LOW IMPACT DEVELOPMENT
HYDROLOGIC CONSIDERATIONS

22nd Annual Nonpoint Source Pollution Conference
Saratoga Springs, NY
May 18, 2011
PRESENTATION AGENDA

• Introduction
• Definitions
• Discuss Impacts to Hydrologic Cycle
• Hydrologic Principles of LID
• Hydrologic Tools of LID
• Examples
LAND USE ALTERATIONS TO HYDROLOGIC CYCLE

- Increased runoff volume
- Increased imperviousness
- Increased flow frequency, duration, and peak runoff rate
- Reduced infiltration
- Modification of flow pattern
- Faster time to peak, due to shorter time of concentration
- Loss of storage
ALTERATIONS TO LANDSCAPE

1. Soils absorb and retain water.

2. Natural topography can promote infiltration.

3. Natural flow paths increase travel time.


5. Deeper roots increases absorption and infiltration.

Illustration from Do-It-Yourself Water Quality
ALTERATIONS TO DRAINAGE PATTERNS

Illustration from Do-It-Yourself Water Quality
DESIGN PRINCIPLES

- **Runoff Volume Control** – Minimize site disturbance, ground cover changes and provide onsite retention.
- **Peak Runoff Rate Control** - Maintain the predevelopment Tc (Time of Concentration i.e. runoff travel time) and use retention or detention throughout site.
- **Flow Frequency/Duration Control** – Post development matches predevelopment.
- **Water Quality Control** – Provided through retention practices.
DESIGN ELEMENTS

1. Reduce Runoff Curve Number (CN) – Reduce impervious cover and preserve existing site conditions.

2. Reduce Time of Concentration (Tc) – Minimize the increase in peak runoff by lengthening flow paths and increasing travel time.

3. Implement Retention – Provide retention storage to maintain same runoff volume.

4. Implement Detention – Provide detention storage to maintain same runoff flow rates.
RUNOFF CURVE NUMBER (CN)

- Developed by the Natural Resource Conservation Service (NRCS).
- Based primarily on land cover.
- Commonly used as the rainfall to runoff transformation term for small watershed hydrologic analyses.
- Development and urbanization increases CN value thereby increasing runoff.
- Initially utilized for traditional agricultural lands but now applied to hydraulic modeling.
FACTORS FOR DETERMINING RUNOFF

Components of the Curve Number (CN):

- **Hydrologic Soil Groups** – Four groups (A-D)
- **Cover Type** – Type of vegetation, percentage of vegetation and impervious covers
- **Hydrologic Conditions** – Effect of cover type
- **Connectedness of impervious cover**
Low Impact Development Techniques that will reduce post development runoff volume:

• Preservation of infiltratable soils.
• Preservation of existing natural vegetation.
• Minimize grading.
• Minimize site imperviousness.
• Disconnect site imperviousness.
• Creation of transition zones and bioretention.
HYDROLOGIC SOIL TYPES

- Preserve Infiltratable Soils (HSG A & B).
- Preserve natural vegetation and depressions.
HYDROLOGIC SOIL TYPES

• Do not locate stormwater management on poorly drained soils (HSG C & D).
DEVELOPMENT ON HYDROLOGIC SOIL TYPES

EXAMPLE SITE DEVELOPMENT:
• 10 acre site
• 5 ac HSG A soils & 5 ac HSG C soils
• Pre development - Wooded (Good condition)
• Development Proposal - 6 single family homes, each 3000 sf with 100 lf driveway & 50 ft clearing around house perimeter
• 300 lf road with 60’x20’ hammerhead turnaround
DEVELOPMENT ON HYDROLOGIC SOIL TYPES

10 ACRE SITE - DEVELOP HSG A SOILS
HYDROLOGIC SOIL TYPES

Compare exact same development scenarios, one with all development on HSG A soils and one with all development on HSG C soils.

<table>
<thead>
<tr>
<th>DEVELOPMENT SCENARIO</th>
<th>RUNOFF (in)</th>
<th>PEAK DISCHARGE (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CN</td>
<td>2-YR</td>
</tr>
<tr>
<td>Undeveloped – HSG A &amp; HSG C</td>
<td>50</td>
<td>0.02</td>
</tr>
<tr>
<td>HSG C Developed – HSG A Undeveloped</td>
<td>53</td>
<td>0.06</td>
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<tr>
<td>Increase from Undeveloped</td>
<td>6%</td>
<td>300%</td>
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<tr>
<td>HSG A Developed – HSG C Undeveloped</td>
<td>57</td>
<td>0.12</td>
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<tr>
<td>Increase from Undeveloped</td>
<td>14%</td>
<td>600%</td>
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</tbody>
</table>

• Development on more infiltratable soils results in a greater percent increase in stormwater runoff.
• Comparison of cover types: Stormwater report claims post development will equal predevelopment.
Comparison of cover types: Should stormwater report analyze just after construction or full revegetation conditions.
• Comparison of hydrologic conditions: Left - Woods (Good) with dense under growth (saplings and brush); Woods (Fair) cleared understory resulting in higher CN value and increased runoff.
### REDUCE POSTDEVELOPMENT CN

<table>
<thead>
<tr>
<th>Suggested Options Affecting Curve Numbers</th>
<th>Limit Use of sidewalks</th>
<th>Reduce road length and width</th>
<th>Reduce driveway length and width</th>
<th>Conserve natural resource areas</th>
<th>Minimize disturbance</th>
<th>Infiltrate soils</th>
<th>Preserve natural depressions</th>
<th>Use Transition Zones</th>
<th>Use vegetated swales</th>
<th>Preserve vegetation</th>
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<tbody>
<tr>
<td>Land Cover Type</td>
<td>✓</td>
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<tr>
<td>Percent of Imperviousness</td>
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<td>Hydrologic Soils Group</td>
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<td>Hydrologic Condition</td>
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<td>Disconnect Impervious Area</td>
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<tr>
<td>Storage and Infiltration</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>Soil Name and Hydrologic Group</td>
<td>Cover Description (assuming residential housing with a density of four houses/acre)</td>
<td>Composite CN (average runoff conditions)</td>
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<td>Collington, B</td>
<td>Conventional development</td>
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<tr>
<td>Collington, B</td>
<td>• 18’ wide residential road with hydraulically connected roof areas and driveways</td>
<td>70</td>
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<td>• Grassed channel conveyance</td>
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<td>Collington, B</td>
<td>• 18’ wide residential road with disconnected roof areas and driveways</td>
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<td>Collington, B</td>
<td>• 18’ wide residential road with disconnected roof areas and driveways</td>
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<td>• 25% of area retained as woodland in good condition</td>
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<tr>
<td>Collington, B</td>
<td>• 18’ wide residential road with disconnected roof areas and driveways</td>
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<td>• 25% of area retained as Woodland in good condition &amp; bioretention area for road stormwater management</td>
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<tr>
<td>Collington, B</td>
<td>100% area retained as Woodland in good condition</td>
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</table>
Tc (TIME OF CONCENTRATION)

- Time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed.
- Influences the shape and peak of runoff hydrograph.
- Development usually decreases Tc, thereby increasing the peak runoff.
FACTORS AFFECTING $T_c$
(TIME OF CONCENTRATION)

- **Surface roughness** – Manning’s “$n$” (Roughness Coefficient)
- **Flow patterns** – Overland, Channel, Sheet, Concentrated
- **Channel shape** – More hydraulically efficient, higher velocities
- **Slopes** – Increased slopes, higher velocities
REDUCE POST DEVELOPMENT Tc

- Disperse and redirect flows through open swales and natural drainage patterns.
- Increase surface roughness.
- Use network of wider and flatter channels.
- Increase channel flowpath.
- Maximize sheet flow regime.
- Flatten grades in impacted areas.
- Disconnect impervious areas.
SURFACE ROUGHNESS

- Unnatural conveyance methods associated with development increases runoff velocity and decreases travel time. Smoother the surface, lower the roughness coefficient which increases runoff.
• Natural conveyance systems slow velocity and increase travel time which reduces peak runoff. Additionally, infiltration potential increases with more pervious surfaces, further reducing runoff.
• **Sheet Flow** – Flow over plain surface. Initial flow in a watershed. Less than 300 feet.
• Shallow flow that is greatly influenced by surface.
• Results in greatest contact with surface which promotes infiltration and pollutant removal.
FLOW PATTERNS

• Shallow Concentrated Flow – After sheet flow, point where water gains measurable velocity.
• Surface influence is limited to paved and unpaved.
• Travel time significantly decreases from sheet flow condition.
FLOW PATTERNS

- **Open Channel Flow** – Point where surveyed cross sections can be obtained for channel.
- Streams can appear on USGS maps.
- Cannot provide control measures.
• More uniform the conveyance surface and shape, greater the hydraulic efficiency. This correlates to decreased travel time and increased peak flows.
• Slope can be increased by development. Increased velocity decreases travel time and infiltration potential creating higher peak flows.
• Slopes also increase when channels are straightened.
## REDUCE POSTDEVELOPMENT Tc

<table>
<thead>
<tr>
<th>Low Impact Development Objective</th>
<th>On-lot bioretention</th>
<th>Wider and flatter swales</th>
<th>Maintain sheet flow</th>
<th>Clusters of trees and shrubs in flow path</th>
<th>Minimize storm drain pipes</th>
<th>Disconnect impervious areas</th>
<th>Save trees</th>
<th>Preserve existing topography</th>
<th>LID drainage and infiltration zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize disturbance</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Flatten grades</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Reduce height of slopes</td>
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<td>✓</td>
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<tr>
<td>Increase flow path (divert and redirect)</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>Increase roughness “n”</td>
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</table>
ON-SITE STORMWATER RETENTION

• Low Impact Development utilizes retention to emulate the hydrologic patterns of predevelopment.
• Better to implemented as uniform distribution at the source.
• Locate on the more pervious soils to maximize infiltration and storage.
• View stormwater as a resource and not a waste product.
ON-SITE STORMWATER DETENTION

- Detention may be needed to maintain predevelopment flow rates if storage for retention is not available.
- Can incorporate as part of conveyance.
- Use of natural methods reduces maintenance costs.
- Remember to increase time of travel for runoff.
Watershed Boundary
## WATERSHED FEATURES

Table 1. Watershed Features

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Drainage Area (acres)</th>
<th>Number of Houses</th>
<th>Houses/acre</th>
<th>Road Length (ft/acre)</th>
<th>Road Width (ft)</th>
<th>Percent Impervious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Impact Development</td>
<td>11.84</td>
<td>40</td>
<td>3.37 houses per acre</td>
<td>187</td>
<td>36</td>
<td>36 %</td>
</tr>
<tr>
<td>(S2 LID)</td>
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<tr>
<td>Conventional Development</td>
<td>8.43</td>
<td>28</td>
<td>3.33 houses per acre</td>
<td>189</td>
<td>24</td>
<td>30 %</td>
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<tr>
<td>(S3 CONV)</td>
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</tbody>
</table>

Provided by Larry Coffman, LLLP Stormwater Services
MONITORING RESULTS

Discharge Comparison

Time, April 6, 2001

Provided by Larry Coffman, LLLP Stormwater Services
LID SITE DESIGN

1992 Somerset, Maryland - Rain Gardens
First Residential Application

2008 Somerset, Maryland - Rain Gardens
LID SITE DEVELOPMENT

EXAMPLE SITE DEVELOPMENT:

- 1.0 acre site with 3000 sf single family dwelling, 150 ft setback to lake. Total site impervious – 4800 sf
- HSG B soils, 11% site slope

Original Site Runoff Conditions:

- Cleared Site with newly graded, pervious soils (CN 86)
- Total Site CN 87; Tc 0.0141 hr
- 2 year event: Runoff = 1.33 in
  Peak Discharge = 2.14 cfs
18% Decrease in Runoff

- 150 foot grass lawn (Poor)
- Total Site CN 84; Tc 0.1142 hr
- 2 year event: Runoff = 1.10 in
  Peak Discharge = 1.75 cfs

Provided by FUND for Lake George
32% Decrease in Runoff

- 10 foot undisturbed wooded buffer (Good); 140 foot grass lawn (Poor)
- Total Site CN 83; Tc 0.1580 hr
- 2 year event: Runoff = 1.06 in
  Peak Discharge = 1.46 cfs

Provided by the FUND for Lake George
58% Decrease in Runoff

- 50 foot undisturbed wooded buffer (Good); 100 foot grass lawn (Poor)
- Total Site CN 80; Tc 0.2635 hr
- 2 year event: Runoff = 0.88 in
  Peak Discharge = 0.92 cfs

Provided by the FUND for Lake George
73% Decrease in Runoff

- 100 foot undisturbed wooded buffer (Good); 50 foot grass lawn (Poor)
- Total Site CN 76; Tc 0.3625 hr
- 2 year event: Runoff = 0.69 in
  Peak Discharge = 0.58 cfs

Provided by the FUND for Lake George
• Let nature do the work.
• Maintain natural cover to reduce CN values.
• Know site soils and preserve well drained soils.
• Utilize natural drainage paths and maintain natural surface to increase time of travel.
• Limit excessive grading to reduce slope alterations.
• Maximize infiltration close to the source.
THANK YOU!!

FOR ADDITIONAL INFORMATION, VISIT www.lakegeorgewaterkeeper.org OR CONTACT OUR OFFICE 518-668-5913.