
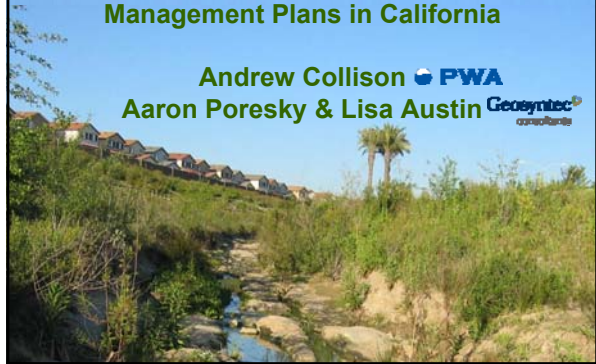


Lessons Learned (and Not Learned) from Developing Hydrograph Modification Management Plans in California

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 Aaron Poresky & Lisa Austin 



Talk structure

- Quick overview of Hydromod
- Step through California's HMPs with a focus on how HMPs have evolved over time
- Summarize what we learned along the way, and what we still need to learn
- What lessons are there for Oregon's regulators and implementers of HMPs?





Some definitions

- Hydromod – changes to the timing, peak, volume and duration of runoff as a result of human action in the watershed (increased impermeable area, increased efficiency of the drainage system)
- Q2 – the “two year peak flow” or the flow with a 50% exceedence probability in a year
- Q10 – the “ten year peak flow” etc
- 0.1Q2 – 10% of the Q2 flow (a common metric for HMPs)
- Critical flow – the lowest stream flow at which channel erosion occurs
- Effective Work – the geomorphic work done by a creek (erosion, sediment transport)
- Continuous rainfall-runoff modeling – modeling based on daily or hourly rain data over many years that accounts for antecedent soil moisture (as opposed to event-based modeling)

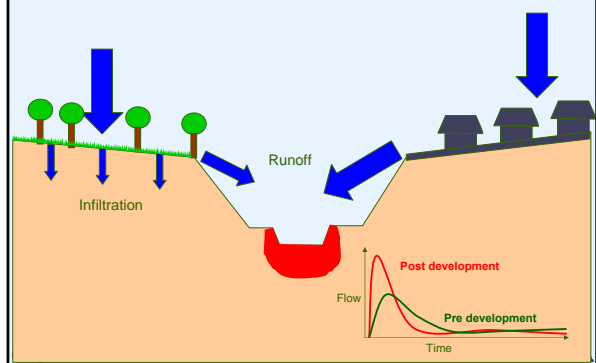




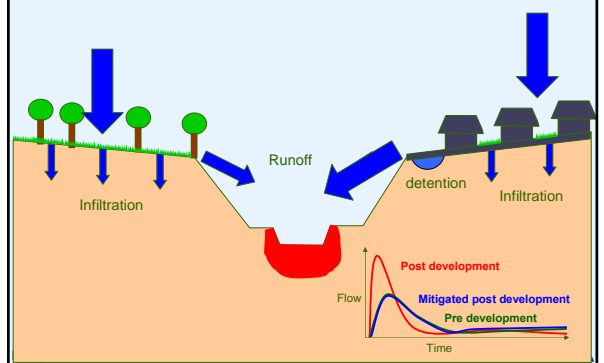
Overview of Hydromod



What is Hydrograph Modification Management?



HMP standards aim to make flows mimic natural hydrology



Consequences of Hydromod



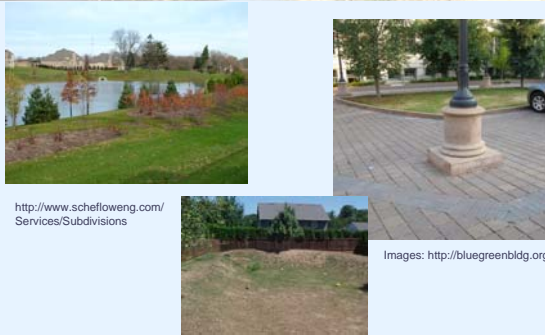
HMP implementation tools



Image: Municipal Research and Services Center of Washington

Images: <http://bluegreenbdg.org>

HMP implementation tools

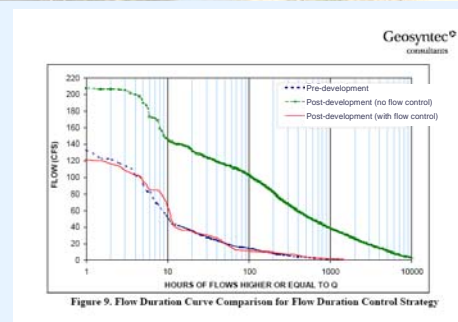


<http://www.scheffloweng.com/Services/Subdivisions>

Images: <http://bluegreenbdg.org>

<http://www.cityofsalem.net>

HMP analysis tools



The California HMP experience



Regulatory Framework for California HMPs

- MS4 permits include hydrograph management criteria
- Most Permittees to develop and implement an HMP within 1 – 2 years from permit adoption date
- 1st HMP – Santa Clara County in 2005
- Contra Costa in 2006
- Alameda, San Mateo, and Fairfield-Suisun in 2007
- San Diego 2010
- Future HMPs:
 - Orange County – HMP/Watershed Master Plans in 2011/2012
 - Sacramento in 2011
 - Ventura County – 180 days after completion of SCCVRP Study
 - All California Counties will have HMPs by 2015?
 - Revisited when MS4 permits renewed

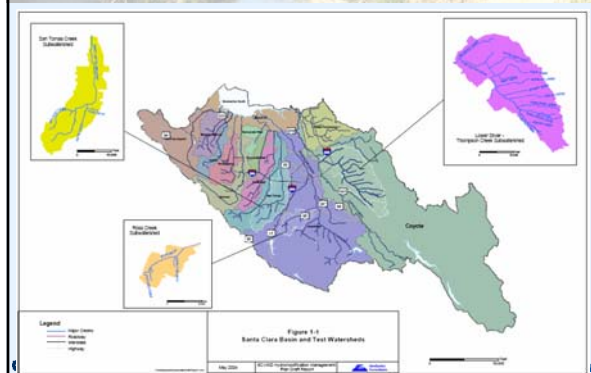
Precedents for California HMPs

- Western Washington 2005 (Clark County 1998)
 - Preserve natural drainage patterns
 - Infiltrate, disperse and retain stormwater onsite to the maximum extent feasible without causing flooding or erosion
 - Match pre-project flow durations from 0.5Q2 to Q50
 - Required continuous rainfall-runoff modeling
- Maryland 2000
 - Developments over 5,000 sq ft must promote infiltration and maintain pre-development groundwater recharge rates
 - 24 hour detention of the Q1 to protect creeks
 - Match Q10 peak flow
- Ontario 2003
 - Change in stream Erosion Potential must not exceed that equivalent to a 10% impervious area without implementing erosion control management measures
 - Required continuous rainfall-runoff modeling to calculate EP

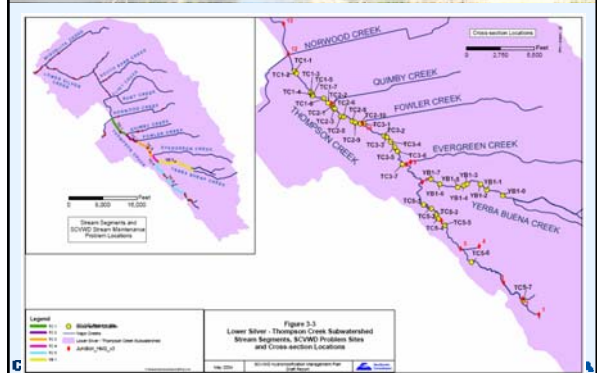
Santa Clara County HMP

- 1st California HMP to be developed
- Created many precedents for subsequent Cal HMPs
- Adopted in 2005
- Required flow duration controls for all projects that increase runoff and that are >1 acre
- Method of developing HMP
 - Geomorphic survey of test creeks – classify as stable or unstable
 - Hydrologic modeling of pre- and post-development hydrographs in test creeks
 - Comparison of relative “Geomorphic Work” in pre-urban and existing channels to produce an “Erosion Potential”
 - Relate increase in “Erosion Potential” to probability of channel instability

Test Watersheds



Test Stream Cross Section Locations



Test Stream Surveys

- Channel Dimensions
- Bed Material
- Bank Material
- Vegetation
- Roughness
- Other characteristics



Figure 3-4 Cross-section survey at YB1-4. A tape was stretched between two pins to measure the channel dimensions, bed material, bank material, vegetation, roughness and other characteristics were described.



Channel stability



The good...



Channel stability

The bad...

Geomatics PWA

Channel stability

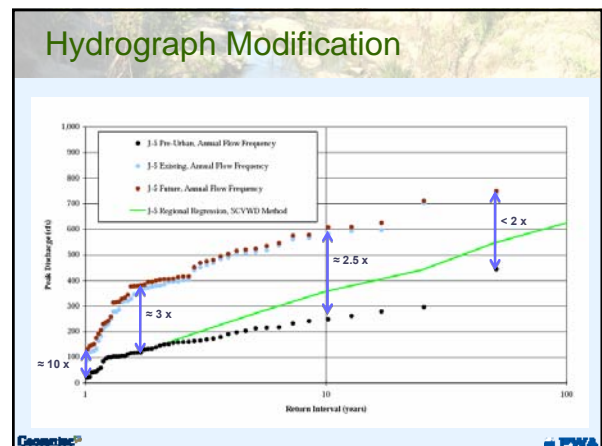
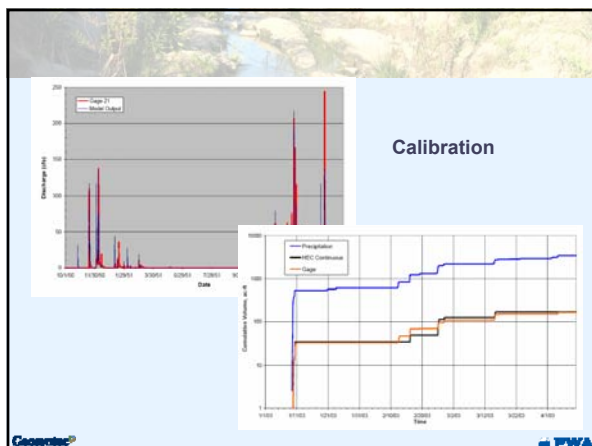
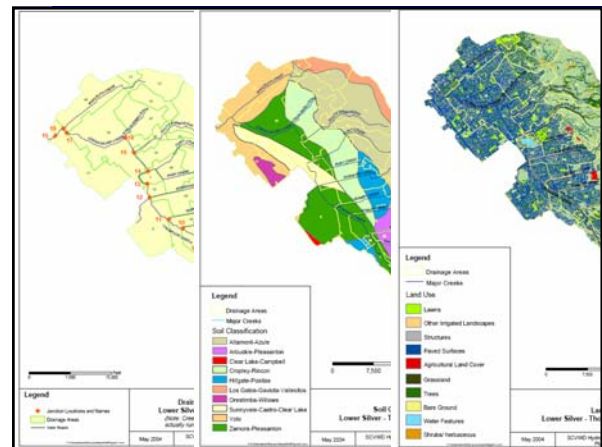
... and the ugly!

Geomatics PWA

Hydrologic Modeling

- Data acquisition and watershed characterization
- Development of continuous HEC-HMS model
- Calibration to existing condition
- Simulate pre-urban, existing, and future conditions
- Summarize hydrographs based on flow-frequency and flow-durations

Geomatics PWA



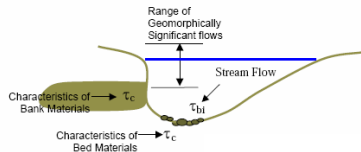
Calculating Effective Work

Effective Work is the cumulative sediment transport capacity of a creek over many years

$$EW = \int_{t_1}^{t_2} \int_{L_1}^{L_2} \tau_c - 0.047 \tau_c^2 \cdot dt \cdot dL$$

$$\tau_c = \frac{1}{2} \rho_s (g - g_{crit})$$

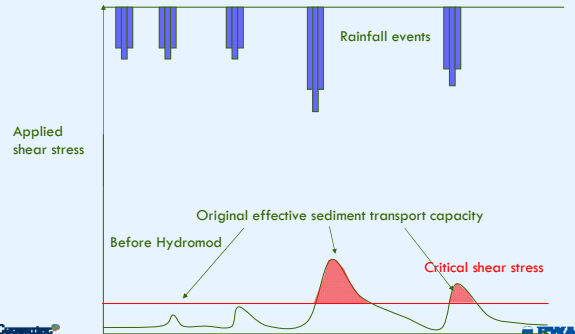
Where t_1 to t_2 is the initial condition, L_1 to L_2 is the length of the reach, τ_c is applied hydraulic shear stress, dt is the duration of time, dL is the length of the reach, ρ_s is density of sediment, g is gravity, g_{crit} is the critical shear stress, EW is the effective work index, L is the length of the reach, and t is the time of the reach.



Geomatics

FWA

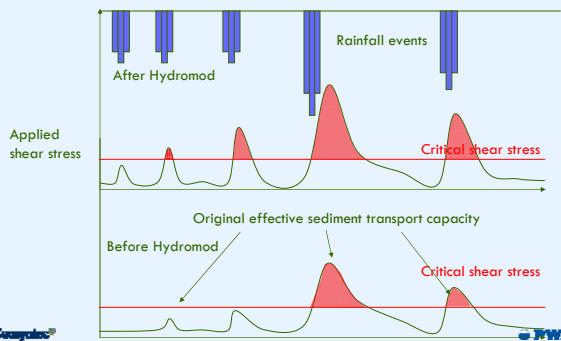
Calculating Effective Work



Geomatics

FWA

Calculating Effective Work

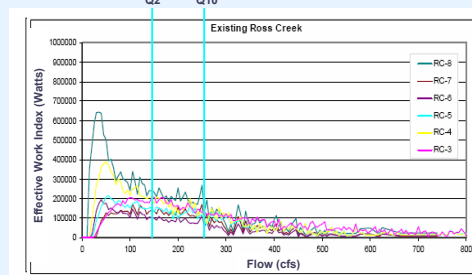


Geomatics

FWA

Most Effective Work occurs during small events

Duration of flows < Q1 become 20-30 times greater

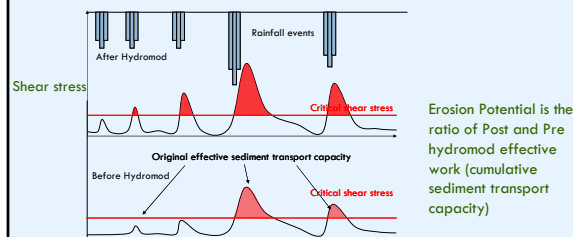


RC-3 through 8 show different cross sections

Geomatics

FWA

Erosion Potential



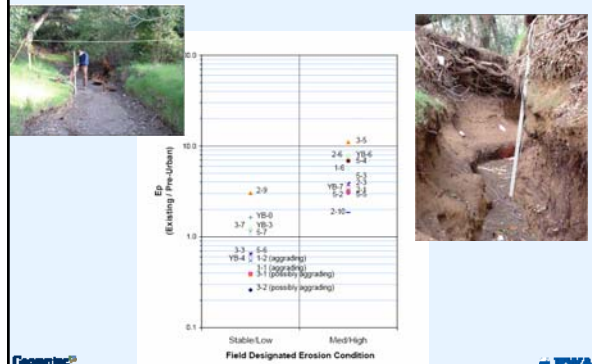
Erosion Potential is the ratio of Post and Pre hydromod effective work (cumulative sediment transport capacity)

Calculate cumulative sediment transport using continuous rainfall-runoff model linked to sediment transport model

Geomatics

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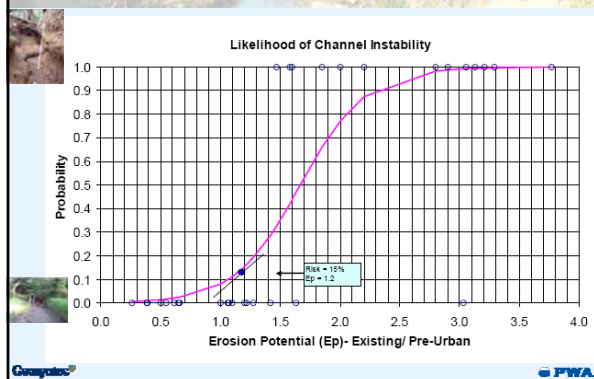
Relationship between Erosion Potential and channel instability



Geomatics

FWA

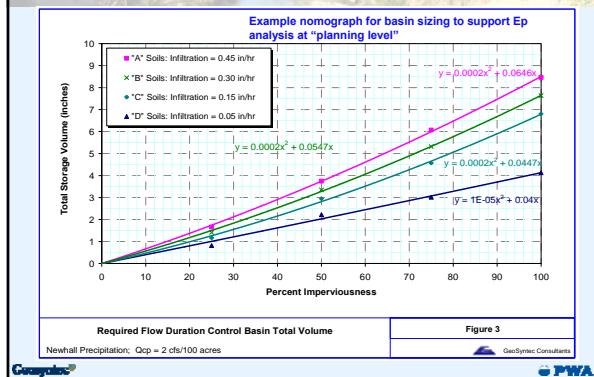
Probability of instability as a function of Ep



Santa Clara County HMP

- Calculated Ep of 1.2 as threshold for likely channel instability
- Calculated Effective Flow range as 0.1Q2 to Q10 based on work curves
- Post-project flow durations curves must match pre-project flow duration curves within 10% between 0.1Q2 and Q10 based on continuous simulation modeling using an approved model (BAHM, HSPF, HEC-HMS, SWMM)
- Applicant builds flow control features into hydrology model until the flow control conditions are met
- Exemptions:
 - Subwatersheds that are >90% urbanized
 - Subwatersheds >65% impermeable
 - Developments <50 acres in subwatersheds that are <65% impermeable
 - Areas that discharge to SF Bay, hardened channels or tidal channels
 - Provision for off-site flow control or in channel mitigation

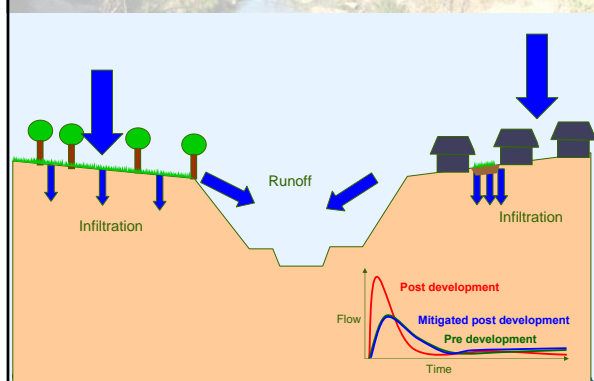
Santa Clara County HMP



Contra Costa County HMP

- 2nd California HMP to be developed (overlapped with Santa Clara)
- Adopted in 2006
- Much more emphasis on small-scale, LID approaches
- Required HMP compliance for all projects that create >0.2 acre impervious area
- 4 options
 - No increase in impervious area or increase in drainage efficiency
 - Prove post-project runoff and duration are less than or equal to pre-project
 - Simulate 30 years of continuous rainfall-runoff modeling using approved models
 - Match flow duration curves to within 10% between 0.1Q2 and Q10
 - Prove increased runoff or duration will not cause increased creek erosion downstream
 - "Low risk" channels (hardened or tidal)
 - Mitigate receiving water so erosion will not occur (requires additional permits)
 - Stormwater Integrated Management Practices
 - Sizing factors for IMPs (e.g. must create infiltration area 4-8% of total area depending on soil type)

Sizing factors for IMPs



Sizing factors for IMPs

Treatment & Flow Control	NRCS Soil Group			
	A	B	C	D
Bioretention Facility				
A	0.07	0.11	0.06	0.05
V ₁	0.058	0.092	0.050	0.042
V ₂	N/A	N/A	0.066	0.055
Flow-through Planter				
A	N/A	N/A	0.06	0.05
V ₁	N/A	N/A	0.050	0.042
V ₂	N/A	N/A	0.066	0.055
Dry Well				
A	0.05	0.06	N/A	N/A
V	0.130	0.204	N/A	N/A
Cistern + bioretention facility				
A (bioretention facility)	0.04	0.04	0.04	0.04
V (cistern)	0.193	0.228	0.088	0.060

Source: Eric Mosolgo, Brown & Caldwell

Sizing Factors built into IMP design tool

Source: Brown & Caldwell

Used as a design tool and to check for compliance

Alameda, San Mateo, and Fairfield-Suisun HMPs

- Adopted in 2007
- Copied the Santa Clara HMP directly
- 0.1Q2 to Q10 flow control range
- Continuous modeling
- Sponsored the Bay Area Hydrology Model (similar to Western Washington version of HSPF) as the standard design tool

San Diego County HMP

- Adopted in 2010
- Similar to Contra Costa County approach – continuous modeling option or IMP sizing tools based on continuous modeling
- Required HMP compliance for all projects that create >5,000 sq ft impervious area and for designated Priority Projects
 - Control post-project runoff peak and duration to be less than or equal to pre-project conditions between Q10 and critical flow threshold
 - Low flow threshold based on channel sensitivity – 0.1Q2, 0.3Q2 or 0.5Q2
 - Simulate 30 years of continuous rainfall-runoff modeling using approved models



One flow thresholds (from SF Bay) does not fit all HMPs

v. coarse unconsolidated sand 0.01 lb/sq ft
 alluvial silt (non colloidal) 0.045 lb/sq ft
 medium gravel 0.12 lb/sq ft
 alluvial silt/clay 0.26 lb/sq ft
 2.5 inch cobble 1.1 lb/sq ft

^a Julien, P.Y. (1998) Erosion and Sedimentation
^b USDA (2007) Stream Restoration National Handbook

Common Elements to California HMPs



HMP elements

County	Flow event controlled	Sizing factors or design tools?
Santa Clara	0.1Q2 – Q10	No sizing factors, can use BAHM as tool
Alameda, San Mateo, Fairfield-Suisun	0.1Q2 – Q10	No sizing factors, can use BAHM as tool
Contra Costa	0.1Q2 – Q10	Sizing factors or continuous model
LA County (interim)	Match Q2	Not developed yet
San Bernardino	Match Q1, Q2, Q5	Not developed yet
Ventura	Qcrit – Q10	Not developed yet
South Orange	0.1Q2 – Q10	Nomograph
San Diego	0.1-0.5Q2 – Q10	Sizing factors or continuous model

Tools in the California HMP box

3 Basic Approaches (can be used in combination)

- **Low Impact Development**
 - Increase infiltration and dispersed surface water detention, slow time to concentration
- **Detain and control releases**
 - Route stormwater to centralized detention facilities, then detain and release at non erosive flow rates
- **Instream mitigation**
 - Harden channel to withstand increased erosive stress
 - Flatten or widen channels to disperse erosive stress

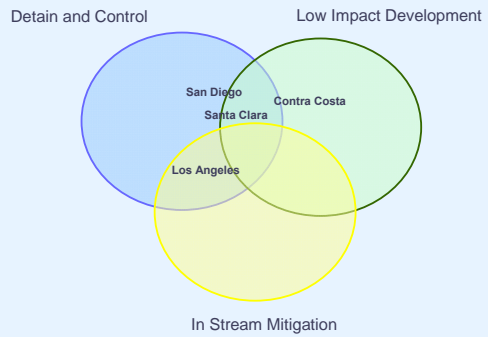
Different counties and RWQCBs have embraced these three approaches to different extents

Pros and Cons

Low Impact Development

- Pros: mimics natural hydrograph and water budget, aids recharge, provides lots of filtration
- Cons: relatively unproven in California, longevity and maintenance issues, paradigm shift for developers and County water agencies, hard to retrofit watersheds once development has started, fears for subsurface seepage
- **Detain and control releases**
 - Pros: links traditional flow collection to centralized detention facilities – developers are familiar and counties trust, maintenance is familiar, retrofit is easier than LID
 - Cons: doesn't necessarily restore water budget, esp. groundwater
- **Instream mitigation**
 - Pros: Easy to retrofit for watersheds that are already developed
 - Cons: Doesn't necessarily preserve beneficial uses of creek

Approach adopted varies with location

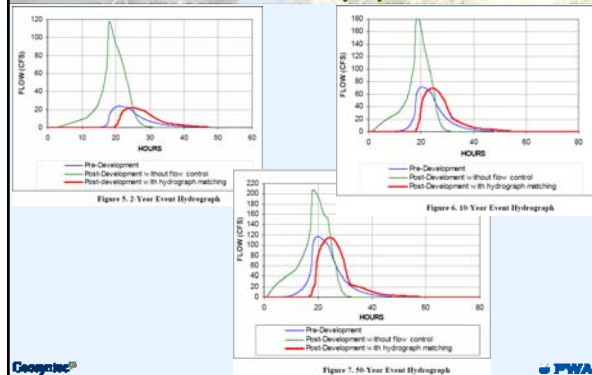


Lessons Learned in California



Lesson 1. It's all about the low flows

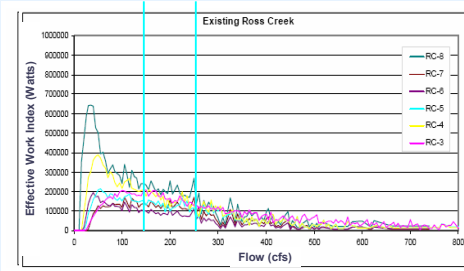
Low flows are most affected by Hydromod



Lesson 1. It's all about the low flows

Low flows cumulatively cause most erosion

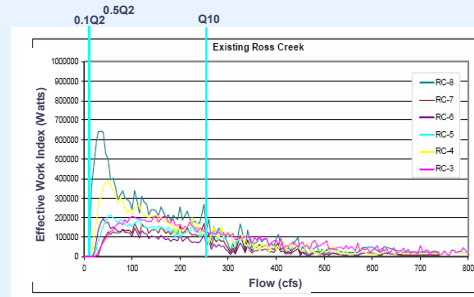
Duration of flows <Q1 become 20-30 times greater



RC-3 through 8 show different cross sections

Lesson 1. It's all about the low flows

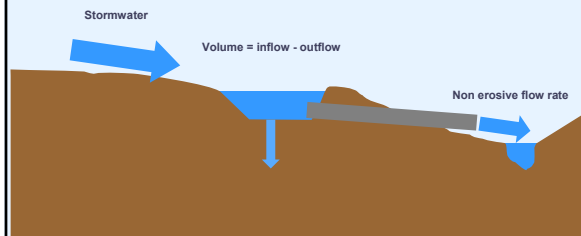
Low flows thresholds are contentious



RC-3 through 8 show different cross sections

Lesson 1. It's all about the low flows

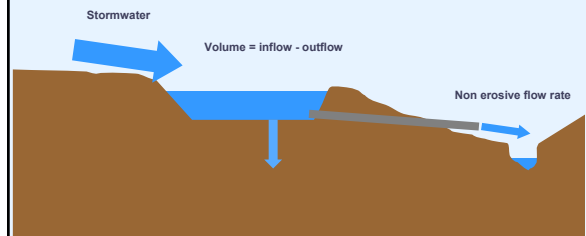
Controlling low flows can be expensive



Lesson 1. It's all about the low flows

Controlling low flows can be expensive

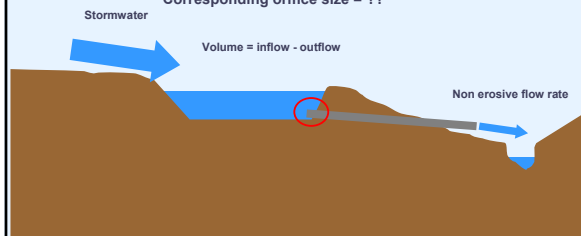
Need to protect the receiving water and minimize area devoted to runoff storage



Lesson 1. It's all about the low flows

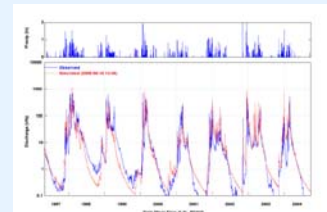
Controlling low flows can be impractical

e.g. for 10 acre sub-watershed, 0.1Q2 = ??
Corresponding orifice size = ??



Lesson 2. Modeling low flows requires continuous modeling

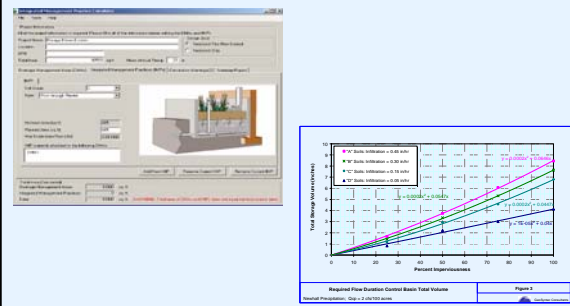
- Low flows (<Q2) highly sensitive to antecedent soil moisture conditions
- Event-based modeling can not simulate these processes and flows



Lesson 2. Modeling low flows requires continuous modeling

- Issues with continuous modeling
 - Requires clean 30 year hourly rain data sets
 - Needs to account for variability across county
 - Attempts to weight a single record across a county based on mean rainfall have been problematic
 - Which Q2 do you mean? Continuous or event?
 - New tools (HSPF, SWMM, HEC-HMS_{cont})
 - Most models are not optimized for such low flows
 - Stability issues with modeling small events

Lesson 3. Applicants don't like continuous modeling: they do like simple tools



Lesson 4. Channel susceptibility varies dramatically with region and bed materials

v. coarse unconsolidated sand 0.01 lb/sq ft
 alluvial silt (non colloidal) 0.045 lb/sq ft
 medium gravel 0.12 lb/sq ft
 alluvial silt/clay 0.26 lb/sq ft
 2.5 inch cobble 1.1 lb/sq ft



Lesson 5. Team up and don't reinvent the wheel

- Santa Clara HMP ~ \$1M
- Alameda, San Mateo and Fairfield-Suisun HMP ~ \$0.5M
- Contra Costa HMP ~ \$1M
- West San Diego HMP ~ \$1M
- If you have a similar physical and regulatory (and cultural?) setting to another partner, team up on your HMP
- However – at a certain point co-permittee groups get too large to make effective decisions

Lessons Not Learned in California



Lesson 6. Flow thresholds for most of state are all based on 3 field sites in Bay Area

- Small, lowland, ephemeral alluvial fan channels, 20-30 inches of rainfall, oak savanna landscape
- We need much more local fieldwork, esp. as we move into new states, ecoregions



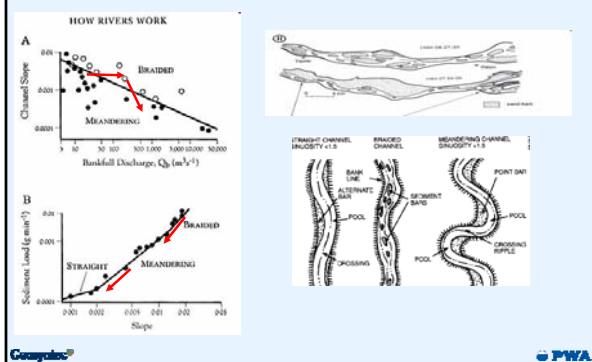
Lesson 7. No HMPs account for sediment reduction

- Halving coarse sediment load has the same effect as quadrupling Q2
- About 50% of hydromod impacts on channel enlargement are probably due to sediment reduction (more if we account for channel functions such as spawning, rearing)
- Central Coast HMP about to look at this but not yet clear how to use water regulations to control sediment

Lesson 8. How far downstream do you look?

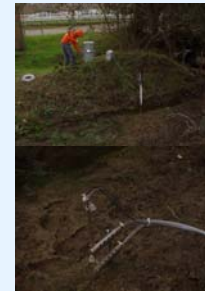
- No consensus on domain of analysis
 - Next tributary?
 - Until flow has doubled?
 - Until channel is hardened?
- How do you deal with variable channels?
 - May be resilient at Point of Compliance but sensitive further downstream
 - (Problem with having variable low flows)

Lesson 9. What about changes in channel form?



Lesson 10. Where's the monitoring and adaptation?

- Little monitoring of LID and duration control effectiveness
- Almost no field testing of flow thresholds for erosion
- No monitoring of whether creeks in HMPs are actually protected
- No feedback loop for adaptation



Building the perfect Oregon HMP?



The perfect (or at least functional) Oregon HMP

- Don't skimp on fieldwork – look at a relatively large number of local streams that are about to be developed
- Develop effective work curves for your creeks - don't copy 0.1Q2 and Q10 flow controls
- Try to keep the rules simple: complexity leads to contention and HMPs get bogged down
 - E.g. Maryland – detain the 1 year flood on site
- Develop simple tools to avoid the need for continuous modeling on most applications
- Monitor, and be prepared to adjust the rules if monitoring shows the rules are not effective or are too conservative

Questions?
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Lesson 1. It's all about the low flows

Low flows cumulatively cause most erosion

