Consideration of Non-Stationary Sediment Dynamics in Watershed Based Plans

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2nd Annual Watershed Health Indicators and Data Science Symposium
Sacramento, CA Thursday June 29, 2017

Image: Monterey County Water Resources Agency
Fine River Sediment

- **Master Variable**

- **Natural Variability** in abundance often spans orders of magnitude within and between systems

- **Non-Stationary** (time dependent) dynamics can sabotage ‘snapshot’ based plans

- **Suggestions**
What is suspended sediment?

- **Shear Velocity**
- **Particle Size**
  - Bedload
  - Suspended Load
  - Coarse
  - Medium
  - Fine
- **Concentration**

**Channel Bed**
All natural water bodies transport sediment.

Sediment is the most prevalent impairment of water bodies.

Bio-geochemical Cycles

Geomorphology

Direct

Physical Habitat

Surface Mediated Transport

Heavy Metals
Pesticides
Herbicides
Nutrients
Organic Carbon
Microbia

1. Milliman and Meade (1983)
Spatially Divergent Demands

Coastal
- Wetland accretion
  - SLR
- Legacy sediments contaminated¹

Interior
- Source restructuring²
  - Damming
  - Agriculture
- Habitat
- Human use

'SClean’ Sediment as Resource

Sacramento-San Joaquin Watershed
from: CA DFW

1. Schoelhamer et al. (2007)
2. McKee et al. (2013)
Fluvial Suspended Sediment Monitoring

• Ambient Characterization

• Dynamical/Flux-Based

Current-meter discharge measurements are made by determining the discharge in each subsection of a channel cross section and summing the subsection discharges to obtain a total discharge.
Suspended Sediment Dynamics

The $C_{ss} - Q$ Relationship
High Variability

1. Lower Salinas River fine suspended sediment
90% of Sediment flux from n% of hydrologic record

5-10%

1-2%

0-1%

Dominated by rare, high magnitude events

Farnsworth and Warrick (2007)
Time Dependent Behavior

Found across a wide range of temporal scales

✓ Event to Interdecadal
Supply Augmentation

**Eel River Christmas Flood**

*December, 1964*

~ 200 year recurrence interval

Log $C_{ss}$

Decreasing temporal trend in $C_{ss}$-$Q$ relationship at the Interdecadal Scale

Warrick et al. (2013)

System Rebound

Goni et al. (2013)
Wildfire-Storm Event Sequencing


Suspended Sediment Response

Post 1977 100x pre-fire
Post 2008 2x pre-fire

Event Scale Disturbance
Interannual Scale
Supply Recovery
Conditioned by Rainfall Intensity

(1) Warrick et al. (2012)
Event Scale Non-Stationarities

Hysteresis

Hydrologic Regime

- Baseflow
- Stormflow
- Reservoir Release

\[ C_{ss} \ (mg/L) \]

\[ Q \ (m^3s^{-1}) \]

1. Williams (1989)
Hydroclimate & Humans

Event to Interannual

Loading/Flushing Regimes

- Drought/Low Flow
- Event magnitude/timing
- Fines: Threshold Supply Suppression
- Sand: General Supply Suppression

Gray et al. (2014)

Decadal

Persistent Hydro-Climatic Cycles

- Persistent Patterns in Hydrologic Conditions
- Sediment flux comparisons

Gray et al. (2015a,b)

Interdecadal

Salinas River

Agriculture

- Salinas River Watershed
  - ~50% increase in crop area from 1965-2011

Drip irrigation
  - Introduced in 1960s.
  - Expanded rapidly from 1990 to present

Gray et al. (2016a)
Variability Rich, Data Poor

Only 23 of 250+ watersheds have 10+ year suspended sediment data sets

- Short duration
- Sporadic, low resolution
- ‘Effective’ flood events missed

Almost no sediment composition/associated contaminant data

Gray et al., in prep.
Automated $C_{ss}$-Q Sampling

Fine sediment ($D < 63 \mu m$) well mixed, and carry most of contaminant load
Sediment Associated Contaminant Dynamics

• **Very, very few studies ever conducted**¹

  Requirements²
  
  • SS dynamics
  • Contaminant analysis
  → LARGE samples (10 – 10³ liters)
  → High volume processing for SS (i.e. large or continuous flow centrifuges)

• **We know very little** about the transport dynamics of sediment associated contaminants through fluvial systems.

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¹ LeBlanc et al. (2004)
² Conn et al. (2016)
Sediment Provenance

Characterize Source/SS

- Trace elements
- Contaminants
- Fallout Radionuclides

Mixing Model

- Geology
- Land use
- Erosion/Transport

The Future of Sediment Management Requires Rethinking Sediment Monitoring

Watershed Based Plans

Beyond reach scale & distributed ‘snapshot’ requirements

• **Dynamical/Flux-based monitoring**
  – Associated contaminant dynamics

• **Emergent technologies**
  – Remote sensing, high resolution surveys, sediment fingerprinting

• **Explicit consideration of time**
References


