Stormwater Treatment Measure Sizing and Design Considerations

SMCWPPP C.3 Workshop
June 21, 2017

Jill Bicknell, P.E., EOA, Inc.
Presentation Overview

- Sizing/Design of Self-Treating and Self-Retaining Areas
- Sizing/Design of Treatment Measures
  - Determining the Water Quality Design Flow and Volume
  - Bioretention and Flow-Through Planters
  - Pervious Pavement and Infiltration Trenches
  - High-Rate Media Filters
Site Design Measures to Reduce Runoff Requiring Treatment

- Self-Treating Areas
- Interceptor Tree Credits
- Self-Retaining Areas
Self-Treating Area

- Pervious area that treats rain falling on itself only, via ponding, infiltration and ET
  - Landscaping
  - Green roof
  - Pervious pavement
  - Artificial turf

- Landscaped areas must retain approx. 1” of rain

- Pervious pavement and artificial turf must be designed to store and infiltrate the C.3.d amount of runoff in order to qualify as self-treating areas
Self-Treating Areas Reduce the Area Requiring Treatment

- Runoff from **pervious** portions of the project (after infiltrating 1”) can flow directly to the storm drain (if not mixing with runoff from impervious areas)
- Runoff from **impervious** areas can flow to a smaller treatment measure
“Interceptor” Tree Credits

- Self-treating area credit allowed based on the interception of rainwater by the tree canopy
- Intended for small areas that can’t be treated

<table>
<thead>
<tr>
<th>Type of Tree Planted or Preserved</th>
<th>Square footage deducted from area requiring stormwater treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen: new planting</td>
<td>200 sq. ft. per tree</td>
</tr>
<tr>
<td>Deciduous: new planting</td>
<td>100 sq. ft. per tree</td>
</tr>
<tr>
<td>Preserve existing trees (either evergreen or deciduous)</td>
<td>Square footage beneath canopy</td>
</tr>
</tbody>
</table>
Self-Retaining Area

- Pervious area that retains first 1” of rainfall on itself and runoff from adjacent impervious area, up to a 2:1 ratio (impervious:pervious)
  - Roof runoff dispersion to depressed landscaped area
  - Partial green roofs
  - Pervious pavement (with adequate storage)
- No special soils required
- Area must be able to retain up to 3” of ponding
Design of Self-Retaining Areas

- Landscaped areas
  - Plan sheet should indicate a relatively flat, concave, landscaped surface with ponding depth as follows:
    \[
    \text{Depth} = 1 \text{ inch} + \left(\frac{\text{Imperv Area}}{\text{Perv Area}} \times 1 \text{ inch}\right)
    \]
  - Elevation of any area drains should be set at top of ponding depth

- Partial green roofs and pervious pavement
  - Calculate depth of water quality volume using equation above
  - Determine depth of media/aggregate require to store the water quality volume
Self-Retaining Areas Reduce the Area that Requires Treatment

- Runoff from **impervious** portions of the project can flow directly to a **pervious** area that is at least 50% of the size of the contributing area.
- Runoff from other impervious areas can flow to a smaller treatment measure.
C.3.d Sizing Criteria for Treatment Measures

- Volume-based sizing criteria:
  - **URQM Method** - use formula and volume capture coefficients in “Urban Runoff Quality Management”, WEF/ASCE MOP No. 23 (1998), pages 175-178
  - **CASQA BMP Handbook Method** - Determine volume equal to 80% of the annual runoff, using methodology in Appendix D of the CASQA BMP Handbook (2003) using local rainfall data

  ‒ Additional sizing information was developed for San Mateo County rain gages (see C.3 Technical Guidance Appendix C)
Treatment Measure
Design Criteria Regions for San Mateo County

Figure 1 in Appendix 3 of the C.3 Technical Guidance
C.3.d Sizing Criteria

- Flow-based sizing criteria:
  - Factored Flood Flow - 10% of the 50-year peak flow rate, determined using Intensity-Duration-Frequency curves from local flood control agency
    - Not generally used
  - Percentile Rainfall Intensity - Flow of runoff produced by a rain event equal to two times the 85th percentile hourly rainfall intensity
    - No local data available for San Mateo County
  - Uniform Intensity - Flow of runoff resulting from a rain event equal to 0.2 inches per hour intensity
C.3.d Sizing Criteria

- Flow-based sizing criteria:
  - Simplified Sizing Approach – Variation of Uniform Intensity Method (0.2 in/hr)
    - Surface area of biotreatment measure is sized to be 4% of the contributing impervious area
    - Based on a runoff inflow of 0.2 in/hr (assume equal to the rainfall intensity), with an infiltration rate through the biotreatment soil of 5 in/hr
      \[ \frac{0.2 \text{ in/hr}}{5 \text{ in/hr}} = 0.04 \]
    - Conservative approach because does not account for surface ponding; but maximizes infiltration
C.3.d Sizing Criteria

- Combination Flow & Volume Design Basis:
  - Treatment systems can be sized to treat “at least 80% of total runoff over the life of the project”
  - Option 1: Use a continuous simulation hydrologic model (typically not done for treatment measures)
  - Option 2: Show how treatment measure sizing meets both flow and volume-based criteria
    - Used for bioretention and flow-through planters
    - See guidance in Chapter 5, Section 5.1 of C.3 Technical Guidance and Combination Flow-Volume Sizing Worksheet
Flow- or Volume-Based Sizing for Treatment Measures?

Table 5-1
Flow and Volume Based Treatment Measure Sizing Criteria

<table>
<thead>
<tr>
<th>Type of Treatment Measure</th>
<th>LID?</th>
<th>Hydraulic Sizing Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention area</td>
<td>Yes</td>
<td>Flow- or volume-based or combination</td>
</tr>
<tr>
<td>Flow-through planter box</td>
<td>Yes</td>
<td>Flow- or volume-based or combination</td>
</tr>
<tr>
<td>Tree well filter</td>
<td>Some</td>
<td>Flow-based</td>
</tr>
<tr>
<td>Pervious pavement</td>
<td>Yes</td>
<td>Volume-based</td>
</tr>
<tr>
<td>Infiltration trench</td>
<td>Yes</td>
<td>Volume-based</td>
</tr>
<tr>
<td>Subsurface infiltration system</td>
<td>Yes</td>
<td>Volume-based</td>
</tr>
<tr>
<td>Rainwater harvesting/use</td>
<td>Yes</td>
<td>Volume-based</td>
</tr>
<tr>
<td>Media filter</td>
<td>No</td>
<td>Flow-based</td>
</tr>
</tbody>
</table>
Sizing Guidance

- Appendix B of C.3 Technical Guidance
  • Sizing examples
- Appendix C of C.3 Technical Guidance
  • Figure 1: Treatment Measure Design Criteria Regions for San Mateo County
  • Figure 2: Mean Annual Precipitation
- Website: www.flowstobay.org/newdevelopment
  • Sizing worksheets for determining water quality design volume, and combination flow/volume
Mean Annual Precipitation (inches)

Figure 2 in Appendix C of the C.3 Technical Guidance
Sizing Example (Volume-based)

- Parking lot in Brisbane
  - Area = 35,000 sq. ft. (0.80 acres)
  - 100% impervious
  - Mean annual precipitation (MAP) = 23”
    - Rainfall Region #5, MAP = 21”
- Use the sizing worksheets to determine the water quality design volume ($V_{WQ}$)
- Answer: $V_{WQ} = 2,332$ cu. ft.
Sizing Bioretention Facilities

- **Simplified Sizing (Flow-Based) Approach**
  - Surface area is 4% of contributing impervious area
  - Does not consider storage in surface ponding area

- **Volume Based Approach**
  - Store $v_{WQ}$ in just surface ponding area
  - Store $v_{WQ}$ in ponding area, soil media & drain rock

- **Combination Flow and Volume Approach**
  - Compute both $Q_{WQ}$ and $v_{WQ}$
  - “Route” through facility, allowing ponding
Simplified Sizing Example

- Parking lot in Brisbane
  - Area = 35,000 sq. ft. (0.80 acres)
  - 100% impervious
  - MAP – not needed
  - Uniform intensity = 0.2 in/hr

- Surface area of bioretention:
  - Area $\times 0.04 = 1,400$ sq. ft.
  - Note: if drainage area contains pervious area, multiply pervious area by 0.1 and add to impervious area to get “effective impervious area”
Sizing Bioretention Facilities: Volume-Based Approach

Optional Mounding Parameters:
Top of mounds at least 2" below crest of overflow riser, low points no more than 12" below crest of overflow riser.

6" Min. ponding

Bio-treatment soil (BSM) mix per specs.

12" Min. of Class II permeable rock per Caltrans specifications

Perforated or slotted sloped underdrain (slope at 0.50% min) with perforations down. See plan for connection to C.B. & for invert elevation.

Cleanout with rim at fin. grade (see municipal standard drawing) beginning of line.

Underdrain cleanout with rim to fin. grade. See utility plan for location & invert.

Native soil do not compact

San Mateo Countywide Water Pollution Prevention Program
Sizing Bioretention Facilities: Volume-Based Approach

Method 1: Store entire volume in surface ponding area

\[ V_1 \]

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Porosity</th>
<th>Volume per sq. ft. (cubic feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Surface Area = \( V_{WQ} \) (cu.ft.) ÷ 0.5 cu.ft./sq.ft.

Sizing Example:

\[ 2,332 \text{ cu.ft.} \div 0.5 \text{ cu.ft./sq.ft.} = 4,664 \text{ sq.ft.} \]
### Sizing Bioretention Facilities: Volume-Based Approach

Method 2: Store volume in ponding area and media

<table>
<thead>
<tr>
<th>V_1</th>
<th>V_2</th>
<th>V_3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth (ft)</td>
<td>Porosity</td>
<td>Volume per sq. ft. (cubic feet)</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>1.0</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>0.30</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>0.5*</td>
<td>0.40</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1.15</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Depth below underdrain at 6” above bottom

**Surface Area = V_{WQ} (cu.ft.) ÷ 1.15 cu.ft./sq.ft.**

- **2,332 cu.ft. ÷ 1.15 cu.ft./sq.ft. = 2,028 sq.ft.**
Sizing Bioretention Facilities: Flow & Volume Approach

- “Hydrograph Approach”
  - Runoff is “routed” through the treatment measure
  - Assume rectangular hydrograph that meets both flow and volume criteria
Sizing Bioretention Facilities: Flow & Volume Approach

- Determine VWQ
- Assume constant rainfall intensity of 0.2 in/hr continues throughout the storm (rectangular hydrograph)
- Calculate the duration of the storm by dividing the Unit Basin Storage by the rainfall intensity
- Calculate the volume of runoff that filters through the biotreatment soil at 5 in/hr over the storm duration
- Calculate the volume that remains on the surface and ponding depth
Sizing Bioretention Facilities: Flow & Volume Approach

- To start the calculation, you have to assume a surface area “\( A_S \)” -- use 3% of the contributing impervious area as a first guess

- Determine volume of treated water “\( V_T \)” during storm:
  \[ V_T = A_S \times 5 \text{ in/hr} \times \text{duration (hrs)} \times 1 \text{ in/12 ft} \]

- Determine volume remaining on the surface “\( V_S \)”:
  \[ V_S = V_{WQ} - V_T \]

- Determine depth “\( D \)” of ponding on the surface:
  \[ D = V_S \div A_S \]

- Repeat until depth is approximately 6 inches
Sizing Example (Combo Method)

- Parking lot in Brisbane
  - Area = 35,000 sq. ft. (0.80 ac.)
  - 100% impervious
  - $V_{wq} = 2,332$ cu. ft.
  - Adj. UBS Volume = 0.80 in.

- Use the combination flow and volume sizing worksheet to determine the bioretention surface area

- Answer: 1,075 sq. ft. (with depth = 6.0")
Sizing Bioretention Facilities: Comparison of Methods

Example: 35,000 sq. ft. parking lot in Brisbane
MAP= 23 inches, 100% impervious
$V_{BMP} = 2,332 \text{ cu. ft. (80\% of annual runoff)}$

<table>
<thead>
<tr>
<th>Sizing Method</th>
<th>Surface Area (sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplified Method (flow-based)</td>
<td>1,400</td>
</tr>
<tr>
<td>Volume ponded on surface</td>
<td>4,664</td>
</tr>
<tr>
<td>Volume stored in unit ($V_1 + V_2 + V_3$)</td>
<td>2,028</td>
</tr>
<tr>
<td>Combination flow &amp; volume</td>
<td>1,075</td>
</tr>
</tbody>
</table>
Sizing Pervious Pavement and Infiltration Trenches

- General Principles
  - Store the $V_{WQ}$ in void space of stone base/subbase and infiltrate into subgrade
  - Surface allows water to infiltrate at a high rate
  - Any underdrains must be placed above the void space needed to store and infiltrate the $V_{WQ}$
Sizing Pervious Pavement and Infiltration Trenches

- Pervious Pavement
  - May be self-treating area or self-retaining area (accept runoff from other areas)
  - Can only be considered a “pervious area” if stone base/subbase sized to store the $V_{wq}$
  - Can work where native soils have low infiltration rates (stored water depths are relatively small)
  - Surface area is usually predetermined
  - Base and subbase thickness usually determined by expected traffic load and saturated soil strength
  - Slope should be $\leq 3\%$ (or use check dams/trenches in subbase)
Pervious Pavement

Typical Section

- Base and subbase layers available for water storage
- Both typically have 40% void space
Pervious Pavement

- Approach to Sizing Pervious Pavement
  - Self-Treating
    - Check the depth of the $V_{wq}$ in base/subbase: $\text{UBSV (in.)} \div 0.40 = \text{Depth (in.)}$
      
    Example: $\text{UBSV} = 1.0$ in., depth = 2.5 in.
    (Minimum depth for vehicular traffic is 10 in.)

    - Check the time required for stored water to drain: $\text{UBSV (in.)} \div \text{Infiltration rate (in/hr)} = \text{Drain time (hrs)}$
      (recommend < 48 hrs)
Pervious Pavement

- Approach to Sizing Pervious Pavement
  - Self-Retaining (receives runoff from adjacent areas)
    - Add the $V_{WQ}$ for adjacent areas to the $V_{WQ}$ for the pervious pavement, divide the total by pervious pavement area
    - Do not exceed 2:1 ratio of contributing area to pervious area
  - Check depth of total $V_{WQ}$ in base/subbase:
    $V_{WQ}$ (in.) $\div 0.40 = $ Depth (in.)
    Example: $V_{WQ} = 3.0$ in., depth = 7.5 in.
  - Check the time required for stored water to drain:
    $v_{WQ}$ (in.) $\div$ Infiltration rate (in/hr) = Drain time (hrs)
Underdrains: New Approach

- Underdrain placed in trench at bottom of section with raised outlet to allow water storage in aggregate reservoir
Underdrain: Upturned Elbow

- TYP. NO. 8, 89, OR 9 AGGREGATE IN OPENINGS
- CONCRETE PAVERS MIN. 3 1/8 IN. (80 MM) THICK FOR VEHICULAR TRAFFIC (ASPECT RATIO < 3)
- CURB/EDGE RESTRAINT WITH CUT-OUTS FOR OVERFLOW DRAINAGE (CURB SHOWN)
- BEDDING COURSE 2 IN. (50 MM) THICK (TYP. NO. 8 AGGREGATE)
- 4 IN. (100 MM) THICK NO. 57 STONE OPEN-GRADED BASE
- MIN. 6 IN. (150 MM) THICK NO. 2 STONE SUBBASE
- NON-PERFORATED OUTLET PIPES SPACED AND SLOPED TO DRAIN STORED WATER TO CATCH BASIN OR WATER COURSE
- GEOTEXTILE ON SIDES OF SUBBASE AND UNDER CURB
- OPTIONAL GEOTEXTILE ON SUBGRADE PER DESIGN ENGINEER
- PERFORATED, SLOPED UNDERDRAINS
- EMBED PIPE IN NO. 57 STONE
- SOIL SUBGRADE SLOPED TO DRAIN
Underdrain: Connection to Catch Basin/Utility Structure
Infiltration Trench Sizing

- Differences from Pervious Pavement
  - More runoff must infiltrate in a smaller footprint
  - Infiltration rate of site soils must be at least 0.5 in/hr (i.e., not suitable for “C” or “D” soils)
  - Trench depths are typically between 3 and 8 feet
  - Infiltration trench is an “infiltration device”
    - Minimum 10-foot separation from seasonal high groundwater level
    - Must meet other MRP requirements
    - Cannot be “deeper than wide” (definition of Class V injection well)
Infiltration Trench Sizing

- **Design Parameters**
  - Trench depth is calculated based on the soil infiltration rate, aggregate void space, and the trench storage time
  - The stone aggregate used in the trench is typically 1.5 to 2.5 inches in diameter, which provides a void space of approximately 35 %
  - Trenches should drain within 72 hours
  - Place underdrain above void space needed for storage of $V_{WQ}$
Infiltration Trench Sizing

- Approach to Sizing Infiltration Trenches
  - Trench unit storage volume: \( S = n \times d \)
    \( n = \) gravel porosity (0.35); \( d = \) gravel depth (ft)
  - Subsoil unit infiltration capacity: \( S_i = k \times t / 12 \)
    \( k = \) subsoil permeability (in/hr); \( t = \) time (hrs)
    (recommend maximum of 72 hrs)
  - Check for trench drainage by infiltration:
    \textbf{If} \( S \leq S_i \): Increase depth of media until \( S = S_i \)
    to match trench capacity to infiltration capacity
    (may decrease surface area needed)
    \textbf{If} \( S > S_i \): Decrease depth of media until \( S = S_i \)
    (surface area may increase)
Infiltration Trench Sizing

- Approach to Sizing Infiltration Trenches
  - Determine required trench area:
    - $A_T = \frac{V_{WQ}}{S}$
      - $A_T =$ Trench area required to store treatment volume (sq.ft.)
      - $V_{WQ} =$ Water quality design volume (cu. ft.)
      - $S =$ Trench unit storage volume (cu.ft./sq.ft.)
  - Determine required trench width:
    - $W = \frac{A_T}{L}$
      - $W =$ Width of trench (ft.)
      - $A_T =$ Required trench area (sq. ft.)
      - $L =$ Length of trench (ft.) (normally length of treatment area)
Sizing High-Rate Media Filters

Media Filters (cartridge type)

- Flow-based Treatment Measure
- Determine $Q_{WQ}$
- Select a product that is certified by Washington State TAPE program*
- Determine the TAPE-approved design flow rate per cartridge
- Divide $Q_{WQ}$ by the cartridge flow rate to calculate the required number of cartridges (round up)

*General Use Level Designation (GULD) for Basic Treatment

Sizing High-Rate Media Filters

Proprietary Tree Box Filters

- Flow-based Treatment Measure
- Determine $Q_{WQ}$
- Select a product that is certified by Washington State TAPE program
- Determine the TAPE-approved infiltration rate for the media
- Calculate the required surface area by dividing $Q_{WQ}$ by the infiltration rate (ft/sec)
- A tree box filter that uses biotreatment soil media can be sized like a flow-through planter
Sizing Example (Flow-based)

- Rooftop in Brisbane (Special Project)
  - Area = 35,000 sq. ft. (0.80 ac.)
  - 100% impervious
  - Uniform intensity = 0.2 in/hr
  - Runoff coefficient = 0.90
- Use the Rational Method (Q = CIA) determine the water quality design flow, $Q_{WQ}$
- Answer: $Q_{WQ} = (0.9)(0.2)(0.8) = 0.144$ cfs
Sizing Example (Flow-based)

- Rooftop in Brisbane (Special Project)
  - $Q_{WQ} = 0.144$ cfs = 64.6 gpm
  - Select media filter type
  - Check for TAPE certification and allowable flow rate

- Example: FloGard Perk Filter
  - “Size at hydraulic loading rate of $\leq 1.5$ gpm/ft$^2$ of media surface area”
  - For 18” cartridge, loading rate is 10.2 gpm/cartridge
  - $64.6 \text{ gpm} \div 10.2 \text{ gpm/cartridge} = 6.3$, or 7 cartridges
Questions?

Jill Bicknell, P.E.
408-720-8811, X 1
jcbicknell@eoainc.com