GOALS:

- Improve understanding of Rate and Volume (Quantity) Stormwater Design
- Improve understanding of strategies to achieve points
- Share successful LEED documentation methodology
- Share past Lessons Learned

Introduction
Rate & Volume Design

Agenda
I. Design intent
II. Design Goals requirements
III. Typical Strategies
IV. Sample calculation
V. Lessons learned
General Intent

✓ Reduce net stormwater runoff rate and quantity leaving the site

Rate = Discharge rate (CFS)
Quantity = Runoff volume (Acre-FT) or (Cu.Ft.) or (Depth)

Typically quantity rules are set by regulatory group or professional guidance (LEED)

“Permanently” capture stormwater volume on site to meet quantity point intent
Example Design Intents

LEED Version 3:

- To limit disruption of natural hydrology by reducing impervious cover, increasing on-site infiltration, reducing or eliminating pollution from stormwater runoff, and eliminating contaminants. No stormwater increase or 25% reduction depending on % Impervious.

- City of Chicago
  - Capture ½” first flush of new impervious runoff
Typical Strategies - Rate

Reduced impervious – Synergy with Quantity

- Open Space
- Green roof

A. Restricted outflow (detention)

Rate control is often a standard regulatory requirement
Typical Strategies - Quantity

A. Reduced Impervious
   1. Open Space
   2. Green roof

B. Infiltration
   1. Permeable pavement
   2. Soak aways
   3. Rain gardens
   4. Bio-infiltration

C. Stormwater Re-use/Rainwater Harvesting
   1. Cisterns

Dry Detention typically is not a quantity strategy (based on past CIR)
Typical Strategies – Quantity
Maximize Open Space | Protect Natural Areas

Reduced impervious

1. Increase Open Space
   • Reduce aisle widths and sidewalk widths
   • Increase planter islands widths
   • Undrained permeable pavement subgrade w/ appropriate freeboard

2. Green Roof
   • Intensive vs. extensive green roofs
   • Manufacturer test data

Applicable to wide open spaces and dense urban areas……
Convert Stormwater to Resource Water

Stormwater Re-use/Rainwater Harvesting

1. Irrigation
   - Above ground and below ground cisterns available
   - Cistern sized based on July irrigation demand. Verify drainage area supports demand
   - Above ground fairy simple and extra benefit of visual feature
   - Below ground cistern involves complicated integrated design

2. Toilet Flushing and washdown

POTENTIAL IMPACT: Subtract irrigation tank volume from gross site runoff volume
Infiltration Methods:

Permeable pavement

Soak aways/French Drain

Bio-infiltration

Maintain 21” depth from surface to HWL
Infiltrate Stormwater aka aquifer recharge

Infiltration
One of two typical scenarios:
- Soil support high rate of infiltration
- Soils do not support high rate of infiltration
**Infiltration Volume**

**Infiltration** - Soil supports infiltration

Test soils to establish infiltration rate. Double ring infiltrometer, Guelph Permeameter, Falling head test

Generally K factor in/hr is useful to determine if soils are suitable for infiltration but not useful for preparing a simple hand calculation…..

The infiltration volume over 24 hrs= ????

Image from Surechem.com
Slow Infiltration - Soil does not support high rate of infiltration (aka Clay or Silt Loam)

Even with 0.1 in/hr rate of infiltration, it would appear there still is value as over time mounded water in infiltration basin will drain to water table.....

Infiltration volume is the volume of infiltration basin below overflow. Actual aquifer recharge during 24 hour period is generally neglected for quantity calculation purposes

IMPACT: Subtract infiltration volume from gross site runoff volume
Infiltration Volume

Common calculation methods:

**Complex:**
- ✔ Apply falling head rate at time steps through a design storm
- ✔ Green Ampt - Dynamic Differential Equation
- ✔ Darcy’s Law - Dynamic Differential Equation

**Simpler:**
- ✔ Volume in vs. Volume out
  \[ W_v = \left( P \times R_v \times A \right) / 12 \]
  \[ R_v = 0.05 + 0.9I_a \]
  RV = from studied value

**Most Simple:**
- ✔ Size infiltration basin based on small storm runoff volume and provide 100% storage. Treat as retention basin neglect infiltration and evapotranspiration
Rational Method to Size Infiltration Volume

Logic Behind Using Rational Method:
- Accepted by City of Chicago for infiltration calculation
- Duplicates Storm sewer calculations
- Conservative volume estimate and coefficients
- Accepted by MWRD and IDOT for small detention analysis
- Original USGBC recommended methodology

Drawbacks:
- Technically meant for conveyance calculations
- Old technology
- Potentially subjective
- Average infiltration outflow rate is not constant
DELINATE PROPOSED BMP DRAINAGE AREAS

Sample Calculation

<table>
<thead>
<tr>
<th>Method #1 Inlet Filter</th>
<th>Flow Rate</th>
<th>N/A</th>
<th>N/A</th>
<th>80%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>7741</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Treatment flow rate and peak TSS removal rate based on Manufacturer Data.

**According to Bulletin 7, rainfall events 1" depth storm with 100% annual probability has 1 hr duration.**

Captured for Treatment:

- 5042 / 4672
- Goal: 90% of Average Annual Re

Weighted TSS Removal Rate:

- Onsite Zone Area 1 * TSS1 + Drainage Zone Area 2 * TSS2 + Drainage Zone Area 3 * TSS3 / Total Area
- Goal: 80% TSS Removal Rate

**Legend**

- DRAINAGE AREA BOUNDARY
- BIO-INFILTRATION ZONE
- SURFACE DRAINAGE DIRECTION
- PERMANENT INLET FILTER
- STORM SEWER
- INFILTRATION AREA
- UNDERDRAIN
Sample Calculation
Determine gross rate and quantity

**PRE-DEVELOPMENT RATE AND QUANTITY**

<table>
<thead>
<tr>
<th>Project Data</th>
<th>Rainfall Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Area = 64072 SF</td>
<td>1.47 Acre</td>
</tr>
<tr>
<td>c= 0.61</td>
<td>1-yr</td>
</tr>
<tr>
<td>Tc= 0.08 hr</td>
<td>2-yr</td>
</tr>
<tr>
<td>5.0 min</td>
<td>24-hr Rainfall Depth (in):</td>
</tr>
</tbody>
</table>

**Rational Method Existing Rate Calculation**

\[
Q_{1yr} = c \times i \times A = 0.61 \times 3.72 \times 1.47 = 3.35 \text{ cfs}
\]

\[
Q_{2yr} = c \times i \times A = 0.61 \times 4.56 \times 1.47 = 4.10 \text{ cfs}
\]

**Rational Method Existing Quantity Calculation**

\[
V_{1yr} = c \times i \times A = 0.61 \times 2.57 \times 64072 \times 1/12 = 8389 \text{ CF}
\]

\[
V_{2yr} = c \times i \times A = 0.61 \times 3.16 \times 64072 \times 1/12 = 10315 \text{ CF}
\]

**POST-DEVELOPMENT RATE AND QUANTITY**

<table>
<thead>
<tr>
<th>Project Data</th>
<th>Rainfall Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Area = 64072 SF</td>
<td>1.47 Acre</td>
</tr>
<tr>
<td>c= 0.76</td>
<td>1-yr</td>
</tr>
<tr>
<td>Tc= 0.08 hr</td>
<td>2-yr</td>
</tr>
<tr>
<td>5.0 min</td>
<td>24-hr Rainfall Depth (in):</td>
</tr>
</tbody>
</table>

**Gross Post Development Rate Calculation**

\[
Q_{1yr} = c \times i \times A = 0.76 \times 3.72 \times 1.47 = 4.17 \text{ cfs}
\]

\[
Q_{2yr} = c \times i \times A = 0.76 \times 4.56 \times 1.47 = 5.11 \text{ cfs}
\]

**Gross Post Development Quantity Calculation**

\[
V_{1yr} = c \times i \times A = 0.76 \times 2.57 \times 64072 \times 1/12 = 10464 \text{ CF}
\]

\[
V_{2yr} = c \times i \times A = 0.76 \times 3.16 \times 64072 \times 1/12 = 12860 \text{ CF}
\]

In this case storm criteria defined by LEED 1 & 2-YR 24 Hr.
## Sample Calculation

### Infiltration Storage Volumes

**DESCRIPTION:** The site contains multiple bioinfiltration zones and bioswales that store water for infiltration. These infiltration zones consist of gap graded stone underbayment that is undrained by conventional methods.

The volume of the bioinfiltration storage reduces the gross runoff volume.

<table>
<thead>
<tr>
<th>Bio-Infiltration Zone #1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area (SF)</strong></td>
<td><strong>Depth (FT)</strong></td>
<td><strong>Volume (CF)</strong></td>
</tr>
<tr>
<td>949</td>
<td>4</td>
<td>1462</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bio-Infiltration Zone #2</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area (SF)</strong></td>
<td><strong>Depth (FT)</strong></td>
<td><strong>Volume (CF)</strong></td>
</tr>
<tr>
<td>482</td>
<td>4</td>
<td>233</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bio-Infiltration Zone #3</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area (SF)</strong></td>
<td><strong>Depth (FT)</strong></td>
<td><strong>Volume (CF)</strong></td>
</tr>
<tr>
<td>668</td>
<td>4</td>
<td>1015</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bio-Infiltration Zone #4</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Area (SF)</strong></td>
<td><strong>Depth (FT)</strong></td>
<td><strong>Volume (CF)</strong></td>
</tr>
<tr>
<td>653</td>
<td>4</td>
<td>993</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bio-Swale Zone #5</th>
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</thead>
<tbody>
<tr>
<td><strong>Area (SF)</strong></td>
<td><strong>Depth (FT)</strong></td>
<td><strong>Volume (CF)</strong></td>
</tr>
<tr>
<td>930</td>
<td>4</td>
<td>1414</td>
</tr>
</tbody>
</table>

**Total Infiltration Volume Capacity:** 5597 CF
Check that goals are met...

<table>
<thead>
<tr>
<th>SUMMARY AND ANALYSIS</th>
<th>A5.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARGET RATES AND VOLUMES:</td>
<td></td>
</tr>
<tr>
<td>Existing impervious exceeds 50%, therefore reduce runoff by 25%</td>
<td></td>
</tr>
<tr>
<td>Target $Q_{pr}$ = 2.51</td>
<td>75% Predevelopment Rate</td>
</tr>
<tr>
<td>Target $Q_{pr}$ = 3.08</td>
<td>75% Predevelopment Rate</td>
</tr>
<tr>
<td>Target $V_{pr}$ = 6292</td>
<td>75% Predevelopment Volume</td>
</tr>
<tr>
<td>Target $V_{pr}$ = 7736</td>
<td>75% Predevelopment Volume</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GROSS RATES AND VOLUMES:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross $Q_{pr}$ = 4.17</td>
<td>REF. A2</td>
</tr>
<tr>
<td>Gross $Q_{pr}$ = 5.11</td>
<td>REF. A2</td>
</tr>
<tr>
<td>Gross $V_{pr}$ = 10464</td>
<td>REF. A2</td>
</tr>
<tr>
<td>Gross $V_{pr}$ = 12866</td>
<td>REF. A2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NET RATES AND VOLUMES:</th>
<th>A5.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>REDUCE GROSS RUN-OFF RATE THROUGH USE OF RESTRICTORS, INFILTRATION STORAGE VOLUME IS PROVIDED TO STORE VOLUME/FLOW CUE</td>
<td>Logic check</td>
</tr>
<tr>
<td>Net $Q_{pr}$ = 1.98 cfs</td>
<td>&lt; 2.51 OKV REF A4</td>
</tr>
<tr>
<td>Net $Q_{pr}$ = 1.98 cfs</td>
<td>&lt; 3.08 OKV REF A4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>REDUCE GROSS RUN-OFF BY INFILTRATION STORAGE VOLUME</th>
<th>Logic check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net $V = Gross V - Infiltration V$</td>
<td>REFER TO AS FOR INFILTRATION STORAGE VOLUME</td>
</tr>
<tr>
<td>Net $V_{pr}$ = 10464 - 5597 = 4867 &lt; 6292 OKV</td>
<td></td>
</tr>
<tr>
<td>Net $V_{pr}$ = 12866 - 5597 = 7269 &lt; 7736 OKV</td>
<td></td>
</tr>
</tbody>
</table>
Lessons Learned

- Watch out for the goat's tongue!

- Ice dams from Green roof

- Excessive erosive forces

- Underdrain Placement
R&Q
Other Modeling Methods

Pond Pack
- Infiltration rate option
- Multiple pond design

Recarga Bio-infiltration model
- University of Wisconsin Model
- Includes Evapotranspiration
- Suitable for wetland detention modeling
- Suitable for site and neighborhood scale models
- Does not model gap graded storage layer

EPA SWMM
XP SWMM
WINSLAMM
SUSTAIN
METHOD COMPARISON

1” Rainfall, 1.47 acres, C=0.76, Cn=90, Type D soil, clay sub soil

<table>
<thead>
<tr>
<th>Method</th>
<th>Required Storage calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rational Method</td>
<td>0.09 acre-ft -&gt;0.24 Acre-ft soak away</td>
</tr>
<tr>
<td>TR-20</td>
<td>0.06 acre-ft -&gt;0.16 Acre-ft soak away</td>
</tr>
<tr>
<td>Recarga</td>
<td>1.0 acre-ft (sand storage clay subsoil)</td>
</tr>
</tbody>
</table>

HYBRID METHOD?
Stormwater Design – Quality Control

**Typical LEED Requirement:**

In plain english......

Remove 80% Total suspended soils (TSS) for 90% of the average annual rainfall

By designing BMP’s in accordance with local standards

OR

Provide product data to demonstrate compliance
Typical Strategies:
A. Planning and Development Strategies (Non Structural)
   1. Day lighting stormwater/disconnected Impervious
   2. Clustered development/maximized open space
   3. Preserve natural drainage features and depressions
   4. Xeriscape
   5. Reduce impervious
   6. Reduce disturbance
   7. Protecting other natural areas

But what is peculiar about these items?
Difficult to measure them for TSS removal without before and calculations and detailed environmental analysis.....
Typical Strategies:
A. Structural Treatment train of BMP’s

Including:
1. Bio Swales
2. Vegetative Filter strips
3. Rain gardens
4. Bio-Infiltration systems
5. Infiltration trenches
6. Soak Aways/French Drains
7. Permeable pavers
8. Level Spreaders
9. Wet Detention
10. Constructed Wetland Detention
11. Constructed Wetlands
12. Pre-engineering systems
   Manufactured systems
13. Inlet Filters

Notice what is not listed:
A. Greenroofs alone
B. Dry Bottom Detention alone
C. Native plantings alone
Remember:

Remove 80% Total Suspended Soils (TSS) for 90% of the average annual rainfall

SO FIRST THINGS FIRST

CAPTURE 90% OF THE DRAINAGE AREA FOR TREATMENT!

OR IT’S ALL FOR NAUGHT…….
Remember:

Remove 80% Total Suspended Soils (TSS) for 90% of the average annual rainfall

But what is TSS and how do you measure its removal…..

Due to the measurement difficulties, designers typically look for TSS removal rate guidance from the local regulatory agency such as:

A. DuPage County
B. Lake County
C. LEED (As of Version3)
Use engineering judgment to select range of treatment... for instance if the design infiltrates 100% of the tributary volume then it would be reasonable to assume 90-100% TSS removal....but if design infiltrates 50% of required volume then adjust rate down....
Treatments are cumulative:

Treatment Rate 1 = 80%
Treatment Rate 2 = 50%
Treatment Rate 3 = 80%

After T1 20% TSS remains
After T2 10% TSS remains
After T3 2% TSS remains

Cumulative TSS removal rate = 98%

Site typically have multiple treatment Trains, determine TSS rate by area.…develop a “weighted” rate.
Remember:

Remove **80%** Total suspended soils (TSS) for **90%** of the average annual rainfall

But what is the average annual rainfall…..?

USGBC LEED V3 defines treating a 1” storm event as treating the average annual rainfall for our region

Regulatory rules soon to come…….
50,000 SF site total

45,000 SF Captured by BMP’s >90% OK

30,000 SF Permeable pavement drains to infiltration trench to dry basin with larger bio-infiltration at outlet
Treatment Train 1: 1) permeable pavement 80% 2) an infiltration trench, 50% 3) bio-infiltration basin 80% -> Treatment Rate = 98%

10,000 SF Building drains to small bio-infiltration basins to infiltration trench to larger bio-infiltration at outlet
Treatment Train 2: 1) bio-infiltration basin 70% 2) infiltration trench 50% 3) bio-infiltration basin 80% -> Treatment Rate = 97%

5,000 SF Native Landscape to larger bio-infiltration at outlet
Treatment Train 3: 1) Filter Strip 40% 2) bio-infiltration basin 80% Treatment Rate = 88%

Weighted rate = \( \frac{30000(.98) + 10000(.97) + 5000 (.88)}{45,000} = 97\% \) TSS removal

Provide BMP volume information in appendix format to document capacity.

TSS Method Proposed By DuPage County Ordinance Revision follow similar methodology
WATER QUALITY
Sample Calculation

Trains 1,2,3 end at infiltration basin with 100% stay on for 1" design storm.
Remember:

Remove 80% Total suspended soils (TSS) for 90% of the average annual rainfall

We have captured 90% of the drainage area

We have determined a weighted treatment rate

Sized system to hold/treat 1” depth of rainfall similar to Quantity point

We have met the point requirements
Regulatory Trends

• City of Chicago – *Volume Based Design Component (SS6.1)* retain ½” volume control for new impervious
• DuPage County, IL – *Water Quality BMP Component (SS6.2)*
• DuPage County, Lake, McHenry IL Future - *Water Quantity BMP Component (SS6.1)*
• Cook County, IL MWRD Future – *Water Quality 1” treatment for Discharge to waterway (SS6.2)*
• Cook County, IL MWRD Future – *Water Quantity 1” treatment for Discharge to combined sewer (SS6.1)*
• Will County, IL - *BMP requirement to show no adverse impact (SS6.2)*
• USACE – *BMP requirement as part of 404 permit (SS6.1 & SS6.2)*
• Federal Projects – Energy Independence Act, restore natural condition (SS6.1 and SS6.2) Project over 5000 SF
• Wisconsin IDNR – Infiltration requirement 60%-90% average annual predevelopment infiltration volume
• New Jersey Stormwater Management– Maintain 100% of average annual preconstruction groundwater recharge.
• Ohio – Big Darby Watershed - overall site post-development groundwater recharge equals or exceeds the predevelopment groundwater recharge
• North Carolina - control and treat the stormwater runoff from all built upon areas of the site from the first 1.5 inches of rain
• West Virginia MS 4 - The first 1 inch of rainfall must be 100% managed with no discharge to surface water

*Not just a LEED issue anymore, and it certainly isn’t going away….***
Thank you!

Wight & company | Wightco.com

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Tpowers@wightco.com