Effectiveness of stormwater management practices in protecting stream channel stability

2: Stormwater Management Assessment, under Theme A: Effectiveness of Restoration Programs at the Watershed Scale

4: Climate Change Impacts to Restoration Practices

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How can we develop land and protect streams?

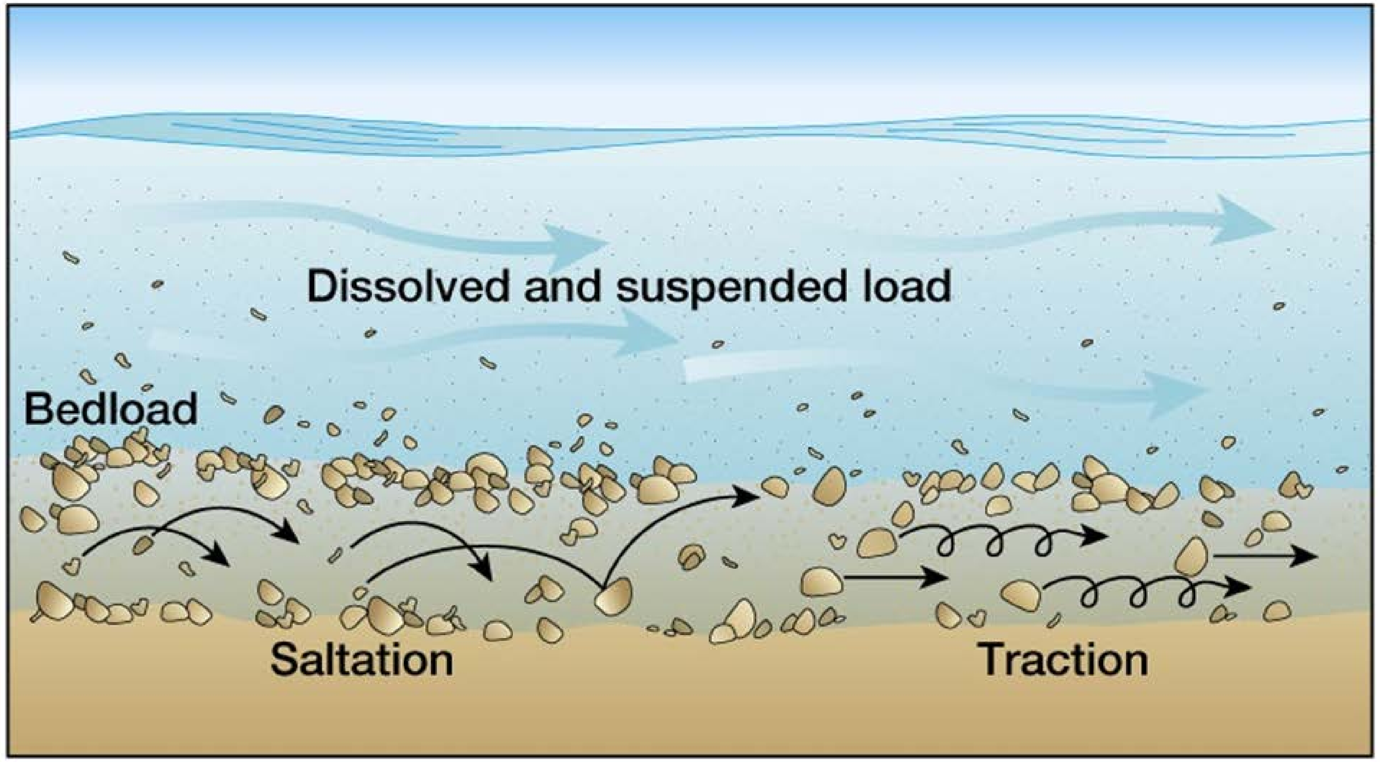
1. Does environmental site design (ESD) protect channel stability under current and future climate?

While ESD provides environmental benefits, it does not protect channel stability.

2. How can we "tweak" ESD to protect channel stability?


Gentle
Reminders!

In this talk, “sediment” is not a four-lettered word.



- Coarse sediment is naturally transported in suspension and along the channel bed.
- Fine sediment does not play a major role in channel morphology.

In this talk, stream "stability" means the channel is not becoming deeper and/or wider

Google Earth

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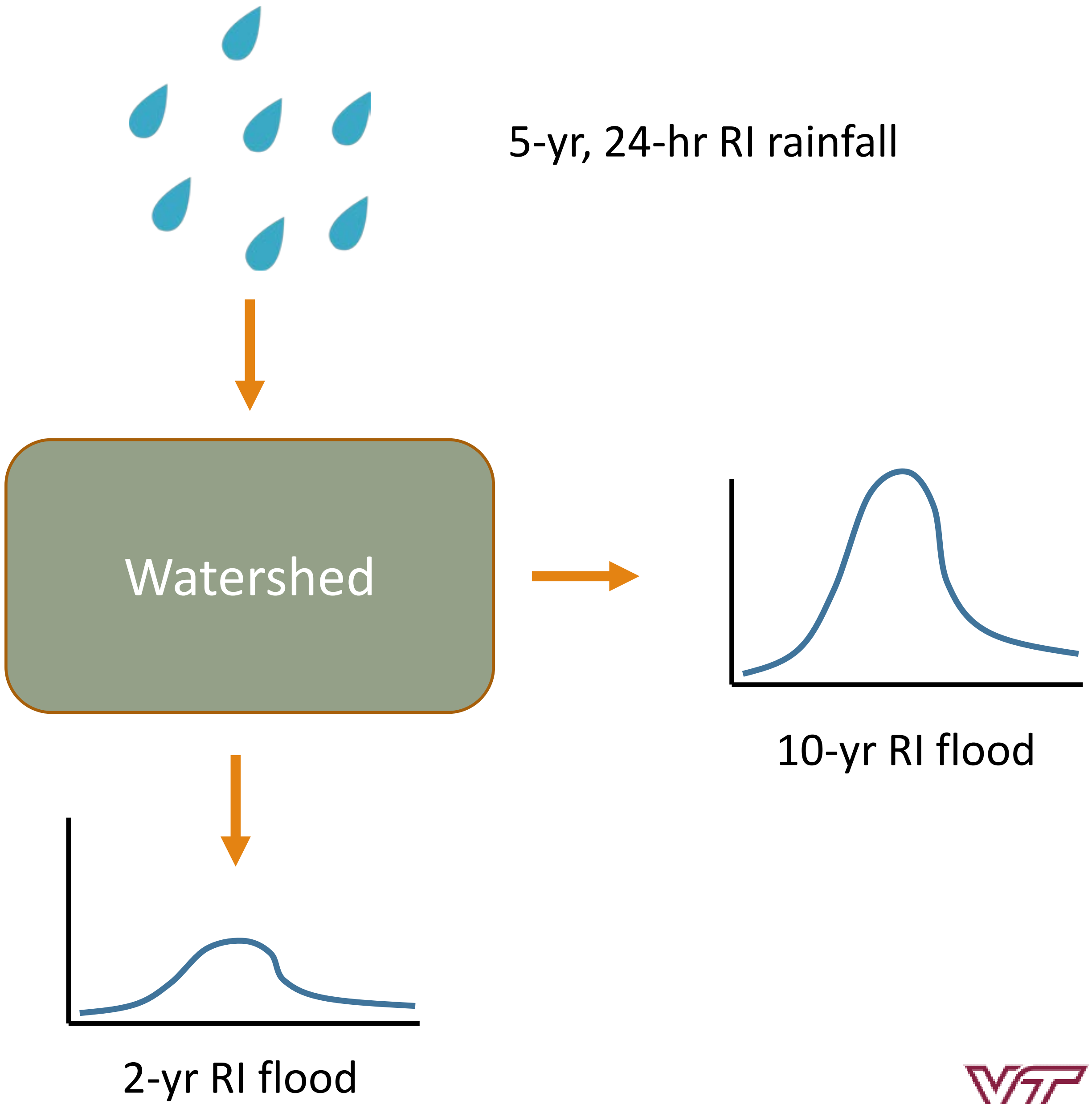
The X-yr storm event does not produce the X-yr flood,

where X = 1, 2, 10, 100…



All models are wrong, but some are useful

- George Box, British statistician

Adjust the model to match observed conditions.

Apply common sense.

http://www.clipartpanda.com/clipart_images/reality-check-ahead-59860852

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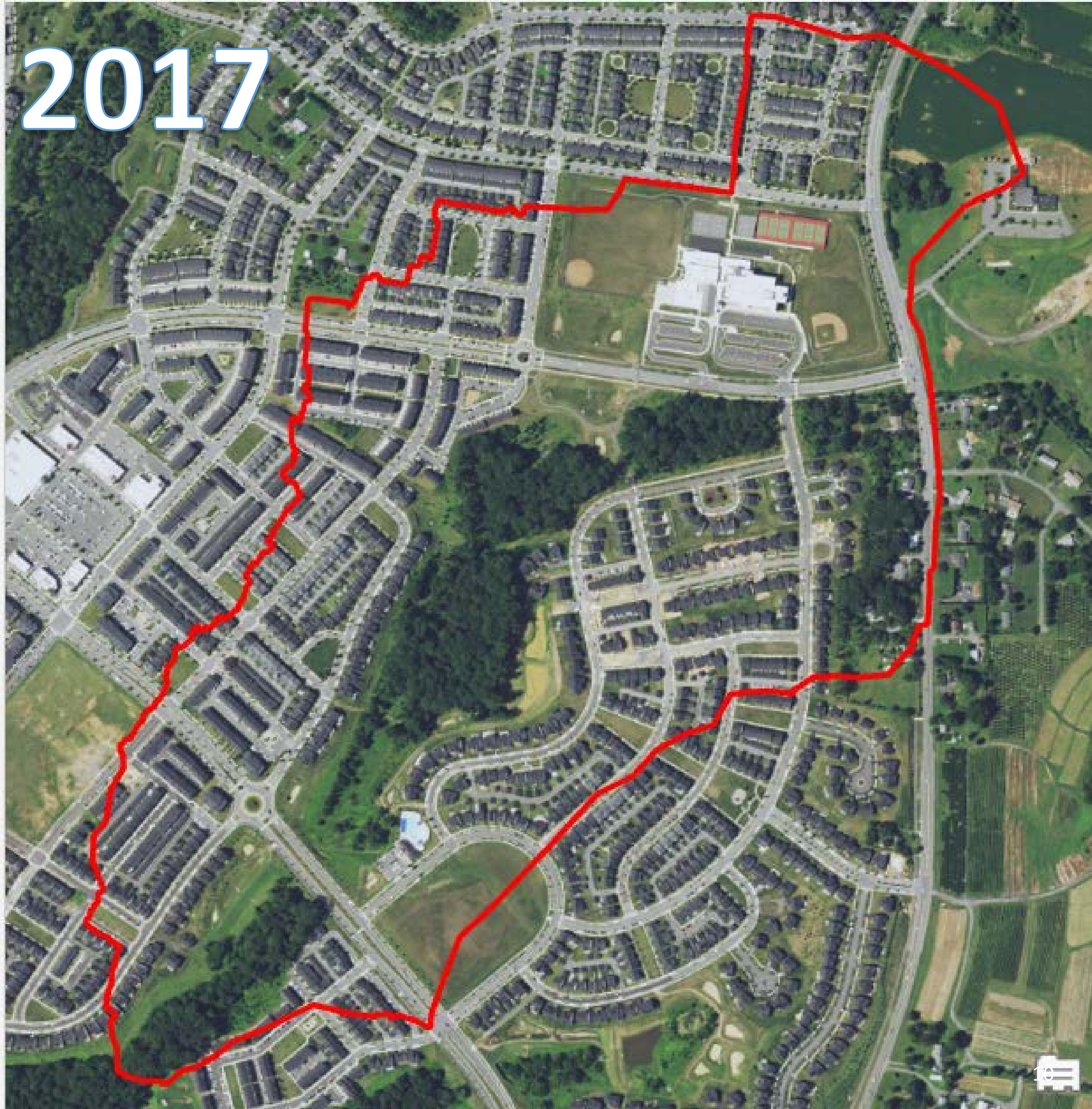
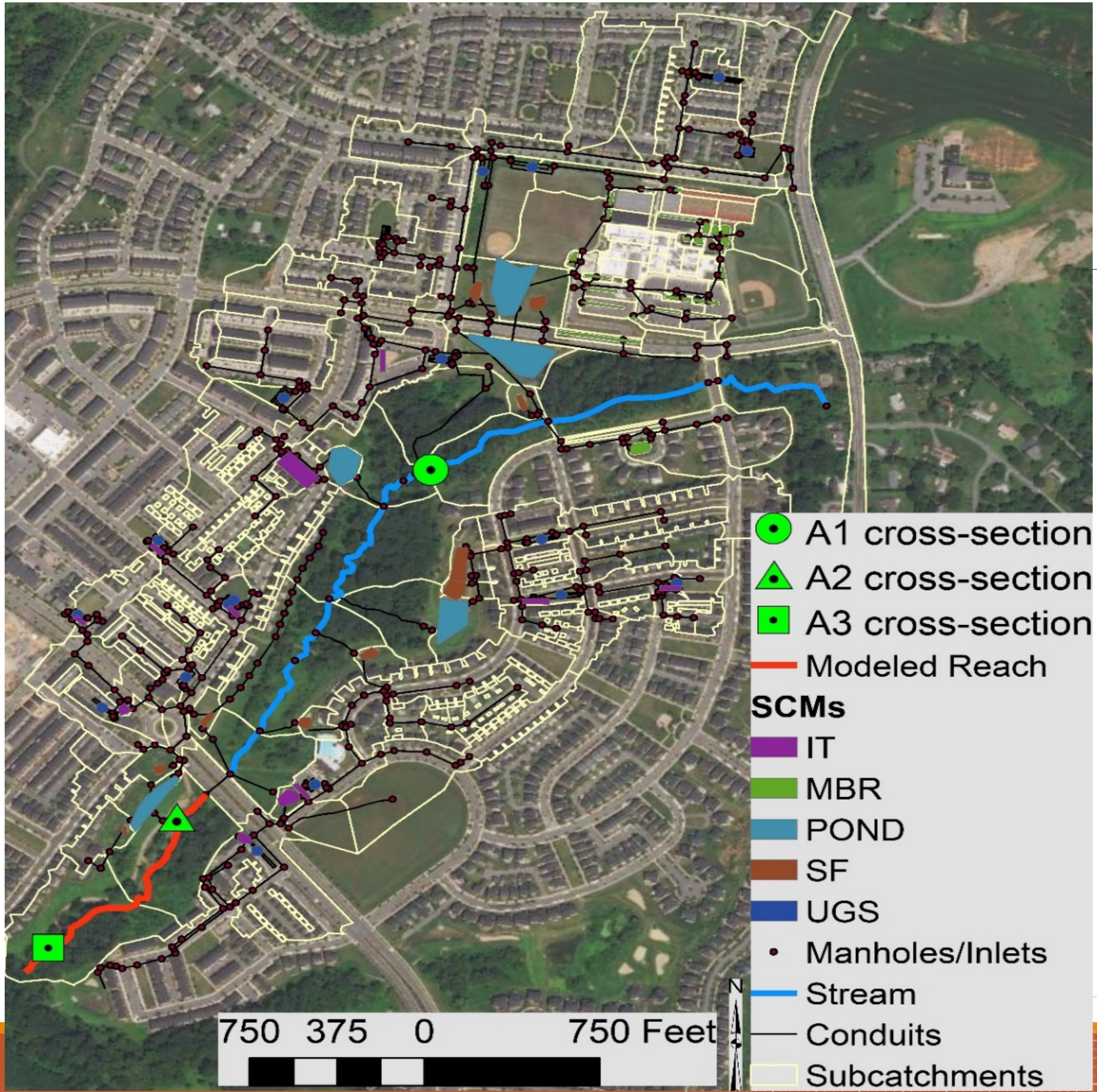
Ok, let’s talk research…

Tributary 109 to Little Seneca Creek served as a case study

- 0.3 mi^2 drainage area, 44% TIA
- Developed 2006 - 2016
- USGS stream gage (2004)
- USGS rain gage
- Montgomery County data
  - Cross sections
  - Longitudinal profiles
  - Pebble counts
- Multiple lidar datasets

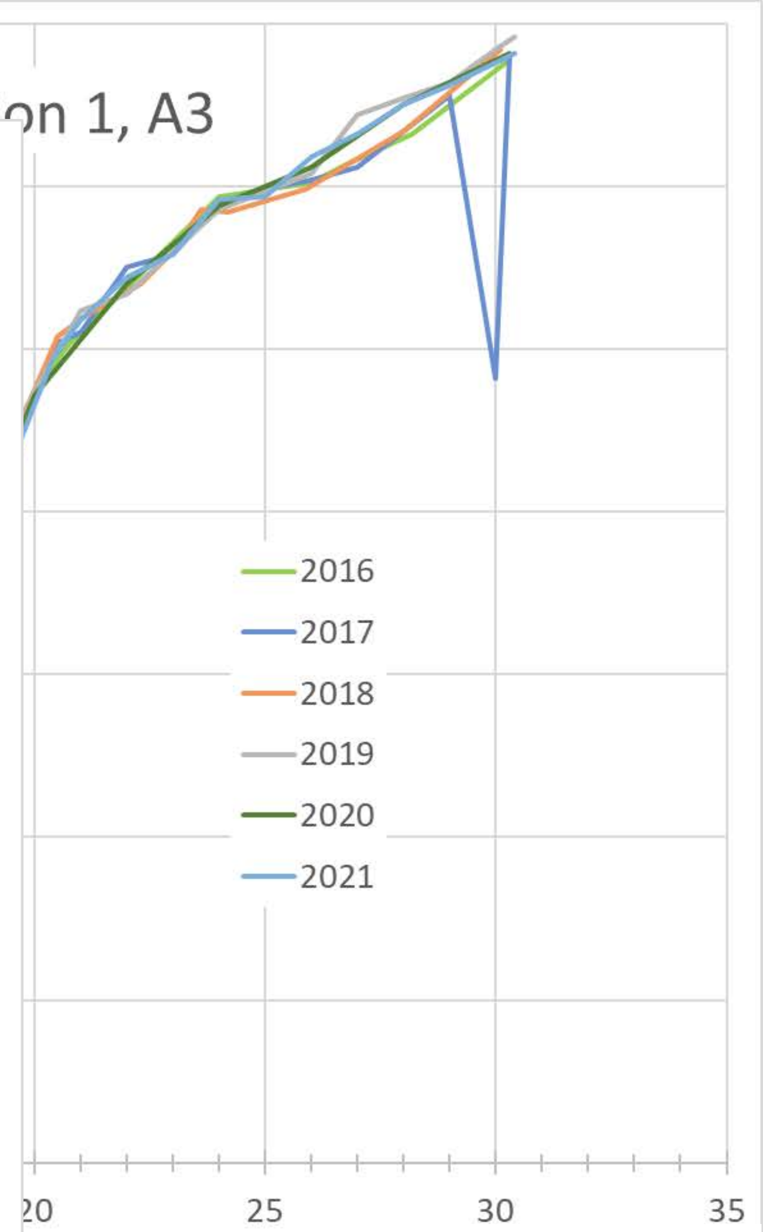


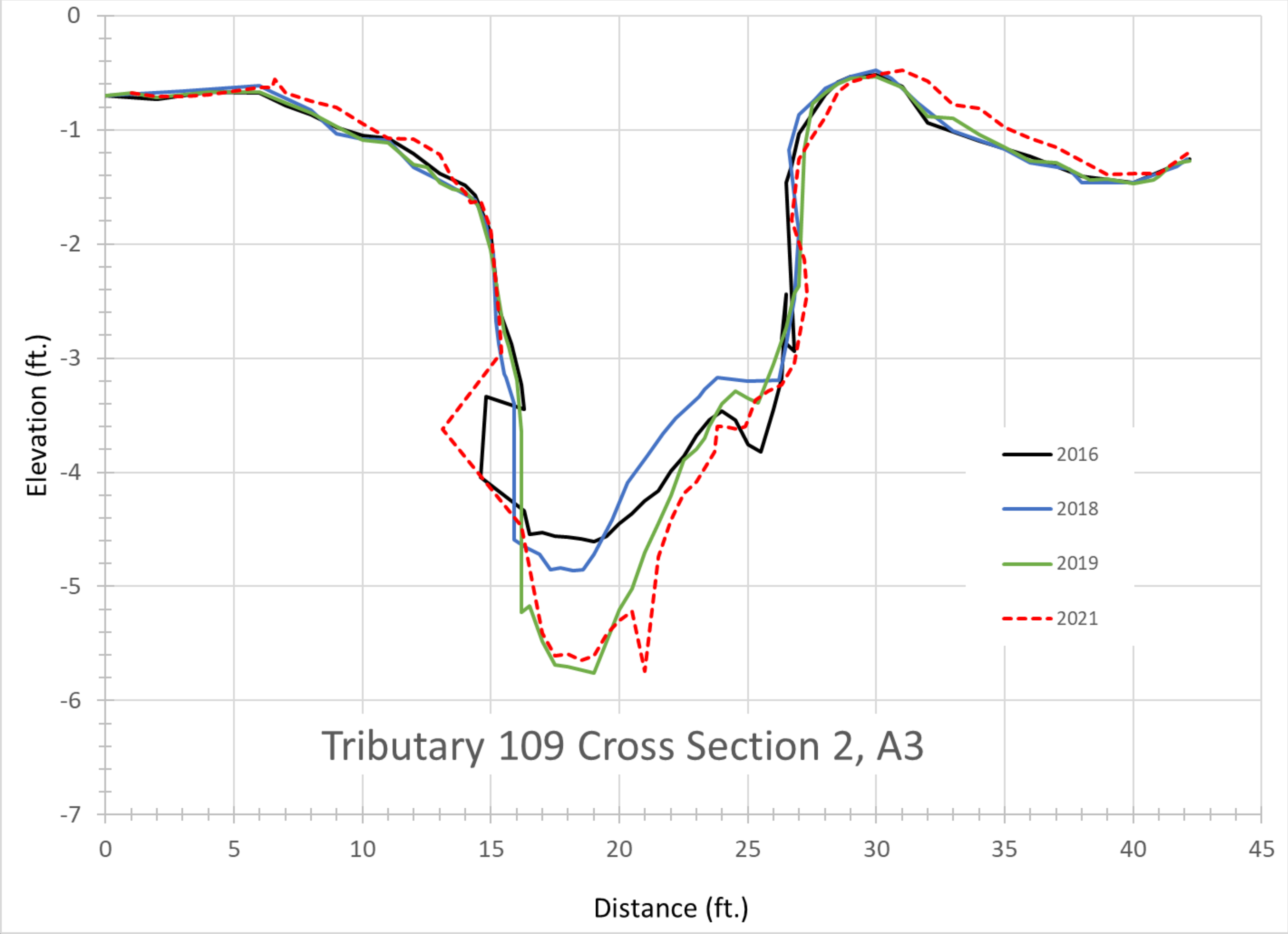


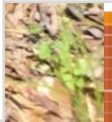
Stormwater system was designed to meet the 2008 ESD requirements:

- 5 ponds
- 26 micro bioretention (MBR)
- 10 infiltration trenches (IT)
- 11 sand filters (SF)
- 18 underground storage facilities (UGS)

“Distributed” stormwater control practices







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Channel stability is a two-part problem

Water

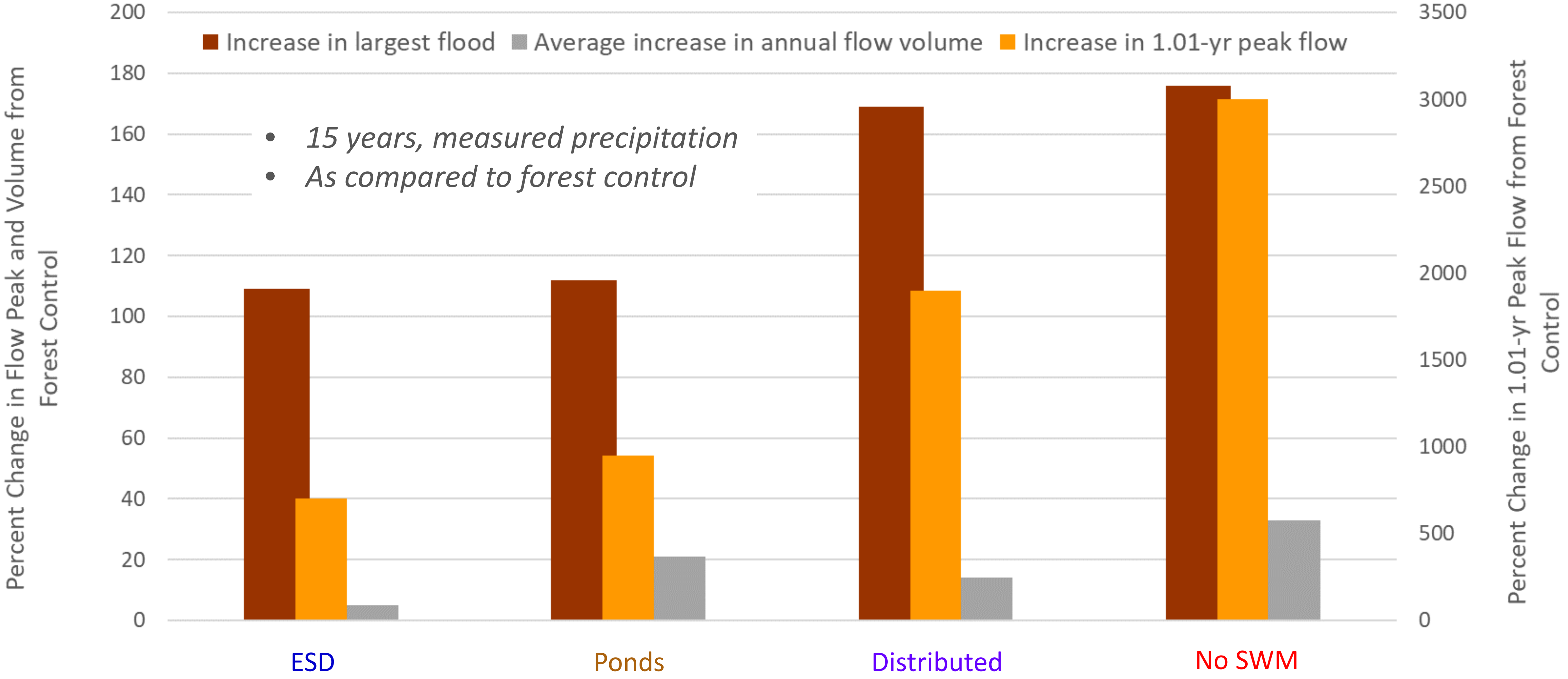
SWMM
Storm Water Management Model

Sediment

HEC-RAS 6.2

Results…

Both ponds (storage) and distributed SCMs are needed to minimize hydrologic impacts of development



In the future, due to climate change…

- Precipitation will generally occur more frequently.
  - Example: the 50th percentile of *time between storms* will decrease from 3 to 2 days.
- However, when there are droughts (time between storms >5 days), they will last longer.
- Change in maximum flow (over 59 years) ranges from a decrease of 18% to an increase of 117% over current conditions.

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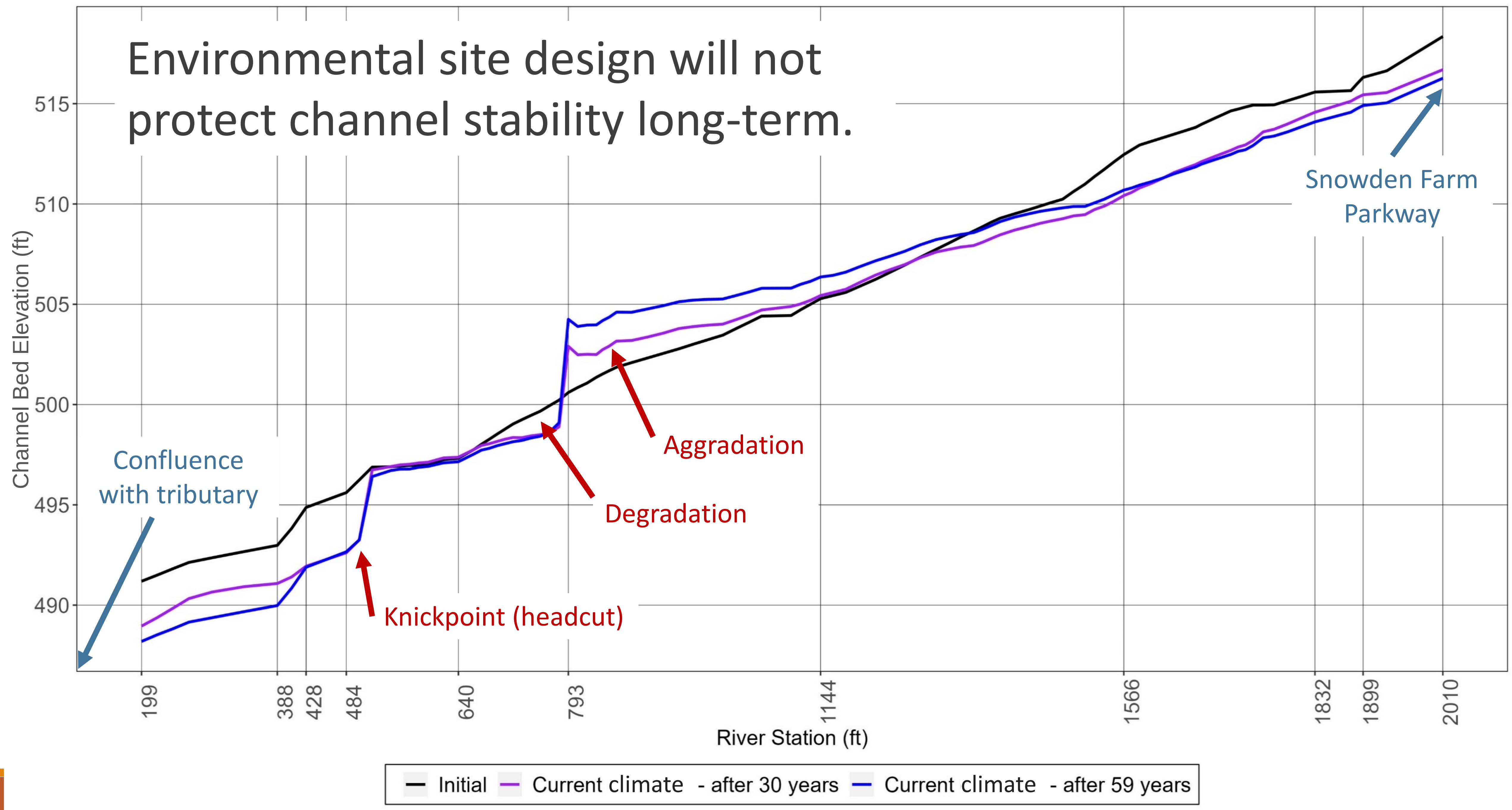
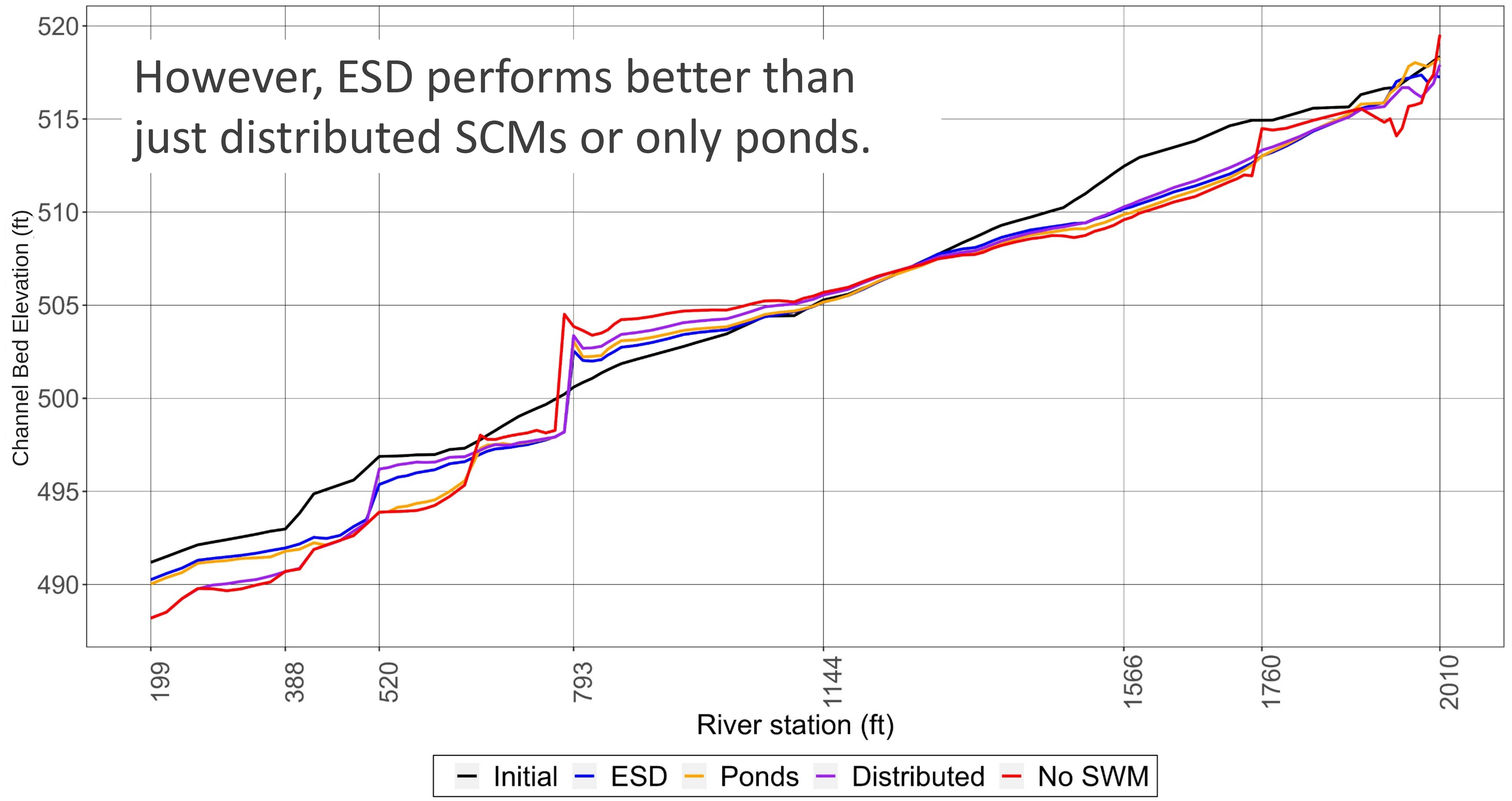
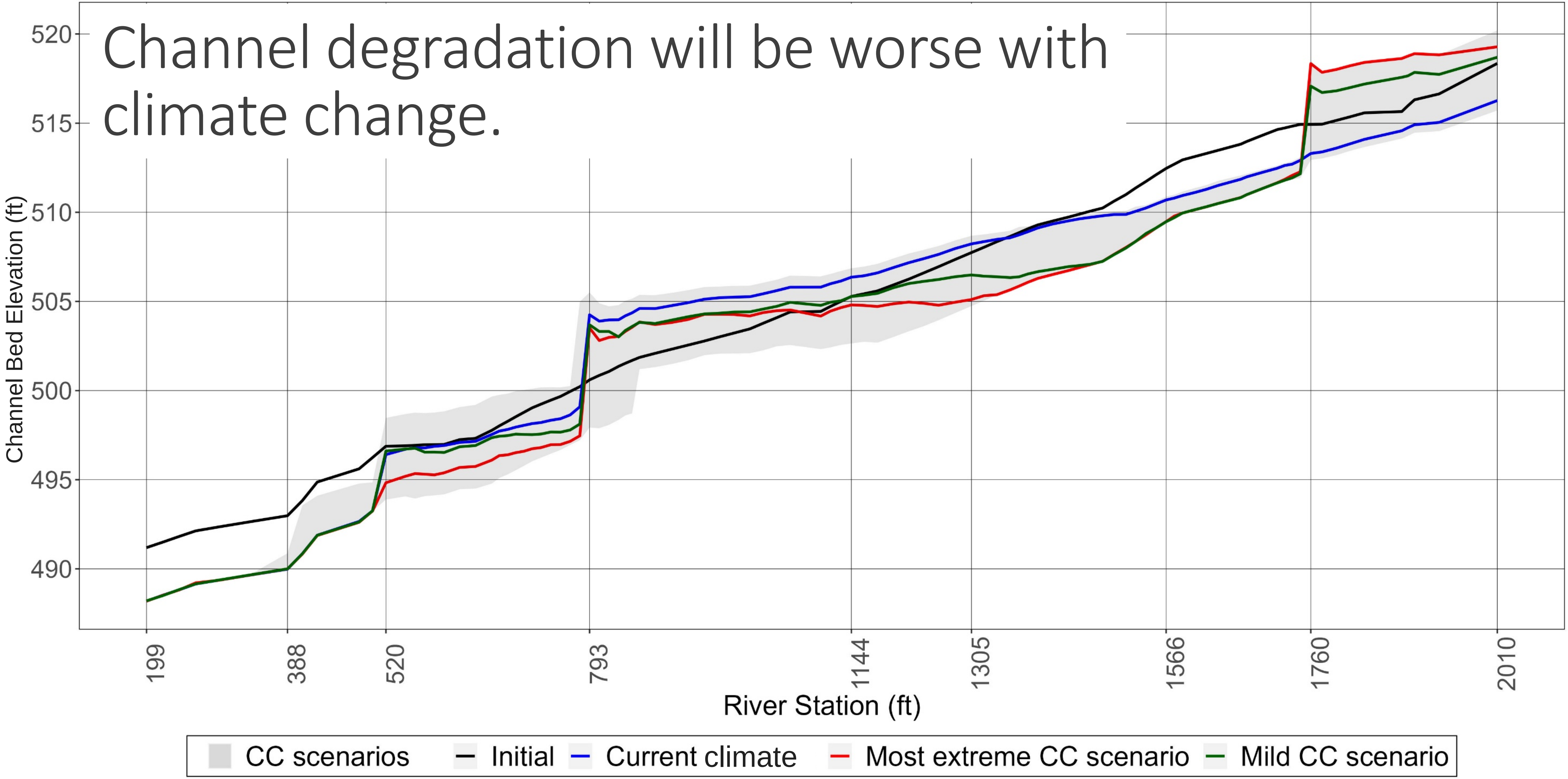
What does the change in hydrology mean for channel stability?

Environmental site design will not protect channel stability long-term.




However, ESD performs better than just distributed SCMs or only ponds.
Channel Bed Elevation (ft)
520
515
510
505
500
495
490
199
388
520
793
1144
1566
1760
2010
River station (ft)
Initial
ESD
Ponds
Distributed
No SWM

Channel degradation will be worse with climate change.



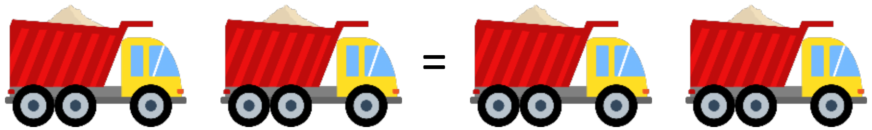
Where do we go from here?

geograph.org.uk

To protect channel stability, we need to consider sediment transport in the receiving stream.

1. Maintain pre-development erosion potential (Washington State)
   - ➢ Total mass sediment transported for a given duration

Pre-development = Post-development



- ➢ for continuous simulation
- ➢ for design storms

2. Maintain pre-development excess shear stress (Santa Clara, CA)
   - ➢ Total “excess shear stress” for a given duration

$$(\tau - \tau_c)$$

https://www.vhv.rs/

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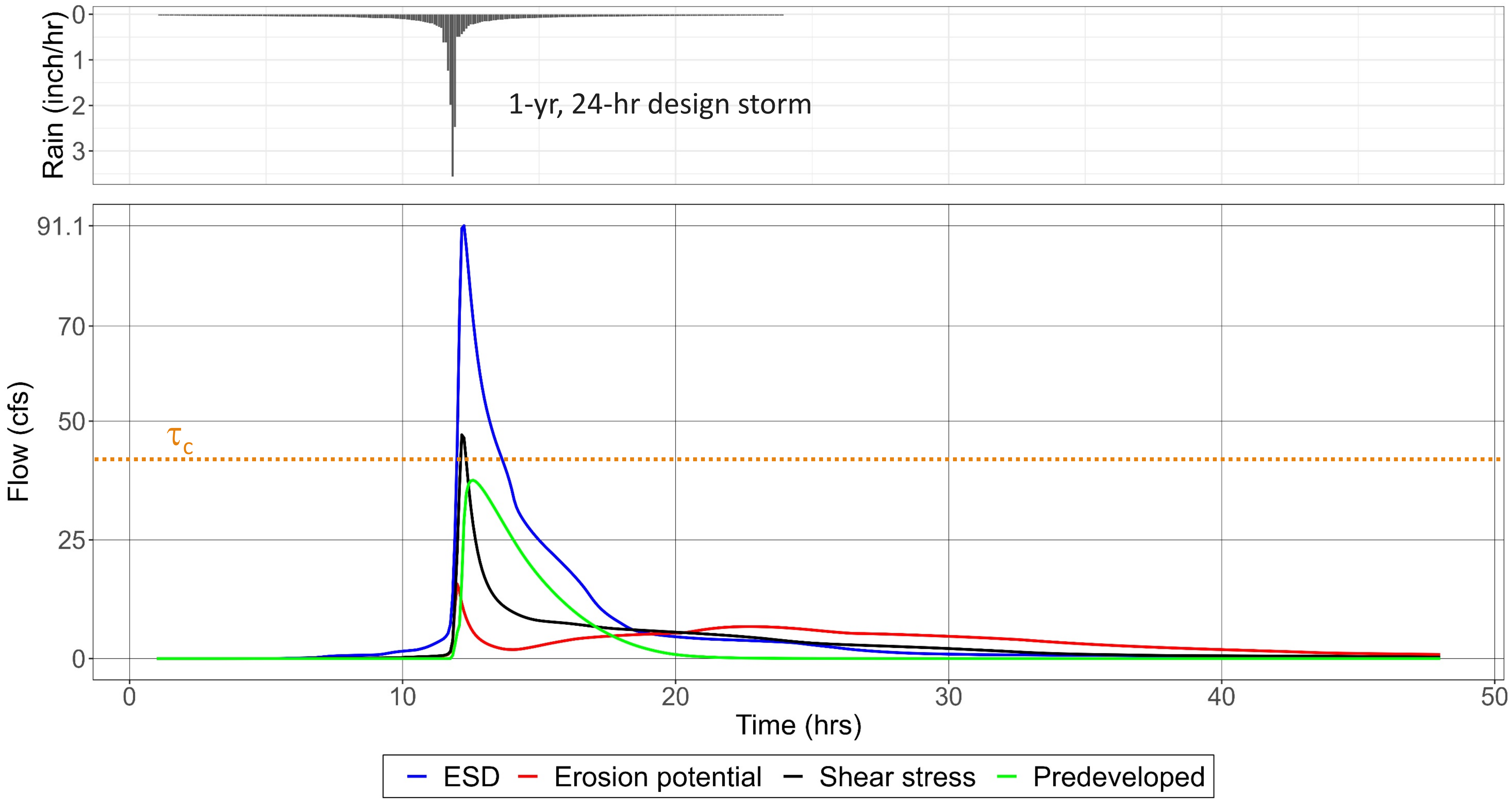
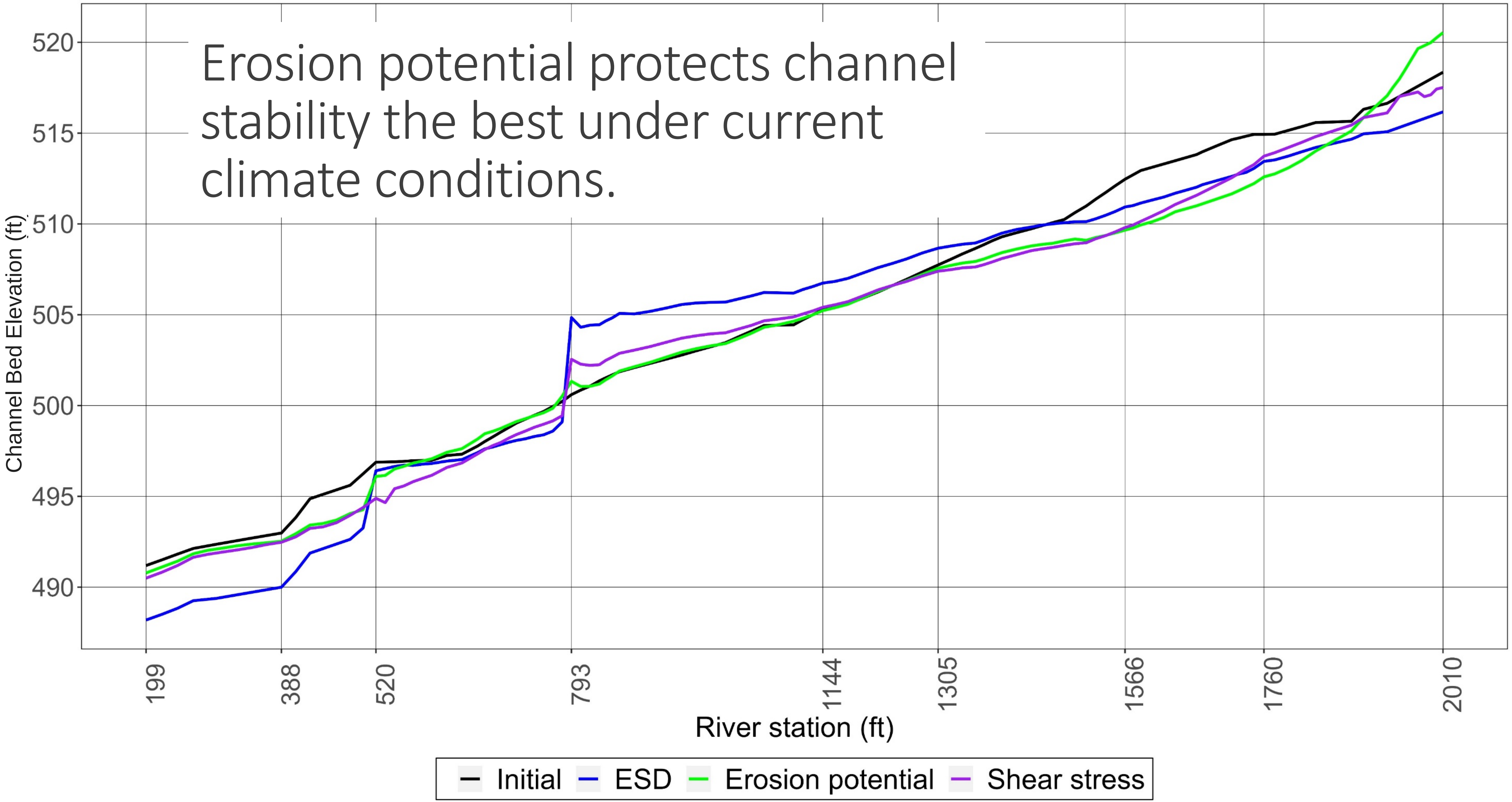
Hawley, Robert J., Kathryn Russell, and Kristine Taniguchi-Quan. 2022. “Restoring Geomorphic Integrity in Urban Streams via Mechanistically-Based Storm Water Management: Minimizing Excess Sediment Transport Capacity.” Urban Ecosystems 25 (4): 1247–64. https://doi.org/10.1007/s11252-022-01221-y.

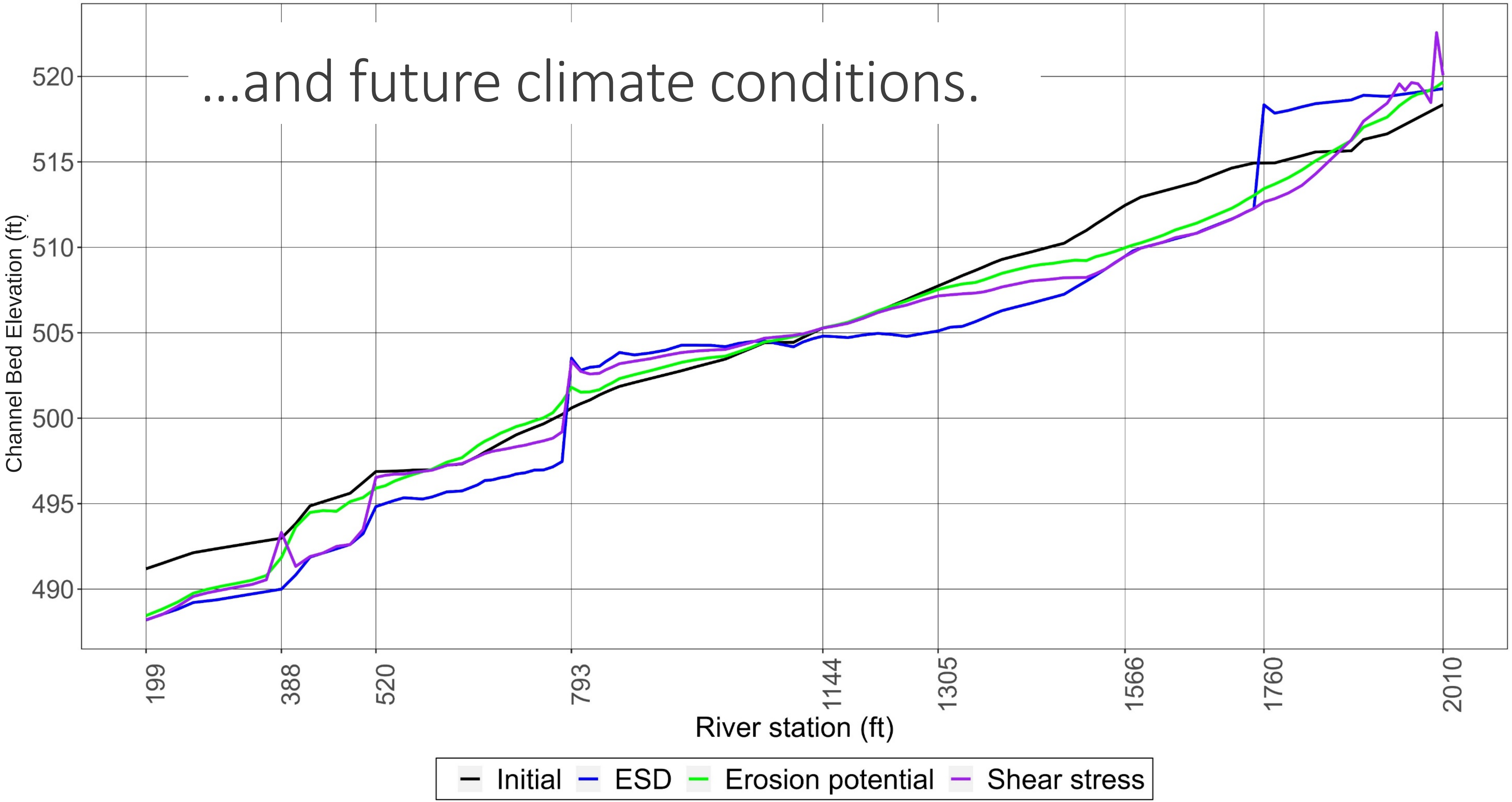


Rain (inch/hr)
0
1
2
3
1-yr, 24-hr design storm
91.1
70
50
25
0
Flow (cfs)
τc
0
10
20
30
40
50
Time (hrs)
ESD
Erosion potential
Shear stress
Predeveloped

Erosion potential protects channel stability the best under current climate conditions.



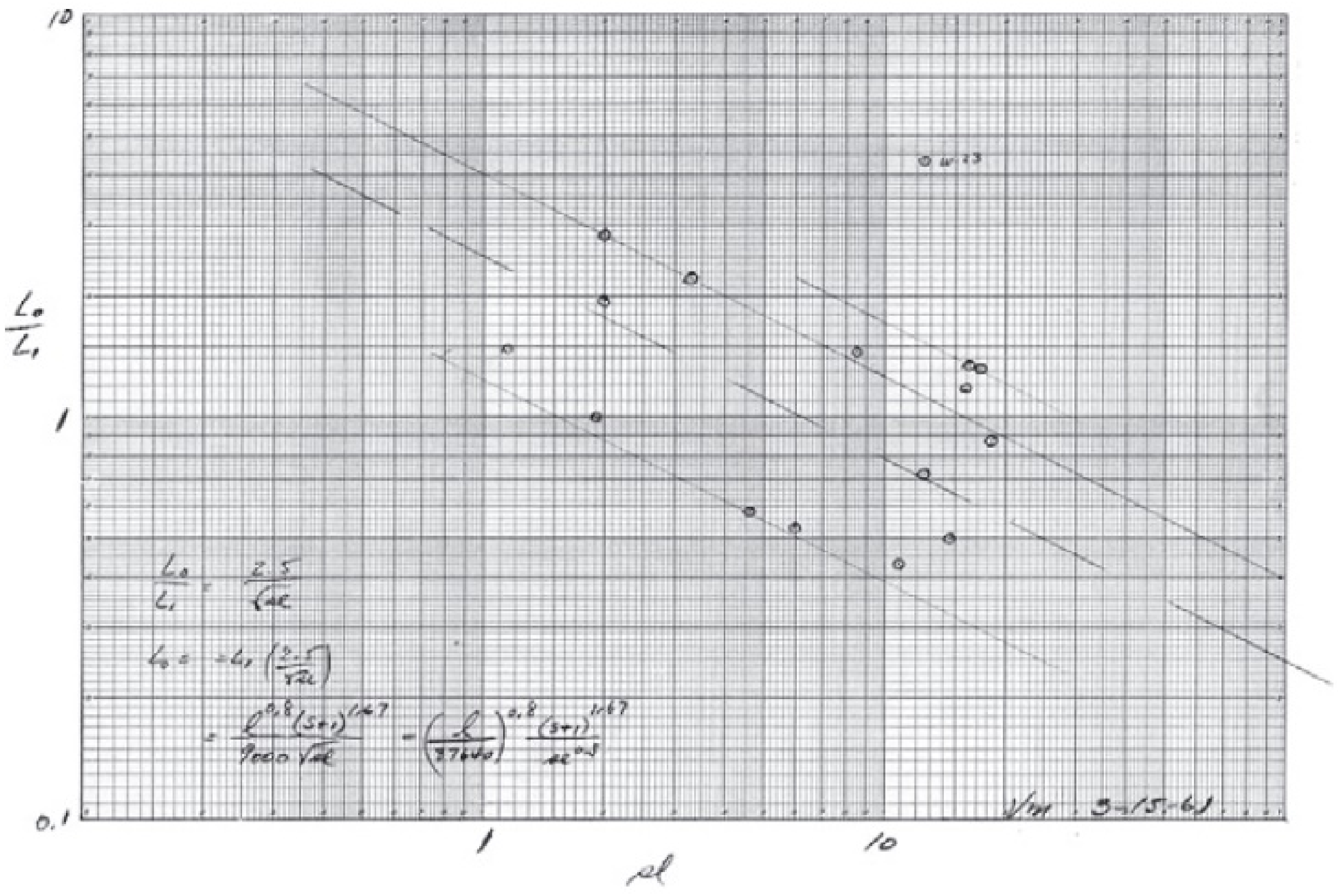
…and future climate conditions.



Summary

- Design storms do not translate directly to watershed response.
- Infiltration practices reduce annual runoff, but do little to reduce peak flows.
- Stormwater storage (ponds) is needed to manage high flows.
- Environmental site design is an improvement over conventional stormwater management, but will not protect channel stability.
- Climate change will exacerbate existing deficiencies in ESD.
- To protect channel stability, stormwater management needs to be designed to meet sediment transport targets.
- Erosion potential shows the most promise for protecting channel stability.
- Continuing this work with Minebank Run case study

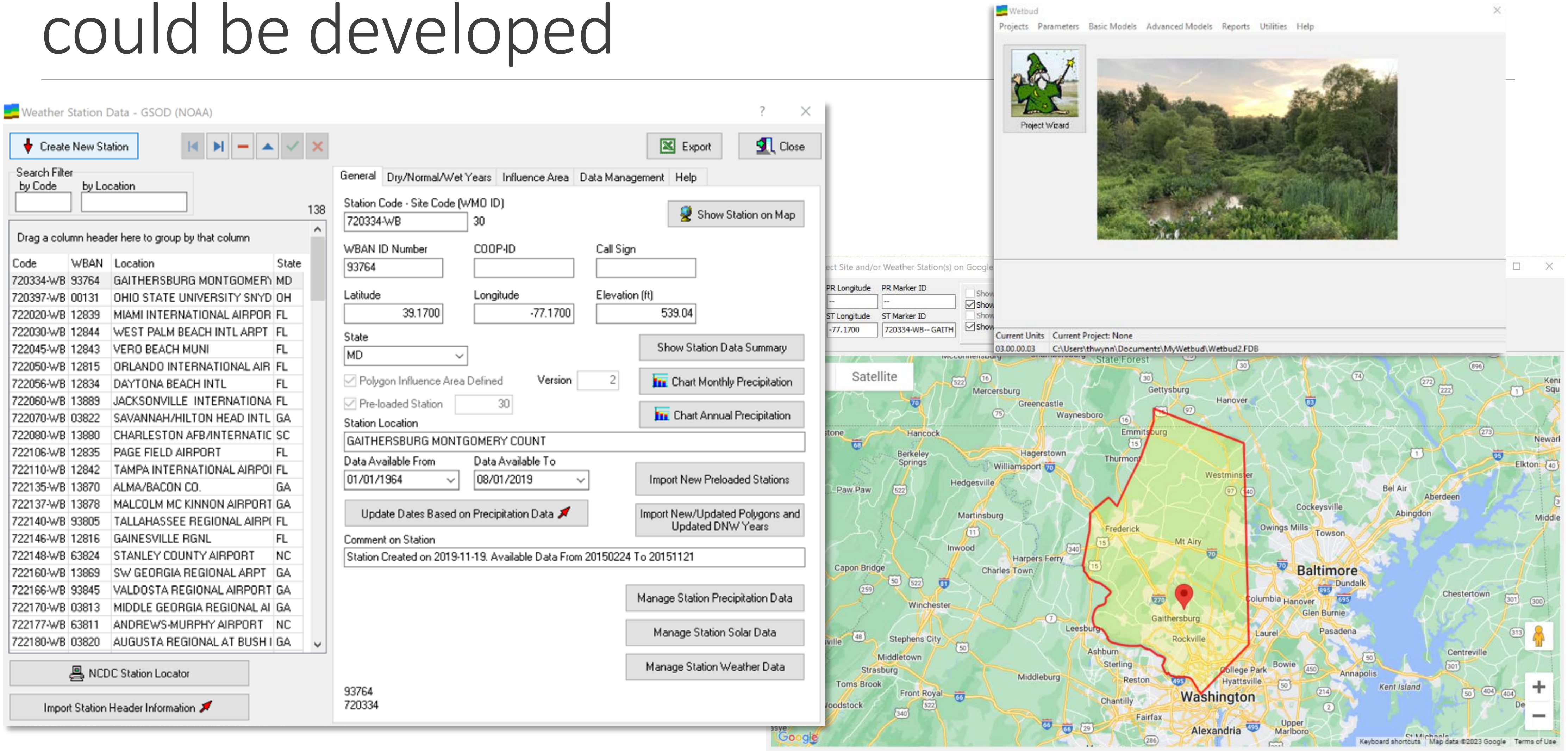
Recommendations



1984 computing power

Parade.com

Software with Maryland-specific climate data could be developed



Wetbud was developed for mitigation wetland design

Acknowledgment Slide

We thank the many partners who support the Restoration Research program for their funding and interest. Major funding for this phase of the work was provided by the U.S. Environmental Protection Agency. We also thank the US Geological Survey and Montgomery County for sharing data and their personal observations of Tributary 109.

What are the take home points?
What does this mean for me?

TRANSLATION SLIDES BY [INSERT POOLED MONITORING ADVISORY COMMITTEE MEMBER NAME HERE]

What does this mean for me?

PMAC member add take-home points of the presentation

What does this mean for me?

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

PMAC member add ~2 ideas here

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

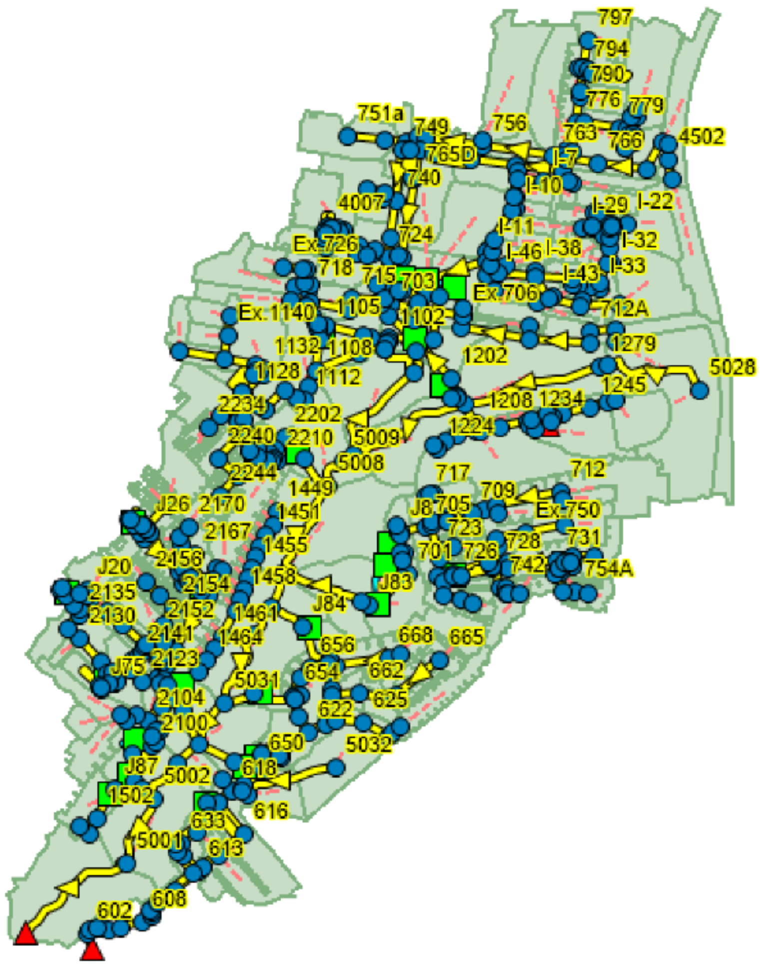
PMAC member add ~2 ideas here

You are done!

Thank you for your hard work to do the research, communicate it clearly to the audience, and translate this into something the audience can do with the information in their work tasks.

SWMM model development

1. Watershed characteristics and stormwater infrastructure attributes entered into models
2. Models calibrated based on observed USGS flow data
3. Calibrated models used to explore 4 stormwater management and 64 climate change scenarios
4. SWMM-modeled stream discharge used as input to HEC-RAS model



HEC-RAS quasi-unsteady, 1-D model development

1. Lidar data and measured cross sections used to create channel geometry
2. Bed particle counts, bulk sediment samples, and USGS suspended sediment data (Fairfax, VA) used to parameterize sediment transport routines
3. Calibrated HEC-RAS to USGS stage data and measured cross section change
4. Modeled channel response to stormwater scenarios and climate change scenarios using SWMM output
5. Evaluated effectiveness of alternative stormwater management design techniques to protect channel stability