An Illustrated Guide to Risk Management:

Reconciling “I-D-F” from the Watershed’s Perspective

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What You Need To Remember From My Presentation...

- Traditional drainage design approaches do not apply when evaluating downstream impacts
- And also, I-D-F =

I = How Strong?

D = How Long?

F = How Often?

So I've Got 15 Minutes to Tell This Story...

- Evaluate stormwater impacts...

Stimulus → Response

- Using these indicators...

Intensity

Duration

Frequency

- Under various land use conditions...

Pre-Development

Post-Dev'pt (uncontrolled)

Post-Development

- In a watershed context...

Source → Pathway → (Outfall) → Receptor

Stormwater management facilities

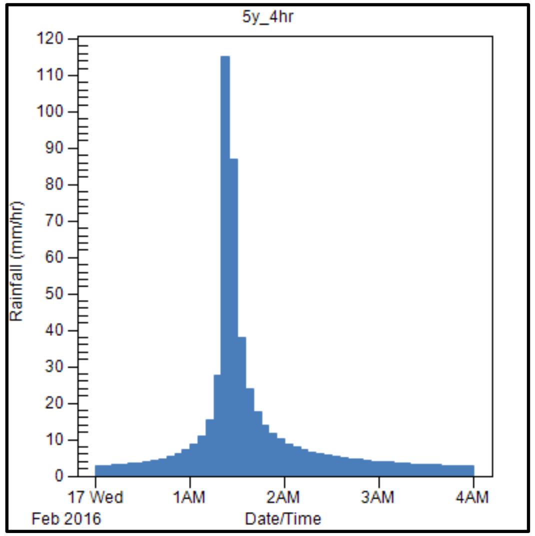
Receiving waters

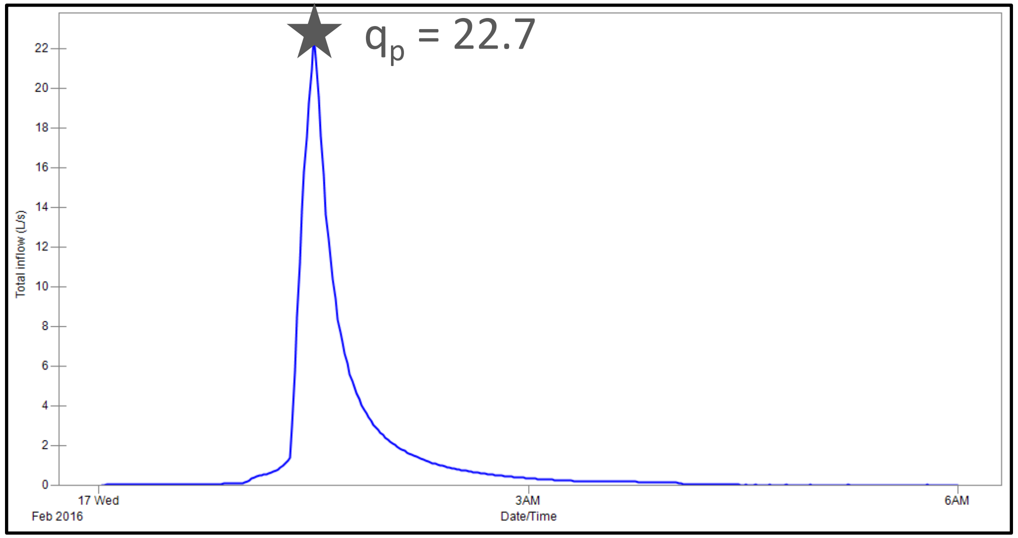
Traditional Drainage Design

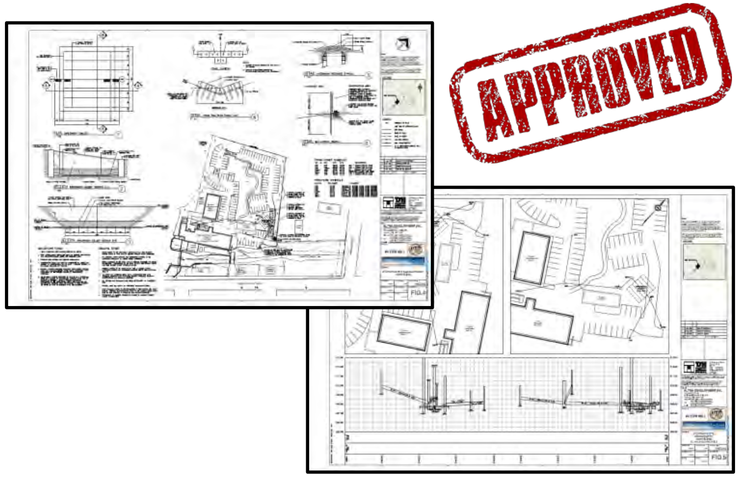
	Rainfall Stimulus
I	Intensity
D	Duration
F	Frequency

	Runoff Response
I	Peak Flow, q_p
F	Design Storm

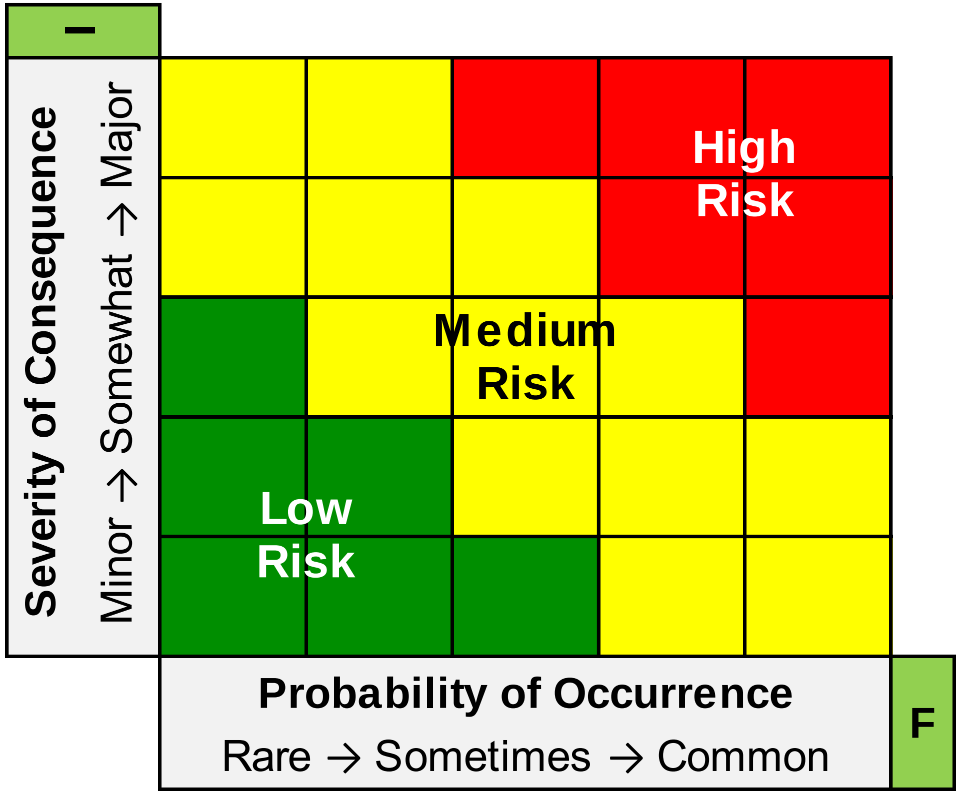
Regulatory Control
q_p post-dev'pt ≤ q_p pre-dev'pt

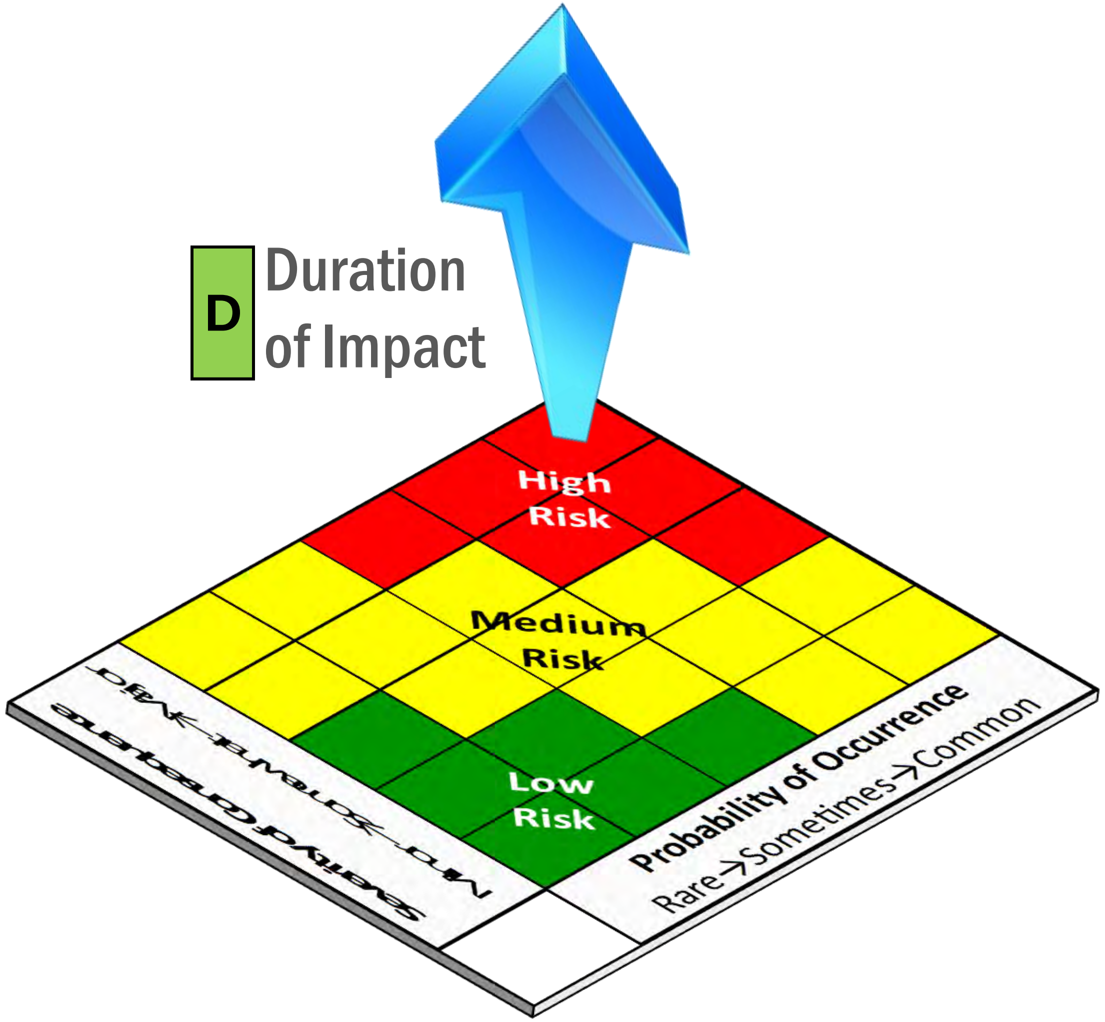






Risk Management





Response Functions

- ## In a catchment context…

	Response Indicator	Climatological Stimulus	Surface Water Hydrologic Response			
I	Magnitude	Precipitation	Runoff	Infiltration	Evaporation	Storage
I	Rate	p	r	i	e	s
I	Volume	P	R	I	E	S
F	Recurrence Interval	Evaluate range of return periods: design storm events (event-based hydrology) or based on flow frequency analysis (continuous simulation)				

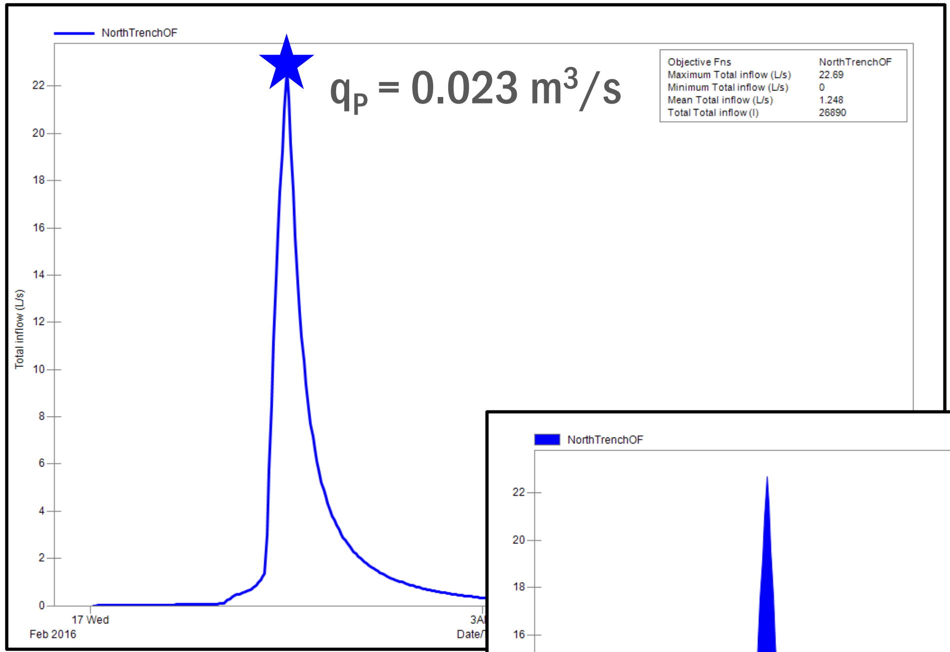
← “water balance” (Volume row)

- ## In a watershed context…

	Response Indicator	Receiving Watercourse Impact				
I	Magnitude	Discharge	Depth	Velocity	Shear Stress	Concentration
I	Peak Value	q_P	d_P	v_P	τ_P	c_P
I	Total Amount / Cross-Product	q_T = volume	$d \times v$ = flood hazard; $v \times \tau$ = erosion hazard			c_T = loading
D	Time of Exceedance	$t_D \geq q_{Crit}$	$t_D \geq d_{Crit}$	$t_D \geq v_{Crit}$	$t_D \geq \tau_{Crit}$	$t_D \geq c_{Crit}$
F	Recurrence Interval	Evaluate range of return periods: design storm events (event-based hydrology) or based on flow frequency analysis (continuous simulation)				

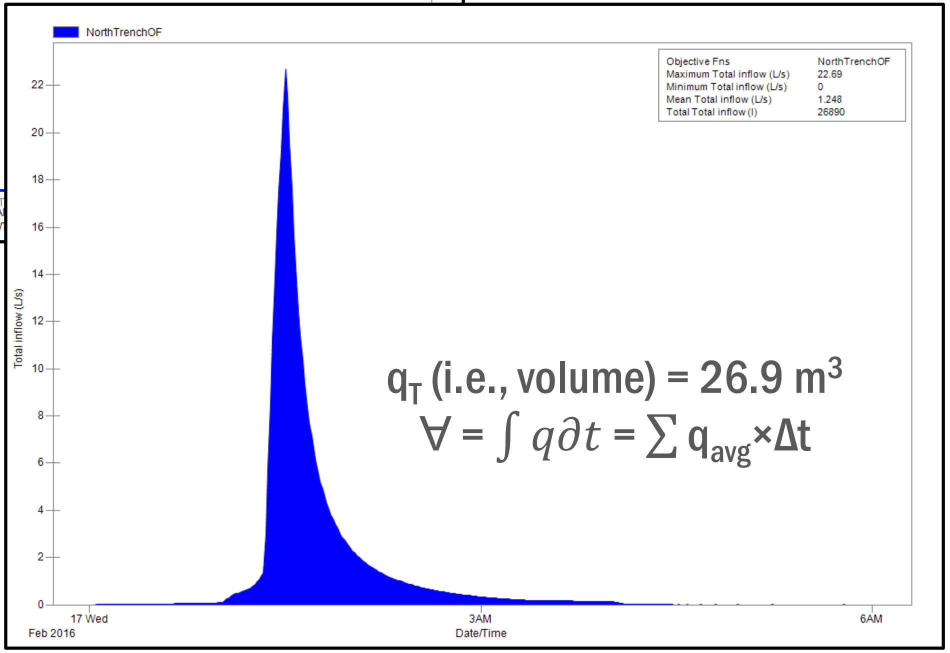
→ etc. (Magnitude row)

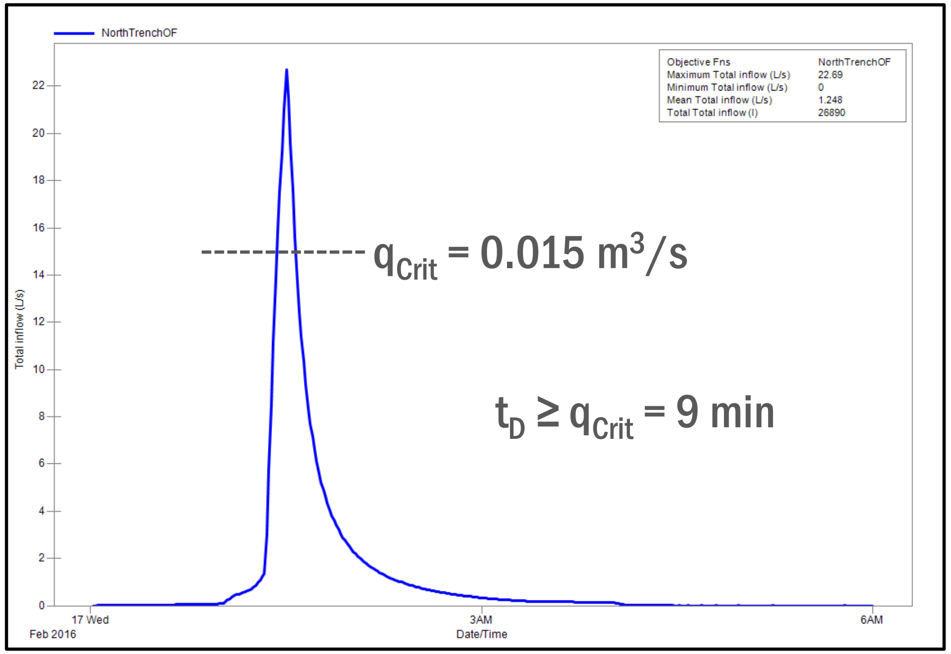
Flow Rate & Volume Impacts – Event-Based Hydrology



Pre-development conditions (100-year/4-hour design storm)

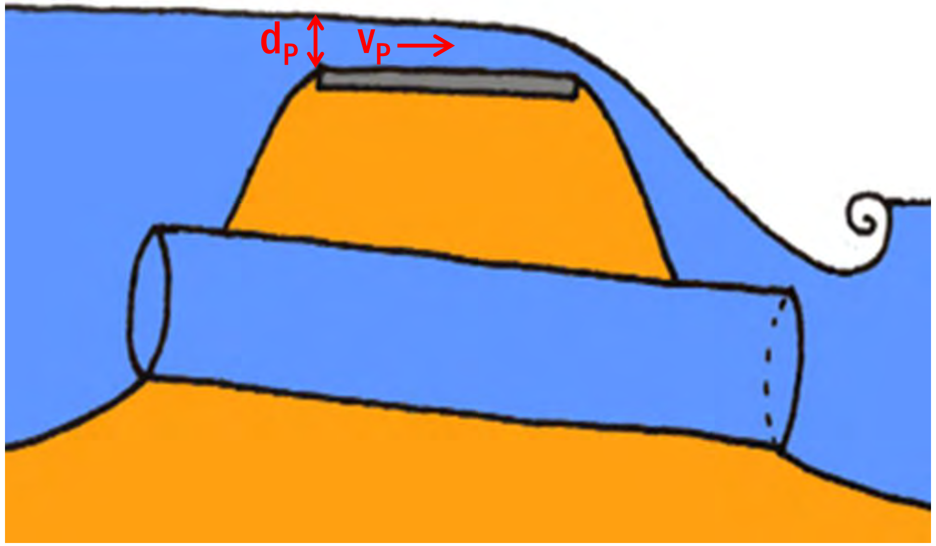
Magnitude	Discharge	Depth	Velocity
Peak Value	q_P	d_P	v_P
Total Amount / Cross-Product	q_T = volume	$d \times v$ = flood hazard	
Time of Exceedance	$t_D \geq q_{Crit}$	$t_D \geq d_{Crit}$	$t_D \geq v_{Crit}$



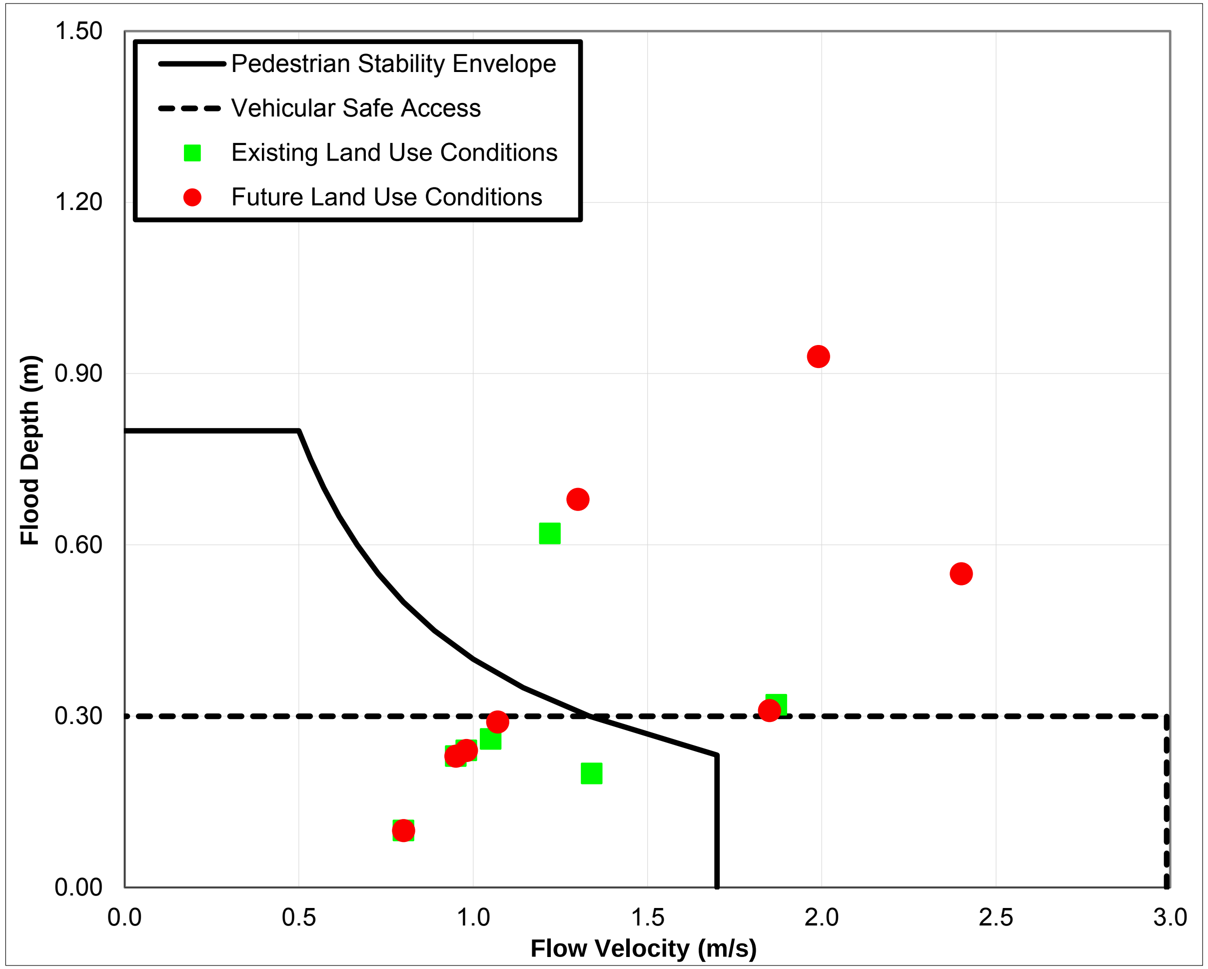


Flood Hazards – Road Overtopping

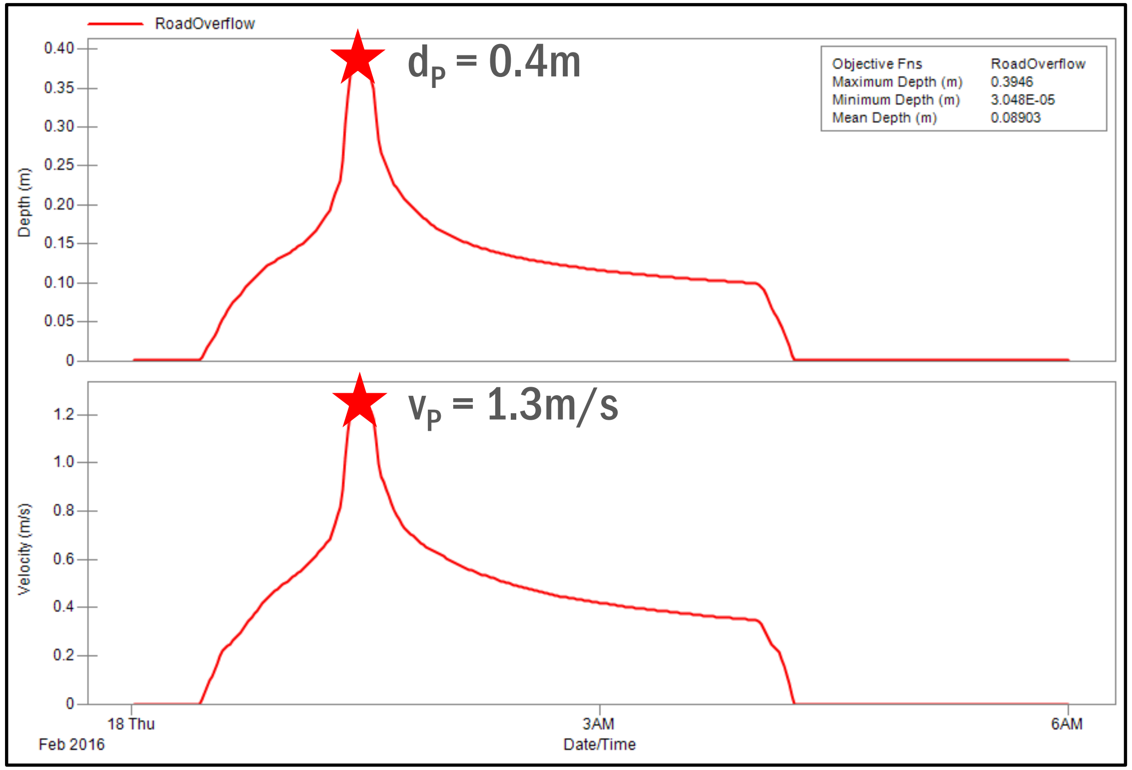
- Overflow at culvert crossing…



- Pedestrian stability criteria: $d_P \leq 0.8$ m, $v_P \leq 1.7$ m/s, and $(d \times v)_P \leq 0.4$ m^2/s
- Emergency vehicle access criteria: $d_P \leq 0.3$ m and $v_P \leq 3$ m/s

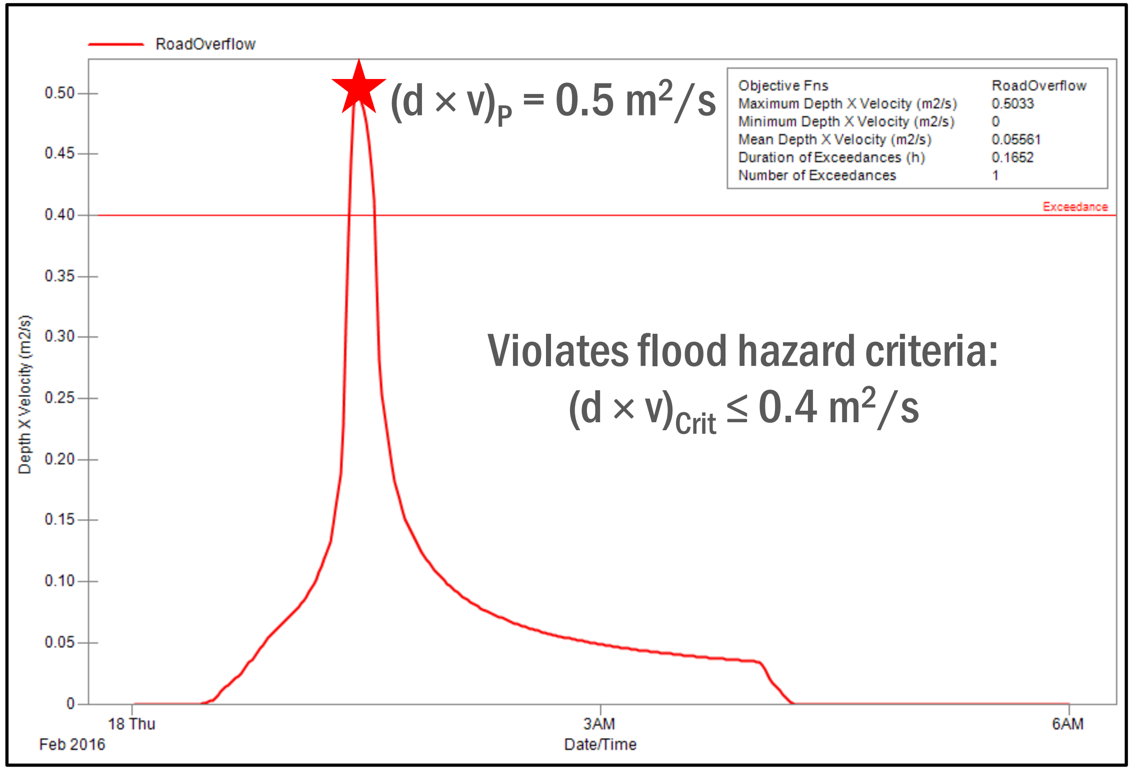


Flood Depth & Velocity Impacts – Event-Based Hydrology

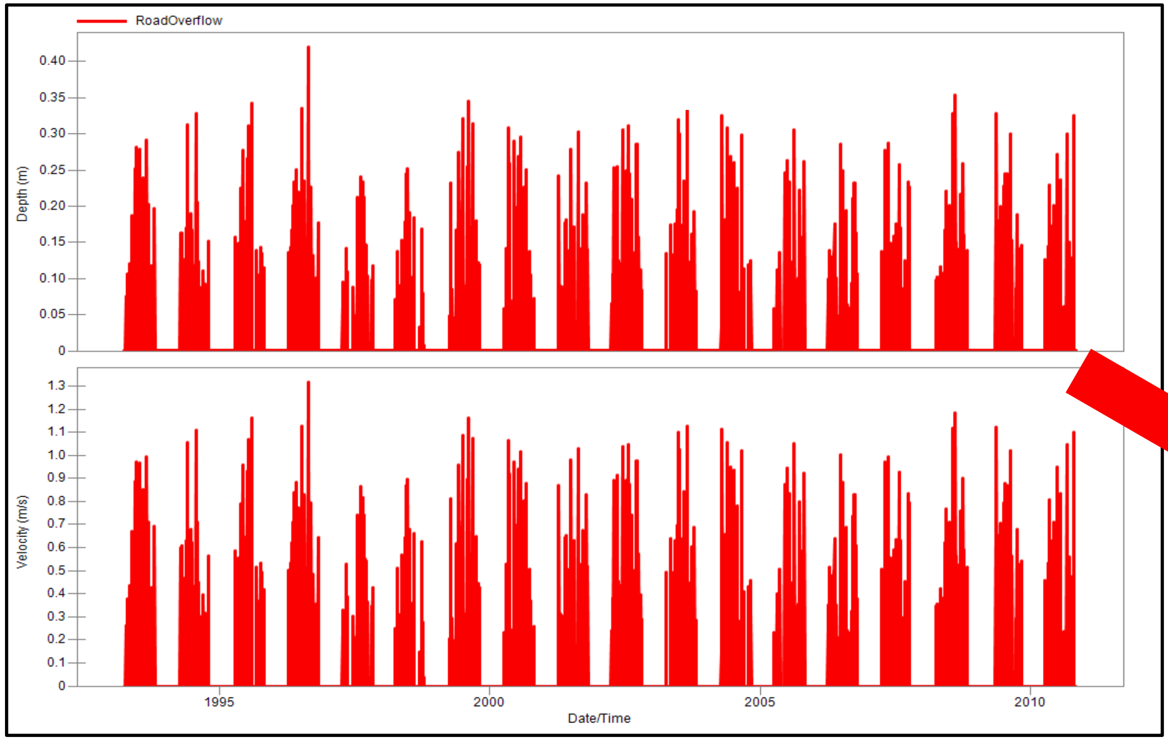


Post-development uncontrolled conditions (100y/4hr)

Magnitude	Discharge	Depth	Velocity
Peak Value	q_P	d_P	v_P
Total Amount / Cross-Product	q_T = volume	$d \times v$ = flood hazard	
Time of Exceedance	$t_D \geq q_{Crit}$	$t_D \geq d_{Crit}$	$t_D \geq v_{Crit}$

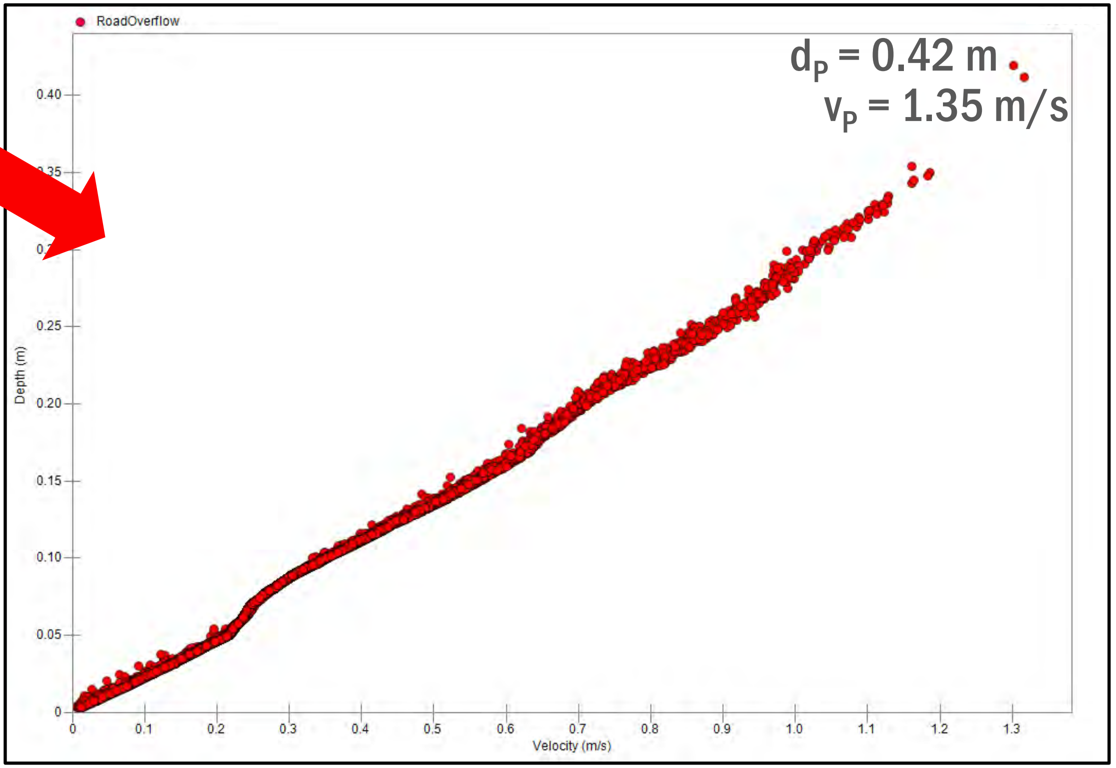


Flood Depth & Velocity Impacts – Continuous Simulation

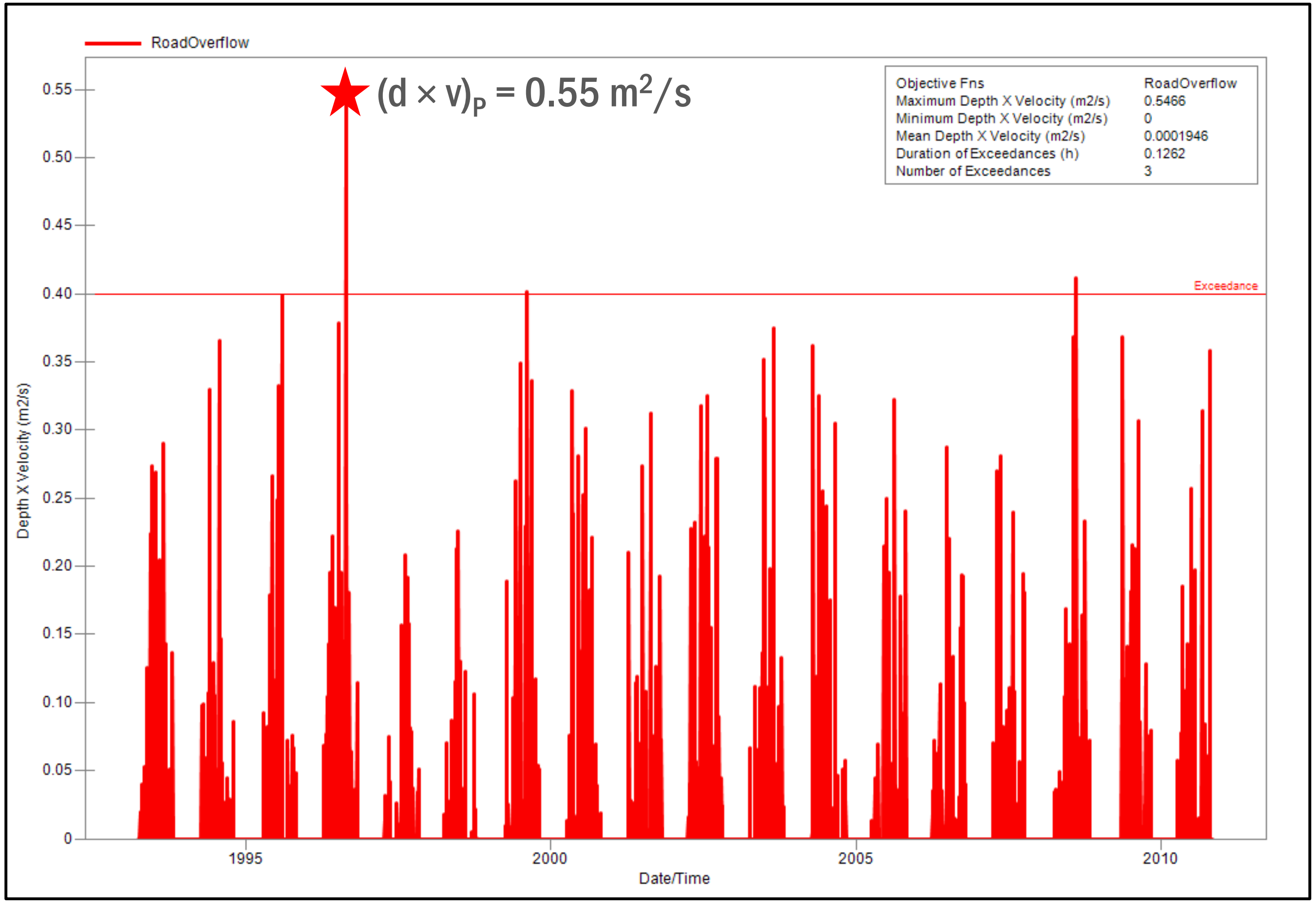


Post-development uncontrolled conditions (18 years)

Magnitude	Discharge	Depth	Velocity
Peak Value	q_P	d_P	v_P
Total Amount / Cross-Product	q_T = volume	$d \times v$ = flood hazard	
Time of Exceedance	$t_D \geq q_{Crit}$	$t_D \geq d_{Crit}$	$t_D \geq v_{Crit}$



Flood Depth & Velocity Impacts – Continuous Simulation



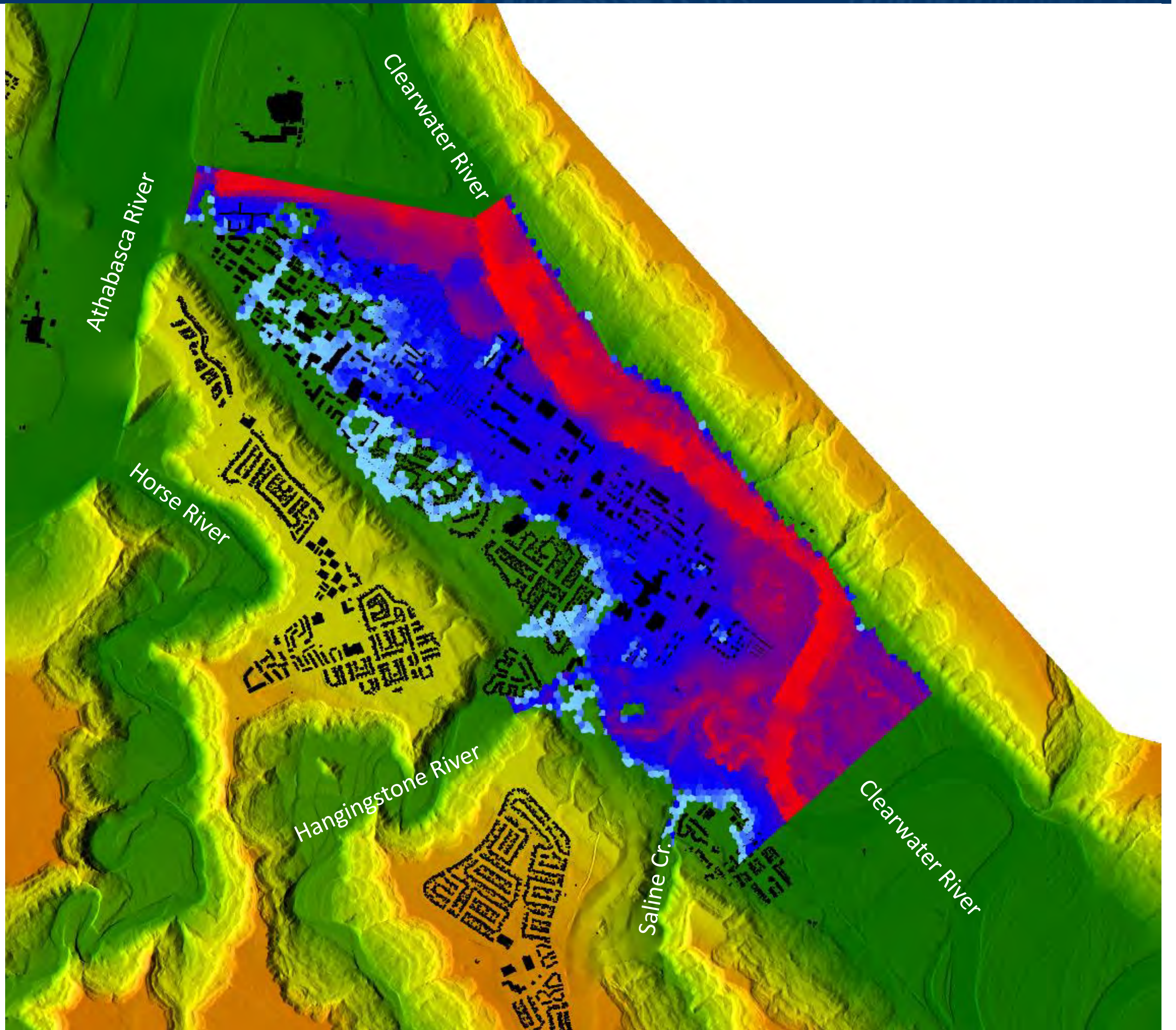
Post-development uncontrolled conditions (18 years)

Magnitude	Discharge	Depth	Velocity
Peak Value	q_P	d_P	v_P
Total Amount / Cross-Product	q_T = volume	$d \times v$ = flood hazard	
Time of Exceedance	$t_D \geq q_{Crit}$	$t_D \geq d_{Crit}$	$t_D \geq v_{Crit}$

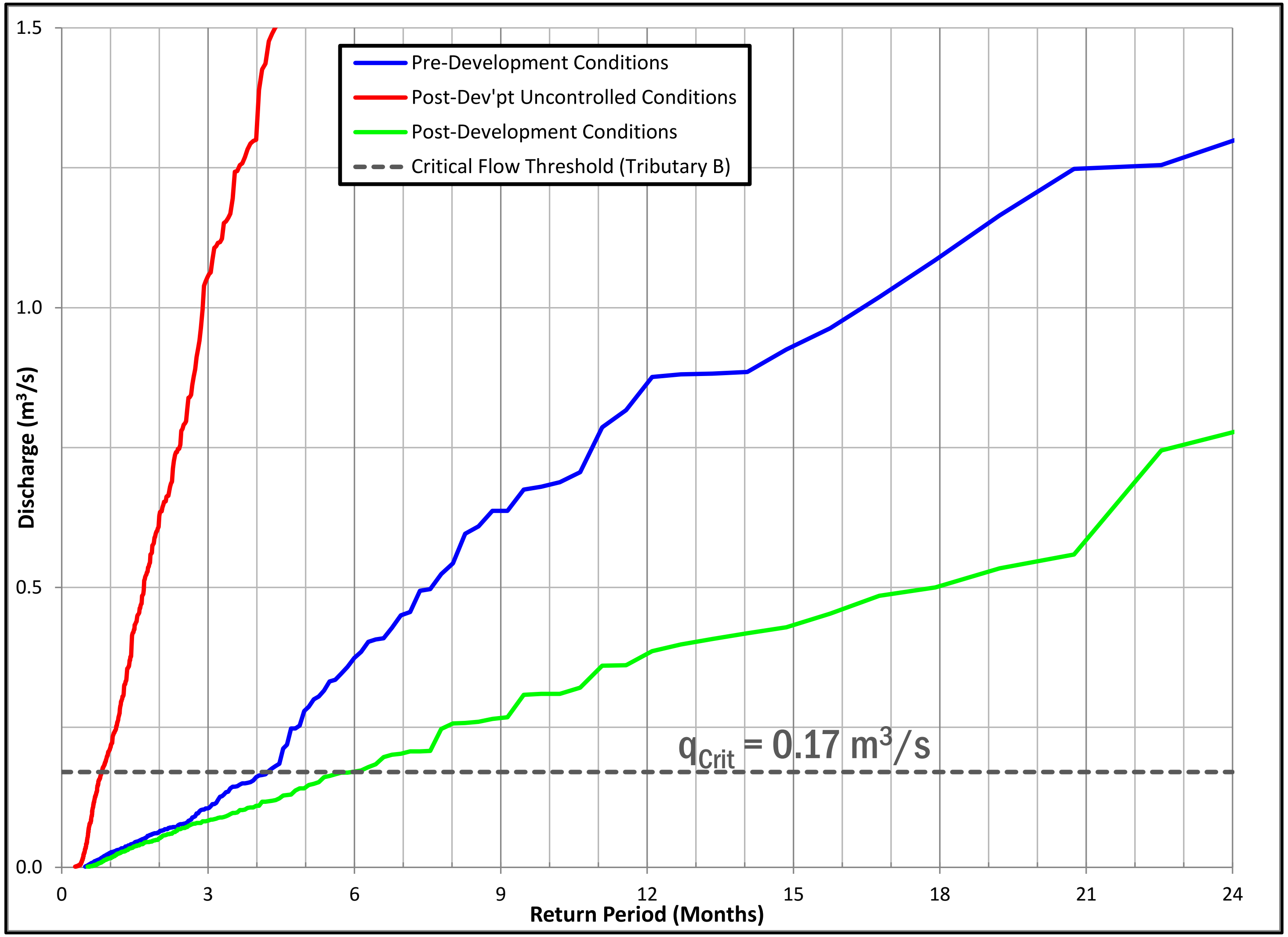
- Violates flood hazard criteria 3 times for a total duration of 0.13 hours, or… $t_D \geq (d \times v)_{Crit}$ = 8 min (in 18 years)

Flood Hazards – Widespread Flooding

- Another indicator of magnitude is extent of flooding: inundated area and spatial variation of flood depths



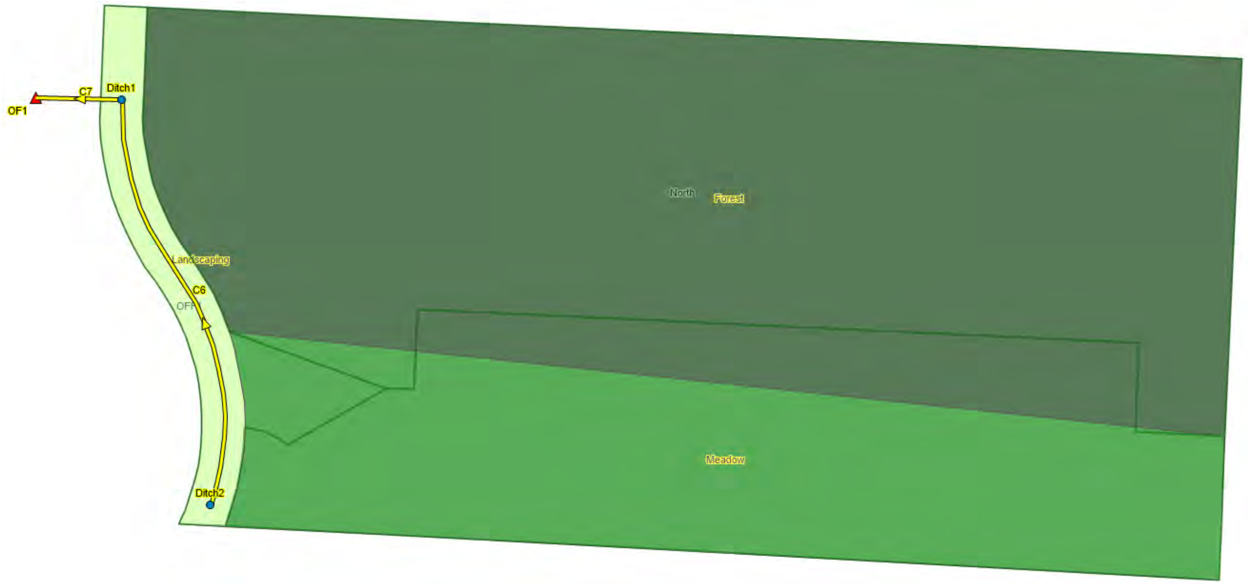
Flow Frequency Analysis – Continuous Simulation



- New 727 ha (1,796 ac) development mixed-use subdivision
  - Pre-Dev'pt = 8% impervious
  - Post-Dev'pt = 26% impervious
- "uncontrolled" = piped discharge, no stormwater management
- Return period of q_{Crit} exceedance (22 years of rainfall):
  - 4 mo. Pre-Development
  - 1 mo. Uncontrolled
  - 6 mo. Post-Development

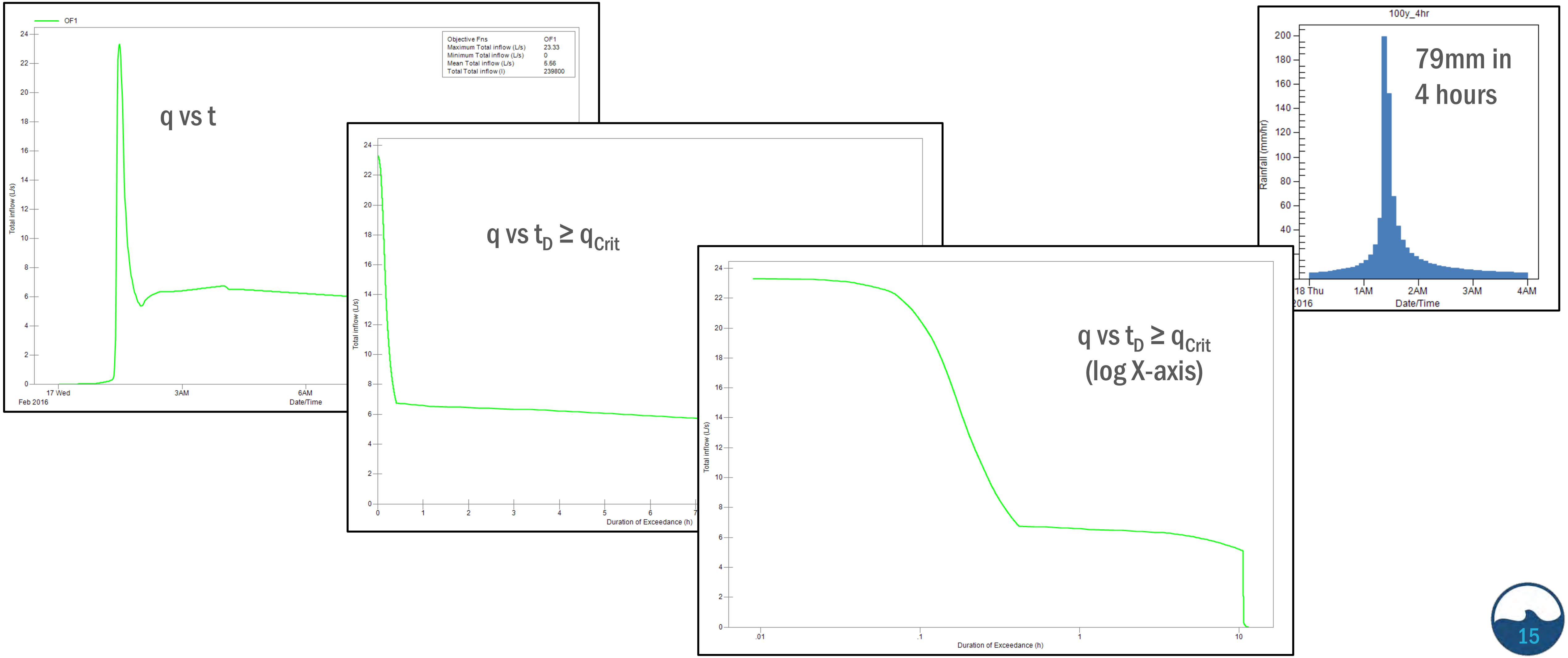
Flow Duration Analysis Example

- Pre-development conditions

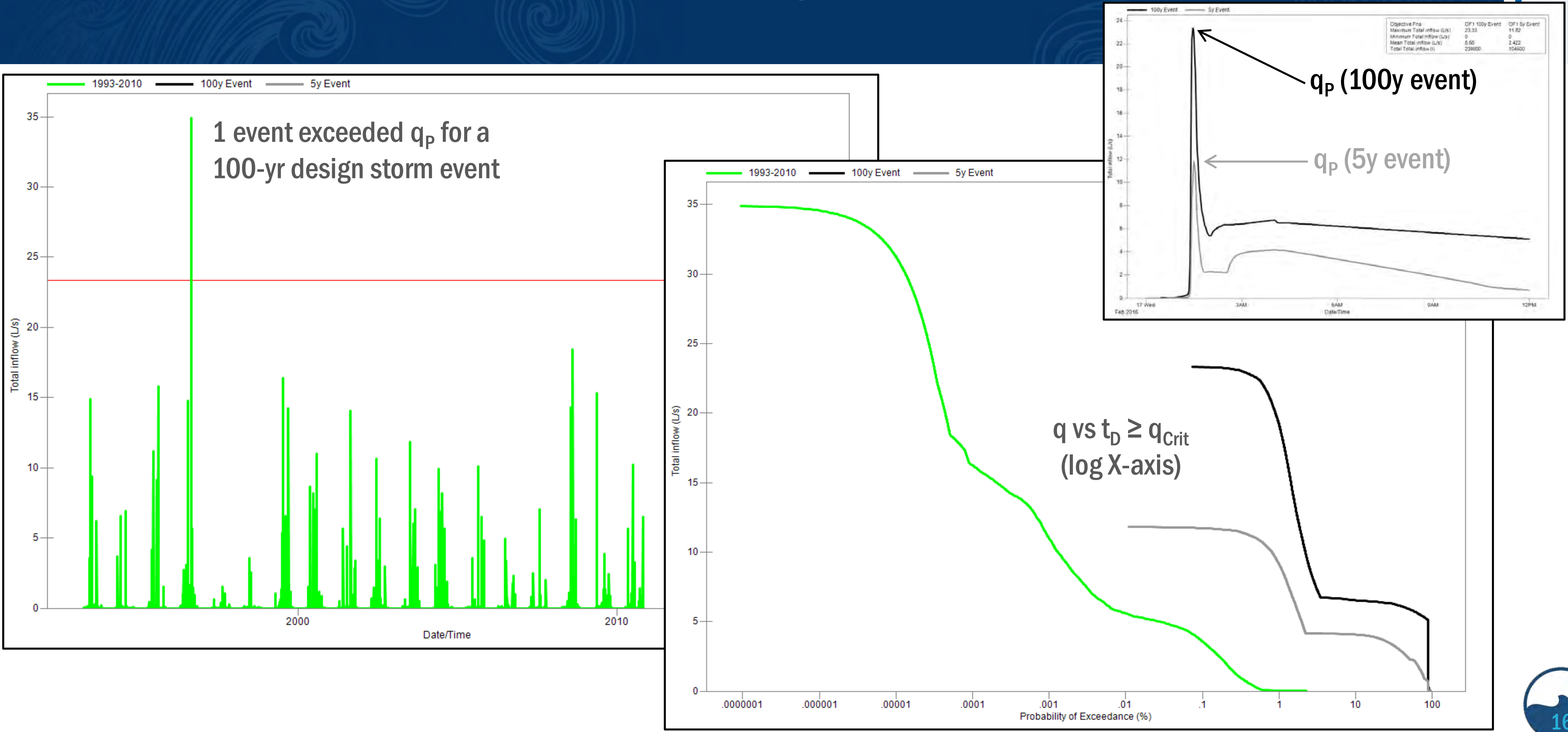


- Post-development (with infiltration trenches)

Flow Duration Exceedance – Event-Based Hydrology

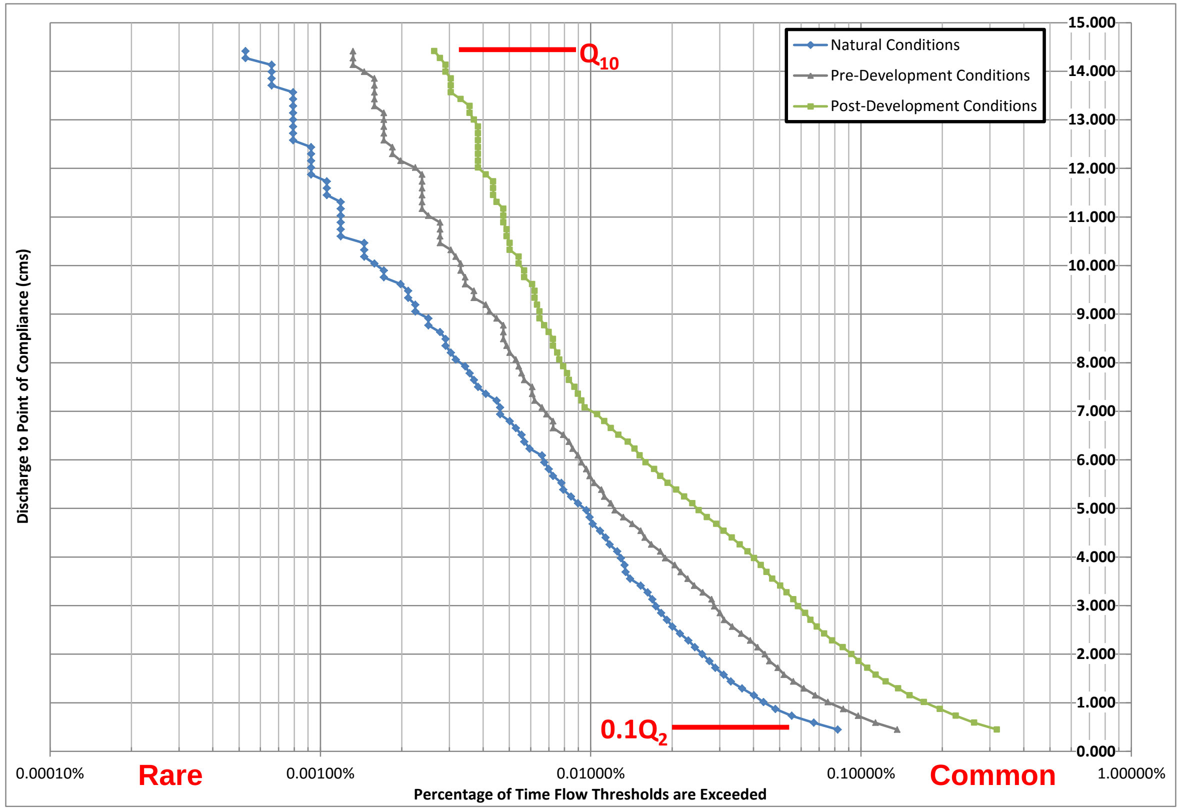


Continuous Simulation vs Design Storm Events



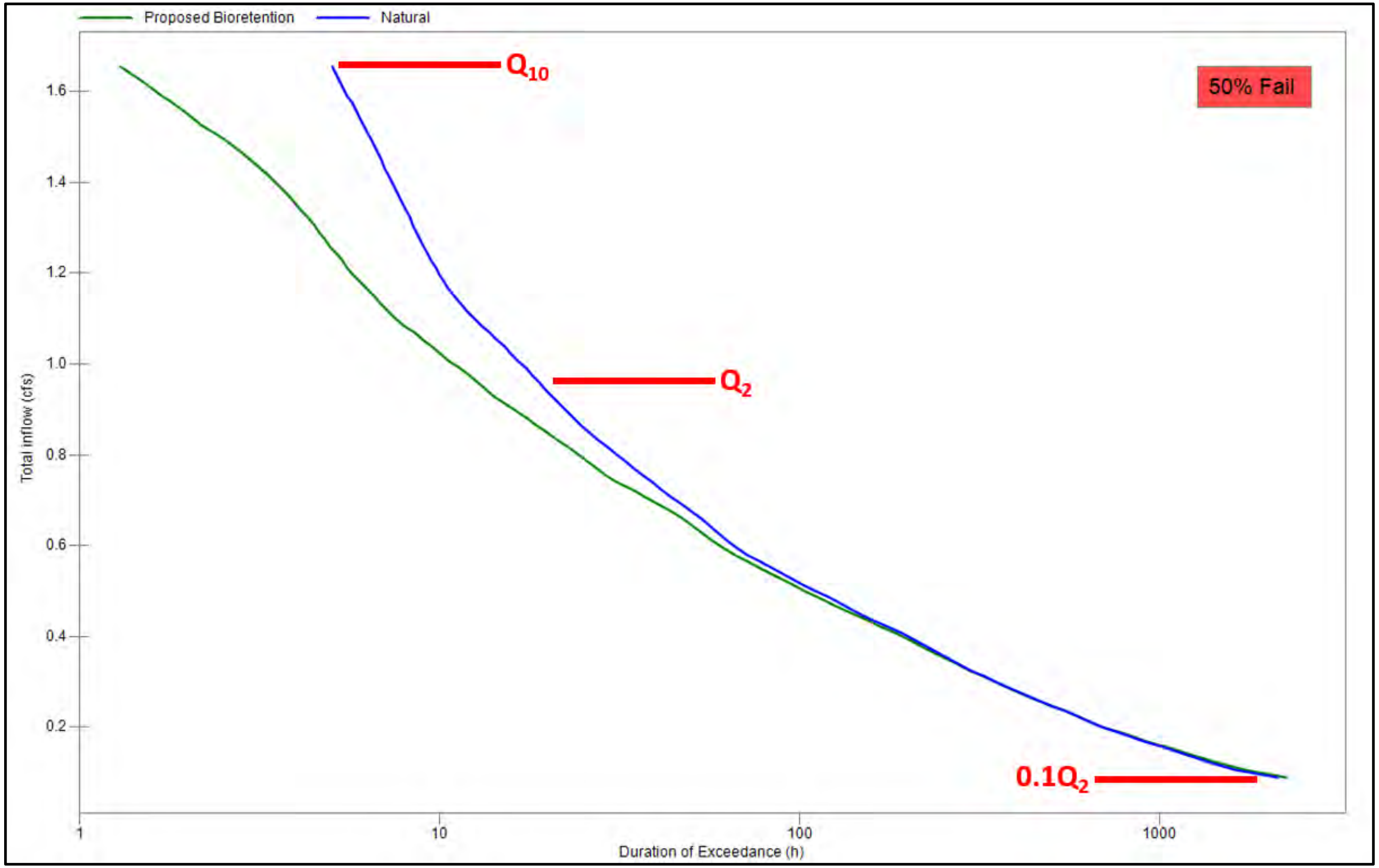
Flow Duration Analysis – Hydromodification Compliance

- California permitting process meant to protect watercourse geomorphology
- Identify 100 equally-spaced flow thresholds from $0.1Q_{2y}$ up to Q_{10y}
- Count cumulative exceedance duration for each flow threshold
- Compute post- to pre-dev'pt exceedance ratio
- Criteria:
  - Values exceeding 110% identified as a Fail
  - A passing score of 90% (i.e., no more than 10 fails) must be obtained to achieve compliance



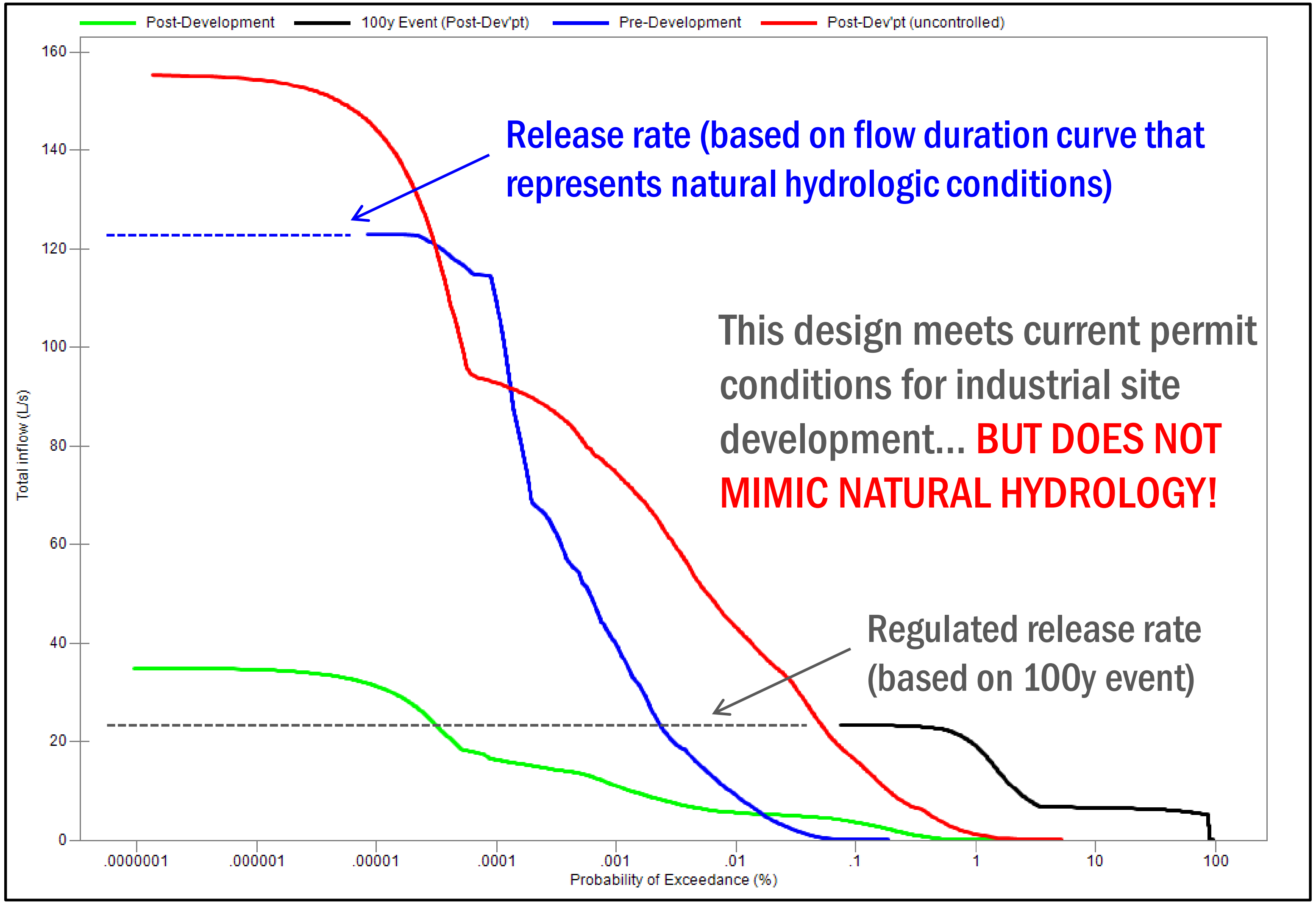
Redevelopment: Post → Pre
New development: Post → Natural

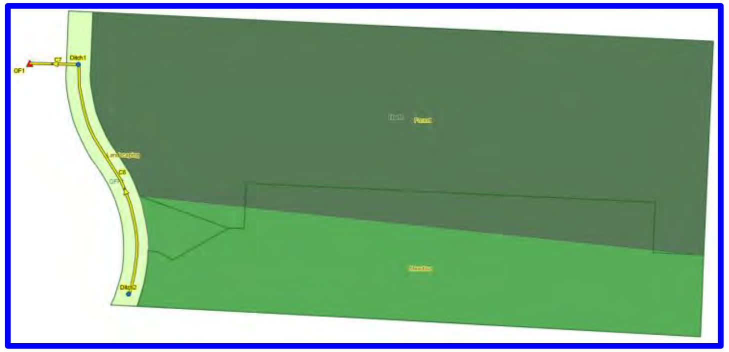
Hydromodification – Non-Compliance Example



- Proposed bioretention cell over-controls flows between Q_{2y} and Q_{10y}
- 50% of values exceed criteria for new development

Flow Duration Exceedance Impacts – Continuous Simulation





But Regulatory Controls Are Evolving Quickly

- Maximum allowable release rates to preserve pre-development conditions
- Runoff volume reduction targets
- Flow duration targets (“hydromodification”)
- Pollutant loading reduction targets
- ...and more to follow...

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News Releases By Date

Governments of Canada and the United States Announce Phosphorus Reduction Targets of 40 percent to Improve Lake Erie Water Quality and Reduce Public Health Risk

Release Date: 02/22/2016
Contact Information: Robert Daguillard (Media Only), daguillard.robert@epa.gov, 202-564-6618

New targets to reduce toxic and nuisance algae blooms affecting Lake Erie

WASHINGTON.- U.S. Environmental Protection Agency Administrator Gina McCarthy and Canada's Environment and Climate Change Minister Catherine McKenna today announced that Canada and the U.S. have adopted targets to reduce phosphorus entering affected areas of Lake Erie by 40 percent. The targets announced today will minimize the extent of low oxygen “dead zones” in the central basin of Lake Erie; maintain algae growth at a level consistent with healthy aquatic ecosystems; and maintain algae biomass at levels that do not produce toxins that pose a threat to human or ecosystem health.

Closing Remarks

- We must consider the impacts of development with respect to broad objectives
  - Mimic natural hydrology
  - Maintain stream stability and watershed health
- Yes, this is a big change from the way we used to do stormwater management
- But not to worry… we have the data, the tools, and the computing power to handle it

Thank you for your attention!

(hope I didn't go too fast)