Sediment Transport Analysis and Creek Restoration- Field Experiences

4th Hydromodification Seminar & Workshop –

Sediment Management and Modeling

November, 21, 2013

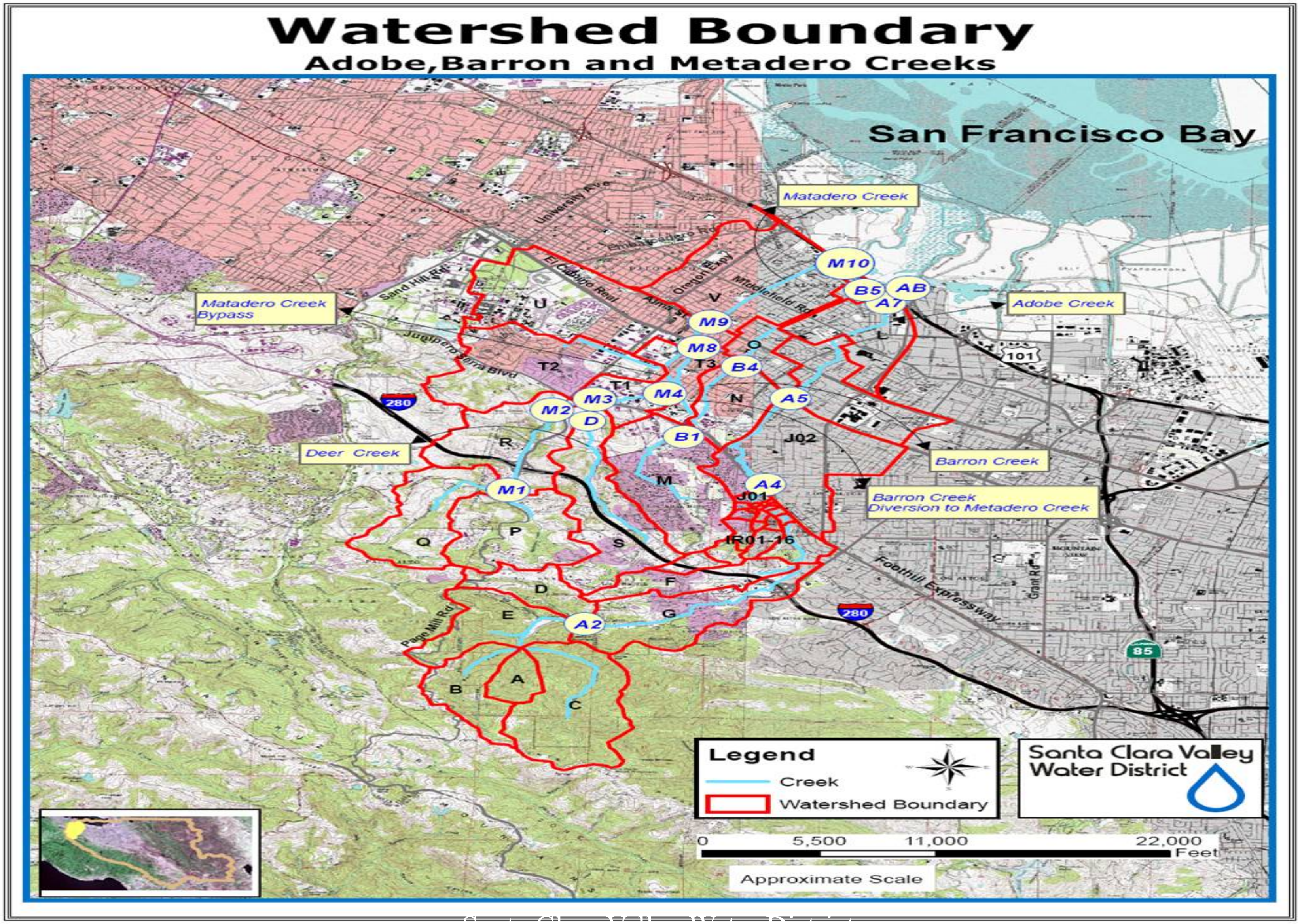
Santa Clara Valley Water District

Topics

- Santa Clara County HMP program
- Stable channel design
- SCVWD regional bankfull curves
- Channel stability analysis

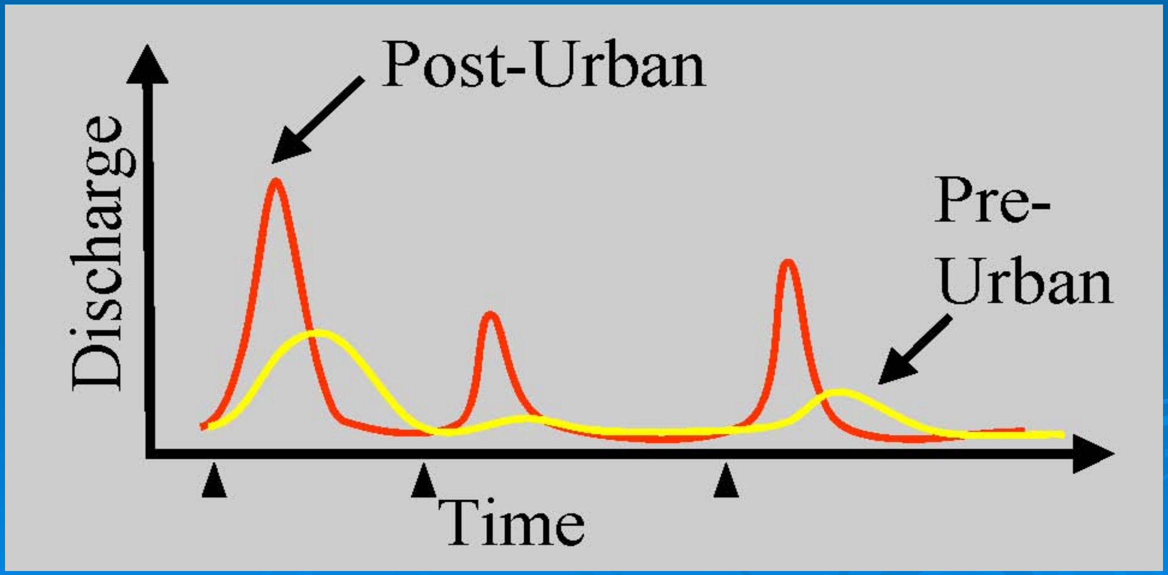
Santa Clara Valley Water District

Urbanized Watersheds



Effects of hydrology by Urbanization

- Less infiltration / evapotranspiration
- More surface runoff (increased volume)
- Runoff leaves the site faster (increased peak flows)
- Runoff occurs more often (increased frequency)
- More runoff conveyed directly to creek

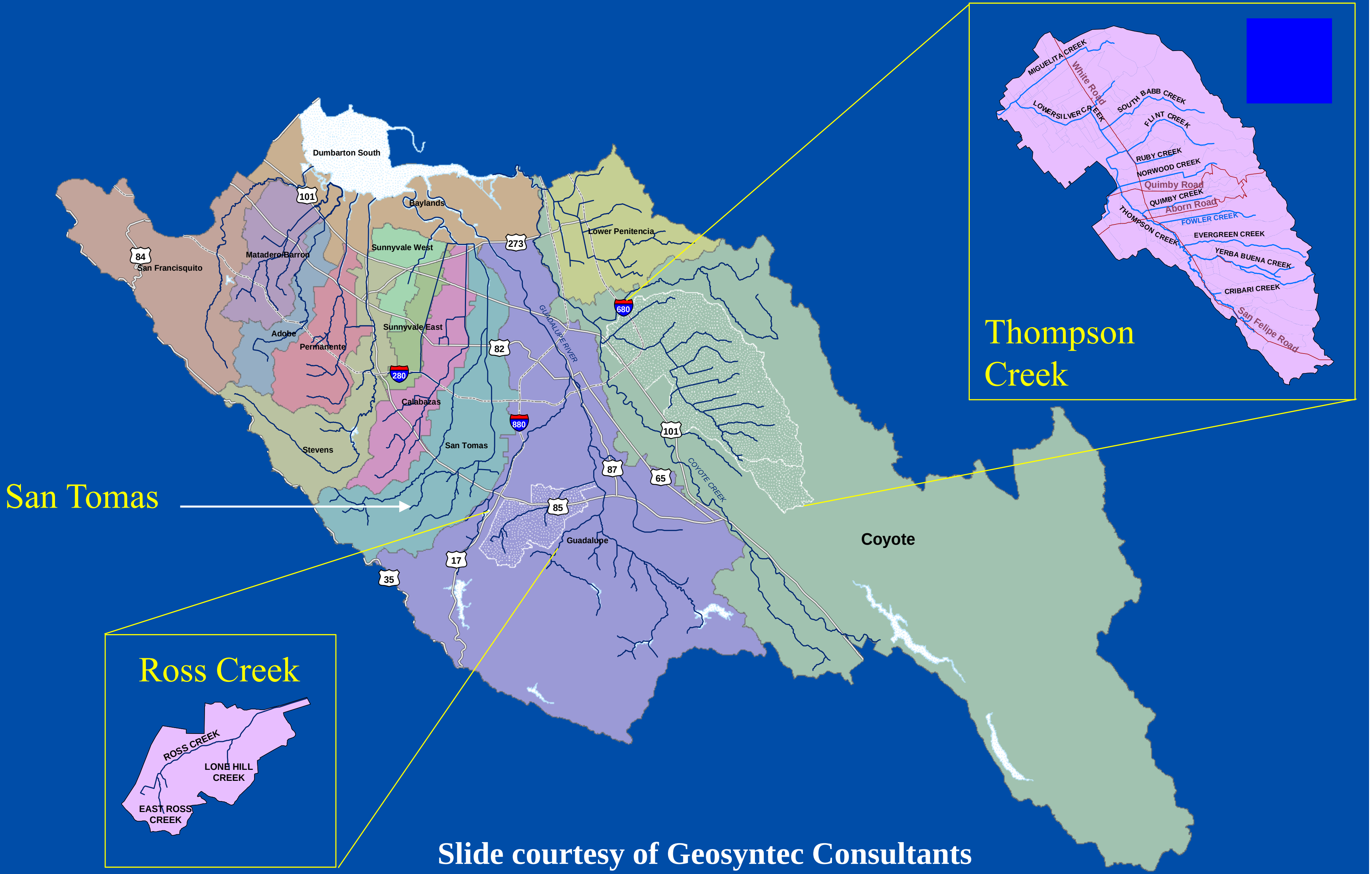


Thompson Creek
Undermining outfall structure

Incising channel bed on Yerba Buena Creek

Unurbanized Stable Stream

Subwatersheds Assessed under HMP

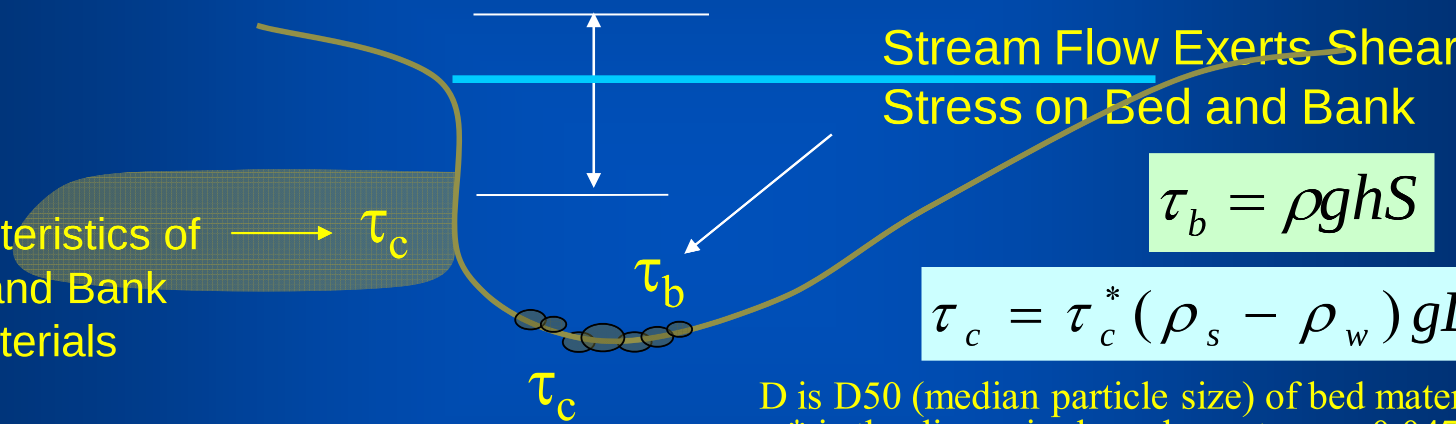


Slide courtesy of Geosyntec Consultants

Velocity, Shear Stress and Excess Total Work (W)

based on Flow-Duration Histogram

$$W = \sum_{i=1}^{n} \left(\tau_b - \tau_c\right)^{e} \cdot v \cdot \Delta t$$



$$\tau_b = \rho g h S$$

$$\tau_c = \tau_c^{*}(\rho_s - \rho_w) g D$$

D is D50 (median particle size) of bed material, τ_c* is the dimensionless shear stress = 0.047 (Julien 2002), s and w are sand/gravel and water

τ_c Critical Shear Stress of bed or weakest layer of bank at cross-section
Lower of the two values applies; if weak layer not at bottom $\tau_c = \tau_{cbank} + \rho g S h_{bank}$

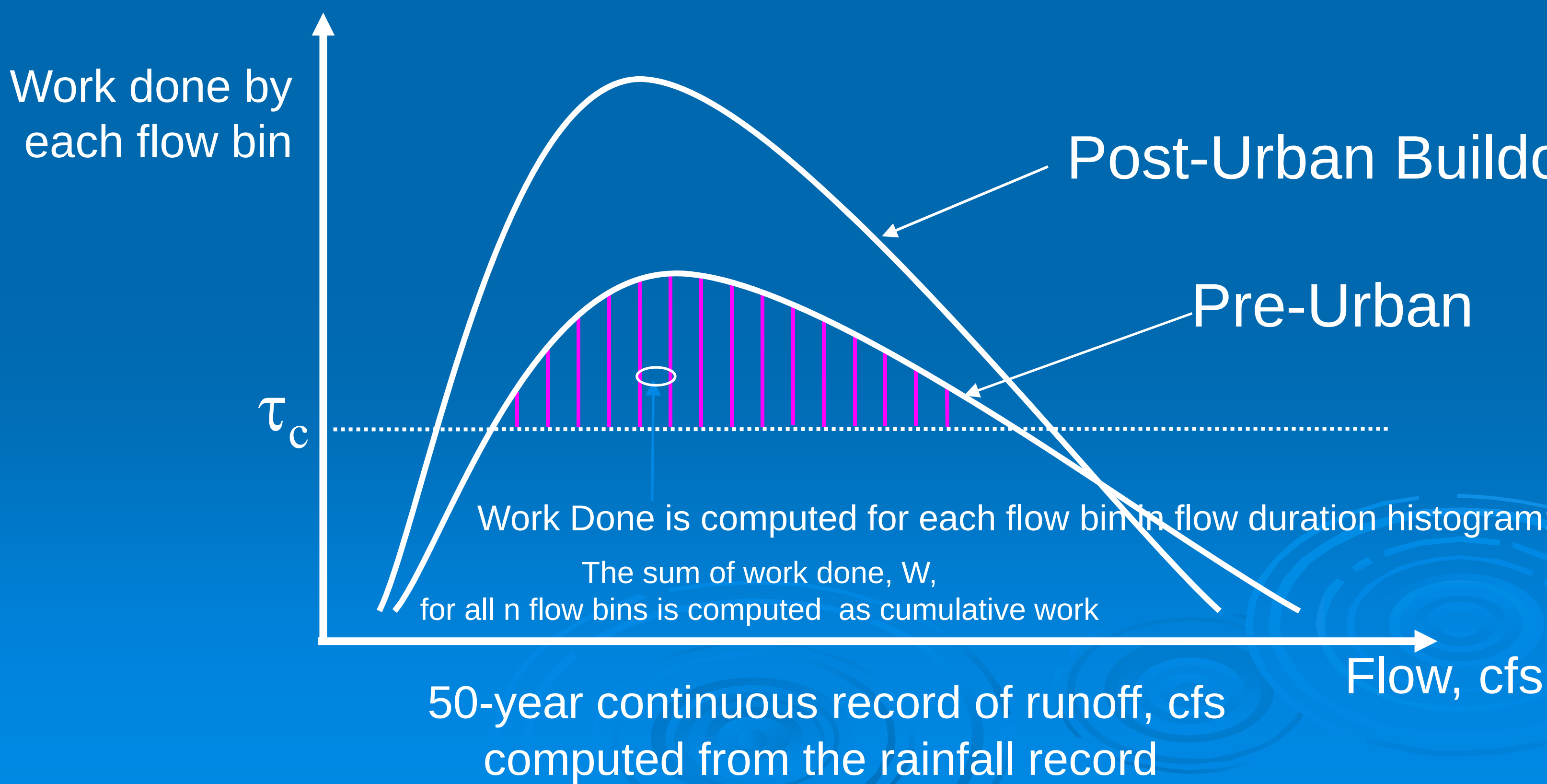
V Mid-stream velocity observed over a duration Δt Which is a time period in histogram

n = number of separate flow bins in the flow duration histogram, e =1 for computations shown

Increase Critical Shear Stress to Reduce Erosive Work Done (W_i)

$$W_i = \left[(\tau_b - \tau_c)^{1.5} \cdot v \cdot \Delta t\right]_i$$

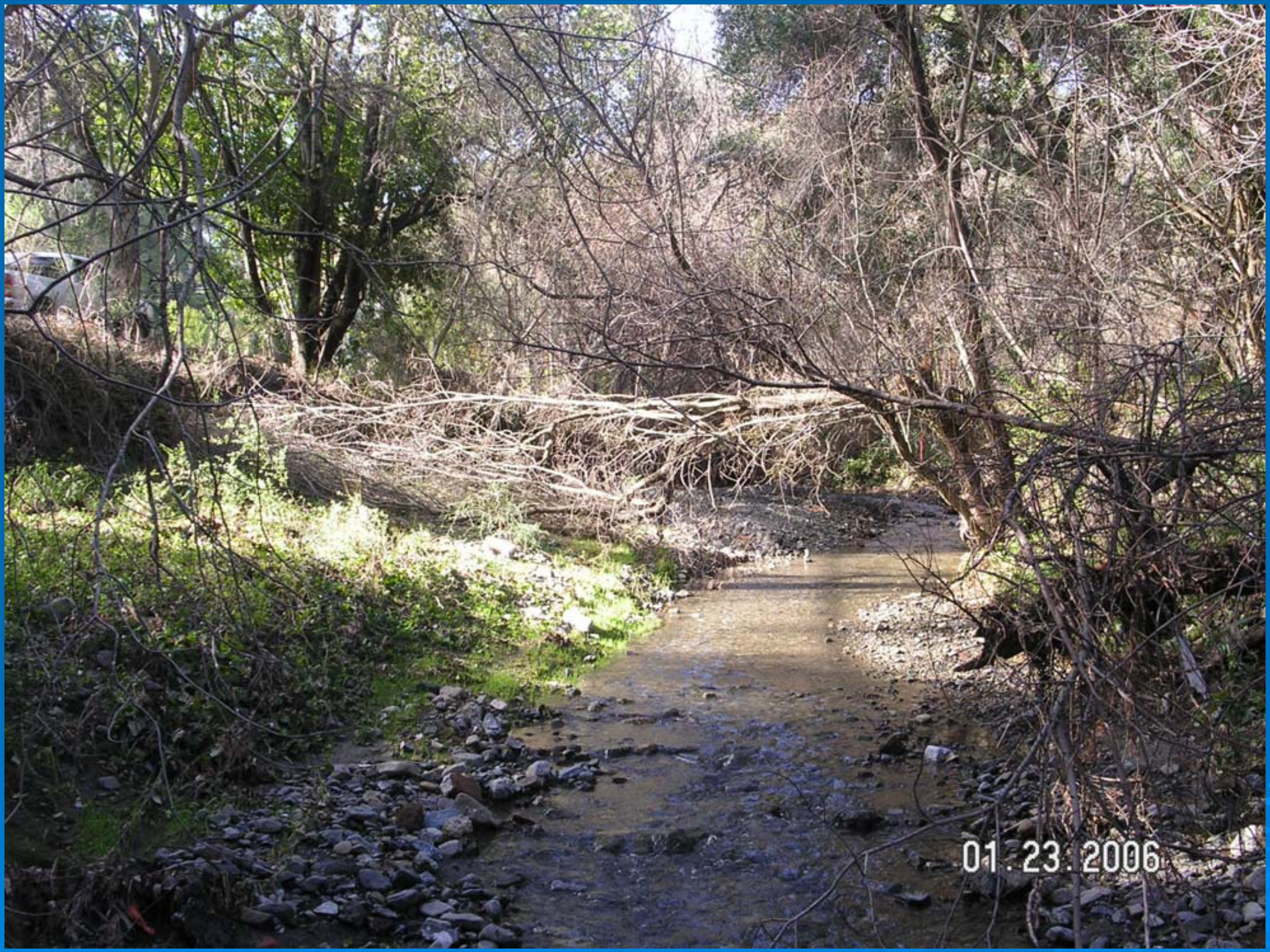
EP=Wexisting/Wpre-urban



Stable Channel Design Procedure

1. Determine bankfull cross-sectional geometry
2. Develop equilibrium slope via. sediment transport modeling (SAM or HEC-6)
3. Identify hardpoints in project reach
4. Layout cross-section and profile and, if necessary, locations of grade control structures
5. Design surface protection

Remnant of Pre-urbanization channel geometry



Bankfull Channel Measurement

Note how bankfull channel is formed within stable flood conveyance channel

BF = bankfull

BF bench or BF floodplain width

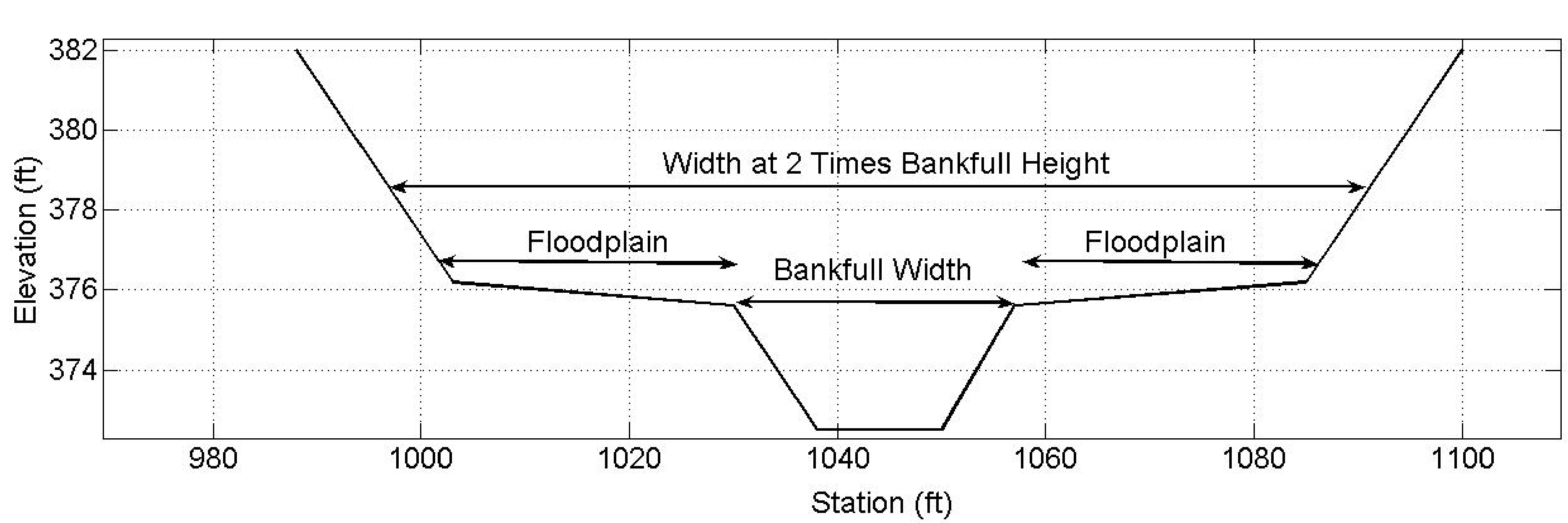
TH = Thalwag

2H:1V bank slope for bankfull channel

2H:1V bank slope

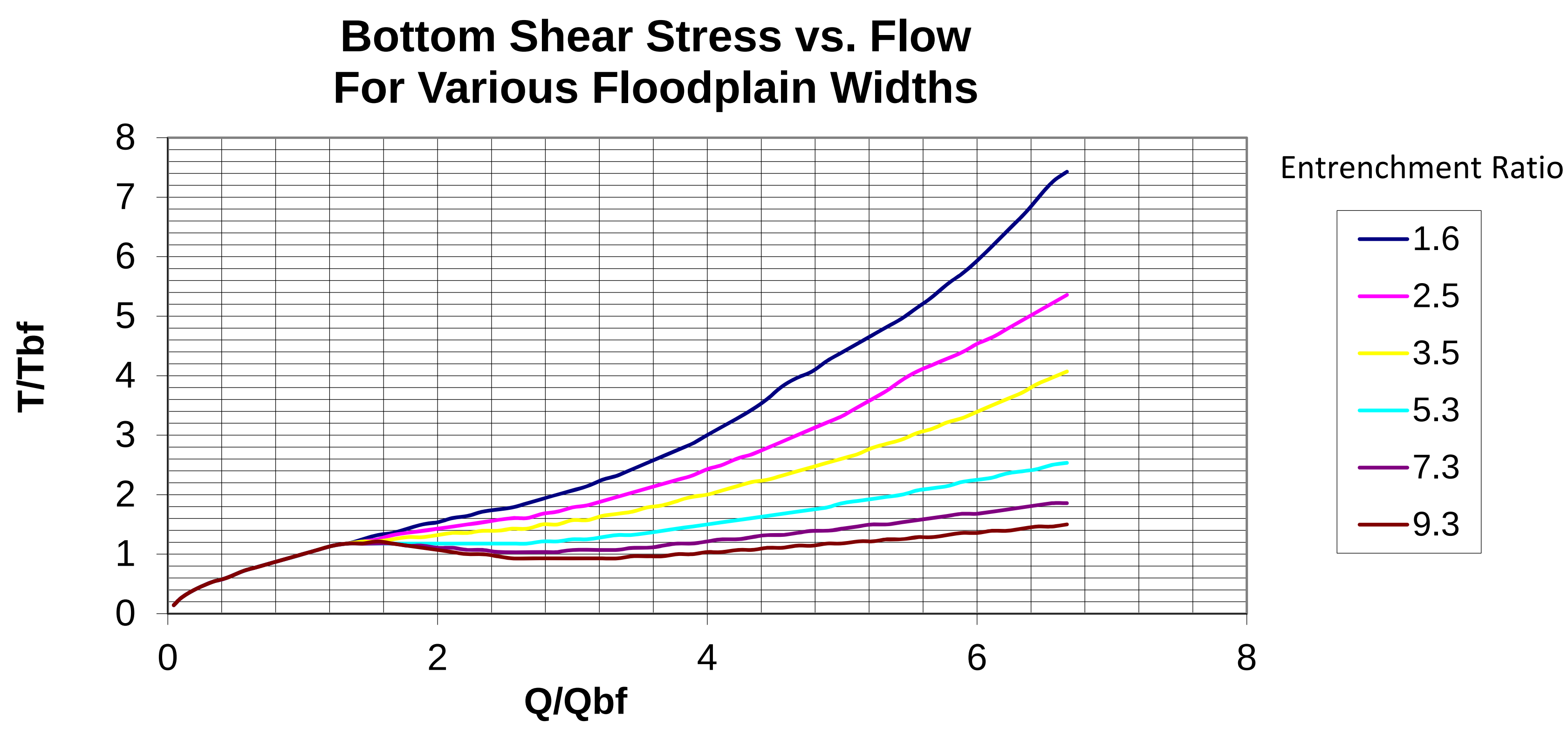
Guadalupe River at Almaden Expressway

Bankfull and Floodplain

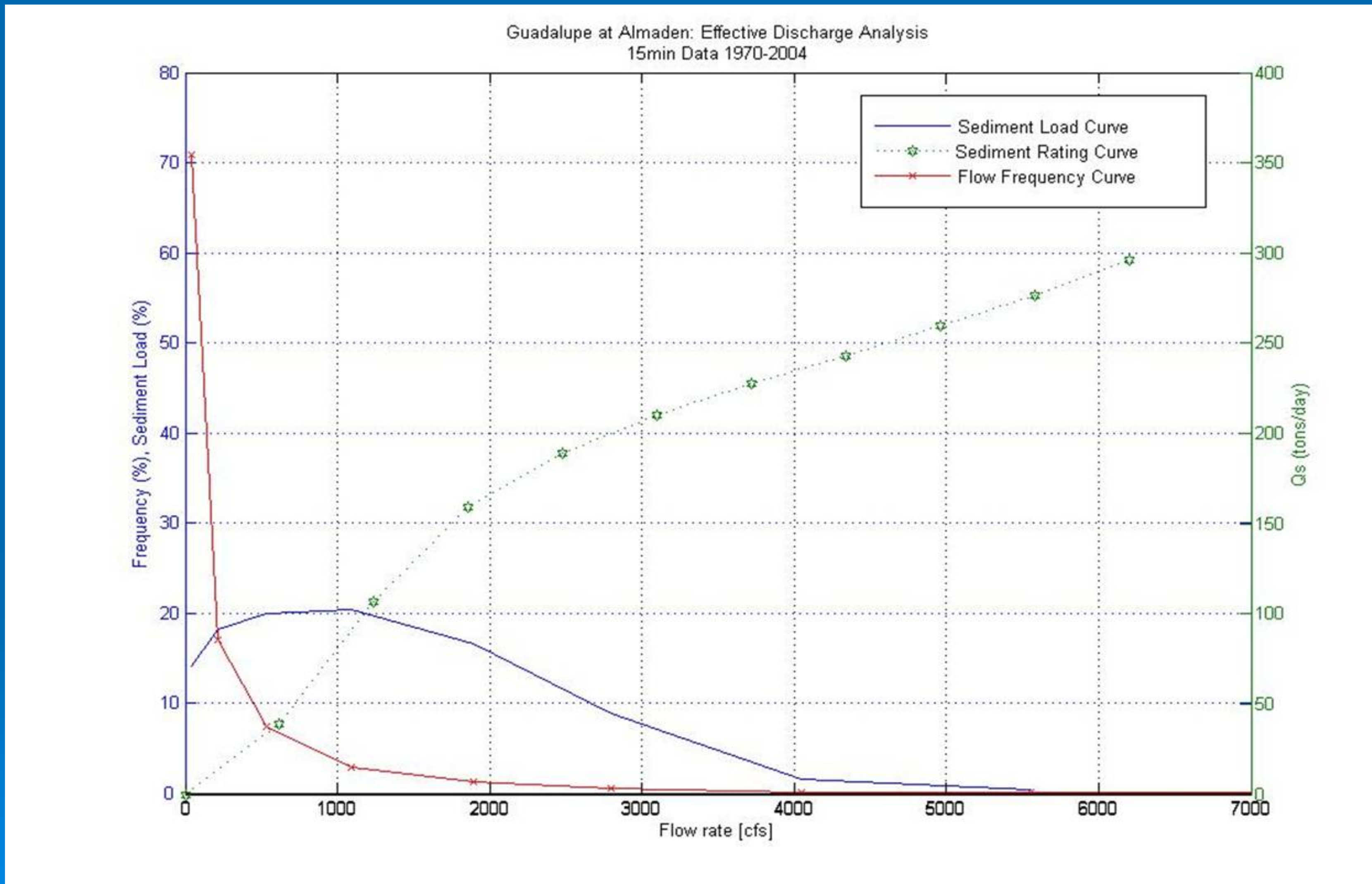


Entrenchment Ratio = ratio of channel width at 2xbankfull depth to bankfull depth
Bottom shear stress $\tau = \gamma RS$

Bankfull Effect on Bottom Shear



Effective Flow Calculation

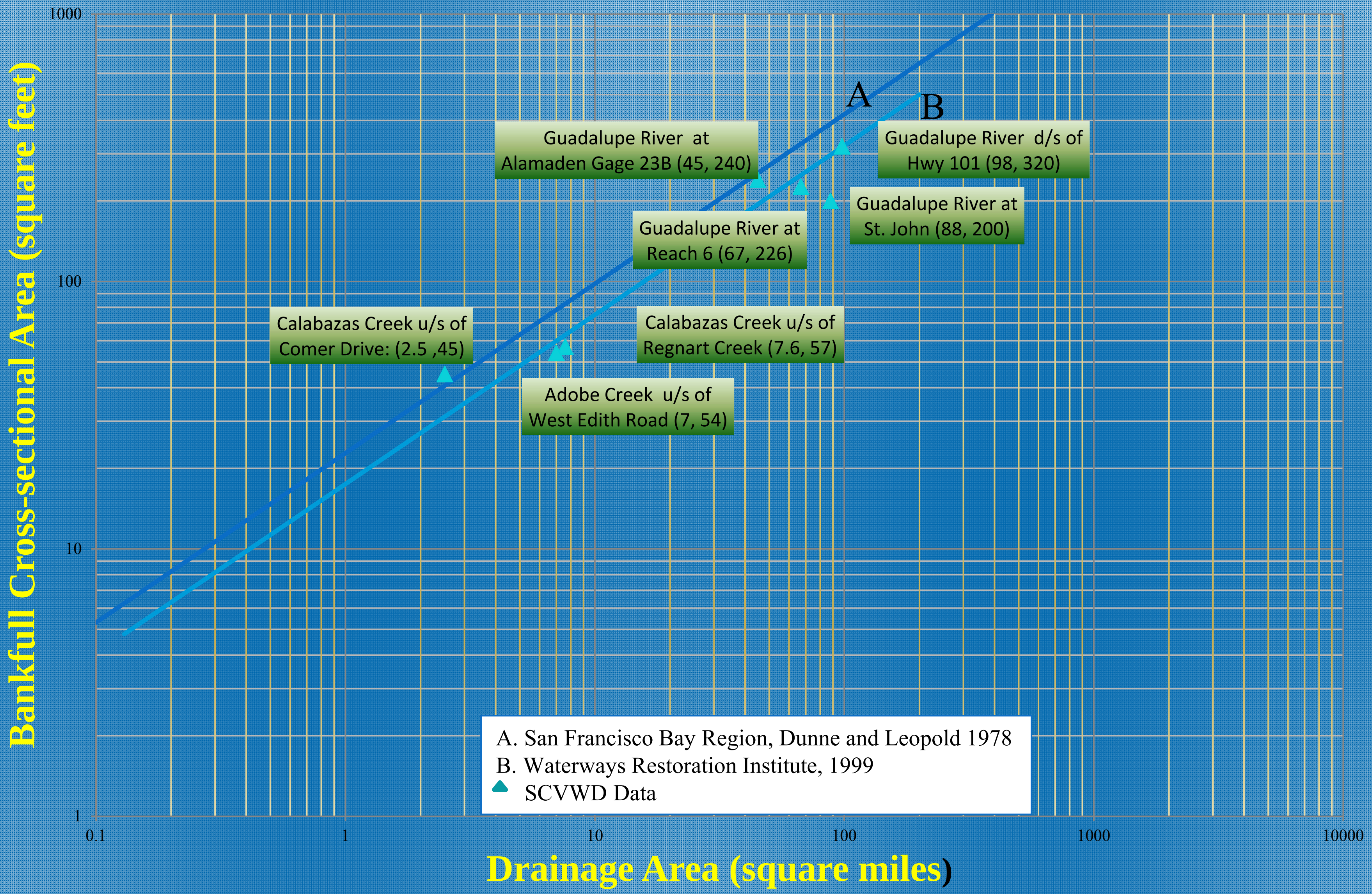


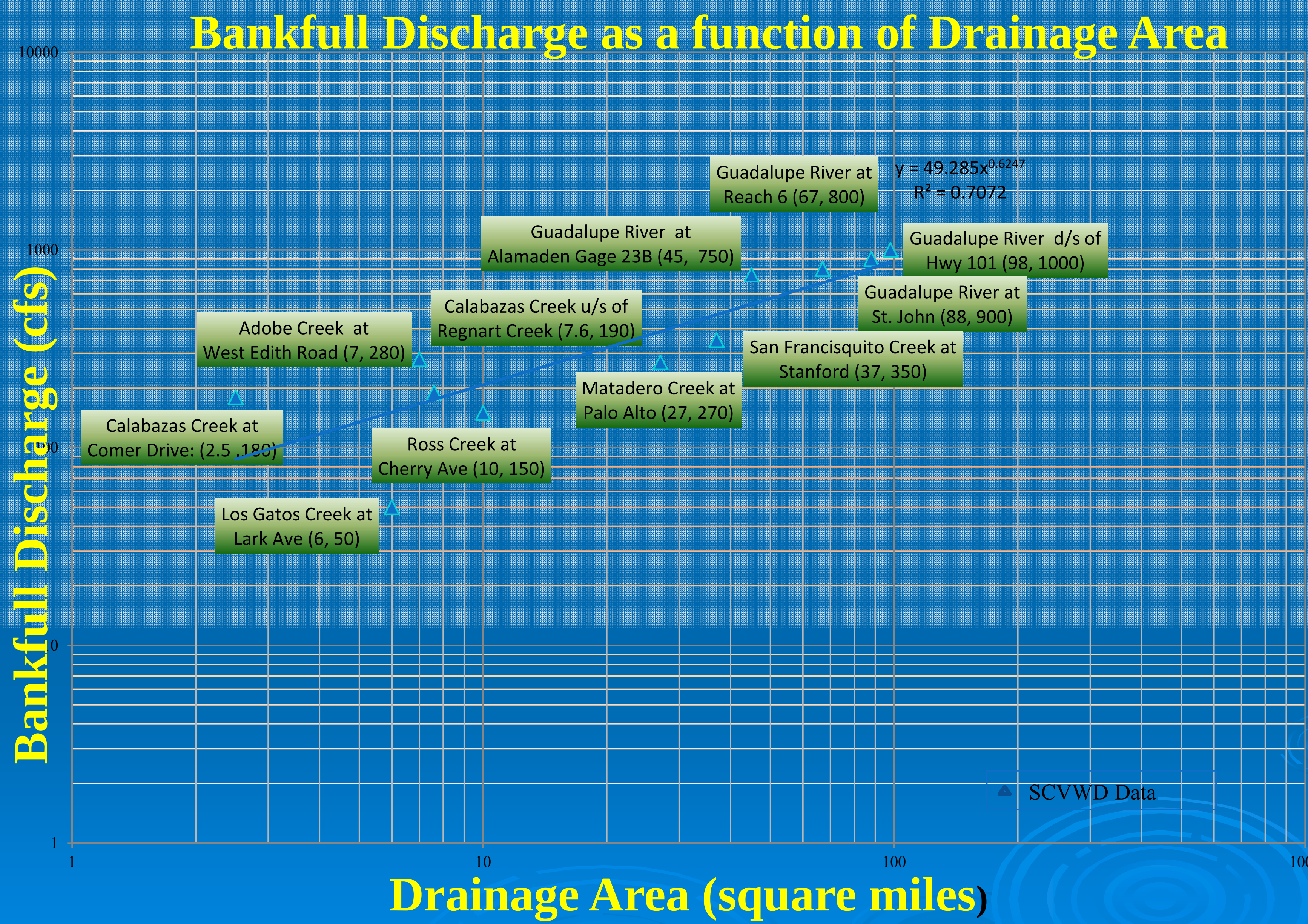
Effective Flow Calculation Results

Gauge Station	Available Gauge Data	Drainage Area (sq mi)	Effective Flow (cfs)	Sediment Transported	Exceedance Frequency (Return Period)
Los Gatos Creek at Lark Ave	1992-2007	6 (44)*	50	45%	94% (1.1)
Ross Creek at Cherry Ave	1956-2007	10	100-200	54%	95-99% (1-1.1)
San Francisquito Creek at Stanford	1987-2007	37	200-500	66%	86-95% (1.1-1.2)
Guadalupe River at Almaden	1970-2004	45 (70)*	700	55%	78-86% (1.2-1.3)
Guadalupe River at Saint John	1987-2003	88 (150)*	900	60%	88% (1.1)
Calabazas Creek at Lawrence	1972-2004	12	250-350	54%	93-97% (1-1.1)
Matadero Creek at Palo Alto	1987-2007	27	270	50%	80% (1.3)

(   )* denotes drainage area including the areas upstream of the reservoir

Drainage Area vs. Bankfull X-sec





Bankfull Discharge as a function of Drainage Area
Bankfull Discharge (cfs)
Drainage Area (square miles)
10000
1000
1
1
10
100
1000
y = 49.285x^0.6247
R² = 0.7072
Guadalupe River at Reach 6 (67, 800)
Guadalupe River at Alamaden Gage 23B (45, 750)
Guadalupe River d/s of Hwy 101 (98, 1000)
Guadalupe River at St. John (88, 900)
Calabazas Creek u/s of Regnart Creek (7.6, 190)
Adobe Creek at West Edith Road (7, 280)
San Francisquito Creek at Stanford (37, 350)
Matadero Creek at Palo Alto (27, 270)
Calabazas Creek at Comer Drive: (2.5 ,180)
Ross Creek at Cherry Ave (10, 150)
Los Gatos Creek at Lark Ave (6, 50)
SCVWD Data

Comer Debris Basin Dam Removal

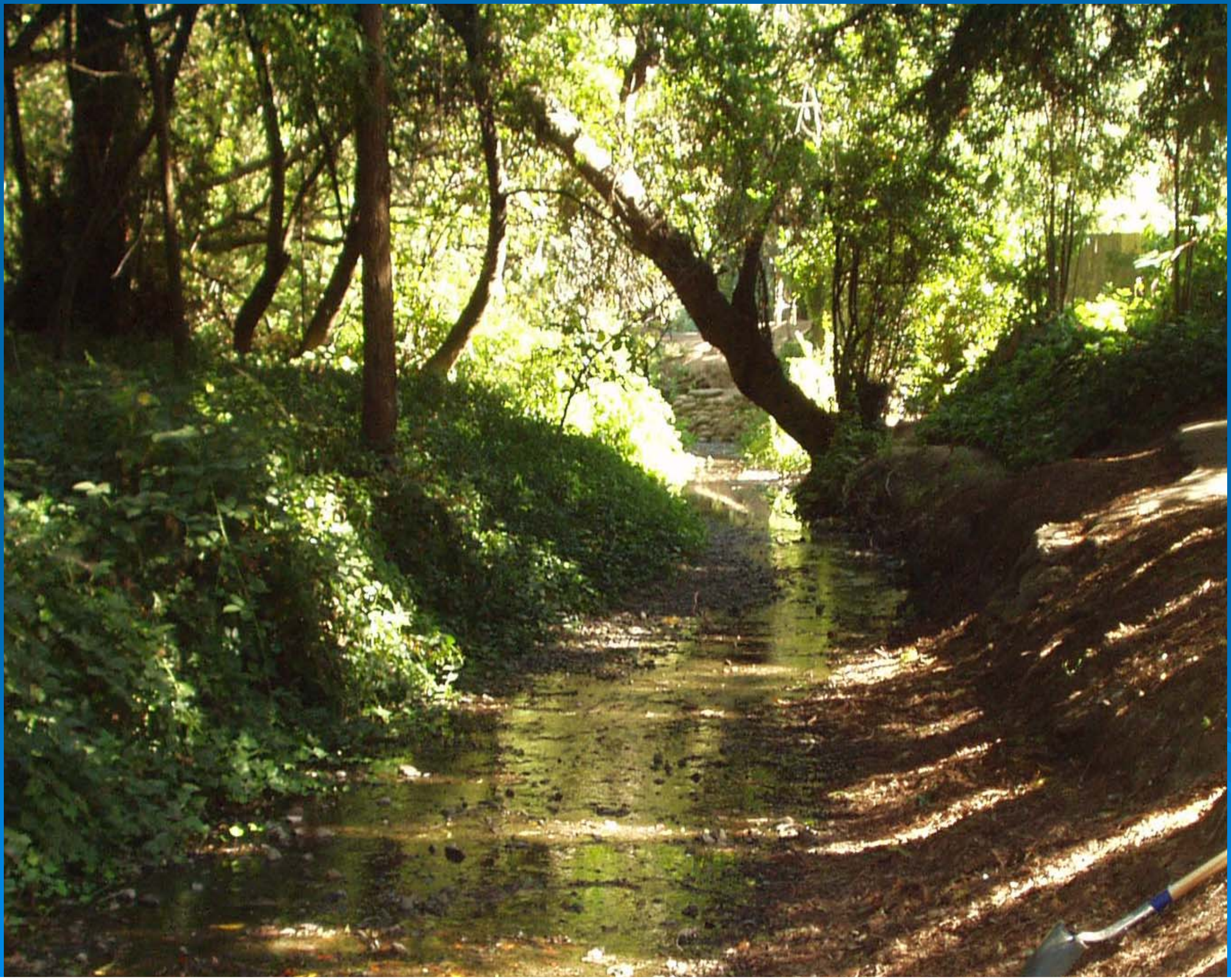
- Debris basin behind dam has silted in
  - Reduced Passage under Comer Dr. Br.
  - Increased Flooding Potential

- Remove Comer Dam

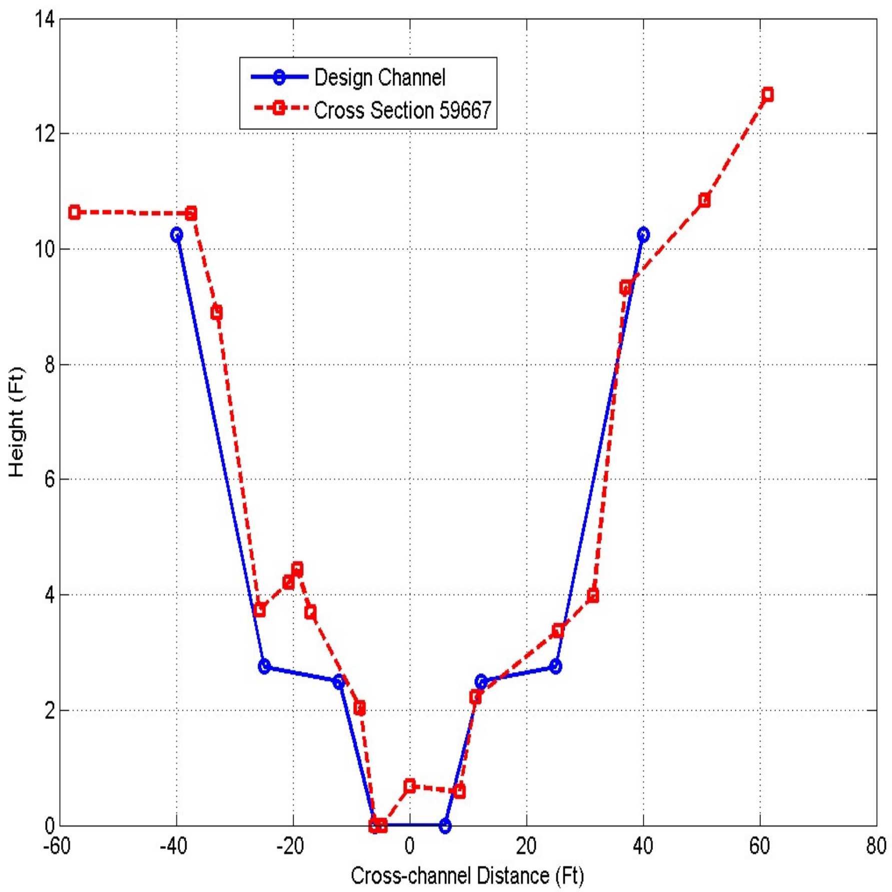
- Design stable channel

Comer Debris Basin

Reference Reach

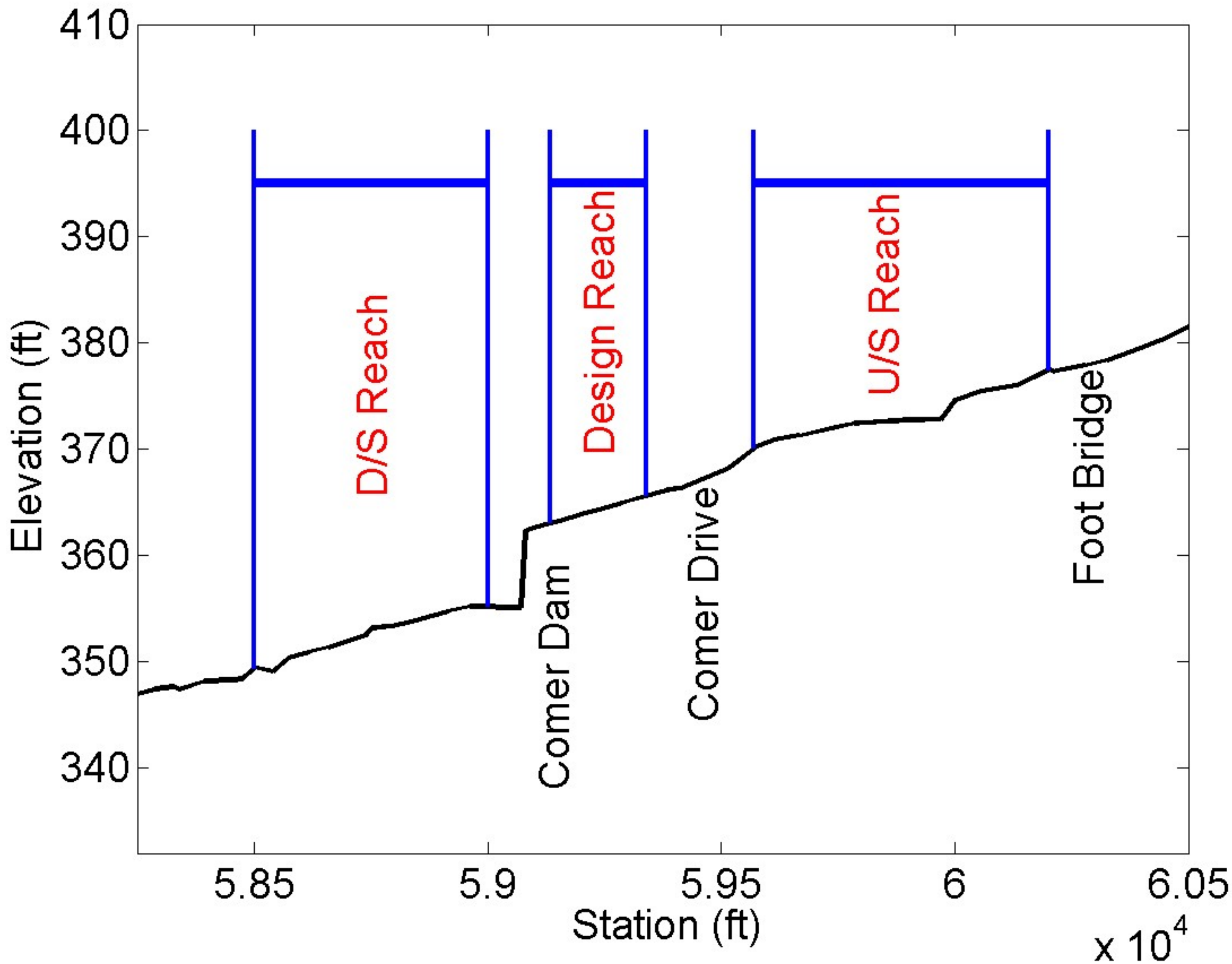


Step 1. Design Stable Cross Section



- Locate stable reach near project area
- Measure bankfull channel dimensions and floodplain slope in field
- Average measurements
- Develop prototypical bankfull channel
- Fit into existing channel by varying floodplain width

Step 2. Estimate Stable Channel Slope



Use SAM to compute Qs: Iteration #1

	Bed Slope (ft/ft)	Qs at bankfull flow (tons/day)
U/S Reach	1.26%	1969
Design Reach	1.25%	3110
D/S Reach	0.9%	2308

Iteration #2

Qs in design reach too large → Reduce slope

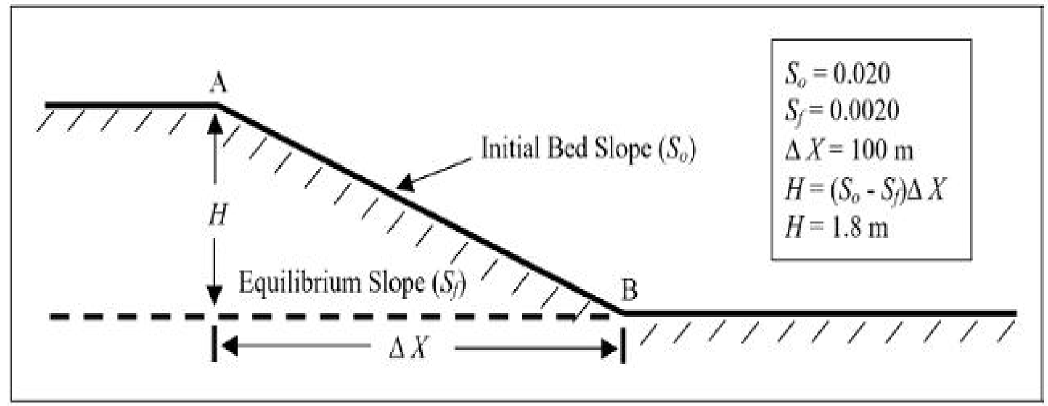
	Bed Slope (ft/ft)	Qs at bankfull flow (tons/day)
U/S Reach	1.26%	1969
Design Reach	1%	2411
D/S Reach	0.9%	2308

Iteration #3: Qs in design reach between Qs u/s and d/s: DONE !!!

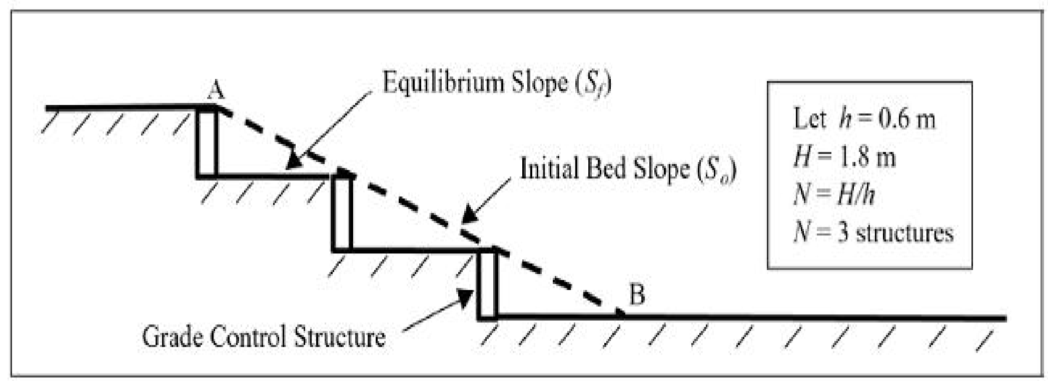
	Bed Slope (ft/ft)	Qs at bankfull flow (tons/day)
U/S Reach	1.26%	1969
Design Reach	0.9%	2103
D/S Reach	0.9%	2308

4. Layout cross-section & profile

- Determine need for grade control
- Design grade control structures (chapter 8, hydraulic design manual)
- Layout plan and profile (workshop in Mar 07)



a. Initial condition of streambed showing degradational zone between points A and B. Total anticipated drop in reach is calculated to be 1.8 m



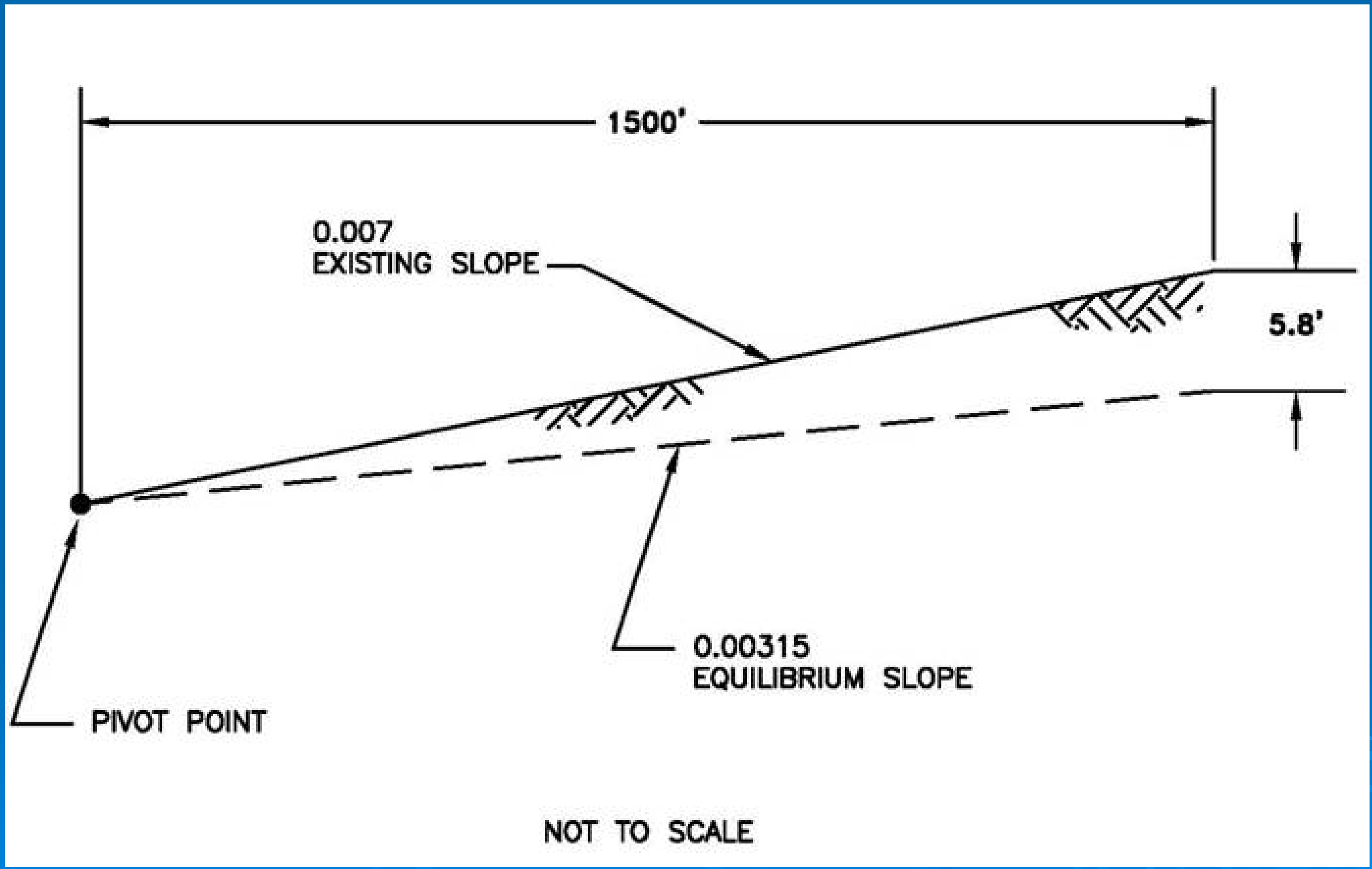
b. Stabilization of degradational zone using three bed control structures. Each structure has a design drop of 0.6 m

5. Design surface protection

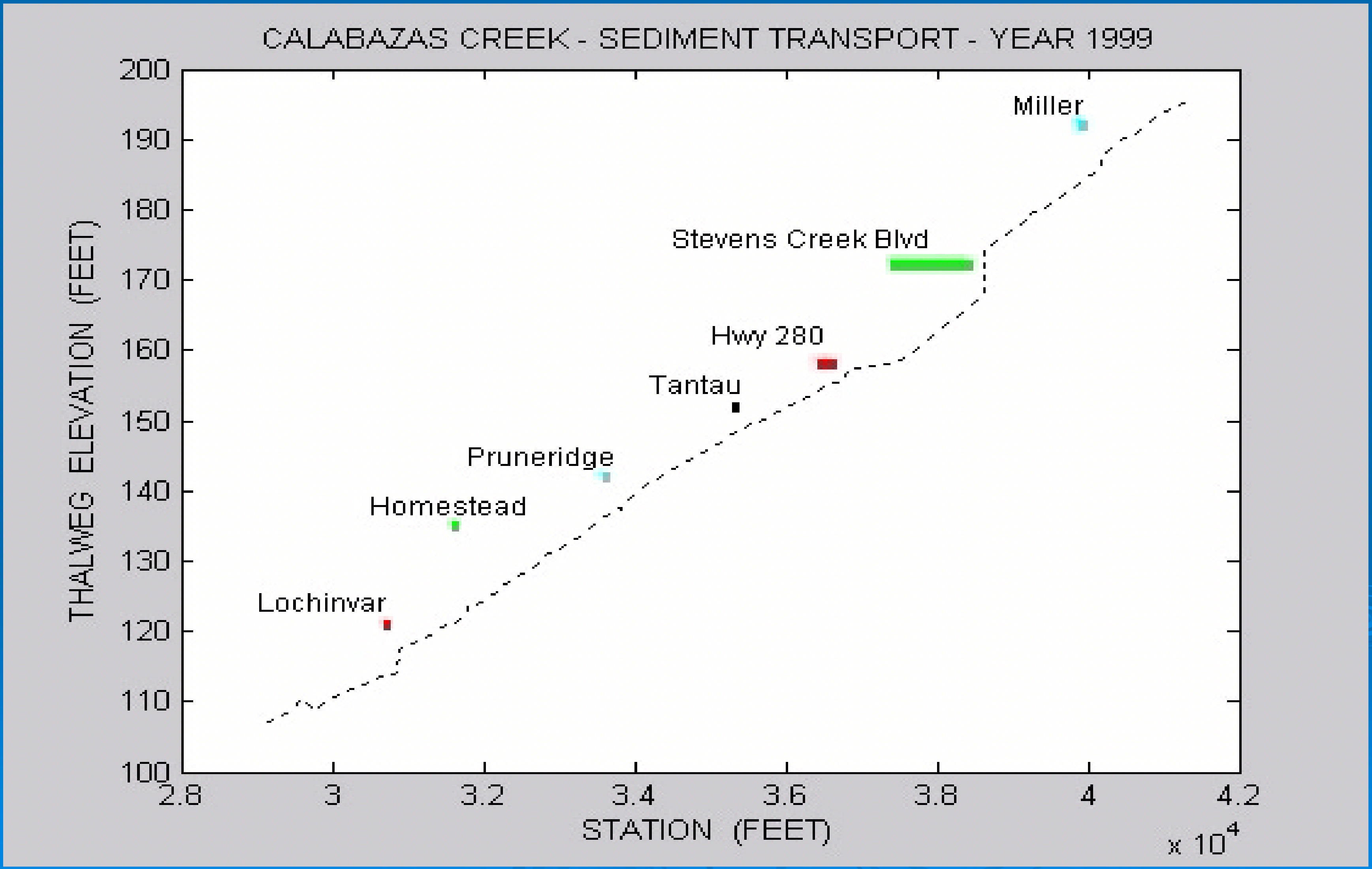
- Although equilibrium slope provides sediment balance, there is continuous sediment deposition and erosion taking place
- Surface armor concept – armor will occur if $D_{critical} \leq D_{90}$ and the D_{90} materials will cover bed surface
- Surface cover should be compatible with flow regime
- To be described in sediment transport workshop

Calabazas Creek Degradation

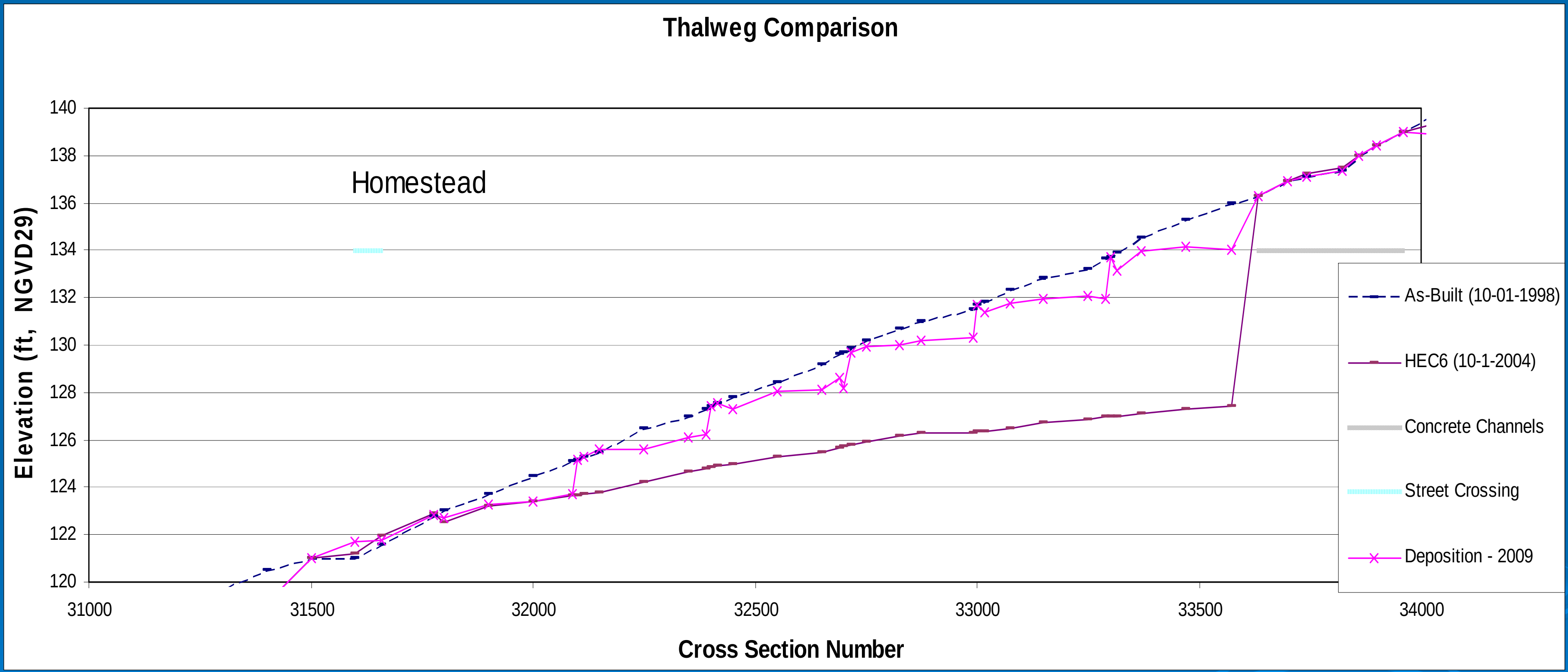
Calabazas Creek Degradation



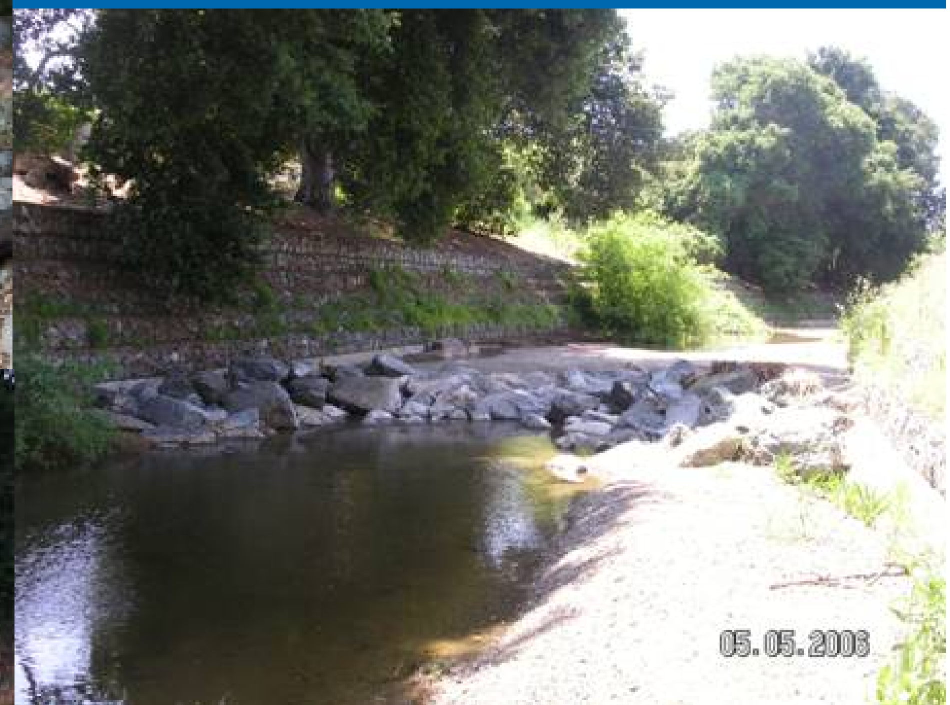
HEC-6 Sediment Transport Analysis



HEC-6 Results for Post Weir Construction



Weir Construction




11/15/2013

Conclusion

- Understand meaning and origin of geomorphologic parameters
- Focus on applicable parameters and incorporate into design
- SCVWD channel modification designs include field data collection and sediment transport modeling
- Emphasize on long term ***stability***

Thanks for Listening!

DO YOU HAVE ANY QUESTIONS?