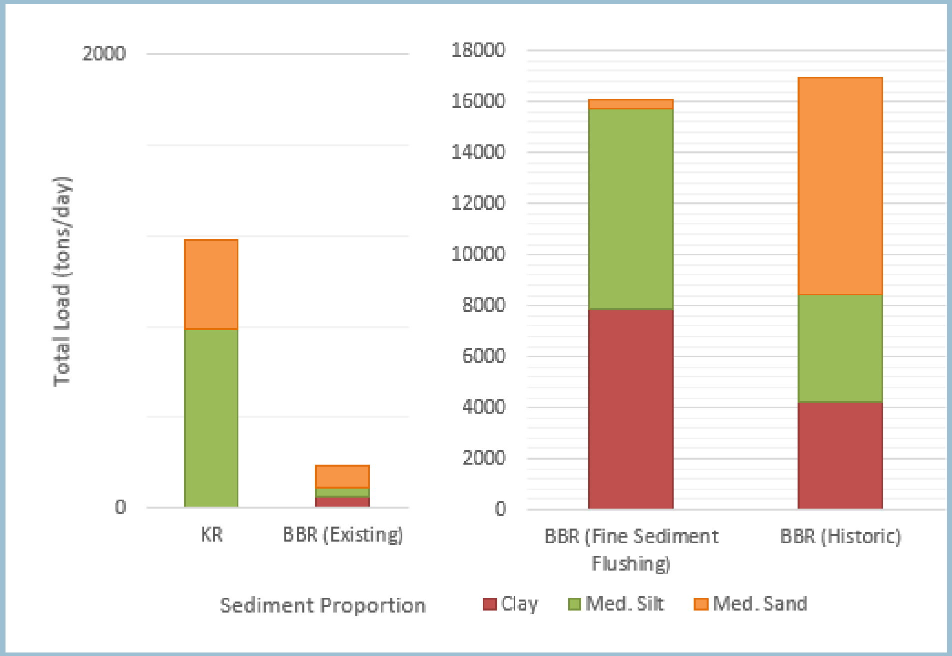






Sediment and Drawdown Scenarios

- Sediment volumes and Gradation:
  - Existing Condition
  - Fine Sediment Flushing
  - Historic
- Drawdown: Clearwater simulation following sediment release
  - Continuous flow volume
  - Reduction of flow



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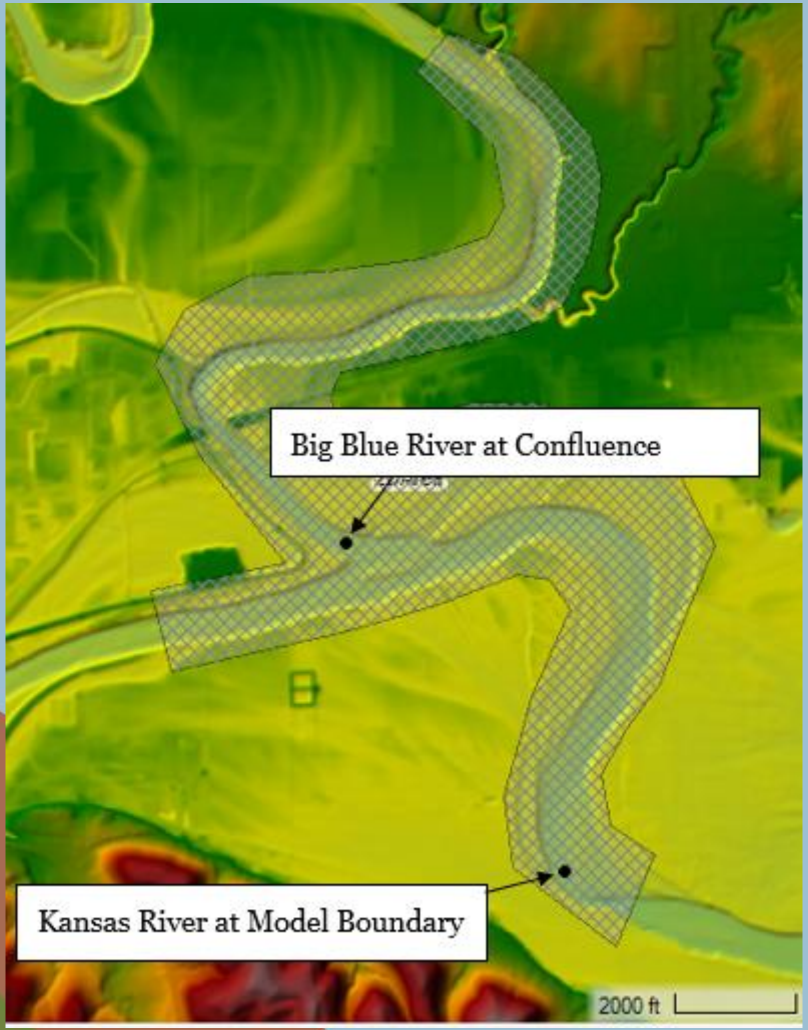
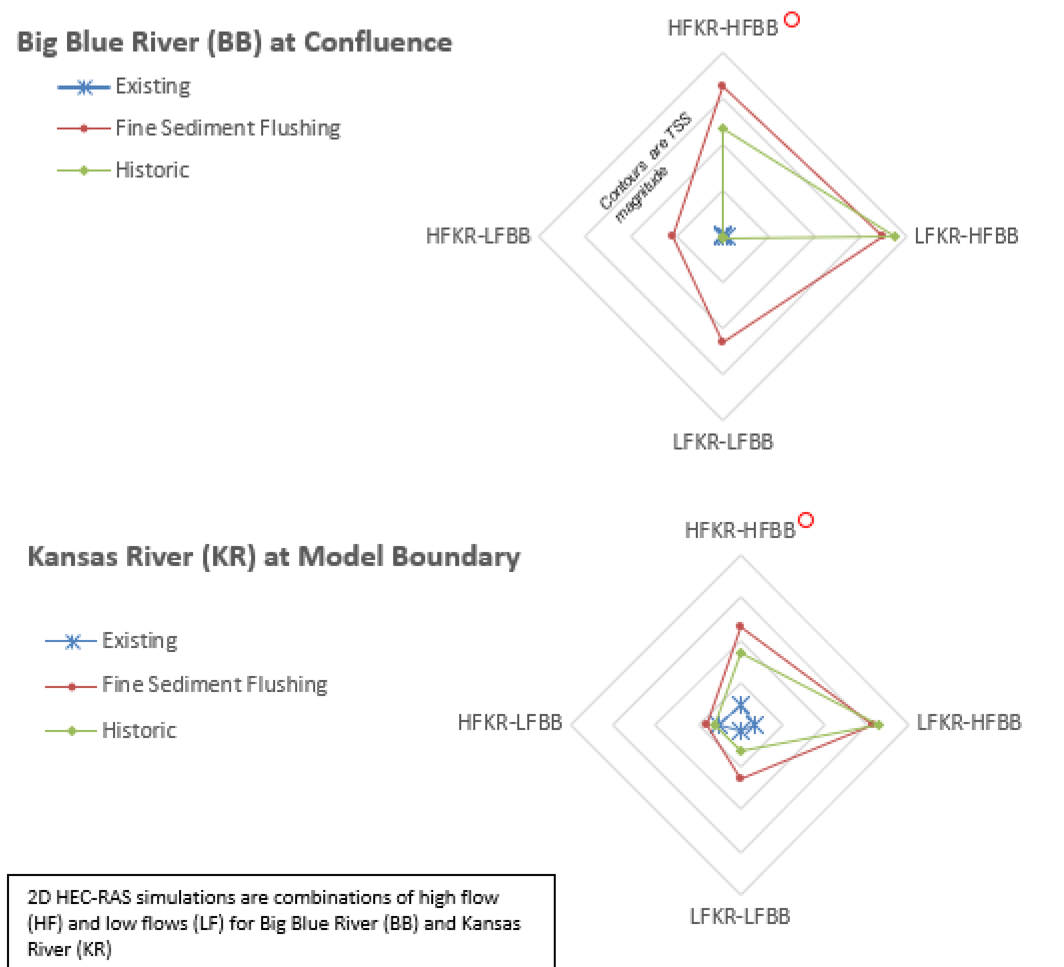
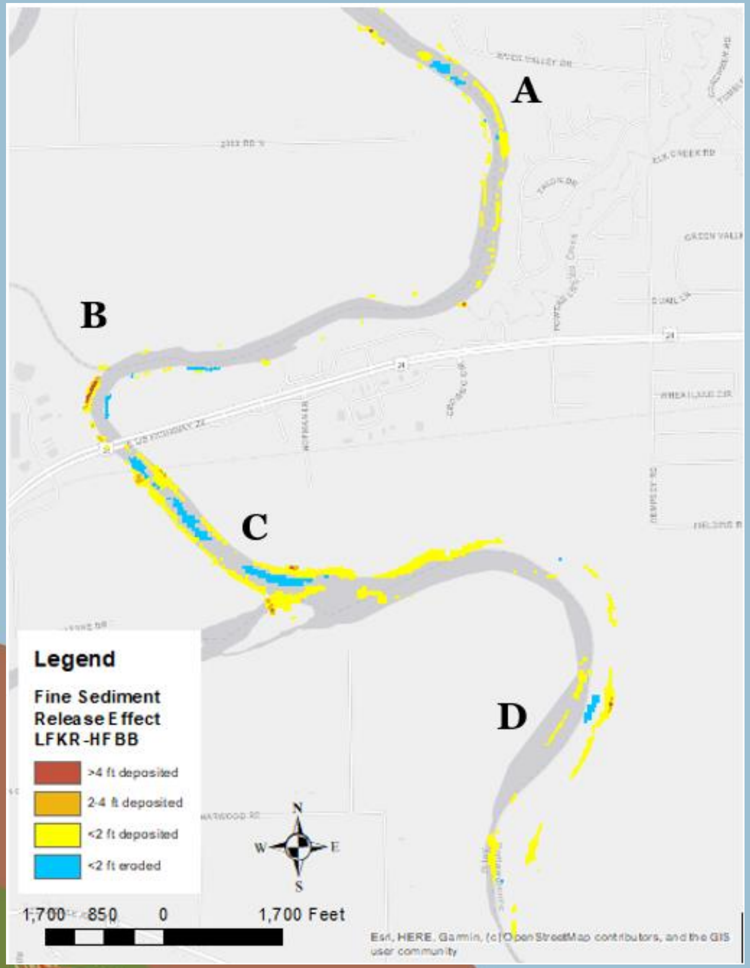
Results: Suspended Sediment Concentration

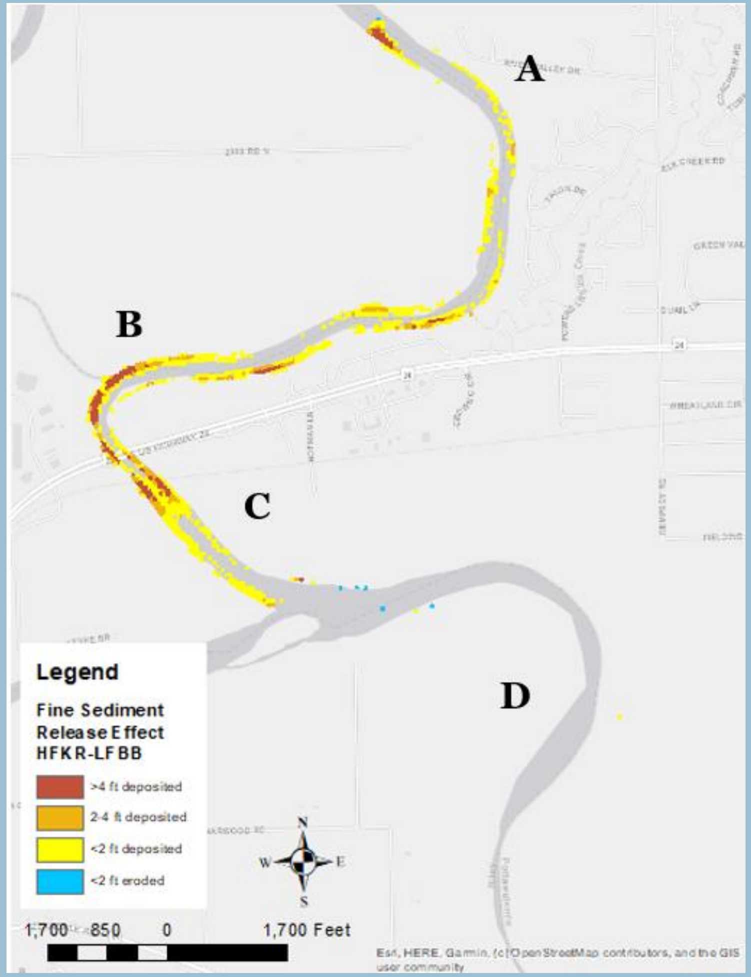




2D HEC-RAS simulations are combinations of high flow (HF) and low flows (LF) for Big Blue River (BB) and Kansas River (KR)

Results: Sediment Deposition/Erosion





- Erosion and deposition depends on backwater effects.
- Deposition occurs at channel edges in Big Blue River
- Erosion occurs near confluence at high Big Blue River flows, in response to slope adjustment.

Results: Drawdown

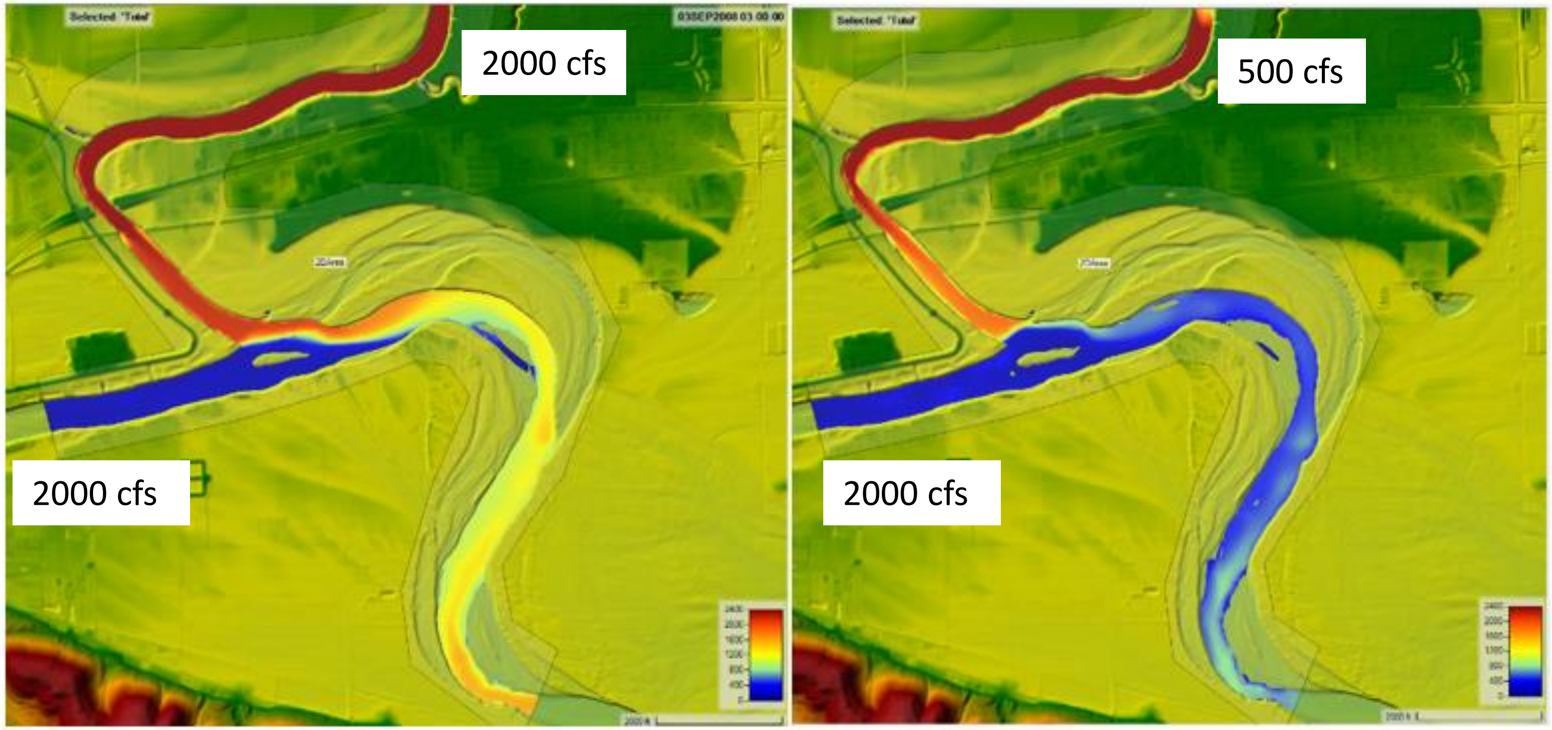
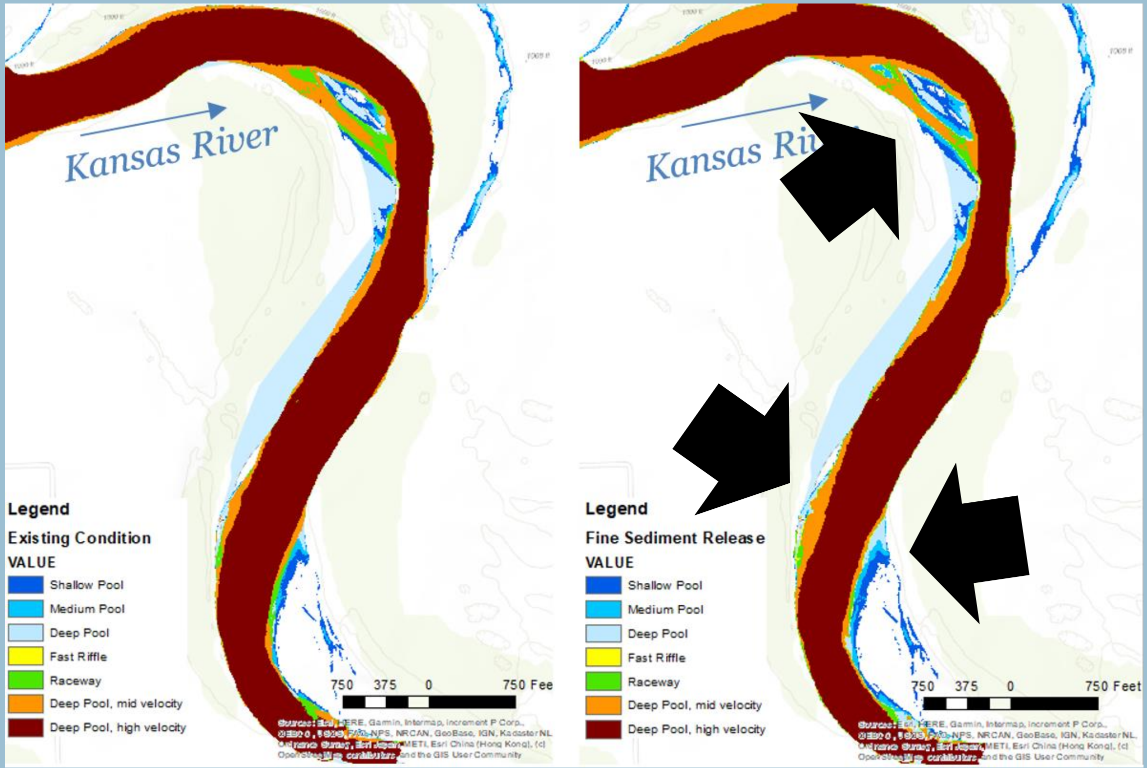


Figure 14. The “Continuous” (left) and “Drawdown” (right) drawdown scenarios for Low-Flow-Kansas River/Low-Flow-Big Blue River at 3 hours following sediment release.

- Backwater effects when Kansas River flow >> Big Blue River, then sediment becomes stored in Big Blue River.

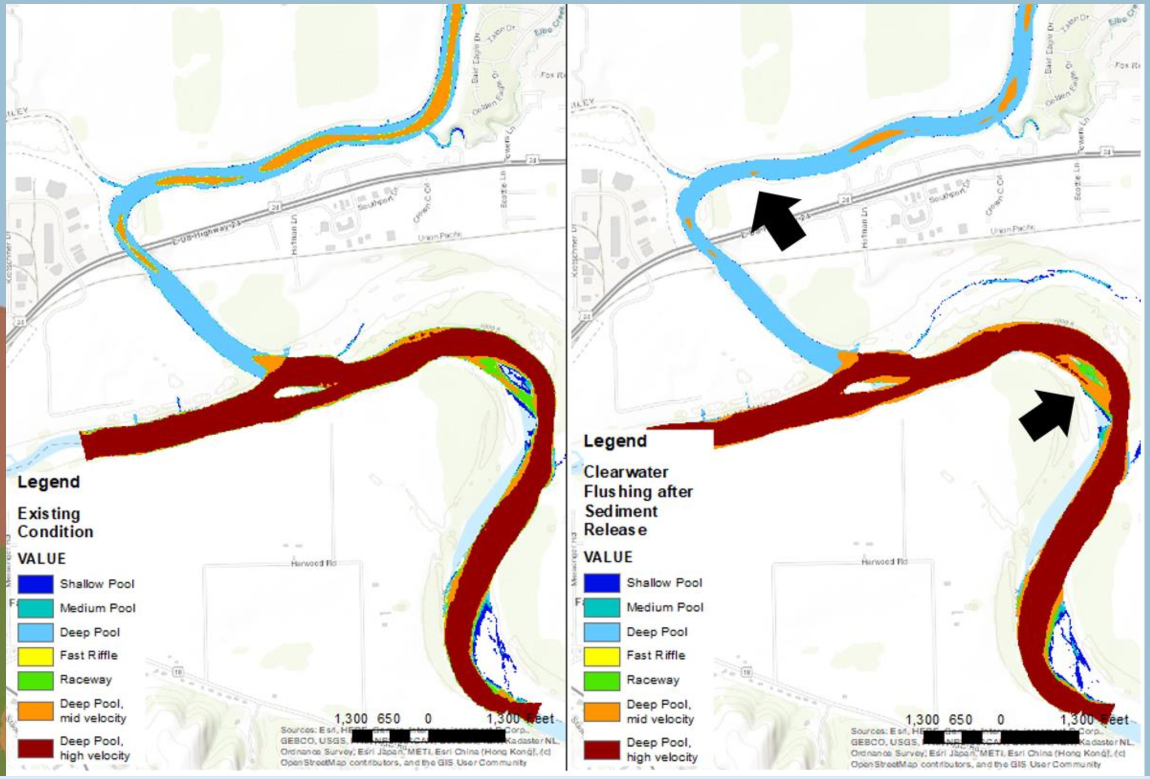
Mesohabitat Change

Fine Sediment Flushing Relative to Existing Sediment Regime	LFKR-LFBB	HFKR-LFBB	HFKR-LFBB & Clearwater Flushing	LFKR-HFBB	LFKR-HFBB & Clearwater Flushing
Shallow Pool	0	0	↑	↑	↑
Medium Pool	↑	0	↑	↑	↑
Deep Pool	0	↓	↑	↑	↑
Raceway	↓	0	↓	↓	↓
Deep Pool, too fast	↓	↑	↓	0	↓



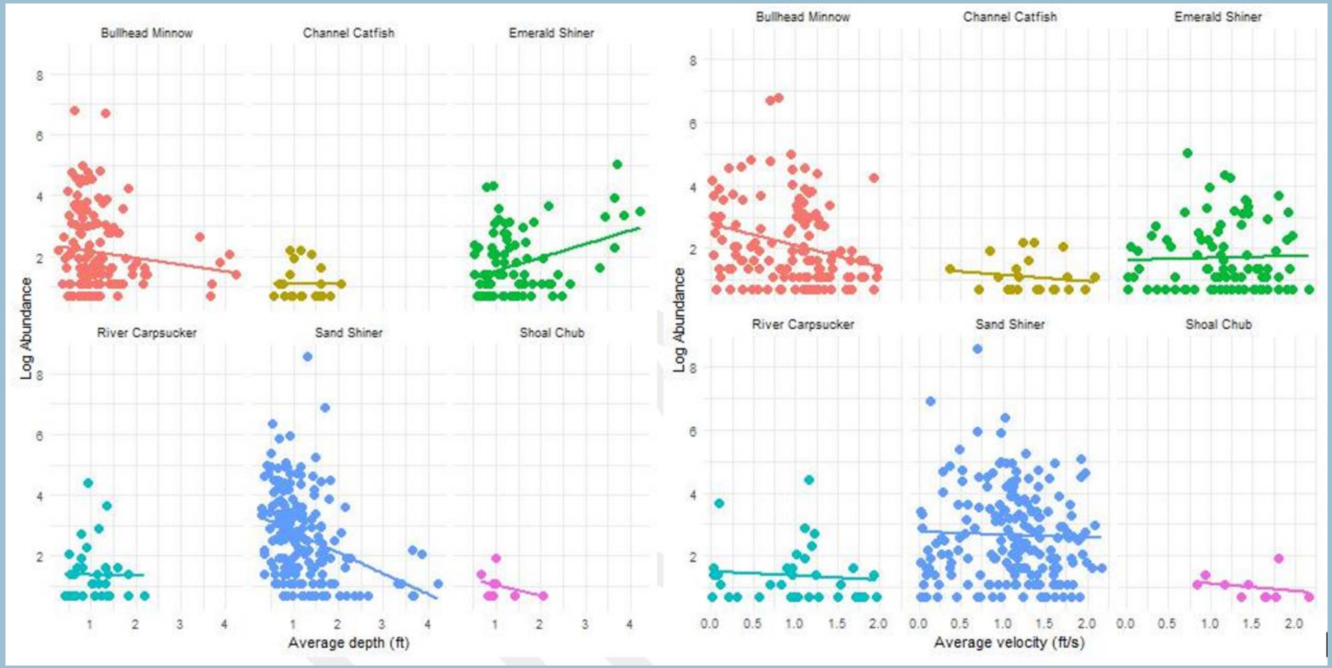
LFKR-LFBB existing (left) versus fine sediment (right)

- Existing planform has depths too great and velocities too great to be considered habitat according to Aadland 1993.
- Changes occurred in channel edges.
- Clearwater flushing increased pool habitats and reduced fast moving areas.

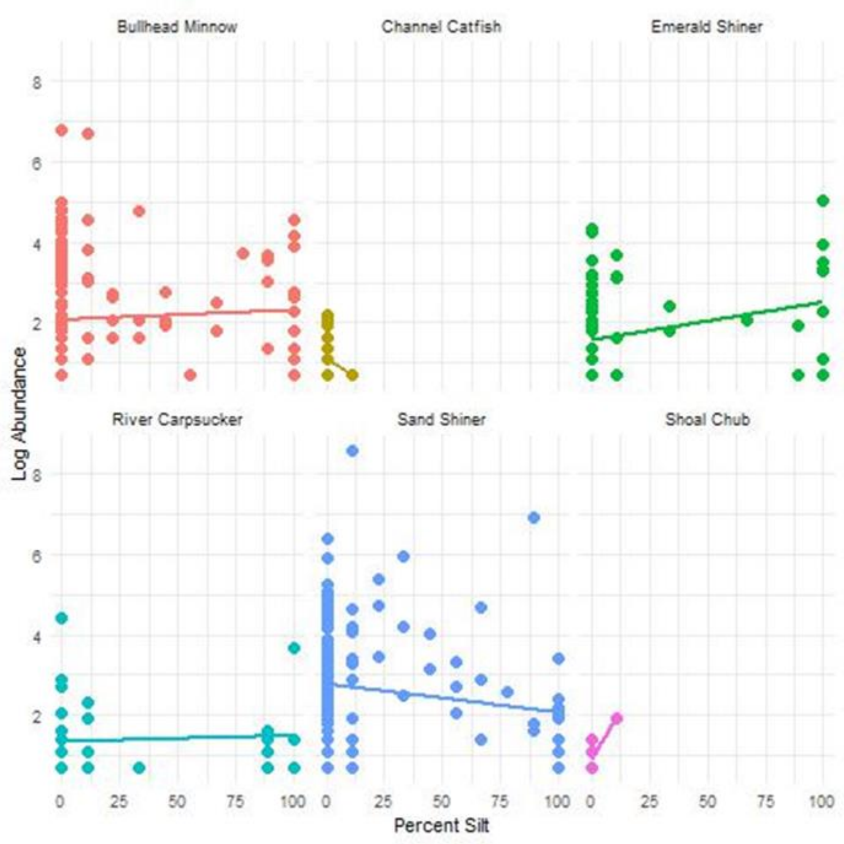


LFKR-HFBB existing (left) versus fine sediment (right) after continuous clearwater flushing.

Results: links to fish ecology



Abundance vs depth



Abundance vs % silt

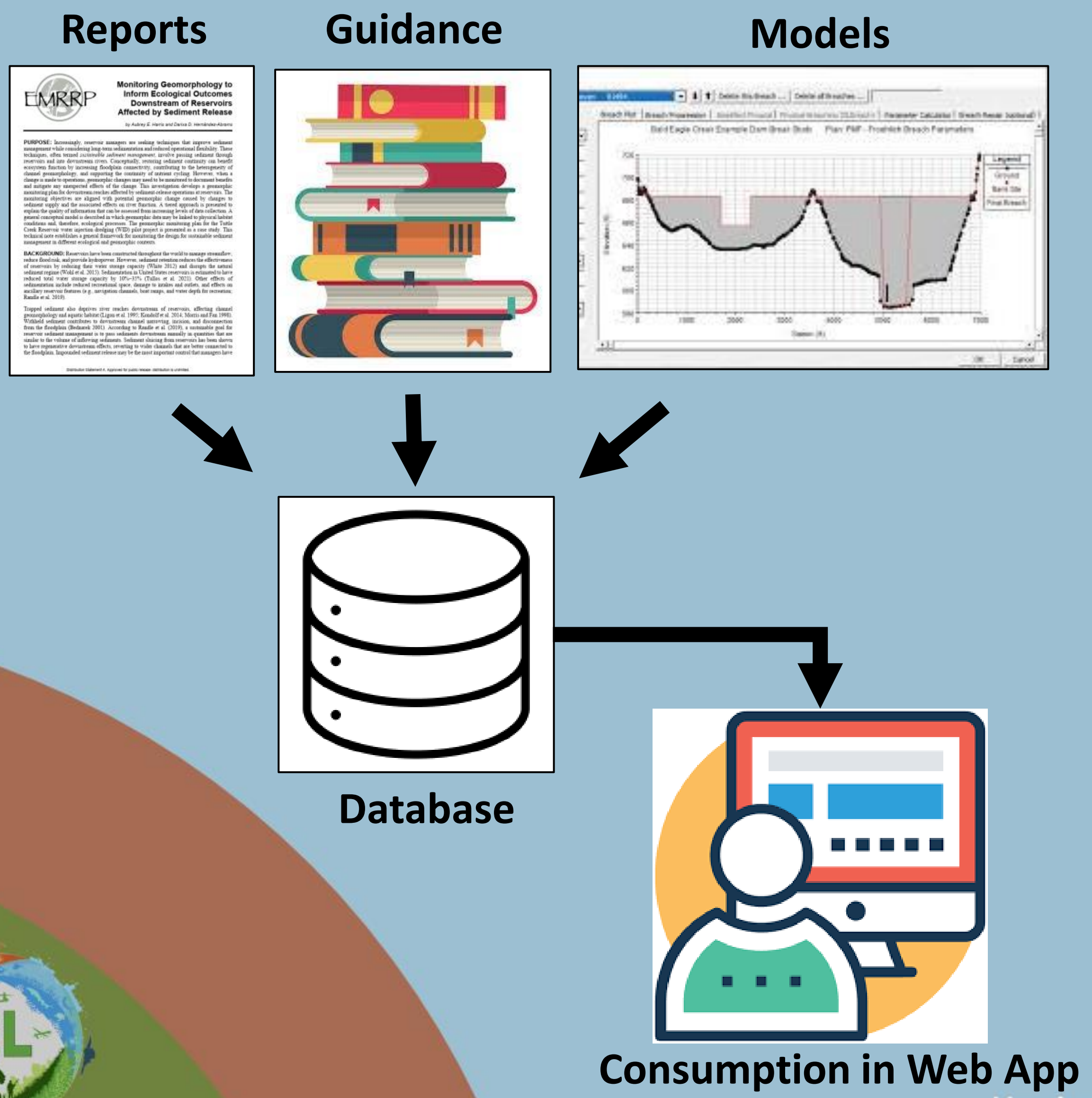
- Abundance generally ↓ **with velocity** and ↓ **with % silt**; depth effects are mixed.
- **Emerald shiner** shows ↑ **with depth**.
- **Shoal chub** only where **velocity > ~0.75 ft/s**; **channel catfish** and **shoal chub** absent when **silt > ~12%**.
- Site-to-site variability is high; **limited sampling** constrains inference strength.

Sediment Release Web Application Tool (Alpha)

Contributors: CESPA (Chris McGibbon, Micael Albonico); CENWP (Trey Crouch, Betsy Summers); EL (Susan Bailey, Phil Gidley); USBR (Jen Bountry, Melissa Foster)

- Collates case studies of sediment release, sediment analysis, and ecological/sediment studies in the US.
- Meant to bring literature and case studies at the finger tips for District and other practitioners about evaluating sediment release.

Why a Web App?



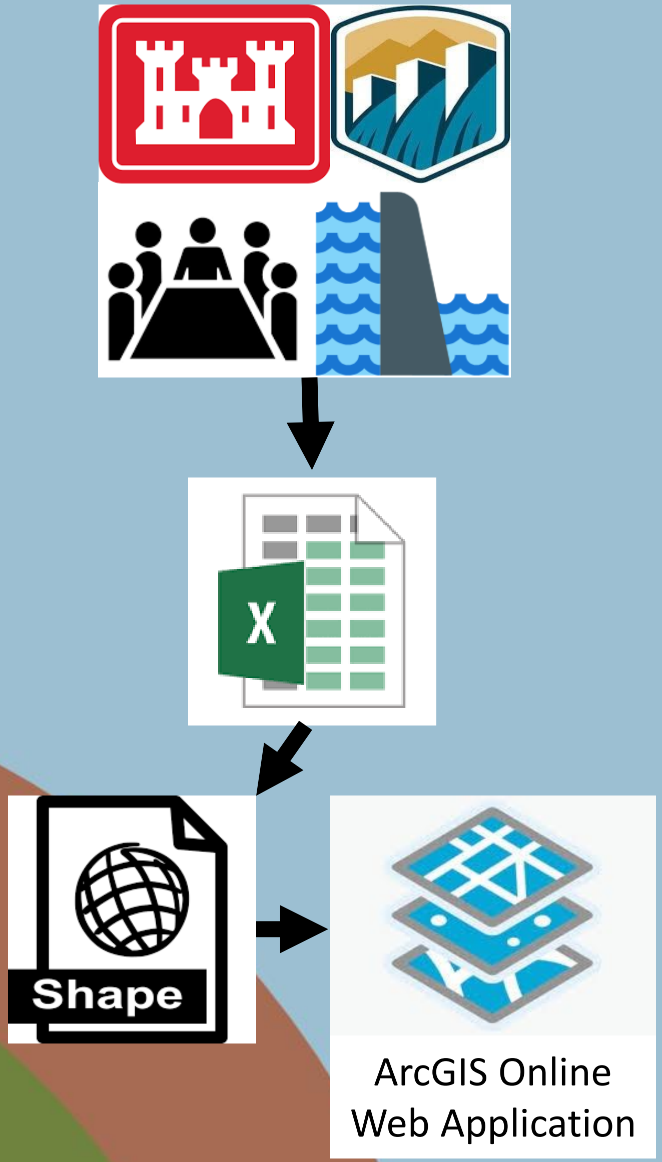
- Hub to share resources and data: Full breadth of available resources
- Browser-based; no installs
- Rapid updates keep pace with evolving science & policy
- Reduces time spent collecting and analyzing resources.
- Exportable data for analysis or comparison across sites or regions

Web App Platform: ArcGIS Experience Builder

ArcGIS Experience Builder

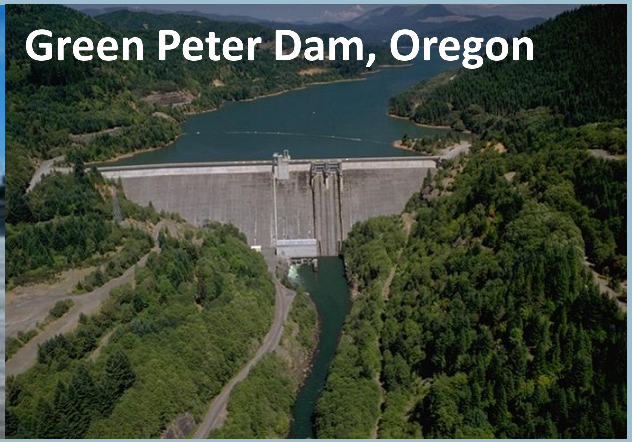
- Cloud-hosted SaaS within ArcGIS Online
- Secure HTTPS URL, no server maintenance
- Widgets for maps, charts, GIS operations, images, surveys
- Built on React/ArcGIS JS API: customizable & responsive

Data Collection and Processing



1. Working with major dam operators including Districts interested in assessing sediment release potential (SPA, NWP) and USBR.
2. Collated case study information from these partners as well as 400+ articles/documents of Sedimentation Investigations in Rivers and Reservoirs
3. Surveys cleaned up and converted from excel workbooks into ArcGIS online hosted feature layers for Web App

Data layer: Sites



- Point Feature Layer
- Point geometry; one row = one monitored reach or reservoir site
- 13 attribute fields describe sediment management activities
- Many fields have predefined choices

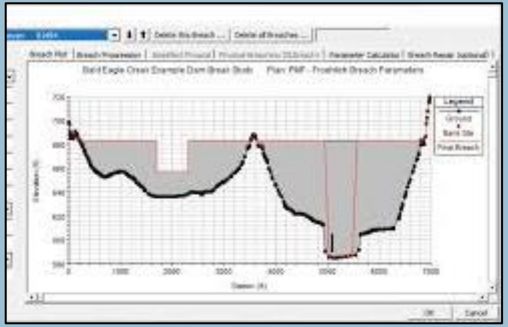
Sites: Example Fields and Predefined Choices			
Site Type	Sediment Release	Ecological Concern	Analysis
Flood Control	Drawdown	Fish Passage	1D Unsteady Sediment
Dry Dam	Water Injection Dredging	Spawning	Field Monitoring
Sediment Control	Dam Removal	Water Quality	2D Sediment
River Training Dike	Diversion	Biological Opinion	Hydraulic
Water supply	Normal Operation	Endangered Species	3D Sediment
Hydropower	Hydraulic Dredging		
Riffle	Dredging		

Data layer: Literature

Reports

Guidance

Models



- Point Feature Layer
- One row = one literature record. Records can be tied to sites
- 17 attribute fields describe sediment management knowledge
- Many fields have predefined choices

Literature: Example Fields and Predefined Choices					
Data Collection	Modeling	Sediment Characteristic	Sediment Source	Sed Management	Special Cases
Bathymetry	Hydraulic Equations	Cohesive	Bank erosion	Sediment release	Debris flow
Water Quality	Hydraulic Modeling	Gravel	Headcut	Dam removal	Wildfire
Sediment	Ecological Modeling	Sand	Reservoir pool	Land management	Landslide
Ecological	Laboratory Analysis	Suspended	Reservoir release	Use dredged materials	Earthquake
Public Involved	Sed Transport Modeling	Rock	Suspended	Flood diversion	Volcanos
Hydraulics	Frequency Analysis	Bedload	Debris	Silt dams	Ice
Bathymetry	Regression	Flocculation	Erosion	Deposition control	

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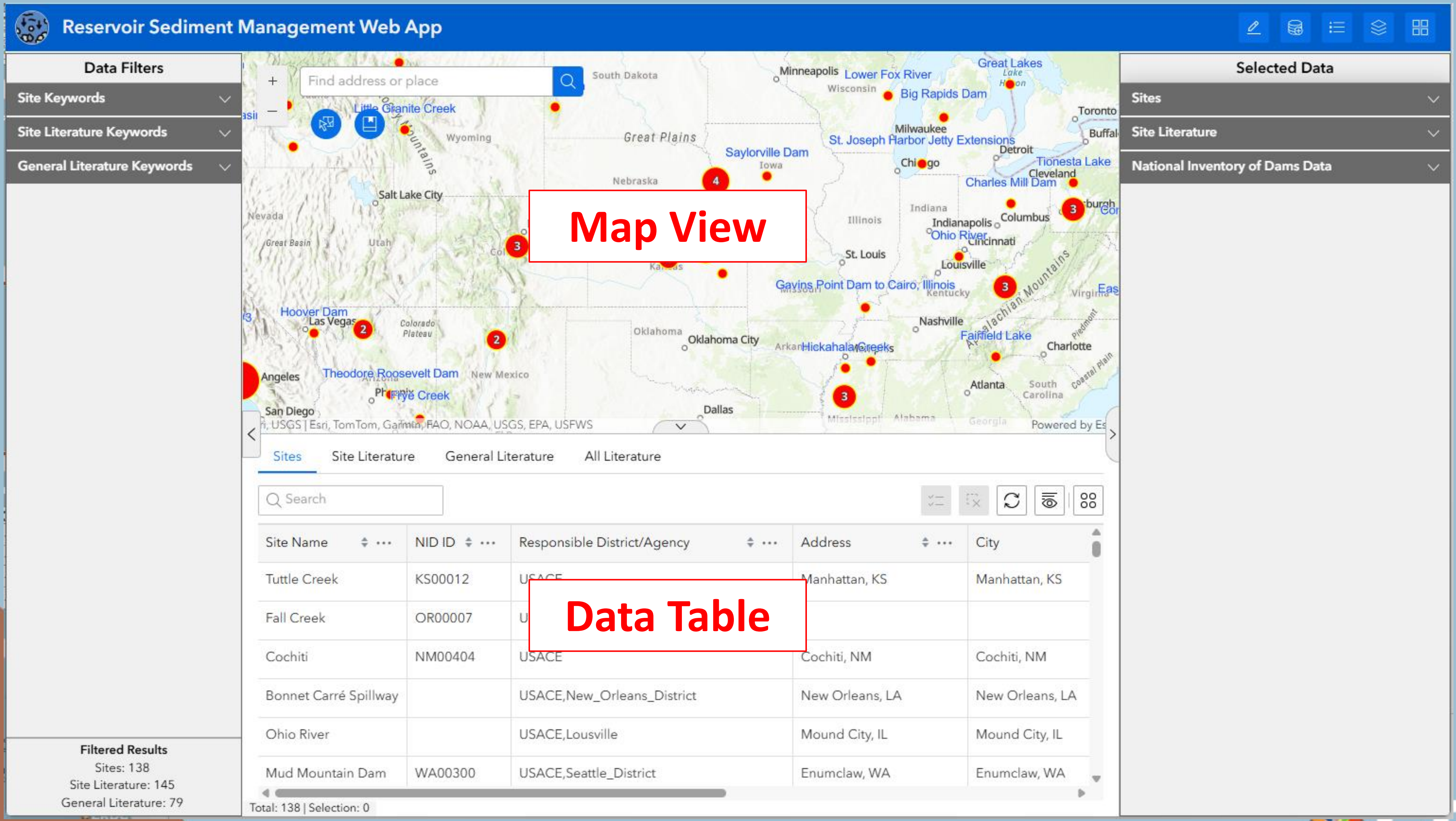
Web App Layout (Alpha)



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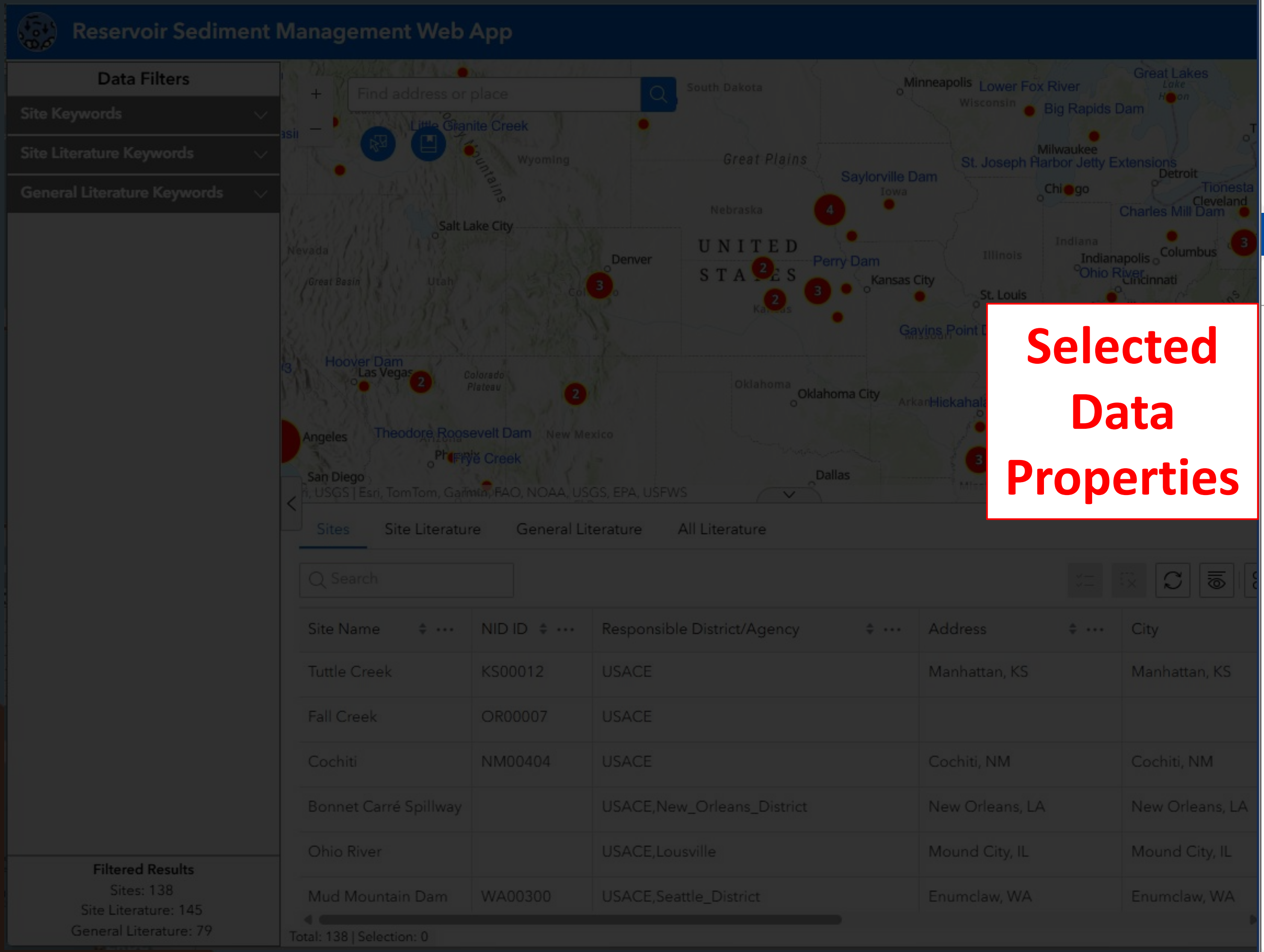

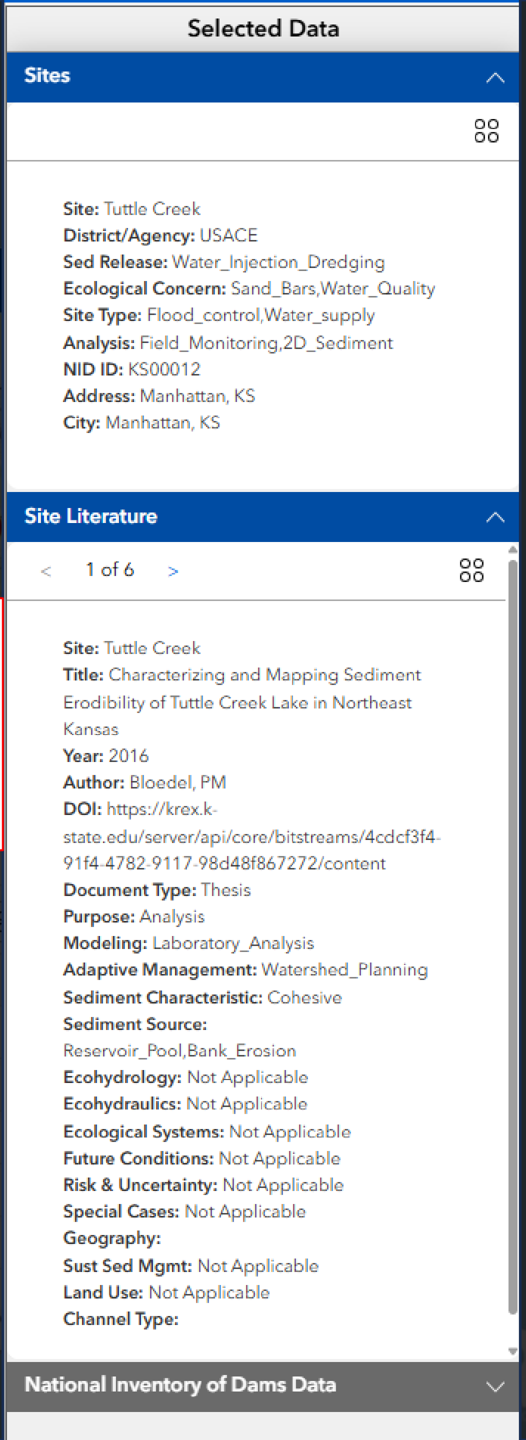

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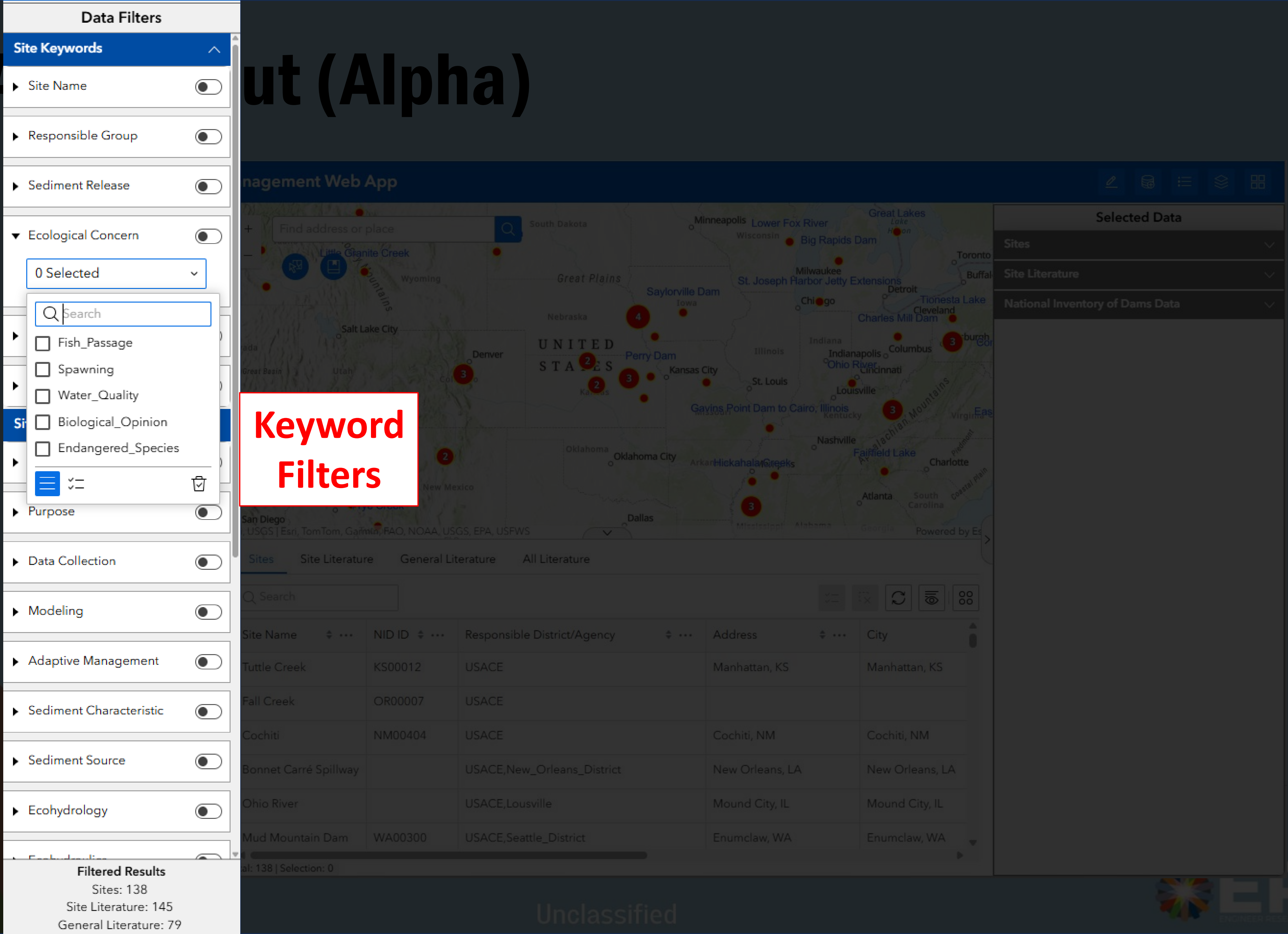
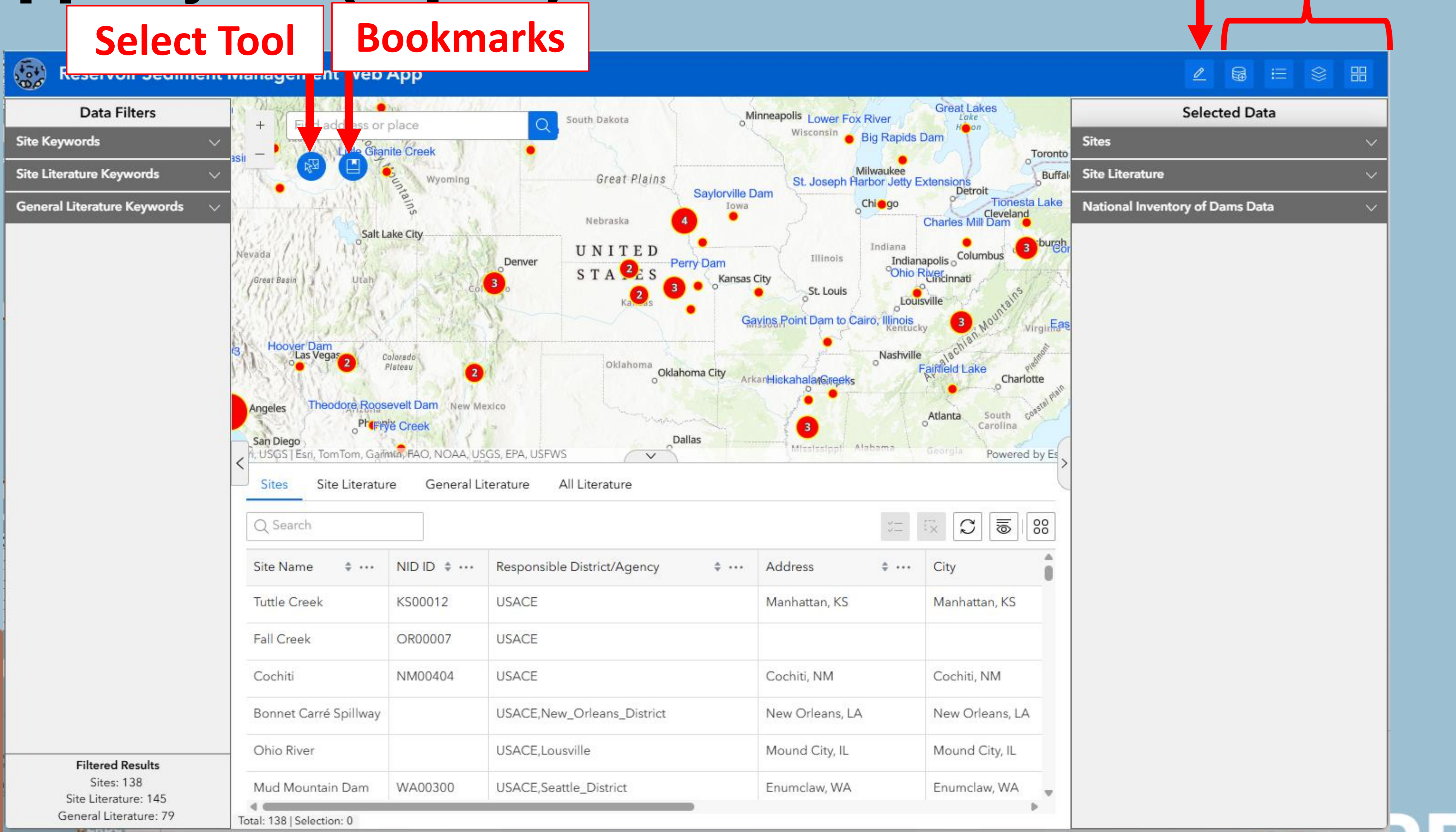


Keyword Filters

Unclassified

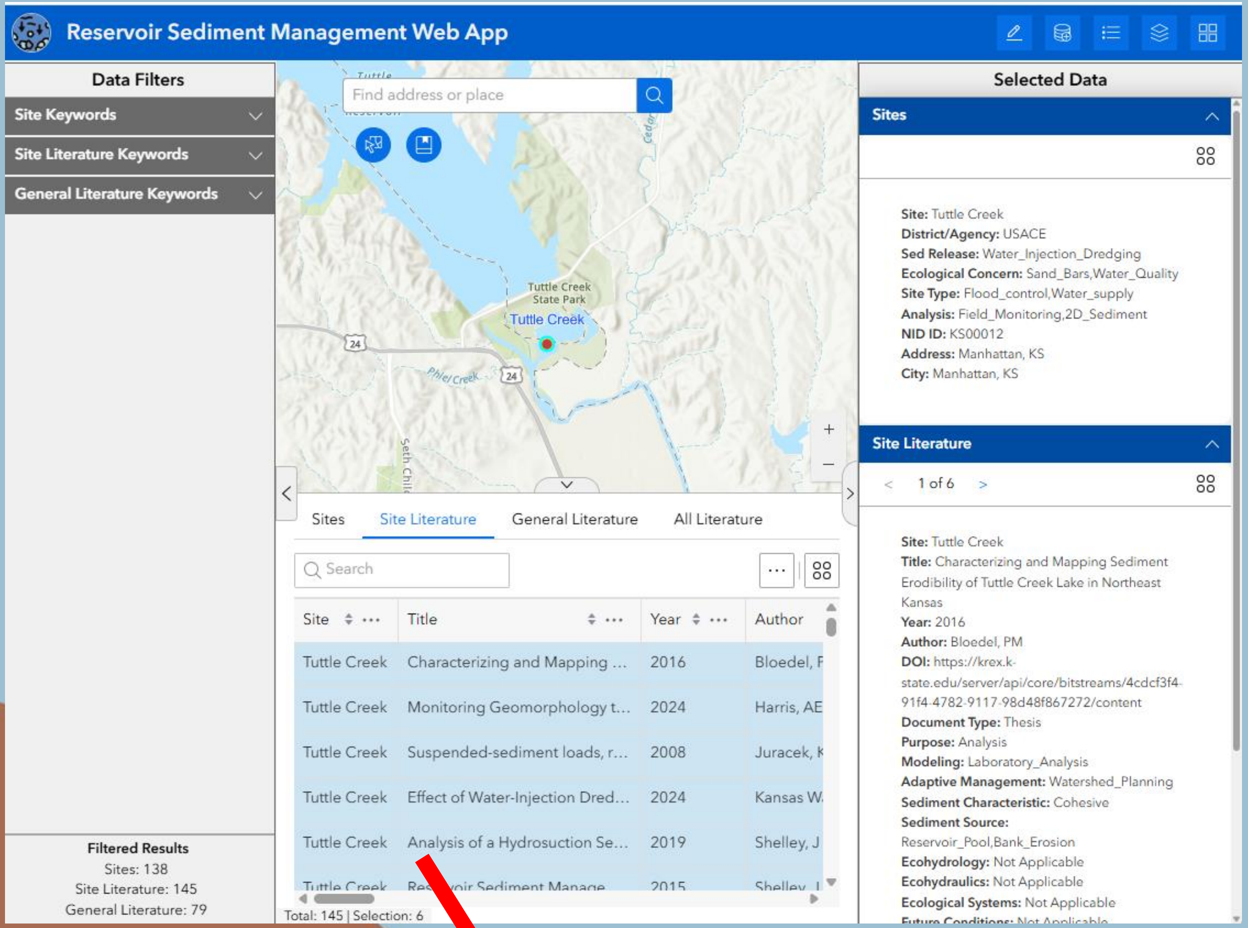
Web App Layout (Alpha)



Example Workflows

#	Starting Point	Web App Actions	Site Data	Site-Specific Literature	General Literature	Ideal for
			Data automatically found by web app			
1	Known site(s)	Search Site → auto-select linked site literature	✓	✓	-	Targeted reservoir analysis
2	Region/HUC	Toggle HUC layer → spatial filter	✓	✓	-	Regional analysis
3	River corridor	Trace river or select by layer → spatial filter	✓	✓	-	Compile longitudinal data
4	Filter Keywords	Use categorical filters or browse data tables	✓	✓	✓	Categorical or thematic review across basins

Workflow Example: Tuttle Creek Dam

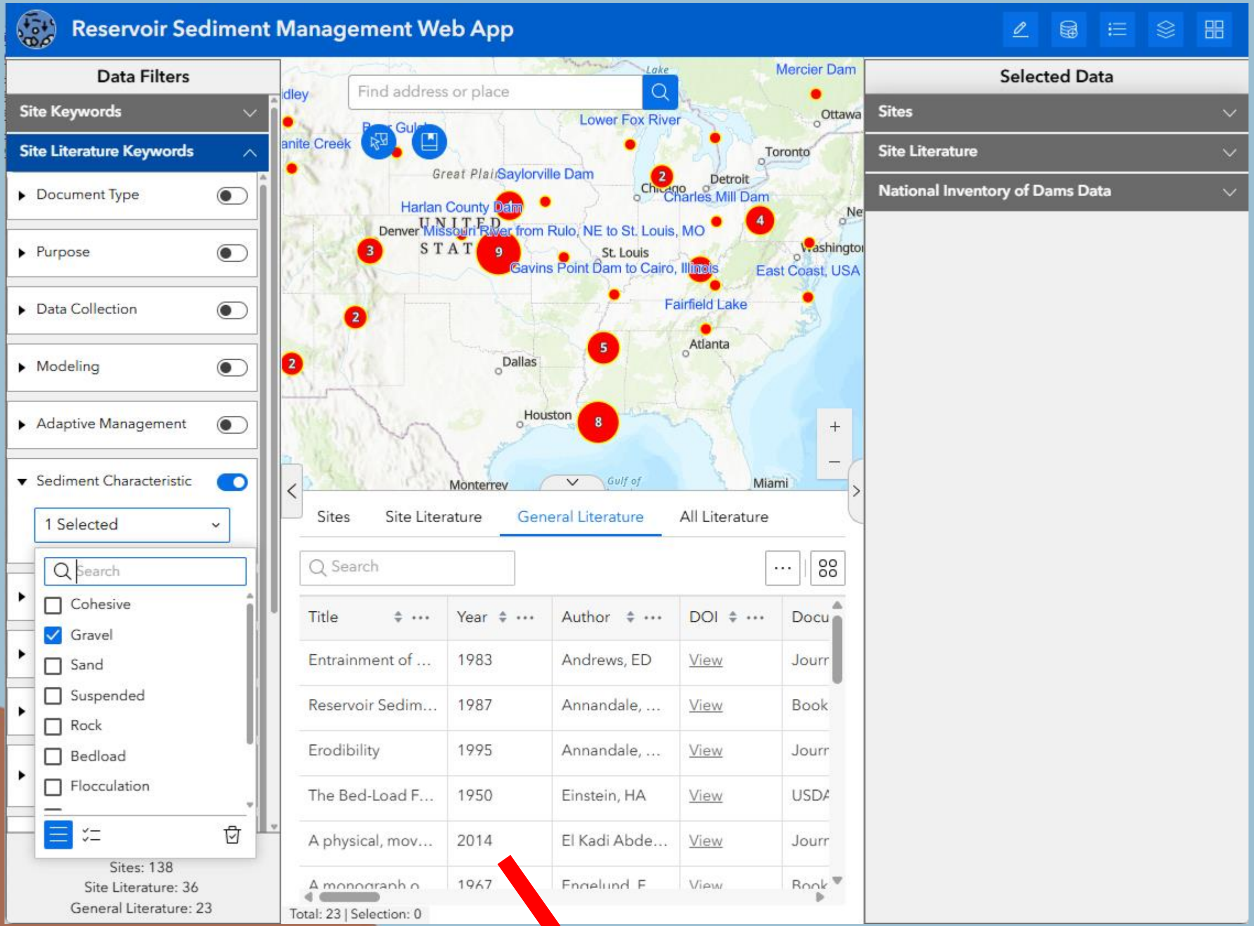


- Zoom to Tuttle Creek or select Tuttle Creek from the Site List
- Site Literature Tab = 6 resources!
- General literature can be separately browsed, selected
- Browse data in web app or export to excel

Site	Title	Year	Author	DOI	Purpose	Data Collection	Modeling	Adaptive Management	Sediment Characteristic	Sediment Source
Tuttle Creek	Characterizing and I	2016	Bloedel, P	https://krex.k	Analysis	Sediment	Laboratory_Analysis	Watershed_Planning	Cohesive	Reservoir_Pool,Ban
Tuttle Creek	Monitoring Geomor	2024	Harris, AE	http://dx.doi.	Analysis,Pla	Bathymetry,Sedim	Hydraulic_Modeling	Operations	Cohesive,Sand,Gravel,S	Reservoir_Release
Tuttle Creek	Suspended-sedime	2008	Juracek, K	USGS SIR 201	Analysis	Sediment,Bathym	Regression	Watershed_Planning	Suspended	Headcut,Suspended
Tuttle Creek	Effect of Water-Injec	2024	Kansas W	https://www.	Planning,Ana	Water_Quality,Se	Regression	Operations	Suspended	Reservoir_Release
Tuttle Creek	Analysis of a Hydros	2019	Shelley, J	ERDC/TN RSM	Operations	Not Applicable	Hydraulic_Equation	Operations	Suspended	Reservoir_Release
Tuttle Creek	Reservoir Sediment	2015	Shelley, J	ERDC/CHL CH	Planning	Public_Participat	Not Applicable	Operations,Maintenance	Not Applicable	Reservoir_Release

Site=Tuttle Creek → 6 Literature Resources

Workflow Example: Gravel Bed Rivers



- Expand literature filters on the left and select Sediment = Gravel
- Across Site and General Tab = 36 resources!
- Browse data in web app or export to excel

Title	Ye	Author	DOI	Document Type	Purpose	Data Collection	Modeling	Adaptive Management	Sediment Characteristic	Sediment
Monitoring Geomor	2024	Harris, AE	http://dx.d	ERDC TN	Analysis, F	Bathymetry, Sed	Hydraulic_Mo	Operations	Cohesive, Sand, Gravel, Sus	Reservoir_
Calibrating a Sedim	2017	Gibson, S	https://do	Conference Pape	Analysis	Bathymetry, Wa	Sediment_Tra	Flood_risk	Gravel, Sand	Suspende
In situ measu	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] ded, F	Debris
A Rainfall Intensity-	1993	Larsen, M	https://do	Journal Article	Analysis	Bathymetry, Hyd	Regression	Watershed_planning	Cohesive, Gravel, Sand	Debris
Mill Creek Channel,	1986	Robinson,	https://hd	ERDC TN	Operation	Bathymetry, Sed	Hydraulic_Mo	Flood_risk, Operations	Gravel, Sand	Erosion, P
Effects of simulated	2001	Saint-Laur	https://do	Journal Article	Planning,	Bathymetry, Sed	Sediment_Tra	Watershed_Planning	Gravel, Sand, Suspended	Bank_eros

Sediment Type=Gravel → 36 Literature Resources

Web App Value (Alpha)

- Streamlines sustainable sediment resource and data consumption
- Accelerates feasibility, permitting, and adaptive-management studies
- Reach out if you’re interested in trying out the web app
- Reach out if you have resources for us to add!

Next Steps

- WebApp Beta version release and guidance document TN (Menichino et al.)
- Sediment transport model sensitivity testing (Harris & Moore Lab)
- WID during and post effect data analyses (Scheduled start Sep 15)
- Tool for turbidity estimation using remote sensing (Hernandez et al.) -JP
- Fish trait analyses for sediment release resiliency (Hernandez et al.) -JP
- Numerical model combining eco-hydro-geomorphic effects- JP
- Expanding geographic breadth (USBR collabs)
- Training modules (WebApp, models)

PUBLISHED WORK

Wiest, S.R., Harris, A.E., and Hernandez, D.D. (2024). Hydraulic model (HEC-RAS) of downstream of Tuttle Creek Reservoir at the confluence of the Big Blue River and the Kansas River near Manhattan, KS. Dryad. https://datadryad.org/stash/dataset/doi:10.5061/dryad.k3j9kd5gr

Harris, A.E., and Hernandez-Abrams, D.D. (2024). Monitoring Geomorphology to Inform Ecological Outcomes Downstream of Reservoirs Impacted by Sediment Release. Engineer Research and Development Center Vicksburg MS Environmental Lab. https://hdl.handle.net/11681/48470

Hernandez-Abrams, D.D., Bailey, S.E., and McKay, S.K. (2022). Environmental Effects of Sediment Release from Dams: Conceptual Model and Literature Review for the Kansas River Basin. Technical note created by Engineer Research and Development Center Environmental Lab, Vicksburg, MS. https://hdl.handle.net/11681/44880