Advanced Design Workshops

Stormwater Basics: Quality vs. Quantity

Note: This course is available as online training on ELMS: https://learning.dot.ga.gov
Always check the current edition of the GDOT Drainage Design for Highways Manual for current policies.

This presentation shall not supersede any policies in the GDOT Drainage Design for Highways Manual (current edition) or any other GDOT policy publications.
Why Are We Here?

...to discuss Post-Construction Stormwater Quantity and Quality:

- How are they different?
- How are they related?
- Why are they both important for GDOT projects?
Points of Discussion

Stormwater Quantity and Quality

- Definition and Importance
- Predominant Stormwater Management Issues
- Current Requirements/Minimum Standards
- GDOT-Specific Stormwater Requirements
- Strategies for Successful GDOT MS4 Compliance
Definition and Importance

Stormwater **Quantity**: How much?
Stormwater **Quality**: How clean?

*Quality is directly related to Quantity*
Predominant Stormwater Issues

• Point/Non-Point Source Discharges
• Impaired Waters/TMDL
• Hydrologic Conditions/Effects of Urbanization
• Stream Degradation
• Flooding
• Threatened and Endangered Species
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Stormwater Quality
How Does Stormwater Affect Water Quality?

- Pollutants are carried by stormwater when it rains...
- Stormwater flows directly to nearby waterways...
- Pollution occurs in our streams, rivers and oceans!
How Does Stormwater Affect Water Quality?

There are two types of discharges from an MS4:

• **Point Sources**: Concentrated flows usually from pipe or channel

• **Non-Point Sources**: Discharges are broad based, overland flows
Impaired Waters

• Each receiving water has a designated use.
  – Fishing
  – Recreation
  – Drinking

• EPD assigns each water body assessed one of the following categories:
  – Supporting designated use
  – assessment pending additional data
  – not supporting designated use (or impaired)

• Water that does not meet its designated use is considered **impaired**.
Why is this Important?

- 2.5% of earth’s water is freshwater (Source: USGS)
- < 1% earth’s freshwater is potable

Georgia rivers & streams

- Meets Designated Use (41%)
- Impaired Waters (59%)
TMDLs quantify the maximum pollutant load a water can handle and still meet designated use.

TMDL Implementation Plans establish procedures/activities to bring water back into compliance with designated use.

\[ \text{TMDL} = \sum \text{WLA} + \sum \text{LA} + \text{MOS} \]

**Note:** GDOT does not currently have WLA requirements, but this could change in the future.
How do I know if my project affects impaired waters?

– GDOT TMDL tool (MicroStation format)

Impaired Waters

How do I know if my project affects impaired waters?

– EPD 305(b)/303(d) (impaired waters) list & GIS shapefile:
  http://epd.georgia.gov/georgia-305b303d-list-documents
  http://epd.georgia.gov/geographic-information-systems-gis-databases-and-documentation

– Google Earth (.KMZ file format)
How do I know if my project affects impaired waters?

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- Google Earth (.KMZ file format)

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**Impact of Sullivan Creek**

**Sullivan Creek**

- FID: 2038
- Reach_ID: R031300050129
- Reach_Name: Sullivan Creek
- Reach_Loc: at 1-265 to Flint River
- Reach_Basin: Flint
- Reach_County: Clayton
- Reach_WBD_T: Stream
- Reach_WUC: Fishing
- Reach_Data: 42
- Reach_Eval: Not Supporting
- Reach_Viol: FC
- Reach_Viol_UR: UR
- Reach_Eflow: 2

**Sullivan Creek**

- TMDL: 4b
- Priority: Y
- Reach Length: 0
Stormwater Quantity
Stormwater Quantity Control

• Factors that affect the amount of runoff:
  – Precipitation
  – Soils
  – Land use (*impervious area, vegetation, etc.*)

• What designers can control with detention:
  – Peak Flow Rate
  – Flow Velocity
Increasing impervious surfaces cause higher runoff volume leading to:

- Habitat and property loss

Source: GSWCC
Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Habitat and property loss
- Exposed or undermined utilities
Increasing impervious surfaces cause higher runoff volume leading to:

- Habitat and property loss
- Exposed or undermined utilities
- Streambank erosion

Source: All Images from GSWCC
Increasing impervious surfaces cause higher runoff volume leading to:

- Habitat and property loss
- Exposed or undermined utilities
- Channel degradation
- Increased pollutants
Increasing impervious surfaces cause higher runoff volume leading to:

- Increased Flooding
Increasing impervious surfaces cause higher runoff volume leading to:

- Increased Flooding
- Infrastructure and property damage
Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Increased Flooding
- Infrastructure and property damage

A washed out bridge is shown Monday, Sept. 21, 2009 in Douglasville, Ga. Heavy rain caused flooding in and around the Atlanta area. (AP Photo/John Bazemore)
Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Increased Flooding
- Infrastructure and property damage

Tributary to Snake Creek, near Whitesburg, Georgia, showing a washed out bridge. Heavy rain caused flooding in and around the Atlanta area. (Photo from USGS)
Water quality and quantity concerns led to stormwater policy and permit requirements (MS4):

- GDOT policy requires analysis to determine if stormwater detention is required to mitigate peak flow increases for all projects.

- MS4 permit requires analysis to determine if post-construction water quality measures and detention are needed in MS4 areas.
GDOT’s MS4 Permit

Minimum Control Measures

- Public Education and Outreach on Stormwater Impacts
- Public Involvement / Participation
- Illicit Discharge Detection and Elimination (IDDE)
- Construction Site Stormwater Runoff Control
- Post-Construction Stormwater Management
- Pollution Prevention/Good Housekeeping for Municipal type Operations
GDOT’s MS4 Permit

• 5-year terms: (Jan 2012 – Jan 2017) (Jan 2017 – Jan 2022)

• Permit goals and requirements for the 6 Minimum Control Measures (MCMs) each permit year

• Annual reports ensure MCM goals are met

• Future permit cycles could become more stringent (2022-2027)....

• Goal is to protect the quality of Georgia’s waters
## GDOT’s MS4 Permit

<table>
<thead>
<tr>
<th>Green Infrastructure/Low Impact Development BMPs</th>
<th>1st Permit Term</th>
<th>2nd Permit Term...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2012</td>
<td>2013</td>
</tr>
<tr>
<td>Develop a program for conducting a low impact development (LID) / green infrastructure (GI) feasibility study, and implementing low impact developments/green infrastructure where feasible.</td>
<td></td>
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<td></td>
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<tr>
<td>Develop the program, including a checklist of possible green infrastructure practices to be considered during the design phase. Submit the proposed program to EPD for review and approval.</td>
<td></td>
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<td></td>
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<tr>
<td>Submit a copy of the completed checklist to EPD with each set of plans. The checklist must show which LID/GI practices are included in the project and must detail why each listed practice was not considered feasible for the project.</td>
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</tr>
<tr>
<td>Track the type and number of each LID/GI practice incorporated into each set of plans.</td>
<td></td>
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</tr>
<tr>
<td>Inspect and maintain the GI/LID structures. Provide documentation of inspections conducted and maintenance performed during the reporting period in each annual report.</td>
<td></td>
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</tr>
</tbody>
</table>
GDOT’s MS4 Permit

GDOT’s MS4 Post-Construction Requirements apply in areas designated by EPD as MS4 (Phase I and Phase II) to:

- Linear roadway projects disturbing ≥ 1 acre
  - OR
- Site development projects adding ≥ 5,000 square feet of impervious area
MS4 Areas in 2012 Permit

One year to phase in the 2017 post-construction stormwater requirements

If one of the following occurs by January 2, 2018, you must comply with the post-construction stormwater requirements in the 2012 permit.

• Received Environmental Approval (Georgia Environmental Policy Act Notice of Decision or National Environmental Policy Act Record of Decision

    OR

• Submitted right-of-way plans for GDOT review and approval

    OR

• Received concept approval (start of preliminary engineering)
New MS4 Areas in 2017 Permit

One year to phase in the 2017 post-construction stormwater requirements

Project receives concept approval on or before January 2, 2018 EXEMPT
Stormwater post-construction BMPs can be utilized to provide both quantity and quality control. Remember...

- Stormwater **quantity** (detention) control requirements apply to all GDOT projects.
- Stormwater **quality** requirements apply to projects located within an MS4 area or for specific environmental considerations.
How Do We Improve Stormwater Quality?

We can treat stormwater with BMPs:

90% of stormwater pollutants are carried in the first 1/2” of rainfall, often called “first flush” (Source: EPA)

BMPs can improve stormwater runoff quality by:

- Treating runoff to remove pollutants
- Providing quantity control in some cases
How Do We Control Stormwater Quantity?

Peak flow rates for a drainage basin increase once it has been disturbed or developed.

BMPs can control stormwater quantity by:

- Attenuating post-project peak flows
- Controlling discharge velocities
Are post-construction BMPs ever required outside of an MS4 area?

- Special environmental concerns may require water quality and quantity management for protection of water and natural resources.
Special Environmental Requirements...

Some watersheds have specific requirements from:

- Georgia EPD Stream Buffer Rules
- Army Corps of Engineers
- US Fish and Wildlife

These requirements are often due to specific impairments or Threatened and Endangered (T&E) species native to that area.
Post-Construction Stormwater
Other Considerations

Non-MS4 Project Locations with Potential Special Environmental Considerations:
Lake Lanier – Nutrient Concern (increased algae population) and TMDL
Non-MS4 Project Locations with Potential Special Environmental Considerations:
Lake Allatoona – Habitat Conservation Plan (HCP) and T&E species
When is PCS Management Required?

What if my project is not in an MS4 area and has no specific environmental considerations?

- Stormwater *quality* treatment is not required but quantity still needs to be evaluated
- Stormwater *quantity* should be controlled for no adverse impacts (downstream analysis)
  - Designer must ensure downstream system has adequate capacity
Tools to Mitigate Quality and Quantity Issues

• Stormwater Planning & Management
• Know the Requirements
• LID/GI
• Unified Sizing Criteria
Stormwater Planning & Management

Incorporating Stormwater Early in Design

• Once the project scope is defined, Conceptual Design **AND** Stormwater Design begin to:
  – Avoid potential redesigns of projects
  – Plan ahead for post-construction stormwater structures
  – Avoid project delays
LID and GI

GDOT’s MS4 permit requires the consideration of Low Impact Development (LID) and Green Infrastructure (GI) during design.

**Low Impact Development (LID)**, as defined by EPA, is

“A management approach and set of practices that can reduce runoff and pollutant loadings by managing runoff as close to its source(s) as possible.”
LID and GI

Common LID practices include...

• Avoiding environmentally sensitive areas
• Reducing project footprint
• Minimizing site impacts
• Adjusting the design with the terrain, while still providing a safe design
Green Infrastructure (GI), as defined by EPA, is

“An adaptable term used to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services.”
Unified Sizing Criteria

A set of five engineering-based criteria:

- Runoff Reduction ($RR_v$)
- Water Quality ($WQ_v$)
- Channel Protection ($CP_v$)
- Overbank Flood Protection ($Q_{p25}$)
- Extreme Flood Protection ($Q_f$)

Runoff Reduction ($RR_v$) is a new criteria that was added to GDOT’s 2017 MS4 permit.
Unified Sizing Criteria

A set of five engineering-based criteria:

- Runoff Reduction ($RR_v$)
- Water Quality ($WQ_v$)
- Channel Protection ($CP_v$)
- Overbank Flood Protection ($Q_{p25}$)
- Extreme Flood Protection ($Q_f$)

When applied together as a whole, provide:

- Quality Control
- Quantity Control

AND....

- Mitigation of Downstream Adverse Impacts
Unified Sizing Criteria

$RR_v$: Retain up to the first 1.0 inch of rainfall on the site

- Removes runoff along with the pollutants dissolved or suspended in it.
- If the 1.0 inch cannot be retained onsite the remaining runoff from a 1.2 inch rainfall event must be treated for water quality.
Unified Sizing Criteria

\( WQ_v \): Remove 80% of total suspended solids (TSS) from the runoff generated by a 1.2” rainfall event

– 85\(^{\text{th}}\) percentile storm
– Treats “first flush”
– Directly related to impervious cover of basin
Unified Sizing Criteria

**CP\textsubscript{v}:** Detain the 1-year 24-hour storm event for 24 hours

- Protects downstream channels
- Not required for post-development flows <2.0 cfs
- The extent of the WQ\textsubscript{v} determines the invert elevation of the CP\textsubscript{v} orifice
Unified Sizing Criteria

$Q_{p25}$: Detain for the 25-year 24-hour storm event (match post-developed flow rates with pre-developed)

- Larger storms partially controlled through control of $Q_{p25}$ event
- The top of the $CP_{v}$ volume determines the elevation of the subsequent $Q_{p25}$ outlet(s)
Unified Sizing Criteria

• $Q_f$: Safely convey the 100-year storm and evaluate the effects on the storm system, adjacent property and downstream facilities and properties.
  
  • A separate analysis is performed comparing $100_{\text{pre}}$ and $100_{\text{post}}$ flows to see negative effects on downstream channels/structures.
Unified Sizing Criteria

- All components of the BMP (storage area and outlet structures) work together to meet water quality and quantity requirements
- Flows should be **routed through all BMP components** to accurately reflect its performance
Unified Sizing Criteria

Detention Requirements May be Waived if:

- Site discharges drain directly to channel with drainage area larger than 5 square miles (waiver for $C_{p_v}$, $Q_{P25}$, and $Q_f$)
- Post-development 1-year 24-hour storm event discharges are less than 2 cfs (waiver for $C_{p_v}$ only)
- Downstream analysis shows detention may cause adverse impacts
Unified Sizing Criteria

Hydrologic methods:

• Post-construction practices require *NRCS TR-55 (SCS Curve Number Method)* instead of Rational Method

• Chapters 4 and 10 of the GDOT Drainage Manual present detailed information on the GDOT required hydrologic methods
Water Quality Volume

How to calculate water quality volume

*WQv is based on basin area and new impervious area percentage*

\[
WQ_v = 1.2 \times R_v \times A / 12
\]

\((ac-ft)\) \qquad \text{(inch)} \qquad \text{(acre)} \qquad \text{(inch/ft)}

*to obtain \(WQ_v\) in ft^3, convert \(A\) (acres) to ft^2:*

\[
WQ_v = 1.2 \times R_v \times A \times 43,560 / 12
\]

\((ft^3)\) \qquad \text{(inch)} \qquad \text{(acre)} \qquad \text{(ft^2/acre)} \qquad \text{(inch/ft)}

\(R_v\) = volumetric runoff coefficient
\[= 0.05 + 0.009 \times I\]

\(A\) = total basin area (acre)

\(I\) = impervious area (%)
Water Quality Volume (WQ$_V$) Example

**Given (new construction example):**

- Site Area: 1.5 acres
- Existing Conditions: undeveloped, wooded/grassed, 0% impervious
- Proposed Conditions: grassed/paved, 80% impervious

**Compute the water quality volume**

\[
R_v = 0.05 + 0.009 \times I \\
= 0.05 + 0.009 \times 80 \\
= 0.77
\]

\[
WQ_v = 1.2 \times R_v \times A \times 43,560/12 \\
= 1.2 \times 0.77 \times 1.5 \times 43,560/12 \\
= 5,032 \text{ ft}^3
\]
**Water Quality Volume (WQ\textsubscript{V}) Example**

Given (redevelopment/improvement example):

- Site Area: 1.5 acres
- Existing Conditions: grassed/paved, 60% impervious
- Proposed Conditions: grassed/paved, 80% impervious

**Compute the water quality volume**

\[
\begin{align*}
R_{\text{Vexist}} &= 0.05 + 0.009 \times I \\
&= 0.05 + 0.009 \times 60 \\
&= 0.05 + 0.54 \\
&= 0.59
\end{align*}
\]

\[
\begin{align*}
R_{\text{Vprop}} &= 0.05 + 0.009 \times I \\
&= 0.05 + 0.009 \times 80 \\
&= 0.05 + 0.72 \\
&= 0.77
\end{align*}
\]

\[
\begin{align*}
R_{\text{vnet}} &= R_{\text{Vprop}} - R_{\text{Vexist}} \\
&= 0.77 - 0.59 \\
&= 0.18
\end{align*}
\]

\[
\begin{align*}
WQ_{\text{V}} &= 1.2 \times R_{\text{V}} \times A \times 43,560/12 \\
&= 1.2 \times 0.18 \times 1.5 \times 43,560/12 \\
&= 1,176 \text{ ft}^3
\end{align*}
\]
## Post-Construction Stormwater BMPs

<table>
<thead>
<tr>
<th>BMP</th>
<th>TSS</th>
<th>Total Phosphorus</th>
<th>Total Nitrogen</th>
<th>Fecal Coliform</th>
<th>Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter Strip</td>
<td>60 %</td>
<td>20 %</td>
<td>20 %</td>
<td></td>
<td>40 %</td>
</tr>
<tr>
<td>Grass Channel</td>
<td>50 %</td>
<td>25 %</td>
<td>20 %</td>
<td></td>
<td>30 %</td>
</tr>
<tr>
<td>Enhanced Dry Swale</td>
<td>80-100%</td>
<td>50-100 %</td>
<td>50-100 %</td>
<td></td>
<td>40-100 %</td>
</tr>
<tr>
<td>Enhanced Wet Swale</td>
<td>80 %</td>
<td>25 %</td>
<td>40 %</td>
<td></td>
<td>20 %</td>
</tr>
<tr>
<td>Infiltration Trench</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sand Filter</td>
<td>80 %</td>
<td>50 %</td>
<td>25 %</td>
<td>40 %</td>
<td>50 %</td>
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<tr>
<td>Dry Detention Basin</td>
<td>60 %</td>
<td>10 %</td>
<td>30 %</td>
<td></td>
<td>50 %</td>
</tr>
<tr>
<td>Wet Detention Pond</td>
<td>80 %</td>
<td>50 %</td>
<td>30 %</td>
<td>70 %</td>
<td>50 %</td>
</tr>
<tr>
<td>Stormwater Wetland – Level I</td>
<td>80 %</td>
<td>40 %</td>
<td>30 %</td>
<td>70 %</td>
<td>50 %</td>
</tr>
<tr>
<td>Stormwater Wetland – Level II</td>
<td>85 %</td>
<td>75 %</td>
<td>55 %</td>
<td>85 %</td>
<td>60 %</td>
</tr>
<tr>
<td>Bioslope</td>
<td>85 %</td>
<td>60 %</td>
<td>25 %</td>
<td>60 %</td>
<td>75 %</td>
</tr>
<tr>
<td>OGFC</td>
<td>50 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioretention</td>
<td>85 %</td>
<td>80-100 %</td>
<td>60-100 %</td>
<td>90-100 %</td>
<td>95-100 %</td>
</tr>
</tbody>
</table>
If pollutant removals are not achieved by one BMP alone, multiple BMPs in series can achieve the required removal rates.
Post-Construction Stormwater BMPs

Total TSS removal = BMP1 removal rate + [(remaining TSS)(BMP2 removal rate)] + ...

OGFC + Filter Strip in series: 50% + [(50%)(60%)] = 80%

OGFC (50%)
Filter Strip (60%)
Removal Rate Achieved!
Post-Construction Stormwater BMPs

Common BMPs used in series to obtain 80% TSS removal:

Filter strip + grass channel: $\text{60\%} + [(\text{40\%})(\text{50\%})] = \text{80.0\%}$

Grass channel + filter strip: $\text{50\%} + [(\text{50\%})(\text{60\%})] = \text{80.0\%}$

OGFC* + filter strip: $\text{50\%} + [(\text{50\%})(\text{60\%})] = \text{80.0\%}$

OGFC* + dry detention: $\text{50\%} + [(\text{50\%})(\text{60\%})] = \text{80.0\%}$

*OGFC must first be approved by GDOT Office of Materials
Channel Protection Volume

How to calculate channel protection volume

CPv is based on basin area and 1-yr, 24-hr post-developed runoff depth:

\[
CP_v = Q_{1,24} \times \frac{A}{12}
\]

to obtain \( CP_v \) in ft\(^3\), convert A (acres) to ft\(^2\):

\[
CP_v = Q_{1,24} \times A \times 3,630
\]

Multi-step process to calculate \( Q_{1,24} \):
- determine post-developed CN and initial abstraction
- determine rainfall depth
- determine runoff volume
Channel Protection (CPv) Example

**Given:**
- Site near Savannah, GA
- Total drainage area: 1.5 acres
- Land cover: 0.3 acres grass (CN 61), 1.2 acres pavement (CN 98)
- Impervious area: 80%
- Tc: 6 minutes

**Compute the channel protection volume**
### Channel Protection ($CP_v$) Example

1. **Compute CN, S, $I_a$**
2. **Obtain NOAA Rainfall Data**
3. **Compute $I_a/P$, Q, and CPv**
4. **Use $q_u$ charts in Drainage Manual**
5. **Use $q_o/q_i$ chart in Drainage Manual**
6. **Compute $V_s/V_r$**
7. **Compute Vs**

---

**Curve Number**

$$CN = \frac{(1.2 \times 98) + (0.30 \times 61)}{1.5} = 91$$

**Ultimate Abstraction**

$$S = \frac{1000}{CN} - 10 = \frac{1000}{91} - 10 = 0.99 \text{ inches}$$

**Initial Abstraction**

$$I_a = 0.2 \times S = 0.198 \text{ inches}$$
Channel Protection (CP\textsubscript{v}) Example

1. Compute CN, S, I\textsubscript{a}

2. Obtain NOAA Rainfall Data

3. Compute I\textsubscript{a}/P, Q, and CP\textsubscript{v}

4. Use q\textsubscript{u} charts in Drainage Manual

5. Use q\textsubscript{o}/q\textsubscript{i} chart in Drainage Manual

6. Compute Vs/Vr

7. Compute Vs

---

**PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)\textsuperscript{1}**

<table>
<thead>
<tr>
<th>Duration</th>
<th>Average recurrence interval (years)</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>500</th>
<th>1000</th>
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<tr>
<td>5-min</td>
<td>0.550</td>
<td>0.620</td>
<td>0.734</td>
<td>0.829</td>
<td>0.960</td>
<td>1.27</td>
<td>1.97</td>
<td>3.16</td>
<td>4.60</td>
<td>11.50</td>
<td>1.994</td>
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<tr>
<td>10 min</td>
<td>0.806</td>
<td>0.908</td>
<td>1.17</td>
<td>1.21</td>
<td>1.41</td>
<td>1.55</td>
<td>1.78</td>
<td>1.80</td>
<td>2.60</td>
<td>2.21</td>
<td>2.70</td>
</tr>
<tr>
<td>15 min</td>
<td>0.983</td>
<td>1.11</td>
<td>1.31</td>
<td>1.21</td>
<td>1.38</td>
<td>1.72</td>
<td>2.08</td>
<td>2.26</td>
<td>2.95</td>
<td>2.51</td>
<td>2.70</td>
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<tr>
<td>30 min</td>
<td>1.19</td>
<td>1.58</td>
<td>1.88</td>
<td>2.15</td>
<td>2.59</td>
<td>3.04</td>
<td>3.67</td>
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<td>5.11</td>
<td>5.56</td>
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<td>60 min</td>
<td>1.79</td>
<td>2.04</td>
<td>2.44</td>
<td>2.79</td>
<td>3.29</td>
<td>3.69</td>
<td>4.08</td>
<td>4.52</td>
<td>5.11</td>
<td>5.56</td>
<td>7.51</td>
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<td>2-hr</td>
<td>2.20</td>
<td>2.49</td>
<td>3.00</td>
<td>3.44</td>
<td>4.08</td>
<td>4.60</td>
<td>5.15</td>
<td>5.74</td>
<td>6.54</td>
<td>7.18</td>
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<td>2.75</td>
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<td>7.51</td>
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<td>11.2</td>
<td>12.5</td>
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<td>5.83</td>
<td>7.01</td>
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<td>10.7</td>
<td>12.6</td>
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<tr>
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<td>4.18</td>
<td>4.87</td>
<td>5.55</td>
<td>6.61</td>
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<td>9.34</td>
<td>10.7</td>
<td>12.6</td>
<td>16.7</td>
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\textsuperscript{1}PDS-based precipitation frequency estimates with 90% confidence intervals (in inches) are provided for various durations and recurrence intervals. The values in the table are in inches.
Channel Protection (CP_v) Example

1. Compute CN, S, Ia
2. Obtain NOAA Rainfall Data
3. Compute Ia/P, Q, and CPv
4. Use q_u charts in Drainage Manual
5. Use q_o/q_i chart in Drainage Manual
6. Compute Vs/Vr
7. Compute Vs

Initial Abstraction Fraction

\[ \frac{I_a}{P} = 0.05 \]

Runoff Depth

\[ Q''_{1,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)} = \frac{(3.71 - 0.2 \times 0.99)^2}{(3.71 + 0.8 \times 0.99)} = 2.74 \text{ inches} \]
Channel Protection Volume

\[
CP_v = Q_{1,24} \cdot A \cdot 3,630
\]

\[
CP_v = 2.74 \text{ inches} \cdot 1.5 \text{ acres} \cdot 3,630
\]

\[
CP_v = 14,919.3 \text{ ft}^3
\]
Channel Protection (CPv) Example

1. Compute CN, S, Ia
2. Obtain NOAA Rainfall Data
3. Compute Ia/P, Q, and CPv
4. Use q_u charts in Drainage Manual
5. Use q_o/q_i chart in Drainage Manual
6. Compute Vs/Vr
7. Compute Vs

CPv Released over 24 hours

\[
14,919 \text{ ft}^3 \div 24 \frac{\text{Hrs}}{\text{Day}} \div 60 \frac{\text{Min}}{\text{Hr}} \div 60 \frac{\text{Sec}}{\text{Min}} = 0.17 \text{ cfs average}
\]

Maximum Peak Discharge

\[
0.17 \text{ cfs average} \times 2 = 0.34 \text{ cfs}
\]
Channel Protection ($CP_v$) Example

1. Compute CN, S, Ia
2. Obtain NOAA Rainfall Data
3. Compute $I_a/P$, $Q$, and $CP_v$
4. Use $q_u$ charts in Drainage Manual
5. Use $q_o/q_i$ chart in Drainage Manual
6. Compute $Vs/Vr$
7. Compute $Vs$

$q_u = 650$
Channel Protection (CP_v) Example

1. Compute CN, S, I_a
2. Obtain NOAA Rainfall Data
3. Compute I_a/P, Q, and CP_v
4. Use q_u charts in Drainage Manual
5. Use q_o/q_i chart in Drainage Manual
6. Compute Vs/Vr
7. Compute Vs

q_o/q_i = 0.03

This chart is for CP_v calculations only, do not use for other detention calculations.
Channel Protection ($CP_v$) Example

1. Compute CN, S, Ia
2. Obtain NOAA Rainfall Data
3. Compute $I_a/P$, $Q$, and $CP_v$
4. Use $q_o/q_i$ chart in Drainage Manual
5. Use $q_u$ charts in Drainage Manual
6. Compute $Vs/Vr$
7. Compute $Vs$

Required Storage Volume to Runoff Volume Ratio

$$\frac{V_S}{V_R} = 0.682 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3$$

$$\frac{V_S}{V_R} = 0.682 - 1.43(0.03) + 1.64(0.03)^2 - 0.804(0.03)^3 = 0.64$$
Channel Protection ($CP_v$) Example

1. Compute $CN$, $S$, $I_a$
2. Obtain NOAA Rainfall Data
3. Compute $I_a/P$, $Q$, and $CPv$
4. Use $q_o/q_i$ chart in Drainage Manual
5. Use $q_u$ charts in Drainage Manual
6. Compute $Vs/V_r$
7. Compute $Vs$

**Required Storage Volume**

\[ V_s = \left( \frac{V_s}{V_r} \right) \times Q \times A \times 3630 \]

\[ = 0.64 \times 2.74 \times 1.5 \times 3630 \]

\[ = 9,548 \text{ ft}^3 \]
Channel Protection Volume

What does channel protection look like?

Storage Volume (CPv)

Discharge over 24 hours

Hyd No. 3

Hyd No. 2
Overbank Flood Protection

Pre- vs. post-developed comparison of peak flows

• Use NRCS method (hand calculations or modeling software) to determine 25-year peak flow for both conditions

• Determine storage volume and outlet control necessary to match pre-developed flow

• Note: Channel protection volume attenuation typically provides a significant portion of the volume required for overbank flood protection
Overbank Flood Protection

What does overbank flood protection look like?

- Post-Developed
- Pre-Developed
- Routed
Extreme Flood Protection

Pre- vs. post-developed comparison of peak flows

• Use NRCS method (hand calculations or modeling software) to determine 100-year peak flow for both conditions

• Check for safe conveyance of 100-year flows

• Ensure downstream flooding is not exacerbated

• Ensure downstream infrastructure is not impacted by increased 100-year flows
When using detention, perform a downstream analysis to ensure no adverse impacts to properties/structures downstream:

- Identify potential impact locations downstream
- Evaluate impacts on those locations

**Note:** In Georgia, we analyze impacts at locations up to a point where the project’s outfall basin makes up 10% of a larger basin
Downstream Analysis

Why we perform downstream analysis

Check for adverse impacts created by peak timing shift due to detention.

Before Development

After Development
Questions

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