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Mackay Dam Failure, Far More Likely Than Previously Thought – No Apparent Action by State and Federal Agencies

A recent article by Anteia McCollum, *Idaho Capital Sun*, "Mackay Dam described as 'accident waiting to happen,' [1] has highlighted that the dam's spillway is too small and is deteriorating. And the earthquakes pose a risk to the dam because of the unknown construction details. The repairs needed for the dam will cost millions of dollars, according the Idaho Department of Water Resources' John Falk. **But funding for major upgrades to the dam has not been found.**

McCollum's article described the two most recent earthquakes in Custer County, Idaho, where the Mackay Dam is located. An earthquake in 2020 in Custer County was a 6.5 magnitude and the 1983 Borah Peak earthquake was a magnitude 6.9.

When reservoir inflows exceed the release capability from outlet works and spillway, the dam will overtop and fail the embankment, rapidly releasing water from the reservoir. A wall of water reaches the town of Mackay within 30 minutes of failure of the dam and that does not provide time for evacuation. Failure of the high hazard dam will cause the loss of life.

Within hours, the floodwaters continue 40 miles downstream and inundate portions of the Idaho National Laboratory where nuclear facilities storing spent nuclear fuel, high-level waste and an operating nuclear reactor are located. Even if radiological releases are avoided, the flooding will certainly entail high costs to address damaged or degraded above ground and below ground nuclear facilities.

The maximum reservoir inflows occurred in 2017 according to a study published in 2021. [2] The resulting outflow from the Mackay Dam was approximately 2,200 cubic feet per second (cfs) occurring in early June 2017. A higher outflow of 2,990 cfs had occurred on June 10, 1921, according to the same report.

[1] Anteia McCollum, *Idaho Capital Sun* (printed in *The Idaho Falls Post Register*), "Mackay Dam described as 'accident waiting to happen," August 17, 2022. See also a related article by McCollum at https://idahocapitalsun.com/2022/08/15/central-idahos-mackay-dam-is-an-accident-waiting-to-happen-officials-say/

[2] McMillen Jacobs Associates, *Potential Failure Mode Analysis and Risk Assessment Report – Mackay Dam*, State Dam Identification D34-2225, National Inventory of Dams ID 00181, Revision 1, June 25, 2021. (Appendix F)

By 2017 it had been recognized by professionals that climate change increases the risk of severe weather and flooding and the risk of failure of dams. [3] Western states can expect storms that produce more frequent and stronger precipitation extremes even while the frequency of light and moderate precipitation decreases, according to a recent report by Thomas W. Corringham and others. [4] [5]

This year recent flooding in the neighboring state of Montana this June exceeded 1-in-500-year flood levels due to unexpected heavy snow followed by heavy rain this spring, despite a dry winter. [6]

A study of alternatives to rehabilitate the Mackay Dam was published in 2021 which found significantly reduced estimates of Mackay Dam release capability. [7] [8] **The likelihood of failure of the Mackay Dam is now far higher than previously thought. At spillway flowrates as low as 500 cubic feet per second (cfs) may fail the spillway and then the dam.** A previous estimate from a 1986 Department of Energy funded study had estimated a spillway capacity of nearly 7000 cfs.

Release capability for a dam is provided by the outlet tunnel normally and also by the spillway when water levels are high enough. Water was flowing on the spillway in 2017 when the maximum inflow of record occurred and flow onto the Mackay Dam spillway has occurred in other years. Several inches of water flowing on the spillway would not be unusual during spring runoff when the dam is full and the spillway flow would be below 100 cfs.

When inflow into a reservoir from snow melt and/or precipitation exceed the normal outlet tunnel capability, the spillway is needed to release the excess water in order to prevent the dam's embankment from overtopping. Overtopping a dam will fail the dam.

The condition of the walls and floor of the concrete spillway for the Mackay Dam, built in the 1930s, has been deteriorating. The spillway is constructed over the embankment and it crosses over the outlet tunnel. The spillway is 640 feet long, approximately 24 ft wide, and exits next to the toe of the dam near the outlet of the tunnel.

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[3] Roche, C. Thygesen, K., Baker, E. (Eds.) *Mine Tailings Storage: Safety Is No Accident*. A UNEP Rapid Response Assessment. United Nations Environmental Programme and GRID-Arendall, Nairobi and Arendal, www.grida.no. 2017. ISBN: 978-82-7701-170-7

[4] Corringham, T.W., McCarthy, J., Shulgina, T. *et al.* "Climate change contributions to future atmospheric river flood damages in the western United States," *Sci Rep* **12,** 13747 (2022). https://doi.org/10.1038/s41598-022-15474-2

[5] Matthew Cappucci, *The Washington Post*, "A 'megaflood' in California could drop 100 inches of rain, scientists warn – It hasn't happened since 1862, but California is due for another one," August 12, 2022.

[6] Associated Press, *The Idaho Falls Post Register*, "High and Fast – How heavy snow, rain flooded Yellowstone," June 19, 2022.

[7] McMillen Jacobs Associates, *Conceptual Design Report Mackay Dam*, State Dam Identification D34-2225, National Inventory of Dams ID 00181, Final Revision 1, June 25, 2021. (Appendix A)

[8] McMillen Jacobs Associates, *Potential Failure Mode Analysis and Risk Assessment Report – Mackay Dam*, State Dam Identification D34-2225, National Inventory of Dams ID 00181, Revision 1, June 25, 2021. (Appendix F)

As part of the effort to develop possible design alternatives for Mackay Dam rehabilitation, McMillen Jacobs prepared an analysis of the Potential Failure Mode Analysis and Risk Assessment and a meeting was held in 2020. This later become Appendix F of the 2021 report. [9] Appendix F identified spillway flow capacity below what had been estimated in a 1986 study for the Department of Energy. [10] **The value for spillway capacity in Appendix F was recognized at only 2,200 cfs whereas the 1986 report had estimated the spillway capacity as being 6,588 cfs. The 1986 estimate had apparently evaluated the flow capacity at the crest of the spillway but had not considered flow restrictions further downstream of the spillway that limit the flow capability.**

The total outlet tunnel plus spillway release capability were estimated as 3010 cfs (outlet) plus 2,200 cfs (spillway) for a combined release capability of 5210 cfs in the 2021 Appendix F by McMillen Jacobs. The total outlet tunnel plus spillway release capability estimated in the 1986 report were far higher at 2,960 cfs (outlet) plus 6588 cfs (spillway), or a combined release capability of 9598 cfs.

Then the McMillen Jacobs prepared the Conceptual Design options reported in Appendix A and published in 2021. **Appendix A stated that the condition of the concrete walls of the spillway was so degraded that they expected the spillway to fail and to subsequently fail the dam if spillway flows were sustained above 500 cfs.**

The Conceptual Design Report (in Appendix A) states: "It is estimated that this significant damage would initiate in those portions of the spillway chute that are in poor condition. This includes areas with adverse transverse and open joints as well as spalled concrete with undermined foundations. As the spillway chute is removed due to stagnation pressures and uplift, the damage works its way towards the crest of the spillway which is sometimes referred to as a 'zipper effect.' This will eventually result in a breach of the embankment and uncontrolled release of the reservoir."

Sustained 500 cfs flows on the spillway would dismantle the spillway and then cause collapse of the dam. The study also found that the usual control of outlet gate

[9]McMillen Jacobs Associates, *Potential Failure Mode Analysis and Risk Assessment Report – Mackay Dam,* State Dam Identification D34-2225, National Inventory of Dams ID 00181, Revision 1, June 25, 2021. (Appendix F, page 15 and others.)

[10] K. N. Koslow and D. H. Van Haaften, Idaho National Engineering Laboratory managed by the U.S. Department of Energy, *Flood Routing Analysis for a Failure of Mackay Dam*, EGG-EP-7184, June 1986.

positions would likely limit the flow to 2000 cfs through the outlet, below the maximum outlet works flow of 3010 cfs.

The 2021 Appendix A estimated 2000 cfs outlet under typical gate positions plus 500 cfs (spillway), or a combined release capability of 2500 cfs for expected gate positioning.

This is summarized as follows:

- 1986 estimate of spillway capacity was stated as 6,588 cfs;
- 2020 estimate found spillway could only pass 2,200 cfs (Appendix F);
- 2021 estimate found dam failure at spillway flow of 500 cfs (Appendix A).

This 2021 finding which the Idaho Department of Water Resources was well aware of, did not cause IDWR to take action. Another state agency, the Department of Environmental Quality regulates hazardous waste at the Idaho National Laboratory (INL) under the Resource Conservation and Recovery Act (RCRA) laws and those regulations require consideration of flooding of RCRA-permitted INL facilities when flooding is more likely than 1-in-100 years.

Spent nuclear fuel, nuclear reactors and some other nuclear facilities at the INL are required to consider flooding, even when is it only 1-in-10,000-year flooding or even less likely.

A 2005 study by the U.S. Department of the Interior was used in hazardous waste permitting of INL facilities and it estimated 100-year flooding to the Idaho National Laboratory as 3,072 cfs and up to about half a meter (or 1.65 ft) of flood depth at INTEC. [11] However, the now recognized failure likelihood of the Mackay Dam is thought to occur with a 25-yr to 50-yr flooding inflow to the reservoir and this would produce far more flooding, releasing perhaps 107,480 cfs from the dam.

The 100-year flooding studies currently used by the Idaho Department of Environmental Quality RCRA permitting underestimated the flooding at some of the INL RCRA permitted facilities because it had been wrongly assumed that the Mackay Dam was reasonably reliable and was not expected to fail at less than a 1-in-100-year likelihood.

The length of time that the nuclear facilities storing spent fuel and high-level waste will remain at the INL is also already decades and may extend more than a few more decades. There is no out-of-state disposal facility for the high-level waste calcine or the sodium-bearing waste. And the Department of Energy has not only put off treating the calcine to place the powdery material into safer canisters than the current bin sets, the DOE has not even decided if or how it will repackage the calcine. The DOE has not yet begun treating the liquid sodium-bearing waste still stored at the tank farm at INTEC although its treatment was due by 2012. DOE continues to

[11] Dean A. Ostenaa and Danial R.H. O'Connell, U.S. Department of the Interior, Bureau of Reclamation, *Big Lost River Flood Hazard Study, Idaho National Laboratory, Idaho*, November 2005. (see HWMA/RCRA Part B Permit Application for the Idaho National Laboratory, Volume 3, DOE/ID-10131, Idaho Cleanup Project, Revision 18, July 2017 on inldigitallibrary.gov)

hint at forever storage of the highly soluble high-level radioactive waste in shallow burial at the INL, as past study reveals this mindset, which still exists today. [12]

From my look at Appendix F and also Idaho Department of Water Resources inspection reports and other reports, **back in 1955 the State Reclamation Engineer described the Mackay Dam spillway capacity as too small and only 2000 cfs.** The finding that the spillway capacity was only 2000 cfs was not the product of a single engineer. The finding was communicated in a letter from the U.S. Department of the Interior, Bureau of Reclamation, Denver Federal Center, Chief Engineer to the Idaho Regional Director on August 1, 1951. [13] Since 1951, changes to the dam to raise the height of the dam with the 5-ft weir at the spillway have increased the stresses on the structure.

A basic timeline of the Mackay Dam is as follows:

- 1894 Carey Act, private capital could be used for the construction of irrigation systems, with the stipulation that the State of Idaho would provide supervision of projects.
- 1909 Construction begins, no spillway planned.
- 1910 Construction commences and photographs are taken by State Engineer of core wall and other construction of the Mackay Dam.
- 1911 A spillway is constructed by the State of Idaho that is 80 ft wide and 5 ft deep. This spillway was built to the left side of the dam with soil and riprap and prevented failure of the dam in 1911 because the outlet works was unable to pass the inflows to the reservoir. Flooding inflows that year were estimated as 2500 cfs with a maximum of 3000 cfs, flowing through this spillway according the Report of the State Engineer as recorded sometime after 1912.
- 1905-1918 Many reports by independent engineering firms made concerning safety problems with the Mackay Dam. Original plan of 120 ft high dam is reduced to 70 ft.
- 1917-1918 Construction restarted under the Utah Construction Company. Structure is restricting flow of the reservoir inflows. Relocation of the heading of the outlet tunnel, not fully documented.
- 1921 A maximum outlet flow of 2880 cfs occurs.
- 1922 Project approved from the standpoint of the Carey Act
- 1927 Water users purchase the project.
- 1931 The old spillway to the left abutment constructed by the state is condemned.

[12] N. A. Chipman, for the Department of Energy, *Potential Near-Surface Disposal Concepts for High-Level Radioactive Waste at the Idaho Chemical Processing Plant*, WINCO-1073, December 1989. See the inldigitallibrary.gov (Please note that this report contains highly incorrect information about the longevity of the current calcine stainless bins in concrete vaults. The stainless steel would be damaged if exposed to groundwater and experience through-wall cracking within two decades. The lines to each bin could fail due to floating of the bins in the vault if flood water leaked into the concrete vault. The concrete is deteriorating and is without documentation as to adequacy. The calcine storage will not retain integrity for the design life in this report of 500 years. The integrity of the calcine bins would be reduced to about two decades should they flood. A flooding event could also lead to a radiological release above or below ground.

[13] Chief Engineer, W. E. Blomgren, Acting, United States Department of the Interior, Bureau of Reclamation, Letter to Regional Director, Boise, Idaho, Subject: Rehabilitation and raising of Mackay Dam, Big Lost River Project, Idaho, August 1, 1951.

- 1932 New concrete spillway constructed that crosses over the outlet tunnel remains in use in 2022. The construction appears to have cut into the core wall extension, a feature that had been stipulated by the Idaho dam inspector during construction of the dam. No analysis of this design modification is conducted.
- 1932, limestone rubble from the spillway construction used to raise the embankment approximately 6 feet to about 6071 feet.
- 1924-1938 Drought conditions are a hardship on irrigators and they seek increased storage capacity. In the 1930s, an intentional bomb blast on the outlet tower causes some damage.
- 1951 Bureau of Reclamation report states that **it considers the Mackay Dam an unsafe structure.** They estimate spillway as passing only 2000 cfs and note serious problems with geology and construction of Mackay Dam.
- 1952 Owners of the dam submit plans to increase storage capacity by 5-ft height increase at spillway using tainter gates and are approved by State Reclamation Engineer.
- 1949 Smooth ground surfaces of the Big Lost River flood plain selected by the Atomic Energy Agency that would become the Department of Energy. Nuclear reactors, fuel storage pools and fuel reprocessing facilities built on the flood plain.
- 1952 Reactor and nuclear fuel reprocessing facilities are operational at the Idaho National Laboratory, then called the National Reactor Testing Station. Spent nuclear fuel storage and calcine storage added prior to 1986 do not consider the flood hazard.
- 1956 Plans to use a concrete ogee weir instead of tainter gates not approved by State Reclamation Engineer. Case heard by Sixth Judicial District Court in 1956 and upheld in the State Supreme Court in 1957 rules against the State Engineer and for the Big Lost River Irrigation District. The 5 ft height increase by the ogee weir at the spillway must be allowed. Conditions of the decree, however, include maintaining the outlet gates and apparatus in good condition and ensuring that the controls of the outlet works will always be accessible. These conditions are not enforced by the IDWR during the coming years.
- 1956 a 6-foot high and narrow 15-foot-wide parapet of gravel is added to the top of the embankment such that the crest of the dam is now claimed as being 6076 ft high.
- 1978 Phase I report by the Army Corps of Engineers, PMF 41,000 cfs and recommendations of further investigation of geology and design with regard to the Mackay Dam seismic vulnerability. These recommendations are not carried out.
- 1983 Borah Peak earthquake on October 28, rather full for October, the reservoir is at 6059 ft, full being at 6067 ft which is below the embankment crest of about 6075 ft.
- 1984 Rock cliff above spillway removed by blasting.
- 1985 Extensive rock fallen rock at the outlet control tower is removed.
- 1986 Department of Energy funds studies: the Koslow and Van Haaften report of flood depths at the Idaho National Laboratory, states wrongly that the spillway can pass approximately 7000 cfs and that while the dam cannot pass the PMF, it can withstand a 1000-year flood.
- 1986 Documented in the Koslow and Van Haaften report is also an update of the PMF by Dr. Dave L. Schreiber, P.E., who recommends the PMF be increased to 82,100 cfs (although rain on snow could reach 139,200 cfs into the Mackay reservoir.)

- 2017 Maximum recorded reservoir inflow to the Mackay Dam (4220 cfs) occurs in three separate peaks. If there had been only one peak, the spillway and dam may have failed (See page 20 Appendix F).
- 2020 Meeting held for draft McMillan Jacobs report which finds decreased spillway capacity of 2200 cfs, not the 7000 cfs stated in the 1986 Koslow and Van Haaften report for the Department of Energy.
- 2021 McMillan Jacobs reports finds that spillway flows sustained above 500 cfs would destroy the spillway and cause failure of the dam. The report finds that the dam cannot pass a 50-year flood, or cannot pass with 95-percent confidence, a 25-year flood. However, the full extent of the risk increase of dam failure due to virtual lack of an adequate spillway is not estimated.

A summary of the increases to dam crest elevation is provided in Table 1. Also provided in Table 1 are the elevation of the spillway floor, walls of the spillway and the elevation of the ogee weir at the entrance to the spillway.

Table 1. Dam crest elevation increases and spillway elevations.

Dam Crest Elevation Increases	**Comment**
Current dam crest, 6075.2 ft	1956, addition of the 15-ft wide gravel parapet, surveys not accurate and often stated at 6076 ft.
Dam crest of 1932, 6070 ft	1932, addition of limestone from the spillway construction
Original dam crest, 6065 ft	1910 original height of the dam crest. Also note that the elevation of the entrance to the original spillway was 6055 ft.
Spillway elevations	**Comment**
Top of spillway walls, around 6070 ft	Spillway constructed in 1932, about 8-ft high walls.
Height of ogee weir, 6067 ft	1956, 5-ft high concrete ogee weir added to spillway entrance to increase the storage capacity of the dam despite IDWR objection
Floor of spillway, 6062 ft	1932, Spillway constructed that is in use today, replacing the spillway that had been on the left side of the dam (looking at the dam from upstream).

Sources: 2021 Appendix F by McMillen Jacobs. Leslie F. Harder, Jr., M. ASCE, *Investigation of Mackay Dam Following the 1983 Borah Peak Earthquake*, circa 1988. Included in the Big Lost River Irrigation District Operations Plan dated February 28, 1994.

The entrance to the spillway is 75 ft wide, but it narrows to 24 ft wide. Some calculations of spillway capacity over the years appear to ignore the narrowing of the spillway. Also, the height of the water was allowed to exceed the spillway wall elevations.

The Department of Energy-funded report by Koslow and Van Haaften in 1986 stated the incorrect Mackay Dam spillway capacity of 6588 cfs. The wildly optimistic spillway capacity in the 1986 report was being cited and unquestioned by either the Department of Energy or the Idaho Department of Water Resources. **The 1986 spillway capacity estimate would allow water to flow over the walls of the spillway by about 4 ft, yet this inappropriate assumption, which would allow failure of the spillway walls and also the dam, was not examined.**

But reassessment of spillway capacity in 2020-2021 in work performed to study possible rehabilitation of the dam estimated the spillway capacity was only 2200 cfs which is basically consistent with the assessment in 1951 of about 2000 cfs.

Also, it was noted in a 1950 inspection report that the spillway, built in 1932, that the concrete was spalling and concrete joints were open and needed sealing. Since that inspection in 1950, the concrete of the spillway has continued to deteriorate and cracks extend through the walls of the spillway. Concrete was also cut out near the entrance of the spillway in order to get equipment into the spillway for periodic rock removal. This cutout lowered the already low walls of the spillway and would route water to the top of the embankment and should never have been allowed. It doesn’t matter much since the spillway walls are, as of 2021, expected to fail at only 500 cfs.

In the past, when I had gazed at the pictures of the small spillway for the Mackay Dam, it had remained in the back of my mind, is some kind of a joke? They don’t expect to ever use the spillway, do they? **The Idaho Department of Water Resources (IDWR) and the Department of Energy have both long implied the dam and its spillway were adequate.**

The spillway is not the only problem. The concrete outlet control tower is over 100 years old and deteriorating. Repairs are regularly made to the tower and gates, but the movement of gates is unreliable. The control tower is located next to rock cliffs that are sluffing off rocks that can at least partially block the lower gates. Attempting to close gates with rocks at the base of the lower gate can bend the control rods, rendering non-functioning gate control until repaired.

Over one hundred years ago in 1910, the opinion of consulting engineering firms was requested and in September a committee of engineers filed a report that the Mackay dam did have defects. **“It was found that the sheet piling only did not extend to bedrock or to the depth specified but had been omitted entirely beneath sections of the dam. The structure was found to be resting on a gravel base and the existence of an impermeable substratum, which is a requisite for such a structure, was questioned.”** [14]

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[14] Bruce L. Schmalz, *The Powell Tract of the Big Lost River Irrigation Project*. Describes the history of developments from the 1894 Carey Act to 1927. Publication date is stated as 1966 and it is an appendix in the State of Idaho, Department of Water Resources for U.S. Army Engineer District, Walla Walla, Corps of

Another candid description was provided in 1947 that is part of the IDWR collection of documents that stated "the [outlet] tower is in a questionable state of well-being. It is not apparent upon first inspection whether the tower is supported by the rock cliff to which it is attached by concrete or visa versa." And "Immediately to the south of the spillway is an almost vertical cliff of rock (not limestone) **stratified with thin layers of clay and silt.** Above… the cliff is overhanging and is very apt within several years to fail and block or crush (or both) the spillway." [Emphasis added.]

Backhoe has Removed Rock and Debris from Gate. Gate on Right has a Bent Stem:

MACKAY DAM
34-2225
October 29, 1985

No work to address the overhanging rock cliffs, as recommended in 1947 and again in 1978, was conducted until after the Borah Peak earthquake in 1983 which dislodged considerable rock fall into the spillway (and also turned leakage from the dam to a milky white). When the work was conducted in 1984, it apparently caused rock fall into the reservoir around the outlet tower, which was then addressed in 1985 at the outlet tower with the reservoir drained.

Pictures are available of the work conducted in November of 1984 by blasting the rock cliff over the spillway, and in October 1985, to remove extensive fallen rock from near the outlet control tower. **It remains officially undocumented as to whether the 1983 Borah earthquake or the blasting of rock cliffs over the spillway caused the extensive fallen rock near the outlet tunnel.** Inspection of the dam after the 1983 Borah earthquake did not identify fallen rock affecting the outlet gates and so it would seem that the rock blasting of the cliffs over the

Engineers, *Big Lost River Basin Mackay Dam Custer Country Federal Number ID 181 State Number D34-2225, Phase I Inspection Report National Dam Safety Program*, September 1978.

spillway in 1984 caused considerable rock fall around the outlet control tower. Rock fall remains a problem that could partially block the lower outlet gate entrances.

The outlet tunnel is concrete lined for most of the tunnel. The outlet tunnel at the toe of the dam is metal pipe surrounded by rather loose fill. The timber and rail apron about the outlet of the tunnel are deteriorating. Tons of loose rock are above the apron. Rock cliffs are to the side of the outlet, beneath the spillway.

Photo 3b (3/27/2013) – Similar view of the tunnel outfall at low flow conditions.

The outlet tunnel condition was considered good in the 1982, with no spalling of concrete on the walls or ceiling and the floor of the tunnel uneven in places with only slight depressions in places. By 1991, a 10-inch-deep hole in the floor required repair. Many other repairs to the floor have been made. By 2003 more holes in the tunnel concrete are being noted and in 2006, an inspection report noted that "There were several holes in the top of the outlet [tunnel] where you could see there was no material for a foot or two." The 2021 McMillen Jacobs Appendix F suggested further investigation of the degradation of the tunnel lining, including "forensic testing of concrete strength" but this does not appear to have been conducted.

In 2007, the condition of the embankment, outlet works and spillway were rated as "good"; by 2011 all were rated as "fair"; by 2017, the outlet and spillway are both being rated as "poor."

The inspections are important, but the inspections of dams, by the IDWR over the years, are very limited in scope.

Obvious problems are typically described in the inspection reports in a sentence or two, highlighting what is visually obvious.

The obviously needed repair work is pointed out to by IDWR to the owner of the dam. But more sophisticated studies of the condition of the dam and its concrete lining the outlet tunnel have not been required of or performed by the owner of the dam.

Inspections of dams is conducted without national standards as each state has different policies and inspection frequencies and the ratings given to the embankment, outlet and spillway are subjective.

The embankment, although allowing leakage through the dam since it was built, does not appear to be degrading. However, the embankment is not properly constructed and is built over a creek bed of over 90-ft deep alluvium deposits. Descriptions by a witness of the driving of pilings during original construction saw some pilings driven downward required little force and that it did not appear that pilings had reached solid material or bedrock (described by State Engineer in notes created in 1947 (of construction prior to 1920) on file with IDWR).

For most of the Idaho Department of Water Resources inspection reports, the Mackay Dam is check marked as an "earthen" dam. Sometimes it is check marked as a "rockfill" dam. In 2021, it was check marked as a "concrete" dam, presumably due to its concrete core wall. But the height of the core wall only ranges between 6013 and 6040 ft while the crest of the dam is at 6075.2 ft. Documentation of the core wall and inspections during construction are lacking.

Mackay Dam is actually a loosely compacted gravel and sand embankment with a partial height concrete core wall, with pilings below the core wall not founded to bedrock. A study by a doctoral student, L. F. Harder, involved two churn drill boreholes drilled into the embankment over where the original river channel was located. The samples of the fill material were studied and it was found that on average the fill was 69 percent gravel, 26 percent sand and 6 percent fines.

Inspections conducted immediately following the 1983 Borah Peak earthquake noted turbidity in the water coming from under the cliff which makes the right abutment of the dam. The water was clear at the seepage and outlet tunnel exit, but turbid milky colored downstream, from under the downstream side of the right abutment. [15] I suspect that this turbidity originated from the concrete core wall. A discussion in the State Engineers log written around 1912 noted the following. During the high water of 1911, when the outlet tunnel would not carry the full flow of the river (and it may be that the original outlet capacity had blocked closed the 10 ft diameter pipe and used valves at the 6 smaller outlet pipes) and the water rose behind the incompleted structure until 3,000 cfs flowed through the temporary spillway which

[15] Normal C. Young, Idaho Department of Water Resources, Memorandum to Mackay Dam File, Post Earthquake Inspection – October 28 and 29, 1983 – November 3, 1983, November 9, 1983. "Leakage from the right abutment showed some turbidity (Photo Nos. 2, 3, 4 and 5). It had cleared noticeably by the afternoon of the October 29th (and was clear on November 3, 1983). The flow rate appeared to be stable and unrelated to the level in the plunge pool below the outlet works." The earthquake occurred about 8 am on October 28, 1983.

had been constructed by the State of Idaho, a stream of several cfs was flowing along a depression along the top of the core wall that reached the cliff of the right abutment and disappears in cracks in the rocks.

No. 2 shows the foundation course for the core wall being placed,

Observation wells OW-9 and OW-10 were also installed by Harder to see the level of saturation (the phreatic level) in the embankment, with measurements made when the reservoir was at an elevation comparable to the level during the 1983 Borah earthquake. Then in August 1984 and in July 1985, nineteen boreholes were made in the embankment to conduct Becker Penetration Tests. **These tests were used to conclude that the estimated average relative density of Mackay Dam gravel was approximately 45 percent. [16] This is a relatively loose fill and is consistent with the lack of compacting of the fill during construction.**

The vulnerability to seismic liquefaction depends on the level of water within the embankment (which will vary according to the level of water in the reservoir) and the density of and composition of the embankment, and the stresses imposed by the earthquake. The approximate peak ground acceleration of 0.22 g was stated in the analysis by Harder. Harder estimated that for the October 1983 Borah Peak earthquake, that the factor of safety against liquefaction was approximately 1.3. **However, portions of the embankment "immediately**

[16] Leslie F. Harder, Jr., M. ASCE, *Investigation of Mackay Dam Following the 1983 Borah Peak Earthquake*, circa 1988. Included in the Big Lost River Irrigation District Operations Plan dated February 28, 1994.

below the phreatic surface" only had a safety factor of from 1.1 to 1.2 and this was with the reservoir not completely filled.

It appears that had the level in the reservoir been higher than 6059 ft at the time of the 1983 Borah earthquake, the safety factors would have been lower. Likewise, had the earthquake been larger, the safety factors would have been lower.

From a 2015 Bureau of Reclamation report for seismic analysis, [17] some embankments constructed prior to the mid-1900s may not be sufficiently dense to preclude liquefaction, as some embankments were not compacted. The 2015 study recommends detailed deformation analysis unless all of the following conditions, that I paraphrase here, are met:

- The dam is well built and compacted to at least a relative density greater than 75 percent. [Neither of these conditions are met.]
- The slopes of the embankment are 2.5:1 or flatter. [The upstream slope is shallow at 3:1; however. the downstream slope of loose rock is too steep at 1.5:1 and does not meet this condition.]
- The phreatic line is well below the downstream face of the embankment. [This is likely not met when the reservoir is nearly full.]
- The peak earthquake acceleration is not more than 0.35 g [Peak accelerations on the embankment would be expected to be near this for return intervals above 5000-yr. Peak acceleration on the embankment would exceed this for the maximum credible earthquake.]
- The safety factors for surfaces of the crest are greater than 1.5 using the reservoir at its maximum capacity. [This is not met.]
- No appurtenant features, (outlet tunnels, outlet gate towers or spillways) would be harmed by small movements of the embankment or harmed by other potential failure mode. [Importantly, this is also not met.]

No studies have been required by the IDWR, but the Mackay Dam is susceptible to earthquake induced failure, including liquefaction. The Bureau of Reclamation report would recommend a detailed deformation analysis. Although there was the unsolicited graduate work by Harder in 1984 and 1985 to look at the embankment composition, density and liquefaction for a single case with the reservoir only partially full, no such comprehensive analysis was performed. Nor was such analysis requested or required by the Idaho Department of Water Resources for continued certification of the Mackay Dam.

While the Mackay Dam did survive the 1983 Borah Peak earthquake, there were troubling signs. The telephone pole at the top of the embankment could now be moved, using both hands, by several feet in the loose gravel. There were two cracks, about a quarter of an inch wide, along

[17] U.S. Department of the Interior, Bureau of Reclamation, *Reclamation Managing Water in the West*, Design Standards No. 13, Embankment Dams, Seismic Analysis and Design, May 2015.

either side of the top parapet of the embankment, one was 200 ft long, the other 100 ft long. There was a turbid milky discharge from below the cliff area called the “right abutment” into the spillway plunge pool. The spillway plunge pool is downstream of the seepage areas of the embankment and also downstream from the pool where the outlet tunnel exits. There was also measured increases in seepage and flows from the dam, noted as 5 percent. The there was considerable rock fall near the entrance of the spillway, more than generally described.

When the level of water in the reservoir increases from, say 6067 ft with storage of 44,500 acre-feet, to a level of 6075.2 ft, the storage capacity increases to 55,091 acre-feet. Likewise, the stresses on the dam are increased more than you might expect as the level of water in the reservoir increases.

The 1983 Borah Peak earthquake and the high flooding levels in 2017 came closer to failure of the Mackay Dam than most people recognize. Had the dam been full during the 1983 earthquake it may have failed. Or had the precipitation and flooding not been spread over three peaks in 2017, causing over 500 cfs to the spillway, it may have failed the spillway and the dam.

The values for predicted surface inflows to the Mackay reservoir from the 1986 study and the 2021 study are shown in Table 2. Peak flooding intervals and corresponding annual exceedance probabilities are provided in Table 3.

Table 2. Predicted surface inflows to the Mackay reservoir from the 1986 report by Koslow and Van Haaften and the 2021 McMillen Jacobs report.

Recurrence Interval (Years)	Inflow to the Reservoir, Peak Flow (cfs) (1986 Koslow and Van Haaften)	Inflow to the Reservoir, Peak Flow (cfs) (2021 McMillen Jacobs)
25	4,030	(20-yr, 3966 cfs)
50	Not available	4,478
100	4,870	4,827
500	5,760	5,524
1000	6,800	Not available
Probable Maximum Flood	82,100	82,100

Table notes: Source: K. N. Koslow and D. H. Van Haaften, Idaho National Engineering Laboratory managed by the U.S. Department of Energy, *Flood Routing Analysis for a Failure of Mackay Dam*, EGG-EP-7184, June 1986. Note that flood inflow estimates and the PMF estimate evolve over time and a variety of values have been used. I provide these values as examples, not as preferred values. McMillen Jacobs Associates, *Potential Failure Mode Analysis and Risk Assessment Report – Mackay Dam*, State Dam Identification D34-2225, National Inventory of Dams ID 00181, Revision 1, June 25, 2021. (Appendix F, page 7.)

Normally, the Probable Maximum Flood (PMF) is used as the design release capability requirement for large, high hazard dams, such as the Mackay Dam. The PMF for the Mackay Dam is estimated at 82,100 cfs, while the 500-year flood estimates do not exceed 5,760 cfs (see Table 4). The current rules for "Safety of Dams Rules" by the Idaho Department of Water Resources require a high hazard dam to be able to release the PMF.

It is estimated that about 0.5 ft of overtopping would fail the Mackay Dam. There are probably other reasons, but given the design of the embankment and condition of the outlet tunnel at the toe of the dam, which is loose fill and a degrading timber and rail apron, this appears appropriate.

Table 3. Peak Flood and Annual Exceedance Probability.

Peak Flood Recurrence Interval	Annual Exceedance Probability	Q is the flow rate corresponding to the peak flood recurrence interval	Annual Failure Probability
2 Year Peak Flood	50% or 40% *		0.4/yr
5 Year Peak Flood	20% or 18% *		0.18/yr
10 Year Peak Flood	10%		0.1/yr
20 Year Peak Flood	5%		5.0E-2/yr
50 Year Peak Flood	2%	Q50	2.0E-2/yr
100 Year Peak Flood	1%	Q100	1.0E-2/yr
200 Year Peak Flood	0.5%		5.0E-3/yr
500 Year Peak Flood	0.2%	Q500	2.0E-3/yr

Table notes: the Q50, Q100 and Q500 notations shown are those used in the draft rule. The Exceedance Probability may be estimated as 1/recurrence interval, e.g., 1/500 = 0.2%. * It may also be more rigorously calculated as [1 – exp [-n/RP] where n is the number of events and RP is recurrence period.

The sudden failure of a dam can cause a wall of water to be rapidly released from the dam. In the case of the Mackay Dam, failure of the dam due to overtopping can occur rapidly and within 30 minutes, wipe out the town of Mackay, taking hundreds of lives. [18] There may be other more refined estimates of the time for the flood wave to reach the town of Mackay under various flooding inflows and dam breach types. The estimated 30 minutes has been deemed too

[18] D. H. Van Haaften et al., EG&G Idaho for the Department of Energy, *Hydrologic Analysis of a Mackay Dam Failure During a Probable Maximum Failure During a Probable Maximum Flood on Big Lost River*, Idaho, SE-A-84-018, May 1984. Cases such as summarized in Table 4 of this article assume the failure of the dam commences at time 0.0 and the dam takes 30 minutes to fail. The estimates in this report state the arrival time of the wave 3.9 miles from the dam is 1.0 hour, including the 30 minutes for the dam to fail. From the time of failure of the dam, it is then 30 minutes for the flood wave to reach Mackay 3.9 miles downstream.

short for evacuation of residents in Mackay and no attempt to put an evacuation system in place has been made. **Failure of the Mackay Dam will result in a flood wave far exceeding 8 ft in height in the town of Mackay and its camping areas near the Big Lost River.** A Mackay Dam failure will cause the loss of life.

Table 4. Four cases of peak flood flow to the Mackay Dam from the 1986 report by Koslow and Van Haaften.

Dam Failure Case	**Breach Type**	**Estimated Peak Reservoir Inflow, cfs**	**Estimated Peak Flow Below Dam, cfs (Total Reservoir Release, acre-feet)**
No failure, maximum flow from Mackay Dam in 2017	No breach	Howell Gage, 3,160 to 4,200 cfs reported	2,200 cfs
Seismic failure (characterized by assuming during 25-year flood inflow)	Trapezoid	4,030 cfs	107,480 cfs (44,830 acre-feet release)
Internal piping failure (characterized by assuming 100-year flood inflow)	Triangle	4,870 cfs	57,740 cfs (41,850 acre-feet)
Internal piping failure (characterized by assuming 500-year flood inflow)	Trapezoid	5,760 cfs	106,680 cfs (44,710 acre-feet)
Probable Maximum Flood (PMF) with dam overtopping	Trapezoid	82,100 cfs	306,700 cfs (142,330 acre-feet)

Table notes: Source: K. N. Koslow and D. H. Van Haaften, Idaho National Engineering Laboratory managed by the U.S. Department of Energy, *Flood Routing Analysis for a Failure of Mackay Dam*, EGG-EP-7184, June 1986. Time to failure is assumed 1 hour. Probable Maximum Flood as estimated by Dr. David L. Schreiber, P.E., Schreiber Consultants, Inc., in 1986 and included in Appendix B of the 1986 Koslow and Van Haaften report. The previous PMF was 41,000 cfs as estimated from US Bureau of Reclamation (USBR) experience curves (see State of Idaho, Department of Water Resources, *Phase I Inspection Report, National Dam Safety Program, Mackay Dam,* September 1978).

The floodwater would flow more than 40 miles further and in as few as 8 hours, reaches the Idaho National Laboratory. Flood depths of 4 to 5 ft are expected at various facilities including the Idaho Nuclear Technology Engineering Center (INTEC) where spent nuclear fuel and high-level waste (calcine and liquid waste) are stored, the Advanced Test Reactor and to the Naval Reactors Facilities. Radiological releases are possible, and very high economic costs can be expected even if no radiological releases occur.

When a dam is in place, the flooding causes the level of water to rise in the dam and the flow of water released from the dam may remain steady, at maximum outlet release capability until the dam is full and flow is also released by the spillway. When the release capability of both the outlet and spillway are exceeded, then with continued inflows to the reservoir, the dam can overtop and fail.

The investigation of possible Mackay Dam modifications, in the end, aims low.

For the Mackay Dam rehabilitation project, the PMF of 82,100 cfs was compared to a reduced 20,000 cfs flooding event. The PMF causing failure of the dam was estimated to release 306,700 cfs (see Table 4). The 20,000 cfs flood event that the dam survives would release the 20,000 cfs, while over and above that, the dam would fail, releasing over 100,000 cfs. The normal releases from the outlet works even during spring runoff do not typically exceed around 2000 cfs from the dam.

Design changes to meet the PMF of 82,100 cfs, or even a reduced 20,000 cfs release capability have been found so expensive that the McMillen Jacobs report (Appendix A) focused on design proposals that would only meet a 500-year flood release capability with a release capability of 5,210 cfs. But no funding for the changes has been found.

Issues of regulatory acceptance by the IDWR seem to indicate that the IDWR would approve any level of reduced release capability of the proposed Mackay Dam rehabilitation using arguments of acceptable "incremental" damage.

Proposed IDWR rule changes would reduce the Inflow Design Flood (IDF) requirement from the Probable Maximum Flood (PMF) to that of the 500-year flooding inflows – stating its basis as being the methods for estimating a fraction of the PMF lack consensus.

In summary, from the 2021 McMillen Jacobs report for the Mackay Dam, [19] [20] we learn that the 1986 report by Koslow and Haaften estimated (wrongly it turns out) that the Mackay Dam could safety pass 1000-year flooding inflows to the reservoir, an estimated 6,588 cfs, before the dam would fail.

The investigation of possible Mackay Dam modifications in 2021 makes identified greatly reduced capacity of the existing spillway. This greatly increased the likelihood of failure of the dam.

Appendix F of the 2021 McMillen Jacobs study had initially estimated that the Mackay Dam could currently pass roughly a 500-year flood beyond which the dam would fail. This was based on an outlet capability of 3010 cfs plus the spillway capability of 2,200 cfs. But this was followed by the finding, described in the Appendix A of the 2021 McMillen Jacobs, that the **spillway would be expected to fail with sustained flows to the spillway about 500 cfs and furthermore, that this would fail the dam.**

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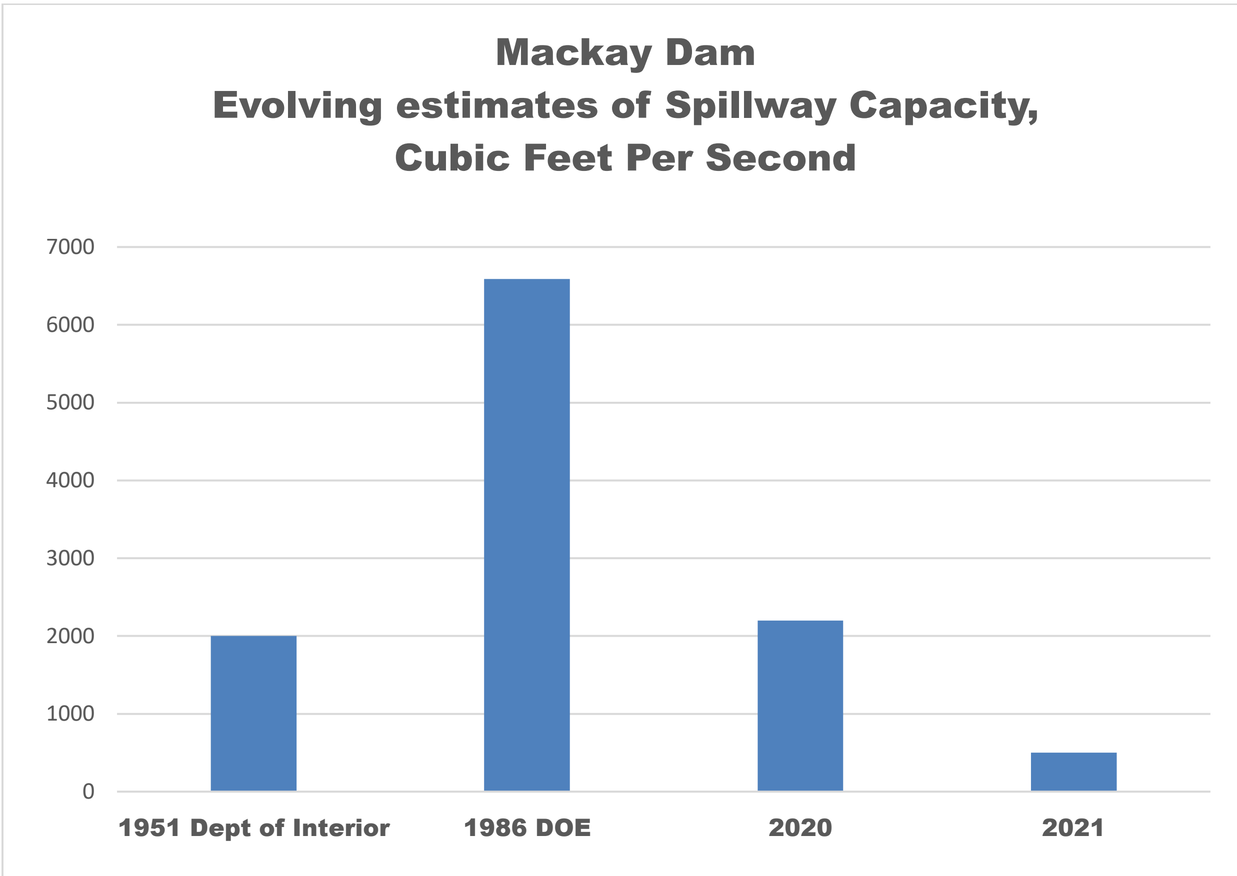
[19] McMillen Jacobs Associates, *Conceptual Design Report Mackay Dam*, State Dam Identification D34-2225, National Inventory of Dams ID 00181, Final Revision 1, June 25, 2021. (Appendix A)

[20] McMillen Jacobs Associates, *Potential Failure Mode Analysis and Risk Assessment Report – Mackay Dam*, State Dam Identification D34-2225, National Inventory of Dams ID 00181, Revision 1, June 25, 2021. (Appendix F)

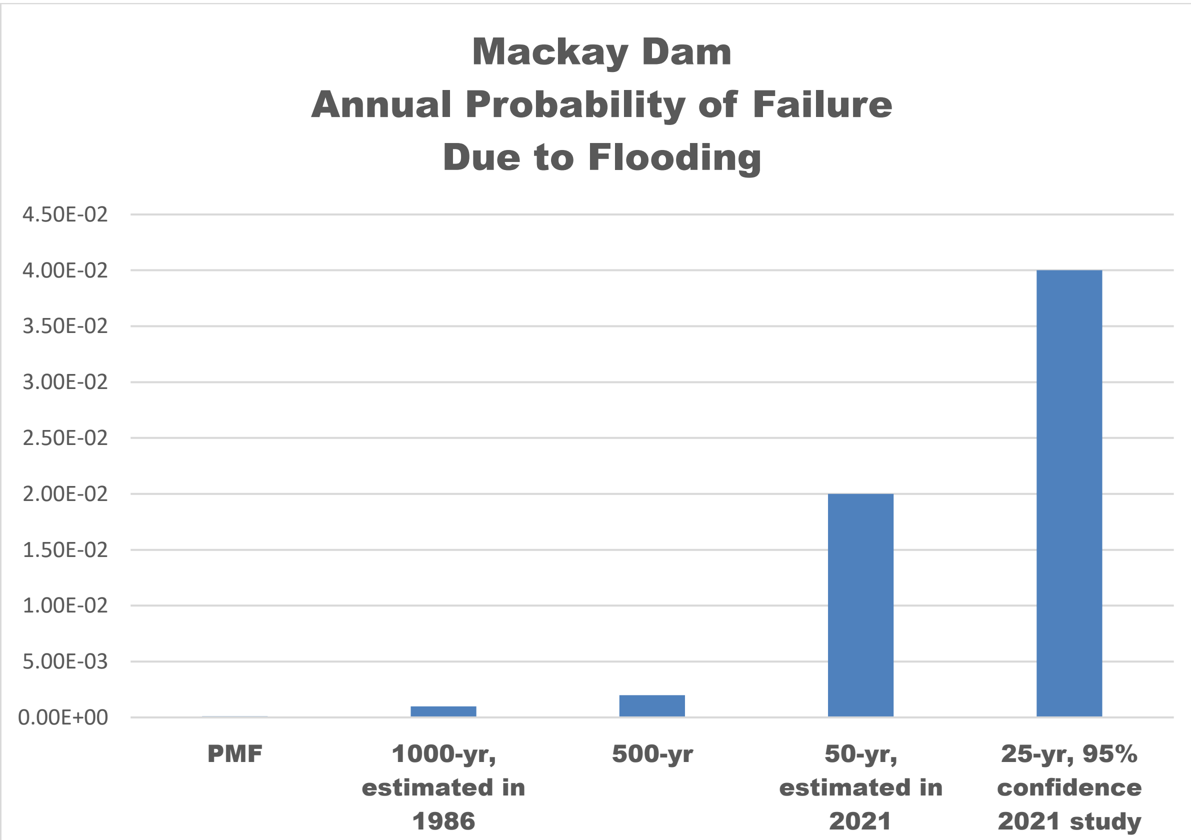
The current release capability of the Mackay Dam now at the risk of failure at between a 50-yr to 25-year return interval flooding would be an "anticipated" event with an annual probability of failure as high as 1-in-25 per year or 4.0E-2/yr. **The reduced spillway capacity means that the Mackay Dam has a very high failure rate not normally accepted for a high hazard dam.**



This estimate takes into account normal gate positioning that would normally be positioned to pass 2000 cfs through the outlet and with reservoir attenuation would allow an inflow to the reservoir of 4,380 cfs (McMillen Jacobs 2021, Appendix A, page. 16). Movement of the gates is unreliable and access to the outlet tower would not be possible when the spillway walls have failed or overtopped. With reservoir attenuation, the 50-yr flood would fail the dam. At 95 percent confidence, the recurrence interval is only about 25-year, according to the graph in Appendix A. Assumptions made to justify the 50-yr flood to fail the dam include favorable timing of the precipitation as occurred in 2017, which was spread over three peaks.

To summarize the annual probability of dam failure from flooding:

- 1986, 1000-year flooding was not expected to fail the dam. But exceeding the release capability of 9548 cfs, with 2,960 cfs from the outlet tunnel and 6,588 cfs from the spillway, would fail the dam. The annual failure probability due to greater than 1000-year flood is less than 1.0E-3 failures/year
- 2020 or 2021, 500-year flooding of 5,210 cfs exceeded the release capability and would fail the dam at 2.0E-3 failures/year
- 2021, 25-year to 50-year flooding exceeding the release capability of 2500 cfs would fail the dam at 4.0E-2 to 2E-2 failures/year. Higher flood inflows into the reservoir can be accommodated, attenuating the higher inflows, until the dam fails but this depends on operating decisions prior to and during the onset of high inflows.



What had been "unlikely" has become an "anticipated" and one that poses a higher likelihood of failure than may have been assumed in previous nuclear safety analyses and may also now be higher than allowed in hazardous waste permits at the INL, see Table 5.

Table 5. Spillway capacity estimate reductions.

Analysis	Flow Inflow to Reservoir	Total Release Capability, cfs	Outlet and Spillway Release Capability, cfs
1986, K. N. Koslow and	1000-yr flood,	9548 cfs	2960 cfs outlet and

D. H. Van Haaften	6,800 cfs		6588 cfs spillway (overestimated spillway capacity)
2020-2021 drafts McMillan Jacobs Appendix F	500-yr flood, 6,400 cfs (Koslow, 5,760 cfs)	5,210 cfs	3010 cfs outlet and 2,200 spillway
2021 McMillan Jacobs Appendix A	4380 cfs, page 16 50-yr, best estimate 25-yr, 95% confidence limit	2500 cfs	2000 cfs outlet for operational practices and gate repair status 500 cfs sustained spillway flow fails spillway which fails dam

Table notes: cfs is cubic feet per second.

Sources: K. N. Koslow and D. H. Van Haaften, Idaho National Engineering Laboratory managed by the U.S. Department of Energy, *Flood Routing Analysis for a Failure of Mackay Dam*, EGG-EP-7184, June 1986.

McMillen Jacobs Associates, *Conceptual Design Report Mackay Dam*, State Dam Identification D34-2225, National Inventory of Dams ID 00181, Final Revision 1, June 25, 2021. (Appendix A). Note that p. 7 states 5-yr flood would occur at 4,478 cfs inflow and thus identifies the 50-yr flood as being below 4380 cfs cited in Appendix A as the 50-year flood. McMillen Jacobs Associates, *Potential Failure Mode Analysis and Risk Assessment Report – Mackay Dam*, State Dam Identification D34-2225, National Inventory of Dams ID 00181, Revision 1, June 25, 2021. (Appendix F)

Department of Energy nuclear facilities are at risk from Mackay Dam failure.

The Department of Energy operates various nuclear facilities at the INL that would be flooded by a Mackay Dam failure. Perhaps the Department of Energy has been treating this information as preliminary. But the reality is that this means that instead of failing at a 1000-year flood, the Mackay dam may fail at a 50-year to 25-year flooding event. The 25-year flooding is approximately the 95th percentile estimate for the analysis of attenuation of high reservoir inflows.

Discussions of INL flooding often discuss the Probable Maximum Flood (PMF) and its flood depths. And the PMF caused by heavy snow and rapid melting and heavy rain is a very large flood and is relatively rare, less likely than 1-in-10,000 years and its likelihood not typically known. But more frequent, yet smaller floods yield similar flood depths at the INL. The siting of nuclear reactors is supposed to avoid locations vulnerable to PMF flooding events, but that was not considered at INL prior to the mid-1980s.

It should be noted that were there no dam, the PMF flooding can still occur. The flooding is increased by the accompanying failure of the dam, but the PMF must still be considered even if the dam were removed. However, the likelihood of the PMF is far less than a 1000-year flood and typically assumed to be a 10,000-year flood or lower likelihood.

It needs to be understood that dams designed to hold water, *when properly designed and properly constructed* tend to be reliable structures. But the Mackay dam in Idaho was not properly designed and construction quality was flawed. The spillway capacity for the Mackay dam was never adequate and despite the IDWR not wanting the Mackay dam capacity increased, legal action in the 1950s allowed its storage capacity to be increased by raising the elevation of the spillway with a 5-ft concrete overflow weir at the entrance to the spillway.

A 1986 report [21] performed for and paid for by the Department of Energy stated that: "Mackay Dam was not built to conform to seismic or hydrologic design criteria. While the structure's ability to withstand further seismic activity is unknown, the performance of the structure during the Borah Peak earthquake demonstrated the stability of the embankment during moderate earthquake ground motion." [Emphasis added.]

A 1978 report issued by the Army Corps of Engineers recommended gathering information about the Mackay Dam there was needed in order to assess its seismic capability. [22] The recommended Phase II and the recommendation to gather needed information was not carried out.

The Three Mile Island spent nuclear fuel stored at the INL's Idaho Nuclear Technology and Engineering Center (INTEC) is one of the few facilities at the INL that is licensed by the U.S. Nuclear Regulatory Commission (see ML19150A336). The fuel was brought to the INL after 1979 and the current dry storage commenced use around 1999. It was designed with knowledge of the possible flood depths at INTEC of up to 5 feet from various floods associated with the Mackay Dam. Other INTEC facilities, particularly those built prior to the mid-1980s did not consider this flooding.

The Naval Reactors Facilities (NRF) area also floods from Mackay Dam failure events. But its dry fuel storage area inside a building has been designed to be at an elevation not vulnerable to this flooding (see ML033640226 dated 2001).

Mackay Dam failure can cause flooding at Central Areas Facility, INTEC, the Advanced Test Reactor Area as well as NRF and could be 4 or 5 ft deep in some locations. And there is a large variety of nuclear facilities and numerous potential vulnerabilities. Even if a significant radiological release did not occur, the storage and repackaging costs could be considerable. Stainless steel, for example, when exposed to chlorides in ground water can experience through-wall cracking within two decades.

Flooding at INL due to a Mackay Dam failure if due to 1000-year flooding would have an annual probability of failure as high as a 1-in-1000 per year or 1.0E-3/yr and would be considered in nuclear safety analysis as an "unlikely" event. It is a big increase in the likelihood

[21] K. N. Koslow and D. H. Van Haaften, Idaho National Engineering Laboratory managed by the U.S. Department of Energy, *Flood Routing Analysis for a Failure of Mackay Dam*, EGG-EP-7184, June 1986.

[22] State of Idaho, Department of Water Resources for U.S. Army Engineer District, Walla Walla, Corps of Engineers, *Big Lost River Basin Mackay Dam Custer Country Federal Number ID 181 State Number D34-2225, Phase I Inspection Report National Dam Safety Program*, September 1978.

of flooding to go from 1000-year flooding being a problem to 25-year or 50-year flooding that would be considered an “anticipated” event.

The 25-year to 50-year flooding that could fail the Mackay Dam, as estimated in 2021 McMillen Jacobs Appendix A, is far higher than the study performed for the Department of Energy in 1986 by Koslow and Van Haaften from 1000-year flooding event.

Failure of the Mackay Dam may claim the lives of perhaps 600 citizens living downstream of the Mackay Dam. And failure of the Mackay Dam poses the additional threat of a radiological release, subsequent unsafe conditions, and of very high costs of addressing radiological releases and of nuclear facility damage involving the Idaho National Laboratory.

I was unable to find any record of an Unreviewed Safety Question for its nuclear facilities being issued in its Occurrence Reports. The Defense Nuclear Facilities Safety Board has written in its June 2022 monthly report at DNFSB.org that stated “Two [DNFSB] staff members participated in a formal interaction with the Department of Energy (DOE) for the ongoing *Potential Flooding Impacts to INL Idaho Clean-up Project (ICP) Facilities* review.”

The Idaho National Laboratory had representative(s) in attendance of at least one meeting of the 2021 McMillen Jacobs studies.

The Certificate for the Mackay Dam expires December 31, 2023 – a little over one year away. The problem is winter months are not conducive to placing the dam in safe status. The dam will remain a hazard as long as it is able to restrict the flow of water, which fills the reservoir.

The IDWR has the problem of having appropriately denied dam capacity increases, and then having the denial overturned in court in the 1956 and by the Idaho Supreme court in 1957. [23] This means the storage of water in the reservoir was increased by raising the height of the spillway entrance even though it was not found to be safe by the State Reclamation Engineer and the spillway capacity was found inadequate in 1951 by the federal engineers at the Department of Interior, Bureau of Reclamation. The Idaho courts ruled against the engineer’s opinion. This was likely due at least in part to a lack of understanding that flooding inflows to a reservoir can sometimes far exceed the typical flows. And a dam that empties each year may seem quite adequate yet still be vulnerable during winter/spring runoff.

Prior to the June comment submittal, I had reviewed only the McMillen Jacob 2021 report Appendix F to review the failure modes for the dam. When I returned to study Appendix A, the Conceptual Report for Mackay Dam “rehabilitation,” I found that Appendix A has identified further assessment of the failure modes and had greatly reduced the estimated release spillway capability of the Mackay Dam. **The 2021 Appendix A McMillen Jacobs report found that far**

[23] State of Idaho, Department of Water Resources for U.S. Army Engineer District, Walla Walla, Corps of Engineers, *Big Lost River Basin Mackay Dam Custer Country Federal Number ID 181 State Number D34-2225, Phase I Inspection Report National Dam Safety Program*, September 1978.

smaller flows on the spillway (500 cfs) would be expected to fail the spillway and would subsequently fail the dam.

Nothing was publicly stated of this stunning development by the IDWR or by the Department of Energy. And so far, no action has been taken either by IDWR or by the Department of Energy with regard to addressing the increased risk of serious flooding events at the Idaho National Laboratory. See the EDI Power-point presentation on the Mackay Dam on the EDI website.

Idaho Department of Water Resources Rulemaking for Water Dams and Tailings Dams Continues With Inexplicable Safety Reductions

The rulemaking for the modification of the "Safety of Dams Rules" and the "Mine Tailings Impoundment Structures Rules" held another meeting August 19. Comments on the last round of proposed changes are due August 26. The May 4, 2022 Idaho Administrative Bulletin identified rulemaking for the Idaho Department of Water Resources and announced a May 27 meeting. [24]

The draft rule can be found at https://idwr.idaho.gov/wp-content/uploads/sites/2/legal/rule-37-03-05/rule-37-03-05-and-rule-37-03-06-202205223-strawman-v1.0.pdf (or link). The existing rules can be found at https://adminrules.idaho.gov/rules/current/37/ . The dam safety rulemaking webpage is located at this https://idwr.idaho.gov/legal-actions/rules/idwr-rulemaking-2022-2023/mine-tailings-impoundment-structure-safety-of-dams-rules/ .

The Idaho Department of Water Resources (IDWR) retreated from its proposed changes last June that would have combined the "Safety of Dams Rules" and the "Mine Tailings Impoundment Structures Rules." The rules will remain separate rules, for now at least.

The biggest surprise was the decision to make only minimal changes to the Mine Tailings rules. The IDWR made mining industry favorable relaxation of the previous 2-year interval for recertification to what could now be 5 years, depending on how often the agency performs its inspections. The inspection frequency will be determined by the hazard level assigned by the IDWR based on unspecified criteria.

Also mining industry favorable, the previous 2-year bonding period is extended to match the unspecified inspection frequency. Inspections must be carried out at least every 5 years, so effectively, the change gave an extension of the bonding period.

It should also be noted that the bonding levels are based on ideal closure conditions and do not address the cost to remediate an accident. Those costs would be born by citizens or State or Federal agencies.

[24] The May 4, 2022, Idaho Administrative Rules Bulletin, Volume 22-5, available in May 2022 at https://adminrules/idaho.gov/bulletin/2022/05.pdf

The Mine Tailings rule excluded all changes developed by the agency this June that had addressed out-of-date seismic design criteria essentially giving a free pass to any existing tailings dam or new dam in the western half of the state.

The current and now-proposed rules will retain the outdated seismic zones and won't require seismic analyses for structures west of the "Range 22E., Boise Meridian" or roughly, west of the 114th meridian or a line drawn south of Salmon, Idaho. While the proposed rule in June would have required all tailings dams to meet the maximum credible earthquake loading (a roughly 1-in-10,000-year return interval), there is no such requirement now. For structures east of the line delineated for Zone 3, the recurrence interval has not been specified. The seismic loads would decrease as the return interval is decreased to 1-in-2500 years or less.

Associated mine tailings dams will, however, be able to use the relaxed release capability requirements in the proposed "Safety of Dams Rules."

Two very important design criteria for dams and Mine Tailings Impoundment Structures (MTISs) are for water release capacity and seismic capacity. Despite long known increasing risk of severe weather events due to climate change, the IDWR has proposed reducing the size of design probable flooding inflows to consider for selection of the design criteria for flooding inflows.

This is despite recent flooding in the neighboring state of Montana, which this June exceeded 1-in-500-year flood levels due to unexpected heavy snow followed by heavy rain this spring, despite a dry winter. [25]

By 2017 it had been recognized by professionals that climate change increases the risk of severe weather and flooding and the risk of failure of MTISs. [26] Western states can expect storms that produce more frequent and stronger precipitation extremes even while the frequency of light and moderate precipitation decreases, according to a recent report by Thomas W. Corringham and others. [27] [28] [29] This rulemaking by the IDWR ignores this reality as they propose reducing design requirements for dam release capability from outlet works and spillways for all but the least hazard, smallest size dams and as they continue to allow the Director to accept dam release capabilities even below the stated inflow design flood levels.

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[25] Associated Press, *The Idaho Falls Post Register*, "High and Fast – How heavy snow, rain flooded Yellowstone," June 19, 2022.

[26] Roche, C. Thygesen, K., Baker, E. (Eds.) *Mine Tailings Storage: Safety Is No Accident*. A UNEP Rapid Response Assessment. United Nations Environmental Programme and GRID-Arendall, Nairobi and Arendal, www.grida.no. 2017. ISBN: 978-82-7701-170-7

[27] Corringham, T.W., McCarthy, J., Shulgina, T. *et al.* "Climate change contributions to future atmospheric river flood damages in the western United States," *Sci Rep* **12,** 13747 (2022). https://doi.org/10.1038/s41598-022-15474-2

[28] Matthew Cappucci, *The Washington Post*, "A 'megaflood' in California could drop 100 inches of rain, scientists warn – It hasn't happened since 1862, but California is due for another one," August 12, 2022.

[29] Zach Rosenthal, Mary Beth Gahan and Annabelle Tinsit, *The Washington Post*, "At least one dead after Dallas area hit by 1-in-1000-year flood," August 22,2022.

The problem of deteriorating dams is not even addressed by IDWR's rulemaking, [30] [31] **and the issue of never-ending compliance periods for correcting problems is only made worse in the proposed changes.**

The U.S. Geological Survey has continued to find higher seismic hazard levels in many states including Idaho. The proposed "Mine Tailings Impoundment Rules" provided no updating of its inadequate seismic analysis requirements. And the proposed rules for seismic criteria were not updated in the "Safety of Dams Rules" to clearly and appropriately assure stringent requirements.

For background, in Table 6 below, I present the relationship of certain probabilities of exceedance to earthquake return interval or return period. Note that the seismic event is more severe and the loading of the structure more challenging for the 2 percent in 50-year probability of exceedance, than the 10 percent in 50-year probability of exceedance. And the "maximum credible earthquake" is the most severe earthquake considered, with the highest loading of the structure.

Table 6. United States Geological Survey Seismic Probabilistic Maps.

Probability of Exceedance	Earthquake Return Period	Severity of Earthquake
10 percent in 50 years	500-year	Lower peak ground acceleration, lower on Modified Mercalli Intensity (MMI) Scale
5 percent in 50 years	1000-year	More severe earthquake than the 500-year earthquake
2 percent in 50 years	2500-year (or 2475-yr)	More severe earthquake than the 1000-year earthquake
Maximum Credible Earthquake (no stated probability of exceedance)	(Sometimes considered 10,000-year return interval, although may not be estimated.)	Highest peak ground acceleration, highest on MMI Scale

Table notes: Probability of exceedance relates to return interval. For example, 1/50 year * 0.1 = 1/500 years, where 0.1 is 10 percent divided by 100.

For the dam classification from the Canada Dam Association, when failure of a dam would take over 100 lives, the design criteria for the dam would be to use the maximum credible earthquake. [32]

[30] Maya Wei-Haas, National Geographic, "The problem America has neglected for too long: deteriorating dams," May 27, 2020. https://www.nationalgeographic.com/science/article/problem-america-neglected-too-long-deteriorating-dams

[31] David A. Lieb, Michael Casey and Michelle Minkoff, AP, "At least 1,680 dams across the US pose potential risk," November 11, 2019. https://apnews.com/article/ne-state-wire-us-news-ap-top-news-sc-state-wire-dams-f5f09a300d394900a1a88362238dbf77

[32] Marc E. Orman, P.E., G.E., et al., Amec Foster Wheeler, Tailings Dam Classification and Breach Analyses, Perspectives from the Canadian Dam Association, Presentation, 2017.

For the “Safety of Dams Rules,” the rules require the use of the maximum credible earthquake for large dams and all high hazard dams. However, new embankments allow using the 2500-year return interval rather than the more stringent maximum credible earthquake.

An example of peak ground accelerations for a variety of earthquake return intervals, see Table 7. The earthquake return period of 10,000 years (the “maximum credible earthquake”) yields higher spectral accelerations than the smaller return period of 5000 years or the even small return period of 2475 years. The maximum ground motion/acceleration generated by the maximum credible earthquake are also larger than the maximum ground motion/accelerations generated by earthquakes of smaller return periods.

The table includes the spectral accelerations for 0.2 second, 0.3 second and 1.0 second periods, with 5 percent damping. Embankment structures would typically respond with the 1 second period.

Table 7. Example of Earthquake Accelerations (2021 McMillen Jacobs, Appendix F).

Probability of Exceedance in 50 Years	Return Period (years)	Peak Ground Acceleration (g)	0.2 Second Spectral Acceleration (g) for 5% damping	0.3 Second Spectral Acceleration (g) for 5% damping	1.0 Second Spectral Acceleration (g) for 5% damping
0.5%	10,000	0.674	1.614	1.317	0.472
1%	5,000	0.492	1.170	0.956	0.331
2%	2475	0.346	0.812	0.659	0.223

In the proposed changes in June, all existing dams of all sizes and hazard classifications were to use the maximum credible earthquake for the seismic design criteria but only if the Director specifically requires the analyses. In the August proposed changes, this was changed to include use of the maximum credible earthquake for only high hazard dams. This leaves out large dams of significant or low hazard and leaves out all significant hazard dams.

The IDWR has long practiced the policy of “don’t ask – don’t tell” with regard to the release capability of dams. This unsafe practice has been doubled-down-on in the proposed rules.

Even for existing dams, the current rules had specifically required analyses, for large sized dams of significant hazard and of high hazard, for release capability. This is no longer required by the proposed rules.

And even for existing dams, the current rules had specifically required analyses, for large, high hazard dams to provide seismic analysis using the maximum credible earthquake. But this will only be required of existing dams if the Director specifically requires the analyses.

The proposed rules for release capability of dams greatly reduces, in many cases, the release capability that should be selected for design of a dam. This is coupled with the longstanding practice of not evaluating the actual release capability of an existing structure.

In the proposed rules for "Safety of Dams Rules," improvements were made to the criteria for hazard classification. But there remains ambiguity about what category a structure would be classified as.

Witnessing the gyrations in the rule changes proposed by the IDWR, the relaxing of requirements, and the refusal to provide a candid and comprehensive discussion of the changes and the rationale for the changes has been illuminating. **It all makes sense and only makes sense when you consider the money flowing from the mining industry into Idaho political campaigns and when you understand that by Idaho Statute, Title 42-1717, no legal action can be brought against the state or the IDWR for failure of dams or tailings dams, due to the IDWR's failure to issue or enforce effective rules.**

The IDWR plans to submit the completed proposed rules to their Board in September and then place proposed rules in the October state bulletin. October 19 will be the last day to request another public meeting and written comments on the proposed rule version placed in the Idaho Administrative Bulletin will be due October 26. The rules would then be published as pending rules in December. The Idaho Legislature can nix, line by line, any rule they don't like.

Read my comment submittal for the recently proposed August 2022 rule changes on the Environmental Defense Institute home page at Environmental-Defense-Institute.org.

Articles by Tami Thatcher for September 2022. Photos are from the Idaho Department of Water Resources collection. Editorial corrections and corrections for clarity were made September 3, primarily on page 8.