

04 Mar 2014

**Colliery Dam (Nanaimo BC)
Risk Assessment**

by Dr. Bill Roberds

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 Develop Colliery Dams (Nanaimo BC) Plan

- 13 Dec 2013 Meeting
 - Objectives - optimal dam rehab option plan
 - Criteria – incremental safety risk, financial, etc.
 - Design Process – identify/evaluate dam rehab options
 - Risk assessment – model, uncertainties, assessments
- 21 Jan 2014 Meeting
 - Risk model framework
 - Linked elements
 - Inputs → outputs
 - Scenarios
 - Inputs – hypothetical / status / plans
- 04 Mar 2014 Meeting – Phase 1 inputs / results

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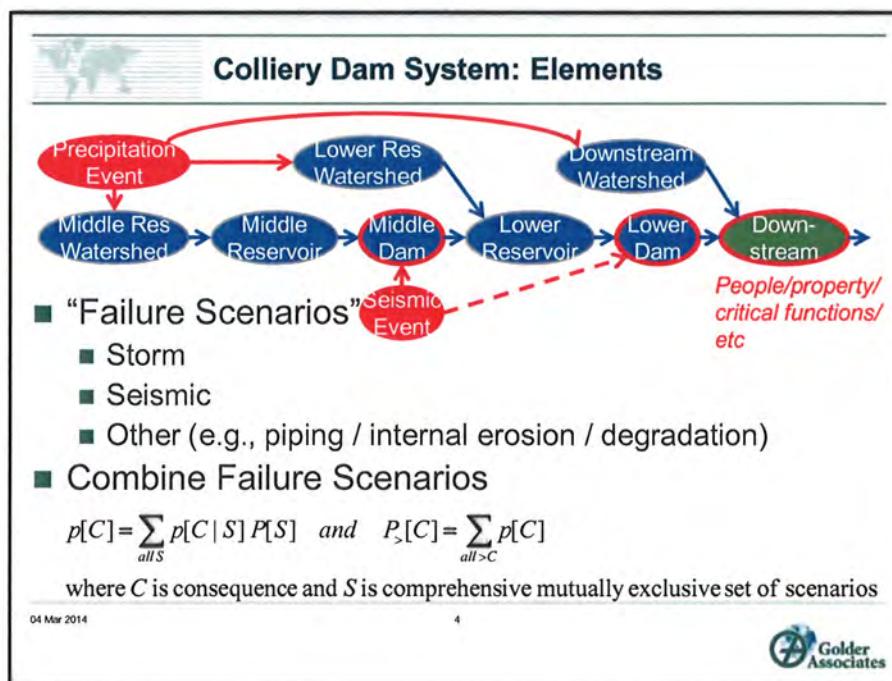
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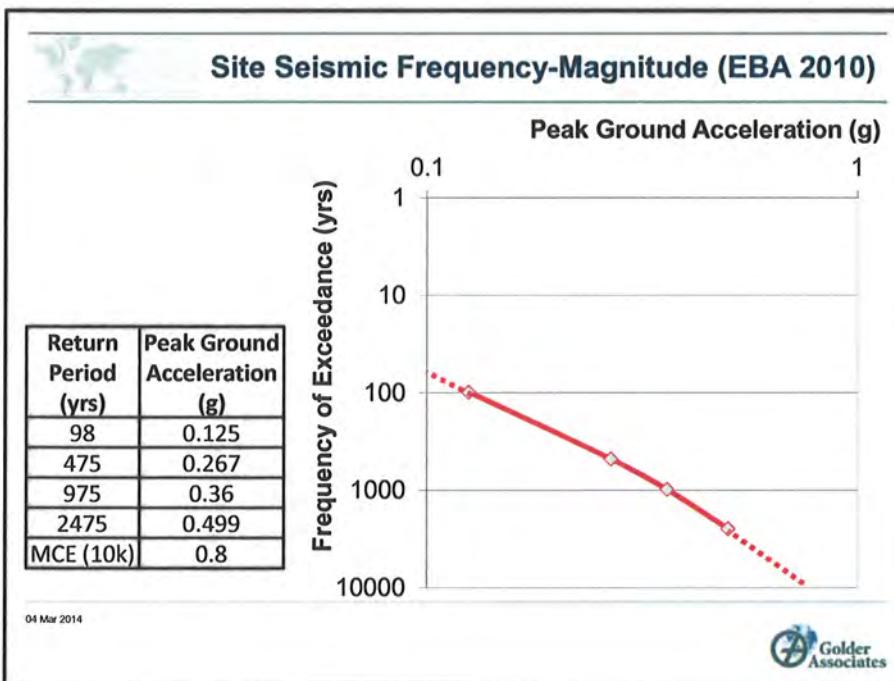
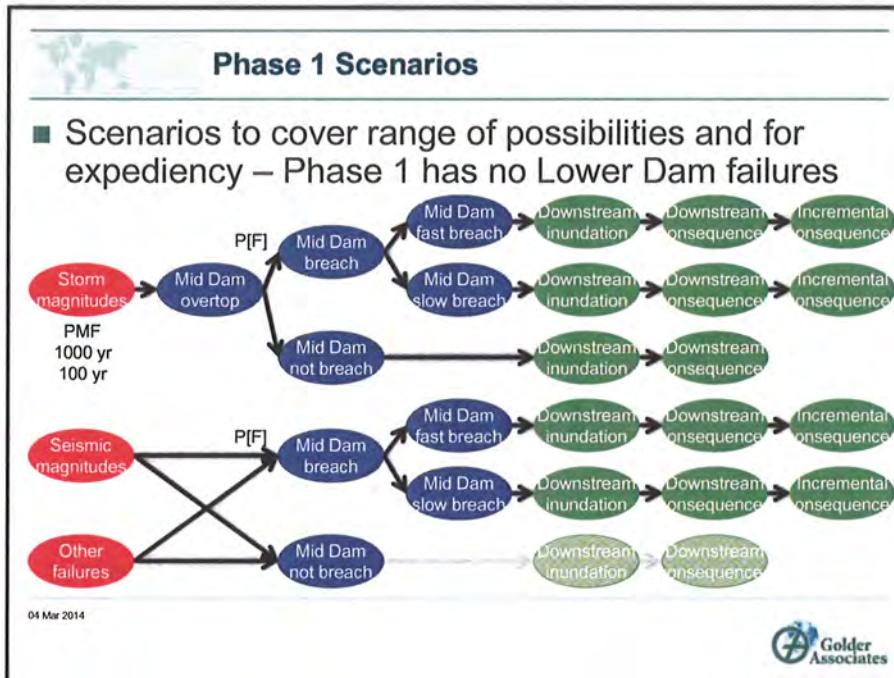
Colliery Dams (Nanaimo BC)

- Watersheds, reservoirs, dams, downstream

Middle Dam: 13m high x 50m long x 5m wide,
0.6m thick reinf concrete core, rockfill, 2.5H:1V
downstream slope, 1.6H:1V upstream slope
Lower Dam: 24m high x 77m long x 10m wide,
1.2m thick reinf concrete core, rockfill, 2.2H:1V
downstream slope, 1.5H:1V upstream slope

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Middle Dam Seismic Failure

- Seismic failure is function of seismic magnitude
- Subjective - considering previous dynamic analysis results (EBA) and new info on Middle Dam conditions

Probability of failure

Seismic event magnitude (pga in g)

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Site Storm Frequency-Magnitude

Return Period (yrs)*, **	24-hr Rainfall (in mm) for each sub-basin			
	Upper Hw19	Lower Hw19	Middle chase	Lower chase
2	70.3	60.8	58.9	58.3
5	88.8	76.8	74.4	73.5
10	101	87.3	84.6	83.7
25	116.5	100.8	97.7	96.5
50	128	110.7	107.3	106.1
100	139.4	120.6	116.9	115.5
200	152.3	131.7	127.7	126.2
500	168.4	145.6	141.1	139.5
1,000	180.5	156.1	151.3	149.6
2,000	192.6	166.6	161.4	159.6
5,000	208.7	180.4	174.9	172.9
10,000	220.8	190.9	185	182.9
50,000	249	215.3	208.6	206.3

24-hr Rainfall (mm)

Frequency of Exceedance (yrs)

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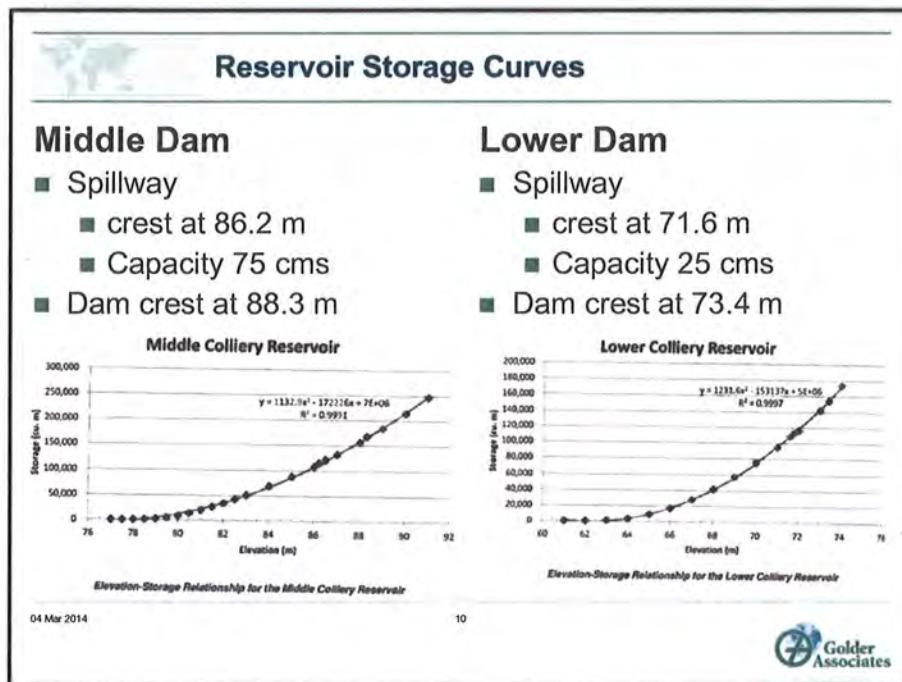
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Runoff and Dam/Reservoirs Capacity/Release

- Several storm scenarios (with characteristics)
- Watershed runoff characteristics
- Middle Dam/Reservoir capacity/release
 - Spillway release
 - Overtopping depth and duration w/o breach
 - Release to Lower Dam
 - w/o breach
 - w breach (assumed geometry / duration)
- Lower Dam/Reservoir capacity/release
 - Release to downstream w/o breach

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Middle Dam Overtopping Failure

- Breaching is function of overtopping depth and duration
- Subjective - considering Middle Dam conditions (incl new info) and case histories

Overtopping Duration (minutes)

Overtopping Depth (m)

$P[F] =$

10%
50%
90%

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Middle Dam Breach Duration

- Once started, breach duration is function of dam condition (release of impoundment)
- Essentially same for seismic and for overtopping
- Subjective – considering Middle Dam conditions (incl new info) and case histories

Probability of Non-exceedance

Breach Duration (minutes)

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Downstream Inundation / Consequence Scenarios

- Limited set (due to time and cost constraints) of modeled scenarios to cover range of possibilities
- No Lower Dam failures included in Phase 1
- Can interpolate/extrapolate for other scenarios (storms, breach time)

Scenario	Storm	Middle Dam Breach
SC1	None (seismic/other)	Fast (10 min)
SC3	PMF	Fast (10 min)
SC4	PMF	Slow (150 min)
SC8	PMF	None
SC5	1000 yr	Fast (10 min)
SC7	1000 yr	None

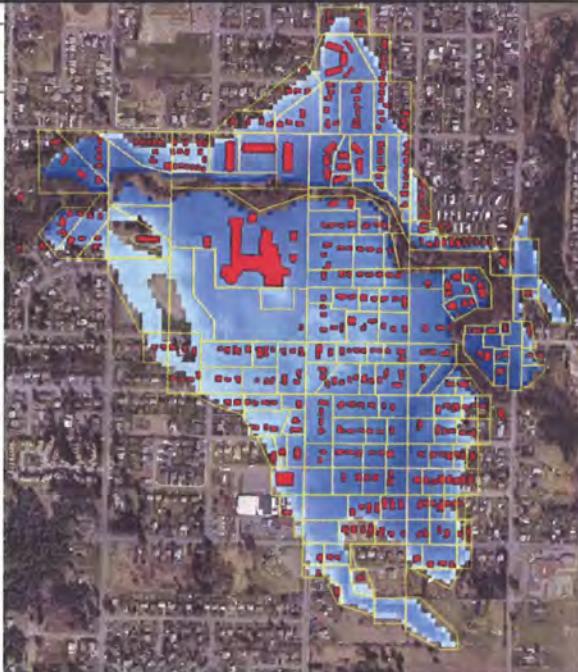
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Downstream Zones

- >Worst Case inundation (from AE 2012 analysis)
- Identified area of interest
- Subdivided area into spatial zones within which properties/ population can be combined

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Inundation Model (AE)

- 2m x 2m = 1 million cells
- 174 potentially affected spatial "zones", each:
 - collective structures (values) & population
 - average inundation
- Middle Dam fast seismic failure shown

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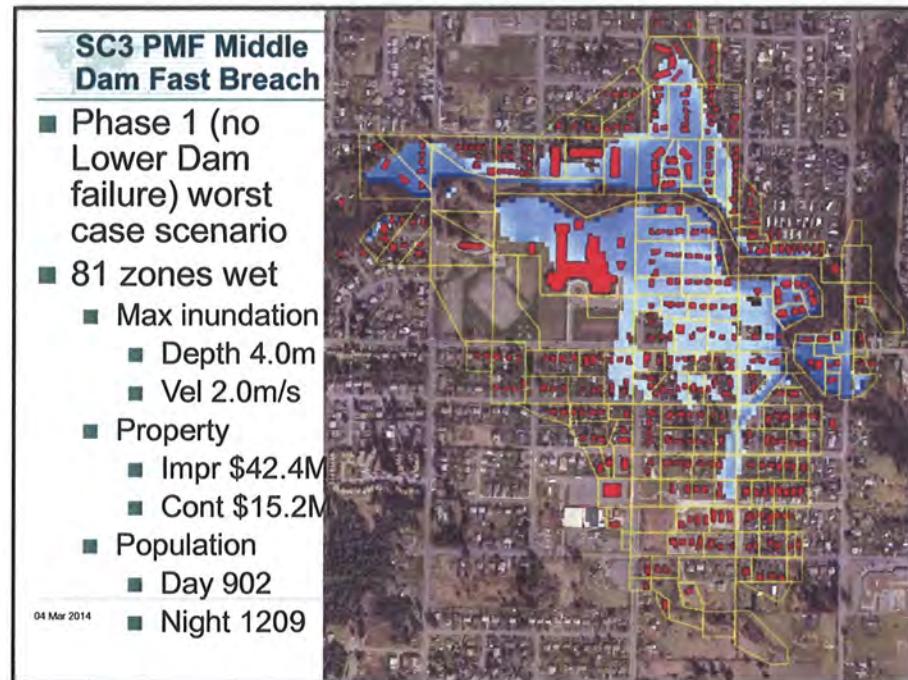
Sum of all zones (2012):	
Adjusted gross improvements	\$68.4M
Contents	\$27.2M
Day population	1070
Night/weekend population	1713

Exposed Population

- Population
 - Average per dwelling unit vs specific properties (AE 2012)
 - Different for work day (25%) vs nights/weekends (75%)
 - Mix of population type and location - averaged
 - Random occurrence (work day vs night/weekend)
- Warning / evacuation (subjective, considering average procedure reliability and effectiveness)
 - Slow breach storms / overtopping – **90% reduction**
 - Fast breach storms / overtopping – **75% reduction**
 - Slow breach seismic / other – **25% reduction**
 - Fast breach seismic / other – **10% reduction**

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Scenarios: Parameters

Scenario ID	Event Type	Return Period	Breach Type	Dam Breach Duration	Warn/evac Effective
SC1	Seismic/Other	?	Middle Dam Only	Fast - 10 min	10%
SC2	Seismic/Other	?	Middle Dam Only	Slow - 150 min	25%
SC3	PMF	~ 50,000 year	Middle Dam Only	Fast - 10 min	75%
SC4	PMF	~ 50,000 year	Middle Dam Only	Slow - 150 min	90%
SC5	1000-year Flood	1000 year	Middle Dam Only	Fast - 10 min	75%
SC6	1000-year Flood	1000 year	Middle Dam Only	Slow - 150 min	90%
SC7	1000-year Flood	1000 year	No Breach	N/A	90%
SC8	PMF	~ 50,000 year	No Breach	N/A	90%
SC9	100-year Flood	100 year	Middle Dam Only	Fast - 10 min	75%
SC10	100-year Flood	100 year	Middle Dam Only	Slow - 150 min	90%

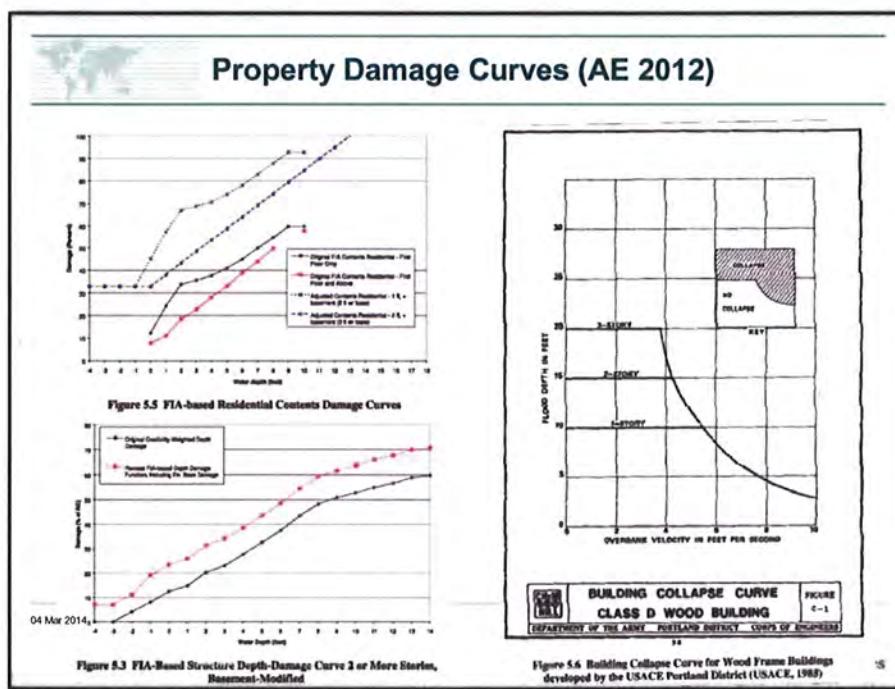
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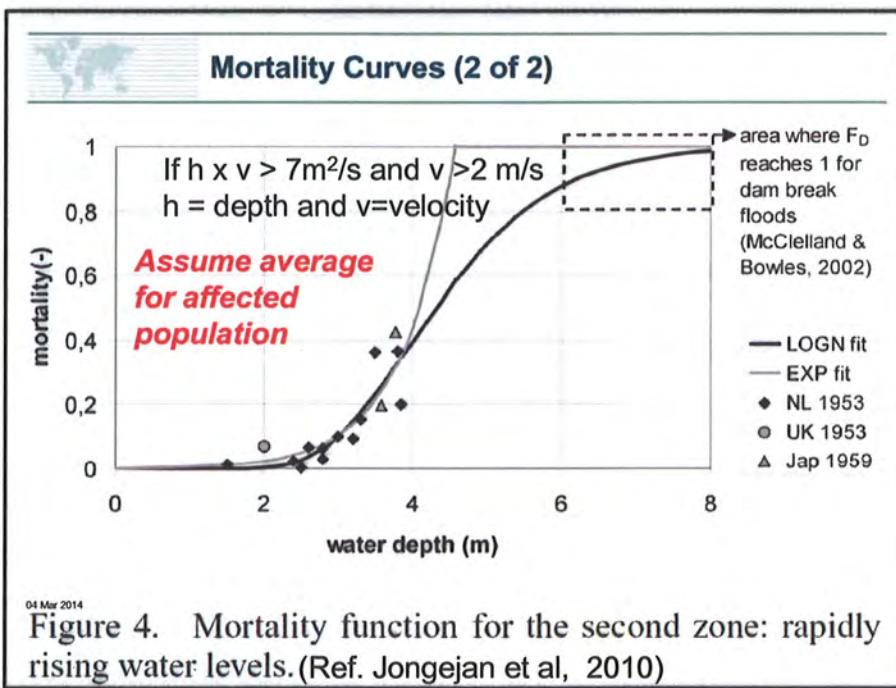
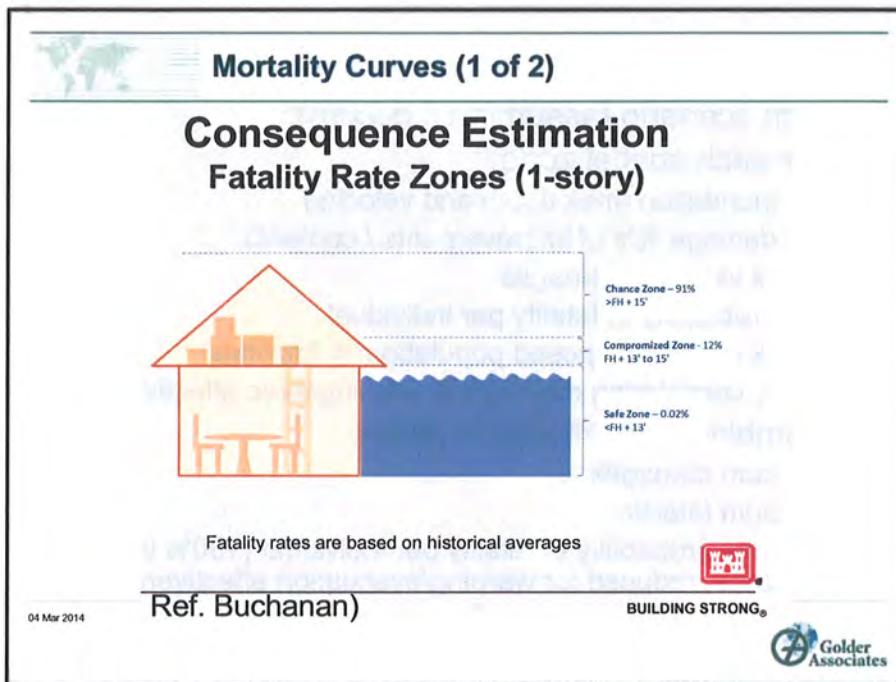
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Scenarios: Inundation									
Scen ID	# Wet Zones	Max Depth (m)	Max Velocity (m/s)	Adj Gross Impr Value	Contents Value	Total Prop Value	Day Pop.	Night Pop.	
SC1	15	2.00	1.50	\$ 5.0	\$ 2.5	\$ 7.5	580	188	
SC2									
SC3	81	4.00	2.00	\$ 42.4	\$ 15.2	\$ 57.6	902	1209	
SC4	52	3.40	1.70	\$ 22.4	\$ 11.2	\$ 33.6	810	1023	
SC5	57	3.70	1.70	\$ 24.2	\$ 12.1	\$ 36.3	824	1065	
SC6									
SC7	37	2.90	1.70	\$ 13.7	\$ 6.8	\$ 20.5	701	631	
SC8	50	3.30	1.70	\$ 21.8	\$ 10.9	\$ 32.7	806	1011	
SC9 incremental consequences essentially the same as seismic									
SC10 incremental consequences essentially the same as seismic									

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"Conditional" Scenario Consequences

For each scenario (assuming it occurs):

- for each spatial zone:
 - inundation (max depth and velocity)
 - damage %'s of improvements / contents
 - x values = damages
 - probability of fatality per individual
 - x average exposed population* = fatalities
 - (*considering day/night & warning/evac effectiveness)
- combine over all spatial zones
 - sum damages
 - sum fatalities
 - max probability of fatality per individual (100% time in zone, reduced for warning/evacuation effectiveness)

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SC3 PMF Middle Dam Fast Breach

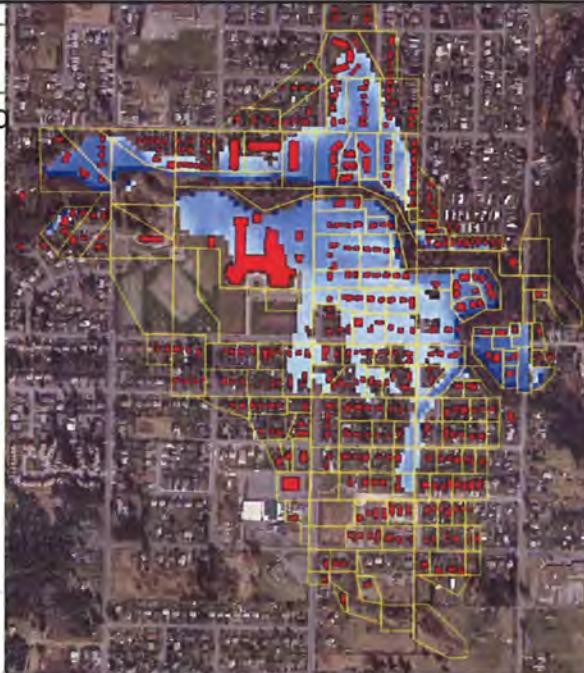
■ Absolute consequences

- Damages
 - Impr \$7.6M
 - Cont \$4.4M
 - Ttl \$12.1M
- Safety
 - #Fatal 3.7
 - Indiv 0.099

■ Incremental consequences

- Damages
 - Ttl \$5.3M
- Safety
 - #Fatal 3.4
 - Indiv 0.087

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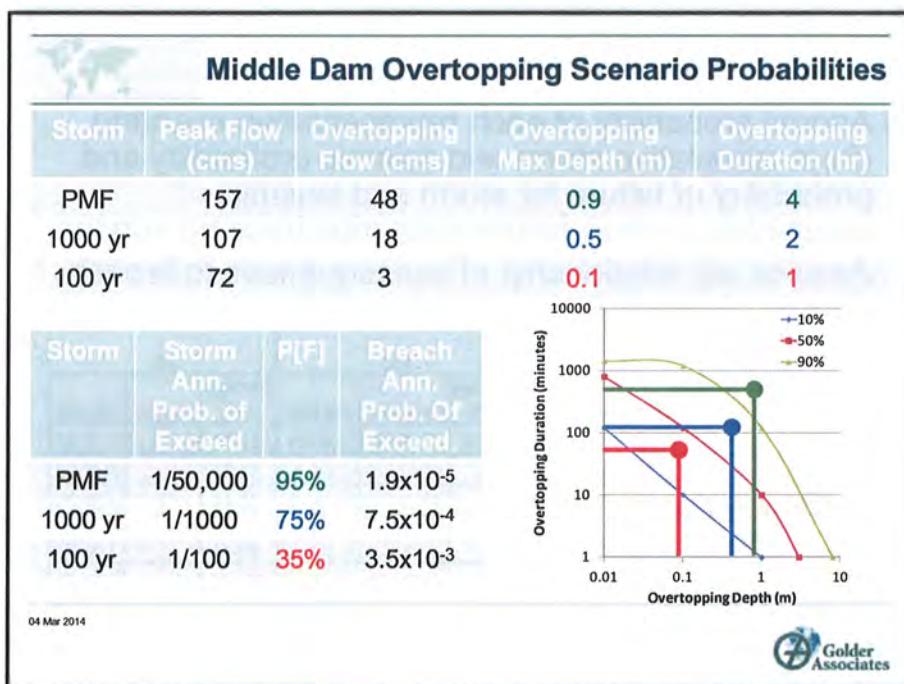


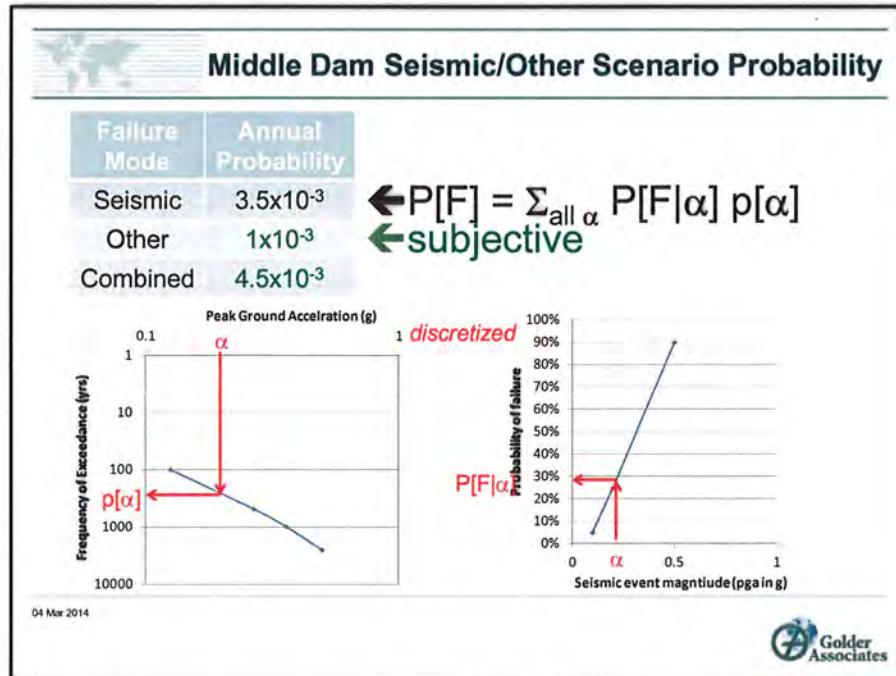
Scenarios: "Conditional" Consequences								
Scen ID	Scenario Consequences					Incremental Consequences		
	Building Damage	Contents Damage	Total Damage	Number Fatalities	Max Ind Ann P[F]	Total Damage	Number Fatalities	Max Ind Ann P[F]
SC1	\$0.8	\$0.5	\$1.3	2.8E-02	2.8E-03	\$ 1.3	2.8E-02	2.8E-03
SC2								
SC3	\$7.6	\$4.4	\$12.1	3.7E+00	9.9E-02	\$ 5.3	3.4E+00	8.7E-02
SC4	\$5.2	\$3.1	\$8.3	3.7E-01	1.4E-02	\$ 1.6	7.4E-02	2.4E-03
SC5	\$5.8	\$3.5	\$9.3	1.6E+00	4.3E-02	\$ 5.5	1.5E+00	3.8E-02
SC6								
SC7	\$2.4	\$1.4	\$3.8	9.4E-02	4.8E-03			
SC8	\$4.2	\$2.5	\$6.7	3.0E-01	1.2E-02			
SC9						\$ 1.3	2.8E-02	2.8E-03
SC10								

Combine with probability of each scenario occurring →



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Scenarios: Results

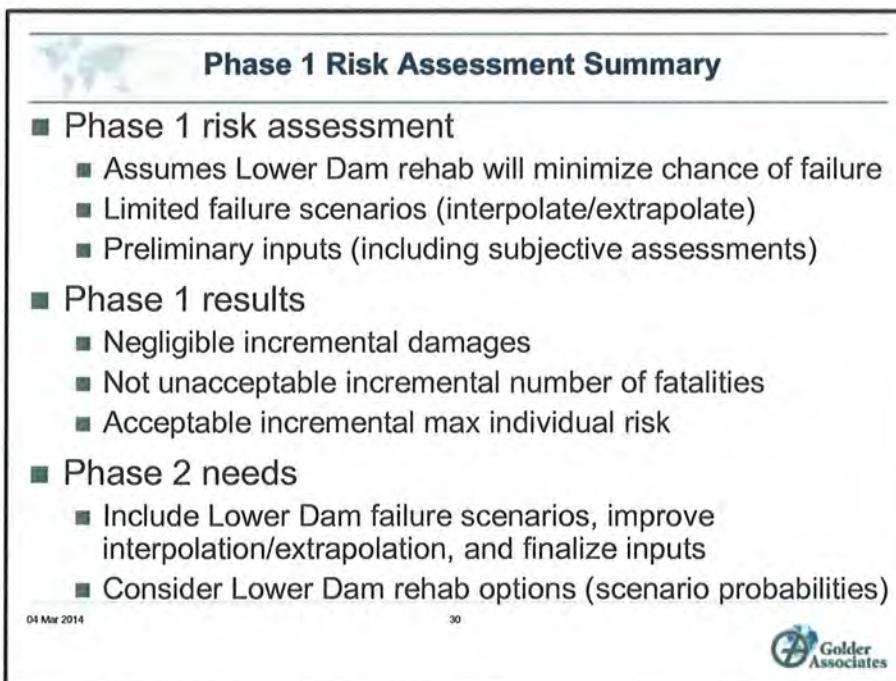
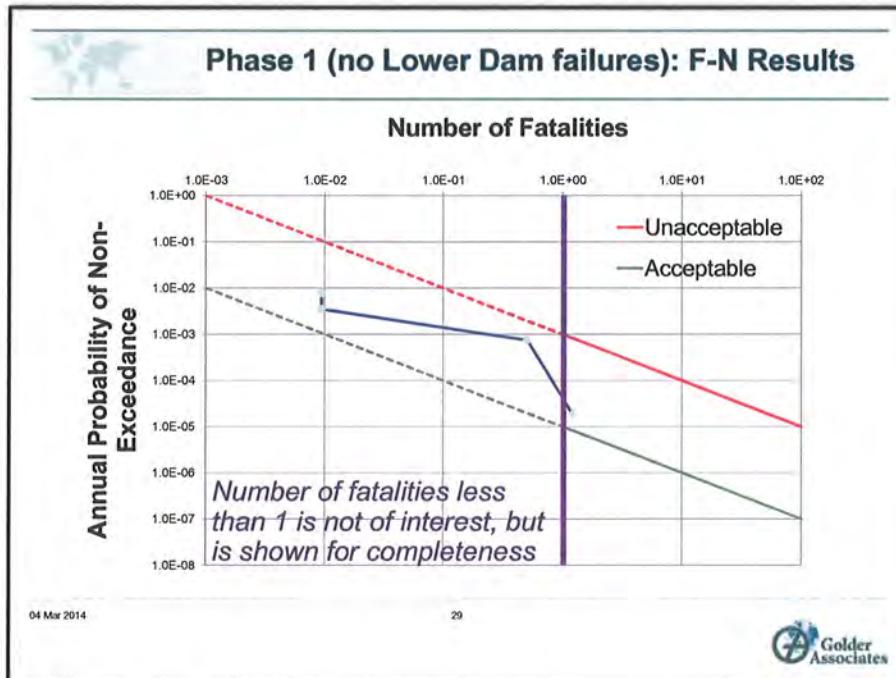
- Annual probability of each representative scenario (from cumulative storm and seismic probability and probability of failure for storm and seismic magnitudes) – non-failure scenarios have no conseq
- Assume log relationship of consequences to breach duration (mean 60 min) for interpolation

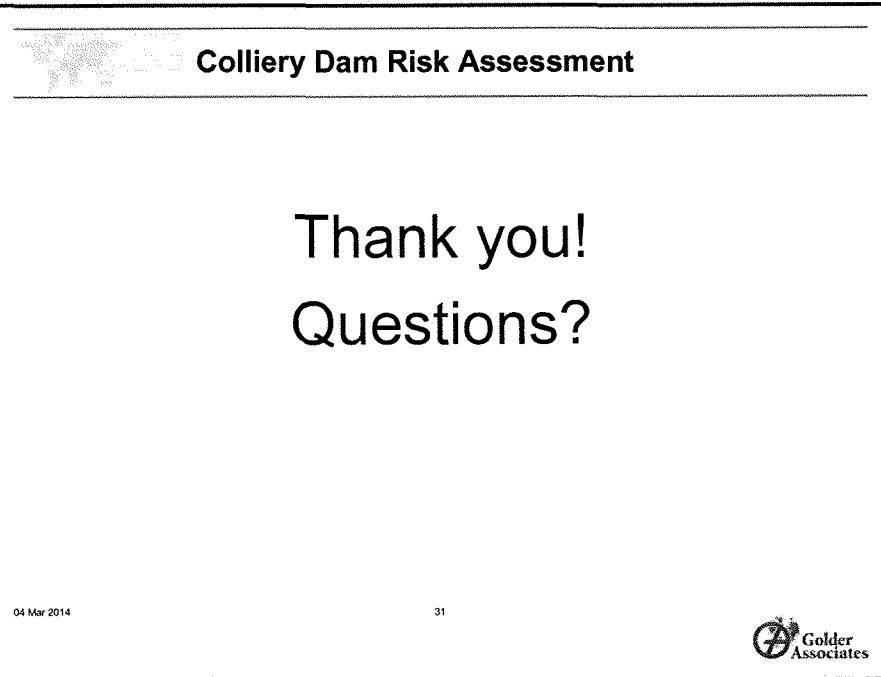
Breach Duration Time (min)	10			150			60			
	Annual P[Scen]	Damage (M)	Fatalities	Ind Risk	Damage (M)	Fatalities	Ind Risk	Damage (M)	Fatalities	Ind Risk
PMF	1.9E-05	\$5.3	3.4E+00	8.7E-02	\$1.6	7.4E-02	2.4E-03	\$2.84	1.2E+00	5.7E-02
1000 yr	7.3E-04	\$5.5	1.5E+00	3.8E-02	\$-	0.00E+00	0.00E+00	\$1.87	5.1E-01	2.4E-02
100 yr	2.8E-03	\$1.3	2.8E-02	2.8E-03	\$-	0.00E+00	0.00E+00	\$0.44	9.4E-03	1.8E-03
Seismic/other	4.5E-03	\$1.3	2.8E-02	2.8E-03	\$-	0.00E+00	0.00E+00	\$0.44	9.4E-03	1.8E-03
Total Expected Annual: \$0.005 4.6E-04 3.2E-05										

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The slide has a decorative border featuring a world map on the left side. At the top center, there is a horizontal line above the title "Colliery Dam Risk Assessment". In the center of the slide, the text "Thank you!" is on one line, and "Questions?" is on the line below it. At the bottom left, the date "04 Mar 2014" is printed. In the bottom right corner, there is a logo for "Golder Associates" which includes a stylized "A" icon.

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Thank you!
Questions?

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