Impacts of stream restoration on nutrient and sediment concentrations and fluxes: An overview

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SPECIFIC STREAM RESTORATION DESIGNS AND FEATURES

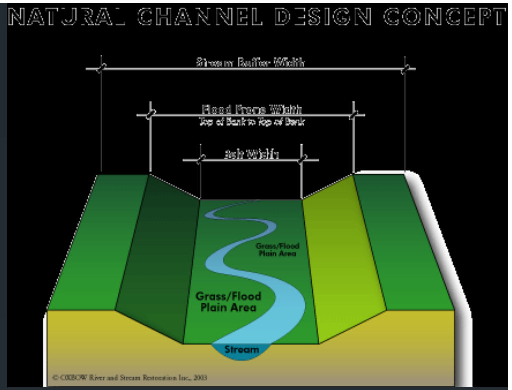
Common Designs:

- Natural channel design (NCD)
- Regenerative Streamwater Conveyance systems (RSCs)
- Stream valley restoration (SVR)/ Legacy sediment removal (LSR)

Specific Features:

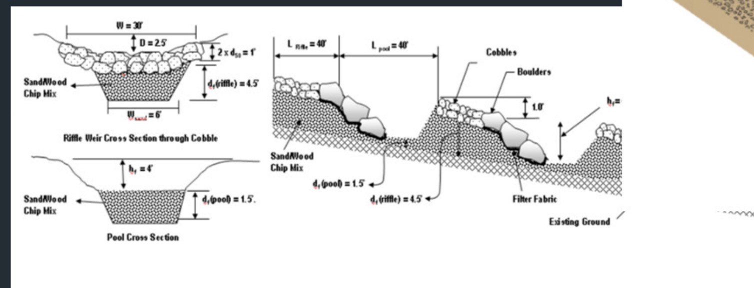
- Floodplain reconnection
- Floodplain wetlands
- Flow modification
- Structural changes (bank stabilization and channel reconfiguration)

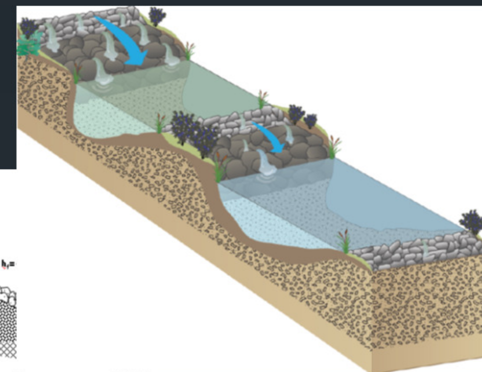
Natural Channel Design (NCD)



- NCD increases transient storage but not enough to improve biogeochemical functions and alter in-stream water chemistry
- Nutrient uptake rates are highly variable
- Functional responses are controlled by initial conditions and magnitude of changes
- N and P uptake saturates with high inputs
- Restored floodplain improves nutrient removal and sediment retention of NCD but it depends on inundation frequency, water residence time and stream geomorphology

Regenerative Streamwater Conveyance (RSCs)

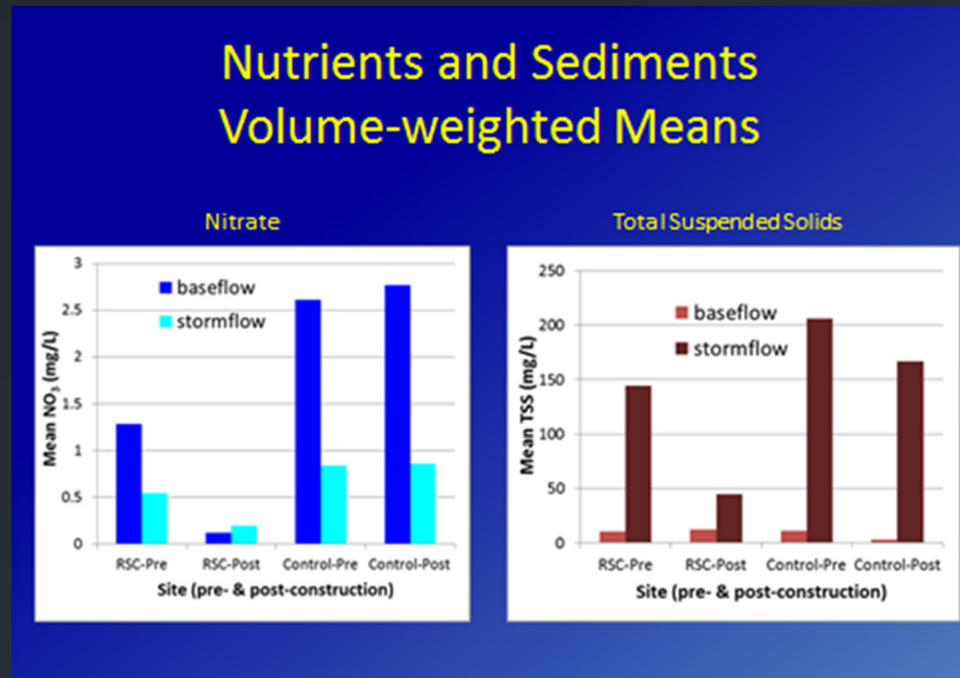




- Consistent decrease in nitrate concentrations and TN fluxes in headwater streams
- Also reduction in sediment export in headwaters
- Downstream, performance of RSCs is more variable, especially if upstream inputs are not minimized
- A dry channel RSC in AAC eliminated stormflow for rain events up to 2.5 in, and reduced N concentrations and fluxes
- A headwater RSC in DC reduced TN and TSS fluxes by > 50%; TP flux reduction ~ 10%
- A headwater RSC in AAC eliminated stormflow for rain events up to 0.24 in; reduced peak discharges and concentrations and fluxes of TN and TSS

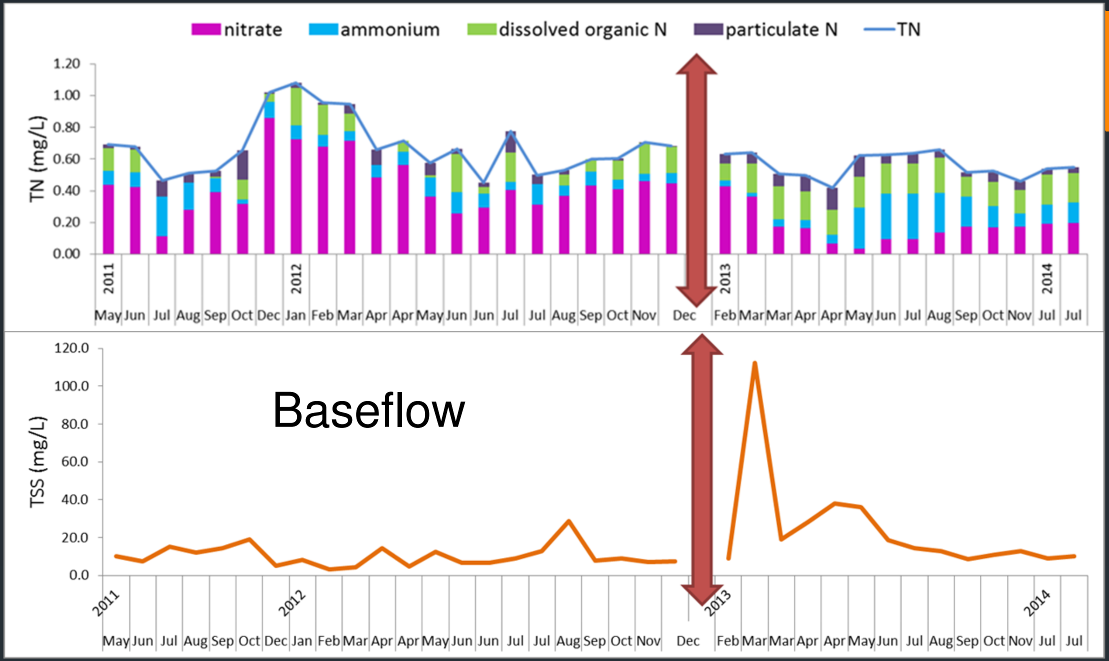
Example of water quality change in headwater RSC

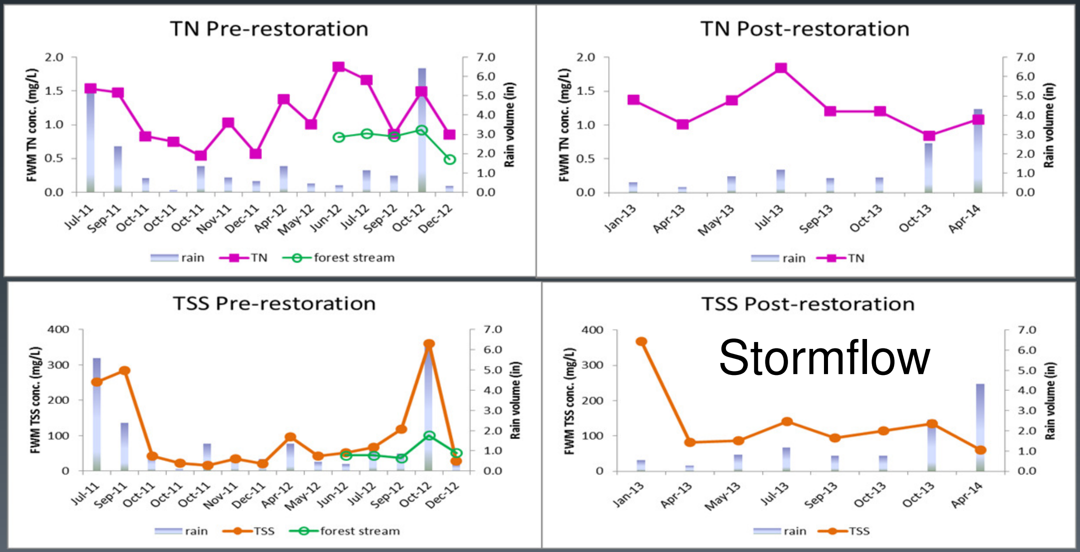
- Monitoring done simultaneously in restoration and control streams.
- For 3 years – 1 yr BEFORE and 2 yrs AFTER restoration in both streams.
- Sampling during baseflow and stormflow conditions.



Pollutant	% reduction from restoration
TSS	76%
Nitrate	42%
Particulate N	22%
Total N	54%
Total P	13%

Example of water quality change in downstream channel RSC





- Monitoring done pre- and post-restoration stream.
- For 2.5 years – 1.5 yr BEFORE and 1 yr AFTER restoration.
- Sampling during baseflow and stormflow conditions.

Stream Valley Restoration/ Legacy Sediment Removal

- Not much information available
- Buried hydric soils do not perform denitrification function; act as source of nitrate
- Nutrient content in legacy sediments varies with source
- Changes in soil evaporation and water balance can make restored wetland soils drier not wetter (Booth and Loheide, 2012)

Conclusions for performance of restoration designs

- RSCs in “dry channels” and headwaters show consistent reduction of nitrate concentrations and nitrogen export, and substantial reduction in sediment export
- The performance of NCD and lowland RSCs is more variable and depends on upstream conditions
- High nutrient and sediment loads to restored reaches limit performance
- Restoration construction has negative impacts to WQ

Floodplain reconnection

Restored Function

- Flow regulation – reduces peak flows and flow velocity
- Sediment retention in floodplain
- Transient storage
- Denitrification
- Burial of N and P in floodplain
- Improves ecological function of riparian zone

Performance Controls

- Volume of transient zone
- Area of floodplain
- Flood frequency and magnitude
- Nitrate concentration
- Water residence time
- C content in sediment

Floodplain wetland

Restored Function

- Flow regulation – reduces peak flows and flow velocity
- Sediment transport control
- Denitrification (oxbowl)
- N and P uptake (algae and vascular plants)

Performance Controls

- Width to depth ratio
- Water residence time
- DON:nitrate concentration
- Sediment C content
- Nitrate concentration
- Presence of impermeable layers
- Age of restoration → key drivers for denitrification, such as soil carbon, are slow to develop

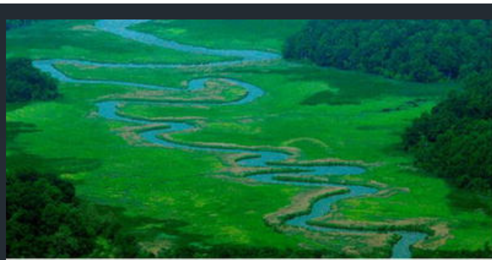
Flow modification

Restored Function

- Surface flow regulation
- Subsurface (hyporheic) flow
- Erosion control
- Sediment dynamics
- In-stream N and P uptake
- Denitrification

Performance Controls

- Size of hyporheic zone
- Geomorphology that flushes large volumes of stream water through hyporheic zone
- Position in the watershed; slope
- C content of hyporheic sediment
- Distance between hyporheic zones
- Concentration of DON:NO_3 in hyporheic zone
- Dissolved N and P concentrations
- Excess of fine sediment



Structural changes:

Bank stabilization and channel modification

Restored Function

- Flow regulation
- Sediment dynamics
- In-stream N and P uptake

✓Infrastructure protection (BS)

Performance Controls

- Scale of change/measure
- N and P concentrations
- Presence of well-established and robust riparian vegetation
- Watershed conditions, climate and frequency of large storm events

Unintended negative impacts of measures/features

FLOODPLAIN RECONNECTION:

- Soil compaction during construction limit denitrification

FLOODPLAIN WETLAND:

- Produces large amounts suspended solids
- Desorption of P from sediment → source of P
- Accumulation of fine suspended sediment →detrimental to benthic organisms and denitrifying microbial community
- Increases water temperature

FLOW MODIFICATION:

- Can limit nitrification

STRUCTURAL CHANGES (bank control, channel reconfiguration):

- Boulders, stones and walls along streams reduce opportunity for nitrate removal (denitrification) and other biogeochemical processes

Conclusion

- Most restoration features and designs provide some degree of recovery of WQ functions
- The scale of the measure is important but the performance of all features and designs depend on different factors which need to be sustained by the restoration
- Performance is also highly influenced by the quantity, quality and timing of stream flow
- Watershed conditions play important role

Knowledge gaps

- We need to know:
- The range of variability in the quantity, quality and timing of flow in reference streams
- What is the optimum range of variability in restored streams that would maximize N, P and sediment retention
- How restoration designs and watershed conditions interact to create this optimum range
- What will be the impacts of climate change

What to do to close knowledge gaps:

- Long-term monitoring of reference streams
- Experiments to determine nutrient uptake rates in restored streams under different hydrological conditions
- Use hydro-chemical models to predict how restoration designs and watershed conditions interact to sustain biogeochemical functions in restored streams
- Address the impacts of climate change
- More studies for LSR restoration

Thanks!

Filoso
Translation Slides

What does this mean for me?

- Function versus technique
- Different factors influence the outcomes (e.g., if you are aiming for floodplain connection, success will depend on how long water hangs around)
- If you are aiming for N removal, then you have to create spaces for denitrification, no matter what you call your practice (a rose by any other name…)
- Must think about watershed – the loads coming in. There are some watersheds where this can “work” and some where not, and we need to find out what factors control this

What does this mean for me?

- What do I take from this if I am a practitioner:

Design attenuation to create hot spots for denitrification.

- What do I take from this if I am a regulator:

If purpose and need of a project is to decrease P and N, then the design should lead to attenuation and inundation of the flood plain. If the design doesn't include these elements, ask whether outcomes can be maximized.