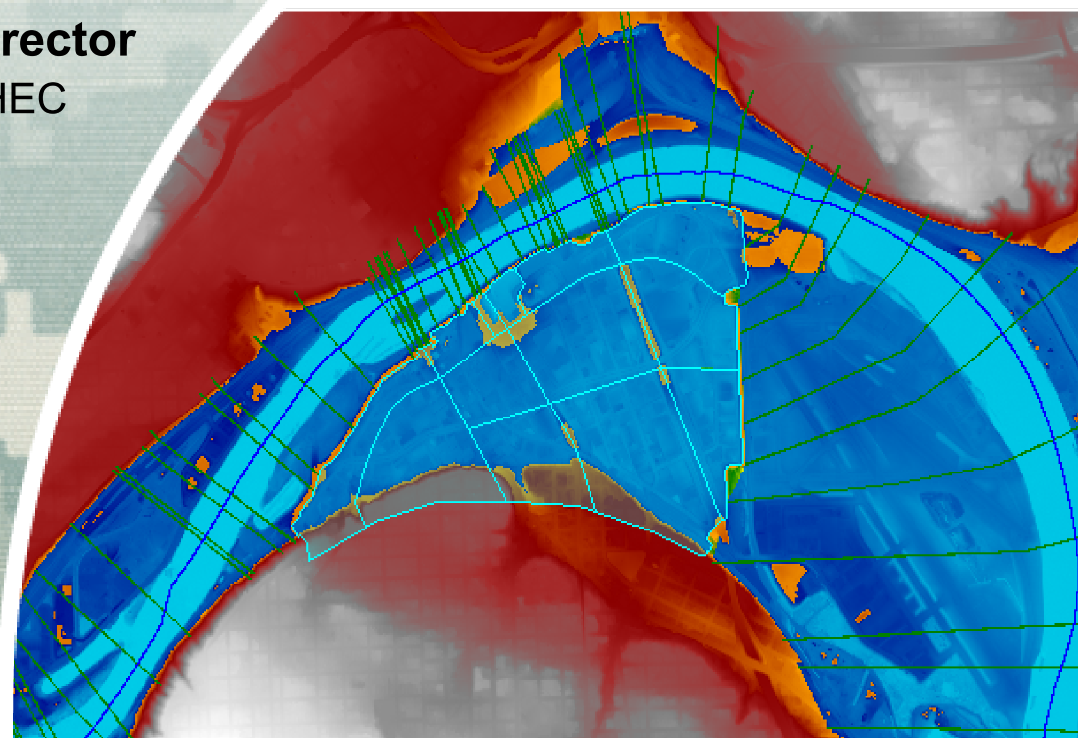
Assessing Levee System Performance Using Existing & Future Risk Analysis Tools

Workshop on Probabilistic Flood Hazard Assessment (PFHA)

Panel 8: Combined Events Flooding



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Combined Events Flooding

Panel 8 focuses on identifying and evaluating combined event scenarios within a risk informed framework. Combined events can include *flooding caused by seismically induced dam or levee failure; flooding caused by combinations of snowmelt, rainfall, and ice; flooding caused by combinations of coastal and riverine events;* ***basin or system wide performance and impacts;*** *human and organizational factors; and many other scenarios.*

Need for System Approaches with Risk Analysis

- ER 1105-2-100, Planning Guidance Notebook, 22 April 2000, requires systems approaches, "*The planning process shall address the Nation's water resources needs in a systems context…*"

- ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies, 3 January 2006, requires risk analysis for all flood damage reduction studies, "*All flood damage reduction studies will adopt risk analysis…*"

- EC 1110-2-6067, USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation, 31 August 2010, defines the objective of a system evaluation: "*verify that the levee system performs as an integrated set of features and components functioning individually and collectively to provide reasonable assurance…*"

- USACE Actions for Change, Themes 1 - 4, required comprehensive systems approaches that include integrated sustainable solutions and decisions are risk-informed.

Risk Analysis Hang-ups

- Design Standard Paradigm. (People tend to be risk adverse.)
- It can't be done. (i.e. Lack of understanding by the practitioners.)
- What is the value added? (How do we make decisions differently?)
- It costs too much.
- How do we communicate to the Stakeholders?
- How do we communicate to the Decision Makers?
- Even for the well informed, terminology/practice continues to change.
  - Risk Based
  - Risk Analysis
  - Risk and Uncertainty
  - Risk Management
  - Risk Assessment
  - Risk Informed
  - Probabilistic Risk Assessment
  - Probabilistic Flood Risk Assessment

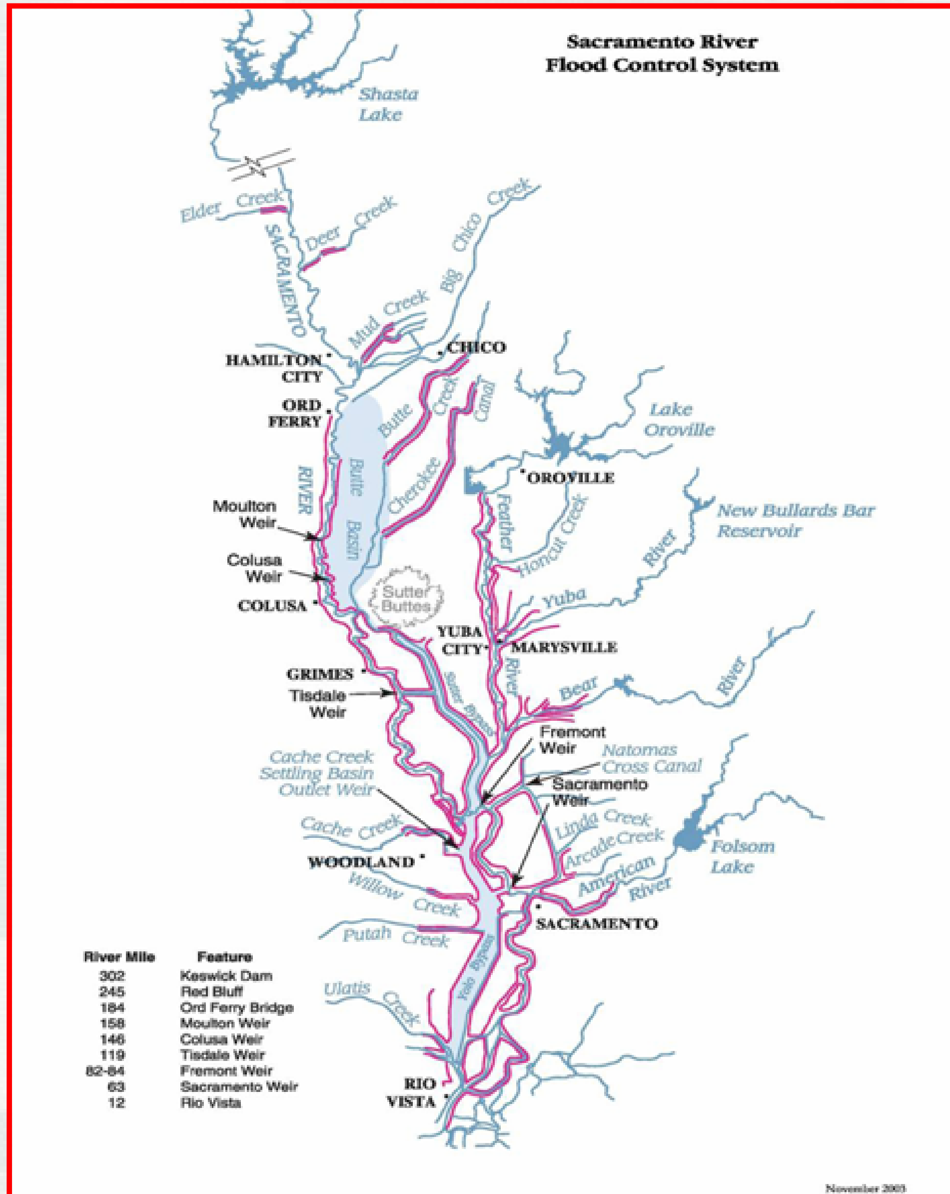
Demonstration Case Study
Using HEC-FDA

- Process for Conducting Risk Impact Analysis for Proposed Modifications to the Sacramento River Flood Control Project Levees

- 408 Policy Guidance
  - Full range of loading conditions
  - Impact on system performance
  - Must include a risk analysis

SRFCP System

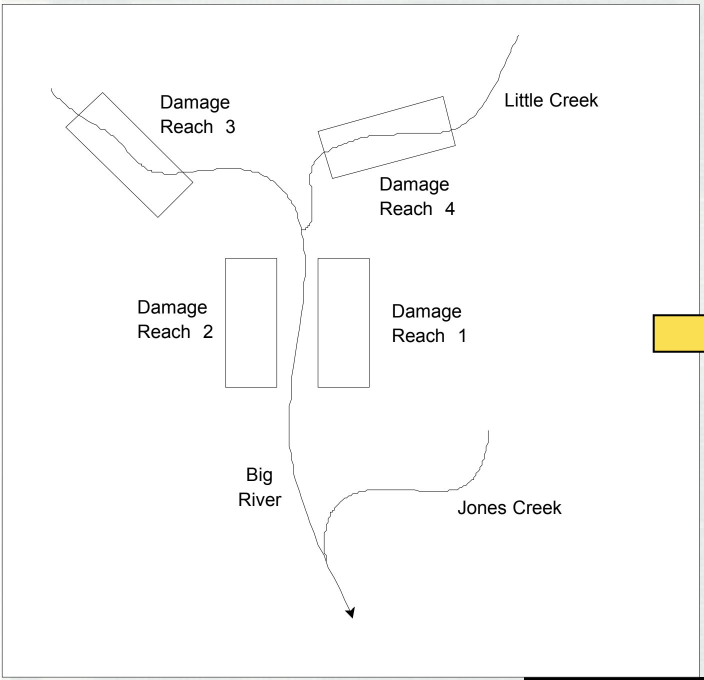
- 1,300 miles of levees
- Protects 800,000 Acres
- Significant Upstream Storage Reservoirs
- Project Report No. 71 - documents the entire process

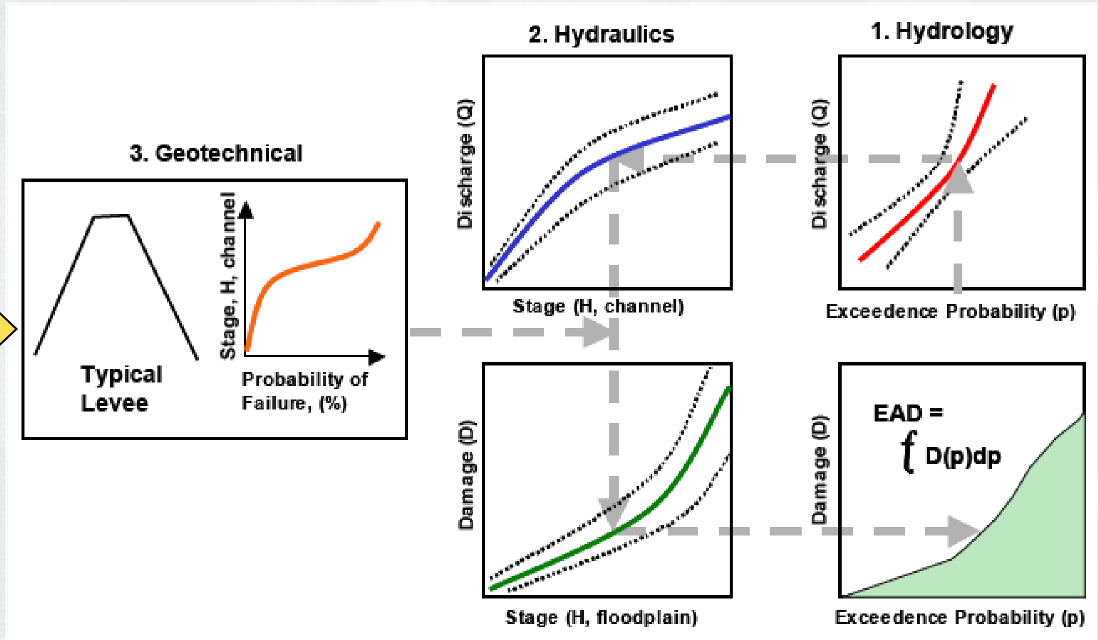


Uncertainties

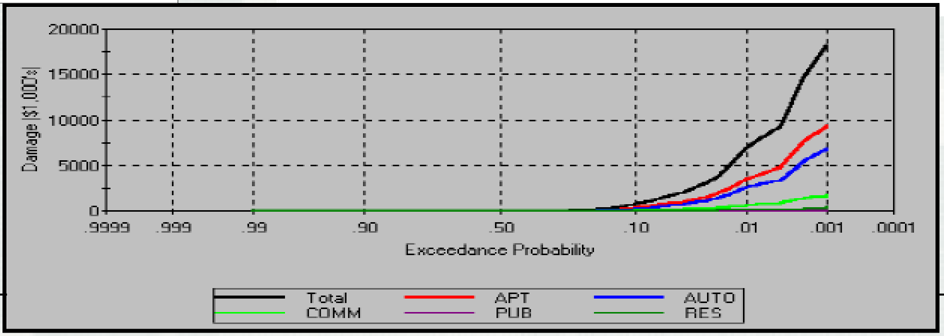
- **Hydrologic**: Inflow hydrographs at hand-off locations, reservoir operations. Uncertainty based on equivalent period of record.
- **Hydraulic**: Topographic data, roughness coefficients, weir coefficients, breach characteristics, downstream boundary, discharge at index locations.
- **Operational**: Levee system performance (based on levee failure criteria), flood fighting activities (not considered).

HEC-FDA – Does not address as an interrelated system



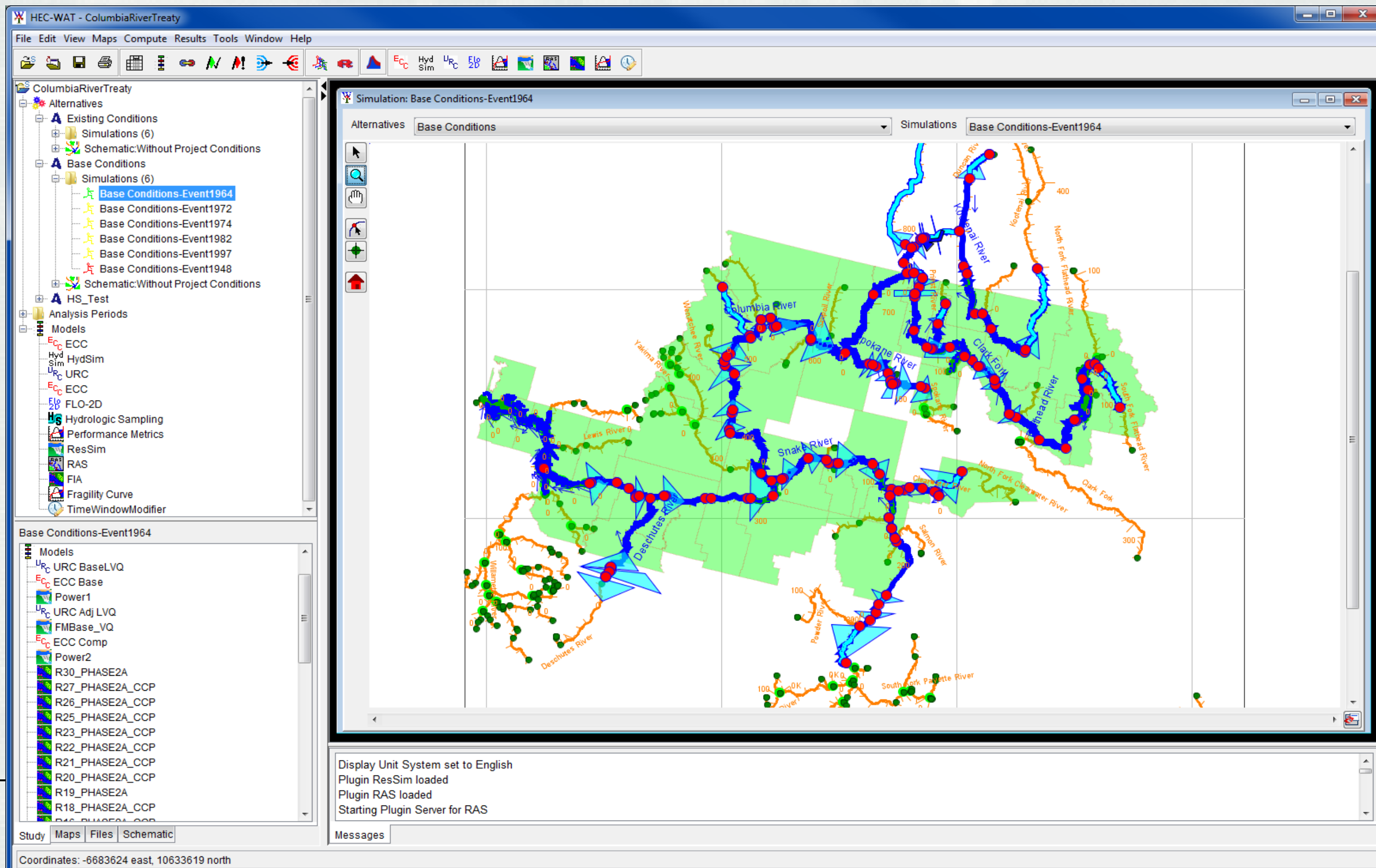


Source: Adapted from Moser (1997)



Watershed Analysis Tool (HEC-WAT)

An overarching interface that allows the PDT to perform water resources studies in a comprehensive, systems based approach by building, editing and running models commonly applied by multi-disciplinary teams and save and display data and results in a coordinated fashion.



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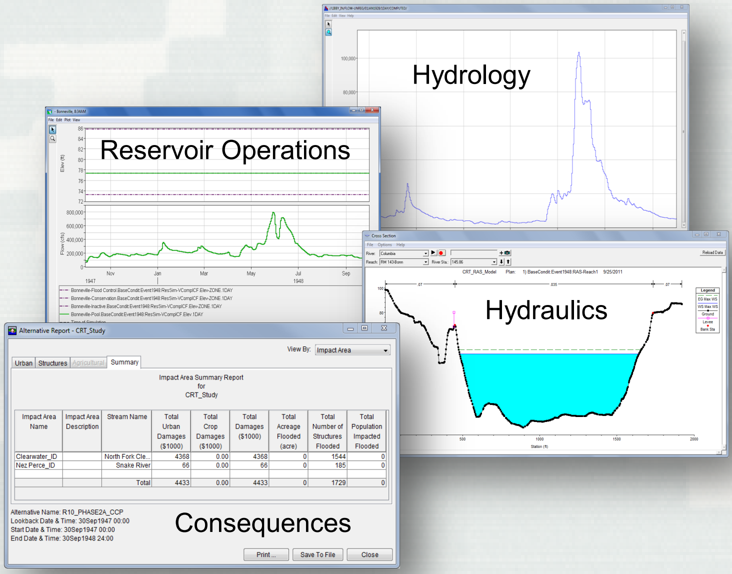
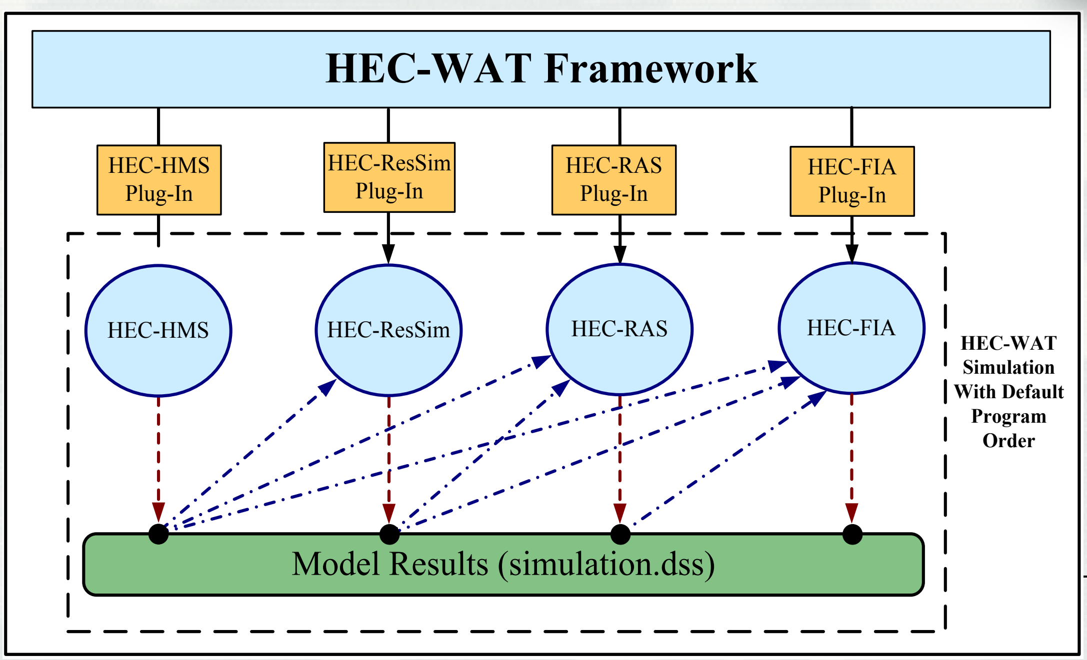
Basic HEC-WAT

- The initial set of models and tools to be used during the analytical process in HEC-WAT were:
  - Hydrology (HEC-HMS)
  - Reservoir Operations (HEC-ResSim)
  - Hydraulics (HEC-RAS)
  - Consequences (HEC-FIA)



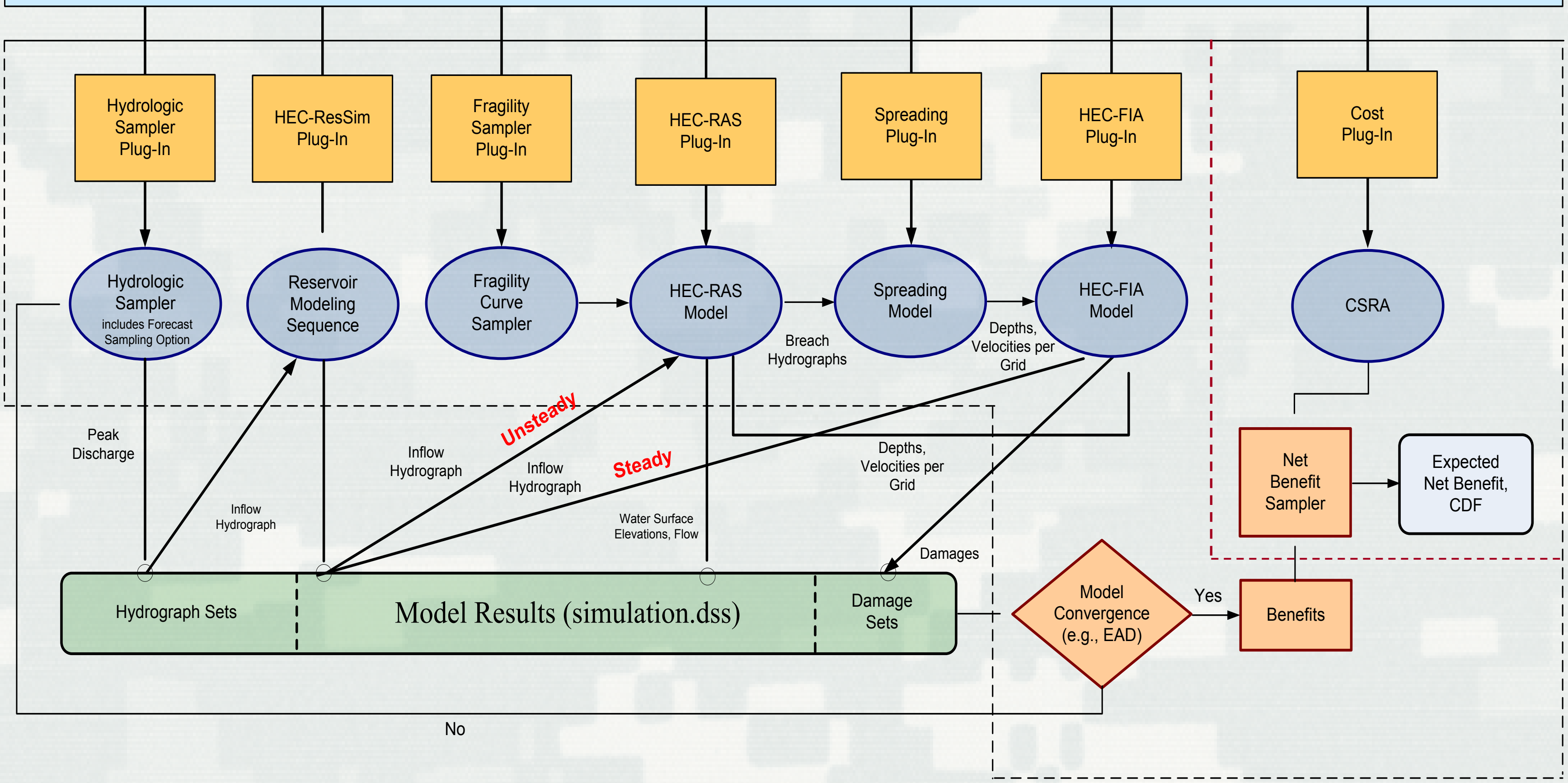


- Data is shared through a common DSS file.
- Version 1.0 provides for an event or P-O-R analysis.

FRA Compute Option

- CEIWR-HEC began researching and creating a tool within the WAT that would perform risk management with a life-cycle approach (Flood Risk Analysis (FRA) compute option).
- Provides a systems and life-cycle approach to plan formulation for assessing risks and uncertainties in simple systems as well as complex, interdependent systems.
- Provides an effective tool for risk communication.
- FRA will apply the Monte Carlo simulation & allow for a life-cycle type computation of consequences (economic and loss-of-life) and associated performance indices.
- Incorporate new computational methodologies.

HEC-WAT Framework with FRA Compute Option & Cost Analysis



FRA Monte Carlo Sampling Sequence

- For each project alternative, a single instance of the project life cycle (e.g., fifty years) is simulated by sampling annual maximum flood events for the duration of the life cycle.
- Sample System-Wide Fragility Functions
- Sample Historic Pool of events with associated Hydrograph Set
- Route Hydrograph Set
  - Consequence Area (CA) system Failures are based on hydraulics and fragility curves
  - Hydrographs will get adjusted as Dictated by Spills/Failures based on hydraulic model
  - Determine Flow and Stage at all Consequence Areas

FRA Monte Carlo Sampling Sequence
(Continued)

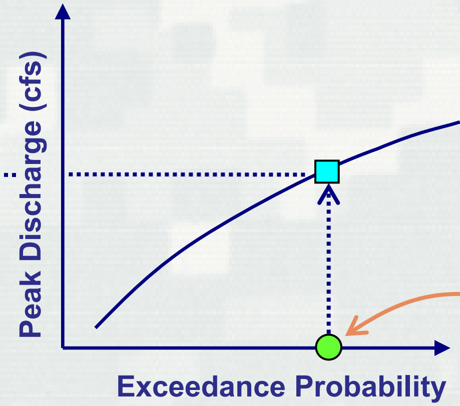
- Two-dimensional spreading can be performed in areas where needed
- Compute Damage/Loss-of-Life for all Consequence Areas
- Repeat

FRA Sampling Sequence

Computing EAD by Event Sampling

Reservoir Analysis
Channel Hydraulics
Levee Behavior

Hydrograph sets



Simple
Monte Carlo
Simulation

stage

One Realization

Random choice of probability U[0,1] to "generate" event
Method 1

Spreading Model (2D?)
Inundation Mapping
Structure Inventory
Damage to Structures

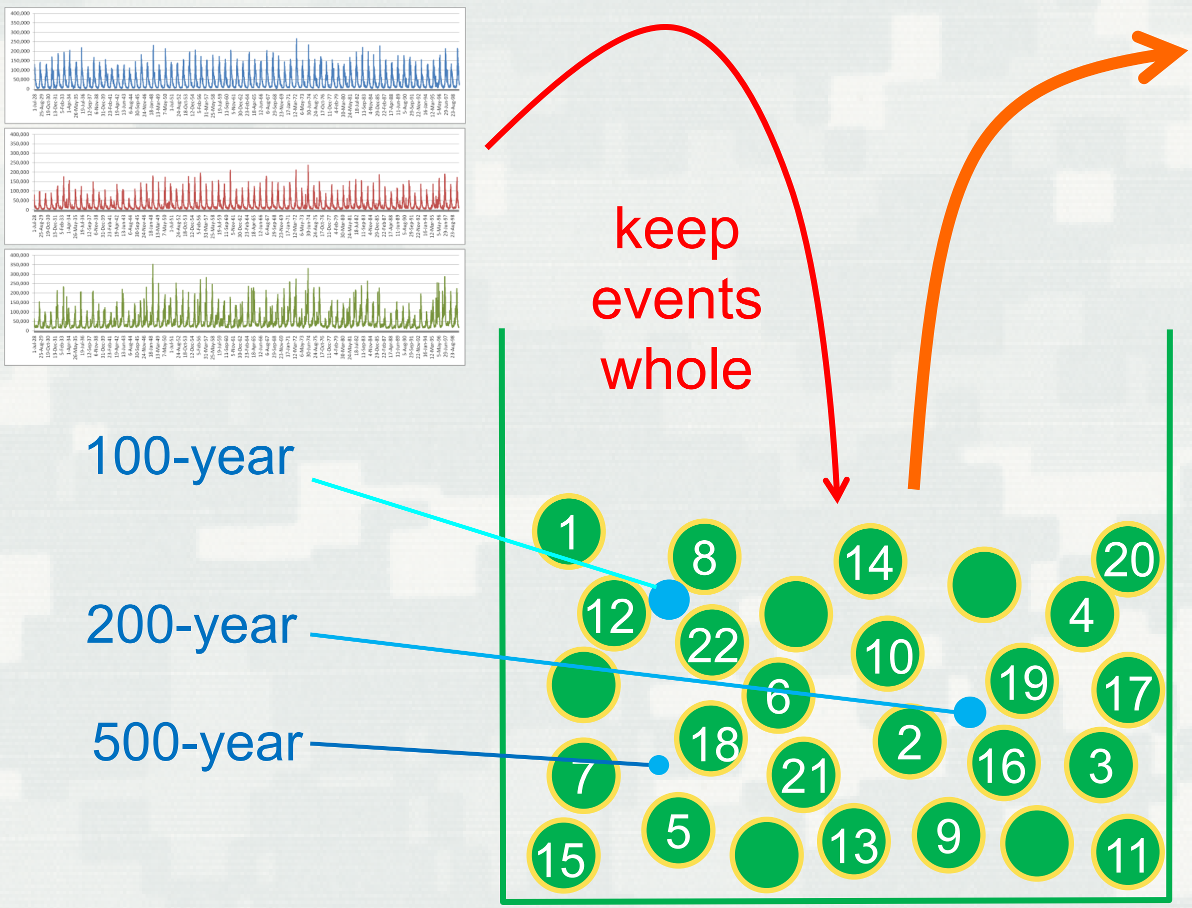
damage

Damage(i)

After all realizations are computed you now have EAD:

$$EAD = \frac{1}{N} \sum_{i=1}^{N} Damage(i)$$

Hydrologic Sampling - Method 2



- pull out an event, use all its hydrographs, put it back…SHAKE
- pull out an event, use all its hydrographs, put it back…SHAKE
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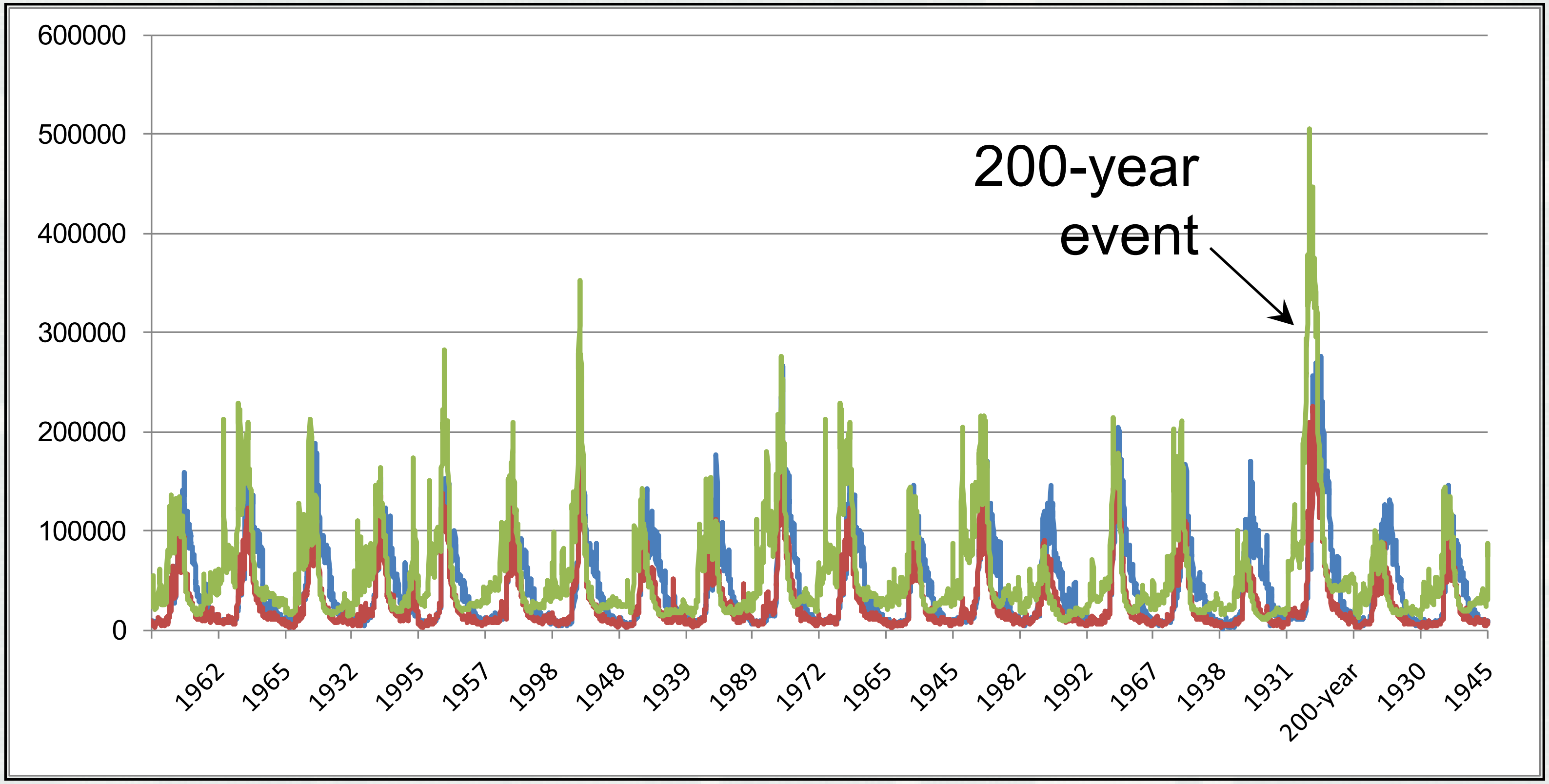
20-years of 50-year life-cycle

after drawing 50 random U[0,1] values



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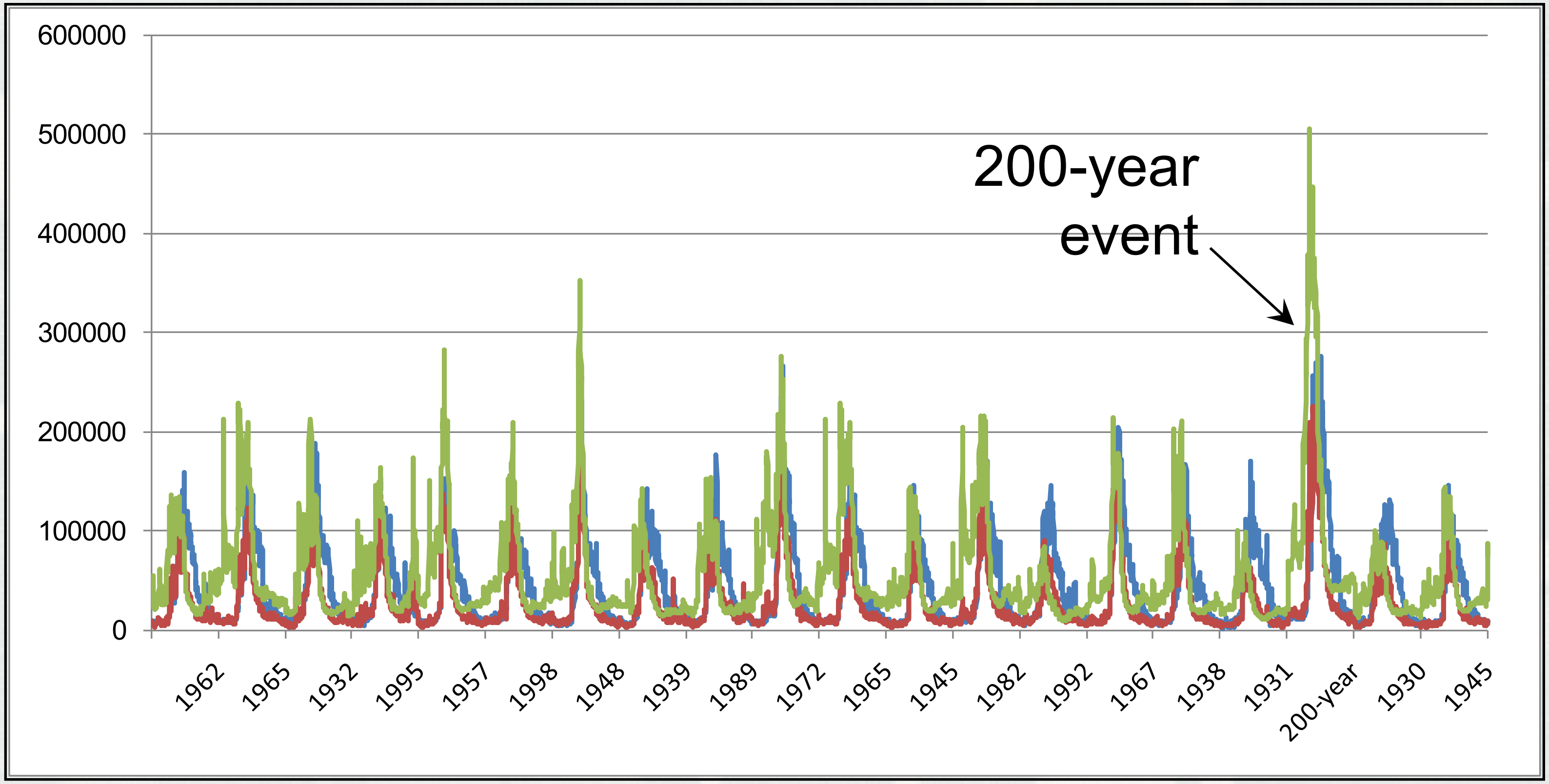
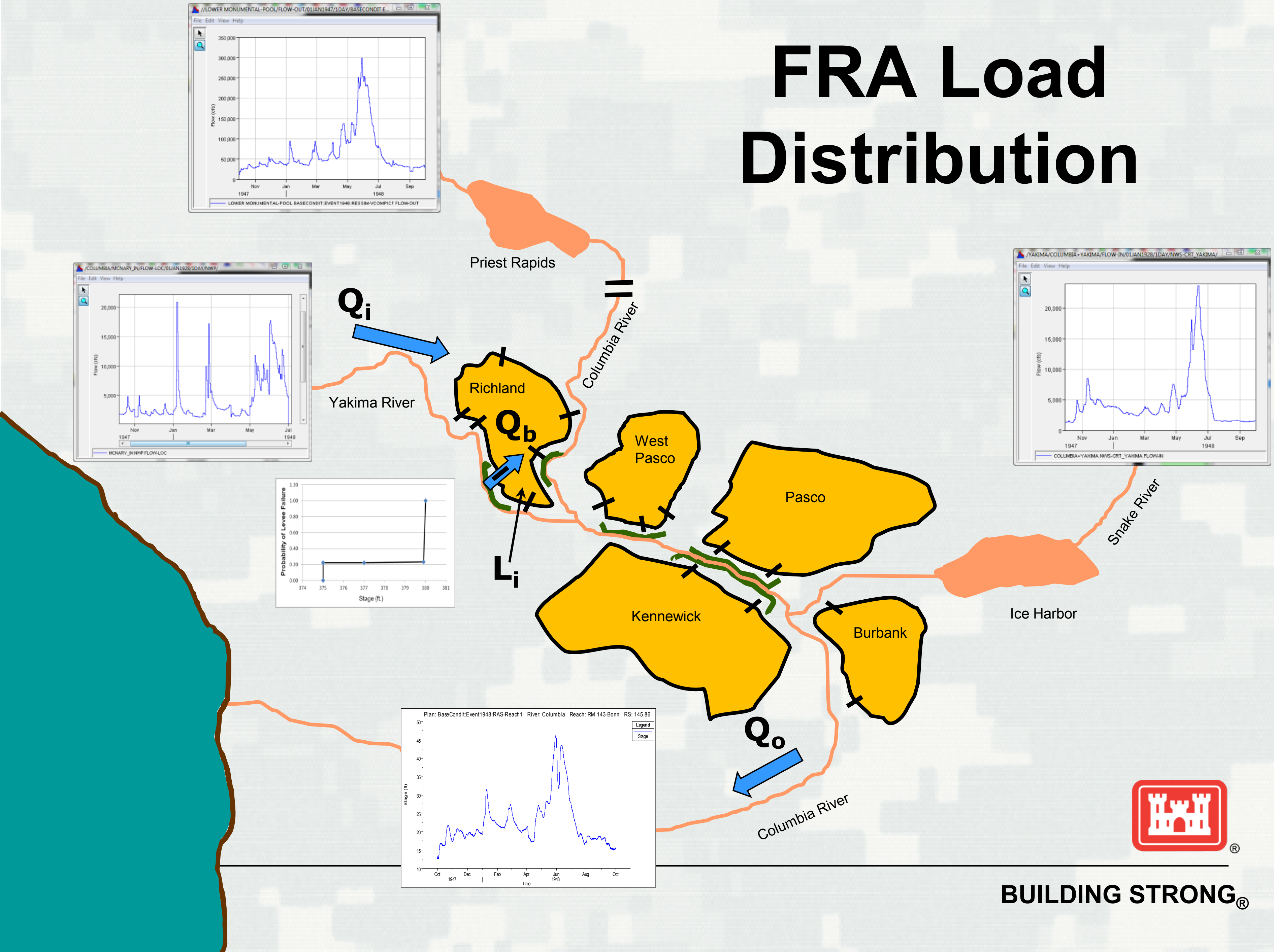
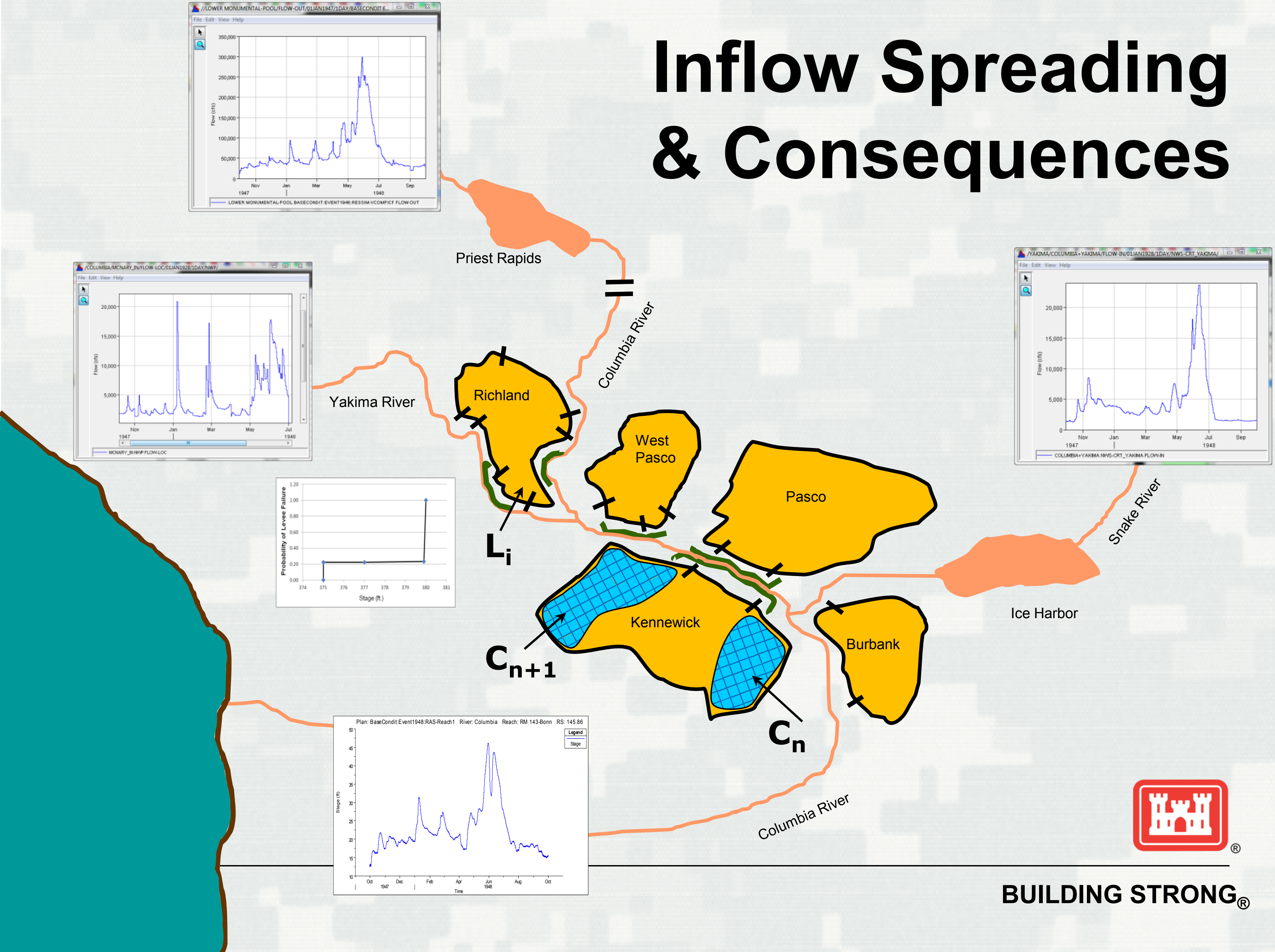


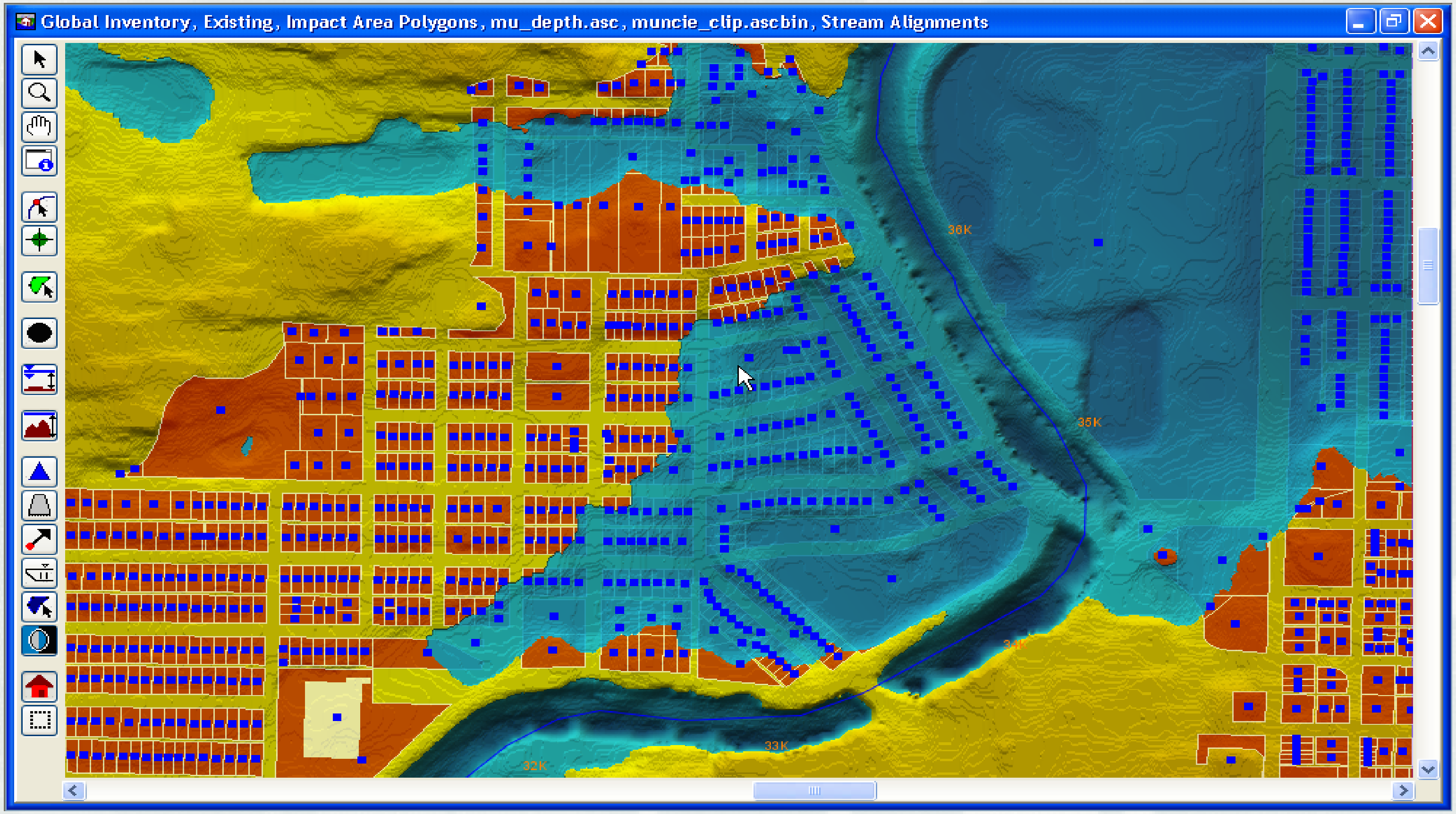
FRA Load Distribution



Inflow Spreading & Consequences

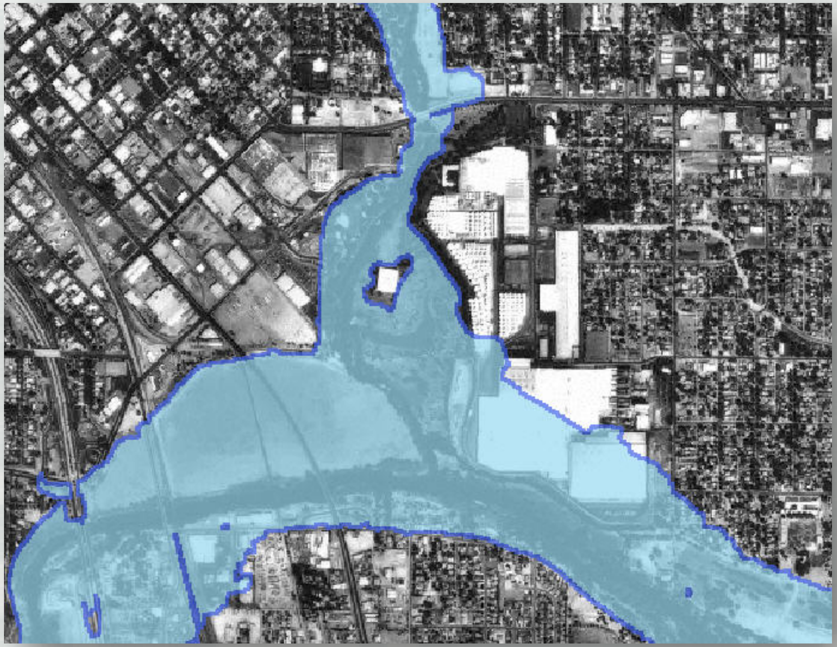


Consequence Analysis
Inundation Mapping on Structure Inventory



Risk Communication

- Economic and Environmental Performance
- Annual Exceedance Probability
- Conditional Non-Exceedance Probability
- Long-Term Exceedance Probability
- Risk Maps
- Loss-of-life



Challenges

- Life Cycle Modeling needs to include rehabilitation, repair and flood recovery
- Consequence evaluation – economic, social, environmental, and Loss-of-Life
- Uncertainty analysis – trade offs between detailed modeling and important sources of uncertainty
- Risk Communication – trade off analysis will likely encourage stakeholder support
- How to reduce computational burden
- How to model multiple failures
- How to maintain technologies

HEC-WAT for the Columbia River Watershed

- 258,000 sq. miles
- 2 countries
- 7 states
- 1,214 miles
- 125 tributaries
- Approximately 176,000 structures
- 51 projects
- 100 fragility curve locations
- 43 consequence areas
- 128 levee systems; 449 miles

Conclusion

- Currently, USACE can conduct risk assessments in a systems context with HEC-FDA.
- HEC-WAT/FRA will be a tool that performs these calculations.
- It will include systems approaches, event sampling, alternative analyses, structural and non-structural analyses, costs, loss-of-life, agricultural damage analyses.
- Could be used nationwide for levee evaluations, levee assessments, and planning and design studies.

QUESTIONS?

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