What a dam safety engineer does

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OSBEELS Symposium

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Safety of Oregon dams

- **Overview**
- **Dam safety now**
- **New Law**
- **My view of risks**
- **What's needed**
  - Safety and resilience

Responsible agencies in Oregon

- USACE
- USBOR
  - Photo Owyhee dam from BOR
- FERC
- OWRD

State versus Federal Regulation

Hazard Rating	Federal Inspected	State Inspected	Totals
High	66	75	141
Significant	29	149	178
Low	153*	719	872*
Totals	248*	943	1191*

*Numbers based on state, not NID thresholds, also another 12,000 permitted smaller ponds

New Law -HB 2085 Changes

- Law effective January 2020
- Major modification is now construction
- Dam Removal
- Emergency authorities and actions
- Owners Engineers for potentially unsafe
- Timeframe authority for correcting deficiency
- Fee for design review
- RAC, rules should be final in June 2020

State regulated Dams

Arock dam in Malheur Co.

North Fork Rock Creek

Dam Safety Engineering

1. Inspecting Existing Dams
2. Design and Construction Used to be # 1
3. Hazard
4. Risk (FEMA HHPD grant)
5. Action if unsafe (major changes)
6. Rehabilitation
7. Removal (new authorities)

Inspecting dams

For a simple embankment

- Seepage changes
- Spillway
- Crest and freeboard
- Conduit
- Movement
- Holes and roots
- Can you see what you need to see

We see a lot, or try to

Not nice nutria

Handle a flood flow?

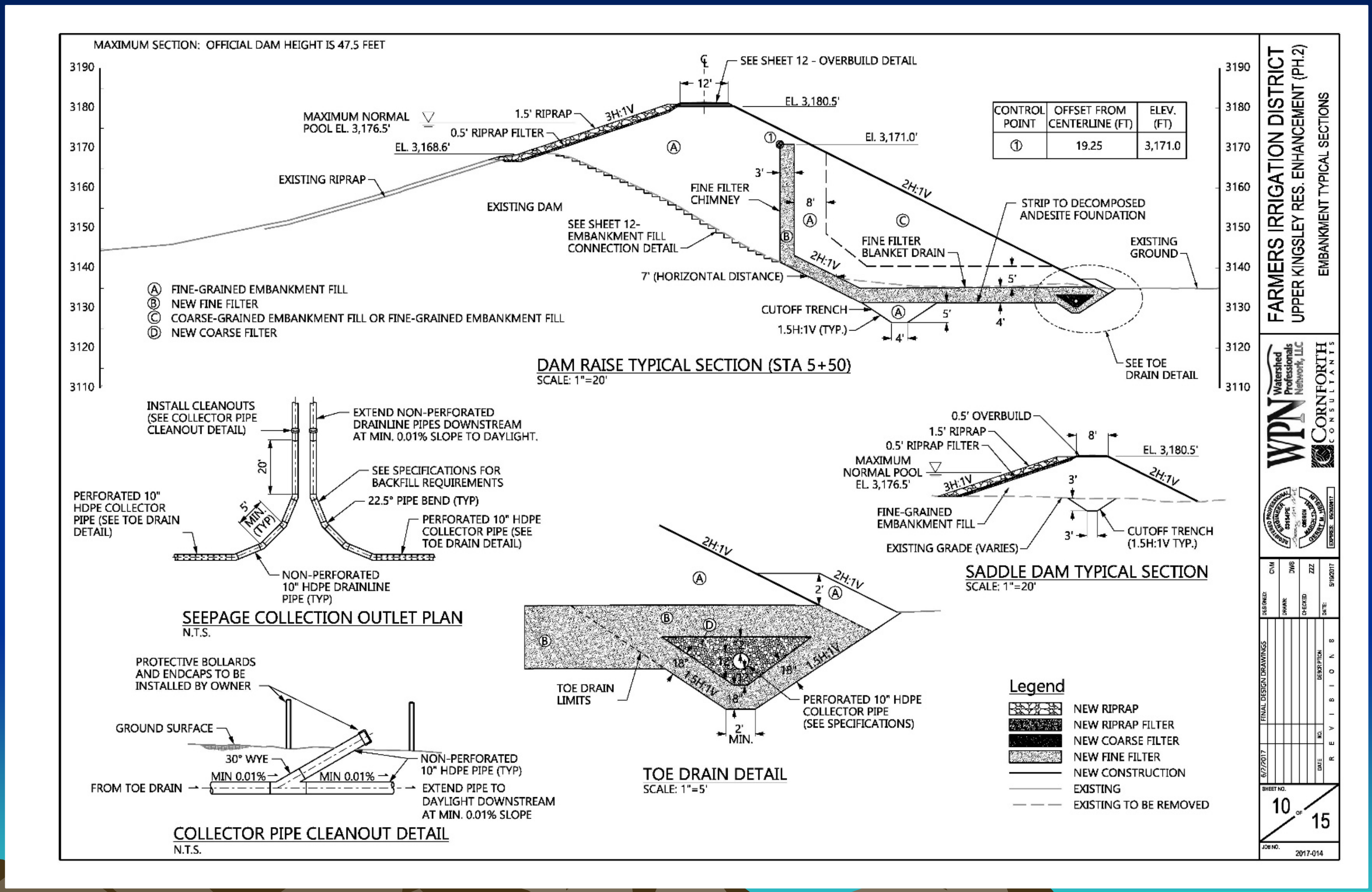
Spillways

Dams of concern

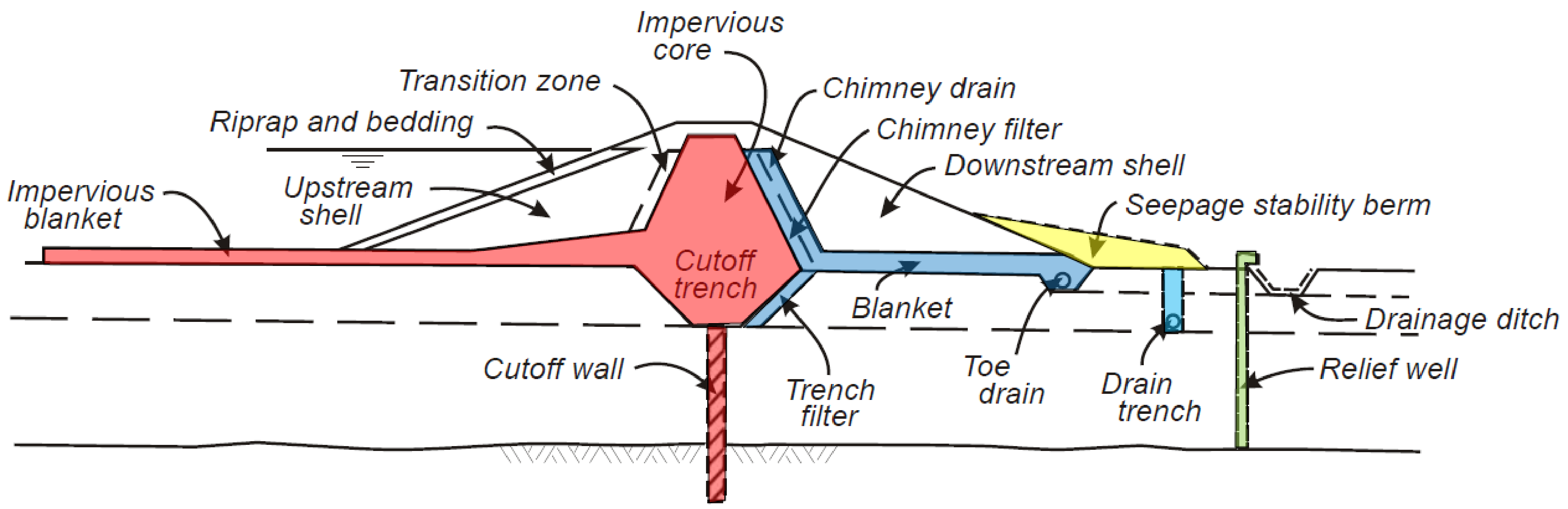
Restricted water level since 1942

110 foot tall dam, note control building

Review/Approval
of construction plans



Key Design Elements
Missing in most older embankment dams



Construction inspections (dam raise)

Engineer of Record

Hazard Rating

- If the dam were to fail
- Dam height, storage
- People and property
- High, Significant, Low
- All new dams
- Existing dams
  - as resources permit

Dam Breach Inundation Analysis

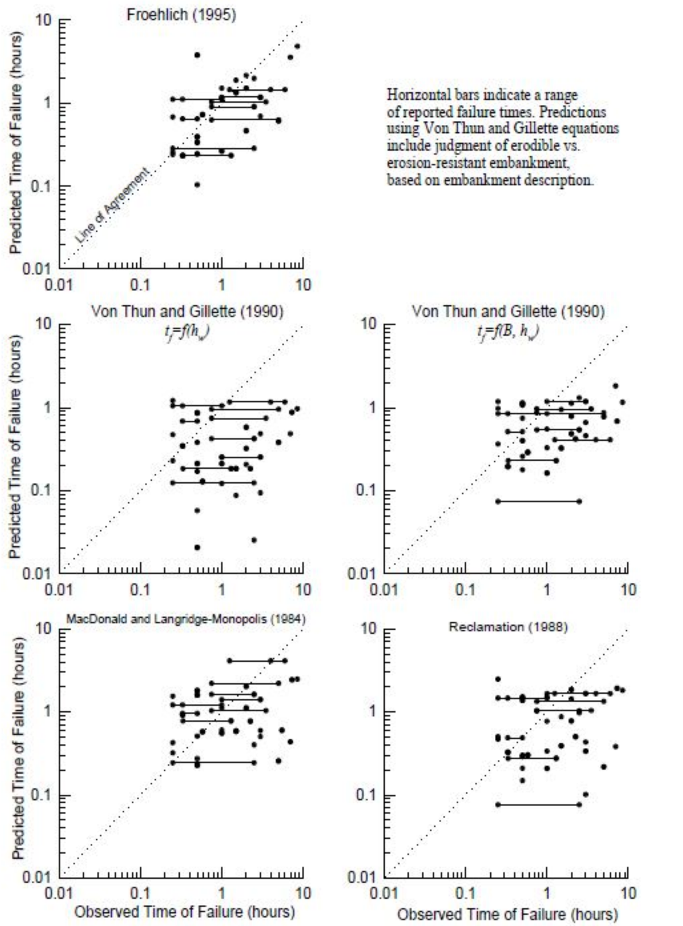
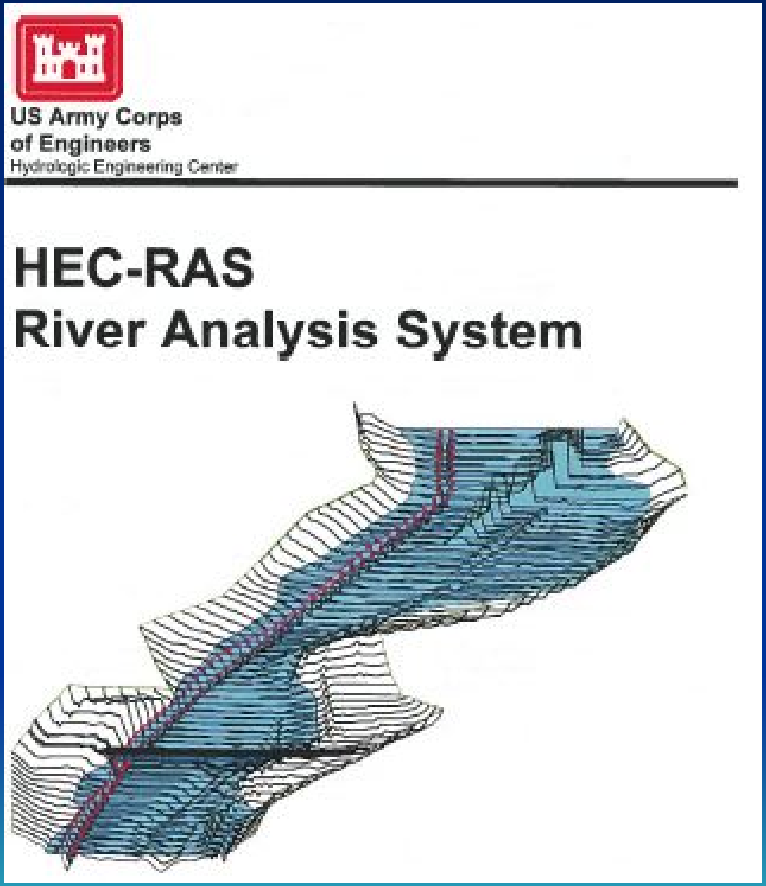


Figure 12. — Predicted and observed time of failure for dams in the case study database.

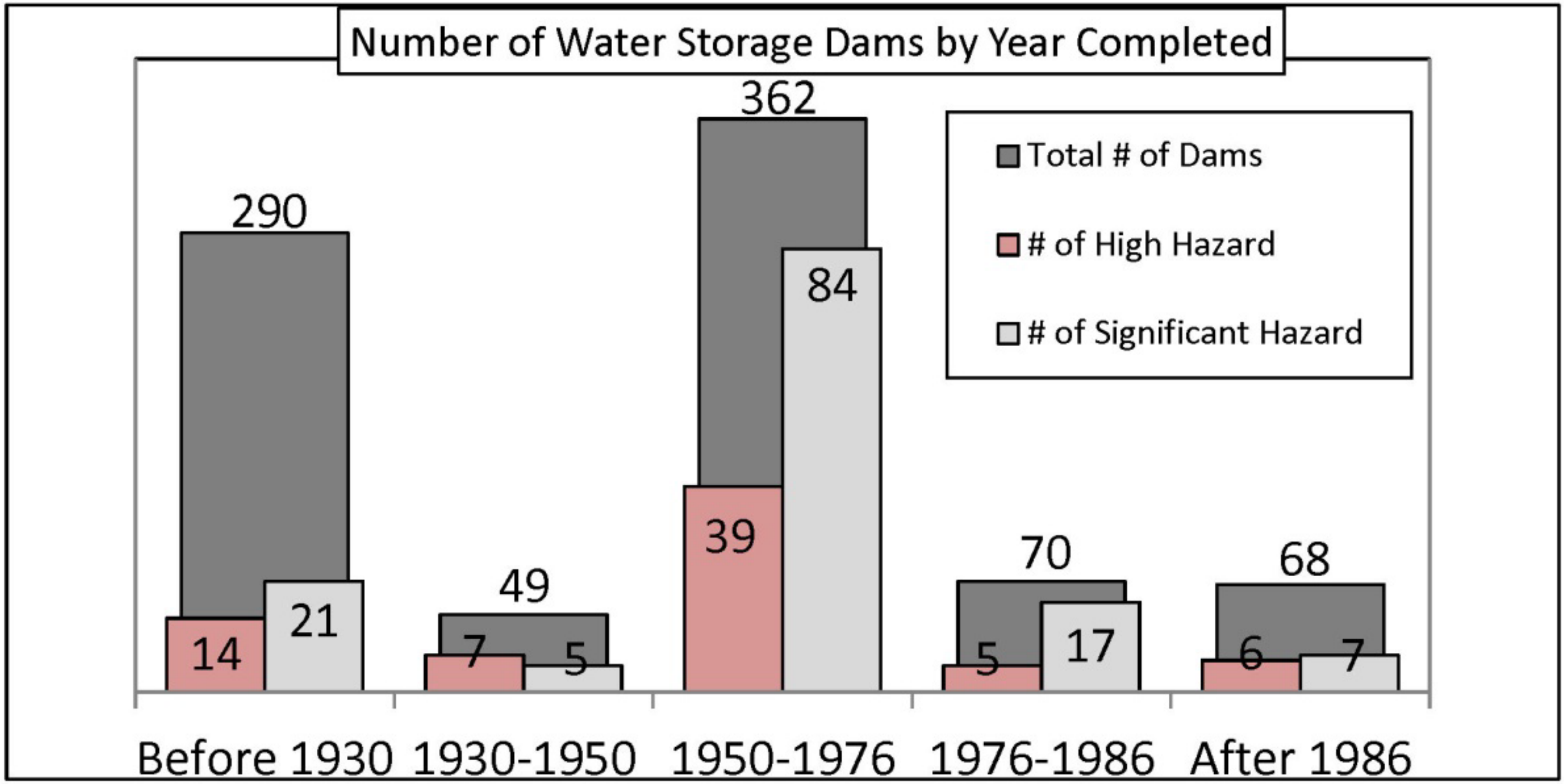


Risks to Oregon dams

- Flood overtopping
- Internal erosion
- Spillway in flood
- Conduit/ gate
- Seismic deformation
- Landslide
- **Unsafe and Potentially Unsafe**

Deterioration
Especially concrete

Oregon's Dams Are Older

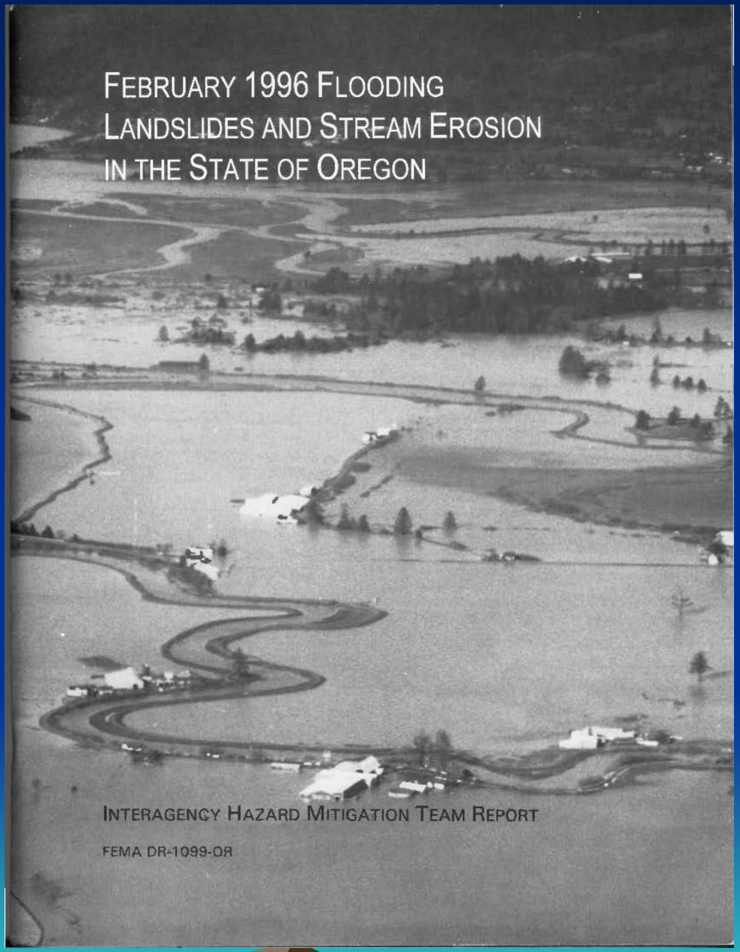


Major Flood Effects

- Westside in winter
  1861, 1948, 1964 and 1996
  Only 1861 Extreme
- Eastern Oregon
  - Heppner 1903
  - **Only on part of the watershed**
- Expect much bigger events

Not close to PMF

(Probable Maximum Flood)



2007 Moderate flood at dam

Water filled to crest, all boats and logs through interior spillway

Intense wildfire at dam

Change in flood flows likely

Internal erosion

Teton Dam June 1976

Internal Erosion

Homogenous dams vulnerable
Conduits vulnerable
Dispersive soil
Can soil form and maintain a roof (arching)

Conduits vulnerable
Seepage collars
Compaction difficult
Roof already there

Lawn Lake Dam Failure

Embankment Dam

Estes Park, Colorado

Built 1903, raised 1931
Failed July 15, 1982
26 feet high, **674** acre feet

Lives Lost: 3

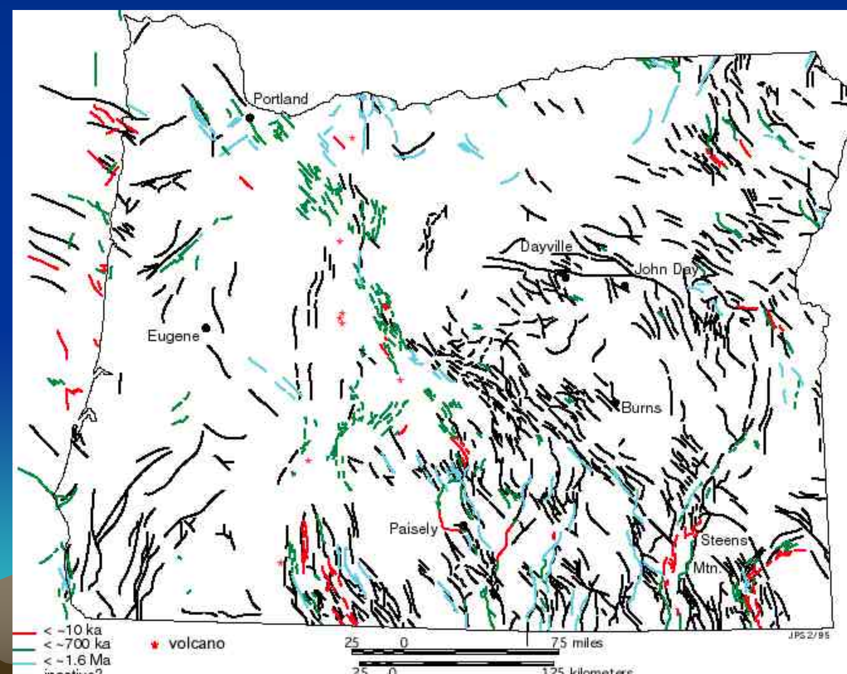
Leaking conduit
Pressure above valve

CAULKING PIPE INTO UPPER FACE OF VALVE.

Dam near Salem

Earthquake Deformation

690-020-0036 (5) Earthquake considerations. Seismic site characterization is required for high hazard dams, and may be required for significant hazard dams. A seismic site characterization shall include earthquake sources, ground motion hazard, peak ground acceleration, and recommended ground motions (time histories).



Seismic and static stability

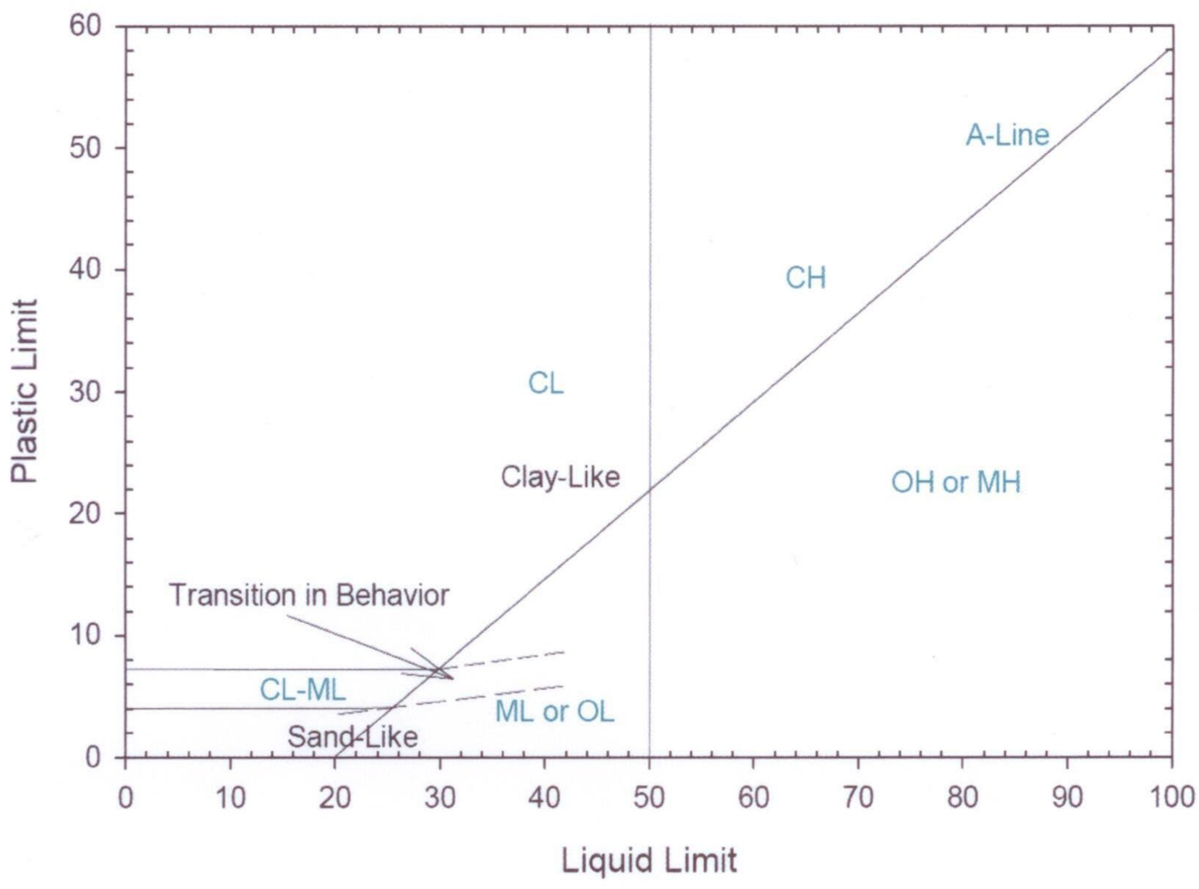


Figure 1.7 Boulanger and Idriss (2004, 2006) liquefaction screening criteri

Credit: USGS

Lower Van Norman Dam

Hydraulic fill embankment

40 miles NW Los Angeles

Constructed: **1912-1918**
Height **142** feet
Storage **20,500** acre feet

February 9, 1971

Lives Lost: 0
Near miss - 80,000 vuln.

Failure of upstream face

Empirical Crest Deformation

(Swaisgood, 2)014, ASDSO

Table 1. EARTHQUAKE INDUCED DEFORMATION OF EMBANKMENT DAMS
(Excluding liquefaction incidents)

ID No	NAME OF DAM	LOCATION	YEAR BUILT	DAM TYPE	CL m	DH m	AT m	DATE	M	D,km	PGA, g	CREST SETTLEMENT m (a)	CREST SETTLEMENT % (b)	RELATIVE DEGREE OF DAMAGE	REFERENCE
1	UPPER MURAYAMA	Japan	1923	E-HF	320	24	3	1 Sep 1923	8.2	18.0	0.32 e	0.20	0.74	Moderate	1, 20, 27, 32
2	ONO	Japan	1914	E	309	41	11	1 Sep 1923	8.2	98.2	0.30 e	0.27	0.53	Serious	1,15,20,27,32
3	CHATSWORTH NO.2	California	1918	HF	610	12	?(c)	30 Aug 1930	5.3	1.0	0.40 e	0.08	0.63	Moderate	1, 27, 32
4	MALPASSO	Peru	1936	ECRD	152	78	30	10 Oct 1938	6	n/a	0.10 e	0.08	0.07	Minor	1, 4
5	COGOTI	Chile	1939	CFRD	159	85	0	6 Apr 1943	7.9	88.6	0.20 e	0.38	0.44	Minor	1 2 4 5 24,32
6	SOUTH HAIWEE	California	1912	HF	457	25	38	21 Jul 1952	7.7	151.3	0.05 e	0.01	0.04	Minor	1, 27, 32
7	HEBGEN	Montana	1914	E	213	35	10	17 Aug 1959	7.6	0.7	0.71 e	1.69	4.82	Serious	24,25, 27,32
8	MIBORO	Japan	1961	ECRD	444	130	0	19 Aug 1961	7.0	20.0	0.15 e	0.03	0.02	Minor	16, 20,24, 37
9	MINASE	Japan	1963	CFRD	210	67	0	16 Jun 1964	7.5	144.9	0.08 e	0.06	0.09	Minor	4, 32
10	UVAS	California	1957	E	335	32	?	18 Dec 1967	5.3	11.3	0.20 e	0.02	0.06	Minor	36
11	U. SAN FERNANDO	California	1921	HF	390	25	18	9 Feb 1971	6.6	1.6	0.55 e	0.91	2.11	Serious	3, 24, 32
12	OROVILLE	California	1967	ECRD	1707	235	0	1 Aug 1975	5.9	6.9	0.10 r	0.01	0.004	None	4, 32,34
13	EL INFIERNILLO	Mexico	1964	ECRD	340	146	0	11 Oct 1975	5.9	79.9	0.08 r	0.04	0.03	None	5,32
14	LA VILLITA	Mexico	1966	ECRD	427	60	75	15 Nov 1975	7.2	20.0	0.04 r	0.02	0.02	None	5, 11, 16, 32
15	EL INFIERNILLO	Mexico	1964	ECRD	340	146	0	15 Nov 1975	7.2	22.9	0.09 r	0.02	0.02	None	5, 32
16	TSENGWEN	Taiwan	1973	ECRD	n/a	133	?	14 Apr 1976	5.3	8.0	0.16 e	0.04	0.03	n/a	16
17	EL INFIERNILLO	Mexico	1964	ECRD	340	146	0	14 Mar 1979	7.6	95.0	0.12 r	0.13	0.09	Minor	5,32
18	LA VILLITA	Mexico	1966	ECRD	427	60	75	14 Mar 1979	7.6	107.9	0.02 r	0.05	0.03	Minor	5, 11, 32
19	VERMILION	California	1954	E	1290	50	50	27 May 1980	6.3	22.0	0.24 r	0.05	0.05	None	37
20	LA VILLITA	Mexico	1966	ECRD	427	60	75	25 Oct 1981	7.3	30.6	0.09 r	0.14	0.11	None	5, 11, 32
21	EL INFIERNILLO	Mexico	1964	ECRD	340	146	0	25 Oct 1981	7.3	54.7	0.05 e	0.06	0.04	None	5,32
22	NAMIOKA	Japan	1983	ECRD	265	52	0	26 May 1983	7.7	144.9	0.08 r	0.06	0.11	None	16
23	COYOTE	California	1936	E	299	43	0	24 Apr 1984	6.2	0.0	0.63 e(d)	0.08	0.18	Minor	30, 32
24	LEROY ANDERSON	California	1950	ECRD	427	72	0	24 Apr 1984	6.2	2.4	0.41 r	0.02	0.02	Minor	30, 32
25	ELMER J. CHESBRO	California	1955	E	220	29	0	24 Apr 1984	6.2	22.2	0.18 e	0.02	0.05	Minor	36
26	UVAS	California	1957	E	335	32	?	24 Apr 1984	6.2	20.0	0.14 e	0.02	0.08	Minor	36
27	MAKIO	Japan	1961	ECRD	264	77	29	14 Sep 1984	6.8	5.2	0.57 e	0.50	0.47	Minor	16,20,32
28	AROMOS	Chile	1979	ECRD	220	43	9	3 Mar 1985	7.8	45.0	0.25 e	0.09	0.18	Minor	38
29	EL INFIERNILLO	Mexico	1964	ECRD	340	146	0	19 Sep 1985	8.1	75.7	0.13 r	0.11	0.08	Minor	5, 16, 32
30	LA VILLITA	Mexico	1966	ECRD	427	60	75	19 Sep 1985	8.1	43.5	0.13 r	0.33	0.24	Minor	5, 11 16, 32
31	LA VILLITA	Mexico	1966	ECRD	427	60	75	21 Sep 1985	7.5	61.2	0.04 r	0.12	0.09	None	5, 11, 16, 32
32	MATAHINA	New Zealand	1967	ECRD	400	86	?	2 Mar 1987	6.3	8.5	0.33 r	0.12	0.14	Moderate	13 16 21 32
33	NAGARA	Japan	1985	ECRD	n/a	52	?	17 Dec 1987	6.9	28.8	0.27 r	0.02	0.04	n/a	29
34	AUSTRIAN	California	1950	E	213	56	0	17 Oct 1989	7.1	1.6	0.57 e	0.85	1.51	Serious	6, 14, 23, 32
35	LEXINGTON	California	1953	E	253	63	0	17 Oct 1989	7.1	3.2	0.45 r	0.26	0.41	Minor	6, 14, 32, 33
36	GUADALUPE	California	1935	E	204	43	0	17 Oct 1989	7.1	9.7	0.42 e	0.20	0.45	Minor	6, 14, 32
37	ELMER J. CHESBRO	California	1955	E	220	29	0	17 Oct 1989	7.1	12.9	0.42 e	0.11	0.39	Moderate	6 14, 32
38	VASONA	California	1935	E	149	10	8	17 Oct 1989	7.1	6.9	0.37 e	0.05	0.27	Minor	6, 14 32
39	LEROY ANDERSON	California	1950	ECRD	427	72	0	17 Oct 1989	7.1	20.9	0.26 r	0.04	0.06	Minor	6, 14, 32
40	SAN JUSTO	California	1987	ECRD	340	40	14	17 Oct 1989	7.1	27.4	0.26 r	0.04	0.07	None	14, 32
41	UVAS	California	1957	E	335	32	?	17 Oct 1989	7.1	9.7	0.40 e	0.02	0.06	None	36
42	STEVENS CREEK	California	1935	E	305	37	?	17 Oct 1989	7.1	16.0	0.30 e	0.02	0.04	None	36
43	ALMADEN	California	1935	E	140	37	?	17 Oct 1989	7.1	8.8	0.44 e	0.03	0.10	Minor	36
44	CALERO	California	1935	E	256	30	?	17 Oct 1989	7.1	12.9	0.38 e	0.01	0.03	None	36
45	RINCONDA	California	1969	E	73	12	?	17 Oct 1989	7.1	9.2	0.41 e	0.02	0.15	Minor	36
46	MASIWAY	Philippines	1977	E	427	25	3	16 Jul 1990	7.7	2.7	0.68 e	1.06	3.79	Serious	19, 28
47	PANTABANGAN	Philippines	1975	ECRD	732	114	0	16 Jul 1990	7.7	5.6	0.58 e	0.28	0.24	Moderate	19 28
48	AYA	Philippines	1975	ECRD	427	102	0	16 Jul 1990	7.7	6.0	0.58 e	0.20	0.20	Minor	19, 28
49	DIAYO	Philippines	1976	ECRD	201	60	0	16 Jul 1990	7.7	17.5	0.38 e	0.07	0.11	Minor	19 28
50	CANILI	Philippines	1976	ECRD	351	70	0	16 Jul 1990	7.7	17.5	0.38 e	0.04	0.06	Minor	19, 28
51	MAGAT	Philippines	1985	ECRD	1296	100	0	16 Jul 1990	7.7	30.5	0.05 e	0.01	0.01	None	19
52	AMBUKLAO	Philippines	1956	ECRF	450	120	5	16 Jul 1990	7.7	10.0	0.49 e	1.10	0.88	Serious	37
53	COGSWELL	California	1934	CFRD	200	81	0	28 Jun 1991	5.8	7.0	0.37 e	0.04	0.05	Minor	17
54	ROBERT MATTHEWS	California	1962	E	132	46	0	25 Apr 1992	6.9	64.4	0.07 e	0.00	0.01	None	35
55	WIDE CANYON	California	1967	E	678	26	?	28 Jun 1992	7.5	29.8	0.10 e	0.03	0.05	None	10, 35
56	YUCAIPA No. 1	California	1977	E	128	13	9	28 Jun 1992	6.6	28.3	0.15 e	0.03	0.03	Minor	10, 35
57	YUCAIPA No. 2	California	1977	E	146	15	9	28 Jun 1992	6.6	28.3	0.15 e	0.00	0.02	Minor	10, 35
58	UPPER LAKE MARY	Arizona	1941	E	247	13	1	29 Apr 1993	5.5	77.3	0.02 e	0.00	0.004	None	7
59	U. SAN FERNANDO	California	1921	HF	390	25	18	17 Jan 1994	6.7	10.5	0.42 e	0.44	1.02	Serious	8, 22, 26, 31
60	L. SAN FERNANDO	California	1915	E-HF	537	38	6	17 Jan 1994	6.7	9.5	0.44 e	0.20	0.46	Serious	8, 22, 26, 31
61	LOS ANGELES	California	1977	E	671	47	0	17 Jan 1994	6.7	9.8	0.43 r	0.09	0.19	Moderate	8, 22, 26, 31
62	NORTH DIKE (LA)	California	1977	E	427	36	0	17 Jan 1994	6.7	10.1	0.43 e	0.03	0.09	Moderate	8, 22, 26, 31
63	LOWER FRANKLIN	California	1922	HF	152	31	?	17 Jan 1994	6.7	18.2	0.30 e	0.05	0.15	Moderate	12, 22, 26, 31
64	SANTA FELICIA	California	1955	E	389	65	0	17 Jan 1994	6.7	33.3	0.58 e	0.02	0.03	Minor	22, 26, 31
65	COGSWELL	California	1934	CFRD	200	81	0	17 Jan 1994	6.7	52.8	0.10 e	0.02	0.03	Minor	28, 26, 31
66	PALOMA	Chile	1967	ECRD	1000	82	14	14 Oct 1997	7.6	45.0	0.23 e	0.14	0.14	Minor	38
67	COGOTI	Chile	1939	CFRD	160	83	0	14 Oct 1997	7.6	45.0	0.23 e	0.25	0.30	Moderate	38
68	SANTA JUANA	Chile	1995	CFRD	390	113	19	14 Oct 1997	7.6	260.0	0.03 r	0.00	0.00	None	38
69	TORATA	Peru	2001	CFRD	600	120	0	23 Jun 2001	8.3	100.0	0.15 e	0.05	0.04	Minor	39
70	KAWANISHI	Japan	1980	ECRD	170	43	3	23 Oct 2004	6.6	6.0	0.57 r	0.28	0.65	Minor	40
71	ZIPINGPU	China	2006	CFRD	635	156	16	12 May 2008	7.9	11.3	0.49 e	0.81	0.47	Moderate	42
72	BIKOU	China	1983	ECRD	298	102	40	12 May 2008	7.9	25.3	0.35 e	0.16	0.11	Minor	42
73	ARATOZAWA	Japan	1998	ECRD	414	74	0	8 Jun 2008	6.9	2.0	0.86 r	0.40	0.54	Minor	41, 45
74	ISHIBUCHI	Japan	1953	CFRD	271	54	0	4 Jun 2008	6.9	4.0	0.67 e	0.55	1.00	Moderate	41, 47
75	KAMOHSAWA	Japan	2009	E	229	19	?	8 Jun 2008	6.9	10.0	0.44 e	0.14	0.74	Minor	41
76	KODA	Japan	2005	ECRD	520	44	0	8 Jun 2008	6.9	8.0	0.49 e	0.04	0.09	Minor	41
77	KOROMODAWA DAM NO.1	Japan	1963	E	212	36	0	8 Jun 2008	6.9	5.5	0.55 e	0.20	0.55	Moderate	48
78	MINABE	Japan	1963	CFRD	210	67	0	8 Jun 2008	6.9	19.0	0.31 e	0.14	0.21	Minor	41
79	CONVENTO VIEJO	Chile	2008	ECRD	600	35	55	27 Feb 2010	8.8	70.0	0.49 r	0.35	0.39	Minor	43, 46
80	SURIKAMIGAWA	Japan	2006	ECRD	718	105	0	11 Mar 2011	9.0	125.0	0.11 r	0.17	0.16	Minor	44
81	ISHIBUCHI	Japan	1953	CFRD	271	54	0	11 Mar 2011	9.0	130.0	0.19 r	0.01	0.02	Minor	44
82	KEJONUMA	Japan	1995	E	280	24	0	11 Mar 2011	9.0	100.0	0.274 r	0.14	0.58	Minor	44

LEGEND
CL = Crest Length   DH = dam height   AT = alluvium thickness
M = earthquake magnitude, Mw
D = distance from nearest ground rupture or epicenter, whichever is closest
PGA = peak horizontal ground acceleration; e = estimated, r = recorded at nearby location

DAM TYPES
HF - Hydraulic Fill
E - Earthfill
ECRD - Earth Core Rockfill Dam
CFRD - Concrete Faced Rockfill Dam

NOTES: (a) - Settlement shown is the single maximum reported or is an average from upstream, downstream and centerline readings
(b) - Determined as a percentage of combined dam height and alluvium thickness.
(c) - If alluvium thickness unknown (?), it is considered to be 0 for % settlement calculations
(d) - Recorded nearby at 1.29g; estimated value from attenuation curves for M = 6.2 at 0.1 mi. distance.

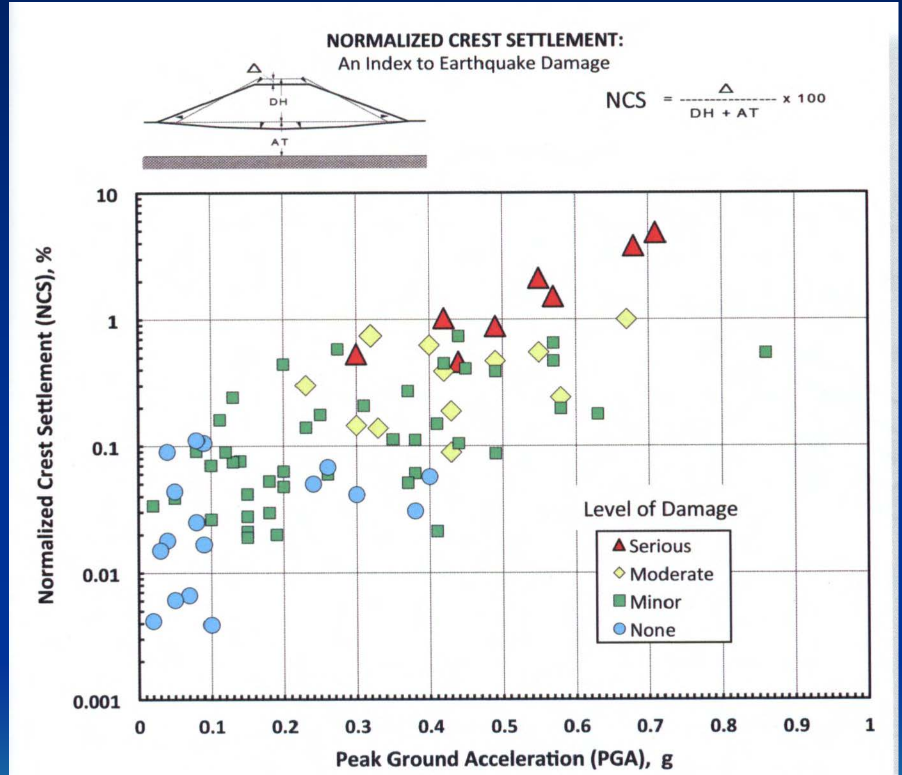


FIGURE 1: SETTLEMENT OF EMBANKMENT DAMS DURING EARTHQUAKE (EXCLUDING SETTLEMENT DUE TO LIQUEFACTION)

Recent Seismic Investigations

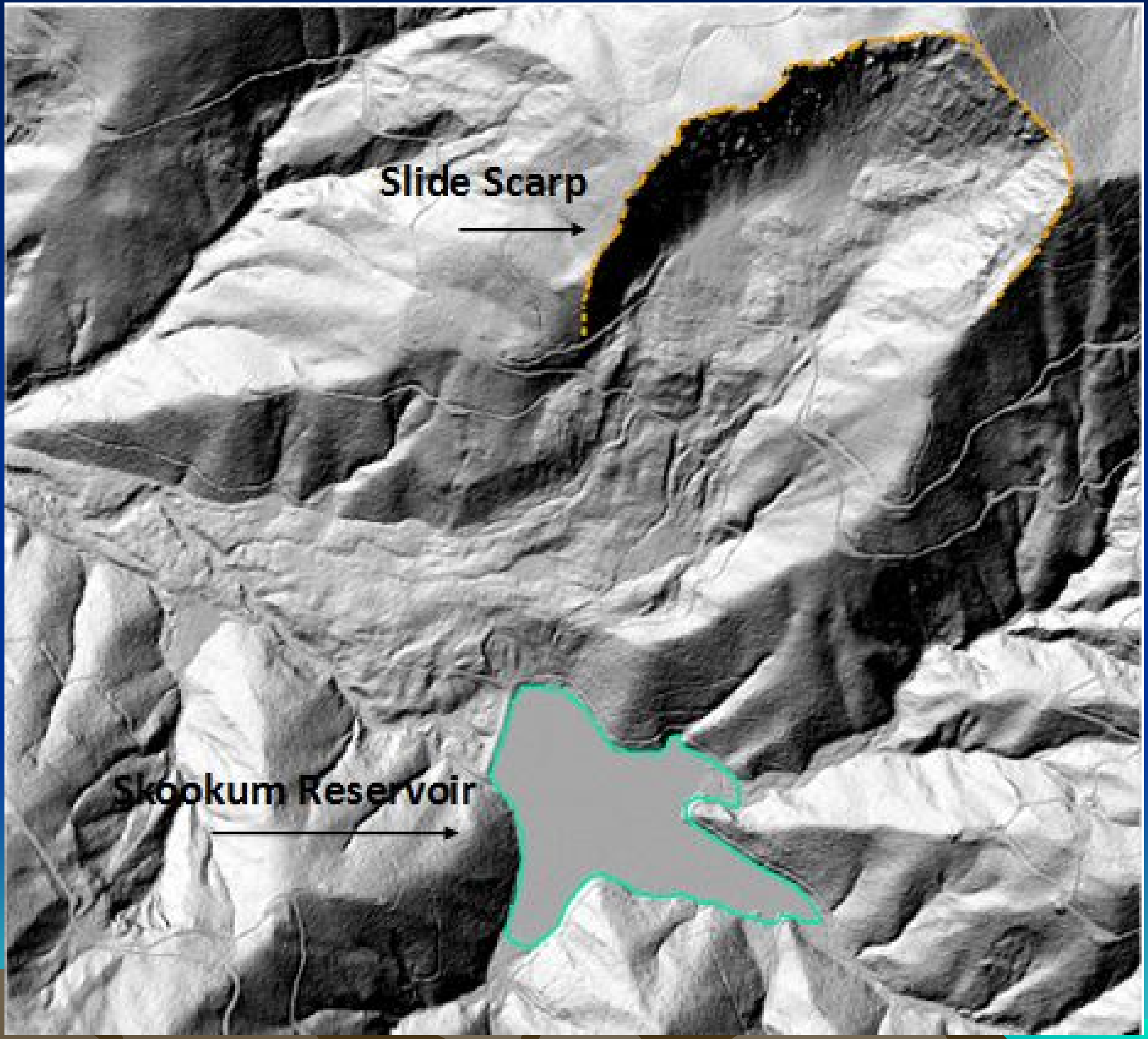
Newport Lower Dam

Bear Creek Dam (Astoria)

Partial funding from Dam Safety and SB 1069
Coos Bay North Bend lower water supply dam also under discussion

Landslides

on LiDAR



Snow or rock avalanche?

Spillway Stability in Flood

Oroville
dam as spillway

Spillways

Resistant rock

The Risk

- Older dams
- Less Rehabilitation
- Earthquake and extreme flood will occur
- Large Federal have had a lot more attention
- Oregon dams got a D+ from ASCE
- Dam Safety focus - HHPD FEMA grant
- Less engineers involved than many states

Monitoring is critical

Investigation and Analysis

- Drawings may not be accurate
- Many less than homogenous
- Confirm with site investigation
- What is the design flood
- Is the spillway stable
- Risk of internal and conduit erosion
- Seismic – analysis can overestimate
- Workshop on the geotechnical aspects

Funding for Rehabilitation

- Feasibility studies funded
- Rehabilitation funding – public benefits
- Kingsley – FID in progress
- Wallowa in progress
- Dedicated funding?

Rehabilitated dams

Removal of Dams

- **New Authority**
- **When owner chooses**
- **Limited to safety from inundation during removal**

Closing

- Big events drive things
- Recent events moderate
- Dams not as in drawings
- Big engineering needs on State regulated dams
  - Investigation
  - Analysis
  - Monitoring
  - Rehabilitation

- New Law, RAC
- Unsafe and Potentially unsafe
- Lot to do

GEOTECHNICAL WORKSHOP FOR ALL ENGINEERS WORKING ON DAMS – February or March 2020