The Effects of Future Increases in Heavy Rain on Measure for the Prevention of Inundation in Urban Areas

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The 9th International Conference on URBAN DRAINAGE MODELLING
In recent years, rainfall exceeded 50 mm/h has occurred frequently in Japan.
Present inundation countermeasures need to be improved against heavy rain.

Today’s Topic

1. Increasing rate of heavy rain
2. Case studies about increase of heavy rain
3. Examples of stormwater storage systems
4. Effective use of stormwater
1. Increasing rate of heavy rain

Is heavy rain occurring more frequently?

- Analysis data from Japan Meteorological Agency
- Annual maximum 10-minute rainfall intensity
- Annual maximum 60-minute rainfall intensity
- For 50 years (1960–2009)
- 57 meteorological observatories
1. Increasing rate of heavy rain

- **5-year probability**
  Increasing rate for 50 years : 8%

- **10-year probability**
  Increasing rate for 50 years : 8%

- **5-year probability**
  Increasing rate for 50 years : 9%

- **10-year probability**
  Increasing rate for 50 years : 10%

Calculated by the Thomas plot method
1. Increasing rate of heavy rain

- Increasing rate of 5-year probable rainfall intensity for 50 years
- 57 meteorological observatories

![Graph showing the increasing rate of rainfall intensity](image-url)
1. Increasing rate of heavy rain

- Increasing rate of 10-year probable rainfall intensity for 50 years
- 57 meteorological observatories
2. Case studies about increase of heavy rain

- Image of Scenario Pattern

- Conventional planned rainfall intensities
- **Scenario A** (1.3 times Increase of 10-minute rainfall intensity)
- **Scenario B** (1.3 times Increase of 60-minute rainfall intensity)
- **Scenario C** (1.3 times Increases both of 10-minute rainfall intensity and 60-minute rainfall intensity)

- Object districts

<table>
<thead>
<tr>
<th></th>
<th>District X</th>
<th>District Y</th>
<th>District Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of drainage district (10^4 m^2)</td>
<td>3,350</td>
<td>62</td>
<td>1,900</td>
</tr>
</tbody>
</table>
2. Case studies about increase of heavy rain

<table>
<thead>
<tr>
<th>District name</th>
<th>District X</th>
<th>District Y</th>
<th>District Z</th>
</tr>
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<tbody>
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<td>Area of drainage district (10⁴ m²)</td>
<td>3,350</td>
<td>62</td>
<td>1,900</td>
</tr>
</tbody>
</table>

**Scenario A**
(Increase of 10-minute rainfall intensity)

<table>
<thead>
<tr>
<th>Increasing rate of inundation area* (inundation depth over 0.2 m)</th>
<th>0.7%</th>
<th>6%</th>
<th>0.4%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main region of inundation</td>
<td>-</td>
<td>Upstream</td>
<td>-</td>
</tr>
</tbody>
</table>

**Scenario B**
(Increase of 60-minute rainfall intensity)

<table>
<thead>
<tr>
<th>Increasing rate of inundation area* (inundation depth over 0.2 m)</th>
<th>7%</th>
<th>0%</th>
<th>7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main region of inundation</td>
<td>Midstream</td>
<td>-</td>
<td>Overall</td>
</tr>
</tbody>
</table>

**Scenario C**
(Increase of 10-minute and 60-minute rainfall intensity)

<table>
<thead>
<tr>
<th>Increasing rate of inundation area* (inundation depth over 0.2 m)</th>
<th>9%</th>
<th>6%</th>
<th>4%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main region of inundation</td>
<td>Midstream</td>
<td>Upstream, Midstream</td>
<td>Overall</td>
</tr>
</tbody>
</table>

*Increase rate of inundation area = ((Inundation area according to the scenario) – (Area inundated by conventional planned rainfall)) / (Total area)

✔ In regards to small catchment areas, it is important to consider the impact of short periods of rainfall.

✔ As for large catchment areas, improving the level of drainage over a wide area is effective.
Comprehensive inundation countermeasures

Reference: Sewage Works in Japan 2009 (Japan Sewage Works Association)
3. Examples of stormwater storage systems

- **Underground storage pipes**

- **Underground storage ponds**

- **Surface storage in parks**

- **Storage in paddy fields**

In recent years, **effective use of stormwater storage** is increasing in Japan.
4. Effective use of stormwater

- 154 stormwater utilization systems of 9 local governments

- Consideration of stormwater use like this figure is important in the efficient use of water resources.
Conclusions

1. Increasing rate of heavy rain

- 10-minute rainfall intensity and 60-minute rainfall intensity of 5 or 10 year probability are likely to increase, and the increasing rates are estimated 1.3 or 1.4 times in 50 years at most.

2. Case studies about increase of heavy rain

- In regards to small catchment areas, it is important to consider the impact of short periods of rainfall.
- As for large catchment areas, improving the level of drainage over a wide area is effective.
Conclusions

3. Examples of stormwater storage systems

- Underground pipes, underground ponds, surface in the parks, and in paddy fields as stormwater storage is increasingly effective in Japan.

4. Effective use of stormwater

- The major use of stormwater is *toilet water*, followed by sprinkler system, etc.

- Consideration of stormwater use is important in the efficient use of water resources.
The authors are deeply grateful to all staff members of local governments who cooperated with this research.

A part of this research is supported financially by Core Research for Evolutonal Science and Technology (CREST) Program "Innovative Technology and System for Sustainable Water Use" of Japan Science and Technology Agency (JST).
Trends of rainfall in the world

- Extremely heavy rain is increasing in Europe, North America and South America.*
- In the long term, total amount of rainfall is increasing in the Southern Hemisphere, but it's not changing significantly in worldwide.**

Reference: Japan Meteorological Agency

*http://www.data.kishou.go.jp/climate/cpdinfo/climate_change/2005/1.3.3.html
**Scenario patterns of rainfall intensity**

Rainfall Intensity was calculated by the formula which can calculate rainfall intensity **only from 10-minute rainfall and 60-minute rainfall.**

- **Conventional planned rainfall intensities**

- **Scenario A** (1.3 times Increase of 10-minute rainfall intensity)
Scenario patterns of rainfall intensity

- **Scenario B** (1.3 times Increase of 60-minute rainfall intensity)

- **Scenario C** (1.3 times Increases of 10-minute and 60-minute rainfall intensity)

To evaluate on more dangerous situation
In order to compare the results of a large catchment area and a small catchment area, we chose three districts.

<table>
<thead>
<tr>
<th>District name</th>
<th>District X</th>
<th>District Y</th>
<th>District Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drained method</td>
<td>Combined</td>
<td>Separate</td>
<td>Combined</td>
</tr>
<tr>
<td>Area of drainage district ($10^4$ m$^2$)</td>
<td>3,350</td>
<td>62</td>
<td>1,900</td>
</tr>
<tr>
<td>Runoff coefficient</td>
<td>0.45</td>
<td>0.60</td>
<td>0.82</td>
</tr>
<tr>
<td>Rainfall intensity (mm/hr)</td>
<td>34.3</td>
<td>50.0</td>
<td>53.4</td>
</tr>
<tr>
<td>60-minute rainfall intensity (mm/hr)</td>
<td>87.1</td>
<td>109.5</td>
<td>114.6</td>
</tr>
<tr>
<td>Minimum diameter of sewer pipe simulated (mm)</td>
<td>1,000</td>
<td>300</td>
<td>500</td>
</tr>
<tr>
<td>Software used for the simulations*</td>
<td>MOUSE</td>
<td>MOUSE</td>
<td>InfoWorks</td>
</tr>
</tbody>
</table>

* The model which each city was using for formulation of sewer plans

- Different characteristics of geographic and rainfall
- Adequate data for inundation simulation
Main region of inundation depends on size of catchment areas.

However, it's not clear only from this result. It is necessary to simulate in other districts.
Suitable countermeasures for each district considered from this research result

Small catchment area (District Y)

In regards to small catchment areas, it is important to consider the impact of short periods of rainfall.

So, peak cut type countermeasures are effective.

Large catchment area (District X, District Z)

As for large catchment areas, improving the level of drainage over a wide area is effective.

So, improvement in drainage capacity is effective. For example, it's the network of large-scale sewer pipes.
Underground storage pipes and underground storage ponds have benefit that large quantity for storage was ensured. However, construction of these takes high cost and long period.

Surface storage in parks and storage in paddy fields are cheaper than large storage systems, but require approval of the park manager or owner of paddy fields.
<table>
<thead>
<tr>
<th>Institution kind</th>
<th>Storage capacity (m³)</th>
<th>Time started to use</th>
<th>Purpose of use</th>
<th>Amount of annual use (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public office</td>
<td>1,095</td>
<td>Feb., 1990</td>
<td>Toilet water, Sprinkler system*¹</td>
<td>10,000</td>
</tr>
<tr>
<td>Public office</td>
<td>86</td>
<td>Oct., 2009</td>
<td>Toilet water, Sprinkler system</td>
<td>744</td>
</tr>
<tr>
<td>Public office</td>
<td>1,200</td>
<td>Jun., 2003</td>
<td>Cooling water<em>², Landscaping water</em>³</td>
<td>2,634</td>
</tr>
<tr>
<td>School</td>
<td>365.4</td>
<td>Apr., 1998</td>
<td>Toilet water, Sprinkler system</td>
<td>3,565</td>
</tr>
<tr>
<td>Communal facility</td>
<td>2,000</td>
<td>May., 1999</td>
<td>Toilet water</td>
<td>35,158</td>
</tr>
<tr>
<td>Tourist facility</td>
<td>500</td>
<td>Dec., 2000</td>
<td>Toilet water</td>
<td>6,000–7,000</td>
</tr>
</tbody>
</table>

*¹ Sprinkler system: Watering a tennis court, a garden, a road, etc.
*² Cooling water: Cooling an air conditioner, etc.
*³ Landscaping water: Creating a artificial river, a artificial pond, etc.
By conducting other simulations and investigations, the countermeasures which have effects in each district are found out.

We will visualize data on a map and exhibit the map on the Internet. By doing so, we promote effective use of stormwater.

Effective use of stormwater in storage systems is increasing, but the area is still restricted. For example, it is an area with few water resources.