Can Stormwater Management Regulations Protect Channel Stability Following Development?

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Paying for good stormwater management now means you don't pay to fix things later.

Before we talk research…

Maryland stormwater history in brief…

Before many of you were born (1984)
- No statewide stormwater regulations
- Local regulations largely focused on flood control

Before some of you were born (1984-2000)
- Statewide stormwater regulations for peak flow control
- Local water quality regulations to treat runoff from first ½" of rainfall

Thanks Stew Comstock!!

2000-2007: Unified stormwater sizing criteria (USC)
- Water quality volume - capture and treat runoff from 1" of rainfall
- Channel protection volume – detain runoff from 1-yr, 24-hr design storm for 12-24 hours – no peak flow control – no flow routing required

2008+ Environmental site design (ESD)
- Required better site planning and use of LID/GI before traditional stormwater ponds
- Changed method for calculating required storage/infiltration volume, resulting in reduced storage

Virginia's Energy Balance method

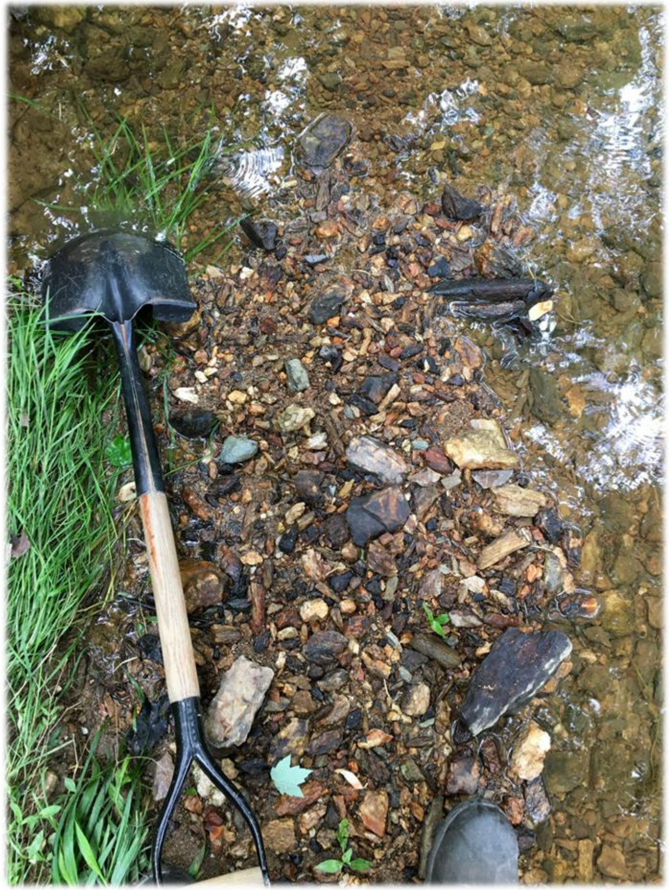
Stormwater design for channel protection based primarily on peak flow control

- Post-development peak flow calculated as:

$$q_{post} \le q_{pre}\left(\frac{Vol_{r,pre}}{Vol_{r,post}}\right) IF$$

- $Vol_{r,post}$ can be reduced using distributed, low impact development practices (Runoff Reduction method)
- Improvement Factor (IF) further reduces post-development peak flow by 80-90%

How do streams “work”?



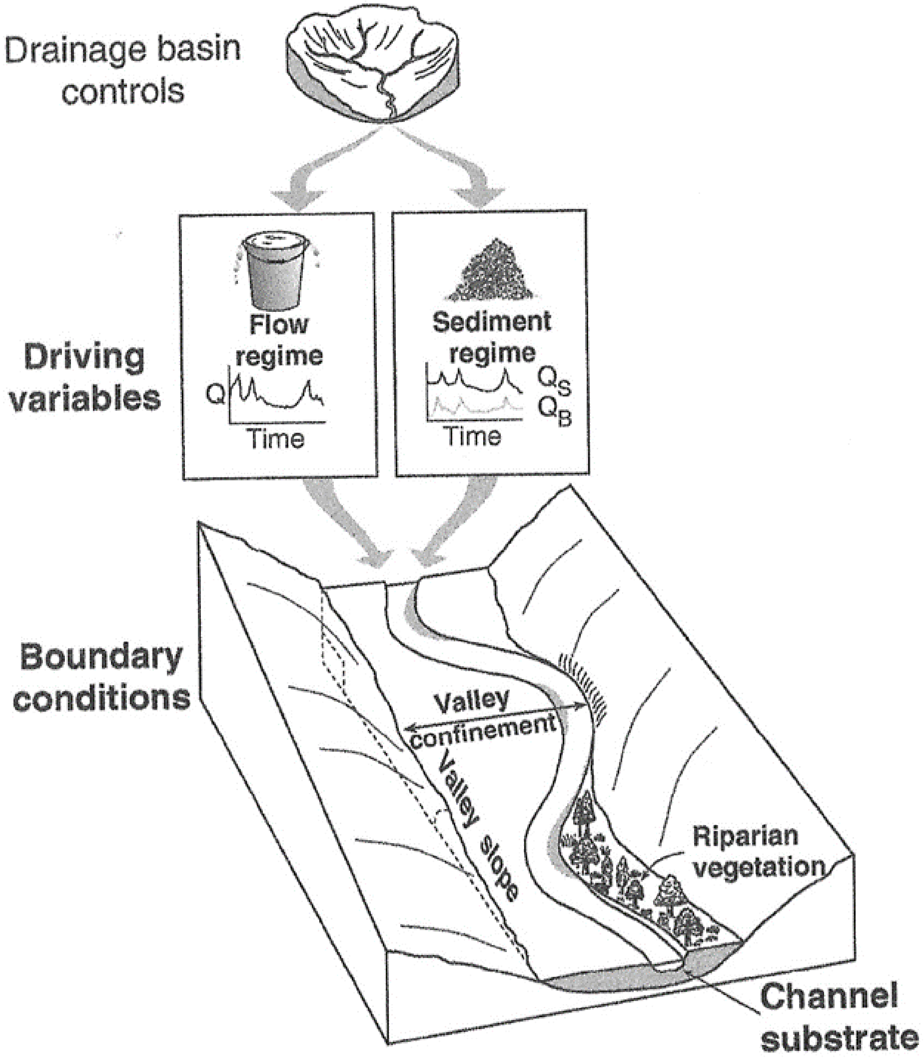
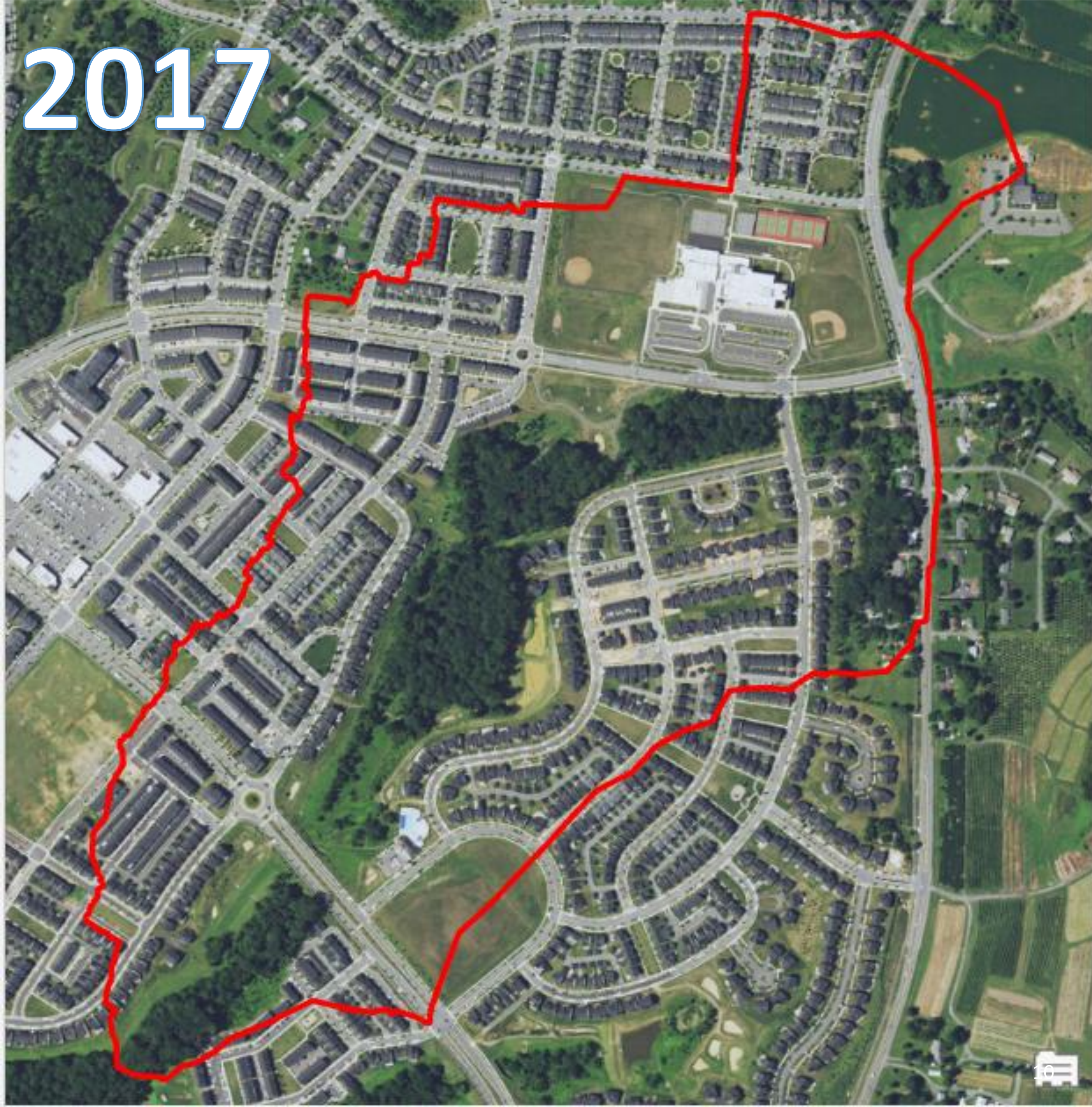


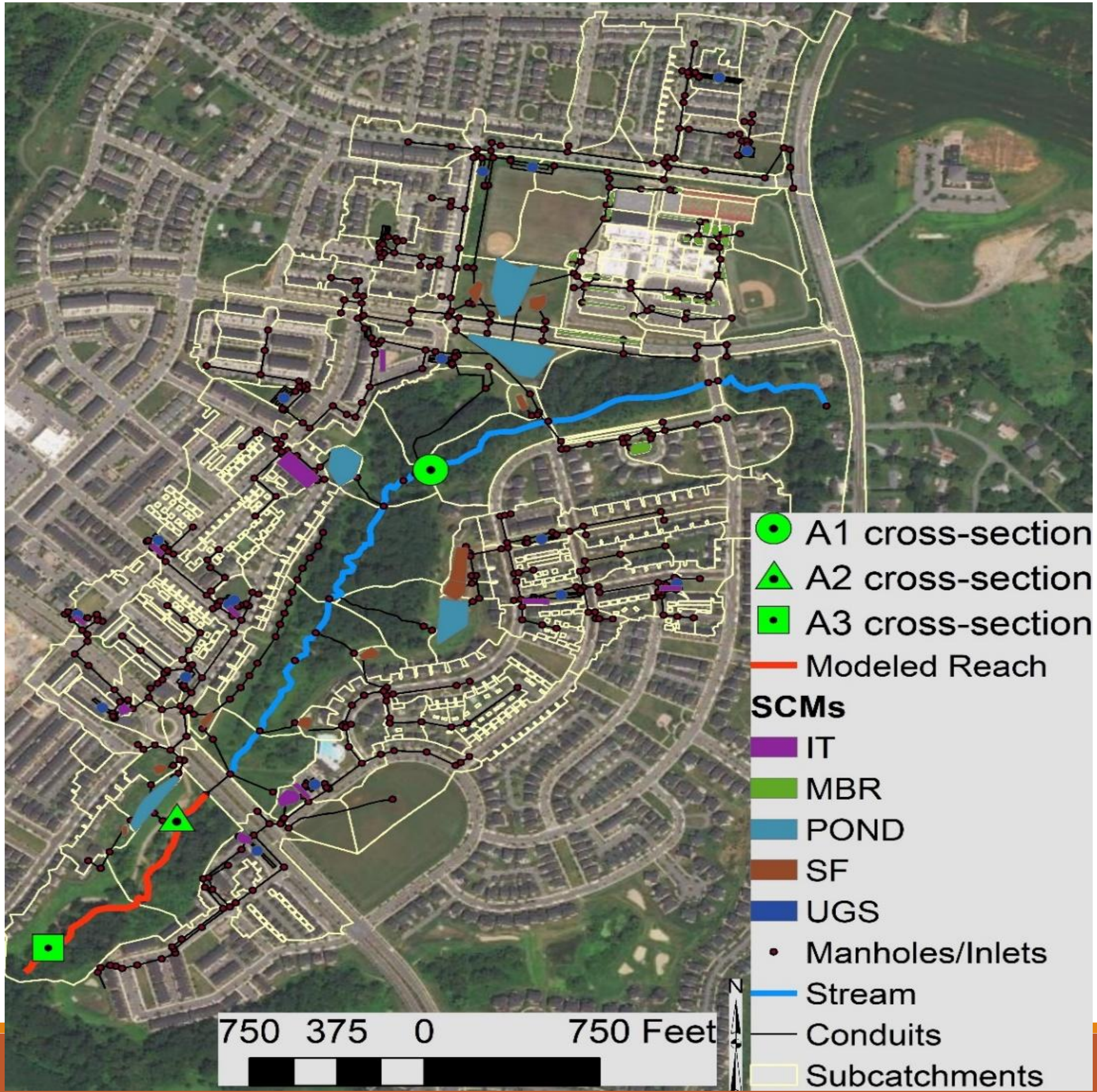
Figure 8.1 The driving variables and boundary conditions that control the form of a channel reach.

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 2000 Unified Stormwater Sizing Criteria (USC):

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

"Distributed" stormwater control practices

Channel stability is a two-part problem

Water

SWMM

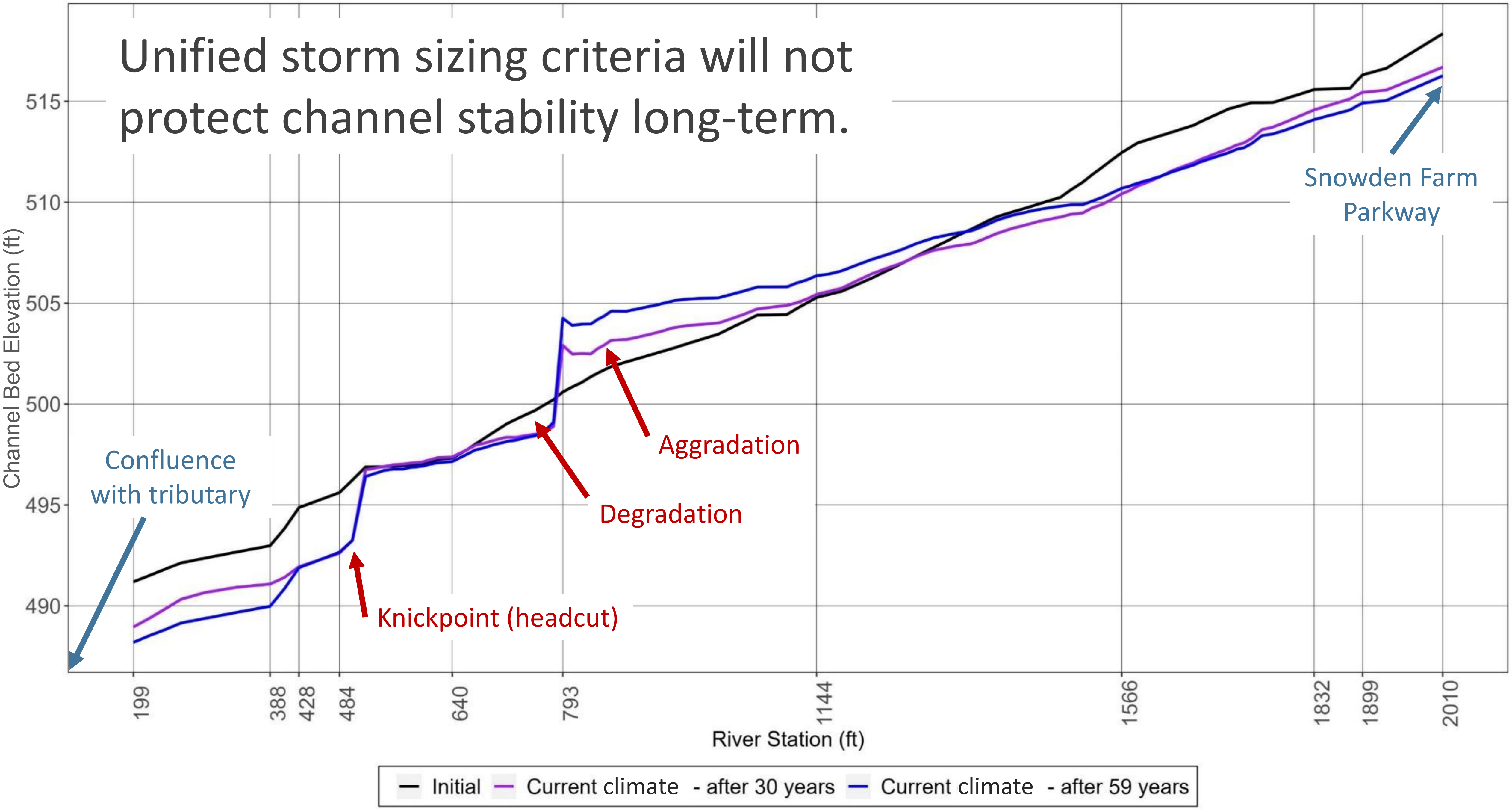
Storm Water Management Model

Sediment

HEC-RAS 6.2

Results…

Unified storm sizing criteria will not protect channel stability long-term.

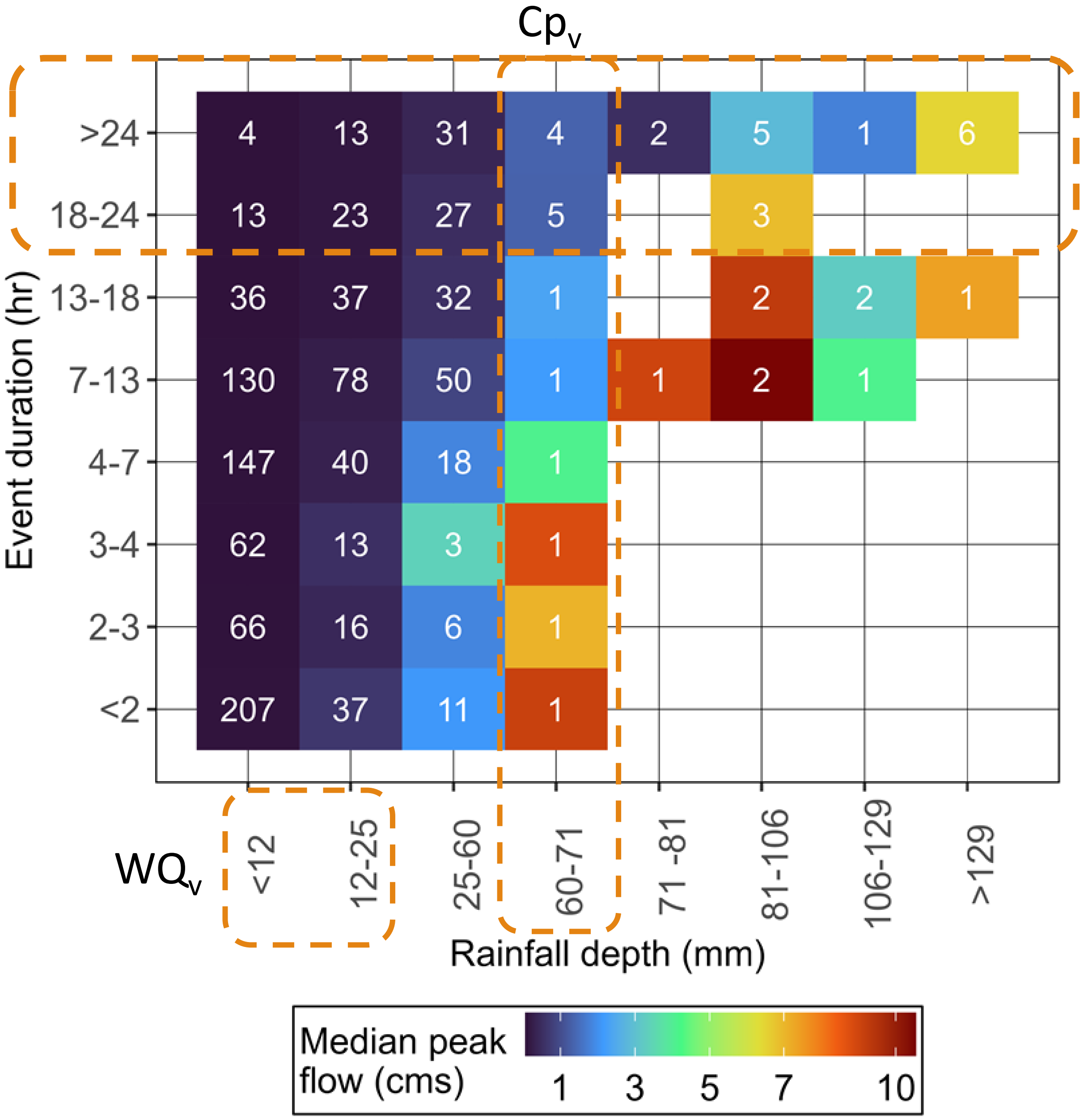


How can we develop land and protect streams?

1. Do Maryland stormwater regulations protect channel stability?

   While the 2000 regulations reduce the impact of urban development, they will not protect channel stability long term.

2. Why?
3. How can the regulations be improved?



Event duration (hr)	<12	12-25	25-60	60-71	71-81	81-106	106-129	>129
>24	4	13	31	4	2	5	1	6
18-24	13	23	27	5		3		
13-18	36	37	32	1		2	2	1
7-13	130	78	50	1	1	2	1	
4-7	147	40	18	1				
3-4	62	13	3	1				
2-3	66	16	6	1				
<2	207	37	11	1				

- 1141 individual rainfall events
- 81% of the storm events had depths <1”
  - **The water quality volume will treat the majority of storm events**
- Wide range of runoff rates from the 1-yr recurrence interval storm event (Cp$_v$)
  - **Regulations and extended detention design standard focus on detaining runoff volume, not reducing peak flows**
- 24-hr duration storm events produce lower peak runoff than shorter-duration, higher intensity storms
  - **In small, urban watersheds, runoff depends most on rainfall intensity, not rainfall depth over 24 hrs**

Why do Maryland stormwater regulations not protect channels?

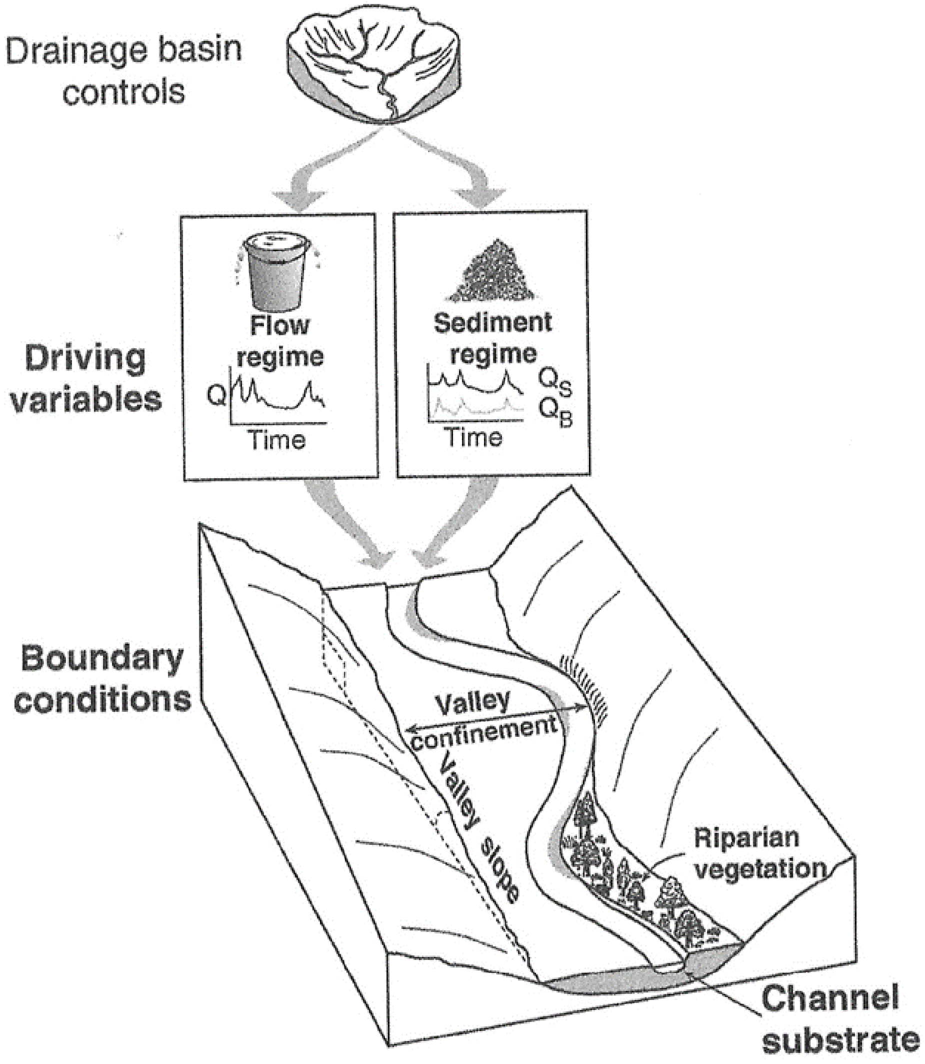


Figure 8.1 The driving variables and boundary conditions s that control the form of a channel reach.

VIRGINIA TECH

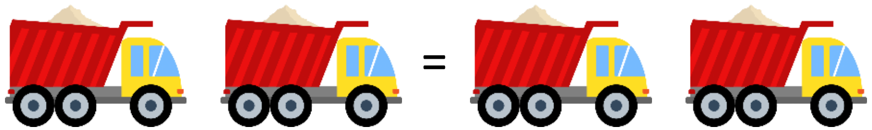
Where do we go from here?

geograph.org.uk

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

1. Maintain pre-development erosion potential
   - ➢ 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
   - ➢ Total "excess shear stress" for a given duration

$$(\tau - \tau_c)$$

https://www.vhv.rs/

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.

We evaluated two different design criteria for stormwater storage that focus on sediment transport.

1-, 2-, 5-yr 24 hr. design storms

Outlet Hydrograph

Cumulative Sediment Transport Mass

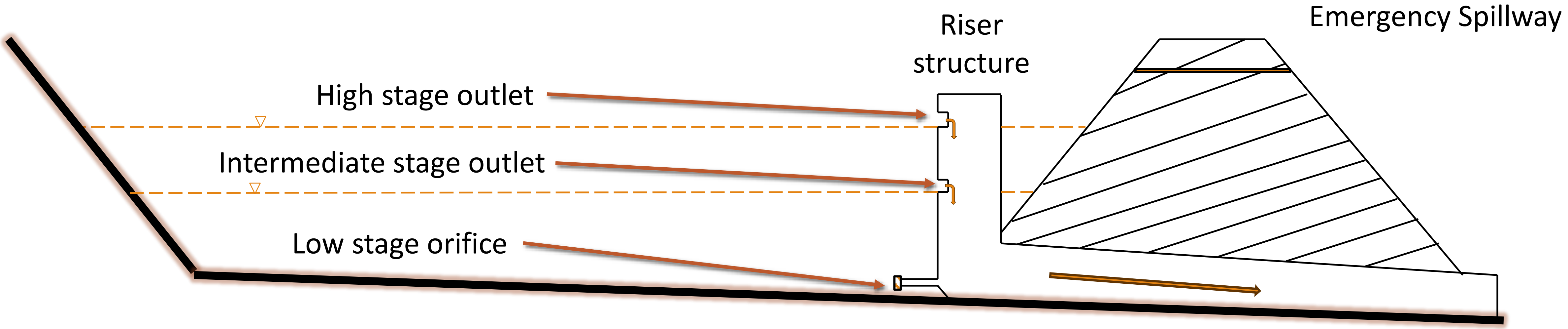
Effective work

Erosion Potential (Ep) Scenario

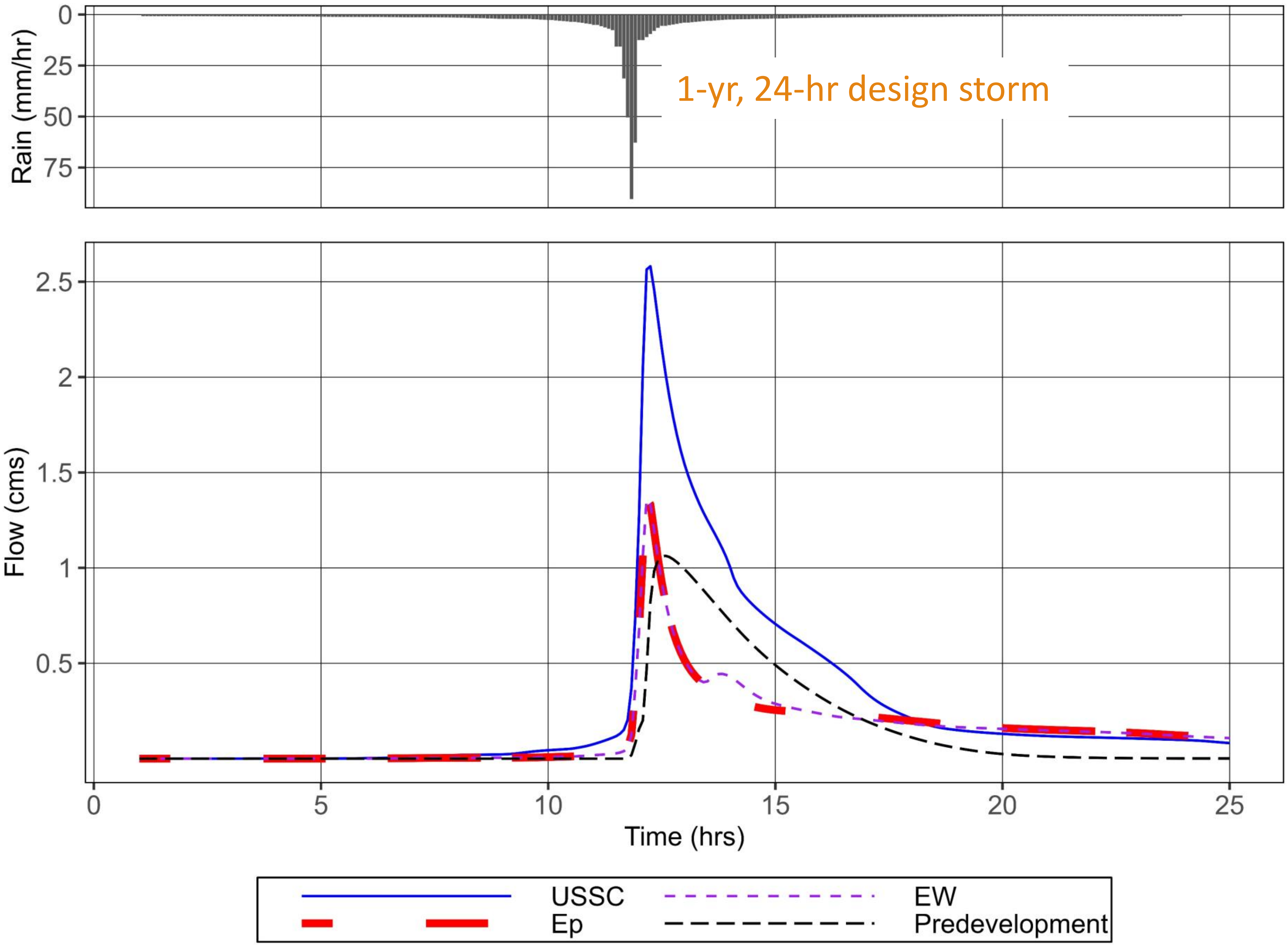
Predeveloped Condition

Effective Work (E_W) Scenario

The pond outlet structures were changed to meet Ep and Ew design targets.

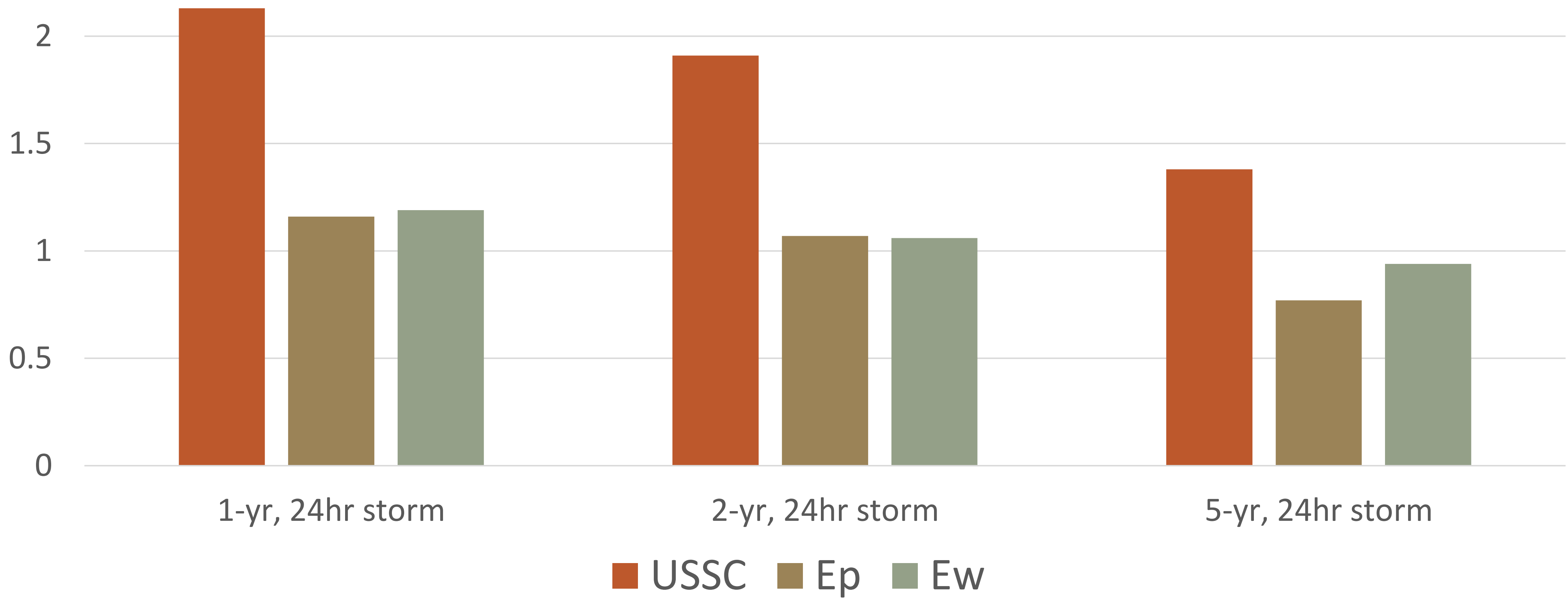


Scenario	Riser structure height increased
Ep	5 ponds
Ew	2 ponds

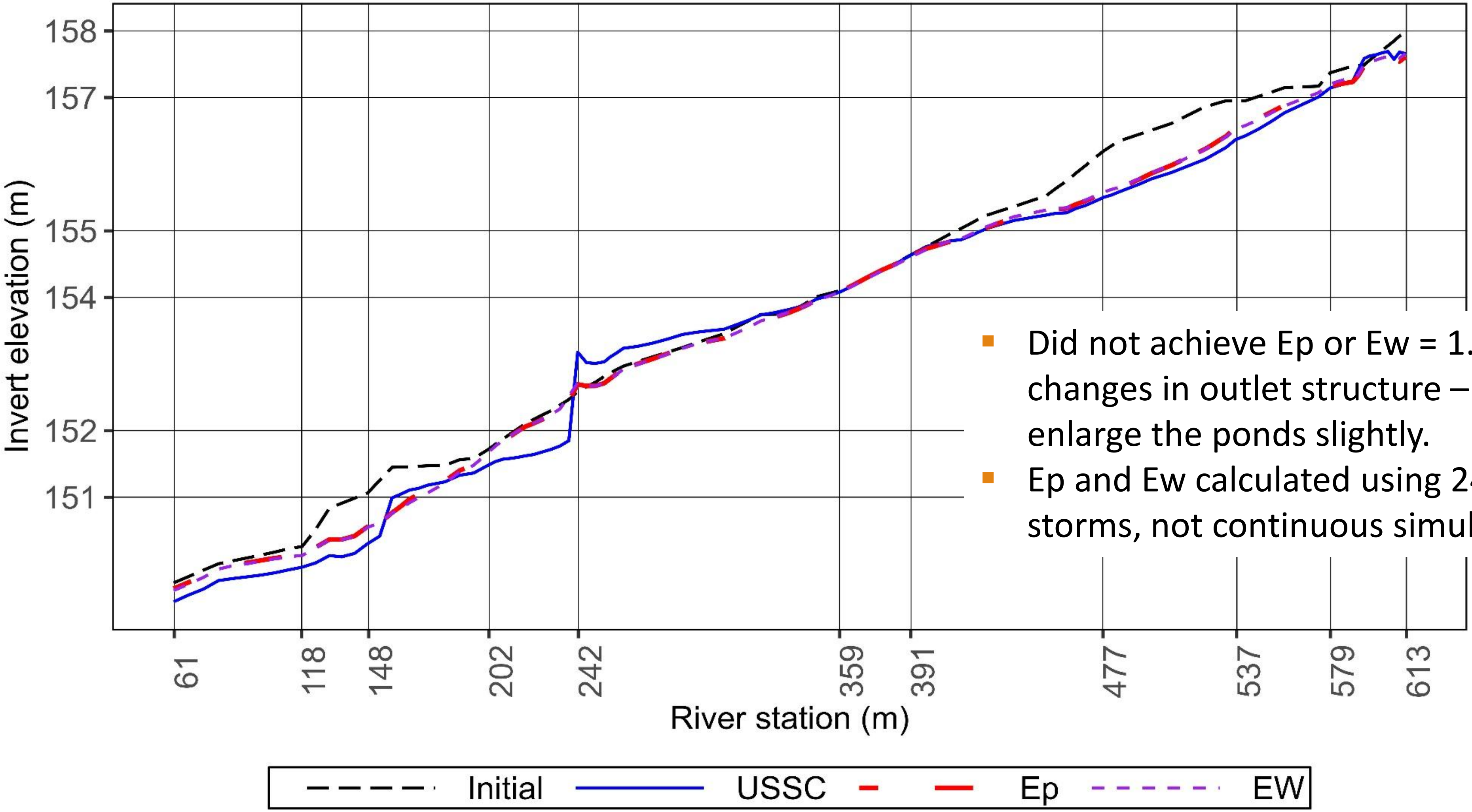


1-yr, 24-hr design storm
Rain (mm/hr)
0
25
50
75
Flow (cms)
2.5
2
1.5
1
0.5
0
5
10
15
20
25
Time (hrs)
USSC
EW
Ep
Predevelopment

Ratio of sediment transported after development to before development



Designing SCMs based on sediment transport considerations significantly reduces channel disturbance

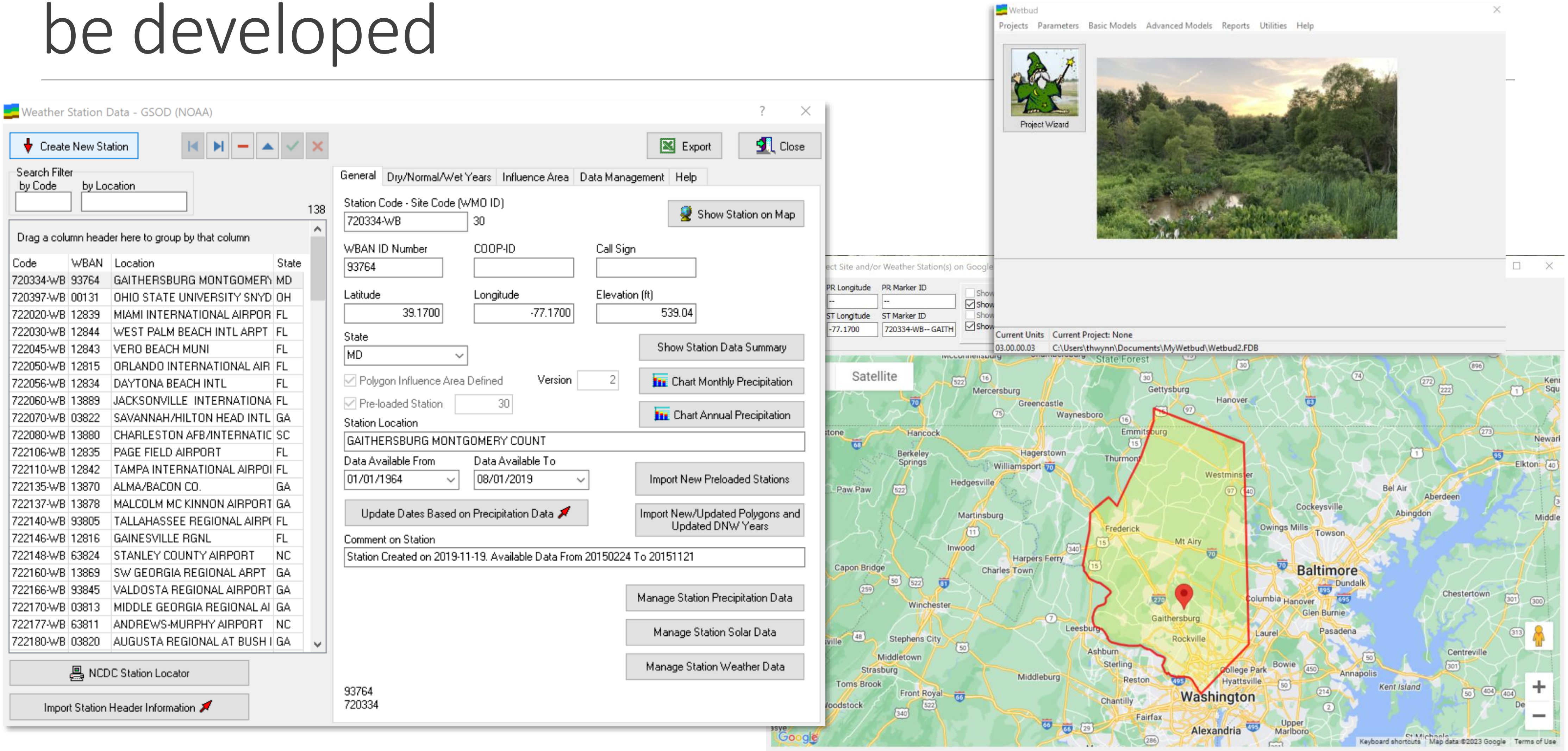


- Did not achieve Ep or Ew = 1.0 with just changes in outlet structure – will need to enlarge the ponds slightly.
- Ep and Ew calculated using 24-hr design storms, not continuous simulation

Summary

- Unified stormwater sizing criteria (and environmental site design) is an improvement over conventional stormwater management, but will not protect channel stability.
- To protect channel stability, stormwater management needs to be designed to meet sediment transport or effective work targets.
- Stormwater storage is needed to manage high flows.
- An investment in good stormwater management now will mean fewer repairs to sewer lines, culverts, and bridges and improved stream physical integrity

Software with Virginia-specific climate data could be developed



Wetbud was developed for mitigation wetland design


Questions?

Why does volume-based stormwater design not protect channel stability?

Assumption:

Maintaining the frequency of bankfull discharge will protect channel stability.

However:

- The link between bankfull discharge and channel form only applies to stable, alluvial channels.
- Many streams in the mid-Atlantic are still responding to past impacts and are still adjusting or "stuck."
- Urban streams are not fully alluvial due to urban infrastructure, such as culverts and sewer lines.
- Urbanization changes both the flow regime and the sediment regime, which changes bankfull discharge.

Why does volume-based stormwater design not protect channel stability?

Assumption:

Bankfull discharge is the 1-2 yr recurrence interval flow.

However:

- Bankfull RI of stable channels can range from 1.01-32 yrs.
- Bankfull discharge occurs multiple times per year in urbanized watersheds

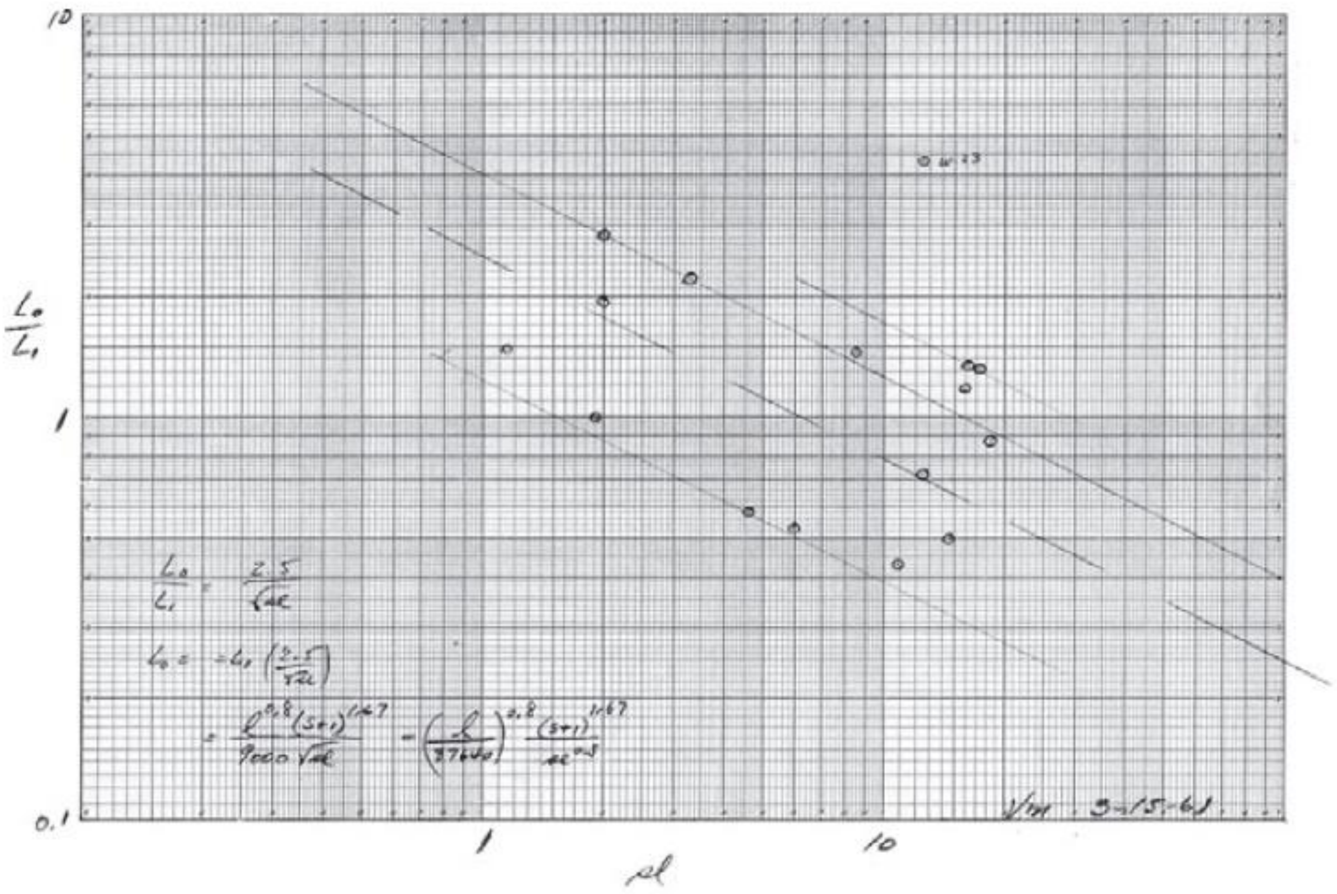
Assumption:

Runoff from the 1-2 yr, 24-hr storm event produces bankfull discharge

However:

- Rainfall intensity drives flows in small urbanized watersheds, not rainfall depth
- Watershed response to rainfall is strongly dependent on antecedent conditions

Recommendations



1984 computing power

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