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Chesapeake Bay Floodplain Ecosystem Services

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November 2020

Introduction

- **Chesapeake Bay Project**
  - Restoration and protection a priority for stakeholders
  - High development pressure
- **Motivation**
  - Lack of information on ecosystem services and their value applicable to local scale at which decisions are made
- **Project Goal**
  - Provide ecosystem service information on streams and floodplains at scale useful to inform decision-making
  - Difficult Run pilot

Interdisciplinary Team

Ecologists

Geographers

Hydrologists

Economists

Team includes: Emily Pindilli, Krissy Hopkins, Greg Noe, Peter Claggett, Marina Metes, Collin Lawrence, Fabiano Franco, Dianna Hogan, Stephanie Gordan

Why Floodplains?

- Floodplains are at the intersection of terrestrial and aquatic ecosystems AND are **biogeochemical hotspots** for nutrient processing
- BUT we have **limited information** on ecosystem service values required for local decision-making

Difficult Run, VA

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Floodplain Ecosystem Services

Capacity of floodplain to **retain sediment, nutrients, and flood waters** provides critical ecosystem services to local and downstream communities?

Ecosystem Services of Interest

Nutrient/Sediment Retention

Flood Attenuation

Carbon Sequestration

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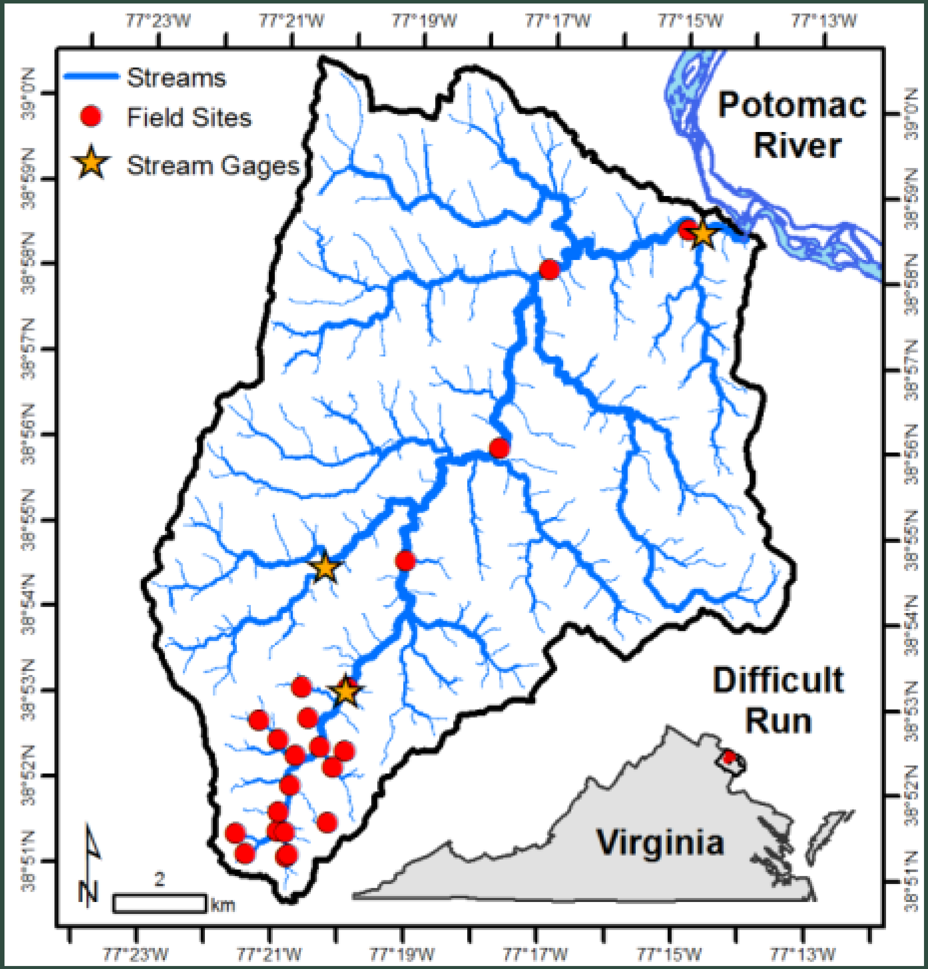
Photos courtesy of Chesapeake Bay Program

Study Area: Difficult Run, Virginia

- 150 km^2 watershed
- Piedmont of Virginia
- 33% forested
- 15% developed



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Sediment and Nutrient Retention Linking Functions to Services

Ecosystem Function → **Ecosystem Service**

Floodplains retain sediment and nutrients

Loads of sediment and nutrients are reduced

Improved water quality

Opportunity to:
- view the environment
- to swim, wade, boat
- catch fish

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Photos courtesy of Chesapeake Bay Program

Sediment and Nutrient Retention Translating Services to Values

Link loads to water quality

Link water quality to ecosystem services

Valuing ecosystem services

Lower nutrient and sediment loads

Improved water quality

Opportunity to:

- view the environment
- to swim, wade, boat
- catch fish

Willingness to Pay for recreation

Proxy
Replacement costs of wastewater treatment

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Photos courtesy of Chesapeake Bay Program

Valuation Approach

- Best approach: estimate consumer surplus associated with water quality improvement
  - Evaluated data availability for benefits transfer and determined approach *currently intractable*

- Next best approach: replacement cost method
  - Evaluating ‘built’ alternative (wastewater treatment plants) to replace function of floodplains

- Methodology requirements
  1. Alternative provides same service
  2. Alternative is the least-cost alternative
  3. Substantial evidence that demand exists

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Replacement Cost Method

- **Estimated costs of replacing nutrient and sediment retention services provided by floodplains**
- $V_e = \sum_i R_i * P_i$
  - Where $V_e = value\ of\ environmental\ purification$ ($)
  - R_i = *quantity of nutrient and sediment (i) retained by the floodplain (pounds)*
  - P_i= *marketable cost of retention ($), based on WWTP costs*

Photos courtesy of DC Water

Difficult Run Replacement Costs

- Blue Plains WWTP
- NPDES permit: 5 mg/L to 4 mg/L
- Enhanced nitrogen removal ($1 billion)

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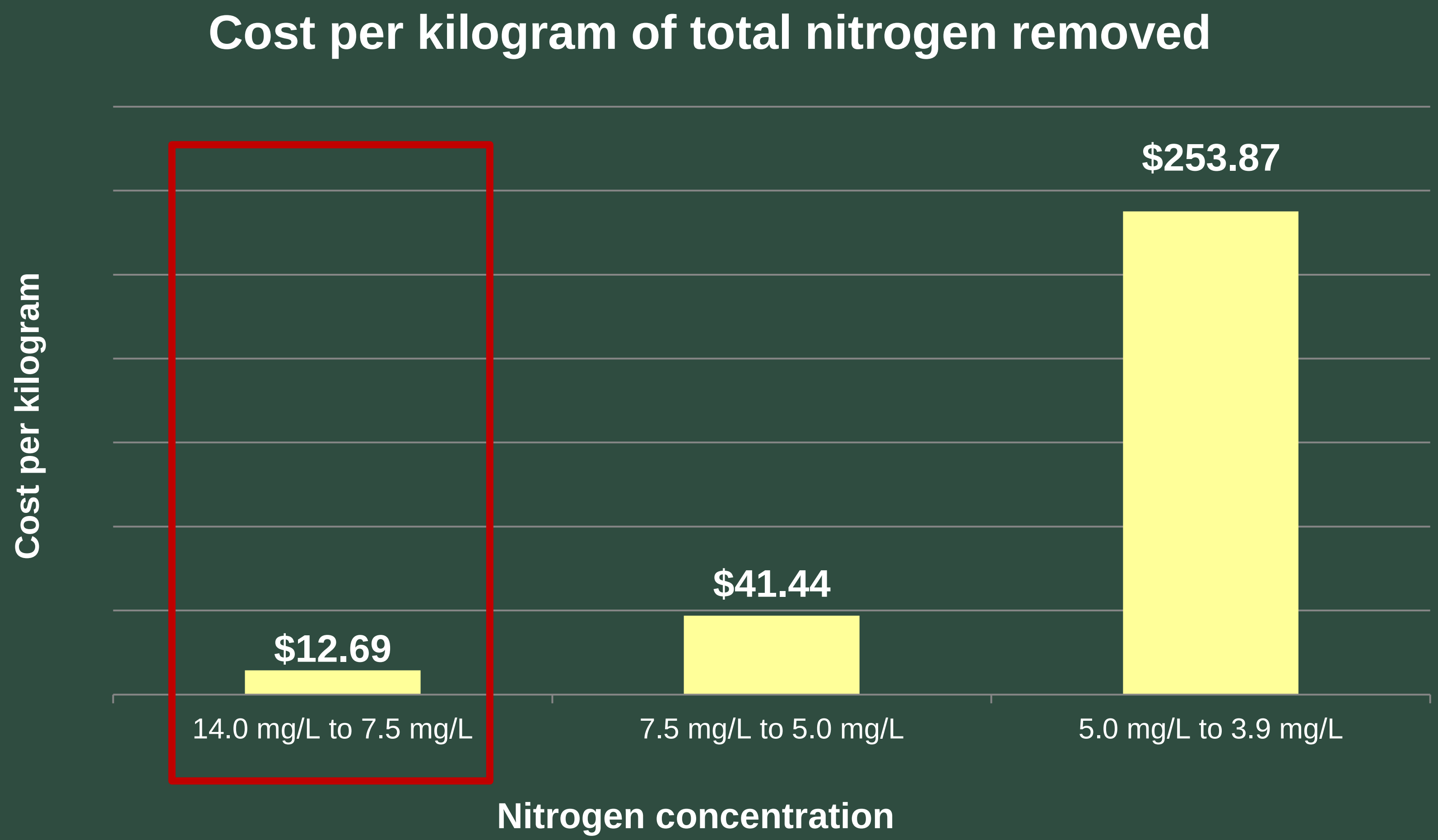
Economic Values



Results suggest a value of $727,226 (±$194,220) for nitrogen retention in Difficult Run

https://doi.org/10.1016/j.jenvman.2018.05.013

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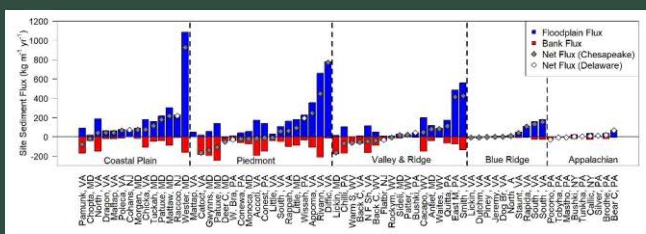
Scaling Up to the Chesapeake Watershed

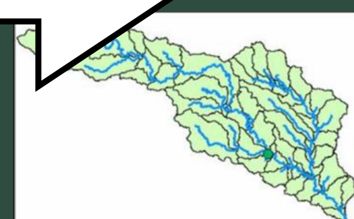
Field Data



Boosted Regression Tree Models

Watershed + Reach Predictors

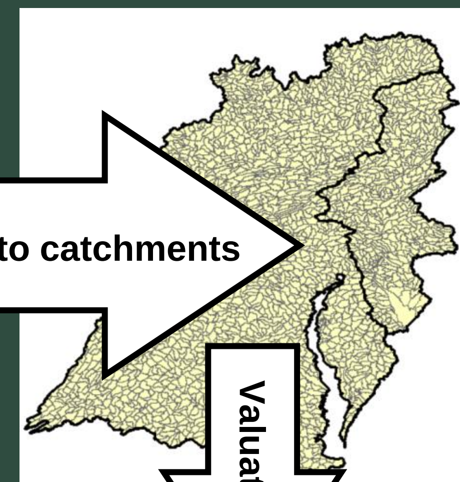
Reach Fluvial Geomorphometry
Floodplain width, bank height, channel width



Upstream Watershed Attributes
Land use, hydrology, soils, topography, slope, area

Wieczorek et al. 2018

Scale to catchments



Valuation

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

Chesapeake Bay Watershed Nitrogen Budget:

Upland erosion (RUSLE2)

-5.9 x 10^7 kg-N/yr

Upland delivered to streams (IC)

-2.9 x 10^7 kg-N/yr

Residual source

-1.7 x 10^7 kg-N/yr

Floodplain Nutrient Retention Service

Erosion: -8.4 x 10^6 kg-N/yr

Deposition: +1.6 x 10^7 kg-N/yr

<u>Net: +7.6 x 10^6 kg-N/yr</u>

~$96,400,000 in nutrient retention annually ($12.69/kg-N)

in deposition

7 kg-N/yr

oad)

These data are preliminary and are subject to revision. They are being provided to meet the need for timely 'best science' information. The assessment is provided on the condition that neither the U.S. Geological Survey nor the United States Government may be held liable for any damages resulting from the authorized or unauthorized use of the assessment.

Flood Attenuation
Linking Functions to Services

Ecosystem Function → **Ecosystem Service**

Floodplains store water during precipitation events

Stream peak flows are reduced

Adjacent community flooding reduced

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Photos courtesy of Chesapeake Bay Program

Floodplain Scenarios

- Natural floodplain
  - Storage during high flow events
- Counterfactual: no floodplain
  - Reduced storage results in faster, higher peak discharge

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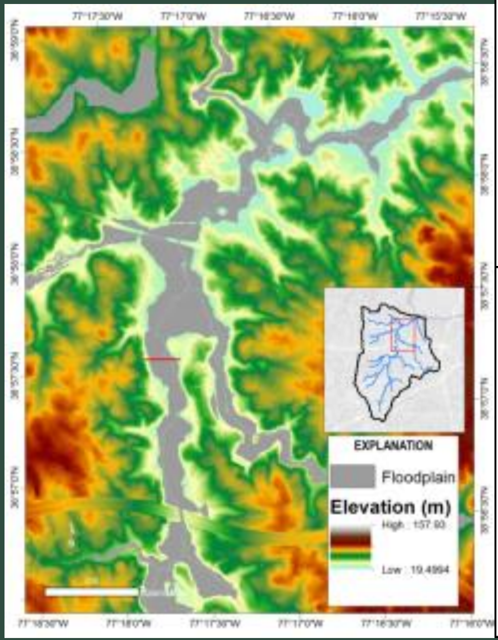
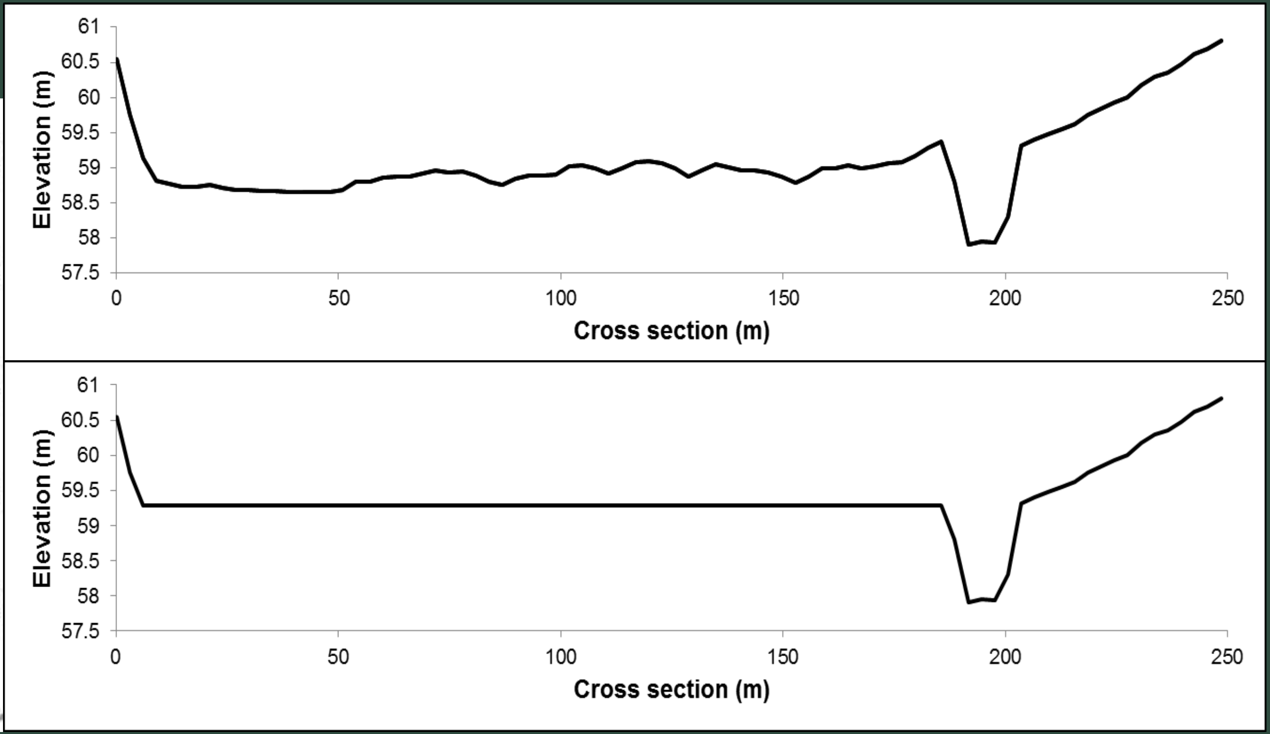
Floodplain Scenarios

- Natural floodplain
- Counterfactual: no floodplain





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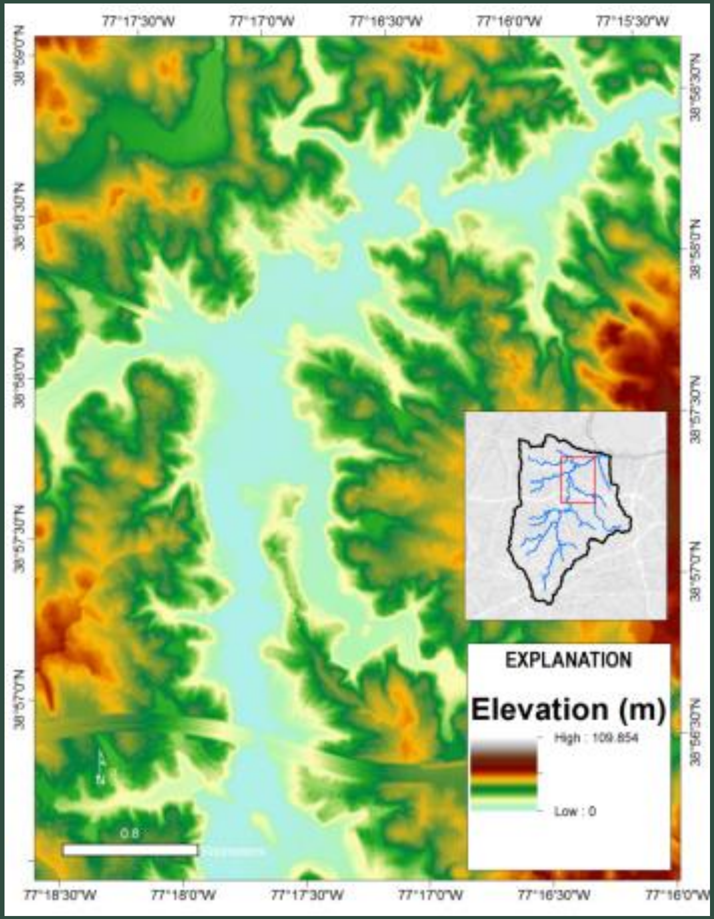
Flood Inundation Mapping

- **GIS Flood Tool**[1]
  - **Based on Manning Equation**

$$V = \frac{1}{n} R^{2/3} \sqrt{S}$$

    - **V: mean velocity (m s^{-1})**
    - **n: Manning coefficient**
    - **R: Hydraulic radius (m)**
    - **S: Slope of energy line**
  - **Input:** DEM, peak flow, n



[1]Verdin et al., (2016). *A software tool for flood inundation mapping*. USGS Report 2016-1038.

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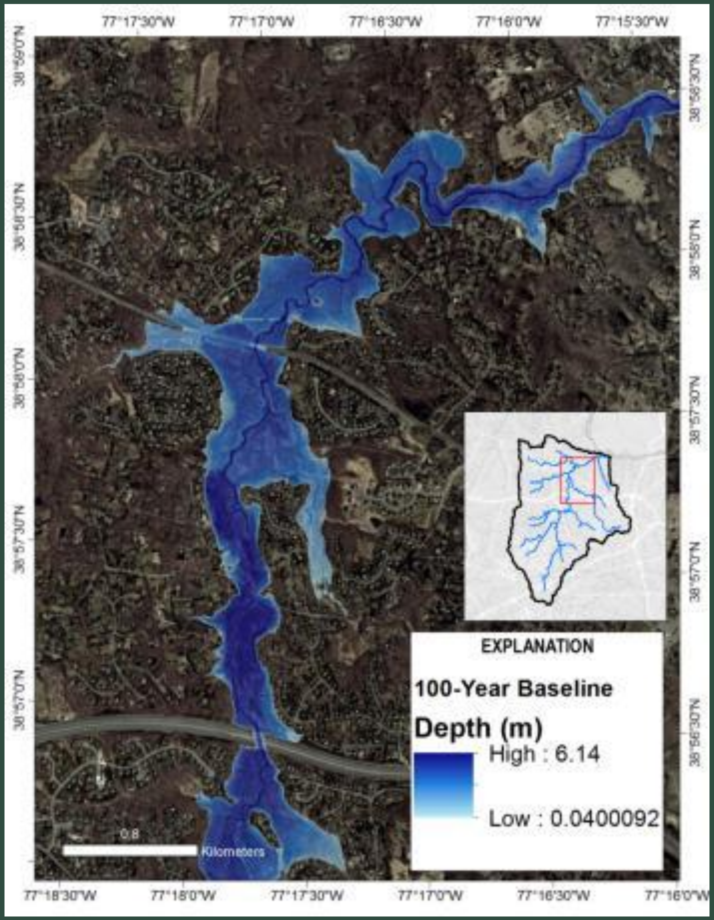
  - **Input:** DEM, peak flow, n
  - **Output:** Inundation depth



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Basemap imagery from ESRI and Digital Globe data

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Flood Attenuation
Translating Services to Values

Method Development: Translating flood attenuation to services and economic values

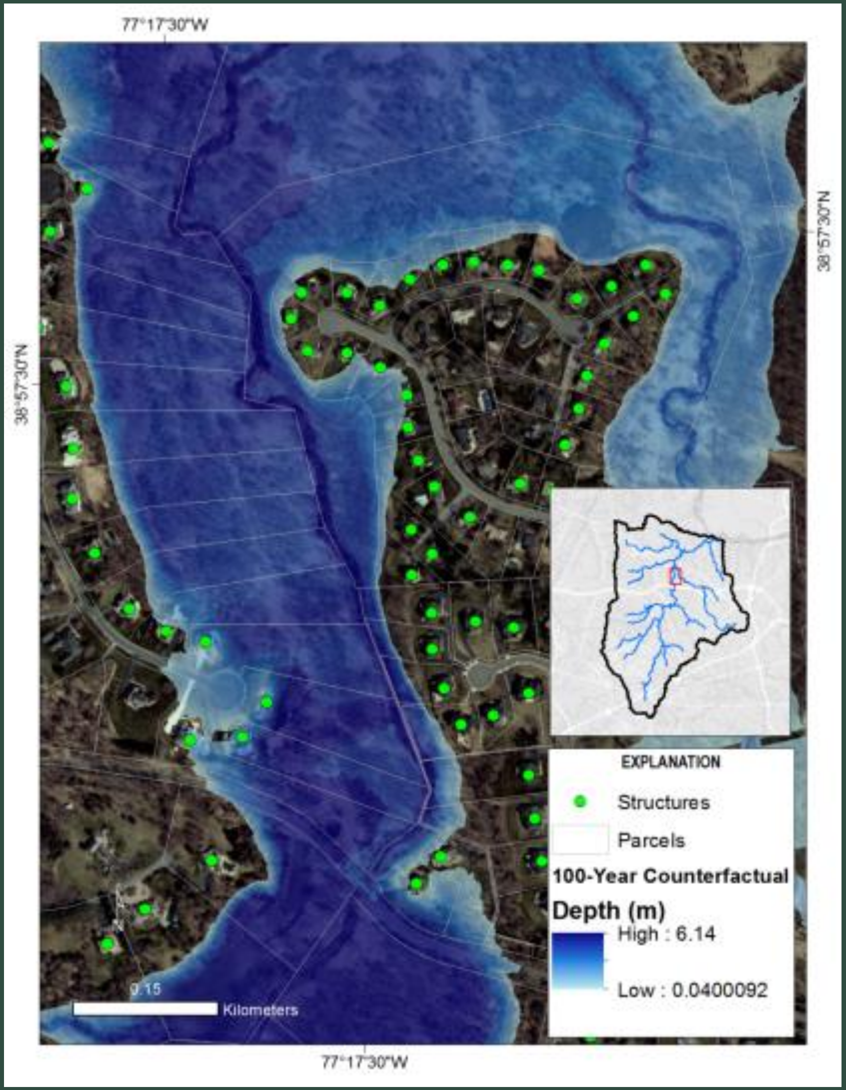
Link water storage to flood attenuation

Link flood attenuation to avoided damages

Photos courtesy of Chesapeake Bay Program

Estimating Avoided Losses

- **Estimate inundation for baseline, counterfactual scenarios**



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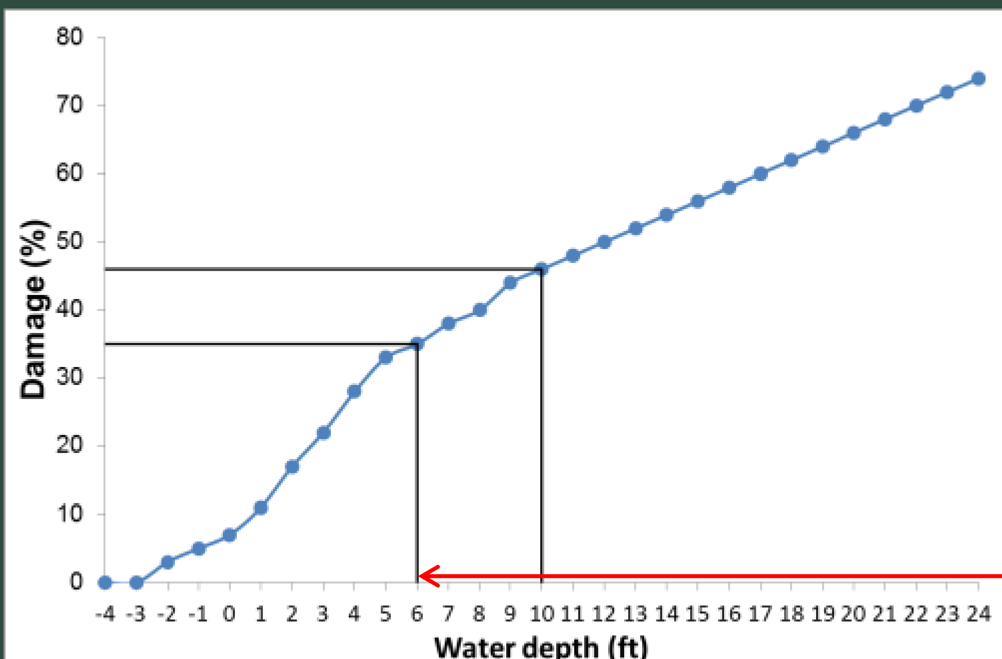
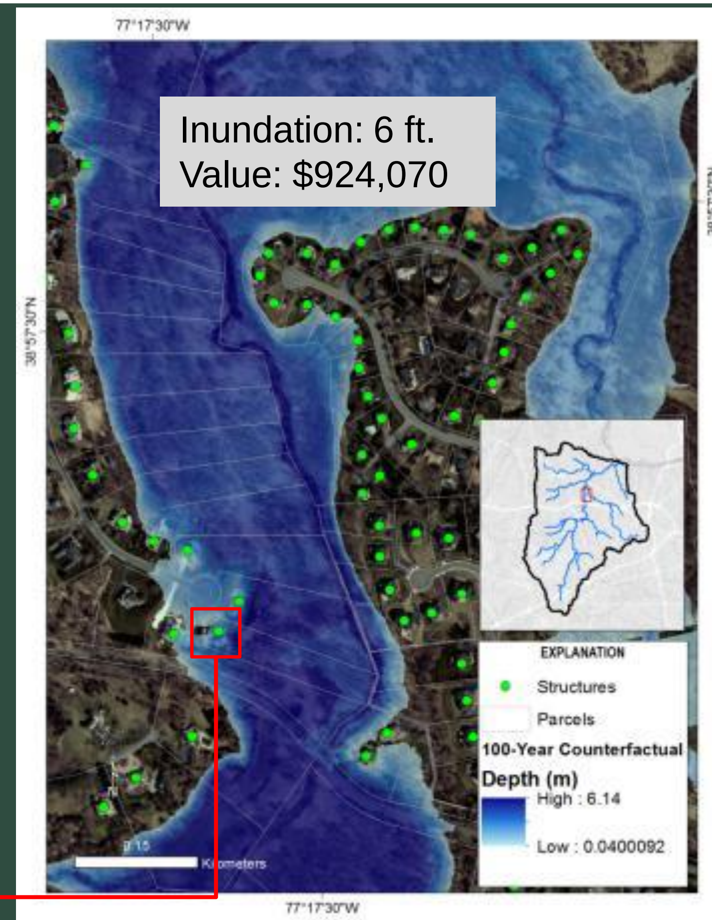
Estimating Flood Damages

- **Depth-Damage curves**





Basemap imagery from ESRI and Digital Globe data
Value based on Fairfax County assessed building estimate

Results suggest an annual value of $73,412 for flood mitigation in Difficult Run
(damages in baseline: $115,596
damages in counterfactual: $42,184)

https://doi.org/10.1016/j.jenvman.2018.10.023

Questions???

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