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International Vision for Research and Development in Resilience of Road Networks

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Norman W. McLeod Chair in Sustainable Pavement Engineering
Director Centre for Pavement and Transportation Technology

Santiago Chile
March 28, 2017

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Presentation Overview

- Introduction
- Natural Disasters
- Approach to Research
- Resilience strategies
- Closing Remarks

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What is a Natural Disaster?

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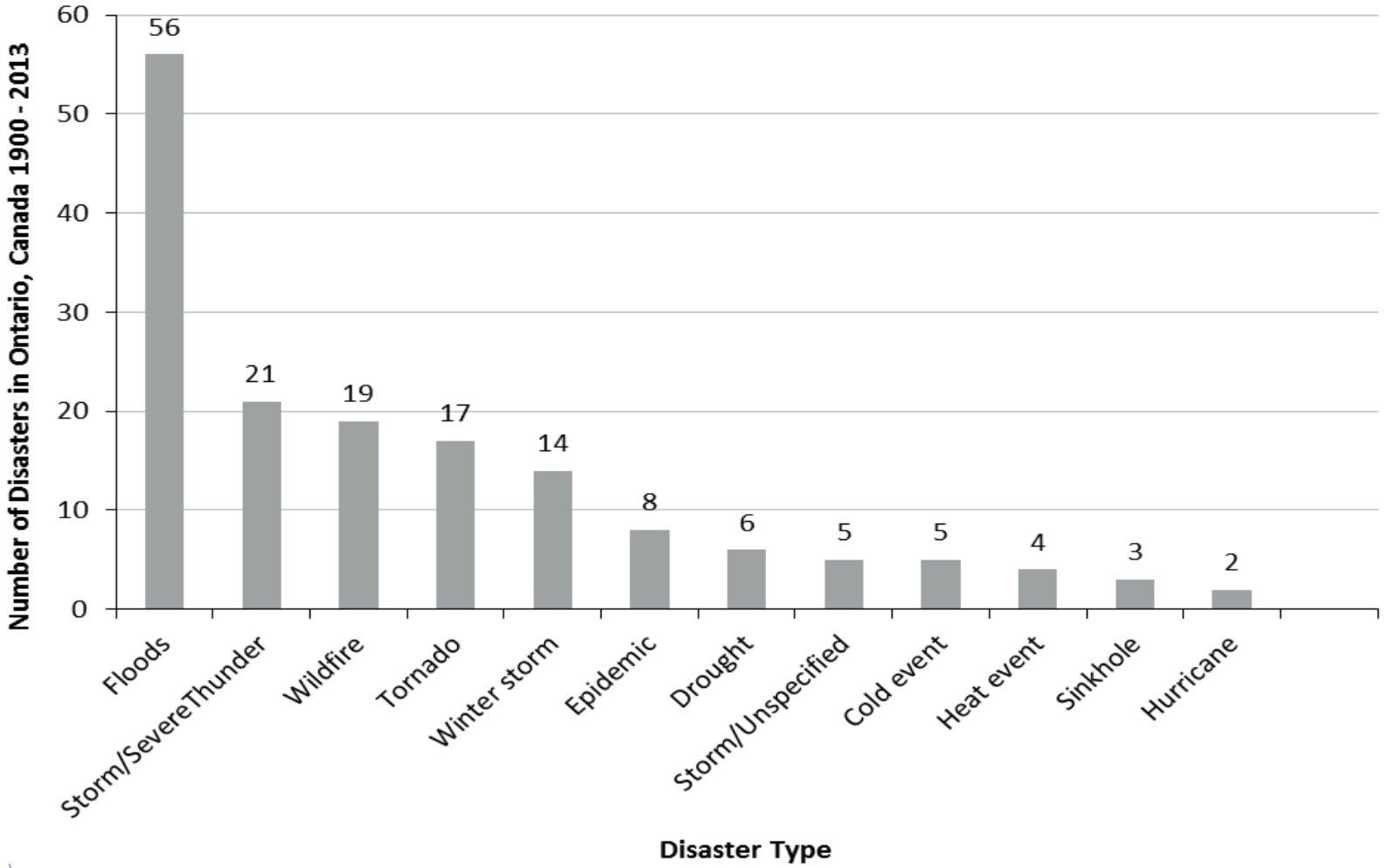
Disaster Types in Ontario 1900 – 2013



Nirupama, N., et al (2014). Natural Hazards in Ontario, Canada: An Analysis for Resilience Building. *Procedia Economics and Finance*, *18*, 55-61.

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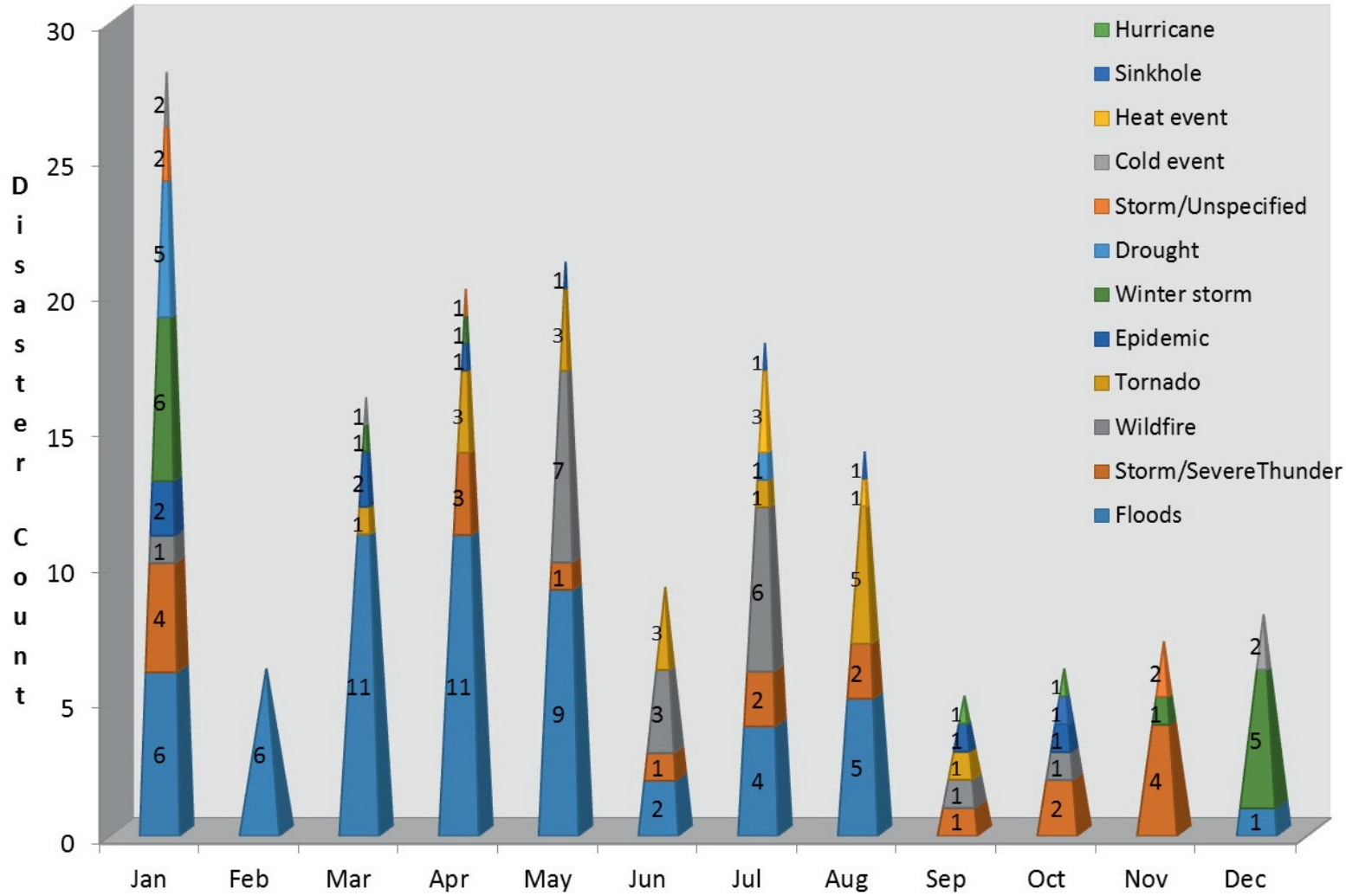
When does flooding occur?



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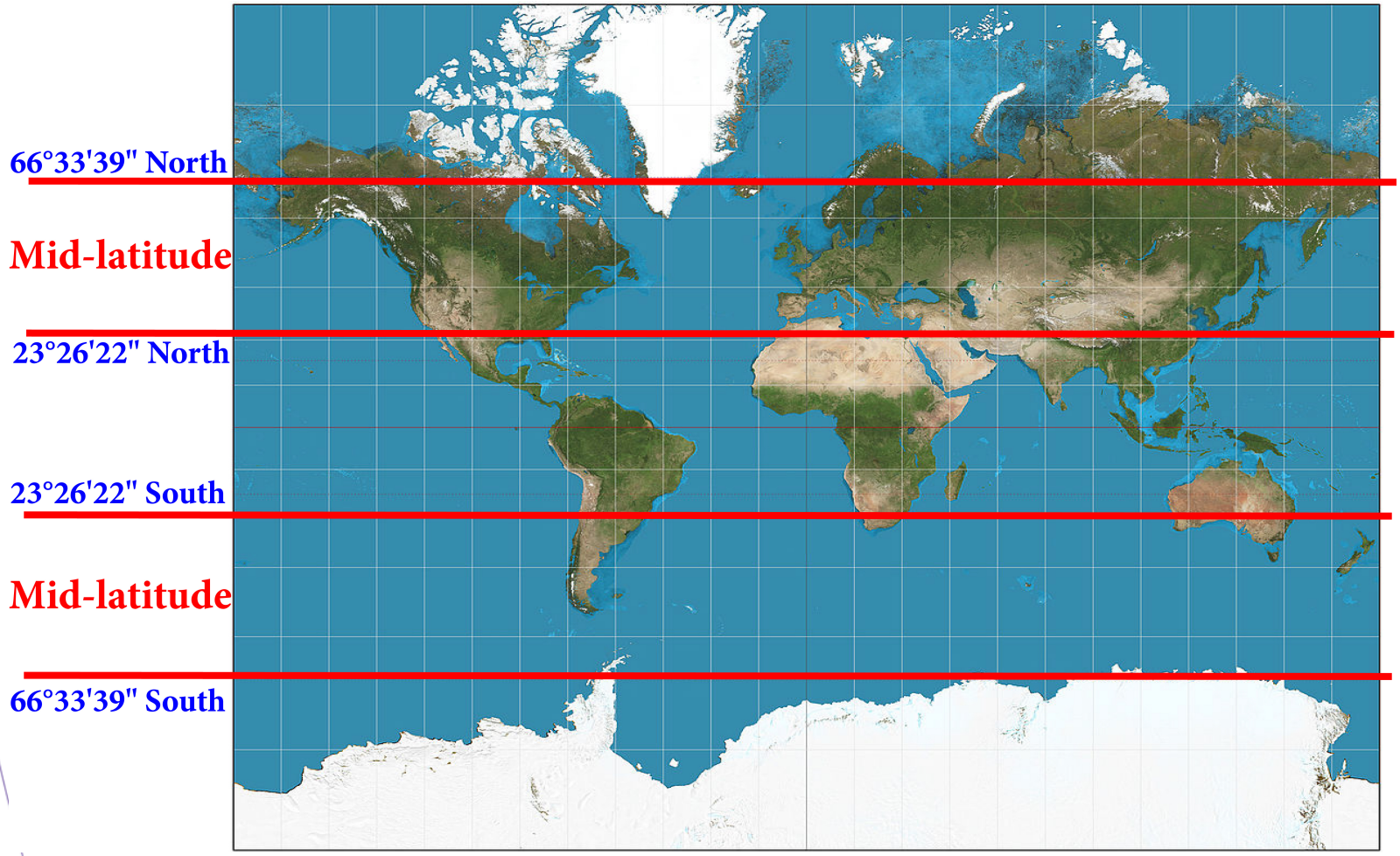
Mid-Latitude Impact, More Intense, Frequent Rainfall Events, IPCC 2014



Chile 17.5° – 56.5° South

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Infrastructure Risk

- Infrastructure Risk Assessment
  - Interaction of hazards with infrastructure
  - Infrastructure exposure and vulnerability
- Climate Change Risk Management
  - Identify and analyze risk posed by climate change
  - Adaptation strategies to deal with them

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Challenge and Opportunity

- Bridge the gap: natural hazard and infrastructure damage
- Quantify infrastructure network risk and address uncertainty
- Adaption opportunity

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Challenge and Opportunity

Risk = Hazard × Vulnerability

Vulnerability = Fragility × Cost

- Hazard: characteristic of extreme events
- Vulnerability: cost of pavement damage
- Fragility: probability of damage given occurrence of extreme events
- Cost: addition life cycle cost, asset value loss
- Risk: hazards, and pavement damage and costs

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Approach to Research

- Economic impact of infrastructure risk
- Examine natural disasters for given country
- Develop hazard data and maps

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Approach to Research

- Develop risk assessment framework, methods, and establish adaptation strategies to manage risk
- Develop fragility models
- Damage cost estimation and vulnerability assessment

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Approach to Research

- Examine infrastructure network risk
- Develop network risk mapping tool
- Prepare adaptation strategies and implementation

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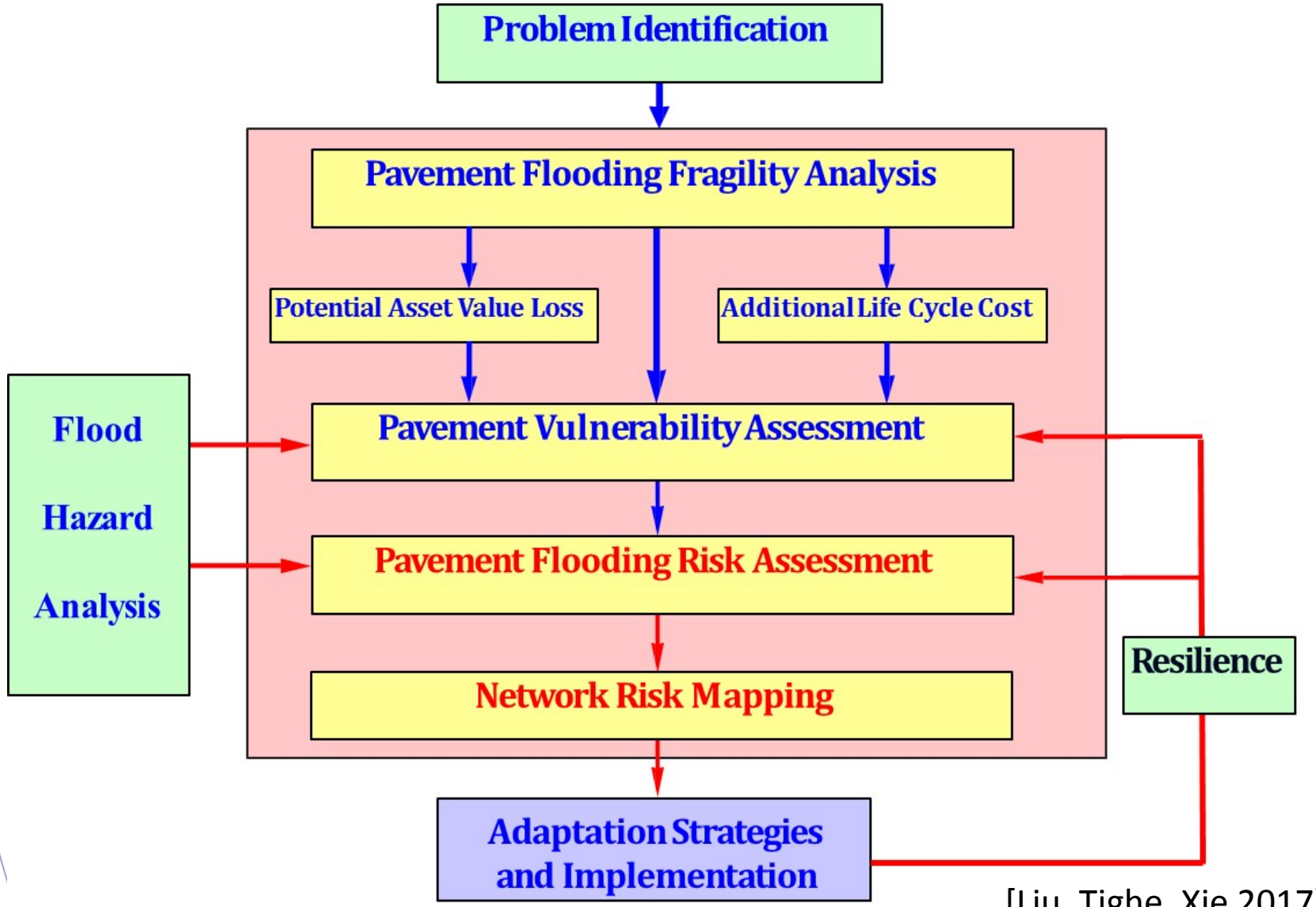
Approach to Research



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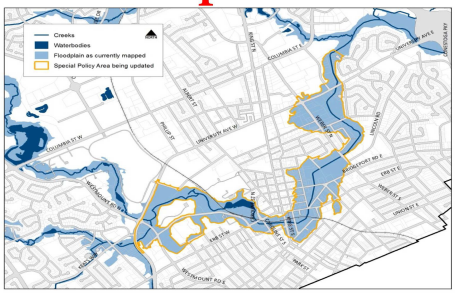
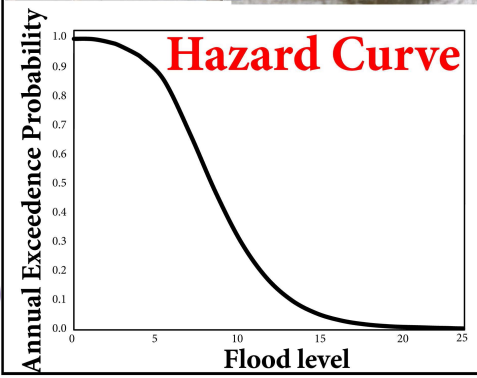
Approach to Research

Hazard Analysis

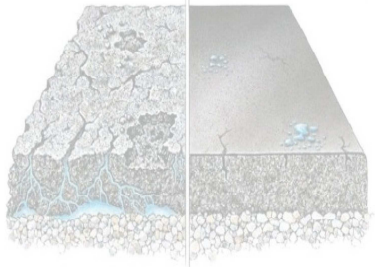
Flood map

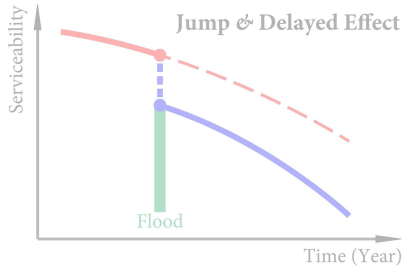


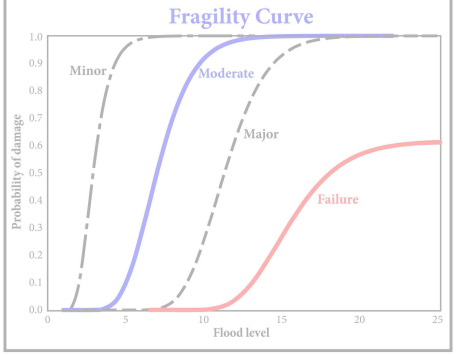


Vulnerability Analysis

Fragility Analysis







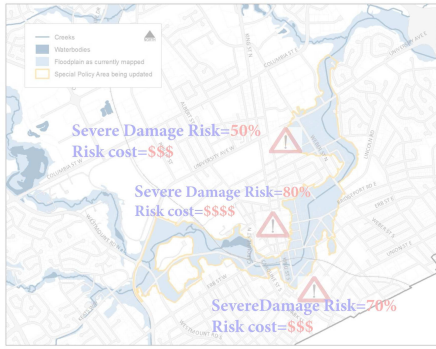
Cost

Maintenance Rehabilitation Costs

Asset Value Losses

Risk

Pavement Network Flood Risk



Adaptation

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Approach to Research

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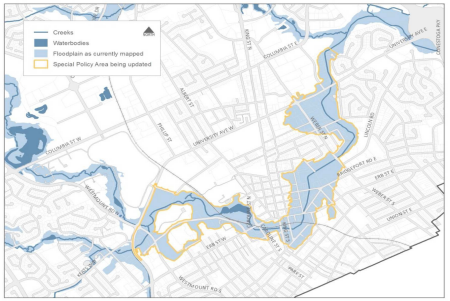
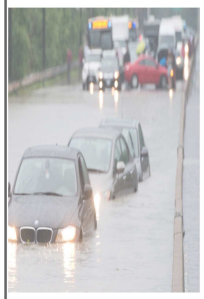
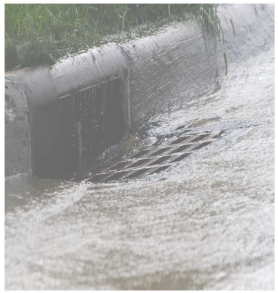
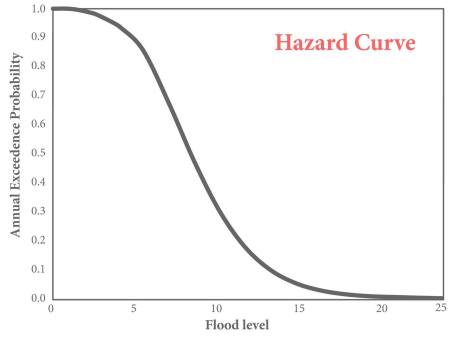


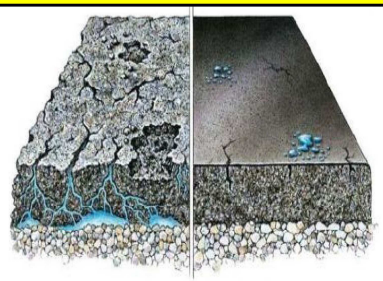


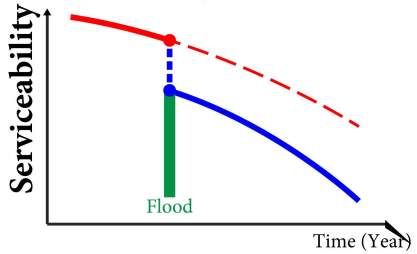




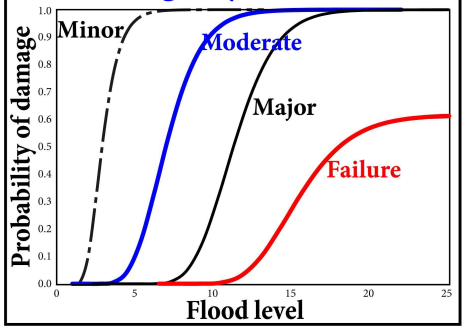
Vulnerability Analysis

Fragility Analysis





Fragility Curve



Cost

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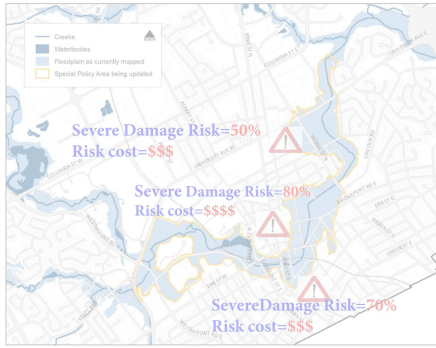

Adaptation

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Approach to Research

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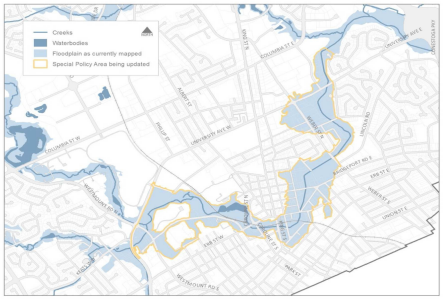
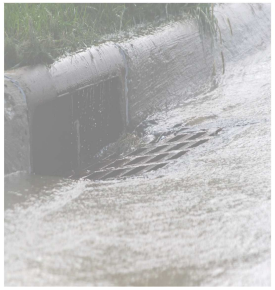
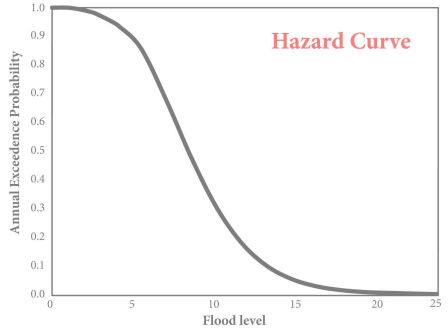
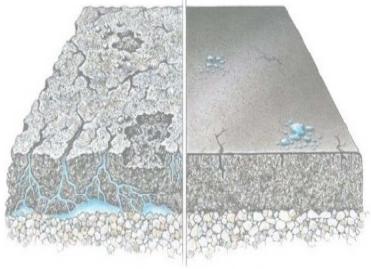


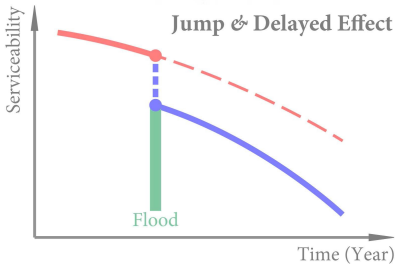


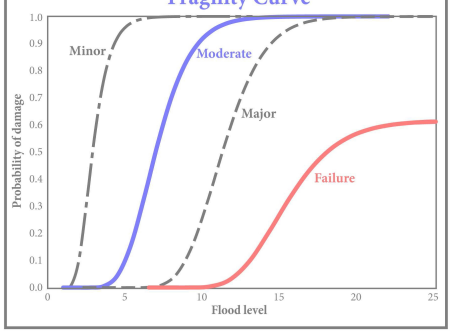


Vulnerability Analysis

Fragility Analysis







Cost

Maintenance Rehabilitation Costs

Asset Value Losses

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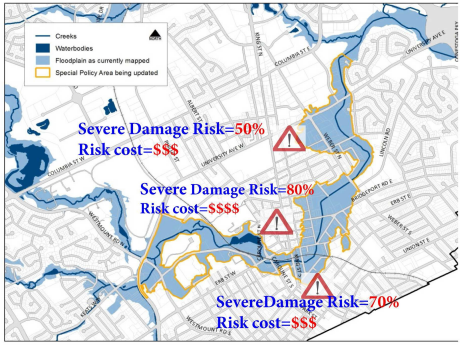
Pavement Network Risk



Adaptation

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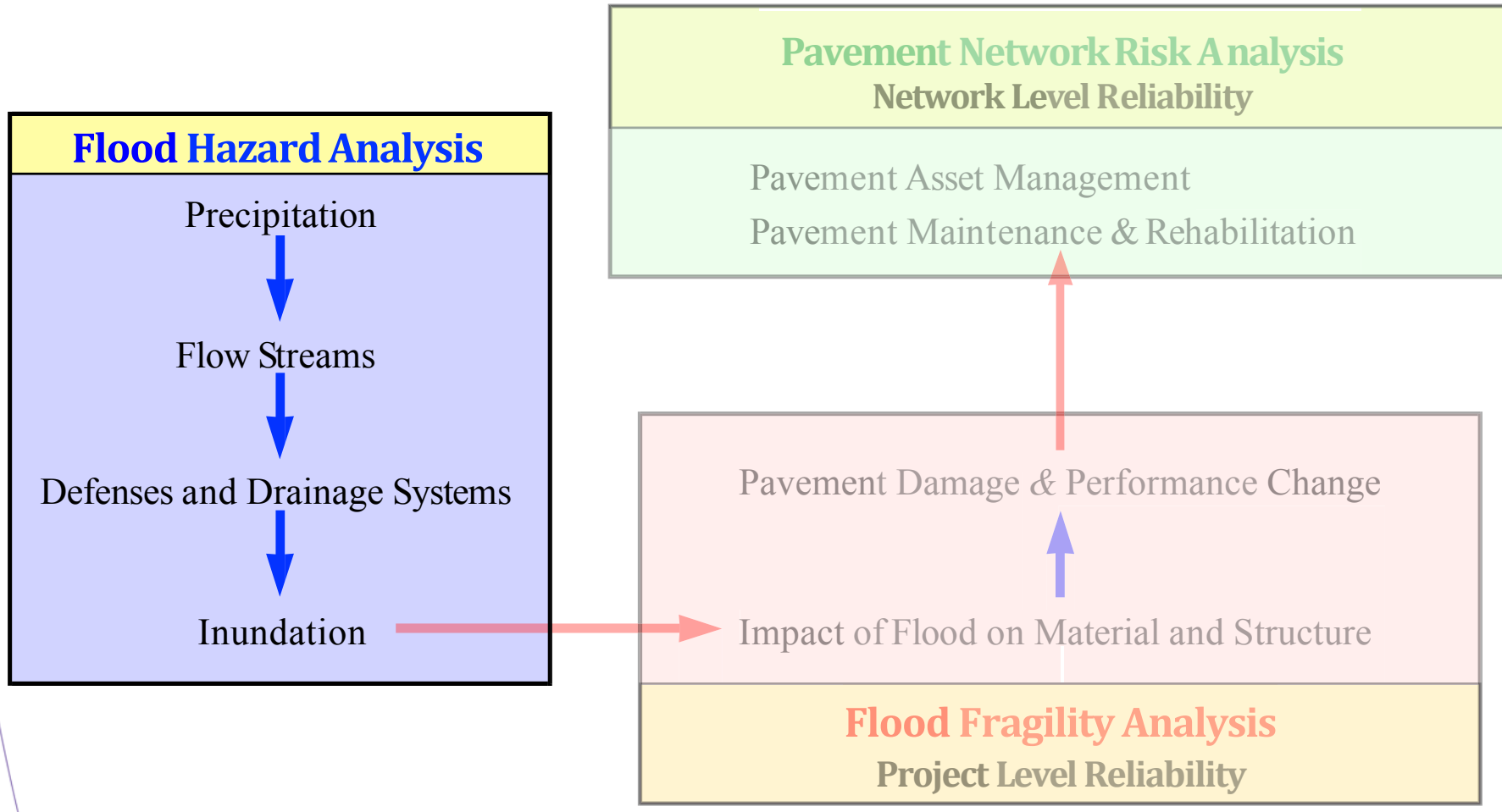
Approach to Research



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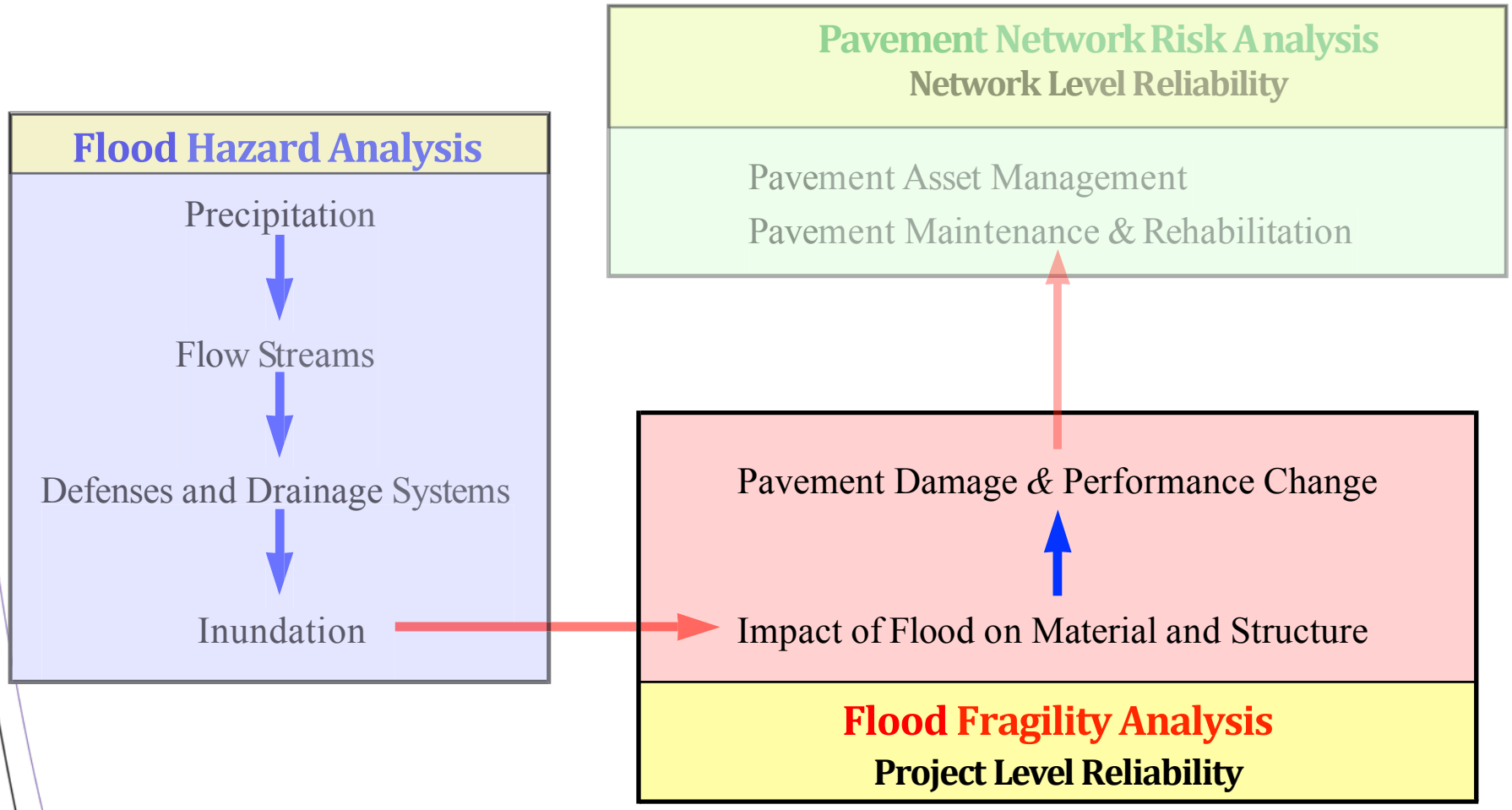

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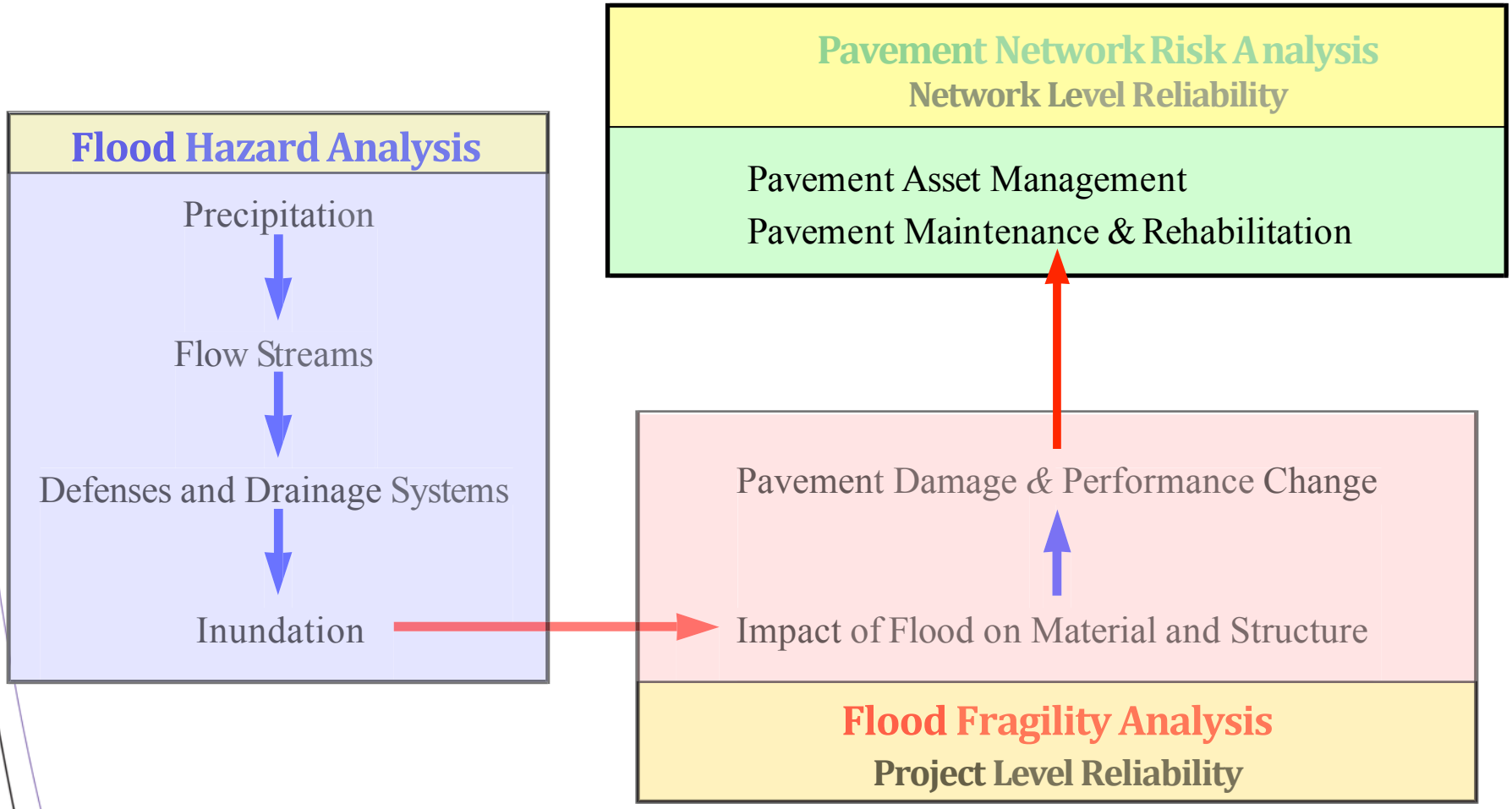

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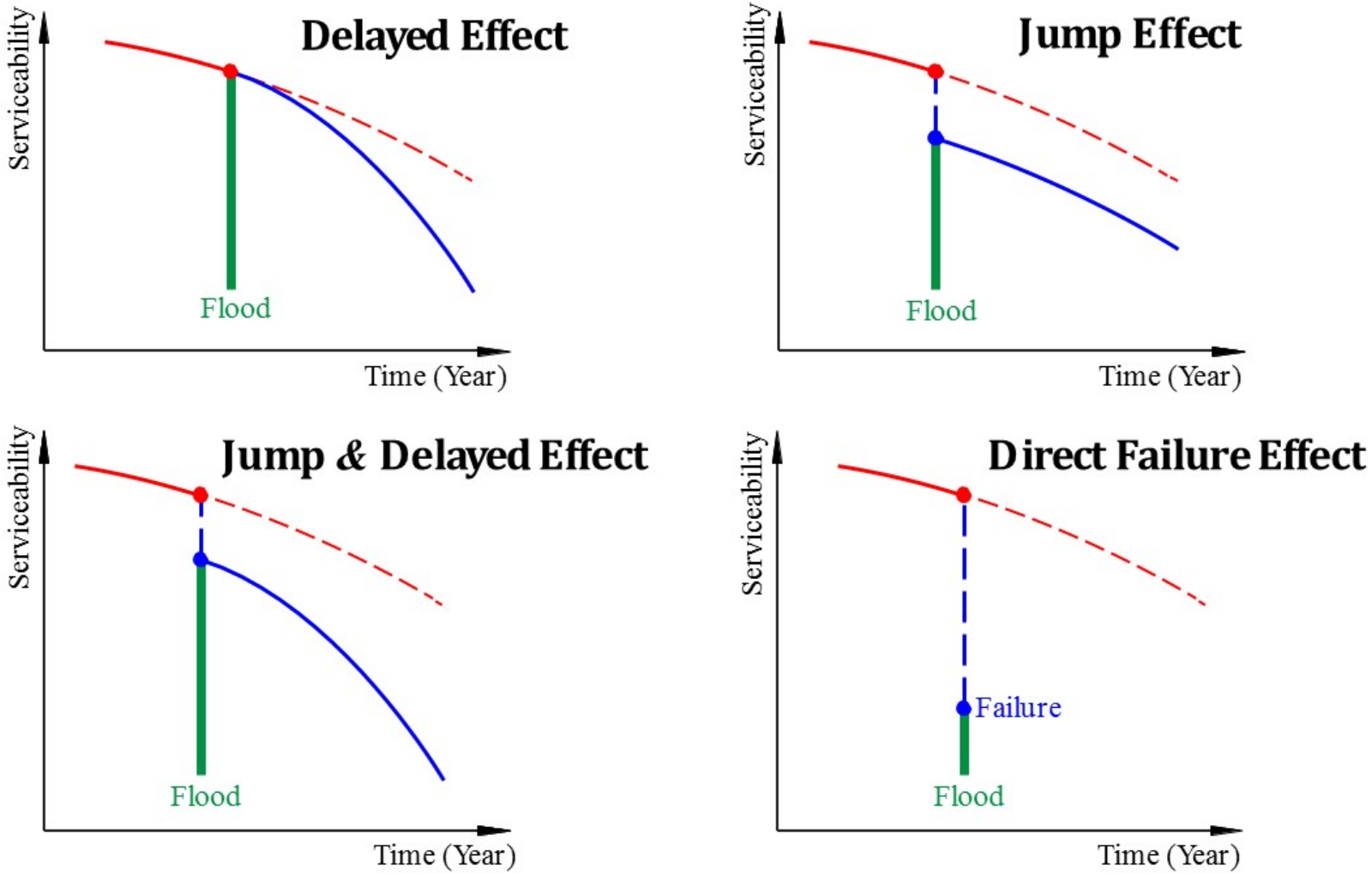

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Impacts on Infrastructure

- Changes occurring in minimum daily temperature
- Changes occurring in maximum daily temperature
- Changes occurring in freezing and thawing indices
- Changes occurring in precipitation, duration and intensity
- All of these changes are impacting infrastructure
- Reconsider current design methods, maintenance and rehabilitation practices
- Manage implications

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Impacts on Infrastructure

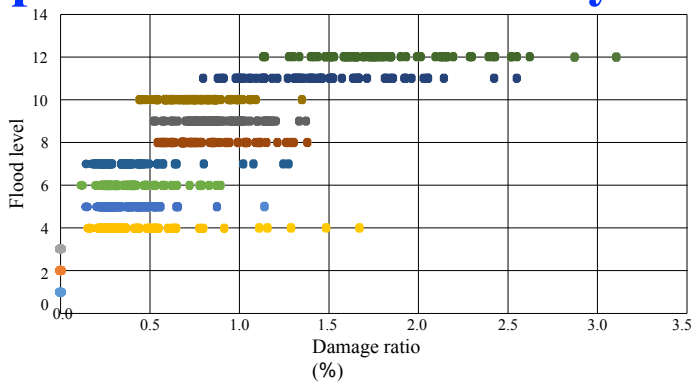
Step 1 Define Damage States

Damage state	Damage level
PDS0	Insignificant
PDS1	Minor
PDS2	Moderate
PDS3	Major
PDS4	Collapse

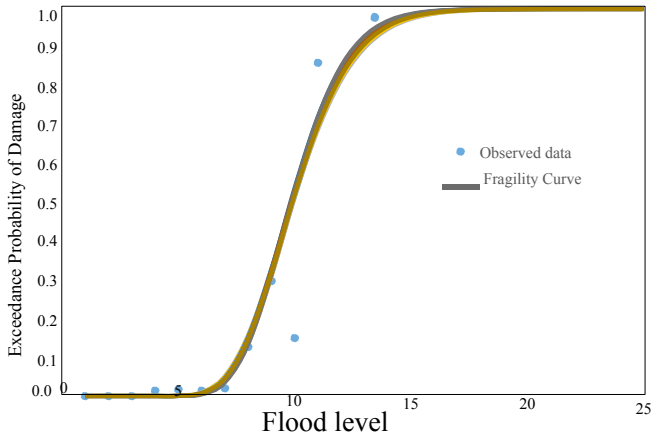
Step 2

Define threshold for each damage state

Step 3 Observed Data Analysis



Step 4 Generating Fragility Curves



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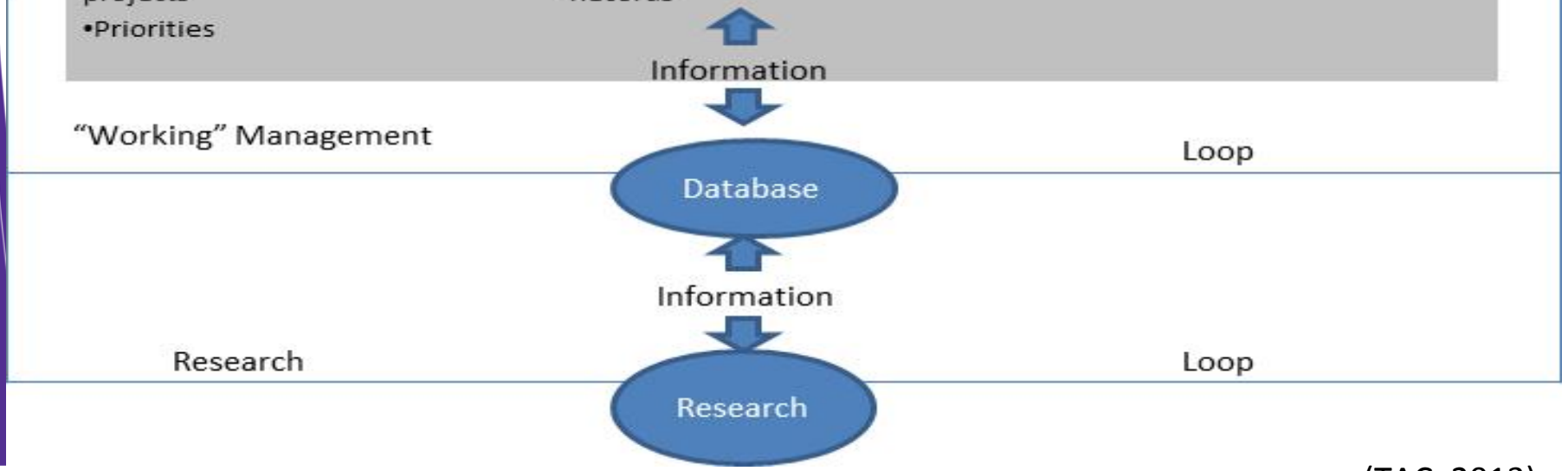
Planning and Programming	Design	Construction	Maintenance, Preservation and Rehabilitation	In-Service Evaluation	End of Service Life
•Traffic and Environmental data information •Assess network deficiencies •Budgets •Establish priorities •Schedule projects •Priorities	•Information on materials, traffic, costs, environment, etc. •Design alternatives •Analysis •Optimization •Sustainability •User costs	•Environment during construction •Specifications •Contracts •Schedules •Construction operations •Quality control/quality assurance •Records	•Standards •Treatments •Schedules •Operations •Budget control •Records •Impact on performance •User costs	•Periodic monitoring of structural adequacy, roughness, surface distress, and surface friction •Assess performance •Prioritize	•Recycling and reuse of materials for reconstruction •Salvage Value •Records •Restoration •Zero Waste Management



(TAC, 2013)

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Long Life Design

- Resilience is the ability to deal with changes in general
- Resilience in engineering design to ensure it withstands hazard with minimum damage of pavement
- Build-in resilience from material
- Infrastructure resilience from post disaster using asset management to better manage future road

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Closing Remarks

- Understand natural hazard risk including Climate Change for Long Life Infrastructure
- Adoption of new materials and designs
- Evaluate potential threats related to climate change and plan for them
- Proactive design and management

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Acknowledgements

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- Partners in Norman W. McLeod Chair
- CPATT Partners

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Questions/Comments

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