Virginia Beach Stormwater Master Plan Model

Model Content and Application Technical Guidance
Meeting Outline

- Introduction
  - Overview
  - Source data and datum

- Methodology
  - Hydrology
  - Hydraulics
  - Boundary conditions
  - Model validation

- Master plan model application
  - Master plan model application
  - Master plan model limitations
  - Examples
City Watersheds and Model Status
Model Software

Storm Water Management Model (SWMM)

Computational Hydraulics International
Model Resolution

Primary stormwater management system (PSMS):

- Open channels and pipes 24-inch diameter and larger
- Stormwater Management Facilities (SWMF)
- Overland flow paths
- 2-D modeling where applicable
- Based on Public Works Stormwater Infrastructure GIS
- Models continue downstream to MS4 outfall and/or tidal boundary condition
- North American Vertical Datum of 1988 (NAVD 88)
  - Included conversions from NGVD 1929 and NGVD 1929 with 1972 adjustment
Hydrology

<table>
<thead>
<tr>
<th>Outlet</th>
<th>10260-270</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ac)</td>
<td>5.51</td>
</tr>
<tr>
<td>Width (ft)</td>
<td>544.82</td>
</tr>
<tr>
<td>Flow Length (ft)</td>
<td>440.541</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Hydrology

Flow Width (three-path approach)

Lx: Flow path length
Sx: Flow path slope
Wx: Flow path width
Hydrology

- Subbasin Runoff Parameters (Landuse)
  - Impervious area
  - Surface runoff roughness (Manning's Roughness Coefficient)
  - Initial abstraction (Depression storage)
  - Subarea routing (Impervious OR pervious)
  - Percent routed between subareas
  - Flow routing method (Kinematic/Dynamic Wave)

<table>
<thead>
<tr>
<th>Imperv. (%)</th>
<th>49.97</th>
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<tbody>
<tr>
<td>N Imperv</td>
<td>0.018</td>
</tr>
<tr>
<td>N Perv</td>
<td>0.178</td>
</tr>
<tr>
<td>Dstore Imperv (i)</td>
<td>0.1</td>
</tr>
<tr>
<td>Dstore Perv (in)</td>
<td>0.15</td>
</tr>
<tr>
<td>Zero Imperv (%)</td>
<td>25</td>
</tr>
<tr>
<td>Subarea Routin</td>
<td>PERVIOUS</td>
</tr>
<tr>
<td>Percent Routed</td>
<td>15.8</td>
</tr>
</tbody>
</table>

Attributes

- Name: WS6_LB_81
- X-Coordinate: 12183446.58
- Y-Coordinate: 3464108.301
- Description
- Tag: 6
- Rain Gage: Universal
- Outlet: 06_1496341053
- Area (ac): 11.12
- Width (ft): 2017
- Flow Length (ft): 240.152
- Slope (%): 6.52
- Imperv. (%): 49.97
- N Imperv: 0.018
- N Perv: 0.178
- Dstore Imperv (i): 0.1
- Dstore Perv (in): 0.15
- Zero Imperv (%): 25
- Subarea Routin: PERVIOUS
- Percent Routed: 15.8

Notes

- Curb Length: 0
- Snow Pack: 0
- LID Controls: 0
- LID Names:
- Groundwater: NO
- Erosion: NO
Hydrology (Rainfall Patterns and Inputs)

- Historical rainfall (Rain gauge data) for model calibration

- Design storm rainfall for master plan simulations
  - NOAA Atlas 14 Type C
  - One set of rainfall hyetographs for the entire City

- Rainfall depth
  - Based on values at the Centroid of the City (Watershed 6)

- Temporal pattern
  - Based on shape of 25-year rainfall hyetograph
Hydrology (Rainfall Patterns and Inputs)

NOAA Atlas 14 Type C Hyetograph
Hydrology (Rainfall Patterns and Inputs)

Choose a Time Series for Raingage Universal

- **03LONDONBRIDGE_Sep...**
- **03LondonBridge31Mar20...**
- **03LONDONBRIDGEOct**
- **100Yr_Type_C**
- **10-yrTypeC**
- **16Plaza_Sep16**
- **16Plaza31Mar2017**
- **16PlazaOcc**
- **18GREENRUN_Sep16**
- **18GREENRUN31Mar2017**
- **18GREENRUNOcc**
- **1Yr_Type_C**
- **1-yrTypeC**
- **25Yr_Type_C**
- **25-yrTypeC**
- **2Yr_Type_C**
- **2-yrTypeC**

**Name:**

- **100-yrTypeC**

**Description:**

For Local Type C rainfall, 100-yr volume, distribution based on 100-yr storm.

- **Use external data file named below**

**Enter time series data in the table below**

<table>
<thead>
<tr>
<th>Date (M/D/Y)</th>
<th>Time (H:M)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/1/2015</td>
<td>0:00</td>
<td>0</td>
</tr>
<tr>
<td>0.06</td>
<td>0.004725</td>
<td></td>
</tr>
<tr>
<td>0.12</td>
<td>0.009639</td>
<td></td>
</tr>
<tr>
<td>0.18</td>
<td>0.0148365</td>
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<td>0.24</td>
<td>0.020223</td>
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<td>0.30</td>
<td>0.0257985</td>
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<td>0.36</td>
<td>0.0316575</td>
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<td>0.42</td>
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<td>0.48</td>
<td>0.0439425</td>
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<td>0.54</td>
<td>0.0503685</td>
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<tr>
<td>1.00</td>
<td>0.057078</td>
<td></td>
</tr>
</tbody>
</table>

[Graph showing data points and trend line]
Hydrology

- **Infiltration (Soil)**
  - Modified Green-Ampt infiltration
    - Suction Head
    - Conductivity
    - Initial Deficit

\[ Q = W \left( \frac{d - d_0}{d_0} \right)^{5/3} S^{1/2} \]
Hydraulics (2-D Area)

2D Grid
Hydraulics (2-D Area)

Dense 2D Grid along roads
Hydraulics (Lake and SMF Example)

Lake Trashmore (storage)

Pipe Length: 147 ft

Model Schematic Length: 660 ft
Hydraulics – Stage Area Relationships

- Conveyance system storage: Stage-area-storage in open (irregular) conduits
- Surface storage at storage nodes: stage-storage area relationships computed from topography (LiDAR and GIS)
- Approach foundation: No double-counting surface area and conveyance system storage
• Irregular links used to equalize flood depths between neighboring subbasins
Hydraulics – Overflow links

- Link transect computed from topography (LiDAR and GIS)

<table>
<thead>
<tr>
<th>Name</th>
<th>O_04520-460:04540-170</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>[Blank]</td>
</tr>
<tr>
<td>Left encroachment station</td>
<td>0</td>
</tr>
<tr>
<td>Right encroachment station</td>
<td>0</td>
</tr>
</tbody>
</table>

**Properties:**

**Bank Stations**

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31.86</td>
<td>95.58</td>
</tr>
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</table>

**Modifiers**

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
<th>Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Roughness**

<table>
<thead>
<tr>
<th></th>
<th>Left Bank</th>
<th>Right Bank</th>
<th>Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.02</td>
<td>0.04</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Value of Manning's roughness for the left overbank portion of the Transect.
Model Representation of Rim

- Ground Elevation at 04520-460: 7.1 ft NAVD 88
- Model rim: 17.1 ft
Model Validation

- Historical rainfall events based on flood call history
- Observed and field surveyed high water elevations from 2016
- 10-year event profile compared with VDOT hydraulic grade line calculation
Coordination and References

Section 2 Model Approach

NEEDED: Pictures to Update the City’s Master Drainage Plans

- [https://www.vbgov.com/government/departments/public-works/storm-water/Pages/storm-pics-master-drain-plan-6-8-17.aspx](https://www.vbgov.com/government/departments/public-works/storm-water/Pages/storm-pics-master-drain-plan-6-8-17.aspx)

Comprehensive Sea Level Rise

Master Plan Model Application
Master Plan Model Application

- Flows and water surface elevations in the PSMS
- Locations with surcharging in the PSMS
- Performance of storage facilities
- Overland flow between subbasins
- Surface flooding (storage node water surface elevations)
- Influence of downstream tidal conditions
Additional Master Plan Model Applications

1. Site specific evaluations
   a. Tailwater to support site design
   b. System flow-routing understanding, “what-if” scenarios for downstream impacts and improvements

2. Starting Point for refined site-specific evaluations
   a. Site specific topography and critical elevations
   b. Site specific drainage features
   c. System flow-routing refinements

3. Intent: Provide information and tools to assist with engineering evaluations and compliance with DPW Standards
Model Application – Tailwater Conditions

- Profile view through Thalia Creek

- Tailwater during 100YR Event

- Time: 9/10/2015 12:05:06 AM

- I 264
- Bonney Road
- Constitution Drive Trib.
- VB Blvd
- Thalia Creek Outfall

- Thalia Creek
- Thalia Creek Outfall
- Overflow Conduits
- Irregular Conduit (Trib.)
- 6 barrel 8' x 7' RCB
- 15” RCP
- Thalia Creek
Model Application – Subbasin Conditions

- **Peak overland flow:** 72.7 cfs
- **Peak storage junction HGL:** 11.46 ft NAVD
- **Peak manhole HGL:** 11.37 ft NAVD
- **Peak pipe flow:** 16.8 cfs
Master Plan Model Limitations

- Results based on available data:
  - GIS stormwater infrastructure
  - GIS invert elevations
  - LiDAR topography data
  - City impervious area
  - City land use
  - City soils data (from NRCS)
- Areas upstream of the modeled PSMS
- Overland flow within a single subbasin located upstream of the subbasin storage node
Example Application for Site of Interest

Project Location: Virginia Beach Boulevard and N Budding Drive
Example Application for Site of Interest
Steep gradient from edge of catchment to storage node

- Desired boundary conditions: 10-year and 100-year HGL
  - Ground elevation 8 feet
  - 10-year HGL = 9.3 feet and 100-year HGL = 10.1 feet
Application for Site of Interest

- Overflow at ground level added from node of concern (04520-494) to the storage node downstream in subbasin 34.

Model 1: Before adding overland flow conduit
Additional Overland Flow Path
Refined Model Results

Model 1 – no overflow link

Model 2 – overflow link added
Refined Model Results

- Desired boundary conditions: 10-year and 100-year HGL
  - Ground elevation 8 feet
  - 10-year HGL = 8.5 feet and 100-year HGL = 8.7 feet
Example Model Refinement

Watershed 10
Veteran Care Center

Master Plan Model Refinement to Reflect Existing Conditions
Example Model Refinement

Step 1:

- Delete all the nodes and links that will be updated/replaced with refined data
Step 2:

- Update the delineation and runoff parameters of the subbasins to represent the new development.
- In this example, it involves splitting two subbasins into six subbasins.
Example Model Refinement

Step 3:

- Add storage nodes to represent surface storage and detention facilities.
- Storage nodes for surface storage are assigned to the subbasin “Outlet”
- Add junctions along the hydraulic system
Example Model Refinement

Step 4:
- Add links to represent the hydraulic system:
  - Open channels
  - Stormwater pipes
Example Model Refinement

Step 5:

- Add overland flow paths connecting adjacent subbasins and the hydraulic system
Example Model Refinement

Step 6a:
- Build and assign a stage-storage curve for each storage node
Example Model Refinement

Step 6b:

- Assign a transect for each open channel, ditch and overland flow path
Example Model Refinement: Storage Assignment
Example Model Refinement: Storage Assignment

- Critical to not double count storage
- Define ditch storage and overbank storage separately
Example Model Refinement: Storage Assignment

Ditch Storage: Transect
Example Model Refinement: Storage Assignment

Subbasin (Overbank) Storage Node
Example Model Refinement

Overview of model refinement elements

- Design drawings or “As-Built” drawings
- GIS refinements (additional pipes and nodes)
- Additional control structures (not in GIS)
- Import new GIS
- Refine subbasins and process parameters
- Storage curves
- New open channels
- New overland flow links
- Initial depths