Climate and Stormwater Modeling

Climate and Stormwater Roundtable
- September 20, 2013, Fort Johnson, Charleston SC
Ecological Thresholds
An ecological threshold is the point at which there is an abrupt change in an ecosystem quality, property or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem. (Groffman et al. 2006)

Shift in ecosystem state
Determination of critical load
Extrinsic factor thresholds

NCCOS, NOS Workshop, 2013_09_09
## NCCOS Research on Impacts of Climate-related Threshold Events on Coastal Ecosystems

### Climate-related events include:
- Sea Level Change
- Storms (waves, storm surge, wind)
- Rainfall and flooding, Droughts
- Temperature extremes (heat waves, cold snaps, longer growing season)
- Ocean Acidification

### Ecosystem impacts include:
- Habitat change or loss
- Species shift or loss
- Productivity change
- Geomorphology change
- Functional change (e.g. food webs, nutrient cycling)

### Coastal Community impacts include:
- fishery decline
- increased erosion and land-loss
- salinity intrusion to aquifers, forests and agriculture
- decline in water quality

NCCOS, NOS Workshop, 2013_09_09
Predicted increases in **frequency** and **intensity** of heavy precipitation events (Bates *et al.* 2008, Gutowski *et al.* 2008)

Increase in very heavy precipitation (heaviest 1%) 1958 to 2007

Projected changes in light, moderate, and heavy precipitation (1990-2090)


NCCOS, NOS Workshop, 2013_09_09
Climate Thresholds – Stormwater Runoff

Runoff Effects

Pollutant vector
Contaminant Exposure
Flooding
Promotes Disease Vectors
Erosion
Sedimentation
Estuarine Freshwater Input

Fecal coliform
http://www.columbiariverkeeper.org/index.php/adopt_river/ecoli_monitoring

Enterococcus
http://microbewiki.kenyon.edu/images/b/bc/Wiki.png

Nitrogen loading
http://www.epa.gov/research/landscience/land-nitrogen.htm

Eastern Equine Encephalitis

Bulls Creek, Charleston SC
Guerin Creek, Charleston SC
Culiseta melanura

Stormwater Runoff, Crosstown, Charleston SC Post & Courier December 2009
Stormwater Runoff – School Dismissal Savannah, Georgia Floodplain Mgt. Department, March 2009

http://www.columbiariverkeeper.org/index.php/adopt_river/ecoli_monitoring
http://microbewiki.kenyon.edu/images/b/bc/Wiki.png
http://www.epa.gov/research/landscience/land-nitrogen.htm
Climate Thresholds – Modeling Runoff

- SWARM (modeling system) provides method to quantify runoff
- Illustrates effect of development and climate change

Rainfall runoff percent

- **2-year 24-hour storm event** – 114 mm (4.5 in)

<table>
<thead>
<tr>
<th>Environment</th>
<th>Runoff (mm)</th>
<th>Rainfall Runoff Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forested</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Suburban Watershed</strong></td>
<td></td>
<td>50%</td>
</tr>
<tr>
<td><strong>Urban</strong></td>
<td></td>
<td>67%</td>
</tr>
</tbody>
</table>

Blair et al. 2013
Climate Thresholds – Modeling Runoff

- Hydrograph adds parameters of rate and time
- Amount is area under the hydrograph curve

<table>
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<tr>
<th>Watershed</th>
<th>Runoff Percent</th>
<th>Peak Rate</th>
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<tbody>
<tr>
<td>Undeveloped - Forested</td>
<td>27%</td>
<td>0.4</td>
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</table>

2-year 24-hour storm event – 114 mm (4.5 in)
Climate Thresholds – Modeling Runoff

- Developed watershed runoff is flashier than in undeveloped ones

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<tr>
<td>Developed Urban</td>
<td>67%</td>
<td>1.9</td>
</tr>
<tr>
<td>Developed Suburban</td>
<td>50%</td>
<td>1.3</td>
</tr>
<tr>
<td>Undeveloped Forested</td>
<td>27%</td>
<td>0.4</td>
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Blair et al. 2013

2-year 24-hour storm event – 114 mm (4.5 in)
SWARM

- Based on USDA-NRCS methods
- Volume – Flow Curve Number (CN)
- Rate & time – Dimensionless Unit Hydrograph

SWARM Calibration

- Temporal rain distribution – changed to NOAA Atlas 14, 1st quartile, 30% distribution
- Adjusted CN values for developed land classes (Lim et al., 2006)
  - $I_a : S$ changed from 0.2 to 0.05  (Woodward et al., 2001; Lim et al., 2006)
- Peak rate factor changed from 484 to 200 (Sheridan et al., 2002; USDA NRCS, 2007)
- Replaced NRCS sheet flow equation with one adapted to flat lands (Zomorodi, 2005)

**2-year 24-hour storm event – 114 mm (4.5 in)**
SWARM – No Modifications

Suburban Watershed

Sequential calibration steps

Runoff (m³/s)

Time (h)
SWARM – Modifications

- Changed temporal rain distribution to NOAA Atlas 14, 1st quartile, 30% distribution

Suburban Watershed

Sequential calibration steps

- Uncalibrated
- Rainfall

2-year 24-hour storm event – 114 mm (4.5 in)
SWARM – Modifications

- Adjusted CN values for developed land classes (Lim et al., 2006)

Suburban Watershed

Sequential calibration steps
- Uncalibrated
- Rainfall
- Soil group

Runoff (m³/s)

Time (h)

2-year 24-hour storm event – 114 mm (4.5 in)
SWARM – Modifications

- Changed $I_a : S$ from 0.2 to 0.05  
  (Woodward et al., 2001; Lim et al., 2006)

Suburban Watershed

Runoff Equation

$$Q_d = \frac{(P - I_a)^2}{(P - I_a) + S}$$

2-year 24-hour storm event – 114 mm (4.5 in)
SWARM – Modifications

- Changed peak rate factor from 484 to 200  (Sheridan et al., 2002; USDA NRCS, 2007)

Suburban Watershed

Sequential calibration steps
- Uncalibrated
- Rainfall
- Soil group
- Initial abstraction
- Peak rate factor

Peak Rate Equation

\[ q_p = \frac{PRFAQ}{T_p} \]

2-year 24-hour storm event – 114 mm (4.5 in)
**SWARM – Modifications**

- Replaced NRCS sheet flow equation with one adapted to flat lands (Zomorodi, 2005)

\[
T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}S^{0.4}}
\]

Zomorodi

\[
T_t = 0.014 \left( \frac{nL}{S^{0.5}} \right)^{0.75}
\]

**NRCS**

Suburban Watershed

2-year 24-hour storm event – 114 mm (4.5 in)
SWARM – Multi-site Validations

Blair et al. 2012
Climate Thresholds – Modeling Runoff

- Runoff conditions can be changed to model climate scenarios

Suburban Watershed

Rainfall runoff percent

Runoff (mm)

2-year 24-hour storm event – 114 mm (4.5 in)
Climate Thresholds – Modeling Runoff

- Climate scenario will be based on 15% increase in rain, 50% decrease in storm duration, change from average to 50% wet conditions

### Runoff, Watershed, 24-hr 114 mm (4.5 in) storm event, average runoff conditions

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Runoff Percent</th>
<th>Peak Rate</th>
<th>Runoff Volume</th>
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<tbody>
<tr>
<td>Suburban</td>
<td>50%</td>
<td>1.3</td>
<td>66 af</td>
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### Suburban Watershed

- Peak Runoff: 1.3 m³/s/km²
- Time: 0-70 hours

24-hr 114 mm (4.5 in) storm event, average runoff conditions
Climate Thresholds – Modeling Runoff

- Climate scenario based on 15% increase in rain, 50% decrease in storm duration, change from average to 50% wet conditions

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<td>50%</td>
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<td>66 af</td>
</tr>
<tr>
<td>Climate impact</td>
<td>65%</td>
<td>2.7</td>
<td>99 af</td>
</tr>
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24-hr 114 mm (4.5 in) storm event, average runoff conditions
Climate impact – 12-hr 131 mm (5.2 in) storm event, semi-saturated runoff conditions
Climate & Stormwater – Citations


