Numerical Simulation of Urban Ponding and Its Application in Beijing

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Background: Urban Ponding in Beijing

Introduction of BUW model

Simulation in Different Scenario

Risk Warning and its Application

Next Work and How to Cooperation
Beijing is a ponding-prone and fragile city

10 JUL 2004

21 JUL 2012

23 JUN 2011

17 JUN 2014
Beijing is a ponding-prone and fragile city

1. Underground Space Development: The hollow overpass, Subway……

All the above cannot be improved in the short term.

So the prediction and risk warning of urban ponding may be a practical breach for disaster prevention.

2. Too Much Impervious Underlying Surface
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Based on the complex terrain and large city characteristics, the geographic information of Beijing was cut into 6458 grids and 14607 channels (Resolution: 1km × 1km). Focused on the urban hydrodynamic and hydrographic process, the Beijing Urban Waterlogging (BUW) numerical model was built to simulate the ponding depth.
Driven by the rainfall data
Elevation is the most important factor
Flow on the surface and in the river is the main object simulated.
Physical Process: Rainfall-Ponding-Pipe Catchment-Pipe Drainage-River Catchment

The drainage network is not real and estimated from roads.
CASE: Torrential Rainstorm on 21 JUL 2012

Precipitation, maximum=541mm

Rainfall intensity in urban area from 10AM to 10PM

The warning grade which the maximum rainfall intensity achieved, (blue>20, yellow>30, orange>40, red>60, black means no warning, unit: mm/h)
CASE: Torrential Rainstorm on 21 JUL 2012
CASE: Torrential Rainstorm on 21 JUL 2012

78 DEAD

Distribution of urban road ponding
CASE: Torrential Rainstorm on 21 JUL 2012

1. Simulated spatial distribution well.
2. The depth in ABC areas is close.
3. The hard-hit Fangshan can be reflected.

But, the depth of area D is obviously lower.

Maximum ponding depth simulated by BUW
CASE: Torrential Rainstorm on 21 JUL 2012

Comparison between simulation and observation of “7.21” depth in concave bridge

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Simulation</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>莲花桥</td>
<td>1.77</td>
<td>0.65</td>
</tr>
<tr>
<td>五路桥</td>
<td>0.65</td>
<td>0.61</td>
</tr>
<tr>
<td>复兴门桥</td>
<td>0.61</td>
<td>0.62</td>
</tr>
<tr>
<td>安华桥</td>
<td>0.62</td>
<td>0.67</td>
</tr>
<tr>
<td>广渠门桥</td>
<td>0.67</td>
<td>0.69</td>
</tr>
<tr>
<td>十里河桥</td>
<td>0.69</td>
<td>0.64</td>
</tr>
<tr>
<td>双营桥</td>
<td>0.64</td>
<td>&gt;2</td>
</tr>
<tr>
<td>&gt;2</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>0.7-0.8</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2-3</td>
<td></td>
</tr>
<tr>
<td>金安桥</td>
<td>0.41</td>
<td>0.05</td>
</tr>
<tr>
<td>西苑桥</td>
<td>0.05</td>
<td>0.24</td>
</tr>
<tr>
<td>丽泽桥</td>
<td>0.24</td>
<td>0.48</td>
</tr>
<tr>
<td>六里桥</td>
<td>0.48</td>
<td>0.78</td>
</tr>
<tr>
<td>正阳桥</td>
<td>0.78</td>
<td>0.10</td>
</tr>
<tr>
<td>安定门桥</td>
<td>0.10</td>
<td>0.66</td>
</tr>
<tr>
<td>东便门桥</td>
<td>0.66</td>
<td></td>
</tr>
</tbody>
</table>

The depth simulated is almost slightly lower, but usable.

Simulation curves of hourly ponding depth in bridge zone
The spatial distribution, ponding time, duration, process, specially the maximum depth can be simulated well by BUW model for the four different combinations.
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Urban ponding simulation in different return-periods

The rainfall data-by-minute are used by Generalized Pareto Distribution (GPD) method to determined the 360-minute rainfall in different return-periods.

<table>
<thead>
<tr>
<th>Return Period</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Year</td>
<td>62.4</td>
</tr>
<tr>
<td>10-Year</td>
<td>98.8</td>
</tr>
<tr>
<td>50-Year</td>
<td>157.1</td>
</tr>
<tr>
<td>100-Year</td>
<td>208.2</td>
</tr>
</tbody>
</table>

Represent the standard of drainage networks used in Beijing now.

Sequence: 34.7, 34.7, 34.7, 34.7, 34.7, 34.7, 0, 0, 0, 0, 0
- There would be some isolated ponding points inside 4th Ring.
- And the ponding point occurred more in the south than in the north, mostly below 25 cm.

- Deeper and joint ponding inside 4th Ring.
- New ponding area between 4th and 5th Ring.
- Diminishing scale from east to the west and from south to the north.

Maximum ponding depth simulated under 2-yr (a), 10-yr (b) return-period scene.
More serious ponding points inside 5-Ring (25-80cm).
Deeper than 50cm gushed water around QINGLENG lake.

Server ponding in the whole 5-Ring, most exceeding 50cm in the south.
Ponding deeper than 80cm maybe caused by flash flood and concave bridge.

Maximum ponding depth simulated under 50-yr (c) and 100-yr (d) return-period
Faced the rainfall of “7.21” in different drainability

- 20% broadening of pipe diameter (120% PIPE)
- 60% broadening of pipe diameter (160% PIPE)
- 100% broadening of pipe diameter (200% PIPE)
- 140% broadening of pipe diameter (240% PIPE)

To assess the role of drainage network and supply for modified plan
Max ponding depth in “7.21” rainstorm with 1.2 (a), 1.6 (b) times pipe diameter

- Urban drainage would not be improved obviously with 20% broadening of pipe diameter.
- The ponding weakened distinctly between 4-Ring and 5-Ring and slightly inside 4-Ring in 60%+PD experiment.
Max ponding depth in “7.21” rainstorm with 2.0 (c), 2.4 (d) times pipe diameter

- When the pipe diameter were broadened continuously, there would no ponding inside 6-Ring in 140%+PD experiment.

- There would be only shallow ponding between 2-Ring and 4-Ring in 100%+PD experiment.
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Risk Warning Grades:

1. According to fording depth of motor vehicles

<table>
<thead>
<tr>
<th>Type</th>
<th>Fording Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Truck</td>
<td>1000-1200</td>
</tr>
<tr>
<td>Truck</td>
<td>450-800</td>
</tr>
<tr>
<td>Large Bus</td>
<td>500-800</td>
</tr>
<tr>
<td>Medium Bus</td>
<td>280-750</td>
</tr>
<tr>
<td>SUV</td>
<td>390-850</td>
</tr>
<tr>
<td>Car</td>
<td>270-600</td>
</tr>
</tbody>
</table>

2. Dividing Ponding Depth into 4 grades

<table>
<thead>
<tr>
<th>Grades</th>
<th>Range (mm)</th>
<th>Affected Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>100≤PD&lt;250</td>
<td>Pedestrian</td>
</tr>
<tr>
<td>Yellow</td>
<td>250≤PD&lt;500</td>
<td>Car, SUV and Medium Bus</td>
</tr>
<tr>
<td>Orange</td>
<td>500≤PD&lt;800</td>
<td>Large Bus and Truck</td>
</tr>
<tr>
<td>Red</td>
<td>PD ≥800</td>
<td>Heavy Truck</td>
</tr>
</tbody>
</table>
In actual service, three rainfall sequences are connected to drive the BUW model.

- The first 5-hr rainfall observation is used for spining-up and initializing ponding depth and pipe flow.
- The second 6-hr blending QPF and last 6-hr BJ-RUC rainfall forecast is used for simulating and forecasting the next 12-hr urban waterlogging risk.
Operator Platform

Auto Mode

Interactive Mode
Furthermore, a decision-making service system based on GIS was built to improve service effect. The ponding observation data and urban waterlogging risk warning update timely in this platform.
Probably 10 service platform used our product, mostly for decision-making.
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- Update the GIS data and drainage networks.
- Improve the description of concave bridge and foreign water.
- Develop the Road Ponding Model.
- Use the MPI parallel computing to raise efficiency.
- Add mountain boundary to suit the terrain in Beijing.
- Learn international achievement and improve BUW
Thank you