Development and utility of a Hydrologic Condition Index

by

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Regulatory Effectiveness (aka “The CAO”) Study

Selection Criteria:

- Puget Lowland Ecoregion - common geology (mostly till), morphology and climate.
- Small headwater watersheds (60 to 1260 ha) w/ fish-bearing channels, no lakes, minimal wetlands
- Single jurisdiction and set of regulations
- Treatment basins: ongoing development with high potential for more
- Reference – forested, no development
A slight problem along the way…
...building permits declined 75%
Land Cover Scenarios
(putting the present in perspective)

• Past (~1900 to 2007)

• Present (2007 – 2102)

• Future - Full Build-out “worst case”

• Urban – 2007 Juanita Creek
The Past - Data Timeline

1907-08 1911
Eastern and Control

1936 1948 1965
Vashon and Control
All Basins

All Basins

Timber
Soil Survey
Aerials

Land Cover 30 m pixels

Tahlequah – Full Build-Out
An Urban Comparison - Juanita Creek

Orthophoto

Impervious cover
To compare scenarios quantify the effect of land cover change (not just the change)

Hydrology the primary driver for response

“Flashiness” most strongly correlated with Biology (DeGasperi et al 2009), so.....
High Pulse Counts*

* From Horner 2013
* Modeled 61-year averages for pre-existing watershed models used to model the HCl
CAUTION

SPATIALLY

EXPLICIT CONTENT
Study Basin
Setting Up the Study Area

- Monitoring point
- Grid cell (1.8 m)
Calculation of Grid Cell Distances

- Monitoring point
- $dSg$
- $dOg$
- Grid cell
Surficial Geology

STUDY BASIN

monitoring point

Low vs. High Permeability

Grid cell (1.8 m)
Factoring in Landcover
Calculating the Hydrologic Condition Index...Step 1

\[ HCVs = \sum_{g=1}^{n} HPCg \left( \frac{1}{dO_g + dS_g} \right) \]
Calculating the Hydrologic Condition Index... Step 2

\[ HCl_s = \frac{HCV_s}{HCV_s_{\text{worst}}} \]
CALCULATION OF THE HYDROLOGIC CONDITION INDEX

\[ HCl_s = \frac{HCV_s}{HCV_{s\text{, worst}}} \]

\[ HCV_s = \sum_{g=1}^{n} HPC_g \left( \frac{1}{dO_g + dS_g} \right) \]

- \( HCl_s \) = the hydrological condition index for a stream site in a watershed, \( s \), given the LULC pattern for a particular year or simulated level of development
- \( HCV_s \) = the hydrological condition value for a stream site in a watershed, \( s \), given the LULC pattern for a particular year or simulated level of development
- \( g \) = an index from 1 to \( n \) for all the grid cells within a watershed
- \( HPC_g \) = an average high pulse count value for each grid cell type, \( g \). There are 24 values for HPC based on the combination of 12 LULC types and 2 underlying geology types
- \( dO_g \) = overland distance (Euclidean) from the grid cell, \( g \), to the stream channel
- \( dS_g \) = stream channel distance measured from the intersection of the overland distance to the grid cell, \( g \), to the sampling point downstream.
Accuracy and utility

Watershed hydrologic models:

- Fair ($r^2 \geq 0.6$) to excellent ($r^2 \geq 0.9$) simulating hourly flow rates and HPCs,

- used for other major assessments (e.g., WRIA 9 Stormwater Retrofit Planning)

- BAS
<table>
<thead>
<tr>
<th>Project timeframe averages for six treatment watersheds</th>
<th>Average Watershed HCl</th>
<th>Average Regulatory Stream Buffer HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>p-value</td>
</tr>
<tr>
<td>Watershed Percent Impervious</td>
<td>0.94</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Watershed Percent Forest</td>
<td>-0.91</td>
<td>&lt;0.01</td>
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<tr>
<td>Average Watershed HCl</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Average Regulatory Stream Buffer HCl</td>
<td>0.71</td>
<td>0.06</td>
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<tr>
<td>Ratio of watershed and buffer HCIs</td>
<td>0.05</td>
<td>0.46</td>
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<tr>
<td>High Pulse Count</td>
<td>0.88</td>
<td>0.01</td>
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<tr>
<td>Average Annual Temp at Baseflow</td>
<td>0.20</td>
<td>0.36</td>
</tr>
<tr>
<td>Conductivity at Baseflow</td>
<td>0.08</td>
<td>0.44</td>
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<tr>
<td>Percent Pool Length of Thalweg</td>
<td>0.44</td>
<td>0.19</td>
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<tr>
<td>CV of Thalweg Depth</td>
<td>-0.44</td>
<td>0.19</td>
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<tr>
<td>Average Velocity at MAD</td>
<td>0.36</td>
<td>0.24</td>
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<tr>
<td>Average Residual Pool Depth</td>
<td>0.08</td>
<td>0.44</td>
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<tr>
<td>Large Wood per 100m</td>
<td>0.64</td>
<td>0.09</td>
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<tr>
<td>Percent Silt and Sand</td>
<td>-0.36</td>
<td>0.24</td>
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<tr>
<td>BIBI</td>
<td>0.42</td>
<td>0.21</td>
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<tr>
<td>X7DADMax</td>
<td>0.94</td>
<td>&lt;0.01</td>
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</tbody>
</table>
Putting it all together
Hydrologic condition over time

- All Paved Road
- Equal forest/grass
- All forest

Legend:
- Paved Road
- Unpaved Road
- Open Water
- Pavement
- Building
- Bare
- Grass
- Recent Thinning
- Wetland
- Pasture
- Shrub
- Forest/Trees
Hydrologic condition over time

Judd Creek

HCl

Equal forest/grass

All forest

Past
Present
BuildOut


Paved Road
Unpaved Road
Open Water
Pavement
Building
Bare
Grass
Recent Thinning
Wetland
Pasture
Shrub
Forest/Trees
Hydrologic condition over time

Judd Creek

Equal forest/grass

All forest

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- Shrub
- Forest/Trees

HCI

- Past
  - 1910
  - 1936
  - 1948
  - 1965
- Present
  - 2007
  - 2009
  - 2010
  - 2012
- BuildOut
Hydrologic condition over time

Judd Creek

<table>
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<tr>
<td>HCl</td>
<td>0.10</td>
<td>0.15</td>
<td>0.20</td>
<td>0.25</td>
<td>0.30</td>
<td>0.35</td>
<td>0.40</td>
<td>0.45</td>
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Legend:
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Hydrologic condition over time

Judd Creek

HCl vs. Time

BuildOut

Legend:
- Paved Road
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Hydrologic condition over time

Judd Creek

“Worst Case”

Equal forest/grass
All forest

HCl

Past Present

- Paved Road
- Unpaved Road
- Open Water
- Pavement
- Building
- Bare
- Grass
- Recent Thinning
- Wetland
- Pasture
- Shrub
- Forest/Trees
Treatment Watersheds

Tahlequah Creek

Taylor Creek

Least  Level of current development  Most

Equal forest/grass

All forest

HCl

BuildOut

1.2Xs = largest change 2012 and FBO
3.9Xs > Taylor Creek at FBO

1.2Xs = largest change between 2012 and FBO
HCI =

- Watershed condition measuring stick
- Effect of distance, land covers and geology (configuration)
- Improved precision in X-axis
- No need to build hydrologic models everywhere in Puget Lowland Ecoregion
End
Context:

Critical Areas Ordinance required use of Best Available Science.

We used it. It survived appeals.

But, was it sufficient?
New regulations needed assessment.

Little information… no certainty

Wanted to know:

Will new regulations be sufficient?

If not, why?

And, what would change?
Measuring Environmental Response

Hydrology – High Pulse Counts

Biology
- Macro-invertebrates
- BIBI

Water Quality
- Conductivity, Temperature

Channel Complexity
- Reach-Averaged Velocity (salt tracers)
- EMAP – substrate, thalweg, pools, LWD
Change in % Forest Cover - 1907-11 to 2007*

Mainland Watersheds

Island Watersheds

Control Watersheds (mainland only)

*Michalak et al. 2013
Estimating the Future Condition
accounting for land cover, geology and distance
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