Predicting Hydromodification Impacts Using a Four Factor Approach

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Objectives

Restoration vs. Hydromod?
Example of hydromod?
How are hydromod impacts modeled?

Hydromod Impact = f(Δhydrology, Δchannel geometry, Δbed & bank material, Δsediment supply)
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
Why care about hydromodification?

Example of geomorphic impact:

Judd 140-290 acre watershed

Pre-Development

Images from GoogleEarth

Post-Development

Hydromod!
How are hydromod impacts modeled?

**Qualitative:** Lane (1955)

\[ Q_s \ D_{50} \ \alpha \ Q_w \ S \]

**Quantitative:**

Geomorphic Impact \( = f(\Delta \text{hydrology}, \Delta \text{channel geometry}, \Delta \text{bed & bank material strength}, \Delta \text{sediment supply}) \)

Source: Rosgen (1996), From Lane, 1955. Reprinted with permissions
Hydrologic Models are applied to simulate the hydrologic response of catchments under pre- and post-developed conditions for a continuous period of record.

Hydrologic Inputs:
- Rainfall
- Catchment Delineation
- Soils
- % Imperviousness
- Lag Time
- In-stream Infiltration
- Evapotranspiration

Δhydrology

Discharge

Post-Urban

Pre-Urban

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

Currently Hydromodification Management focuses on Δhydrology. State of the practice is flow-duration matching.
Cross-sections and longitudinal profiles of the active channel are surveyed at strategic locations.
Δbed & bank material strength

For each cross-section surveyed, a measure of critical shear stress is obtained on the bed and bank material.

Non-cohesive bed:
Wolman Pebble Count and/or Sieve Analysis

Cohesive bed and bank:
Jet Test or Tables

Vegetated bank:
Tables

<table>
<thead>
<tr>
<th>Bank Material Type</th>
<th>$\tau_c$ (lbs/ft$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCE Manual No. 77</td>
<td></td>
</tr>
<tr>
<td>Hardpans</td>
<td>0.67</td>
</tr>
<tr>
<td>Compacted Clays</td>
<td>0.50</td>
</tr>
<tr>
<td>Stiff Clays</td>
<td>0.32</td>
</tr>
</tbody>
</table>
Sediment yields are estimated using field data and a GIS raster based analysis. Sediment generated from developed land and areas tributary to detention facilities are removed in the post-project condition.
Step 1: Stage, effective shear stress, and flow velocity are computed using discharge and channel geometry data as inputs to a hydraulic model.

\[ \tau = \gamma R S \]

\[ V = \frac{1.49R^{2/3}S^{1/2}}{n} \]
Model Summary

Hydrology → Hydraulic Model
Channel Geometry →

Shear, Velocity → Transport Model
Bed & Bank Material →

Transport → Sediment Supply

post/pre → Regional Field Assessment
post/pre → Empirical Model

Probability of Impact
Model Summary

Step 2: Stage, effective shear stress, flow velocity, and critical bed / bank material strength are then input into the applicable work or sediment transport equation and summed over the period of record.

http://water.epa.gov/scitech/datait/tools/warssss/dimless.cfm
Model Summary

Hydrology → Hydraulic Model
Channel Geometry → Transport Model
Shear, Velocity → Bed & Bank Material
Step 3

Transport Supply → post/pre

Regional Field Assessment → Empirical Model
probability of Impact
Step 3: Ratio of Transport is calculated by comparing relative changes in total work/transport capacity in the pre- and post-development conditions:
Model Summary

Hydrology → Hydraulic Model

Channel Geometry → Transport Model

Shear, Velocity → Bed & Bank Material

Transport → post pre

Sediment Supply → post pre

Regional Field Assessment → Empirical Model

Probability of Impact
Model Summary

Step 4: Sediment supply loss can be accounted for by reducing the baseline Ratio of Transport by the Ratio of Sediment Supply to that computation point.

Target Ratio of Transport = \frac{\text{Sediment Supply post}}{\text{Sediment Supply pre}}
Model Summary

Hydrology → Hydraulic Model

Channel Geometry → Shear, Velocity

Hydraulic Model → Transport Model

Bed & Bank Material → Transport

Sediment Supply → Regional Field Assessment

Transport → Empirical Model

post/pre → Probability of Impact
**Model Summary**

**Step 5:** Ratio of Transport is compared to the Target Ratio to get a Probability of Channel Instability.
Empirical Relationship

Santa Clara Valley Hydromodification Management Plan

40 Cross Sections:
- Thompson Creek
- Ross Creek
- San Tomas Creek

Field Designated Erosion

Graph showing the ratio of transport with stable/low and med/high categories.
Thank You!  Questions?
OR
Mitigation Strategies ... to be continued...

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

Acknowledgements:

Peter Mangarella
Gary Palhegyi
Lisa Austin
Will Lewis
Out-of-Stream Mitigation

Hydrology → Hydraulic Model

Channel Geometry → Shear, Velocity

Bed & Bank Material → Transport Model

Transport Supply → Sediment Supply

Transport → post/pre

Regional Field Assessment → Empirical Model

Empirical Model → Probability of Impact
Out-of-Stream Mitigation
Route post-development runoff through detention facilities to mimic pre-development hydrology.
Out-of-Stream Mitigation

Regional Detention Basin

On-Site Bio-Retention
In-Stream Mitigation

Reduce longitudinal slope with grade control structures to mimic pre-development work/sediment transport.

Goal: Conserve Transport

- Natural
- Developed
In-Stream Mitigation

- $S_o$: Initial Bed Slope
- $S_{eq}$: Equilibrium Slope
- $H$: Structure Height
- $L$: Length between Structures
• Equilibrium Slope = 0.2% to 0.5% may not be feasible to construct.

• Outfall structure needs to be retrofit to properly dissipate energy.

• Opportunity for combined flow control and grade control mitigation.
Project Solution?

Profile View

In-Stream Detention
Thank You!
Questions?

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

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>ATTRIBUTE</th>
<th>NATURAL CONDITION</th>
<th>DEVELOPED CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYDROLOGY</td>
<td>Drainage Area</td>
<td>~286 acres</td>
<td>~296 acres</td>
</tr>
<tr>
<td></td>
<td>Average Annual Rainfall</td>
<td>18.4 inches</td>
<td></td>
</tr>
<tr>
<td>Hydrologic Soil</td>
<td>88% Type B, 10% Type C, 2% Type A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>Imperviousness</td>
<td>0 to 1%</td>
<td>33%</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>600 cfs</td>
<td></td>
<td>731 cfs</td>
</tr>
<tr>
<td>Runoff Coefficient</td>
<td>0.033</td>
<td></td>
<td>0.349</td>
</tr>
</tbody>
</table>
### Channel geometry: SEVERE

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>ATTRIBUTE</th>
<th>NATURAL CONDITION</th>
<th>DEVELOPED CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal</td>
<td>Slope</td>
<td>3.0%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Plan Form</td>
<td>Multiple braided</td>
<td></td>
<td>Single incised channel cutoff from the floodplain. Severe meanders at the downstream end cut into hill slope toe.</td>
</tr>
<tr>
<td>Channel Depth</td>
<td>0.5 to 2 feet</td>
<td>12 to 18 feet</td>
<td></td>
</tr>
<tr>
<td>Channel Width</td>
<td>5 to 30 feet</td>
<td>50 to 140 feet</td>
<td></td>
</tr>
<tr>
<td>Hydraulic</td>
<td>Roughness</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unvegetated: n = 0.035</td>
<td></td>
<td>Unvegetated: n = 0.035</td>
</tr>
<tr>
<td></td>
<td>Vegetated: n = 0.06</td>
<td></td>
<td>Vegetated: n = 0.05</td>
</tr>
</tbody>
</table>

**Vegetated:**
- Unvegetated: $n = 0.035$
- Vegetated: $n = 0.05$
### Bed & Bank Material Strength: Slight

<table>
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<th>NATURAL CONDITION</th>
<th>DEVELOPED CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bed and Bank Material</strong></td>
<td>Median Grain Size of Bed (D50)</td>
<td>1 to 2 mm</td>
<td>Sand bed with abundant granitic cobble and gravel. Cobble and gravel is absent further downstream.</td>
</tr>
<tr>
<td></td>
<td>Bed Material</td>
<td>Sand bed with interspersed gravel and cobble.</td>
<td>Sand bed with abundant granitic cobble and gravel. Cobble and gravel is absent further downstream.</td>
</tr>
</tbody>
</table>
**Δsediment supply: SEVERE**

<table>
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<th>NATURAL CONDITION</th>
<th>DEVELOPED CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEDIMENT SUPPLY</td>
<td>Sediment Yield</td>
<td>0.5 to 1.0 ac-ft/sq-mi/yr</td>
<td>~0 ac-ft/sq-mi/yr</td>
</tr>
</tbody>
</table>
\[ \sum (\text{Duration} \times \text{Transport}) = \text{Cumulative Transport} \]
Out-of-Stream Mitigation

[Diagram of an out-of-stream mitigation structure, showing:
- Length
- Width
- Zone A
- Zone B
- 2:1 side slopes
- Infiltration
- Weir Opening (elevation at 4 feet)
- 6-feet deep
- Qcp]
Underground Vault Products

CONTECH CMP Systems
CONTECH CON/SPAN
CONTECH CON/STORM
CUDO Water Storage System
StormTech Chambers
StormTrap Detention