Application of Direct and Indirect Methods for Estimation of Ice Jam Flood Frequency

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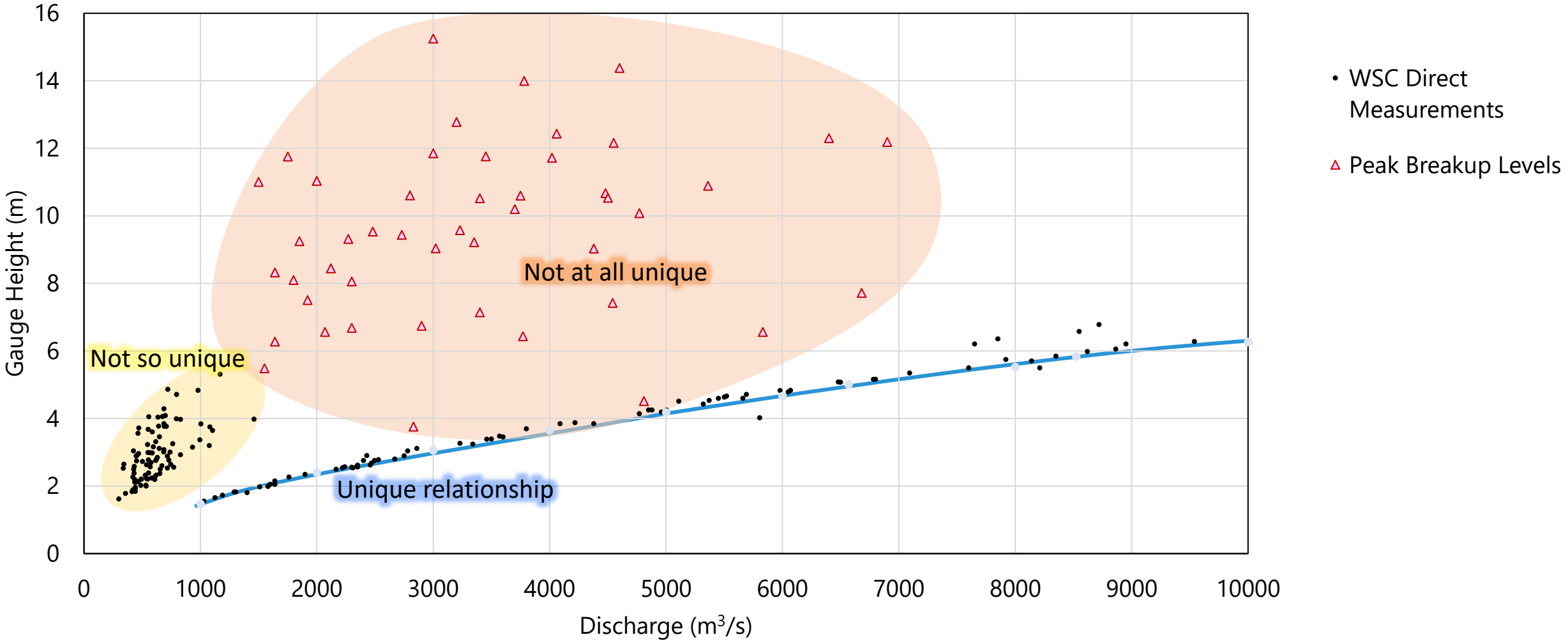
Open Water vs Ice Jam Flood Frequency

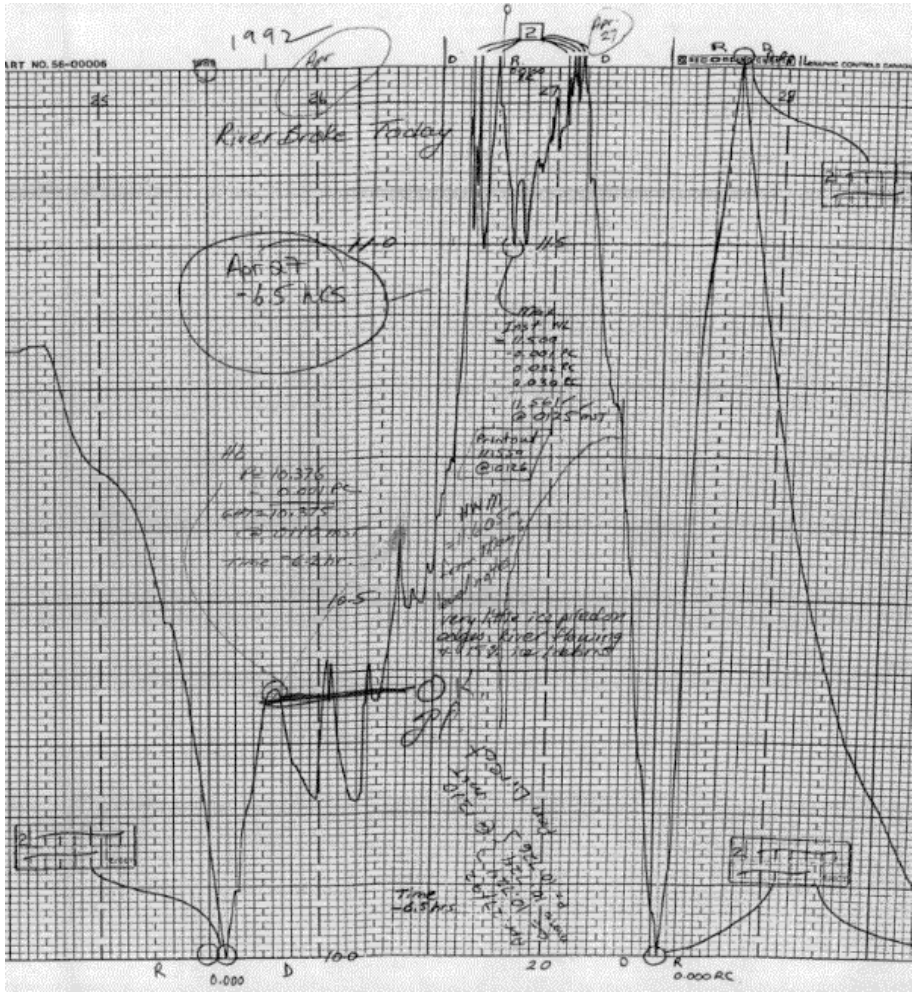
- Stage – discharge relationship (rating curve).
  - Under open water conditions, there can exist a unique relationship between stage and discharge.
  - Under ice-affected conditions, there is not.
- Flood frequency magnitude
  - For open water we typically express flood frequency magnitude in terms of discharge (m^3/s).
    - Thanks to the unique rating curve relationship.
  - For ice-affected conditions we express flood frequency magnitude in terms of level (m).
  - While the approaches are slightly different, the resulting flood frequency magnitudes are considered technically equivalent.

Liard River near the Mouth (10ED002)



Preparation

- Assemble a data set for frequency analysis.
  - Local observational data (e.g. highwater marks, flood level data, and documented accounts)
  - Published data – daily, peak, annual statistics
    - National Water Data Archive (HYDAT Database)
    - Canadian River Ice Database (CRID)
  - Unpublished data
    - Province, Territory, WSC, University, Industry
  - Chart records



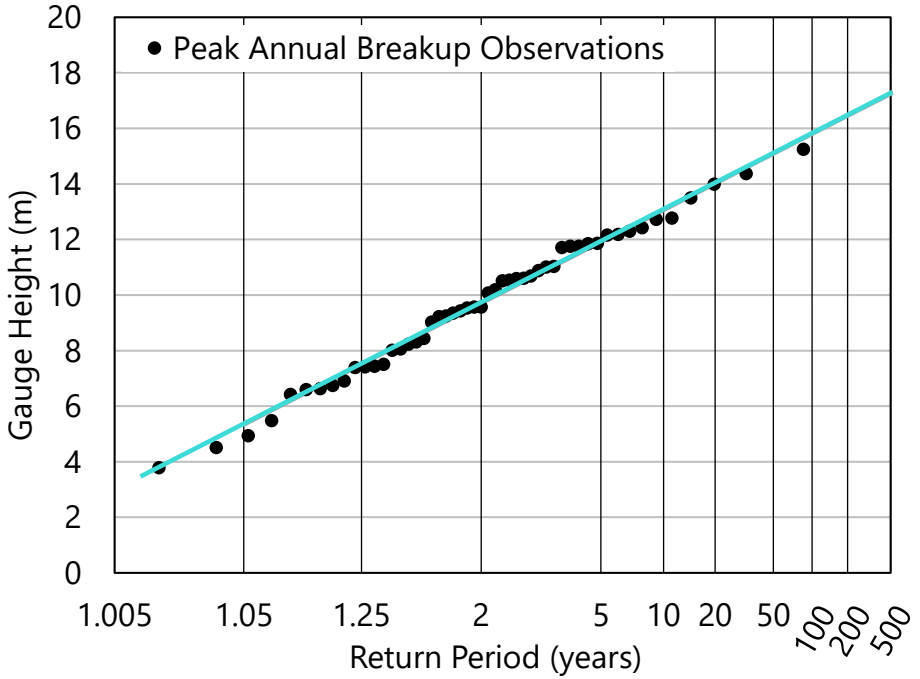
1992 breakup, Peace River at Peace Point

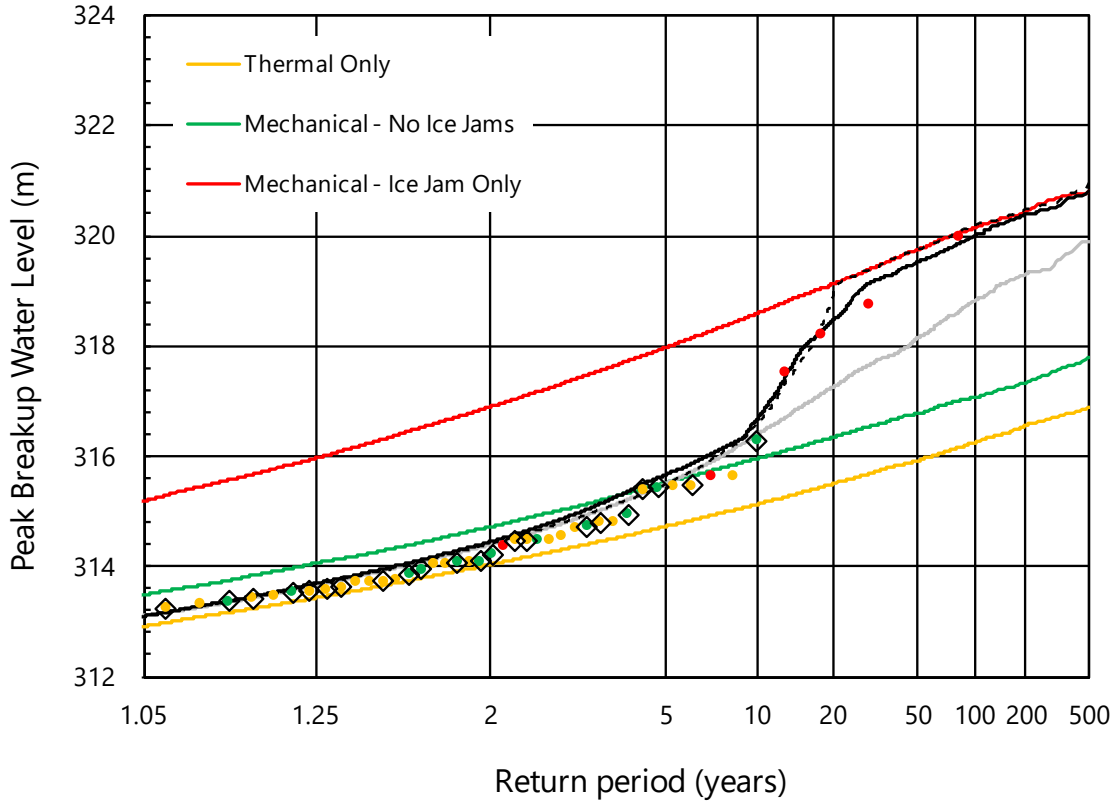
Data preparation with classification

- Determine year-by-year
  - Level
  - Discharge
  - Type (e.g. thermal or mechanical)

Indirect methods

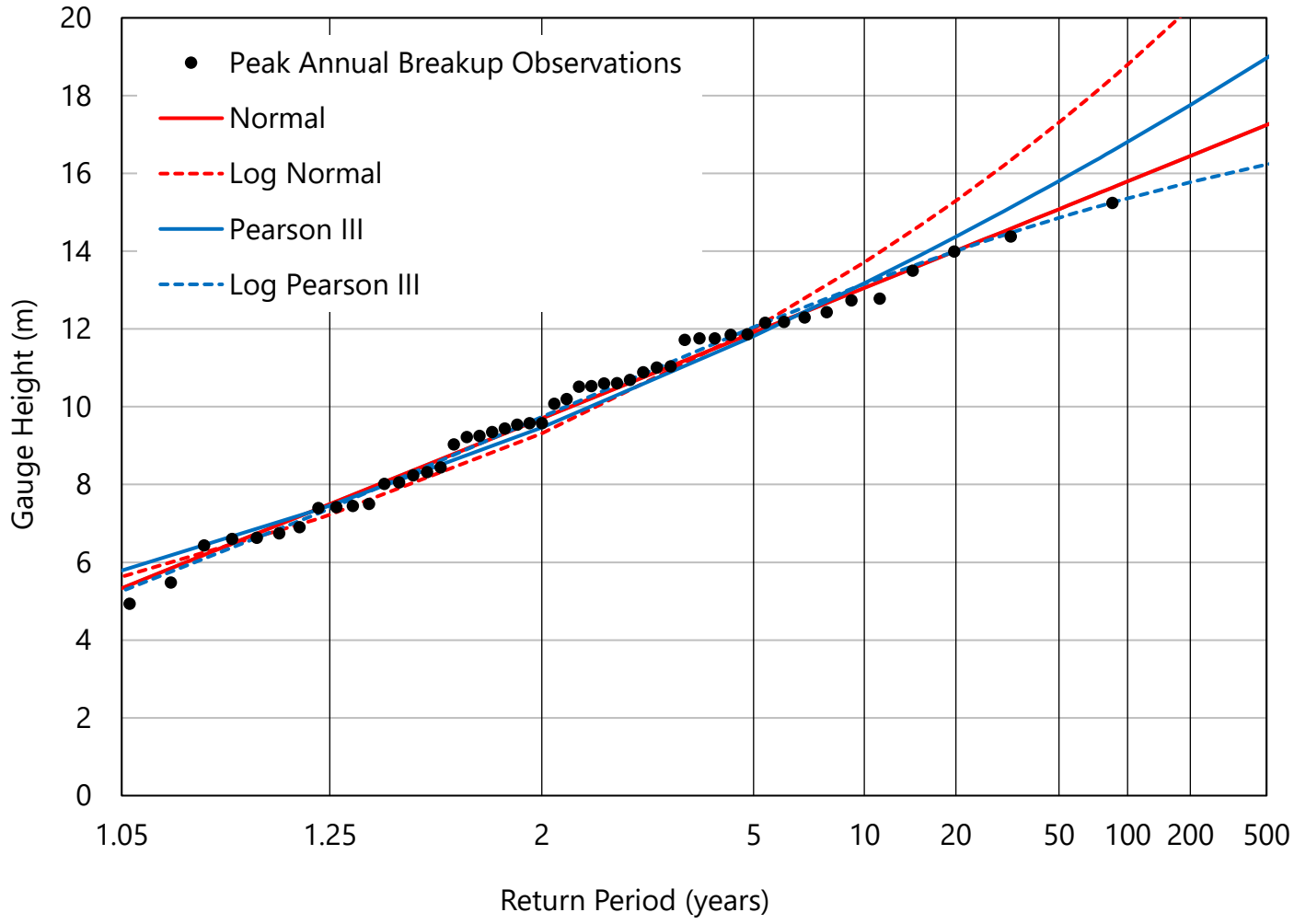
Direct methods





Direct Flood Frequency Estimation

- Like an open water analysis.
- Least applicable when extrapolating beyond the range of observed values.
- Incremental influence of ice effects diminish as ice jam thickness tends towards a maximum.
  - ice supply may reach a limit
  - floodplain flows may become appreciable



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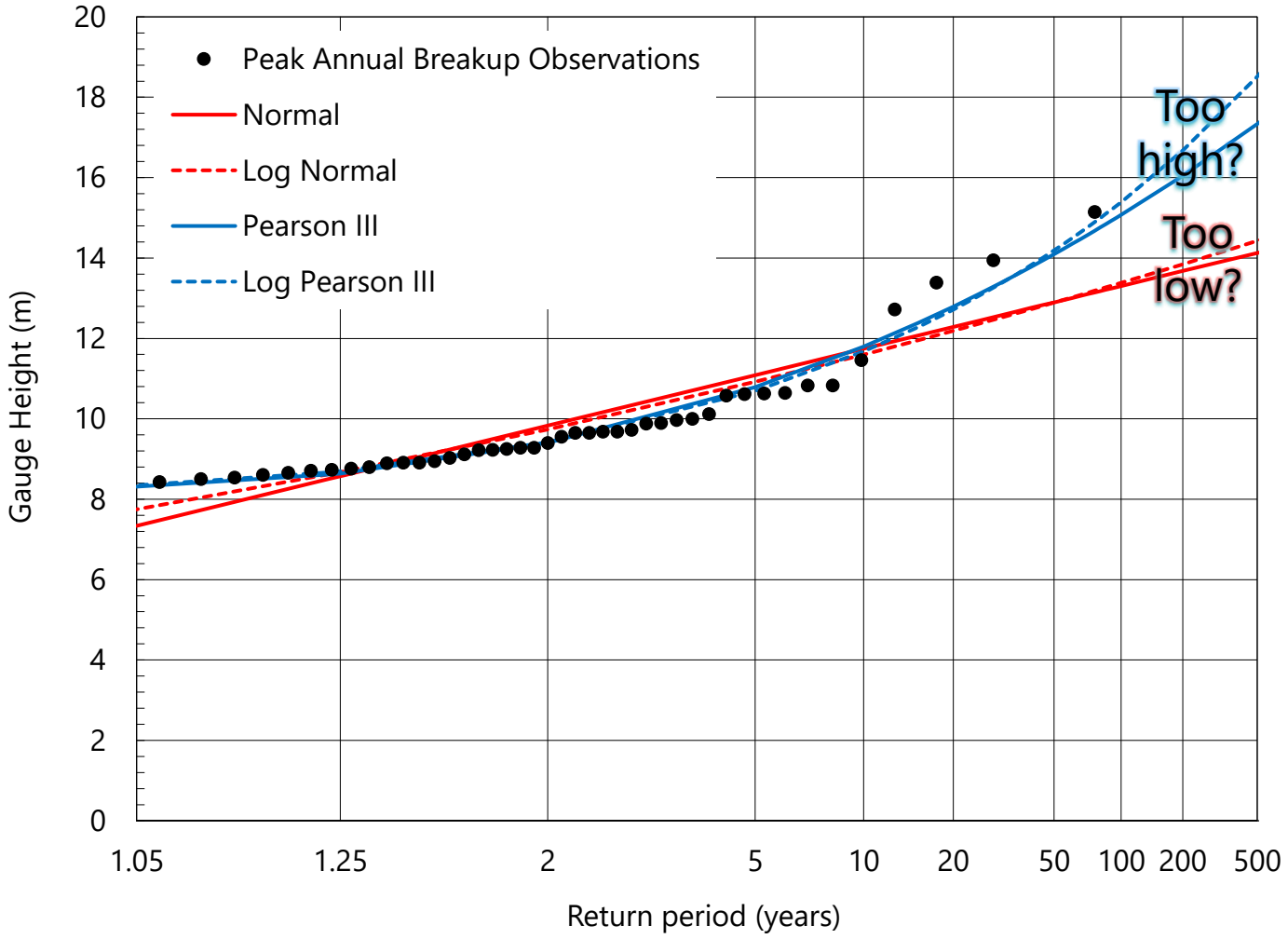
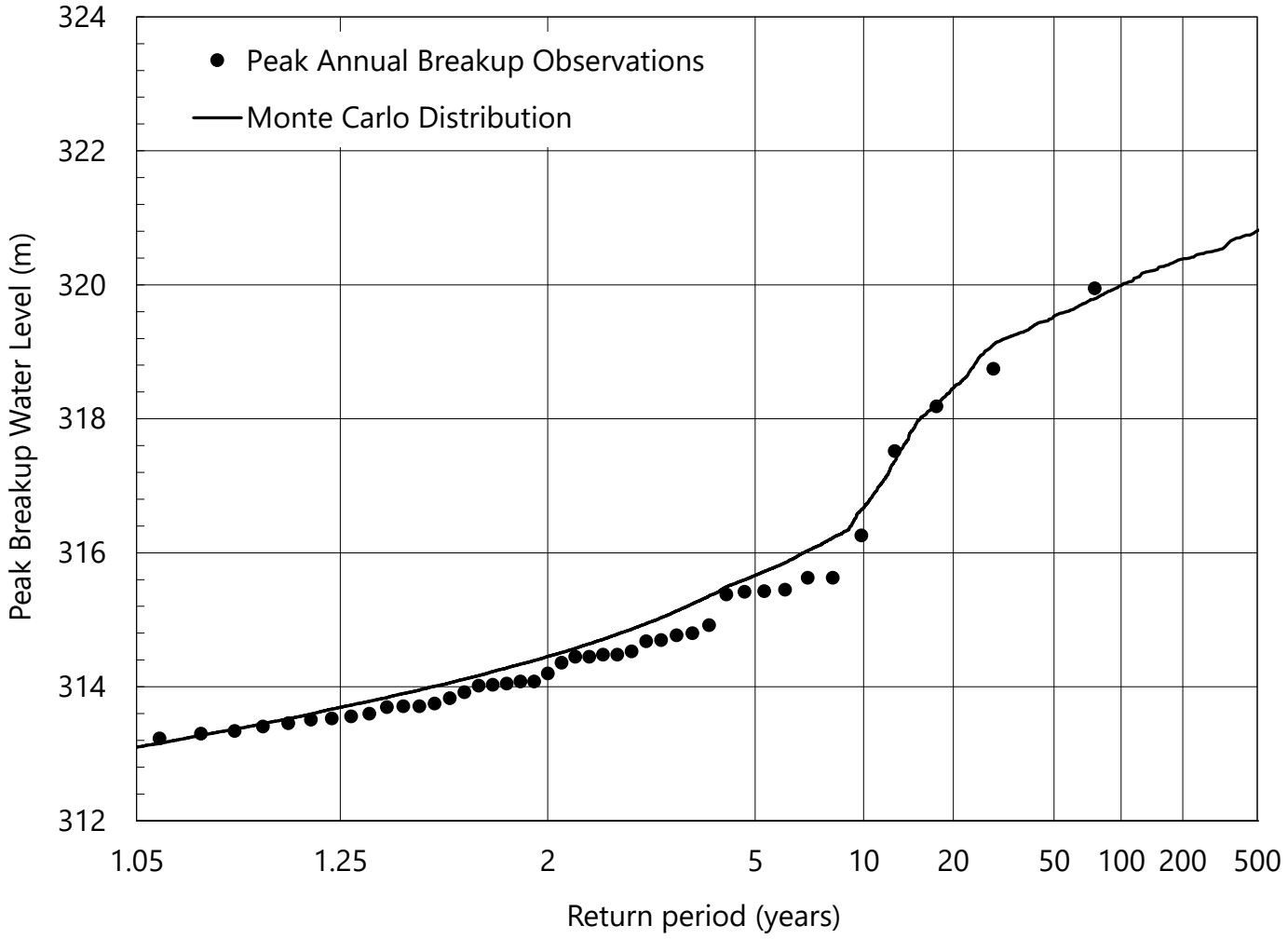
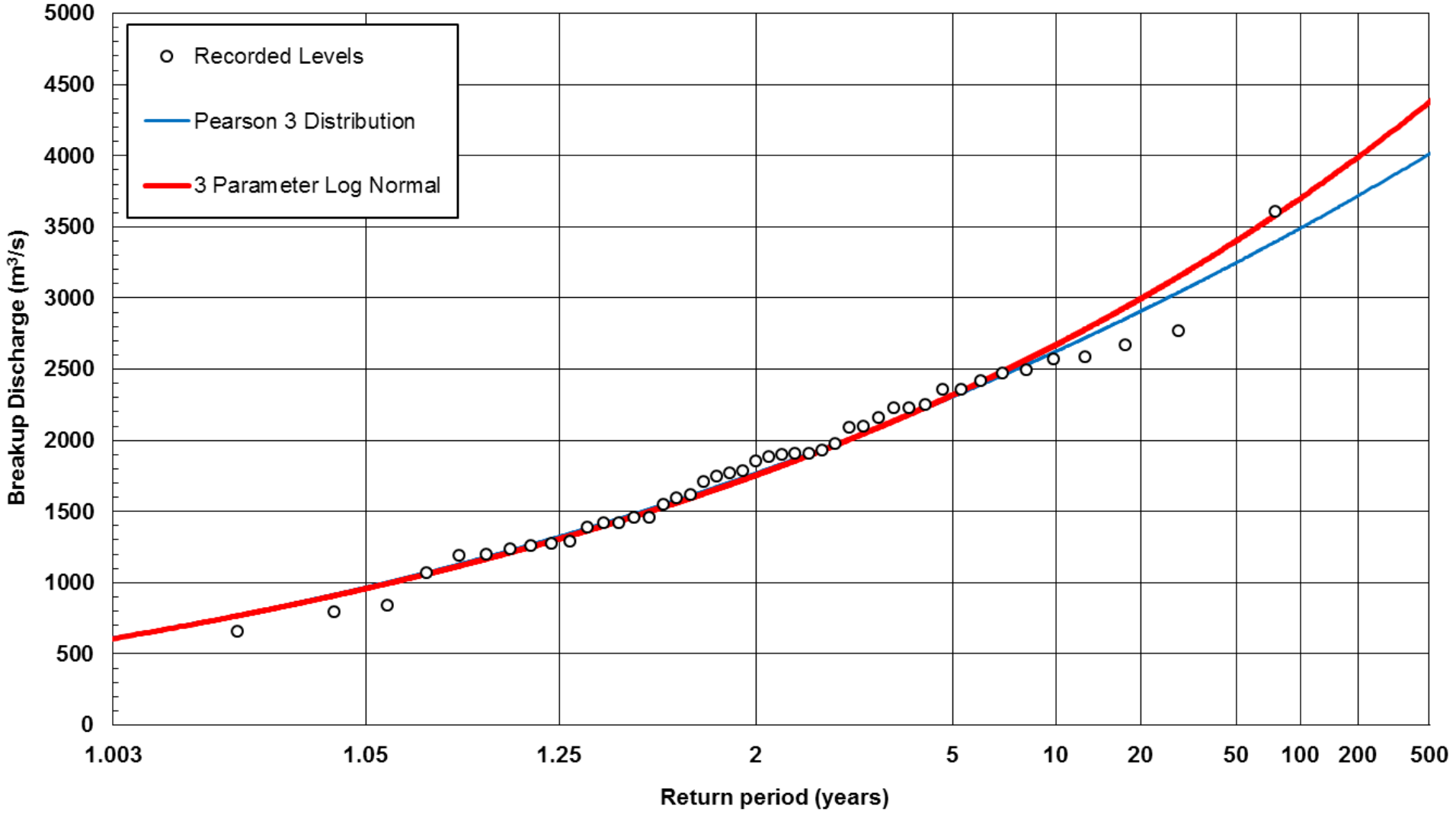


Indirect Flood Frequency Estimation

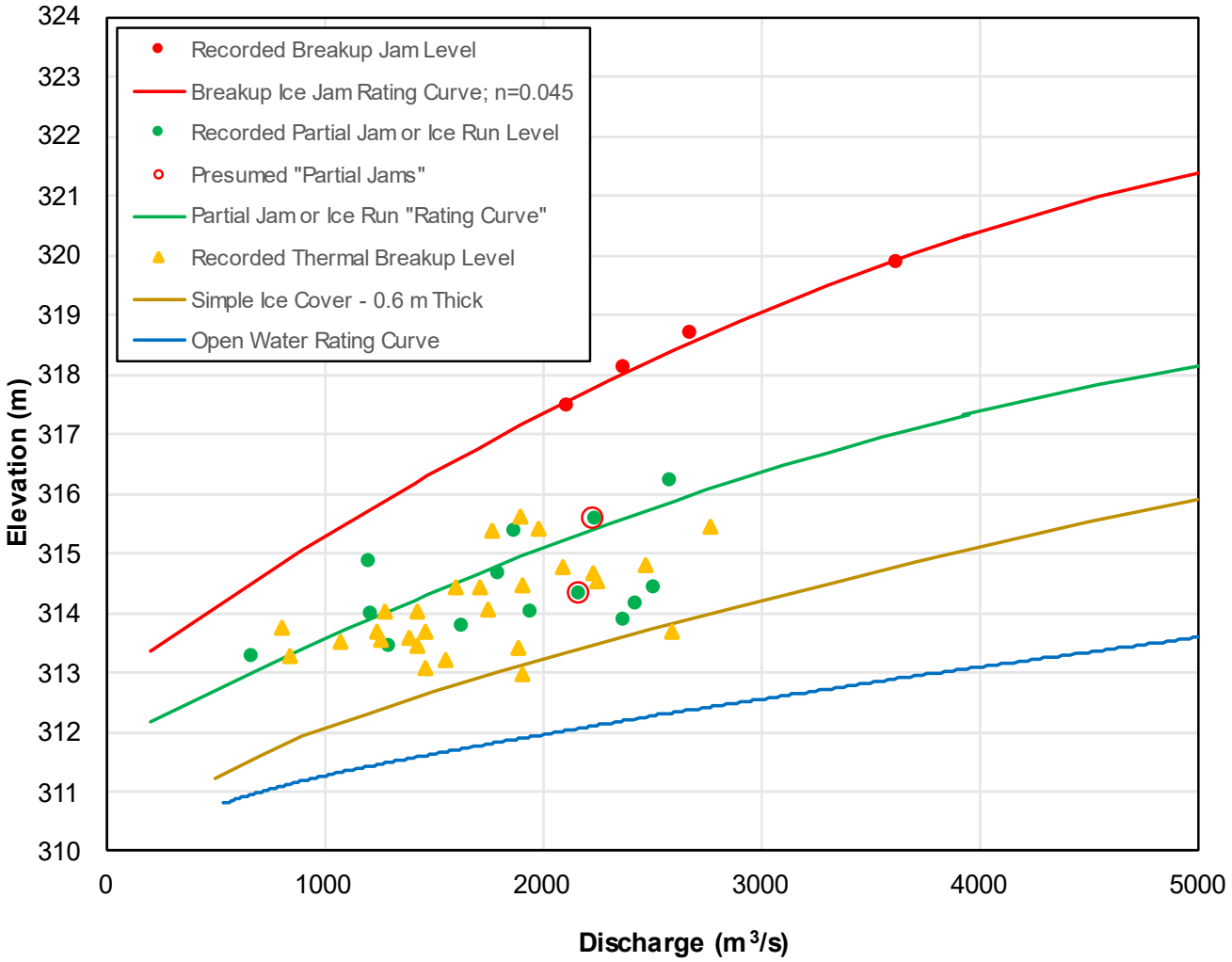
- Monte-Carlo based approach
- Random sampling from predetermined distributions of discharge and depth-discharge relationships according to breakup type
  - Breakup discharge frequency
  - Breakup rating curves for each breakup type
  - Probability factors for breakup type



Indirect Flood Frequency Estimation
Breakup Discharge Frequency Distribution



Indirect Flood Frequency Estimation
Classification and Breakup Rating Curves



Fully developed ice jam

Ice run or partially-developed ice jam

Thermal – approximated by simple cover

Open water (for comparison)

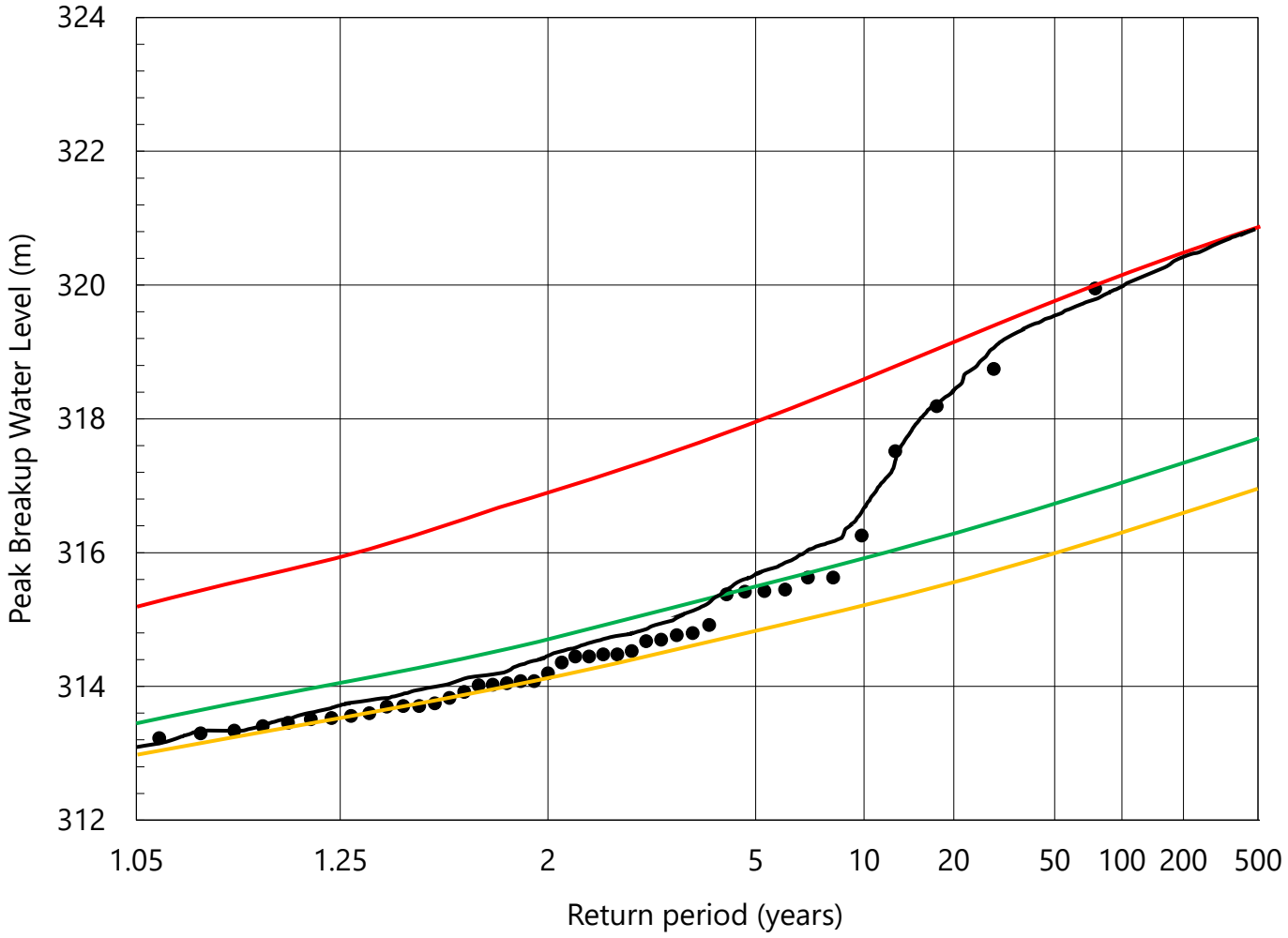
Indirect Flood Frequency Estimation Probability Factors

- Year-by-year classification by breakup type.
- Estimate probability factors for breakup type from observational data.

Year	Breakup Discharge (m^3/s)	Peak Breakup Gauge Height (m)	Breakup Mechanism
…	…	…	…
2014	4770	10.08	Ice Run
2015	4480	10.67	Ice Jam
2016	3770	6.43	Thermal
2017	4540	7.42	Ice Run
2018	4380	9.03	Ice Jam
…	…	…	…

Breakup Type		# of Events	% of Total
Thermal		27	60%
Mechanical	Ice run or partial jam	12	27%
	Fully developed jam	6	13%

Indirect Flood Frequency Estimation
Monte-Carlo Envelopes



100% fully developed ice jams

Monte-Carlo

100% ice runs or partial jams

100% thermal breakup

Indirect Flood Frequency Estimation
Monte-Carlo Workflow

Determine peak breakup level and discharge by year and characterize by breakup mechanism.

Year	Breakup Discharge (m^3/s)	Peak Breakup Gauge Height (m)	Breakup Mechanism
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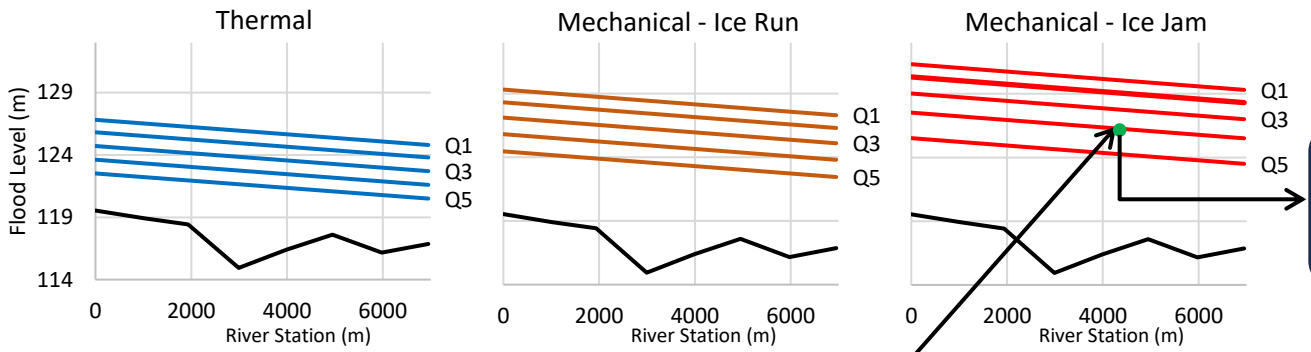
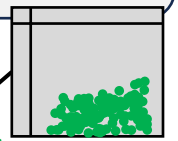
Develop a family of ice-affected flood level profiles for each breakup mechanism (rating curves).



4. Store the breakup flood level to the synthesized population of breakup levels for each section and repeat the process (e.g. 10,000 + iterations).



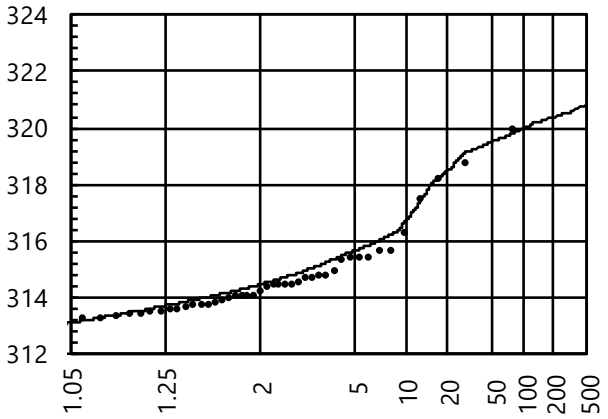
repeat, many times…

Determine probability factors by breakup mechanism.

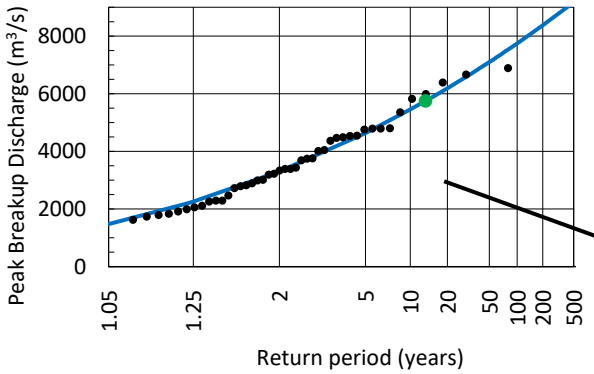
$P_{mechanical} = 0.82$ { $P_{jam\ if\ mechanical} = 0.42$
$P_{thermal} = 0.18$ { $P_{ice\ run\ if\ mechanical} = 0.58$

3. Determine the ice-affected flood level based on the breakup type and the respective breakup discharge – water level relationship.

5. Rank and plot the series with a standard plotting position formula to form a distribution of breakup flood levels and compare to the estimated breakup flood levels based on observational data.



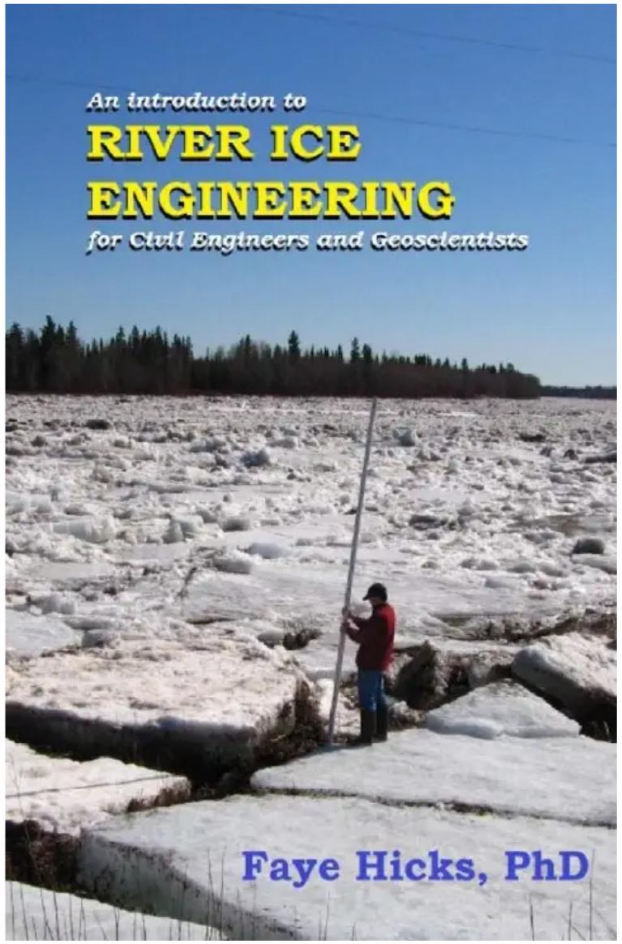
Estimate breakup discharge frequency distribution.

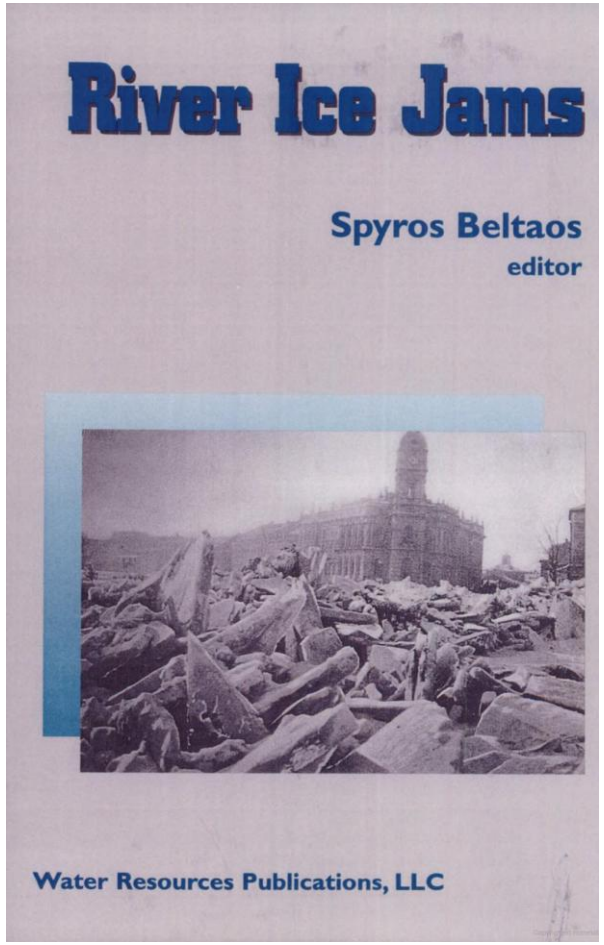


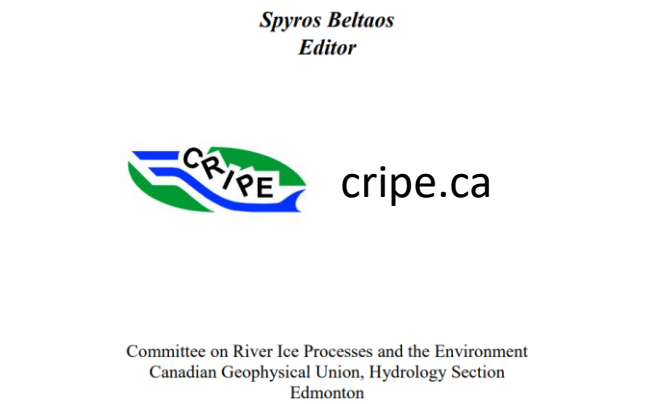
2. Randomly select a breakup mechanism based on probability factors.

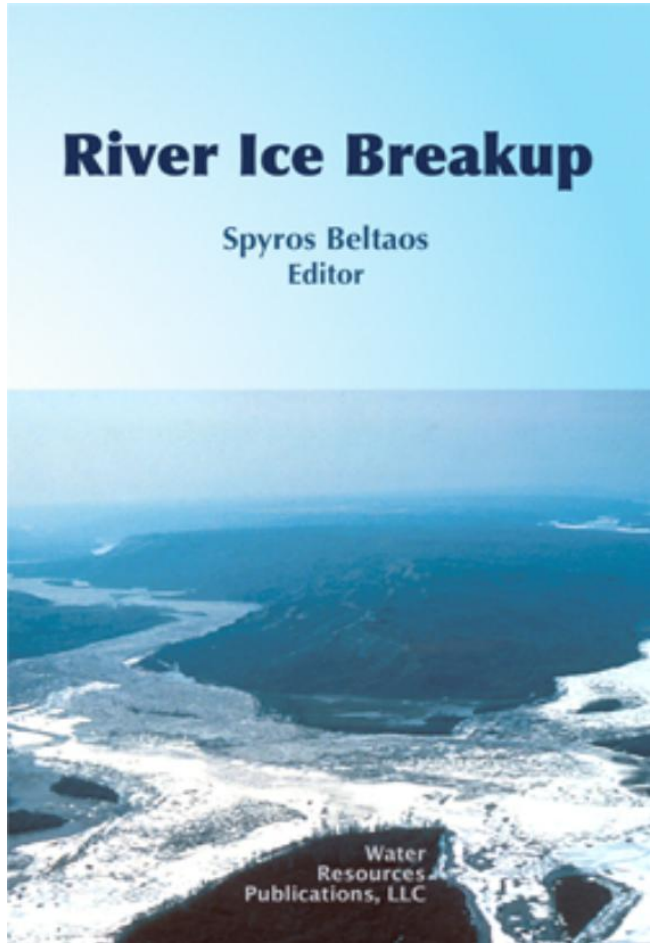
1. Randomly select a value from the breakup discharge frequency distribution

Thank you & Questions









some good reads to get started…