<table>
<thead>
<tr>
<th>No., Subject, Presenter</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How to Review a Project 1, Tim</td>
<td>60 minutes</td>
</tr>
<tr>
<td><strong>Goal One:</strong> Learn to identify which design and performance standards must be met on site</td>
<td></td>
</tr>
<tr>
<td><strong>Goal Two:</strong> Learn how to review for compliance with the nonstructural, water quantity, water quality, and groundwater recharge standards</td>
<td></td>
</tr>
<tr>
<td><strong>Goal Three:</strong> Learn how to review BMPs for compliance with the design criteria in the BMP Manual</td>
<td></td>
</tr>
<tr>
<td><strong>Goal Four:</strong> Learn how to review for the safety requirements</td>
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<tr>
<td>2. How to Review a Project 2, Changi</td>
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<tr>
<td><strong>Goal One:</strong> Learn how to review soil testing results for compliance with Chapter 12/Appendix E</td>
<td></td>
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<tr>
<td><strong>Goal Two:</strong> Calculate Detention Time</td>
<td></td>
</tr>
<tr>
<td><strong>Goal Three:</strong> MTD MTFR vs drainage area</td>
<td></td>
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<tr>
<td><strong>Goal Four:</strong> Groundwater Recharge Spreadsheet</td>
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<tr>
<td><strong>Goal Five:</strong> Groundwater Mounding Analysis</td>
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<td>3. Groundwater Mounding Examples, Lisa</td>
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<td>Quiz 3 – Presentations 1, 2 &amp; 3, Jim</td>
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<tr>
<td>Review Quiz 3, Jim</td>
<td>15 minutes</td>
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HOW TO REVIEW A PROJECT 1
Presentation Goals

Goals

• Learn to identify the design and performance standards that must be met onsite
• Learn how to review applications for compliance with the nonstructural, water quantity, water quality, and groundwater recharge standards
• Learn how to review BMPs for compliance with the design criteria in the BMP Manual
• Learn how to review soil testing results for compliance with Chapter 12
• Learn how to review for compliance with safety requirements
Checking Application

The applicant needs to submit, at a minimum...

- **Pre-** and **post-construction site** plans
- **Pre-** and **post-construction grading** plans
- Stormwater report with calculations
- Details of BMPs
Determining Applicable Design & Performance Standards

Where does it discharge to?

- Watershed
- Category 1
- Flooding problems
- Water quality impairments or TMDLs
- Is the site in a regulated area?
  - Flood Hazard Area
  - CAFRA
  - Freshwater Wetlands
  - Highlands
- Is the site in the Pinelands?
Determining Applicable Design & Performance Standards

Is the project a major development?

- Does the project disturb one acre or more?
- Does the project increase impervious coverage by ¼ acre or more?
- What is the SCO’s definition of major development?
“Major Development” definitions:

- Residential Site Improvement Standards:
  - 1 acre of more of disturbance (N.J.A.C. 5:21)
- Stormwater Control Ordinance:
  - 1 acre or more of disturbance or
  - More stringent standard adopted by municipality
- NJDEP Division of Land Use Regulation:
  - 1 acre or more of disturbance
  - ¼ acre or more increase in impervious coverage
Design and Performance Standards for Major Developments:

- Nonstructural strategies
- Water quantity
- Water quality
- Groundwater recharge
Are there waivers or exemptions?

Sometimes...
Waivers or variances can be granted if...

- Municipality has an adopted mitigation plan in MSWMP
- Mitigation is for same standard that cannot be met onsite
- Mitigation is in same drainage area
Specific exemptions exist for...

- Water Quantity, if in Tidal Flood Hazard Area and flooding will not be increased
- Water Quality, if site has NJPDES permit with specific effluent limit
- Groundwater Recharge, for previously developed areas in urban redevelopment area
Urban Redevelopment Area

- “Previously developed portions” of areas:
  - Delineated on State Plan Policy Map as:
    - Planning Area 1
    - Designated Centers, Cores, or Nodes
  - CAFRA Centers, Cores, or Nodes
  - Urban Enterprise Zones
  - Urban Coordinated Council Empowerment Neighborhoods
Determining Applicable Design & Performance Standards

Linear development exemptions exist for...

- Construction of underground utility line, if revegetated upon completion
- Construction of aboveground utility line, if existing conditions are maintained to MEP
- Construction of public pedestrian access, if made of permeable materials and no greater than 14 ft. wide
Determining Applicable Design & Performance Standards

Waivers from strict compliance exist for...

- Enlargement of road or railroad, construction or enlargement of public pedestrian access, if applicant demonstrates:
  - Public need for project that can’t be met another way
  - D&P Standards met to maximum extent practicable
  - Meeting the standards would require condemning existing in-use structures
  - Applicant does not have and cannot get rights to other lands for mitigation
Possible waivers/variances (summary):

- Construction of utility lines, public pedestrian access
- Enlargement of road, railroad, public pedestrian access
- Tidal Flood Hazard Area
- Urban Redevelopment Area
- NJPDES Permits w/ discharge limits
- Mitigation plan
Reading the Report

Report should contain:

• A site description
• Discussion of applicable design and performance standards
• Calculations


https://www.nj.gov/dep/dwq/pdf/Tier_A/Tier_A_Chapter_3-4.pdf
Site description

- Existing conditions
- Proposed conditions
- Disturbance and change in impervious cover
- Soil survey information
Design and Performance Standards

• What’s required
• Applicable exemptions
• How standards were met
  o Nonstructural strategies
  o Peak flow information
  o TSS removal rates
  o Groundwater recharge information
Reading the Report

Calculations

- Time of concentration – calculated, not assumed, for NRCS methodology (see Chapter 5 revisions)
- Storm routings
- Hydrographs
- Groundwater recharge spreadsheet
- Water quality calculations
NONSTRUCTURAL STRATEGIES
Nonstructural Strategies

Nonstructural strategies are...
- Ways of minimizing adverse effects of development
- Intended to maintain pre-development hydrology
Nonstructural Strategies

Nonstructural strategies

• Must be used to the maximum extent practicable to meet design and performance standards

• Required on all new developments and redevelopments
Nonstructural Strategies

Remember that development usually...

- Removes beneficial vegetation
- Increases impervious coverage
- Reduces time of concentration
- Causes soil compaction
Nonstructural Strategies

Nonstructural strategies include...

- Protecting beneficial vegetation
- Minimize impervious coverage
- Minimize decrease in time of concentration
- Prevent soil compaction
Nonstructural Strategies

Nine Nonstructural Strategies:

1) Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss

2) Minimize impervious surfaces and break up or disconnect the flow over impervious surfaces
Nonstructural Strategies

Nine Nonstructural Strategies:

3) Maximize the protection of natural drainage features and vegetation

4) Minimize the decrease in the time of concentration
Nonstructural Strategies

Nine Nonstructural Strategies:

5) Minimize land disturbance including clearing and grading

6) Minimize soil compaction
Nonstructural Strategies

Nine Nonstructural Strategies:

7) Provide low-maintenance landscaping, native vegetation and minimize the use of lawns, fertilizers and pesticides.

8) Provide vegetated open-channel conveyance
Nonstructural Strategies

Nine Nonstructural Strategies:

9) Provide source controls to prevent or minimize the use or exposure of pollutants
Nonstructural Strategies

Nonstructural strategies

• Must be identified as being incorporated into the site design

• If a strategy can’t be met, the applicant must provide a basis

• Only acceptable reasons for not incorporating a strategy:
  o Engineering
  o Environmental
  o Safety
Nonstructural Strategies

Nonstructural strategies

• Must be protected via:
  o Dedicated to a government agency or
  o Subject to conservation restriction or
  o Other equivalent restriction
WATER QUANTITY
Water Quantity

The water quantity standard...

• Protects against flooding
• Can be met in three different ways
• Must be met for each point of analysis
**OPTION 1:**

Demonstrate that at no point does the post-development hydrograph exceed the pre-development hydrograph for 2, 10, and 100 year storms (N.J.A.C. 7:8-5.4)

- Applicant must submit pre- and post-development hydrographs
- Total runoff volume must be equal or lower in post-development

**Tips:**
- Almost never used for new development, but common in redevelopment
- Almost always requires decrease in impervious coverage
- Almost always requires same pre- and post-construction $T_c$
OPTION 2:

Demonstrate no increase in peak flows and no increase in flood damage due to change in volume or timing assuming full build-out under current zoning (N.J.A.C. 7:8-5.4)

- Applicant must submit pre- and post-development peak flows
- Requires extremely complicated and detailed analysis
- **Tips:**
  - Almost never successfully used
  - Beware of any attempt to use this option
OPTION 3:

Reduce the post-development peak flows to 50, 75, and 80% of pre-development peak flows for 2-, 10-, and 100-year storms (N.J.A.C. 7:8-5.4)

- Applicant must submit routing calculations
- Most commonly used standard
- **Tips:**
  - Expect this standard on nearly all new development
  - Almost always requires installation of a detention structure
Water Quantity

Water Quantity Calculations – Acceptable Methods

• Rational Method for peak flows & Modified Rational Method for hydrographs

• NRCS Method
Water Quantity

Water Quantity Calculations – Required Information

- Information required from site plans/report:
  - Topography
  - Land cover
  - Soils
  - Rainfall data
Water Quantity

Topography

• Allows reviewer to identify where stormwater flows

• Required to determine drainage areas and time of concentration
Water Quantity

Topography

• Site plans must show:
  o Existing and proposed contours
  o Point of analysis
  o $T_c$ flowpath
  o Drainage area to each point of analysis
Water Quantity

Topography

• For sites with multiple drainage areas that don’t converge or have very different cover:
  o Each DA should be calculated separately
  o Each DA should have separate Tc calculation
  o Each DA should meet water quantity standard
Water Quantity

Topography

• Reviewer needs to verify:
  o All drainage areas are delineated correctly
  
  o Verify that proper time of concentration flow path is used
  
  o Verify that time of concentration is calculated properly
Topography

• Look for depressions on existing site

• Water ponds in natural depressions

• Ignoring depression storage will overestimate existing discharge volumes and peak flows
Water Quantity

AREA EX-2 (DRAINAGE TO POI-B)
297 SF = IMPERVIOUS SURFACES
401 SF = DIRT ROAD, HSG A
Water Quantity

Land Cover

• Should be clearly marked on plans

• Should be specific: forest, grass, bare soil, impervious coverage

• Include any existing BMPs
Land Cover

- Reviewer needs to verify:
  - What’s on site plan matches actual conditions
  - Land cover used in the calculations is the most pervious cover that has existed in past 5 years
Soils

• Soils on-site must be determined

• Required information: HSG and soil type

• Should be submitted with report

• Best way to find soil info is NRCS Web Soil Survey:
  o [https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm](https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm)
  o Google “Web Soil Survey”
Water Quantity

Soils

• Sometimes cannot be found in soil survey

• If information not available, two ways to find HSG:
  o Default hydrologic soil groups
  o Soil testing

• Information on both methods in Chapter 12
Water Quantity

Soils

Default Hydrologic Soil Groups:
- In coastal plain:
  - Pre-developed: HSG A
  - Post-developed: HSG D
- Outside coastal plain:
  - Pre-developed: HSG B
  - Post-developed: HSG D
Soils

• Ideal case – soil data overlain on site plan

• Normal case – soil survey is printed or scanned and attached to report
Soils

• Reviewer needs to verify:
  o HSGs and soil types are properly identified

  o HSGs and soil types are applied to proper areas (square footage and land cover)

  o *Soil testing meets requirements of Appendix E/Chapter 12*
Soils

- Poor soil testing is one of the most common review issues encountered

- Soil testing can make or break a stormwater management design

- Often the best practice to review soil testing first
Water Quantity

Time of Concentration

• Required for both Rational/Modified Rational Methods and NRCS Method

• Should be calculated in accordance with the NEH and also Chapter 5 of the BMP Manual
Water Quantity

Time of Concentration

• Three flow conditions:
  o Sheet flow
  o Shallow concentrated flow
  o Channel flow
Water Quantity

Time of Concentration

• Sheet flow calculations
  o Flow length should not be above 100 feet
  o Sheet flow roughness coefficient must match cover
  o Slope should be measured directly from the plan
  o 2-year, 24-hour rainfall should come from NOAA or NRCS

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

Time of Concentration

- Sheet flow calculations
  - Calculation is very sensitive to slope and roughness
  - Maximum roughness coefficient is 0.4
  - For two distinctly different covers in first 100 feet, use two separate sheet flow calculations
Water Quantity

Time of Concentration

- Shallow concentrated flow calculations
  - Flow velocity found using chart in National Engineering Handbook
  - Velocity based on land cover and slope

\[ T_t = \frac{L}{3600V} \]
Water Quantity
Water Quantity

Time of Concentration

• Shallow concentrated flow calculations
  
  o Ensure proper land cover and slope
  
  o Check charts to be sure that the right velocity curve was used
Water Quantity

Time of Concentration

- Channel flow calculations
  - Only exists when a defined channel exists on-site
  - Must use Manning’s roughness coefficient for open channels

\[
T_t (hr) = \frac{L(n)}{3600(1.49R^3s^{0.5})^2}
\]
Water Quantity

Time of Concentration

- $T_c =$ sheet flow + shallow concentrated flow + channel flow (if applicable)

- Rational/Modified Rational Method: minimum $T_c$ of 10 minutes

- NRCS Method: minimum $T_c$ of 6 minutes must be calculated
Water Quantity

Time of Concentration Common Errors:

• Using minimum $T_c$ of 10 minutes instead of 6 minutes for NRCS method

• Standard $T_c$ calculations won’t work if there are significant depressions on-site

• Assuming minimum time of concentration in post-construction conditions is conservative
Water Quantity

Time of Concentration

• Takeaways:
  o $T_c$ generally significantly decreased in post-construction
  o Runoff flows much more slowly over vegetated areas
  o SCS Unit Hydrograph calculations (flow rate) inversely related to time of concentration

$$q_p = \frac{726AQ}{t_c}$$
Time of Concentration

• Let’s say the reviewer requires applicant to use:
  o Nonstructural strategy #2: Minimize impervious surface and break up or disconnect the flow over impervious surfaces
  o Nonstructural strategy #8: Provide vegetated open-channel conveyance

• They would also probably achieve:
  o Nonstructural strategy #4: Minimize the decrease in the time of concentration
Water Quantity

Time of Concentration

• Achieving nonstructural strategy #4 will also reduce the increase in the peak flow
• Contributes to meeting water quantity control standard
• For example, increasing $T_c$ from 6 minutes to 10 minutes on 1 acre site can reduce peak flow as much as 12-12.5%
In summary...

- Review sheet flow, shallow concentrated flow, and channel flow inputs
- Don’t mix up minimum $T_c$ for rational/modified rational method and NRCS method
- Pre-construction $T_c$ should always be proven by calculation
- Post-construction $T_c$ can no longer be assumed as an allowable minimum
Water Quantity

Curve Numbers/Runoff Coefficients

• Used to calculate amount of runoff caused by given precipitation

• Curve numbers – NRCS Method

• Runoff Coefficients – Rational/Modified Rational
Curve Numbers/Runoff Coefficients

• Stormwater report and plans should clearly show area for each different land cover and HSG

• Both must always be based on “good” hydrologic condition
## Water Quantity

### Curve Numbers/Runoff Coefficients

<table>
<thead>
<tr>
<th>Area (sf)</th>
<th>Land Cover</th>
<th>Soil Type</th>
<th>Hydrologic Soil Group</th>
<th>Curve Number</th>
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<tbody>
<tr>
<td>38,173</td>
<td>Pavement</td>
<td>Bucks silt loam</td>
<td>B</td>
<td>98</td>
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<tr>
<td>24,689</td>
<td>Lawn</td>
<td>Bucks silt loam</td>
<td>B</td>
<td>61</td>
</tr>
<tr>
<td>14,787</td>
<td>Lawn</td>
<td>Lehigh silt loam</td>
<td>C</td>
<td>74</td>
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<tr>
<td>9,950</td>
<td>Forest</td>
<td>Dunellen sandy loam</td>
<td>A</td>
<td>30</td>
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<tr>
<td>2,654</td>
<td>Pavement</td>
<td>Lehigh silt loam</td>
<td>C</td>
<td>98</td>
</tr>
</tbody>
</table>
Water Quantity

Curve Numbers/Runoff Coefficients

- Curve numbers can all be verified from *Chapter 5*

- Runoff coefficients are generally estimates with ranges

- Reviewer is responsible for ensuring that the designer’s chosen value is reasonable
Water Quantity

Subarea Routing

• Required to route pervious and impervious areas separately

• Never use a weighted average of pervious and impervious areas
  o Underestimates flow rates and volumes
Rainfall

• For NRCS Method:
  o 2-, 10- and 100-year, 24-hour storms (NOAA or NRCS)
  o Water Quality Design Storm (BMP Manual Chapter 5)

• For Rational/Modified Rational Method:
  o 2-, 10- and 100-year, IDF Curves (NOAA or BMP Manual Chapter 5)
  o Water Quality Design Storm Intensity-Duration Curve (BMP Manual Chapter 5)
Rainfall Distribution (NRCS Method only)

- BMP Manual mentions Type III rainfall distribution
- NRCS developed other distributions for NJ in 2012:
  - NOAA_C
  - NOAA_D
- NOAA_C and NOAA_D already built into many stormwater modeling programs
Water Quantity

Design Storm Event (Modified Rational Method)

• Applicant must show critical storage volume calculation

• Detention basin design must be based on storm event that results in critical storage volume
Water Quantity

Unit Hydrograph (NRCS Method only)

- SCS Unit Hydrograph may be acceptable throughout the entire state, but must be used outside coastal plain area
- DelMarVa Hydrograph is acceptable in the coastal plain area only
- Must use the same hydrograph in both pre and post conditions
Water Quantity

In summary…

- Curve numbers required for each segment with different soils or cover
- Never use a weighted average of pervious and impervious areas
- DelMarVa Unit Hydrograph – only used for applicable areas of coastal plain
- Type NOAA_C or D rainfall distributions for NRCS
Stormwater Quantity Control BMPs

Detention Structures

• Excavated or natural depressions, or excavated underground chambers

• Store runoff for extended period of time (generally 24-72 hours)

• Slowly release runoff through outlet structure
Detention Structures

- Various BMPs can be designed to provide detention:
  - Extended detention basins
  - Constructed wetlands
  - Infiltration basins
  - Bioretention systems
  - Sand filters
  - Pervious paving systems
  - Blue roofs
Outlet Structure

- Contains one or more orifices or weirs
- Designed to achieve specific outflow rates
- Flow leaving basin governed by outlet size and hydraulic head
Stormwater Quantity Control BMPs

Hydrologic Routing

• Given inflow hydrographs, basin storage and outlets, determine outflow hydrograph

• Most commonly achieved using routing software

• Basin information usually put in using stage-storage data and outlet design
## Basin Design

### Stormwater Quantity Control BMPs

#### Stage / Storage Table

<table>
<thead>
<tr>
<th>Stage (ft)</th>
<th>Elevation (ft)</th>
<th>Contour area (sqft)</th>
<th>Incr. Storage (cuft)</th>
<th>Total storage (cuft)</th>
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#### Culvert / Orifice Structures

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#### Weir Structures

| [A] | [B] | [C] | [D] | [E] | [F] | [G] | [H] | [I] | [J] | [K] | [L] | [M] | [N] | [O] | [P] | [Q] | [R] | [S] | [T] | [U] | [V] |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Crest Len (ft) | = 12.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Crest El. (ft)  | = 124.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| Weir Coeff.     | = 3.33  | 0.00 | 0.00 | 0.00 | 0.00 |
| Weir Type       | = Rect  | ---  | ---  | ---  | ---  |
| Multi-Stage     | = No   | No   | No   | No   | No   |

Exfiltration = 0.000 in/hr (Contour) Tailwater Elev. = 0.00 ft
### Stormwater Quantity Control BMPs

#### OUTLET STRUCTURE INPUT DATA

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| # of Openings | = 1 |
| Crest Elev. | = 105.45 ft |
| Weir Length | = 2.00 ft |
| Weir Coeff. | = 0.100000 |

Weir TW effects (Use adjustment equation)

#### USER DEFINED VOLUME RATING TABLE

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#### Structure Data

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<tbody>
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</tbody>
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| # of Openings | = 1 |
| Invert Elev. | = 102.70 ft |
| Diameter | = 0.7500 ft |
| Orifice Coeff. | = 0.600 |

<table>
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<tbody>
<tr>
<td>Structure Type</td>
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</tr>
</tbody>
</table>

| # of Openings | = 1 |
| Invert Elev. | = 100.20 ft |
| Diameter | = 0.2500 ft |
| Orifice Coeff. | = 0.600 |
Stormwater Quantity Control BMPs

Detention Structures Summary

• Reviewer needs to verify:
  o Basin design input matches plans and details
  o Correct subareas are routed to the basin
  o Outputs make sense
  o Infiltration was not included in the routings
Dealing With Depression Storage

- Depressions and high permeability soils clearly provide stormwater management benefits

- Nonstructural strategy #3: Maximize the protection of natural drainage features and vegetation
Dealing With Depression Storage

- Not possible to accurately calculate time of concentration

- Depression storage should be modeled as an existing basin in pre-development conditions
Water Quantity

Dealing With Depression Storage
Dealing With Depression Storage

- Determine time of concentration to depression area

- Calculate stage-storage data for depression area

- Model outlet from depression area as a weir

- Route contributory drainage area to depression area
Water Quantity

Dealing With Depression Storage

AREA EX-2  ➔  Depression Storage
Stormwater Quantity Control BMPs

Dealing With Depression Storage

<table>
<thead>
<tr>
<th>Volume</th>
<th>Invert</th>
<th>Avail.Storage</th>
<th>Storage Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>49.10'</td>
<td>1,228 cf</td>
<td>Custom Stage Data (Prismatic) Listed below (Recalc)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>49.10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>49.70</td>
<td>4,093</td>
<td>1,228</td>
<td>1,228</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Device</th>
<th>Routing</th>
<th>Invert</th>
<th>Outlet Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Primary</td>
<td>49.60'</td>
<td>22.0' long x 1.0' breadth Broad-Crested Rectangular Weir</td>
</tr>
</tbody>
</table>

Primary OutFlow Max=0.50 cfs @ 12.44 hrs HW=49.64' (Free Discharge)

1=Broad-Crested Rectangular Weir (Weir Controls 0.50 cfs @ 0.55 fps)
Water Quantity

Dealing With Depression Storage

• If depression area is in middle of site:
  o Model depression area
  o Calculate time of concentration from depression outlet to point of interest
  o Lag depression outflow hydrograph by calculated time of concentration
  o Calculate time of concentration for remaining area and route it separately
WATER QUALITY
Water Quality

Water Quality Criteria

• Remove TSS by 80%

• Remove nutrients to maximum extent feasible

• Applies at ¼ acre increase of impervious coverage
Water Quality

Water Quality Criteria

• Removal rates apply to each on-site drainage area, unless the runoff converges on-site

• Pursuant to FHACA Rules, runoff from WQDS discharged within a 300-foot riparian zone must reduce TSS by 95%
Water Quality

Water Quality Criteria

- New impervious surface:
  - Any net increase in impervious surface
  - Any change in an existing stormwater drainage system, where the proposed change increases the capacity of the existing stormwater system
  - Existing impervious where runoff is provided with existing water quality treatment, but which is proposed to be collected and discharged into a regulated area
Definitions to Clarify Applicability
N.J.A.C. 7:8-1.2

- Added definition of “regulated motor vehicle surface”
- Added definition of “regulated impervious surface”
- Changed definition of major development
  - 1 acre of disturbance; or
  - ¼ acre of regulated impervious surface; or
  - ¼ acre of regulated motor vehicle surface
- Definitions of regulated motor vehicle surface and regulated impervious surface will include FAQ 10.2 (newly collected impervious surface and changes to existing drainage systems count as “new”)
Water Quality

Water Quality Criteria

• Pervious paving areas
  o Often used to replace traditional pavement – collect same pollutants as regular impervious areas
  o Considered new impervious area toward the ¼ acre increase
  o If designed properly, pervious paving systems can provide required TSS removal
Water Quality

Water Quality Criteria

• Rooftop runoff
  o Not considered significant source of TSS
  o Does not require treatment for TSS
  o Can be infiltrated using dry well
  o Can be significant source of nutrients
Water Quality

Water Quality Design Storm

- Design storm based on historic data
- Nonlinear rainfall distribution resulting in 1.25 inches of precipitation in 2 hours
- Relatively common and intense storm
- Designed to capture frequent storms that cause significant stormwater runoff pollution
Stormwater Runoff Quality

Water Quality
Design
Storm
Stormwater Runoff Quality

Figure 5-3: NJDEP 1.25-Inch/2-Hour Stormwater Quality Design Storm Rainfall Intensity-Duration Curve

- Rainfall Intensity (Inches/Hour)
- Time of Concentration (Minutes)
Water Quality

Water Quality BMPs

• Water quality criteria met through implementation of BMPs

• NJ BMP Manual contains design criteria for various BMPs
  o Chapter 9 – current location for all BMPs
  o New Rules – BMPs will be in Chapters 9, 10 & 11 to match rules
    • Chapter 9 – Table 5-1 GI BMPs
    • Chapter 10 – Table 5-2 GI BMPs with a Waiver or Variance
    • Chapter 11 – Table 5-3 BMPs with a Waiver or Variance

• Most BMPs have adopted TSS removal rates, meaning they can be used for Water Quality
Water Quality

Structural BMPs

*Chapter Nine*: provides general information on Structural Stormwater Management Measures

- Chapter 9.1 Bioretention Systems
- Chapter 9.2 Standard Constructed Wetlands
- Chapter 9.3 Dry Wells
- Chapter 9.4 Extended Detention Basins
- Chapter 9.5 Infiltration Basins
- Chapter 9.6 Manufactured Treatment Devices
- Chapter 9.7 Pervious Paving Systems
- Chapter 9.8 Blue Roofs
- Chapter 9.9 Sand Filters
- Chapter 9.10 Vegetative Filter Strips
- Chapter 9.11 Wet Ponds
- Chapter 9.12 Grass Swales
- Chapter 9.13 Subsurface Gravel Wetlands
- Chapter 9.14 Green Roofs ***NEW***
- Chapter 9.15 Cisterns ***NEW***
# Water Quality

## Water Quality BMPs

<table>
<thead>
<tr>
<th>BMP</th>
<th>TSS Removal Rate</th>
<th>Phosphorus Removal Rate*</th>
<th>Nitrogen Removal Rate*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention Systems</td>
<td>80-90%</td>
<td>60%</td>
<td>30%</td>
</tr>
<tr>
<td>Standard Constructed Wetlands</td>
<td>90%</td>
<td>50%</td>
<td>30%</td>
</tr>
<tr>
<td>Extended Detention Basins</td>
<td>40-60%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Infiltration Basins</td>
<td>80%</td>
<td>60%</td>
<td>50%</td>
</tr>
<tr>
<td>Manufactured Treatment Devices</td>
<td>Varies</td>
<td>Varies</td>
<td>Varies</td>
</tr>
<tr>
<td>Pervious Paving Systems</td>
<td>80%</td>
<td>60%</td>
<td>50%</td>
</tr>
<tr>
<td>Sand Filters</td>
<td>80%</td>
<td>50%</td>
<td>35%</td>
</tr>
<tr>
<td>Vegetative Filter Strips</td>
<td>60-80%</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>Wet Ponds</td>
<td>50-90%</td>
<td>50%</td>
<td>30%</td>
</tr>
<tr>
<td>Grass Swales</td>
<td>≤ 50%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Subsurface Gravel Wetlands</td>
<td>90%</td>
<td>N/A</td>
<td>90%</td>
</tr>
</tbody>
</table>
Water Quality

Water Quality BMPs in Series

• Not all BMPs meet 80% TSS removal

• Can use multiple BMPs in series to achieve reduction

• For two BMPs in series: \( R = A + B - \frac{AXB}{100} \)
Water Quality

Water Quality BMPs in Series

• When using BMPs in series, arrange BMPs from upstream to downstream in:
  1. Ascending order of TSS removal rate
  2. Ascending order of nutrient removal rate
  3. By relative ease of sediment and debris removal

• Should not use two of same BMPs in series

  Vegetative Filter Strip (60%)
  Wet Pond (70%)

  \[ R = 60 + 70 - \left(\frac{60\times70}{100}\right) = 88\% \]
Water Quality

Nutrient Removal

• Required on all major developments

• Some BMPs have adopted nutrient removals

• Nutrient removal often best performed through source control
Nutrient Removal

• Nonstructural Strategy #7: Provide low-maintenance landscaping that encourages retention and planting of native vegetation and minimizes the use of lawns, fertilizers, and pesticides

• Nonstructural Strategy #9: Provide source controls to prevent or minimize the use or exposure of pollutants
Water Quality

Water Quality BMPs

- Stormwater Management rules require:
  - Design BMPs in accordance with BMP Manual or
  - Alternative designs if design engineer provides documentation demonstrating capability of alternative removal rates and methods

- Any approved alternatives must be submitted to the Department
Water Quality

Water Quality Review

• Ensure water quality BMPs chosen are adequate to achieve required TSS removal rate
• Ensure runoff from all drainage areas requiring water quality treatment is being collected and treated
• Ensure BMP design meets criteria under applicable BMP Manual subchapter
Water Quality

Water Quality BMPs – General Design Criteria

• All BMPs must drain within 72 hours of storm
  o Exceptions: wet ponds, constructed wetlands, gravel wetlands

• In general, most BMPs require at least 1 ft separation from seasonal high groundwater table
  o Exception: all infiltration BMPs require at least 2 ft
Water Quality

Water Quality BMPs

- Commonly used BMPs:
  - Extended detention basins
  - Infiltration basins
  - Bioretention systems
  - Wet ponds
  - Manufactured treatment devices
9.5 Infiltration Basins

Infiltration basins are stormwater management systems constructed with highly permeable components designed to both maximize the removal of pollutants from stormwater and to promote groundwater recharge. Pollutants are treated through settling, filtration of the runoff through, and biological and chemical activity within, the components. The total suspended solids (TSS) removal rate is 80%.

| N.J.A.C. 7:8 Stormwater Management Rules - Design and Performance Standards |
|-------------------------------------------------|---------------------------------------------------|
| Nonstructural Strategy                         | Assist with Strategy #2; See Page 3               |
| Water Quantity                                  | Yes, when designed as an on-line system           |
| Groundwater Recharge                            | Yes                                               |
| Water Quality                                   | 80% TSS Removal                                   |
Infiltration Basins

• Designed to infiltrate runoff into subsoil

• 80% TSS removal rate

• Can also be used to meet the water quantity and groundwater recharge requirements
Infiltration Basins – Design Criteria

• Can only be designed to infiltrate water quality design storm volume
  o No exfiltration is allowed for quantity storms

• Must meet infiltration criteria and permeability testing in accordance with Chapter 12

• Maximum ponding depth from water quality design storm of 24 in.
Infiltration Basins – Design Criteria

• Must include a 6 in. sand layer

• Bottom of basin must be level and un-compacted

• Subsurface infiltration basins require 80% TSS pretreatment

• Design permeability rate 0.5 – 10 inches/hour
Infiltration Basins – you shouldn’t see...

- Designed for water quantity control but no outlet structure
  - Exfiltration for the 2-, 10-, 100- year storms

- Underdrains or liners

- Topsoil or vegetation

- No standing water 72 hours after the precipitation stops
Water Quality

Courtesy of NJDOT
9.1 Bioretention Systems

Bioretention systems are stormwater management facilities used to address the stormwater quality and quantity impacts of land development. The system consists of a soil bed planted with vegetation; it can be underdrained, or runoff can infiltrate into the subsoil. Pollutants are treated through the processes of settling and uptake and filtration by the vegetation. Pollutants are also treated within the soil bed through infiltration. The total suspended solids (TSS) removal rate is 80 - 90%; this rate will depend on the depth of the soil bed and the type of vegetation selected.

<table>
<thead>
<tr>
<th>N.J.A.C. 7:8 Stormwater Management Rules - Design and Performance Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nonstructural Strategies</strong></td>
</tr>
<tr>
<td><strong>Water Quantity</strong></td>
</tr>
<tr>
<td><strong>Groundwater Recharge</strong></td>
</tr>
<tr>
<td><strong>Water Quality</strong></td>
</tr>
</tbody>
</table>
Water Quality

Bioretention Systems
- Thick soil bed and dense vegetation to enhance pollutant removal
- TSS removal rate based on types of plants and soil bed thickness

<table>
<thead>
<tr>
<th>Desired TSS Removal Rate</th>
<th>Design Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum Depth of Soil Bed</td>
</tr>
<tr>
<td>80%</td>
<td>18 Inches</td>
</tr>
<tr>
<td>80%</td>
<td>24 inches</td>
</tr>
<tr>
<td>90%</td>
<td>24 inches</td>
</tr>
</tbody>
</table>
Water Quality

Bioretention Systems

• Vary in size from small rain gardens to large basins

• Can be designed to infiltrate or to be underdrained
Water Quality

Bioretention Systems – Design Criteria

• Must include a soil bed at 18-24” thick

• Bioretention mix must consist of following:
  o 85-95% sand (< 25% fine or very fine sand)
  o No more than 15% silt and clay
  o 2-5% clay
  o Amended with 3-7% organics, by weight
Water Quality

Bioretention Systems – Design Criteria

• Maximum water quality depth of 12 in. for flat-bottomed systems or 18 in. for sloped systems

• Maximum bottom slope of 10%

• Minimum density of vegetation of 85%
Water Quality

Bioretention Systems – you shouldn’t see...

- Designed for water quantity control but no outlet structure
  - No infiltrating 2-, 10-, 100-year storm

- Topsoil, sand cover, turf grass, etc.
Water Quality

Infiltration Criteria

- Applies to any BMP designed to infiltrate runoff
  - Infiltration basin
  - Dry well
  - Bioretention basin (w/o underdrain)
  - Sand filter (w/o underdrain)
Water Quality

Infiltration Criteria

• Soil permeability must be tested

• Must apply a factor of 2 to any tested permeability

\[
Design \ Permeability = \frac{Field \ Permeability}{2}
\]

• Minimum design permeability of 0.5 inches/hour, maximum of 10 inches/hour
Water Quality

Infiltration Criteria

- Must have at least 2 ft. of separation from seasonal high water table
- Depth to Seasonal High Water Table must be proven via soil testing
- Must assess groundwater mounding impacts
Infiltration BMPs – What you should see

- Calculation of water quality design storm volume

- Maximum storage depth of water quality design storm volume

- Outlet set at the storage depth of water quality design storm
Infiltration BMPs – What you should see

• Protection of infiltration area from compaction and sedimentation during construction

• Nonstructural strategy #6: Minimize soil compaction

• Post-construction soil testing to verify as-built conditions are sufficient to allow infiltration
More Information:

Bureau of Nonpoint Pollution Control
Division of Water Quality
401 East State Street
PO Box 420, Mail Code 401-2B
Trenton, NJ 08625-420
Tel: 609-633-7021
www.njstormwater.org

Timothy Ebersberger
timothy.ebersberger@dep.nj.gov
HOW TO REVIEW
A PROJECT 2

Changi Wu
NJDEP Division of Water Quality
SWMDR Training Module 3
September 1, 2020
9.4 Extended Detention Basins

An extended detention basin is a stormwater management facility that temporarily stores and attenuates stormwater runoff. In addition, extended detention basins provide pollutant treatment for runoff from the Water Quality Design Storm through settling. When designed in accordance with this chapter, the total suspended solids (TSS) removal rate is 40 - 60%, depending on the duration of runoff detention.

<table>
<thead>
<tr>
<th>N.J.A.C. 7:8 Stormwater Management Rules - Design and Performance Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Icon] Nonstructural Strategies</td>
</tr>
<tr>
<td>![Icon] Water Quantity</td>
</tr>
<tr>
<td>![Icon] Groundwater Recharge</td>
</tr>
<tr>
<td>![Icon] Water Quality</td>
</tr>
</tbody>
</table>
Extended Detention Basins

• Treats runoff through settling

• TSS removal rate based on detention time

• Detention Time: time between when the maximum storage volume is achieved to when only 10% of the maximum volume remains

• Use Water Quality Design Storm for TSS removal rate calculation
TSS Removal Rate of Extended Detention Basins

- TSS Removal Rate (%)
- Detention Time (Hours)

- 60% removal at 24 hours
- 40% removal at 12 hours

Graph showing linear increase in TSS removal rate with detention time.
Water Quality

Extended Detention Basins – Design Example

Courtesy of NJDOT
### Water Quality

#### Extended Detention Basins – Design Example

<table>
<thead>
<tr>
<th>TIME vs. VOLUME (ac-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time (hrs)</strong></td>
</tr>
<tr>
<td>.3000</td>
</tr>
<tr>
<td>.5500</td>
</tr>
<tr>
<td>.8000</td>
</tr>
<tr>
<td>1.0500</td>
</tr>
<tr>
<td>1.3000</td>
</tr>
<tr>
<td>1.5500</td>
</tr>
<tr>
<td>1.8000</td>
</tr>
<tr>
<td>2.0500</td>
</tr>
<tr>
<td>2.3000</td>
</tr>
<tr>
<td>2.5500</td>
</tr>
<tr>
<td>2.8000</td>
</tr>
<tr>
<td>3.0500</td>
</tr>
<tr>
<td>3.3000</td>
</tr>
</tbody>
</table>
Extended Detention Basins – Design Example

- Maximum storage: 0.832 acre-ft at 2.10 hrs
- 10% of maximum storage: 0.0832 acre-ft
## Extended Detention Basins – Design Example

<table>
<thead>
<tr>
<th>Time (hrs)</th>
<th>Volume (ac-ft)</th>
<th>Time on left represents time for first value in each row.</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.5500</td>
<td>.136</td>
<td></td>
</tr>
<tr>
<td>16.8000</td>
<td>.125</td>
<td></td>
</tr>
<tr>
<td>17.0500</td>
<td>.115</td>
<td>.133</td>
</tr>
<tr>
<td>17.3000</td>
<td>.106</td>
<td>.123</td>
</tr>
<tr>
<td>17.5500</td>
<td>.096</td>
<td>.113</td>
</tr>
<tr>
<td>17.8000</td>
<td>.086</td>
<td>.102</td>
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<td>.077</td>
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<td>.051</td>
<td>.062</td>
</tr>
<tr>
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<td>.042</td>
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<tr>
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<td>.045</td>
</tr>
<tr>
<td>19.5500</td>
<td>.026</td>
<td>.037</td>
</tr>
</tbody>
</table>
Extended Detention Basins – Design Example

- Maximum storage: 2.10 hr
- Detention time ends at 17.85 hr
- Detention time = 17.85 - 2.10 = 15.75 hr
- TSS removal rate ≈ 47%
9.11 **Wet Ponds**

Wet ponds, also known as retention basins, are used to address the stormwater quantity and quality impacts of land development. This type of stormwater facility has an elevated outlet structure that creates a permanent pool where stormwater runoff is detained and attenuated. Wet ponds can be designed as multi-stage, multi-function systems; extended detention in the permanent pool provides pollutant treatment for runoff from the Water Quality Design Storm through sedimentation and biological processing; detention and attenuation are also provided for larger storm event through the higher elevation outlets. When designed in accordance with this chapter, the total suspended solids (TSS) removal rate is 50 - 90%, depending upon the storage volume in the permanent pool and the duration of detention time, if extended detention is provided.

<table>
<thead>
<tr>
<th>N.J.A.C. 7:8 Stormwater Management Rules - Design and Performance Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nonstructural</strong></td>
</tr>
<tr>
<td><strong>Water Quantity</strong></td>
</tr>
<tr>
<td><strong>Groundwater Recharge</strong></td>
</tr>
<tr>
<td><strong>Water Quality</strong></td>
</tr>
</tbody>
</table>
Wet Ponds

- Large basins designed with a permanent pool
- Often used to provide aesthetic benefits in addition to stormwater management
- Can be designed with extended detention to meet the water quantity standard
- Pretreatment is recommended
Water Quality

Wet Ponds – Design Criteria

- Minimum 0.25 acre permanent pool surface area
- Minimum ratio of the permanent pool volume to the Water Quality Design Storm volume is 1:1
- Minimum drainage area of 20 acres
- Requires very low permeability soils or an impermeable liner
Water Quality

Wet Ponds TSS Removal Rate

• Without extended detention time
  o TSS removal rate is based on the ratio of volume in the permanent pool to the volume of the Water Quality Design Storm volume
  o Ratio is from 1:1 to 3:1 for TSS removal rate from 50% to 80%

• Additional TSS removal up to 90% can be provided using extended detention
  o ratio of permanent pool volume to Water Quality Design Storm runoff volume (1:1 to 3:1) and
  o Detention time (12 to 24 hours)
TSS Removal Rate of Wet Pond Systems

- Ponds with Extended Detention:
  - Detention Time = 24 Hours
  - Detention Time = 18 Hours
  - Detention Time = 12 Hours

- Ponds without Extended Detention

Ratio of Permanent Pool Volume to Stormwater Quality Storm Runoff Volume
Water Quality

Wet Ponds – Design Example
The basin has been designed in accordance with the following standards as set forth in the Best Management Practices Manual:

- Minimum 20 acre drainage area
  - Proposed 52.10 Acres
- Minimum permanent pool surface area of 0.25 Ac.
  - Proposed 1.04 Acres
- Mean permanent pool depth of 3-6 feet
  - Proposed 7.5 feet

Factors to determine TSS Removal Rate

- Minimum permanent pool volume to be three times greater than the water quality design storm runoff volume ratios
  - Proposed permanent pool volume = 5.613 Ac. Ft.
  - Water quality storm runoff volume = 2.511 Ac. Ft.
  - Ratio = 5.613/2.511 = 2.23
## Wet Ponds – Design Example

<table>
<thead>
<tr>
<th>Time (hrs)</th>
<th>Time</th>
<th>Volume (ac-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3000</td>
<td>5.613</td>
<td>5.613</td>
</tr>
<tr>
<td>0.5500</td>
<td>5.621</td>
<td>5.629</td>
</tr>
<tr>
<td>0.8000</td>
<td>5.696</td>
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<td>6.013</td>
<td>6.191</td>
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<tr>
<td>1.3000</td>
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<td>7.241</td>
</tr>
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</tr>
<tr>
<td>1.8000</td>
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<td>7.761</td>
<td>7.757</td>
</tr>
<tr>
<td>2.3000</td>
<td>7.710</td>
<td>7.694</td>
</tr>
<tr>
<td>2.5500</td>
<td>7.624</td>
<td>7.606</td>
</tr>
</tbody>
</table>

Output Time increment = 0.0500 hrs

Time on left represents time for first value in each row.

- 5.613
- 7.762
Water Quality

Wet Ponds – Design Example

- Maximum volume: 7.762 acre-ft at 2.0 hr
- Maximum storage volume above permanent pool: $7.762 - 5.613 = 2.149$ acre-ft
- 10% of maximum storage above permanent pool = 0.2149 acre-ft
- Total volume at 10% of maximum storage = $5.613 + 0.2149 = 5.828$ acre-ft
### Wet Ponds – Design Example

**TIME vs. VOLUME (ac-ft)**

Output Time increment = .0500 hrs

<table>
<thead>
<tr>
<th>Time (hrs)</th>
<th>Time on left represents time for first value in each row</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.3000</td>
<td>5.836 5.835 5.834 5.834 5.833</td>
</tr>
<tr>
<td>20.5500</td>
<td>5.832 5.832 5.831 5.830 5.830</td>
</tr>
<tr>
<td>20.8000</td>
<td>5.829 5.828 5.827 5.827 5.826</td>
</tr>
<tr>
<td>21.0500</td>
<td>5.825 5.825 5.824 5.823 5.823</td>
</tr>
<tr>
<td>21.3000</td>
<td>5.822 5.821 5.821 5.820 5.819</td>
</tr>
<tr>
<td>21.5500</td>
<td>5.819 5.818 5.817 5.817 5.816</td>
</tr>
<tr>
<td>21.8000</td>
<td>5.815 5.815 5.814 5.813 5.813</td>
</tr>
</tbody>
</table>
Detention time ends at 20.85 hr
Detention time = 20.85 – 2.0 = 18.85 hr
TSS removal rate ≈ 83.8%
9.6 MANUFACTURED TREATMENT DEVICES

Manufactured treatment devices (MTD) are proprietary stormwater treatment systems used to address the stormwater quality impacts of land development. MTDs rely upon a variety of mechanisms to remove pollutants from stormwater runoff. When selecting an MTD for a particular site, the peak flow rate of the Water Quality Design Storm, the contributory drainage area, and the physical size limits of the MTD installation area must be known in advance. An MTD must have a Department-issued certification letter in order to be accepted for use and be sized in accordance with its published verification report. Currently, the total suspended solids (TSS) removal rate is either 50 or 80%, depending upon the individual certification of the device, which may be found at: http://www.njstormwater.org/treatment.html.

<table>
<thead>
<tr>
<th>N.J.A.C. 7:8 Stormwater Management Rules - Design and Performance Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonstructural Strategy</td>
</tr>
<tr>
<td>Water Quantity</td>
</tr>
<tr>
<td>Groundwater Recharge</td>
</tr>
<tr>
<td>Water Quality</td>
</tr>
</tbody>
</table>
Water Quality

Manufactured Treatment Devices (MTD)

- Proprietary devices designed to provide water quality treatment
- Must be verified by NJCAT and certified by NJDEP
- Devices that are not currently certified by NJDEP cannot be used to meet the design and performance standards
- Sizing calculation in the certification letter
- [http://www.njstormwater.org/treatment.html](http://www.njstormwater.org/treatment.html)
MTD – Design Criteria

- MTDs are commonly sized using the rational method
- \[ Q = ciA \]
- Many people mistakenly think the intensity of the Water Quality Design storm is the average of the 1.25 inches of rain in two hours
  - \[ 1.25 \text{ inches} / 2 \text{ hours} = 0.625 \text{ inches/hour} \]
    - This is not correct!
MTD – Design Criteria

- Remember, the intensity used in the rational method is dependent on the time of concentration

- The proper intensity comes from Figure 5-3 in Chapter 5 of the BMP Manual
Water Quality

Figure 5-3: NJDEP 1.25-Inch/2-Hour Stormwater Quality Design Storm
Rainfall Intensity-Duration Curve

- Time of Concentration (Minutes)
- Rainfall Intensity (Inches/Hour)

- 3.00
- 1.00
- 0.50
- 0.00

- 10

- 2.00
- 2.50
- 3.00
- 3.50
Highly impervious areas often result in minimum $T_c$ (10 minutes for rational method)

- For $T_c = 10$ minutes, $i = 3.2$ inches/hr
  - Using 0.625 inches/hr underestimates flow by 80.5%
MTD – Sizing a Filter Type MTD

- Sizing configuration by the maximum treatment flow rate (MTFR) and maximum inflow impervious area, \textit{whichever results in a higher minimum configuration}.

Sample paragraph in the MTD Certification Letter:

6. Sizing Requirements:

The calculation of the minimum number of cartridges for use in the Filtration System is based upon both the MTFR and the maximum inflow drainage area. It is necessary to calculate the required number of cartridges using both methods and to rely on the method that results in the highest number of cartridges determined by the two methods.
Water Quality

In summary…

• BMPs should be designed to meet criteria in Chapter 9 of BMP Manual

• Multiple BMPs can be used in series when necessary

• Infiltration BMPs require detailed soil permeability testing

• Detention BMPs must calculate the detention time to determine TSS removal rate

• Use Rainfall Intensity Curve in Figure 5-3 when using Rational Method to size MTD
GROUNDWATER RECHARGE
Groundwater Recharge

Groundwater Recharge Criteria

- Demonstrate that 100% of the pre-development groundwater recharge is maintained or

- Infiltrate the difference in the 2-year storm runoff volume
Groundwater Recharge

Infiltrate 2-year storm difference:

• Pros:
  o Simple calculation

• Cons:
  o Requires larger infiltration structure,
  o Greater risk of failure,
  o Larger groundwater mound
The calculation of the 2-year storm difference should...

- Use NRCS Method

- Show pre- and post-construction 2-year runoff volumes

- Follow all other assumptions of NRCS Method
  - Curve numbers and time of concentration match quantity and quality analyses
Groundwater Recharge

Maintain 100% of pre-development groundwater recharge:

- Requires use of New Jersey Groundwater Recharge Spreadsheet

- Need to review:
  - Pre-development vs. post-development land use inputs
  - BMP designs
## Annual Groundwater Recharge Analysis (based on GSR-32)

### Pre-Developed Conditions

<table>
<thead>
<tr>
<th>Land Segment</th>
<th>Area (acres)</th>
<th>TR-55 Land Cover</th>
<th>Soil</th>
<th>Annual Recharge (in)</th>
<th>Annual Recharge (cu.ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.4</td>
<td>Open space</td>
<td>Woodtown</td>
<td>12.9</td>
<td>66,498</td>
</tr>
<tr>
<td>2</td>
<td>0.3</td>
<td>Gravel, dirt</td>
<td>Woodtown</td>
<td>6.9</td>
<td>7,536</td>
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<tr>
<td>3</td>
<td>3.6</td>
<td>Woods-grass combination</td>
<td>Woodtown</td>
<td>13.5</td>
<td>171,255</td>
</tr>
<tr>
<td>4</td>
<td>1.4</td>
<td>Open space</td>
<td>Keyport</td>
<td>13.4</td>
<td>66,146</td>
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<tr>
<td>5</td>
<td>0.5</td>
<td>Gravel, dirt</td>
<td>Keyport</td>
<td>7.5</td>
<td>13,857</td>
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<tr>
<td>6</td>
<td>3.3</td>
<td>Woods-grass combination</td>
<td>Keyport</td>
<td>13.9</td>
<td>165,983</td>
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</tbody>
</table>

**Total = 16.4**

<table>
<thead>
<tr>
<th>Land Segment</th>
<th>Area (acres)</th>
<th>TR-55 Land Cover</th>
<th>Soil</th>
<th>Annual Recharge (in)</th>
<th>Annual Recharge (cu.ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.5</td>
<td>Impervious areas</td>
<td>Keyport</td>
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<td>-</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
<td>Gravel, dirt</td>
<td>Woodtown</td>
<td>6.9</td>
<td>40,191</td>
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<tr>
<td>3</td>
<td>3.65</td>
<td>Open space</td>
<td>Keyport</td>
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<td>177,687</td>
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<td>3.65</td>
<td>Open space</td>
<td>Keyport</td>
<td>13.4</td>
<td>170,752</td>
</tr>
</tbody>
</table>

**Total = 16.4**

### Annual Recharge Requirements Calculation

**Post-Development Annual Recharge Deficit = 103,435**

---

For each land segment, first enter the area, then select TR-55 Land Cover, then select Soil. Start from the top of the table.
Groundwater Recharge

Groundwater Recharge Spreadsheet – Page 1 (Annual Recharge Worksheet)

• Inputs (Orange cells):
  o Municipality
  o Pre- and post-development land covers
  o Pre- and post-development soils
  o Acres

• Output:
  o Post-development annual recharge deficit
Groundwater Recharge

Groundwater Recharge Spreadsheet – Page 1 (Annual Recharge Worksheet)

• Soils and land covers must match site plans
• Soils determined by soil survey or Appendix E defaults
• Pre- and post-development areas should match
Groundwater Recharge

Table 2: Default Soil Series for NJGRS Recharge Computations

<table>
<thead>
<tr>
<th>Hydrologic Soil Group</th>
<th>Default Soil Series Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Fort Mott</td>
</tr>
<tr>
<td>B</td>
<td>Nixon</td>
</tr>
<tr>
<td>C</td>
<td>Venango</td>
</tr>
<tr>
<td>D</td>
<td>Any D soil</td>
</tr>
</tbody>
</table>
## Groundwater Recharge

### Sample Project

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMP Area</td>
<td>ABMP</td>
<td>6656.0</td>
<td>sq.ft</td>
</tr>
<tr>
<td>BMP Effective Depth, this is the design variable</td>
<td>dBMP</td>
<td>5.2</td>
<td>in</td>
</tr>
<tr>
<td>Upper level of the BMP surface (negative if above ground)</td>
<td>dBMPu</td>
<td>-5.2</td>
<td>in</td>
</tr>
<tr>
<td>Depth of lower surface of BMP, must be &gt;= dBMPu</td>
<td>dEXC</td>
<td>0.0</td>
<td>in</td>
</tr>
<tr>
<td>Post-development Land Segment Location of BMP</td>
<td>SegBMP</td>
<td>0</td>
<td>unitless</td>
</tr>
</tbody>
</table>

### Root Zone Water capacity Calculated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty Portion of RWC under Post-D Natural Recharge</td>
<td>ERWC</td>
<td>0.57</td>
<td>in</td>
</tr>
<tr>
<td>ERWC Modified to consider dEXC</td>
<td>EDRWC</td>
<td>0.57</td>
<td>in</td>
</tr>
<tr>
<td>Empty Portion of RWC under Infl. BMP</td>
<td>RERWC</td>
<td>0.44</td>
<td>in</td>
</tr>
<tr>
<td>Inches of Runoff to capture</td>
<td>Qdesign</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inches of Rainfall to capture</td>
<td>Pdesign</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recharge Provided Avg. over Imp. Area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Runoff Captured Avg. over imp. Area</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### BMP Calculated Size Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABMP/Aimp</td>
<td></td>
<td>unitless</td>
</tr>
<tr>
<td>BMP Volume</td>
<td>2,873</td>
<td>cu.ft</td>
</tr>
<tr>
<td>BMP Location</td>
<td></td>
<td>Location</td>
</tr>
</tbody>
</table>

### System Performance Calculated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vdef</td>
<td>69,282</td>
<td>cu.ft</td>
</tr>
<tr>
<td>Annual BMP Recharge Volume</td>
<td>114,456</td>
<td>cu.ft</td>
</tr>
<tr>
<td>Avg BMP Recharge Efficiency</td>
<td>85.5%</td>
<td>%</td>
</tr>
<tr>
<td>%Rainfall became Runoff</td>
<td>77.6%</td>
<td>%</td>
</tr>
<tr>
<td>%Infiltration Recharged</td>
<td>66.5%</td>
<td>%</td>
</tr>
</tbody>
</table>

### Post-D Deficit Recharge (or desired recharge volume)

- **Vdef**: 69,282 cu.ft

### Post-D Impervious Area (or target Impervious Area)

- **Aimp**: 70,132 sq.ft

---

_Calculation Check:
- Volume Balance: OK
- dBMP Check: OK
- dEXC Check: OK

_Other Notes:_

- Qdesign is accurate only after BMP dimensioning.
Groundwater Recharge Spreadsheet – Page 2 (BMP Calculation)

- Parameter from Annual Recharge Worksheet
  - Vdef: Post-development deficit recharge
    - Default from page 1 or other input
  - Aimp: Post-D Impervious area (Targeted Impervious area) contributing to recharge calculation
    - Default value is the total impervious surface from the first page
    - Can be partial impervious surface runoff to recharge BMP

- Automatically populated output
  - Annul BMP recharge volume
Groundwater Recharge

Parameter from Annual Recharge Worksheet

- segBMP = the post-developed site segment in which the proposed recharge BMP will be located
  - Used to specify where on the site the recharge BMP will be located
  - Can be set to zero if this is still undetermined or if BMPs will be placed over multiple segments
  - Porous pavement, segment shall be the impervious area of the post-development
Groundwater Recharge

BMP Design Inputs

• **ABMP = BMP Area** (the footprint of a BMP, excluding sloped areas)

• **dBMP = BMP effective depth** (maximum equivalent water depth that can be achieved in the BMP before overflow begins)
  
  o If the BMP is filled with stone, the effective depth is the actual depth x the porosity
  
  o For sloped BMP like bioretention swale, use averaged dBMP but adjust ABMP to keep that ABMP x dBMP should always equal the storage volume
Groundwater Recharge

BMP Design inputs

• \( d_{BMPu} \) = Vertical distance from the vegetated ground surface to the maximum water level of the BMP
  o Positive if the maximum level is below the ground surface and negative if above the ground surface

• \( d_{EXC} \) = Vertical distance from the vegetated ground surface to the bottom of the BMP
Groundwater Recharge

Groundwater Recharge Spreadsheet
BMP Design

Diagram of groundwater recharge with labels:
- Depth to Upper Level (dBMPu)
- Negative Value
- Note: Depth to Lower Level (dEXC) = 0
- Root Zone Depth
Groundwater Recharge

Groundwater Recharge Spreadsheet
BMP Design

[Diagram showing groundwater recharge with labels for depth to upper and lower levels, root zone depth, and sand bottom.]
Groundwater Recharge

Groundwater Recharge Spreadsheet
BMP Design
Groundwater Recharge
Groundwater Recharge

BASIN SECTION DETAIL

N.T.S.

MAINTAIN MINIMUM 1’ FREEBOARD

100 YEAR EL. = 14.77

10 YEAR EL. = 14.16

2 YEAR EL. = 13.65

WATER QUALITY = 12.50

GROUND = 12.00

6” SAND LAYER SHALL CONSIST OF K5 SAND WITH A MAXIMUM OF 15% FINES AND A MINIMUM PERMEABILITY RATE OF 20” HOUR

E.S.H.W. = 9.50

MAINTAIN 2’ SEPARATION TO E.S.H.W. TABLE. SOILS SHALL NOT BE COMPACTED UNDER THE BASIN.
Groundwater Recharge
Groundwater Recharge

GL EL. = 15

Berm EL. = 16

Maintain minimum 1' freeboard

100 Year EL. = 14.77

10 Year EL. = 14.16

2 Year EL. = 13.65

Water Quality = 12.50

Ground = 12.00

6" sand layer shall consist of K5 sand with a maximum of 15% fines and a minimum permeability rate of 20" hour

E.S.H.W. = 9.50

Maintain 2' separation to E.S.H.W. Table. Soils shall not be compacted under the basin.

Unvegetated Surface Recharge BMP

Depth to Upper Level (dBMPu) (Positive Value)

Depth to Lower Level (dEXC)
Groundwater Recharge

Groundwater Recharge Spreadsheet
BMP Design

• \( \text{dBMP}_u = 15 \text{ (GL)} - 13.36 \text{ (orifice)} \)
  \( = 1.64 \text{ ft (19.7 inches)} \)
• \( \text{dEXC} = 15 - 12 = 3 \text{ ft (36 inches)} \)
Groundwater Recharge Spreadsheet

BMP Design

- The BMP effective depth: 1.36 ft (13.36 – 12 ft)
- Volume below first outlet: 59,400 ft³
Groundwater Recharge

Groundwater Recharge Spreadsheet

BMP Design

• dBMP = 1.36 ft
• ABMP = ?
  o Remember: BMP area times effective depth must equal volume
  o $ABMP = \frac{V}{dBMP} = \frac{59,400}{1.36} = 43,676 \text{ ft}^2$
Groundwater Recharge

What if this BMP had been designed as a bioretention system?

- ABMP = 43,676 ft² (the same)
- dBMP = 1.36 ft (the same)
- dBMPu = -1.36 feet (16.3 inches)
- dEXC = 0 inches
Groundwater Recharge

- Recharge of stormwater with high pollutant loading or industrial stormwater exposed to source material is prohibited
- All recharge BMPs must meet the infiltration criteria and structural design criteria in Chapter 9
- All BMPs designed to infiltrate must consider adverse hydraulic impact on the groundwater table
GROUNDWATER MOUNDING
Groundwater Mounding

Background
- NJAC7:8-5.4(a)2.iv “The design engineer shall assess the hydraulic impact on the groundwater table and design the site so as to avoid adverse hydraulic impacts. “
- Localized increase in the height of the groundwater table as a result of infiltration
- Caused by concentrating large amount of recharge into one area
- Can cause basin failure or damage to nearby structures
Groundwater Mounding

[Diagram showing groundwater mound and related terms such as potentially affected nearby structure, impervious surfaces, stormwater infiltration basin, depth of basin, unsaturated zone, ground water mound, maximum height of groundwater mound, seasonal high water table, maximum extent of 0.25-foot increase in water level, saturated zone, and thickness of aquifer (prior to stormwater infiltration).]

Groundwater Mounding

Calculation

- Hantush equation developed in 1967 to calculate mounding beneath infiltration basin

- Easiest way to use the Hantush method is a spreadsheet developed by USGS

- Can only calculate the maximum mound, not the mounding over time
Groundwater Mounding

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
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<td>6</td>
<td><strong>Input Values</strong></td>
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<tr>
<td>23</td>
<td></td>
<td><strong>Groundwater Mounding, in feet</strong></td>
<td></td>
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<td></td>
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<tr>
<td>24</td>
<td></td>
<td>Distance from center of basin in x direction, in feet</td>
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<td>33</td>
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<tr>
<td>34</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

https://www.njstormwater.org/bmp_manual/

Chapter 13
Download Hantush Excel Spreadsheet
Groundwater Mounding

Hantush Spreadsheet

• Inputs:
  o Recharge rate (in/hr)
  o Specific yield (dimensionless)
  o Horizontal hydraulic conductivity (in/hr)
  o Basin dimensions (feet)
  o Duration of infiltration (hours)
  o Initial thickness of saturated zone (ft)
Groundwater Mounding

Hantush Spreadsheet

- Inputs:
  - Recharge rate (ft/day)
    - Design soil permeability rate (vertical saturated soil hydraulic conductivity)
  - Horizontal hydraulic conductivity
    - Rarely a tested parameter
    - In the coastal plain: 5 \times \text{recharge rate}
    - Outside the coastal plain: 1 \times \text{recharge rate}
Groundwater Mounding

Hantush Spreadsheet

• Specific yield
  o Specific yield governs how much water the unsaturated zone can store when recharged runoff reaches the water table
  o The volume of water that will drain from the soil, as a result of gravity, divided by the total volume of the soil
  o Default value 0.15 and up to a maximum value 0.2, with supporting soil test results

USGS, 1967
Groundwater Mounding

Hantush Spreadsheet

• Inputs:
  o Basin dimensions (assumes rectangular and vertical sides)
    • Input as ½ length in x-direction and ½ length in y-direction of the footprint of a BMP
      o Circular shape BMP use the radius of the circular basin as both x and y.
      o Irregular shape BMP, convert the shape to a rectangular shape that has same depth of stormwater runoff to be infiltrated and is best fitted to the original shape.
      o If a BMP is designed with sloped sides, use the bottom footprint as the length and the width of the BMP and use the total volume of the runoff to be infiltrated divided by the area of the bottom footprint to calculate the duration of infiltration period
Groundwater Mounding

Hantush Spreadsheet

- Inputs:
  - Initial thickness of saturated zone (ft)
    - Unless proven by a field test showing the thickness of saturated zone beneath the proposed BMP, the default value is 10 ft.
    - Note that the thickness of saturated zone used in the Hantush spreadsheet is not the thickness of a large regional aquifer. It is the distance from the Seasonal High Water Table (SHWT) to the first hydraulically restrictive layer.
Groundwater Mounding

**Hantush Spreadsheet**

- **Inputs:**
  - Duration of infiltration (hours)
    - Time for infiltrating the runoff volume through the BMP
    - Using the recharge rate in the input
    - Maximum value is 72 hr
  - When the mounding height is higher than the bottom of the BMP, the recharge rate is impacted because of the reduced hydraulic gradient
    - Use a smaller recharge and longer duration of infiltration
    - The recharge rate times the duration of infiltration and the areas of the footprint shall be equal to the volume infiltrated
Groundwater Mounding

**Hantush Spreadsheet**

- **Effects of Inputs**
  - Maximum mounding height decreases
  - when following inputs increase:
    - Horizontal hydraulic conductivity increases
    - specific yield increases
    - initial thickness of saturated zone increases

- When result shows that mounding height reaches to the bottom of the infiltration BMP
  - decrease recharge rate & longer infiltration period, or
  - design a larger but shallower basin
Summary

• Highlights of BMPs
  o Extended detention basins
  o Wet ponds

• Soil Testing – Appendix E/ Chapter 12

• Groundwater Recharge

• Analysis of adverse hydraulic impact to groundwater table
More Information:

Bureau of Nonpoint Pollution Control
Division of Water Quality
401 East State Street
PO Box 420, Mail Code 401-2B
Trenton, NJ 08625-420
Tel: 609-633-7021
www.njstormwater.org

Changj Wu
Chang.i.wu@dep.nj.gov
Introduction

Presentation Goals

• Demonstrate simple analysis
• Demonstrate stretching the time interval
• Demonstrate applicability to drainage pipes
• Demonstrate calculating impacts to nearby structures
Examples

Scenarios:

1. No adverse hydraulic impact to groundwater
2. Adverse hydraulic impact to groundwater and adjustment of infiltration period
3. Underground perforated pipe
4. Drywell
No Adverse Hydraulic Impact to Groundwater Scenario

- A major development located in the coastal plain proposes an infiltration basin, whose bottom footprint measures 50 ft by 50 ft, to infiltrate 5,000 cf of runoff generated by the Water Quality Design Storm (WQDS).
  - The maximum depth of ponding water is designed to be 2 ft
  - Soil testing was performed in accordance with Chapter 12
  - The soil testing report shows that the Seasonal High Water Table (SHWT) is 7.5 ft below the 6 inch thick bottom sand layer of the basin
  - The tested soil permeability rate of the most restrictive soil horizon below the basin is 4 in/hr
  - No nearby underground structures are present
Step #1: Calculate the duration of infiltration period

Duration of infiltration period, \( t \) (hours)

\[
= \frac{\text{volume of runoff to be infiltrated (cf)} \times 12 \text{ in/ft}}{\text{Infiltration area (sf)} \times \text{Recharge rate (in/hr)}}
\]

Infiltration area

\[= 50 \text{ ft} \times 50 \text{ ft} = 2,500 \text{ sf}\]

Recharge Rate = \( \frac{1}{2} \) Tested Infiltration rate

\[= 0.5 \times 4 \text{ in/hr} = 2 \text{ in/hr}\]

Therefore, \( t \)

\[
= \frac{5,000 \text{ cf} \times 12 \text{ in/ft}}{2,500 \text{ sf} \times 2 \text{ in/hr}} = 12 \text{ hr}
\]
## No Adverse Hydraulic Impact to Groundwater Scenario

### Step #2: Prepare the inputs for the spreadsheet

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge rate ( (R) )</td>
<td>2 in/hr (4 ft/day)</td>
</tr>
<tr>
<td>Specific yield ( (S_y) )</td>
<td>0.15</td>
</tr>
<tr>
<td>Horizontal hydraulic conductivity ( (Kh) )</td>
<td>10 in/hr (20 ft/day)</td>
</tr>
<tr>
<td>( \frac{1}{2} ) length of basin (x direction)</td>
<td>25 ft</td>
</tr>
<tr>
<td>( \frac{1}{2} ) length of basin (y direction)</td>
<td>25 ft</td>
</tr>
<tr>
<td>Duration of infiltration period ( (t) )</td>
<td>12 hr (0.5 days)</td>
</tr>
<tr>
<td>Initial thickness of saturated zone ( (hi(0)) )</td>
<td>10 ft</td>
</tr>
</tbody>
</table>
**No Adverse Hydraulic Impact to Groundwater Scenario**

### Step #2: Input Section of the *Hantush Spreadsheet*

<table>
<thead>
<tr>
<th>Value</th>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00</td>
<td>$R$</td>
<td>Recharge rate (permeability rate) (in/hr)</td>
</tr>
<tr>
<td>0.150</td>
<td>$Sy$</td>
<td>Specific yield, $Sy$ (dimensionless) default value is 0.15; max value is 0.2 provided that a lab test data is submitted</td>
</tr>
<tr>
<td>10.00</td>
<td>$Kh$</td>
<td>Horizontal hydraulic conductivity (in/hr) $Kh = 5R$ in the coastal plan; $Kh=R$ outside the coastal plan</td>
</tr>
<tr>
<td>25.000</td>
<td>$x$</td>
<td>1/2 length of basin ($x$ direction, in feet)</td>
</tr>
<tr>
<td>25.000</td>
<td>$y$</td>
<td>1/2 width of basin ($y$ direction, in feet)</td>
</tr>
<tr>
<td>12.00</td>
<td>$t$</td>
<td>Duration of infiltration period (hours)</td>
</tr>
<tr>
<td>10.000</td>
<td>$h(0)$</td>
<td>Initial thickness of saturated zone (feet)</td>
</tr>
</tbody>
</table>
No Adverse Hydraulic Impact to Groundwater Scenario

Step #2: Results Section of the *Hantush Spreadsheet*

<table>
<thead>
<tr>
<th>Groundwater Mounding, in feet</th>
<th>Distance from center of basin in x direction, in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.073</td>
<td>0</td>
</tr>
<tr>
<td>4.900</td>
<td>20</td>
</tr>
<tr>
<td>2.066</td>
<td>40</td>
</tr>
<tr>
<td>1.205</td>
<td>50</td>
</tr>
<tr>
<td>0.676</td>
<td>60</td>
</tr>
<tr>
<td>0.350</td>
<td>70</td>
</tr>
<tr>
<td>0.196</td>
<td>80</td>
</tr>
<tr>
<td>0.086</td>
<td>90</td>
</tr>
<tr>
<td>0.041</td>
<td>100</td>
</tr>
<tr>
<td>0.011</td>
<td>120</td>
</tr>
</tbody>
</table>

Maximum thickness of saturated zone (beneath center of basin at end of infiltration period)

Maximum groundwater mounding (beneath center of basin at end of infiltration period)

Re-Calculate Now

Groundwater Mounding, in feet

SHWT
A major development located in the coastal plain proposes an infiltration basin, whose bottom footprint measures 88 ft by 88 ft, to infiltrate 15,000 cf of runoff generated by the 2-year design storm.

- The maximum depth of ponding water is designed to be 2 ft
- Soil testing was performed in accordance with Chapter 12
- The soil testing report shows that SHWT is 7.5 ft below the 6 inch thick bottom sand layer of the basin
- The tested soil permeability rate of the most restrictive soil horizon below the basin is 4 in/hr
Step #1: Calculate the duration of infiltration period

Duration of infiltration period, \( t \) (hours)

\[
= \frac{\text{volume of runoff to be infiltrated (cf)} \times 12 \text{ in/ft}}{\text{Infiltration area (sf)} \times \text{Recharge rate (in/hr)}}
\]

Infiltration area

\[= 88 \text{ ft} \times 88 \text{ ft} = 7,744 \text{ sf} \]

Recharge Rate = \( \frac{1}{2} \) Tested Infiltration rate

\[= 0.5 \times 4 \text{ in/hr} = 2 \text{ in/hr} \]

Therefore, \( t \)

\[
= \frac{15,000 \text{ cf} \times 12 \text{ in/ft}}{7,744 \text{ sf} \times 2 \text{ in/hr}} = 11.62 \text{ hr}
\]
**Step #2: Prepare the inputs for the spreadsheet**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge rate ((R))</td>
<td>2 in/hr ((4 \text{ ft/day}))</td>
</tr>
<tr>
<td>Specific yield ((S_y))</td>
<td>0.15</td>
</tr>
<tr>
<td>Horizontal hydraulic conductivity ((K_h))</td>
<td>10 in/hr ((20 \text{ ft/day}))</td>
</tr>
<tr>
<td>(\frac{1}{2}) length of basin ((x \text{ direction}))</td>
<td>44 ft</td>
</tr>
<tr>
<td>(\frac{1}{2}) length of basin ((y \text{ direction}))</td>
<td>44 ft</td>
</tr>
<tr>
<td>Duration of infiltration period ((t))</td>
<td>11.62 hr ((0.48 \text{ days}))</td>
</tr>
<tr>
<td>Initial thickness of saturated zone ((h_i(0)))</td>
<td>10 ft</td>
</tr>
</tbody>
</table>
**Step #2: Results Section of the *Hantush Spreadsheet***

<table>
<thead>
<tr>
<th>Groundwater Mounding, in feet</th>
<th>Distance from center of basin in x direction, in feet</th>
<th>Maximum thickness of saturated zone (beneath center of basin at end of infiltration period)</th>
<th>Maximum groundwater mounding (beneath center of basin at end of infiltration period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.513</td>
<td>0</td>
<td>19.51</td>
<td>9.51</td>
</tr>
<tr>
<td>8.842</td>
<td>20</td>
<td>16</td>
<td>9.51</td>
</tr>
<tr>
<td>6.422</td>
<td>40</td>
<td>16</td>
<td>9.51</td>
</tr>
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<td>4.376</td>
<td>50</td>
<td>16</td>
<td>9.51</td>
</tr>
<tr>
<td>2.728</td>
<td>60</td>
<td>16</td>
<td>9.51</td>
</tr>
<tr>
<td>1.587</td>
<td>70</td>
<td>16</td>
<td>9.51</td>
</tr>
<tr>
<td>0.868</td>
<td>80</td>
<td>16</td>
<td>9.51</td>
</tr>
<tr>
<td>0.449</td>
<td>90</td>
<td>16</td>
<td>9.51</td>
</tr>
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<td>0.221</td>
<td>100</td>
<td>16</td>
<td>9.51</td>
</tr>
<tr>
<td>0.048</td>
<td>120</td>
<td>16</td>
<td>9.51</td>
</tr>
</tbody>
</table>

Re-Calculate Now

Groundwater Mounding, in feet

![Graph showing groundwater mounding](image)
### Step #3: Adjust the inputs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge rate (R)</td>
<td>1 in/hr (2 ft/day)</td>
</tr>
<tr>
<td>Specific yield ($S_y$)</td>
<td>0.15</td>
</tr>
<tr>
<td>Horizontal hydraulic conductivity (Kh)</td>
<td>20 in/hr (40 ft/day)</td>
</tr>
<tr>
<td>$\frac{1}{2}$ length of basin (x direction)</td>
<td>44 ft</td>
</tr>
<tr>
<td>$\frac{1}{2}$ length of basin (y direction)</td>
<td>44 ft</td>
</tr>
<tr>
<td>Duration of infiltration period ($t$)</td>
<td>23.24 hr (0.96 days)</td>
</tr>
<tr>
<td>Initial thickness of saturated zone ($h_i(0)$)</td>
<td>10 ft</td>
</tr>
</tbody>
</table>
### Adverse Hydraulic Impact to Groundwater and Adjustment of Drain Time Scenario

#### Step #3: New Results

<table>
<thead>
<tr>
<th>Groundwater Mounding, in feet</th>
<th>Distance from center of basin in x direction, in feet</th>
<th>Maximum thickness of saturated zone (beneath center of basin at end of infiltration period) h(max)</th>
<th>Maximum groundwater mounding (beneath center of basin at end of infiltration period) Δh(max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.325</td>
<td>0</td>
<td>17.33</td>
<td>7.33</td>
</tr>
<tr>
<td>6.853</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.244</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.956</td>
<td>50</td>
<td></td>
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</tr>
<tr>
<td>2.850</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.985</td>
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<tr>
<td>1.339</td>
<td>80</td>
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<td></td>
</tr>
<tr>
<td>0.877</td>
<td>90</td>
<td></td>
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</tr>
<tr>
<td>0.559</td>
<td>100</td>
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<td></td>
</tr>
<tr>
<td>0.211</td>
<td>120</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Graph:**

- **Groundwater Mounding, in feet**

- **x-axis:** Distance from center of basin in x direction, in feet
- **y-axis:** Maximum thickness of saturated zone (beneath center of basin at end of infiltration period) h(max)
A Comparison of Mounding Effects Caused by Different Recharge Rates

- \( R = 2.0 \text{ in/hr} @ 11.62 \text{ hrs} \)
- \( R = 1.0 \text{ in/hr} @ 23.24 \text{ hrs} \)

SHWT (7.5 ft below sand layer)
Underground Perforated Pipe Scenario

- A site is located in the coastal plain. A 500 LF, 36-inch diameter underground perforated pipe is proposed to store and infiltrate 12,000 cf of runoff.
  - The proposed duration of infiltration period is 24 hr
  - The building has a basement floor located just above the groundwater table. The center of the underground pipe is 20 ft away from the building
  - Soil testing was performed in accordance with Chapter 12
  - The soil testing report shows that Seasonal High Water Table (SHWT) is 2 feet below the pipe
  - The tested soil permeability rate of the most restrictive soil horizon below the basin is 8 in/hr
Step #1: Calculate the duration of infiltration period

Infiltration area
\[ = 500 \text{ ft} \times (36 \text{ in} / (12 \text{ in} / \text{ ft})) = 1,500 \text{ sf} \]

Recharge Rate = \( \frac{1}{2} \) Tested Infiltration rate
\[ = 0.5 \times 8 \text{ in/hr} = 4 \text{ in/hr} \]

Duration of infiltration period, \( t \) (hours)
\[ = \frac{\text{volume of runoff to be infiltrated (cf)} \times 12 \text{ in/ft}}{\text{Infiltration area (sf)} \times \text{Recharge rate (in/hr)}} \]

Therefore, \( t \)
\[ = \frac{12,000 \text{ cf} \times 12 \text{ in/ft}}{1,500 \text{ sf} \times 4 \text{ in/hr}} = 24 \text{ hr} \]
**Underground Perforated Pipe Scenario**

**Step #1: Prepare the inputs for the spreadsheet**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge rate ((R))</td>
<td>4 in/hr</td>
</tr>
<tr>
<td>Specific yield ((S_y))</td>
<td>0.15</td>
</tr>
<tr>
<td>Horizontal hydraulic conductivity ((Kh))</td>
<td>20 in/hr</td>
</tr>
<tr>
<td>(\frac{1}{2}) length of basin ((x) direction)</td>
<td>1.5 ft</td>
</tr>
<tr>
<td>(\frac{1}{2}) length of basin ((y) direction)</td>
<td>250 ft</td>
</tr>
<tr>
<td>Duration of infiltration period ((t))</td>
<td>24 hr</td>
</tr>
<tr>
<td>Initial thickness of saturated zone ((hi(0)))</td>
<td>10 ft</td>
</tr>
</tbody>
</table>
Underground Perforated Pipe Scenario

Step #2: Results Section of the *Hantush Spreadsheet*

<table>
<thead>
<tr>
<th>Groundwater Mounding, in feet</th>
<th>h(max)</th>
<th>Δh(max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.66</td>
<td>1.66</td>
<td></td>
</tr>
<tr>
<td>1.659</td>
<td>1.209</td>
<td></td>
</tr>
<tr>
<td>1.209</td>
<td>0.819</td>
<td></td>
</tr>
<tr>
<td>0.819</td>
<td>0.662</td>
<td></td>
</tr>
<tr>
<td>0.662</td>
<td>0.528</td>
<td></td>
</tr>
<tr>
<td>0.528</td>
<td>0.416</td>
<td></td>
</tr>
<tr>
<td>0.416</td>
<td>0.324</td>
<td></td>
</tr>
<tr>
<td>0.324</td>
<td>0.250</td>
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<tr>
<td>0.250</td>
<td>0.191</td>
<td></td>
</tr>
<tr>
<td>0.191</td>
<td>0.110</td>
<td></td>
</tr>
</tbody>
</table>

Maximum thickness of saturated zone (beneath center of basin at end of infiltration period)

Maximum groundwater mounding (beneath center of basin at end of infiltration period)

### Graph

- **Groundwater Mounding, in feet**
- **Perforated-Pipe**
- **SWHT**

---

19
Underground Perforated Pipe Scenario

Step #2: Results Section of the *Hantush Spreadsheet*

![Diagram showing groundwater mounding and Hantush spreadsheet results.](image)
• A site is located outside the coastal plain. A 7 ft high by 5 ft diameter drywell is proposed to store and infiltrate 137.4 cf of roof runoff from a single-family home for the Water Quality Design Storm.

  o The house has a basement floor located just above the groundwater table.
  o The center of the drywell is 10 ft away from the house.
  o Soil testing was performed in accordance with Chapter 12
  o The soil testing report shows that SHWT is 2 ft below the bottom of the drywell
  o The tested soil permeability rate of the most restrictive soil horizon below the basin is 4 in/hr
  o The duration of infiltration period is 42 hr
# Drywell Scenario

## Step #1: Prepare the inputs for the spreadsheet

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge rate (R)</td>
<td>2 in/hr (4 ft/day)</td>
</tr>
<tr>
<td>Specific yield ($S_y$)</td>
<td>0.15</td>
</tr>
<tr>
<td>Horizontal hydraulic conductivity (Kh)</td>
<td>2 in/hr (4 ft/day)</td>
</tr>
<tr>
<td>$\frac{1}{2}$ length of basin (x direction)</td>
<td>2.5 ft</td>
</tr>
<tr>
<td>$\frac{1}{2}$ length of basin (y direction)</td>
<td>2.5 ft</td>
</tr>
<tr>
<td>Duration of infiltration period ($t$)</td>
<td>42 hr</td>
</tr>
<tr>
<td>Initial thickness of saturated zone ($h_i(0)$)</td>
<td>10 ft</td>
</tr>
</tbody>
</table>
Drywell scenario

Step #2: Results Section of the *Hantush Spreadsheet*

<table>
<thead>
<tr>
<th>Groundwater Mounding, in feet</th>
<th>Distance from center of basin in x direction, in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.115</td>
<td>0</td>
</tr>
<tr>
<td>0.740</td>
<td>5</td>
</tr>
<tr>
<td>0.487</td>
<td>10</td>
</tr>
<tr>
<td>0.343</td>
<td>15</td>
</tr>
<tr>
<td>0.247</td>
<td>20</td>
</tr>
<tr>
<td>0.180</td>
<td>25</td>
</tr>
<tr>
<td>0.132</td>
<td>30</td>
</tr>
<tr>
<td>0.097</td>
<td>35</td>
</tr>
<tr>
<td>0.072</td>
<td>40</td>
</tr>
<tr>
<td>0.054</td>
<td>45</td>
</tr>
</tbody>
</table>

Maximum thickness of saturated zone (beneath center of basin at end of infiltration period)

Maximum groundwater mounding (beneath center of basin at end of infiltration period)

Re-Calculate Now

Centerline of the drywell

SWHT
Drywell Scenario

Step #2: Results Section of the *Hantush Spreadsheet*

<table>
<thead>
<tr>
<th>Groundwater Mounding, in feet</th>
<th>Distance from center of basin in x direction, in feet</th>
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<tr>
<td>0.054</td>
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</tr>
</tbody>
</table>

Maximum thickness of saturated zone (beneath center of basin at end of infiltration period):
- Maximum groundwater mounding (beneath center of basin at end of infiltration period)

Re-Calculate Now

![Graph showing groundwater mounding, SWHT, and Centerline of the drywell](image)

- Basement
- SWHT
- Centerline of the drywell
- 12.5 ft
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 QUIZ 3

https://www.njstormwater.org/smdrc_training.html

NJDEP Division of Water Quality
SWMDR Training Module 3
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