Application of Continuous Simulation Modeling to Inform Hydromodification Management Design Decisions

Judd Goodman

jgoodman@geosyntec.com

3rd Hydromodification Seminar & Workshop:

Modeling for Hydromodification

July 17, 2013

Geosyntec consultants

engineers | scientists | innovators

Objectives

- Impact Evaluation
- Management Strategies
- BMP Sizing Sensitivities

Hydromod Impact = *f*(Δhydrology, Δchannel geometry, Δbed & bank material, Δsediment supply)

Restoration vs. Hydromod Management

Hydromodification = Changes in runoff characteristics and in-stream processes caused by altered land use.

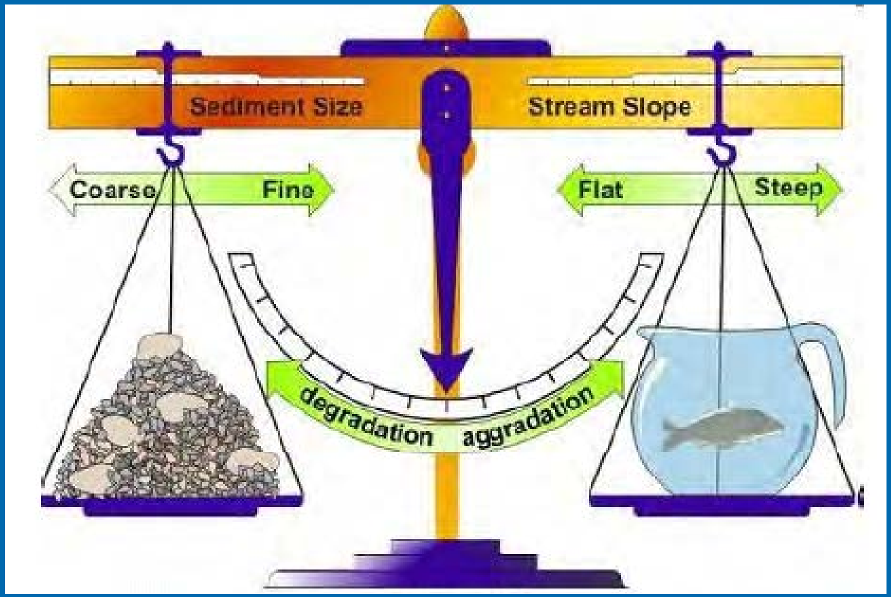
Restoration	vs.	Hydromod Management
⇩		⇩
fix an existing geomorphic impact		prevent a future geomorphic impact

Impact Evaluation

How are hydromod impacts modeled?

Qualitative: *Lane (1955)*

$Q_s \, D_{50} \; \alpha \; Q_w \, S$



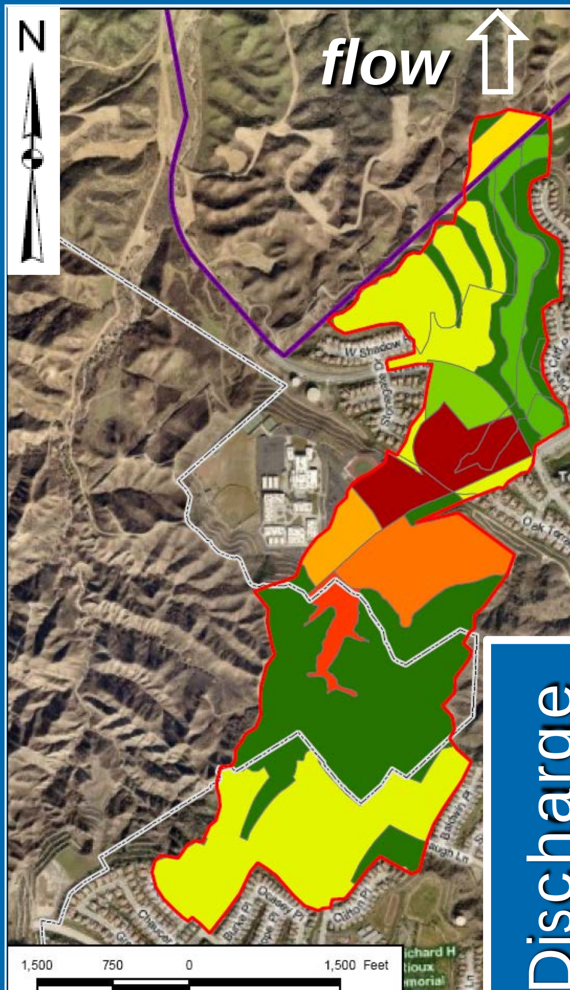
Source: Rosgen (1996), From Lane, 1955.
Reprinted with permissions

Quantitative:

Geomorphic Impact = *f*(Δhydrology, Δchannel geometry, Δbed & bank material strength, Δsediment supply)

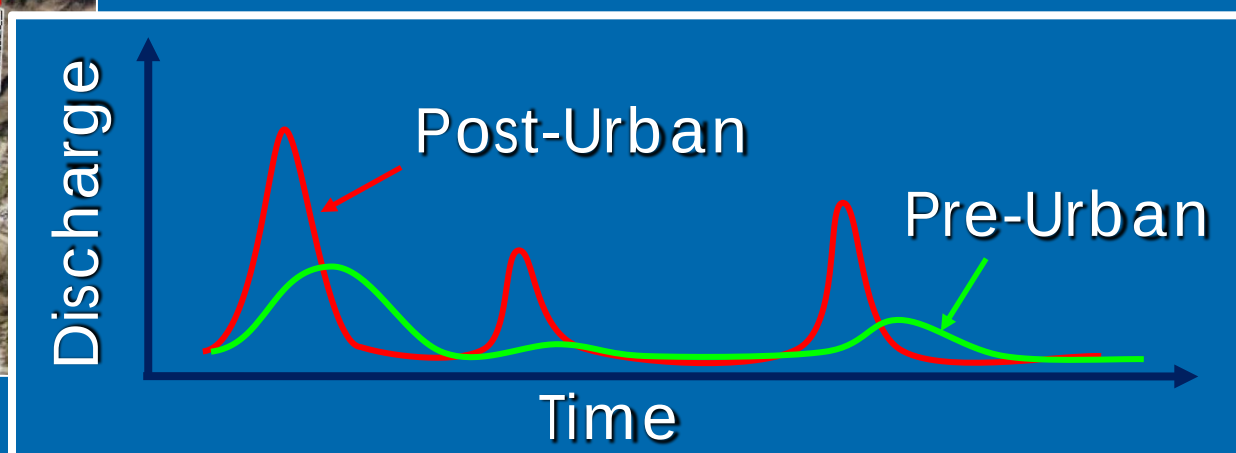
Δhydrology

Simulate the hydrologic response of catchments under pre- and post-developed conditions for a continuous period of record.

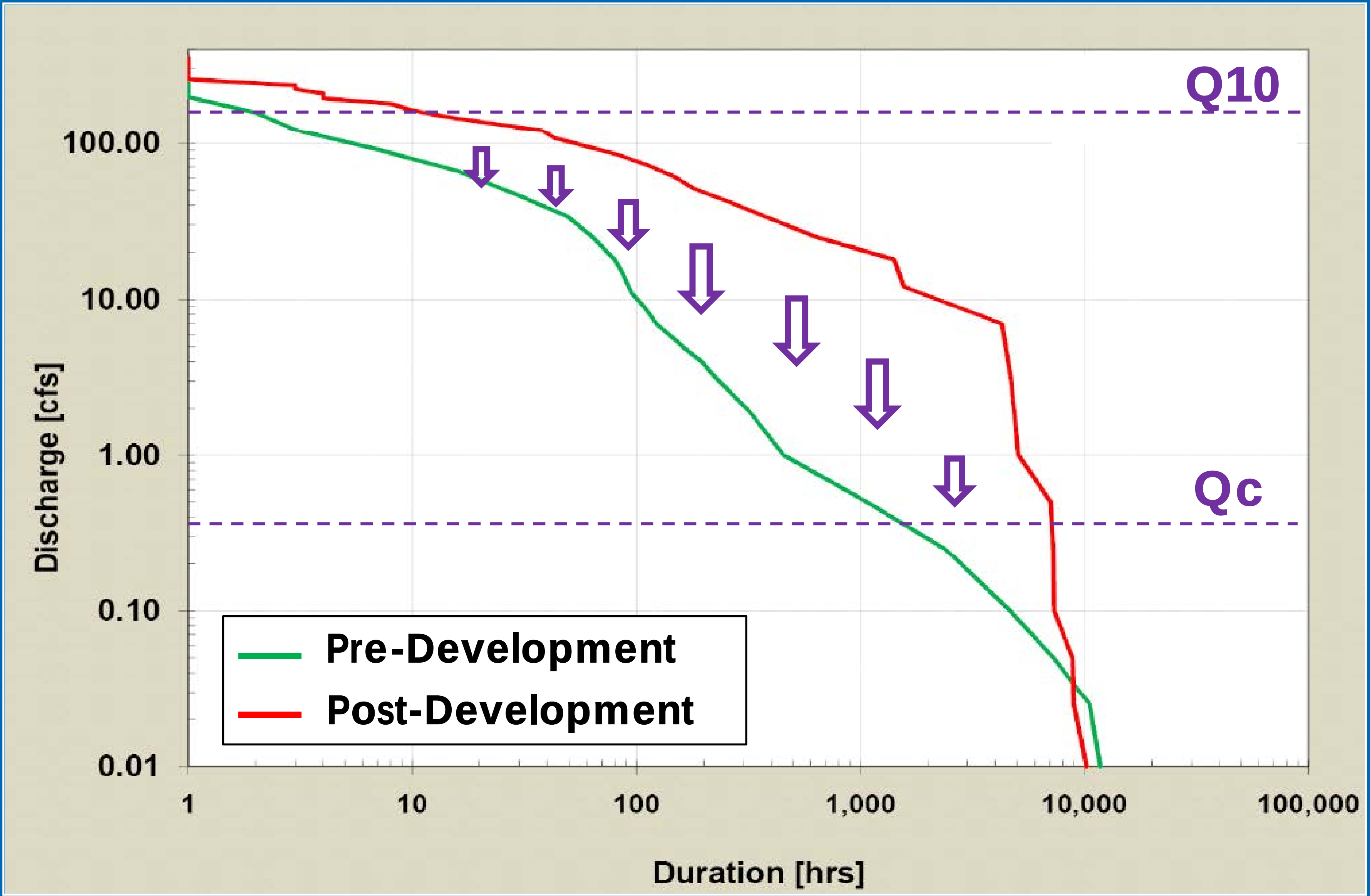


<u>*Input*</u>:
- Rainfall
- Catchment Delineation
- Soils
- *% Imperviousness*
- Lag Time
- In-stream Infiltration
- Evapotranspiration

<u>*Output*</u>:
- Flow

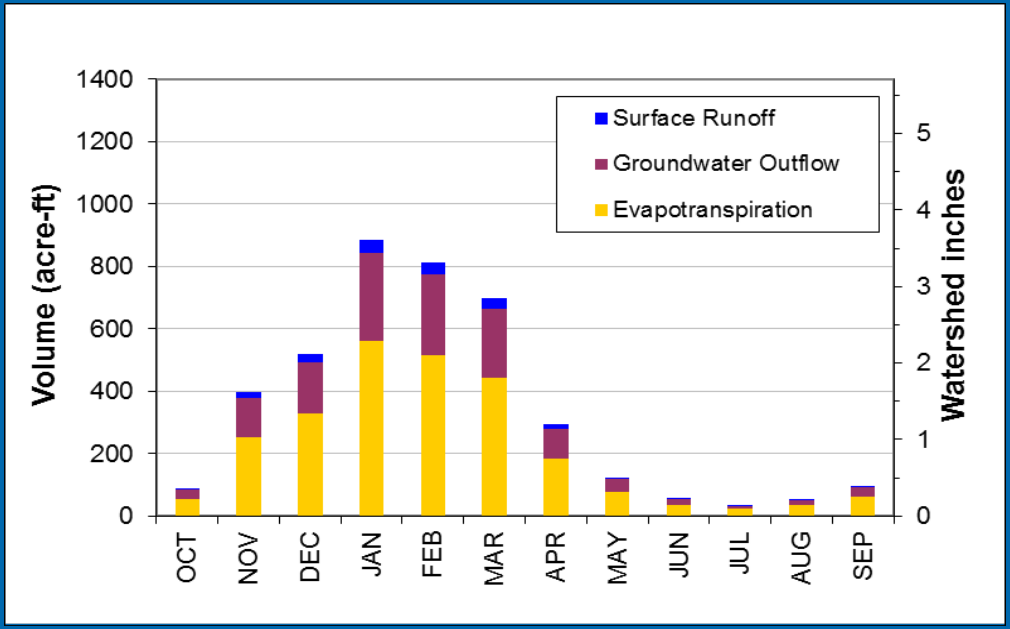


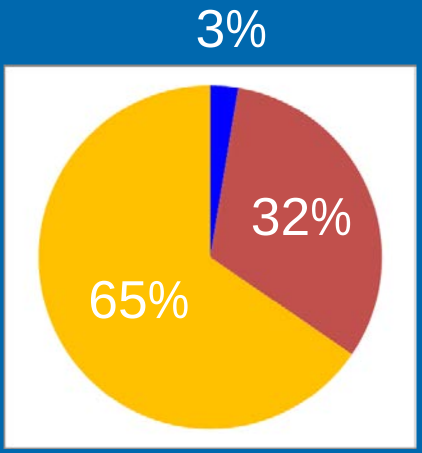
Δhydrology Flow output from hydrologic model is used to generate flow duration curves.



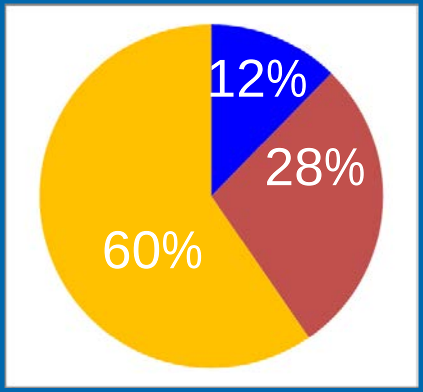
Δhydrology

Output from hydrologic model can be used to evaluate water balance.





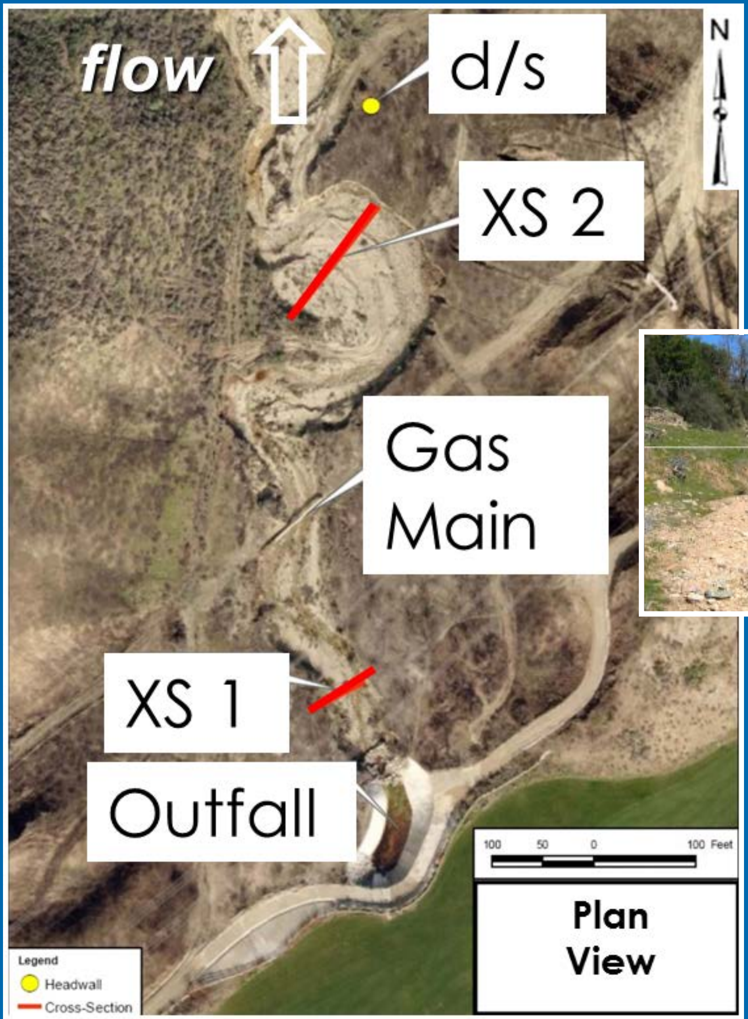
Pre-Development

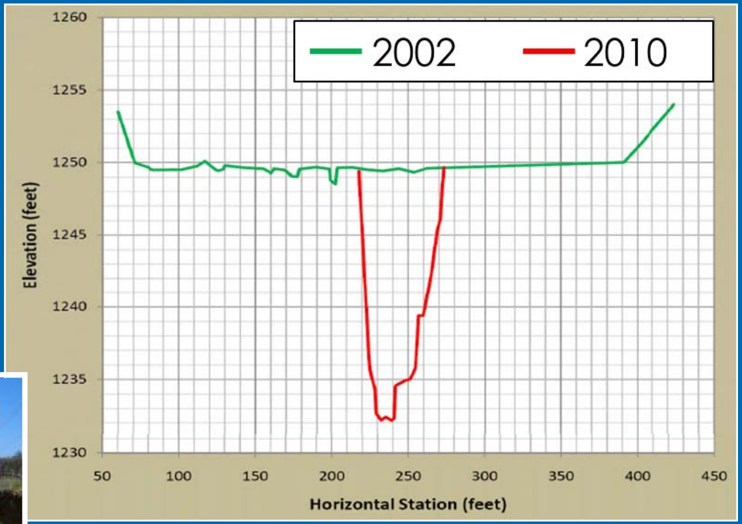


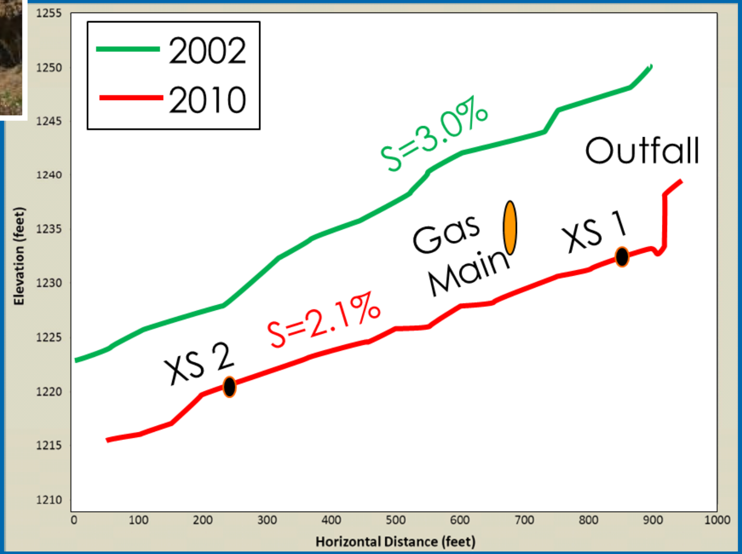
Post-Development

Δchannel geometry

Cross-sections and longitudinal profiles of the active channel are surveyed at strategic locations.

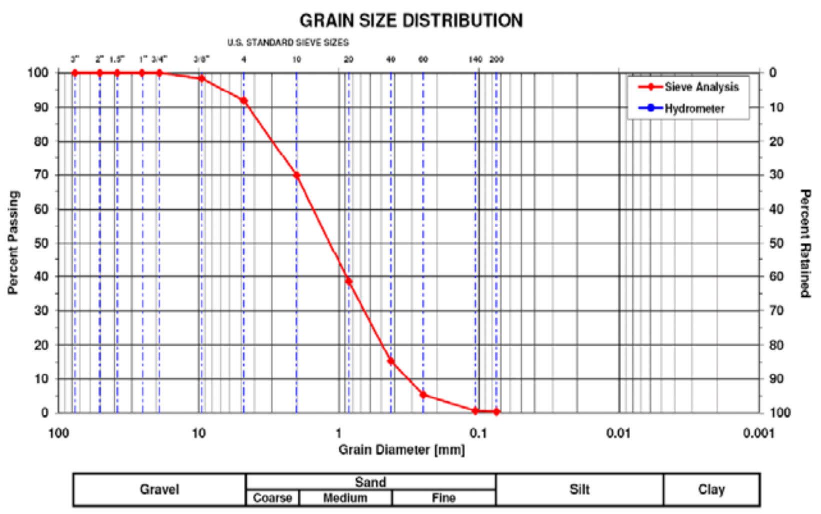






Δbed & bank material strength

For each reach surveyed, a measure of critical shear stress is based on the bed and bank material.



<u>Non-cohesive bed</u>:

Wolman Pebble Count and/or Sieve Analysis

<u>Cohesive bed and bank</u>:

Jet Test or Tables

<u>Vegetated bank</u>:

Tables

Bank Material Type	τ_c (lbs/ft^2)
ASCE Manual No. 77	
Hardpans	0.67
Compacted Clays	0.50
Stiff Clays	0.32

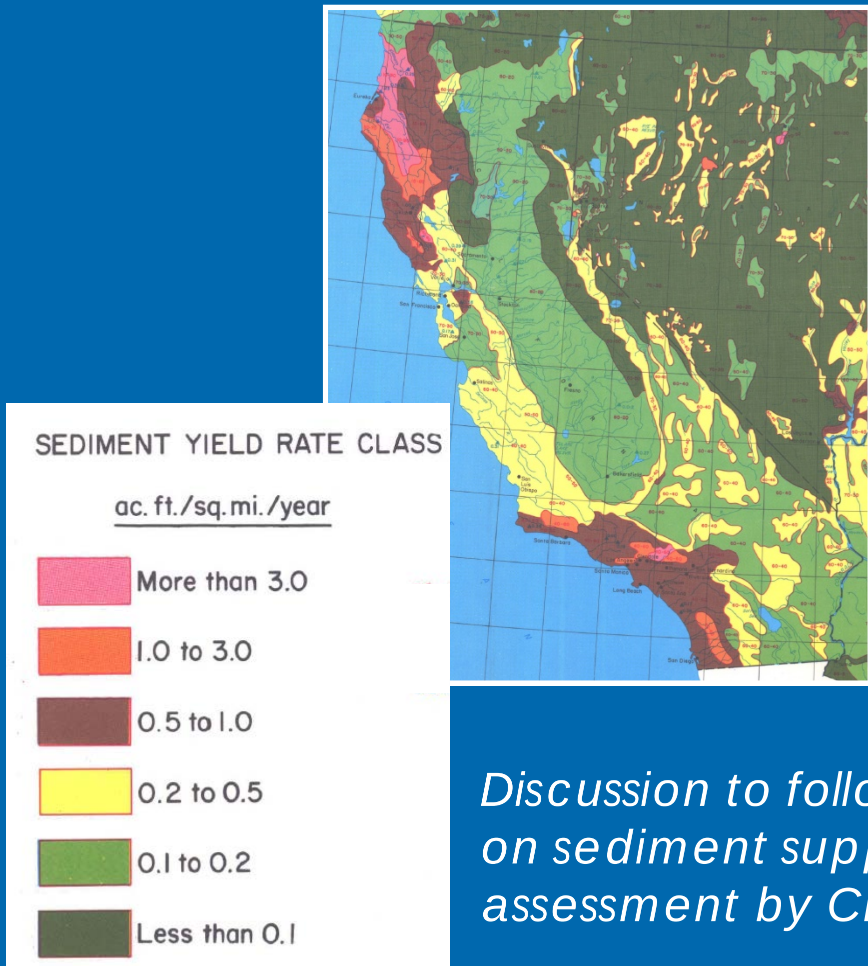
Δbed & bank material strength
Δchannel geometry

Google Trekker for geomorphic monitoring

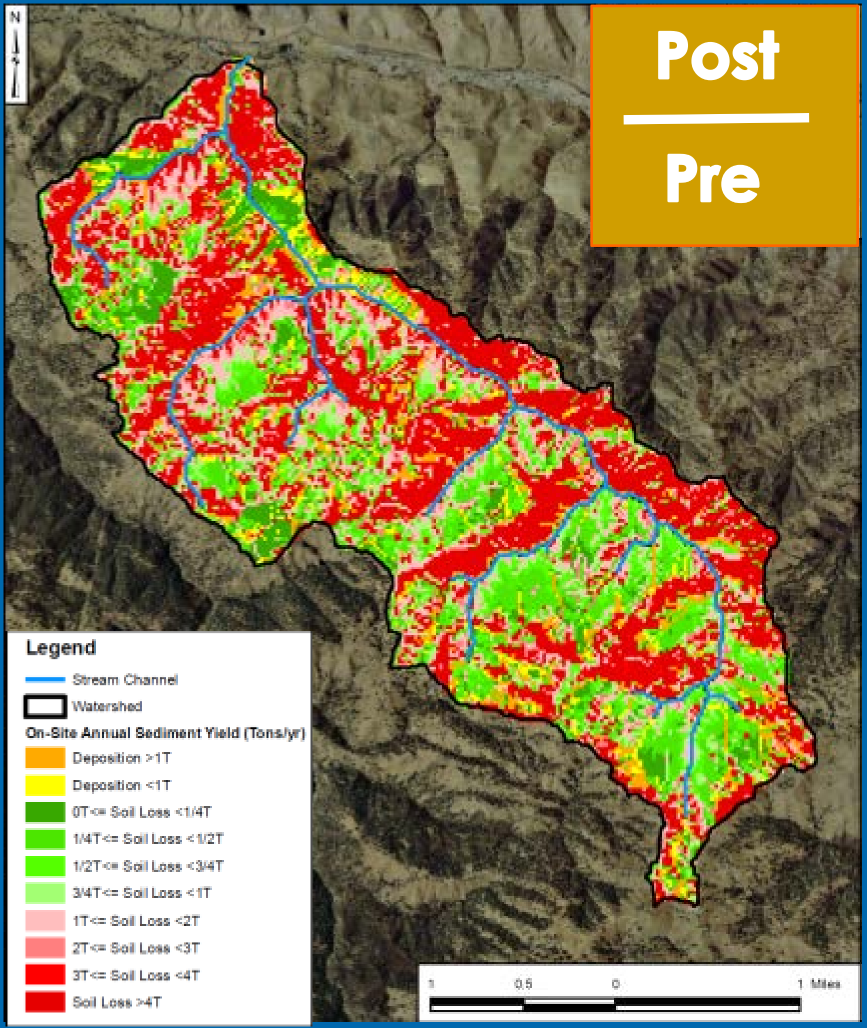
http://maps.google.com/help/maps/streetview/learn/cars-trikes-and-more.html#trekker

Δsediment supply

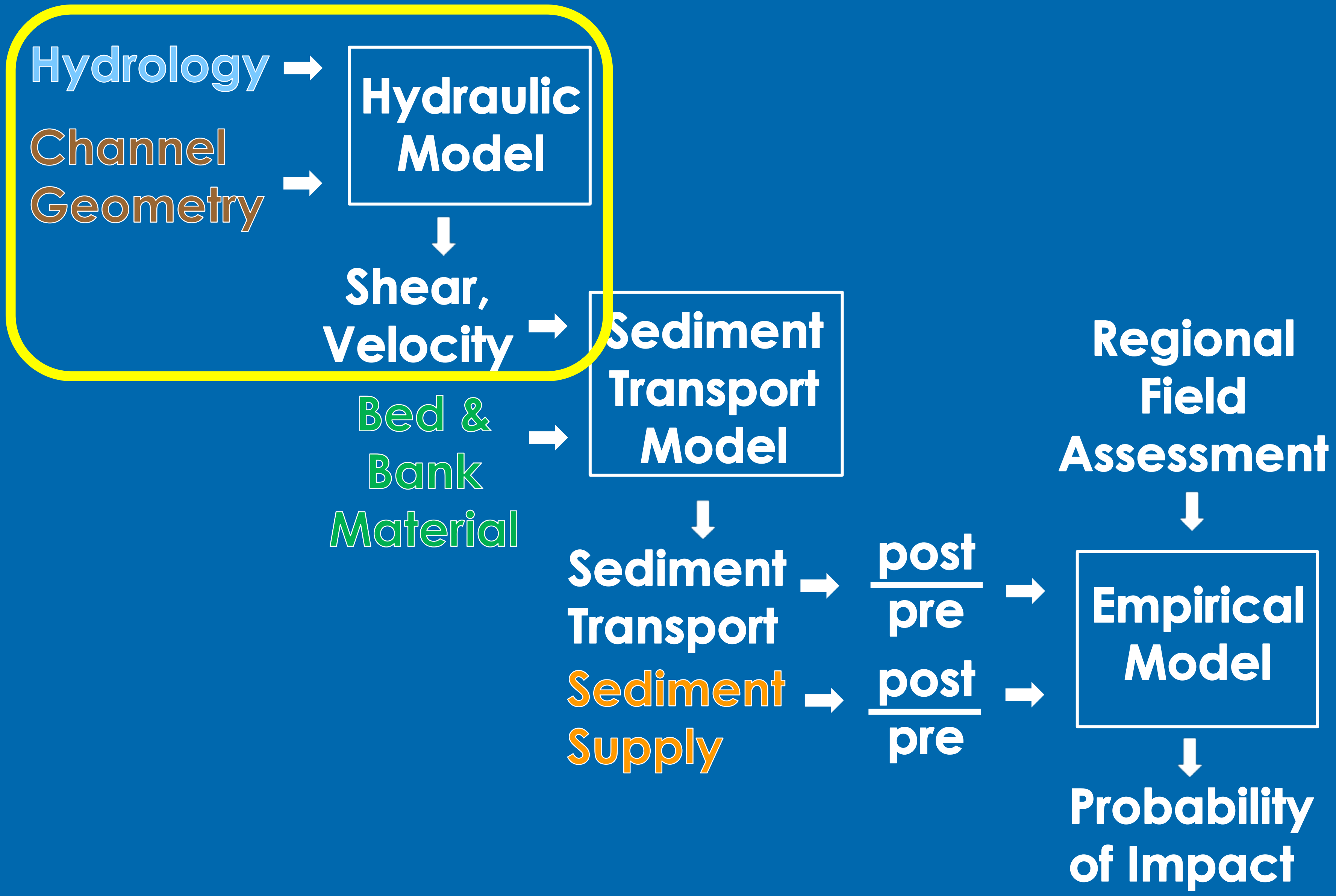
<u>Bed</u> sediment yields are estimated using field data and GIS analysis of hillslope gradient, geology, and land cover.



Discussion to follow on sediment supply assessment by Cid

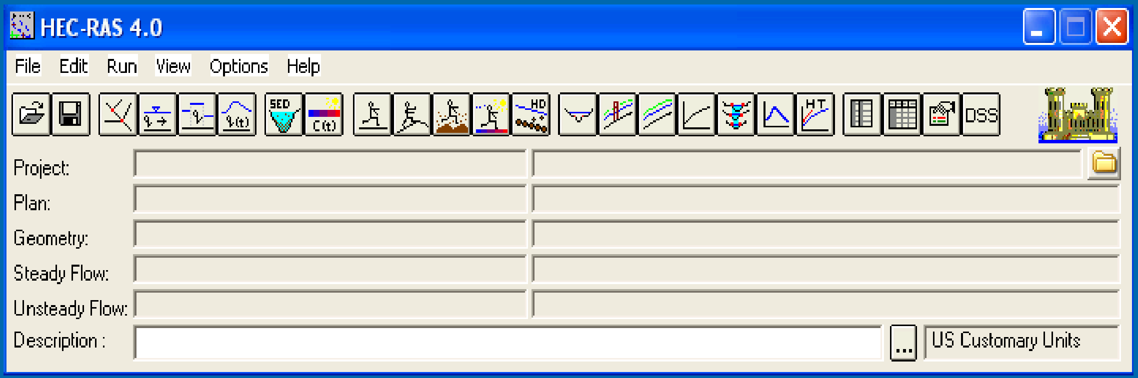


Model Summary



Model Summary

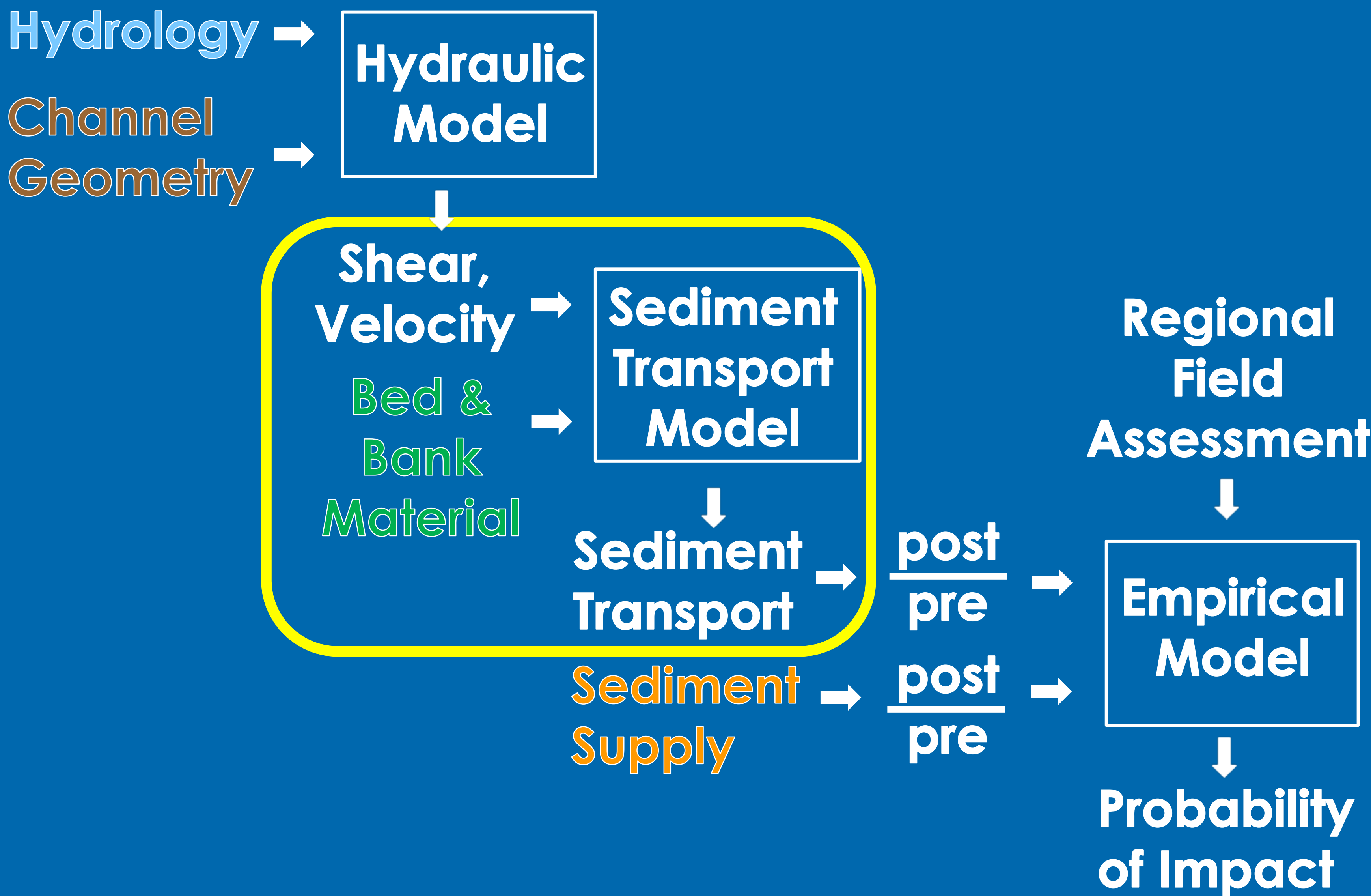
Stage, effective shear stress, and flow velocity are computed using discharge and channel geometry data as inputs to a hydraulic model.



$$\tau = \gamma R S$$

$$V = \frac{1.49 R^{2/3} S^{1/2}}{n}$$

Model Summary

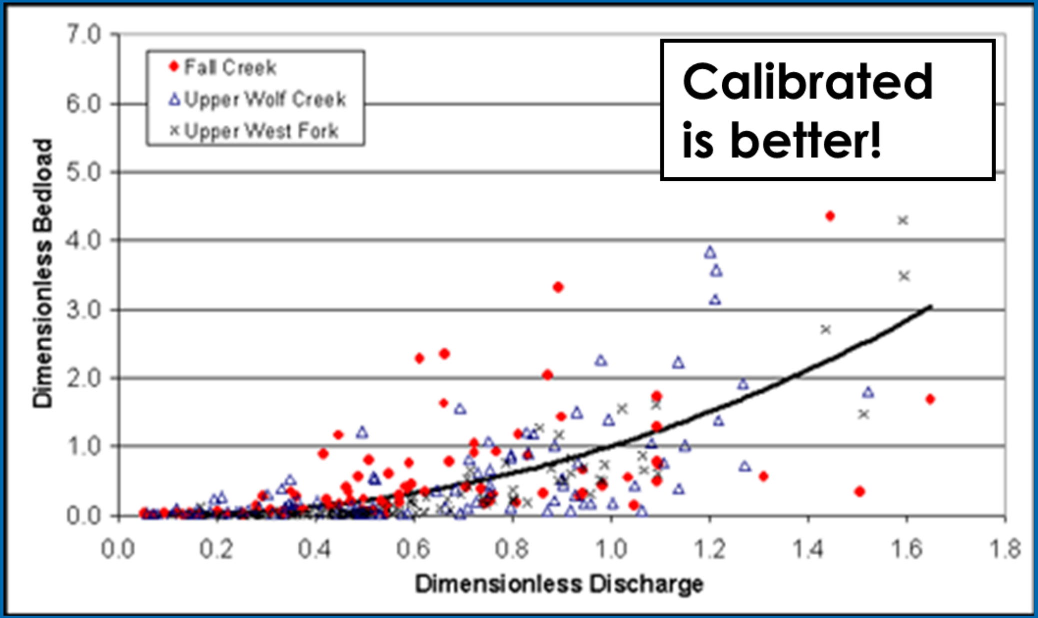


Model Summary

Stage, effective shear stress, flow velocity, and critical bed / bank material strength are input into the applicable work or sediment transport equation and summed over the period of record.

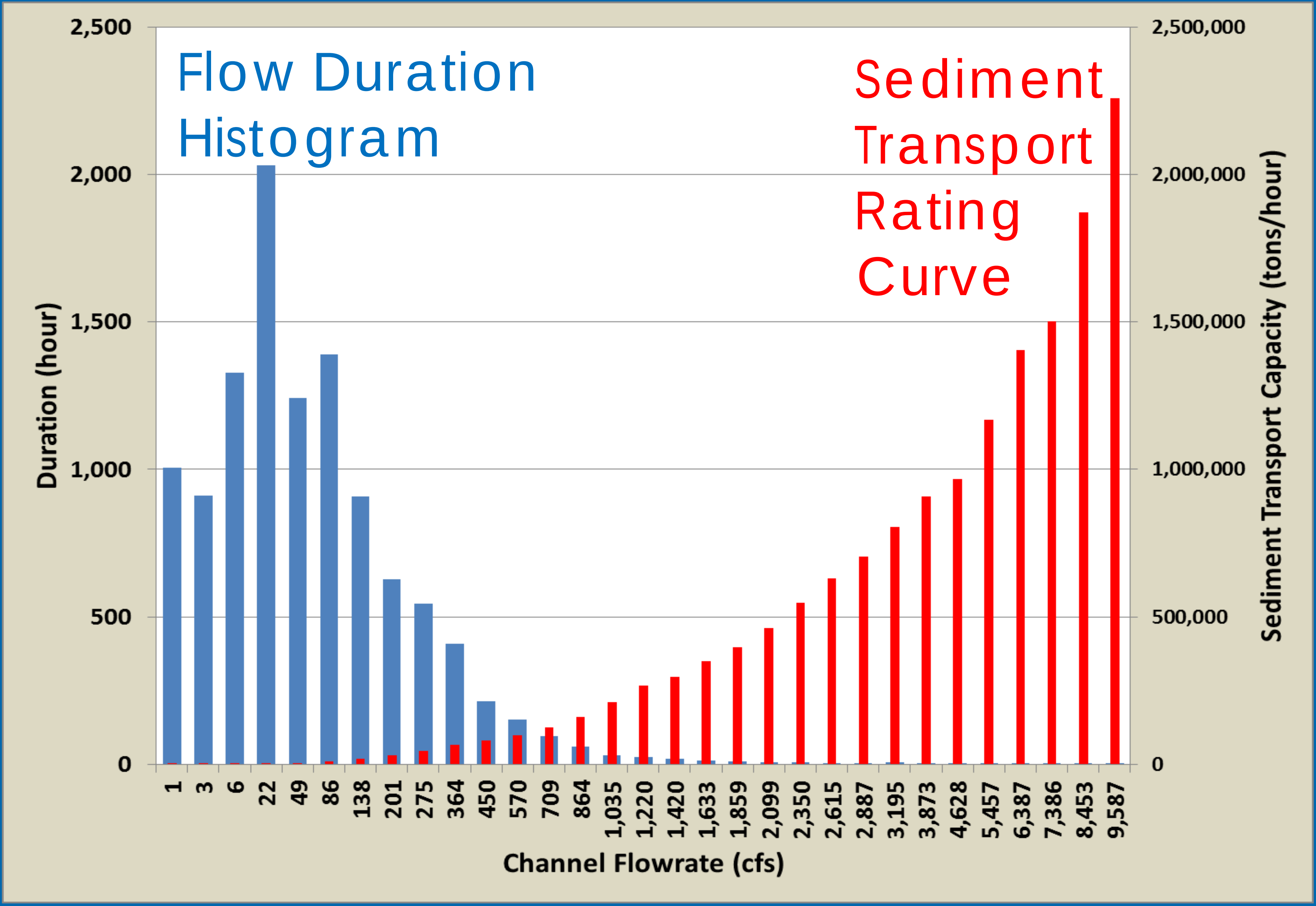
Work Equation:

$$W = \sum_{i=1}^{n} \left(\tau_i - \tau_c\right)^{1.5} \cdot V \cdot \Delta t_i$$

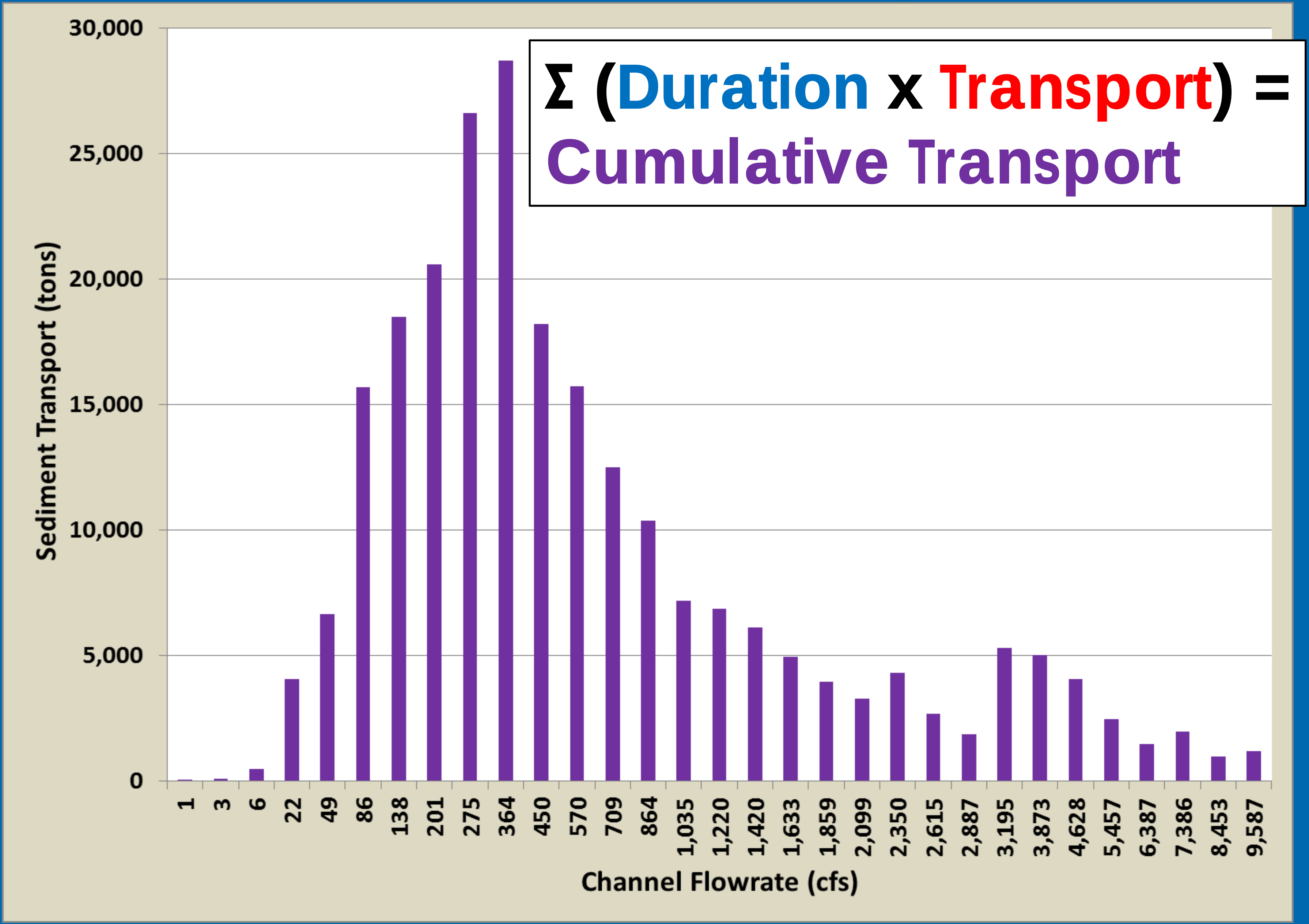


http://water.epa.gov/scitech/datait/tools/warsss/dimless.cfm

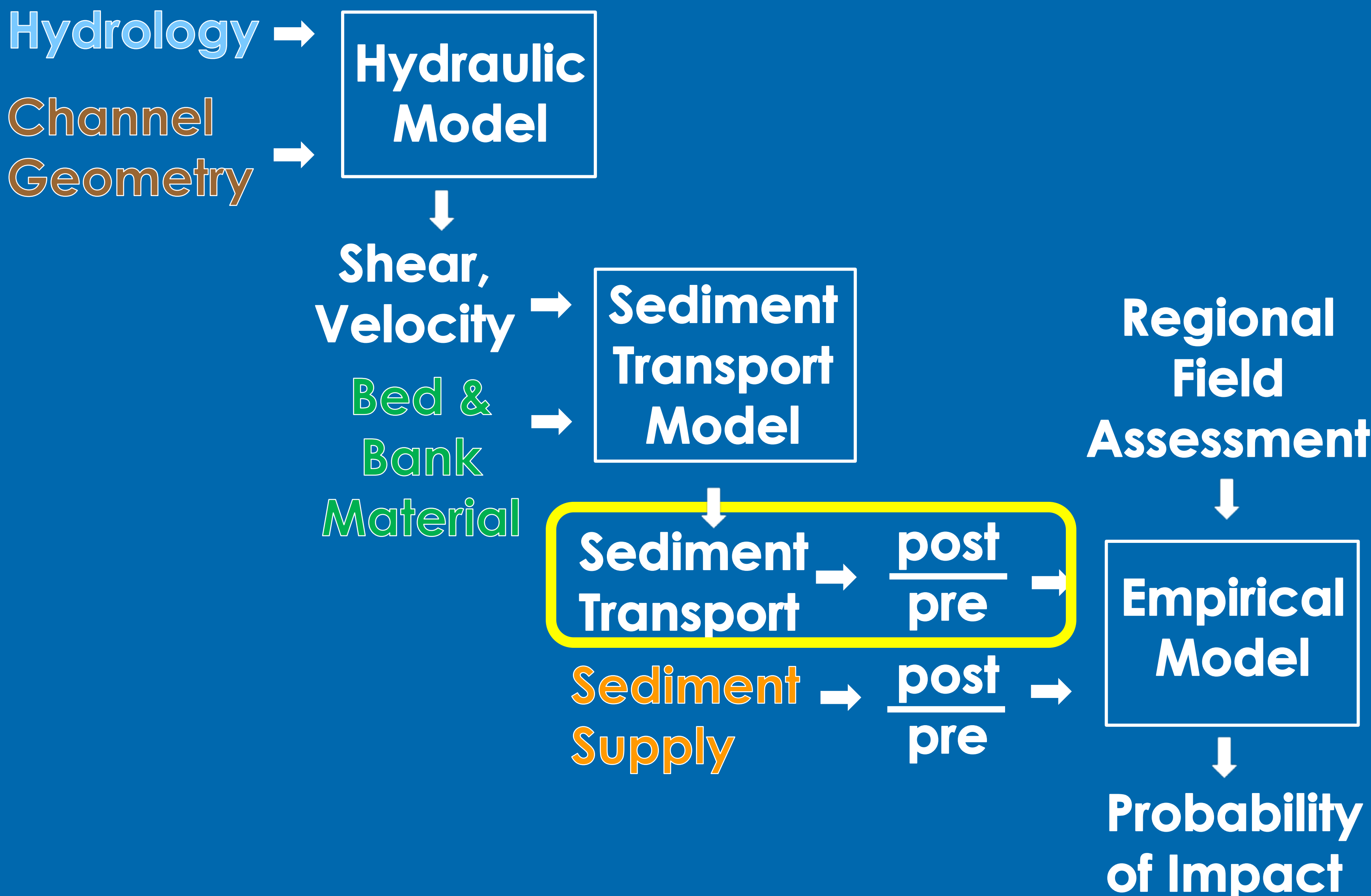
Model Summary



Model Summary

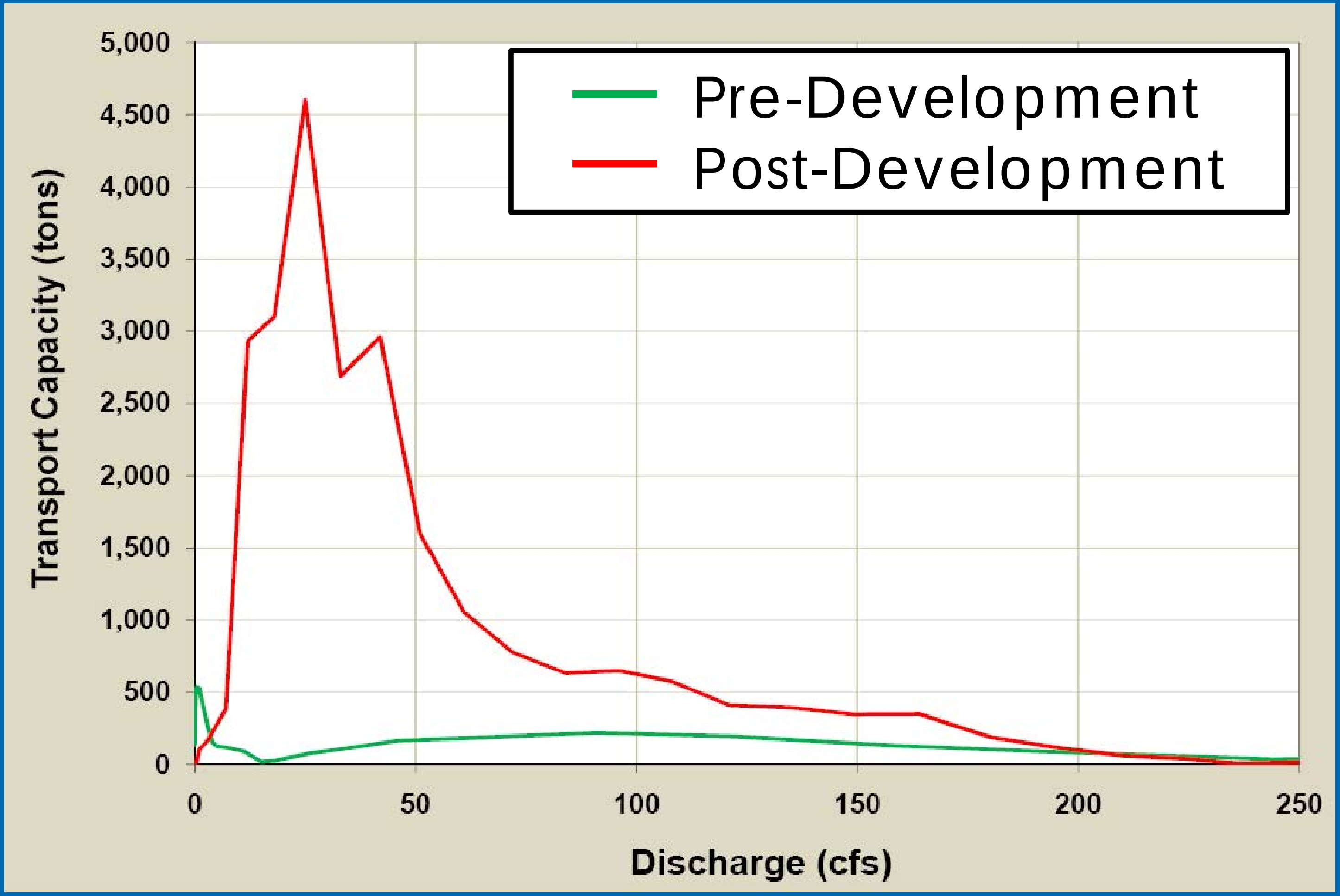


Model Summary

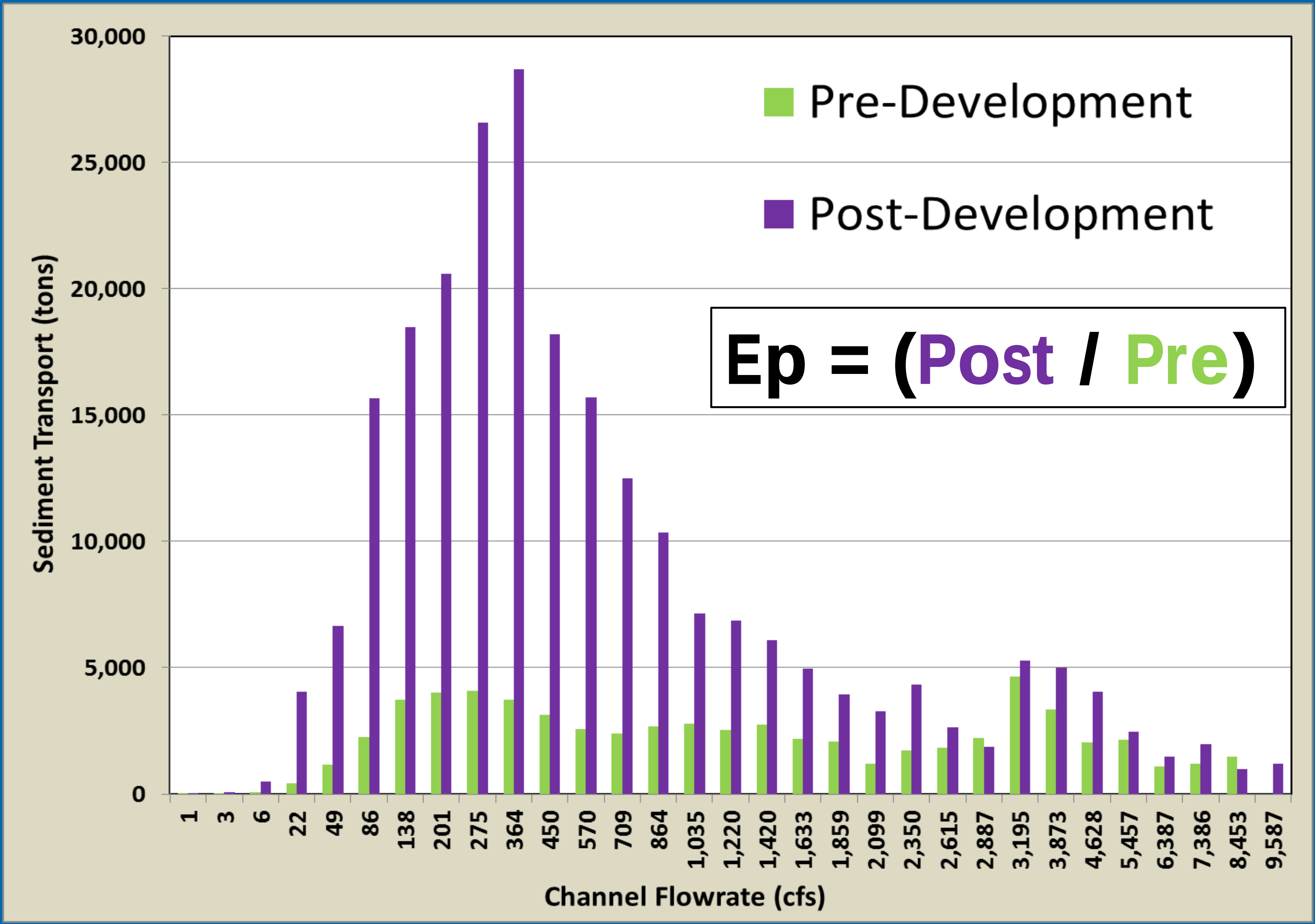


Model Summary

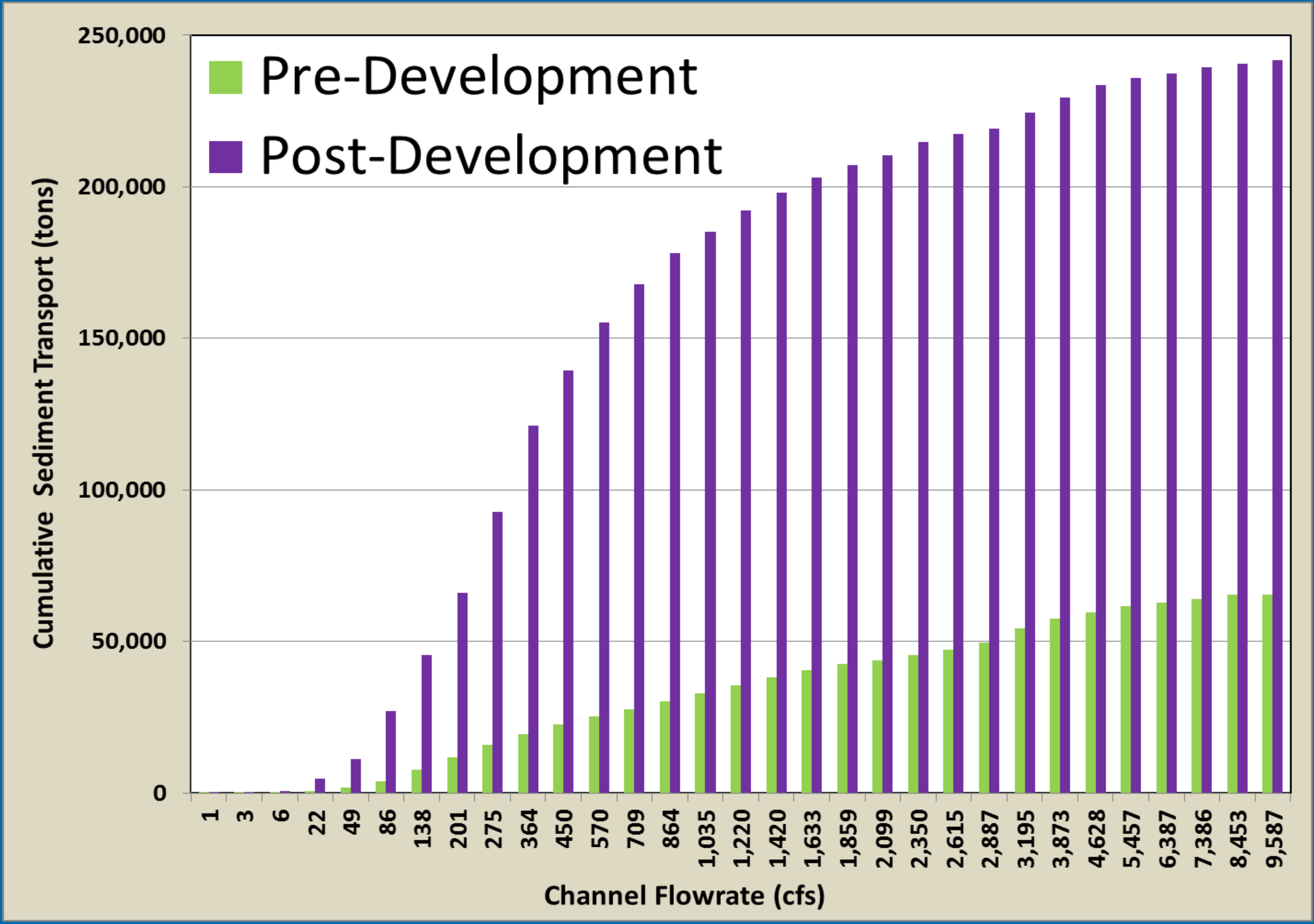
Erosion Potential (Ep) is calculated by comparing relative change in cumulative sediment transport capacity in the pre- and post-development conditions:



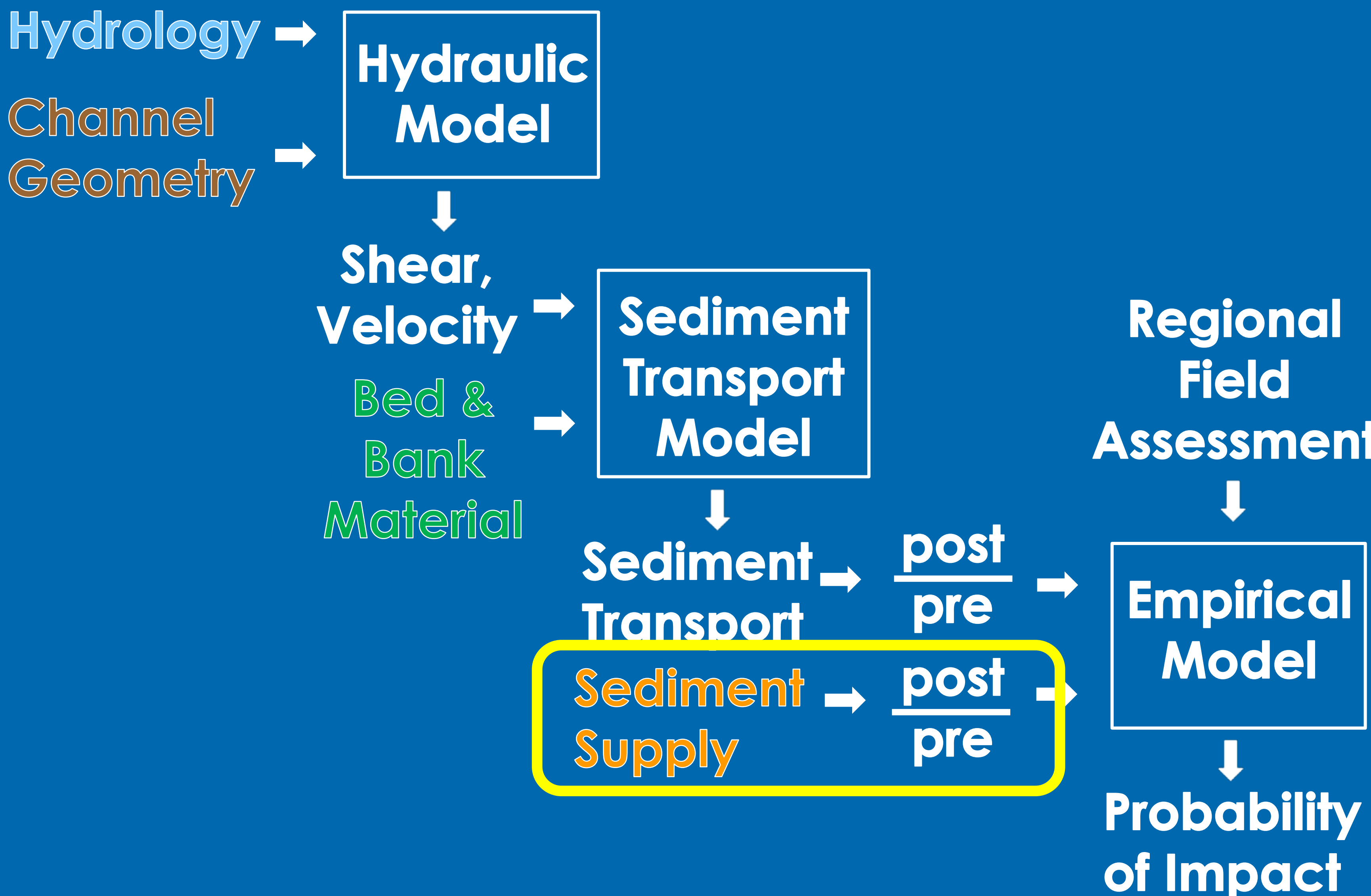
Model Summary



Model Summary



Model Summary



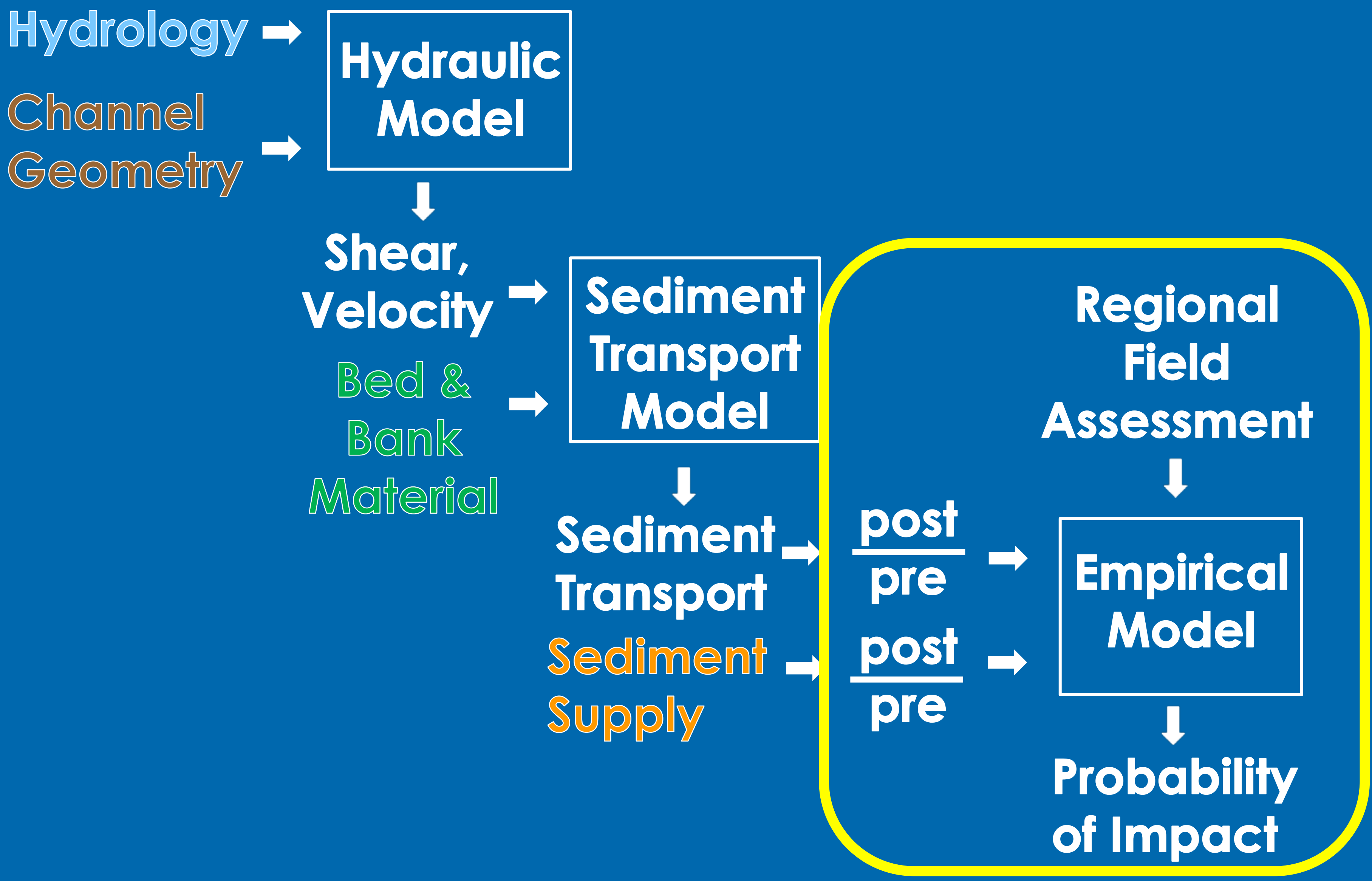
Model Summary

Sediment supply loss can be accounted for by reducing the Target Ep by the ratio of bed sediment supply (Sp) to that computation point.

$$Sp = \frac{\text{Sediment Supply}_{\text{post}}}{\text{Sediment Supply}_{\text{pre}}}$$

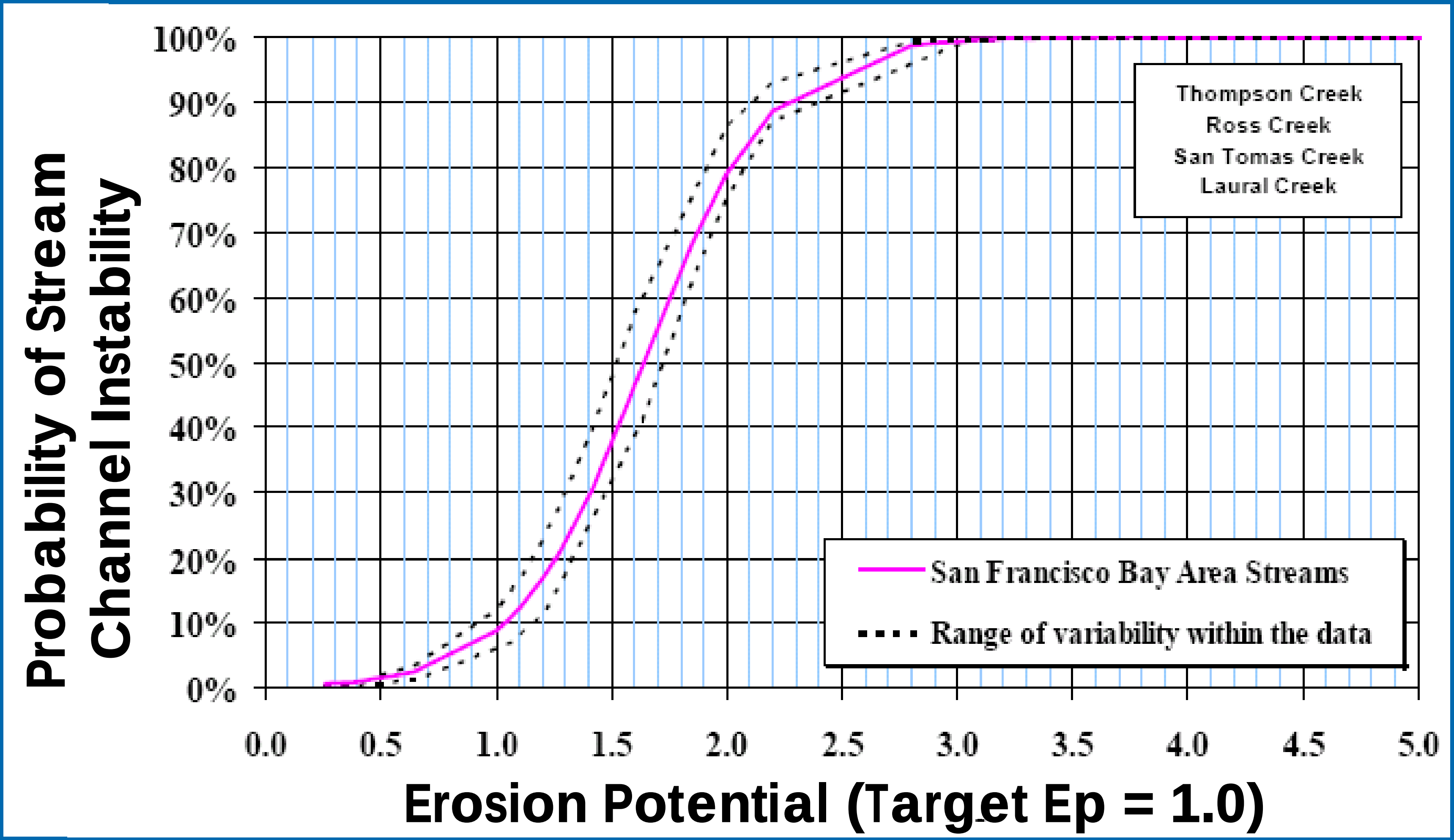
http://www.dnr.wa.gov/researchscience/topics/geologichazardsmapping/pages/landslides_murphys.aspx

Model Summary



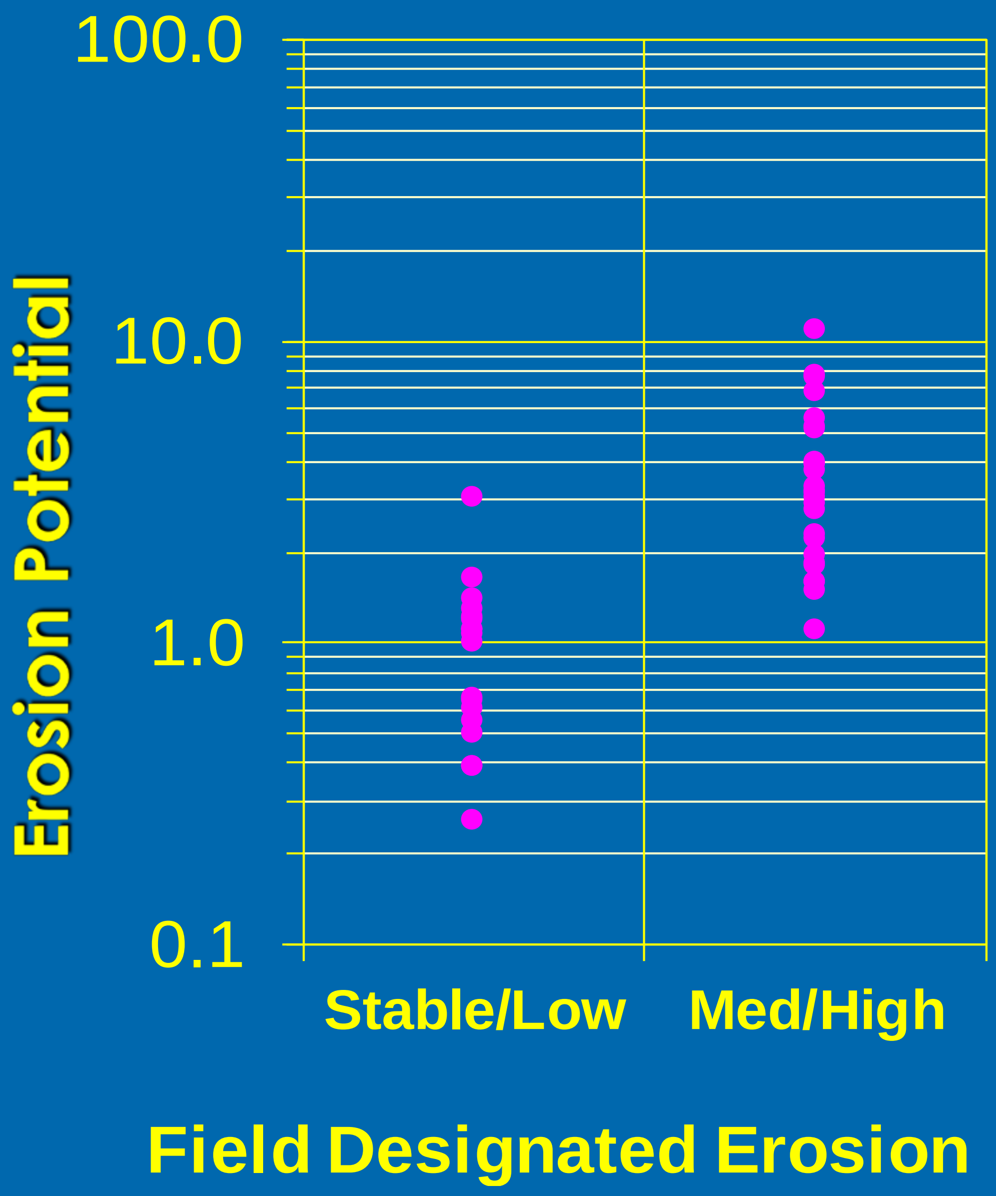
Model Summary

Ep is compared to the Target Ep (Sp) to get a Probability of Channel Instability.



Model Summary

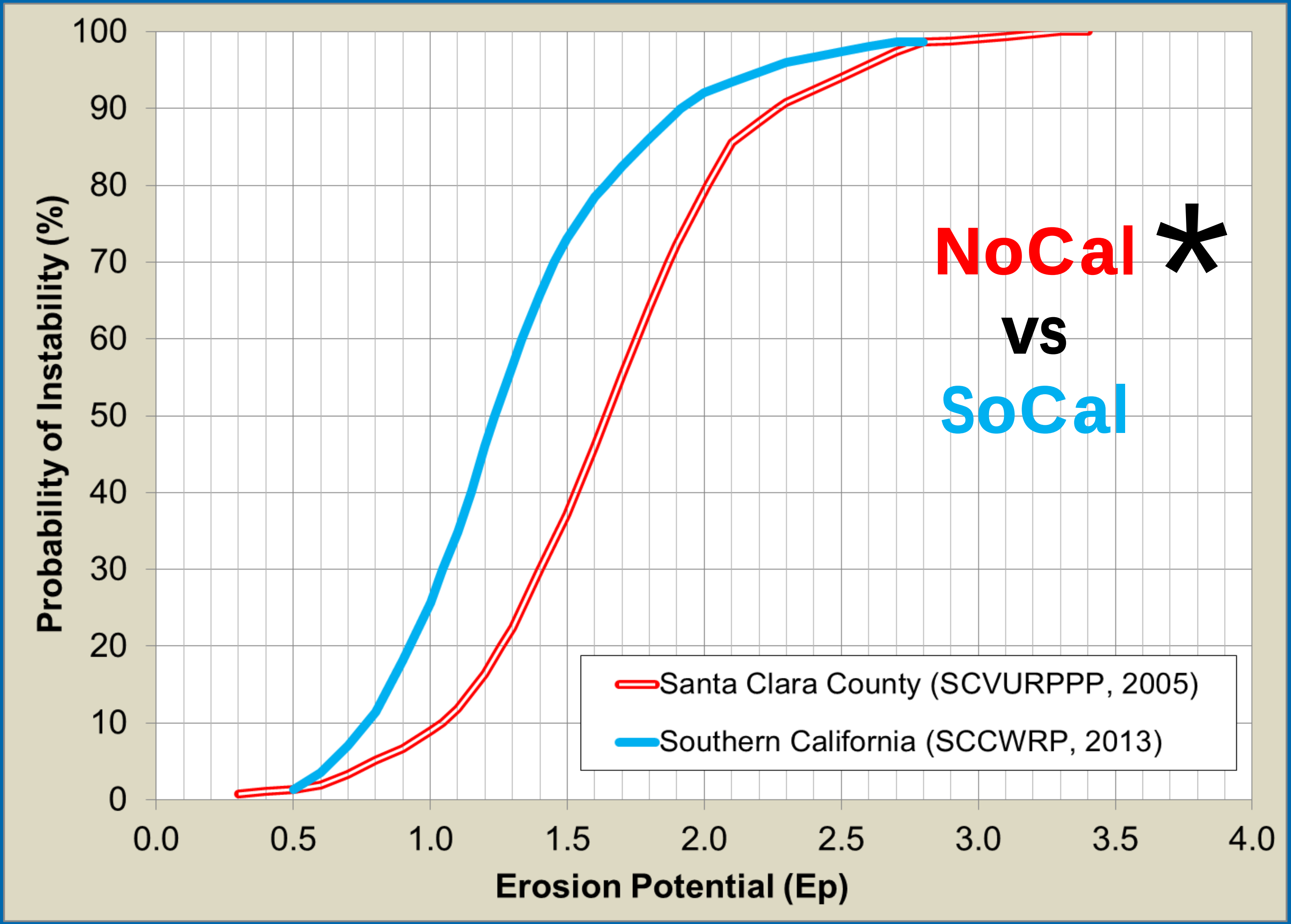
Santa Clara Valley Hydromodification Management Plan



40 Cross Sections:

- Thompson Creek
- Ross Creek
- San Tomas Creek

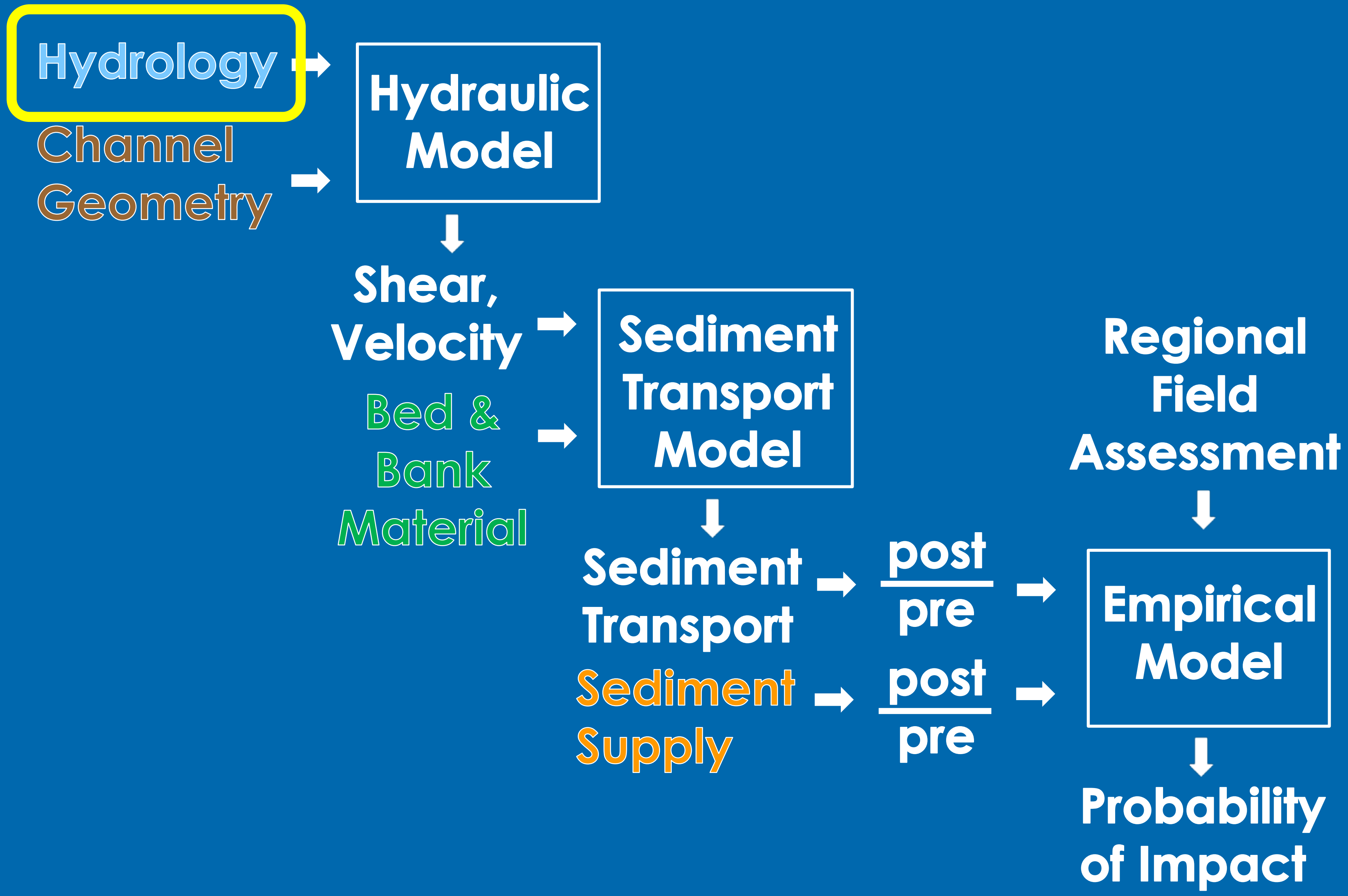
Model Summary



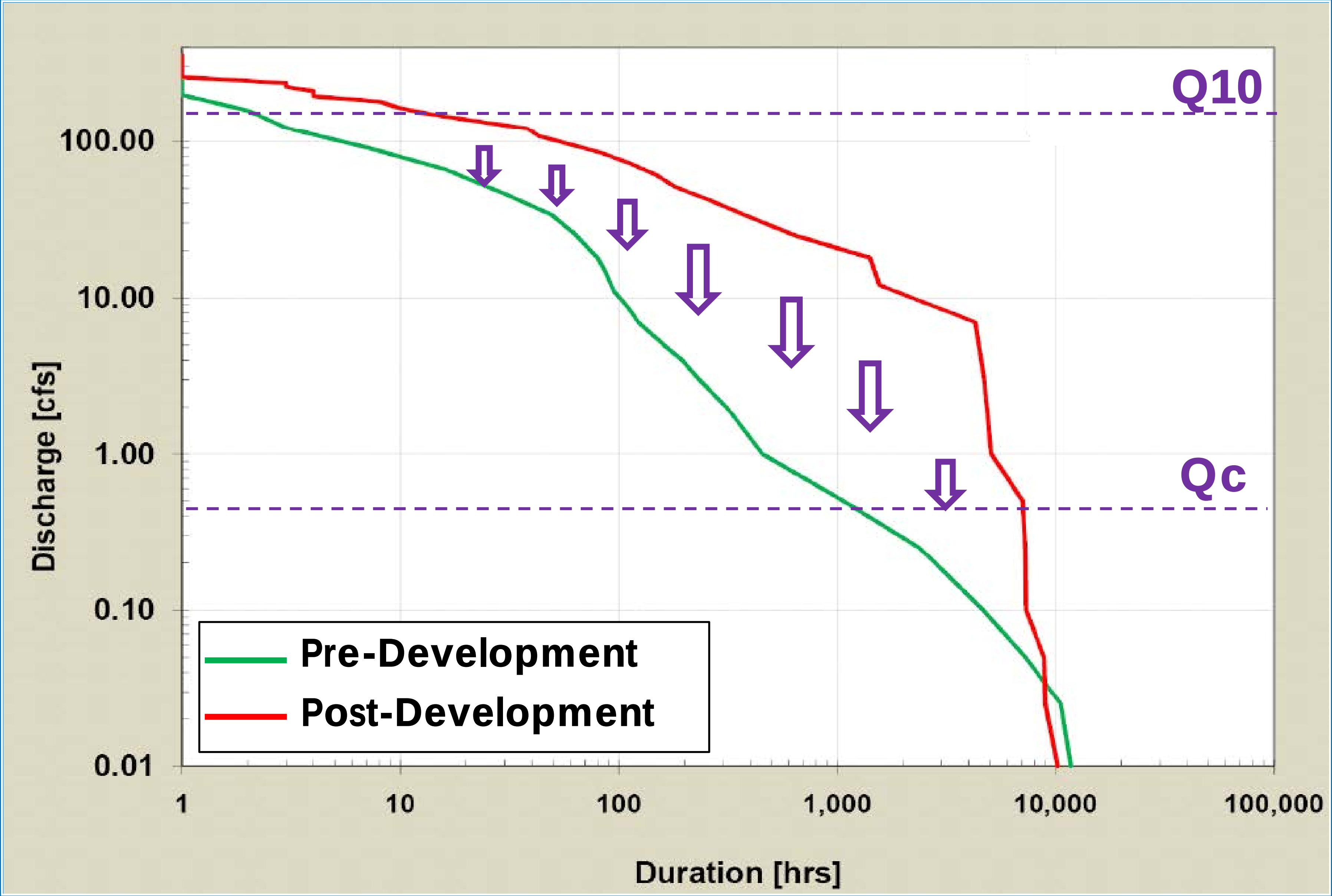
Discussion to follow on probabilistic models by Ashmita

Management Strategies

Out-of-Stream Management

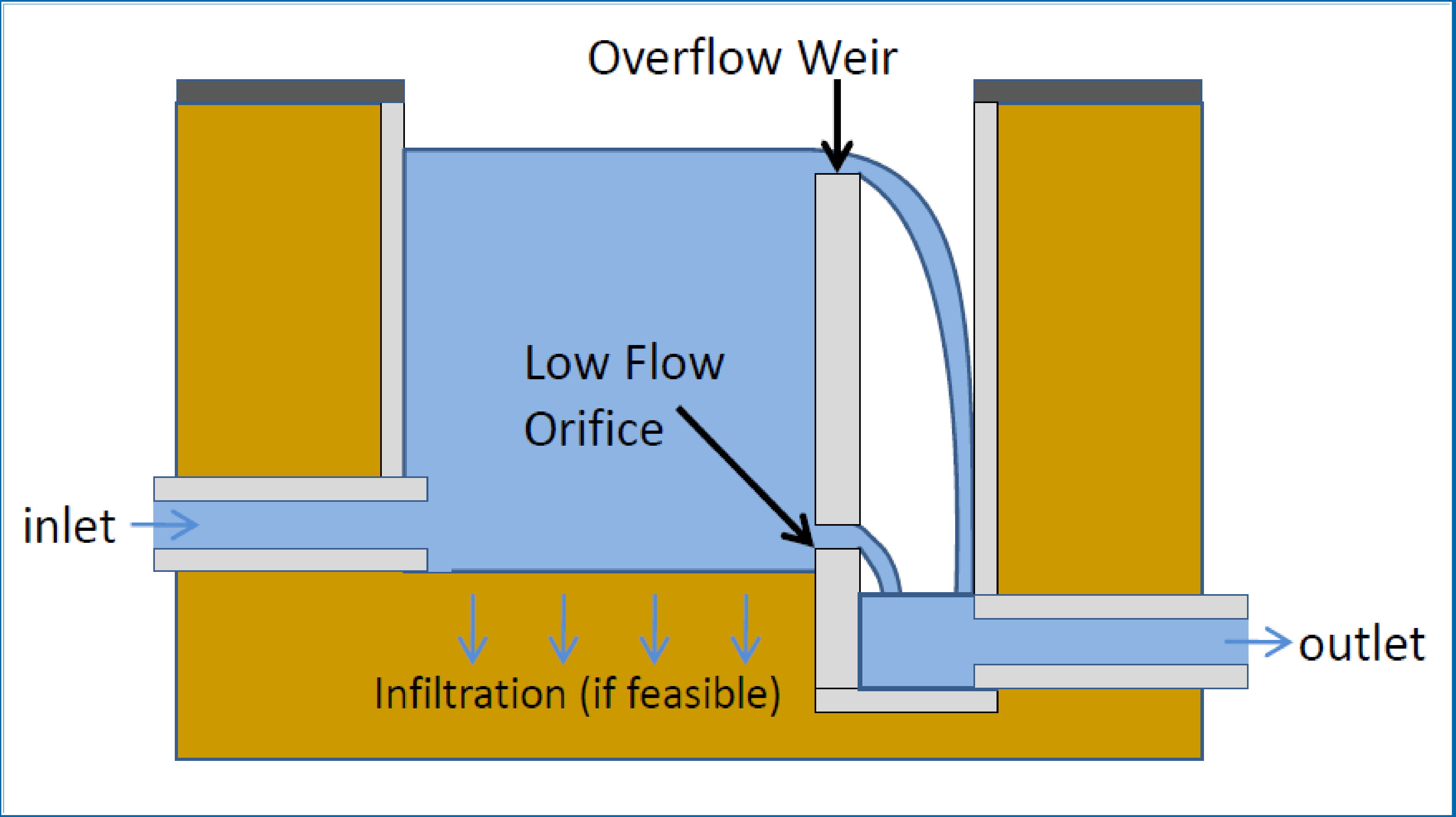


Out-of-Stream Management



Out-of-Stream Management

Route post-development runoff through BMPs to mimic pre-development hydrology.



Out-of-Stream Management

Regional Detention Basin

Discussion to follow on Flow Monitoring by Felicia

Onsite Bioretention

Underground Detention/Retention

CONTECH

StormTrap

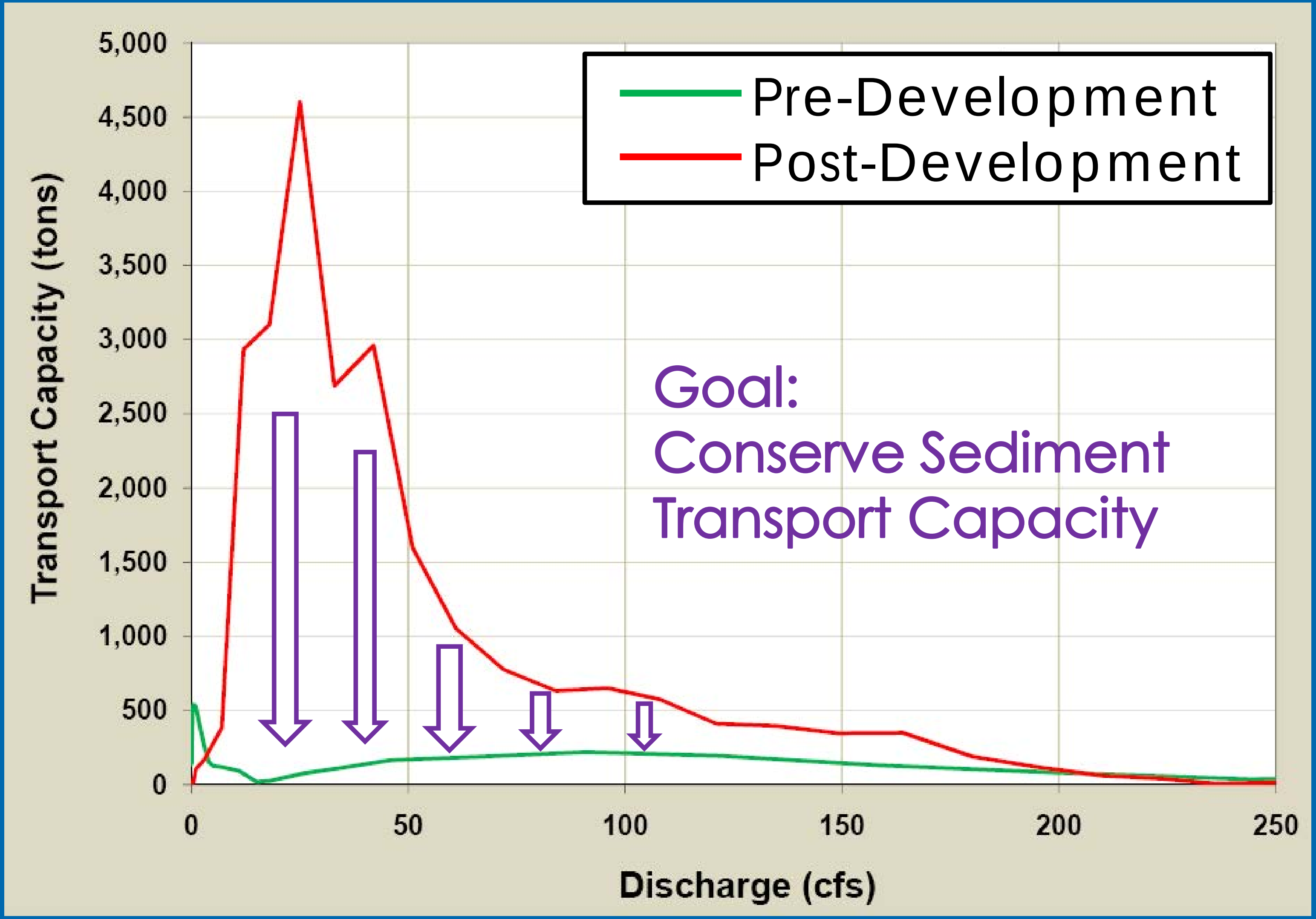
In-Stream Management

Hydrology →
Channel Geometry →
Hydraulic Model
↓
Shear, Velocity →
Bed & Bank Material →
Sediment Transport Model
↓
Sediment Transport → post / pre →
Sediment Supply → post / pre →
Regional Field Assessment
↓
Empirical Model
↓
Probability of Impact

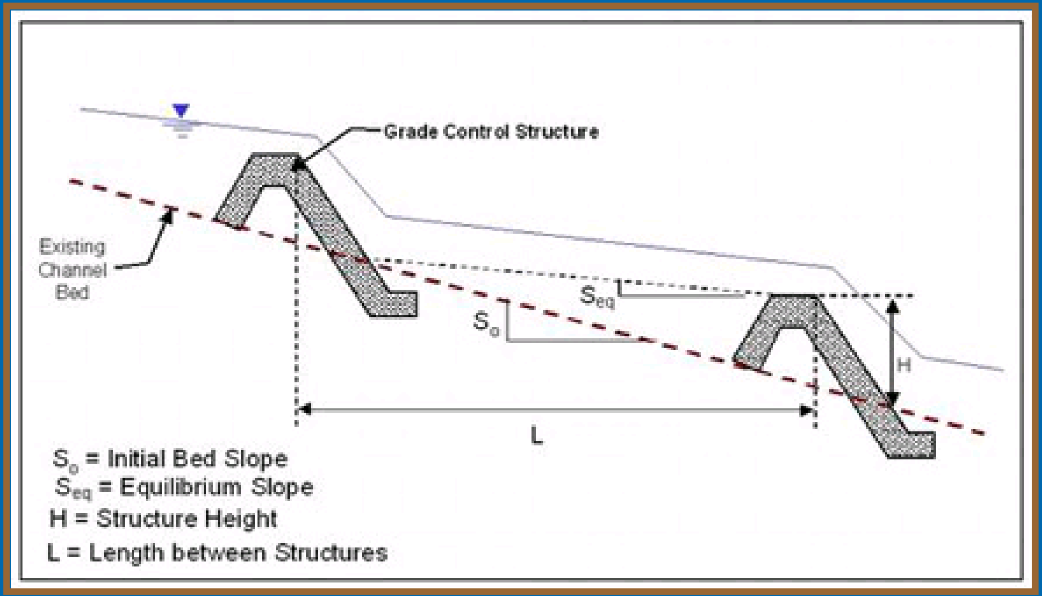
In-Stream Controls are appropriate where hydromodification impacts already exist, not pristine streams.

In-Stream Management

Modify the stream morphology to mimic pre-development work/sediment transport.



In-Stream Management

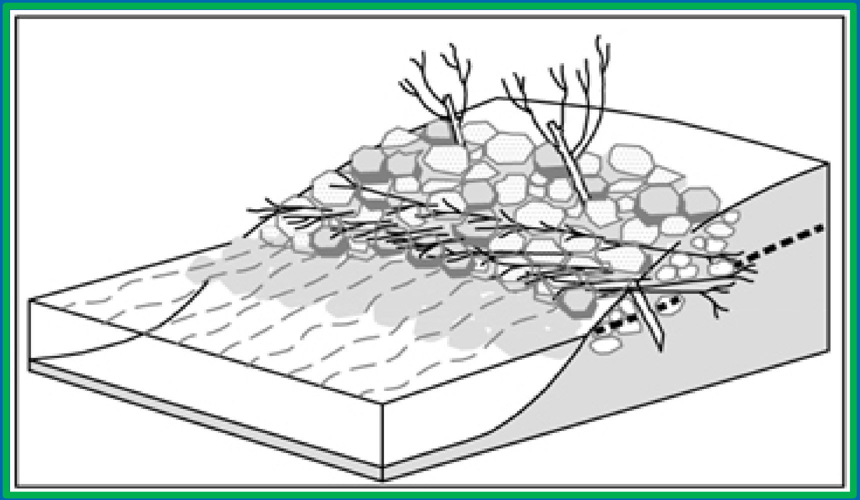


ESA-PWA

Grade Control

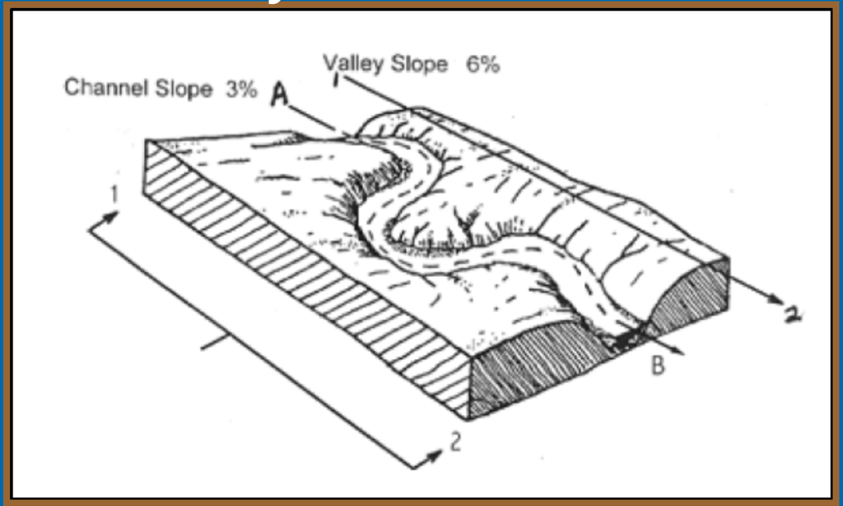
ESA-PWA

Channel Reinforcement



Salix Applied Earthcare, 2004

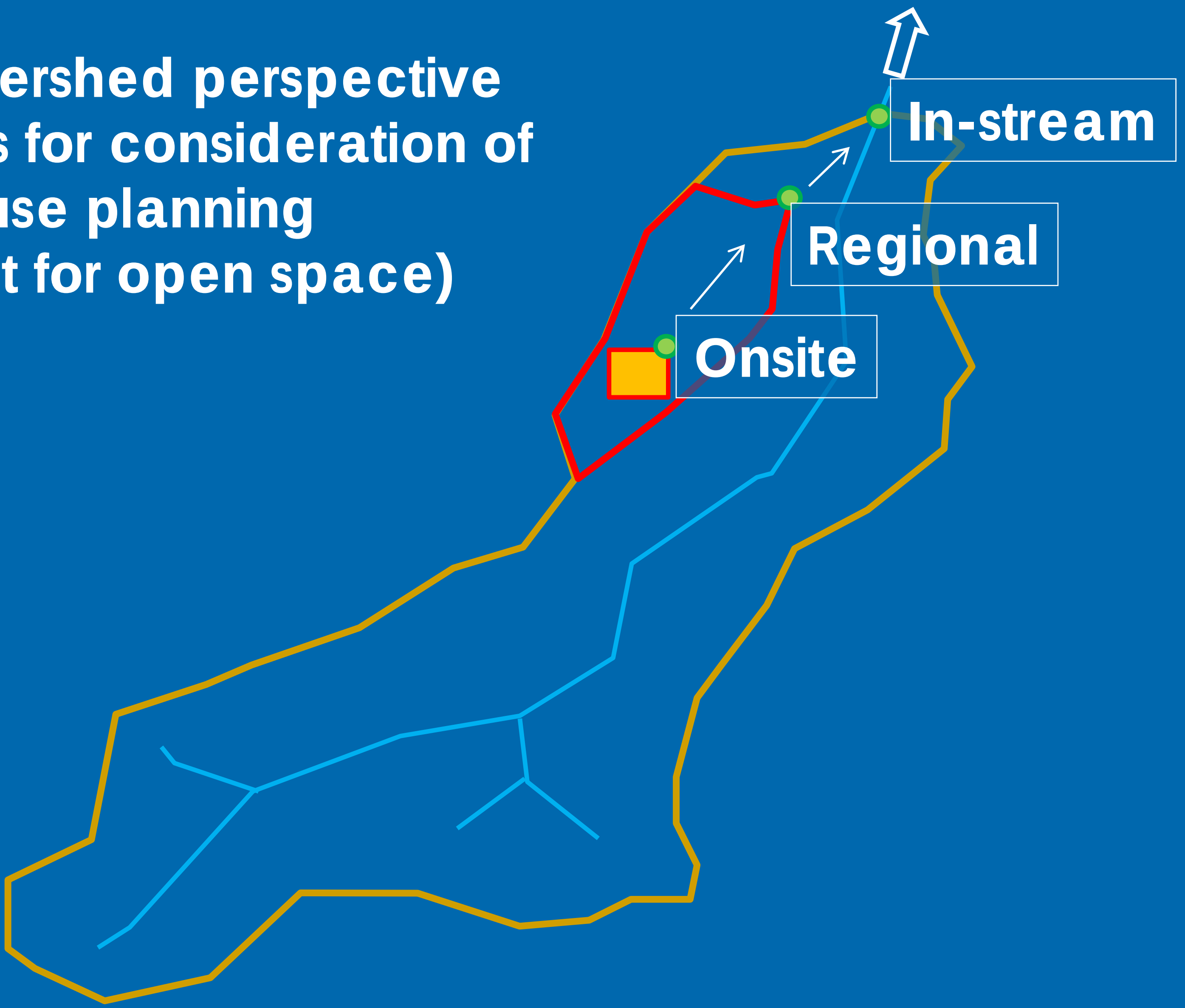
Sinuosity



County of San Diego, 2009

Management Scales

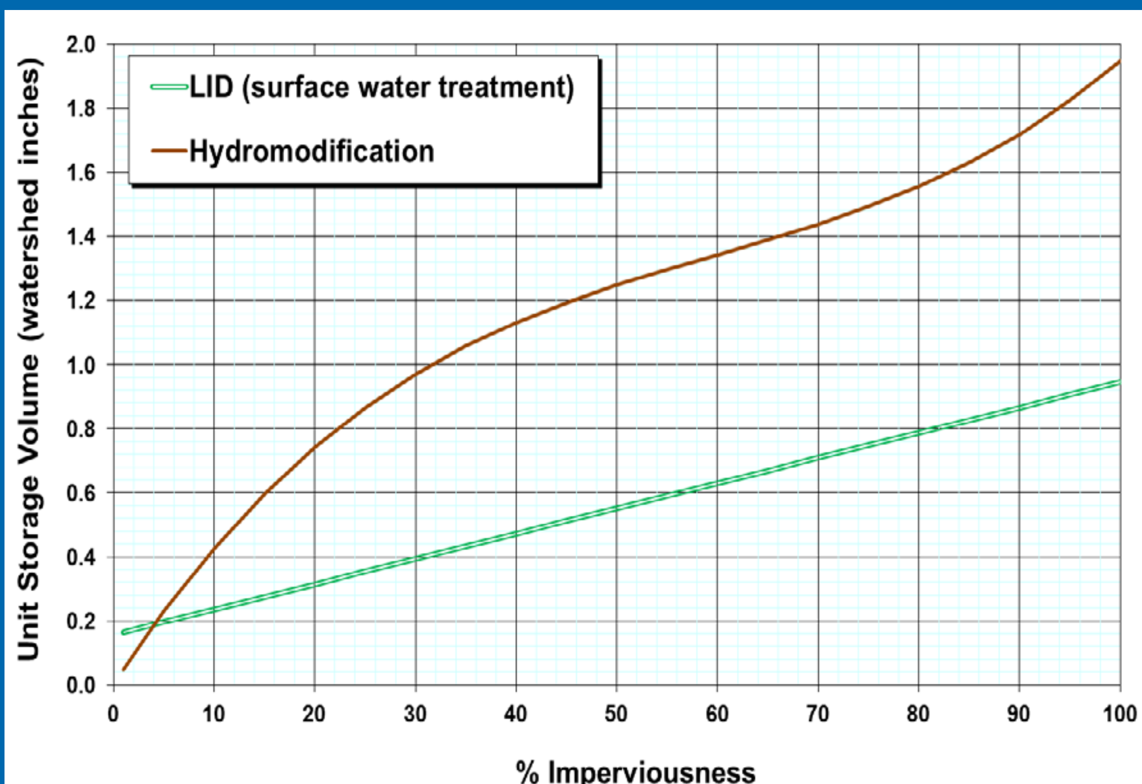
A watershed perspective allows for consideration of land use planning (credit for open space)

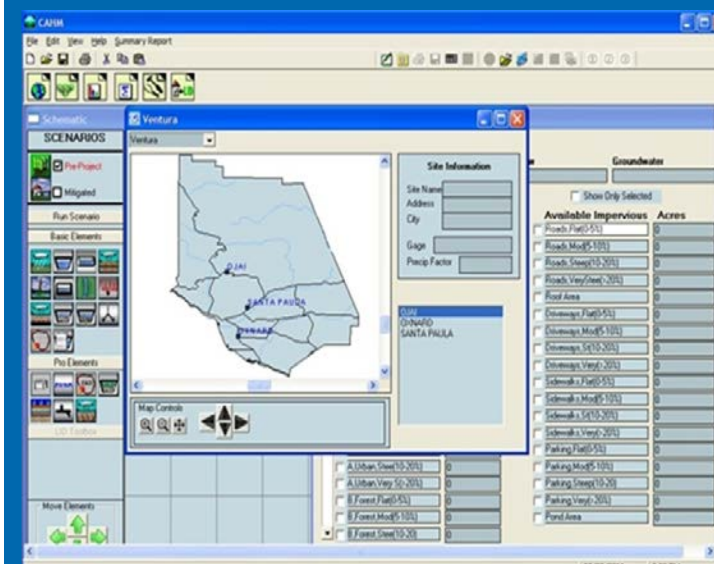


BMP Sizing Options

	Onsite	Regional	In-Stream
Nomographs or Sizing Factors	X		
Regional Models	X	X	
System-Specific Analysis	X	X	X

↓ Complexity



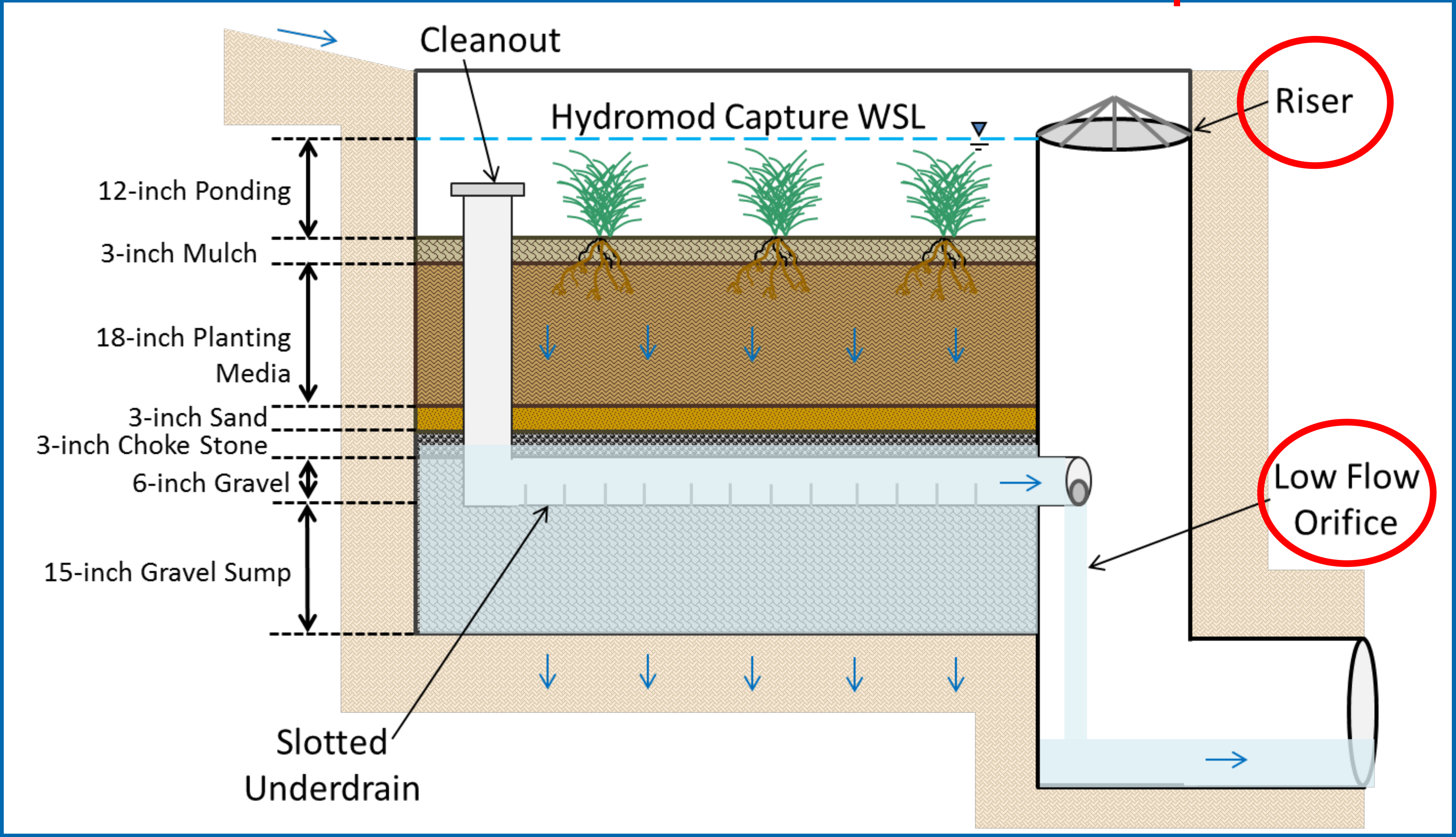


Clear Creek Solutions

BMP Sizing Sensitivities

LID-Type BMPs

simple outlet



Hydromod LID BMPs look similar to those designed for surface water quality, except they tend to be larger.

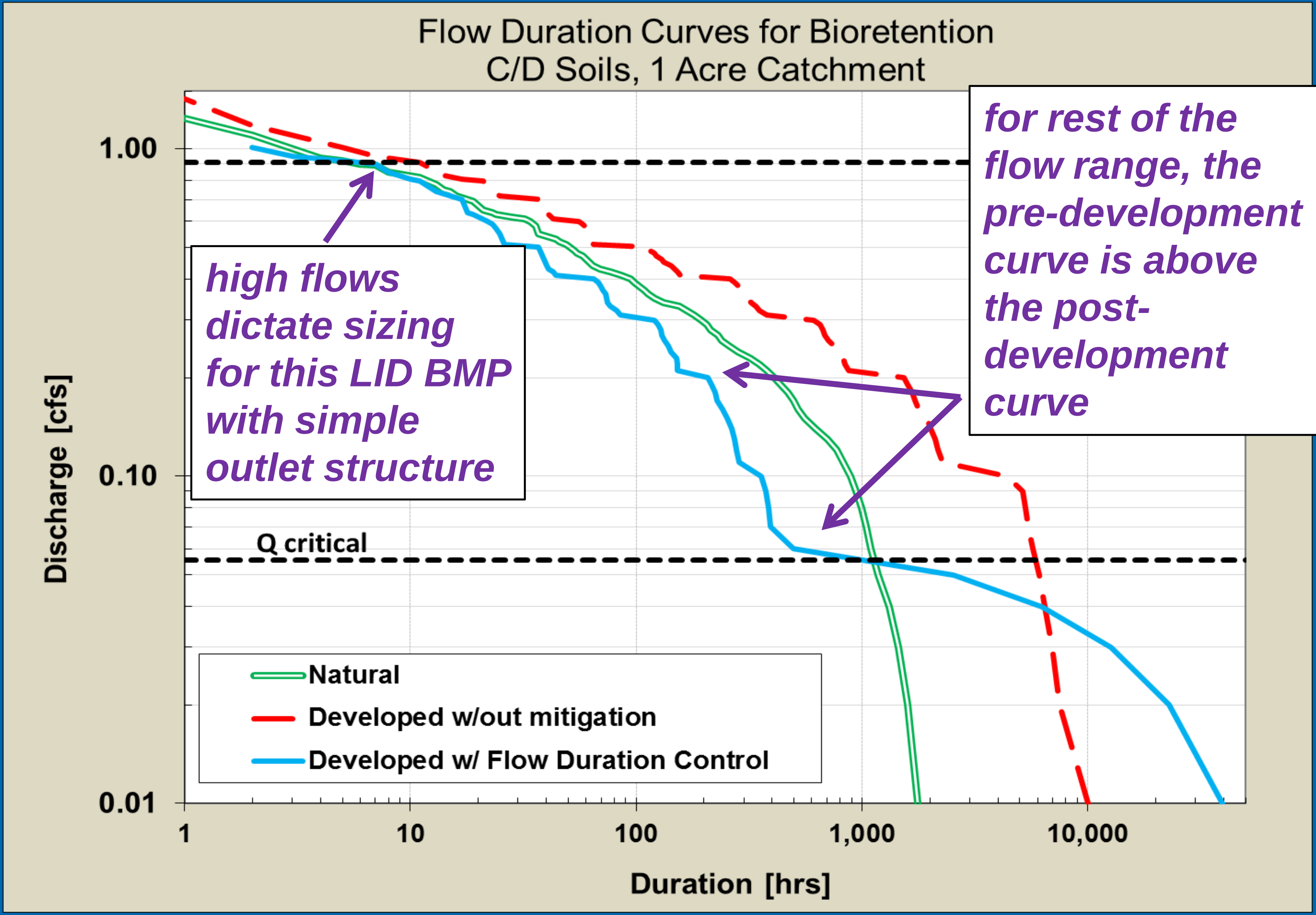
Performance Standard

Flow Duration Control (FDC)

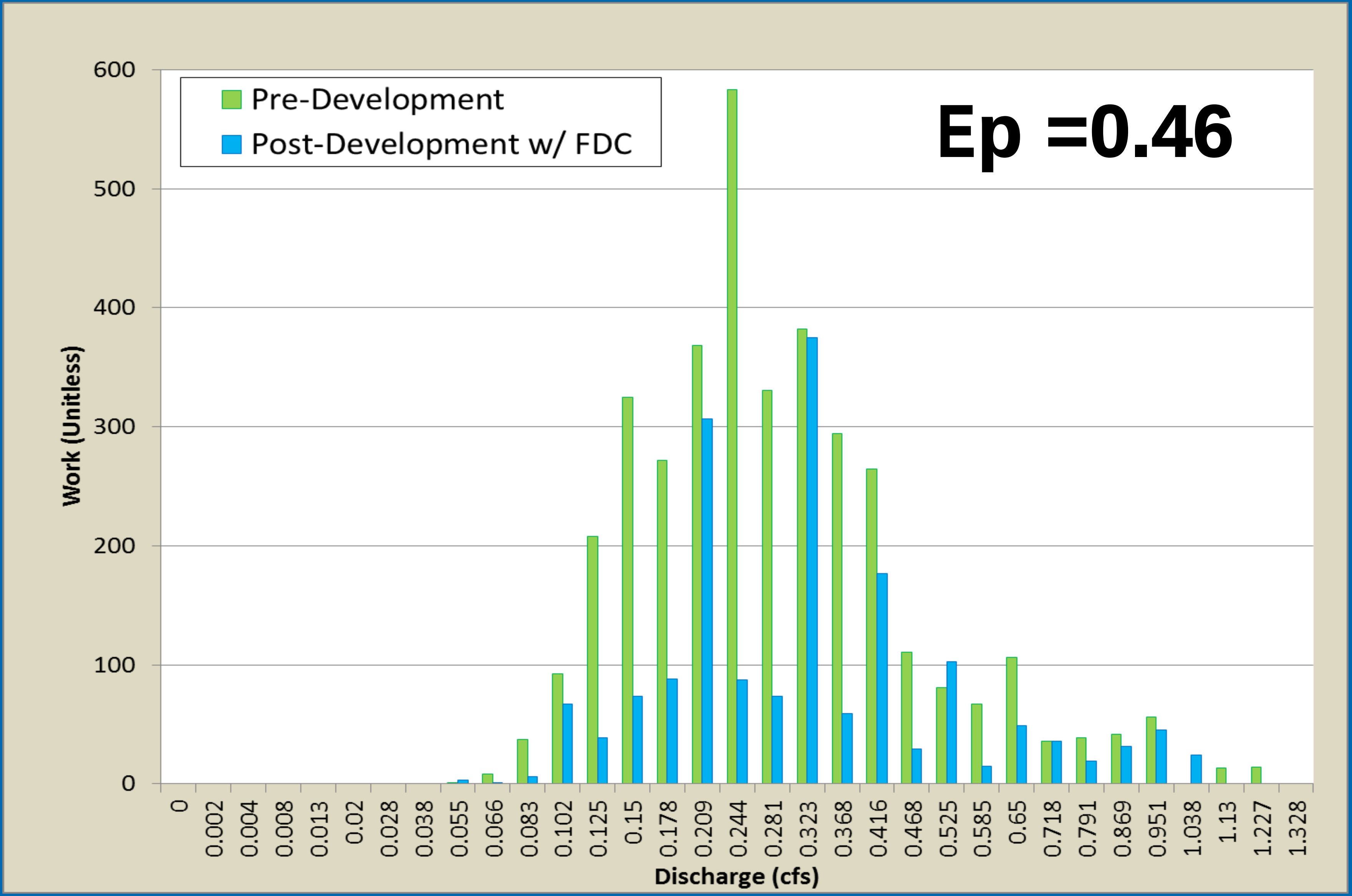
vs.

Erosion Potential (Ep)

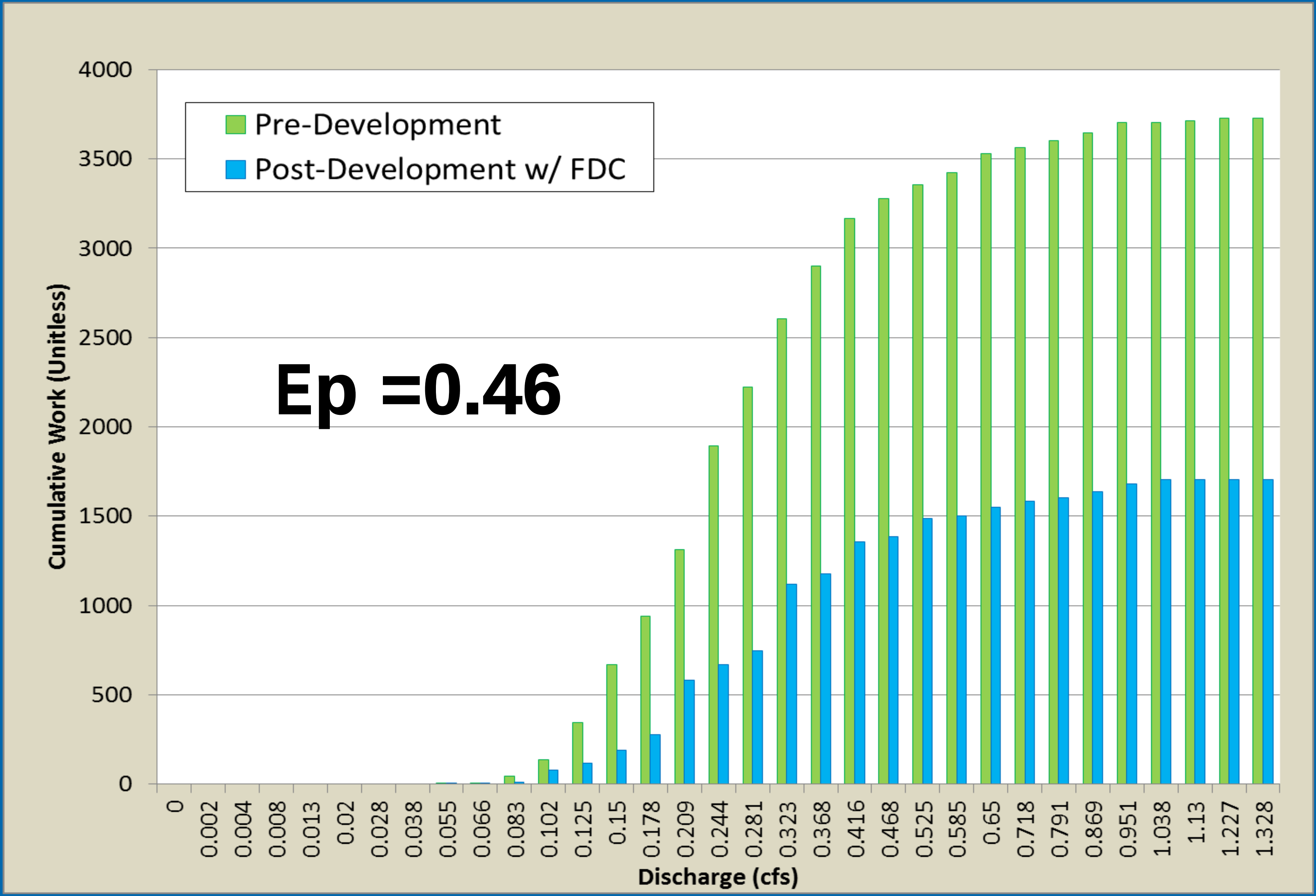
Performance Standard



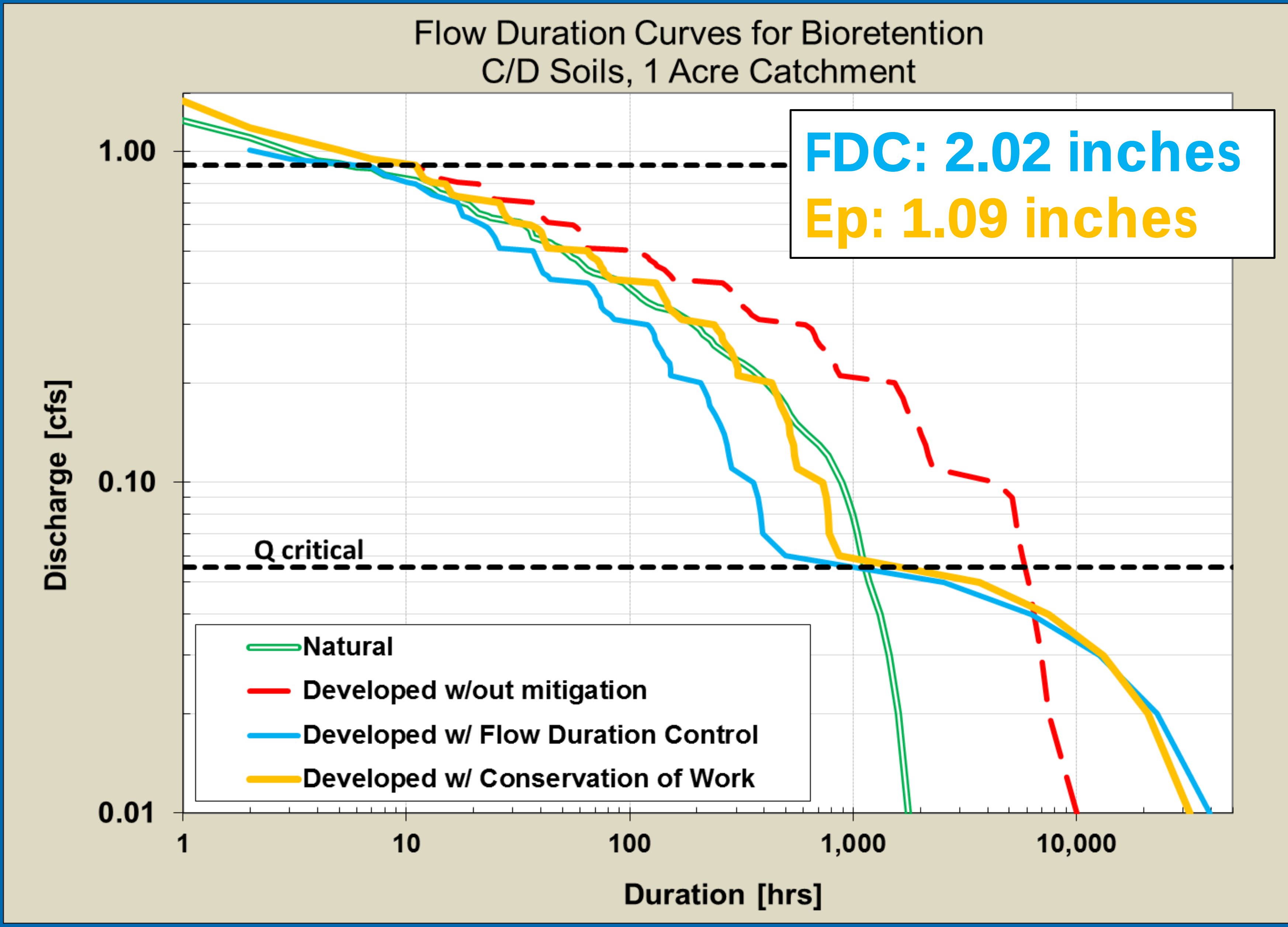
Performance Standard



Performance Standard

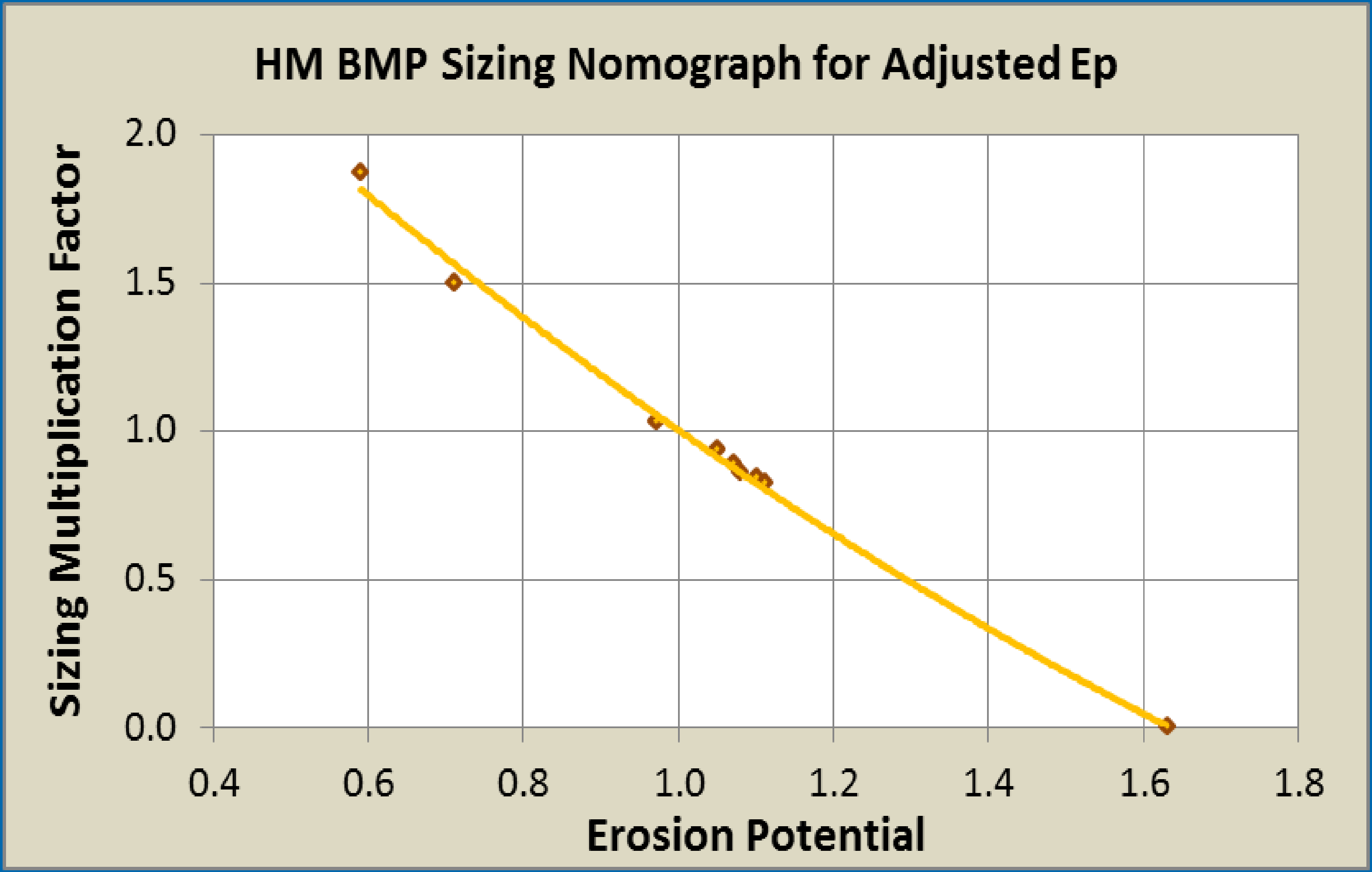


Performance Standard



Performance Standard

Ep lends itself to incorporating changes in sediment supply



Performance Standard

- FDC is the status quo, but Ep can result in smaller BMPs for simple outlets
- Ep alone does not mimic the distribution of erosive flows
- Ep can account for sediment supply loss, but FDC cannot


ESA-PWA

Low Flow Threshold

5% Q_2

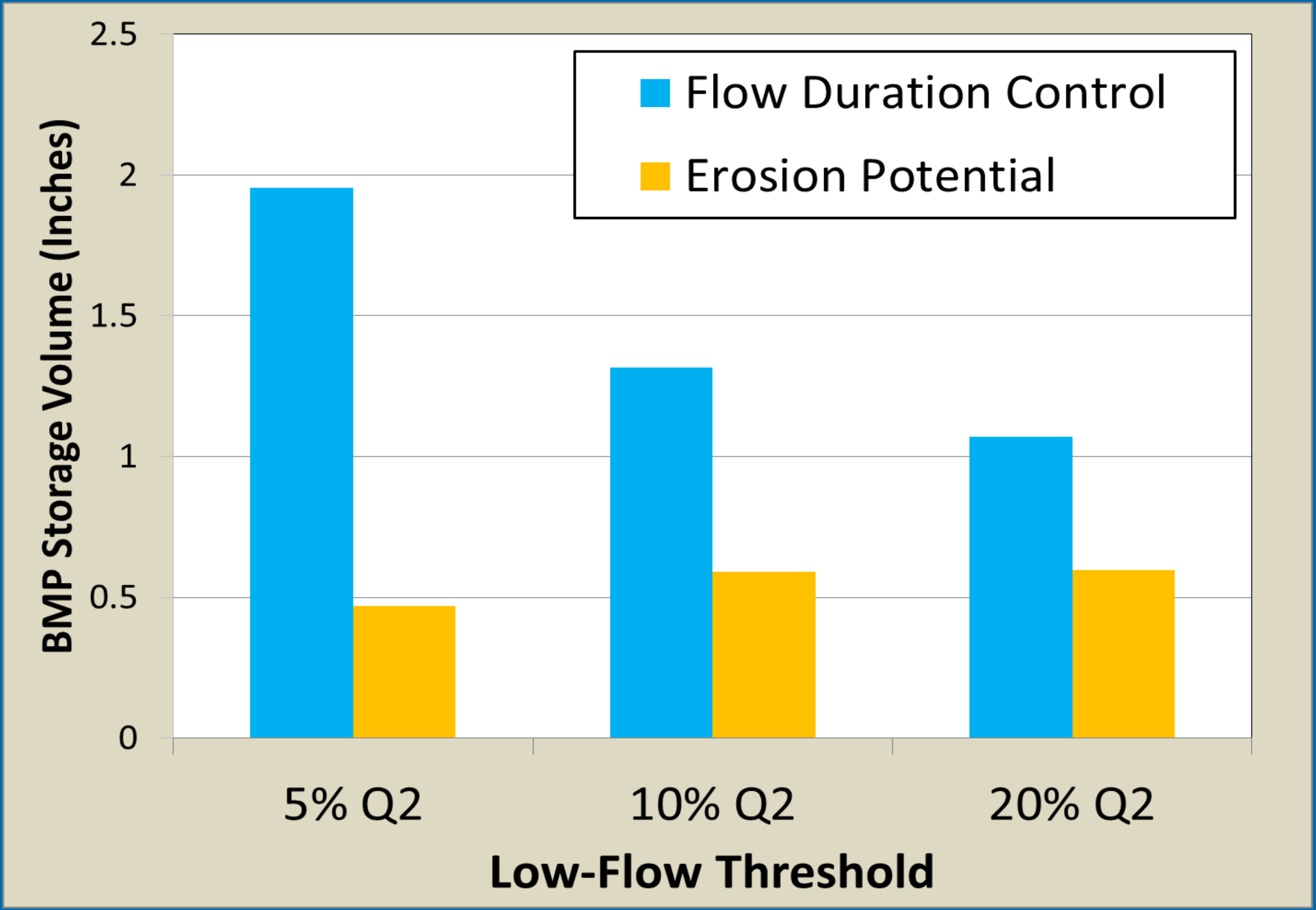
vs.

10% Q_2

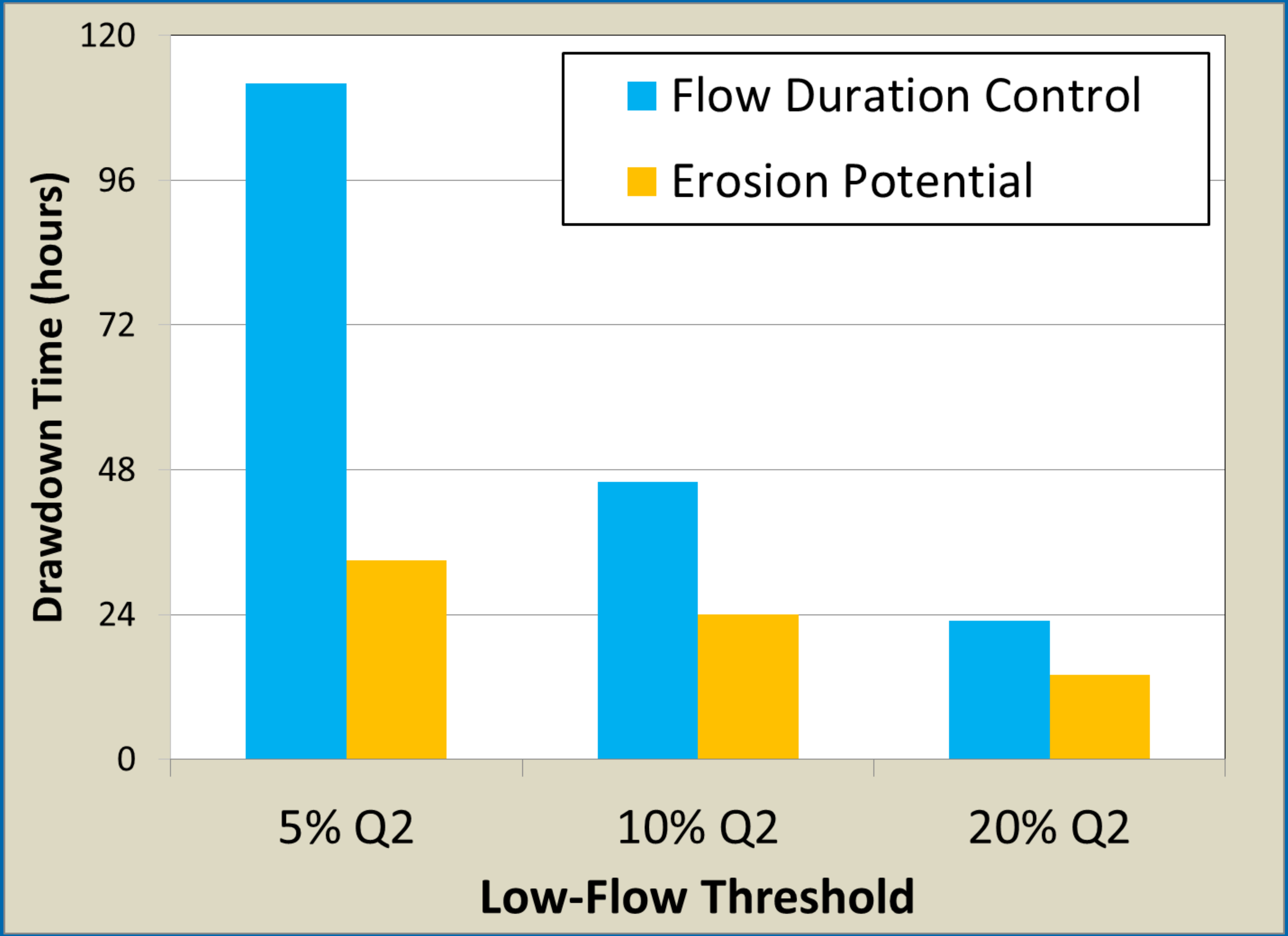
vs.

20% Q_2

Low Flow Threshold



Low Flow Threshold



Low Flow Threshold

- FDC
  - BMP size & drawdown time decrease with increased low flow threshold
- Ep:
  - BMP size is not as sensitive to low flow threshold
  - BMP drawdown time decreases with increased low flow threshold

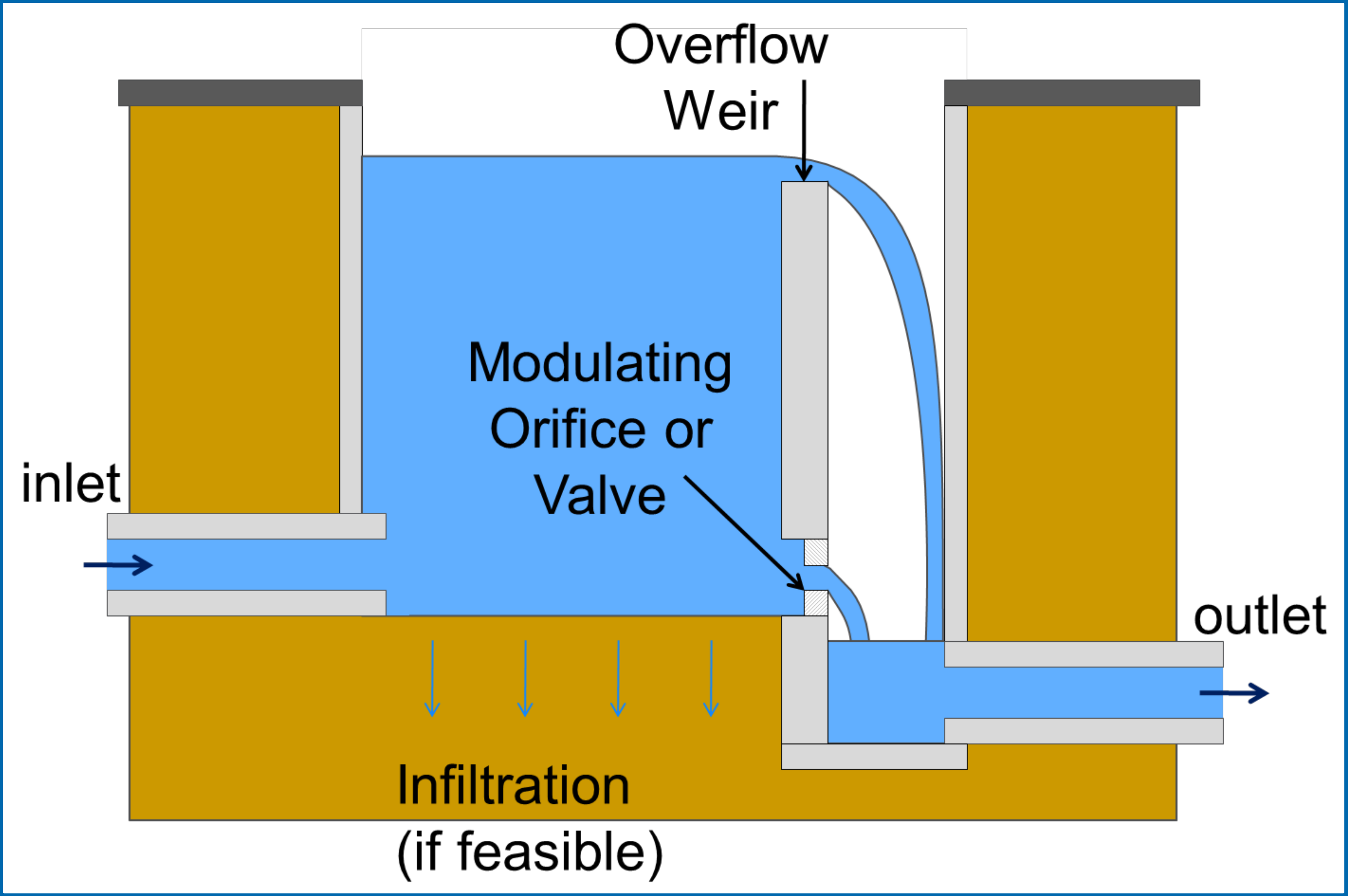
Outlet Design

Passive Controls

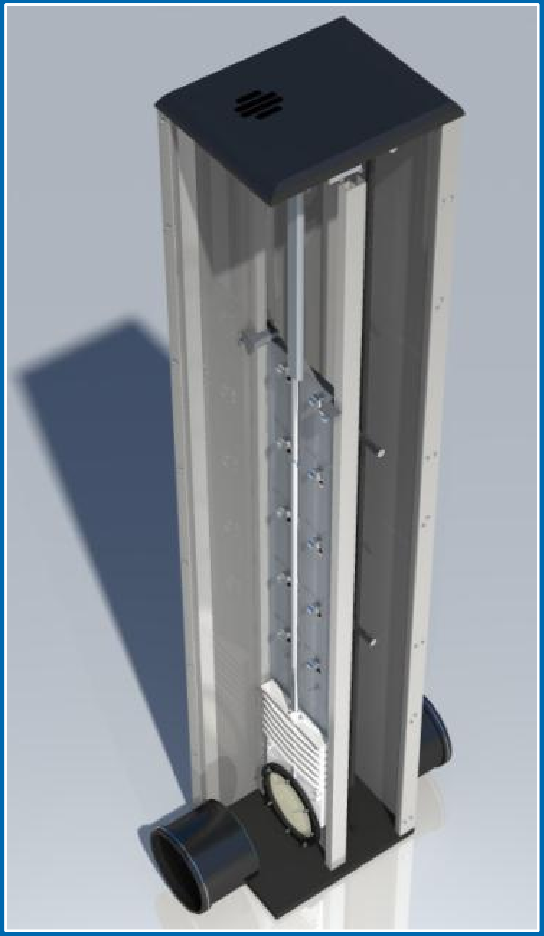
vs.

Active Controls

Outlet Design

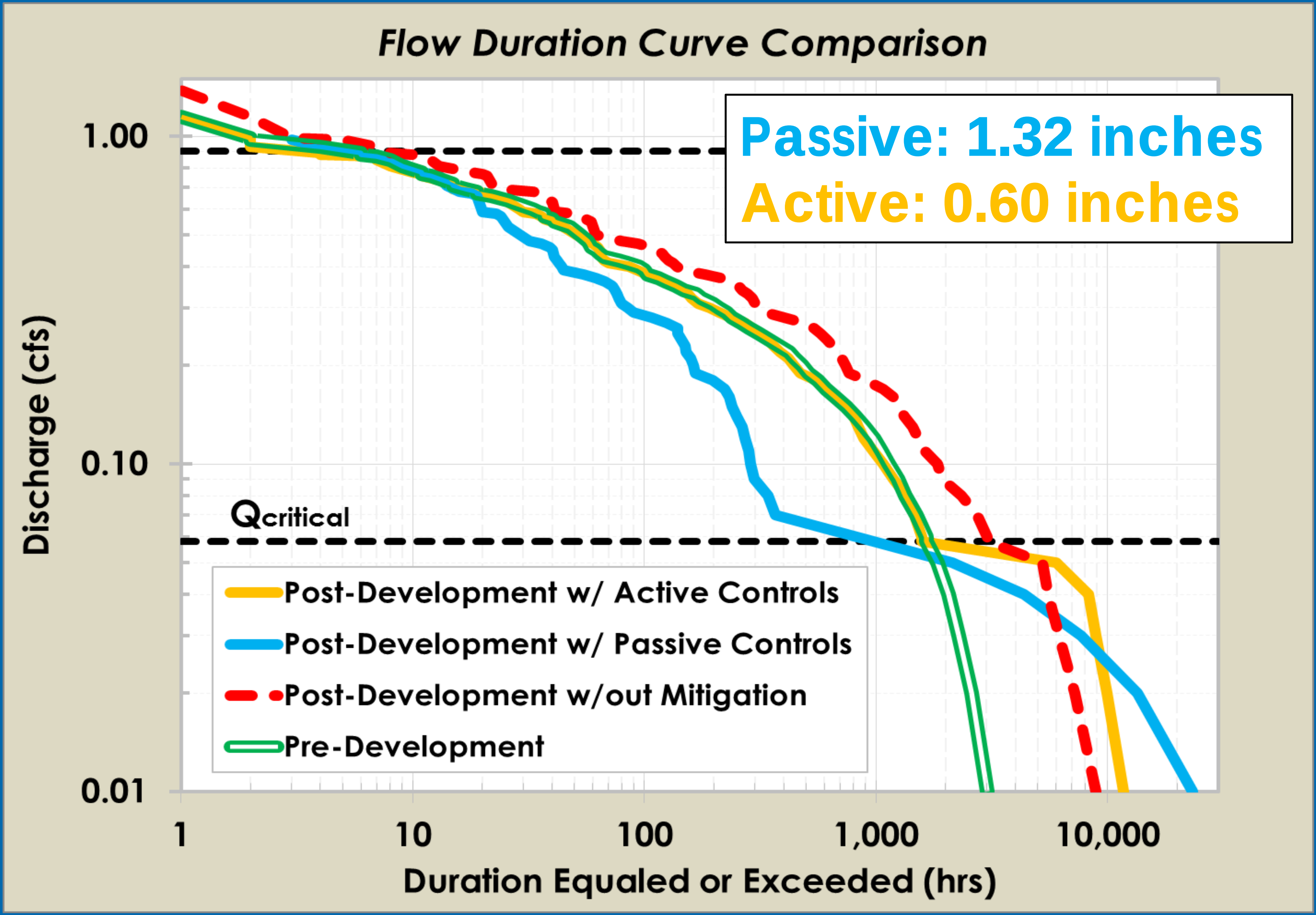


Outlet Design



Active Controls

Outlet Design



Outlet Design

Benefits of Active Controls

- Retrofit
  - Existing flood control basins can provide hydromod control
- New Development
  - BMP size decreases, making hydromod management feasible
- Adaptive Management
  - Data available in real-time
  - Adjust flow releases without physical retrofit

Thank You!
Questions?

$$\text{Geomorphic Impact} = f\left(\begin{array}{l}\Delta\text{hydrology},\\ \Delta\text{channel geometry},\\ \Delta\text{bed \& bank material},\\ \Delta\text{sediment supply}\end{array}\right)$$

jgoodman@geosyntec.com

Acknowledgements:

Venkat Gummadi

Raina Dwivedi

Marcus Quigley