Evaluation of Legacy Sediment Removal and Floodplain Reconnection as a Restoration Technique

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Towson University
INGREDIENTS FOR A MEANDERING RIVER

Gravel, sand, and water come in from upstream

Vegetation slows erosion

Cuts into bank

Point bar

Stream deposits gravel ...then sand

Fine sediment helps block off chutes

Over time stream wanders

Downstream
State boundaries in 1840

Mill density in mills/sq-km (number of mills)

- 0
- > 0 to 0.02 (5909)
- > 0.02 to 0.05 (14370)
- > 0.05 to 0.10 (22377)
- > 0.10 to 0.20 (12291)
- > 0.20 to 0.61 (1217)
Legacy Sediment is the impairment to the aquatic resource
Hard Armor Approach

Cost $200 - $250 / lf

**Short Term Benefit**
- Reduced erosion of impairment
- Minimal improvement to aquatic resource

**Long Term Risk**
- Failure of armoring resulting in renewed erosion of impairment

Legacy Sediment
Hydric Soils
Basal Gravels
Artificially Elevated Streambed

Existing Grade
Imbricated Wall
Floodplain Restoration

Cost $100 - $200 / lf

Short & Long Term Benefit
- Removal of impairment
- Restored function of aquatic resource
Natural Piedmont Stream Valley

Connectivity between rooting zone, groundwater, and stream flow

- Roots extend to groundwater
- Floodplain Soils – Shallow, Peaty, Organic, & Porous
- Cobble/Gravel Bed (Groundwater)
- Bedrock
Evaluation of Legacy Sediment Removal and Floodplain Reconnection as a Restoration Technique

• Vegetation
  • Increased dominance of hydric vegetation
  • Response to disturbance? Invasives?
  • Change in community composition

• Water chemistry
  • Relationship with drainage area? Impervious cover? Project length?
  • Decrease in N, P and TSS due to increased overbank events and longer residence time.
## Study sites

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- Beetree Run (2016)
- First Mine Run (2017)
- North Stirrup Run (2015)
- Cabbage Run (2014)
- Bear Cabin Branch (2018)
- Plumtree Run (2017)
- Baltimore City
First Mine Run
Plum Tree Run
WARNING
DO NOT PLAY, SWIM OR FISH

SEWAGE OVERFLOW
EXPOSURE TO WATER MAY CAUSE ILLNESS.

TOAN

Department of Public Works
501 Churchville Road
Bel Air, Harford 21014
410-838-4448
(8 a.m. to 4:00 p.m., M-F)

After Hours:
Central Police Department
(410-838-4500)
Vegetation Methods
Three sites sampled in spring and fall for two years

Reference

Sampled in spring and fall for two years

Restored

Three sites

Sampled in spring and fall for one year before and one year after restoration
Average 81% DECREASE in basal area

Reference/Restored Reaches
- Cabbage Run
- North Stirrup Run
- Bee Tree Run

Pre/Post Restoration Reaches
- Bear Cabin Branch
- First Mine Run
- Plum Tree Run
Significant increase in hydrophytic vegetation in both the herbaceous and woody layers (Herb p = 0.028; Woody p = 0.028)
Top 30 herbaceous and top 10 woody species by Importance Value

Increase in OBL and FACW
Decrease in FACU
Significant increase in native vegetation in herbaceous layer. Trend toward increase in woody layer. (Herb \( p = 0.046 \); woody \( p = 0.075 \))
Top 30 herbaceous and top 10 woody species by Importance Value

Decrease in invasive species
Herbaceous vegetation – Change in composition, sites maintain identity

Axis 1
-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

Axis 2
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

BA
WWIS

Axis 1   \( r^2 = 0.626 \)
Axis 2   \( r^2 = 0.233 \)

References
Pre-restoration
Post-restoration
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Bear Cabin Branch
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Bee Tree Run
Top 30 herbaceous species by Importance Value

Decrease in vines and woody, increase in graminoids
### Indicators of unrestored reaches

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<tr>
<th>Plant Name</th>
<th>Common Name</th>
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<tr>
<td><em>Alliaria petiolata</em></td>
<td>garlic mustard</td>
</tr>
<tr>
<td><em>Rosa multiflora</em></td>
<td>multiflora rose</td>
</tr>
<tr>
<td><em>Lindera benzoin</em></td>
<td>spicebush</td>
</tr>
<tr>
<td><em>Viola sororia</em></td>
<td>blue violet</td>
</tr>
<tr>
<td><em>Circaea lutetiana</em></td>
<td>enchanter's nightshade</td>
</tr>
<tr>
<td><em>Geum canadense</em></td>
<td>white avens</td>
</tr>
<tr>
<td><em>Symlocarpus foetidus</em></td>
<td>skunk cabbage</td>
</tr>
</tbody>
</table>

Sources:
- [Viola sororia](https://www.prairiemoon.com/viola-sororia-common-blue-violet-prairie-moon-nursery.html)
- [Wildflowers in Illinois](https://www.illinoiswildflowers.info/grasses/plants/ny_fern.htm)
Average 79% DECREASE in skunk cabbage cover

https://www.nps.gov/miss/learn/nature/skunkcabbage.htm
https://urbanecologycenter.org/blog/native-plant-eastern-skunk-cabbage.html
Indicators of restored reaches

24 species identified

Herb/Graminoid = 92%
Obligate/FACW = 63%
Native = 67%
Planted = 25%

Majority of dominant/indicator species were NOT PLANTED

Evidence for seed bank?
Woody vegetation
Change in composition, sites maintain identity

Reference
Pre-restoration
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Axis 2
-1.0 -0.5 0.0 0.5 1.0 1.5 2.0
Axis 3
-2.0
-1.5
-1.0
-0.5 0.0 0.5 1.0

Axis 2 $r^2 = 0.392$
Axis 3 $r^2 = 0.322$
## Woody Indicator Species

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<th>Restored Reaches</th>
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<td><em>Celastrus orbiculatus</em> – bittersweet</td>
<td><em>Salix purpurea</em> – basket willow</td>
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<td><em>Rosa multiflora</em> – multiflora rose</td>
<td><em>Platanus occidentalis</em> - sycamore</td>
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<tr>
<td><em>Rubus phoenicolasius</em> - wineberry</td>
<td><em>Salix nigra</em> – black willow</td>
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<td><em>Lonicera japonica</em> – J. honeysuckle</td>
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<td><em>Lindera benzoin</em> - spicebush</td>
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All indicators of restored reaches were planted at three to five of the six study sites.
Sampling approach

Pre-Restoration

Three sites

Upstream

Direction of streamflow

Downstream

Flux/load =

Downstream – Upstream
Sampling approach

Flux/load = \textit{Downstream} – \textit{Upstream}
Sampling approach

Three sites

Upstream

Post-Restoration

Flux/load = Downstream – Upstream

Pre-Restoration

Direction of streamflow

Downstream
Biggest control for N: land use
Pre-/Post-restoration: no significant difference (yet)
Biggest control for N: land use
Pre-/Post-restoration: no significant difference (yet)
Little dilution of N with increased discharge. Result is substantial loads.
Little dilution of N with increased discharge. Result is substantial loads
2017 vs 2018 baseflow discharge

Only showing sites with at least 15 measurements per year

Discharge (ft³/s)

PTR  BCB  NSR  CAB  BTR  FMR

Most urban

Most active agriculture
2017 vs 2018 baseflow discharge

2018 was high precipitation & discharge year – so higher fluxes/loads quite likely

Only showing sites with at least 15 measurements per year

Most active agriculture

Most urban
Baseflow fluxes seem to have changed post-restoration

Difference = Downstream – Upstream load

Higher export from downstream site
Baseflow fluxes seem to have changed post-restoration

**Difference** = Downstream – Upstream load

- **Higher export from downstream site**
- **Lower export from downstream site**

**First Mine Run**
- Restoration

**Plumtree Run**
- Restoration

**Baseflow fluxes** seem to have changed post-restoration.
Baseflow fluxes seem to have changed post-restoration.
Suspended sediment load shows a decrease in bigger storms

First Mine-Down
First Mine-Up

April 24, 2019

Storm load (kg/d/km²)

April 26, 2019
Storm 1
April 26
Storm 2

FMRU
FMRD

8.4% increase
22.4% decrease

FMR: Site with highest agricultural intensity

Estimated from rating curve & sediment vs discharge rating curve
Suspended sediment load shows a decrease in bigger storms.

First Mine - Down
First Mine - Up
April 24, 2019

Storm 1
8.4% increase
22.4% decrease
1.0% decrease
1.8% increase

April 26, 2019
Storm 2

FMR: Site with highest agricultural intensity
Perhaps overtopping banks & reaching floodplain

Estimated from rating curve & sediment vs discharge rating curve
Suspended sediment load shows a decrease in bigger storms

FMR: Site with highest agricultural intensity

Perhaps overtopping banks & reaching floodplain

**April 26, 2019**
- Storm 1: 8.4% increase
- Storm 2: 22.4% decrease

**April 24, 2019**
- Storm load: 1.0% decrease

**May 9**
- Storm load: 1.8% increase

Estimated from rating curve & sediment vs discharge rating curve
Temperature

Most active agriculture

Most urban
Temperature

Sites with pre-/post-restoration data

Most active agriculture

Most urban
Temperature: no statistically significant post-restoration change

Sites with pre-/post-restoration data

Caveats: as few as 9 points & no summer for FMR; ongoing high-frequency temperature
Summary - Vegetation

• Decrease in woody vegetation
  • Removal of trees
  • Near-complete elimination of vines

• Increase in hydrophytic, native vegetation
  • Loss of species (like skunk cabbage) that don’t disperse/regenerate well from seed
  • Loss of forest understory species
  • Increase in graminoid species (grasses, rushes, sedges)
    • Response to hydrology and light
Summary - Water

• No significant difference in N (yet)
  • Surrounding land use controls N levels
• Little dilution of N with increased discharge. Result is substantial loads.
• Record rainfall year obscures any changes in N fluxes
• Suspended sediment load shows a decrease in bigger storms
• No significant effect of restoration on water temperature
Acknowledgements

• Funding
  • Chesapeake Bay Trust, Towson University,

• Logistical support – Ecotone, Inc.

• Landowners – Henry and David Pitts, Rigdon Family, Edwards Family, Harford County, City of Bel Air

• Students – Patrick McMahon, Patrick Baltzer, Ginny Jeppi
What does this mean for me?

• The wet year of 2018 obscured some results in research
  • Nutrients, Sediment, and Temperature inconclusive
  • Why no dilution in higher discharges?

• Land Use of Watershed has dominant impacts
  • Are urban loads correlating with Bay Model?

• Legacy Sediment Removal increases hydrophytic vegetation establishment and decreases invasives at these sites

• Majority of herbaceous vegetation established was not planted, majority of woody vegetation was planted
What does this mean for me?

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

• What is optimal selection of floodplain access elevation?
  Significance of baseflow versus flood flow nutrient and sediment fluxes?

• Siting of projects relative to land use

• Planting plan strategies, less overall but trees and skunk cabbage

• Look for ways to increase retention time for storm flows

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

• Temperature fluctuations may be small but additional data in normal year and summer needed

• Lower risk of invasives

• Higher likelihood of self mitigating wetland impacts with hydrophytic vegetation quickly established?
Study sites – for questions

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Baltimore City
Biggest control for N: land use – *C also but generally opposite*
Pre-/Post-restoration: no significant difference (yet)
TSS – questions

FMR Concentration Non-Storm vs Stormflow

TSS concentration: mg/L

FMRU  FMRD  FMRU Storm  FMRD storm
2018 was high precipitation & discharge year – for questions
What does this mean for me?

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