



Overview of NRC Probabilistic Flood Hazard Assessment Research Program

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Outline

- Objectives
- Key Challenges
- Main Themes
- Current Projects

PFHA Research Objectives

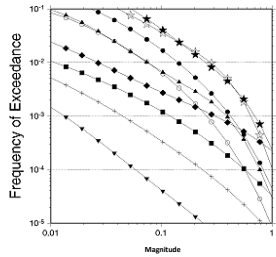
- Support development of risk-informed licensing and oversight guidance and tools for assessing flooding hazards and consequences
 - *Addresses significant gap in probabilistic basis for external hazards*
 - Seismic and wind hazard assessments currently have probabilistic basis
- Support both new reactor licensing and oversight of operating reactors
 - *Design basis flood hazard assessments for new facilities*
 - 10 CFR Part 50 - traditional construction permits and operating licenses
 - 10 CFR Part 52 - early site permits (ESPs), combined operating licenses (COLs)
 - *Operating reactor oversight program (ROP)*
 - Significance determination process (SDP) analyses for evaluating deficiencies related to flood protection at operating facilities

Implementation

- Phased Approach
 - *Phase 1 (Technical basis, draft guidance)*
 - *Phase 2 (Pilot studies)*
 - *Phase 3 (Finalize guidance)*
- Implementation time-frame
 - *~5 years for Phase 1*
 - ***now into 4th year of implementation***
 - *~2 years for Phases 2+3*
 - ***need to begin discussion of pilot studies***
- Contract technical support
 - *Interagency Agreements*
 - *DOE Laboratories, USACE, USBR, USGS*
 - *Commercial contracts*
- External Collaborations
 - *Federal Working Groups (e.g., ACWI/SOH)*
 - *EPRI (MOU in place)*
 - *International (e.g., IRSN)*

Risk-informed Assessment of Flooding Hazards and Consequences

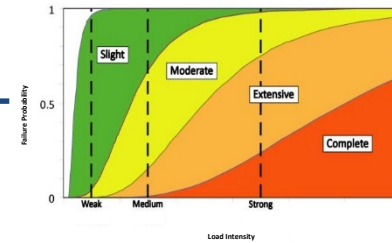
$$L_1(\bar{x}, t) \quad L_2(\bar{x}, t) \quad \dots \quad L_N(\bar{x}, t)$$



Hazard Curves :
Quantitative probabilistic
assessment
of flood hazard(s)

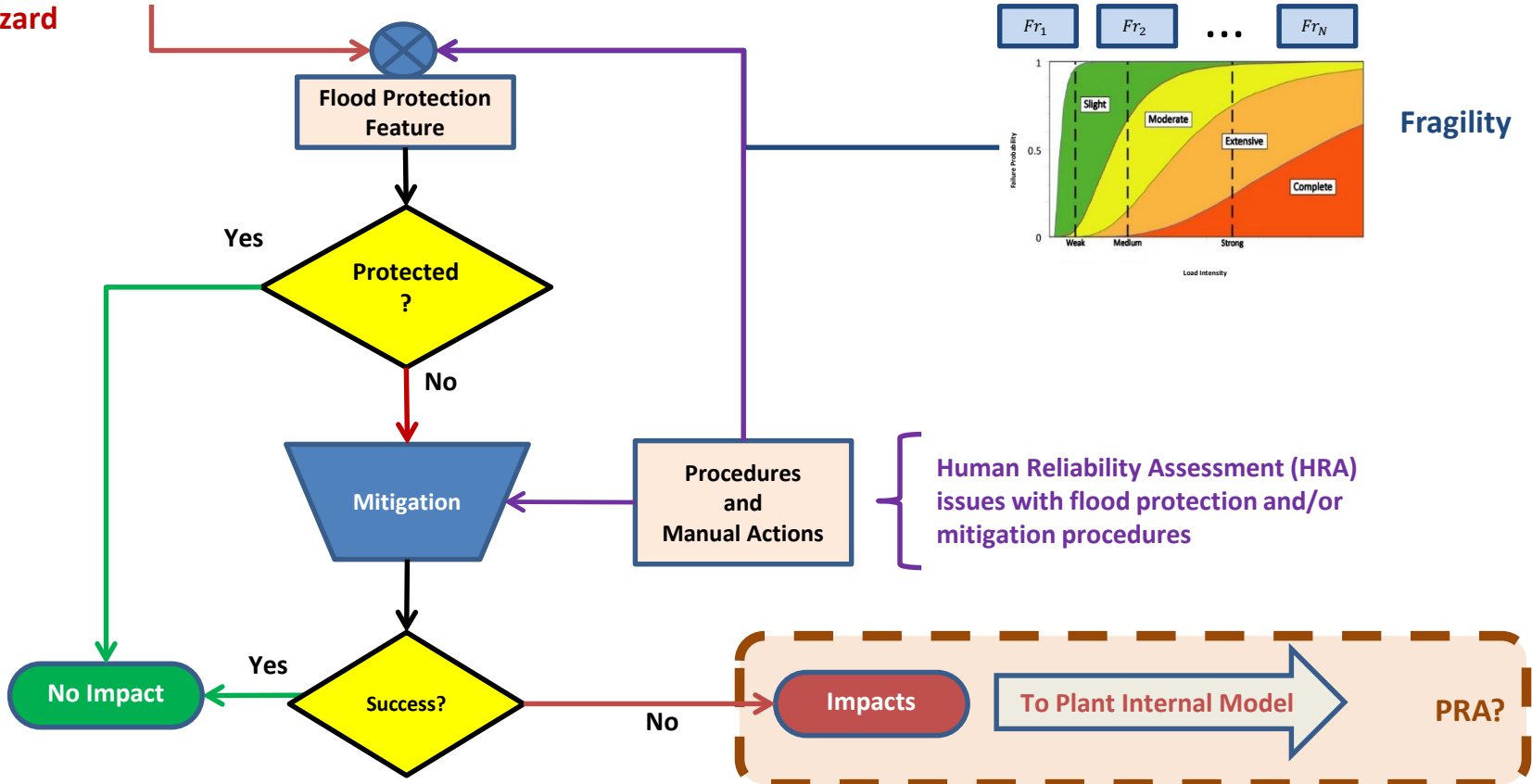
Fragility Curves :
Quantitative Reliability of Passive and
Active Flood Protection Features

$$Fr_1 \quad Fr_2 \quad \dots \quad Fr_N$$



Fragility

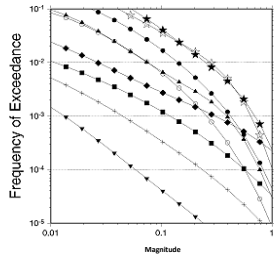
Hazard



Human Reliability Assessment (HRA)
issues with flood protection and/or
mitigation procedures

Risk-informed Assessment of Flooding Hazards and Consequences

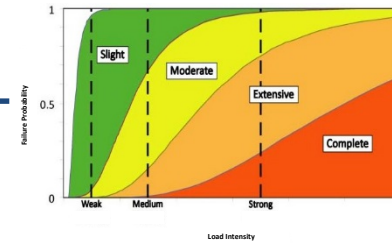
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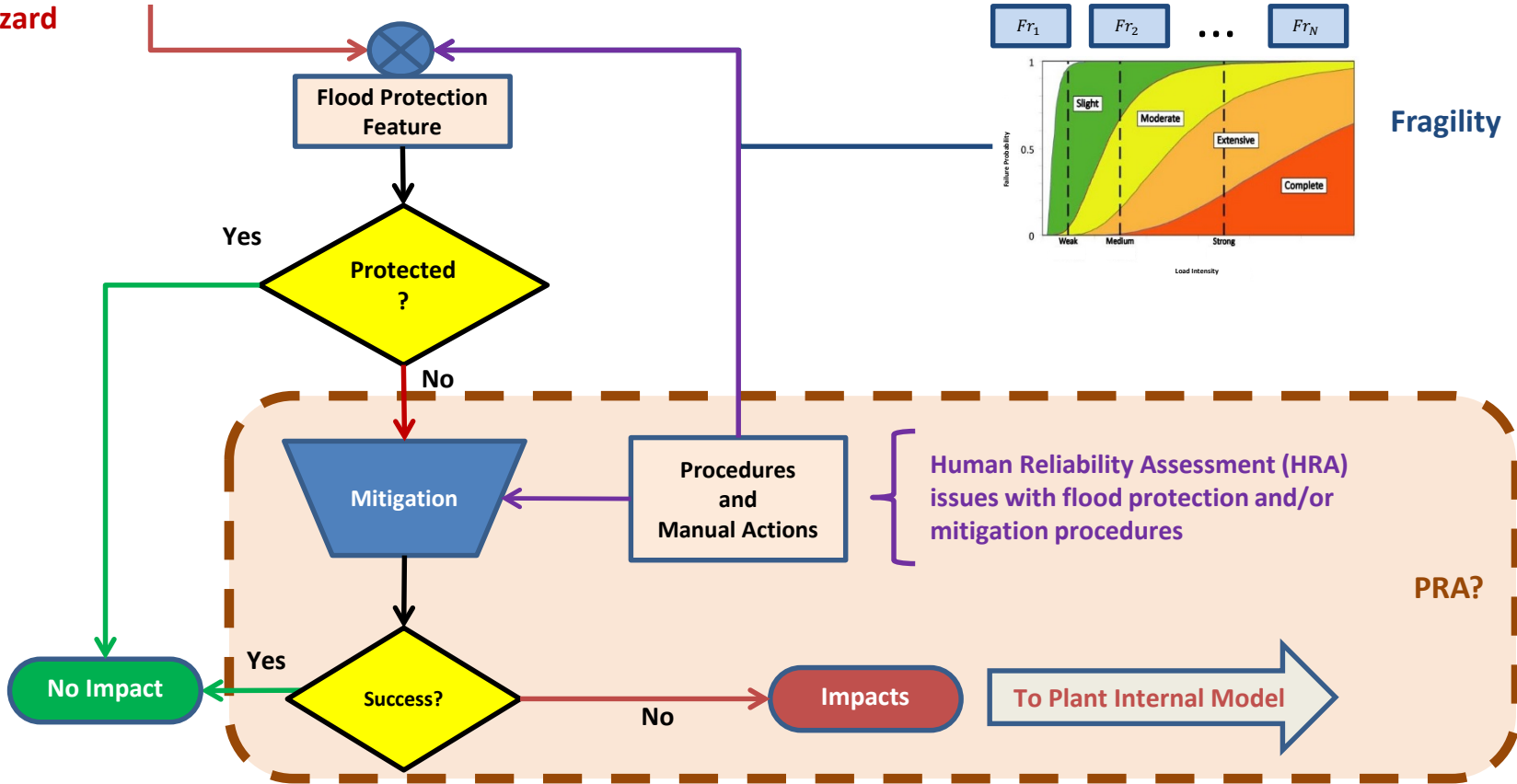
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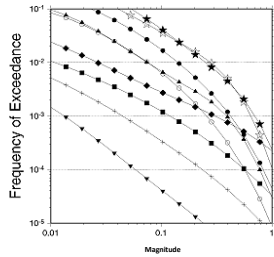
Fragility

Hazard



Risk-informed Assessment of Flooding Hazards and Consequences

$$L_1(\bar{x}, t) \quad L_2(\bar{x}, t) \quad \dots \quad L_N(\bar{x}, t)$$



Hazard Curves :
Quantitative probabilistic
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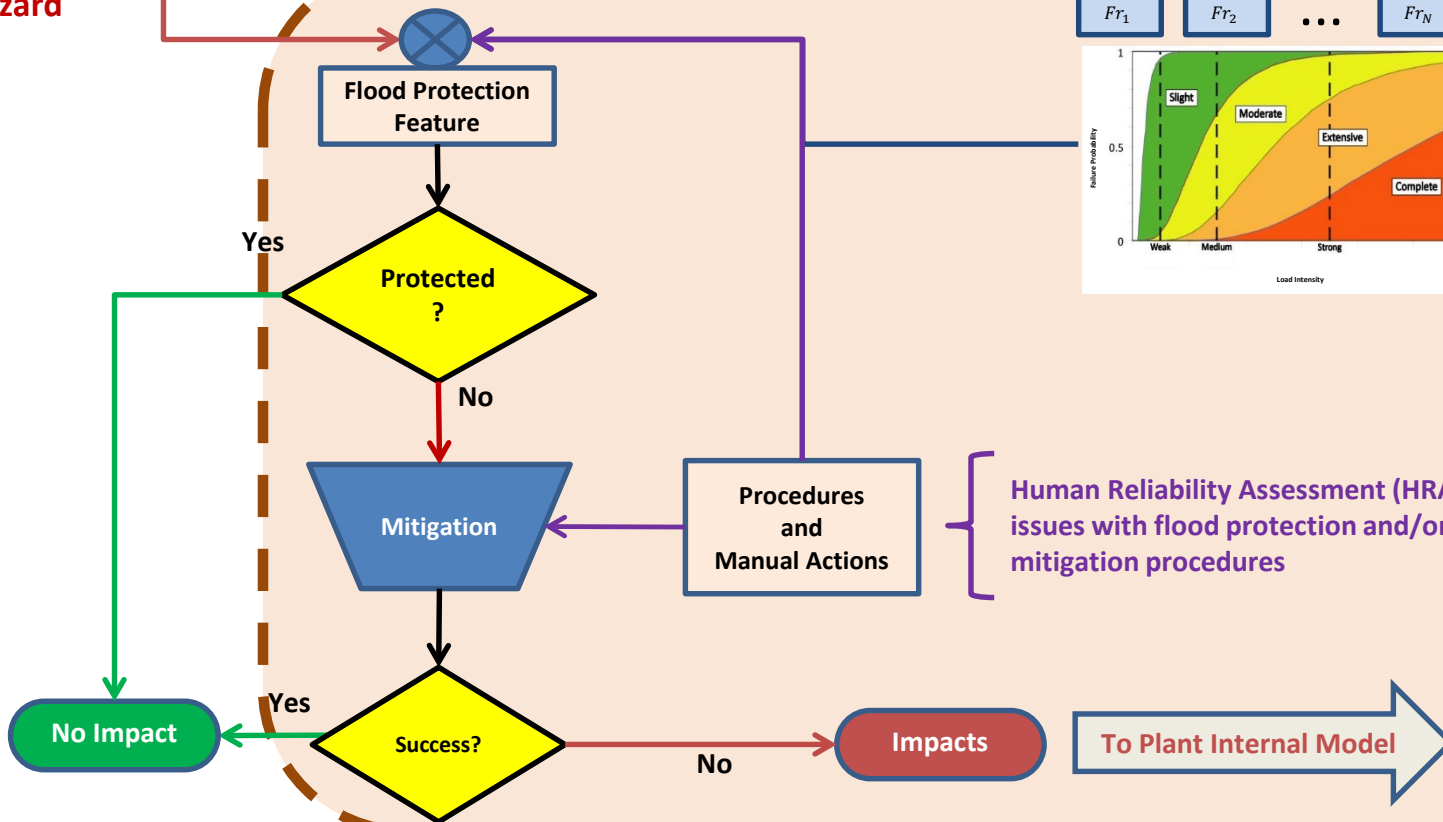
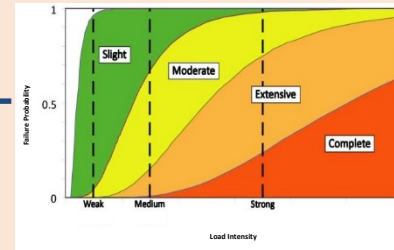
Fragility Curves :
Quantitative Reliability of Passive and
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Hazard

Fragility

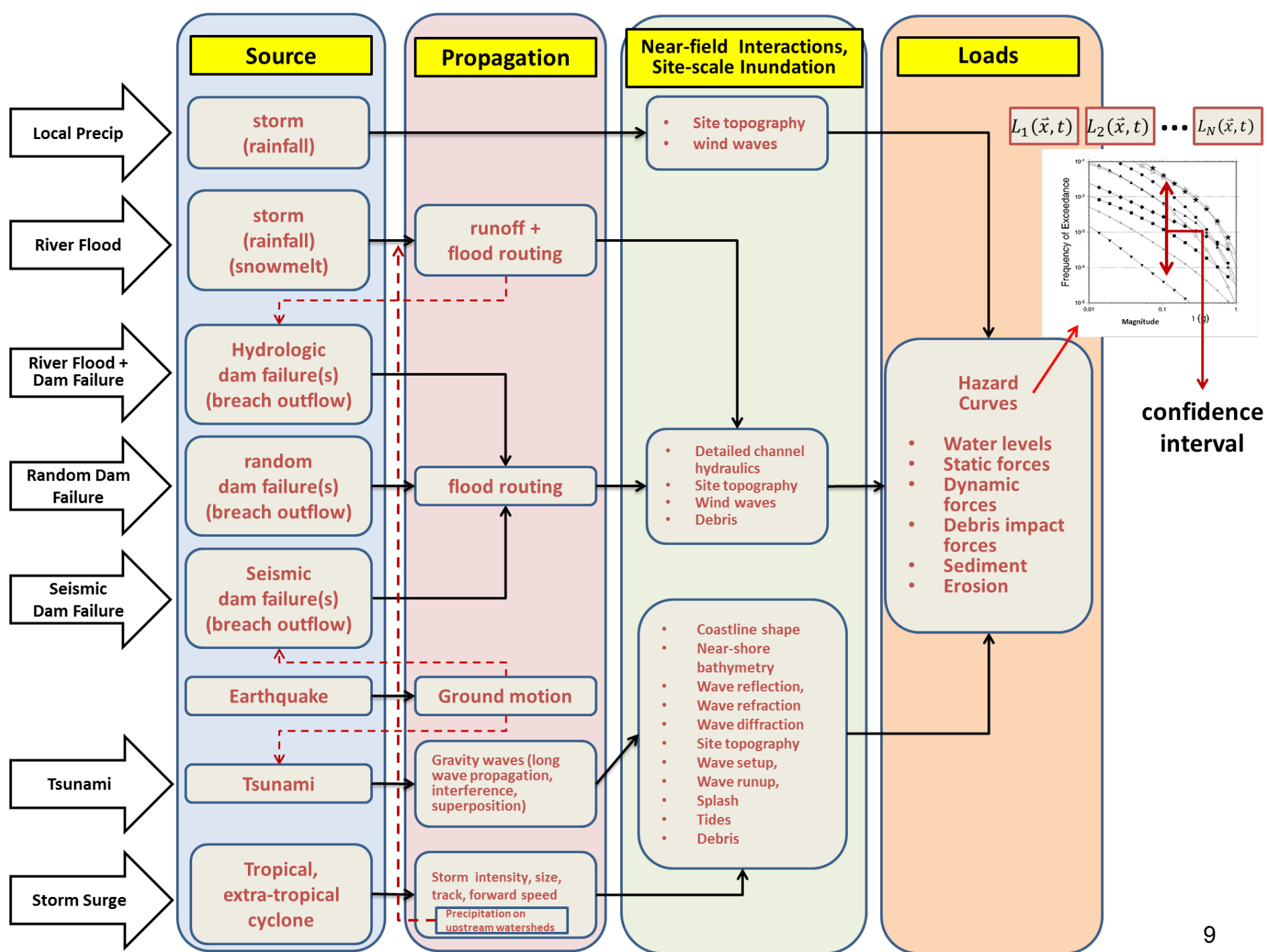
PRA?

$$Fr_1 \quad Fr_2 \quad \dots \quad Fr_N$$



Key Challenges

- Interested in range of annual exceedance probabilities (AEPs) from moderately rare to extreme floods
 - *Full hazard curves needed*
 - Aleatory and epistemic uncertainties
 - *AEPs in the range $1e-4$ to $1e-6$ desired*
- Large uncertainties
- Component fragility and human reliability information is sparse
- Flooding impacts exhibit cliff-edge effects
- Complexity
 - Coincident and correlated mechanisms
 - Associated effects

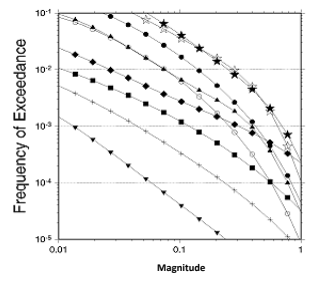


Main Research Themes

- Approaches and methods to leverage available flood hazard information
- Application of improved modeling techniques for processes and mechanisms associated with flooding
- PFHA modeling framework(s) for range of flooding scenarios and range of AEPs
- Methods to assess potential impacts of dynamic and nonstationary processes on flood hazard assessments and flood protection
- Methods to assess reliability of flood protection, mitigation, and plant response to flooding events

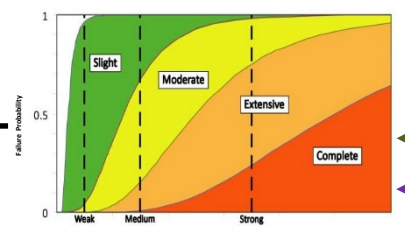
Research Themes

$L_1(\bar{x}, t)$ $L_2(\bar{x}, t)$... $L_N(\bar{x}, t)$



Hazard Curves

Fr_1 Fr_2 ... Fr_N



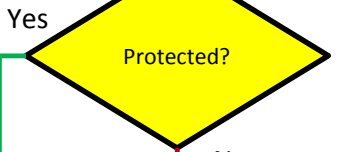
Fragility Curves

- Improved Modeling Methods
- potential impacts of dynamic and nonstationary processes
- PFHA Frameworks

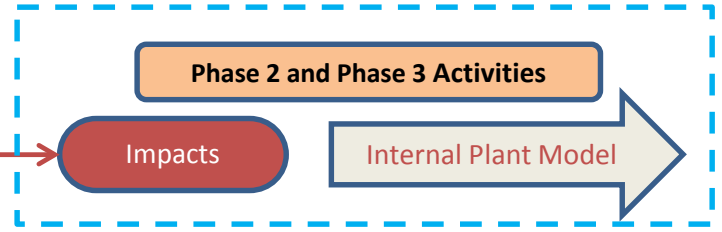
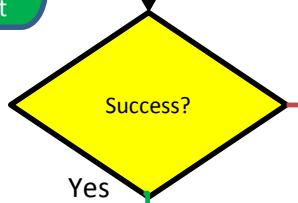
Leverage Available Flooding Information

Reliability of Flood Protection and Plant Response

Flood Protection Feature Failure Model



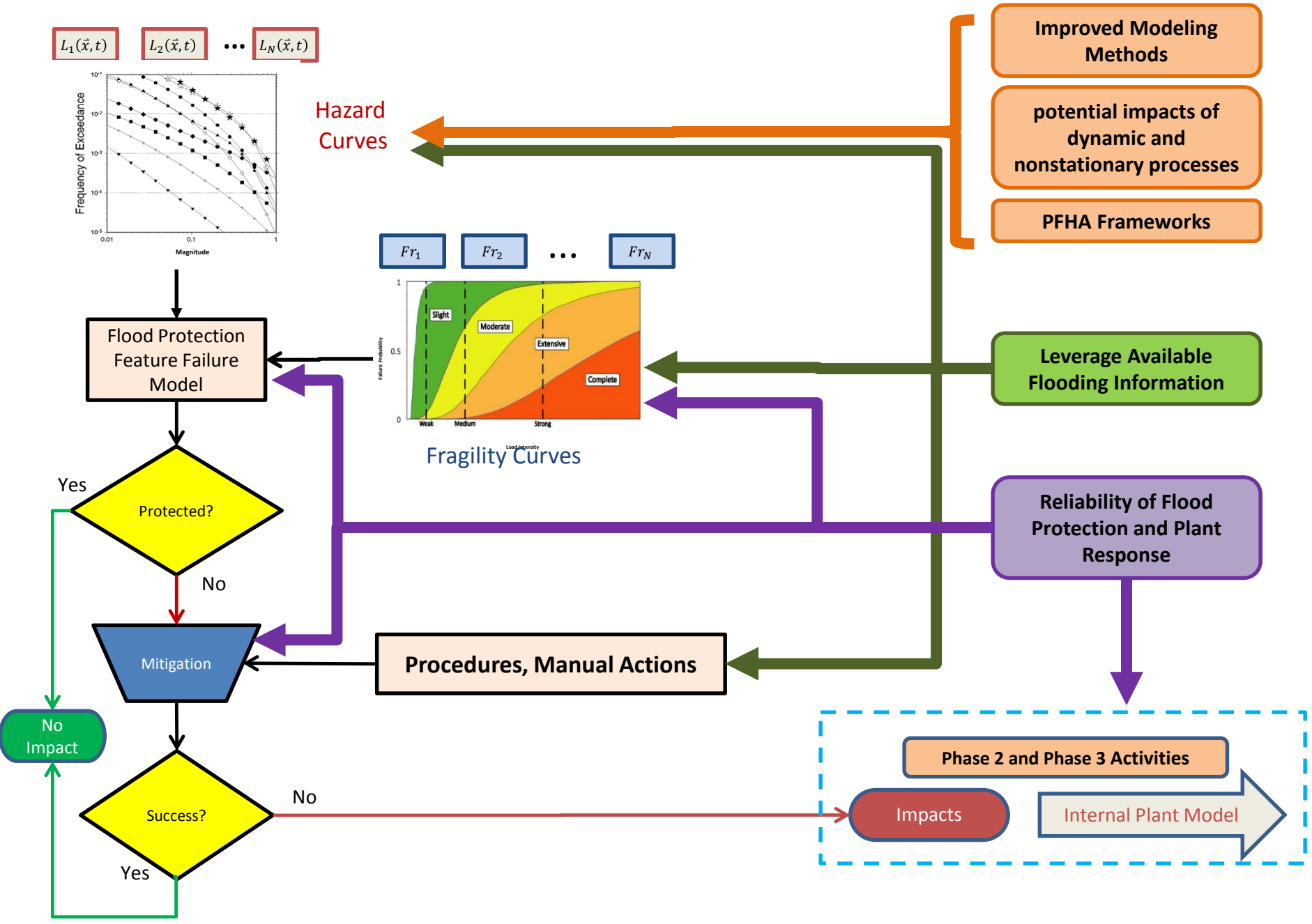
Procedures, Manual Actions



No Impact

Impacts

Internal Plant Model



Current Projects

Leverage Available Flooding Information

- **Development of Flood Hazard Information Digests for Operating NPP Sites**
 - *Contractor: Idaho National Laboratory (INL)*
 - *NRC PM: Meredith Carr*

- **Guidance on Application of State-of-Practice Flood Frequency Analysis Methods and Tools**
 - *Contractor: U.S. Geological Survey (USGS)*
 - *NRC PM: Meredith Carr*

Leverage Available Flooding Information

- **Technical Basis for Extending Frequency Analysis Beyond Current Consensus Limits**
 - *Contractor: U.S. Bureau of Reclamation (USBR)*
 - *NRC PM: Joseph Kanney*
- **Research to Develop Guidance on Extreme Precipitation Frequency in Orographic Regions**
 - *Contractor: USBR*
 - *NRC PM: Joseph Kanney*
- **Detailed TN River Paleoflood Study**
 - *Contractor: USGS*
 - *NRC PM: Mark Fuhrmann*

PFHA Frameworks

- **Technical Basis for Probabilistic Flood Hazard Assessment – Riverine Flooding**
 - *Contractor: Pacific Northwest National Laboratory (PNNL)*
 - *NRC PM: Joseph Kanney*
- **Probabilistic Flood Hazard Assessment Framework Development**
 - *Contractor: U.S. Army Corps of Engineers (USACE)*
 - *NRC PM: Joseph Kanney*
- **Structured Hazard Assessment Committee Process for Flooding**
 - *Contractor: PNNL*
 - *NRC PM: Joseph Kanney*

Improved Process Modeling

- **Numerical Modeling of Local Intense Precipitation Processes**
 - *Contractor: University of California Davis/USGS*
 - *NRC PM: Elena Yegorova*
- **Quantifying Uncertainties in Probabilistic Storm Surge Models**
 - *Contractor: USACE*
 - *NRC PM: Joseph Kanney*
- **Erosion Processes in Embankment Dams**
 - *Contractor: USBR*
 - *NRC PM: Jacob Philip*

Reliability of Flood Protection and Plant Response to Flooding Events

- **Performance of Flood Penetration Seals at NPPs**
 - *Contractor: Fire Risk Management (FRM)*
 - *NRC PM: Tom Aird*
- **Effects of Environmental Factors on Manual Actions for Flood Protection and Mitigation at NPPs**
 - *Contractor: PNNL*
 - *NRC PM: Meredith Carr*
- **Modeling Plant Response to Flooding Events**
 - *Contractor: INL*
 - *NRC PM: Joseph Kanney*

Dynamic and Nonstationary Processes

- **Regional Climate Change Projections: Potential Impacts to Nuclear Facilities**
 - *Contractor: PNNL*
 - *NRC PM: Elena Yegorova*