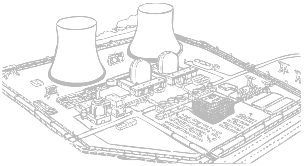

Case study: estimating height of a dike

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Dikes and flooding

Source: flickr.com/photos/william_veerbeek/7703915786/, CC BY-NC-SA licence

Dikes and flooding

Flood protection equipment in New Orleans after passage of hurricane Katrina

Dikes and flooding

Source: flickr.com/photos/tomlawrence/621868082, CC BY-NC-SA licence

Illustration of dike failure

Modelling flood risk

- In reality, dike design is a function of many parameters:
  - dike geometries and materials
  - hydrological, hydraulic and topographic data
  - wind speed and directions
  - linked wave effects
  - changing roughness due to seasonal vegetation
  - effect of sediment transport on flow resistance
- In this work, **very simplified equations** are used
  - main aim is to illustrate different risk assessment approaches

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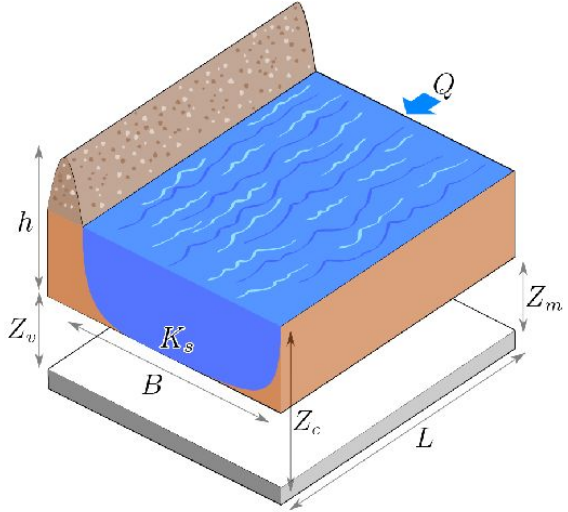
Model parameters



Source: B. Iooss, P. Lemaître, *A review on global sensitivity analysis methods*, 2015, hal-00975701

The system model

The maximal water level of the river (Z_c) is given as a function of several parameters, some of which are uncertain:

$$Z_c = \left(\frac{Q}{K_s \times B \times \sqrt{(Z_m - Z_v)/L}} \right)^{3/5}$$

uncertainty

where

- ▷ Z_c is flood level (variable of interest)
- ▷ Z_m and Z_v are level of the riverbed, upstream and downstream (uncertain)
- ▷ Q is maximal annual flowrate of the river (uncertain)
- ▷ K_s is Strickler's roughness coefficient (uncertain)
- ▷ B and L are the width and length of the river cross-section (certain)

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Input parameters

Input	Description	Unit	Probability distribution
Q	Maximal annual flowrate	m^3/s	Fit to observations
K_s	Strickler coefficient	-	Truncated normal $\mathcal{N}(30, 8)$ on $[15, +\infty[$
Z_v	River downstream level	m	Triangular $\mathcal{T}(49, 50, 51)$
Z_m	River upstream level	m	Triangular $\mathcal{T}(54, 55, 56)$
L	Length of the river stretch	m	5000
B	River width	m	300

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Flowrate measurements

You have the following measurements of the maximum flowrate in the river from the past 20 years (observations are expressed in m³/s):

```
1114, 773, 570, 1069, 1340, 2653, 2956, 892, 701, 1169,
525, 683, 2102, 1060, 296, 2107, 1720, 849, 1361, 2024
```


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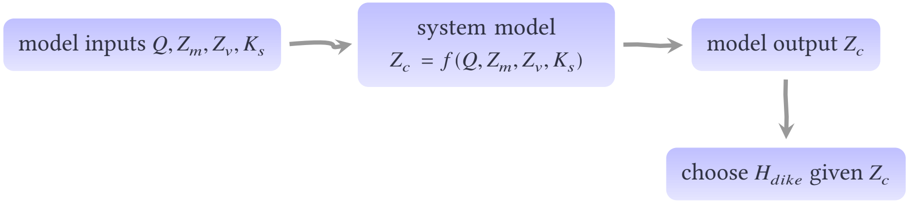
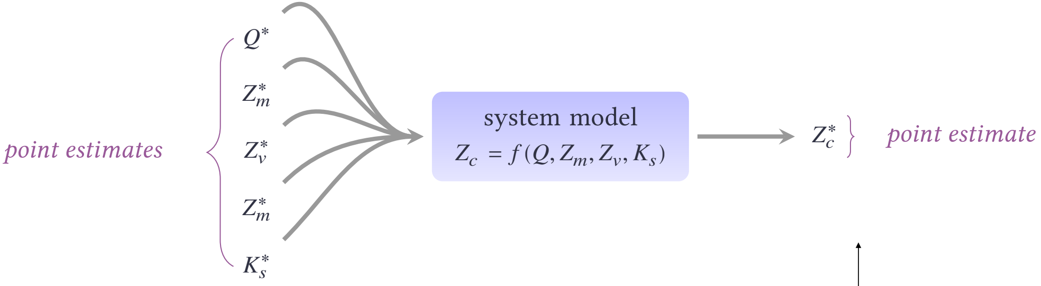
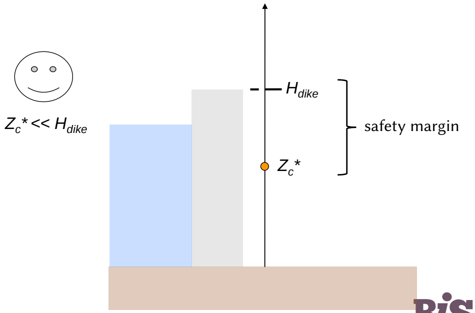
System model and risk

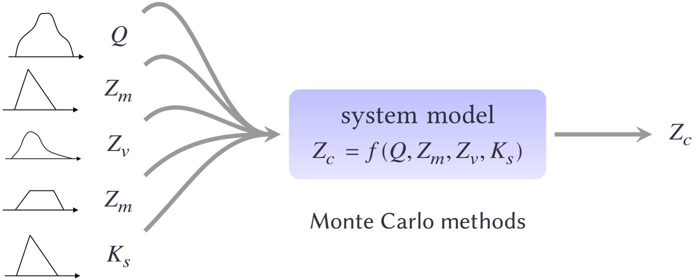


Deterministic approach to risk assessment



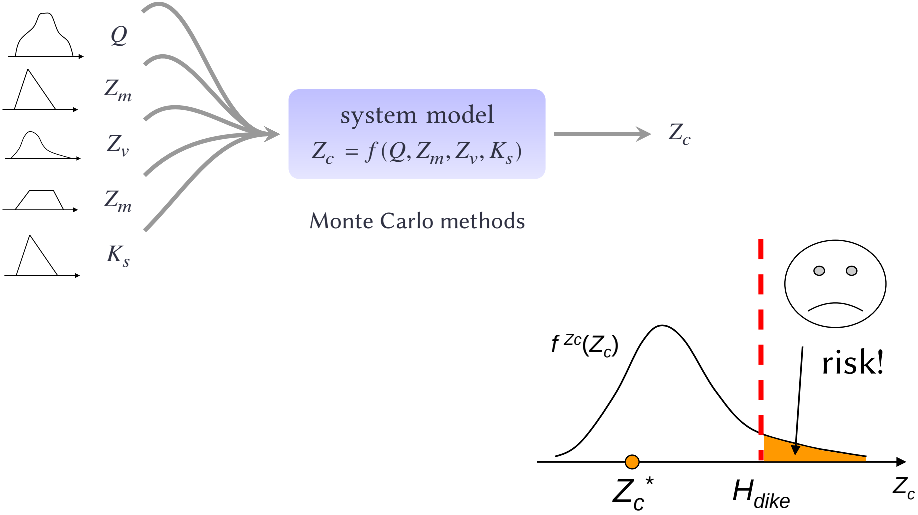


Probabilistic approach to risk assessment



Monte Carlo methods

Probabilistic approach to risk assessment



Task

- ▷ Fit a lognormal distribution to the measurements of maximal flowrate
  - check that a lognormal distribution fits this data well, using a probability plot
- ▷ Calculate the average height of the river by making a deterministic calculation
  - use median values for each uncertain parameter
- ▷ Calculate the maximum ("worst case") height of the river using a deterministic approach
- ▷ Produce a histogram of possible water levels, given the input uncertainty, using a Monte Carlo approach
- ▷ Estimate the 100-year flood level for this river
  - note: specialists use the term "0.01 annual exceedance probability" flood, meaning a flood that has a 1% chance of happening in any given year

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Hints

- To fit a lognormal distribution to data, use

  ```
  shape, loc, scale = scipy.stats.lognorm.fit(obs)
  ```

- A probability plot can be drawn with

  ```
  scipy.stats.probplot(obs, dist=scipy.stats.lognorm(shape,loc,scale),
  plot=plt.figure().add_subplot(111))
  ```

- To obtain a random variate from a probability distribution, use method `rvs()`
- To obtain a random number from a triangular probability distribution, use

  ```
  numpy.random.triangular(min, centre, max)
  ```

- A left-truncated probability distribution can be obtained using (left truncation at 15)

  ```
  max(15, random_variate)
  ```

- The square root of *x* is given by `numpy.sqrt(x)`
- Plot a histogram with `plt.hist(obs)` (first say `import matplotlib.pyplot as plt`)

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