Lower Dudley Branch Flood Study: A 2D Hydraulic Analysis

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Purpose/Background

- Why the project was necessary
- What the end result will be used for
When 2D is a better option than 1D...

- Where 1D models have limitations
  - Complex patterns
  - Multiple confluences
  - Split flows
- Timing and volume as river overflows or spills
- Diversions
- Spill in undefined flow path
- Flow is allowed to spread out
- No interpolating on floodplain
When is 2D a better option than 1D...
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When is 2D a better option than 1D...
Software selection

- Various 2D software available
  - XP-SWMM
  - InfoWorks RS or ICM
  - MIKE Flood

- Why we selected XP-SWMM
  - FEMA approval
  - Model results review, XP-SWMM reader
  - Coupled 1D/2D Model
2D Scoping Considerations

• Inputs & Parameters
  – Topography (LiDAR)
  – Survey
  – As-built Plans
  – Hydrology
  – Existing Models
  – Data and File Size requirements

• Results
  – Calibration/validation
  – Review Plan
  – Output Format
  – End Uses (Planning, Design, CLOMR/LOMR)
  – Comparisons to effective BFEs
Know What to Expect

• Large files
  – Multiple GBs (2 GB+ per simulation)

• “Unlimited” may vary depending on hardware

• Qualified Reviewers

• Deliverables (GIS data, model output, animations, reports)
Lower Dudley Branch Flood Study: Approach/Methodology

- **Model Schematic**
  - 1D links: Inflow into 2D
    - FEMA or USACE CDC HEC-RAS
    - FEMA or USACE CDC HEC-1
    - or HEC-HMS hydrographs
  - 2D Area
    - LiDAR/Topo
    - 1D/2D Interface lines
    - Boundary Conditions
  - Back into 1D Domain
Lower Dudley Branch Flood Study: Model Development
Lower Dudley Branch Flood Study: Model Development

1D Inflow
HEC-HMS
HEC-1
Lower Dudley Branch Flood Study: Model Development

• 2D Surface
Lower Dudley Branch Flood Study: Model Development

- **Approach/Methodology**
  - 2D area

  - LiDAR/Topo ➔ DTM ➔ Point Grid ➔ XPTIN

- Topo Under Bridge
- Breaklines
Lower Dudley Branch Flood Study: Model Development

- **Approach/Methodology**
  - 2D area
    - LiDAR/Topo → DTM → Point Grid → XPTIN
  - ESRI Terrain
Lower Dudley Branch Flood Study: Model Development

- **Approach/Methodology**
  - 2D area

  ![Diagram](image-url)

  - LiDAR/Topo ➔ DTM ➔ **Point Grid** ➔ XPTIN
Lower Dudley Branch Flood Study: Model Development

- **Approach/Methodology**
  - 2D area

  LiDAR/Topo → DTM → Point Grid → XPTIN
Lower Dudley Branch Flood Study: Model Development

- **Approach/Methodology**
  - Back into 1D domain
  - Uses 1D-2D interface
    - Captures flow
    - Compares WSEL
  - Used single 1D node
Lower Dudley Branch Flood Study: Model Development
## Lower Dudley Branch Flood Study: Results to Date

### Data:
- 2D Results compared to FEMA RAS models
- 2D Results compared to DFIRM Floodplain
- 2D Results compared to DFIRM BFEs
- Routed hydrology

### Differences
- Steady State Direct Step vs. Unsteady St. Venant & SWE.
- Output interpolation detail
- Ground surface models???
- 1D vs. 2D, not unidirectional
- Steady vs. Unsteady & 1D vs. 2D Attenuation
## Lower Dudley Branch Flood Study: Results to Date

- **2D vs. RAS at Select Locations**

<table>
<thead>
<tr>
<th>Location (Physical Description)</th>
<th>RAS River Station</th>
<th>XPSWMM WSEL (ft)</th>
<th>HEC-RAS WSEL (ft)</th>
<th>Δ (ft)</th>
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</thead>
<tbody>
<tr>
<td>Downstream reach of model</td>
<td>76475</td>
<td>439.22</td>
<td>438.33</td>
<td>0.89</td>
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<tr>
<td>Upstream of Beltline Bridge</td>
<td>87428</td>
<td>440.91</td>
<td>440.63</td>
<td>0.28</td>
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<tr>
<td>Upstream of Sandy Lake Bridge</td>
<td>93927</td>
<td>443.82</td>
<td>444.52</td>
<td>-0.7</td>
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<tr>
<td>Downstream of I35E Bridge</td>
<td>110074</td>
<td>450.89</td>
<td>450.44</td>
<td>0.45</td>
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<tr>
<td>Upstream of I35E Bridge</td>
<td>110475</td>
<td>451.7*</td>
<td>451.37</td>
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<tr>
<td>Downstream of SH121 Bridge North of RR Tracks</td>
<td>122744</td>
<td>453.8*</td>
<td>453.08</td>
<td>0.72</td>
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<tr>
<td>Downstream of SH121 Bridge South of RR Tracks</td>
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<td>453.3*</td>
<td>453.08</td>
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<tr>
<td>Upstream of SH121 Bridge North of RR Bridge</td>
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<td>453.9*</td>
<td>453.12</td>
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<tr>
<td>Upstream of SH121 Bridge South of RR Bridge</td>
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<td>453.4*</td>
<td>453.12</td>
<td>0.28</td>
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<tr>
<td>Upstream of Eisenhower Bridge</td>
<td>7065*</td>
<td>459.05</td>
<td>457.78</td>
<td>1.27</td>
</tr>
</tbody>
</table>

* Indicates approximate 2D water surface elevations. Actual elevations will vary over distance.

+ River station from Lower Dudley Branch model.
Lower Dudley Branch Flood Study: Results to Date

- 2D Results compared to DFIRM Floodplain
Lower Dudley Branch Flood Study: Results to Date

- 2D Results Compared to FEMA BFEs
Lower Dudley Branch Flood Study:
Results to Date

- Differences in flow routing due to higher attenuation in 2D area
**Lessons Learned**

- **Model setup**
  - LIDAR & Topo are KEY to stability
  - Stability = lower run times, better results

- **Diligence in defining LIDAR & survey areas**
  - Too much = wasted money
  - Not enough = bad model

- **Limitations of software**
  - Grid cell size is very important
  - Ability to model 1D structures
  - XPSWMM “Reader” difficulties

**Next Steps**

- Final Report to Client
- Discuss LOMR effort
- Potentially re-model tribus using TW condition (G&S Section C) and/or extending through the confluence to I35E.
Lower Dudley Branch Flood Study: Benefits of the Study

- New issues identified from 2D Analysis
  - Trib starting WSE
    - Not normal depth
    - Impacts trib WSE’s in highly urbanized reaches
  - Frankford Road Flooding
    - Not depicted in FEMA 1D Analysis
    - Corroborated by City Staff
  - Development Considerations
  - More detailed floodplain
Lower Dudley Branch Flood Study:
Benefits of the Study

Frankford Road Flooding:
FEMA 1D RAS Floodplain
Lower Dudley Branch Flood Study: Benefits of the Study

Frankford Road Flooding: 2D Results
Lower Dudley Branch Flood Study: Conclusions

• Why 2D
  – Complex confluences and mixing flows
  – Refine 1D Assumptions
    • Tailwater
    • Overflows

• Scoping Considerations
  – LiDAR/Topo Data
  – Large data sizes (16+ GB)
  – Know software limitations up front

• Modeling Considerations
  – Different Needs
  – 2D Results differ from 1D
    • Unsteady, Attenuation, Different set of equations, etc…

• Benefits
  – Can resolve 1D model assumptions
  – Identify potential issues missed by 1D.
Questions?