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IOWA HIGH HAZARD DAM ASSESSMENTS

Dam Risk Reviews and Rankings

IOWA HIGH HAZARD DAM ASSESSMENTS

Iowa DNR Dam Safety

August 11, 2023
Section 1
Des Moines, IA

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of Iowa.

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August 11, 2023

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1 INTRODUCTION

This report is intended to serve as a deliverable for the screening-level risk assessment, ranking, and mitigation recommendations of 39 dams in the State of Iowa, contracted by the Iowa DNR Dam Safety Division (2022-23). The locations of the 39 assessed dams are shown in Figure 1. A tabular list of assessed dams and accompanying information is shown in Table 1 with label numbers corresponding to the labels shown in Figure 1. This effort utilized funds from the Federal Emergency Management Agency (FEMA) High Hazard Dams Grant Program. The level of assessment, methodologies used, and results are presented here within.

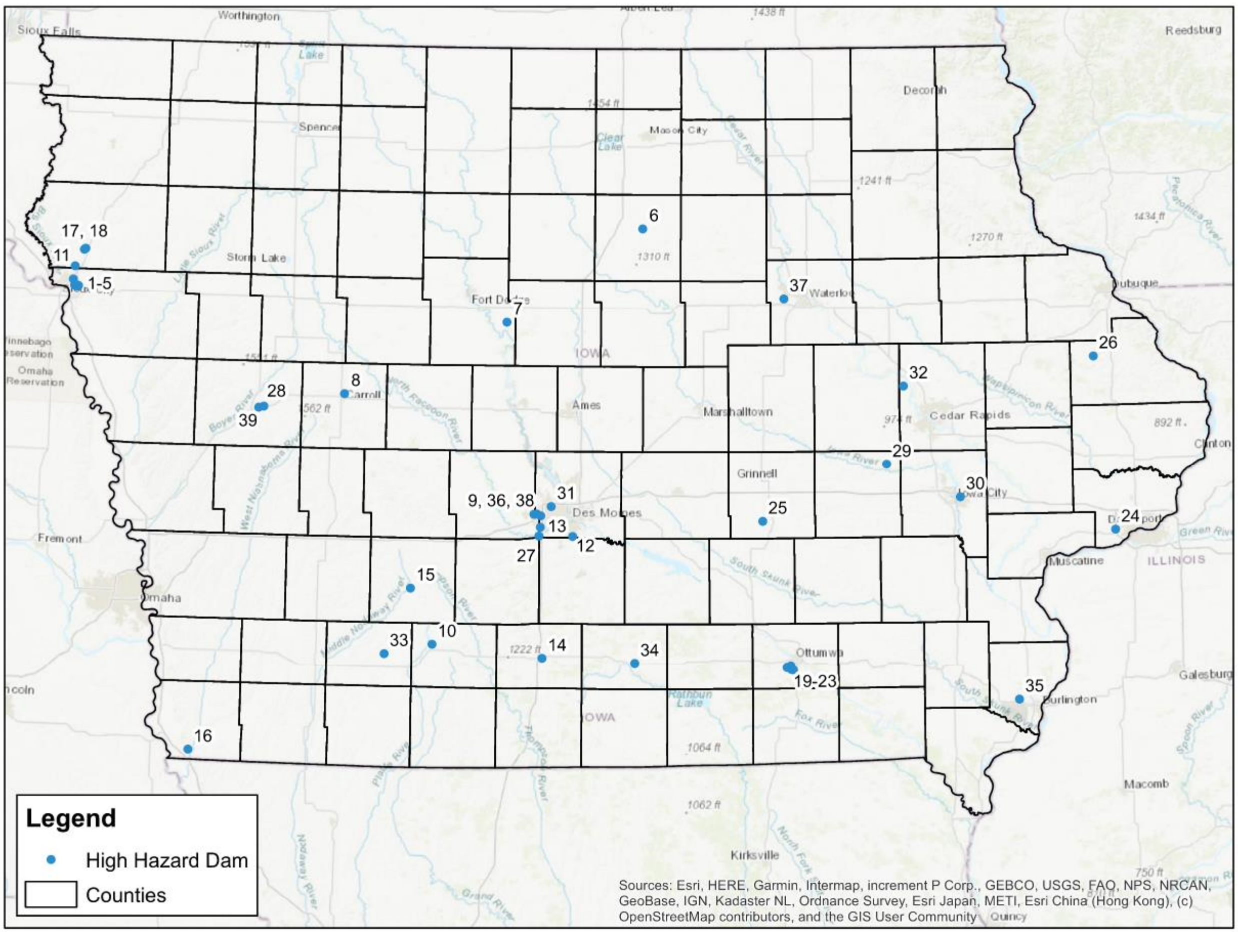

Figure 1. High hazard dam locations

Table 1. Assessed dams with associated owner, city, and county names.

Dam No.	Dam Name	Owner Name	City Name	County Name
1	Bacon Creek Watershed Site A-1-1	City of Sioux City	Sioux City	Woodbury
2	Bacon Creek Watershed Site A-2-4	City of Sioux City	Sioux City	Woodbury
3	Bacon Creek Watershed Site A-3	City of Sioux City	Sioux City	Woodbury
4	Bacon Creek Watershed Site A-3-1	City of Sioux City	Sioux City	Woodbury
5	Bacon Creek Watershed Site C-1	City of Sioux City	Sioux City	Woodbury
6	Beeds Lake Dam	Iowa Dept. of Natural Resources	Hampton	Franklin
7	Brushy Creek Dam	Iowa Dept. of Natural Resources	Fraser	Webster
8	Carroll Stormwater Detention Dam	City of Carroll	Carroll	Carroll
9	Clive Lake Dam	Country Club Owners Association, HOA Management Solutions	Clive	Polk
10	Creston Flood Prevention Dam	City of Creston	Creston	Union
11	Focht & Schindel Dam	Gary Schindel	Sioux City	Plymouth
12	Fort Des Moines Park Dam	Polk Co Conservation Board	Des Moines	Polk
13	Glen Oaks Country Club Dam	Concert Glen Oaks LLC	West Des Moines	Polk
14	Grade Lake Dam	City of Osceola	Osceola	Clarke
15	Greenfield Reservoir Dam	Greenfield Municipal Utilities	Greenfield	Adair
16	Hamburg Watershed Site M-1	Fremont Co SWCD	Hamburg	Fremont
17	Held Watershed Site E-3	Plymouth Co SWCD	Hinton	Plymouth
18	Held Watershed Site E-4	Plymouth Co SWCD	Hinton	Plymouth
19	Jefferson Park Watershed Site 1	City of Ottumwa	Ottumwa	Wapello
20	Jefferson Park Watershed Site 10	City of Ottumwa	Ottumwa	Wapello
21	Jefferson Park Watershed Site 3	City of Ottumwa	Ottumwa	Wapello
22	Jefferson Park Watershed Site 4	City of Ottumwa	Ottumwa	Wapello
23	Jefferson Park Watershed Site 5	City of Ottumwa	Ottumwa	Wapello
24	Lake of the Hills Dam	Iowa Dept. of Transportation	Davenport	Scott
25	Lake Ponderosa Dam	Poweshiek Co Board of Supervisors	Montezuma	Poweshiek
26	Leisure Lake Dam	Ron Kirchhoff	Fulton	Jackson
27	Maffitt Reservoir Dam	Des Moines Water Works	West Des Moines	Dallas
28	Meyer Dam	Richard Meyer	Denison	Crawford
29	Middle Pond Dam	Amana Colonies Golf Course, Inc	Middle Amana	Iowa
30	North Branch Ralston Creek Dam	City of Iowa City	Iowa City	Johnson
31	Parkview Lake Dam	City of Urbandale	Urbandale	Polk
32	Pleasant Creek Lake Dam	Iowa Dept. of Natural Resources	Palo	Linn
33	Prescott Flood Prevention Dam	City of Prescott	Prescott	Adams
34	Red Haw Dam	Iowa Dept. of Natural Resources	Chariton	Lucas
35	Schoenewe Dam	Fred Schoenewe	Burlington	Des Moines
36	Southfork Dam	Southfork Lake Lot Owners Assn.	Clive	Dallas
37	Viking Road Detention Dam	City of Cedar Falls	Cedar Falls	Black Hawk
38	West Lakes Office Park Dam	Farm Bureau Life Insurance Co.	West Des Moines	Polk
39	Yellowsmoke Park Dam	Crawford Co Conservation Board	Denison	Crawford

2 ANALYSIS

2.1 TASK 1: SITE ASSESSMENT AND ANALYSIS

The objective of this task was to collect dam data from inspection reports, as-built plan sets, geotechnical reports, hydrology and hydraulic reports, and other studies. The data is summarized in tables for use in further evaluation in the screening level assessment. Reports and studies were obtained through the Iowa Online Dam Inventory site or provided directly from Iowa Dam Safety. All work done was a “desktop level” assessment utilizing this information, and no site visits were conducted. Follow up assessment recommendations are made in the Task 4: Develop Mitigation Goals and Recommendation Actions section (2.4).

2.2 TASK 2: SCREENING LEVEL ASSESSMENT

The objectives of this task were to assess the three main potential failure modes (PFMs), including static, hydrologic, and seismic PFMs, as is the industry standard and per FEMA’s Requirements for Rehabilitation of High Hazard Potential Dams and Risk-Based Prioritization Methods (FEMA, 2020). The assessment consisted of using industry standard criteria for each to mitigate subjectivity when evaluating the risk associated with the dams detailed in this report, as well as any future dams that are assessed. The 39 dams included in the assessment were ranked separately based on review of information inventoried during Task 1 (Section 2.1) as it relates to key aspects of PFMs. Each criterion was ranked on a scale of 1 to 5, with 1 being the lowest concern and 5 being the highest concern, these rankings can be found on the following pages. A score of zero was applied if the criterion did not apply to the dam being assessed. If no information could be obtained for the individual site, it was assumed to be the highest risk and noted as such for further evaluation. If a criterion does not have a description provided for each numerical ranking from 1-5, it can be assumed that the intermediate ranking is a continuum between ranking descriptions provided. Each evaluation criteria were then applied a weighting factor of 1 to 10 to capture a comparative risk to categories that would likely contribute to a higher chance of failure.

Each category weight and criteria score were multiplied and summed to get a total score for each dam to provide a quantitative comparison. The methodology and assumptions for each criterion ranking are described in more detail below. Results are provided in Appendix D and summarized in Table *8*.

2.2.1 STATIC PFM

The static potential failure mode refers to the risk of failure during normal operations of the dam. This is also referred to as a sunny-day failure. The criteria in Table 2 is broken down by specific dam components and evaluation criteria related specifically to risk of a static failure. There are many potential failure mechanisms within a static failure, however, this report does not detail a potential failure mode analysis (PFMA) for each dam and it appurtenant structures.

Table 2: Static Potential Failure Criteria

	Dam Component	Evaluation Criteria - Static	Criteria Weight (1-10)
Static	**Embankment**	Static Stability (sediment pool, age)	2
		Surface Obstructions (trees, animal burrows, etc.)	2
		Noted Deformities (slumps, depressions, etc.)	8
		Subsurface Material Concerns (material susceptibility to piping, presence of sand, etc.)	7
		Seepage Observed / Seepage History	8
		Lateral Drainage Design Concerns (filter compatibility)	4
		Embankment Design Concerns (zoned embankment, TR210-60)	6
	Principal Spillway	Conduit Integrity (Inflow and Infiltration)	10
		Structural Damage	5
		Seepage Observed Adjacent to Principal Spillway	6
		Operations Concerns (Principal Spillway not functioning correctly)	5
		Low-Level Drawdown Operation and Design Concerns	6
		Design Concerns	6

- **Static Stability (sediment pool, age) – Criteria Weight 2**

This criterion was evaluated for the stability of the embankment foundation soils for the potential to fail during a static event. The age of the structure was used as an indicator of stability, as it is typically indicative of how much sediment has deposited beneath the permanent pool. In general, the higher the amount of sediment accumulation in the normal pool, the reduced risk of hydraulic connectivity to potential foundation defects, such as sand seams. Reduced hydraulic connectivity to foundation defects is assumed to reduce potential embankment failure. This may seem counter-intuitive to potentially ranking dams as a higher risk with age, but in terms of static stability, the sediment deposition likely serves to improve stability. Dry dams still capture sediment, although at a lower efficiency than dams with reservoirs, but were ranked similarly.

Static Stability (sediment pool, age)	
1	Structure is 50+ years old
2	Structure is 40-50 years old
3	Structure is 20-40 years old
4	Structure is 10-20 years old
5	Structure is <10 years old

Surface Obstructions (trees, animal burrows, etc.) – Criteria Weight 2

Surface obstructions such as trees, holes, and animal burrows are defects that provide paths of seepage through the dam embankment and reduce embankment stability. These obstructions were ranked using the most recent inspection report with the criteria in the table below.

Surface Obstructions (trees, animal burrows, etc.)	
1	No surface obstructions
2	Minimal surface obstructions that can easily be removed or fixed (overgrown vegetation, shrubs, saplings, etc.)
3	Surface obstructions that can be removed or fixed (small - medium trees (<16" dia.), shallow holes, etc.)
4	Surface obstructions that cannot be removed without significant maintenance (large trees (>16" dia.), deep holes, etc.)
5	Surface obstructions are severe enough that dam embankment is altered and would require rehabilitation

Noted Deformities (slumps, depressions, etc.) – Criteria Weight 8

Deformities along the embankment include slumps, depressions, cracks, and slides. These can be a sign of preliminary mass movement of soil, weak foundation materials, poor compaction, or uneven settlement eventually leading to embankment failure. These deformities were ranked using the most recent inspection report and the ranking criteria in the table below.

Noted Deformities (slumps, depressions, etc.)	
1	No deformities on dam embankment
2	Embankment has 1 minor deformity
3	Embankment has multiple minor deformities
4	Embankment has 1 major deformity
5	Embankment has major deformities

Subsurface Material Concerns (material susceptibility to piping, presence of sand? Etc.) – Criteria Weight 7

Foundation materials such as sand have high hydraulic conductivity resulting in higher seepage rates. As a result, they are susceptible to piping and the conveyance of soil materials that potentially lead to failure. Different foundation materials were ranked using the criteria in the table below. As-built plans and other geotechnical reports were utilized to rank each dam.

Subsurface Material Concerns (material susceptibility to piping, presence of sand, etc)	
1	Embankment/core material comprised of CH and/or CLs
2	
3	Embankment/core contains some sands/silts
4	
5	Embankment/core is comprised of large portions of fine sands/silts (ML, MH) or other granular material

- **Seepage Observed / Seepage History – Criteria Weight 8**

Seepage through a dam is a natural occurrence, however, if the seepage flow exceeds the dam foundation's or filter system's ability to convey the flow rate safely, it will eventually create issues. Large seepage forces through the earthen embankment can lead to mobilization of sediment resulting in piping, "boils", or sinkholes on the face of the dam. Mobilization of sediment as a result of embankment seepage can result in dam failure. DNR inspection reports were reviewed to establish the history and severity of observed seepage at each dam to rank seepage issues using the criteria below.

Seepage Observed / Seepage History	
1	Seepage has never been observed
2	Minimal seepage observed in past but not currently
3	Seepage observed in past but not currently
4	Observed seepage but not increasing
5	Observed seepage and increasing

- **Lateral Drainage Design Concerns (filter compatibility) – Criteria Weight 4**

Lateral drains and filters are constructed in dams to control the seepage flow through the embankment or relieve seepage pressure. Over time, these drains can become clogged with microorganisms, roots, and sediment and no longer function as designed. Additionally, dam design standards have changed over time, often resulting in older dams not meeting current design standards, or the dam may have been designed without any drainage collection. The table below shows the criteria used to rate each dam and its lateral drainage components.

Lateral Drainage Design Concerns (filter compatibility)	
1	Contains state-of-the-practice lateral drainage system (uses fine aggregate similar to what is used in concrete (ASTM C33))
2	Has filter system that has evidence of working (inspection) but is not considered up to date
3	Has filtration system, but no evidence that the filter is working
4	Filtration system does not work as designed
5	Does not have lateral filter system

- **Embankment Design Concerns (zoned embankment, TR210-60) – Criteria Weight 6**

USDA NRCS TR210-60 provides the current design standard for earthen embankment dams constructed by the USDA-NRCS. The table below shows the criteria used to rate each dam related to today's dam design standards for earthen dams.

Embankment Design Concerns (zoned embankment, TR210-60)	
1	The dam meets current federal design standards, 3:1 or flatter side slopes and TOD to meet TR210-60
2	The dam meets current state design standards but not current federal design standards
3	The dam was designed to meet federal standards that are now outdated; 2.5:1 side slope
4	The dam was designed to meet state standards that are now outdated
5	The dam does not meet any design standards; 1:1 side slope and TOD width does not meet NRCS TR210-60

Conduit Integrity – Criteria Weight 10

Principal spillway conduits and other spillway variations can deteriorate over time and lead to defects, such as joint separation, cracking, corrosion, and/or infiltration. These defects can compromise embankment stability through soil migration due to preferential flow paths adjacent to the pipe, eventually leading to mass sediment transfer and failure of the dam. Inflow and infiltration assessed from in-field inspection reports was used as an indicator of these defects and the table below describes the rating criteria used for principal spillway conduits.

Conduit Integrity (Inflow/Infiltration)	
1	No observed inflow/infiltration for conduit or riser tower
2	Minimal corrosion noted at joints or other locations
3	Some corrosion is noted at joints or other locations. Signs of leakage or riser damage in inspections
4	Substantial corrosion or small leakages observed in inspections.
5	Significant inflow/infiltration entering conduit/riser tower

Structural Damage – Criteria Weight 5

Outlet works, including risers/inlets, conduits, pipe supports, energy dissipators, and other components, are often made of pre-fabricated or cast-in-place concrete. With time, or with damage occurring from past runoff events, concrete and other materials can become damaged and fail to perform as designed. The table below describes the rating system used in assessing the structural damage and its ability to contribute to the failure of the outlet works.

Structural Damage	
1	No known existing damage, pipe material is non-corrosive and rigid
2	Minor spalling, etc.
3	Minimal joint separation, hairline cracking on structural elements, etc.
4	Damage to spillway shape, exposure of reinforcement, slip lining done in past
5	Significant damage/deformation, PS is flexible or highly corrosive, separated joints

Seepage Observed Adjacent to Principal Spillway – Criteria Weight 6

Principal spillway conduits through an embankment provide a discontinuity in the embankment. This discontinuity can result in a preferential path of seepage, higher flow rates, and increased force from the seepage. If the erosion force becomes too high sediment can start to mobilize and lead to a piping failure. The table below describes the criteria used from inspection reports for seepage adjacent to principal spillway.

Seepage Observed Adjacent to Principal Spillway	
1	Seepage has never been observed
2	Minimal seepage observed in past but not currently
3	Seepage observed in past but not currently
4	Observed seepage but not increasing
5	Observed seepage and increasing

Operations Concerns (Principal Spillway not functioning correctly) – Criteria Weight 5

It is important that the principal spillway maintain its designed hydraulic capacity so that it maintains the designed pool elevations. Maintaining hydraulic capacity requires the inlet areas of overflow spillways and trash racks of riser/conduit spillways to be clear of trees, debris, obstructions, and any other objects that may limit the hydraulics of the spillway. Not having trash racks is a concern because the debris can enter the spillway with risk of clogging and cannot be easily removed. The table below describes the criteria used to rank each dam based on the dam's risk associated with the principal spillway operations.

Operations Concerns (Principal Spillway not functioning correctly)	
1	Principal spillway functioning correctly with no obstructions, clean trash rack
2	Minimal debris or minor obstruction that can be fixed with routine maintenance (clogged trash rack, sticks or trash by inlet, etc.)
3	Minor obstructions causing reduced flow capacity but can be removed
4	Observed major obstructions or debris reducing flow capacity, trash rack is blocked or no trash rack present
5	Observed major obstructions or debris blocking flow, trash rack is blocked or no trash rack

Low-Level Drawdown Operation and Design Concerns – Criteria Weight 6

Low-level drawdown structures are required in all new high hazard structures to meet dam safety criteria. Low-level drawdown operation is necessary to be able to lower the water level and perform routine inspections on dam embankments and appurtenant structures. Without a low-level drawdown pipe constructed, it is not possible to do a full inspection and perform maintenance on the dam without the use of large pumps, siphons, or expensive rehabilitation methods. It is also important to exercise the use of the drawdown structure to prevent or flush any sediment build-up and ensure the structure functions during future uses. As-builts and inspection reports were used to identify if a structure has a low-level drawdown and if the structure has been exercised recently. If it was uncertain if the drawdown structure can function, the criteria was assumed to receive a rating of 5. The table below shows the criteria for low-level drawdown operations.

Low-Level Drawdown Operation and Design Concerns	
1	Low-level drawdown has no observed issues and has been tested within last year; has O&M plan and continually gets followed and updated
2	Low-level drawdown has no observed issues; has not been tested within last year
3	Low-level drawdown works but not to full design capacity
4	Low-level drawdown works but has severe maintenance issues
5	Low-level drawdown does not exist or is not inspectable/operable

Design Concerns – Criteria Weight 6

The materials used for principal spillway conduits are important to the overall performance and longevity of the conduit. There are a number of additional design considerations that could lead to an increase including pipe slope, minimum diameter per TR210-60 standards, the use of pipe collars, and more. This category encompasses many of the dam design concerns that could not be captured in the other categories, and it can be assumed that the intermediate ranking is a continuum between ranking descriptions provided. The table below shows the criteria and scoring based on the design concerns for the principal spillway conduit.

Design Concerns	
1	Principal spillway material is corrosion-resistant (concrete, steel, plastic), slope <5% and >0.5%, min. diameter of 30”, adequate outlet protection, diaphragm plates or seepage filter present
2	
3	
4	
5	Principal spillway material is corrosive, slope <0.5% or >10%, dia < 30”, no outlet protection, diaphragm plates or seepage filter not present, bend in conduit

The static failure overall risk scores and prorated risk scores are shown in Figure 2 and Figure 3, respectively, and are summarized in Table 3.

Table 3. Total static risk score sorted from highest to lowest risk

Dam No.	Dam	Static Risk Score	Static Prorated Risk Score (1-5)	Static Rank
29	Middle Pond Dam	312	4.2	1
35	Schoenewe Dam	270	3.6	2
26	Leisure Lake Dam	263	3.5	3
3	Bacon Creek Watershed Site A-3	238	3.2	4
2	Bacon Creek Watershed Site A-2-4	217	2.9	5
11	Focht & Schindel Dam	212	2.8	6
22	Jefferson Park Watershed Site 4	206	2.7	7
17	Held Watershed Site E-3	204	2.7	8
18	Glen Oaks Country Club Dam	200	2.6	9
19	Held Watershed Site E-4	198	2.6	10
28	Jefferson Park Watershed Site 1	197	2.6	11
23	Meyer Dam	195	2.6	12
27	Jefferson Park Watershed Site 5	194	2.5	13
6	Maffitt Reservoir Dam	188	2.5	14
32	Beeds Lake Dam	185	2.4	15
16	Pleasant Creek Lake Dam	182	2.4	16
14	Hamburg Watershed Site M-1	180	2.4	17
37	Grade Lake Dam	179	2.4	18
13	Viking Road Detention Dam	178	2.3	19
7	Red Haw Dam	175	2.3	20
34	Brushy Creek Dam	175	2.3	20
15	Greenfield Reservoir Dam	173	2.3	22
10	Lake Ponderosa Dam	172	2.3	23
25	Creston Flood Prevention Dam	172	2.3	23
33	Prescott Flood Prevention Dam	172	2.3	23
39	Yellowsmoke Park Dam	167	2.2	26
12	Fort Des Moines Park Dam	157	2.1	27
30	North Branch Ralston Creek Dam	152	2.0	28
31	Parkview Lake Dam	151	2.0	29
8	Carroll Stormwater Detention Dam	149	2.0	30
4	Bacon Creek Watershed Site A-3-1	148	2.0	31
21	Jefferson Park Watershed Site 3	148	2.0	31
38	West Lakes Office Park Dam	140	1.9	33
5	Bacon Creek Watershed Site C-1	123	1.6	34
36	Southfork Dam	121	1.6	35
24	Lake of the Hills Dam	119	1.6	36
9	Clive Lake Dam	113	1.5	37
1	Bacon Creek Watershed Site A-1-1	109	1.5	38
20	Jefferson Park Watershed Site 10	104	1.4	39

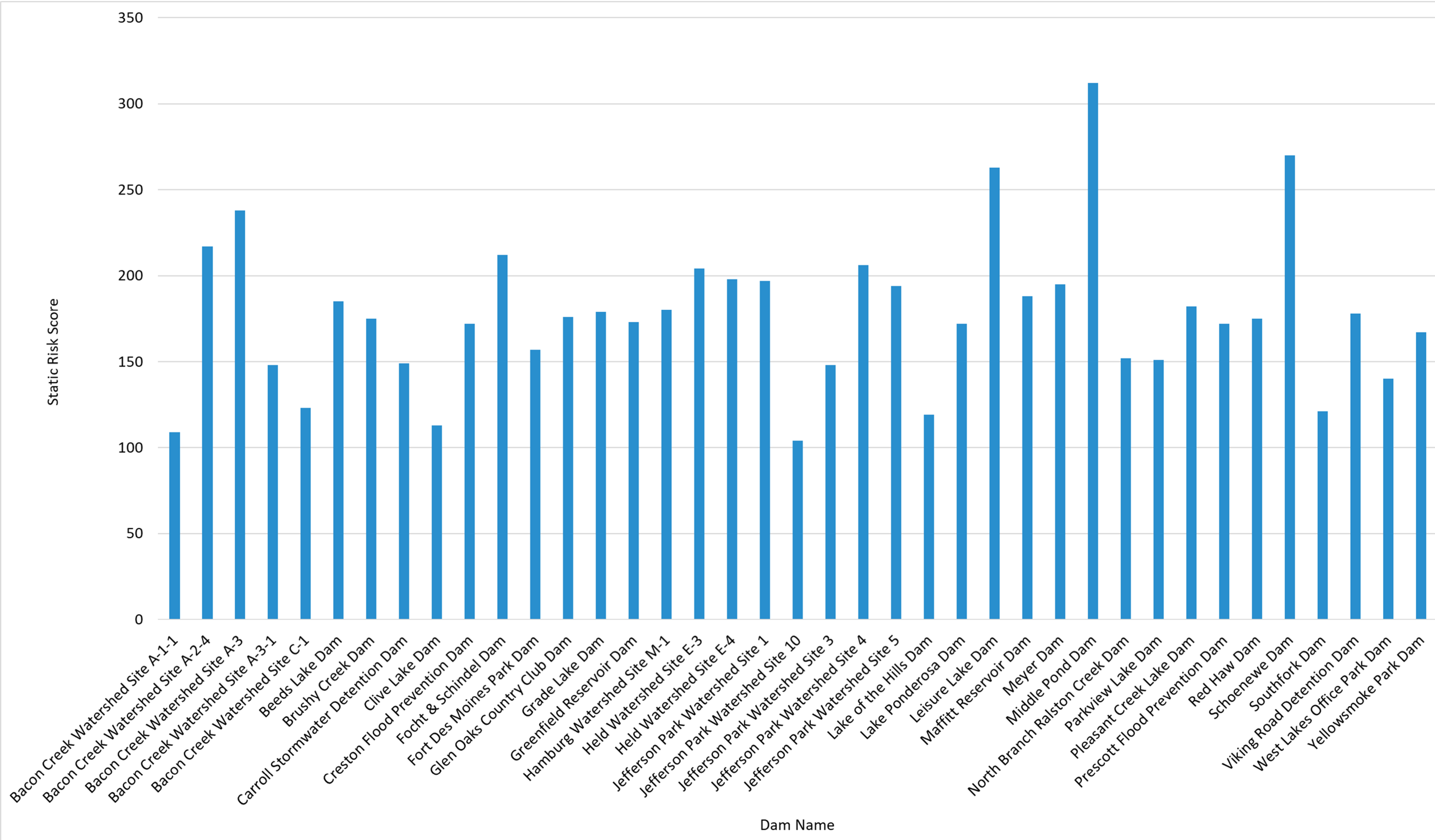

Figure 2. Total static risk score for each assessed dam

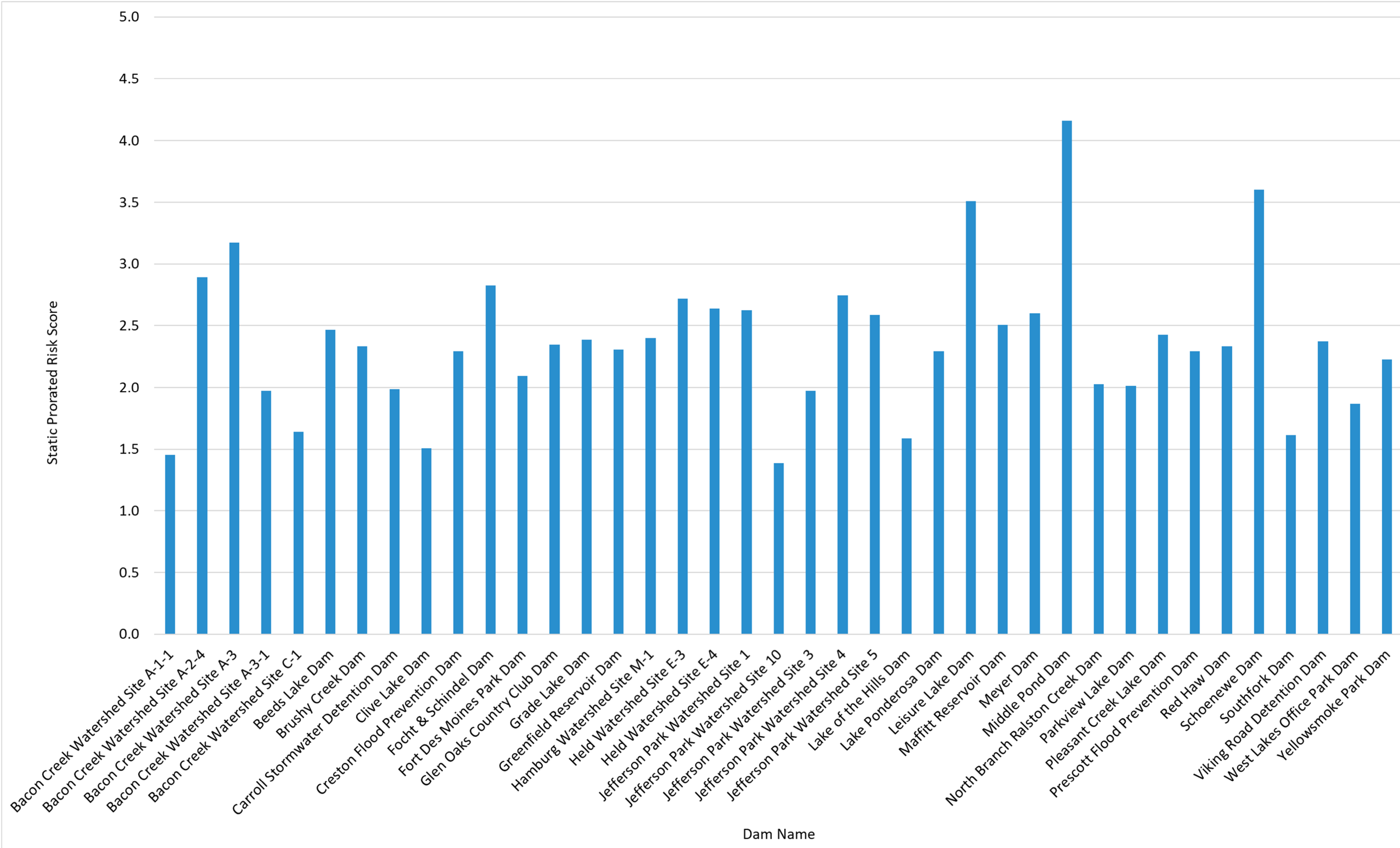

Figure 3. Static prorated risk score for each assessed dam

2.2.2 HYDROLOGIC PFM

The hydrologic potential failure mode refers to the risk of failure during a runoff event. This is also referred to as a rainy-day failure. The criteria in Table 4 is broken down by specific dam components and evaluation criteria related specifically to risk of a hydrologic failure. There are many potential failure mechanisms within a hydrologic failure, however, this report does not detail a potential failure mode analysis (PFMA) for each dam and it appurtenant structures.

	Dam Component	Evaluation Criteria - Hydrologic	Criteria Weight (1-10)
Hydrologic	Embankment	Hydrologic Stability Criteria	10
		Frequency of Overtopping	10
		Overtopping Protection	6
	Principal and Auxiliary Spillway(s)	Hydrologic Criteria Met	8
		Clogging Potential	6
		Operational Requirements to Pass Design Storm	5
		Erosion Potential of Spillways	8
		Maintenance Concerns	7
		Outlet stability	3

Table 4: Hydrologic Potential Failure Criteria

- **Hydrologic Stability Criteria – Criteria Weight 10**

During a hydrologic event, the phreatic surface through the dam embankment is typically raised and can increase the seepage conveyance. There are multiple factors that can increase stability of the embankment to prevent seepage, including cohesive soils, flatter side slopes, and constructed filters. As-builts, boring logs, and inspection reports were used to rank the hydrologic stability criteria using the table below.

Hydrologic Stability Criteria	
1	3:1 or flatter, PI 20 and over, chimney drain, structure is 50+ yrs old, sediment collected by embankment
2	
3	
4	
5	2.5:1 or steeper, PI 13 and below if no chimney drain, erosions in form of gullies, structure is <10 yrs old, sand seam, reservoir has issues staying full but no seepage around embankment/conduit, no sediment collected by embankment

- **Frequency of Overtopping – Criteria Weight 10**

State regulations require that new high hazard dams are required to be designed to pass the probable maximum flood (PMF); however, hydrologic changes and downstream developments can alter the hazard class of dams and the original as-built design may not comply with new hazard class design requirements. As-built drawings and supplemental hydrology reports and studies were used to rank each dam according to the table below.

Frequency of Overtopping	
1	PMF or greater
2	0.5 PMF or 1000 YR or 500 YR with 2+ feet of freeboard
3	500 YR
4	100 YR
5	Less than 100 YR

- **Overtopping Protection – Criteria Weight 6**

The overtopping of a dam can quickly lead to failure. Protection from overtopping can include sufficient freeboard to reduce the risk of overtopping and physical design elements, including flattened slopes and armoring, or other erosion control measures. The table below shows the scoring and criteria for this category, considering these factors.

Overtopping Protection	
1	Hard armored, no observed wave erosion
2	
3	Vegetated, flatter downstream slopes
4	
5	Wave erosion observed, steep downstream slopes

- **Hydrologic Criteria Met – Criteria Weight 8**

The principal spillway on high hazard dams is typically required to pass the 1-percent annual exceedance probability (AEP) flood, also known as the 100-year flood, without overflowing any auxiliary spillway. Over time, rainfall standards have changed, and dams may have altered hydrology and hazard classifications from when they were originally designed. Atlas 14 is considered the standard rainfall reference in Iowa and has replaced older data published in NWS Technical Paper 40. As a part of this risk category, Technical Paper 40 rainfall values were compared to Atlas 14 values as shown in Figure 4. When comparing standard rainfall depths, there were no dams which Atlas 14 values decreased and some even showed increases up to 20%.

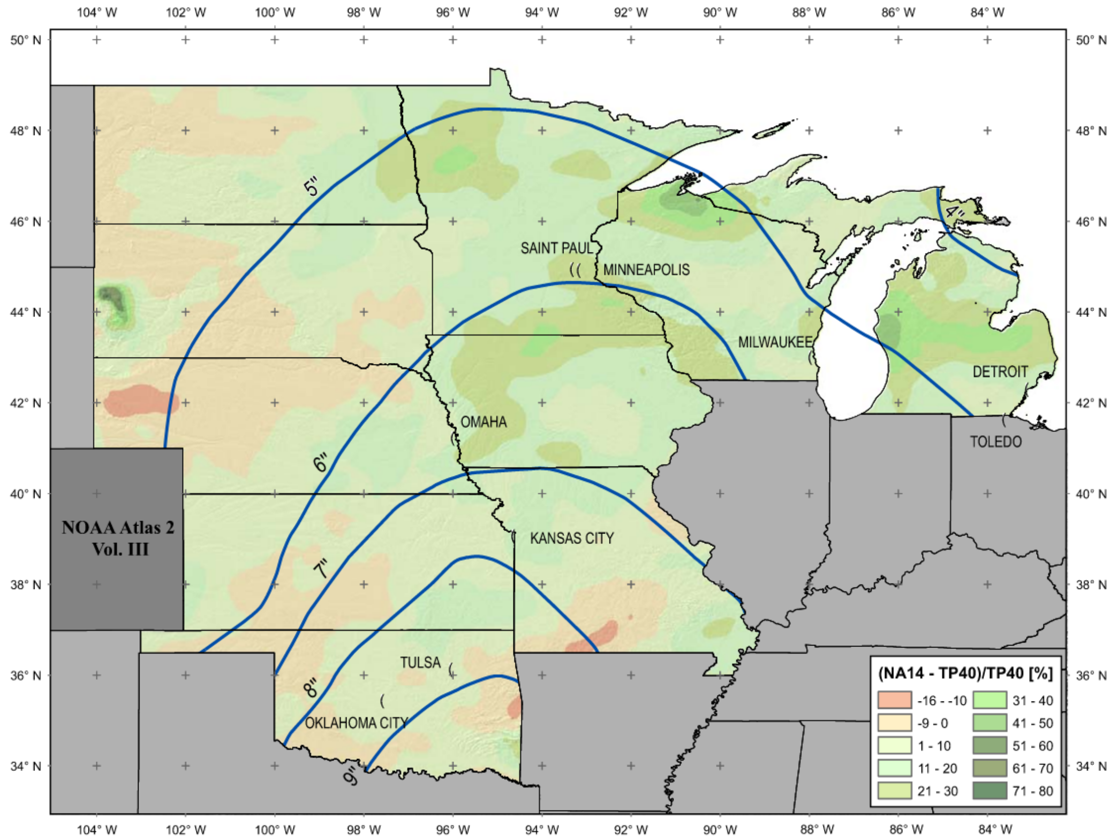

Figure 4. Percent difference in 100-year 24-hour precipitation estimates between NOAA Atlas 14 Volume 8 and U.S. Weather Bureau Technical Paper 40

The criteria below outline how dams were ranked based on the principal spillway design event and how the original precipitation data and hydrologic routings taken from the as-built plans or supplemental hydrologic studies and reports meet current criteria.

Hydrologic Criteria Met	
1	Current criteria met with current precipitation data; efficient riser (no barrel flow), passes 100-yr
2	
3	Criteria met but old precipitation data used (TP40 vs Atlas 14)
4	
5	Criteria not met

- **Clogging Potential– Criteria Weight 6**

This category was used to rank the risk associated with having one versus multiple spillways. Spillways may malfunction during hydrologic events due to debris clogging the inlets or outlets, resulting in reduced capacity, physical damage to the spillway, or a mechanical failure. The size and type of spillway determines its clogging potential. Open chute and larger diameter principal spillways tend to have a lower risk of clogging than a smaller conduit spillway. Additionally, auxiliary spillways can act as a backup during a clogging situation and pass excess flow. The table below outlines how this criterion was ranked across the dams.

Clogging Potential	
1	Open chute w/ AS or >48" PS w/ AS
2	Single open chute w/o AS or >30" PS w/ AS
3	Single conduit <48" and no AS
4	Single conduit <30" with AS
5	Single conduit <30" and no AS

- **Operational Requirements to Pass Design Storm– Criteria Weight 5**

Gated outlet structures can have operations concerns due to gate malfunction from physical damage, clogging, mechanical failure of a motor, etc. Inspection reports, as-builts, and hydraulic studies were assessed to determine the risk associated with manual operation of a gated structure. The table below shows the criteria and scoring for these concerns during a runoff event.

Operational Requirements to Pass Design Storm	
1	No operation required to pass high flows
2	
3	Operation required for more than 50% capacity
4	
5	Operation required for 100% capacity

- **Erosion Potential of Spillways – Criteria Weight 8**

Principal and auxiliary spillways may be constructed from several different materials. Auxiliary spillways may be reinforced with concrete, articulated concrete block mats, riprap, or other materials to help prevent erosion. There are multiple ways earthen auxiliary spillways are constructed including excavating native ground adjacent to the top of dam, placing fill made from local native soils, or placing fill from off-site. Auxiliary spillways that are cut from existing ground are generally accepted as the best practice as they are often the least erosive due to uniformity in the soils. The table below describes the rating criteria below based on the dam spillway's resistance to erosion.

Erosion Potential of Spillways	
1	No erosion potential (spillways are concrete or on solid rock)
2	
3	Some erosion potential (one of the spillways is vegetated)
4	Spillways have tight bends or constructed on fill (ramp spillway)
5	All spillways are vegetated

- **Maintenance Concerns – Criteria Weight 3**

Surface obstructions such as large trees, overgrown vegetation, debris, fences, clogged trash racks, and other objects can hinder discharge capacity of the principal and auxiliary spillways which can cause the reservoir to rise higher than the design and potentially overtop the dam. Obstructions within the auxiliary spillway can also create turbulence when flows encounter obstructions causing progressive erosion and eventual failure. Existing inspection reports were used with the table below to rate each dam.

Maintenance Concerns	
1	No evidence of clogged trash racks or obstruction in open chute spillways
2	
3	Some potential for clogged trash racks and/or obstruction in open chute spillways
4	
5	Trash racks frequently clogged and/or heavy growth in open chute spillways, no trash rack on conduit PS

- **Outlet Stability – Criteria Weight 3**

Outlet erosion can occur when there is inadequate protection of the downstream outlet channel to accommodate the energy and flow from the principal and auxiliary spillways. This erosion can progress upstream in the form of a headcut and lead to mass erosion of the embankment's maximum section around the principal spillway, eventually leading to failure of the dam. As-builts were used to determine designed conditions and inspection reports were used to validate as-builts and assess the current conditions. The table below describes the ranking criterion used for outlet protection.

Outlet Stability	
1	Outlets are well armored with limited potential for erosion
2	
3	Outlets have some potential or existing erosion problems
4	
5	Outlets erosion is undercutting spillways

The overall hydrologic risk scores and prorated risk scores for each dam are shown in Figure 5 and Figure 6, respectively, and are summarized in Table 5.

Table 5. Total hydrologic risk score and prorated risk score sorted from highest to lowest risk

Dam No.	Dam	Hydrologic Score	Hydrologic Prorated Risk Score (1-5)	Hydrologic Rank
23	Jefferson Park Watershed Site 5	249	4.0	1
11	Focht & Schindel Dam	240	3.8	2
28	Meyer Dam	225	3.6	3
17	Held Watershed Site E-3	223	3.5	4
20	Jefferson Park Watershed Site 10	216	3.4	5
22	Jefferson Park Watershed Site 4	216	3.4	6
18	Held Watershed Site E-4	215	3.4	7
13	Glen Oaks Country Club Dam	211	3.3	8
35	Schoenewe Dam	208	3.3	9
21	Jefferson Park Watershed Site 3	204	3.2	10
26	Leisure Lake Dam	201	3.2	11
8	Carroll Stormwater Detention Dam	188	3.0	12
37	Viking Road Detention Dam	183	2.9	12
34	Red Haw Dam	182	2.9	14
29	Middle Pond Dam	179	2.8	15
3	Bacon Creek Watershed Site A-3	177	2.8	16
19	Jefferson Park Watershed Site 1	177	2.8	16
2	Bacon Creek Watershed Site A-2-4	174	2.8	18
4	Bacon Creek Watershed Site A-3-1	174	2.8	19
16	Hamburg Watershed Site M-1	174	2.8	20
31	Parkview Lake Dam	174	2.8	21
12	Fort Des Moines Park Dam	171	2.7	22
1	Bacon Creek Watershed Site A-1-1	167	2.7	23
7	Brushy Creek Dam	165	2.6	23
30	North Branch Ralston Creek Dam	163	2.6	25
5	Bacon Creek Watershed Site C-1	159	2.5	26
15	Greenfield Reservoir Dam	157	2.5	27
9	Clive Lake Dam	154	2.4	28
32	Pleasant Creek Lake Dam	152	2.4	29
6	Beeds Lake Dam	150	2.4	30
10	Creston Flood Prevention Dam	147	2.3	31
33	Prescott Flood Prevention Dam	141	2.2	32
25	Lake Ponderosa Dam	131	2.1	33
39	Yellowsmoke Park Dam	127	2.0	34
14	Grade Lake Dam	123	2.0	35
36	Southfork Dam	121	1.9	35
38	West Lakes Office Park Dam	117	1.9	37
27	Maffitt Reservoir Dam	101	1.6	38
24	Lake of the Hills Dam	95	1.5	39

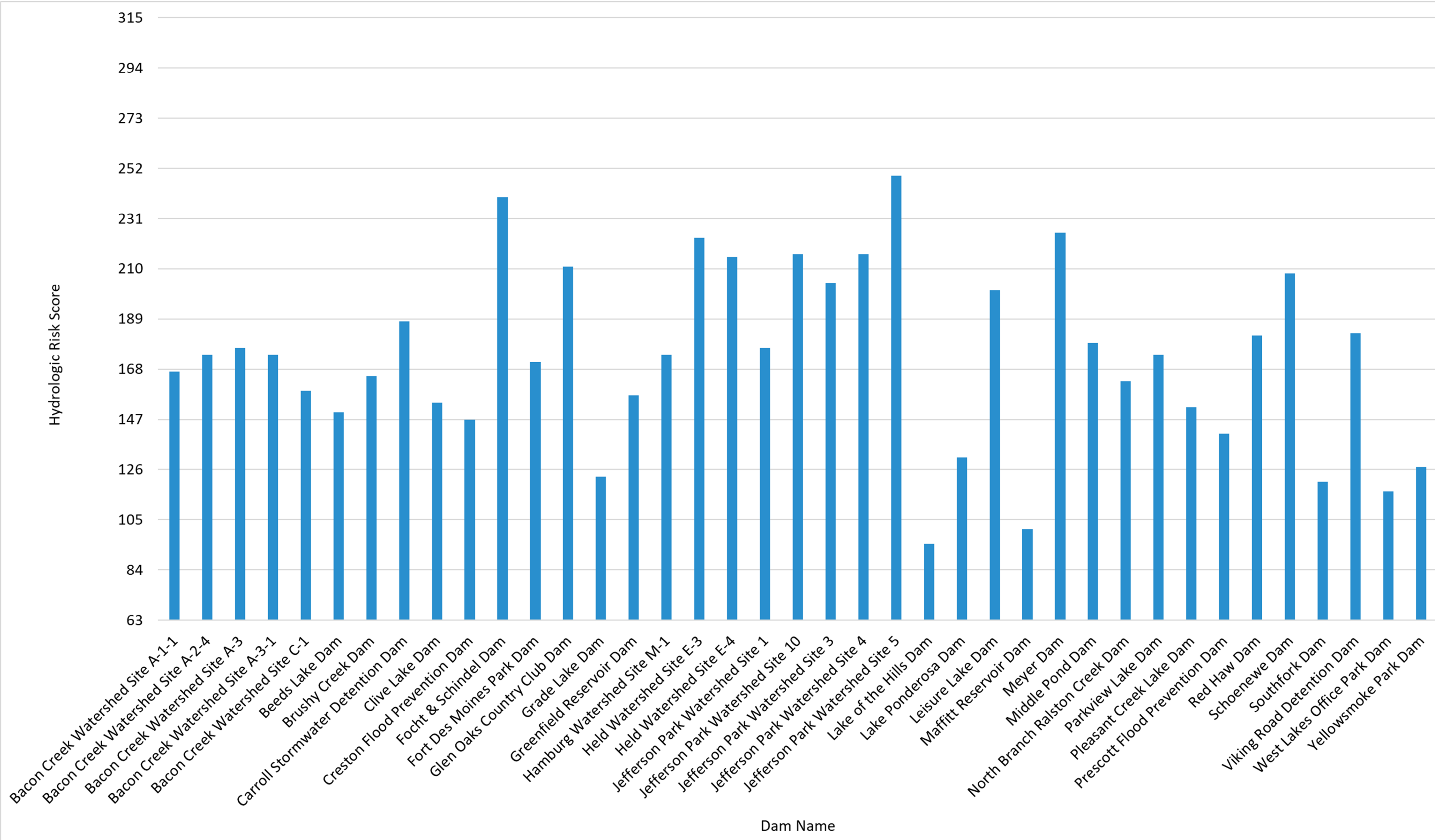

Figure 5. Total hydrologic risk scores for each assessed dam

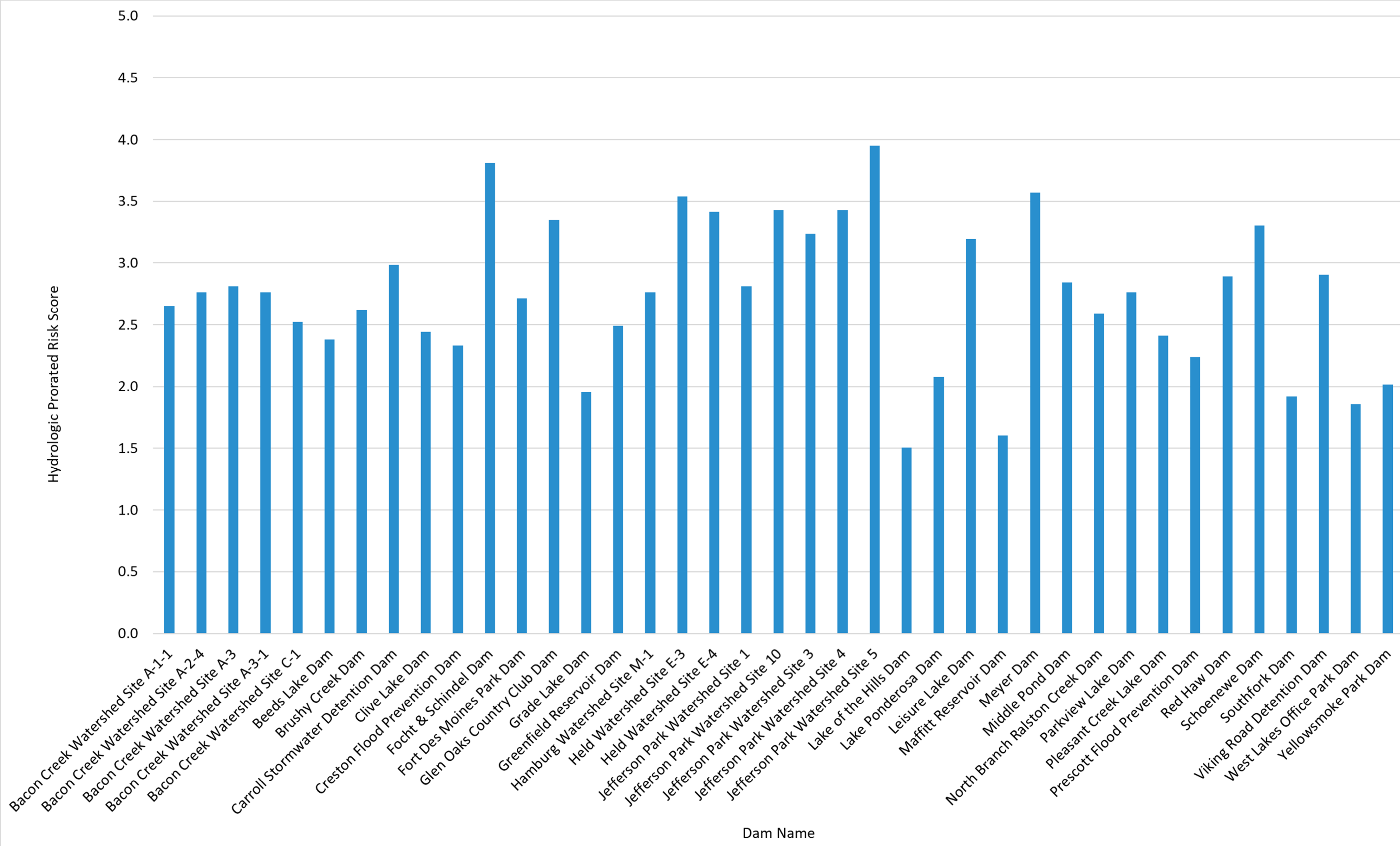

Figure 6. Hydrologic prorated risk score for each assessed dam

2.2.3 SEISMIC PFM

The seismic potential failure mode refers to the risk of failure due to seismic activity during normal operations of the dam. Seismic events can result in large slides in earthen structures and/or liquefaction of dams. The criteria in Table 6 focuses on the dam embankment and evaluation criteria related specifically to risk of a seismic failure.

Table 6: Seismic Potential Failure Criteria

	Dam Component	Evaluation Criteria - Seismic	Criteria Weight (1-10)
Seismic	Embankment	Meets Seismic Stability Criteria	10
		Seismic Risk Zone (High Risk = 5, Low = 1)	10
		Liquifiable Subsurface Soils	10

- **Meets Seismic Stability Criteria – Criteria Weight 10**

The seismic requirements of the dam when considering slope stability must be met to meet the required factors of safety. The seismic zone in which the dam is situated can influence the requirements as well.

Meets Seismic Stability Criteria	
1	Meets seismic stability criteria and in low-risk zone
2	
3	Does not meet seismic stability criteria but in low-risk zone
4	
5	Does not meet seismic stability criteria but in high-risk zone

- **Seismic Risk Zone (High Risk = 5, Low = 1) – Criteria Weight 10**

The risk associated with the dam's seismic zone setting can affect the overall risk of the dam failing during a seismic event. Two-percent probability of exceedance in 50 years values were obtained using the Unified Hazard Tool provided by USGS. Figure 7 shows values for the entire country and how Iowa is in a low-risk zone.

Seismic Risk Zone (High Risk = 5, Low = 1)	
1	Value on 2% 50-yr seismicity map 0-0.039; no history of dam failures in area due to seismic events
2	Value on 2% 50-yr seismicity map 0.04-0.09
3	Value on 2% 50-yr seismicity map 0.1-0.19
4	Value on 2% 50-yr seismicity map 0.2-0.39
5	Value on 2% 50-yr seismicity map 0.4-0.8; previous dam failures in area due to seismic event

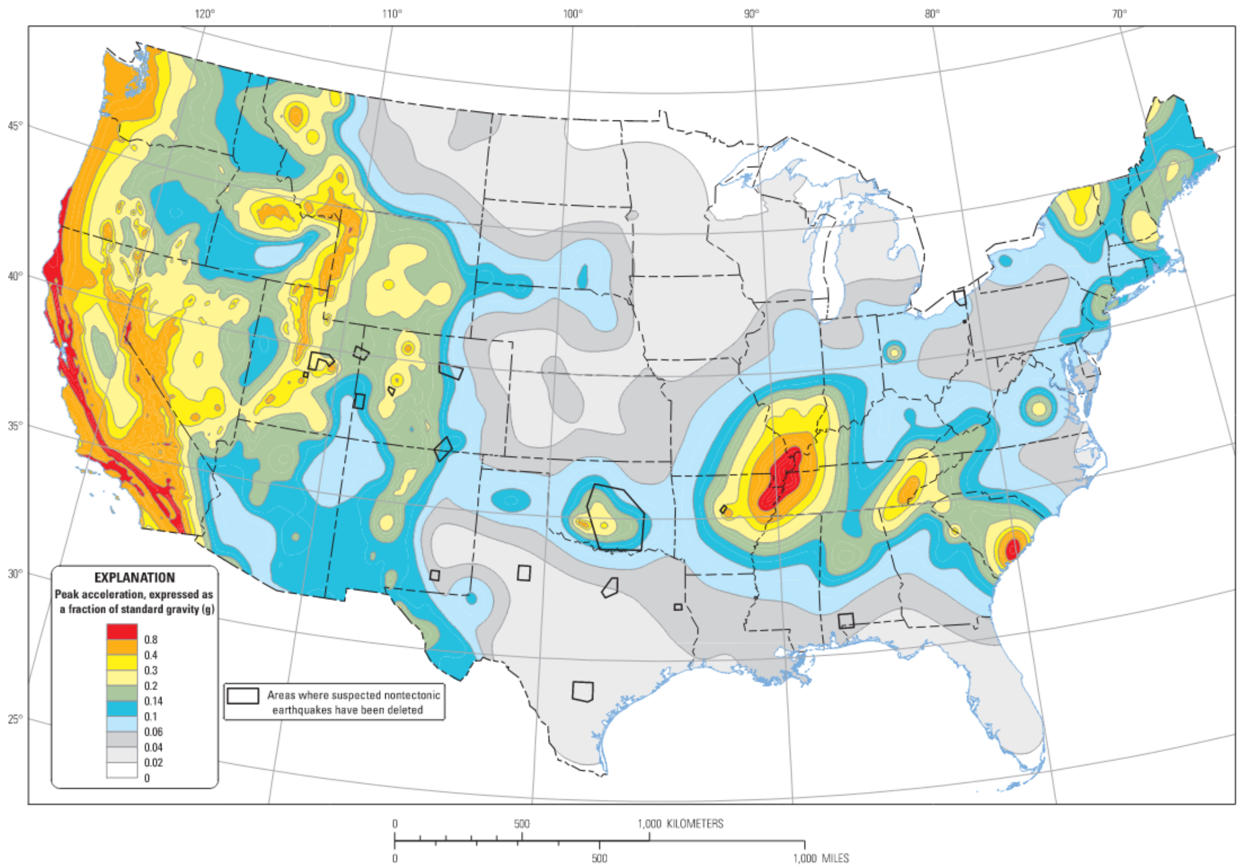

Figure 7. Two-percent probability of exceedance in 50 years map of peak ground acceleration

- **Liquifiable Subsurface Soils – Criteria Weight 10**

Liquefaction during seismic events can occur in saturated alluvial soils. The presence of alluvial deposits or other low strength soils in a saturated condition can lead to dam foundation failure during a seismic event.

Liquifiable Subsurface Soils	
1	No layers of sand and/or silty sand below water table
2	
3	Contains a layer of sand and/or silty sand below water table
4	
5	Contains multiple layers of sand and/or silty sand below water table

The overall seismic risk scores for each dam are shown in Table 7 and Figure 8.

Table 7. Total seismic risk score and prorated risk score sorted from highest to lowest risk

Dam No.	Dam	Seismic Score	Seismic Prorated Risk Score (1-5)	Seismic Rank
35	Schoenewe Dam	80	2.7	1
11	Focht & Schindel Dam	70	2.3	2
13	Glen Oaks Country Club Dam	70	2.3	2
23	Jefferson Park Watershed Site 5	70	2.3	2
26	Leisure Lake Dam	70	2.3	2
28	Meyer Dam	70	2.3	2
30	North Branch Ralston Creek Dam	70	2.3	2
34	Red Haw Dam	70	2.3	2
37	Viking Road Detention Dam	70	2.3	2
1	Bacon Creek Watershed Site A-1-1	60	2.0	10
2	Bacon Creek Watershed Site A-2-4	60	2.0	10
3	Bacon Creek Watershed Site A-3	60	2.0	10
4	Bacon Creek Watershed Site A-3-1	60	2.0	10
5	Bacon Creek Watershed Site C-1	60	2.0	10
9	Clive Lake Dam	60	2.0	10
18	Held Watershed Site E-4	60	2.0	10
27	Maffitt Reservoir Dam	60	2.0	10
7	Brushy Creek Dam	50	1.7	18
8	Carroll Stormwater Detention Dam	50	1.7	18
14	Grade Lake Dam	50	1.7	18
15	Greenfield Reservoir Dam	50	1.7	18
16	Hamburg Watershed Site M-1	50	1.7	18
17	Held Watershed Site E-3	50	1.7	18
19	Jefferson Park Watershed Site 1	50	1.7	18
29	Middle Pond Dam	50	1.7	18
31	Parkview Lake Dam	50	1.7	18
32	Pleasant Creek Lake Dam	50	1.7	18
38	West Lakes Office Park Dam	50	1.7	18
24	Lake of the Hills Dam	40	1.3	29
6	Beeds Lake Dam	30	1.0	30
10	Creston Flood Prevention Dam	30	1.0	30
12	Fort Des Moines Park Dam	30	1.0	30
20	Jefferson Park Watershed Site 10	30	1.0	30
21	Jefferson Park Watershed Site 3	30	1.0	30
22	Jefferson Park Watershed Site 4	30	1.0	30
25	Lake Ponderosa Dam	30	1.0	30
33	Prescott Flood Prevention Dam	30	1.0	30
36	Southfork Dam	30	1.0	30
39	Yellowsmoke Park Dam	30	1.0	30

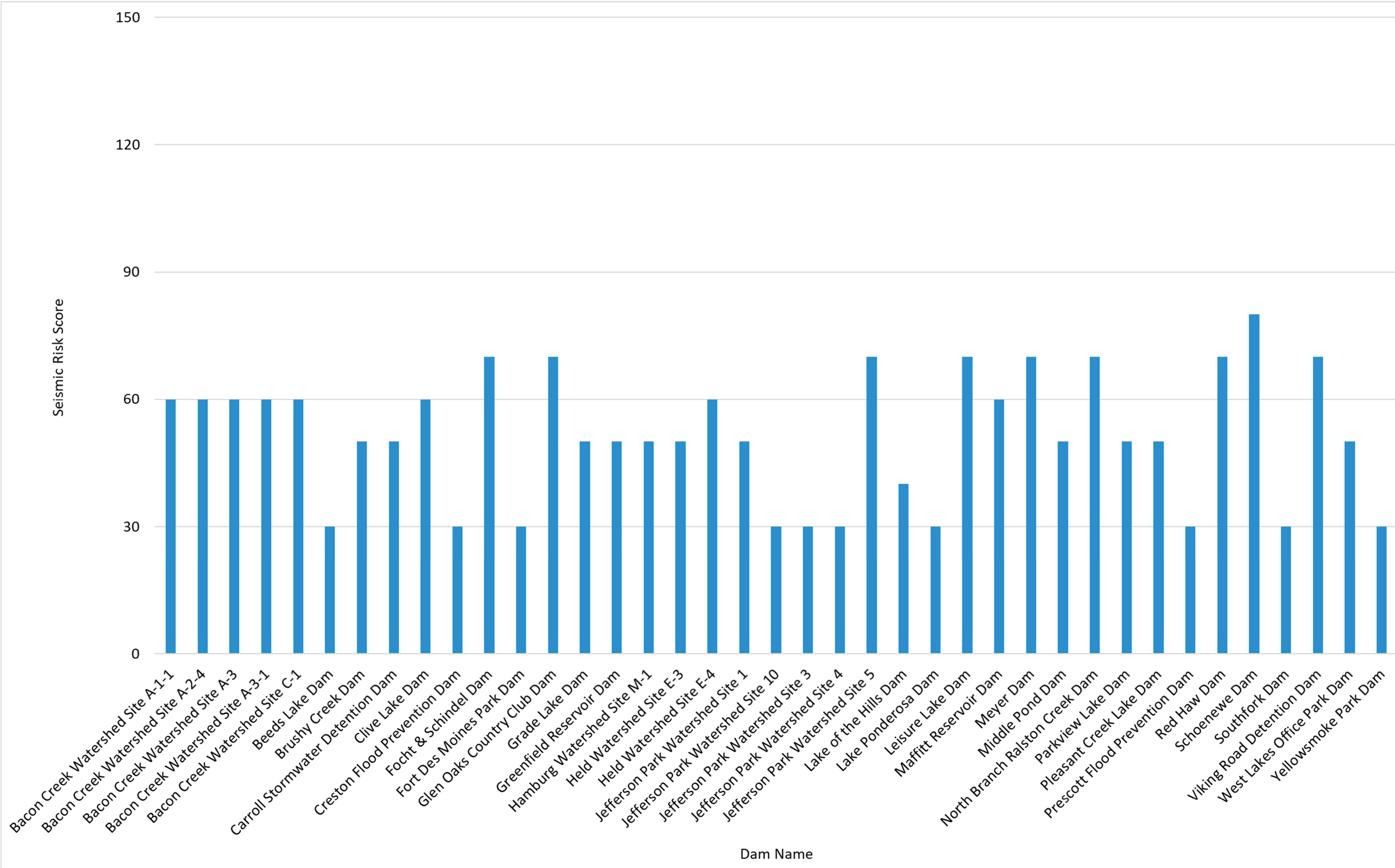

Figure 8. Total seismic risk scores for each assessed dam

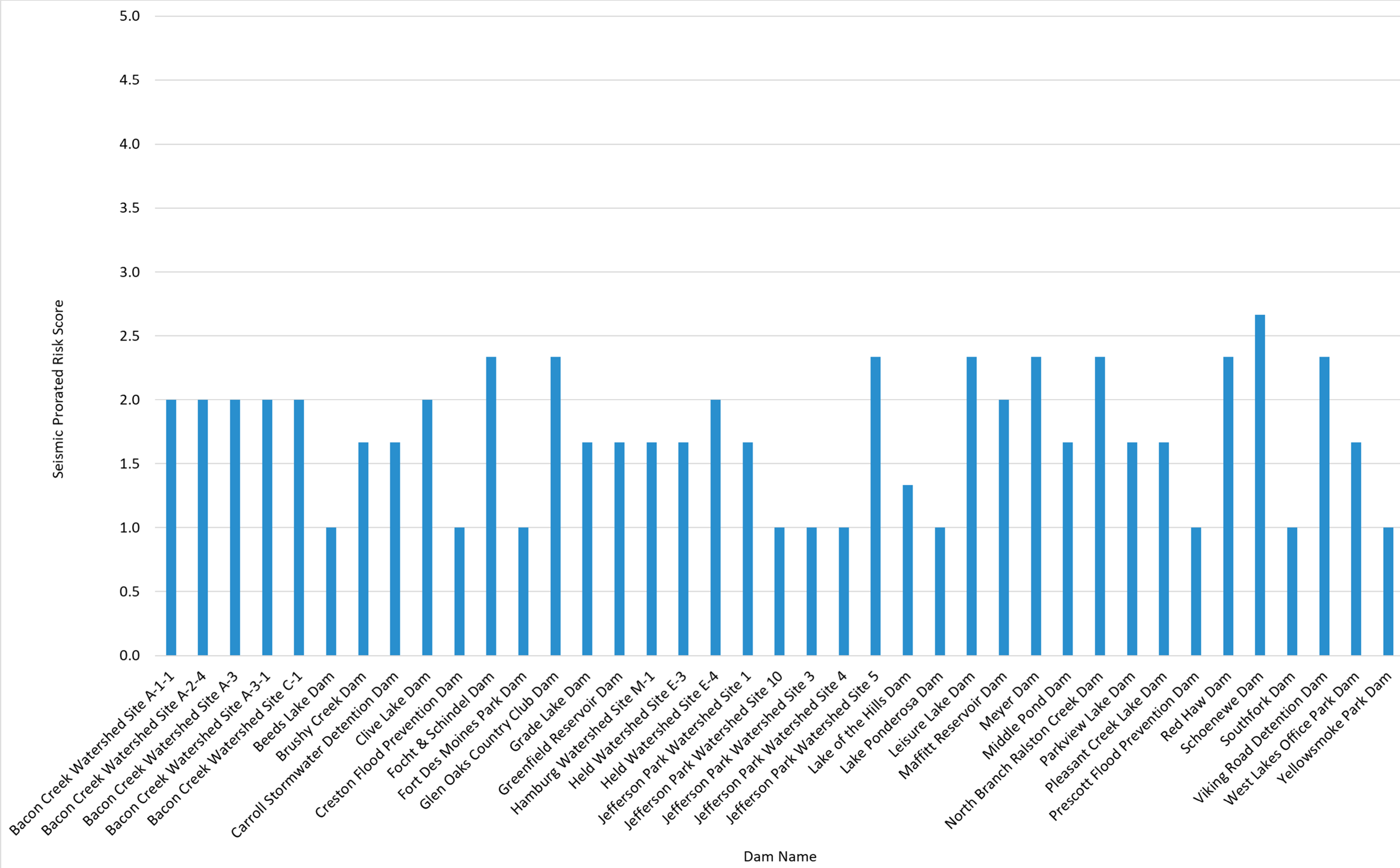

Figure 9. Seismic prorated risk score for each assessed dam

2.2.4 COMBINED RESULTS

The combined overall risk score and prorated risk scores for each dam are shown in Figure 10 and Figure 11, respectively, and are summarized in Table 8. For each category, dams have been ranked from highest risk to lowest risk with a 1 being the highest risk. The table is sorted from highest to lowest static and hydrologic combined risk. Red represents a score with a higher risk and green represents a score with a lower risk when compared to each other.

Table 8. Total static, hydrologic, seismic, combined, and static and hydrologic combined risk scores

Dam No.	Dam Name	Static Score	Static Prorated Risk Score	Static Rank	Hydrologic Score	Hydrologic Prorated Risk Score	Hydrologic Rank	Seismic Score	Seismic Prorated Risk Score	Seismic Rank	Overall Score	Overall Prorated Risk Score	Overall Rank	Static + Hydrologic Score	Static + Hydrologic Prorated Risk Score	Static + Hydrologic Rank
29	Middle Pond Dam	312	4.2	1	179	2.8	15	50	1.7	18	541	3.2	2	491	3.6	1
35	Schoenewe Dam	270	3.6	2	208	3.3	9	80	2.7	1	558	3.3	1	478	3.5	2
26	Leisure Lake Dam	263	3.5	3	201	3.2	11	70	2.3	2	534	3.2	3	464	3.4	3
11	Focht & Schindel Dam	212	2.8	6	240	3.8	2	70	2.3	2	522	3.1	4	452	3.3	4
23	Jefferson Park Watershed Site 5	194	2.6	12	249	4.0	1	70	2.3	2	513	3.1	5	443	3.2	5
17	Held Watershed Site E-3	204	2.7	8	223	3.5	4	50	1.7	18	477	2.8	7	427	3.1	6
22	Jefferson Park Watershed Site 4	206	2.7	7	216	3.4	5	30	1.0	30	452	2.7	11	422	3.1	7
28	Meyer Dam	195	2.6	11	225	3.6	3	70	2.3	2	490	2.9	6	420	3.0	8
3	Bacon Creek Watershed Site A-3	238	3.2	4	177	2.8	16	60	2.0	10	475	2.8	8	415	3.0	9
18	Held Watershed Site E-4	198	2.6	9	215	3.4	7	60	2.0	10	473	2.8	9	413	3.0	10
2	Bacon Creek Watershed Site A-2-4	217	2.9	5	174	2.8	18	60	2.0	10	451	2.7	12	391	2.8	11
13	Glen Oaks Country Club Dam	176	2.3	19	211	3.3	8	70	2.3	2	457	2.7	10	387	2.8	12
19	Jefferson Park Watershed Site 1	197	2.6	10	177	2.8	16	50	1.7	18	424	2.5	15	374	2.7	13
37	Viking Road Detention Dam	178	2.4	18	183	2.9	13	70	2.3	2	431	2.6	13	361	2.6	14
34	Red Haw Dam	175	2.3	20	182	2.9	14	70	2.3	2	427	2.5	14	357	2.6	15
16	Hamburg Watershed Site M-1	180	2.4	16	174	2.8	18	50	1.7	18	404	2.4	16	354	2.6	16
21	Jefferson Park Watershed Site 3	148	2.0	31	204	3.2	10	30	1.0	30	382	2.3	21	352	2.6	17
7	Brushy Creek Dam	175	2.3	20	165	2.6	24	50	1.7	18	390	2.3	17	340	2.5	18
8	Carroll Stormwater Detention Dam	149	2.0	30	188	3.0	12	50	1.7	18	387	2.3	18	337	2.4	19
6	Beeds Lake Dam	185	2.5	14	150	2.4	30	30	1.0	30	365	2.2	25	335	2.4	20
32	Pleasant Creek Lake Dam	182	2.4	15	152	2.4	29	50	1.7	18	384	2.3	20	334	2.4	21
15	Greenfield Reservoir Dam	173	2.3	22	157	2.5	27	50	1.7	18	380	2.3	23	330	2.4	22
12	Fort Des Moines Park Dam	157	2.1	27	171	2.7	22	30	1.0	30	358	2.1	26	328	2.4	23
31	Parkview Lake Dam	151	2.0	29	174	2.8	18	50	1.7	18	375	2.2	24	325	2.4	24
4	Bacon Creek Watershed Site A-3-1	148	2.0	31	174	2.8	18	60	2.0	10	382	2.3	21	322	2.3	25
20	Jefferson Park Watershed Site 10	104	1.4	39	216	3.4	5	30	1.0	30	350	2.1	28	320	2.3	26
10	Creston Flood Prevention Dam	172	2.3	23	147	2.3	31	30	1.0	30	349	2.1	29	319	2.3	27
30	North Branch Ralston Creek Dam	152	2.0	28	163	2.6	25	70	2.3	2	385	2.3	19	315	2.3	28
33	Prescott Flood Prevention Dam	172	2.3	23	141	2.2	32	30	1.0	30	343	2.0	31	313	2.3	29
25	Lake Ponderosa Dam	172	2.3	23	131	2.1	33	30	1.0	30	333	2.0	34	303	2.2	30
14	Grade Lake Dam	179	2.4	17	123	2.0	35	50	1.7	18	352	2.1	27	302	2.2	31
39	Yellowsmoke Park Dam	167	2.2	26	127	2.0	34	30	1.0	30	324	1.9	36	294	2.1	32
27	Maffitt Reservoir Dam	188	2.5	13	101	1.6	38	60	2.0	10	349	2.1	29	289	2.1	33
5	Bacon Creek Watershed Site C-1	123	1.6	34	159	2.5	26	60	2.0	10	342	2.0	32	282	2.0	34
1	Bacon Creek Watershed Site A-1-1	109	1.5	38	167	2.7	23	60	2.0	10	336	2.0	33	276	2.0	35
9	Clive Lake Dam	113	1.5	37	154	2.4	28	60	2.0	10	327	1.9	35	267	1.9	36
38	West Lakes Office Park Dam	140	1.9	33	117	1.9	37	50	1.7	18	307	1.8	37	257	1.9	37
36	Southfork Dam	121	1.6	35	121	1.9	36	30	1.0	30	272	1.6	38	242	1.8	38
24	Lake of the Hills Dam	119	1.6	36	95	1.5	39	40	1.3	29	254	1.5	39	214	1.6	39

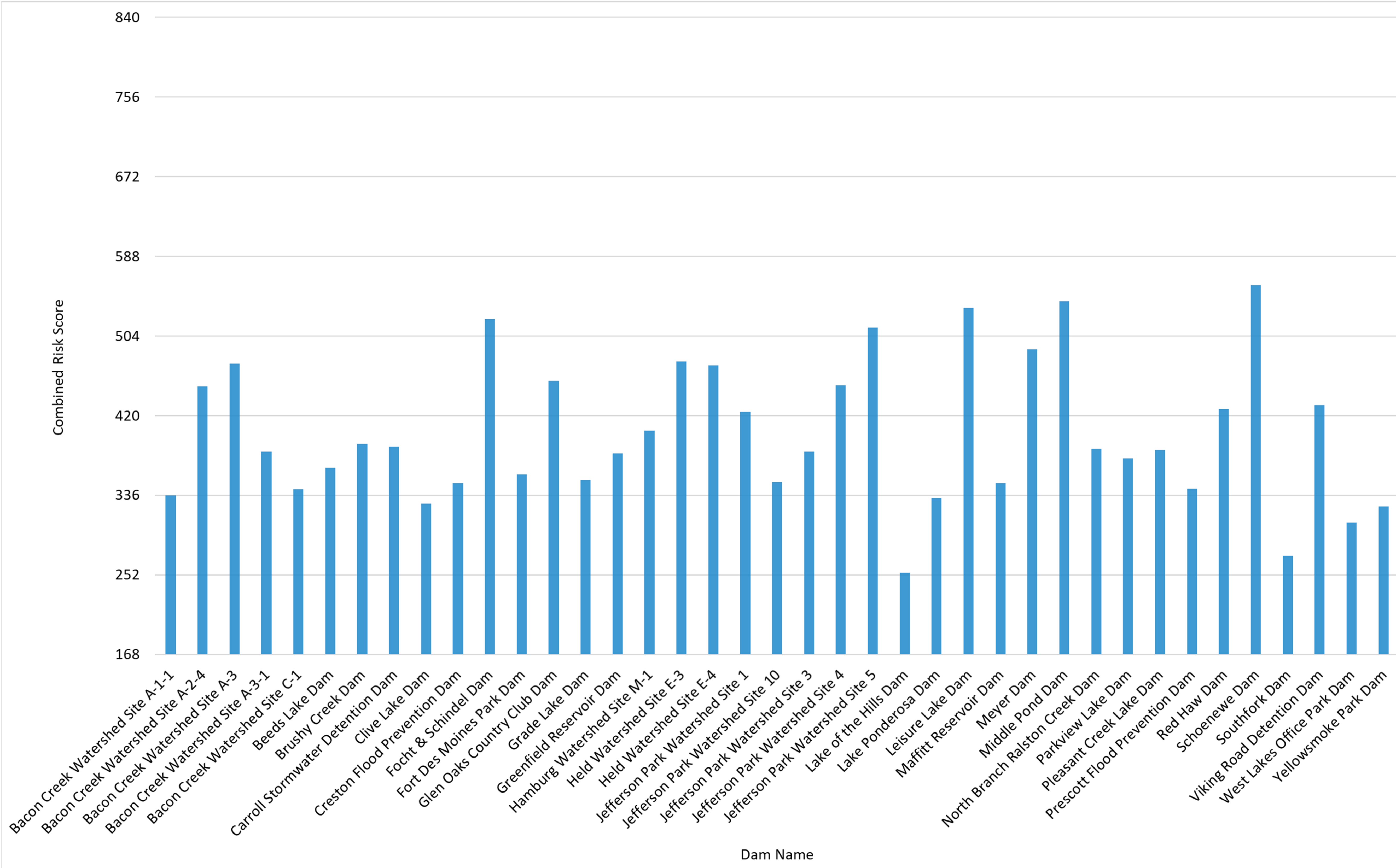

Figure 10. Combined total risk scores for each assessed dam

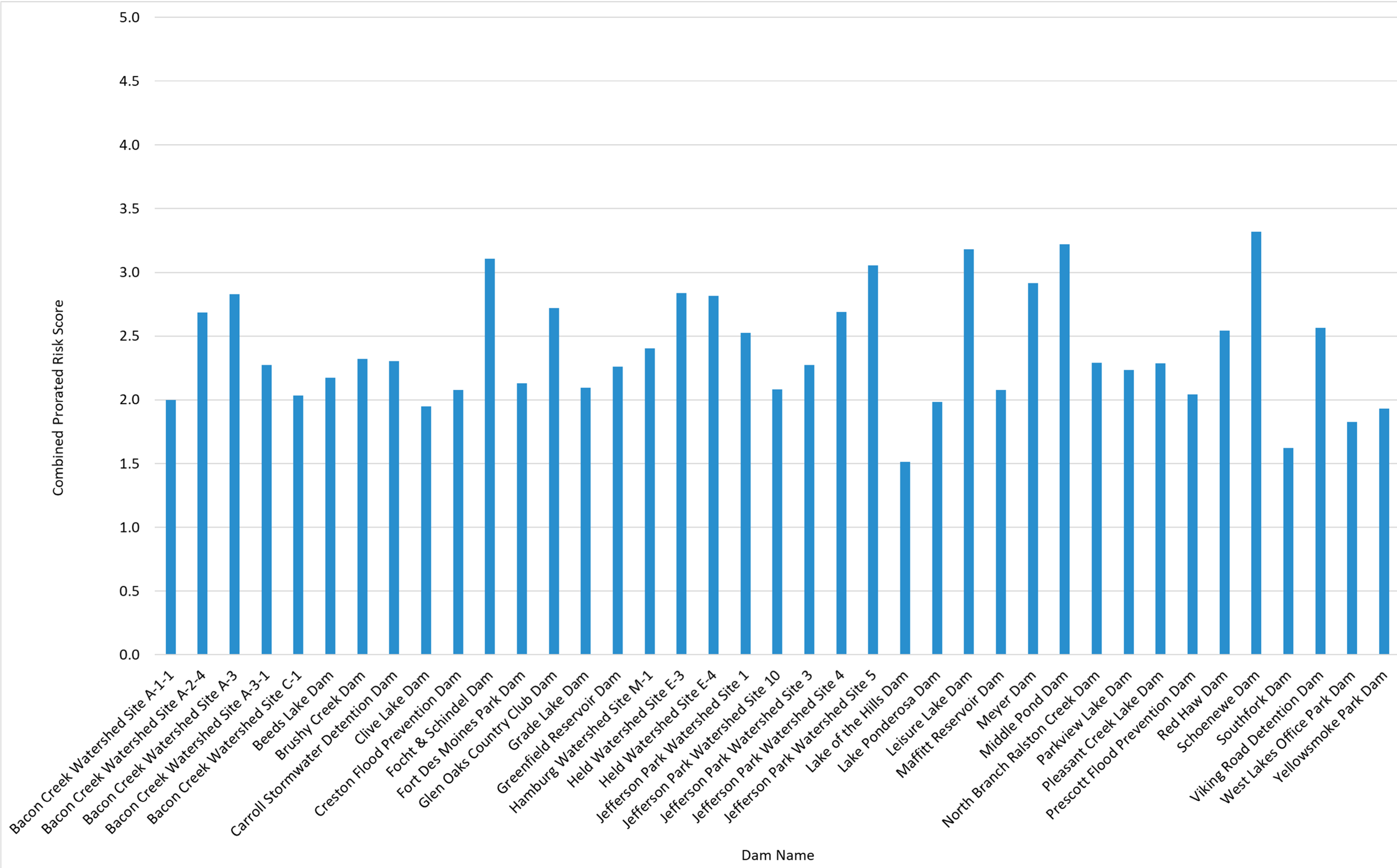

Figure 11. Combined prorated risk score for each assessed dam

In order to better illustrate the lack of seismic influence in the region, Figure 12 and Figure 13 were developed to show the static and hydrologic combined risk score and prorated risk score for each dam. These figures are summarized in Table 9.

Table 9. Static and hydrologic combined score, prorated risk score, and comparative rank for each assessed dam. Dams are sorted from highest to lowest risk score.

Dam No.	Dam Name	Static + Hydrologic Score	Static + Hydrologic Prorated Risk Score (1-5)	Static + Hydrologic Rank
29	Middle Pond Dam	491	3.6	1
35	Schoenewe Dam	478	3.5	2
26	Leisure Lake Dam	464	3.4	3
11	Focht & Schindel Dam	452	3.3	4
23	Jefferson Park Watershed Site 5	443	3.2	5
17	Held Watershed Site E-3	427	3.1	6
22	Jefferson Park Watershed Site 4	422	3.1	7
28	Meyer Dam	420	3.0	8
3	Bacon Creek Watershed Site A-3	415	3.0	9
18	Held Watershed Site E-4	413	3.0	10
2	Bacon Creek Watershed Site A-2-4	391	2.8	11
13	Glen Oaks Country Club Dam	387	2.8	11
19	Jefferson Park Watershed Site 1	374	2.7	13
37	Viking Road Detention Dam	361	2.6	14
34	Red Haw Dam	357	2.6	15
16	Hamburg Watershed Site M-1	354	2.6	16
21	Jefferson Park Watershed Site 3	352	2.6	17
7	Brushy Creek Dam	340	2.5	18
8	Carroll Stormwater Detention Dam	337	2.4	19
6	Beeds Lake Dam	335	2.4	20
32	Pleasant Creek Lake Dam	334	2.4	20
15	Greenfield Reservoir Dam	330	2.4	22
12	Fort Des Moines Park Dam	328	2.4	23
31	Parkview Lake Dam	325	2.4	24
4	Bacon Creek Watershed Site A-3-1	322	2.3	25
20	Jefferson Park Watershed Site 10	320	2.3	26
10	Creston Flood Prevention Dam	319	2.3	27
30	North Branch Ralston Creek Dam	315	2.3	28
33	Prescott Flood Prevention Dam	313	2.3	28
25	Lake Ponderosa Dam	303	2.2	30
14	Grade Lake Dam	302	2.2	31
39	Yellowsmoke Park Dam	294	2.1	32
27	Maffitt Reservoir Dam	289	2.1	32
5	Bacon Creek Watershed Site C-1	282	2.0	34
1	Bacon Creek Watershed Site A-1-1	276	2.0	34
9	Clive Lake Dam	267	1.9	36
38	West Lakes Office Park Dam	257	1.9	37
36	Southfork Dam	242	1.8	38
24	Lake of the Hills Dam	214	1.6	39

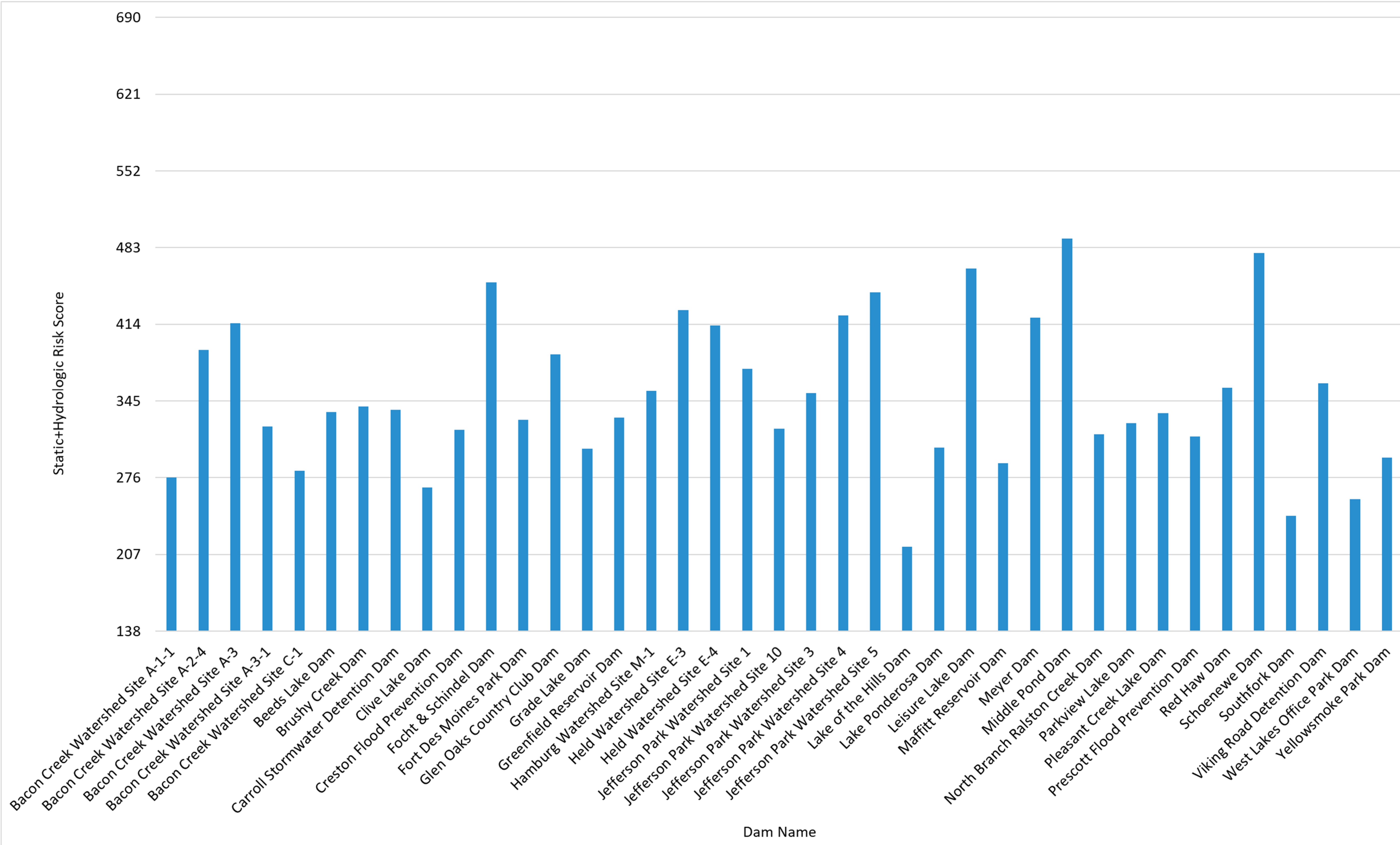

Figure 12. Static and hydrologic combined risk score for each assessed dam

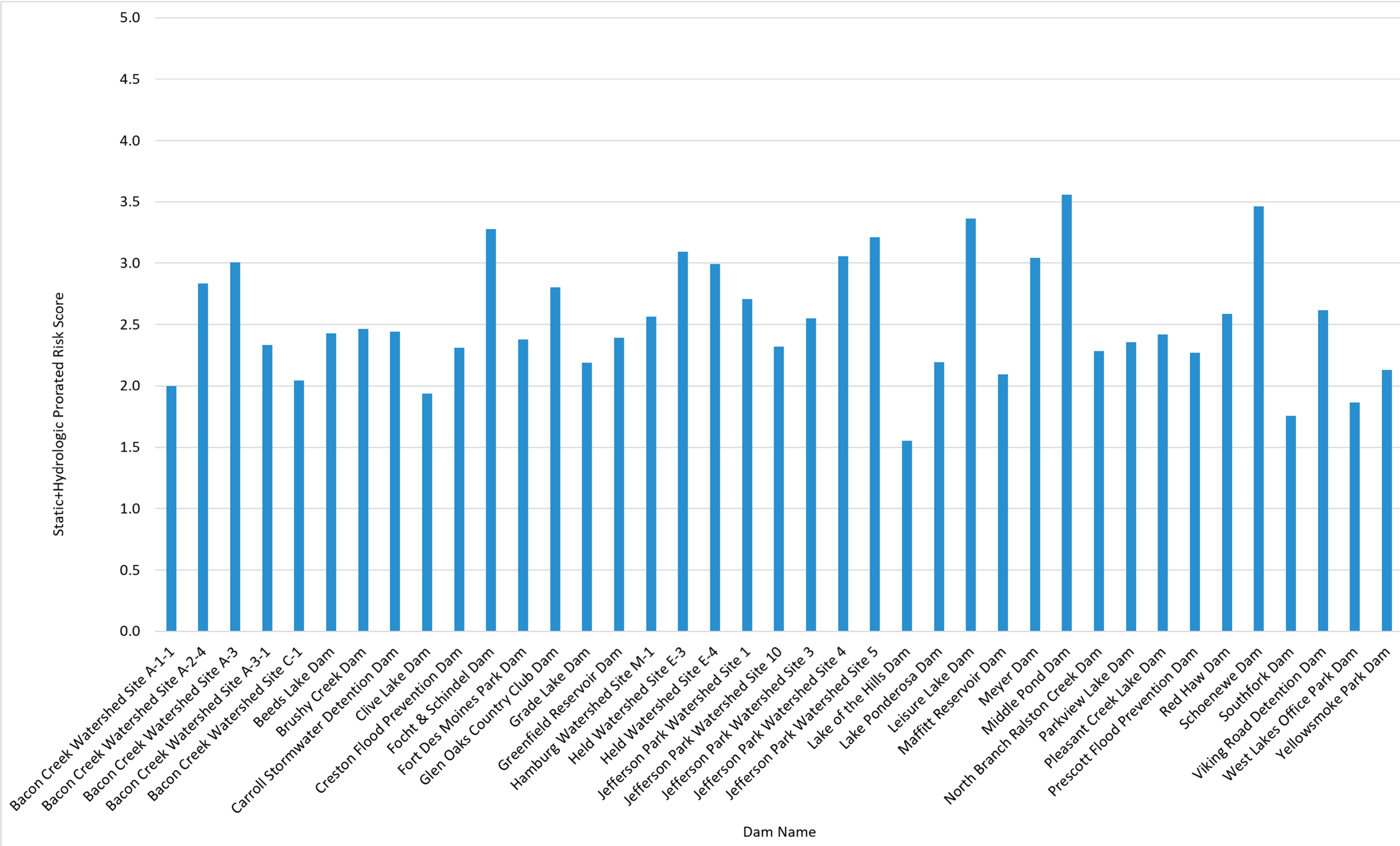

Figure 13. Static and hydrologic combined prorated risk score for each assessed dam

2.3 TASK 3: DOWNSTREAM IMPACTS ASSESSMENT

2.3.1 POPULATION AT RISK (PAR)

Population at Risk (PAR) measures the number of people potentially caught within the breach path downstream of a dam during a dam failure. Iowa DNR performed a breach analysis on each high hazard dam using DSS-WISE; a FEMA-supported flood modeling and mapping program. The loading condition chosen for the breach analysis was assumed to be at the auxiliary spillway elevation. Due to the program's inability to model dynamic outlet works flows during a breach, the loading condition selected was the most consistent across all the dams. If no auxiliary spillway exists on the dam, the loading condition was assumed to be at the 100-year water surface elevation as that is a minimum design standard for principal spillway hydrographs on high hazard dams in Iowa. If neither the auxiliary spillway nor principal spillway was used for the loading conditions, another known benchmark was chosen by the DNR as they saw best fit. DSS-WISE produces both inundation extents and PAR. The PAR calculation combines flood simulation results, 2010 census block data, and LandScanUSA gridded nighttime and daytime population data. The PAR is a summation of individuals at risk within the inundation area for each flood hazard category. For more detailed methodology see DSS-WISE HCOM: Human Consequences of Dam Break Floods (FEMA, 2018). To give each dam a rating, the maximum PAR value between the total nighttime and total daytime PARs was used. The rating scale was based on industry standards grouping the PAR into population ranges and adjusted to fit the five-option ranking system.

PAR (Individuals)	
1	0
2	1-10
3	10-100
4	100-1000
5	1000+

To verify the DSS-WISE results, 2020 census block data and the inundation flood extents were processed in ArcGIS to calculate the number of structures with the inundated area and population in affected census blocks. Both values were compared to the DSS-WISE outputs and similar trends were noticed to accept the DSS-WISE PAR results. However, HEI recommends that once DSS-WISE updates the census data from 2010 to 2020 that the PAR rankings be reevaluated and adjusted if necessary. HEI also recommends that future 2D breach analyses are performed with the maximum breach potential with a top of dam loading condition and with the dam's supplemental flows to estimate downstream impacts and population at risk. A tabular list of the dam's PAR values is shown in Table 10.

Table 10. PAR values for each assessed dam

Dam No.	Dam Name	PAR
1	Bacon Creek Watershed Site A-1-1	21
2	Bacon Creek Watershed Site A-2-4	1405
3	Bacon Creek Watershed Site A-3	194
4	Bacon Creek Watershed Site A-3-1	24
5	Bacon Creek Watershed Site C-1	126
6	Beeds Lake Dam	31
7	Brushy Creek Dam	9
8	Carroll Stormwater Detention Dam	274
9	Clive Lake Dam	293
10	Creston Flood Prevention Dam	307
11	Focht & Schindel Dam	119
12	Fort Des Moines Park Dam	8
13	Glen Oaks Country Club Dam	43
14	Grade Lake Dam	4
15	Greenfield Reservoir Dam	15
16	Hamburg Watershed Site M-1	181
17	Held Watershed Site E-3	102
18	Held Watershed Site E-4	120
19	Jefferson Park Watershed Site 1	5
20	Jefferson Park Watershed Site 10	2944
21	Jefferson Park Watershed Site 3	1056
22	Jefferson Park Watershed Site 4	89
23	Jefferson Park Watershed Site 5	178
24	Lake of the Hills Dam	1786
25	Lake Ponderosa Dam	9
26	Leisure Lake Dam	7
27	Maffitt Reservoir Dam	57
28	Meyer Dam	164
29	Middle Pond Dam	7
30	North Branch Ralston Creek Dam	2199
31	Parkview Lake Dam	141
32	Pleasant Creek Lake Dam	12
33	Prescott Flood Prevention Dam	38
34	Red Haw Dam	6
35	Schoenewe Dam	8
36	Southfork Dam	95
37	Viking Road Detention Dam	1040
38	West Lakes Office Park Dam	61
39	Yellowsmoke Park Dam	12

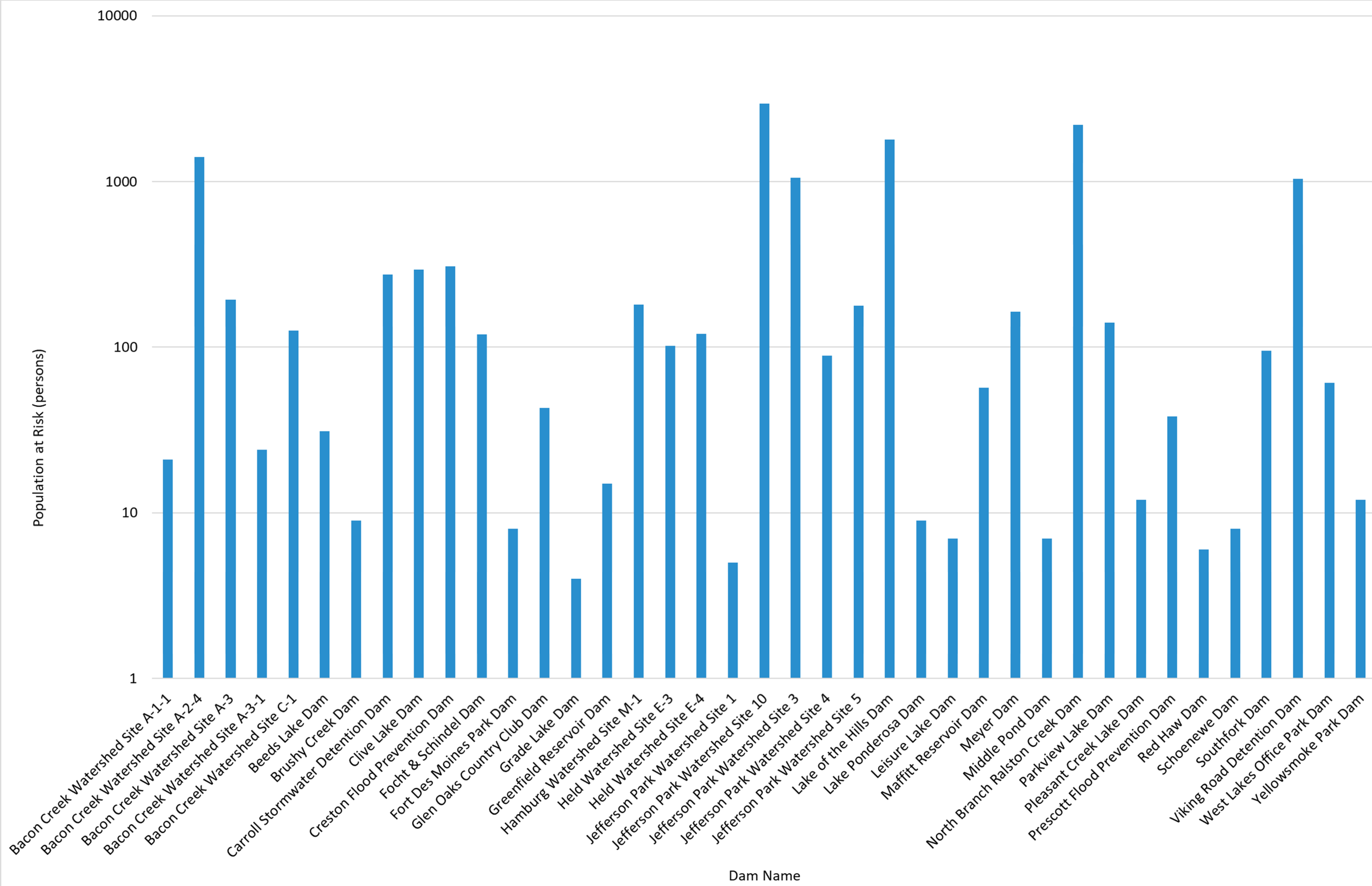

Figure 14. Maximum PAR (log-scale) downstream of each dam

2.3.2 ENVIRONMENTAL IMPACTS

The risk to environmental facilities downstream of a dam breach can have large impacts on the surrounding area. The impacts can cause environmental damage and potential human exposure to various environmental hazards. Some of the major environmental impacts due to a dam failure include:

- Flooding and Erosion: A dam breach can result in a sudden and large-scale release of water, leading to downstream flooding. This flooding can cause erosion of the surrounding soil, potentially damaging or destroying environmental facilities in its path. Infrastructure, buildings, and equipment in low-lying areas can be particularly vulnerable.
- Water Contamination: The water released during a dam breach may contain sediments, pollutants, and debris that can contaminate downstream water bodies. Environmental facilities relying on clean water sources, such as water treatment plants may be directly affected by the influx of polluted water. Contamination can lead to disruption of operations, reduced water quality, and potential harm to aquatic ecosystems and human health.
- Release of Hazardous Materials: Depending on the nature of the dam breach and the facilities located upstream, there is a risk of hazardous materials being released into the downstream environment. Industrial facilities, storage sites, or chemical plants located near the dam can pose a threat if their contents are swept away by the floodwaters. The release of toxic substances can have long-lasting effects on the environment, wildlife, and human health.
- Long-term Environmental Recovery: The environmental impacts of a dam breach can persist long after the initial event. Restoration and recovery of ecosystems, soil quality, and water bodies downstream can take years or even decades. The disruption of environmental facilities can further delay the recovery process and hamper the restoration of the affected area.

GIS analysis was performed to determine the number of environmental facilities impacted by a potential dam failure. This consisted of intersecting the breach inundation extents with a 100-foot buffer of the critical facility point. The buffer was used to account for the uncertainty of the point encompassing the entire facility. This analysis does not account for depth or velocities observed at each facility. The data for environmental facilities was obtained through the Iowa Geospatial Data website (https://geodata.iowa.gov/). The specific classes of facilities included in the GIS coverage include air facilities, chemical storage facilities, commercial manure applications, contaminated sites facilities, solid waste facilities, solid waste land application, stormwater industrial rock and asphalt facilities, wastewater industrial facilities, wastewater treatment plants, and water treatment plant facilities.

The total sum of environmental facilities in the breach paths ranged from 0 to 38 as shown in Figure 15. Each of these facilities was weighed the same amount for impact and importance. A breakdown of the specific environmental facilities at risk for each dam is shown in Appendix E.

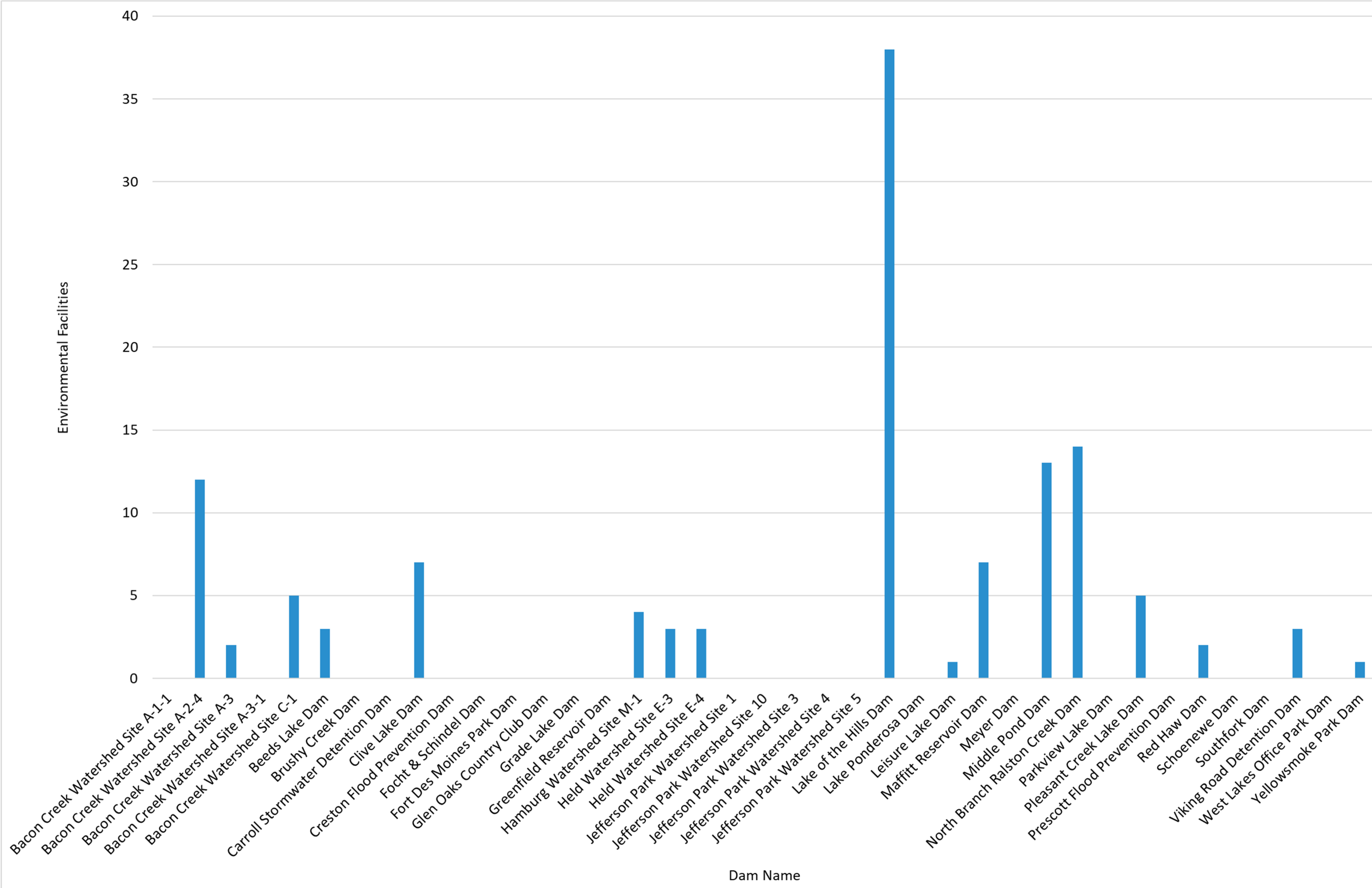

Figure 15. Environmental facilities impacted at maximum inundation

2.3.3 INFRASTRUCTURE/CRITICAL FACILITY IMPACTS

Critical facilities refer to essential buildings and infrastructure that play a crucial role in supporting a community during and after a disaster. These facilities are typically vital for the stability of operations for communities, emergency response, and the well-being of the affected population. These facilities included hospitals, medical clinics, fire stations, police stations, emergency operation centers, schools, colleges/universities, bridges, railways, power plants, potable water facilities, and wastewater pipes. Critical facility GIS data was obtained through HAZUS, a software tool developed by FEMA in the United States.

GIS analysis was performed to determine the number of critical facilities impacted by a potential dam failure. The GIS analysis consisted of intersecting the breach inundation extents with a 100-foot buffer around the critical facility point. The buffer was used to account for the uncertainty of the point encompassing the entire facility. This analysis does not account for depth or velocities observed at each facility.

The table In Appedix F breaks down critical facilities by type and quantity at each site. Total critical facilities in the breach paths ranged from 0 to 31, as shown in Figure 16. Each of these facilities was weighted the same amount for impact and importance.

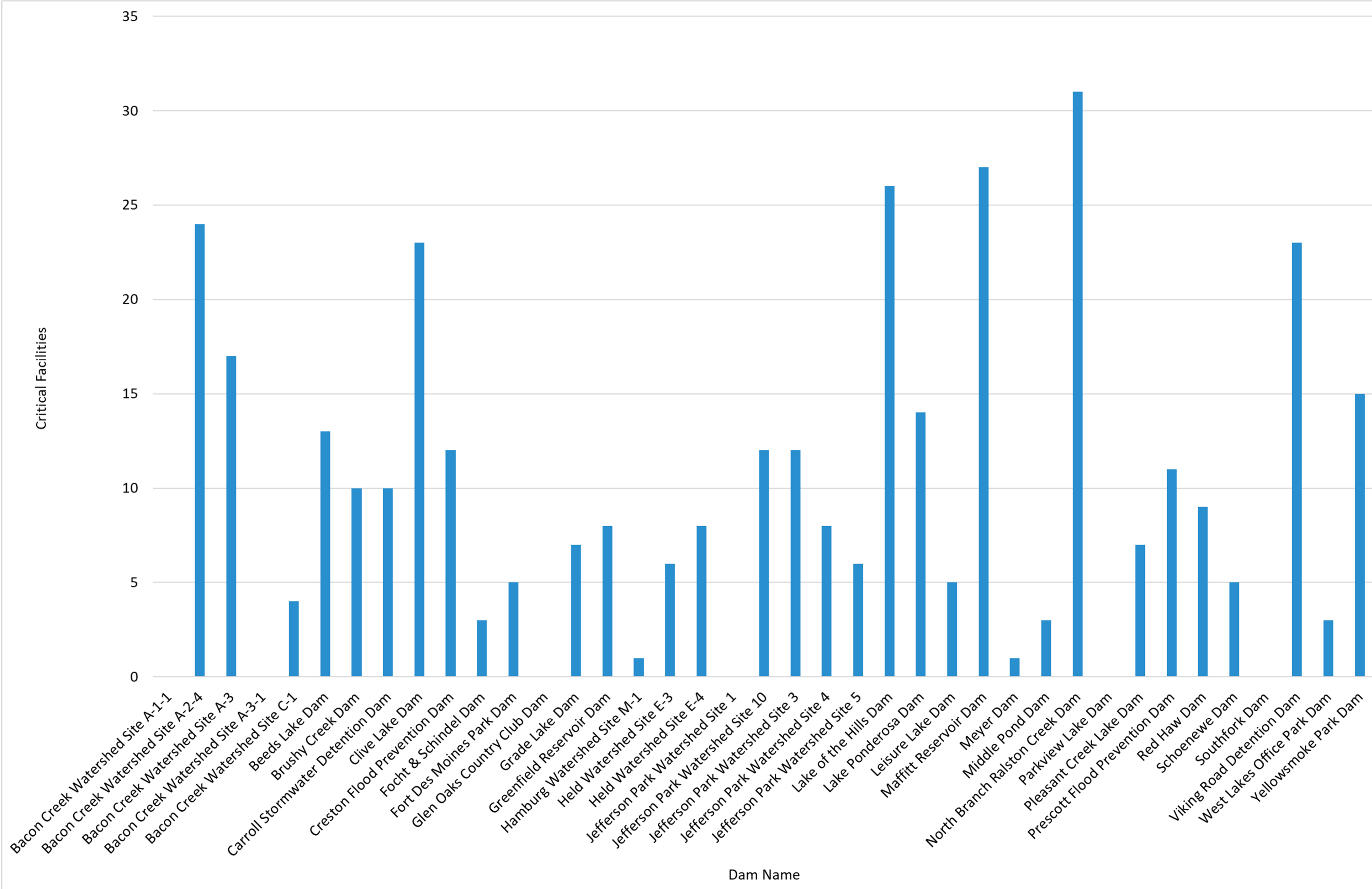

Figure 16. Number of critical facilities impacted by each dam's maximum inundation

To incorporate the environmental and critical facilities into the final risk, the values were combined to get a total number of impacted sites. A tabular summary of these values is shown in Table 11.

Table 11. Total Impacted Facilities

Dam No.	Dam Name	Environmental Sites	Critical Facilities	Total Sites Impacted
1	Bacon Creek Watershed Site A-1-1	0	0	0
2	Bacon Creek Watershed Site A-2-4	12	24	36
3	Bacon Creek Watershed Site A-3	2	17	19
4	Bacon Creek Watershed Site A-3-1	0	0	0
5	Bacon Creek Watershed Site C-1	5	4	9
6	Beeds Lake Dam	3	13	16
7	Brushy Creek Dam	0	10	10
8	Carroll Stormwater Detention Dam	0	10	10
9	Clive Lake Dam	7	23	30
10	Creston Flood Prevention Dam	0	12	12
11	Focht & Schindel Dam	0	3	3
12	Fort Des Moines Park Dam	0	5	5
13	Glen Oaks Country Club Dam	0	0	0
14	Grade Lake Dam	0	7	7
15	Greenfield Reservoir Dam	0	8	8
16	Hamburg Watershed Site M-1	4	1	5
17	Held Watershed Site E-3	3	6	9
18	Held Watershed Site E-4	3	8	11
19	Jefferson Park Watershed Site 1	0	0	0
20	Jefferson Park Watershed Site 10	0	12	12
21	Jefferson Park Watershed Site 3	0	12	12
22	Jefferson Park Watershed Site 4	0	8	8
23	Jefferson Park Watershed Site 5	0	6	6
24	Lake of the Hills Dam	38	26	64
25	Lake Ponderosa Dam	0	14	14
26	Leisure Lake Dam	1	5	6
27	Maffitt Reservoir Dam	7	27	34
28	Meyer Dam	0	1	1
29	Middle Pond Dam	13	3	16
30	North Branch Ralston Creek Dam	14	31	45
31	Parkview Lake Dam	0	0	0
32	Pleasant Creek Lake Dam	5	7	12
33	Prescott Flood Prevention Dam	0	11	11
34	Red Haw Dam	2	9	11
35	Schoenewe Dam	0	5	5
36	Southfork Dam	0	0	0
37	Viking Road Detention Dam	3	23	26
38	West Lakes Office Park Dam	0	3	3
39	Yellowsmoke Park Dam	1	15	16

Below is how the values were grouped to fit the 5 tier ranking system. This scale was used to adjust the graphical point size on the figures in section 2.3.4 to represent the risk of facilities impacted; the bigger the point size the more facilities at risk.

Environmental + Critical Facility Impacts	
1	0 facilities
2	1 – 5 facilities
3	6 – 10 facilities
4	11 – 20 facilities
5	21+ facilities

2.3.4 COMBINED ANALYSIS

Using guidance from FEMA, a graph comparing failure risk with PAR was used to analyze the overall risk of each High Hazard dam (Figure 17). The y-axis is the total combined failure risk, ranging from 150 as the lowest risk to 950 as the highest risk. The x-axis is the PAR on a log-10 scale.

Figure 18 shows the same dataset but with a prorated risk score on the y-axis. The raw scores were prorated to adjust to the 1-5 rating system used throughout this analysis. Figure 19 and Figure 20 incorporate a third dimension to illustrate the number of environmental and critical facilities at risk. The size of the data point represents how many environmental and critical facilities are impacted if the dam fails. For dams with similar PAR and PFM scores, impacts to environmental and critical facilities can help with further differentiating similar dams. This graph can act as a prioritization tool to help assess risk and prioritize future dam rehabilitation based on potential failure score, PAR, and impacts to environmental and critical facilities. Dam safety officials can allocate resources to highest priority dams and focus on specific elements of a dam based on the risk of each separate PFM. Figure 21, shows each PFM score and the PAR to help demonstrate the higher PFM risk associated with each PAR.

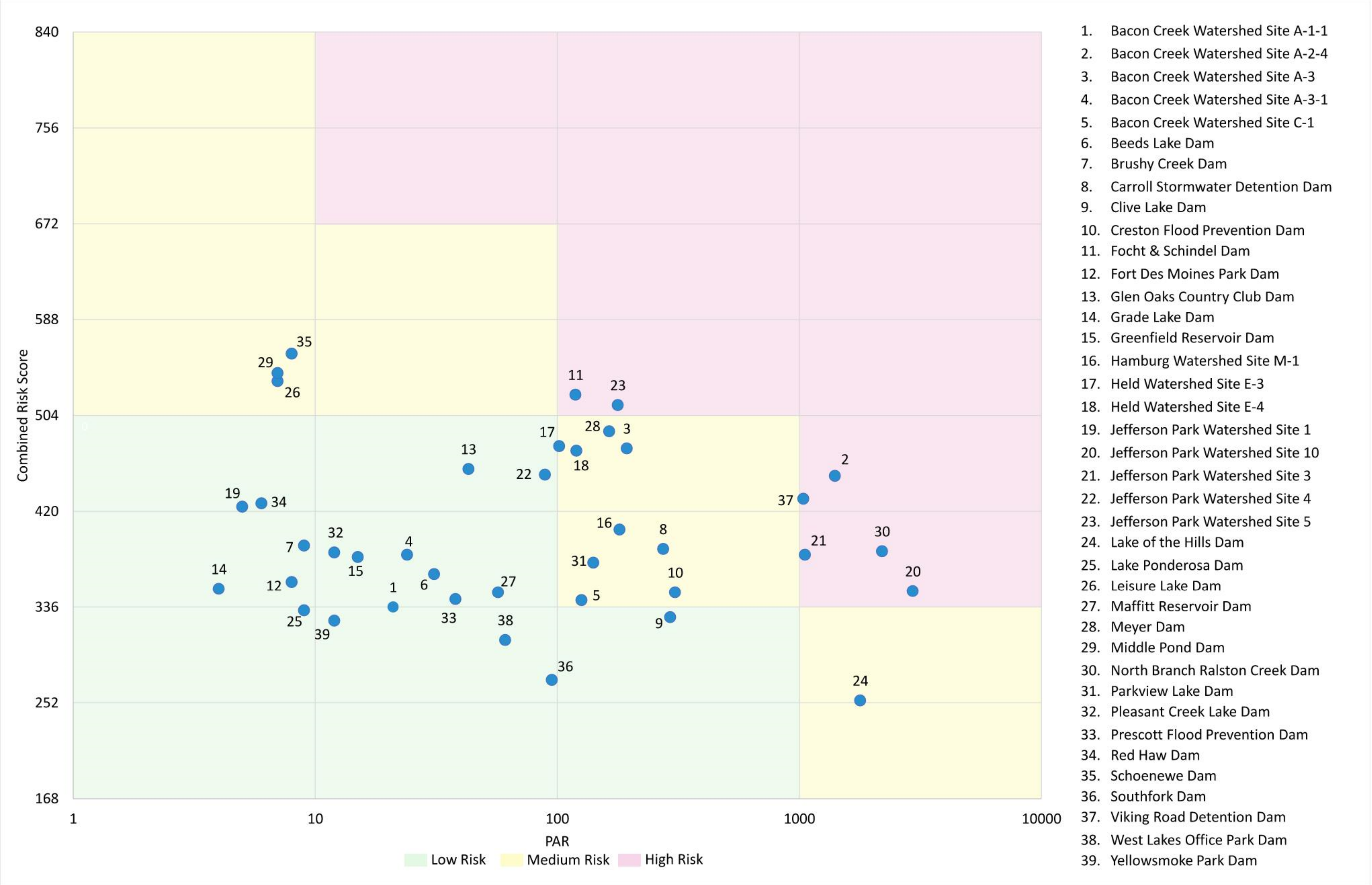

Figure 17. Combined risk score as a function of PAR

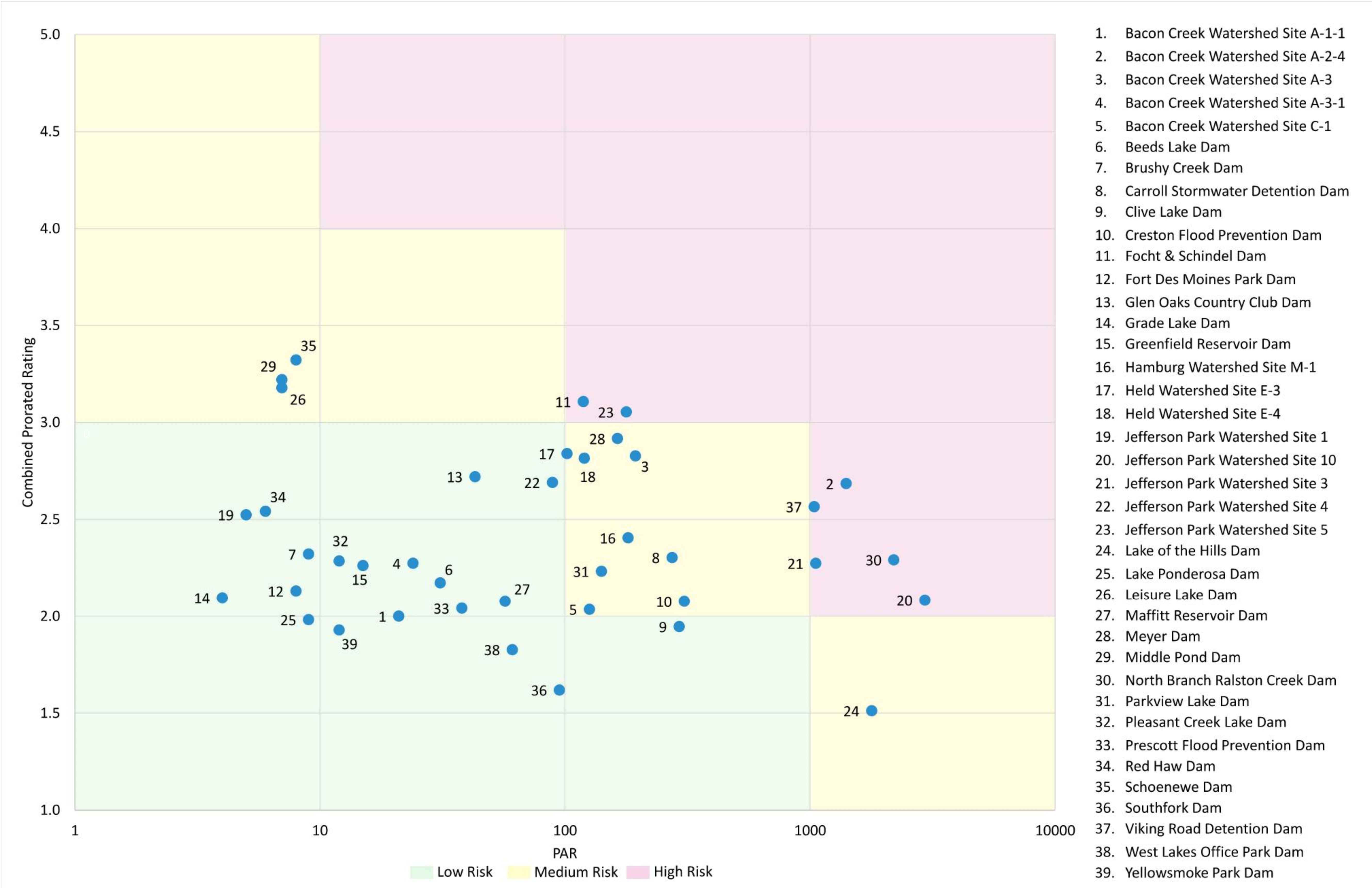

Figure 18. Combined prorated risk score as a function of PAR

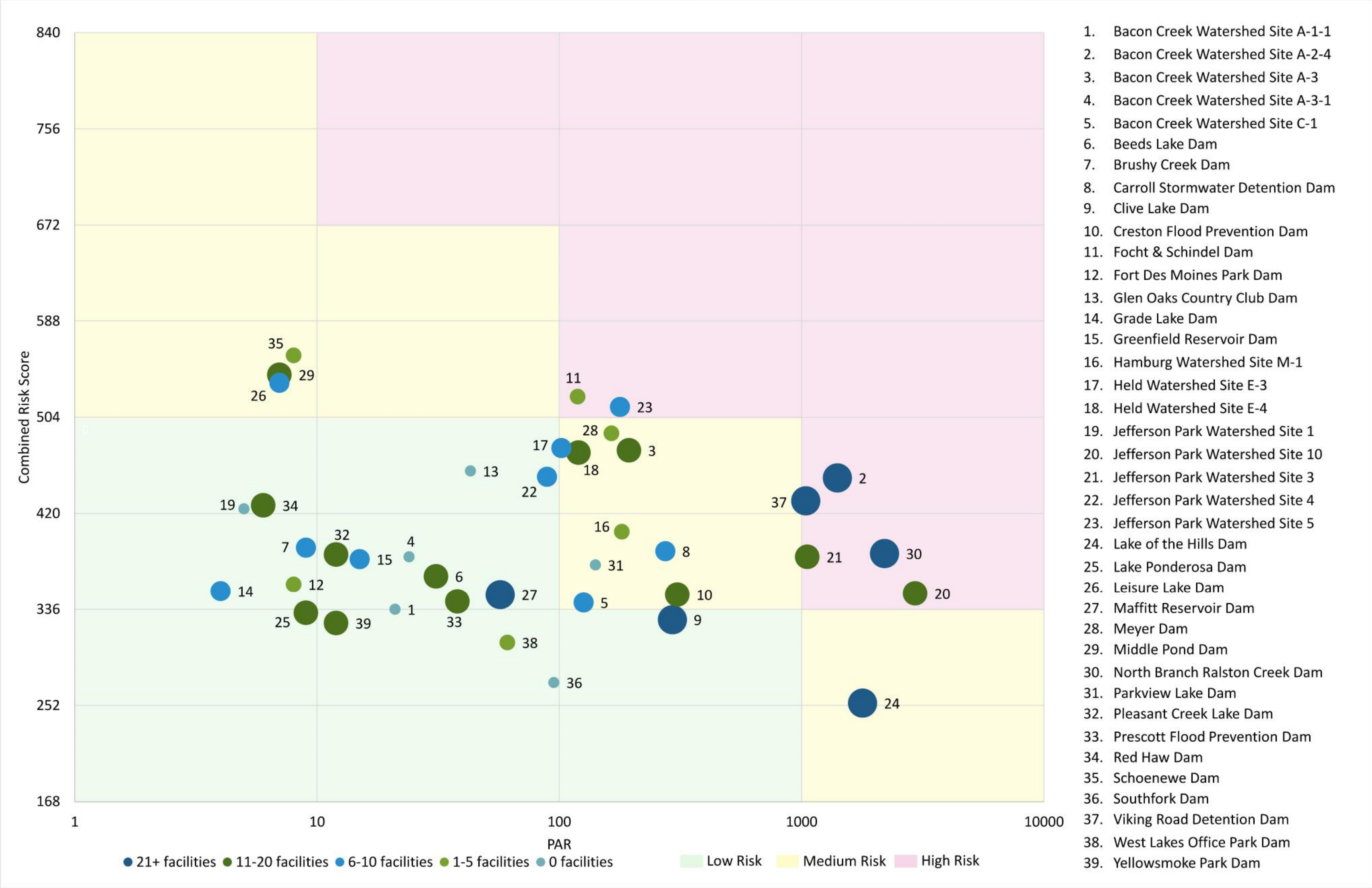

Figure 19. Combined risk score as a function of PAR with varying dot size to represent total downstream facilities at risk

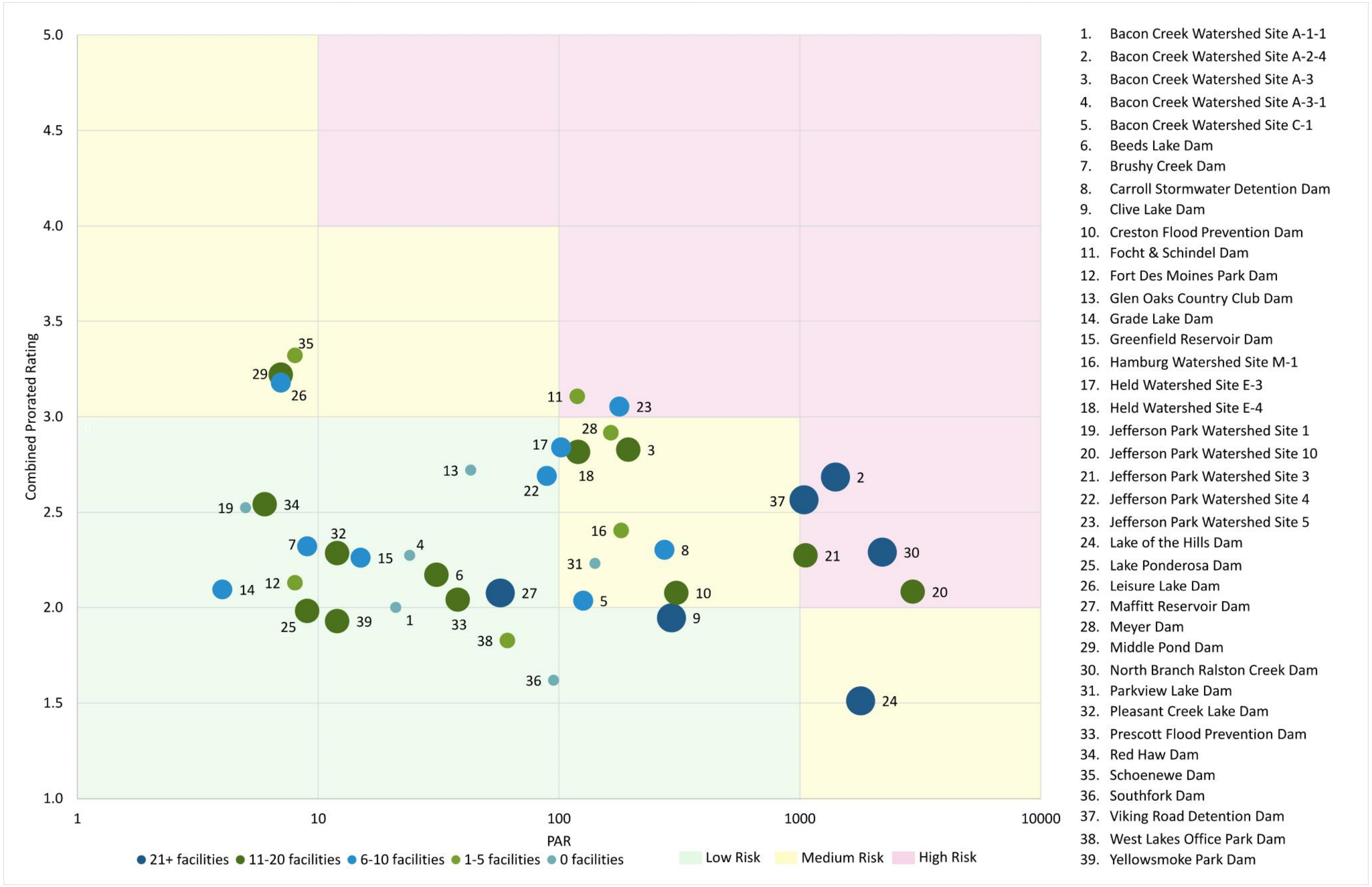

Figure 20. Combined prorated risk score as a function of PAR with varying dot size to represent total downstream facilities at risk

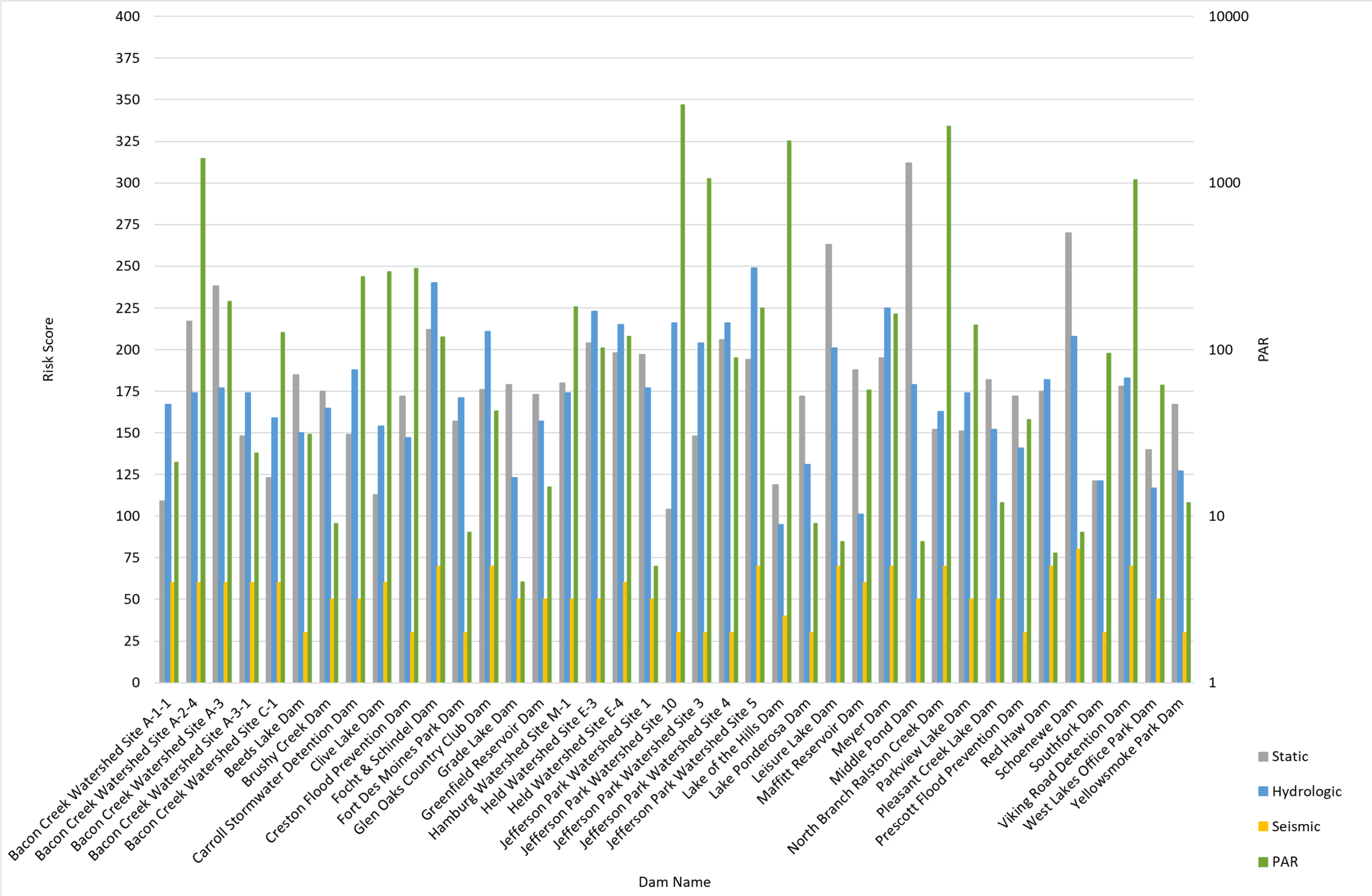

Figure 21. Categorical risk scores (primary axis) and PAR (secondary axis) for each assessed dam

For further information, graphs comparing static failure and hydrologic failure versus PAR were also included (Figure 22 and Figure 26, respectively) to better understand each dam's overall risk. A seismic graph was not included due to low seismic risk and no history of dam failure due to seismic activity in Iowa (Figure 7).

Figure 22. Static risk score as a function of PAR

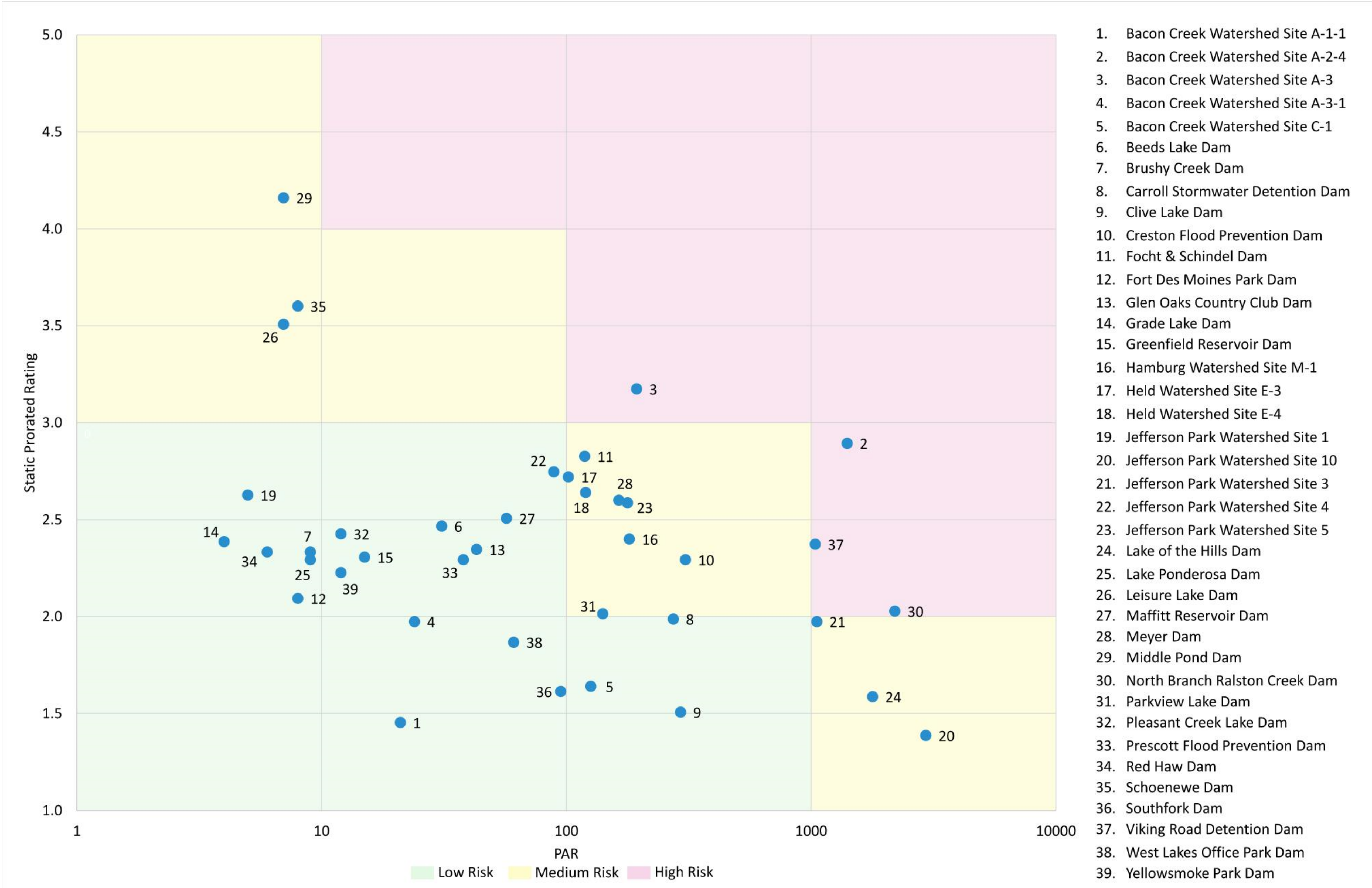

Figure 23. Static prorated risk score as a function of PAR

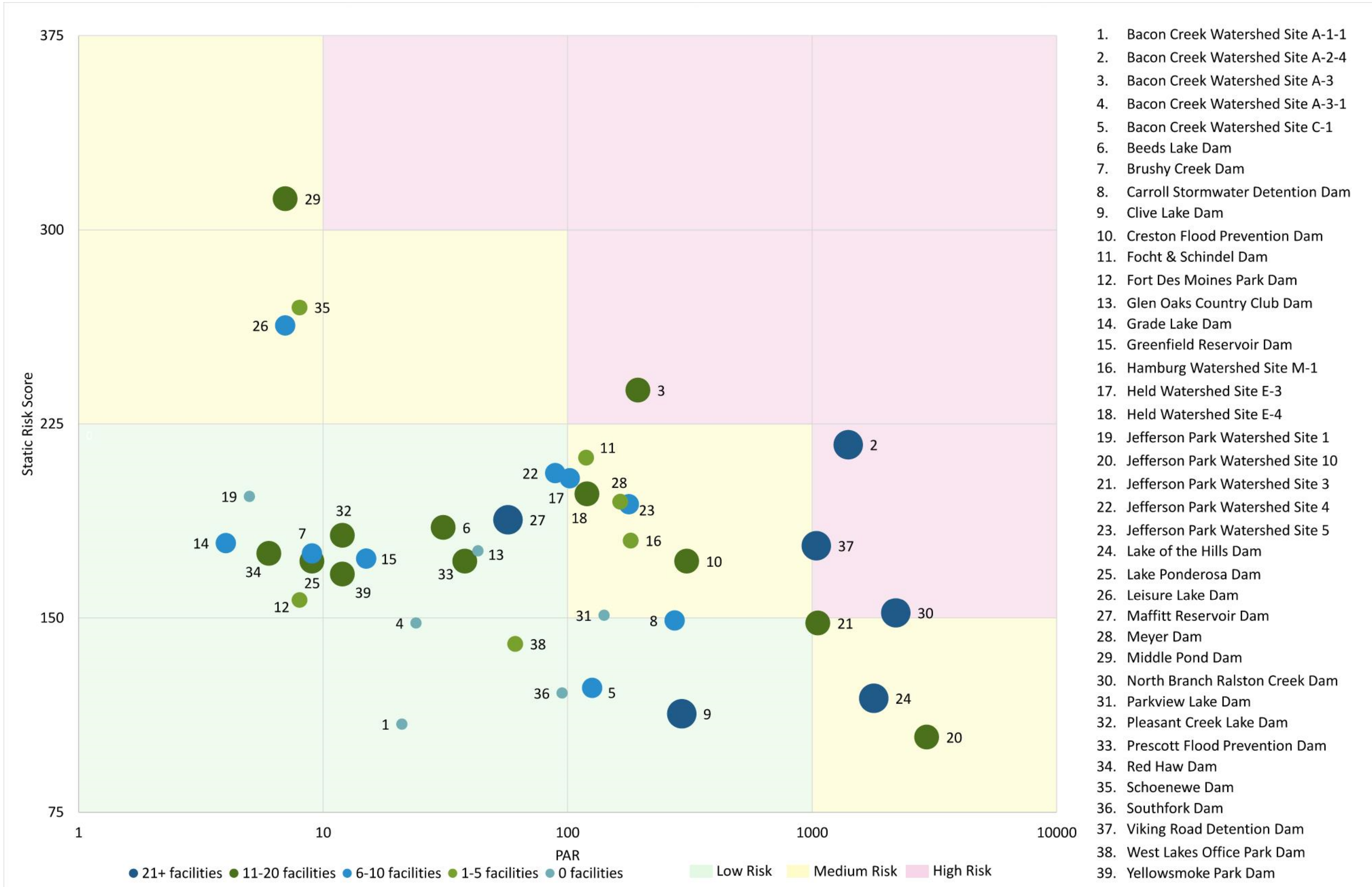

Figure 24. Static risk score as a function of PAR with varying dot size to represent total downstream facilities at risk

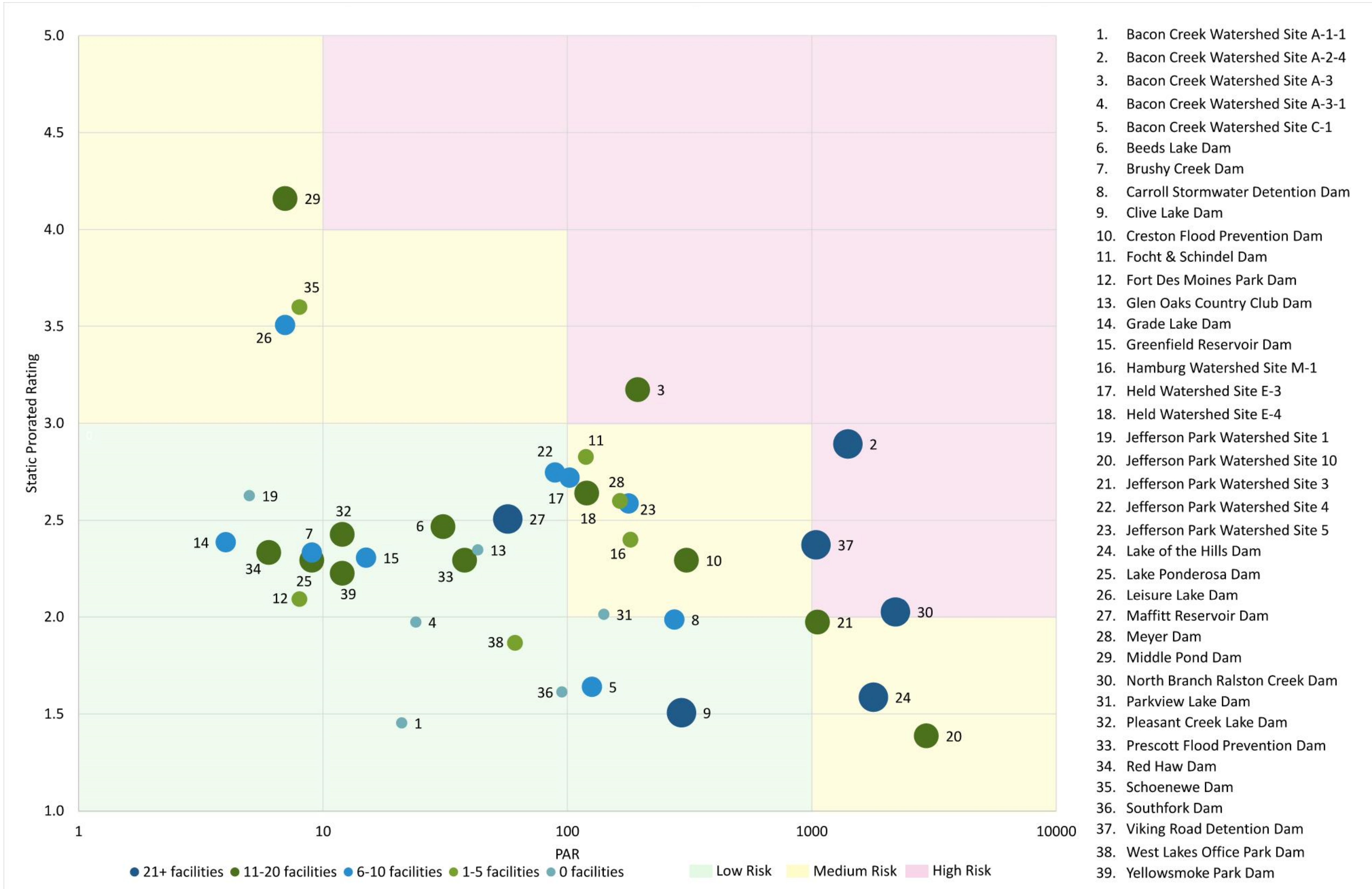

Figure 25. Static prorated risk score as a function of PAR with varying dot size to represent total downstream facilities at risk

Figure 26. Hydrologic risk score as a function of PAR

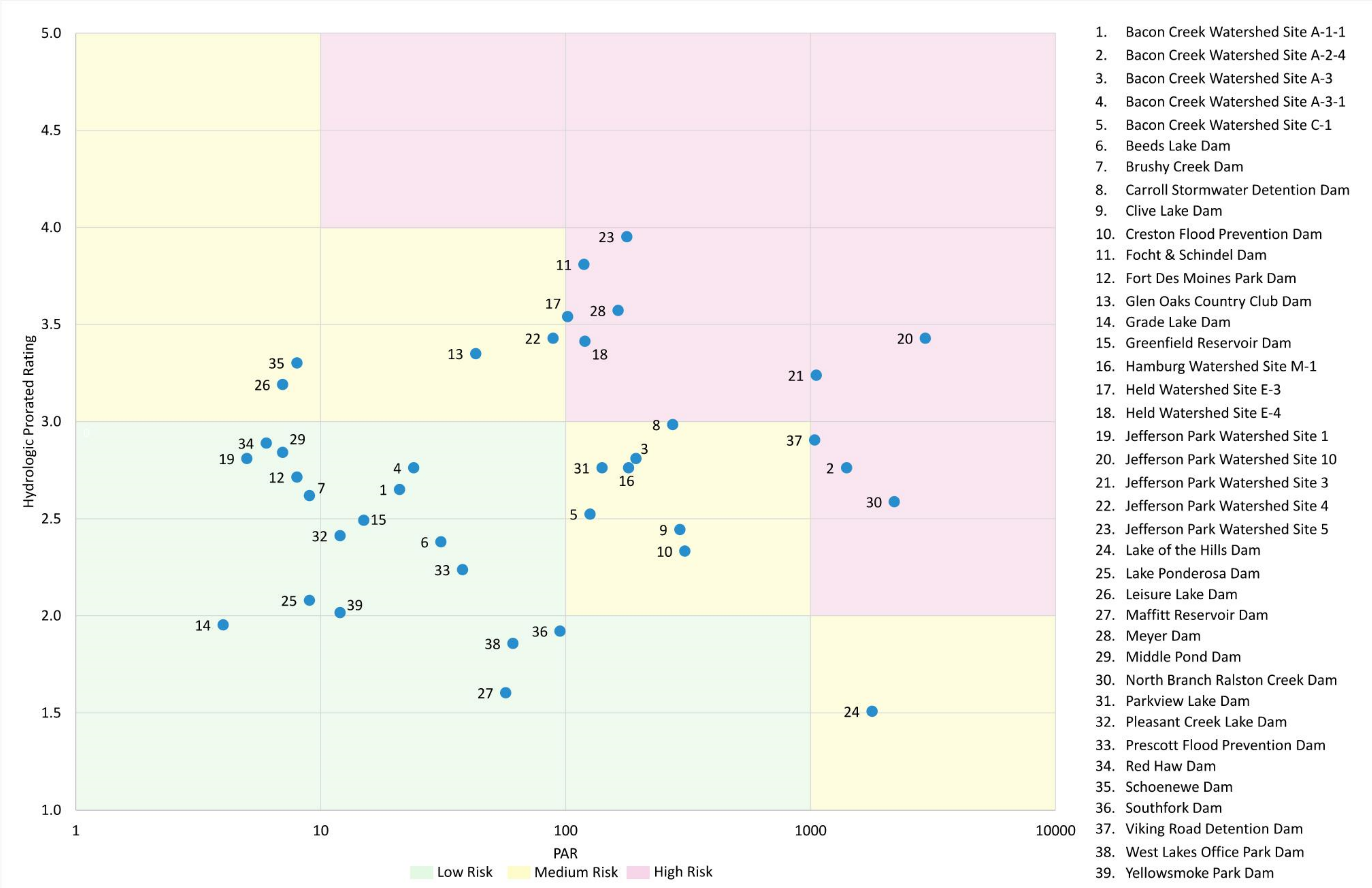

Figure 27. Hydrologic prorated risk score as a function of PAR

Figure 28. Hydrologic risk score as a function of PAR with varying dot size to represent total downstream facilities at risk

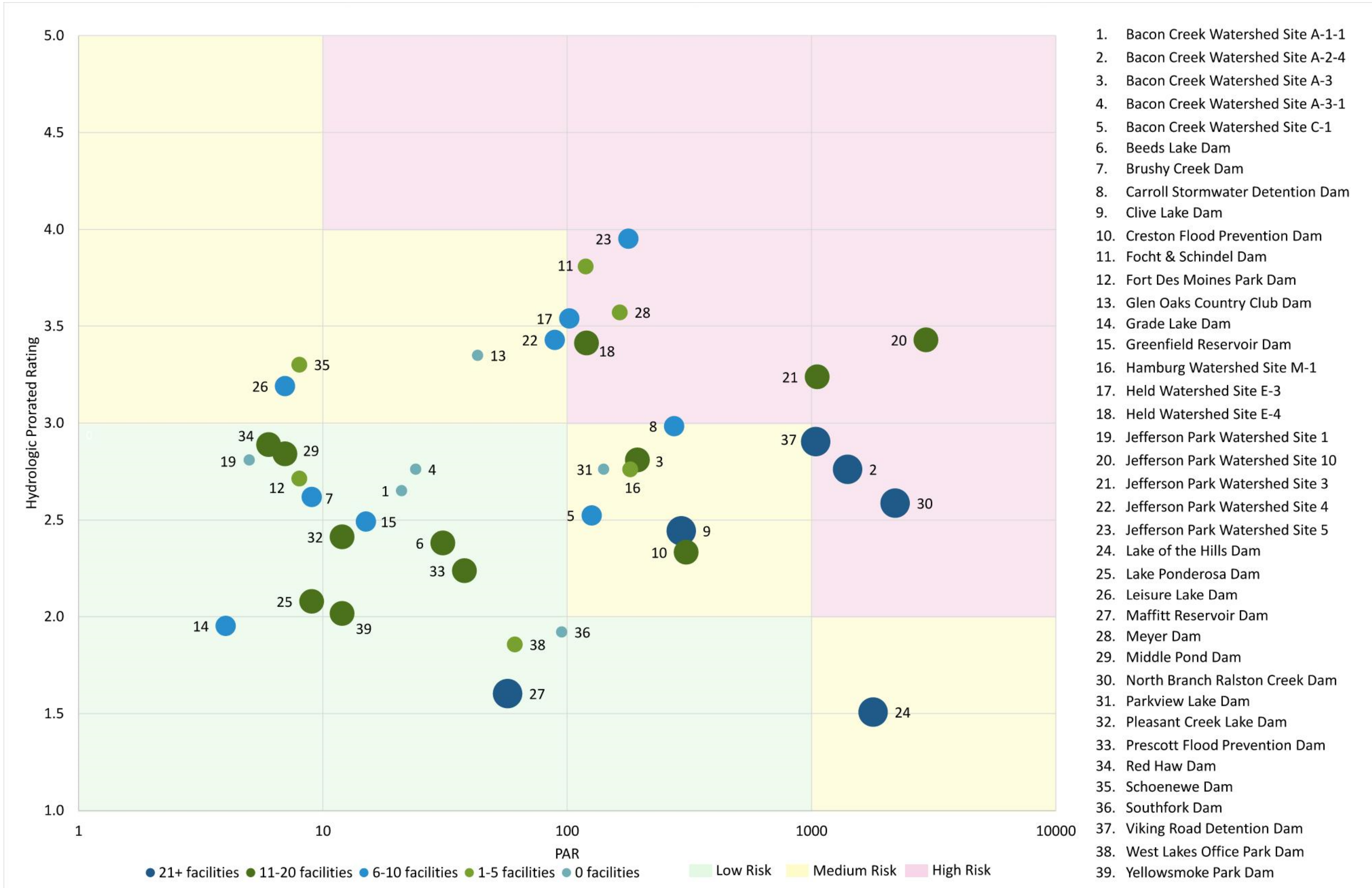

Figure 29. Hydrologic prorated risk score as a function of PAR with varying dot size to represent total downstream facilities at risk

2.4 TASK 4: DEVELOP MITIGATION GOALS AND RECOMMENDED ACTIONS

2.4.1 GENERAL RECOMMENDATIONS

After reviewing the current Iowa Dam Safety high hazard dam inspection reports and looking at surrounding state's inspection reports, there are some general recommendations that Iowa DNR can add to further their understanding of each dam and its risks. These items are found in the table below.

Table 12. General recommendations for the Iowa DNR inspection process

General Inspection Recommendations	
Action Items during inspection	Pipe inspection video
	Test drawdown (if applicable)
	Check/install piezometer readings (if applicable)
	Make sure emergency personnel have updated inundation maps
	EAP up to date
	Create record of significant flood events
Notes to add to inspection reports	Development in flood pool
	Development in upstream watershed
	Easement violations
	Distinct vegetation change
	Outlet channel degrading
	Foundation drain rodent barrier
	Unsecured boats/docks
	Any alternations to dam and why
	Inadequate riprap
	Structure instrumented
	Instrument monitoring performed
	Public allowed on dam
	Obstacles to inlet or drawdown tower
	Embankment misalignment
	Conduit misalignment
	Stop Log condition
	Inlet modified to alter water surface
	New homes downstream
	Wet areas downstream
	Bike trails downstream

Iowa Dam Safety regulations specify that Emergency Action Plans (EAP) are required for existing and future high hazard dams. At the time of writing this report, many Emergency Action Plans (EAPs) have been developed and many EAPs are in the process of being developed. These plans should be considered to help assess the risk and items to consider are if the document is up-to-date and has been recently exercised. An Emergency Action Plan (EAP) for a dam is a crucial document that outlines the necessary procedures and protocols to respond effectively in case of a dam failure or potential breach.Table 13 shows the dams that have developed an EAP.

Table 13. Existing Emergency Action Plans

Dam No.	Dam Name	EAP
1	Bacon Creek Watershed Site A-1-1	Y
2	Bacon Creek Watershed Site A-2-4	Y
3	Bacon Creek Watershed Site A-3	Y
4	Bacon Creek Watershed Site A-3-1	Y
5	Bacon Creek Watershed Site C-1	Y
6	Beeds Lake Dam	Y
7	Brushy Creek Dam	Y
8	Carroll Stormwater Detention Dam	Y
9	Clive Lake Dam	Y
10	Creston Flood Prevention Dam	Y
11	Focht & Schindel Dam	Y
12	Fort Des Moines Park Dam	Y
13	Glen Oaks Country Club Dam	Y
14	Grade Lake Dam	
15	Greenfield Reservoir Dam	Y
16	Hamburg Watershed Site M-1	Y
17	Held Watershed Site E-3	Y
18	Held Watershed Site E-4	Y
19	Jefferson Park Watershed Site 1	Y
20	Jefferson Park Watershed Site 10	Y
21	Jefferson Park Watershed Site 3	Y
22	Jefferson Park Watershed Site 4	Y
23	Jefferson Park Watershed Site 5	Y
24	Lake of the Hills Dam	
25	Lake Ponderosa Dam	Y
26	Leisure Lake Dam	
27	Maffitt Reservoir Dam	
28	Meyer Dam	
29	Middle Pond Dam	Y
30	North Branch Ralston Creek Dam	
31	Parkview Lake Dam	Y
32	Pleasant Creek Lake Dam	
33	Prescott Flood Prevention Dam	Y
34	Red Haw Dam	
35	Schoenewe Dam	
36	Southfork Dam	Y
37	Viking Road Detention Dam	
38	West Lakes Office Park Dam	Y
39	Yellowsmoke Park Dam	Y

2.4.2 DAM-SPECIFIC RECOMMENDATIONS

Iowa Dam Safety has general recommendations for dams that include maintenance, monitoring, and engineering items, shown in Table 14. They also provide a maintenance manual for all dam owners (Iowa DNR, 2010) and should be used to help guide dam owners to properly maintain their dam.

Table 15 includes general analysis and design recommendations DNR can implement as they see fit. Table 16 contains specific recommendations for each dam categorized into maintenance, missing information, design deficiencies, and consequence reductions.

Table 14. Iowa DNR general maintenance, monitoring, and engineering recommendations for dam owners

IDNR General Recommendations
Maintenance Items
Mow or burn vegetation on dam
Clear vegetation from riprap areas
Removed debris from spillway inlet
Exercise and perform required maintenance on the gate
Monitor Items
Seepage
Minor erosion
Minor embankment depressions or slides
Clear trees and brush from embankment and spillway areas
Backfill rodent burrows and initiate rodent control program
Repair and stabilize eroded areas
Engineering Items
Perform a geotechnical evaluation to determine cause of slides and/or depressions
Evaluate and repair spillway structures
Develop plans and specifications for proper repair of the dam

Table 15. General recommendations for Iowa DNR

General HEI recommendations	
Engineering Analysis	2D breach analysis with multiple loading conditions
	Dam in-series breach analysis (if applicable)
	Better record of historical events
	Steady state seepage analysis to be completed at the PMF elevation
	Incremental Consequence analysis and auxiliary spillway modeling
	Detailed PFMA for each dam
	Geotechnical stability analysis
High Hazard Design Updates	Design and construct low-level drawdown at next opportunity (if applicable)
	Install seepage filter system at next opportunity (if applicable)
	Update outlet works to meet current hydraulic standards at next opportunity

Table 16. Specific recommendations for each assessed dam

Dam	Maintenance	Missing Information	Design Deficiency	Consequence Reduction
Bacon Creek Watershed Site A-1-1	■ Reestablish vegetation on auxiliary spillway		■ Install drawdown at next opportunity	
Bacon Creek Watershed Site A-2-4	■ Clear overgrown vegetation by inlet and outlet ■ Remove vegetation from shoreline along dam embankment	■ Breach analysis at auxiliary spillway		■ Review home downstream of auxiliary spillway
Bacon Creek Watershed Site A-3	■ Clear overgrown vegetation by inlet and outlet ■ Repair principal spillway chute ■ Add erosion protection at principal spillway outlet. ■ Add erosion protection or re-establish vegetation on auxiliary spillway		■ Install drawdown at next opportunity.	■ Review home downstream of auxiliary spillway
Bacon Creek Watershed Site A-3-1	■ Clear overgrown vegetation by inlet and outlet ■ Unblock drawdown ■ Repair burrows per IDNR Maintenance Manual for Dam Owners	■ Breach analysis at auxiliary spillway		■ Review home downstream of auxiliary spillway
Bacon Creek Watershed Site C-3	■ Clear overgrown vegetation by outlet ■ Continue to monitor auxiliary spillway erosion			
Beeds Lake Dam	■ Clear trees on embankment and around principal spillway ■ Repair concrete on platform	■ Geotechnical report ■ Update HH analysis	■ Install internal drain at next opportunity ■ Continue to monitor seepage ■ Check capacity of auxiliary spillway ■ Install drawdown at next opportunity	

Dam	Maintenance	Missing Information	Design Deficiency	Consequence Reduction
Brushy Creek Dam	■ Seal cracks in chute and riser ■ Monitor slide and trench on downstream embankment ■ Remove logs and debris in chute and trash rack ■ Revegetate or add erosion protection on auxiliary spillway ■ Remove trees on embankment			
Carroll Stormwater Detention Dam	■ Add riprap by inlet to stabilize erosion	■ Obtain as-builts	■ Update outlet to comply with high hazard criteria	
Clive Lake Dam	■ Clear trees by outlet ■ Repair or replace flared end section	■ Update HH analysis		
Creston Flood Prevention Dam	■ Add riprap to shoreline to reduce wave erosion ■ Clear trees on embankment ■ Continue to monitor drain outlet for clogging		■ Assess and install additional internal drains to capture seepage ■ Jet outlet drains	
Focht & Schindel Dam	■ Clear trees on embankment ■ Clear outlet area ■ Clear brush on auxiliary spillway ■ Assess wave erosion and repair if necessary ■ Assess condition of principal spillway outlet	■ Geotechnical report ■ Update HH analysis ■ Locate and assess condition of drain outlets in flume	■ Replace principal spillway to have a minimum diameter of 30" and upgrade to meet current hydraulic requirements (currently passing the 50-yr) ■ Monitor slide and consider movement markers ■ Install drawdown at next opportunity	
Fort Des Moines Park Dam	■ Clear area by inlet and outlet ■ Clear auxiliary spillway of obstructions	■ Determine if internal drains exist and assess condition	■ Install internal drains at next opportunity ■ Increase embankment slopes to 3:1 at next opportunity	
Glen Oaks Country Club Dam		■ Obtain a complete set of as-builts ■ Geotechnical report ■ Update HH analysis	■ Address items in the IDNR letters	■ Review home downstream of dam

Dam	Maintenance	Missing Information	Design Deficiency	Consequence Reduction
Grade Lake Dam	▪ Clear trees on embankment		▪ Install drawdown at next opportunity ▪ Increase embankment slopes to 3:1 at next opportunity	
Greenfield Reservoir Dam	▪ Clean up riprap on embankment ▪ Clear trees on left abutment ▪ Rehabilitate internal drains ▪ Fix joints on principal spillway		▪ Increase embankment slopes to 3:1 at next opportunity	
Hamburg Watershed Site M-1	▪ Clear principal spillway of sediment ▪ Repair burrows per IDNR Maintenance Manual for Dam Owners		▪ Install drawdown at next opportunity ▪ Update principal spillway to prevent submergence at next opportunity	
Held Watershed Site E-3	▪ Add slope protection to shoreline to reduce wave erosion ▪ Rehabilitate principal spillway ▪ Reestablish vegetation or add erosion protection to auxiliary spillway		▪ Update outlet to comply with high hazard criteria ▪ Install drawdown at next opportunity	
Held Watershed Site E-4	▪ Add slope protection to shoreline to reduce wave erosion ▪ Repair the cut in the embankment from farmer ▪ Clear overgrown vegetation ▪ Rehabilitate riser ▪ Add erosion protection to principal spillway outlet		▪ Update outlet to comply with high hazard criteria ▪ Install drawdown at next opportunity	

Dam	Maintenance	Missing Information	Design Deficiency	Consequence Reduction
Jefferson Park Watershed Site 1	■ Monitor seepage. ■ Clear trash rack, inlet, and outlet of vegetation and debris ■ Monitor low area by principal spillway inlet and repair if necessary	■ Find internal drain outlets and assess condition	■ Install drawdown at next opportunity	
Jefferson Park Watershed Site 10	■ Clear principal spillway inlet ■ Monitor principal spillway outlet erosion and add any necessary protection	■ Update HH analysis ■ Find internal drain outlets and assess condition	■ Verify if drawdown and if not, install at next opportunity	
Jefferson Park Watershed Site 3	■ Add slope protection to shoreline to reduce wave erosion. ■ Monitor principal spillway outlet erosion and add any necessary protection. ■ Remove trees by outlet	■ Update HH analysis ■ Find internal drain outlets and assess condition	■ Install drawdown at next opportunity	
Jefferson Park Watershed Site 4	■ Remove trees and vegetation on embankment ■ Clear inlet and outlet of debris and trees	■ Update HH analysis	■ Install drawdown at next opportunity	
Jefferson Park Watershed Site 5	■ Add riprap to shoreline to reduce wave erosion ■ Clear inlet of debris	■ Update HH analysis ■ Obtain as-builts ■ Geotechnical report	■ Install drawdown at next opportunity	
Lake of the Hills Dam	■ Clear heavy vegetation on downstream side of embankment ■ Monitor seepage and joints, repair if necessary	■ Dam in-series breach analysis ■ Verify if there is an auxiliary spillway		

Dam	Maintenance	Missing Information	Design Deficiency	Consequence Reduction
Lake Ponderosa Dam	■ Reestablish vegetation on trail (restrict access or add gravel if residents are going to continue to drive on it) ■ Remove trees and vegetation from riprap on embankment ■ Clear trash rack of debris ■ Remove the smaller trash rack ■ Fix concrete by inlet ■ Clear trees by outlet ■ Reseal principal spillway chute joints to prevent undermining	■ Dam in-series breach analysis ■ Find internal drain outlets and assess condition	■ Update principal spillway outlet to comply with high hazard freeboard requirements at next opportunity ■ Install drawdown at next opportunity	
Leisure Lake Dam	■ Clear trees on embankment ■ Clear principal spillway inlet and outlet ■ Hard armor principal spillway chute ■ Address seepage	■ Geotechnical report ■ Online inundation map	■ Update dam to meet high hazard criteria	■ Buy out downstream property and remove from breach path
Maffitt Reservoir Dam	■ Repair cracking on upstream embankment slope ■ Clear trees and vegetation on embankment ■ Clear principal spillway inlet ■ Seal and repair joints	■ Find internal drain outlets and assess condition ■ Online inundation map		

Dam	Maintenance	Missing Information	Design Deficiency	Consequence Reduction
Meyer Dam	■ Line plunge pool ■ Add slope protection on shoreline to reduce wave erosion ■ Monitor erosion by inlet and repair if necessary ■ Clear principal spillway outlet ■ Add erosion protection to groin of dam		■ Upgrade principal spillway to meet high hazard criteria ■ Increase top of dam width to meet TR210-60 criteria ■ Install drawdown at next opportunity	
Middle Pond Dam	■ Line plunge pool ■ Implement rodent control ■ Clear trees on embankment ■ Add slope protection on shoreline to reduce wave erosion ■ Locate internal drain outlets ■ Clear principal spillway inlet and outlet ■ Inspect cleared rise and assess condition ■ Add erosion protection at principal spillway outlet		■ Raise principal spillway to pass 100-year event using a minimum 30" diameter pipe ■ Increase top of dam width to meet TR210-60 criteria ■ Install drawdown at next opportunity	
North Branch Ralston Creek Dam	■ Add slope protection on shoreline to reduce wave erosion ■ Clear principal spillway inlet ■ Add erosion protection at principal spillway outlet ■ Clear trees on embankment	■ Geotechnical report ■ Online inundation map ■ Find internal outlets and assess condition		

Dam	Maintenance	Missing Information	Design Deficiency	Consequence Reduction
Parkview Lake Dam	■ Remove and replace trash rack ■ Seal cracks or replace flared end section ■ Clear inlet and outlet area ■ Add erosion protection at principal spillway outlet ■ Remove trees on auxiliary spillway		■ Install internal drain ■ Increase top of dam width to meet TR210-60 criteria	
Pleasant Creek Lake Dam	■ Clear trees and debris from principal spillway outlet ■ Fix crack on top of dam road ■ Clear trees and brush on embankment ■ Monitor concrete riser for additional spalling ■ Remove trees on auxiliary spillway	■ Update HH analysis with PMF		
Prescott Flood Prevention Dam	■ Line plunge pool ■ Add slope protection on shoreline to reduce wave erosion ■ Monitor erosion by inlet and repair if necessary ■ Clear principal spillway outlet ■ Add erosion protection to groin of dam		■ Install drawdown at next opportunity	

Dam	Maintenance	Missing Information	Design Deficiency	Consequence Reduction
Red Haw Dam	▪ Add slope protection on shoreline to reduce wave erosion ▪ Clear tree on embankment ▪ Find internal drains ▪ Clear principal spillway inlet and outlet ▪ Add erosion protection at principal spillway outlet ▪ Monitor slides on upstream and downstream slopes	▪ Geotechnical report		
Schoenewe Dam	▪ Clear principal spillway inlet and outlet ▪ Remove and replace trash rack	▪ Geotechnical report ▪ Online inundation map	▪ Replace principal spillway to have a minimum diameter of 30” ▪ Install drawdown at next opportunity ▪ Increase auxiliary spillway crest to minimum 25’ at next opportunity	
Southfork Dam	▪ Clear principal spillway outlet of debris ▪ Monitor internal drain outlets for sand			
Viking Road Detention Dam	▪ Clear overgrown vegetation and debris from embankment ▪ Add erosion protection at principal spillway outlet	▪ Geotechnical report		
West Lakes Office Park Dam	▪ Coordinate inspection with a burn year ▪ repair joints of concrete slab at principal spillway outlet			
Yellowsmoke Park Dam	▪ Monitor erosion adjacent to principal spillway outlet		▪ Install internal drain at next opportunity	

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4 APPENDICES

Appendix A: Human Consequences Reports

Appendix B: Flood Simulation Reports

Appendix C: Seismic Assessment Reports

Appendix D: Failure Mode Ranking Matrix

Appendix E: Environmental Site Impacts

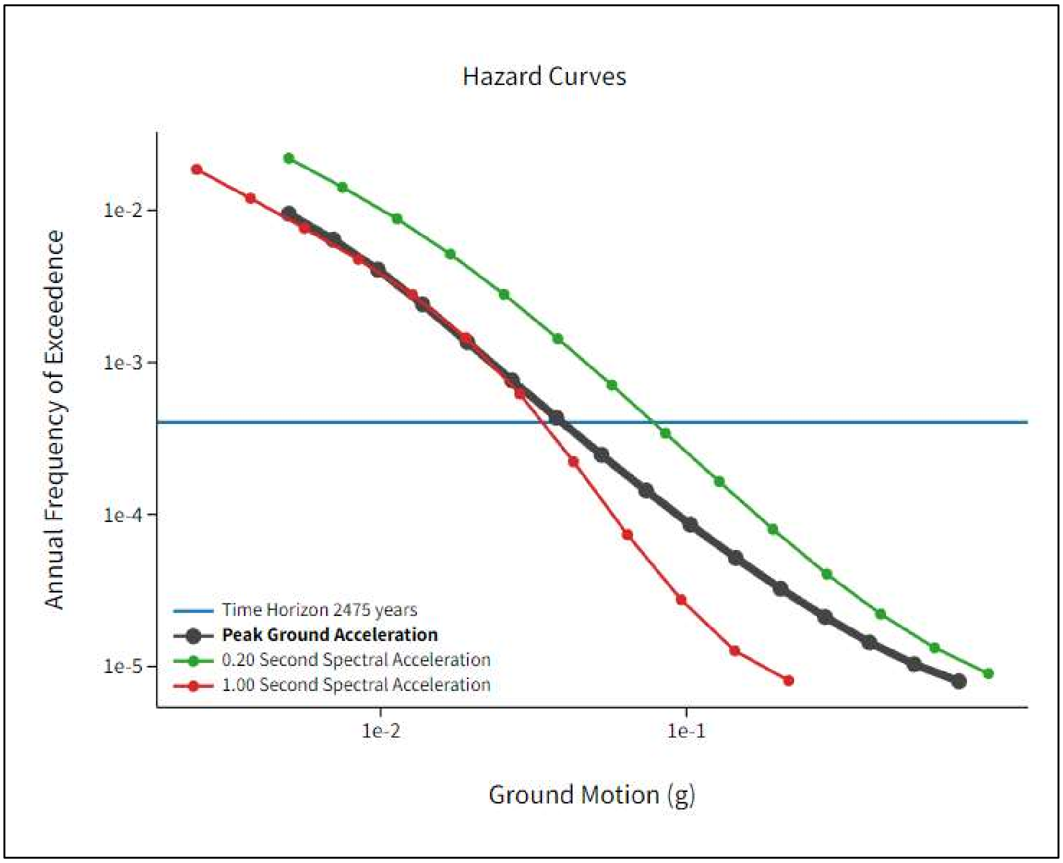
Appendix F: Environmental Facility Impacts

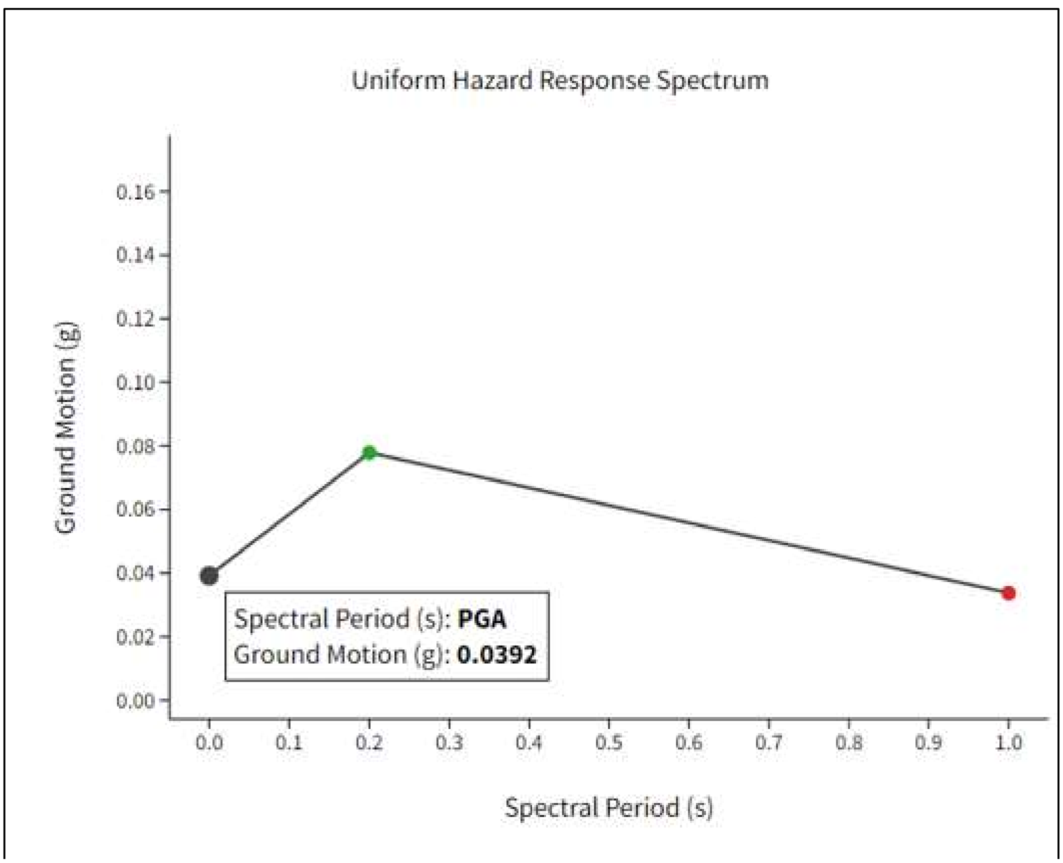
4.1 APPENDIX A: HUMAN CONSEQUENCES REPORTS

4.2 APPENDIX B: FLOOD SIMULATION REPORTS

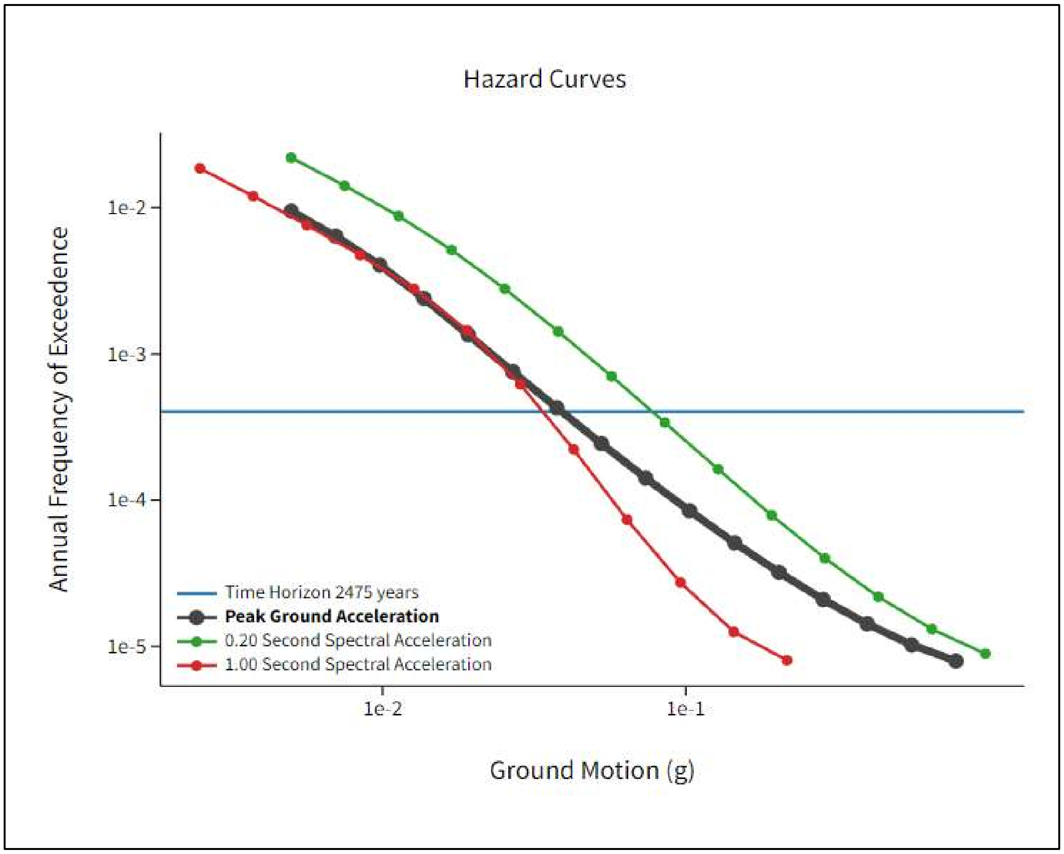
4.3 APPENDIX C: SEISMIC ASSESSMENT RESULTS

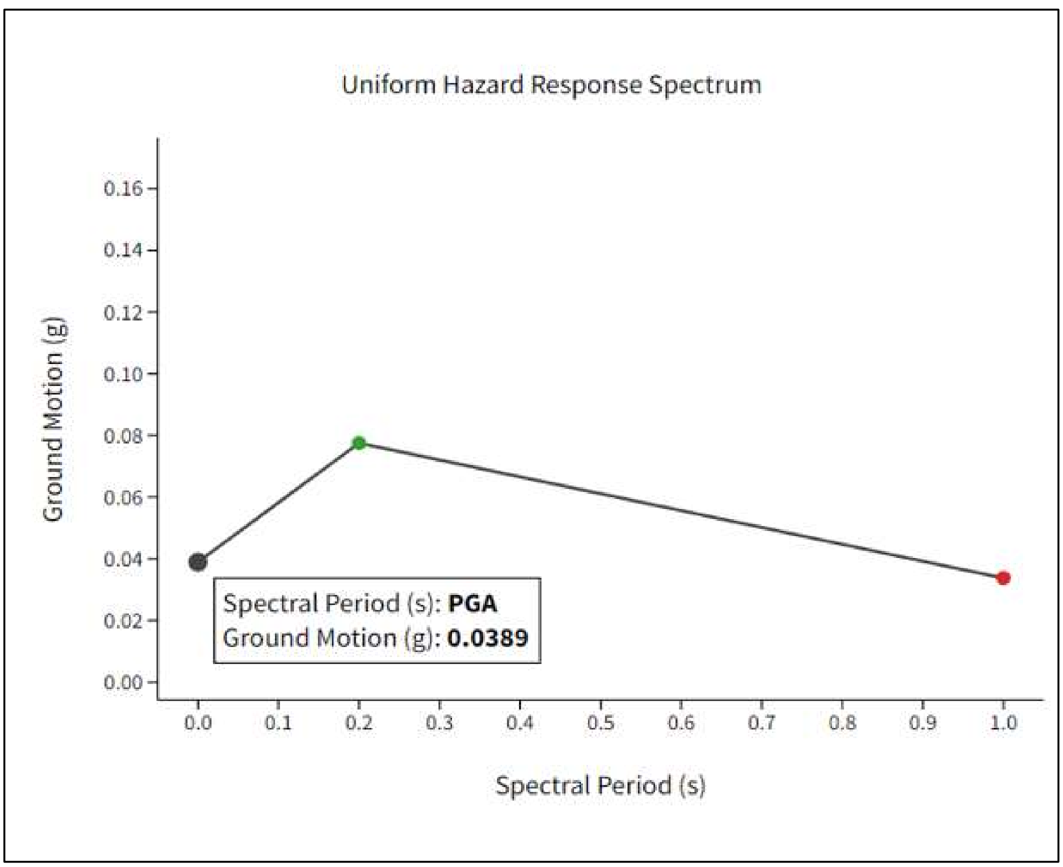
Seismic Assessment - Bacon Creek Watershed Site A-1-1



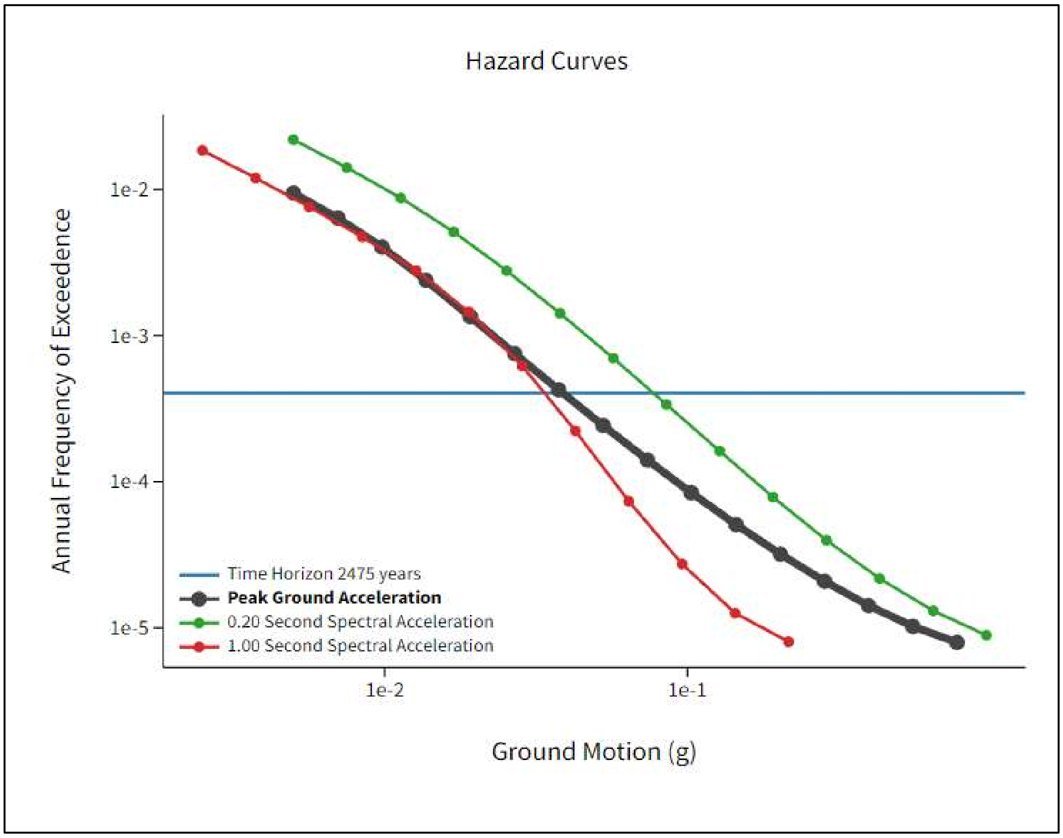


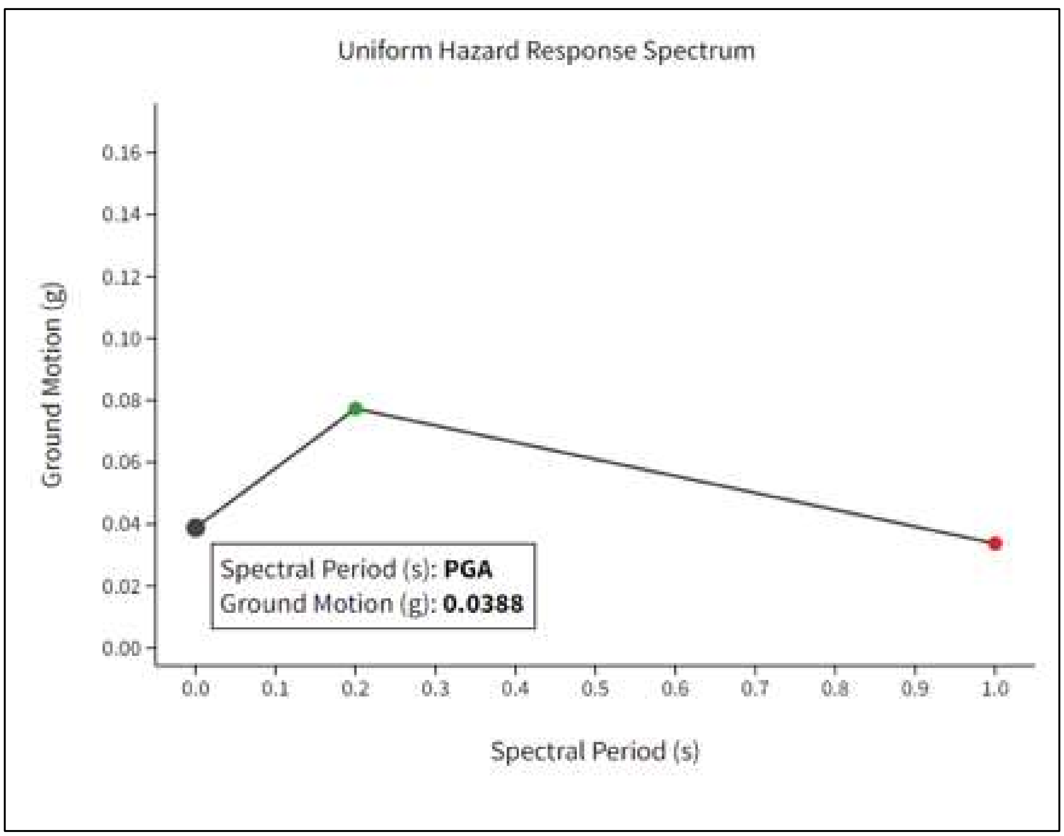
Seismic Assessment - Bacon Creek Watershed Site A-2-4



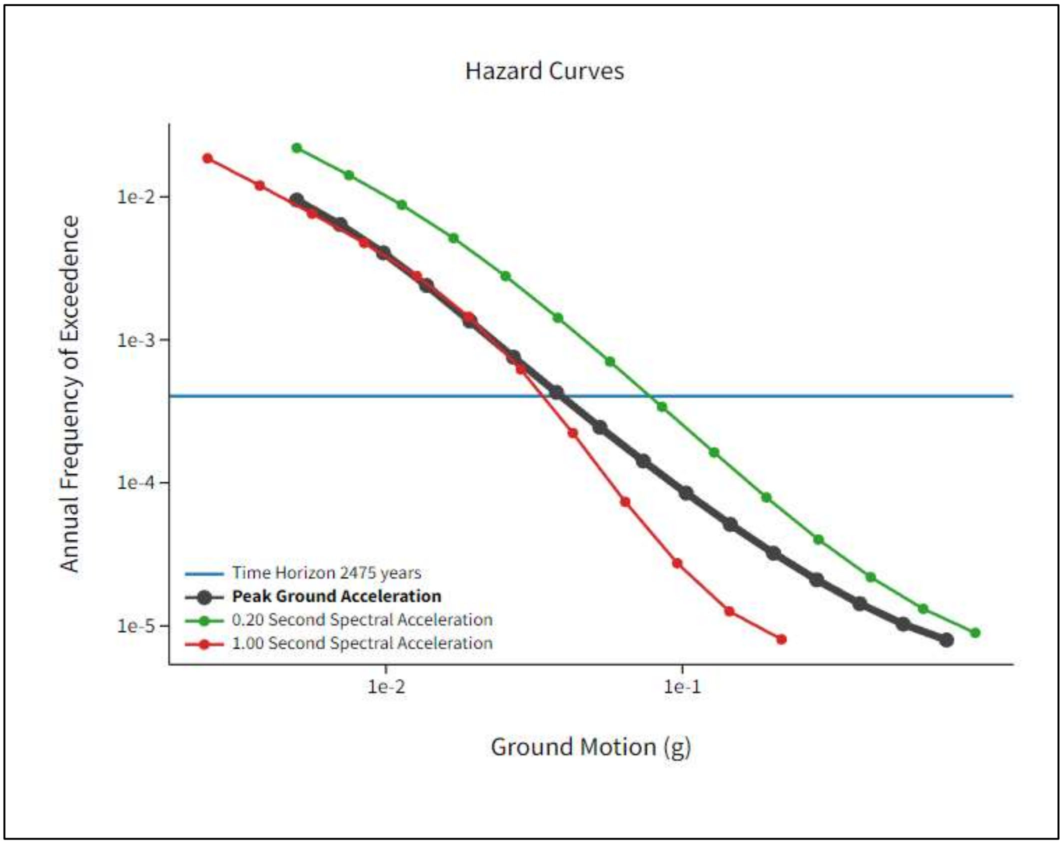


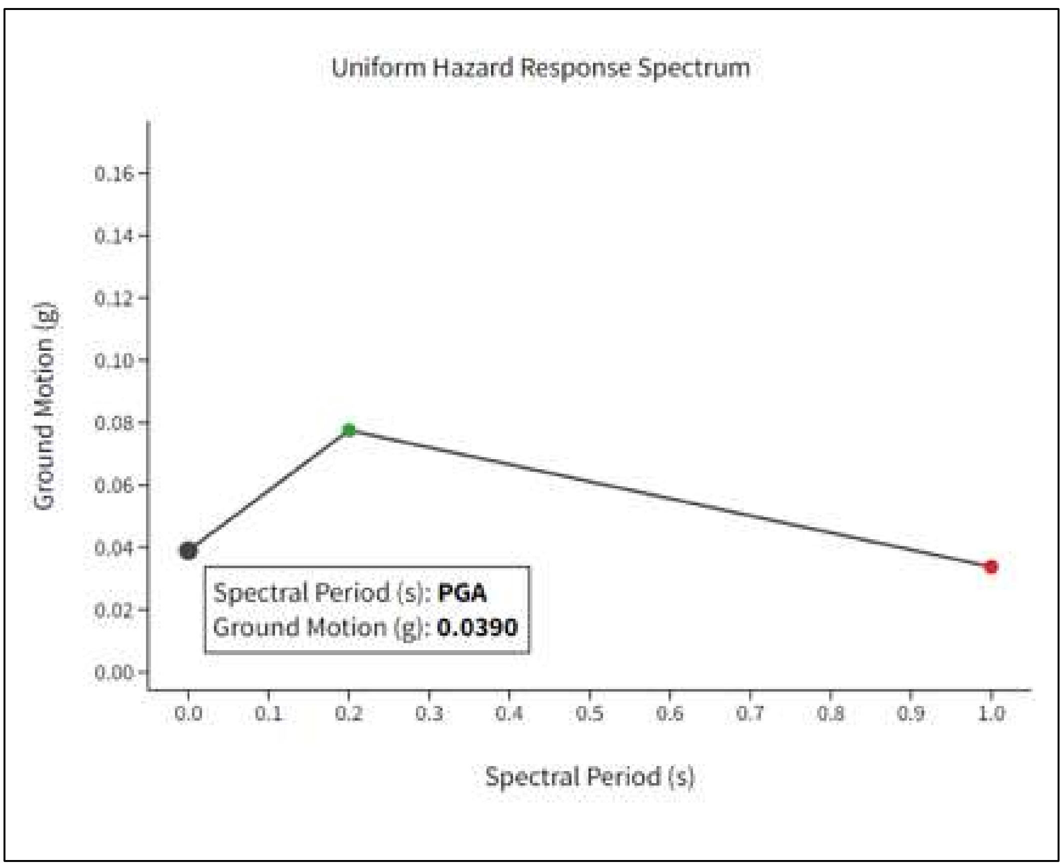
Seismic Assessment - Bacon Creek Watershed Site A-3



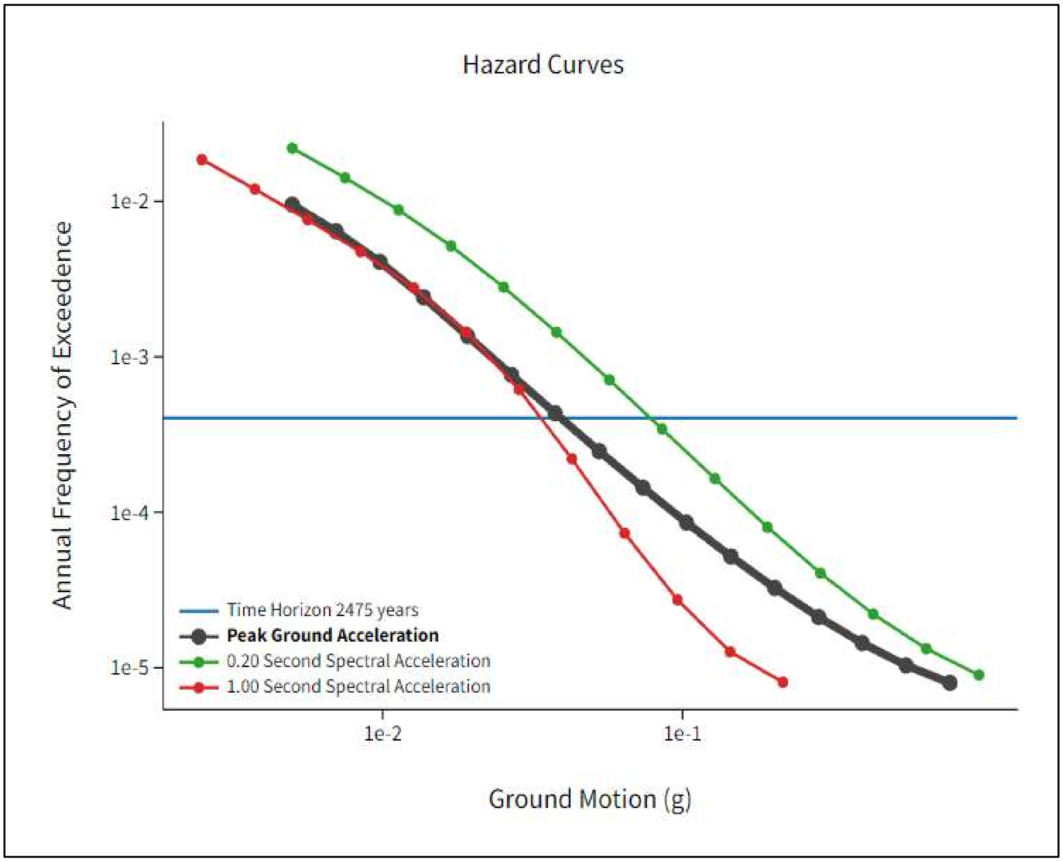


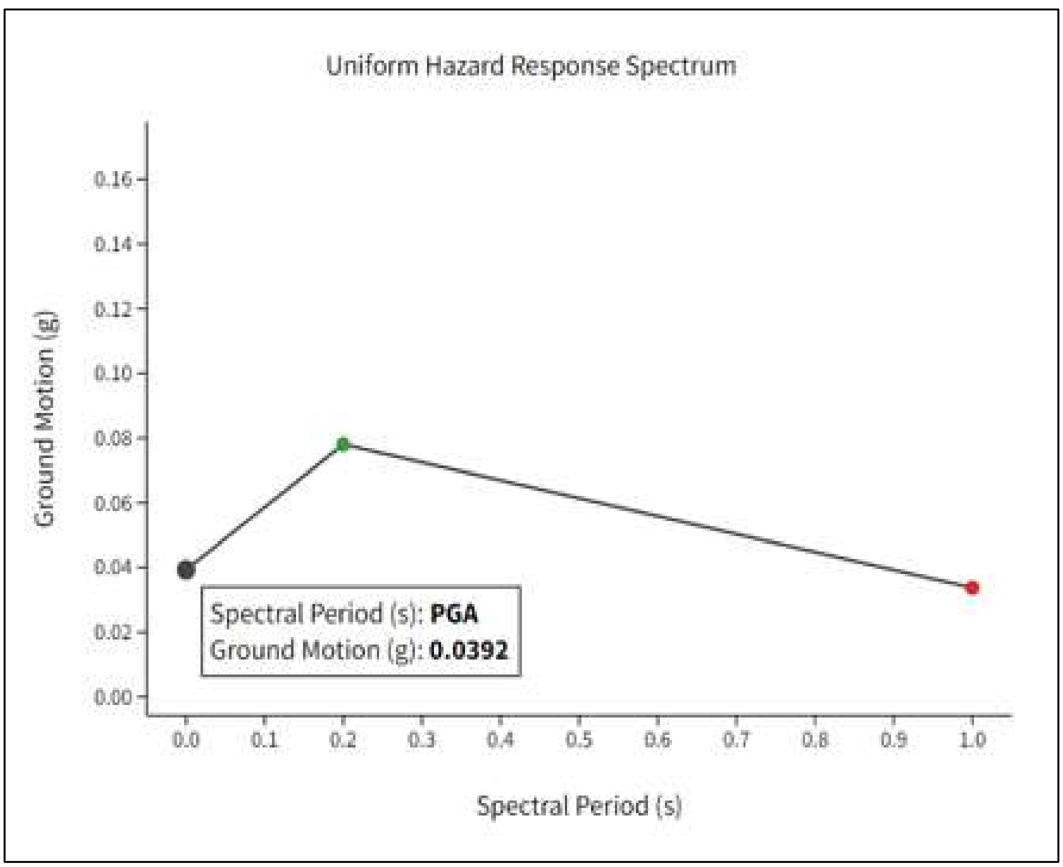
Seismic Assessment - Bacon Creek Watershed Site A-3-1



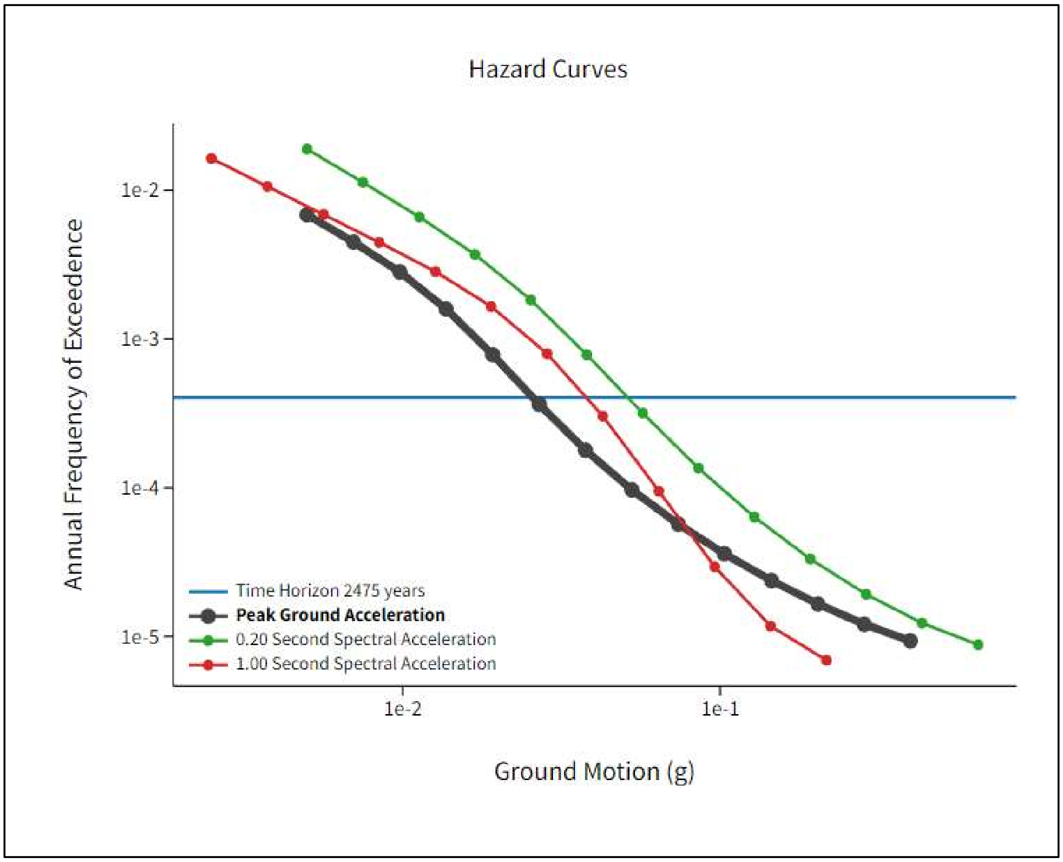


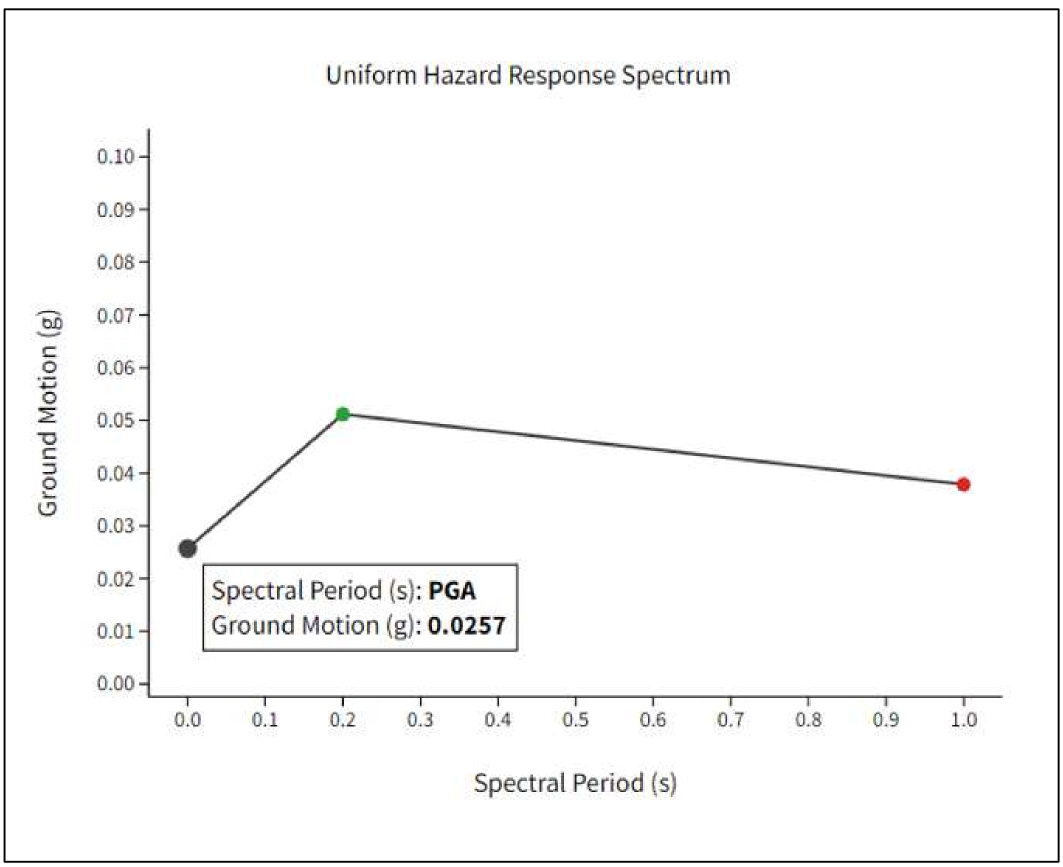
Seismic Assessment - Bacon Creek Watershed Site C-1



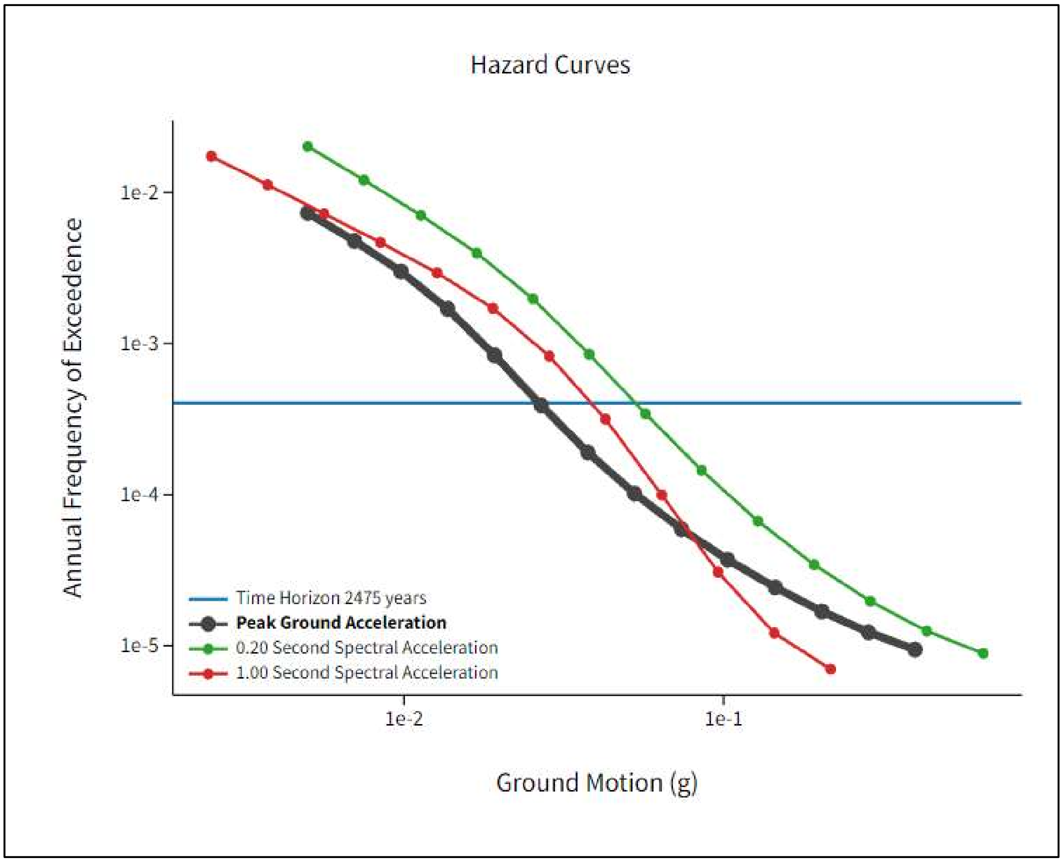


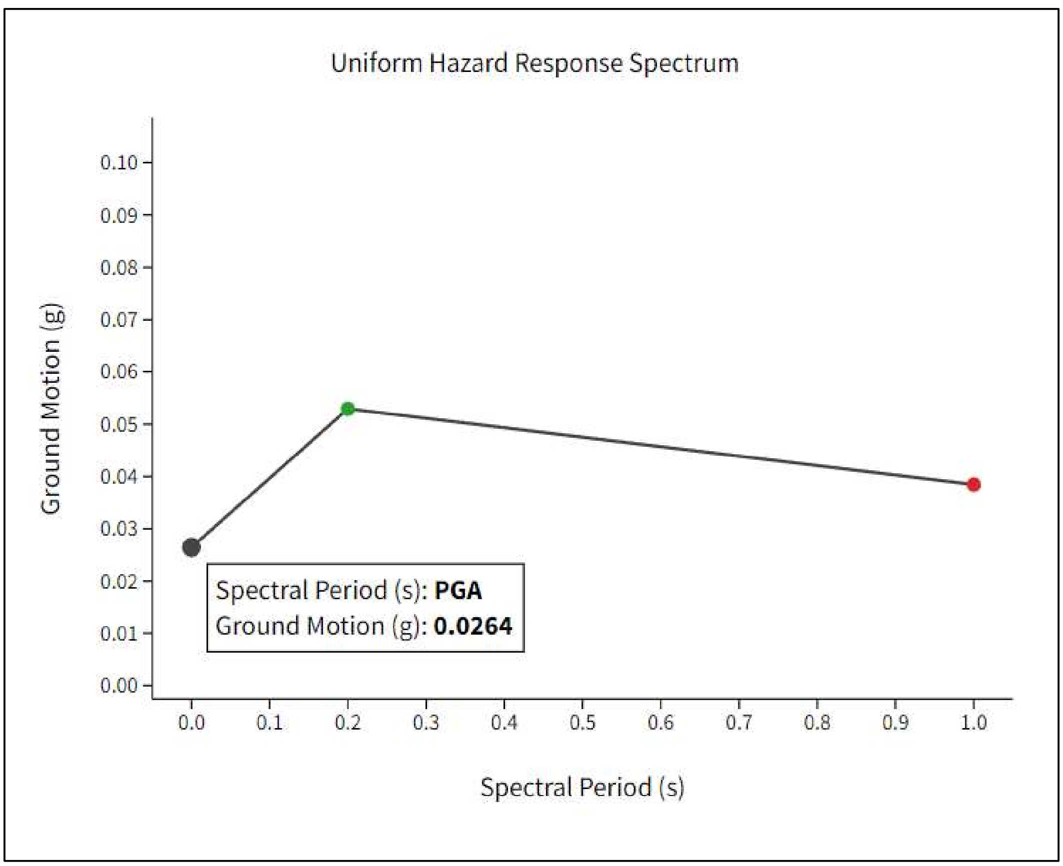
Seismic Assessment - Beeds Lake Dam



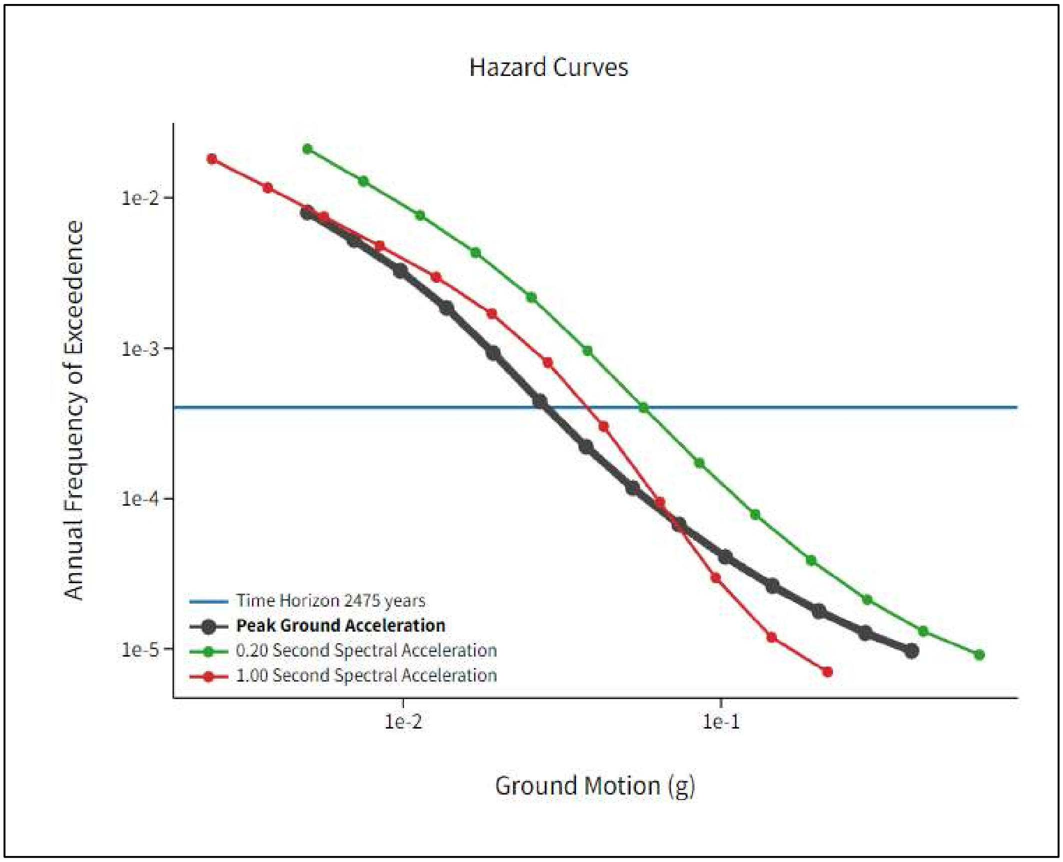


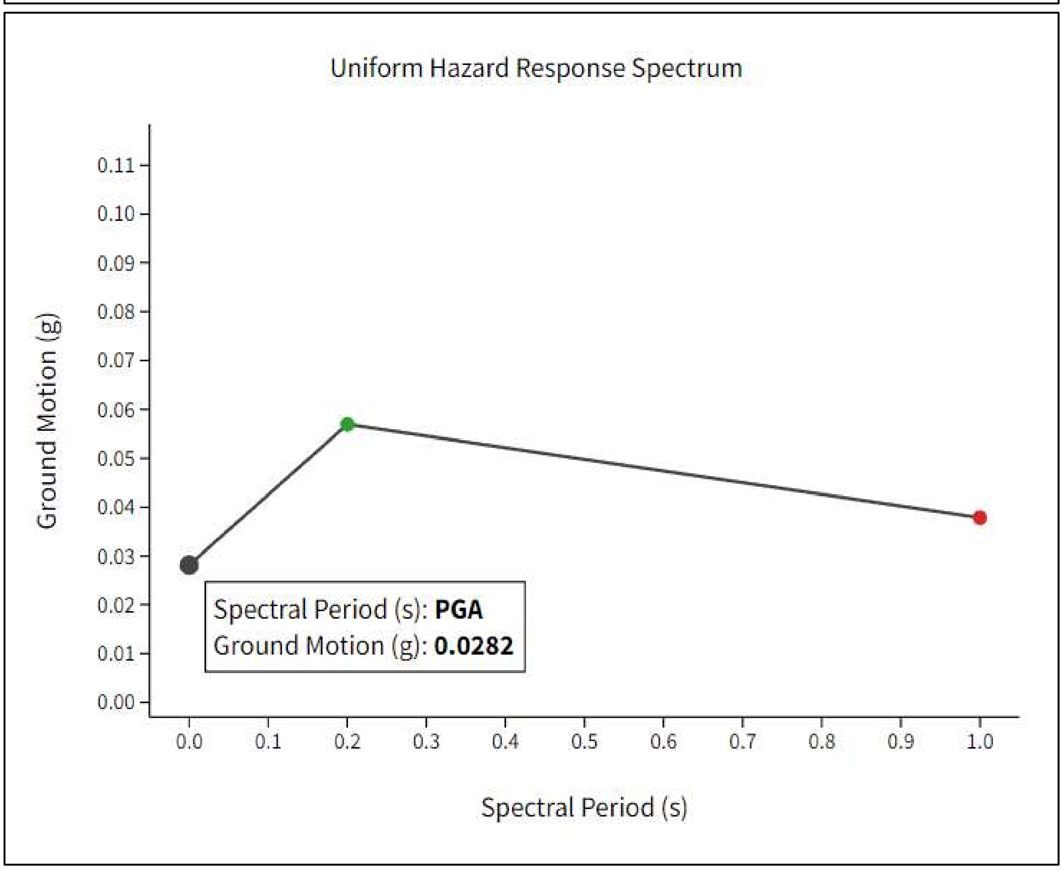
Seismic Assessment - Brushy Creek Dam



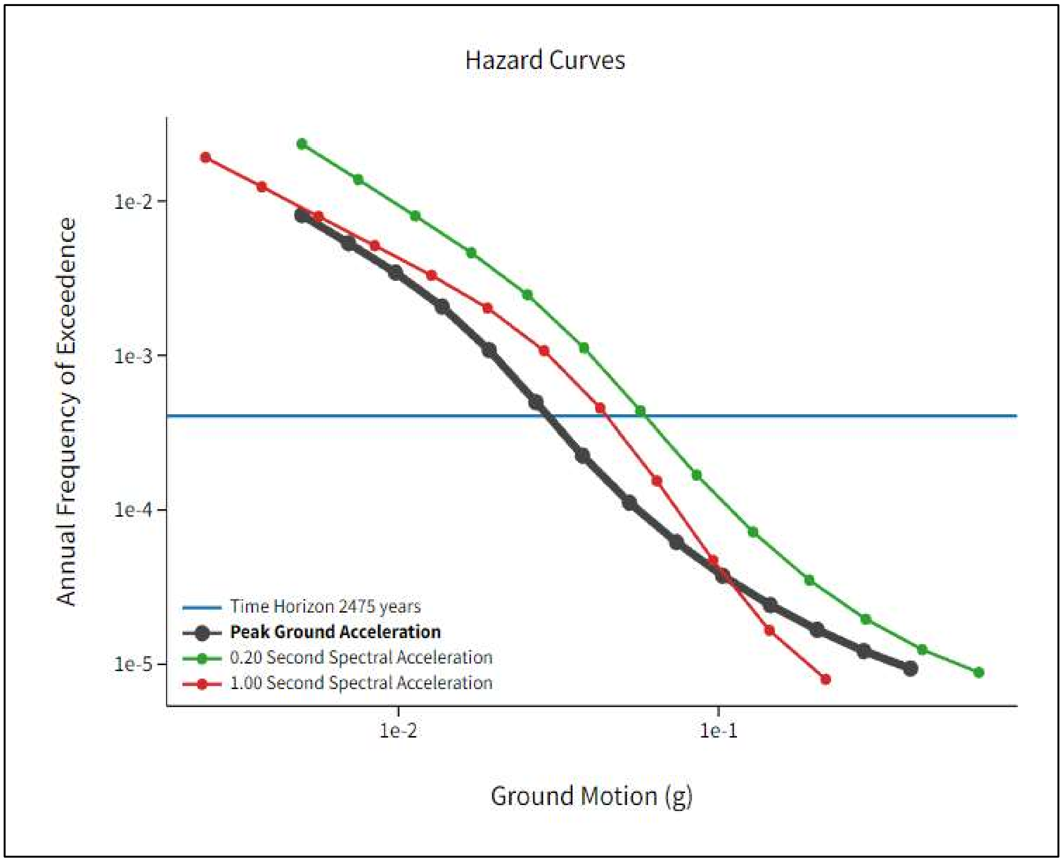


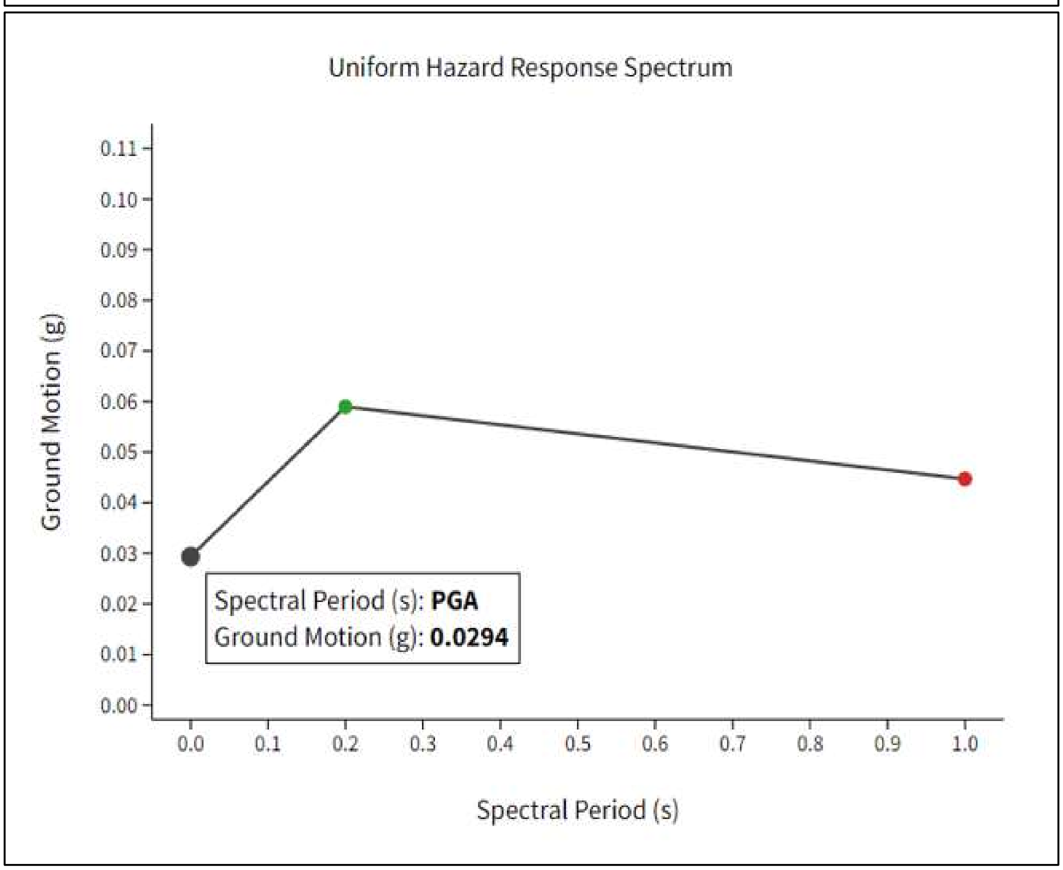
Seismic Assessment - Carroll Stormwater Detention Dam



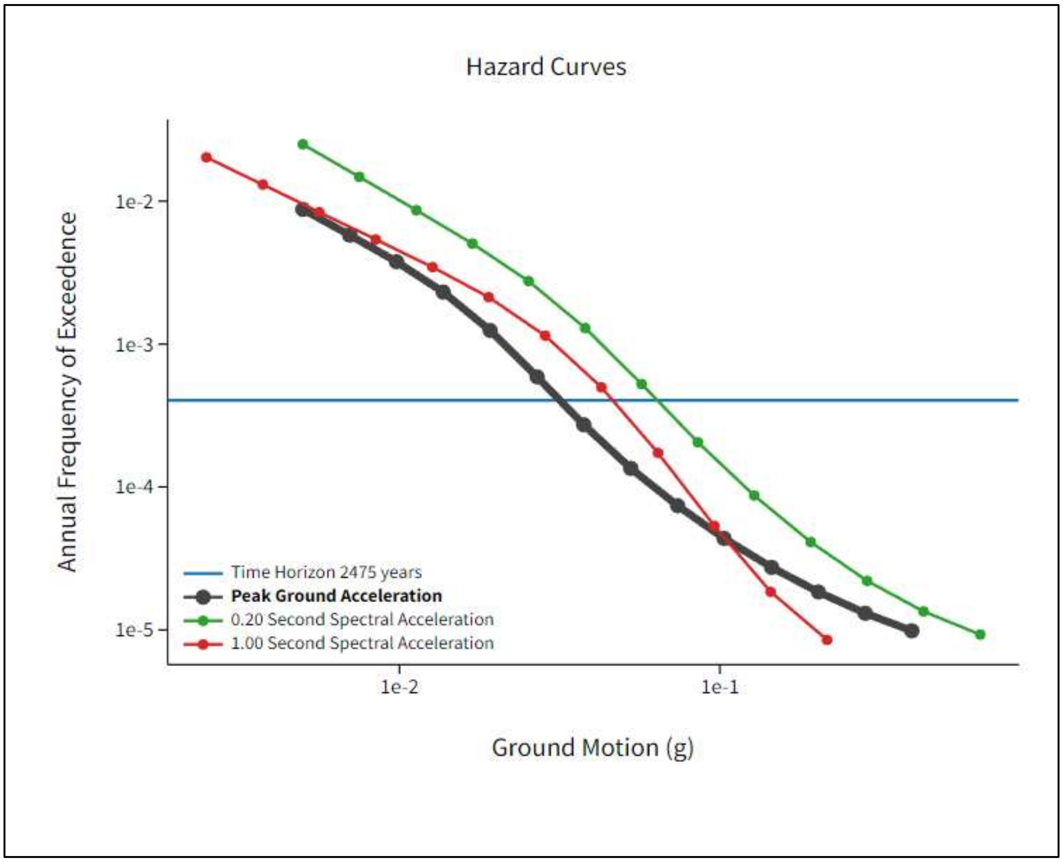


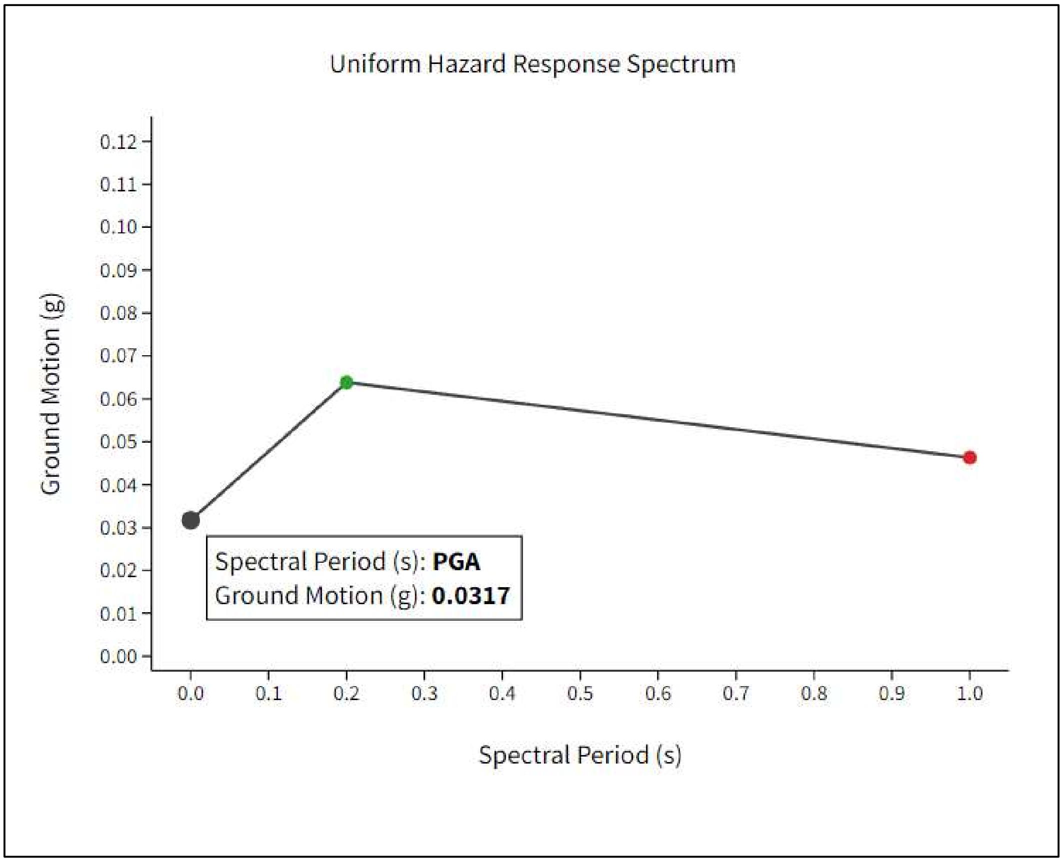
Seismic Assessment - Clive Lake Dam



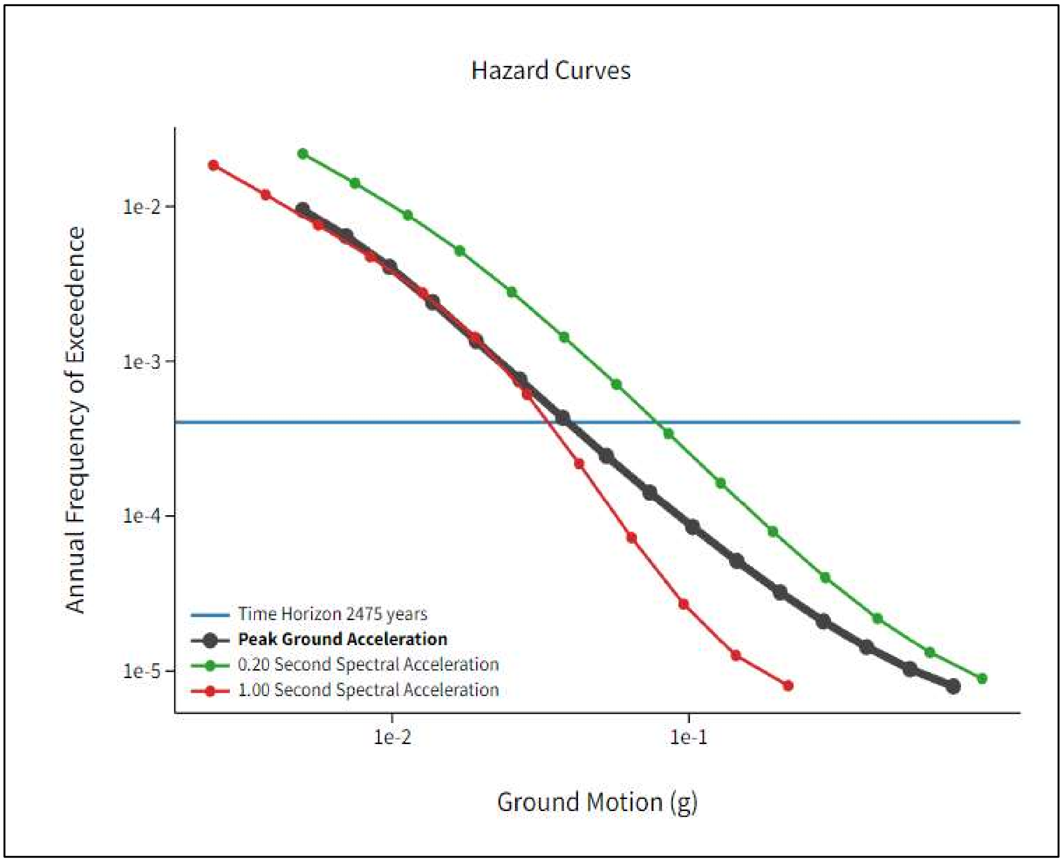


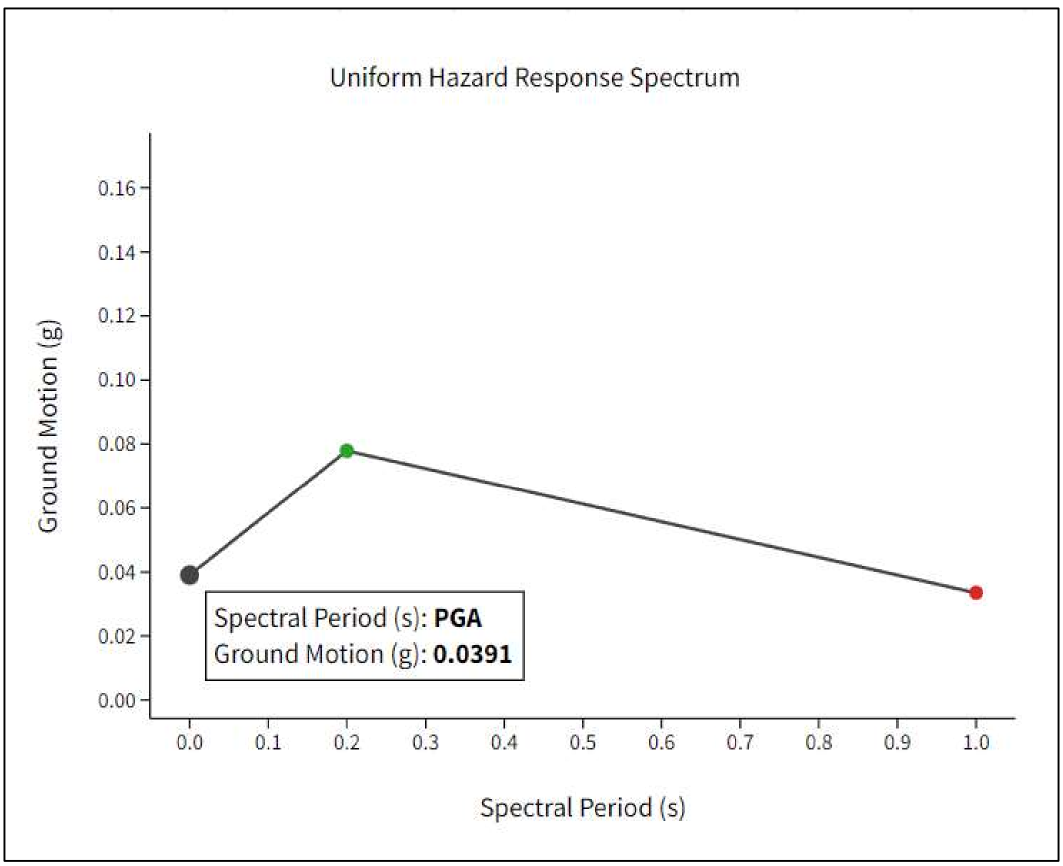
Seismic Assessment - Creston Flood Prevention Dam



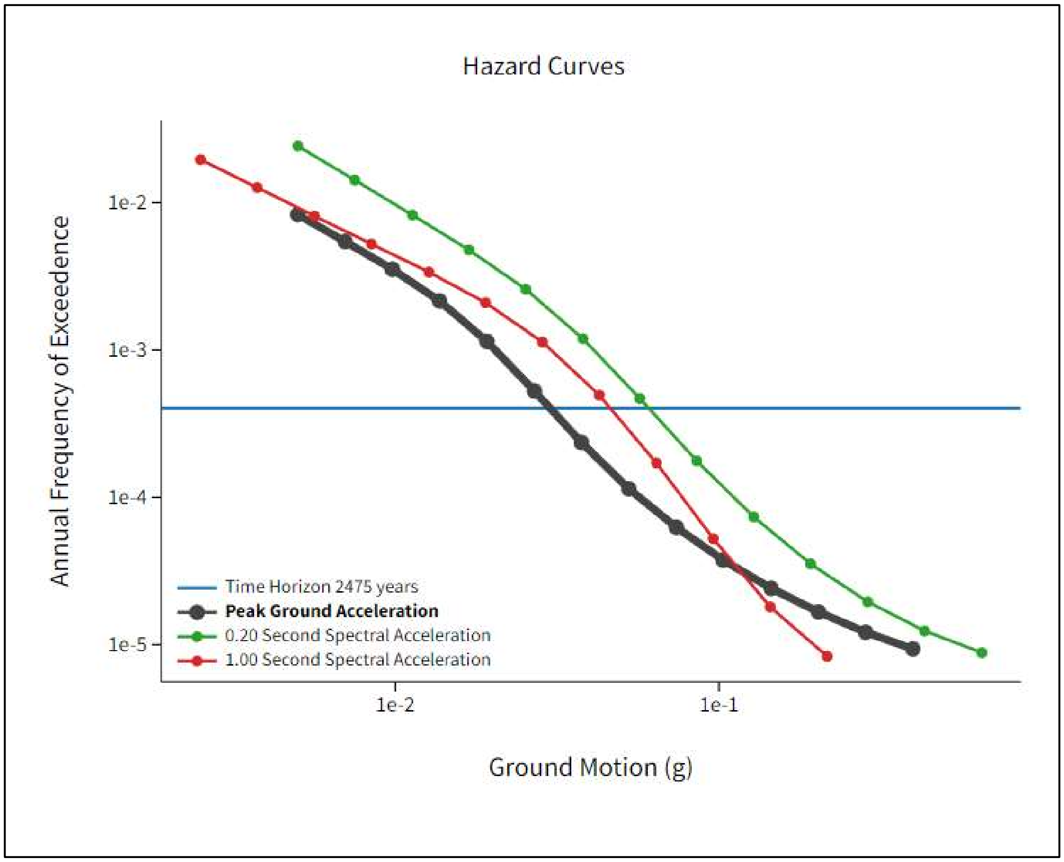


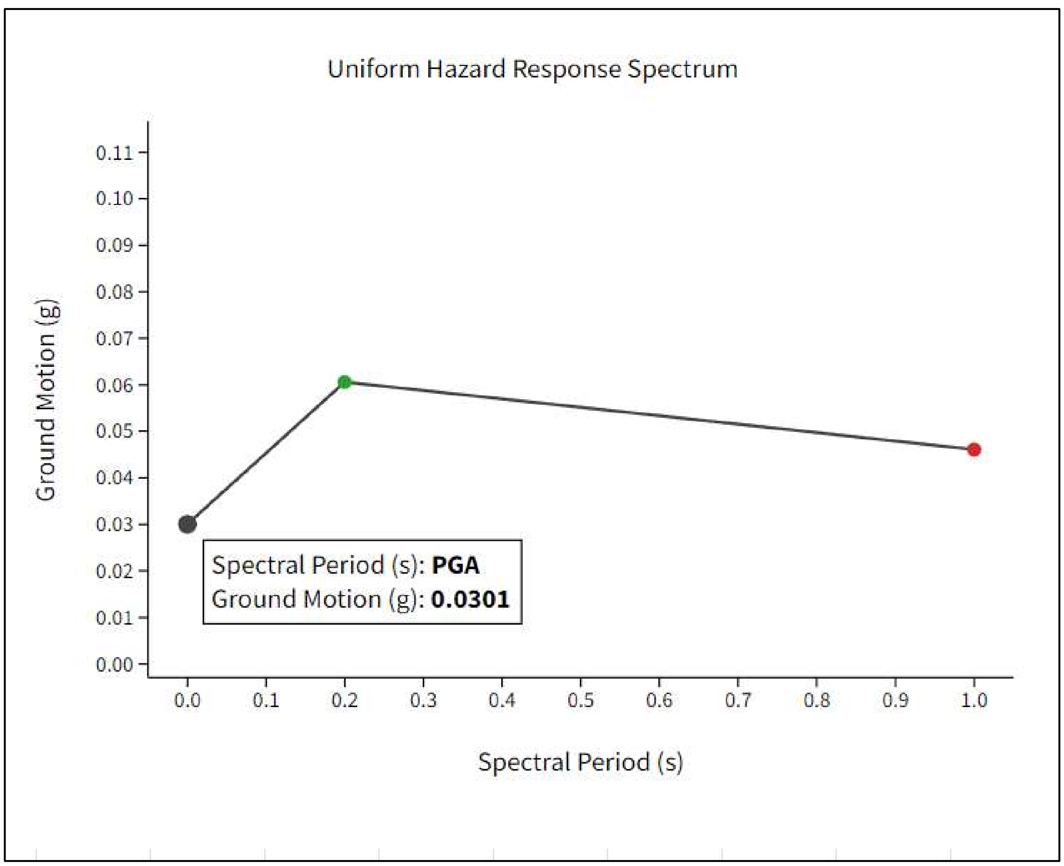
Seismic Assessment - Focht & Schindel Dam



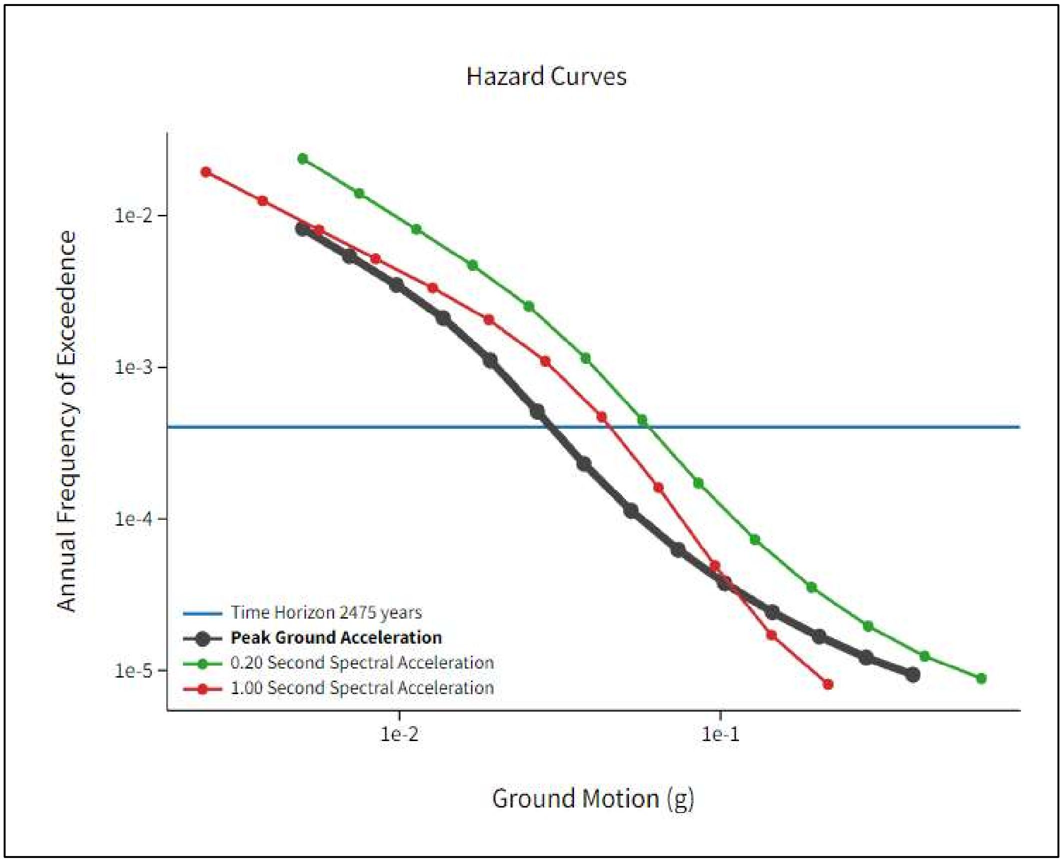


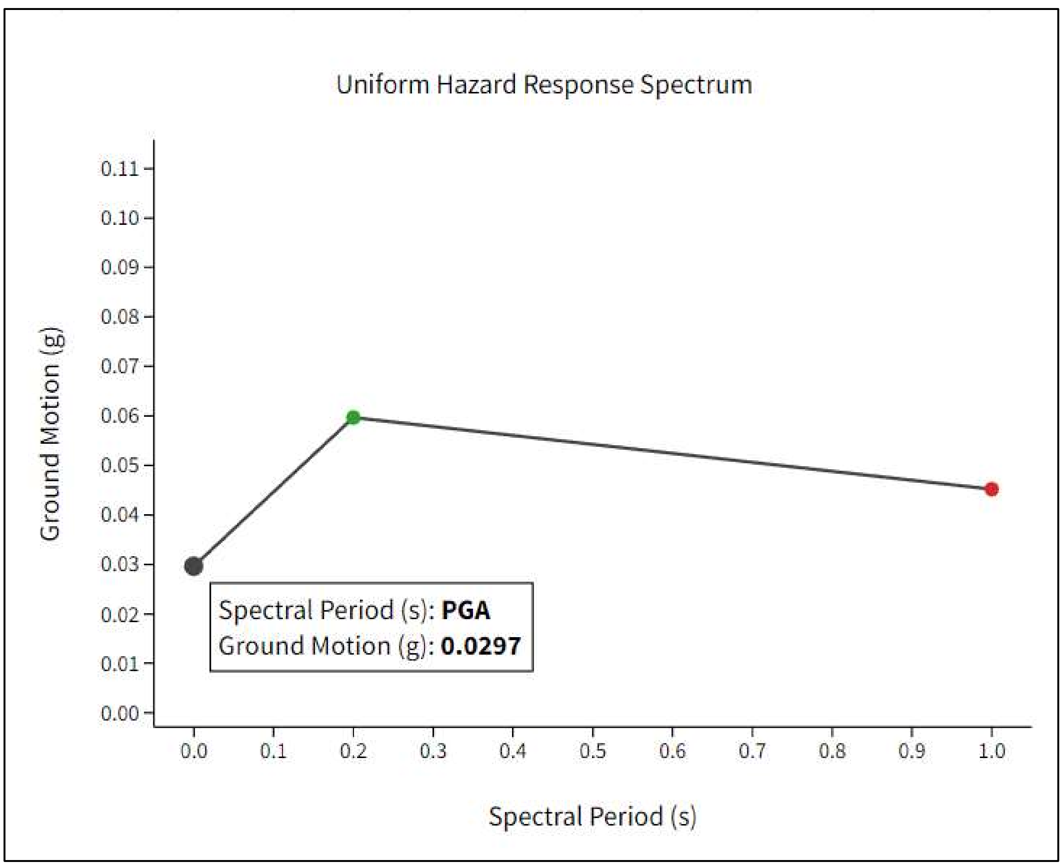
Seismic Assessment - Fort Des Moines Park Dam



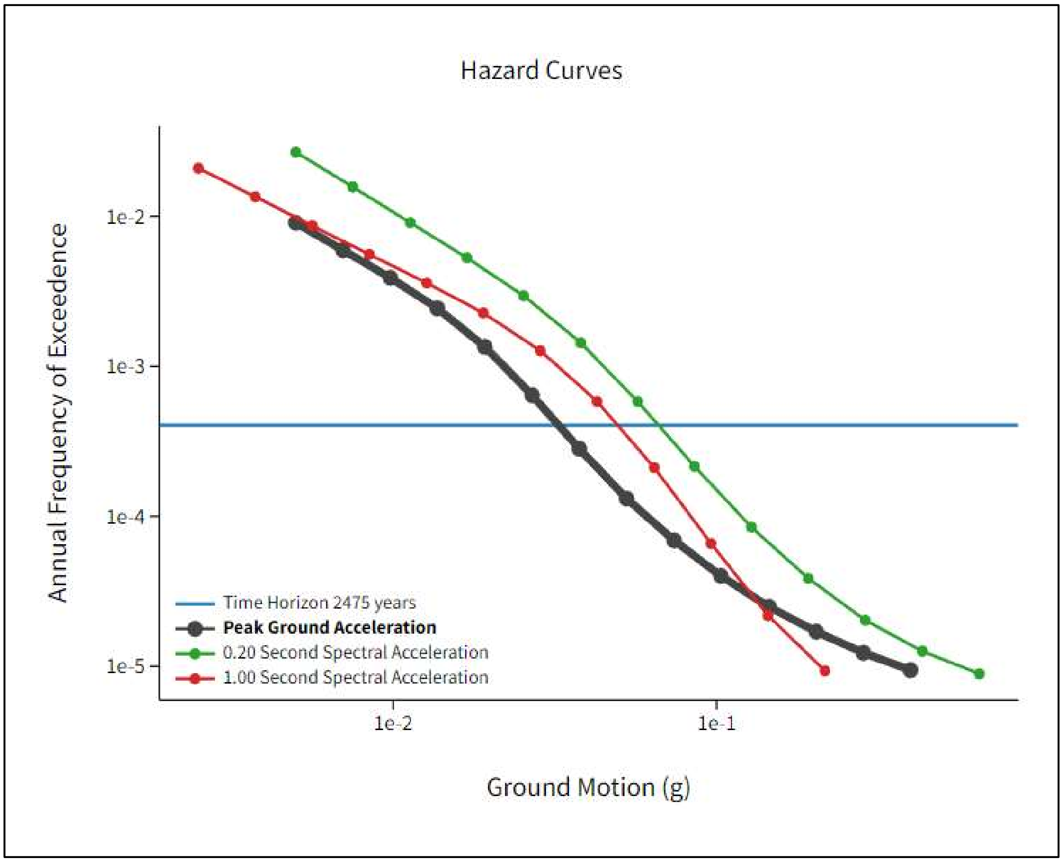


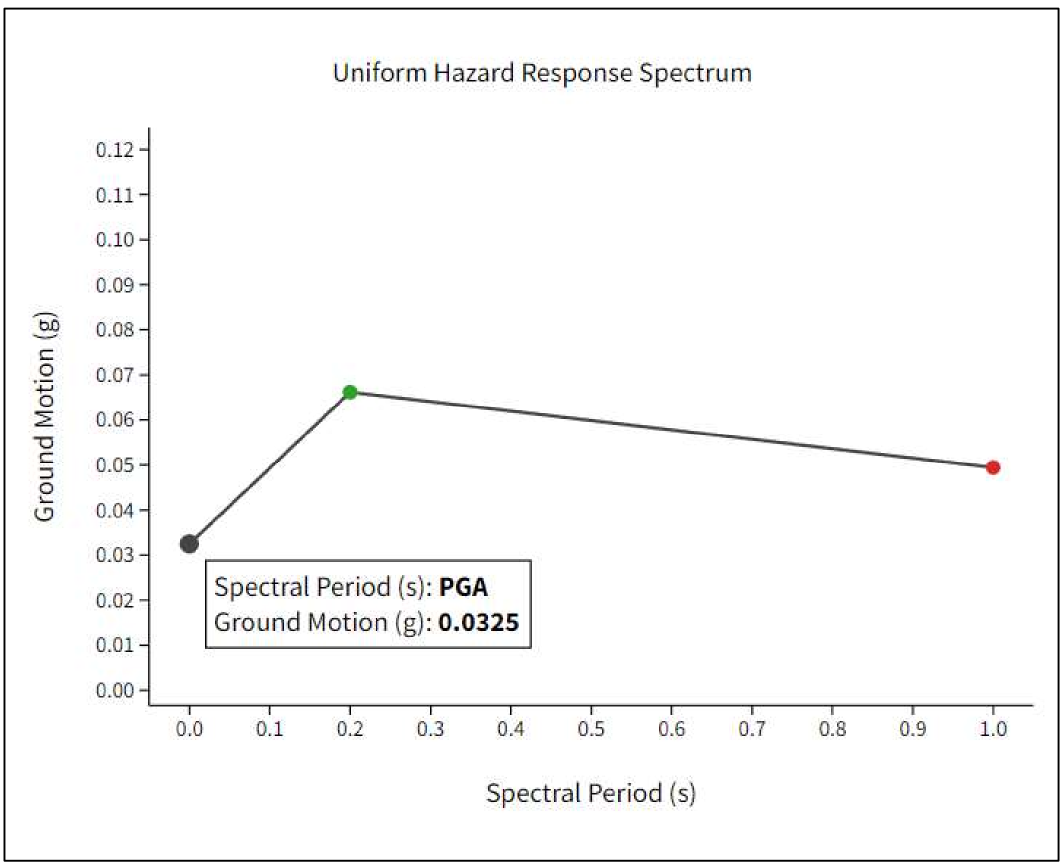
Seismic Assessment - Glen Oaks Country Club Dam



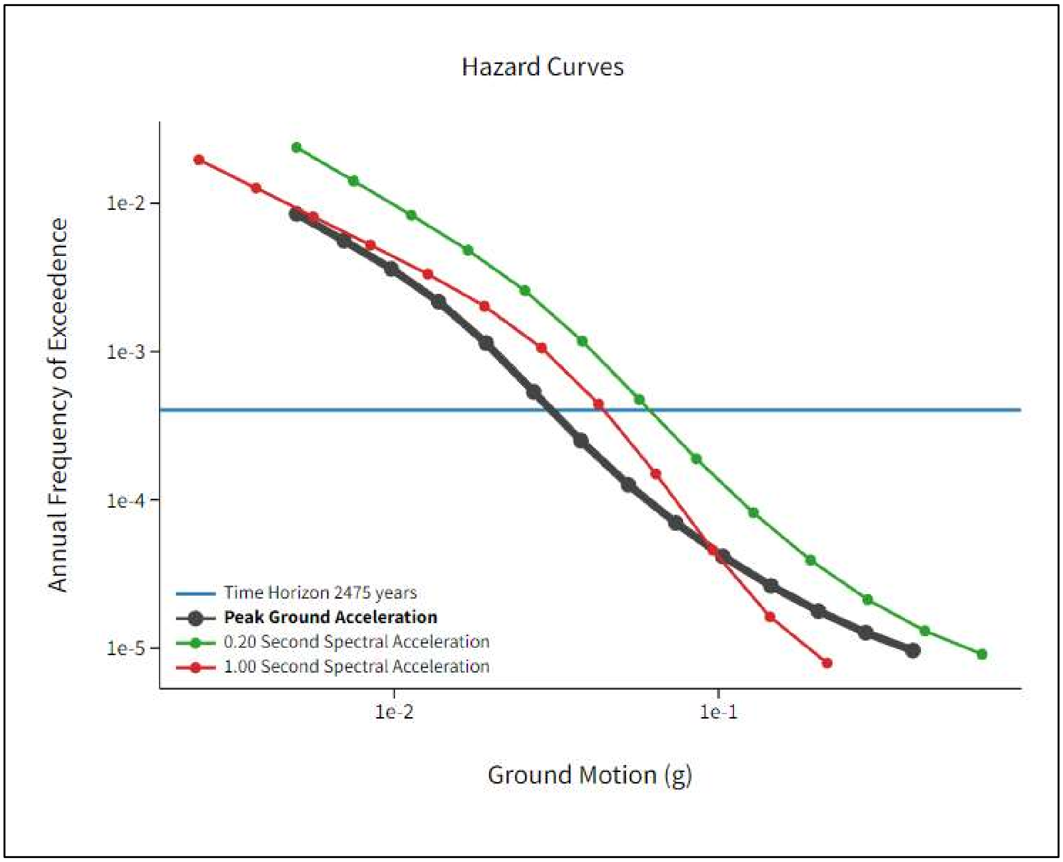


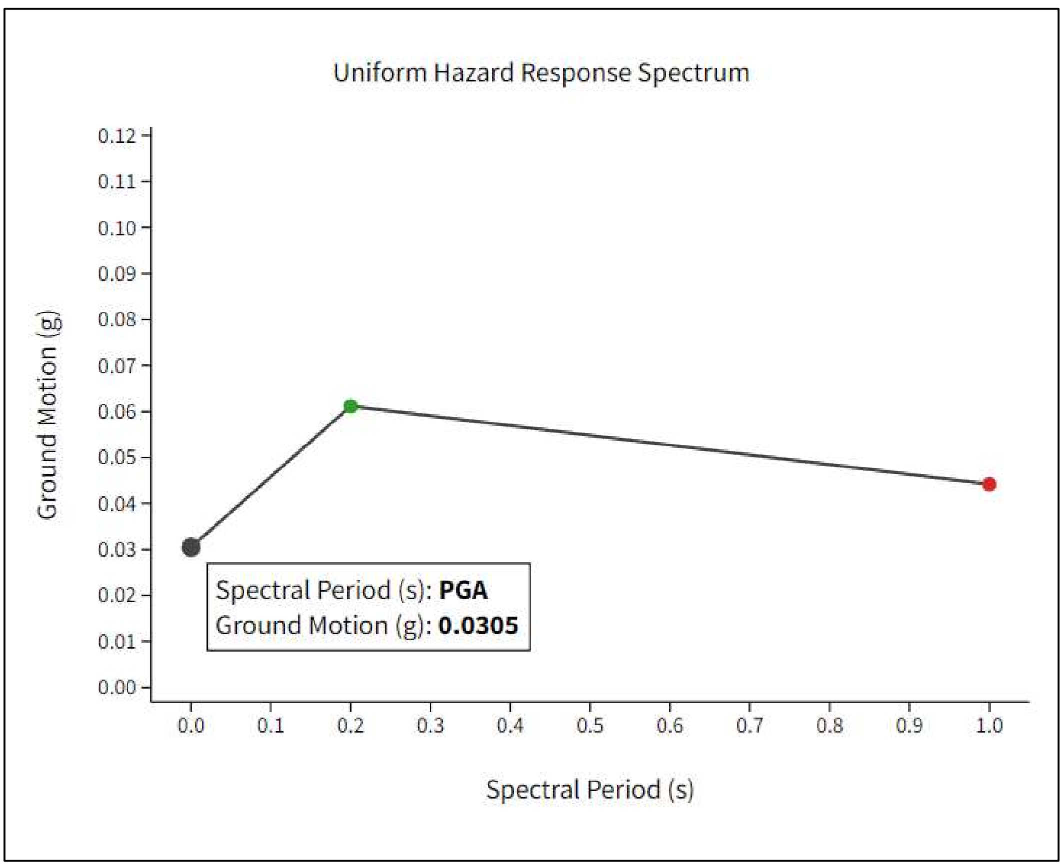
Seismic Assessment - Grade Lake Dam



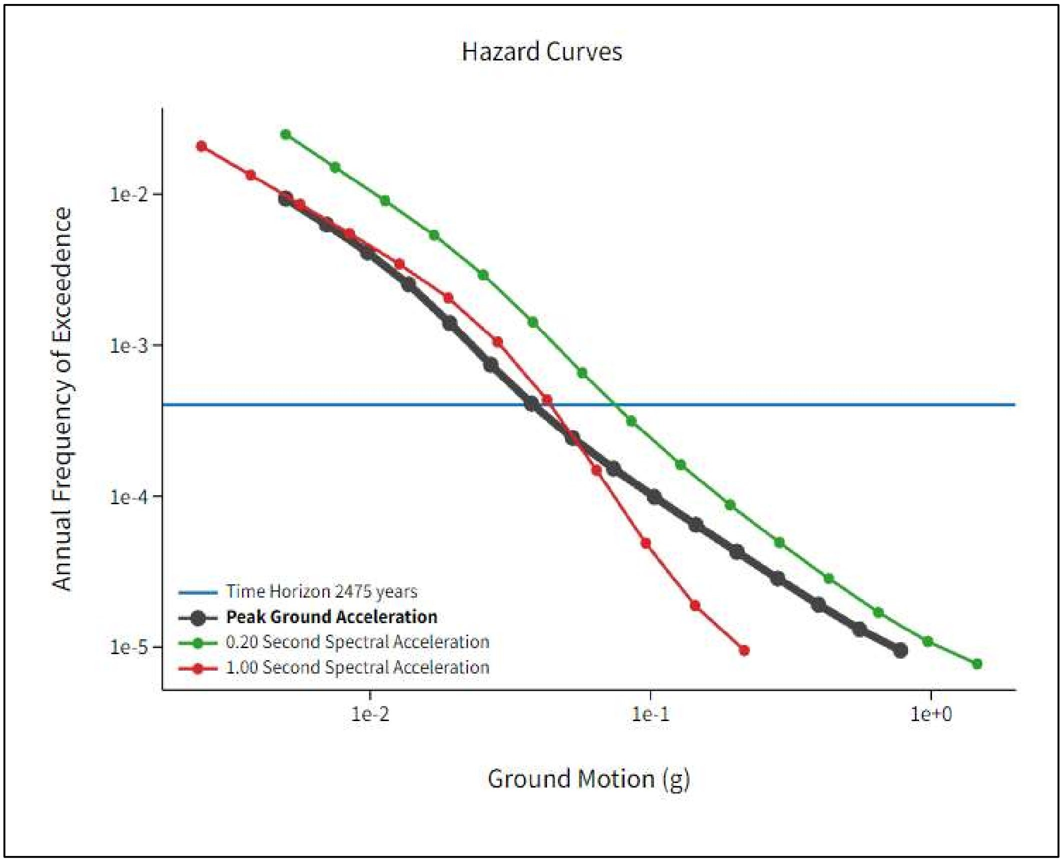


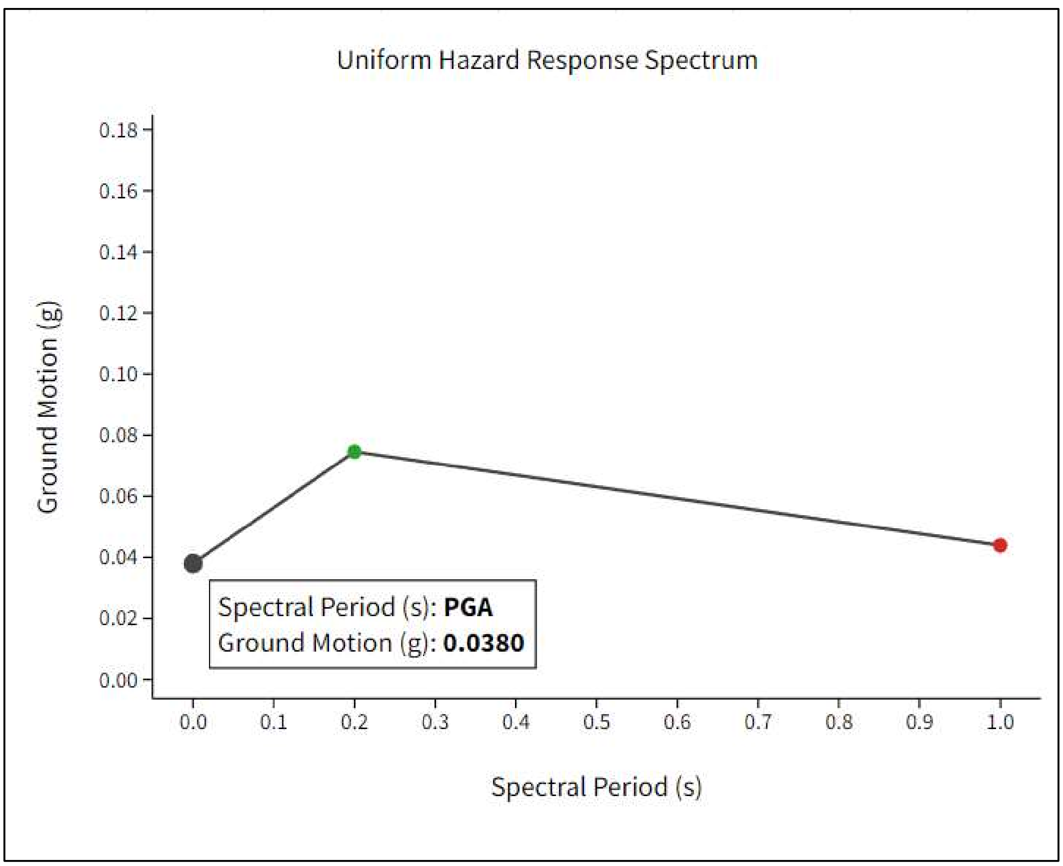
Seismic Assessment - Greenfield Reservoir Dam



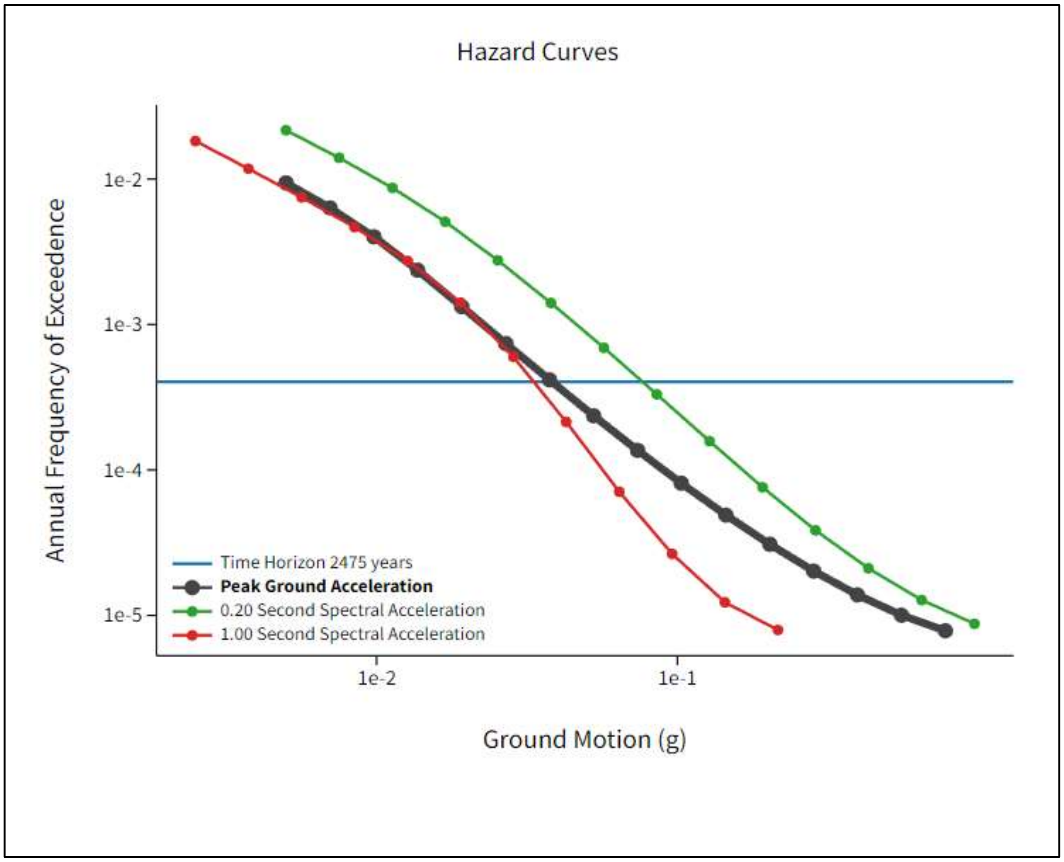


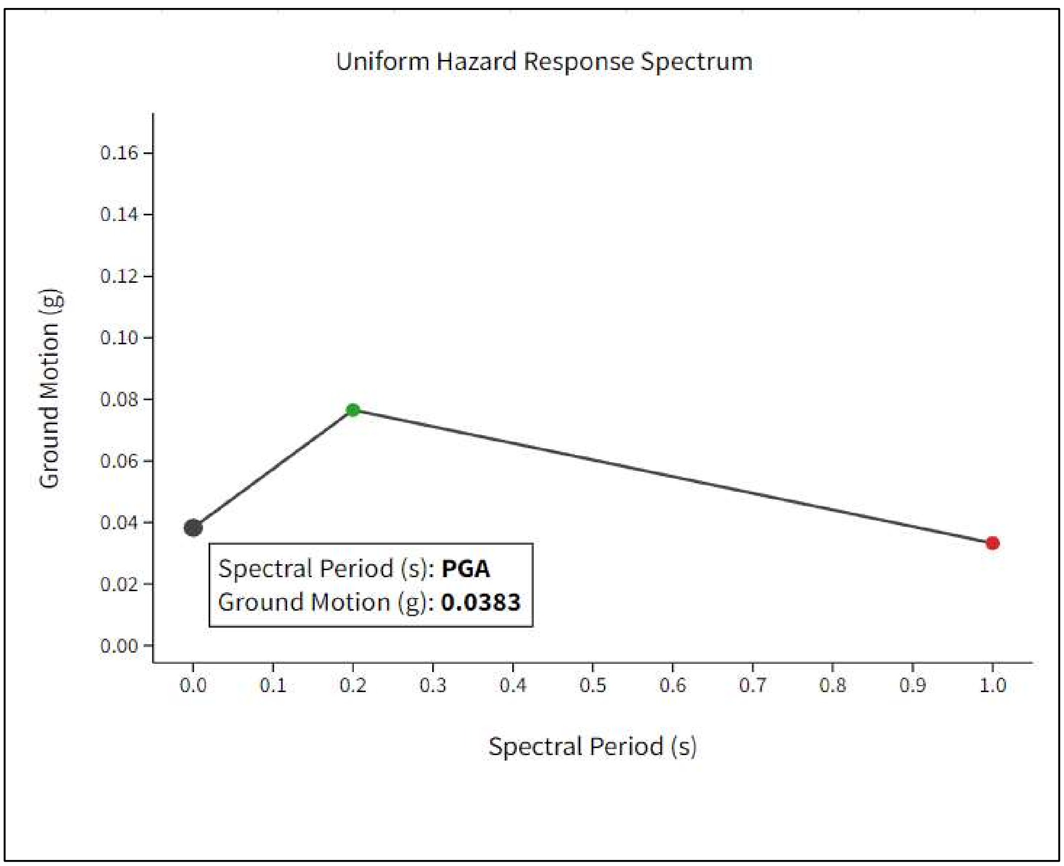
Seismic Assessment - Hamburg Watershed Site M-1



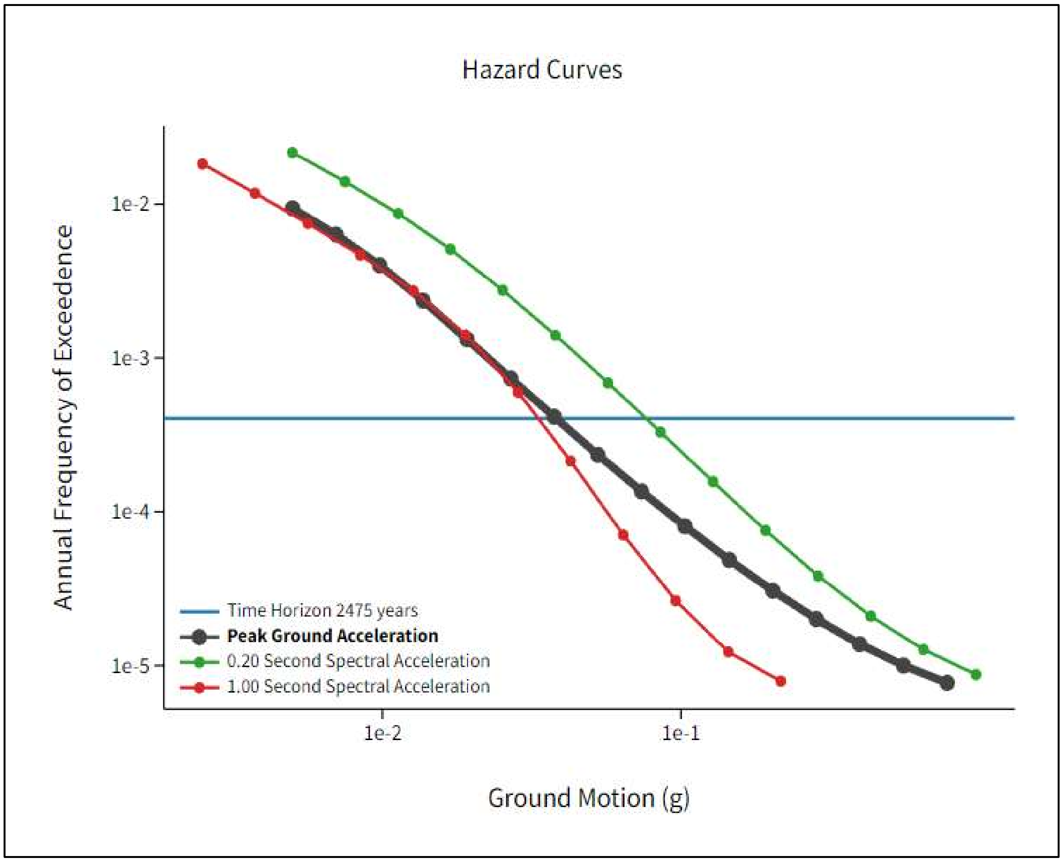


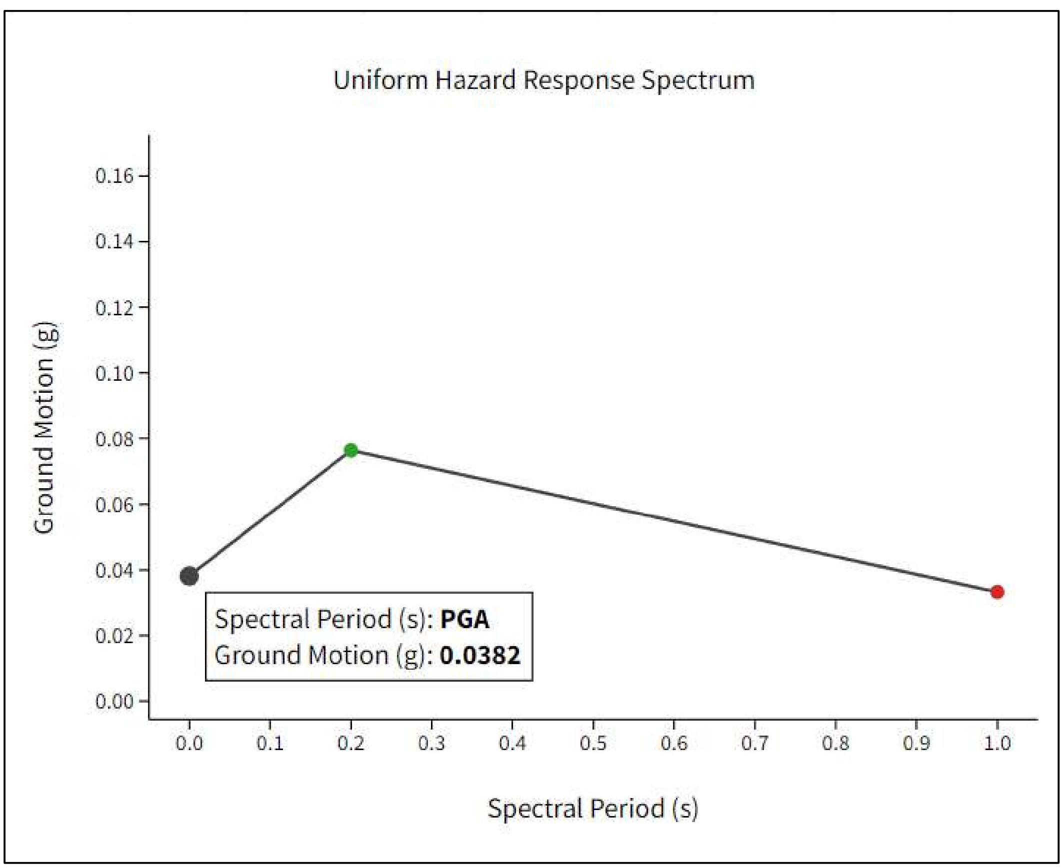
Seismic Assessment - Held Watershed Site E-3



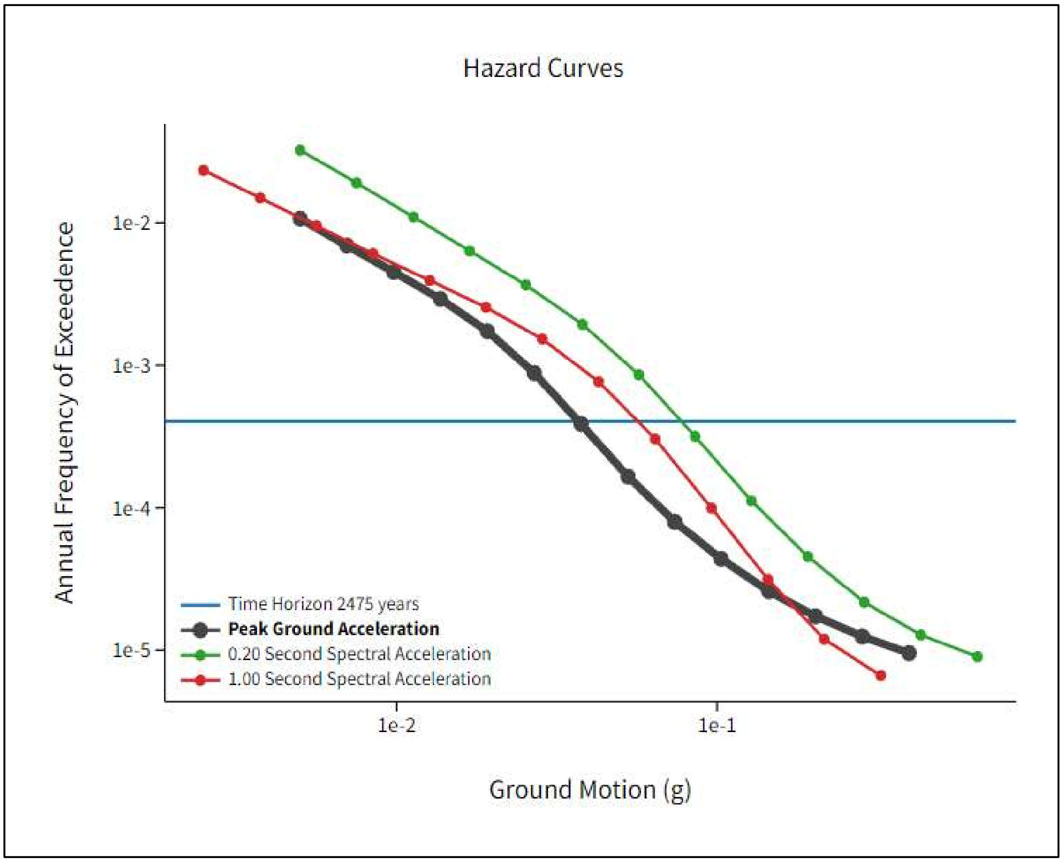


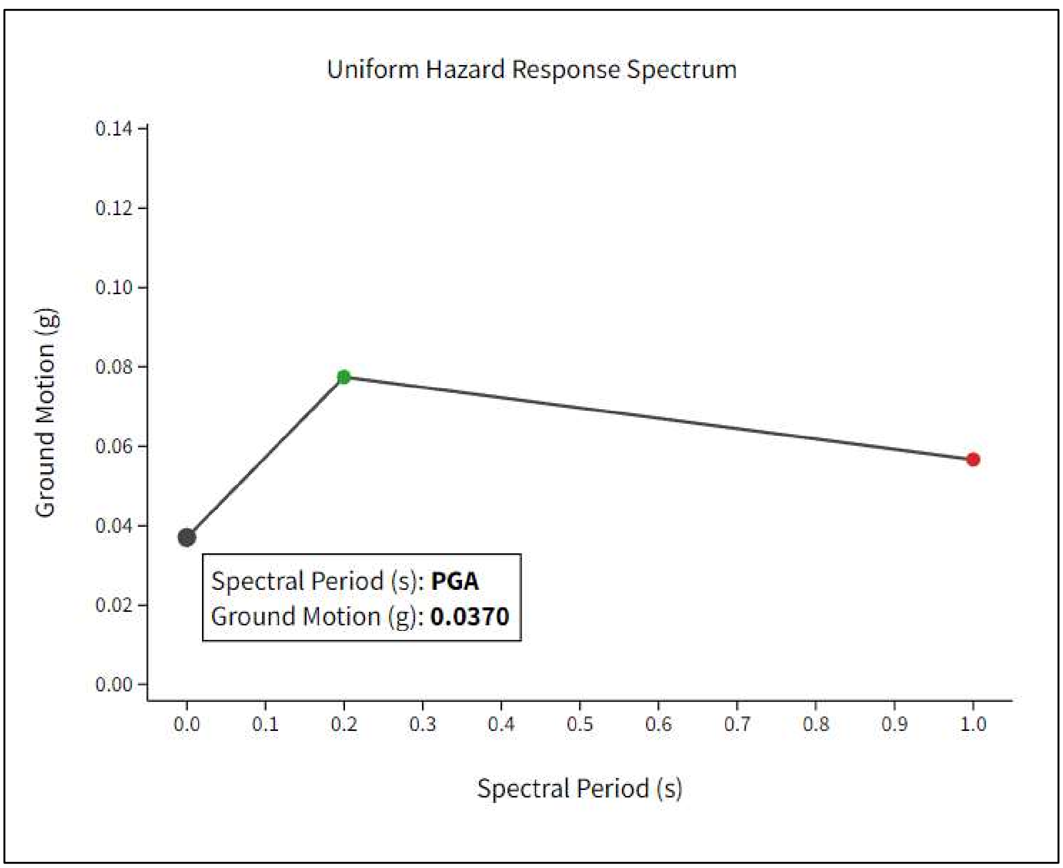
Seismic Assessment - Held Watershed Site E-4



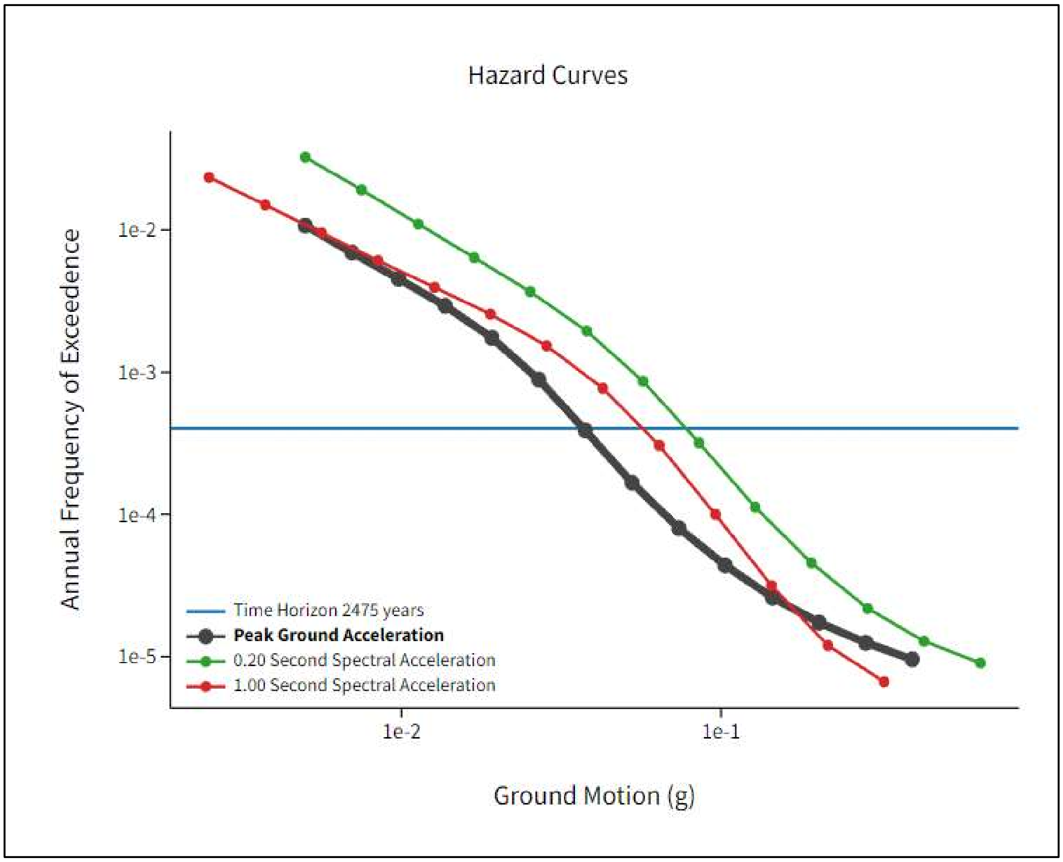


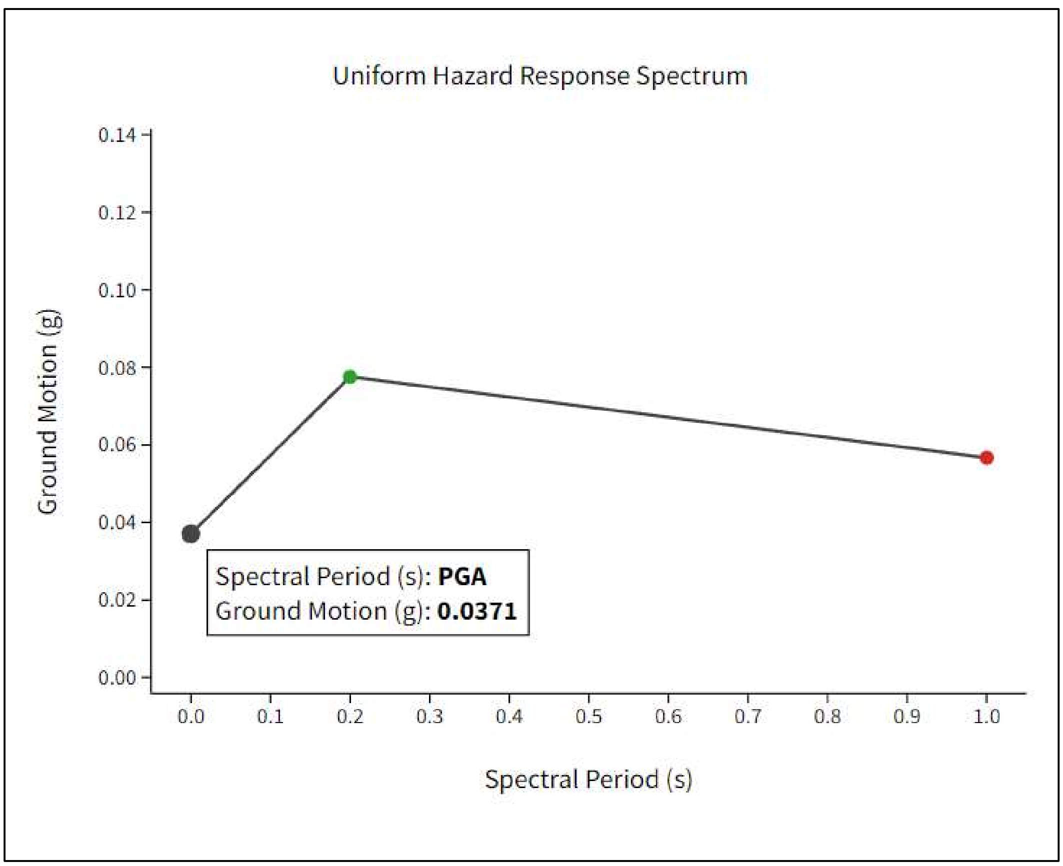
Seismic Assessment - Jefferson Park Watershed Site 1



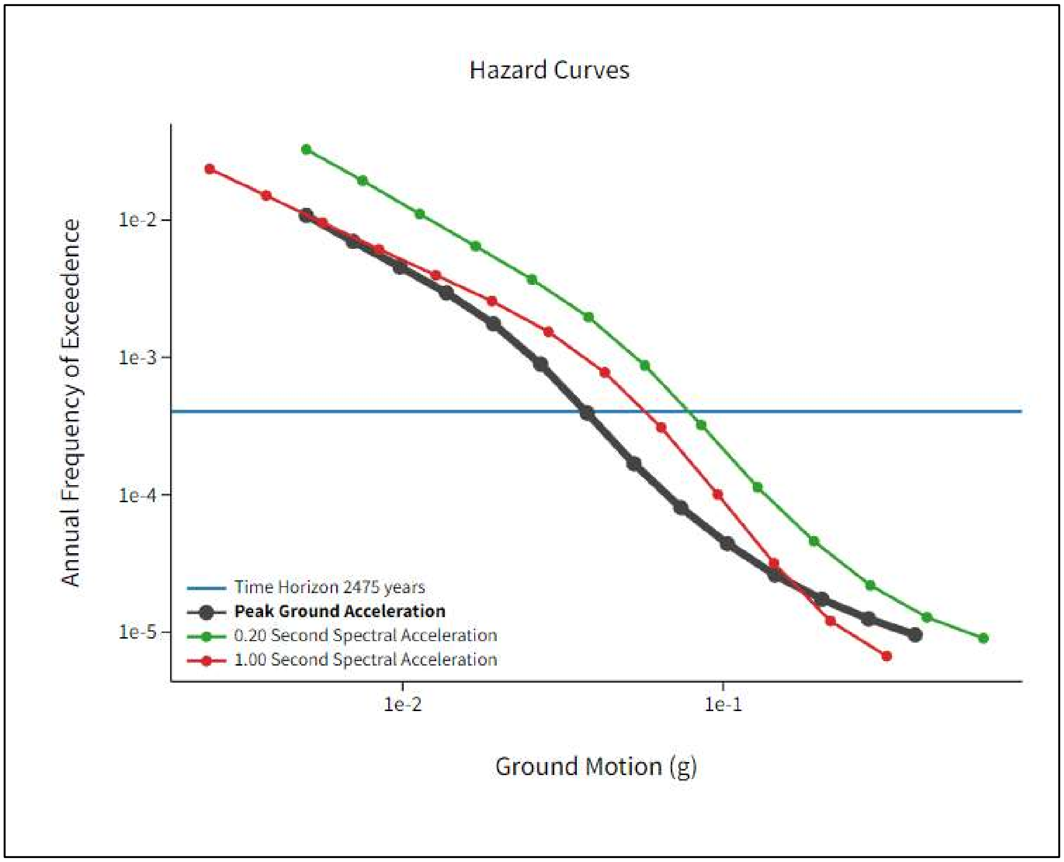


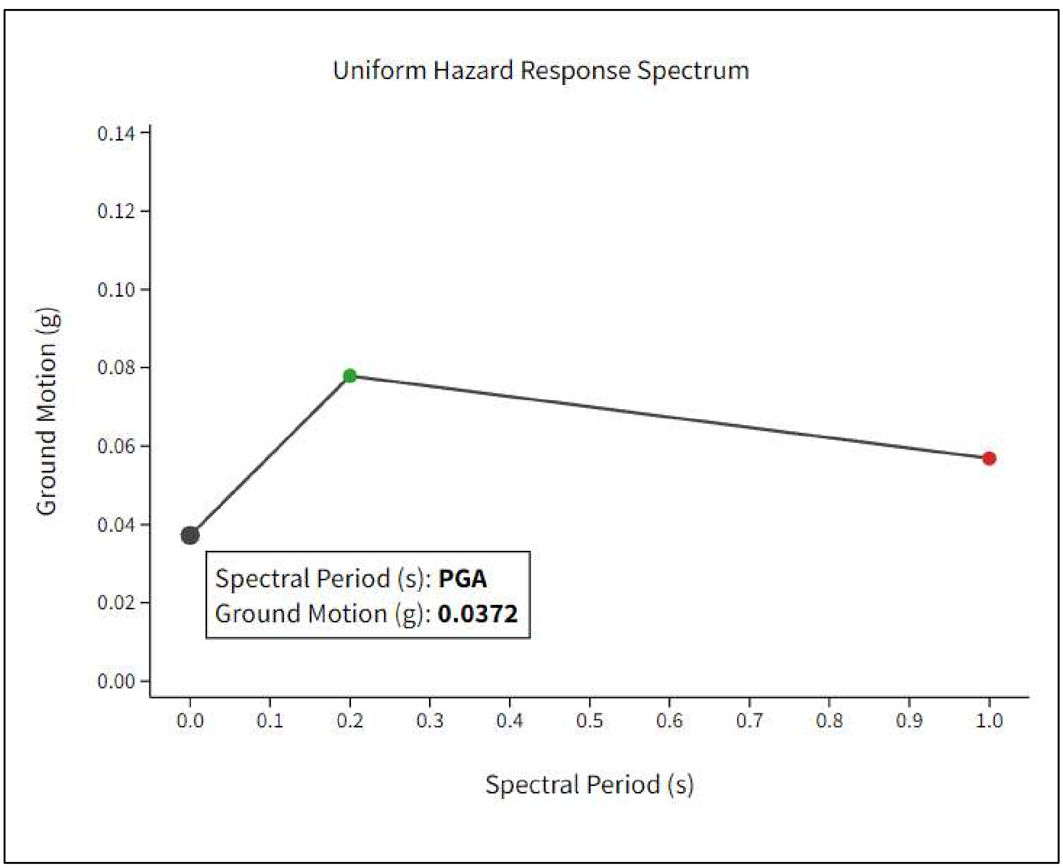
Seismic Assessment - Jefferson Park Watershed Site 10



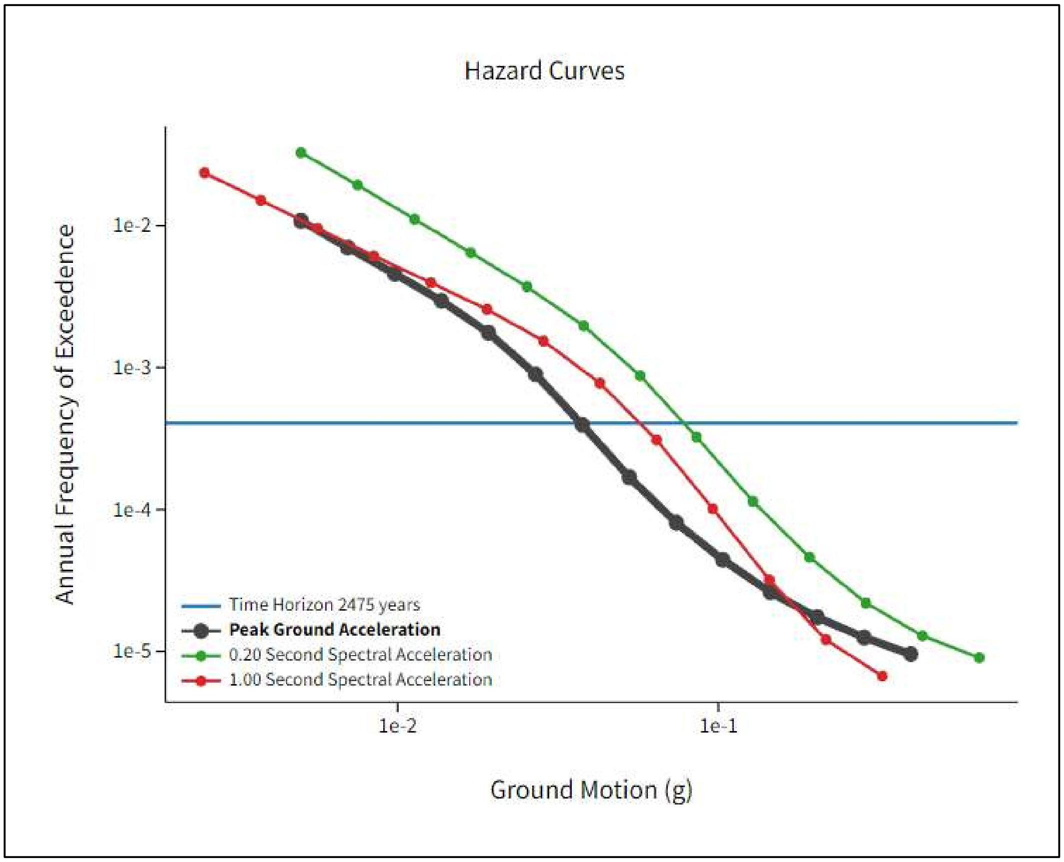


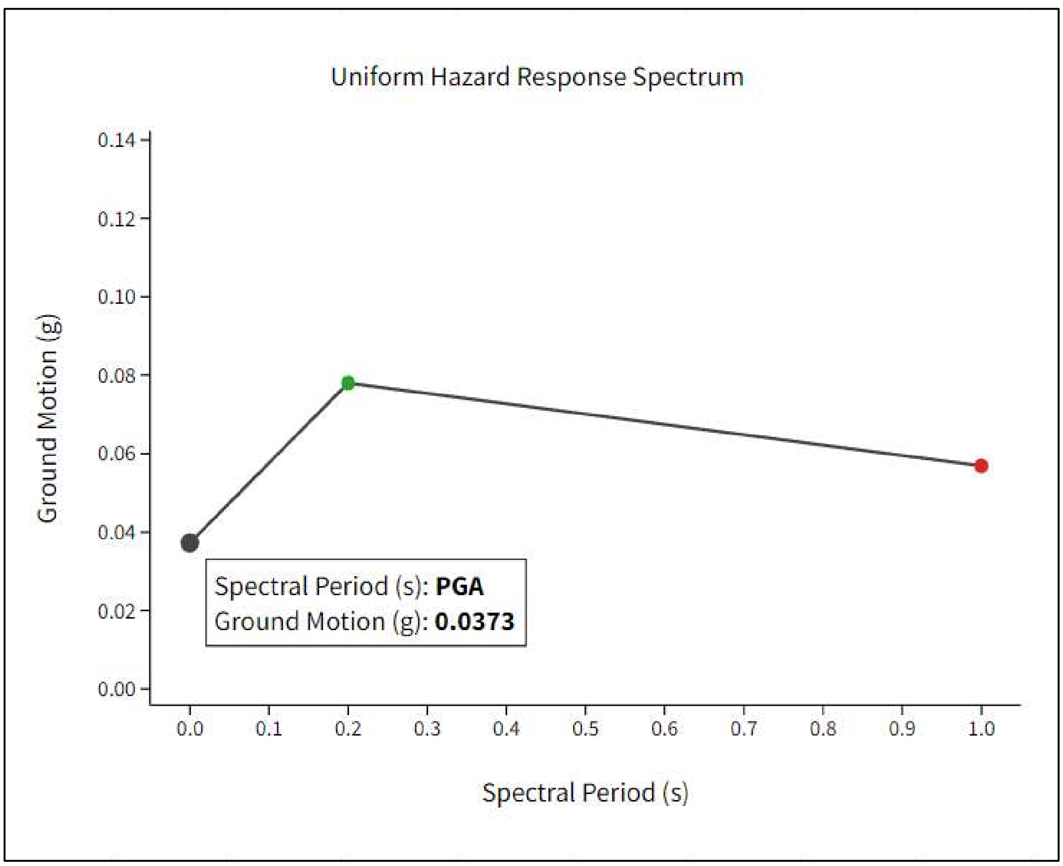
Seismic Assessment - Jefferson Park Watershed Site 3



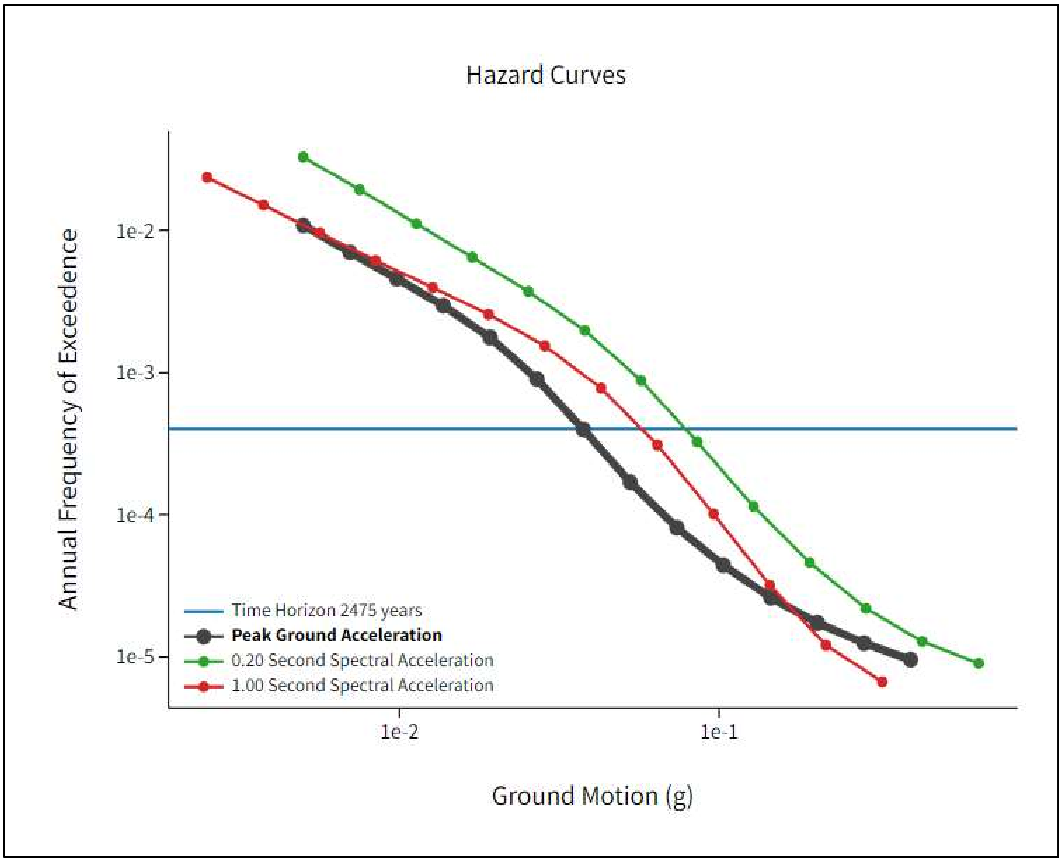


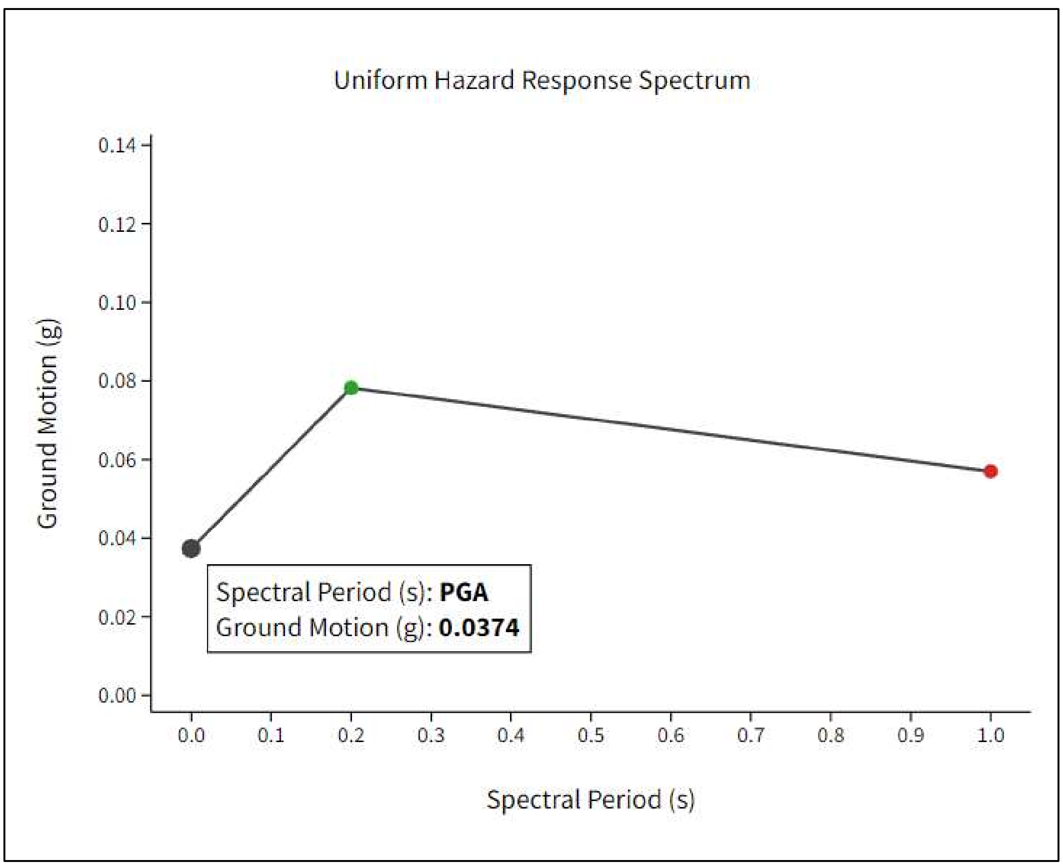
Seismic Assessment - Jefferson Park Watershed Site 4



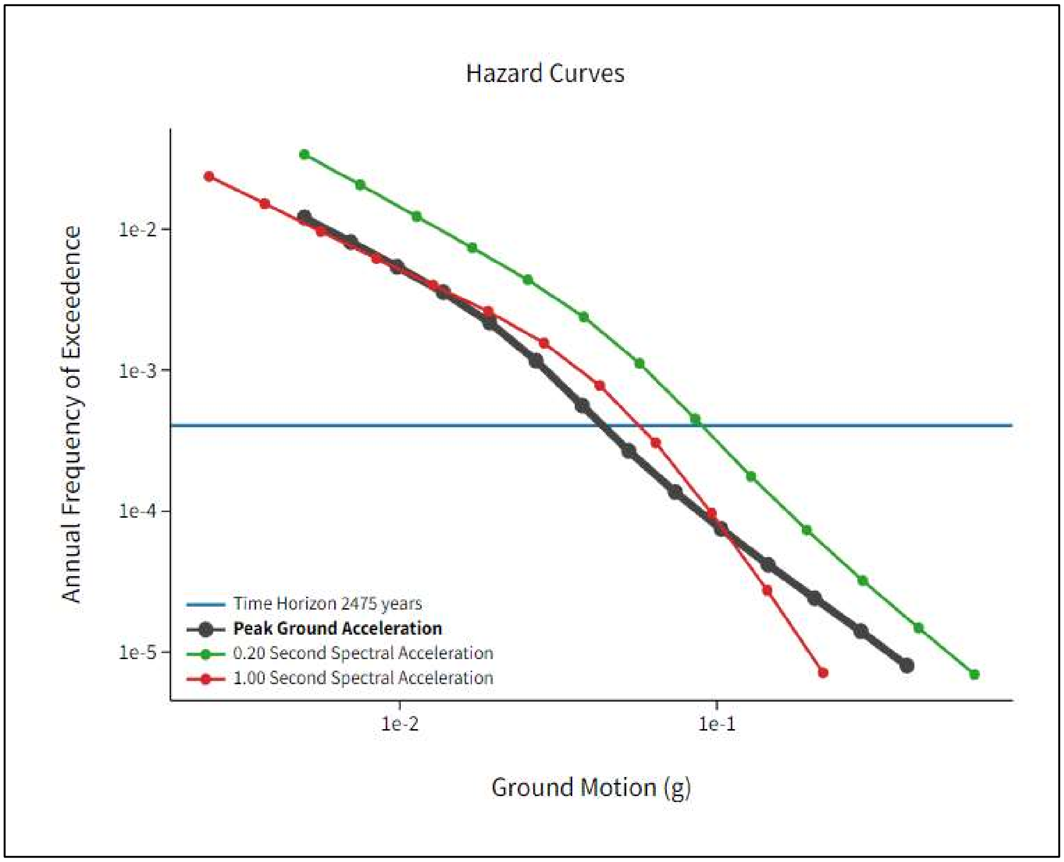


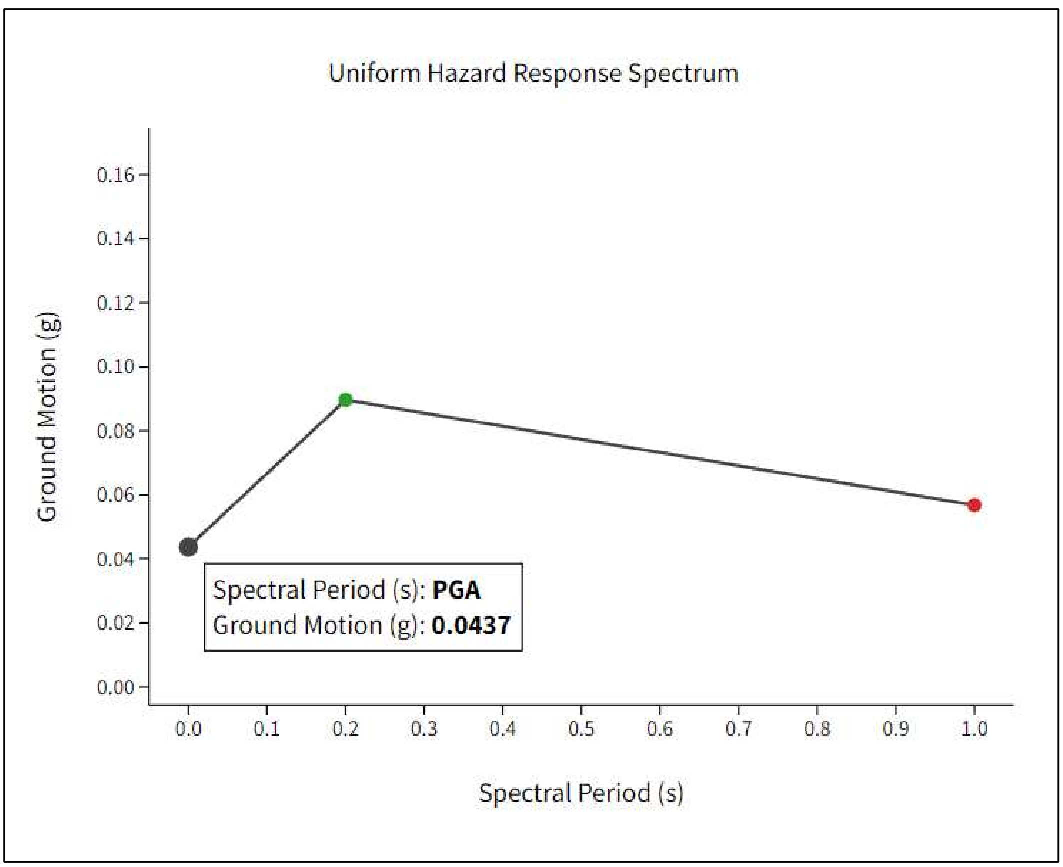
Seismic Assessment - Jefferson Park Watershed Site 5



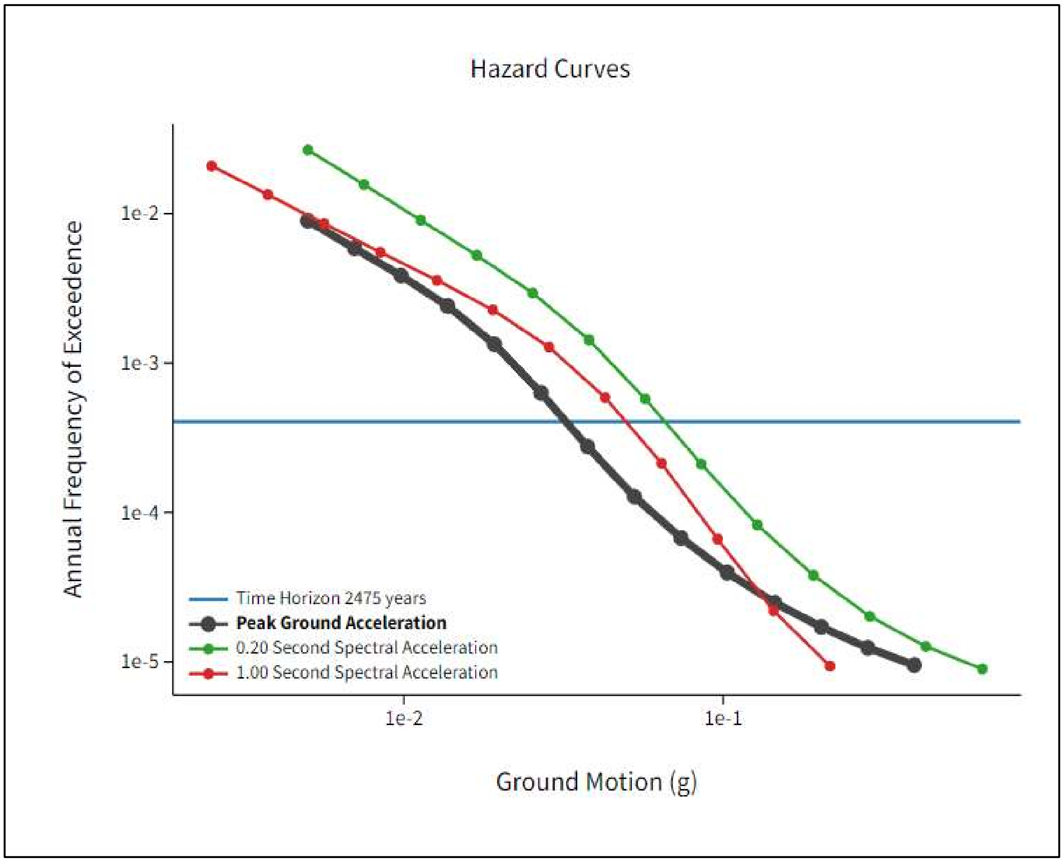


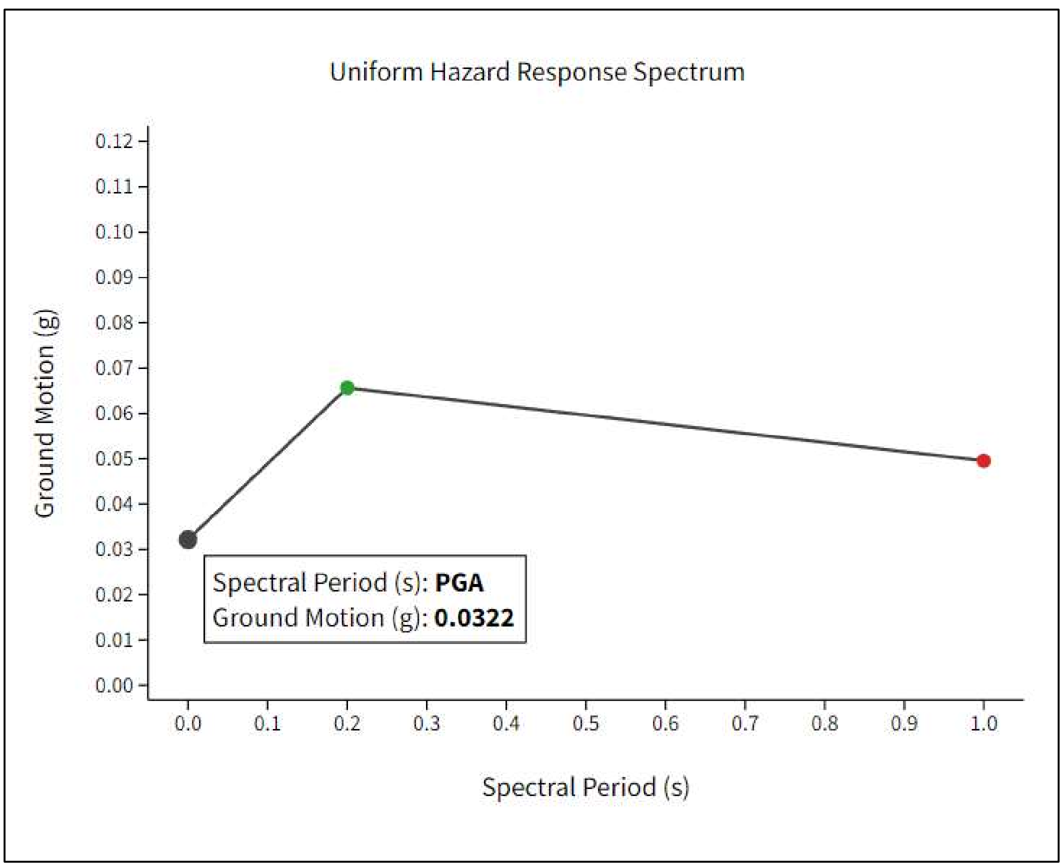
Seismic Assessment - Lake of the Hills Dam



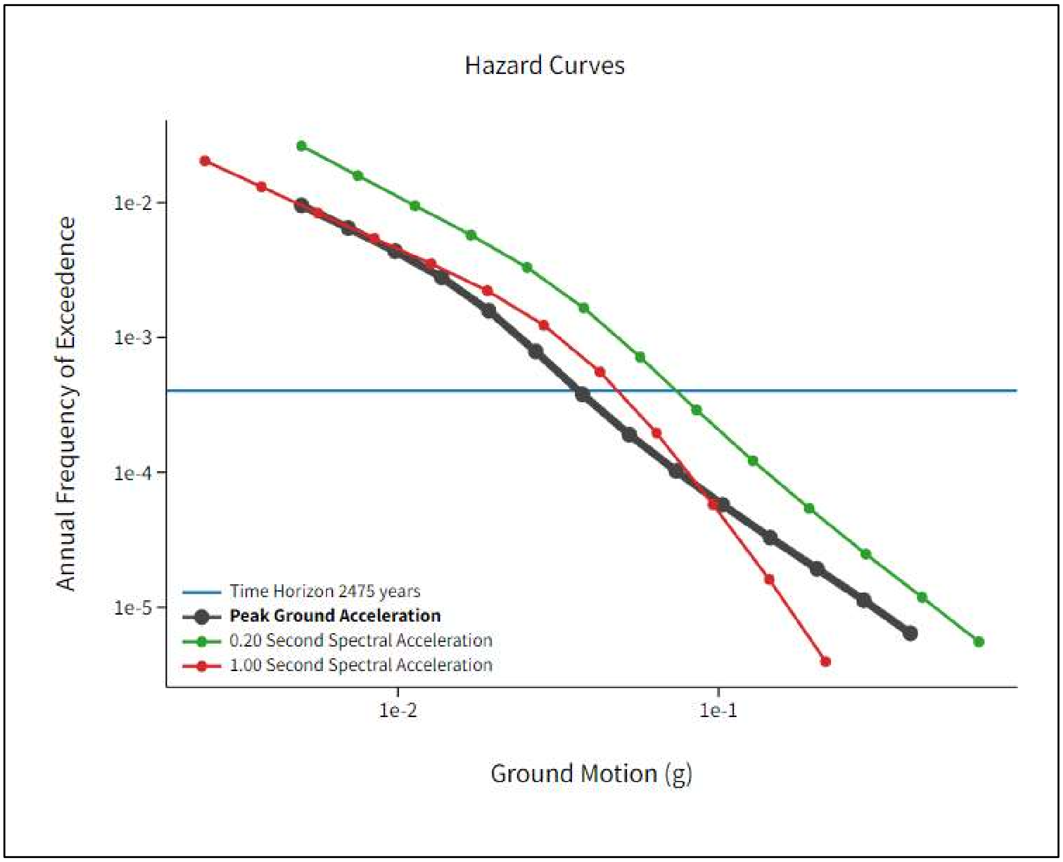


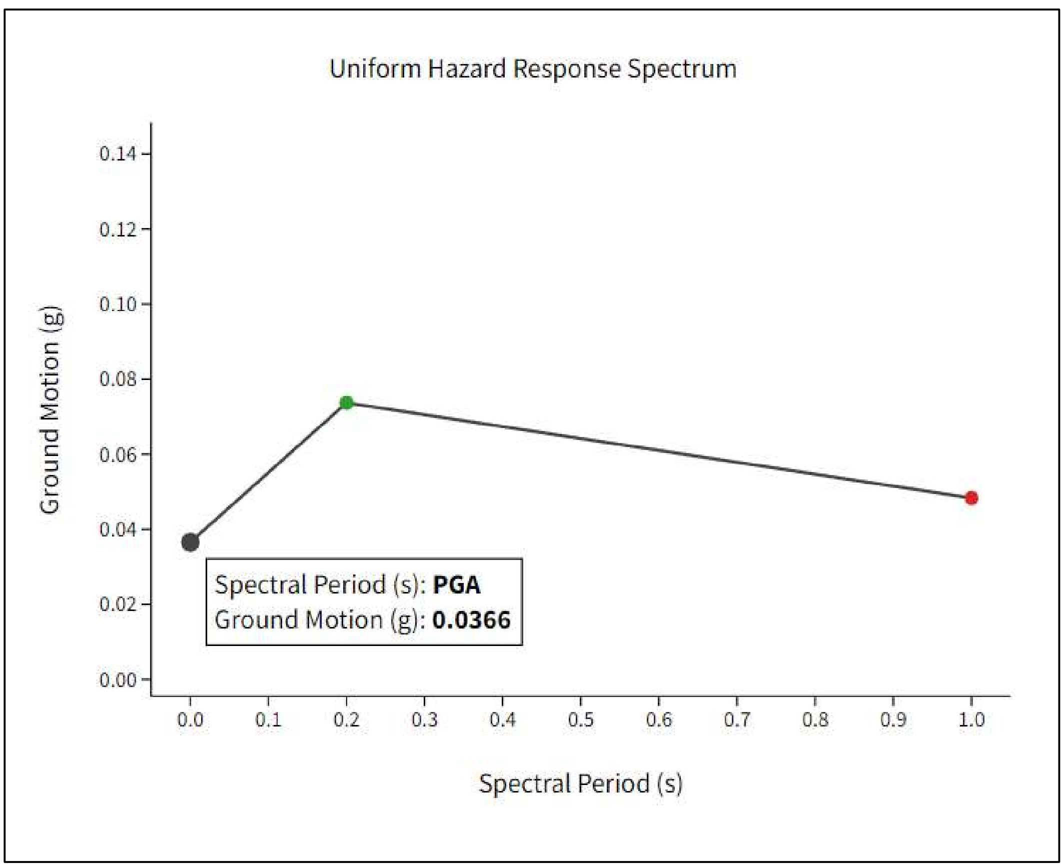
Seismic Assessment - Lake Ponderosa Dam



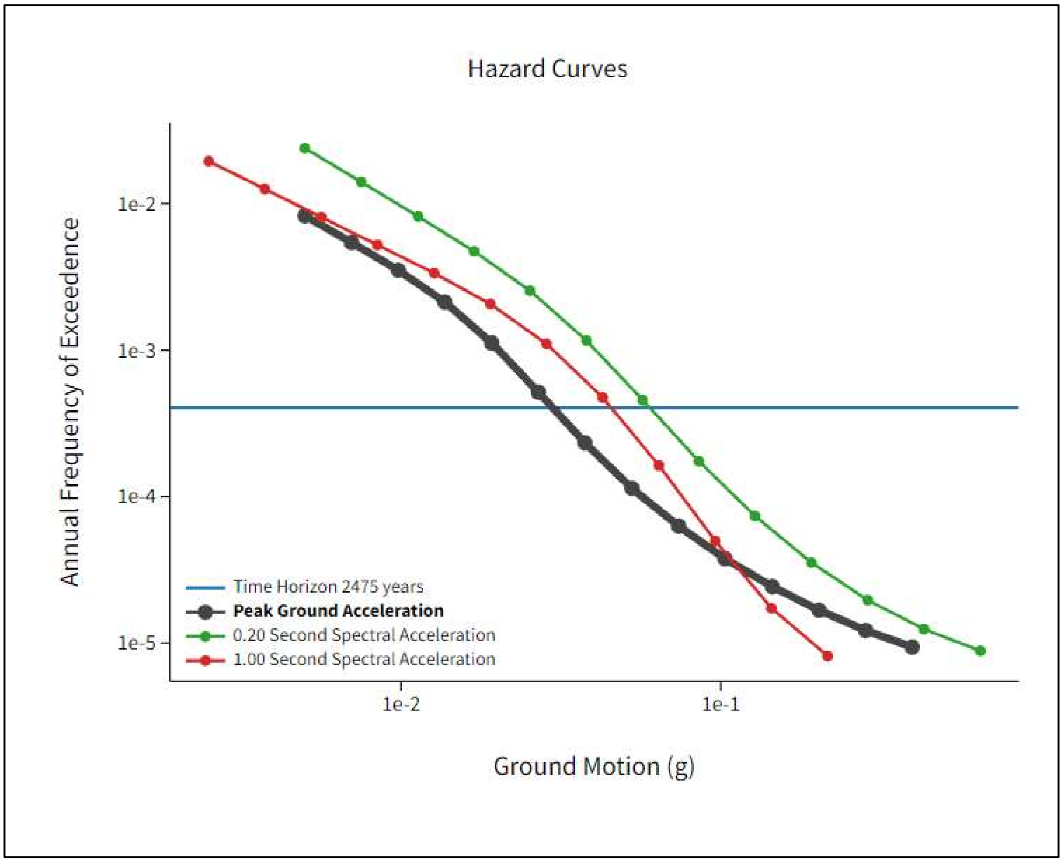


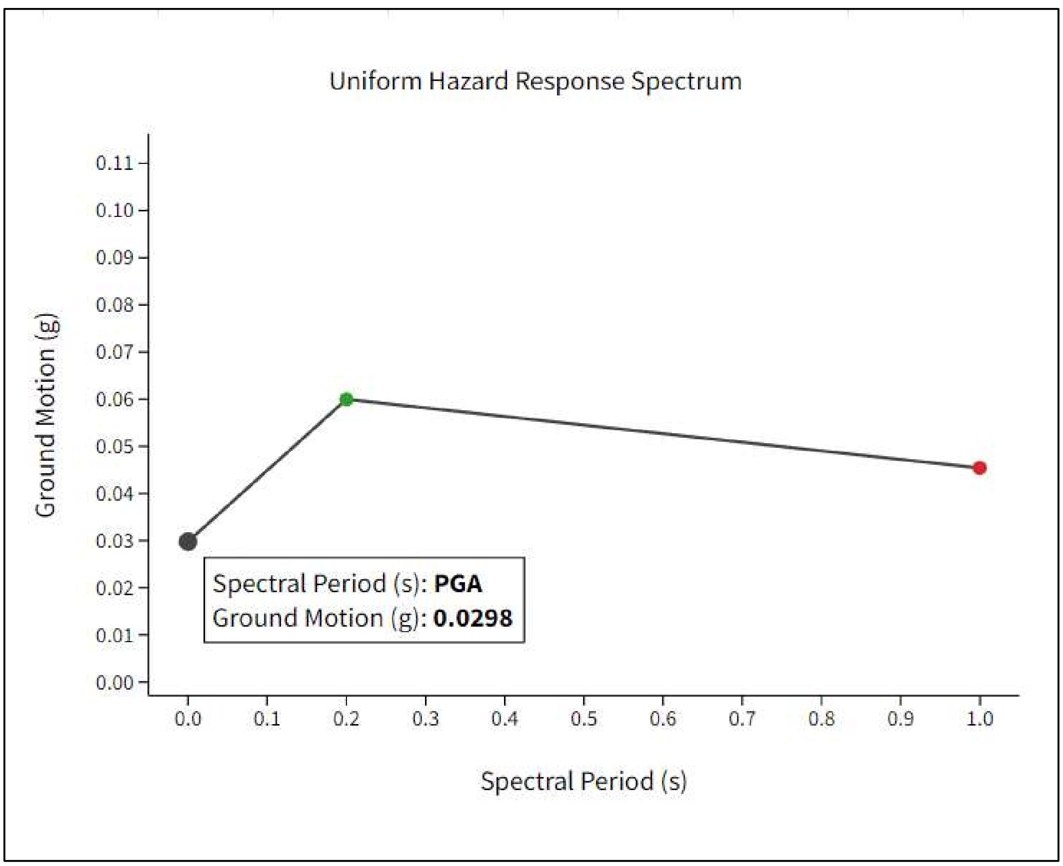
Seismic Assessment - Leisure Lake Dam



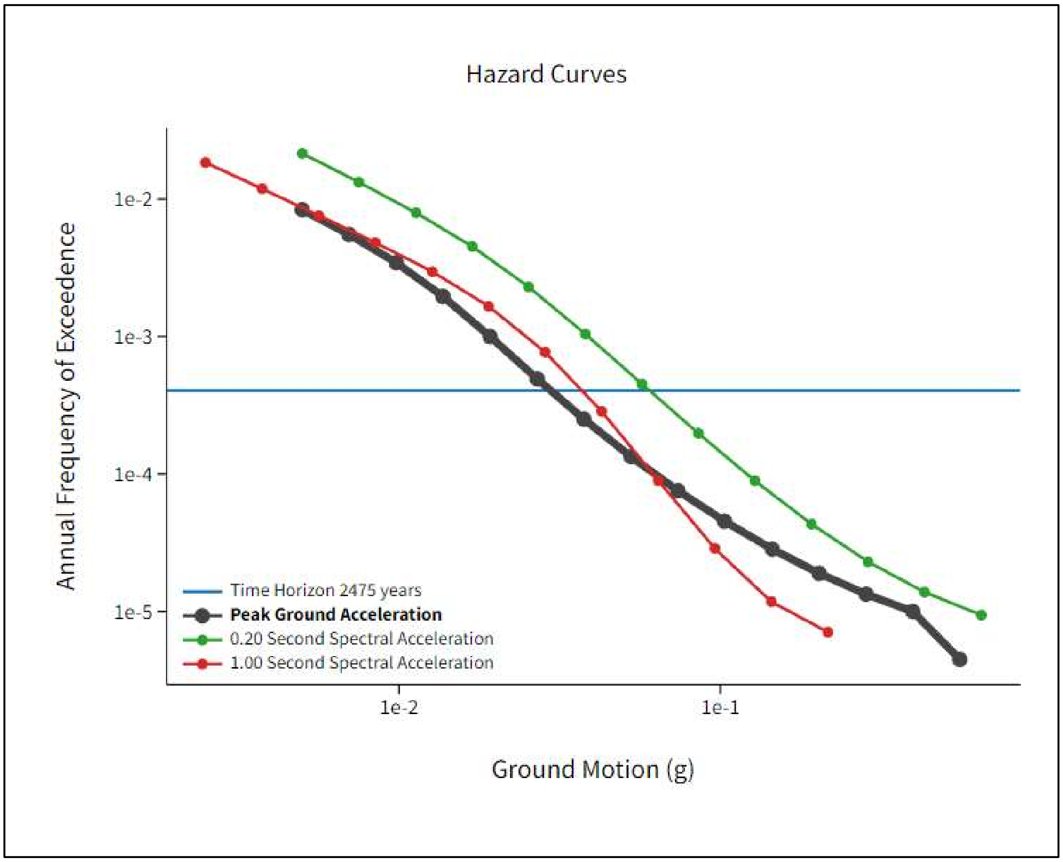


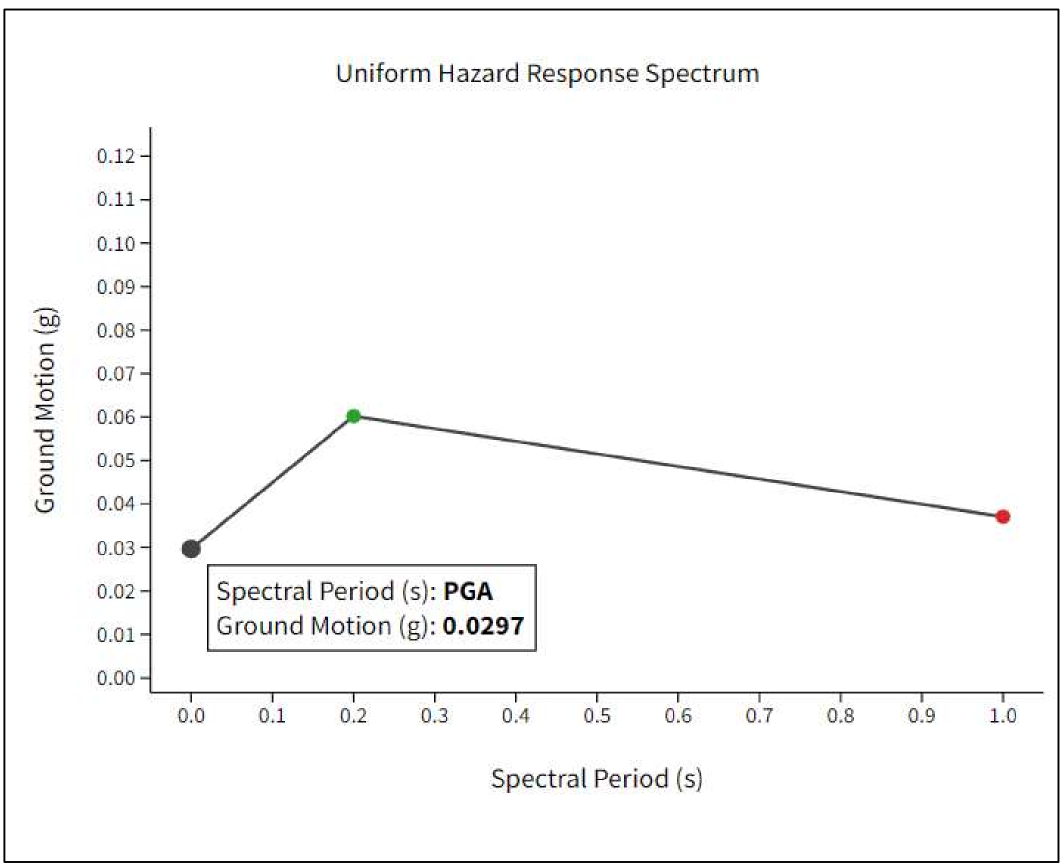
Seismic Assessment - Maffitt Reservoir Dam



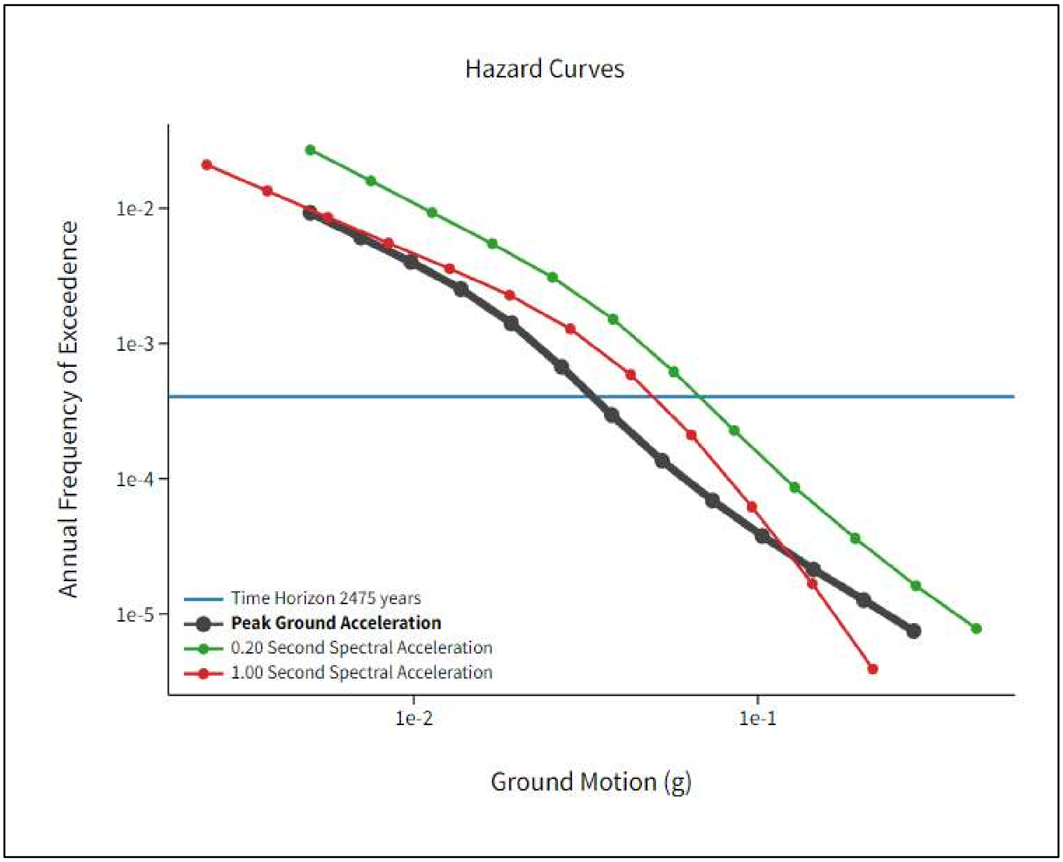


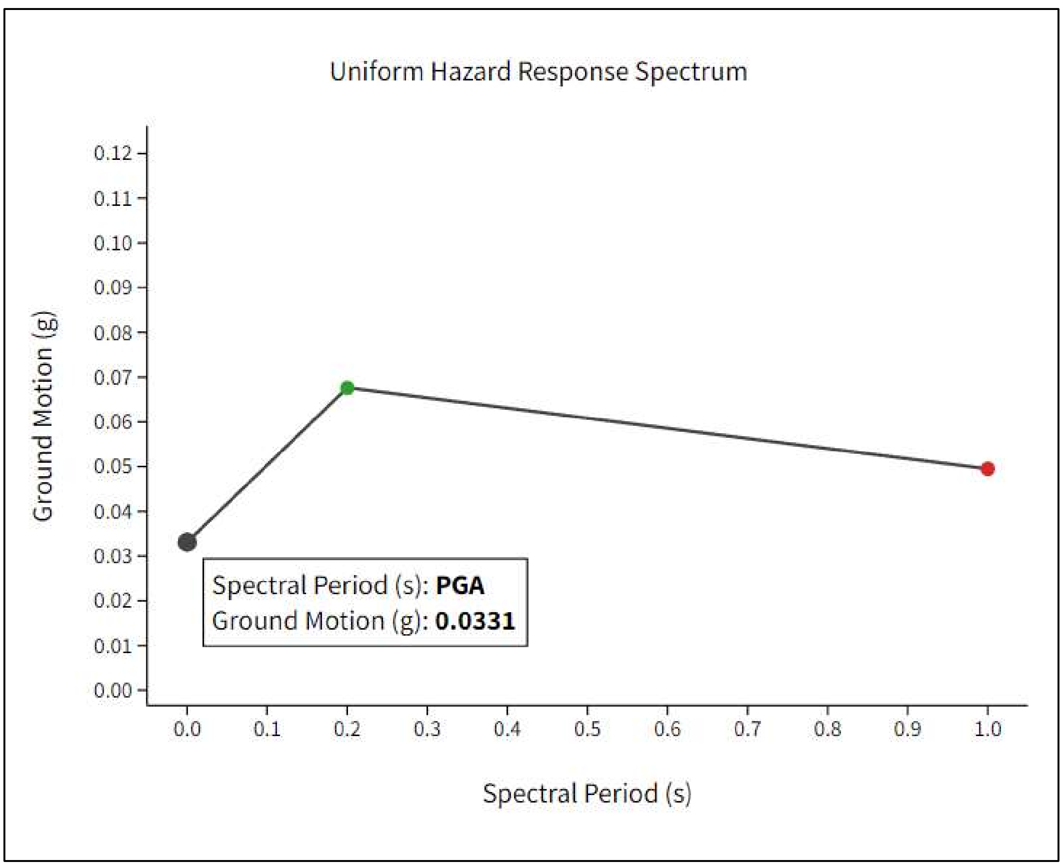
Seismic Assessment - Meyer Dam



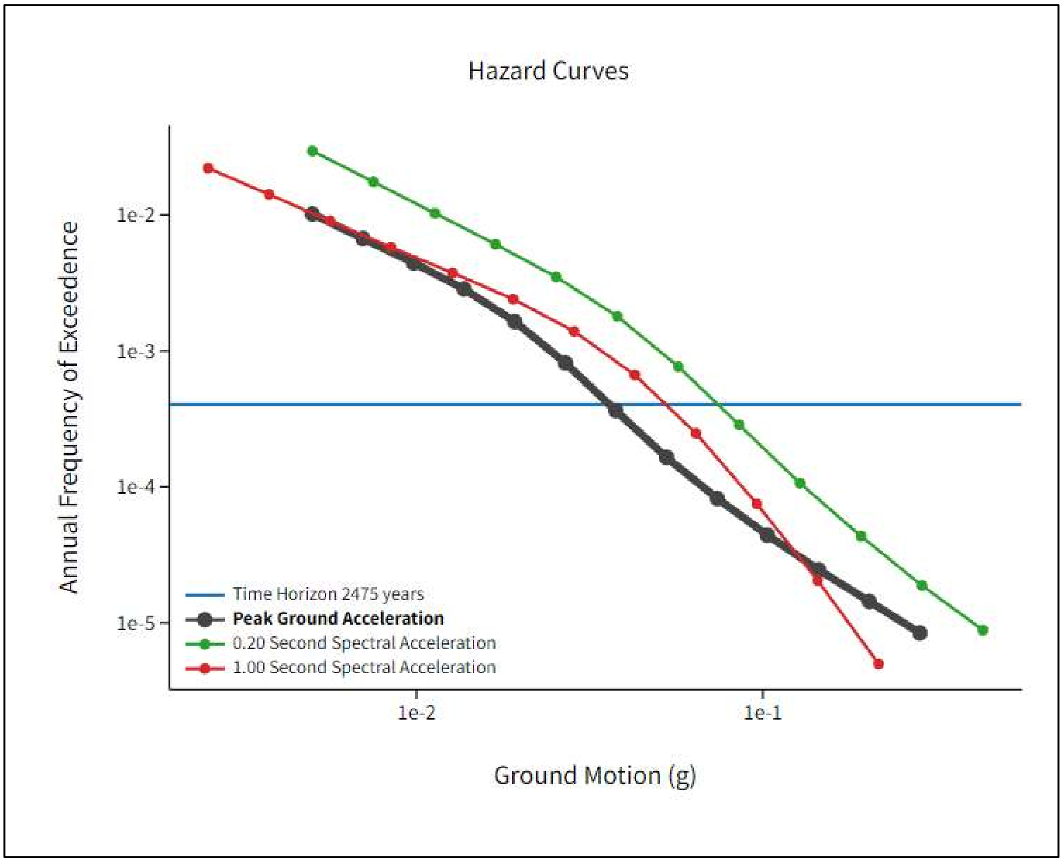


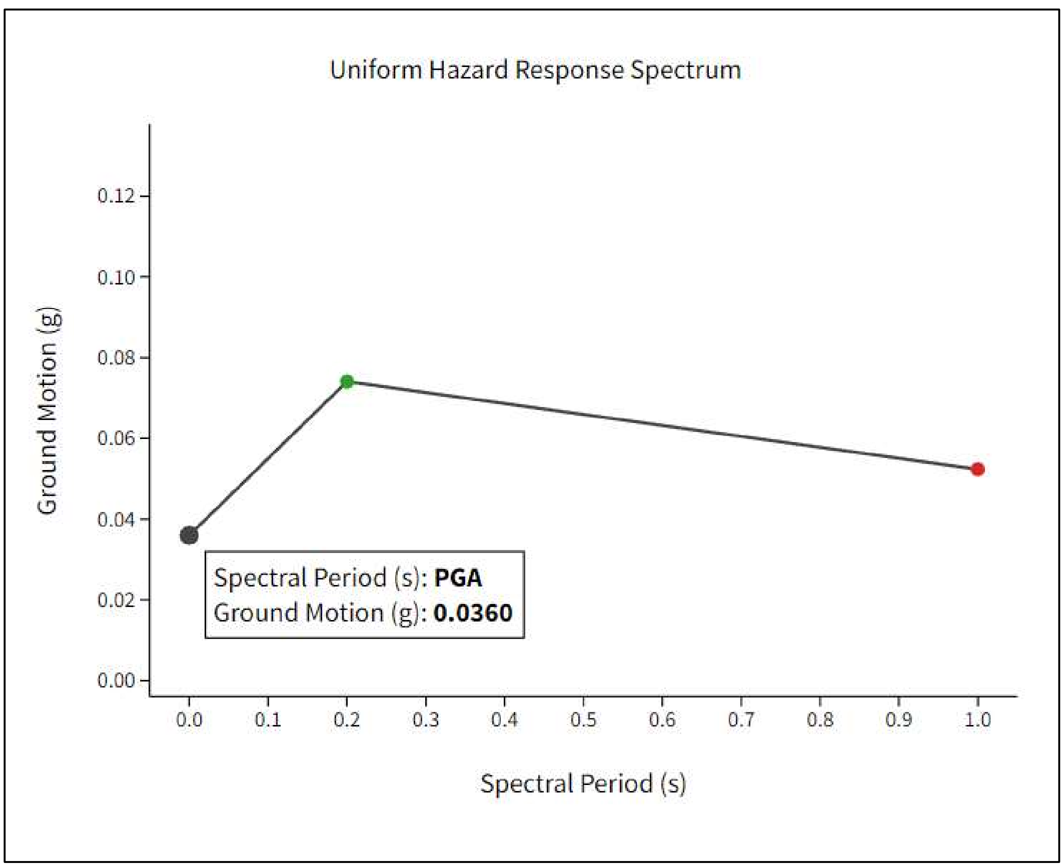
Seismic Assessment - Middle Pond Dam



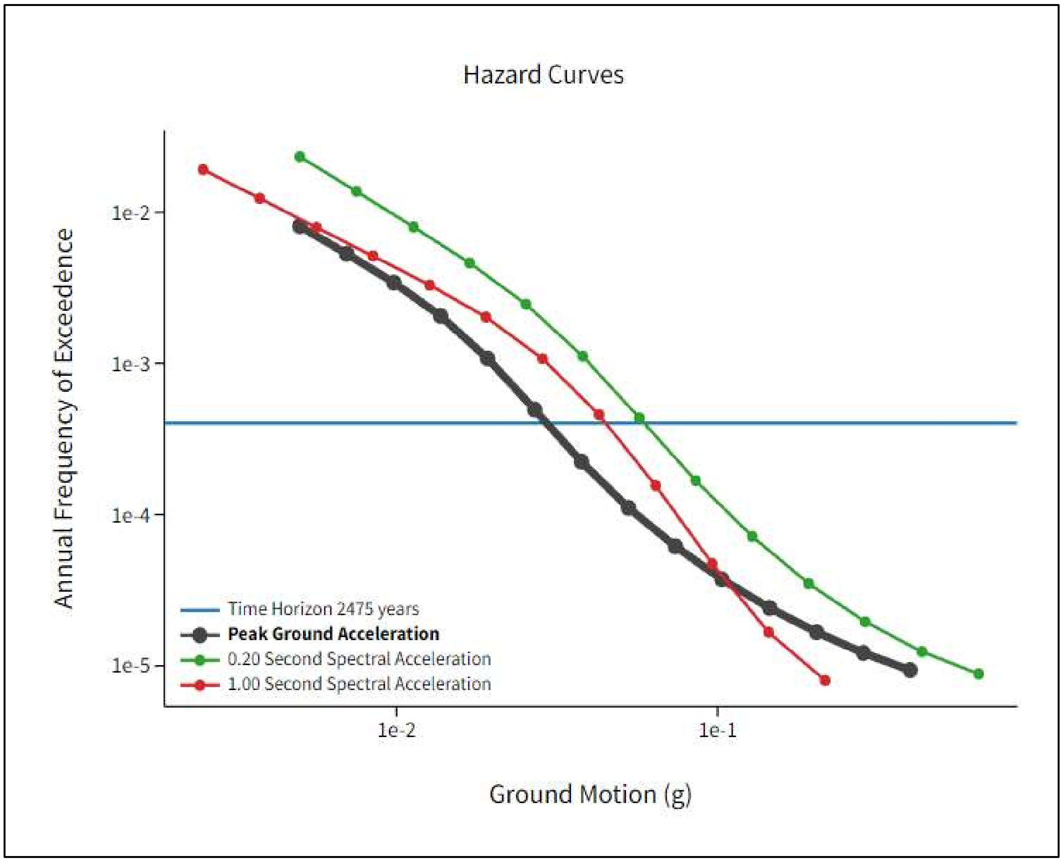


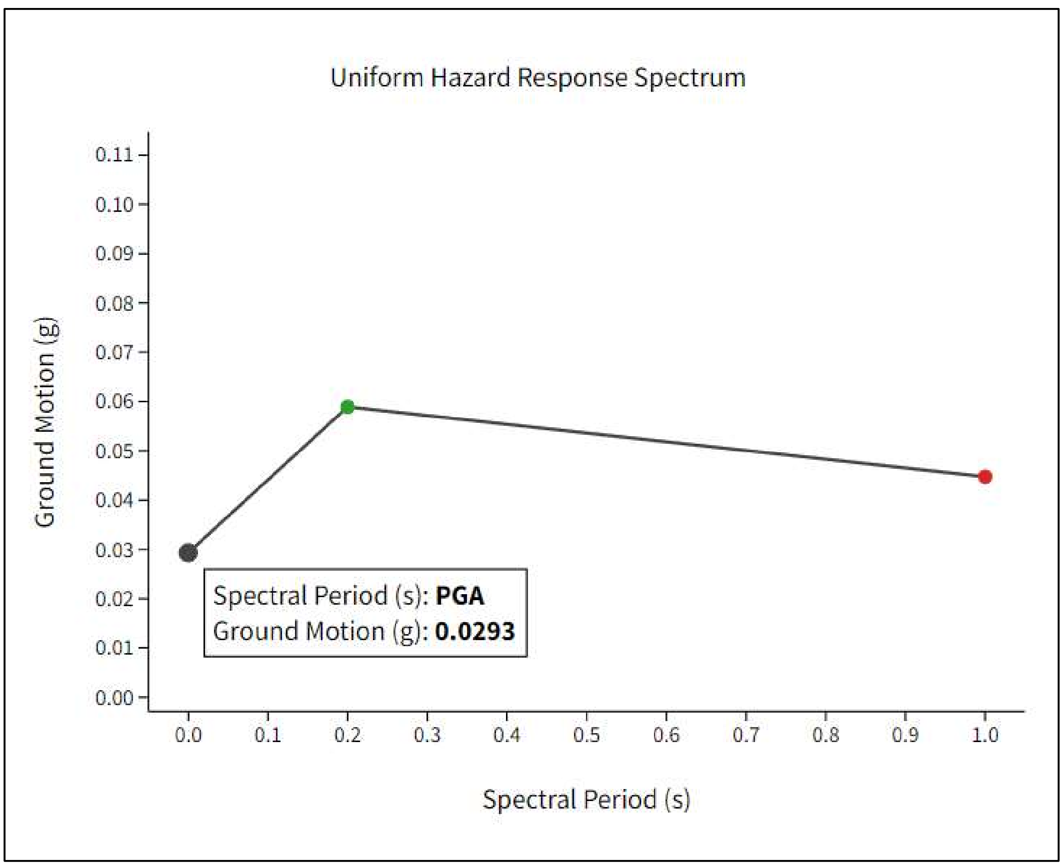
Seismic Assessment - North Branch Ralston Creek Dam



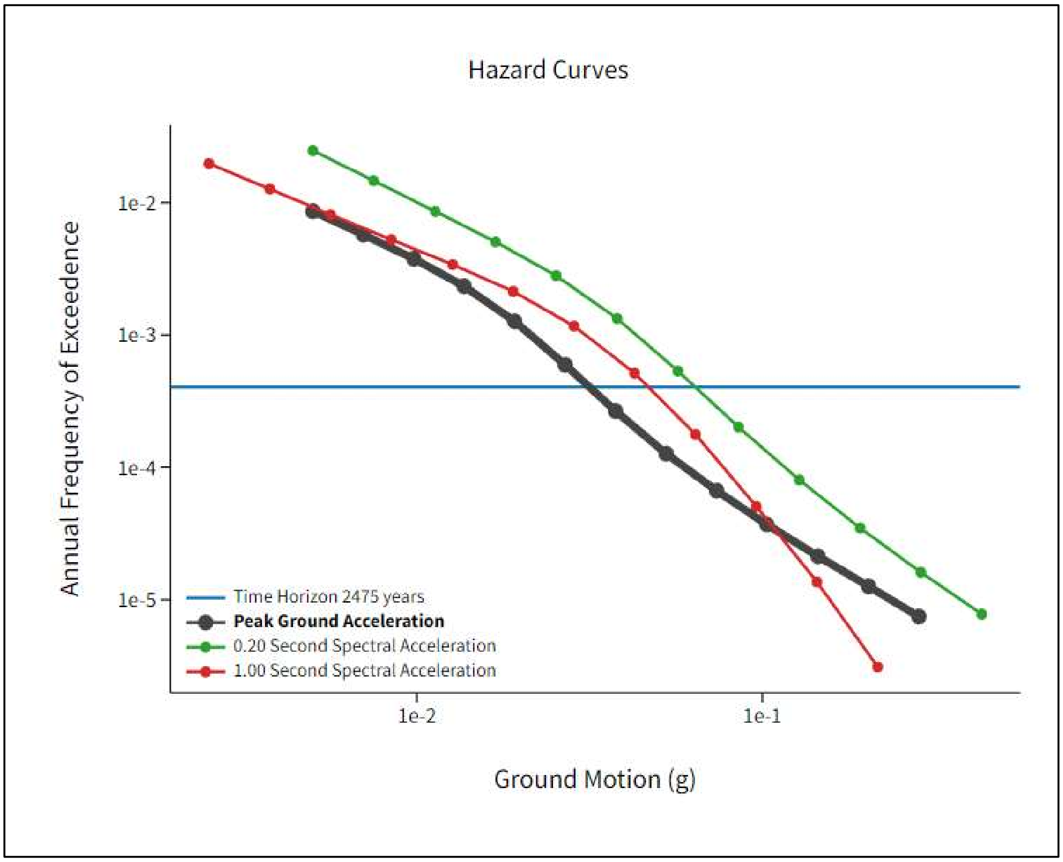


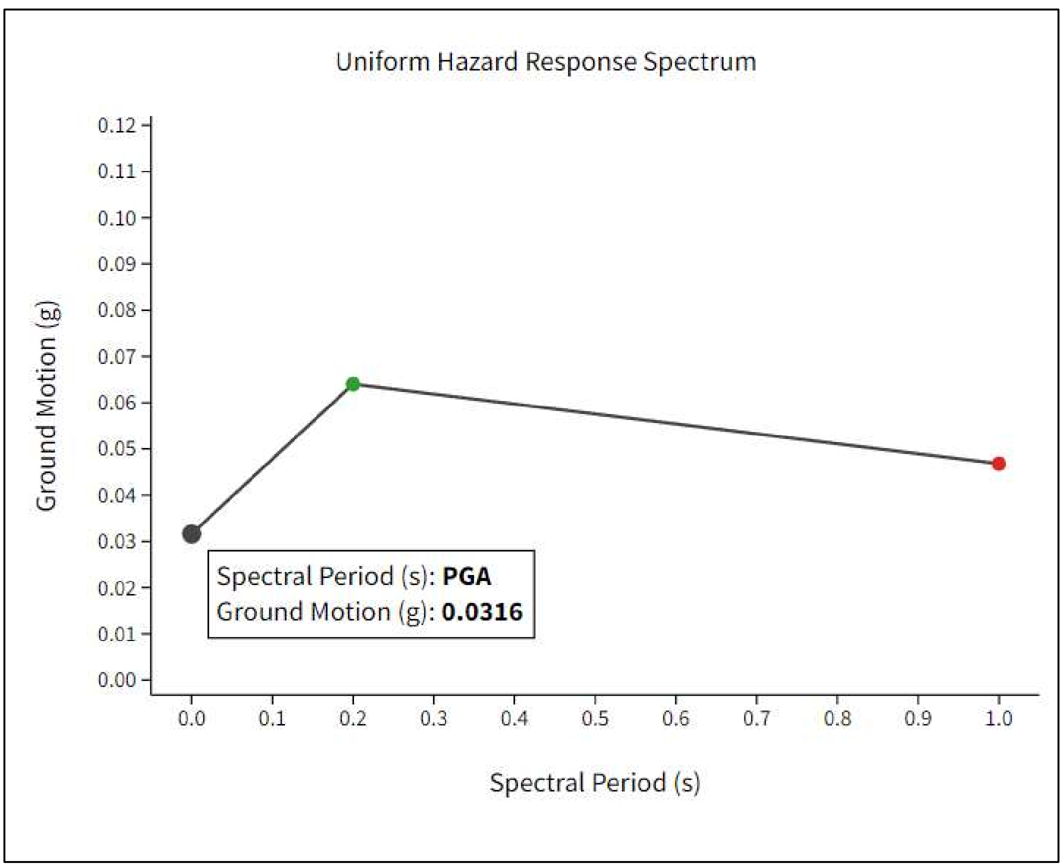
Seismic Assessment - Parkview Lake Dam



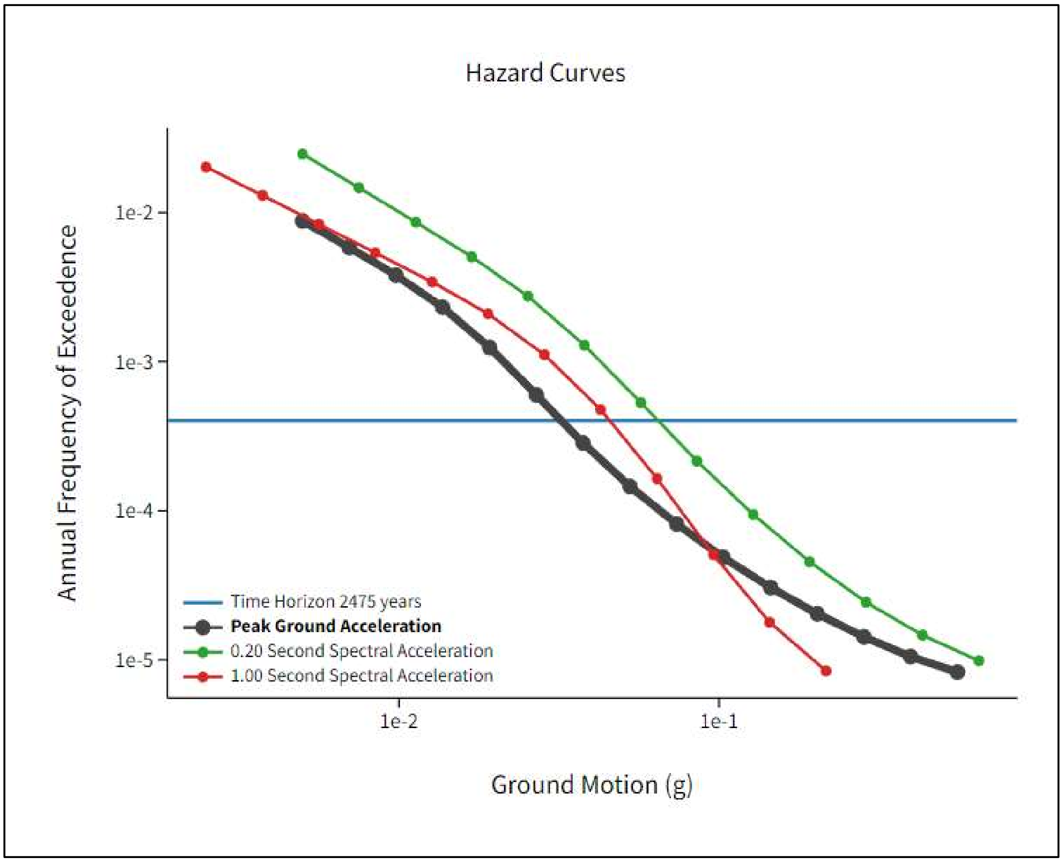


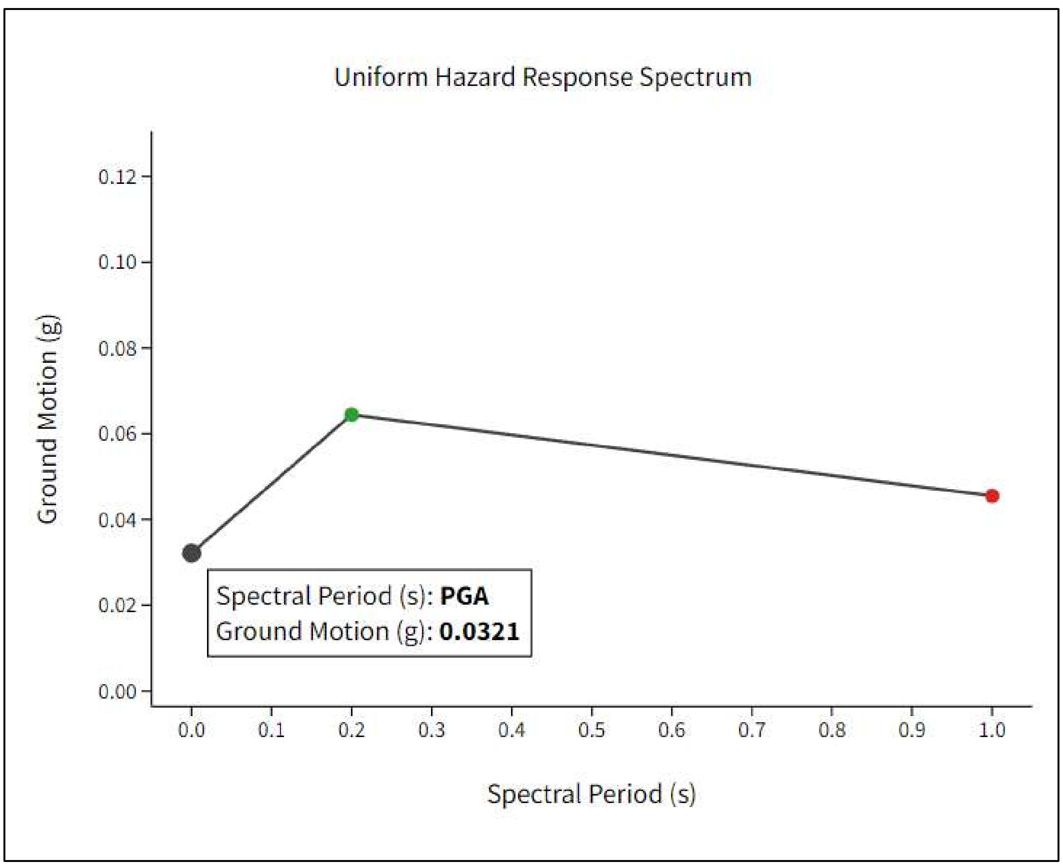
Seismic Assessment - Pleasant Creek Lake Dam



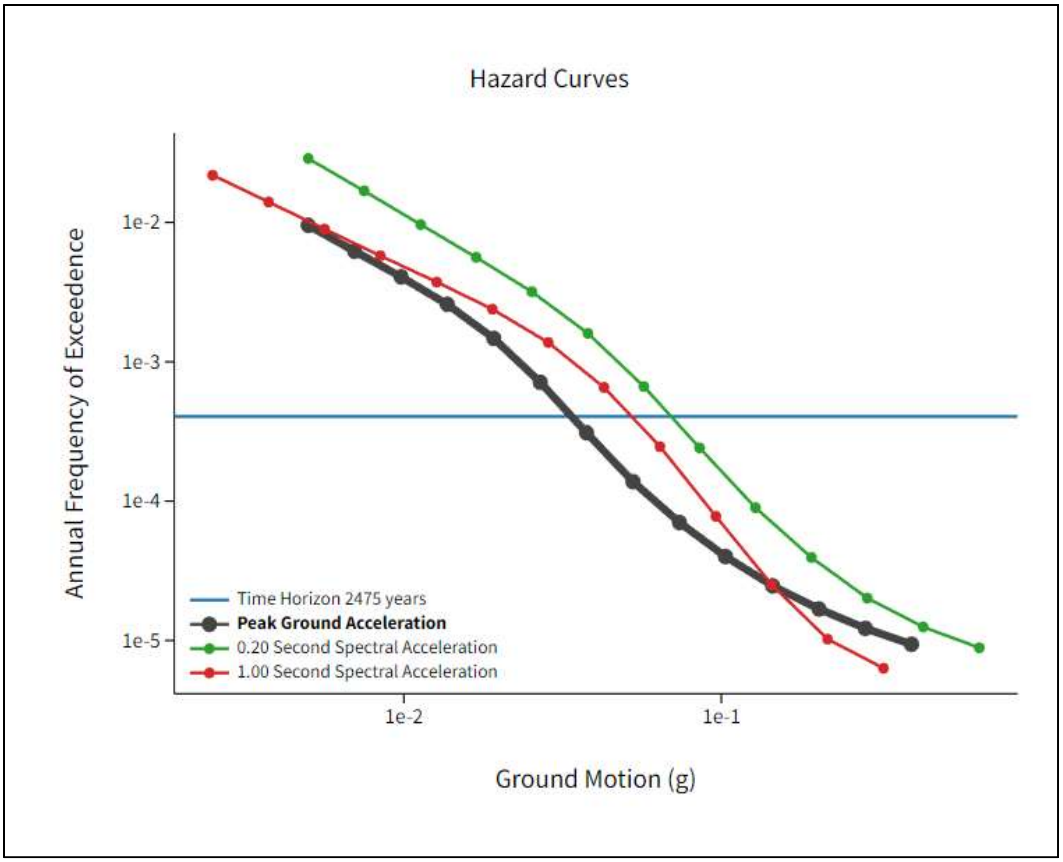


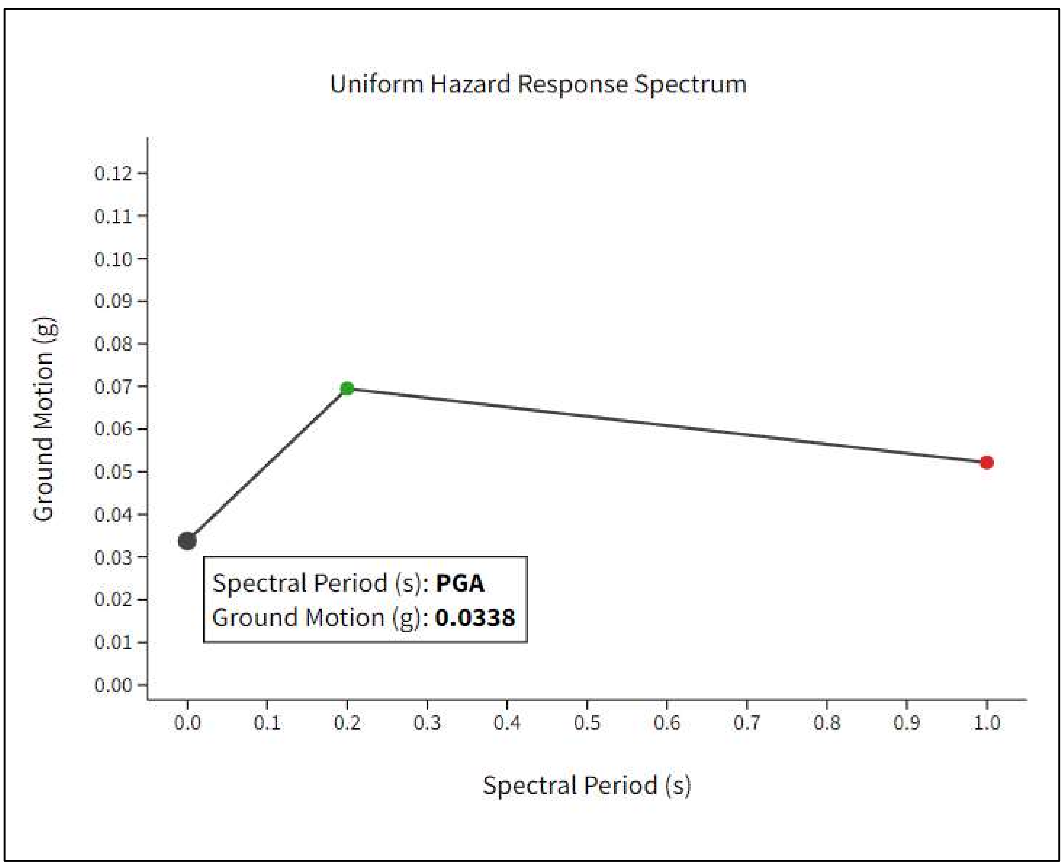
Seismic Assessment - Prescott Flood Prevention Dam



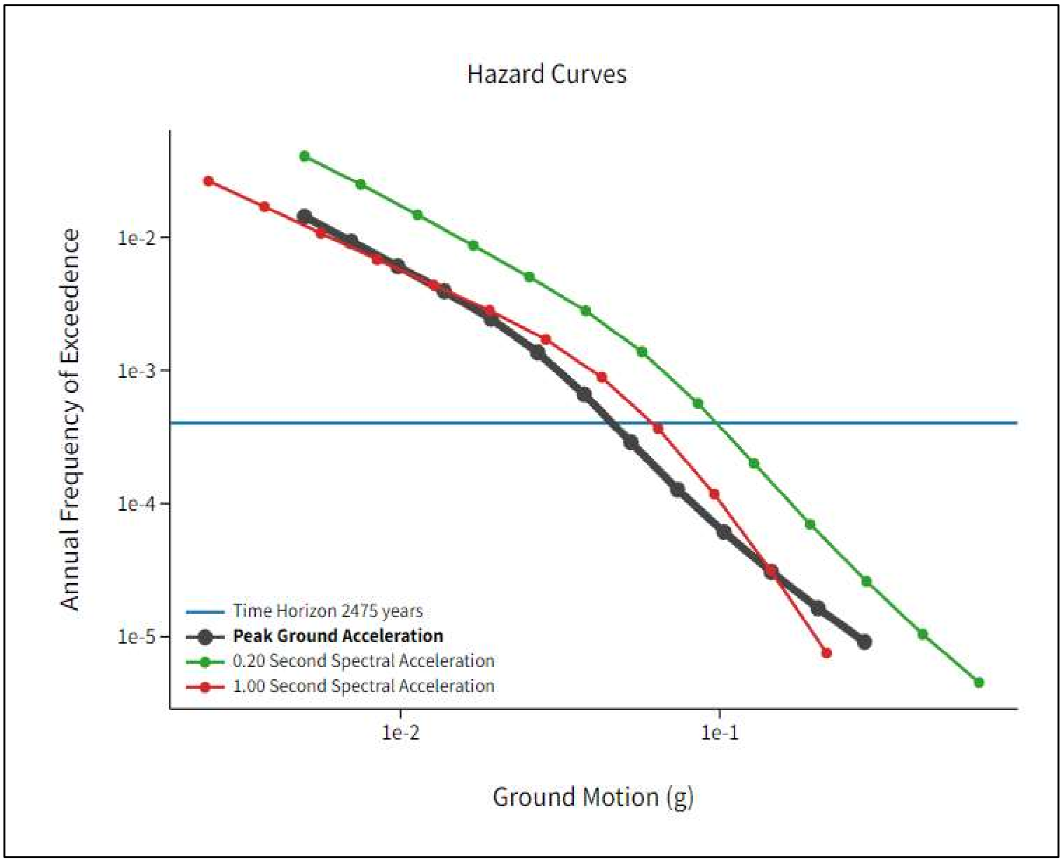


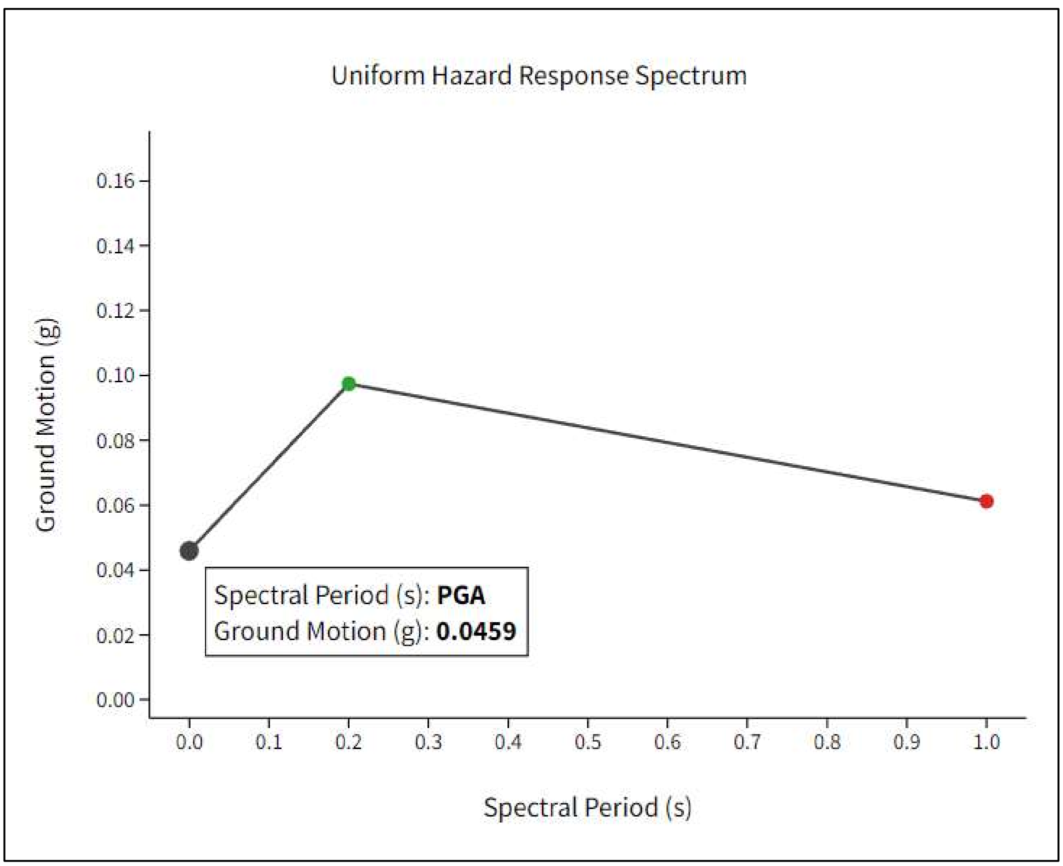
Seismic Assessment - Red Haw Dam



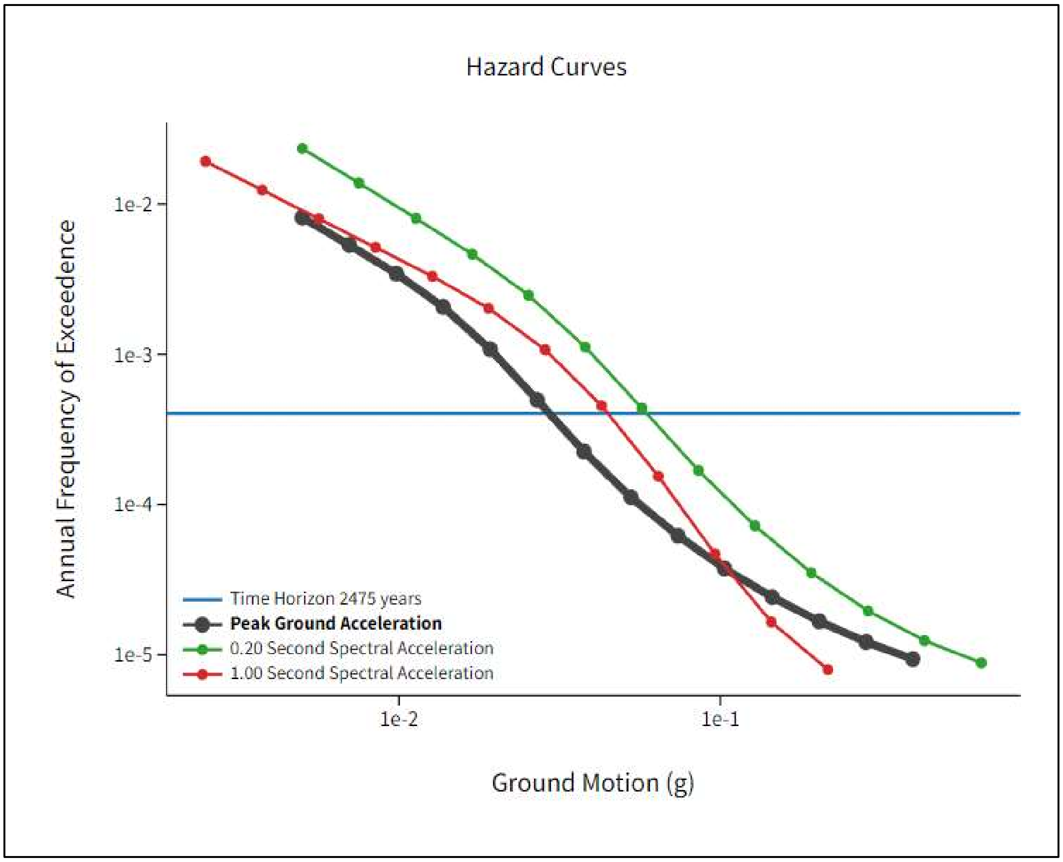


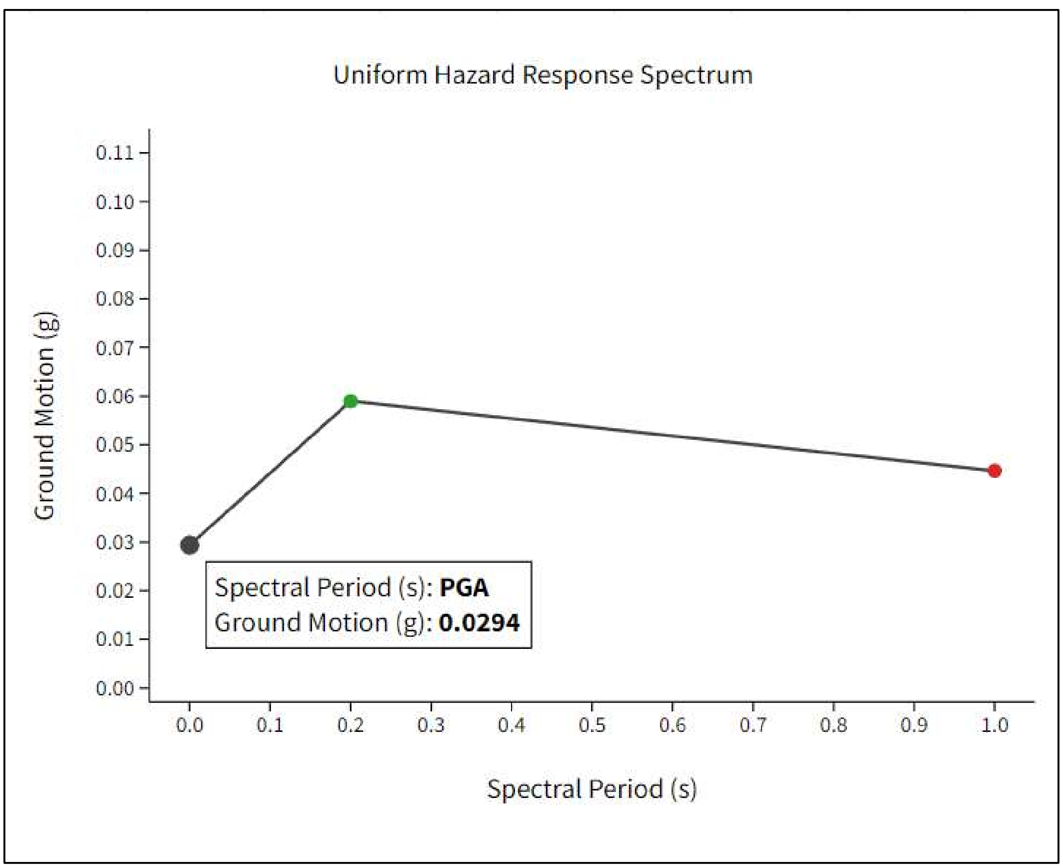
Seismic Assessment - Schoenewe Dam



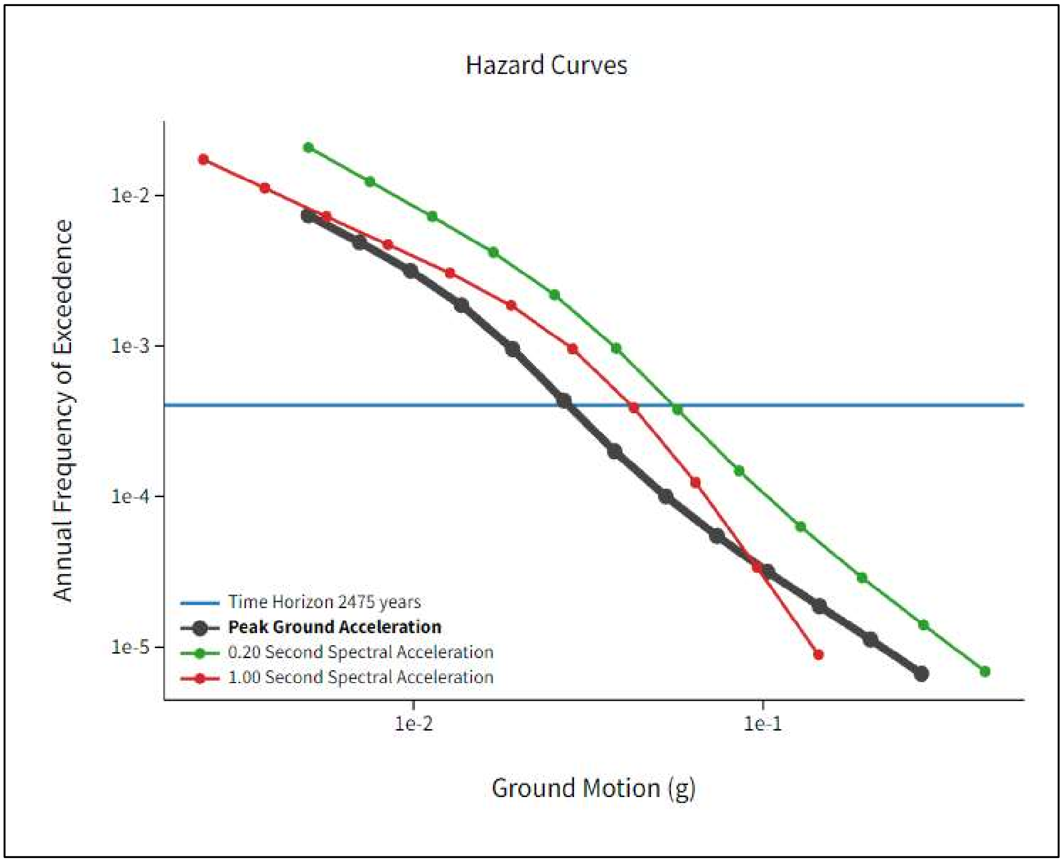


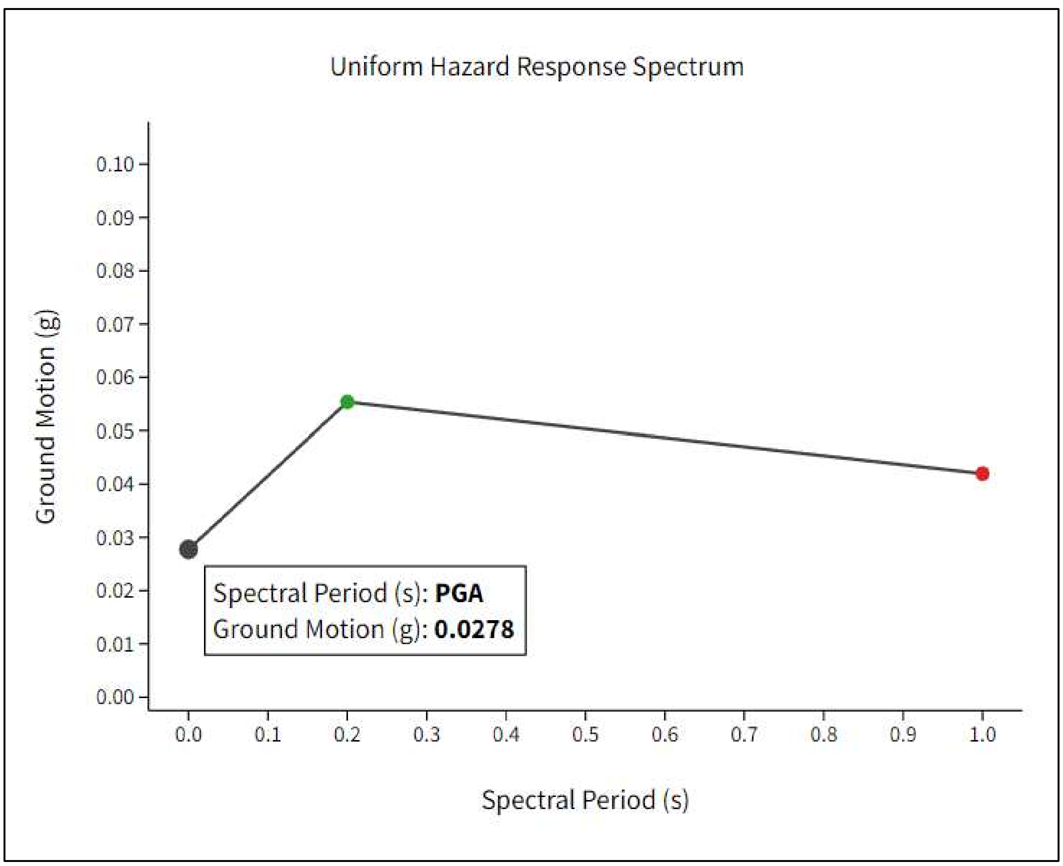
Seismic Assessment - Southfork Dam



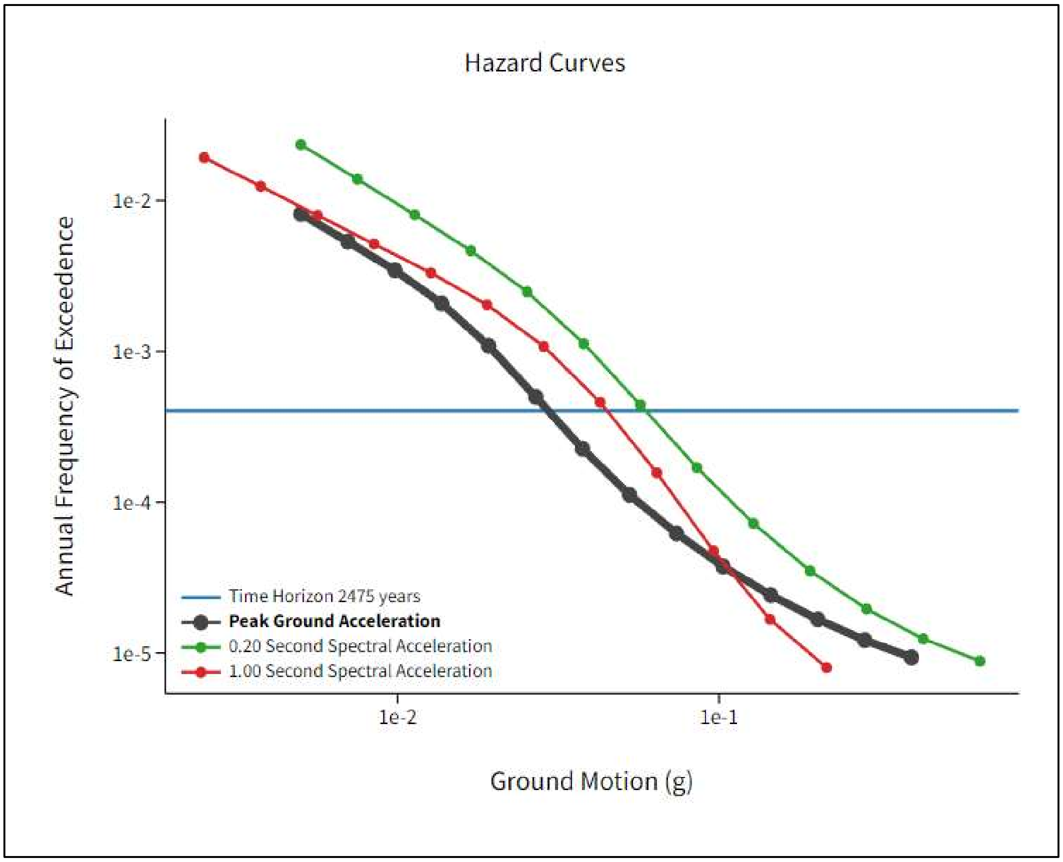


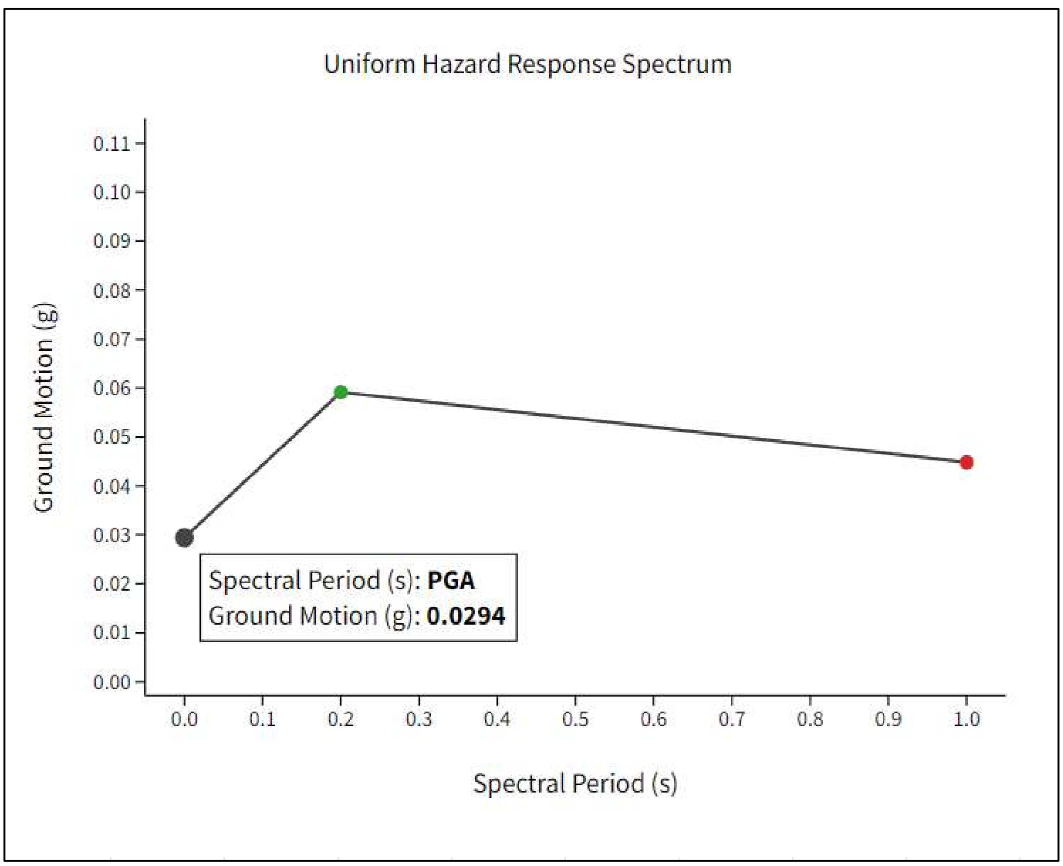
Seismic Assessment - Viking Road Detention Dam



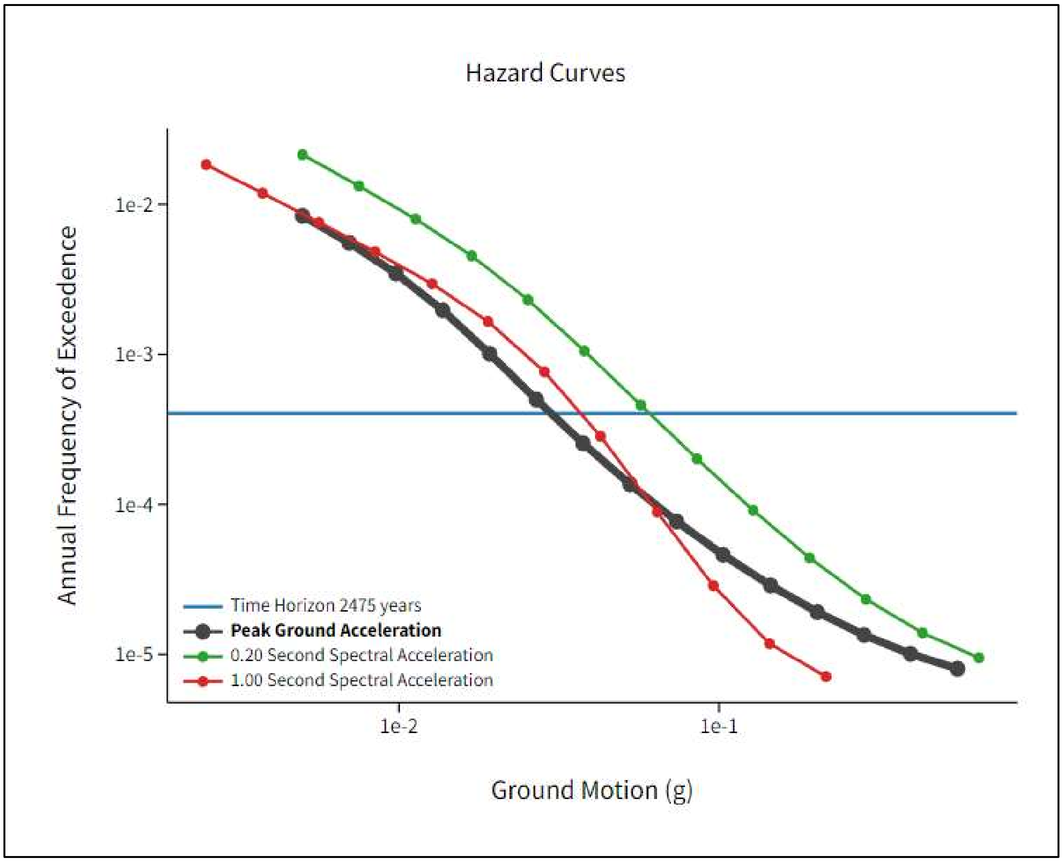


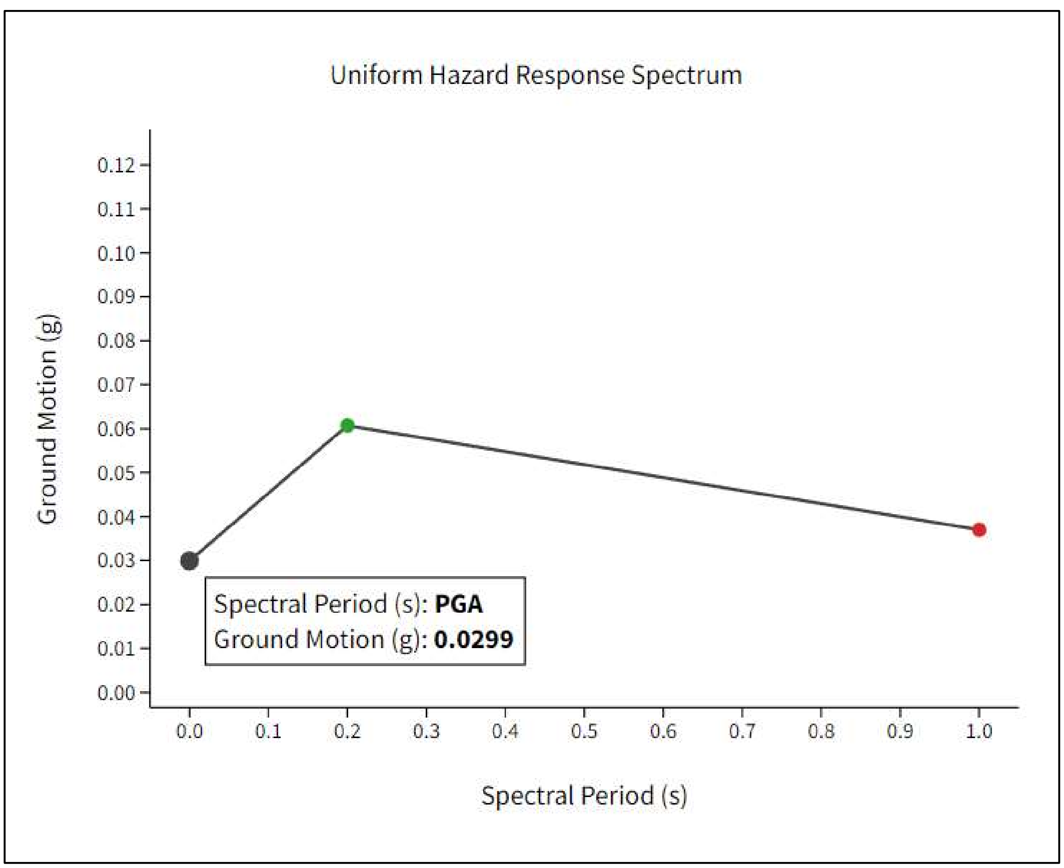
Seismic Assessment - West Lakes Office Park Dam





Seismic Assessment - Yellowsmoke Park Dam





4.4 APPENDIX D: FAILURE MODE RANKING MATRIX

Type of Failure	***Static Failure***													
Dam Component	**Embankment**							**Principal Spillway**						**TOTAL**
Evaluation Category	**Static Stability (sediment pool, age)**	**Surface Obstructions (trees, animal burrows, etc.)**	**Noted Deformities (slumps, depressions, etc.)**	**Subsurface Material Concerns (material susceptibilty to piping, presence of sand?, etc.)**	**Seepage Observed / Seepage History**	**Lateral Drainage Design Concerns (filter compatibility)**	**Embankment Design Concerns (zoned embankment, TR210-60)**	**Inflow and Infiltration**	**Structural Damage**	**Seepage Observed Adjacent to PS**	**Operations Concerns (PS not functioning correctly)**	**Low-Level Drawdown Operation and Design Concerns**	**Design Concerns**	
Weight	**2**	**2**	**8**	**7**	**8**	**4**	**6**	**10**	**5**	**6**	**5**	**6**	**6**	**375**
Dam Name	Level of Concern Associated with Each Category (1 = No Concern, 2 = Minimal Concern, 3 = Minor Concern, 4 = Moderate Concern, 5 = Major Concern)													
Bacon Creek Watershed Site A-1-1	2	1	1	4	1	1	1	1	1	1	2	0	3	**109**
Bacon Creek Watershed Site A-2-4	2	3	1	4	1	3	1	5	3	5	4	2	3	**217**
Bacon Creek Watershed Site A-3	2	3	1	4	1	4	1	5	4	4	4	5	3	**238**
Bacon Creek Watershed Site A-3-1	2	2	1	4	1	4	1	1	1	1	1	5	3	**148**
Bacon Creek Watershed Site C-1	2	1	1	5	1	4	1	1	1	1	1	0	3	**123**
Beeds Lake Dam	2	3	1	2	4	5	1	1	3	1	2	5	4	**185**
Brushy Creek Dam	3	4	5	3	1	1	2	1	3	1	3	3	2	**175**
Carroll Stormwater Detention Dam	3	1	1	3	1	5	3	1	2	1	2	0	5	**149**
Clive Lake Dam	3	2	1	4	1	1	1	1	1	1	2	2	1	**113**
Creston Flood Prevention Dam	2	4	3	2	4	3	1	1	1	3	3	2	2	**172**
Focht & Schindel Dam	1	5	3	5	5	4	1	1	1	1	2	5	3	**212**
Fort Des Moines Park Dam	5	3	1	2	1	5	3	1	1	1	2	2	5	**157**
Glen Oaks Country Club Dam	1	1	1	5	1	5	5	1	1	1	4	1	4	**176**
Grade Lake Dam	1	3	3	3	3	4	3	1	1	2	1	5	1	**179**
Greenfield Reservoir Dam	2	3	3	3	4	3	3	1	1	1	1	3	2	**173**
Hamburg Watershed Site M-1	1	2	3	3	4	3	1	1	1	1	2	5	3	**180**
Held Watershed Site E-3	3	1	5	3	1	3	1	2	4	1	3	5	3	**204**
Held Watershed Site E-4	2	3	5	4	1	3	1	1	3	1	3	5	3	**198**
Jefferson Park Watershed Site 1	2	3	1	3	5	4	1	1	1	3	3	5	3	**197**
Jefferson Park Watershed Site 10	3	2	1	1	1	4	1	1	1	1	2	0	3	**104**
Jefferson Park Watershed Site 3	2	2	3	1	1	4	1	1	1	1	2	5	3	**148**
Jefferson Park Watershed Site 4	2	3	4	2	5	5	1	1	1	1	3	5	3	**206**
Jefferson Park Watershed Site 5	3	2	2	5	1	4	5	1	1	1	2	5	3	**194**
Lake of the Hills Dam	1	3	1	2	1	1	1	2	1	3	2	2	1	**119**
Lake Ponderosa Dam	1	3	4	1	1	3	1	1	4	1	3	5	3	**172**
Leisure Lake Dam	1	4	4	5	4	5	1	1	4	4	4	5	4	**263**
Maffitt Reservoir Dam	1	2	4	4	3	3	1	3	2	3	2	1	1	**188**
Meyer Dam	1	3	2	5	1	3	1	1	4	1	4	5	4	**195**
Middle Pond Dam	1	4	4	3	5	3	3	5	5	5	4	5	4	**312**
North Branch Ralston Creek Dam	2	3	2	5	1	3	1	1	1	1	4	0	4	**152**
Parkview Lake Dam	2	1	1	3	1	5	3	1	3	1	3	1	3	**151**
Pleasant Creek Lake Dam	2	3	4	3	2	2	1	1	3	1	2	5	3	**182**
Prescott Flood Prevention Dam	1	2	3	2	1	2	1	1	5	2	1	5	4	**172**
Red Haw Dam	1	3	5	5	2	1	1	1	2	1	2	3	2	**175**
Schoenewe Dam	2	3	1	5	4	5	1	4	5	5	2	5	4	**270**
Southfork Dam	3	1	1	2	1	1	1	1	1	1	2	4	3	**121**
Viking Road Detention Dam	3	5	5	5	1	5	1	1	1	1	4	0	2	**178**
West Lakes Office Park Dam	3	3	3	3	1	1	1	1	4	1	1	1	3	**140**
Yellowsmoke Park Dam	2	2	4	2	1	5	1	1	2	1	1	5	3	**167**

*information is unknown for category, a score of 5 was given to assume worst case scenario

****highlighted category weight indicates categories to be updated during future dam inspections**

Type of Failure	Hydrologic										Seismic				Combined Failure Score
Dam Component	**Embankment**			**Principal and Auxiliary Spillways**							**Embankment**				
Evaluation Category	**Hydrologic Stability Criteria**	**Frequency of Overtopping (1 = PMP or Greater, 5 = Less than 100Y)**	**Overtopping Protection**	**Hydrologic Criteria Met**	**Clogging Potential**	**Operational Requirements to Pass Design Storm**	**Erosion Potential of Spillways**	**Maintenance Concerns**	**Outlet stability**	**TOTAL**	**Meets Seismic Stability Criteria**	**Seismic Risk Zone (High Risk = 5, Low = 1)**	**Liquifiable Subsurface Soils**	**TOTAL**	**TOTAL**
Weight	10	10	6	8	6	5	8	7	3	315	10	10	10	150	840
Dam Name	Level of Concern Associated with Each Category (1 = No Concern, 2 = Minimal Concern, 3 = Minor Concern, 4 = Moderate Concern, 5 = Major Concern)														
Bacon Creek Watershed Site A-1-1	5	1	3	3	2	1	4	1	3	167	1	1	4	60	336
Bacon Creek Watershed Site A-2-4	4	1	3	3	2	1	3	5	2	174	1	1	4	60	451
Bacon Creek Watershed Site A-3	4	1	3	2	2	1	4	5	3	177	1	1	4	60	475
Bacon Creek Watershed Site A-3-1	4	1	3	3	2	1	3	5	2	174	1	1	4	60	382
Bacon Creek Watershed Site C-1	4	2	3	3	2	1	3	1	3	159	1	1	4	60	342
Beeds Lake Dam	3	2	4	3	1	1	3	2	1	150	1	1	1	30	365
Brushy Creek Dam	4	1	2	3	2	1	3	5	1	165	1	1	3	50	390
Carroll Stormwater Detention Dam	4	3	3	3	5	1	3	2	1	188	1	1	3	50	387
Clive Lake Dam	3	1	4	3	2	1	4	2	1	154	1	1	4	60	327
Creston Flood Prevention Dam	2	1	5	3	2	1	3	1	5	147	1	1	1	30	349
Focht & Schindel Dam	4	5	5	5	4	1	3	3	2	240	1	1	5	70	522
Fort Des Moines Park Dam	5	1	3	1	2	1	3	5	3	171	1	1	1	30	358
Glen Oaks Country Club Dam	5	4	3	5	4	1	3	1	1	211	1	1	5	70	457
Grade Lake Dam	3	1	3	3	3	1	1	1	1	123	1	1	3	50	352
Greenfield Reservoir Dam	4	1	2	3	2	1	4	1	5	157	1	1	3	50	380
Hamburg Watershed Site M-1	4	1	3	3	2	1	4	3	4	174	1	1	3	50	404
Held Watershed Site E-3	4	2	5	5	2	1	4	5	3	223	1	1	3	50	477
Held Watershed Site E-4	4	2	5	5	2	1	3	5	3	215	1	1	4	60	473
Jefferson Park Watershed Site 1	3	1	3	5	2	1	3	5	1	177	1	1	3	50	424
Jefferson Park Watershed Site 10	2	5	3	5	2	1	3	5	4	216	1	1	1	30	350
Jefferson Park Watershed Site 3	2	5	5	5	2	1	3	2	3	204	1	1	1	30	382
Jefferson Park Watershed Site 4	3	5	3	5	2	1	3	4	3	216	1	1	1	30	452
Jefferson Park Watershed Site 5	5	5	5	5	2	1	3	5	1	249	1	1	5	70	513
Lake of the Hills Dam	3	1	1	1	3	1	1	1	1	95	1	2	1	40	254
Lake Ponderosa Dam	2	3	3	1	3	1	1	3	1	131	1	1	1	30	333
Leisure Lake Dam	4	5	2	5	2	1	1	4	2	201	1	1	5	70	534
Maffitt Reservoir Dam	3	1	2	1	3	1	1	1	1	101	1	1	4	60	349
Meyer Dam	4	1	5	5	4	1	4	5	3	225	1	1	5	70	490
Middle Pond Dam	3	1	5	3	2	1	3	5	3	179	1	1	3	50	541
North Branch Ralston Creek Dam	4	1	3	2	1	1	3	5	3	163	1	1	5	70	385
Parkview Lake Dam	4	1	3	3	1	1	3	5	4	174	1	1	3	50	375
Pleasant Creek Lake Dam	3	3	3	1	1	1	3	4	1	152	1	1	3	50	384
Prescott Flood Prevention Dam	2	1	5	3	2	1	3	1	3	141	1	1	1	30	343
Red Haw Dam	4	1	5	3	2	1	3	4	3	182	1	1	5	70	427
Schoenewe Dam	4	1	3	5	4	1	3	5	4	208	1	2	5	80	558
Southfork Dam	3	1	2	3	1	1	3	1	1	121	1	1	1	30	272
Viking Road Detention Dam	5	1	4	3	3	1	1	5	3	183	1	1	5	70	431
West Lakes Office Park Dam	4	1	2	1	2	1	1	1	5	117	1	1	3	50	307
Yellowsmoke Park Dam	3	1	1	3	2	1	3	1	3	127	1	1	1	30	324

*information is unknown for category, a score of 5 was given to assume worst case scenario

highlighted category weight indicates categories to be updated during future dam inspections

4.5 APPENDIX E: ENVIRONMENTAL FACILITY IMPACTS

Dam	Air Facilities	Chemical Storage Facilities %2C Tier II	Contaminated Sites Facilities	Solid Waste Facilities	Solid Waste Land Application	Stormwater Industrial Rock and Asphalt Facility	Wastewater Industrial Facility	Wastewater Treatment Plant	Water Treatment Plant Facilities	Total Environmental Sites
Bacon Creek Watershed Site A-1-1										**0**
Bacon Creek Watershed Site A-2-4	5	2	4	1						**12**
Bacon Creek Watershed Site A-3		1		1						**2**
Bacon Creek Watershed Site A-3-1										**0**
Bacon Creek Watershed Site C-1			4	1						**5**
Beeds Lake Dam								1	2	**3**
Brushy Creek Dam										**0**
Carroll Stormwater Detention Dam										**0**
Clive Lake Dam		2						1	4	**7**
Creston Flood Prevention Dam										**0**
Focht & Schindel Dam										**0**
Fort Des Moines Park Dam										**0**
Glen Oaks Country Club Dam										**0**
Grade Lake Dam										**0**
Greenfield Reservoir Dam										**0**
Hamburg Watershed Site M-1	2	2								**4**
Held Watershed Site E-3	1	2								**3**
Held Watershed Site E-4	1	2								**3**
Jefferson Park Watershed Site 1										**0**
Jefferson Park Watershed Site 10										**0**
Jefferson Park Watershed Site 3										**0**
Jefferson Park Watershed Site 4										**0**
Jefferson Park Watershed Site 5										**0**
Lake of the Hills Dam	6	1	24	4			2	1		**38**
Lake Ponderosa Dam										**0**
Leisure Lake Dam								1		**1**
Maffitt Reservoir Dam			6		1					**7**
Meyer Dam										**0**
Middle Pond Dam	1	1			11					**13**
North Branch Ralston Creek Dam		1	9					4		**14**
Parkview Lake Dam										**0**
Pleasant Creek Lake Dam						1		4		**5**
Prescott Flood Prevention Dam										**0**
Red Haw Dam								1	1	**2**
Schoenewe Dam										**0**
Southfork Dam										**0**
Viking Road Detention Dam	1			1				1		**3**
West Lakes Office Park Dam										**0**
Yellowsmoke Park Dam	1									**1**

4.6 APPENDIX F: CRITICAL FACILITY IMPACTS

Dam	Fire Station	Police Station	Schools	Colleges/ Universities	Bridges	Railway (Bridge/ Crossing)	Power Plant	Potable Water Facility	Wastewater Pipe	Total Critical Facilities
Bacon Creek Watershed Site A-1-1										**0**
Bacon Creek Watershed Site A-2-4	1				12	9		1	1	**24**
Bacon Creek Watershed Site A-3					8	8			1	**17**
Bacon Creek Watershed Site A-3-1										**0**
Bacon Creek Watershed Site C-1						4				**4**
Beeds Lake Dam					11	2				**13**
Brushy Creek Dam					9				1	**10**
Carroll Stormwater Detention Dam				1	7	2				**10**
Clive Lake Dam					17	6				**23**
Creston Flood Prevention Dam			1		9	2				**12**
Focht & Schindel Dam					3					**3**
Fort Des Moines Park Dam					5					**5**
Glen Oaks Country Club Dam										**0**
Grade Lake Dam					6				1	**7**
Greenfield Reservoir Dam					8					**8**
Hamburg Watershed Site M-1					1					**1**
Held Watershed Site E-3					2	4				**6**
Held Watershed Site E-4	1	1			2	4				**8**
Jefferson Park Watershed Site 1										**0**
Jefferson Park Watershed Site 10			2		10					**12**
Jefferson Park Watershed Site 3			2		10					**12**
Jefferson Park Watershed Site 4					8					**8**
Jefferson Park Watershed Site 5					6					**6**
Lake of the Hills Dam			2		13	4		5	2	**26**
Lake Ponderosa Dam					14					**14**
Leisure Lake Dam					5					**5**
Maffitt Reservoir Dam					15	12				**27**
Meyer Dam						1				**1**
Middle Pond Dam					1	2				**3**
North Branch Ralston Creek Dam	1	1			20	8	1			**31**
Parkview Lake Dam										**0**
Pleasant Creek Lake Dam					5	2				**7**
Prescott Flood Prevention Dam	1				5	4			1	**11**
Red Haw Dam					7	2				**9**
Schoenewe Dam					5					**5**
Southfork Dam										**0**
Viking Road Detention Dam			1		18	2	1		1	**23**
West Lakes Office Park Dam					3					**3**
Yellowsmoke Park Dam					9	6				**15**