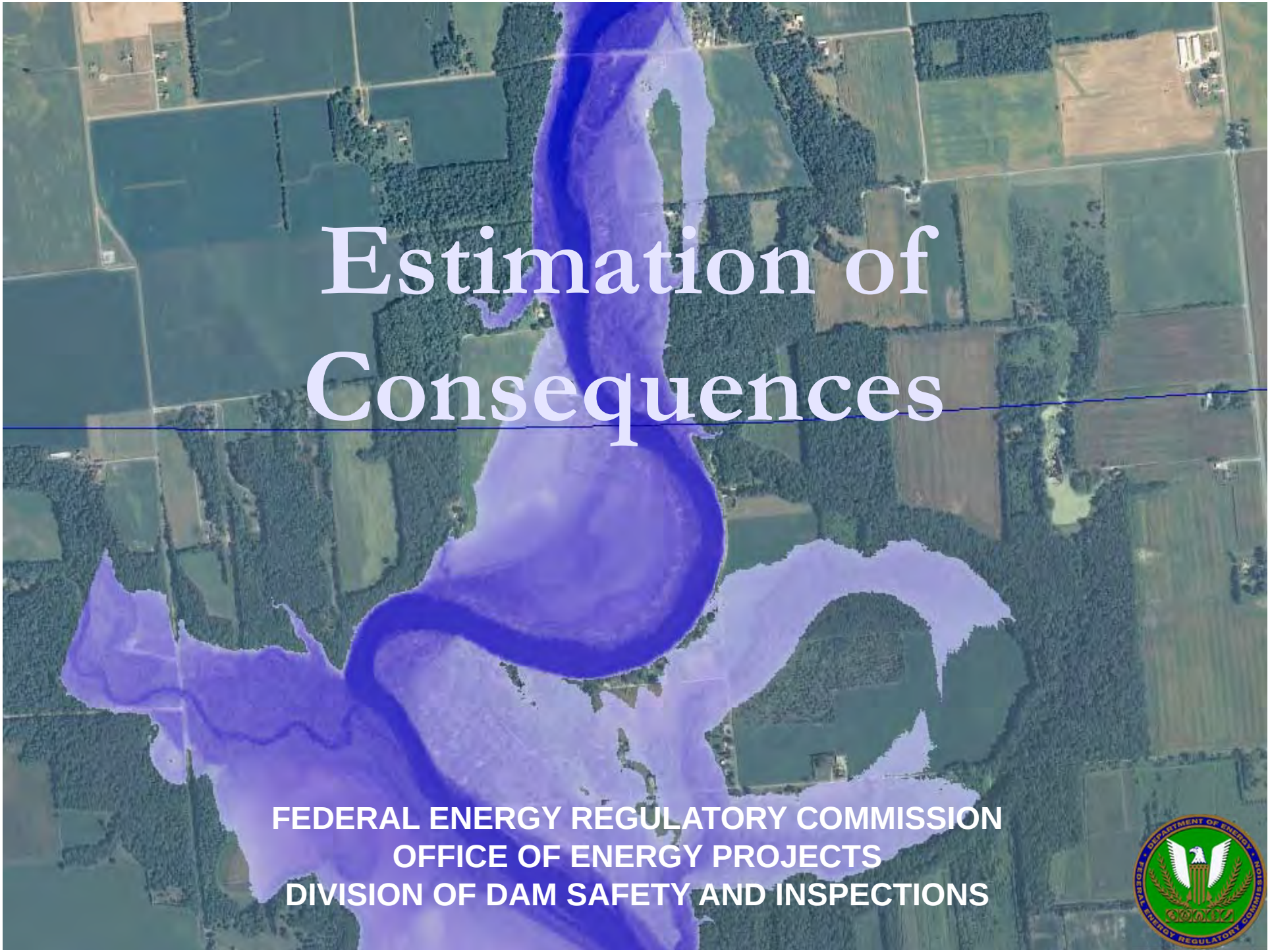


Estimation of Consequences

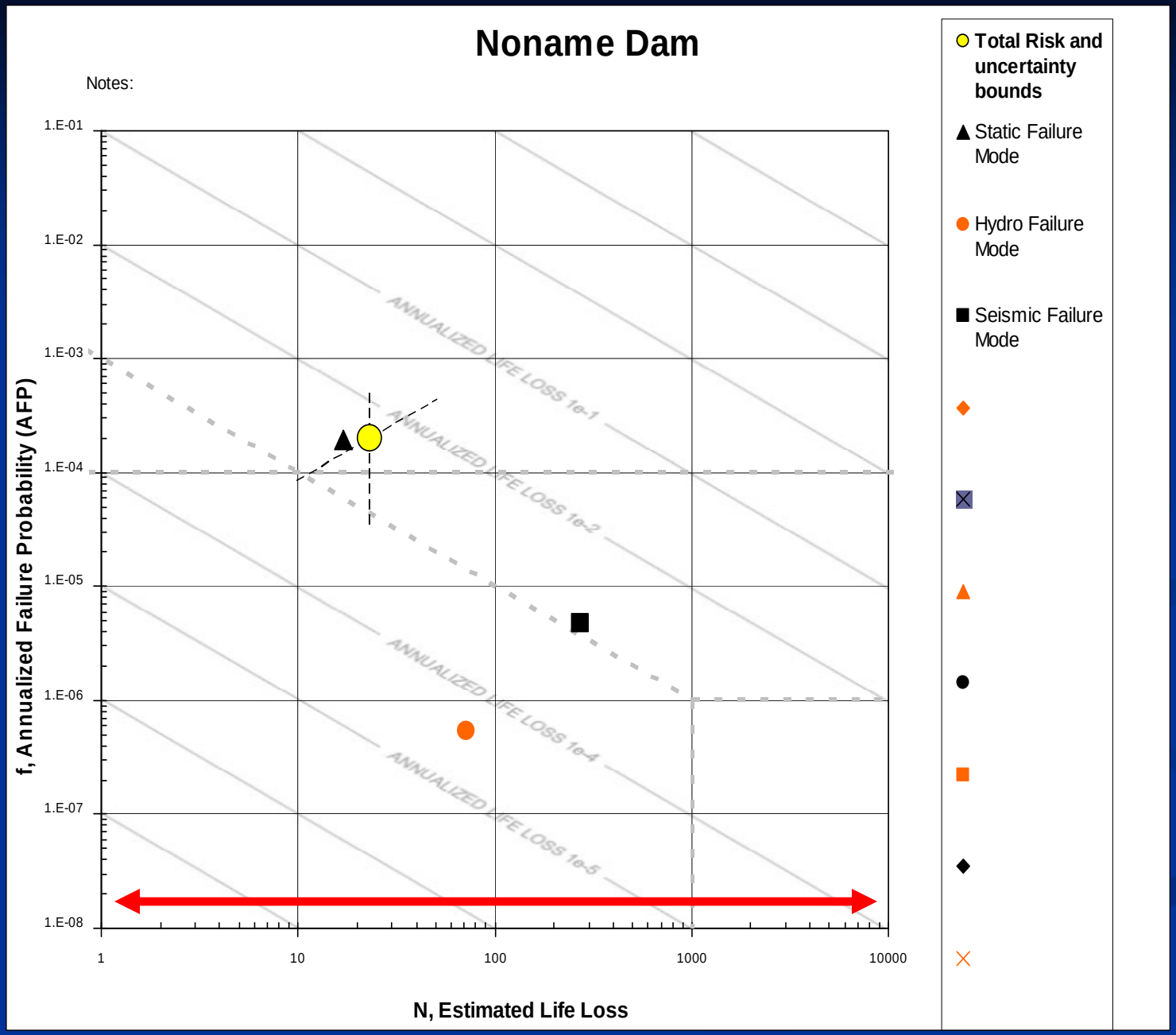
FEDERAL ENERGY REGULATORY COMMISSION
OFFICE OF ENERGY PROJECTS
DIVISION OF DAM SAFETY AND INSPECTIONS

A little bit of review…

What is Risk?

- "The product of the likelihood of an adverse event and the consequences of that event." *U.S. Bureau of Reclamation, Guidelines for Achieving Public Protection in Dam Safety Decisionmaking, 2003*
- "Measure of the probability and severity of undesirable consequences." *U.S. Army Corps of Engineers, Draft ER, 2009*

Risk = Probability of Failure x Consequences


Noname Dam
Notes:
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
f, Annualized Failure Probability (AFP)
ANNUALIZED LIFE LOSS 1e-1
ANNUALIZED LIFE LOSS 1e-2
ANNUALIZED LIFE LOSS 1e-4
ANNUALIZED LIFE LOSS 1e-5
1
10
100
1000
10000
N, Estimated Life Loss
Total Risk and uncertainty bounds
Static Failure Mode
Hydro Failure Mode
Seismic Failure Mode

Consequences

- In general consequences (from dam failure) are divided into two categories:
  - Life Loss
  - Economic
- Environmental and Social damages can also be considered, but are more difficult to quantify and do not lend themselves to automated analyses.

Purpose

- To give an overview of DSO-99-06 and the principles of notional consequence determination.
- Discuss how to apply a simplified version of the method to our training example

The Graham Method (USBR DSO-99-06)

DSO-99-06 is an empirical life loss estimation tool developed with the following input.

- Every U.S. dam failure that resulted in more than 50 fatalities and every dam failure that occurred after 1960 resulting in any fatalities
- developed using a data set which totaled approximately 40 floods, many of which were caused by dam failure.

The Graham Method (USBR DSO-99-06)

The procedure is composed of 7 steps:

- 1) Determine dam failure scenarios to evaluate.
- 2) Determine time categories for which loss of life estimates are needed.
- 3) Determine when dam failure warnings would be initiated.
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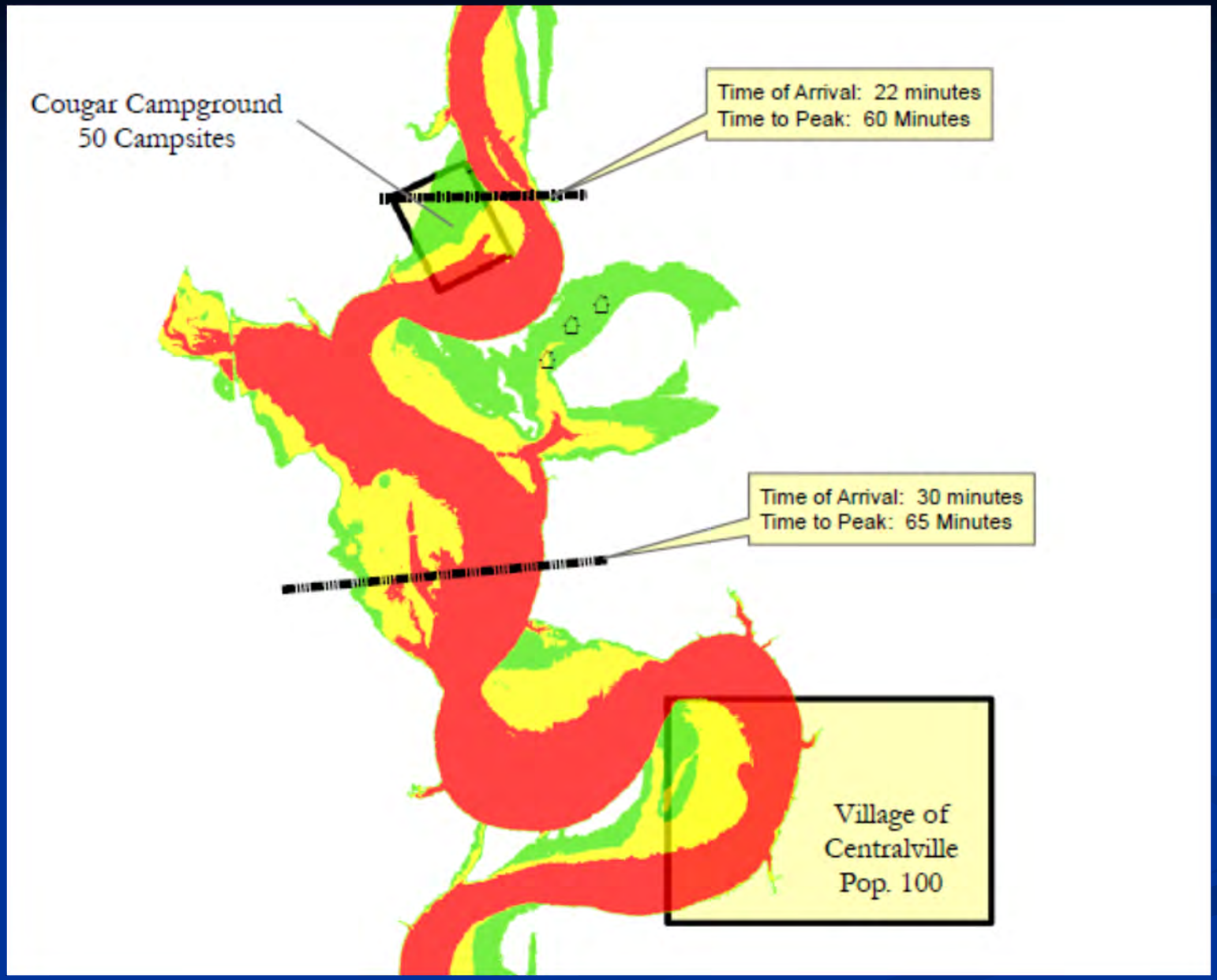
- 5) Estimate the number of people at risk for each dam failure scenario and time category.
- 6) Apply empirically-based equations or methods for estimating the number of fatalities.
- 7) Evaluate uncertainty.

Warning Time

- Past dam-break flood instances show that, in general, the number of fatalities decreases as the distance downstream increases
- PLL decreases when the travel time begins to exceed the amount of time required to warn and evacuate the population at risk.
- A combination of breach development rate and flood wave velocity determines the flood wave arrival time for a given distance.

Table 2
Guidance for Estimating When Dam Failure Warnings Would be Initiated (Earthfill Dam)

Dam Type	Cause of Failure	Special Considerations	Time of Failure	When Would Dam Failure Warning be Initiated?	
				Many Observers at Dam	No Observers at Dam
Earthfill	Overtopping	Drainage area at dam less than 100 mi^2 (260 km^2)	Day	0.25 hrs. before dam failure	0.25 hrs. after fw reaches populated area
		Drainage area at dam less than 100 mi^2 (260 km^2)	Night	0.25 hrs. after dam failure	1.0 hrs. after fw reaches populated area
		Drainage area at dam more than 100 mi^2 (260 km^2)	Day	2 hrs. before dam failure	1 hr. before dam failure
		Drainage area at dam more than 100 mi^2 (260 km^2)	Night	1 to 2 hr. before dam failure	0 to 1 hr. before dam failure
	Piping (full reservoir, normal weather)		Day	1 hr. before dam failure	0.25 hrs. after fw reaches populated area
			Night	0.5 hr. after dam failure	1.0 hr. after fw reaches populated area
	Seismic	Immediate Failure	Day	0.25 hr. after dam failure	0.25 hr. after fw reaches populated area
			Night	0.50 hr. after dam failure	1.0 hrs. after fw reaches populated area
		Delayed Failure	Day	2 hrs. before dam failure	0.5 hrs. before fw reaches populated area
			Night	2 hrs. before dam failure	0.5 hrs. before fw reaches populated area


Cougar Campground
50 Campsites
Time of Arrival: 22 minutes
Time to Peak: 60 Minutes
Time of Arrival: 30 minutes
Time to Peak: 65 Minutes
Village of
Centralville
Pop. 100

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- 7) Evaluate uncertainty.

Dam Failure Modeling

- Dam failure modeling is slowing shifting from NWS Dambreak to HEC-RAS and GeoRAS.
- Combined with GIS and topographic data from the USGS, HEC-RAS can produce good inundation maps.
- Modeled dam failures should relate to viable PFMs.

Dam Failure Modeling

- Model output includes:
  - The inundation area outline.
  - Water surface elevations.
  - Channel velocities
  - Floodplain depth
  - Timing of the flood wave.

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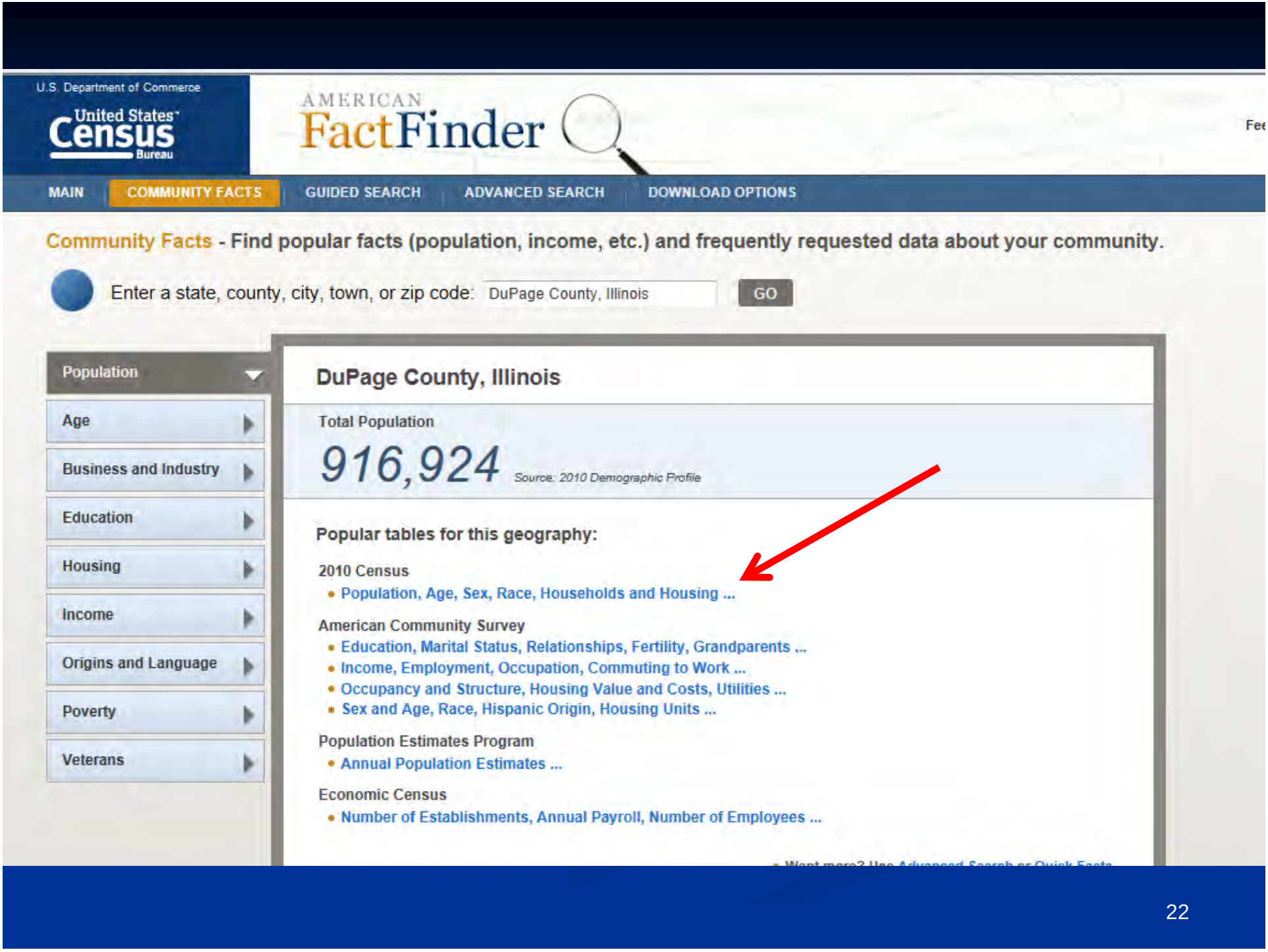
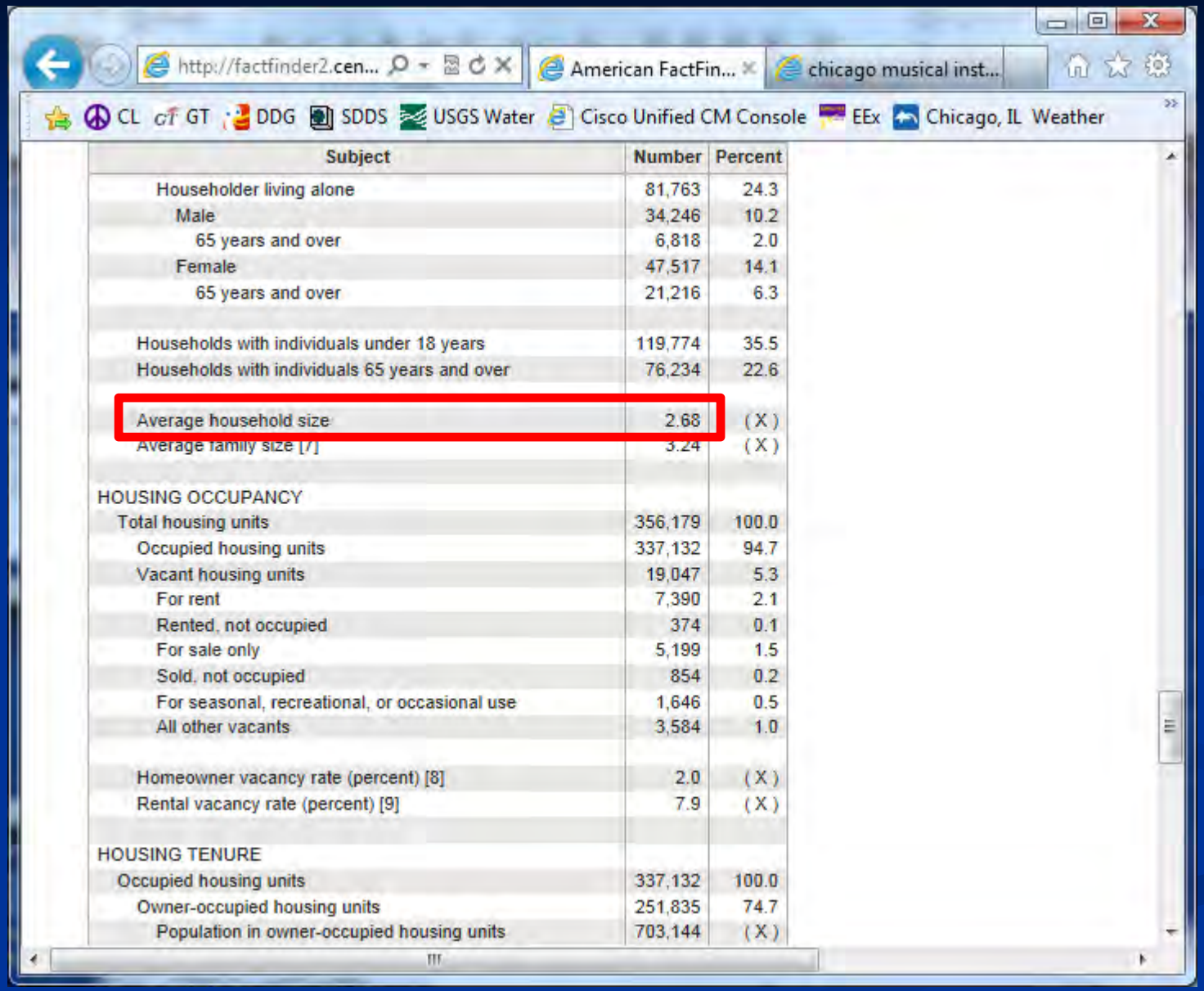
Population at Risk (PAR)

- Population at risk (PAR) is defined as the number of people occupying the dam failure floodplain prior to the issuance of any warning.
- The number can include permanent residents, vacation residents, and recreationists.
- PAR can vary with:
  - Time of day
  - Time of year

Population at Risk

- For relatively small populations, the population at risk can be counted or estimated using internet resources such as Google Earth.
- An estimate of 3 persons per residence (more for larger, nonresidential structures) is often used to roughly estimate the downstream PAR. Additional consideration should be given to other day and night use of facilities within the inundation area such as transitory hikers, campers, etc.

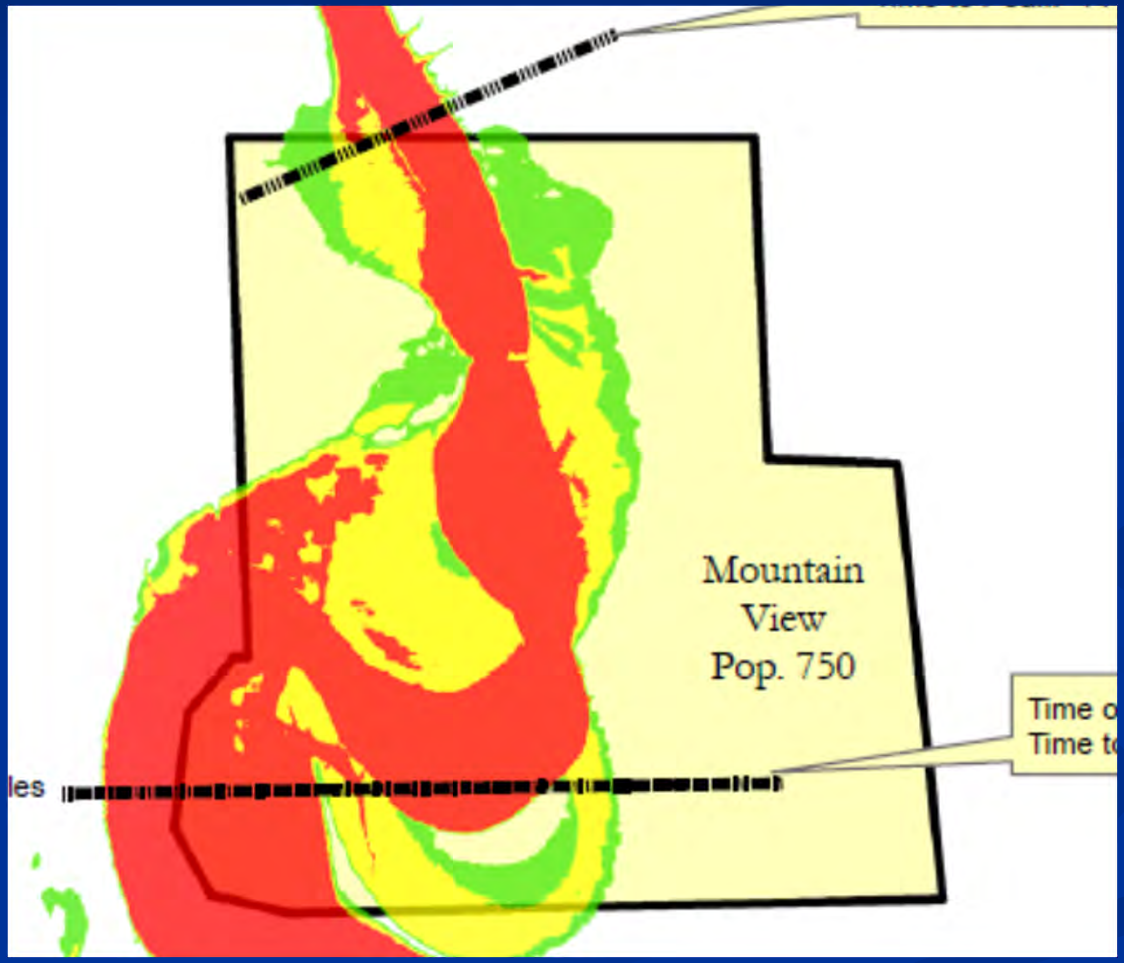

U.S. Department of Commerce
United States Census Bureau
AMERICAN FactFinder
MAIN
COMMUNITY FACTS
GUIDED SEARCH
ADVANCED SEARCH
DOWNLOAD OPTIONS
Community Facts - Find popular facts (population, income, etc.) and frequently requested data about your community.
Enter a state, county, city, town, or zip code:
DuPage County, Illinois
GO
Population
Age
Business and Industry
Education
Housing
Income
Origins and Language
Poverty
Veterans
DuPage County, Illinois
Total Population
916,924
Source: 2010 Demographic Profile
Popular tables for this geography:
2010 Census
Population, Age, Sex, Race, Households and Housing ...
American Community Survey
Education, Marital Status, Relationships, Fertility, Grandparents ...
Income, Employment, Occupation, Commuting to Work ...
Occupancy and Structure, Housing Value and Costs, Utilities ...
Sex and Age, Race, Hispanic Origin, Housing Units ...
Population Estimates Program
Annual Population Estimates ...
Economic Census
Number of Establishments, Annual Payroll, Number of Employees ...



Subject	Number	Percent
Householder living alone	81,763	24.3
Male	34,246	10.2
65 years and over	6,818	2.0
Female	47,517	14.1
65 years and over	21,216	6.3
Households with individuals under 18 years	119,774	35.5
Households with individuals 65 years and over	76,234	22.6
Average household size	2.68	(X)
Average family size [7]	3.24	(X)
HOUSING OCCUPANCY		
Total housing units	356,179	100.0
Occupied housing units	337,132	94.7
Vacant housing units	19,047	5.3
For rent	7,390	2.1
Rented, not occupied	374	0.1
For sale only	5,199	1.5
Sold, not occupied	854	0.2
For seasonal, recreational, or occasional use	1,646	0.5
All other vacants	3,584	1.0
Homeowner vacancy rate (percent) [8]	2.0	(X)
Rental vacancy rate (percent) [9]	7.9	(X)
HOUSING TENURE		
Occupied housing units	337,132	100.0
Owner-occupied housing units	251,835	74.7
Population in owner-occupied housing units	703,144	(X)

Population at Risk

- PAR Analysis using Census Data and GIS
  - Census data are available in many forms from the Data Sets tab of the American FactFinder website. The U.S. Census Bureau site also has population data available in various formats.
  - http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html
  - http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml


Mountain
View
Pop. 750

The Graham Method (USBR DSO-99-06)

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- 7) Evaluate uncertainty.

Possible Life Loss (PLL)

- The PLL is the portion of the PAR which may be expected to perish during a dam failure.
- Survivability is determined by three factors:
  - Timing (Warning and Evacuation)
  - Flood Severity – channel geometry
  - Awareness of population

Flood Severity

- Flood Severity is a function of the depth and velocity of the flow.
- There are critical two depth-velocities to consider
  - When flooding prevents horizontal evacuation (by foot, car, etc.), forcing people to evacuate vertically to upper floors or roofs.
  - When flooding destroys shelters (i.e. sweeps homes and/or buildings off foundations).

Flood Severity

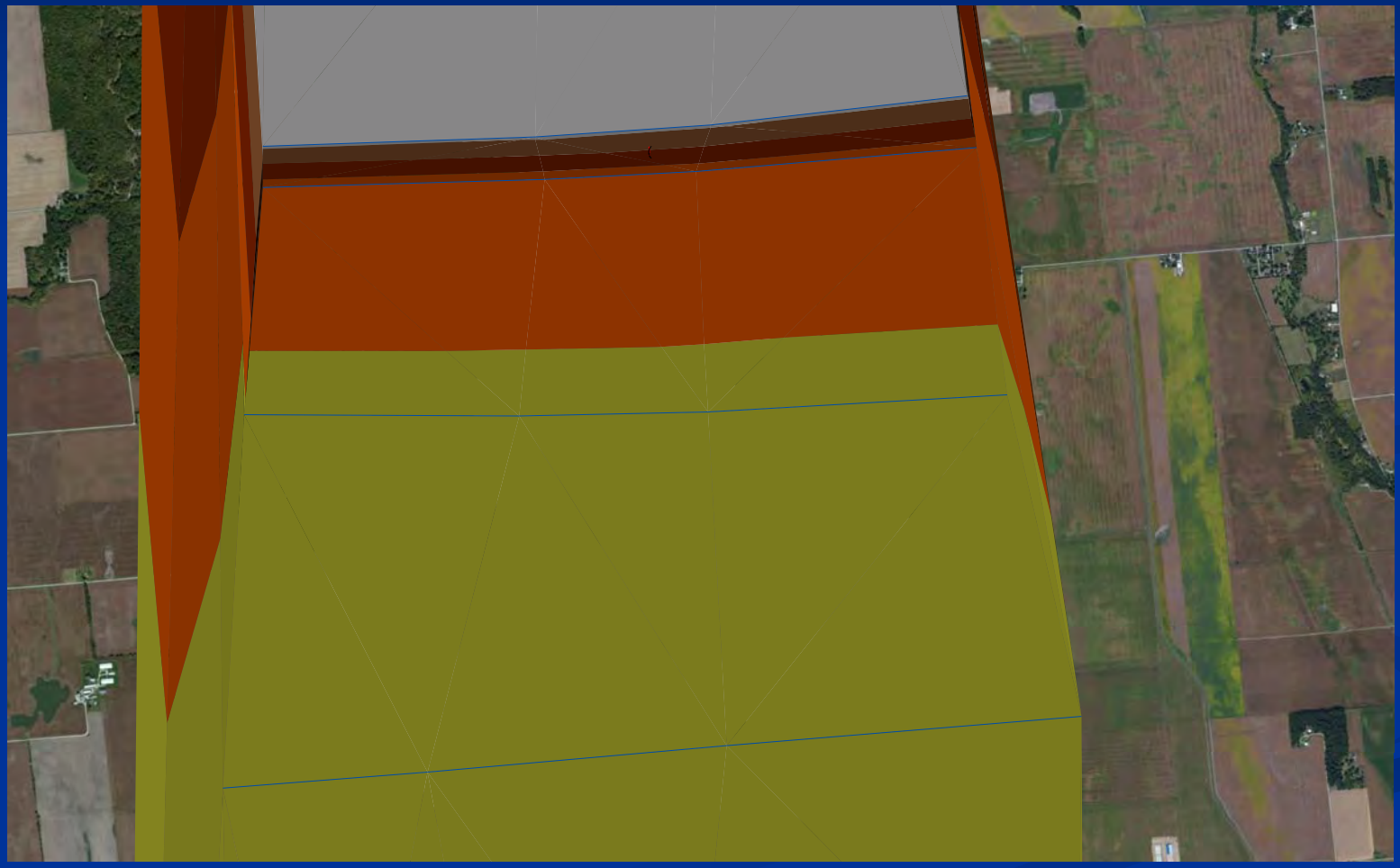
- DSO-99-06 severity definitions:
  - Low - Homes are flooded but not destroyed.
  - Medium - Destruction of homes and businesses. Trees and some homes remain and these trees or rooftops may provide temporary refuge until the flooding recedes.
  - High - catastrophic magnitude. The floodplain is swept clean. Houses are crushed, washed away and there is little or no trace of their prior existence.

High Depth Velocity, Home swept off foundation

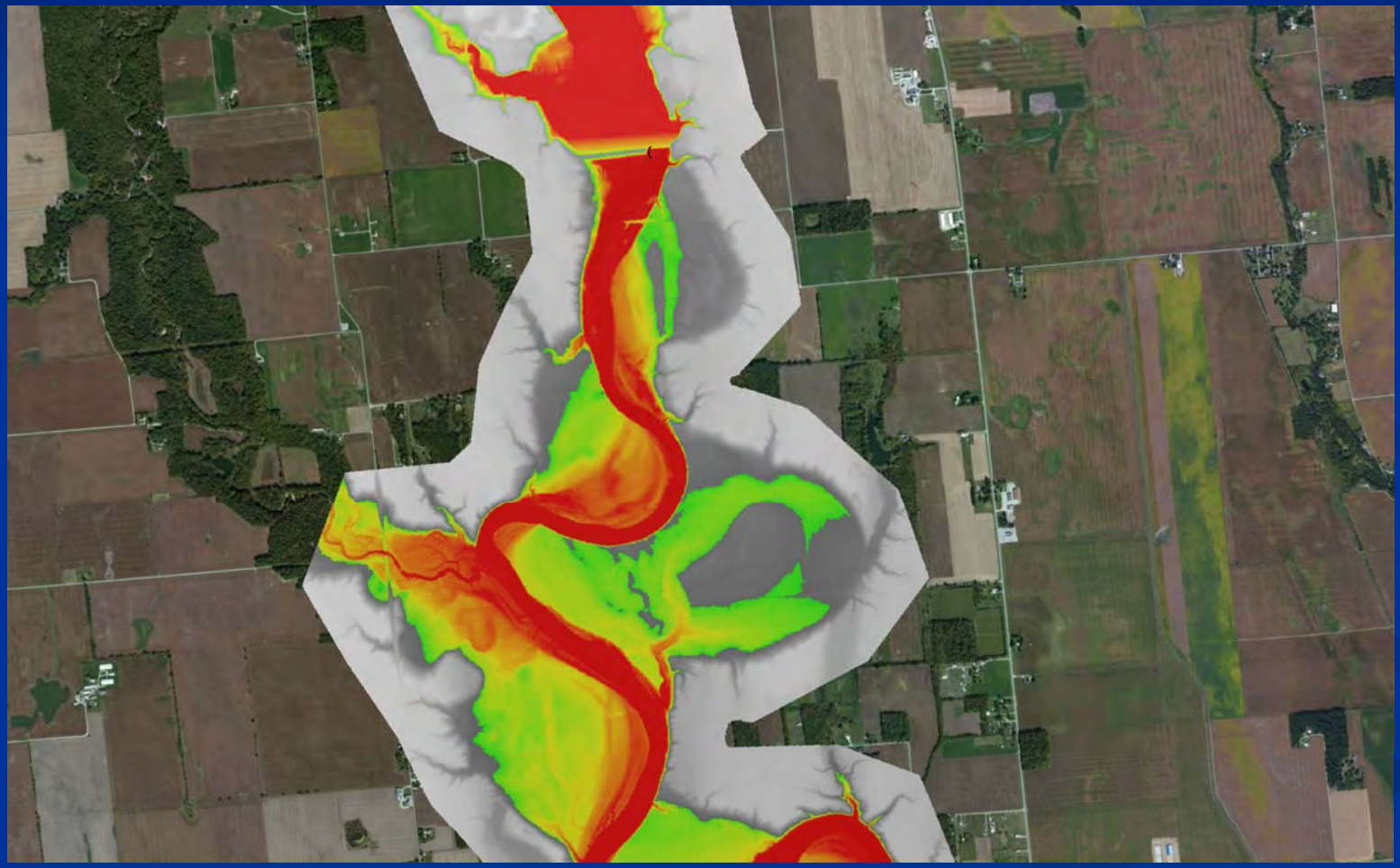
Waterline
Approx. 15-20 ft

Low Velocity, Structure Survives

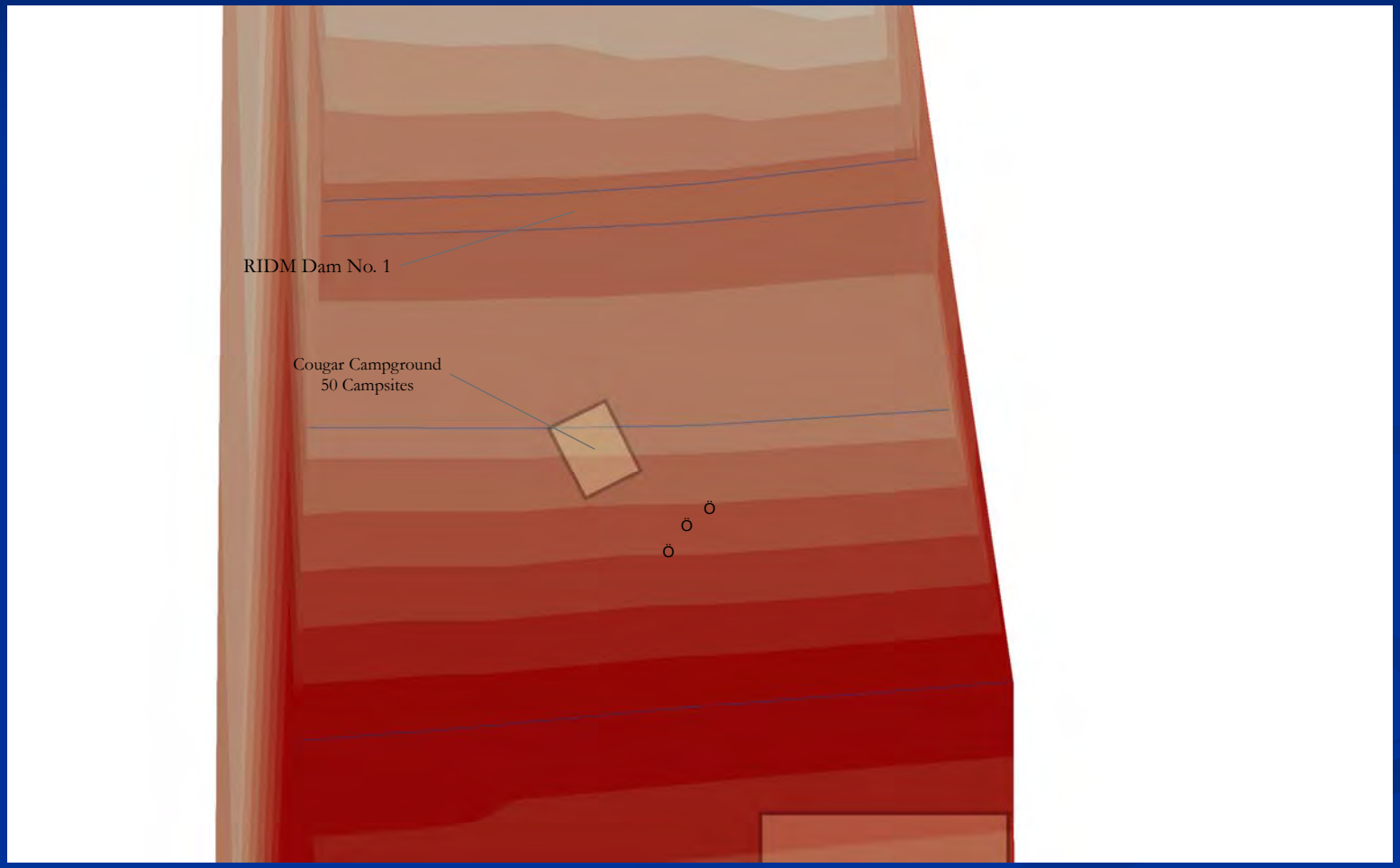
Water Surface Profile



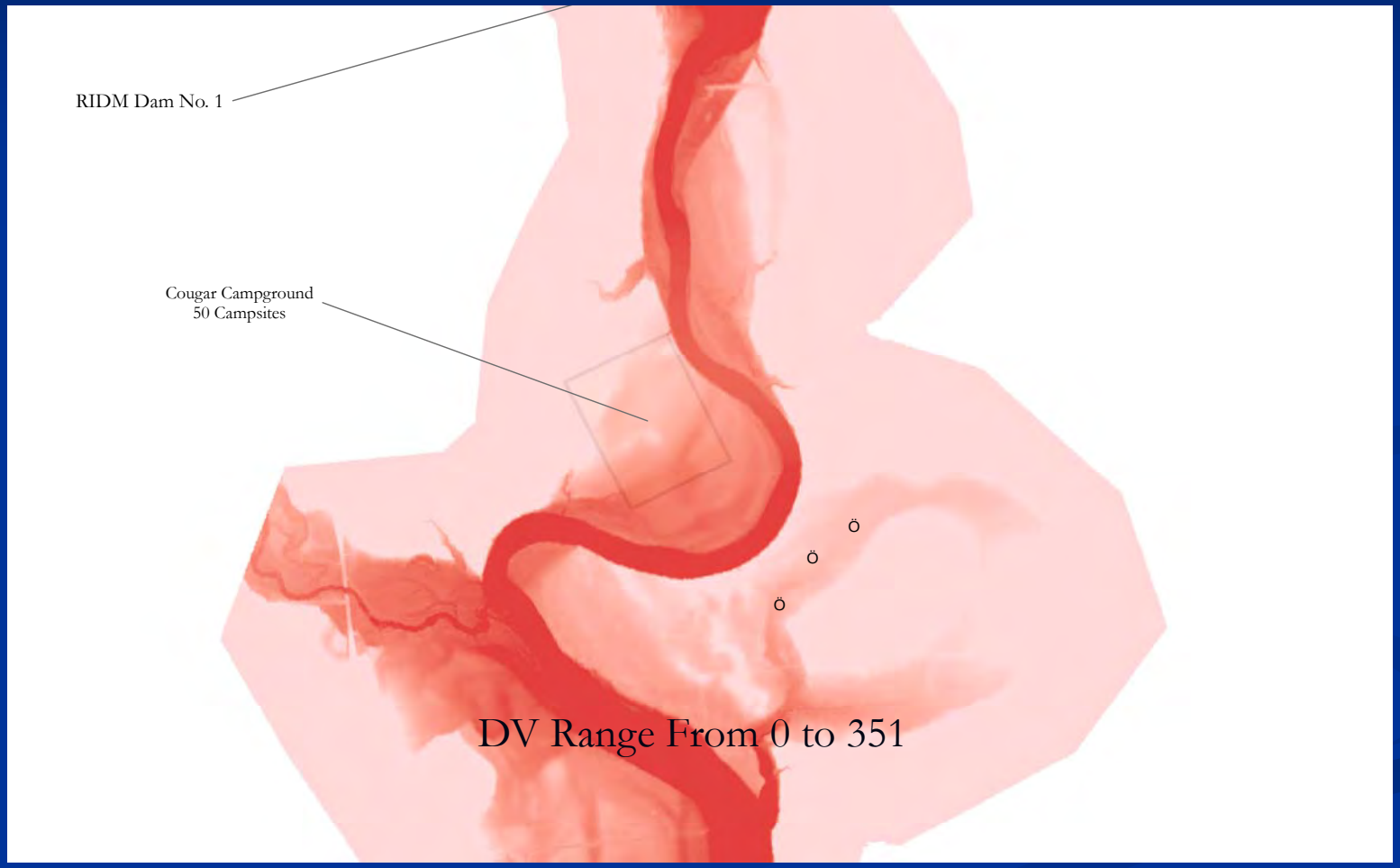
Flood Depths



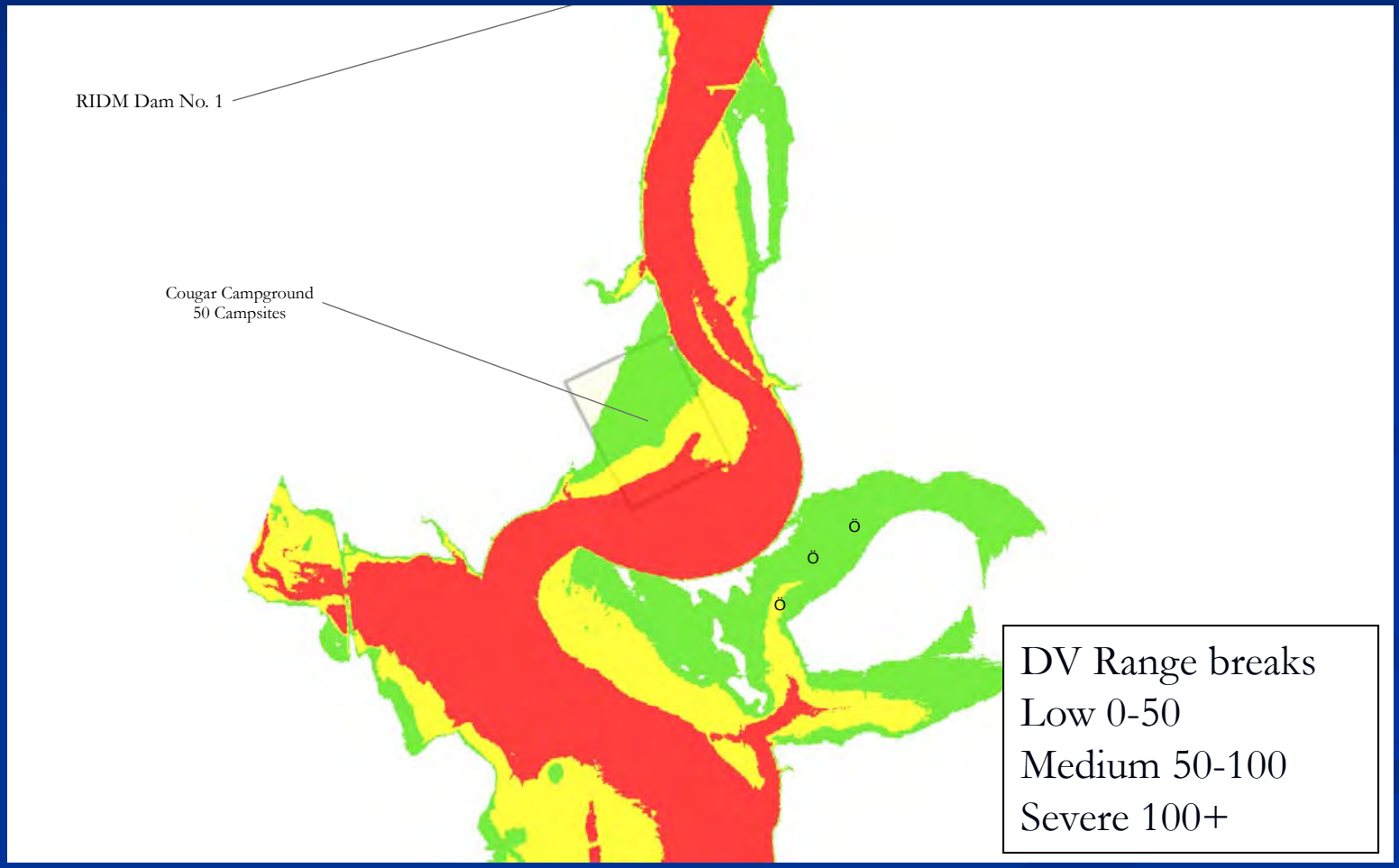
Velocity Profile



Depth-Velocity Grid



Categorization



Life Loss Estimates

- The consequence adjustment factors for the appropriate combination are multiplied by the estimated population at risk to provide an estimate of human life loss.

Fatality Rates from DSO-99-06

Table 6
Fatality Rates Derived from Case Studies
(Use Table 7 for selecting fatality rates)

Flood Severity	Warning Time (minutes)	Flood Severity Understanding	Fatality Rate (Fraction of people at risk that died)	
			Average	Range
HIGH	no warning	not applicable	0.76	0.3 to 1.00
	15 to 60	vague	No case fit this category.	
		precise	No case fit this category.	
	more than 60	vague	No case fit this category.	
		precise	No case fit this category.	
MEDIUM	no warning	not applicable	0.14	0.02 to 0.43
	15 to 60	vague	0.014	only one case
		precise	0.01	only one case
	more than 60	vague	0.05	only one case
		precise	0.035	0.0 to 0.080
LOW	no warning	not applicable	0.007	0.0 to 0.025
	15 to 60	vague	0.0095	0.007 to 0.012
		precise	0.0	only one case
	more than 60	vague	No case fit this category	
		precise	0.0003	0.0 to .002

Consequence Adjustment Factors

	Low Flood Severity	Medium Flood Severity	High Flood Severity
	(No buildings washed off foundation, less that 10-foot depth of flooding) <50 DV	(Homes destroyed but trees or mangled homes remain, greater than 10-foot depth of flooding) >50 DV	(Instantaneous dam failure, inundation area swept clean of structures, deep flood depth reached very quickly)
No Warning (Less than 15 minutes)	0.01	0.15	0.75
Some Warning (15 to 60 minutes)	0.005	0.03	0.4
More Warning (Greater than 60 minutes)	0.0003	0.02	0.2

Life Loss Estimates

- The total estimated life loss is computed and used to determine the appropriate consequence category using the following table.

	RIDM Training Tool	
	Potential Life Loss (PLL) Consequence	
Potential Life Loss	General Description	Consequence Category
0	• No direct loss of human life is expected. • Downstream discharge results in significant damage to a moderate to large number of permanently occupied structures, critical facilities (schools, hospitals, etc.), or critical infrastructure such as major roadways or significant regional bridges within the inundation zone (~$25 - $50 million). • Costs associated with re-constructing the project features and negative publicity associated with a dam failure would also be incurred.	6
1-10	• Direct loss of human life possible, related primarily to difficulties in warning and evacuating recreationists and few scattered individual houses close to the dam or downstream population centers with extensive warning time. • Minor to significant damage to permanently occupied structures, roadways and bridges throughout the inundation zone (~$50 to $100 M). • Local to regional disruption of essential facilities and access. • Medium environmental damage • Less than 1 year recovery.	7
10-100	• Loss of human life is expected due to the severity of the flooding and nearby population centers (10-100 people). • Downstream discharges result in significant property damage (~$100 M to $500 M) • Regional disruption of essential facilities and access. • Significant environmental damage • 1 - 2 year recovery .	8

	RIDM Training Tool	
	Potential Life Loss (PLL) Consequence	
Potential Life Loss	General Description	Consequence Category
100-1000	• Significant loss of human life is expected due to the severity of the flooding and moderate population affected within close proximity of the dam. • Significant property damage over a large area (~$500 M to $1 B)... • Multi-regional disruption of essential facilities and access. • Large environmental damage • Multi-year recovery 2-5 years.	9
1000 – 10,000	• High loss of human life is expected due to the severity of the flooding and moderate population affected within close proximity of the dam. • Large property damage over a large area (> $1 B). • Multi-state to Multi-regional disruption of essential facilities and access. • Large environmental damage, some permanent. • Recovery over an very long time (5-10 years)	10
>10,000	• Extreme loss of human life is expected due to the severity of the flooding and large population affected. • Extreme property damage would be incurred over a large area (> $10 B). • Massive environmental mitigation cost or impossible to mitigate. • National to Multi-state disruption of essential facilities and access. • Recovery over an extreme length of time (10 to 20 years).	11

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- 7) Evaluate uncertainty.

Uncertainty

- Discussion after the exercise…

DISCUSSION/QUESTIONS?