

2016 Project Management Symposium

Rare Event-based Operation Risk Analysis for Complex Technological Projects



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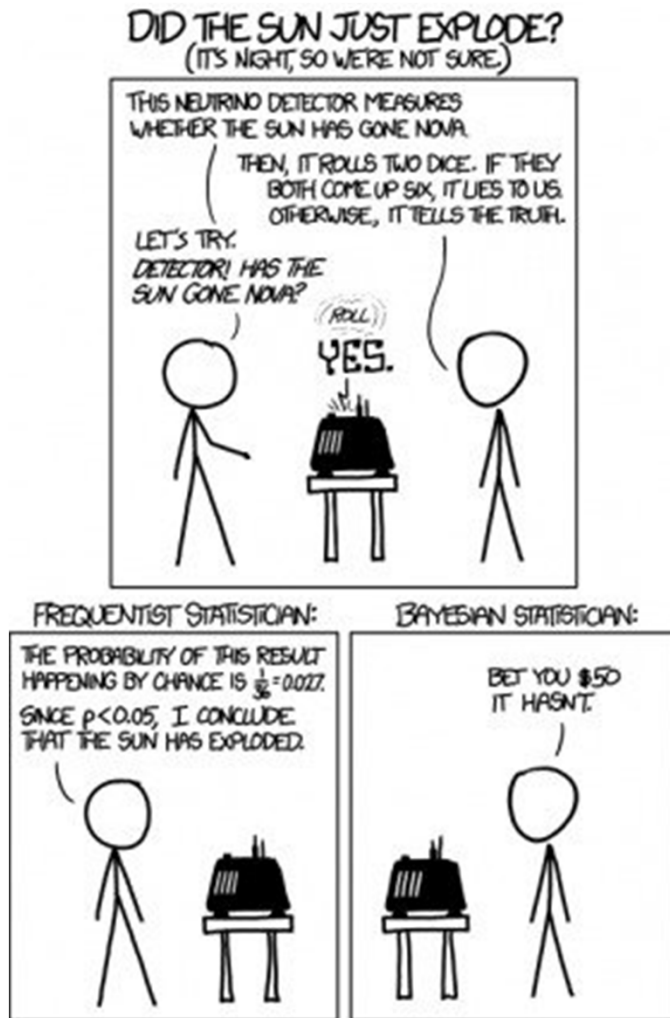
Ph.D student, Department of Civil and Environmental Engineering
University of Maryland, College Park



Adiel Komey

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Rare Events



Rare Events



Frequentist statistician: Yes!

$\Pr(\text{say explode} | \text{not explode})$

$$= 1/36 = 0.027$$

$$\text{Alpha} = 0.05$$

$$\Pr(\text{say explode} | \text{not explode}) < 0.05$$

Bayesian statistician: No!

$$\Pr(\text{say explode} | \text{not explode})\Pr(\text{not explode})$$

$$= 0.027\Pr(\text{not explode})$$

$$> \Pr(\text{explode})$$

$$> \Pr(\text{say explode} | \text{explode})\Pr(\text{explode})$$

$$\Pr(\text{not explode} | \text{say explode}) > 0.5$$

Rare Event Risks in Complex Technological Projects

Reliability analysis: Tuffin (2009), Dai et al. (2012), Grooteman (2008)

Power system: Wang et al.(2011), Perninge et al.(2012)

Financial engineering: Li (2005), Bassamboo et al. (2008)

Public health: Clemencon et al. (2013), Kuwahara & Mura (2008)



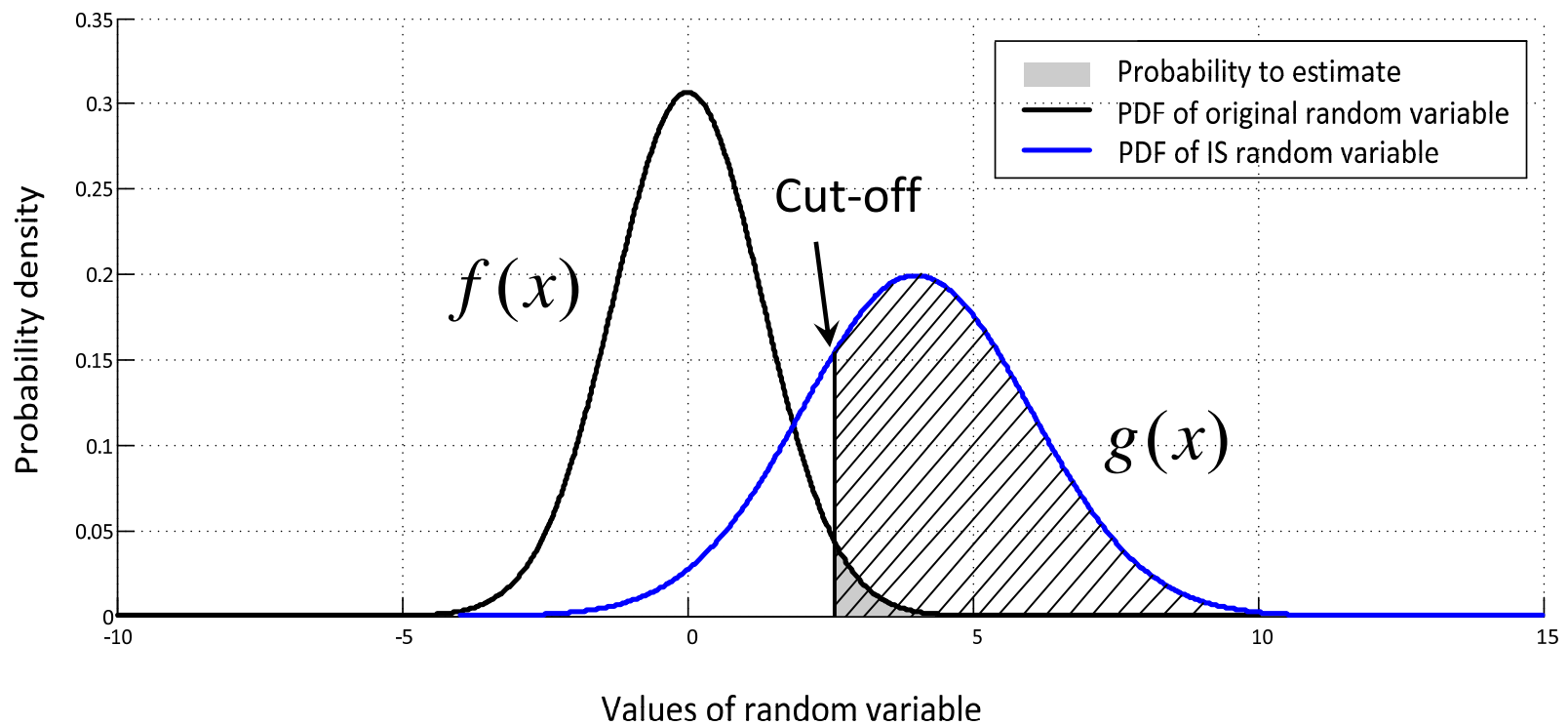
Rare Event Simulation

An umbrella term for a group of computer simulation methods intended to selectively **sample “special” regions** of the dynamic space of systems which are unlikely to visit through crude simulation. (Juneja and Shahabuddin, 2002)

- Importance sampling method
- Splitting method

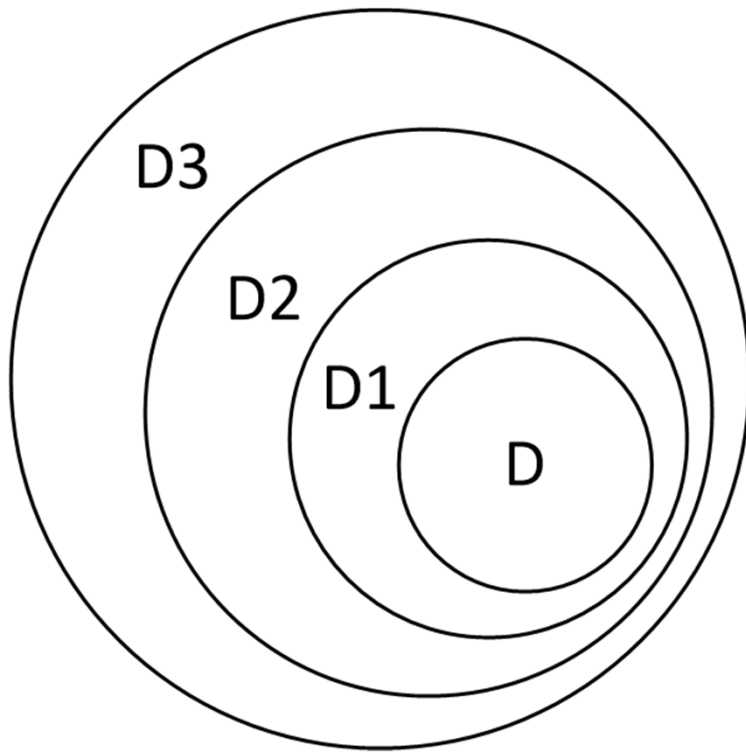
Rare Event Simulation – Importance Sampling

Importance sampling-based rare event simulation



Rare Event Simulation - Splitting

Splitting-based rare event simulation

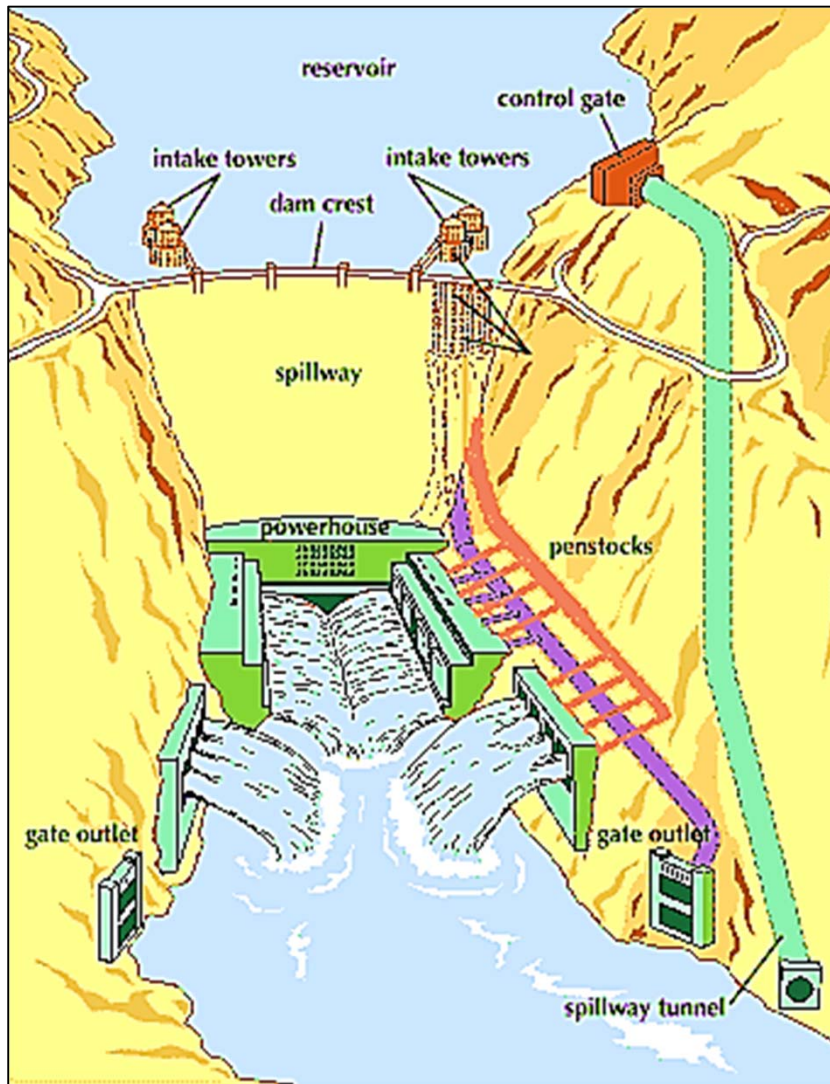


$$D = D_0 \subset D_1 \subset \dots \subset D_m$$

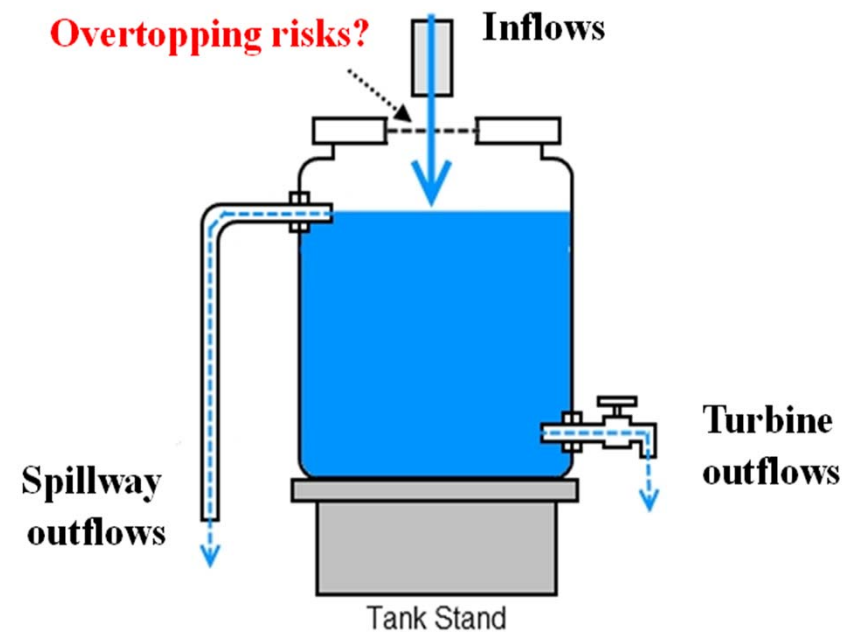
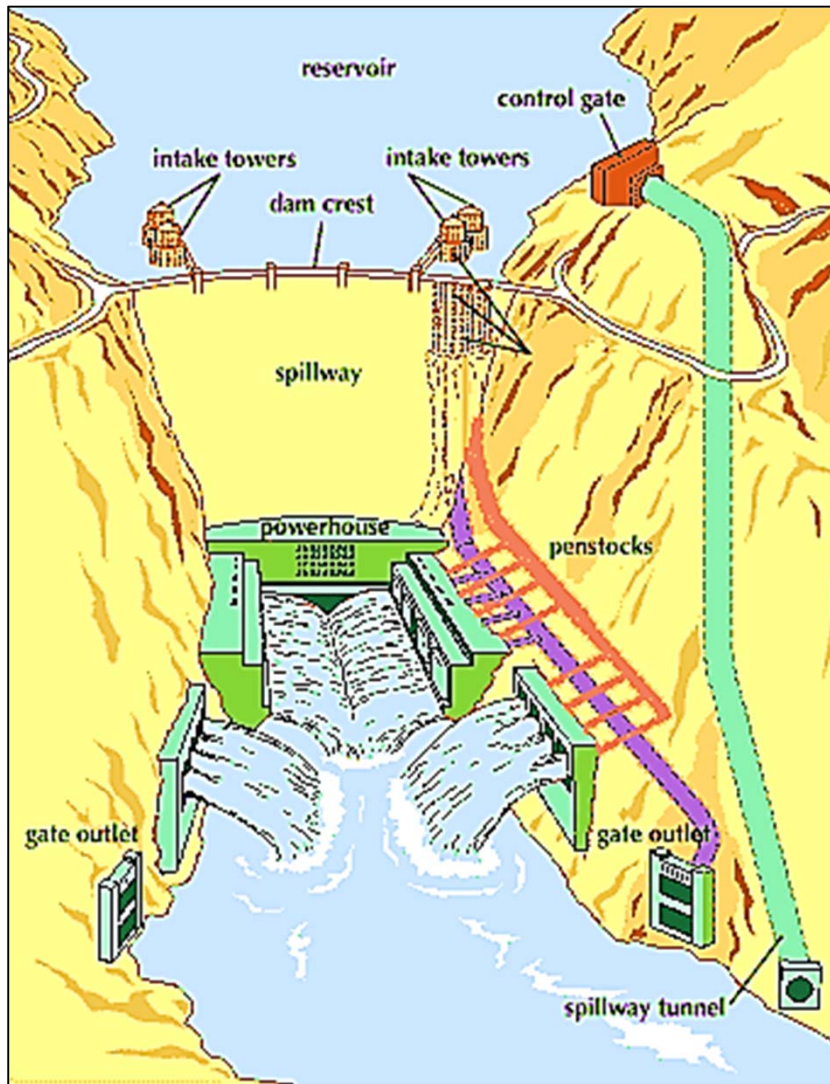
$$P(D)$$

$$= P(D_m)P(D_{m-1} | D_m) \dots P(D_0 | D_1)$$

Case Study on Dam-Reservoir Systems



Case Study on Dam-Reservoir Systems



- Inflow rates;
- Outflow rates;
- Reservoir water elevation

Case Study on Dam-Reservoir Systems

Lawn Lake Dam (Colorado, 1982)



Auburn Cofferdam (California, 1986)



Rainbow Dam (Michigan, 1986)

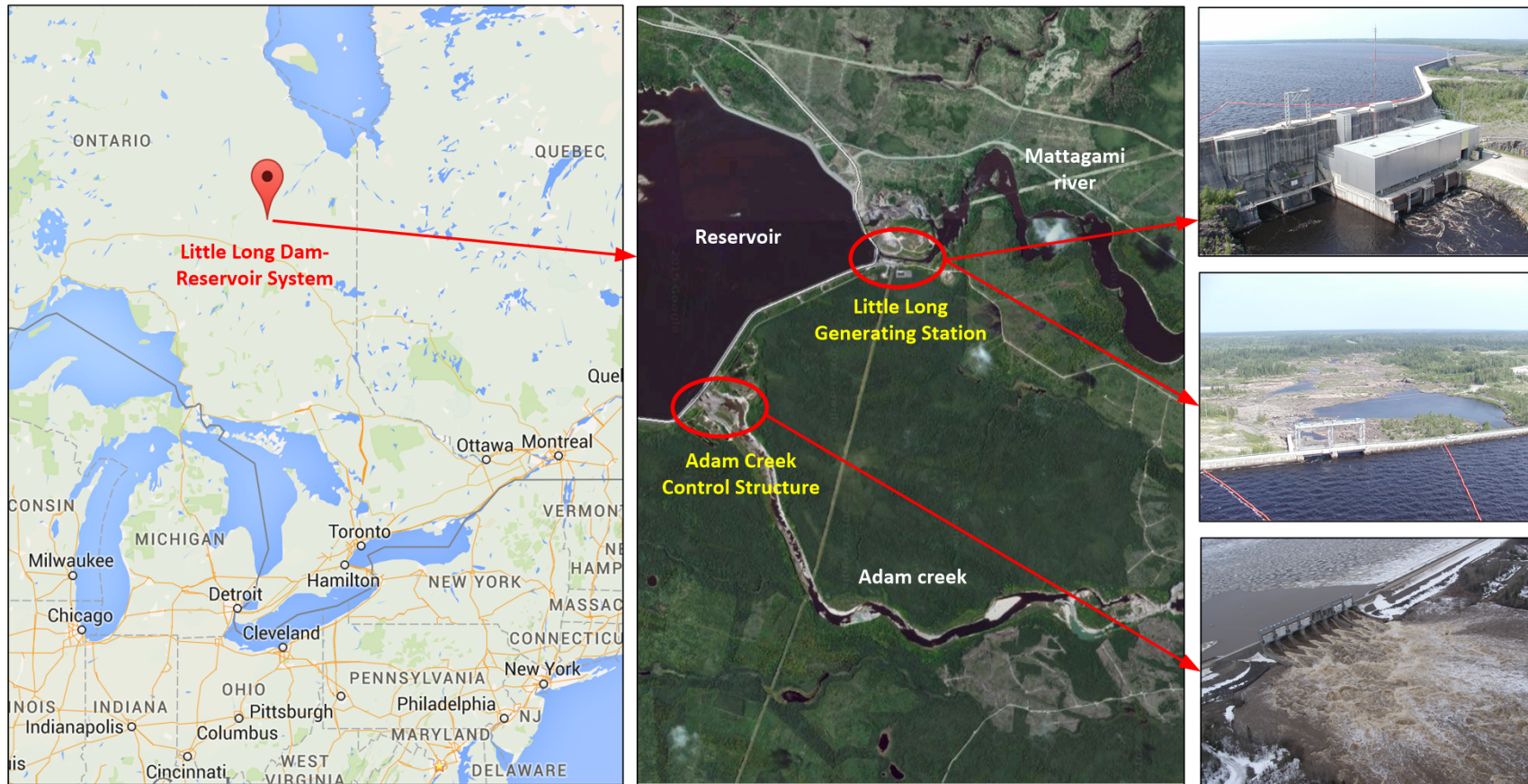


Taum Sauk Dam (Missouri, 2005)



Case Study on Dam-Reservoir Systems

Little Long Dam-Reservoir System



Case source: Ontario Power Generation (OPG)

<http://www.opg.com/Pages/home.aspx>

Case Study on Dam-Reservoir Systems

How to evaluate risks of reservoir-dam systems?

1) Modeling

2) Simulation

Case Study on Dam-Reservoir Systems

How to evaluate risks of reservoir-dam systems?

1) Modeling

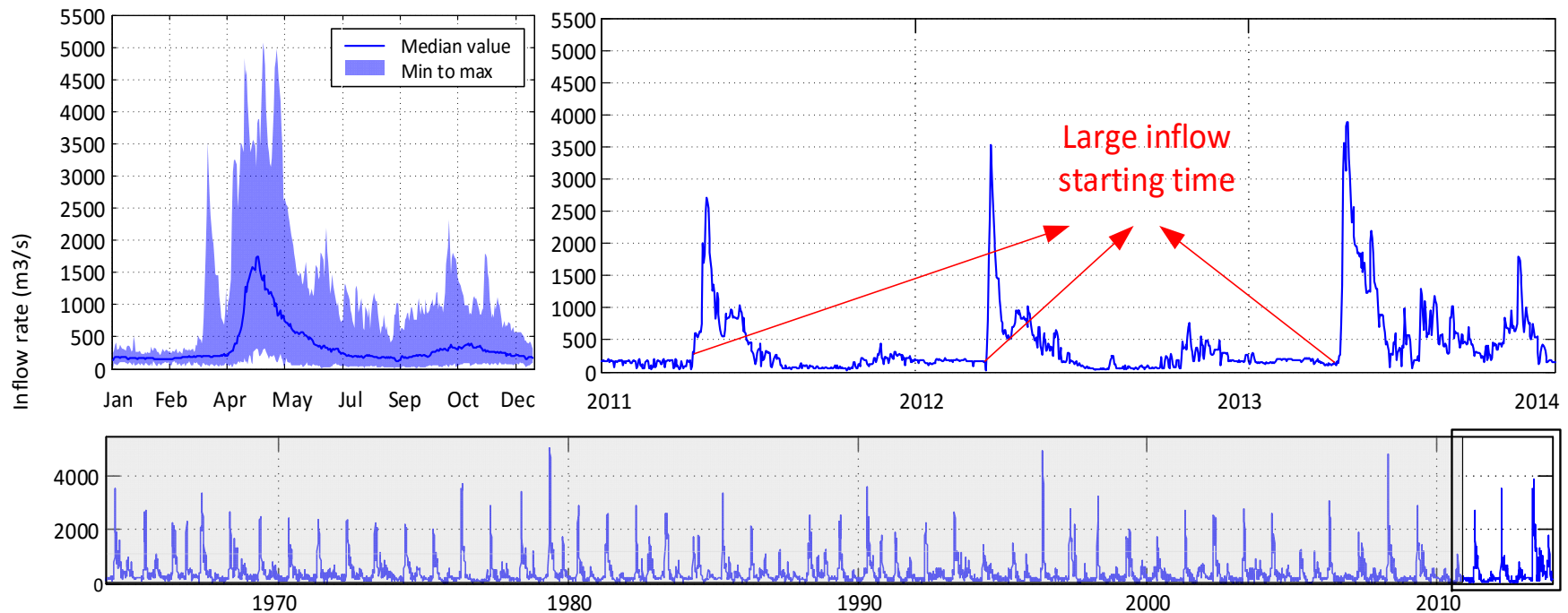
- Inflow hydrograph modeling
- Dam-reservoir system operation modeling

2) Simulation

- Crude Monte Carlo simulation
- Importance sampling based Monte Carlo simulation

Case Study on Dam-Reservoir Systems

Historical Inflows of Little Long reservoir system (1964-2013)

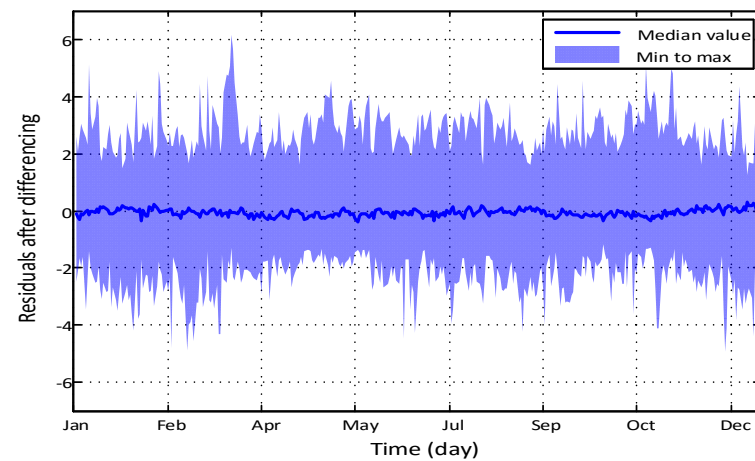
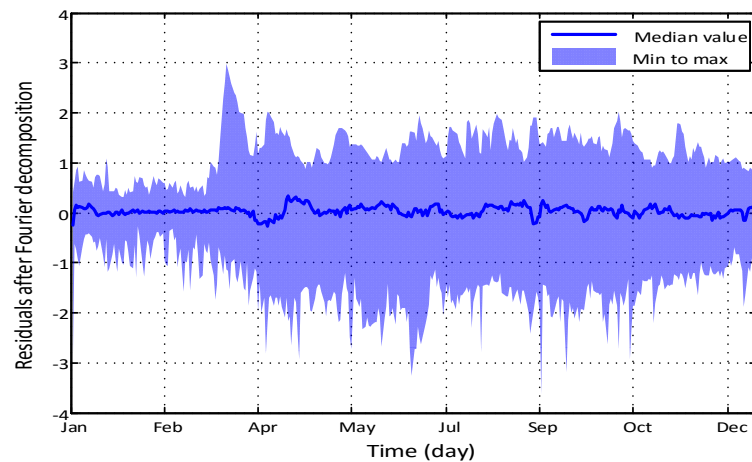
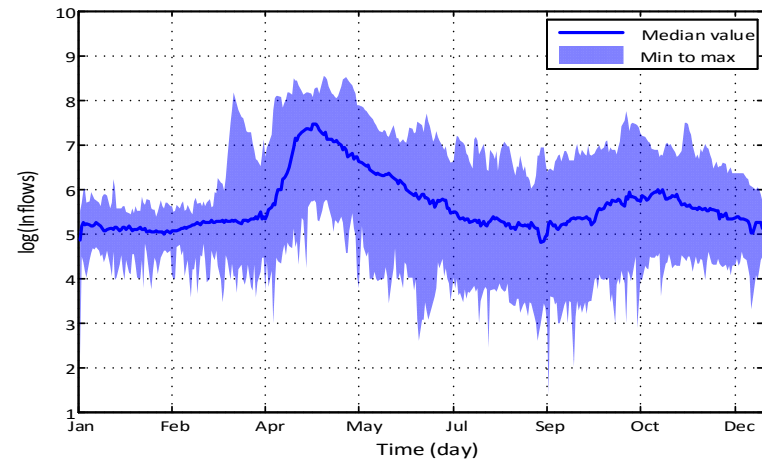
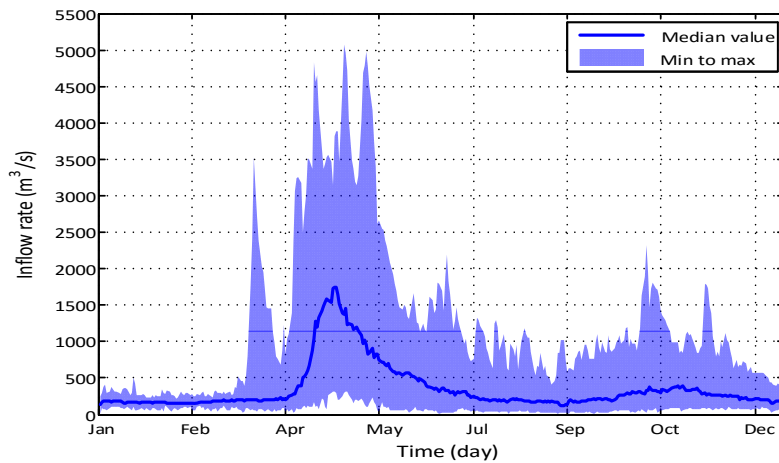


Case source: Ontario Power Generation (OPG)

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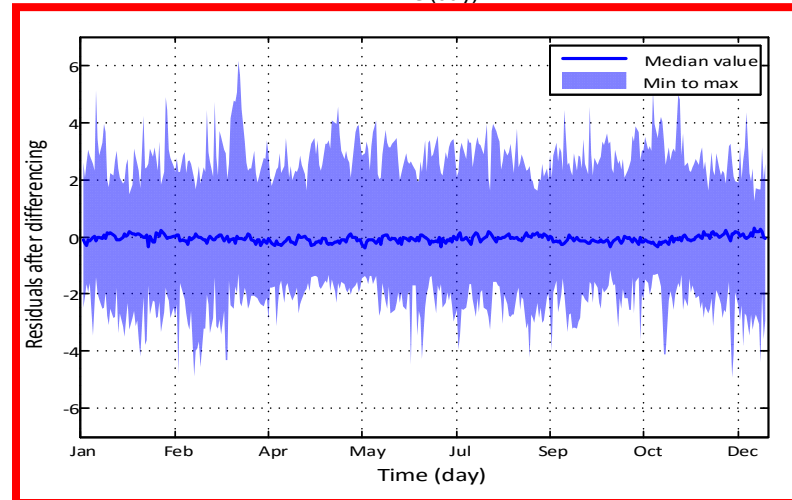
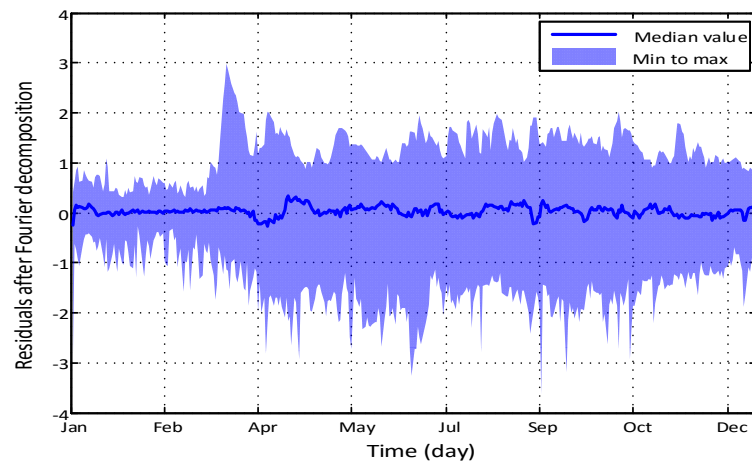
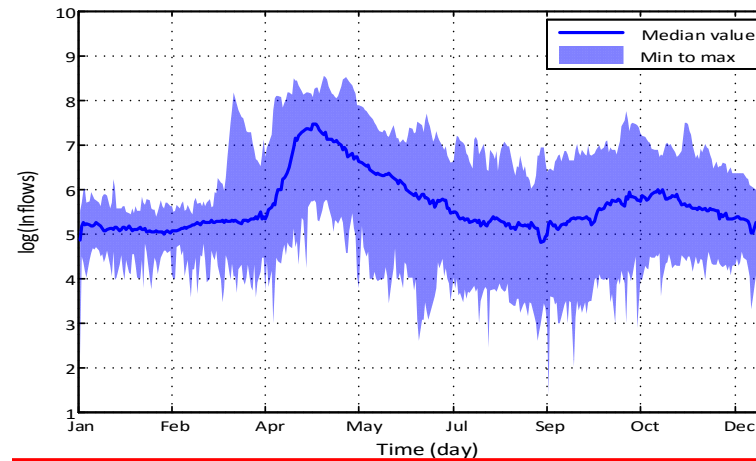
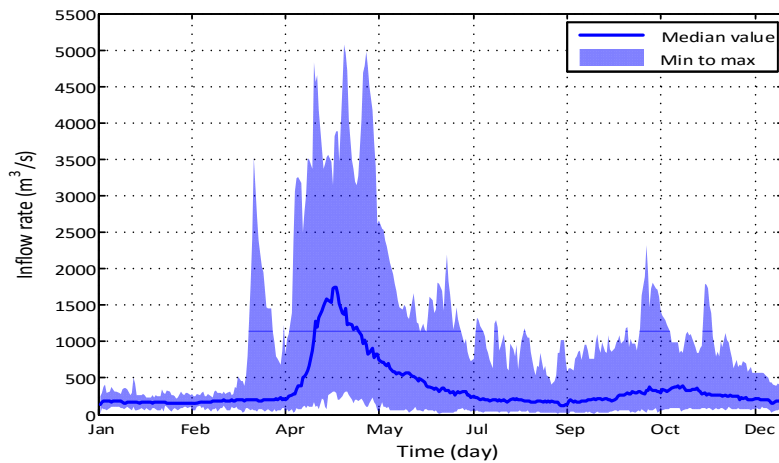
Case Study on Dam-Reservoir Systems

Preprocessing average daily inflow rate data

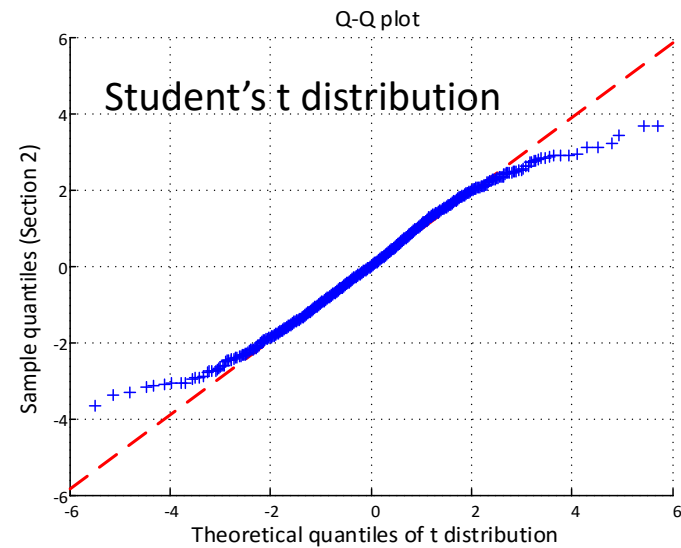
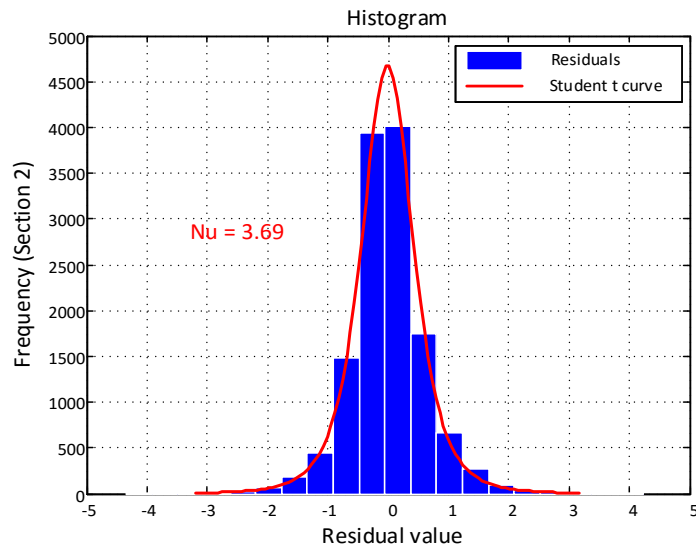
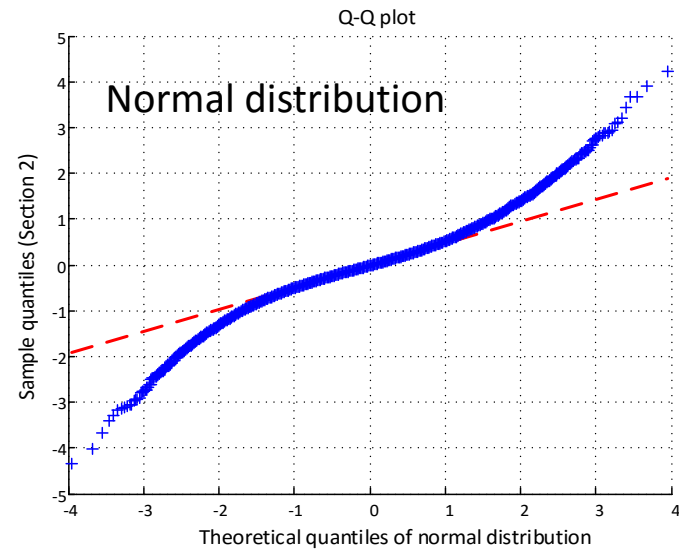
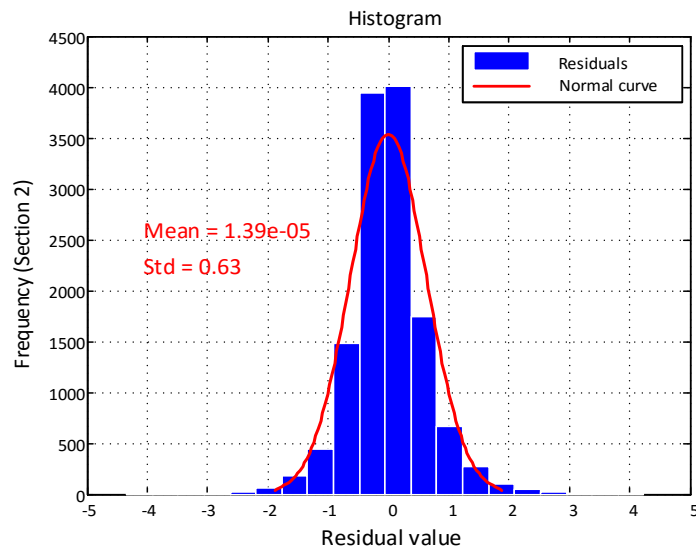


Case Study on Dam-Reservoir Systems

Preprocessing average daily inflow rate data

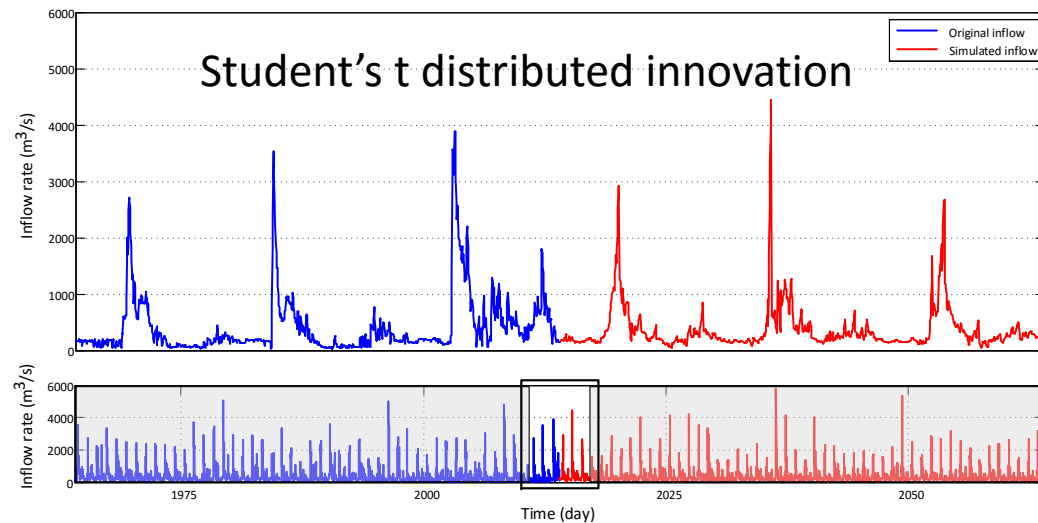
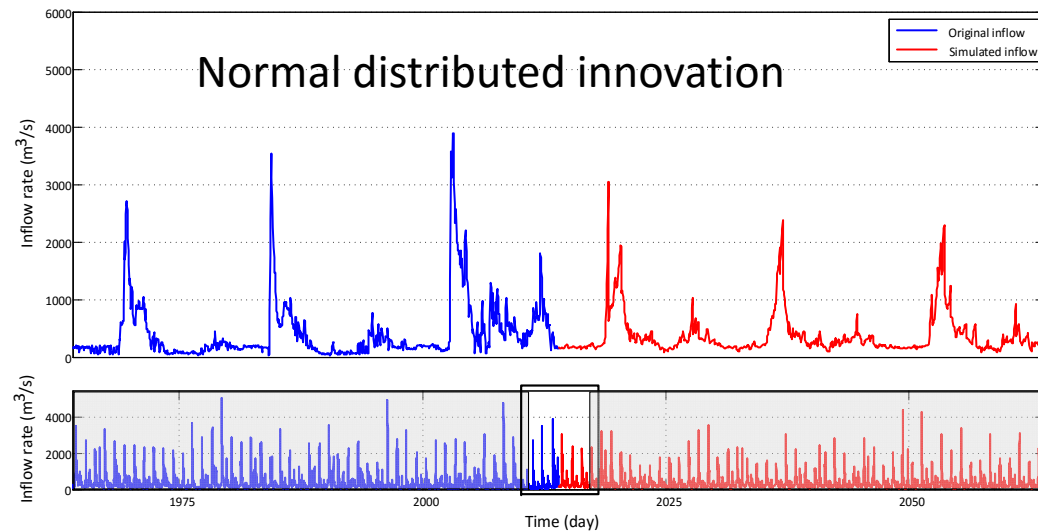


Case Study on Dam-Reservoir Systems



Case Study on Dam-Reservoir Systems

Sample paths of
historical and simulated
inflow hydrographs



Case Study on Dam-Reservoir Systems

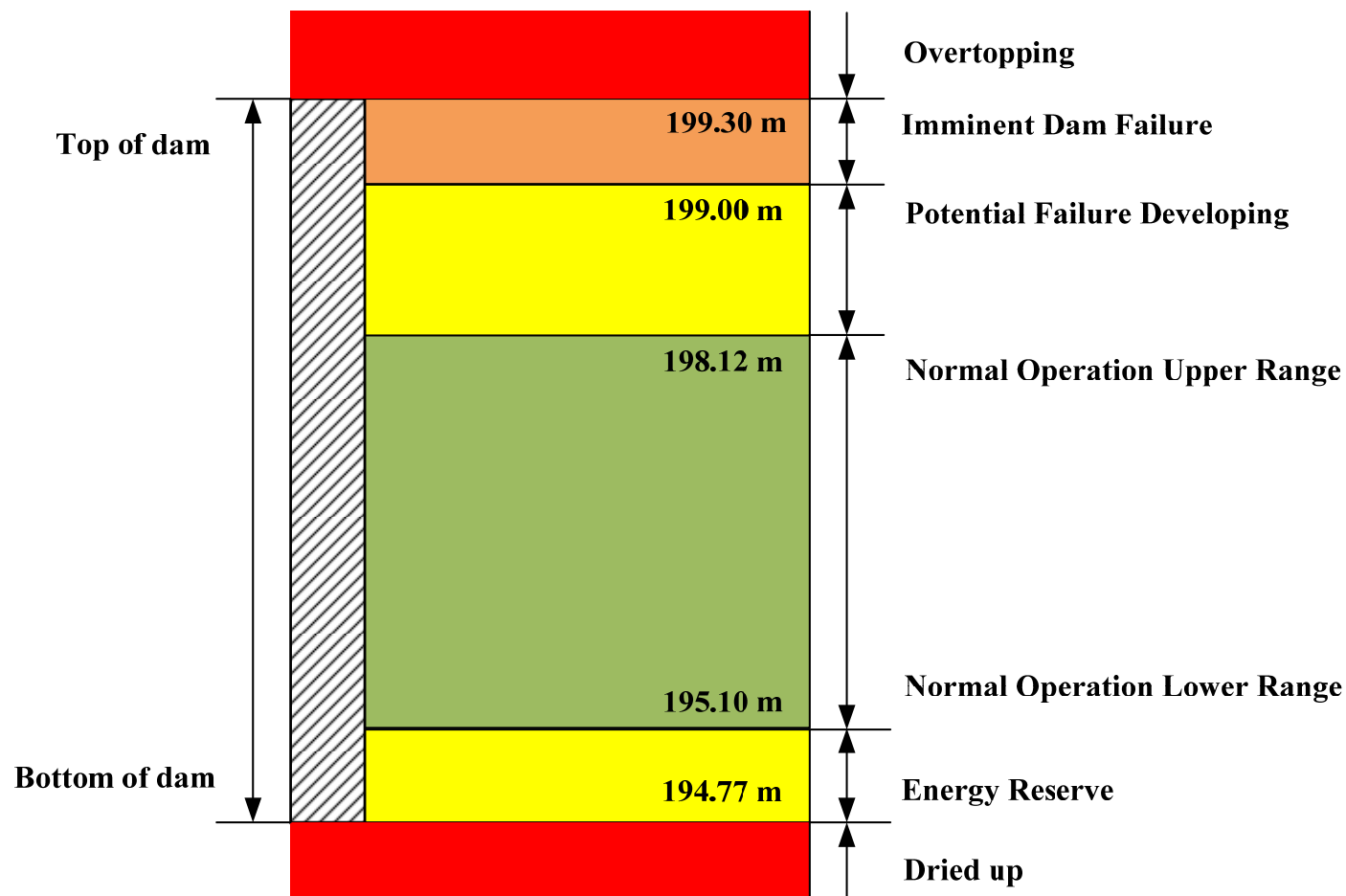
Outflow controls

- 2 Units of turbine with max capacity of 583 m³/s;
- 2 Sluices Open into the Lower Mattagami River System with max capacity of 1217.6 m³/s;
- 8 Sluices Open into the Adam Creek Bypass with max capacity of 4870.4 m³/s at max operating elevation.

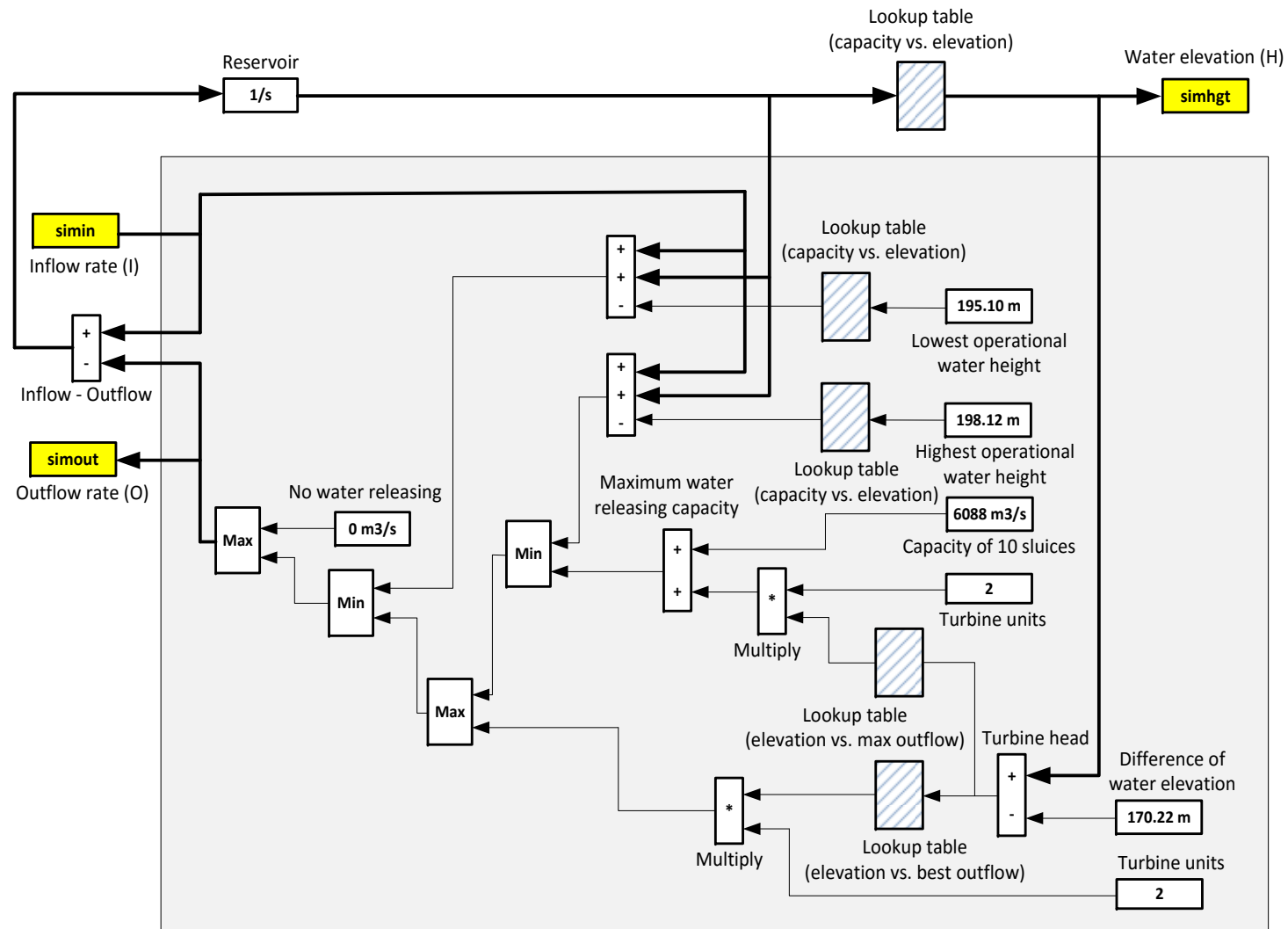


Case Study on Dam-Reservoir Systems

Water elevation boundaries for Little Long dam-reservoir system

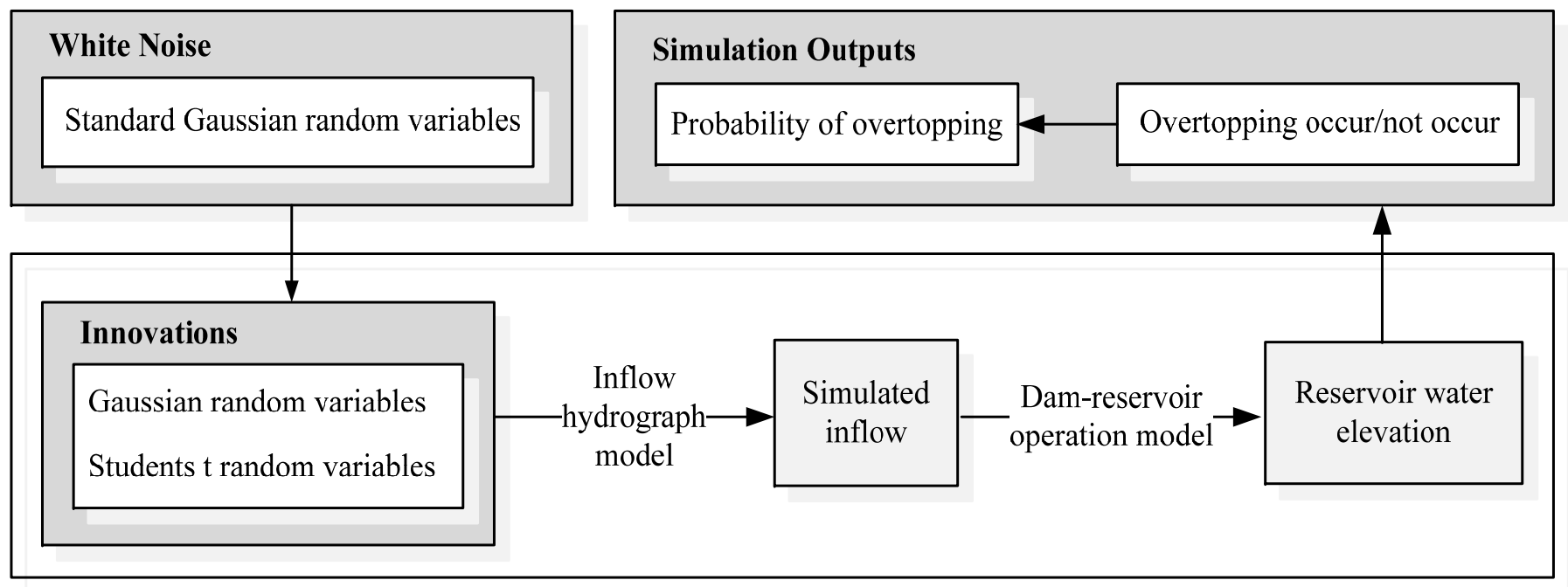


Case Study on Dam-Reservoir Systems



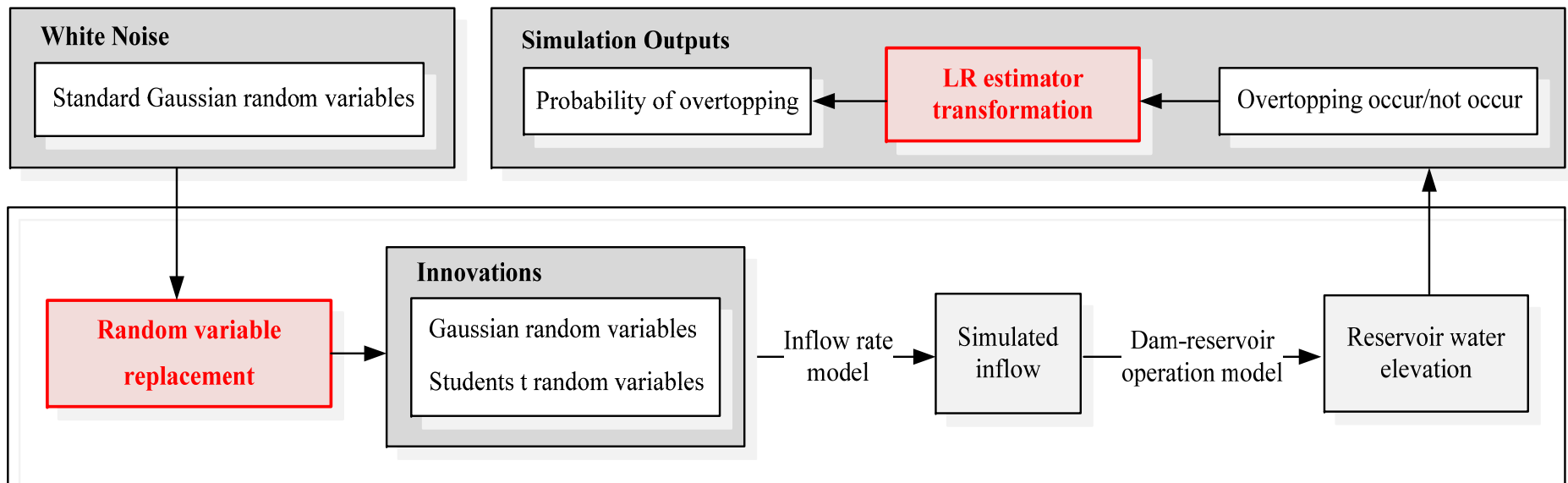
Case Study on Dam-Reservoir Systems

Crude Monte Carlo-based rare event simulation



Case Study on Dam-Reservoir Systems

Importance sampling-based rare event simulation



Summary

Contributions:

- **Industrially:** an importance index to guide the future dam safety investigations and studies
- **Theoretically:** improve the rare event risk estimation methodology (accelerate the computation and reduce estimation variances)

Future work:

- Optimal IS density function searching
- Simulation implementation
- Expansion to other projects

THANKS !

