# FLOOD RISK MANAGEMENT – PLANNING CENTER OF EXPERTISE (FRM-PCX)

# FRM-PCX WEBINAR SERIES #7

# LIFE SAFETY RISK ASSESSMENTS IN FRM PLANNING STUDIES

**Prepared/Presented by Jesse Morrill-Winter, Nick Lutz, and Nick Applegate**

**9 January 2020**



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# FRM-PCX – WE'RE HERE TO HELP!!!

**…BUT WE NEED YOUR HELP TOO!**

- **The Goal:**
  - Timely webinars on specific topics that can help you and your FRM study RIGHT NOW!
  - Provide individual presentations/training to teams on specific topics relevant for your FRM study
  - Provide individual support to teams to help work through specific FRM challenges


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# PRESENTATION SUMMARY – LIFE SAFETY RISK ASSESSMENTS IN FRM PLANNING



- **The "so-what"**: Life Safety Risk Assessments need to be scalable to an appropriate level of detail for relevant Planning decisions

- **Policy/Guidance**: PB 2019-04 and ECB 2019-15
  - The 1st FRM PCX Webinar on Incorporating Life Safety in FRM Planning (Aug '19) can be found here: https://planning.erdc.dren.mil/toolbox/resources.cfm?Id=0&WId=491&Option=Planning%20Webinars

- The goal of this presentation is to answer the following questions:
  - What are the critical items in the life safety policy that study teams need to know about?
  - What is incremental risk why are the Tolerable Risk Guidelines (TRG's) important?
  - How does a life safety focused risk assessment differ from an economic focused analysis?
  - When/how should teams incorporate a risk assessment into the planning process?
  - What is the appropriate level of risk assessment and what are the options?
  - Where can the team find assistance in conducting life safety studies?

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# FLOOD RISK FRAMEWORK


- Purpose of Risk Assessment:
  - To understand all factors that drive the risk (Hazard, Performance, & Consequence).
  - Have sufficient level of detail to clearly understand the factors that are driving the risk
  - Allows for proper structural/non-structural measures to be evaluated in the study.

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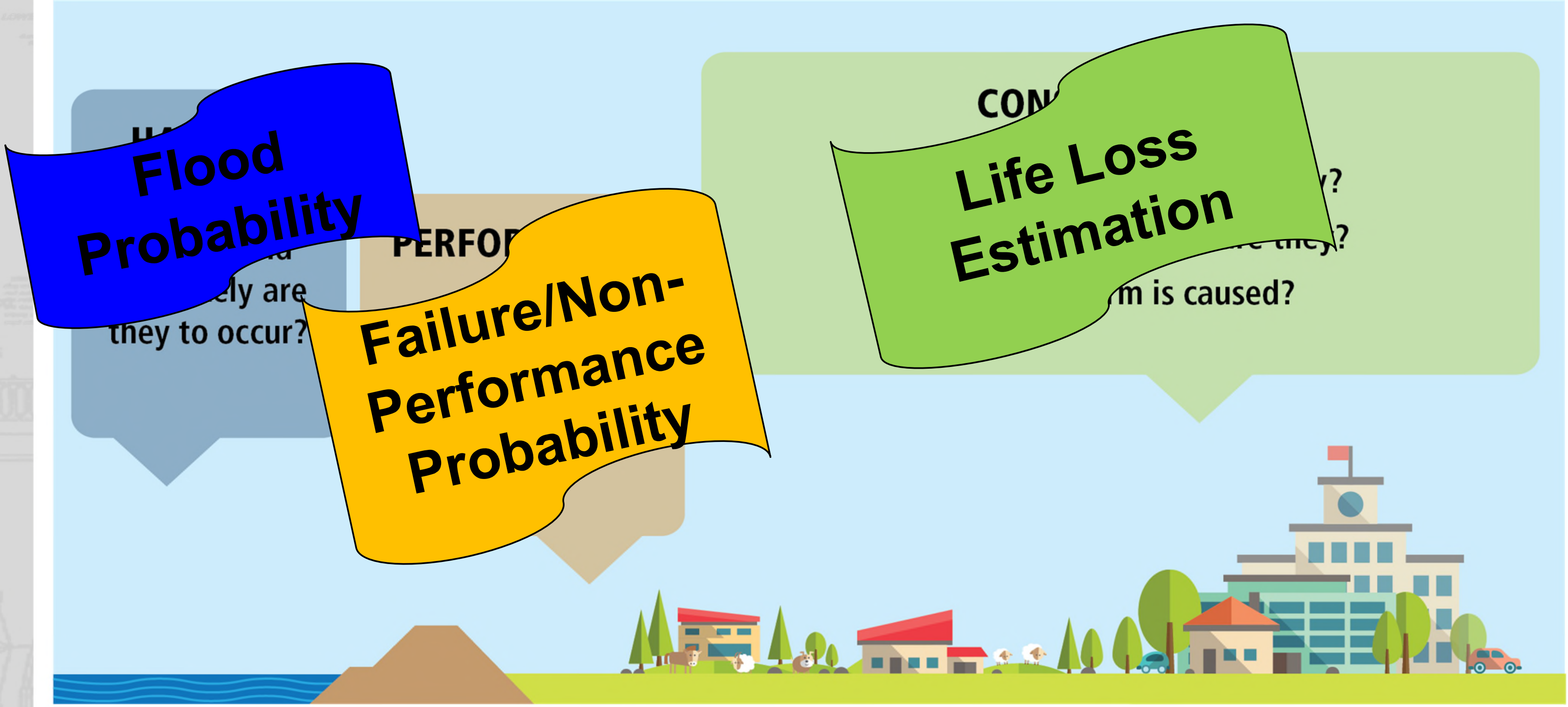
# LIFE SAFETY RISK ASSESSMENT FRAMEWORK




RISK = f (HAZARD, PERFORMANCE, CONSEQUENCE)

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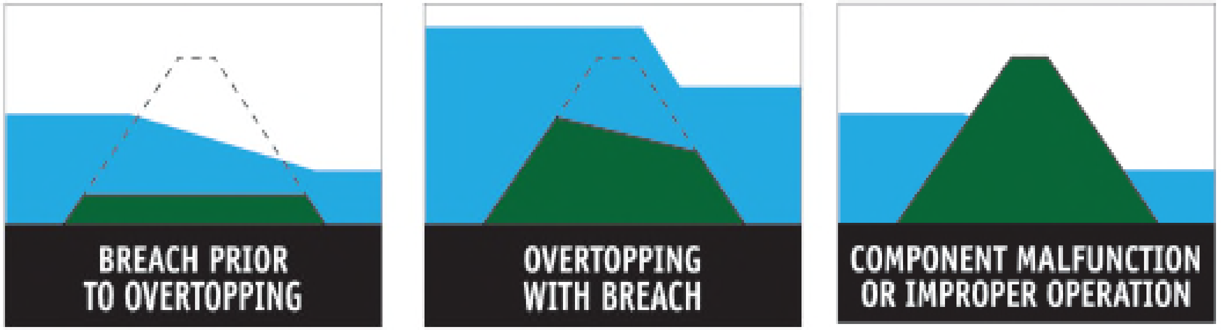
# RESIDUAL RISK VS. INCREMENTAL RISK VS. NON-BREACH RISK

**Residual Risk (aka “Flood Risk”)** – The risk at any point in time (incl. incremental and non-breach). There are no “targets” to meet for residual risk. Just try to do some good! Consider as other non-monetary benefits for formulation, evaluation and comparison.

**Incremental Risk** – Risk to the floodplain/downstream occupants that can be attributed to the presence of the levee or dam.  Difference between Breach and non-breach risk.  Have predetermined agency guidelines that any USACE structure should meet, known as the “Tolerable Risk Guidelines (TRGs).”




**Non-breach Risk** – The risk in the floodplain/downstream area even if the levee or dam functions as intended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# EXAMPLE - RESIDUAL RISK VS. INCREMENTAL LIFE LOSS

Life Loss Risk — Life Loss Consequences only

| **Project Condition** | ***Annualized Life Loss (Residual Risk)*** | **Breach/Non-Perform Life Loss** | **Non-Breach Life Loss** | **Incremental Life Loss (Breach/Non-Perform minus Non-breach)** |
|---|---|---|---|---|
| No Levee (pre-project) | *4* | N/A | 60 | |
| Bypass | *2* | N/A | 30 | |
| Levee | *1* | 75 | 5 | |

- The levee does the best overall good for reducing life safety residual risk (4 annual lives lost to 1 annual life lost, BUT…
  - The levee also introduces incremental risk that wasn't present pre-project and we must assess this risk!

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| Bypass | *2* | N/A | 30 | 0 |
| Levee | *1* | 75 | 5 | 70 |

- The levee does the best overall good for reducing life safety residual risk (4 annual lives lost to 1 annual life lost, BUT…
  - The levee also introduces incremental risk that wasn't present pre-project and we must assess this risk!

# LIFE SAFETY POLICY - PB 2019-04 REVIEW



**All studies:**

- Identify potential risks to life safety in the **problems, opportunities, and/or objectives**, as appropriate, *early in the study*.

- **Floodplain Management Plan**
  - Encourage early development by Non-Fed partners
  - Should include **Emergency Action Plan**

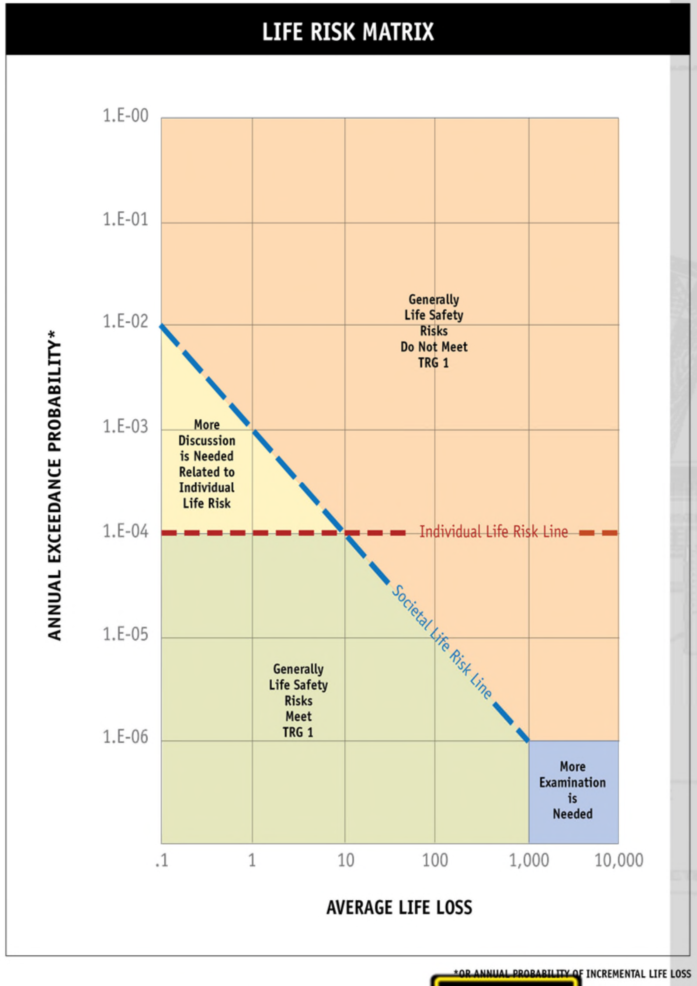
- Level of detail in **data collection and modeling** efforts should be commensurate with the uncertainty, complexity of the problem and cost of addressing risks.

- Always consider the **RESIDUAL RISK** related to life safety.

# LIFE SAFETY POLICY - PB 2019-04 REVIEW (CONT.)

## Studies with existing and/or proposed Levee Systems and Dams:

- Must consider **incremental risk**
- Goal is to achieve all 4 TRG's
  - PDT should include specific objectives regarding achieving TRG's
  - **One alternative must be identified that addresses TRG's 1 and 4**
- **If new levees or dams are recommended, a life safety risk assessment on the TSP** is required.
- Modifications to existing dams or levees require **coordination of the relevant senior oversight group (SOG)**
- Planning and Dam/Levee Safety must coordinate and communicate vertically and horizontally!
  - PDT must **engage the district Dam/Levee Safety Officer and Dam/Levee Safety Program Manager** throughout the study.
- A trained facilitator, **endorsed by the RMC**, will be assigned to lead the life safety risk assessment

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# LIFE SAFETY POLICY – ECB 2019-15 REVIEW

## Studies with existing and/or proposed Levee Systems and Dams:

- **BLUF: ECB 2019-15 guides us in risk-informed design of features/plans that we've formulated following Planning Policy (incl. PB 2019-04).**
- Hold **life safety paramount**
- A **technical lead** should be assigned to each study (IAW ECB 2015-18)
- Use Risk Assessments to Guide Improved Design Decisions
  - **Designs will consider, refine, and evaluate** structural and nonstructural measures to manage overtopping resilience per ECB 2019-8
- **Scale risk assessments** to the magnitude of the decision
- Since the formal application of risk-informed design is a new requirement, the risk assessments must be scaled to **fit within the constraints of current schedules and budgets**
  - New start studies will need to fully scope and comply

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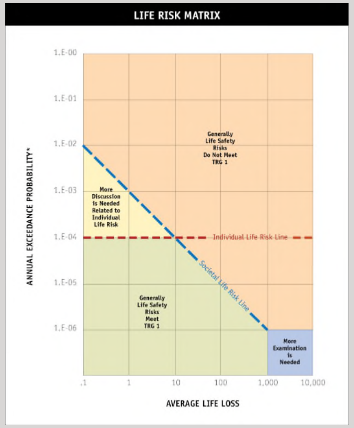
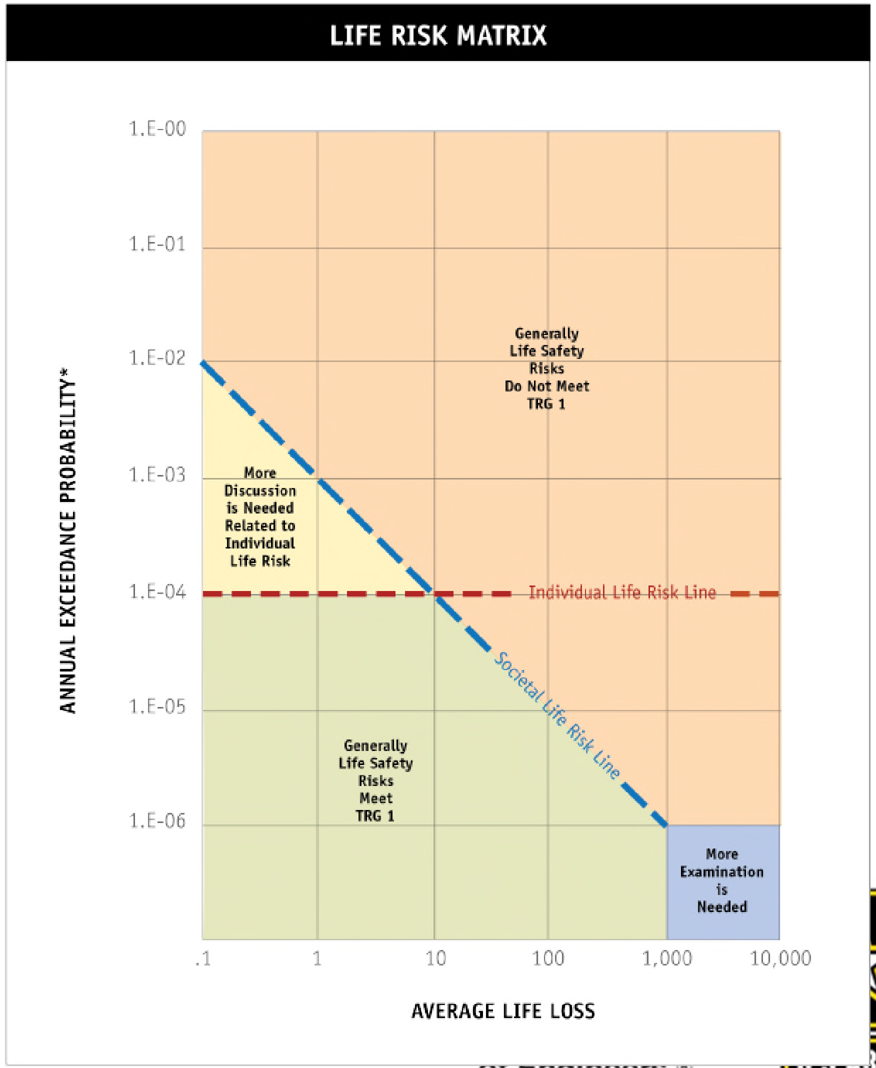
# TOLERABLE RISK GUIDELINES (PER PB 2019-04)

<table>
<tr><th>TRG</th><th>Description</th><th>Evaluation Method</th></tr>
<tr><td>1</td><td>Understanding the Risk</td><td>

<br>Evaluation of Societal Life Risk<br>Evaluation of Individual Life Risk<br>Evaluation of Economic Risk<br>Evaluation of Environmental Risk</td></tr>
<tr><td>2</td><td>Building Risk Awareness</td><td>will be determined qualitatively</td></tr>
<tr><td>3</td><td>Fulfilling Daily Responsibilities</td><td>determined qualitatively</td></tr>
<tr><td>4</td><td>Actions to Reduce Risk</td><td>(1) Have appropriate actions been taken to reduce risks?<br>(2) Could any action reasonably be taken that would reduce risks further?<br>(3) What is the cost to reduce the risk and how much is the risk reduced?<br>(4) Should action be evaluated in a detailed study?<br>(5) Is there demonstrated progress towards implementing risk reduction measures?</td></tr>
</table>

# F-N PLOTS

- f-N̄
  - Not a cuss word
  - Not that complicated
  - It’s simply a illustrative diagram delineated by order of magnitude divisions that is used in quantitative risk assessments to indicate when incremental societal and individual risks may exceed established tolerable risk guidelines.
  - Easy!



# F-N PLOTS

- But…why?
  - Mostly precedent and equity

Bureau of Reclamation (2011) "Rationale Used to Develop Reclamation's Dam Safety Public Protection Guidelines."

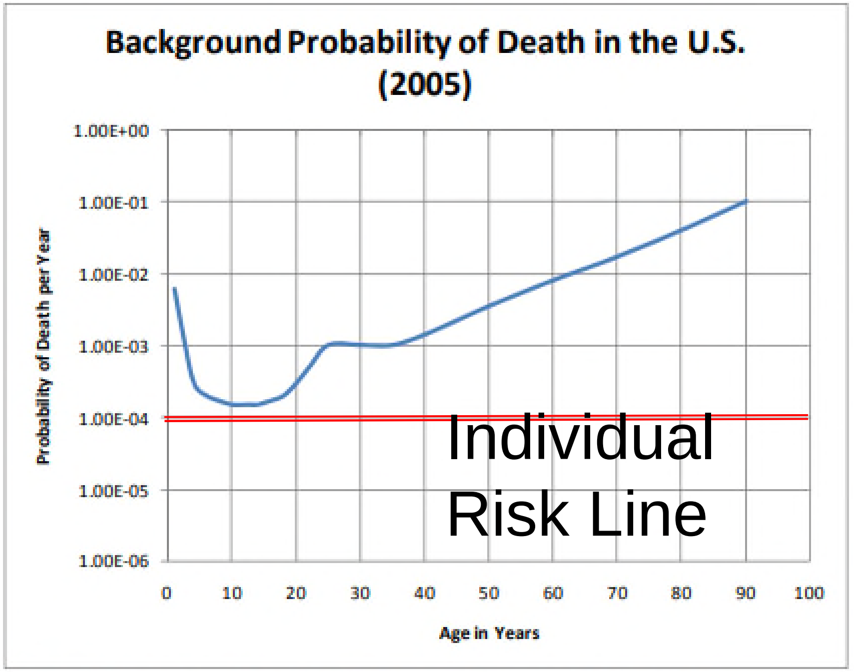



Figure 2. Background Probability of Death (from the CDC, 2005)

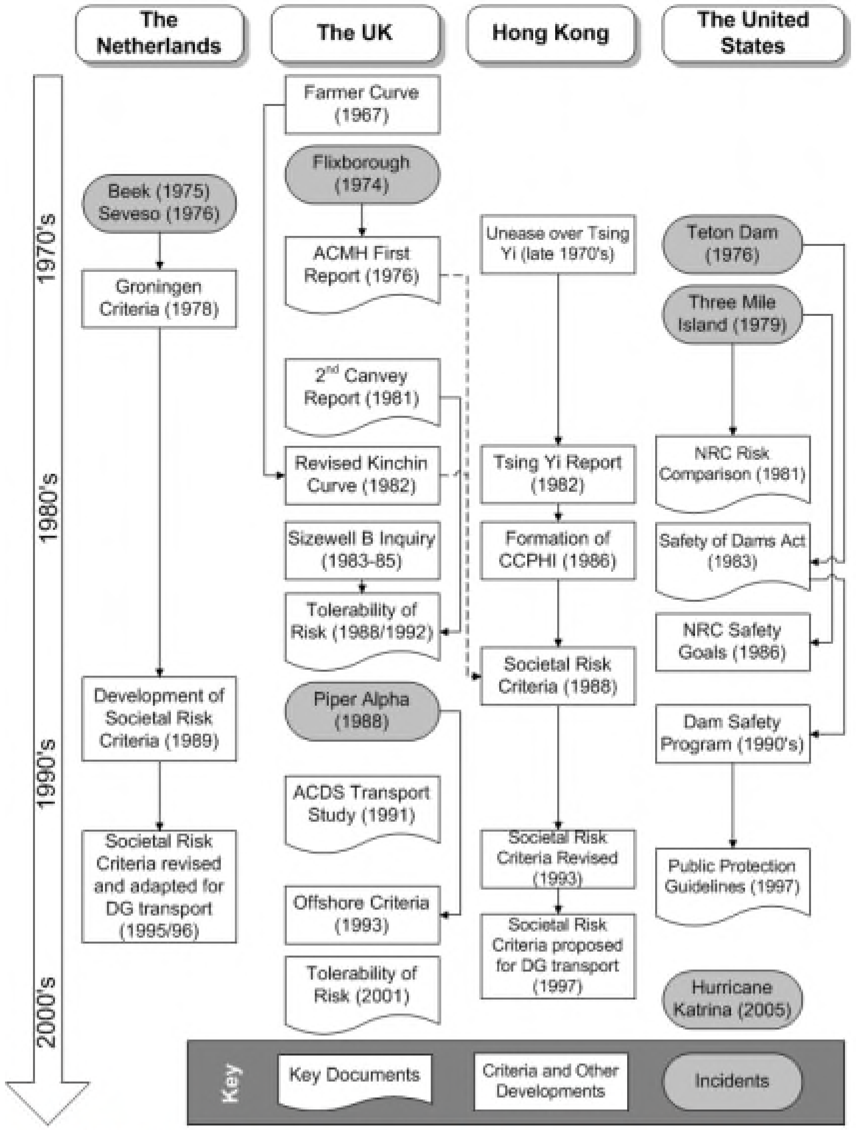
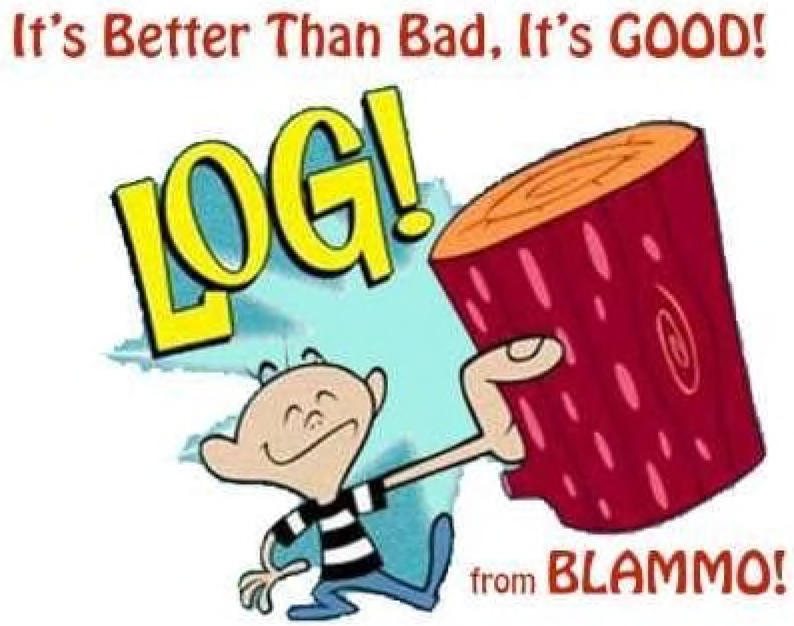
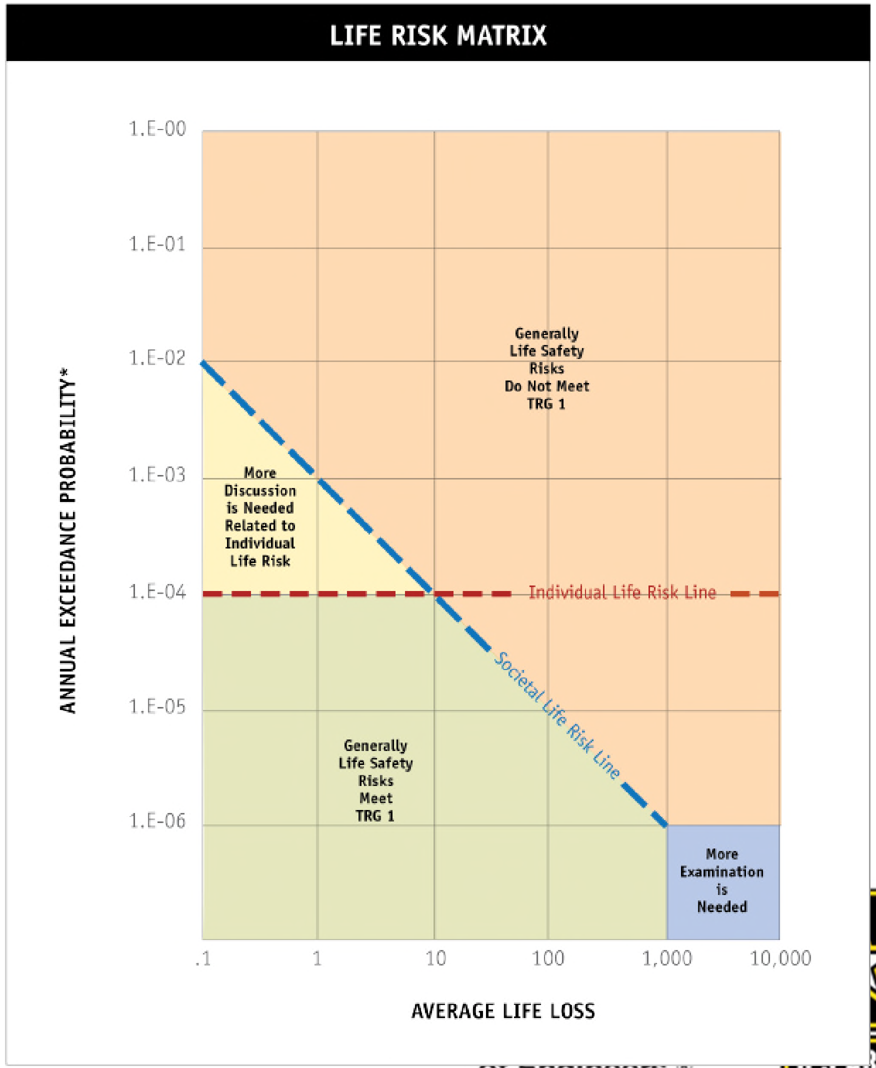



Figure 3. Milestones in the Development of Societal Risk Guidelines

# F-N PLOTS

- Demystifying the matrix
  - Y axis (on the left) is the annual chance of a bad thing

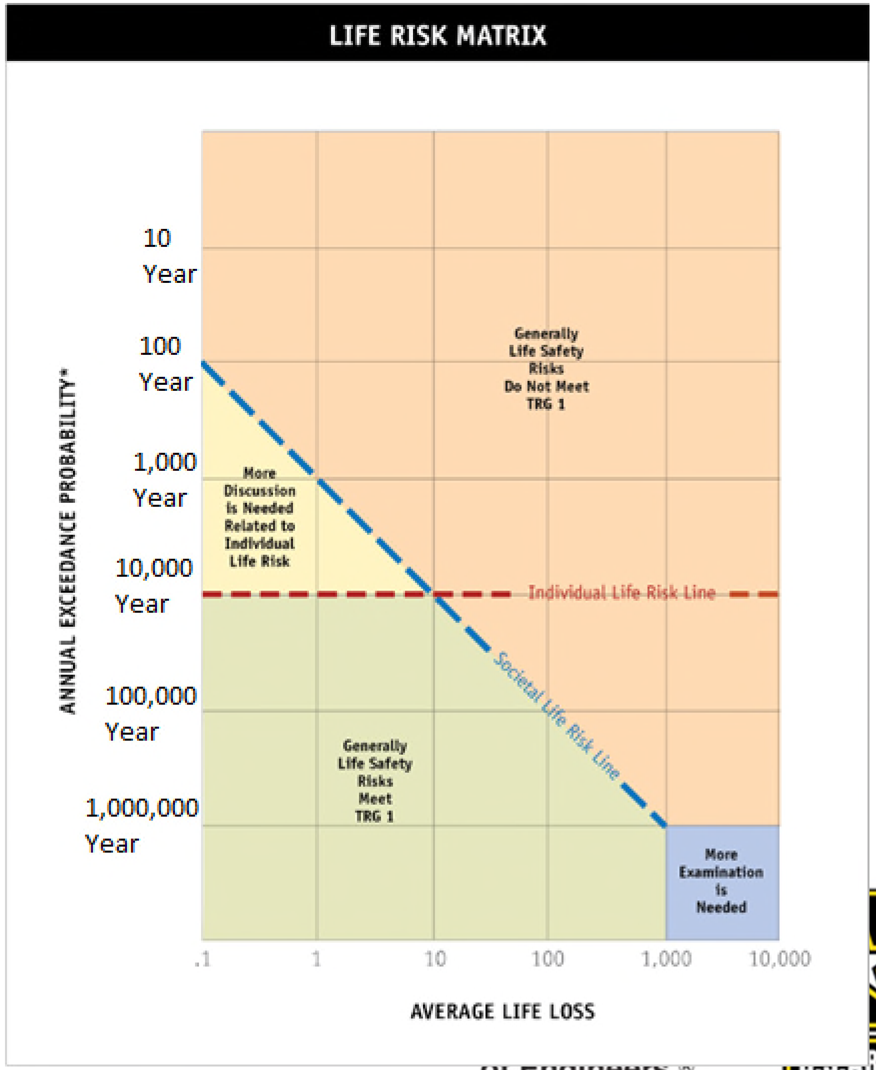


# F-N PLOTS

- Demystifying the matrix
  - Y axis (on the left) is the annual chance of a bad thing
  - Notation, it's just counting the zeros

| Scientific | Probability | Decimal | Recurrence |
|---|---|---|---|
| 1.00E+00 | 100% | 1.00 | 1 |
| 1.00E-01 | 10% | 0.1 | 10 |
| 1.00E-02 | 1% | 0.01 | 100 |
| 1.00E-03 | 0.1% | 0.001 | 1,000 |
| 1.00E-04 | 0.01% | 0.0001 | 10,000 |
| 1.00E-05 | 0.001% | 0.00001 | 100,000 |
| 1.00E-06 | 0.0001% | 0.000001 | 1,000,000 |

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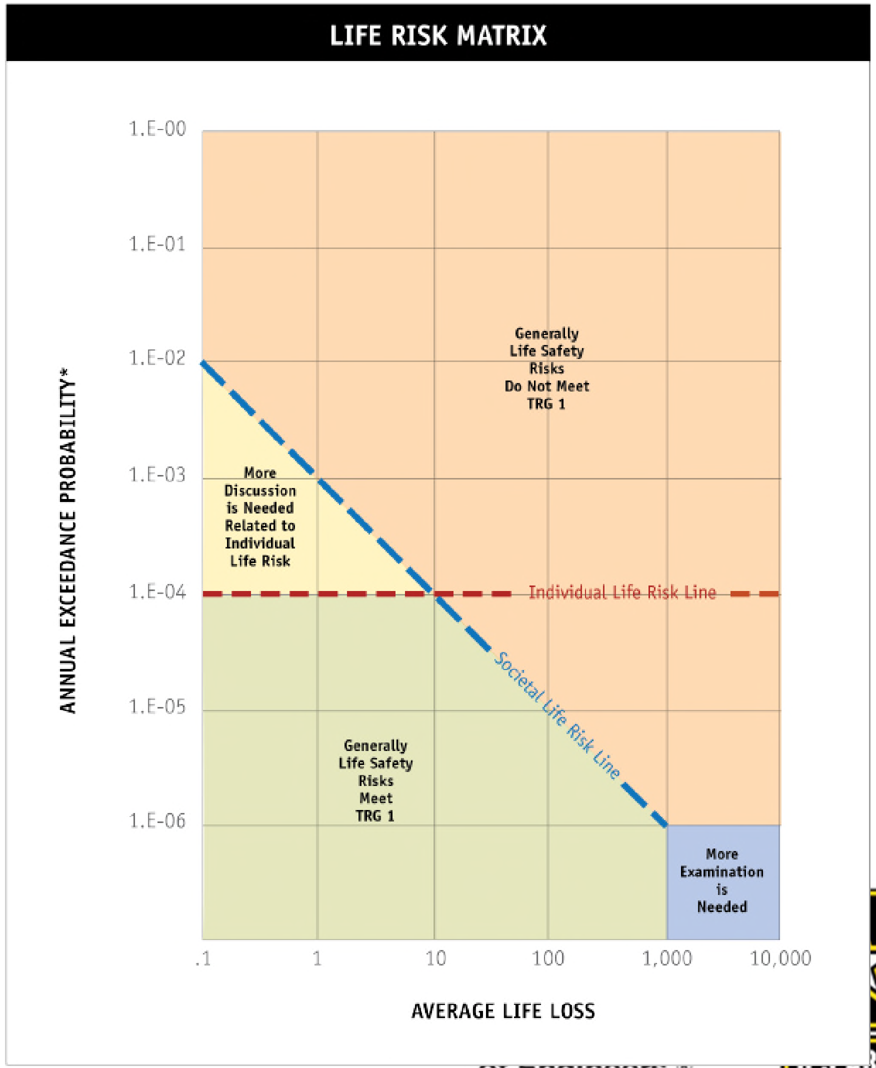
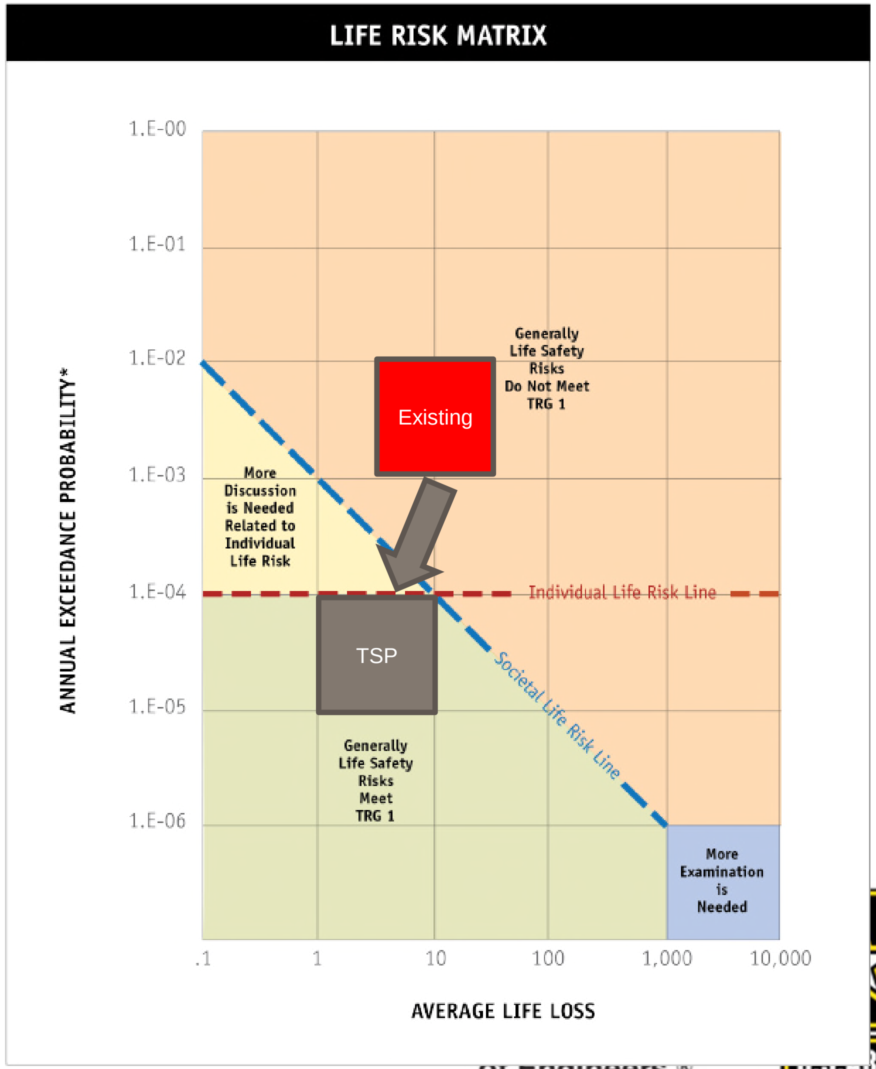
# F-N PLOTS

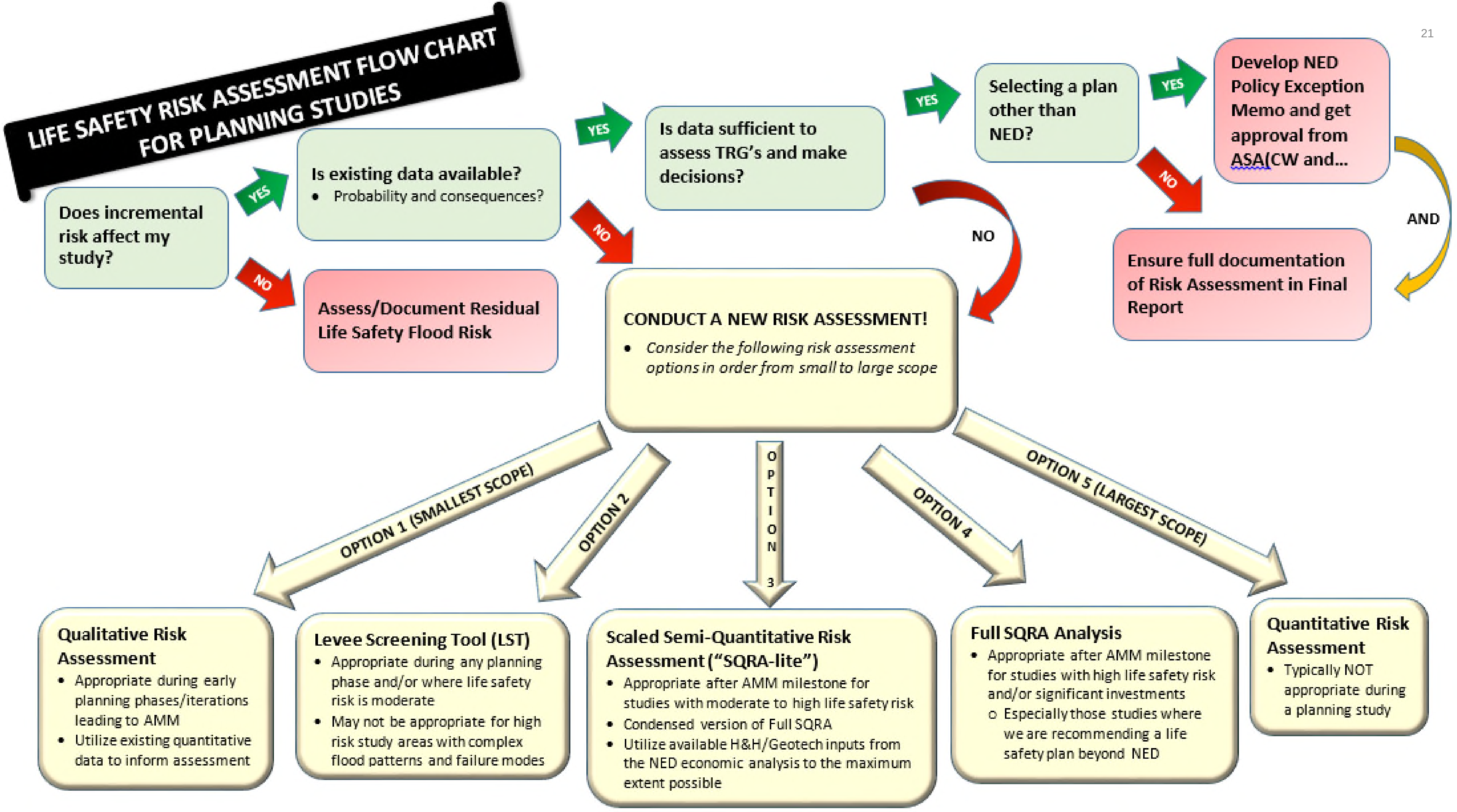
- Demystifying the matrix
  - Y axis (on the left) is the annual chance of a bad thing
  - X axis (the bottom) is the life loss that would happen if failure happens
  - Together they give you a quantitative risk assessment: Average Annual Life Loss (AALL)
  - If that risk is higher than one of the dashed lines…you **may** have an issue



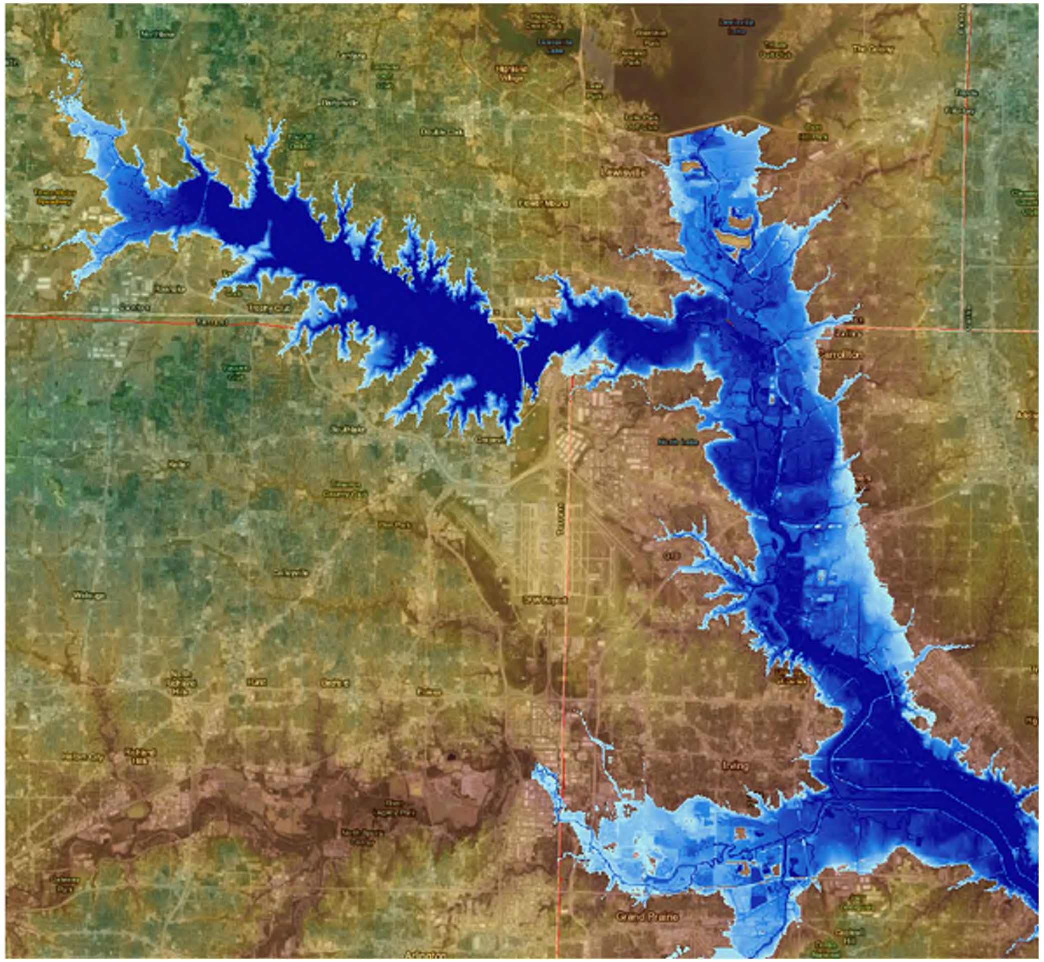
# F-N PLOTS

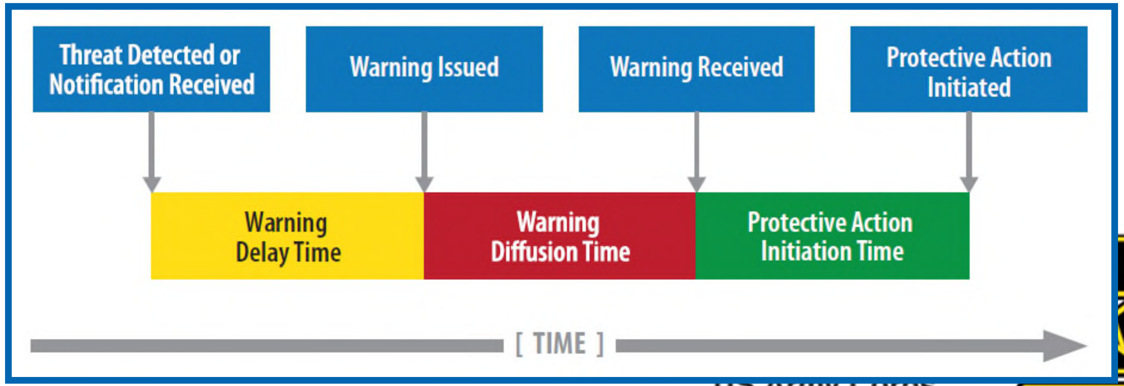
- With and without comparison
  - If your risk is high, you'll need to find alternatives to reduce it
  - If an alternative is not practicable…
    - Practicable means environmentally acceptable, engineering feasible, and economic efficient
    - It's not enough to say the option isn't popular
    - You'll have to make the case for why

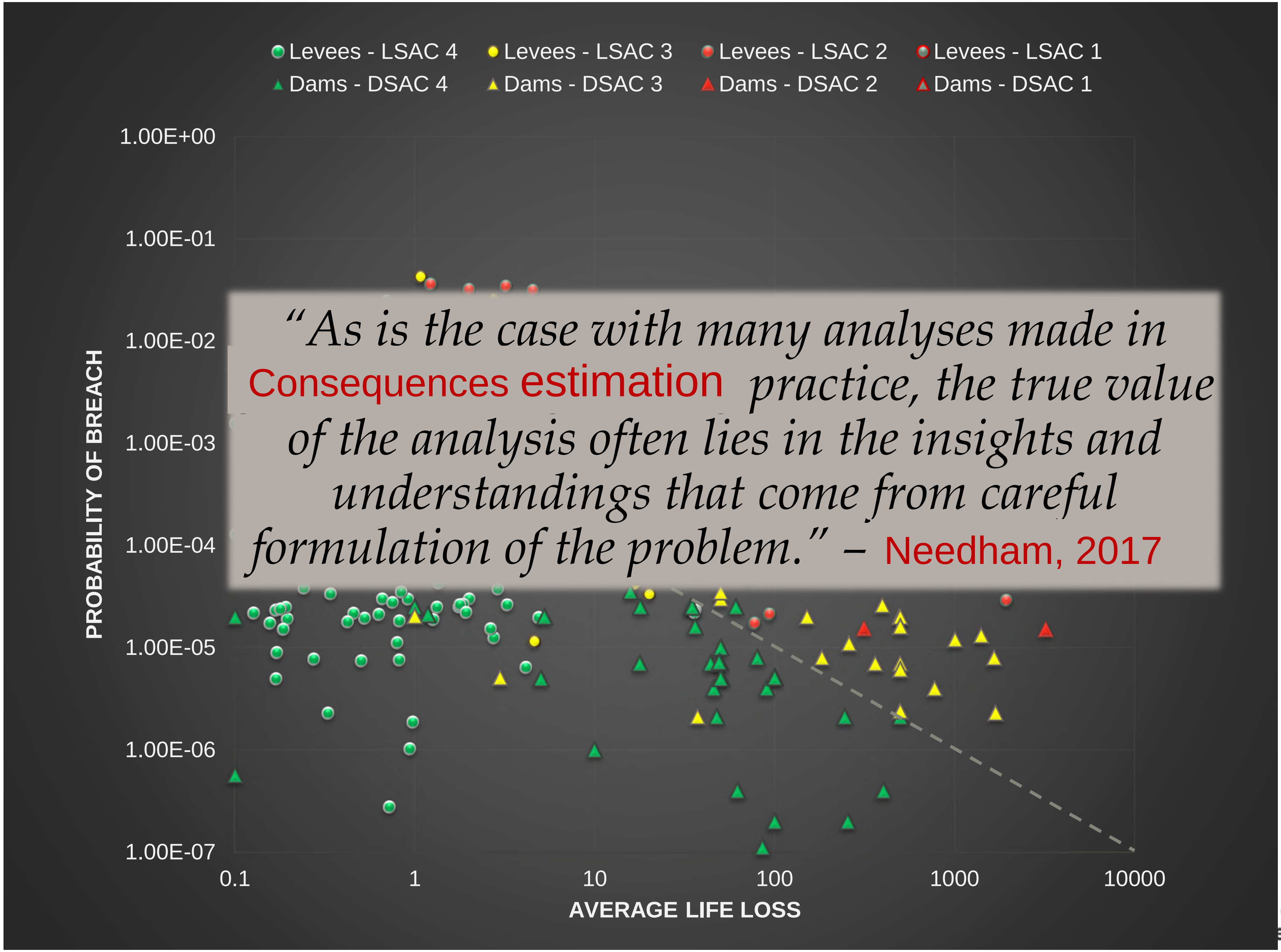



LIFE SAFETY RISK ASSESSMENT FLOW CHART FOR PLANNING STUDIES
Does incremental risk affect my study?
YES
NO
Is existing data available?
• Probability and consequences?
YES
NO
Assess/Document Residual Life Safety Flood Risk
Is data sufficient to assess TRG's and make decisions?
YES
NO
Selecting a plan other than NED?
YES
NO
Develop NED Policy Exception Memo and get approval from ASA(CW and...
AND
Ensure full documentation of Risk Assessment in Final Report
CONDUCT A NEW RISK ASSESSMENT!
• Consider the following risk assessment options in order from small to large scope
OPTION 1 (SMALLEST SCOPE)
OPTION 2
OPTION 3
OPTION 4
OPTION 5 (LARGEST SCOPE)
Qualitative Risk Assessment
• Appropriate during early planning phases/iterations leading to AMM
• Utilize existing quantitative data to inform assessment
Levee Screening Tool (LST)
• Appropriate during any planning phase and/or where life safety risk is moderate
• May not be appropriate for high risk study areas with complex flood patterns and failure modes
Scaled Semi-Quantitative Risk Assessment ("SQRA-lite")
• Appropriate after AMM milestone for studies with moderate to high life safety risk
• Condensed version of Full SQRA
• Utilize available H&H/Geotech inputs from the NED economic analysis to the maximum extent possible
Full SQRA Analysis
• Appropriate after AMM milestone for studies with high life safety risk and/or significant investments
o Especially those studies where we are recommending a life safety plan beyond NED
Quantitative Risk Assessment
• Typically NOT appropriate during a planning study

# EVALUATING LIFE RISK






*"As is the case with many analyses made in* Consequences estimation *practice, the true value of the analysis often lies in the insights and understandings that come from careful formulation of the problem."* – Needham, 2017

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# LIFE LOSS ESTIMATION – ESSENTIAL ELEMENTS

- Initial distribution of people
- Redistribution of people
  - Warning
  - Response
  - Evacuation potential

  (Warning, Response, Evacuation potential: Evacuation Effectiveness)
- Flood characteristics
  - Arrival time, depth, velocity
- Shelter provided by final location
- Fatality rates
- Potential for indirect life loss

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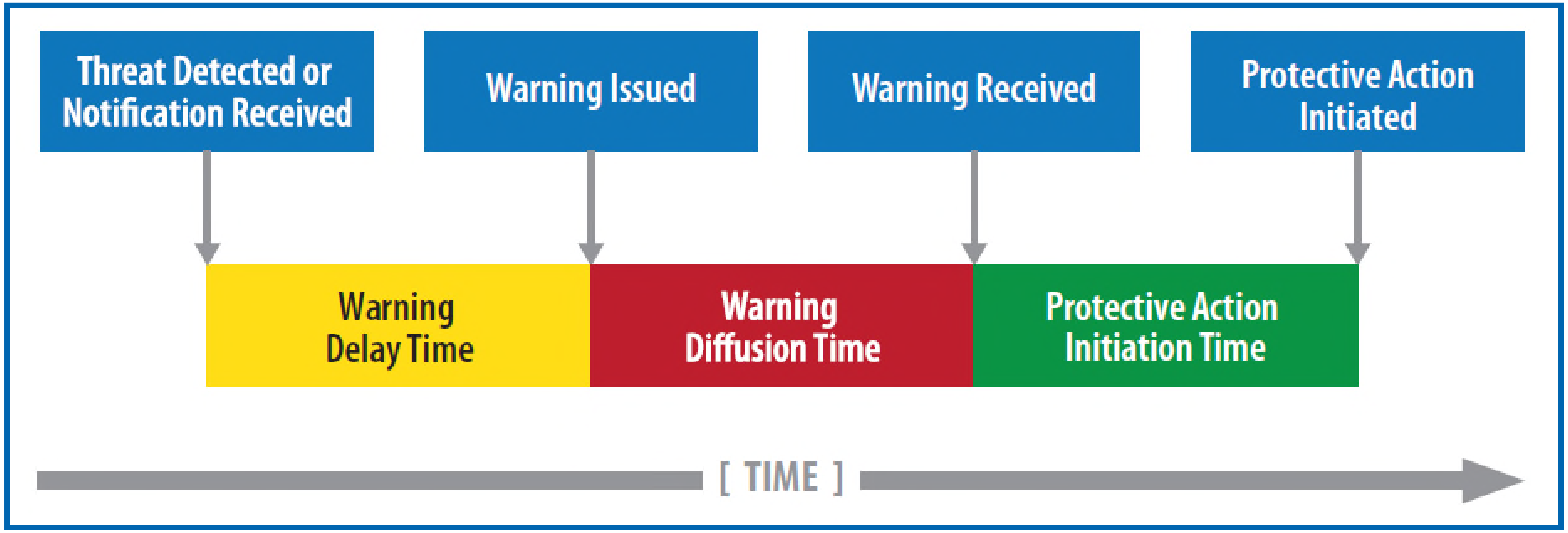
# REDISTRIBUTION OF PAR



# SHELTER AND FATALITY RATE ZONES

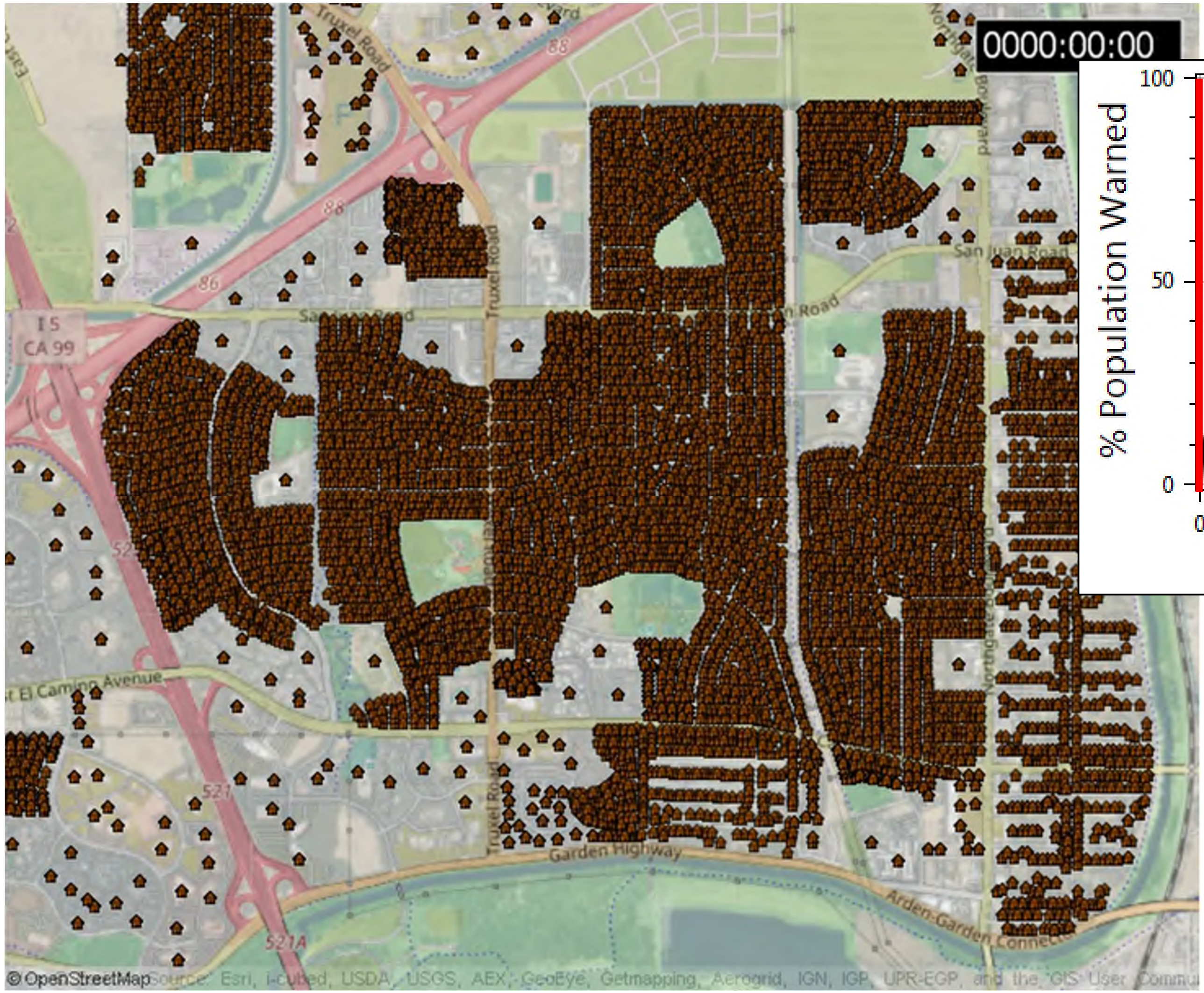
## High Hazard:

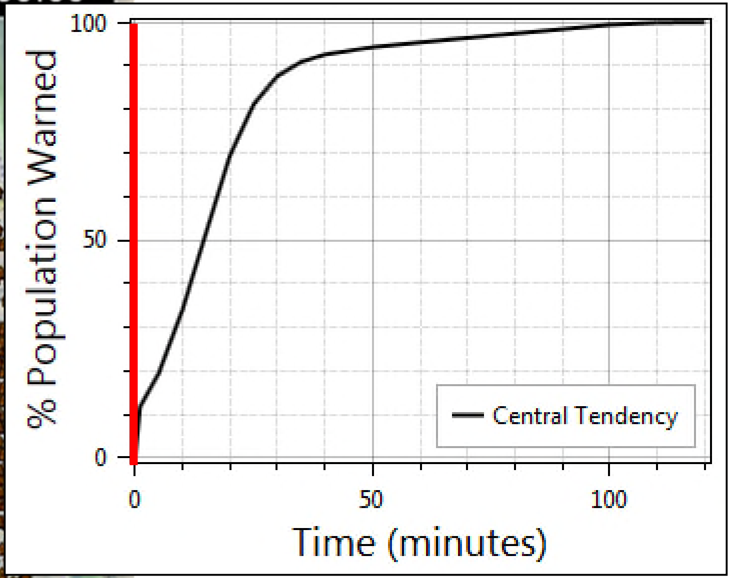
– Stability criteria or submergence criteria of the person (if out in the open), the vehicle (if caught while evacuation), or the structure (if not mobilized) has been exceeded. In that situation, the victims are typically swept downstream, buried in a collapsed building, or trapped underwater.

## Low Hazard:

– Exposed to relatively calm floodwaters, where their stability or the stability of their shelter is not at risk. A hazard exists due to the potential for bad things to happen when people come in contact with water in locations not meant for such an interaction.

# WARNING AND MOBILIZATION




Not Warned
Warned
Mobilized
Caught Vehicle
Caught Structure

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# CHOOSE METRICS WISELY, OR THEY CAN LEAD YOU ASTRAY

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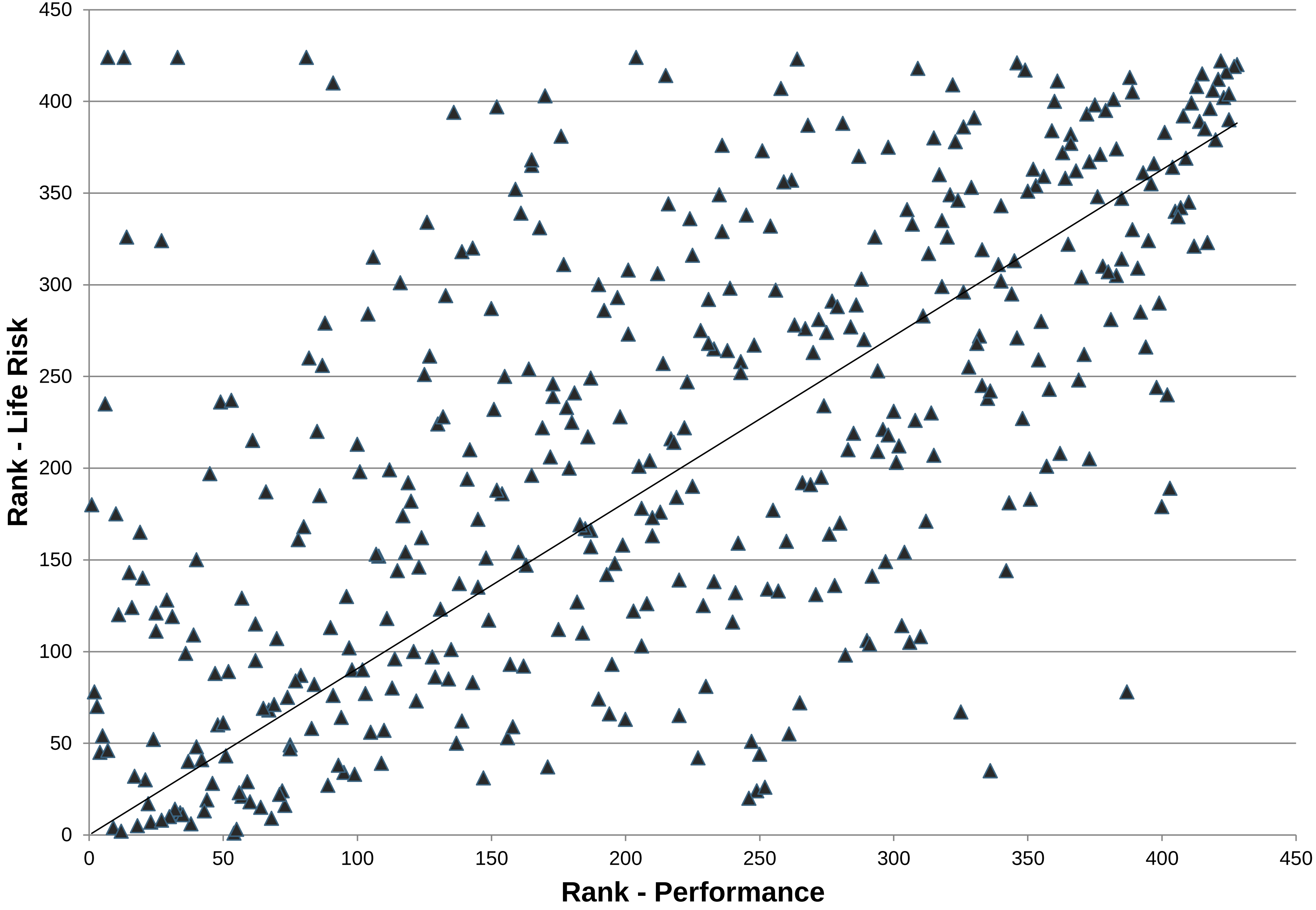
# Life Risk vs Performance





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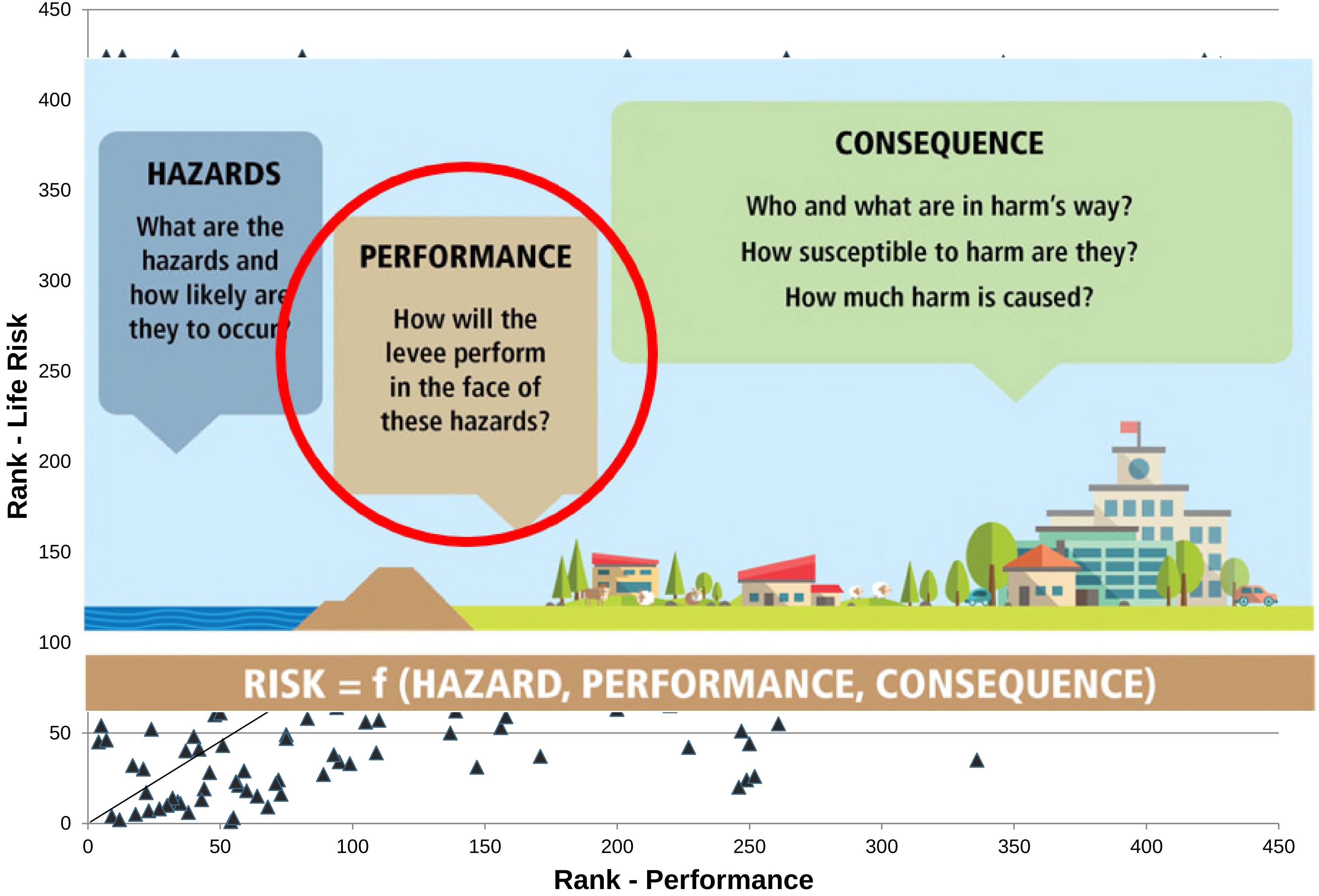
# Life Risk vs Performance





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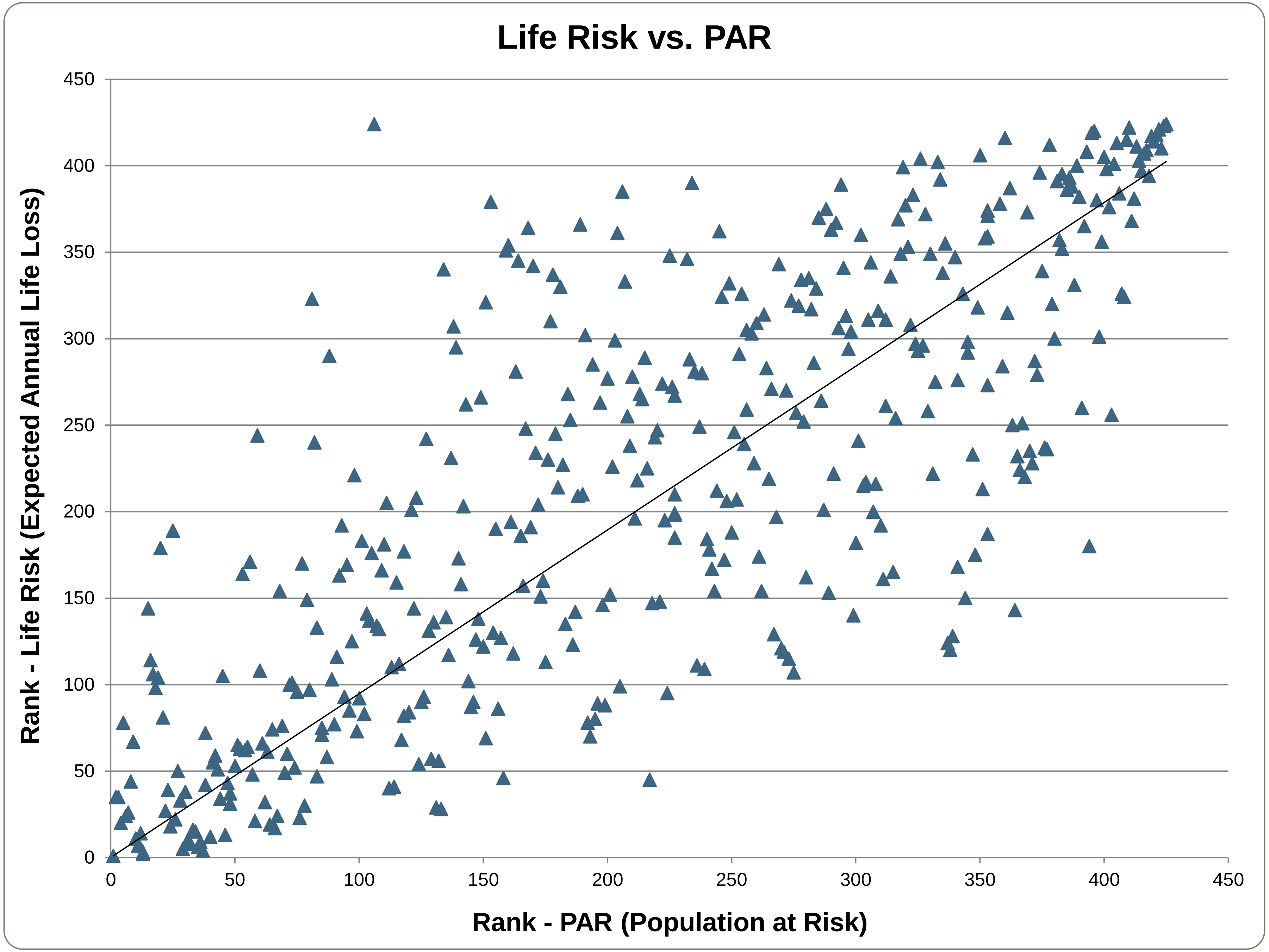



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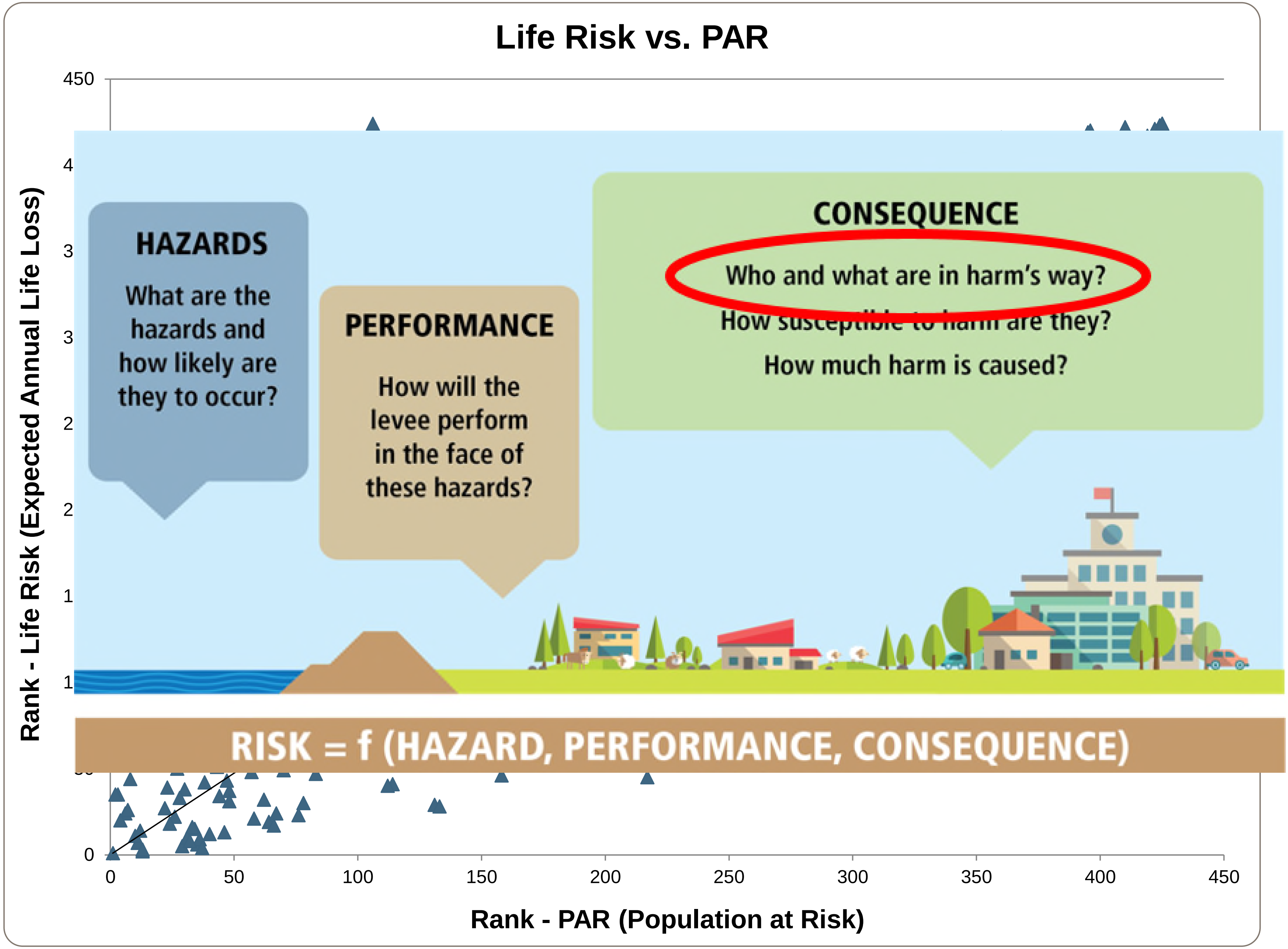



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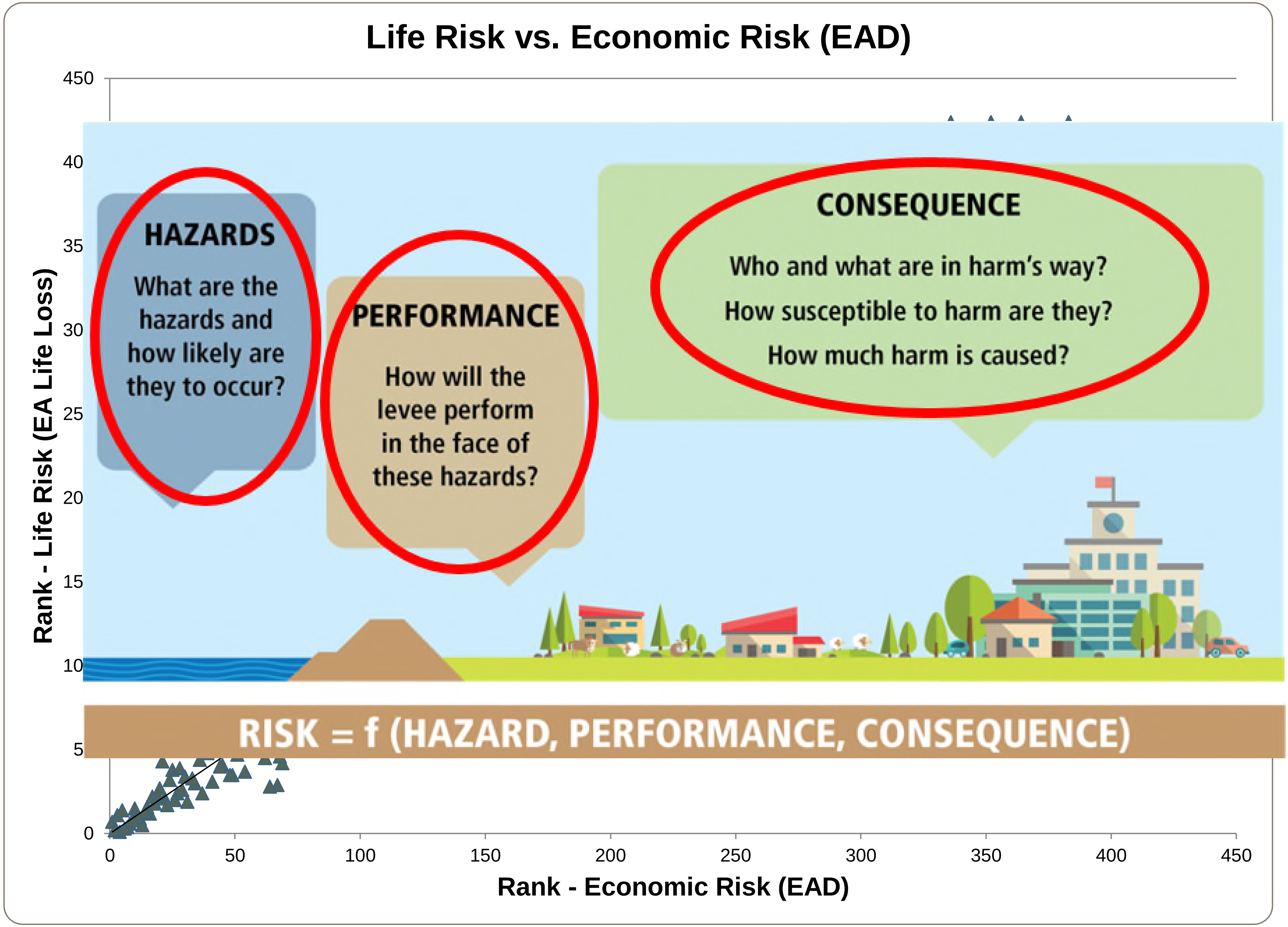



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# HALFTIME QUESTIONS?

- Any big questions before we get into the different types of risk assessments???

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# QUALITATIVE RISK ASSESSMENT

- **Appropriate during initial planning phases/iterations**
- **Utilizes Quantitative data**, just doesn't do additional modeling
  - Assess **available data** and key risk indicators
    - Existing LST data
    - PA's/SQRA's/etc.
    - Warning Times
    - Exposed PAR (> 2ft, > 9ft)
    - Flood Arrival Times
    - Evacuation times
    - Depth of Flooding
    - Velocity of Flooding
    - Probability of Failure
      - Can use PFMA Template
    - Etc.
  - If there are very few indicators of high life safety risk, the a qualitative assessment ***MAY*** be the only assessment needed during feasibility.

**PROJECT NAME**
**POTENTIAL FAILURE MODE ANALYSIS**
**PFM #**
(JUDGED TO BE SIGNIFICANT OR CREDIBLE)

**( PFM # ___ )**

**Loading:**
Hydrologic, Seismic

**Description:**

**Background:**

| Conditions making PFM Likely (Unfavorable Factors) | Conditions making PFM Unlikely (Favorable Factors) |
|---|---|
| • . | • . |

* - Major Contributing Factors or Risk Driving Conditions

| | |
|---|---|
| **Project Feature Requirements that will Reduce the Probability of Failure** (Stability Berm, Drain, Filtered Exit, Grouting, Parapet Wall, etc) | **Incorporate into TSP ?** (Why/Why Not and Impact or Risk) |
| **Knowledge Gaps and Uncertainties:** (Information that if available would add confidence to the design and project cost) | **How to Address in this study ?** (Additional Study/Analysis, add Contingency Cost Range for best/worst case and expected value, etc) |

**Recommended Future Investigation and Engineering Study Requirements to Reduce Uncertainty**
(Activities that should be scoped, scheduled, and budgeted for PED)

**Potential Risk Reduction Actions for Completed Project**

**Recommended Long Term Monitoring and Instrumentation to detect potential failure mechanisms**
• .

**Ability to Intervene, Issue Warnings, and Reduce Downstream Consequences**
(On-Site Equipment, Supplies, Manpower, EAP, EMA Coordination, Communication Networks, etc)
• .

**Existing Projects: Should Interim Risk Reduction Measures be recommended until modifications are made ?:**
• .

**Other Structural or NonStructural Risk Reduction Considerations that should be addressed:**

**Technical Data for Consequence Analysis :**

| Pool Elevation | | Warning Opportunity Time: | Breach Formation Time: | Estimated Breach Width: |
|---|---|---|---|---|
| Normal | | | | |
| Spillway | | | | |
| Unusual | | | | |
| PMF | | | | |
| Other | | | | |

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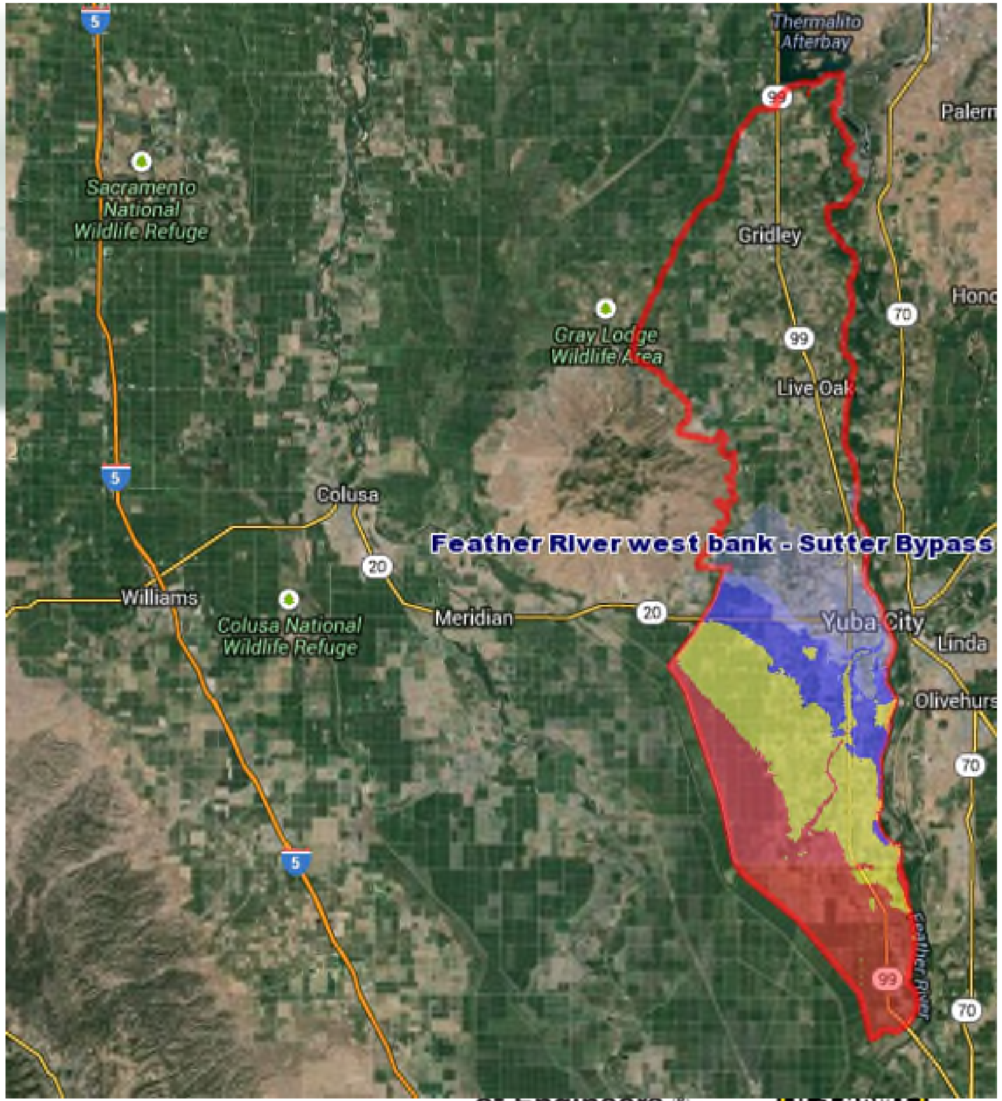
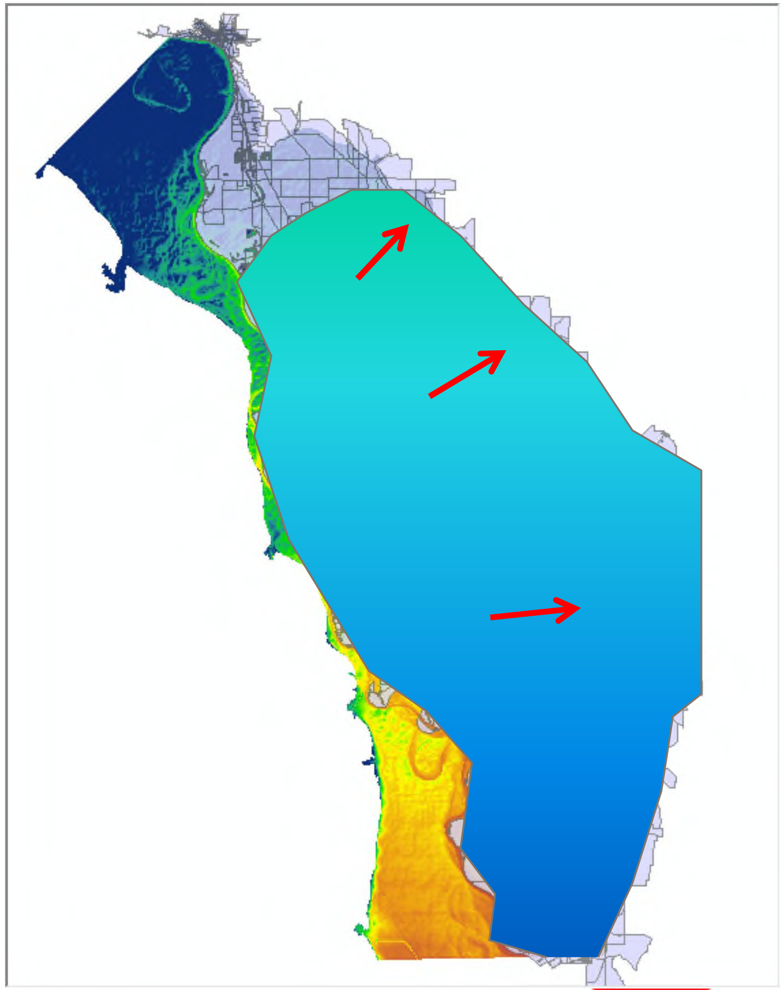
# LEVEE SCREENING TOOL

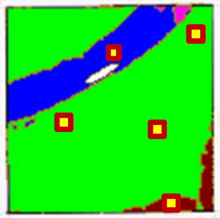
# LEVEE SCREENING APPROACH - CONSEQUENCES

- Initial data distribution
- Population re-distribution
- Depths, fatality rates, and consequences



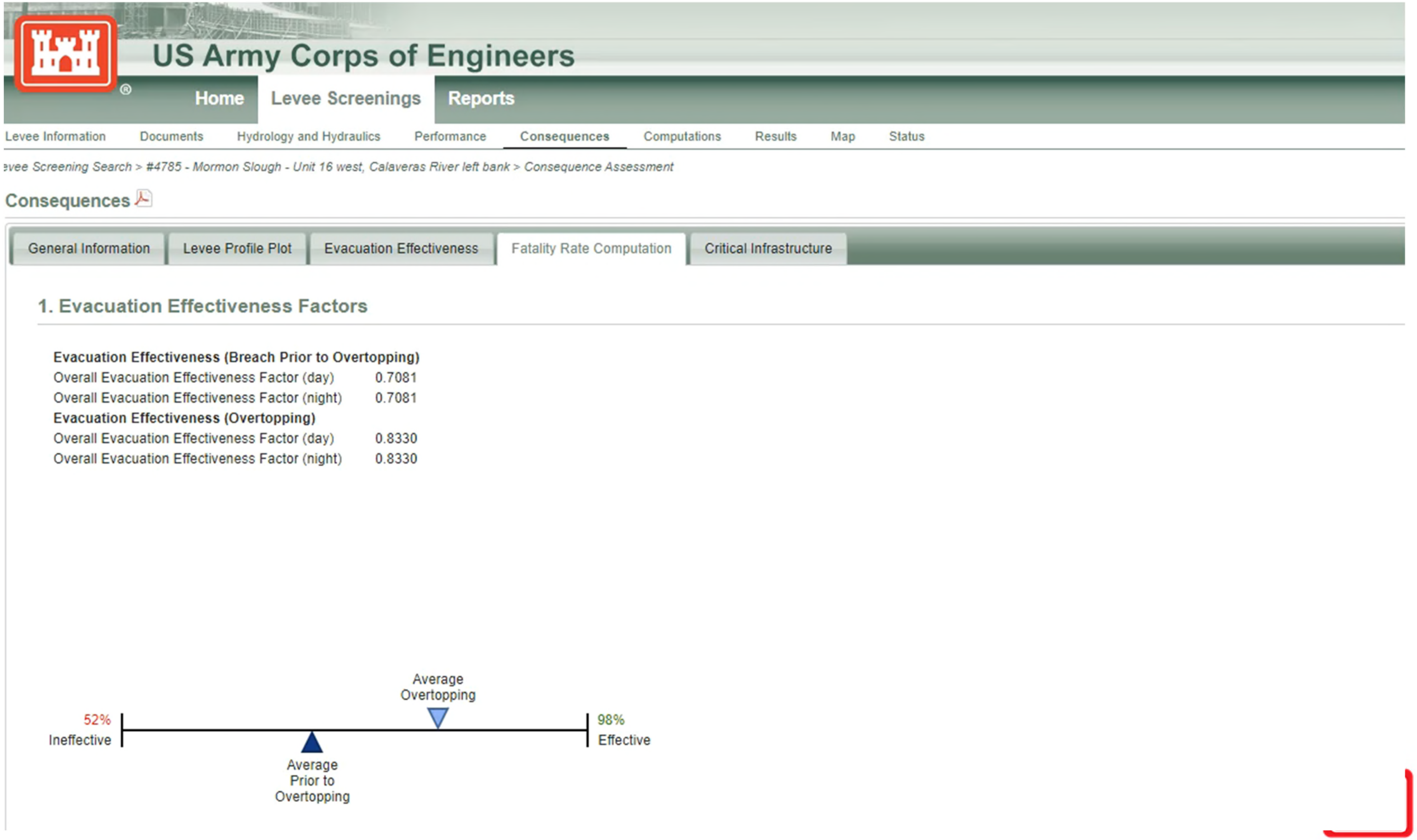
# EXPOSURE CURVES EXAMPLE





| Census Block<br>Population = 250<br>Total Value = $10,000 | | | |
|---|---|---|---|
| Elevation (ft) | Percent Area | Aggregate Value ($) | Aggregate Population |
| 0 | 0 | 0 | 0 |
| 0.5 | 5 | 500 | 12.5 |
| 1 | 17 | 2200 | 55 |
| 1.5 | 68 | 9000 | 225 |
| 2 | 10 | 10000 | 250 |

# LST RESULTS– FATALITY RATE COMPUTATION TAB



# LST RESULTS – CONSEQUENCES SUMMARY

## 3. Consequence Results Summary

| | |
|---|---|
| Population at Risk (Day) | 96,170 |
| Population at Risk (Night) | 127,697 |

**Breach Prior to Overtopping**

| | |
|---|---|
| Threatened Population (Day) | 28,077 |
| Threatened Population (Night) | 37,281 |
| Loss of Life (Day) | 126.02 |
| Loss of Life (Night) | 184.72 |

**Overtopping**

| | |
|---|---|
| Threatened Population (Day) | 16,060.35 |
| Threatened Population (Night) | 21,325.33 |
| Loss of Life (Day) | 72.08 |
| Loss of Life (Night) | 105.66 |

**Exposure Values**

| | |
|---|---|
| Day | 0.45 |
| Night | 0.55 |

**Exposure Weighted Life Loss Estimates**

| | |
|---|---|
| Estimated Loss of Life (Breach Prior to Overtopping) | 158.3 |
| Estimated Loss of Life (Overtopping) | 90.55 |

**Summary**

| | |
|---|---|
| Weighted Fatality Rate (%) | 0.45% |
| Loss of Life as % of PAR | 0.13% |
| Property Damages (in 1000s) | $6,216,947.87 |
| Number of Structures Inundated | 42,636 |

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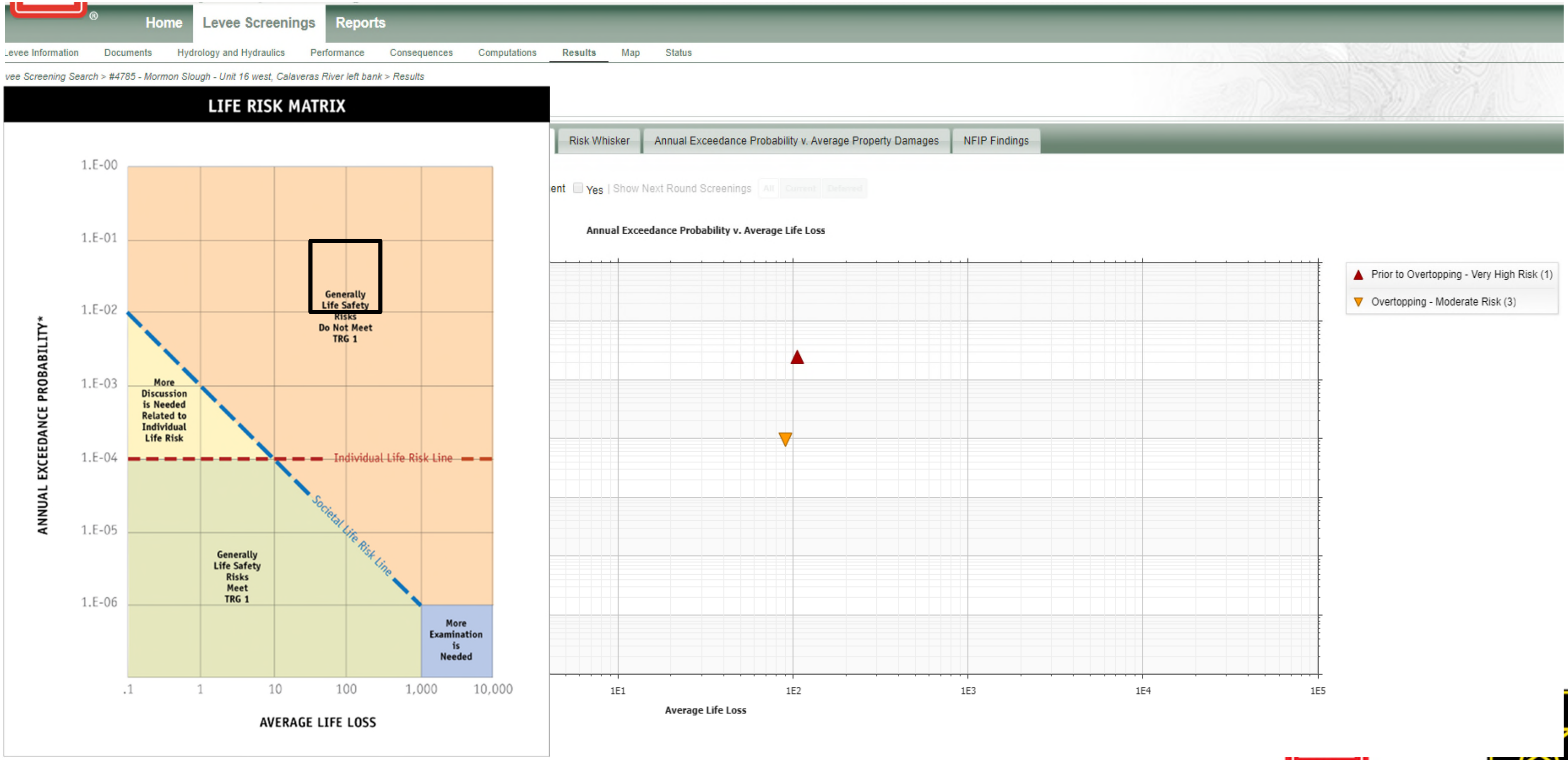
# LST RESULTS – RISK RESULTS

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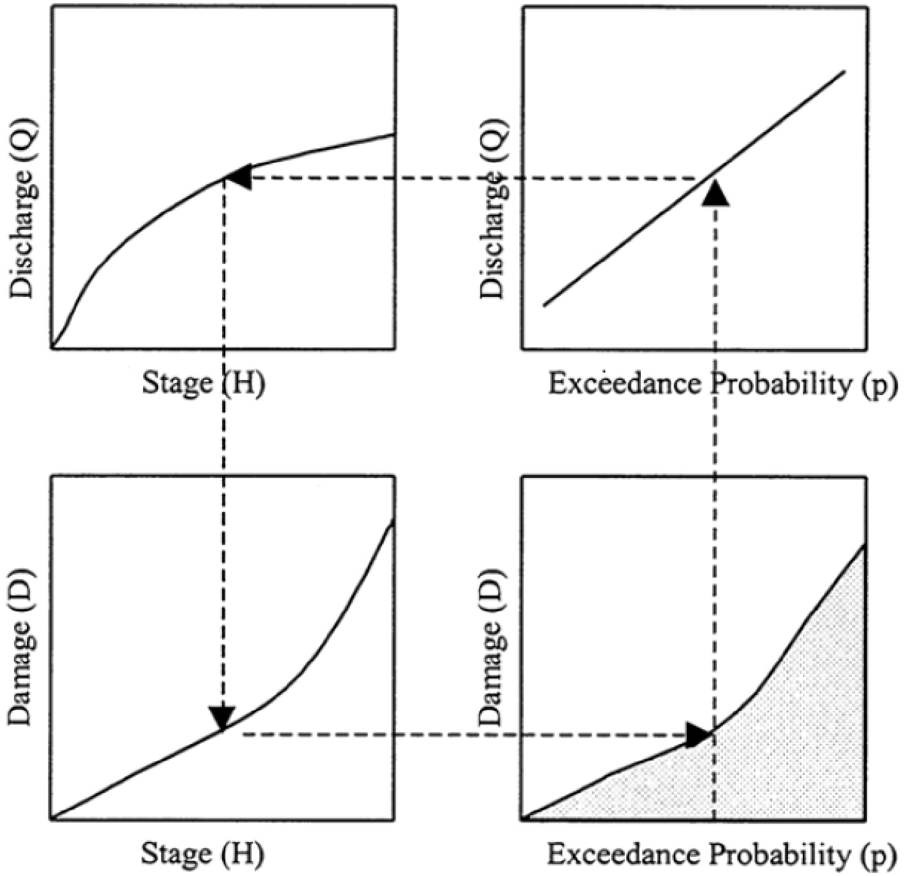
# RISK ASSESSMENT PROCESS





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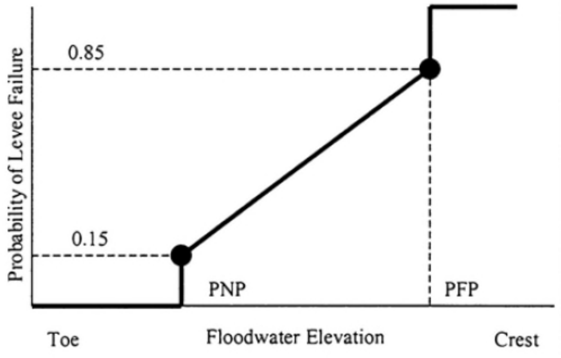
# SQRA

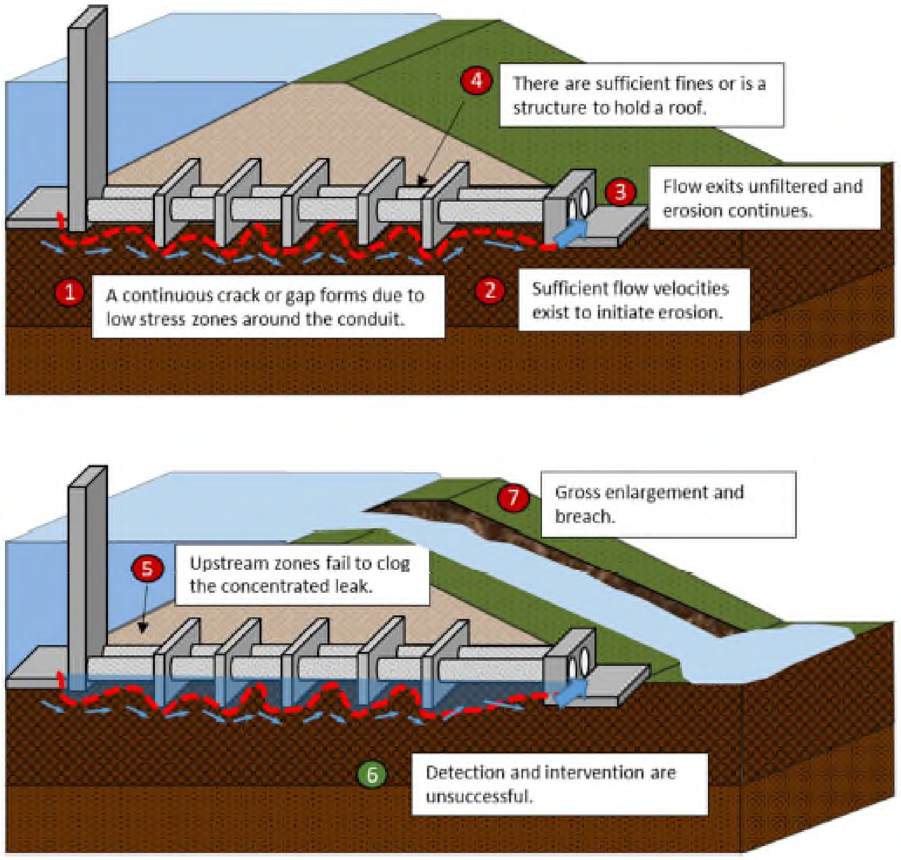
- A Semi-Quantitative Risk Assessment (SQRA) provides information
  - Background information
  - Potential Failure Mode Analysis
  - Risk Assessment
- How do you do one?
  - Recruit a risk cadre (expensive)
  - Use the framework (scalable)
- What makes it “Semi”?
  - There’s usually a lot of subjectivity
  - There’s usually not a lot of “nodal probabilities”
  - Not the full range, focus is on a critical load

# SQRA

- PFMA /SQRA
  - List of ways a project could fail
  - Order of magnitude probability of failure
  - Order of magnitude consequences




| Potential Failure Mode | Description |
|---|---|
| PFM PS1 | Mechanical/Electrical Failure of the Pumps leads to Inability to Pump and Increased Interior Ponding |
| PFM PS2 | Concentrated Leak Erosion along the Embankment/Pump Station Contact |
| PFM PS3 | Track Rack Clogs reducing Pumping Capacity |
| PFM PS4 | Loss of Power prevents Closure of Gravity Flow Gates |
| PFM PS5 | Internal Erosion under Pump Station |
| PFM PS6 | Debris leads to Clogging of a Gravity Flow Gate |
| PFM PS7 | Mechanical Failure of the Gravity Flow Gate at a Pump Station |
| PFM PS8 | Failure of the Gravity Storm Drain at/between Flood Gate 2 and Flood Gate 5 at Beargrass Creek Pumping Station |
| PFM PS9 | Landside Slope Failure due to Rapid Drawdown of the Ponding Area |
| PFM PS10 | Erosion of the Riverside Toe Due to Discharge from the Pump Station leads to Slope Instability |
| PFM PS11 | Failure of the Landside Wing Wall at the Pond Creek PS leads to Slope Instability |
| PFM PS12 | Failure of the Landside Wing Wall at the Pond Creek PS leads to Reduced Pumping Capacity |
| PFM CS1 | Concentrated Leak Erosion along Closure Structure Abutment/Embankment Contact |
| PFM CS2 | Failure to Install Closure Structure |
| PFM CS3 | Structural Failure of the Closure |
| PFM CS4 | Concentrated Leak Erosion along the "Culvert" at the 27th Street Closure |
| PFM CS5 | Impact to Closure leads to Failure |
| PFM CS6 | Internal Erosion under the Closure Structure Sill |
| PFM TW1 | Internal Erosion of the Foundation under a T-Wall |
| PFM TW2 | Overtopping leads to Scour of the Landside Toe Destabilizing the T-Wall |
| PFM TW3 | Overturning of the T-Wall |
| PFM TW4 | Instability of the T-walls Incorporated into Other Structures |
| PFM TW5 | Structural Failure of the T-Wall Stem |
| PFM TW6 | Sliding Stability of the T-Wall |
| PFM TW7 | Failure to the T-Wall at 16th Railroad Closure Damaged by Impact from a Train |
| PFM TW8 | Failure of Canal Power Station Floodwall |
| PFM IW1 | Rotational Instability Prior to Overtopping |
| PFM IW2 | Overtopping leads to Scour of the Landside Toe and Rotational Instability |
| PFM IW3 | Backward Erosion Piping under the I-Wall Due to Riverside Gap and Shorten Seepage Path |
| PFM IW4 | Brittle Fracture of the Type II I-Wall |
| PFM IW5 | Brittle Fracture of the Type I I-Wall along a Cold Joint |
| PFM IW6 | Global Instability Prior of the I-wall prior to Overtopping |
| PFM IW7 | Overtopping leads to Scour of the Landside Toe and Global Instability of the I-wall |
| PFM LW1 | Internal Erosion of the Foundation Under a L-Wall |
| PFM LW2 | Overtopping leads to Scour of the Landside Toe Destabilizing the L-Wall |
| PFM LW3 | Overturning of the L-Wall |
| PFM LW4 | Structural Failure of the L-Wall Stem |
| PFM LW5 | Sliding Stability of the L-Wall |
| PFM P1 | Concentrated leak Erosion along a Pipe Penetration |
| PFM P2 | Internal Erosion into a Defect along a Pipe Penetration |

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# SQRA: BASICS OF CONSEQUENCES MODELING

- Hydraulics
  - Arrival times and velocity matter, not just max depths

# SQRA: BASICS OF CONSEQUENCES MODELING

- Inventory
  - Must estimate Population at-Risk (PAR), not just structure values


| OccType | N_Stories | BldgType | FoundHt | Pop2amU65 | Pop2amO65 | Pop2pmU65 | Pop2pmO65 | StructVal |
|---|---|---|---|---|---|---|---|---|
| RES1-1SWB | 1 | W | 2 | 2 | 1 | 1 | 1 | 132643.5 |
| RES1-SLNB | 1 | W | 2 | 2 | 1 | 1 | 1 | 111119.6 |
| RES1-2SNB | 2 | W | 2 | 1 | 0 | 0 | 0 | 172379 |
| RES1-2SNB | 2 | W | 2 | 3 | 0 | 1 | 0 | 259572.8 |
| RES1-1SNB | 1 | M | 2 | 2 | 0 | 0 | 0 | 156392.3 |
| RES3B | 1 | W | 1 | 5 | 0 | 2 | 0 | 346808.6 |
| RES3B | 1 | M | 1 | 4 | 0 | 2 | 0 | 333705.8 |
| RES3C | 1 | M | 1 | 6 | 1 | 2 | 0 | 634792.3 |
| RES1-1SNB | 1 | M | 2 | 2 | 1 | 1 | 1 | 171410.5 |
| RES1-1SWB | 1 | W | 2 | 1 | 0 | 0 | 0 | 124296.9 |
| RES3B | 1 | W | 1 | 4 | 0 | 2 | 0 | 342453.7 |

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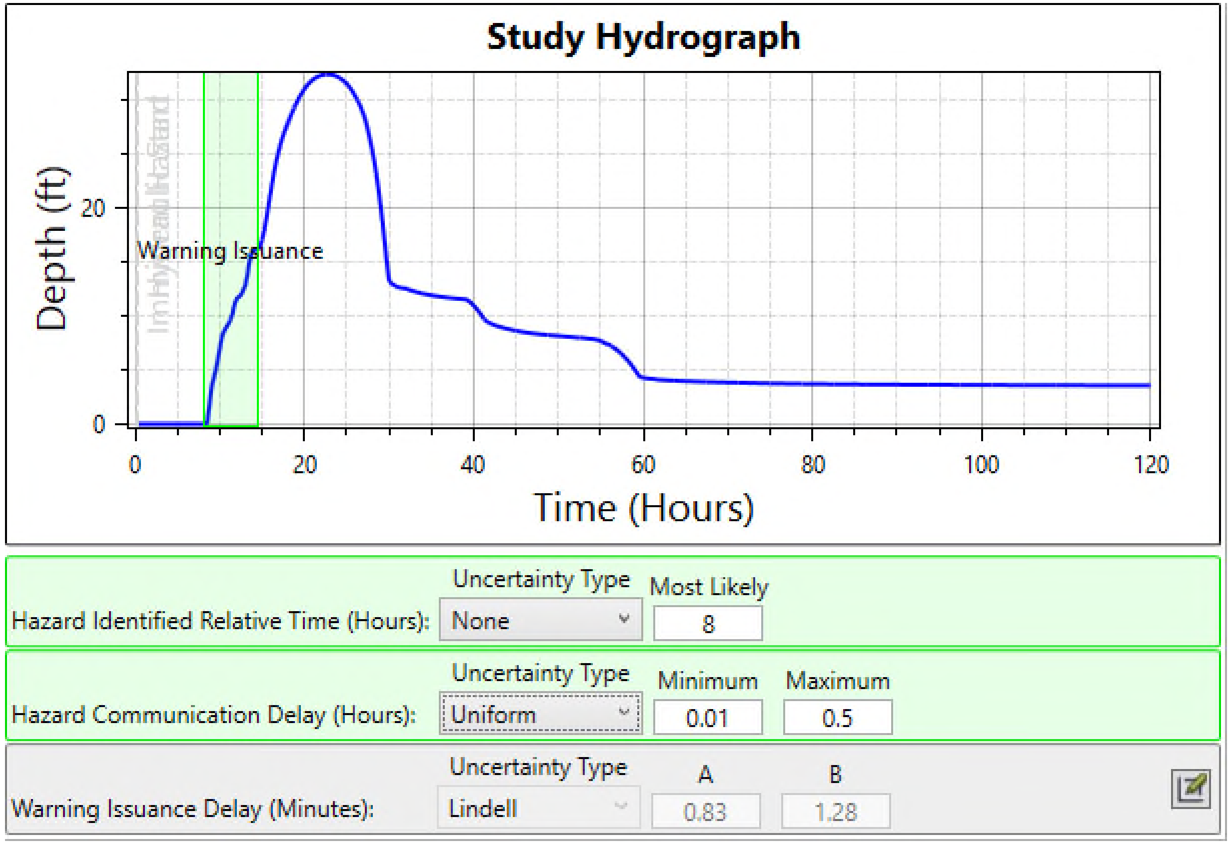
# SQRA: BASICS OF CONSEQUENCES MODELING

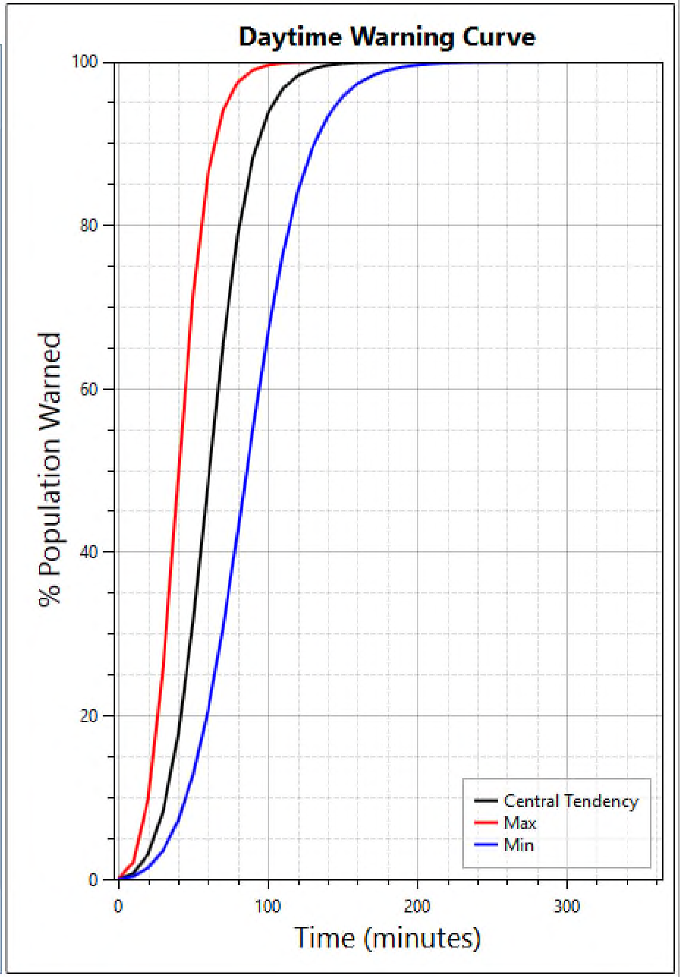
- Life Loss Assumptions
  - Warning




Warning Diffusion: Moderate

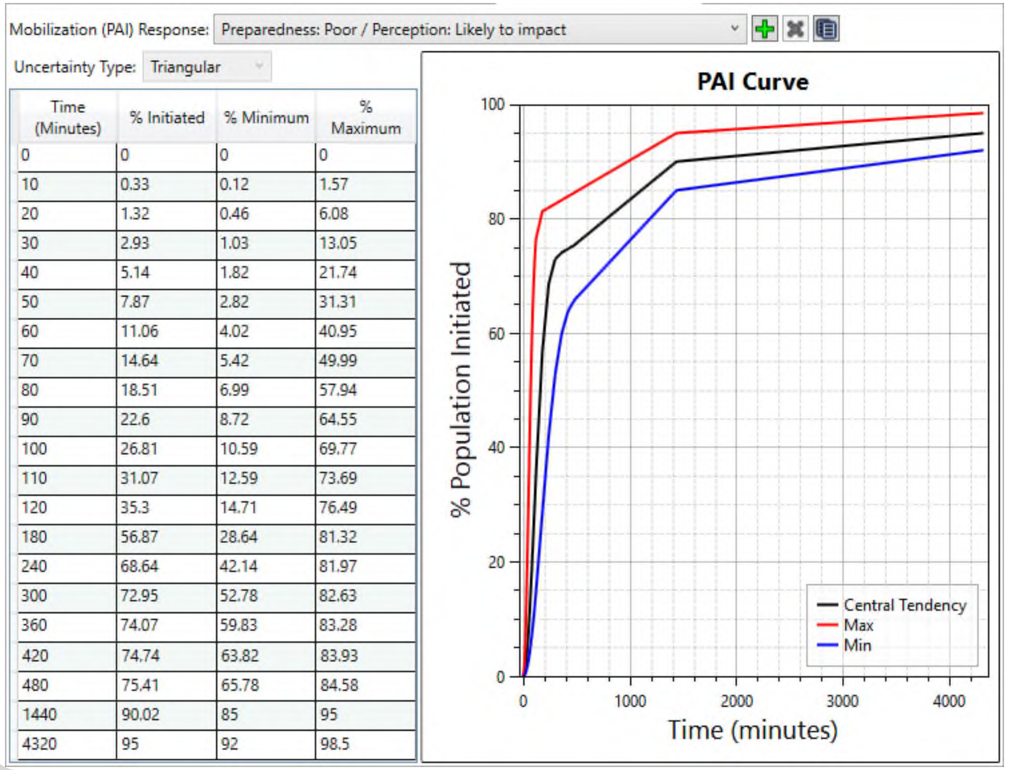
Uncertainty Type: Triangular

| Time (Minutes) | % Warned | % Minimum | % Maximum |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 10 | 0.66 | 0.31 | 2.04 |
| 20 | 3.08 | 1.37 | 9.85 |
| 30 | 8.34 | 3.51 | 25.99 |
| 40 | 17.63 | 7.15 | 49.04 |
| 50 | 31.44 | 12.74 | 71.35 |
| 60 | 48.46 | 20.61 | 86.34 |
| 70 | 65.39 | 30.76 | 94.07 |
| 80 | 79.01 | 42.61 | 97.53 |
| 90 | 88.21 | 55.03 | 98.98 |
| 100 | 93.69 | 66.68 | 99.58 |
| 110 | 96.71 | 76.51 | 99.82 |
| 120 | 98.31 | 84.1 | 99.92 |
| 130 | 99.14 | 89.56 | 99.97 |
| 140 | 99.56 | 93.29 | 99.99 |
| 150 | 99.77 | 95.74 | 99.99 |
| 160 | 99.88 | 97.33 | 100 |
| 170 | 99.94 | 98.33 | 100 |
| 180 | 99.97 | 98.96 | 100 |
| 190 | 99.98 | 99.35 | 100 |
| 200 | 99.99 | 99.59 | 100 |
| 210 | 100 | 99.75 | 100 |
| 220 | 100 | 99.84 | 100 |
| 230 | 100 | 99.9 | 100 |
| 240 | 100 | 99.94 | 100 |
| 270 | 100 | 99.98 | 100 |
| 300 | 100 | 100 | 100 |

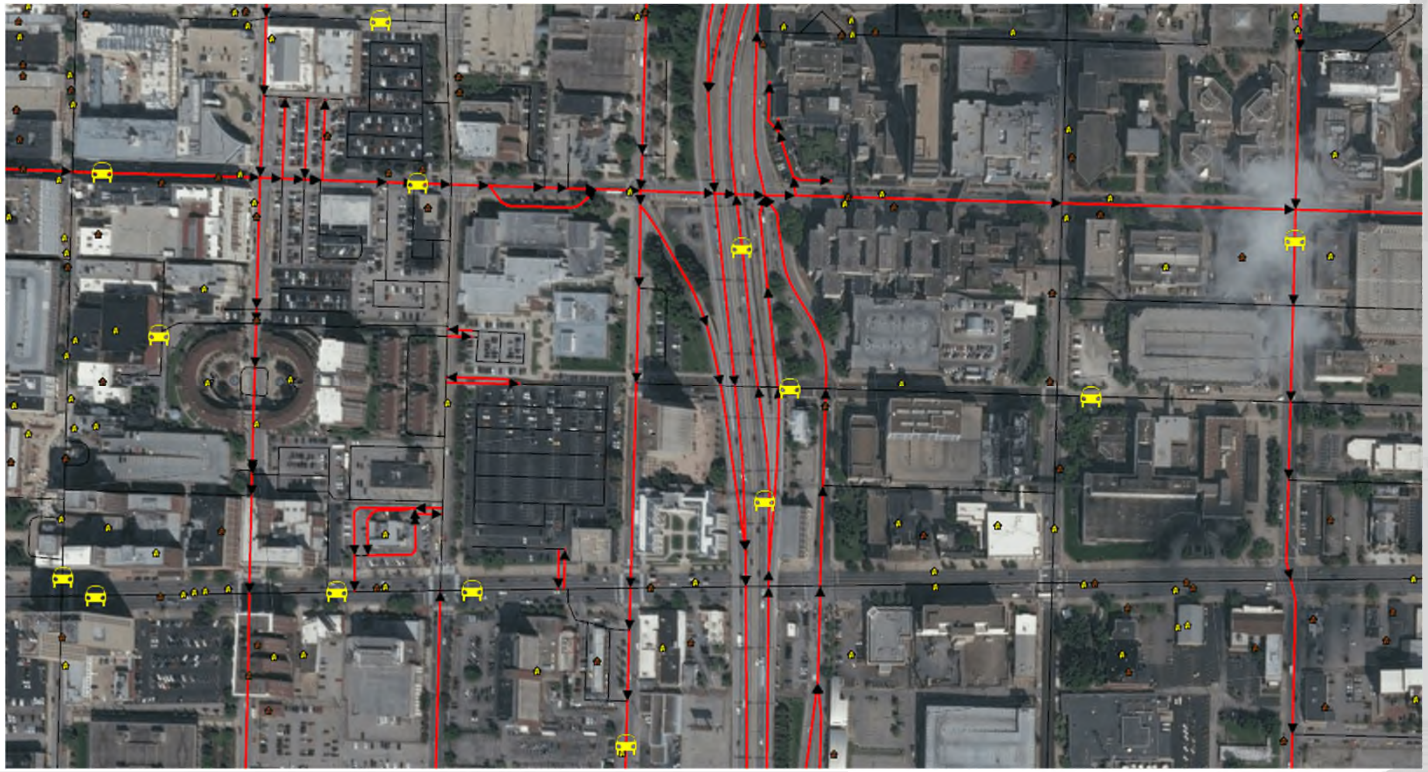


# SQRA: BASICS OF CONSEQUENCES MODELING

- Life Loss Assumptions
  - Evacuation

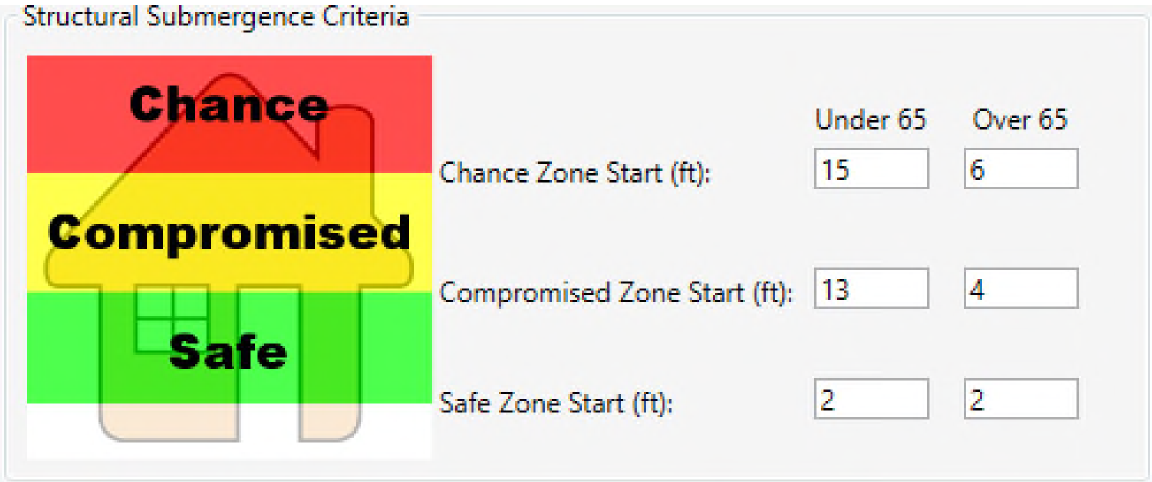


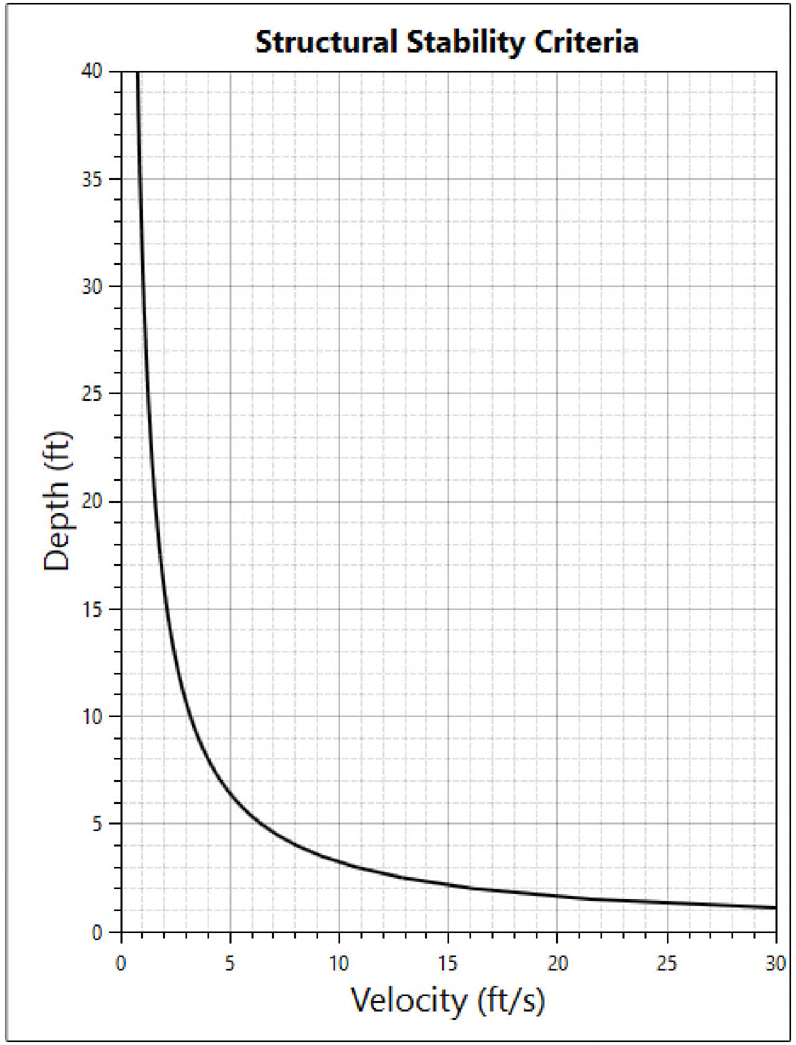

| Time (Minutes) | % Initiated | % Minimum | % Maximum |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 10 | 0.33 | 0.12 | 1.57 |
| 20 | 1.32 | 0.46 | 6.08 |
| 30 | 2.93 | 1.03 | 13.05 |
| 40 | 5.14 | 1.82 | 21.74 |
| 50 | 7.87 | 2.82 | 31.31 |
| 60 | 11.06 | 4.02 | 40.95 |
| 70 | 14.64 | 5.42 | 49.99 |
| 80 | 18.51 | 6.99 | 57.94 |
| 90 | 22.6 | 8.72 | 64.55 |
| 100 | 26.81 | 10.59 | 69.77 |
| 110 | 31.07 | 12.59 | 73.69 |
| 120 | 35.3 | 14.71 | 76.49 |
| 180 | 56.87 | 28.64 | 81.32 |
| 240 | 68.64 | 42.14 | 81.97 |
| 300 | 72.95 | 52.78 | 82.63 |
| 360 | 74.07 | 59.83 | 83.28 |
| 420 | 74.74 | 63.82 | 83.93 |
| 480 | 75.41 | 65.78 | 84.58 |
| 1440 | 90.02 | 85 | 95 |
| 4320 | 95 | 92 | 98.5 |



# SQRA: BASICS OF CONSEQUENCES MODELING

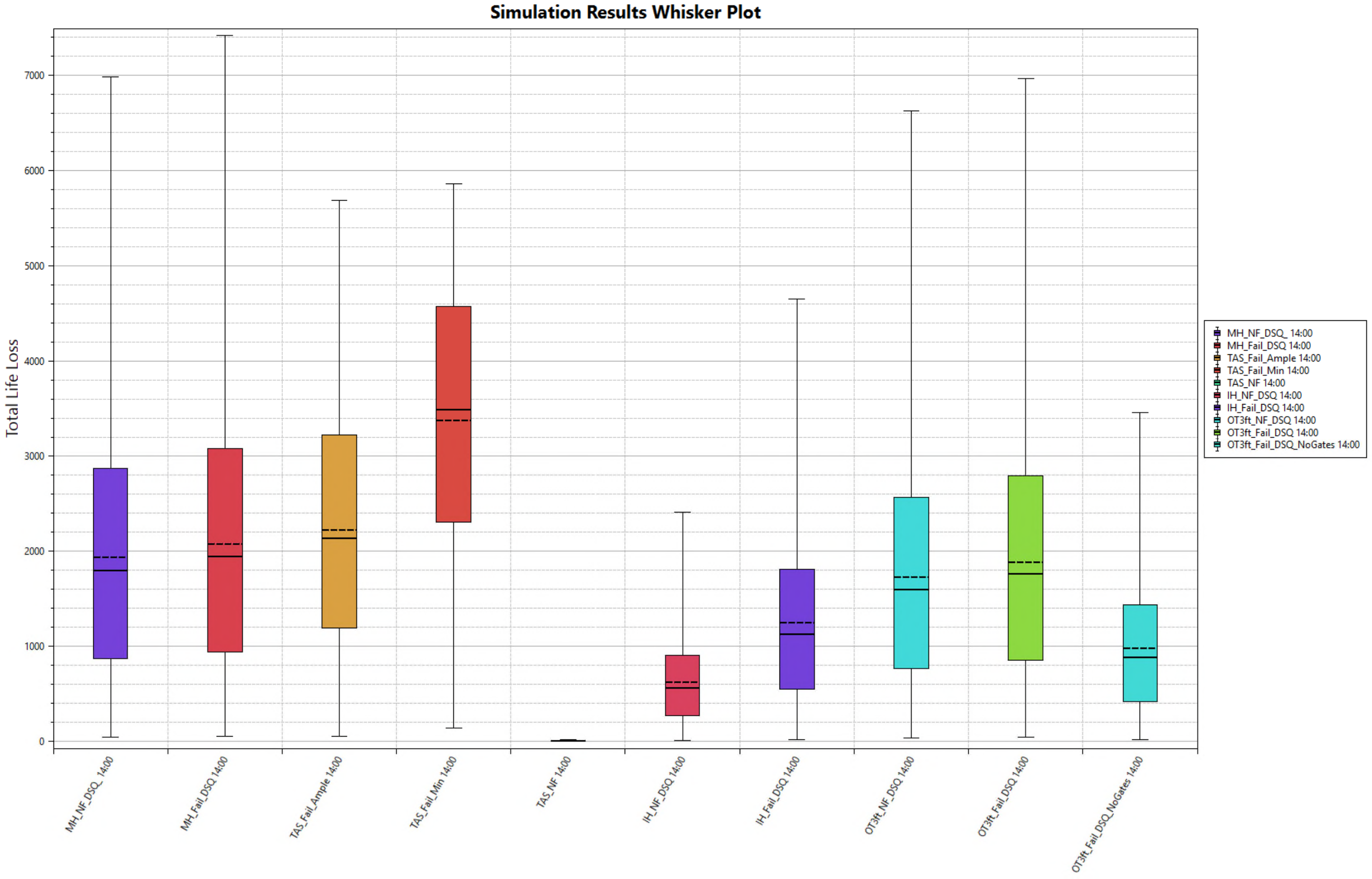
- Life Loss Assumptions
  - Fatality



# SQRA: BASICS OF CONSEQUENCES MODELING

- Life Loss Results

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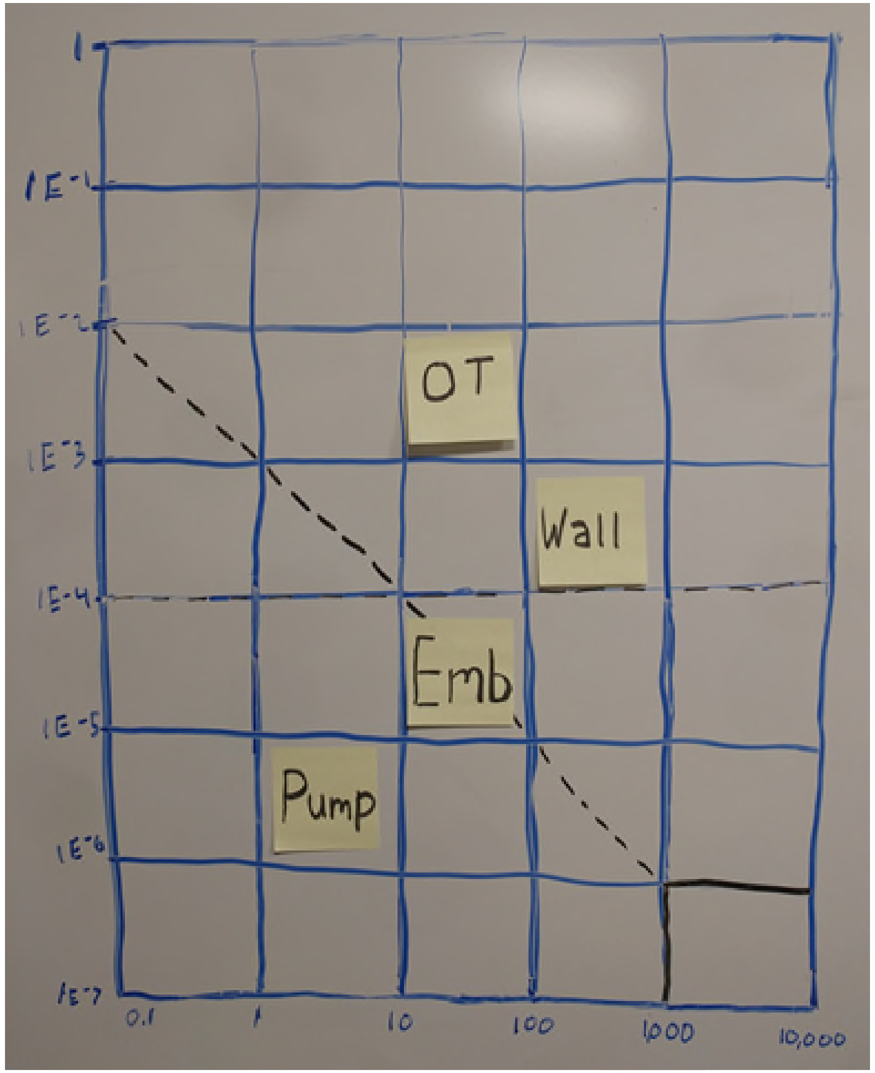
# SQRA: OUTCOMES OF PROCESS

- Categorical Ratings of Existing Risk
  - Life Loss informed by modeling
  - Qualitative issues also considered
    - Indirect Life Loss
    - PFM specific considerations not modeled
    - Etc.

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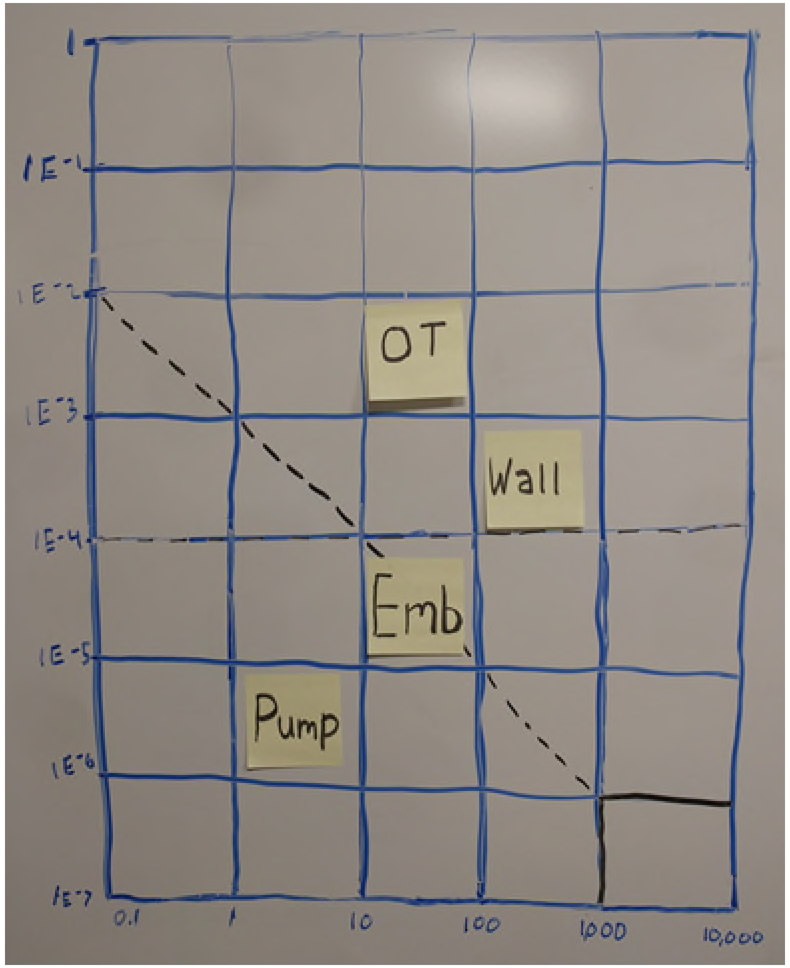
# USING SQRAS FOR PLANNING PURPOSES

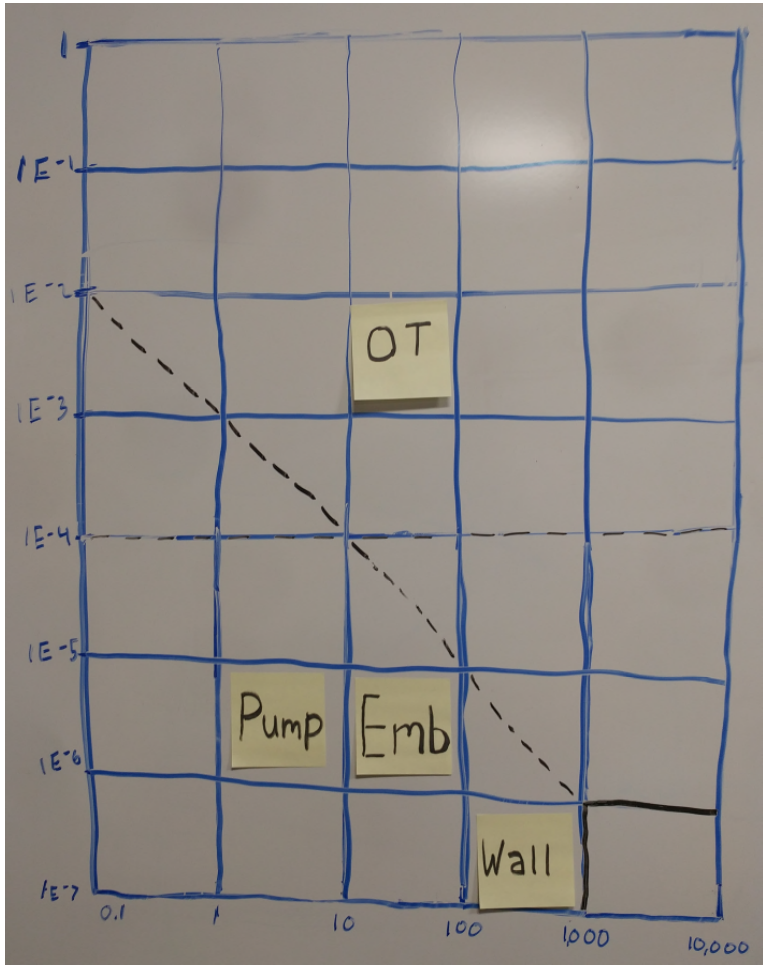
- Existing and Future Conditions
  - Background Data, Risk Plots
- Formulation
  - Address Failure Modes and/or Consequences
- Evaluation
  - Assess categorical rating changes (Probability and consequences)
- Comparison
  - "Benefits" and "Costs", Trade-offs
- Selecting a Plan
  - Meeting TRGs, metrics, exceptional circumstances

# SQRA: ALTERNATIVE COMPARISON

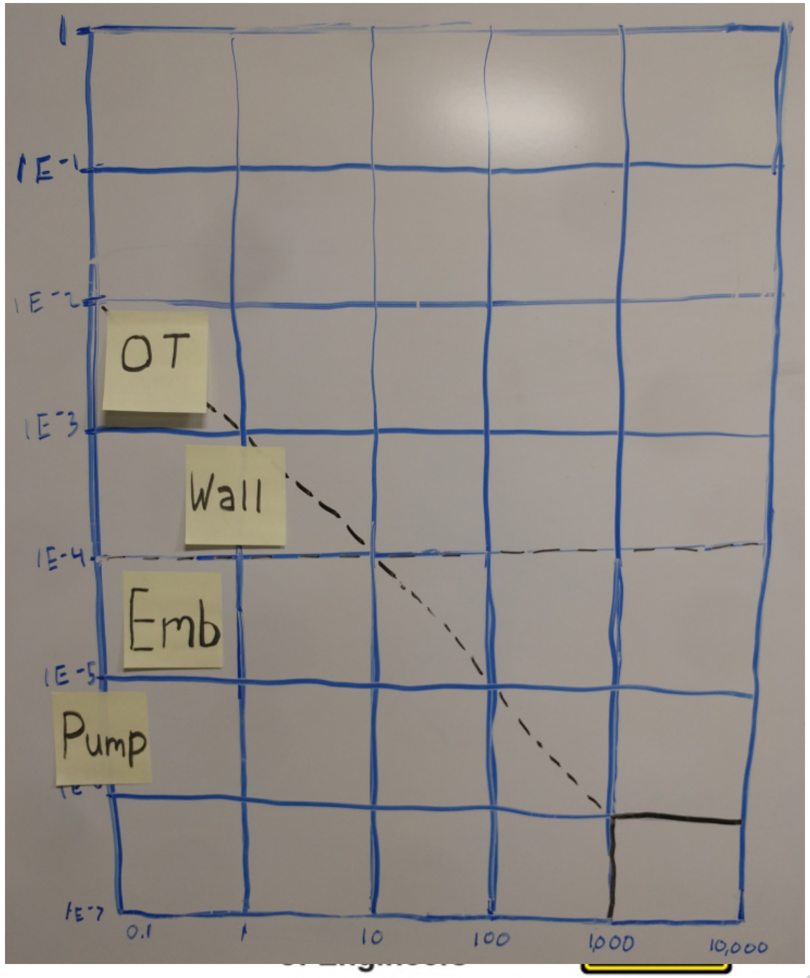
## No Action




## Structural




## Non Structural



# SCALED SQRA RISK ASSESSMENT – MENU OF MAJOR INPUTS

**Life Loss Inputs** — Low Detail → High Detail

| | | | | |
|---|---|---|---|---|
| • Floodplains | FEMA / FIS | Water Surface Elev at TOL | Breach Simulations | |
| • Exposed PAR | Census | NSI | NSI2 | Custom |
| • Warn/Evacuation | Expert Judgment | LST Range | LifeSim | Elicitation Based |
| • Fatality Rates | Expert Judgment | Jonkman Curve | LifeSim Modeled | |

| EXAMPLES | QUALITATIVE | LEVEE SCREENING | SQRA | QRA |
|---|---|---|---|---|

**Probability Inputs** — Low Detail → High Detail

| | | | |
|---|---|---|---|
| • Stage-Frequency | FEMA / FIS | FWOP modeling | Study/Plan specific modeling |
| • Probable Failure Modes | Professional Judgment (less data/people) | Expert Elicitation (more data/people) | |

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# EXAMPLE - SCALED SQRA RISK ASSESSMENT – MENU OF MAJOR INPUTS

**Life Loss Inputs** — Low Detail → High Detail

| | | | | |
|---|---|---|---|---|
| Floodplains | FEMA / FIS | Water Surface Elev at TOL | Breach Simulations | |
| Exposed PAR | Census | NSI | NSI2 | Custom |
| Warn/Evacuation | Expert Judgment | LST Range | LifeSim | Elicitation Based |
| Fatality Rates | Expert Judgment | Jonkman Curve | LifeSim Modeled | |
| **EXAMPLES** | **QUALITATIVE** | **LEVEE SCREENING** | **SQRA** | **QRA** |

**Probability Inputs** — Low Detail → High Detail

| | | | |
|---|---|---|---|
| Stage-Frequency | FEMA / FIS | FWOP modeling | Study/Plan specific modeling |
| Probable Failure Modes | Professional Judgment (less data/people) | Expert Elicitation (more data/people) | |

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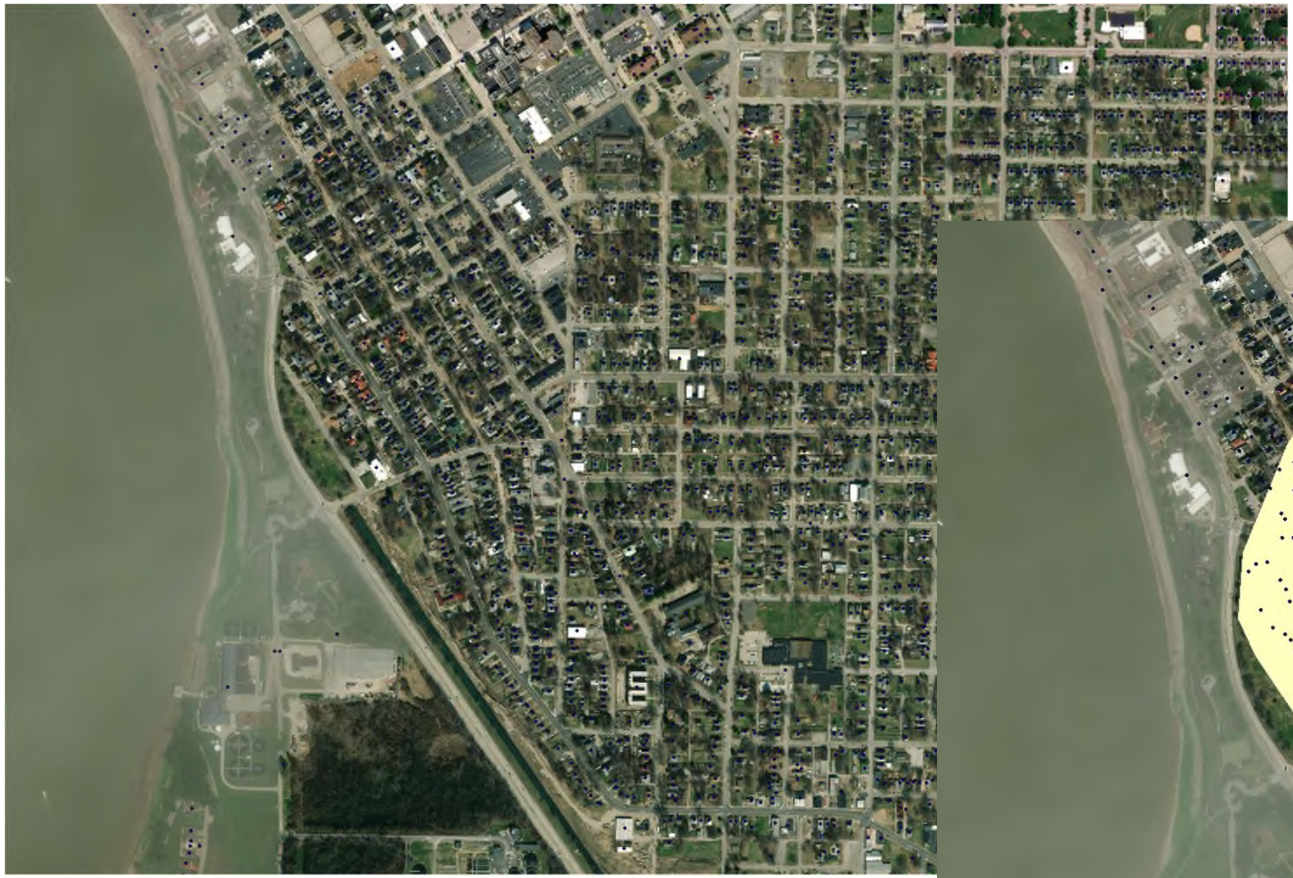
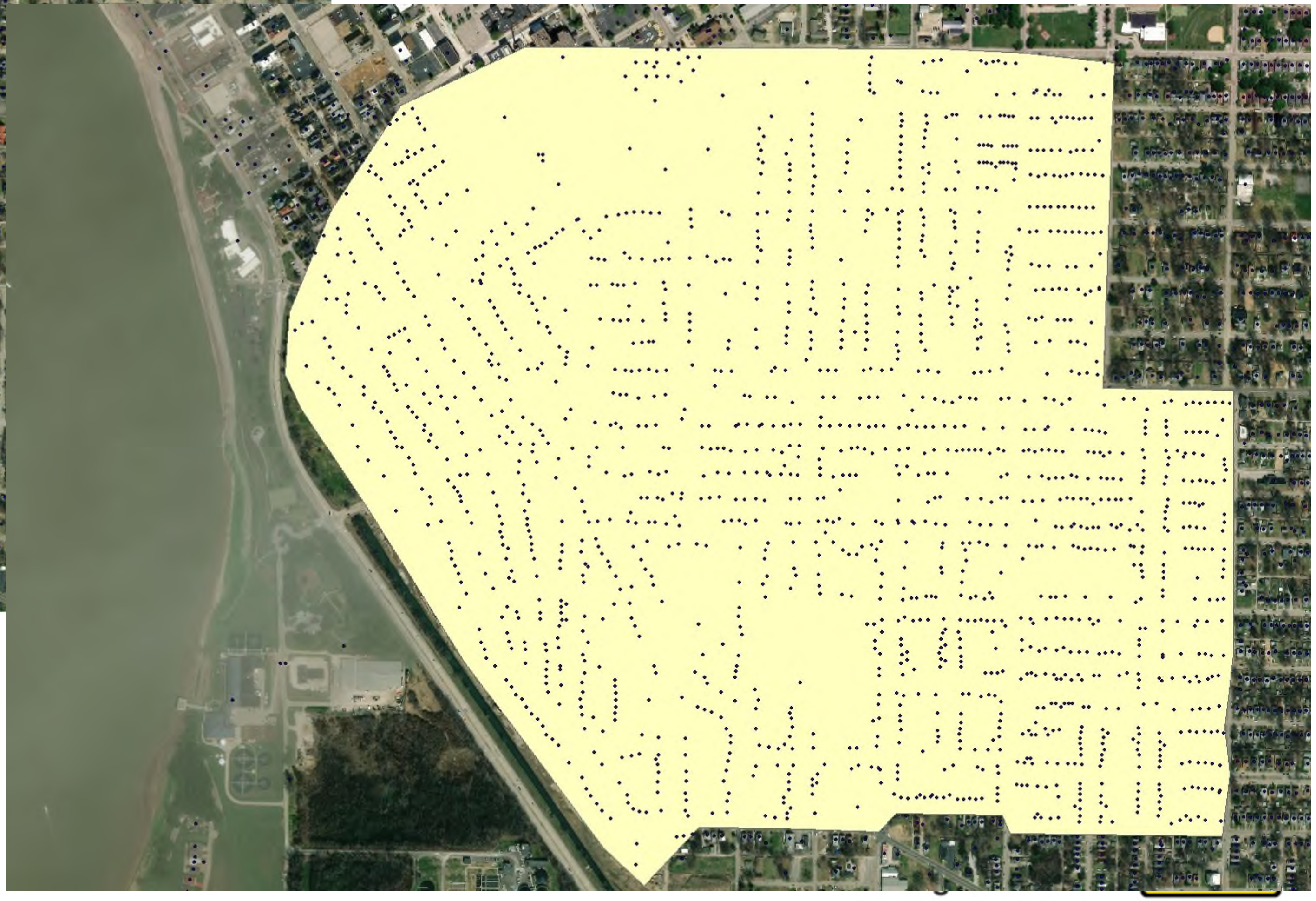
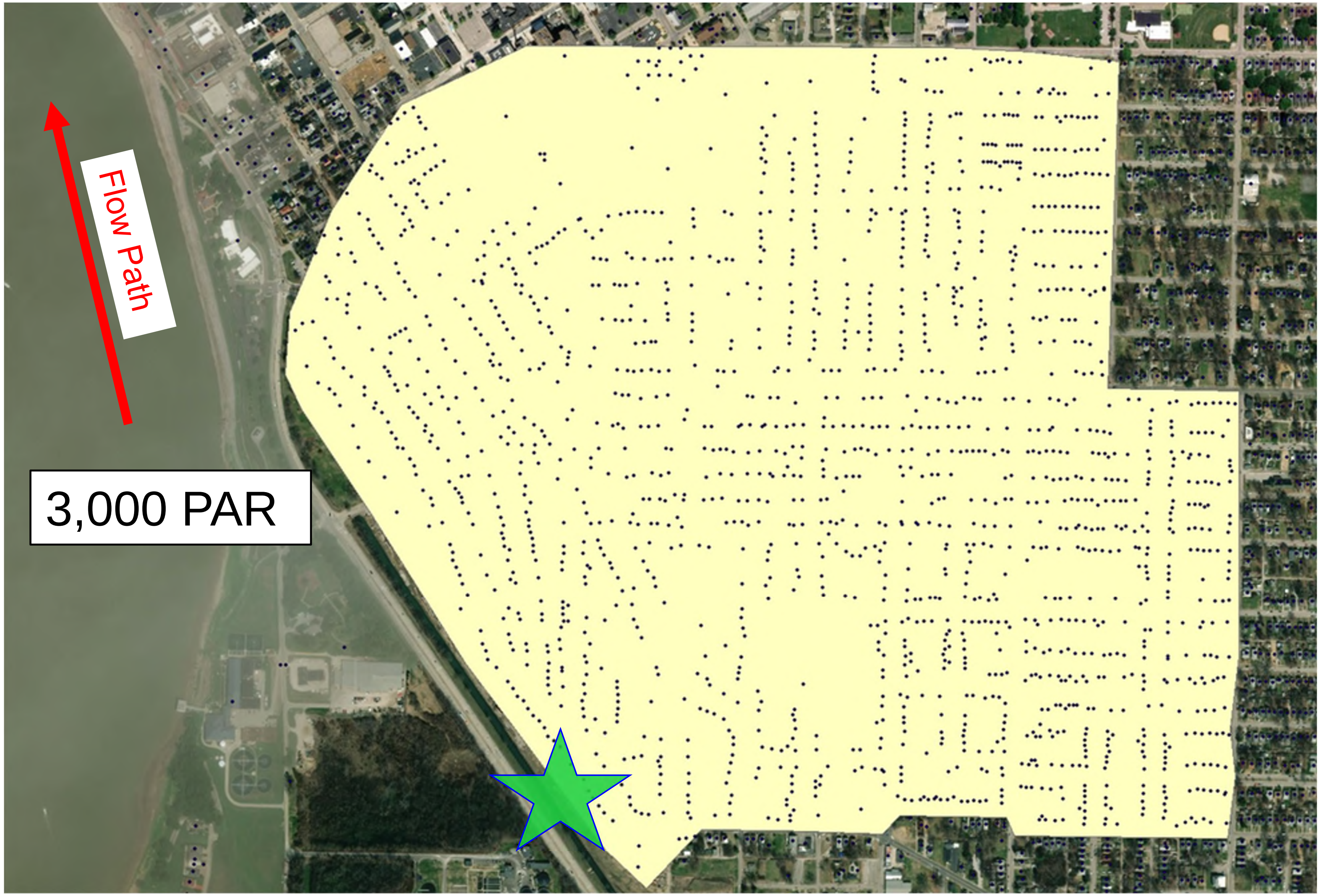
# EXAMPLE SCALED SQRA





# EXAMPLE SCALED SQRA

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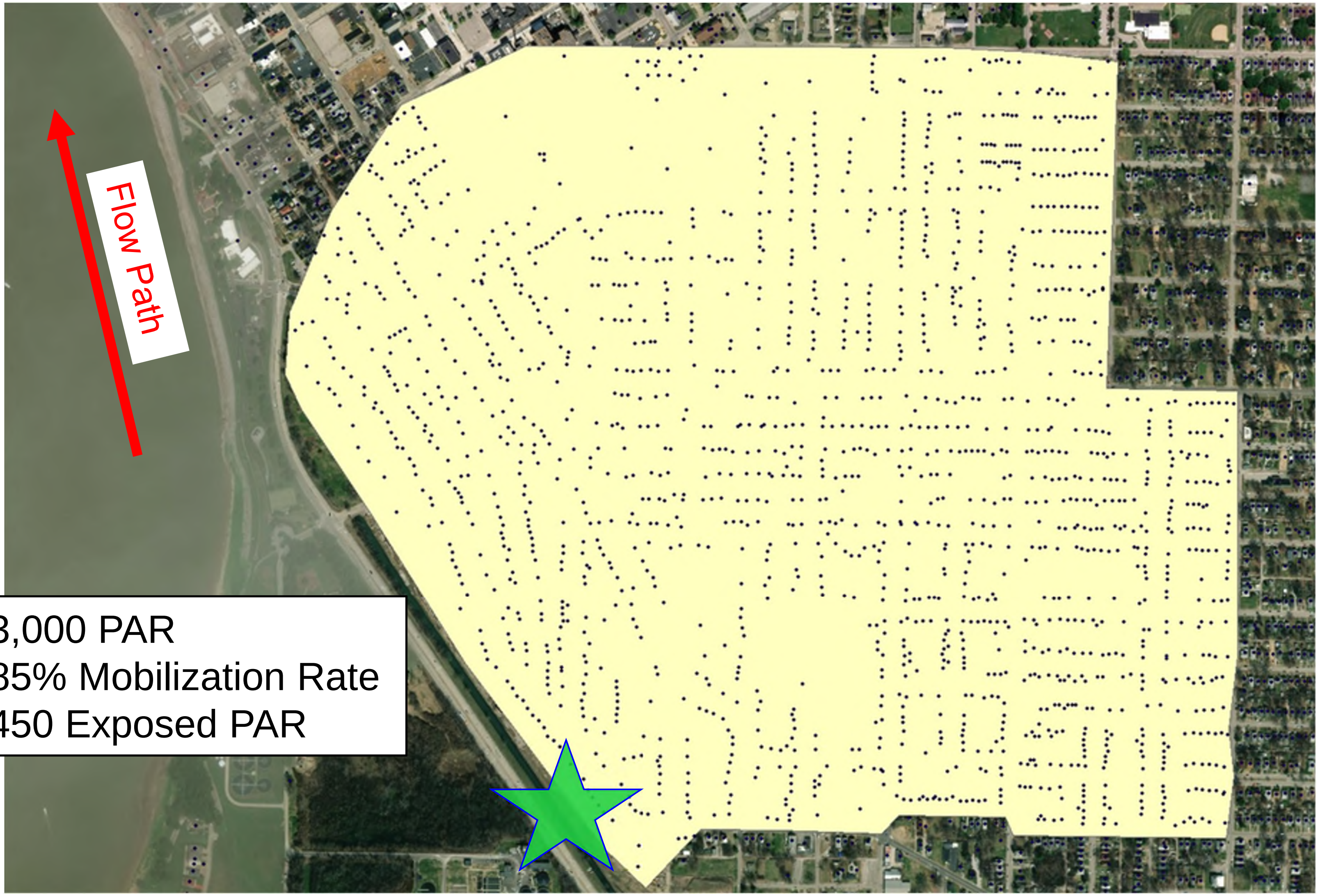
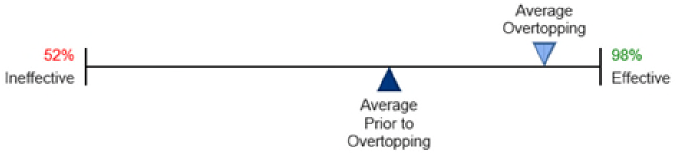
# EXAMPLE SCALED SQRA




3,000 PAR
85% Mobilization Rate
450 Exposed PAR

## 1. Evacuation Effectiveness Factors

| | |
|---|---|
| **Evacuation Effectiveness (Breach Prior to Overtopping)** | |
| Overall Evacuation Effectiveness Factor (day) | 0.7914 |
| Overall Evacuation Effectiveness Factor (night) | 0.7914 |
| **Evacuation Effectiveness (Overtopping)** | |
| Overall Evacuation Effectiveness Factor (day) | 0.9310 |
| Overall Evacuation Effectiveness Factor (night) | 0.9310 |

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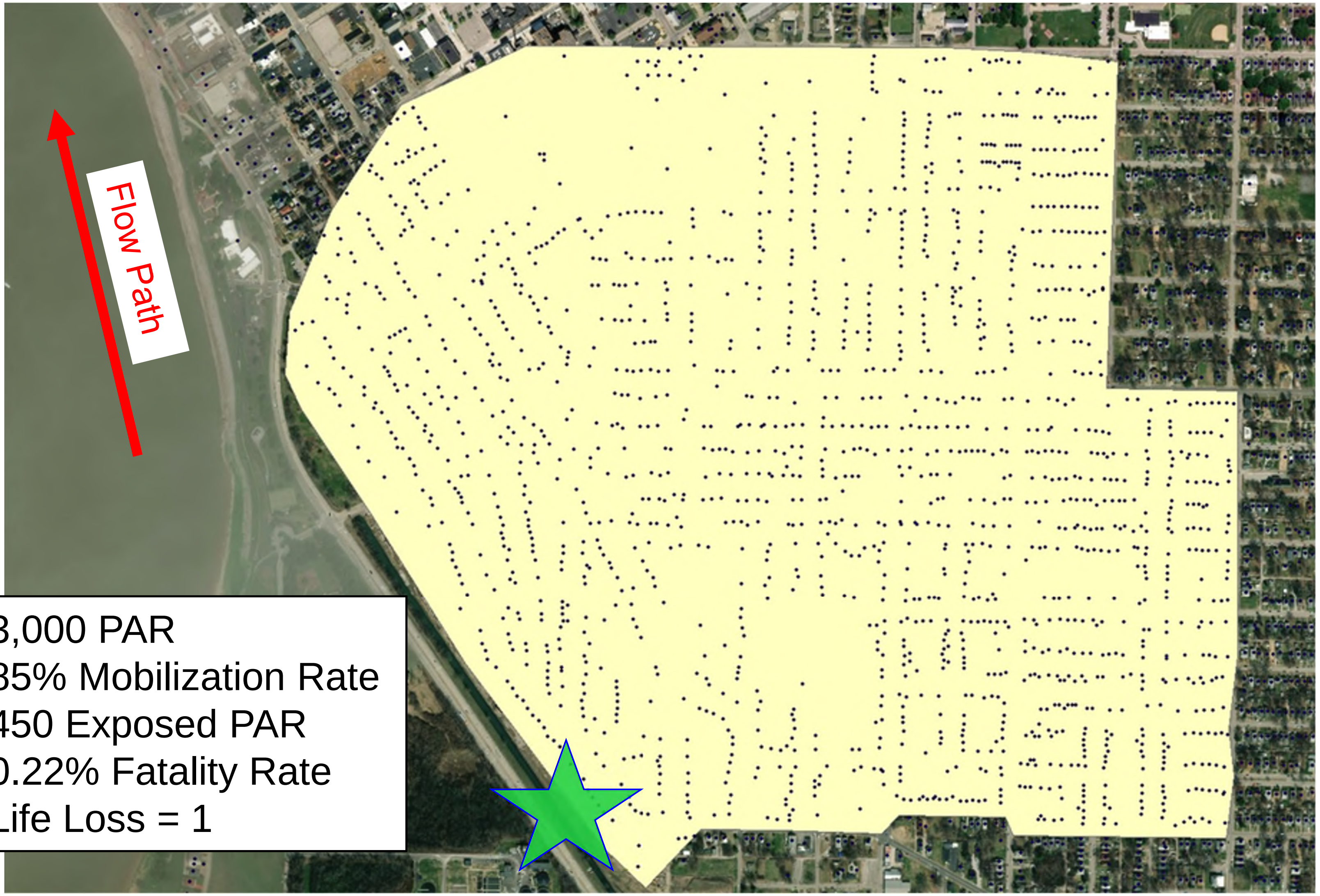
# EXAMPLE SCALED SQRA




3,000 PAR
85% Mobilization Rate
450 Exposed PAR
0.22% Fatality Rate
Life Loss = 1

System Profile Minimum to Segment Maximum

| Elev. | yA Ave. Depth | Fatality Rate | Econ. Factor | # Structures | Prop. Damage ($ |
|---|---|---|---|---|---|
| 55.2 | 2.000 | 0.22% | 32% | 4.1 | |

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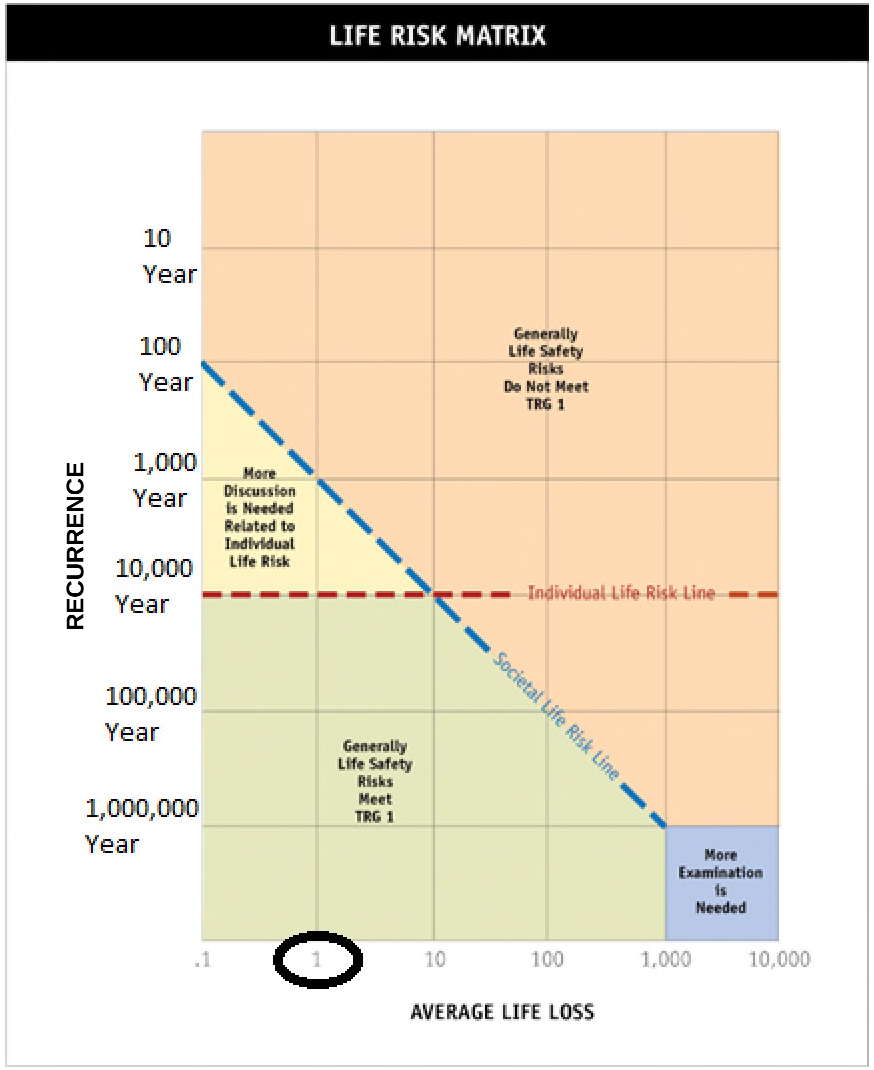
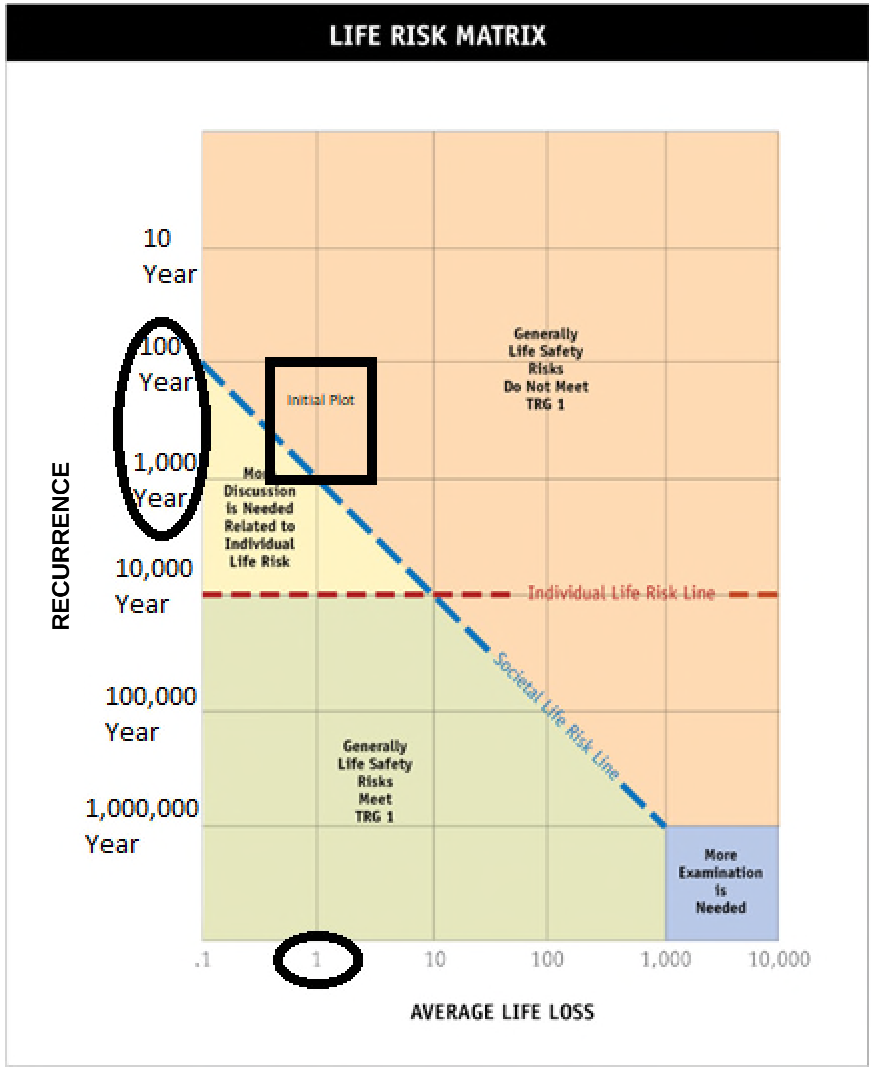
# EXAMPLE SCALED SQRA

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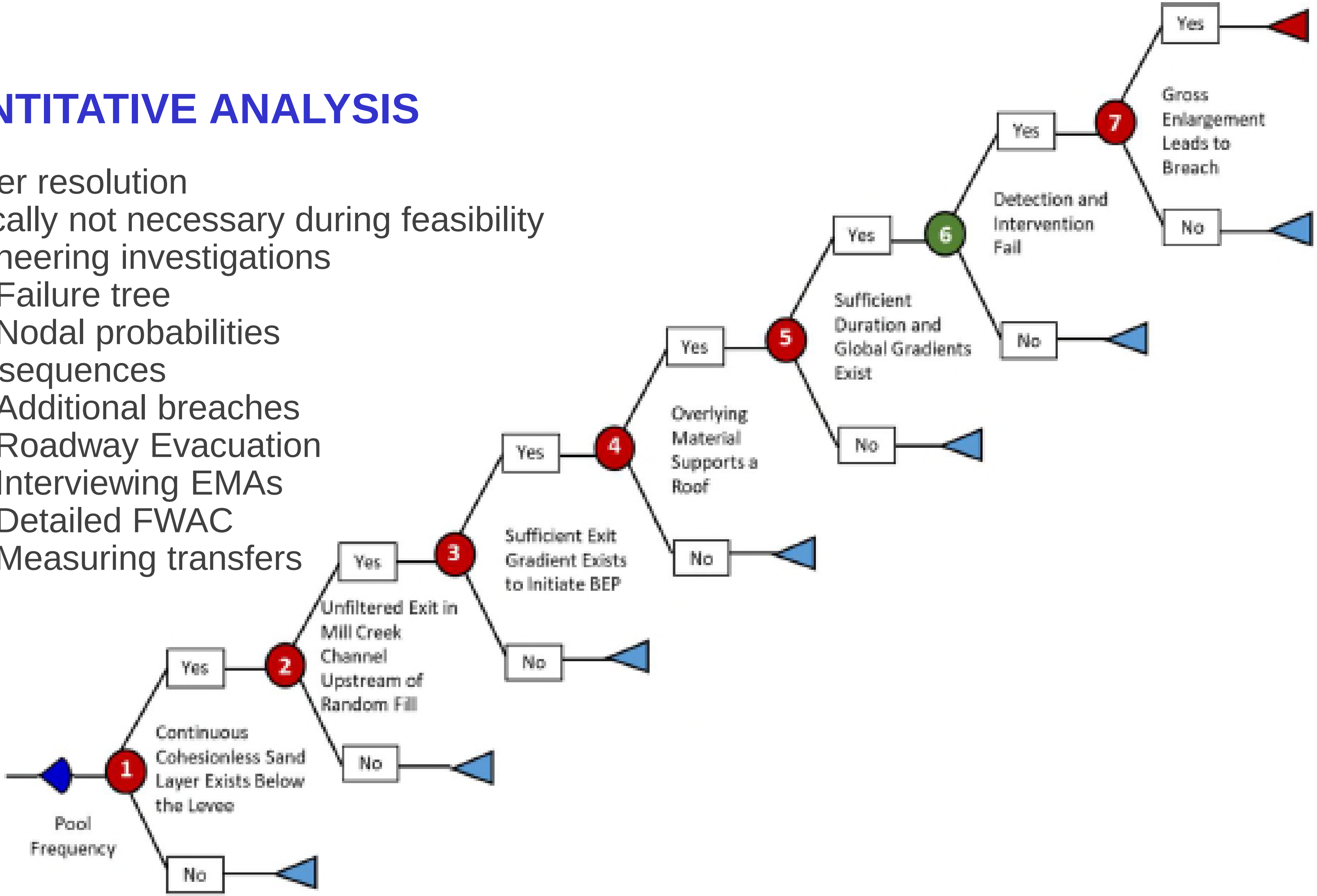
# QUANTITATIVE ANALYSIS

- Higher resolution
- Typically not necessary during feasibility
- Engineering investigations
  - Failure tree
  - Nodal probabilities
- Consequences
  - Additional breaches
  - Roadway Evacuation
  - Interviewing EMAs
  - Detailed FWAC
  - Measuring transfers



# DECISION MAKING AND LIFE LOSS

- If you're going to justify based on life loss, expect extra scrutiny
  - TRG, LL reduction, Residual Risk

| Metric | No Action | Buyout | Wall + Emb | Just Wall |
|---|---|---|---|---|
| AALL | 0.34 | 0.003 | 0.167 | 0.169 |
| Implementation Cost | N/A | $ 100,000,000 | $ 70,000,000 | $ 50,000,000 |
| Annualized Cost | N/A | $3,795,000 | $2,656,000 | $1,897,000 |
| Reduced AALL | N/A | 0.332 | 0.168 | 0.167 |
| Annual Damages | $ 733,333 | $ 366,667 | $ 667,333 | $ 673,333 |
| Annualized Benefit | N/A | $ 366,667 | $ 66,000 | $ 60,000 |
| BCR | N/A | 0.10 | 0.02 | 0.03 |

# DECISION MAKING AND LIFE LOSS

- Even if you justify based on economics, you still have life safety concerns
  - Reduced life safety risk
  - Or, induced risk elsewhere in the system
- Releasing to public
  - Talk to your team and SOG
  - But in general:
    - Communicating residual risk is important
    - Little reason for showing breach locations, etc
  - ER 1105-2-101

h. All project increments comprise different risk management alternatives represented by the tradeoffs among engineering performance, project cost, economic and environmental resilience, and life loss consequences. These increments contain differences in flood damage reduced, residual risk, local and federal project cost, impacts to the environment, and life loss. USACE must effectively communicate to local sponsors and residents so they understand these tradeoffs and can participate fully in informing the decision-making process.

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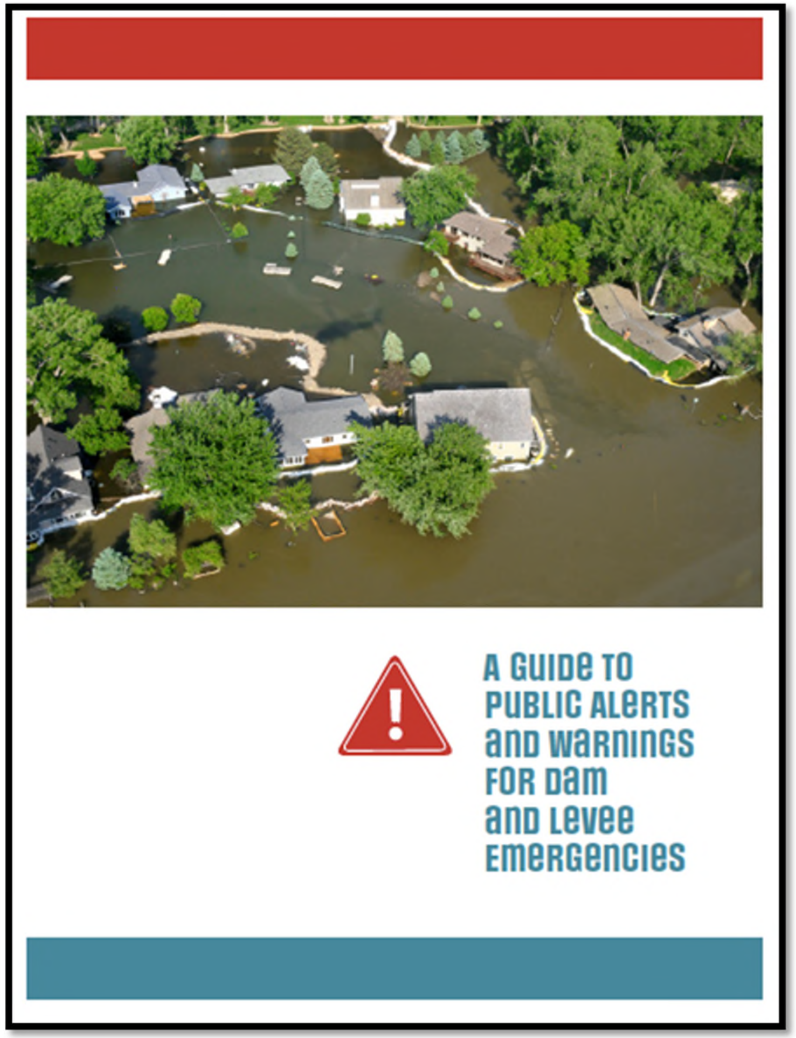
# HELPFUL TOOLS AND FUTURE LESSONS

- Data and Software
  - National Structure Inventory
  - HEC-LifeSim
  - Warning Guidebook
- Classes
  - HEC-LifeSim
  - Consequence Analysis
  - Best Practices
- Good Contacts
  - Your Levee Safety Officer & Dam Safety Officer
    - **<u>Required to engage them</u>**
  - National Centers
    - Risk Management Center
    - Dam Safety Modification Mandatory Center of Expertise
    - Levee Safety Center
    - Modeling Mapping and Consequences Production Center
  - Senior Oversight members
  - Consequences Working Group

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# REVIEW REQUIREMENTS

- The same as the rest of your Feasibility study!
- Regardless of what type of Risk Assessment is used, it is important to complete a risk assessment that is defendable and credible.
- It is important that review plan identify the risk assessment (of whatever type) so that the RMO can verify appropriate reviewers have been assigned.

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# SUMMARY – LIFE SAFETY AND FRM PLANNING



- **The "so-what"**: Life safety risk assessments are required when incremental risk is present.

- **Policy/Guidance**: PB 2019-04 and ECB 2019-15

**Key Takeaways:**

- Tolerable Risk Guidelines (TRG's) ONLY APPLY TO INCREMENTAL RISK!

- Risk assessments must include BOTH probability and consequences
  - Plot on f-N Chart and assess TRG's without and with project

- Risk assessments are scalable and should always utilize available data when possible
  - Start with a small scope and work your way up if necessary

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# QUESTIONS / FEEDBACK?

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- **Jesse Morrill-Winter,** (SPK, RTS Dam Safety Economics)
  - *916-557-7244, Jesse.E.Morrill-Winter@usace.army.mil*
- **Nick Applegate** (FRM-PCX, Economic and Risk Analysis)
  - 916-557-6711, *Nicholas.J.Applegate@usace.army.mil*

Please contact us with:

- Questions?
- Comments?
- Recommendations for improvement?

## FRM-PCX POC's:

- **Eric Thaut**, *Deputy Director*
- **Nick Applegate**, *NTS (Economics and Risk)*
- **Peter Blodgett**, NTS (H&H)
- Regional Managers:
  - **Karen Miller** *(LRD/NAD)*
  - **Michelle Kniep** *(MVD/SAD)*
  - **Charyl Barrow** *(NWD/POD)*
  - **Sara Schultz** *(SPD/SWD)*