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Estimation of a small number of combinations of parameter sets to describe multiple hydrographs by combinatorial optimization

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Introduction

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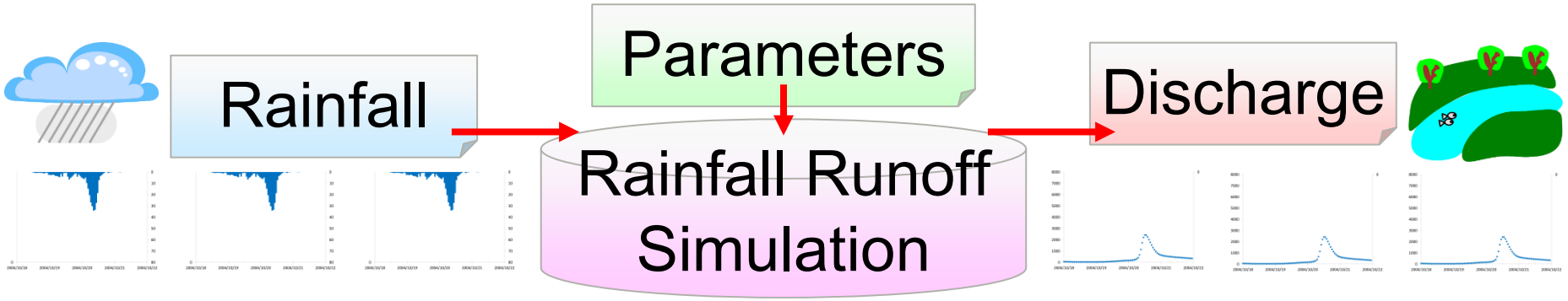
- Rainfall Runoff simulation



- Previous research
  - Single objective optimization
  - Multi objective optimization
  - Data assimilation
- Proposed method
  - Combinatorial optimization

Continuous optimization

Discrete optimization

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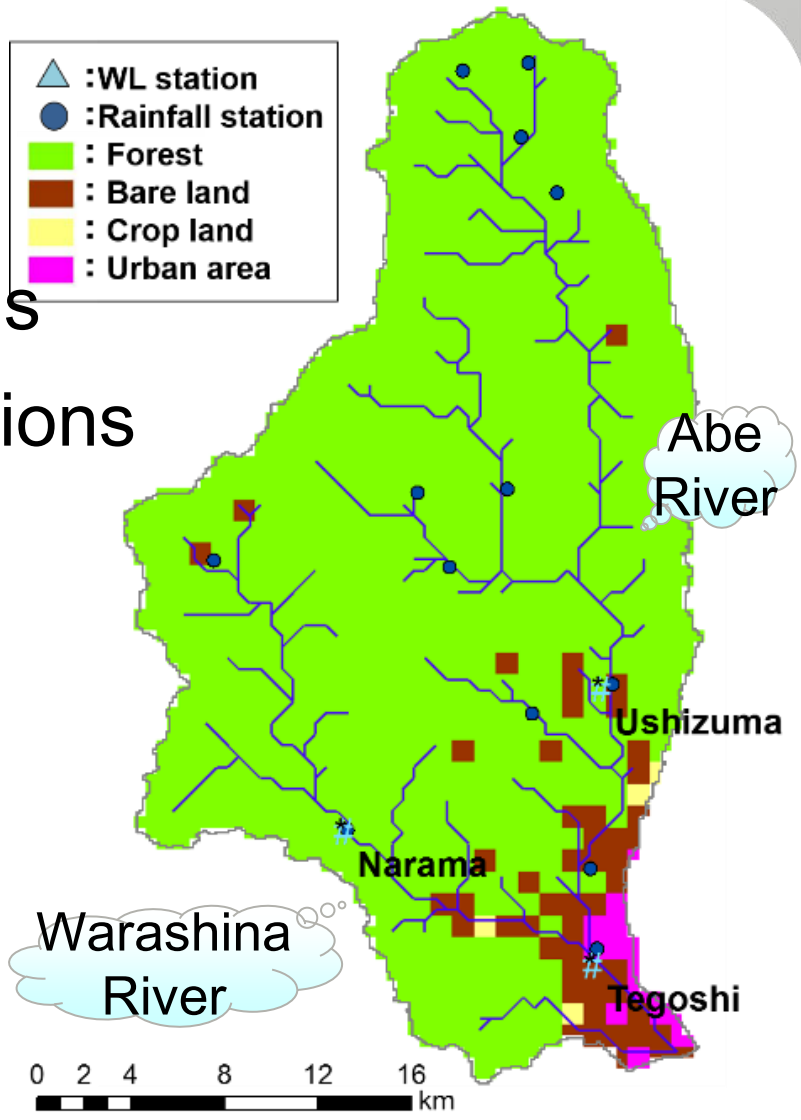
Target basin

- Abe River basin in Japan
  - 567.0 km^2
- 13 rainfall observation stations
- 3 water level observation stations
  - Upstream
    - Ushizuma … Abe River
    - Narama … Warashina River
  - Downstream
    - Tegoshi … Abe River
- 5 kinds of land uses
  - Almost covered with forest



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Target flood events

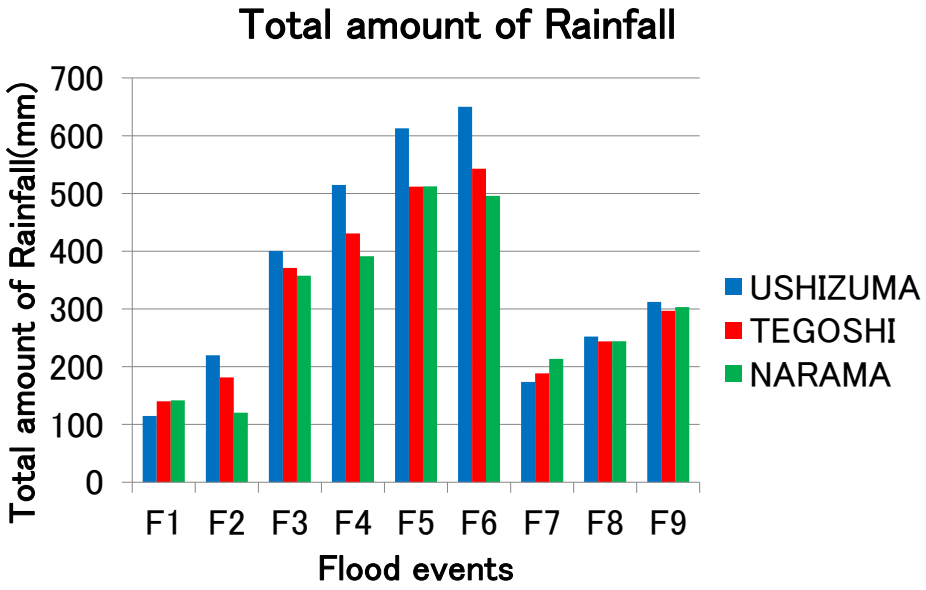
- 9 flood events x 3 water level stations
  - 27 hydrographs

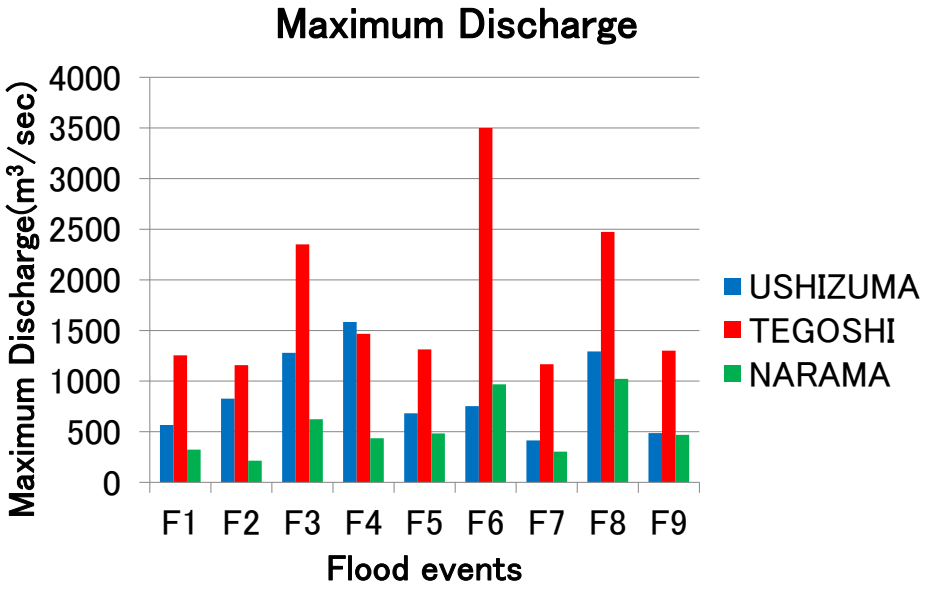
Month:
June to November

Simulation time:
2 to 8 days

Total amount of Rainfall:
115 to 650 mm

Maximum discharge:
214 to 3,501 m^3/s





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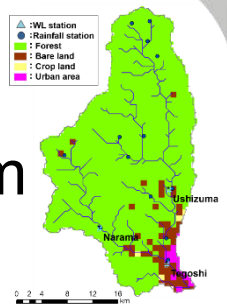
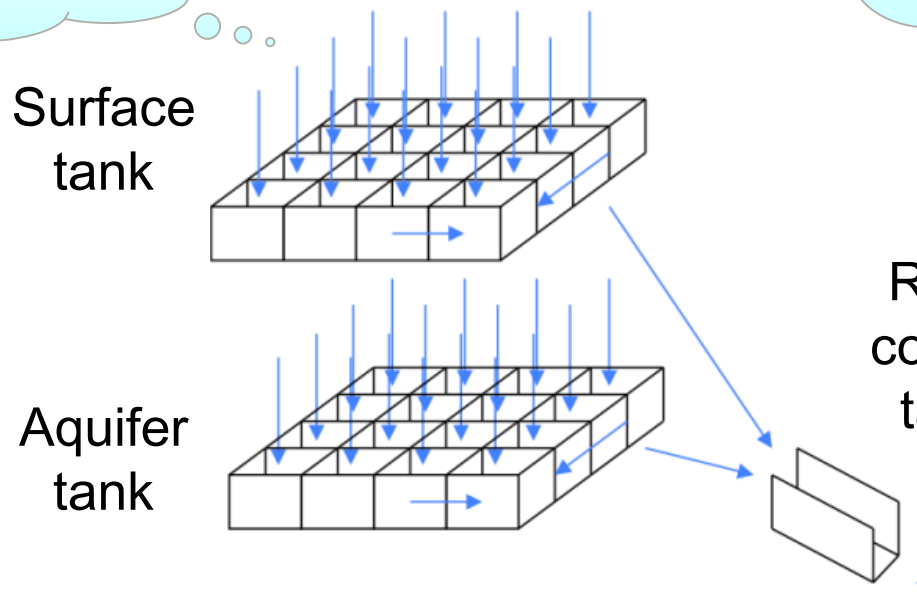
PWRI distributed hydrological model

- Researched and developed by ICHARM
  - Available in IFAS - Integrated Flood Analysis System
- Abe River Basin



2 layered tanks

Basin area
567.0 km^2



Mesh size
500 x 500 m

Total number of meshes
3,213

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Discharge calculation

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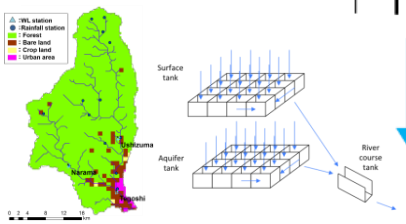

Evapotranspiration (option)

Rainfall

Surface flow (Manning's law)

5 types of land use

$$Q_{sf} = \frac{1}{N} L (h_s - S_{f2})^{\frac{5}{3}} \sqrt{i}$$

S_{f2}

h_s

S_{f0}

S_{f1}

Rapid unsaturated subsurface flow

$$Q_{ri} = \alpha_n A f_0 \frac{h_s - S_{f1}}{S_{f2} - S_{f1}}$$

Infiltration to subsurface tank or aquifer tank

$$Q_0 = A f_0 \frac{h_s - S_{f0}}{S_{f2} - S_{f0}}$$

S_g

h_g

Slow saturated subsurface flow

$$Q_{g1} = A_u^2 (h_g - S_g)^2 A$$

Aquifer base flow

$$Q_{g2} = A_g h_g A$$

12 parameters to optimize

Unaccountable aquifer loss (option)

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Criteria for satisfaction

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- Avoid underestimation of maximum discharge
  - Maximum of observed discharge
    ≦ Maximum of simulated discharge
    ≦ Maximum of observed discharge x allowance β
- Avoid underestimation of discharge
  - Observed discharge ≦ Simulated discharge
- Avoid underestimation of duration
  - Minimize the difference of observed and simulated durations when underestimating
- Improve the fit of discharge
  - Minimize the mean squared errors of the discharges

Before the observed discharge reaches the maximum

While the observed discharge increases

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Optimization procedure

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- Prepare the candidate hydrographs

50,005 samples

$N \cdot f_0 \cdot A_u \cdot A_g$	UTANK	LTANK	Candidates
Uniform sampling	0.00	1.00	10,001
Uniform sampling	0.00	2.00	10,001
Uniform sampling	0.01	1.00	10,001
Uniform sampling	0.01	2.00	10,001
Uniform sampling	Uniform sampling	Uniform sampling	10.001

- Select candidates by the constraint conditions
  - Avoid underestimation of maximum discharge
  - Avoid underestimation of discharges while increasing
- Select candidates by the objective function
  - Minimize mean squared errors of the discharges
    + penalty for the underestimation of the duration

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Number of satisfactory samples

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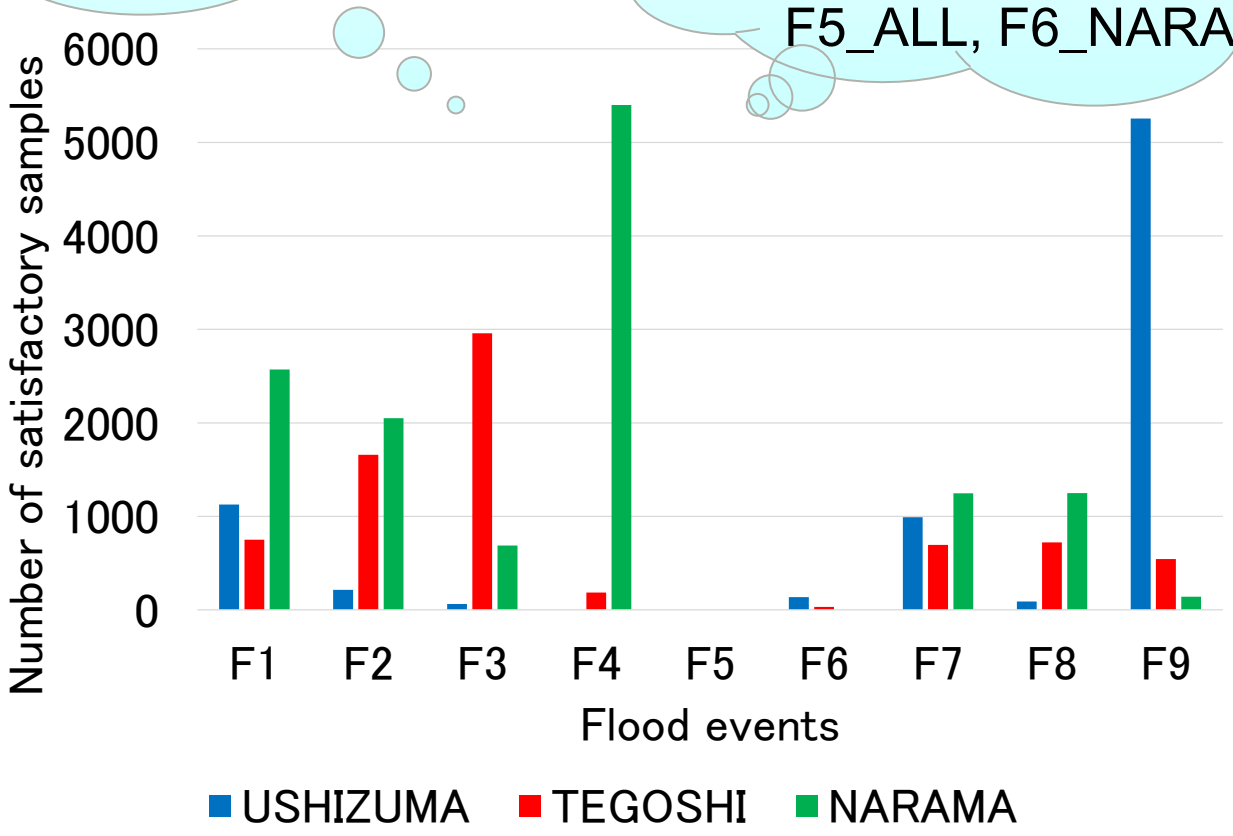
For hydrographs with satisfactory samples, preferable hydrographs were selected from satisfactory samples.

For hydrographs with no satisfactory samples, preferable hydrographs were selected from all samples.
… F4_USHIZUMA, F5_ALL, F6_NARAMA



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Number of parameter sets

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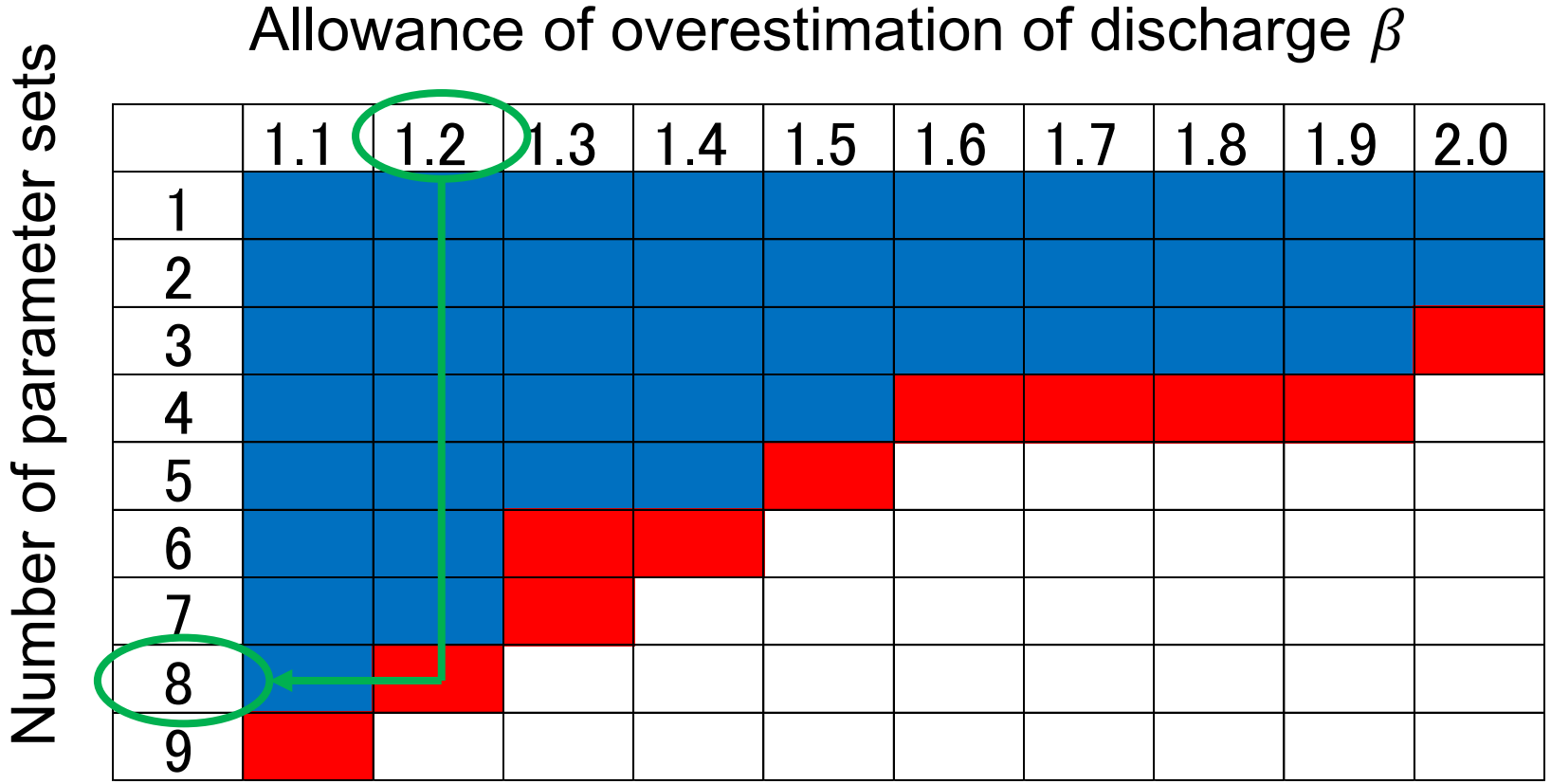
- Allowed 20% overestimation for maximum discharge
  - Allowance = 1.2 ←→ Number of parameter sets = 8



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Results - Clustering

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- Allowed 20% overestimation for maximum discharge
  - 8 combinations of parameter sets were necessary.
- 8 combinations of parameter sets … A to H
  - Most common … E
  - Explains only USHIZUMA … A
  - Explains only TEGOSHI … F
  - Explains only NARAMA … C, D

7 hydrographs

	F1	F2	F3	F4	F5	F6	F7	F8	F9
USHIZUMA	G	G	A	B	B	H	B	A	E
TEGOSHI	E	H	E	B	E	F	H	E	F
NARAMA	E	E	C	D	G	D	H	D	C

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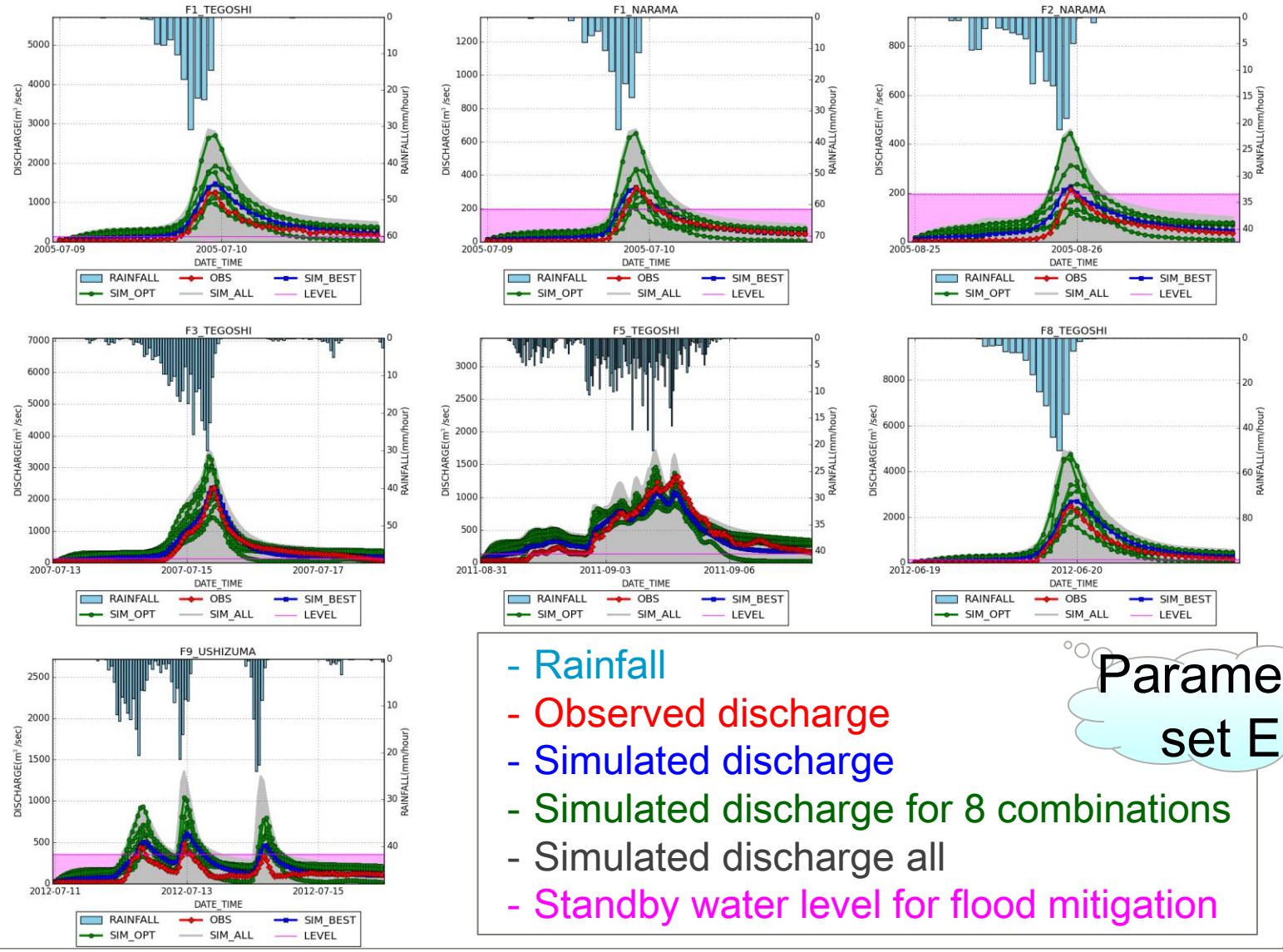
Result - Hydrographs



- Rainfall
- Observed discharge
- Simulated discharge
- Simulated discharge for 8 combinations
- Simulated discharge all
- Standby water level for flood mitigation

Parameter set E

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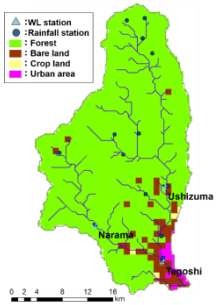
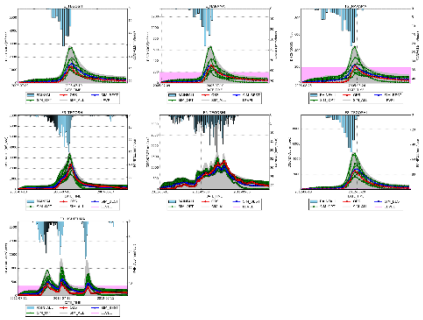
Conclusions

- Clarified four criteria in which hydrographs are satisfactory.
  - 2 criteria for constraint conditions
  - 2 criteria for objective function
- Proposed an optimization procedure using two constraint conditions and one objective function.
- Presented 8 combinations of parameter sets were selected from 50,005 candidates to describe 27 hydrographs observed in 9 flood events at 3 water level stations in the Abe River basin.



	F1	F2	F3	F4	F5	F6	F7	F8	F9
USHIZUMA	G	G	A	B	B	H	B	A	E
TEGOSHI	E	H	E	B	E	F	H	E	F
NARAMA	E	E	C	D	G	D	H	D	C



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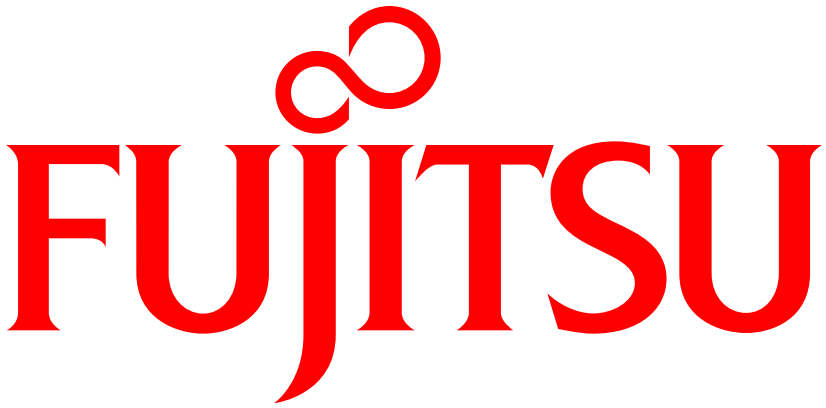

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