Union of Concerned Scientists

Dam Failures and Flooding at U.S. Nuclear Plants

A Possible U.S. Fukushima

Nuclear reactors are built next to rivers, lakes, and oceans because they require vast quantities of cooling water. Many U.S. nuclear plants along a river have one or more dams located upstream. If a dam fails, the ensuing flood waters could overwhelm the plant's protective barriers and disable important safety equipment, causing an accident that could release a large amount of radiation, just as it did in the accident at Fukushima, Japan in March 2011. In that case the flooding was caused by a tsunami rather than a broken dam, but the result could be similar.

The risk of such a nuclear accident is appears to be greater than previously thought. A July 2011 report by Nuclear Regulatory Commission (NRC) staff states that its analysis "suggests that external flooding due to upstream dam failure poses a larger than expected risk to plants and public safety" and that the probability and consequence of those events require NRC attention.

In particular, that report states that 34 reactors—one-third of the U.S. nuclear fleet—may face flooding hazards greater than they are designed to withstand, as a result of the failure of upstream dams (see list below). The NRC has known about some of these problems for 15 years and has not effectively addressed them.

Flooding Risks

The U.S. nuclear power industry and the NRC have repeatedly said "Fukushima can't happen here." Yet in an NRC memo written five days after the Fukushima accident, an NRC staffer drew the parallel between a flood at the Oconee Nuclear Station in South Carolina and the tsunami at Fukushima, saying:

> "Although the scope of such a disaster might be more limited at Oconee than in Japan—that is, the Japanese have other problems on their hands than a nuclear crisis, which is slowing them down to a degree—the Oconee disaster would be no less severe on the units. Everything on site would be destroyed or useless."

The flooding at Fukushima resulted in the meltdown of three reactor cores and the release of radiation that led to the evacuation of 100,000 citizens. According to FEMA, 90,688 people lived within 10 miles of Oconee at the time of the 2000 census.

34 reactors may face flooding hazards greater than they are designed to withstand, due to dam failures.

The potential higher-than-assumed flooding risk from upstream dam failures at 34 reactors was recognized in part because of updated flooding analyses of Oconee and Fort Calhoun Station in Nebraska that went beyond studies typically done for reactors. Based on those studies, the July 2011 NRC staff report concludes the NRC should systematically investigate these other sites using more detailed analysis and more accurate data than past studies.

In particular, the report found that past analyses of flood levels at Oconee and Fort Calhoun were "based on relatively outdated flood estimation methods and/or probable precipitation estimates." In addition, it stated that new flood estimates should include better analyses of dam breakage that are available today, as well as changes in land-use since the plants were built, which can have a significant impact on local watersheds, and therefore on flooding. These considerations are likely to produce flooding estimates that are different than previous studies' estimates, including those used for reactor licensing and safety regulations.

In the case of Oconee, the NRC report notes that the licensing process did not consider the possible consequence of a failure of the nearby Jocassee Dam. This appears to be true for other plants as well.

However, a 1992 Duke Energy study looked at the consequences of a Jocassee dam failure. It found that flood waters would reach the Oconee plant within five hours after the failure and would exceed the plant's protection, leading to a station blackout—the loss of all

external and internal power. Duke's study found that "core damage occurs in about 8 to 9 hours following the dam break and containment failure in 59 to 68 hours," and that "significant [radioactivity] dose to the public would result." Because Oconee has three reactors, each of which is larger than those damaged at Fukushima, the amount of radiation released to the environment could be on the scale of the Fukushima accident.

The NRC has generally known about this situation since at least 1996 from reports it received from Duke Energy,[1] but has not required safety enhancements.

Similarly, a recent detailed NRC study of the Fort Calhoun reactors has questioned whether past flood estimates, which are the basis of safety requirements, are accurate. The July 2011 report states that:

> "Fort Calhoun Station may not have been protected from flooding even without consideration of upstream dam failure. An upstream dam failure further exacerbates this condition."

The report points out that flood response at Fort Calhoun and some other plants requires active measures by plant personnel, including erecting temporary barriers such as sand bags, and that such measures may not be successful. This situation is exacerbated by the fact that flooding from dam failures differs from floods that plants are required to consider (from excessive rainfall, snowmelt, etc.) in part because a catastrophic dam failure could result in a much more sudden flood, limiting the time for preparatory measures like building temporary barriers.

The report also notes that other safety features may not be effective since "at most nuclear power plants, flood protection dikes, levees, doors, and other features have not been tested against a flood," so that their reliability under those conditions is unknown.

How Likely is a Dam Failure?

A 2009 NRC letter states that "a Jocassee Dam failure is a credible event" and that "NRC staff expressed concerns that Duke has not demonstrated that the Oconee Nuclear Station units will be adequately protected."[2]

The July 2011 NRC report notes that "dam failure incidents are common," and that over 700 have occurred in the United States since 1975. Of these, 148 failures were of large dams, with heights of 40 feet or more.

Oconee Nuclear Station and Jocassee Dam

NRC staff has estimated the odds that dams constructed like Jocassee will fail is 2.8×10^{-4} per year, or about 1 in 3,600 chance of failure per year.[3] Oconee is licensed to operate for another 20 years. The odds of the Jocassee Dam failing over that period are 1 in 180. Those may sound like good odds. However, the NRC requires risks of various kinds to be addressed if they have a frequency of more than 1 in 10,000 years. That means for a reactor operating 40 years, these risks must be addressed if they have greater than a 1 in 250 chance of occurring.

If Oconee's life is extended for an additional 20 years (i.e., allowed to operate for a total of 80 years, as the NRC is currently considering), the chance of a dam failure over its remaining lifetime increases to 1 in 90.

The 34 reactors of concern are downstream from a total of more than 50 dams, more than half of which are roughly the size of the Jocassee dam. Assuming the NRC's failure rate applies to all of those dams, the probability that one will fail in the next 40 years is roughly 25 percent—a 1 in 4 chance.

Even if this assumption is not correct, this estimate shows that the cumulative probability of a dam failure may be great enough that the NRC should prioritize understanding and addressing the risk.

Moreover, these dam failure rates do not include the risks posed by earthquakes or terrorism. As a result, the actual

probability could be higher than that given above.

The NRC report notes that NRC safety regulations related to dam failures focus heavily on failures from earthquakes, but that historically earthquakes account for less than 10 to 20 percent of dam failures. The report therefore questions "whether the regulatory guidance forming the licensing basis of most existing nuclear power plants comprehensively addressed the statistically most common dam failure modes." The NRC must reconsider this issue.

The NRC's Responsibility?

To resolve this safety issue, the NRC must require plants to address known flooding hazards, and thoroughly investigate other plants that may be at risk and require them to resolve any hazards that are discovered. The Oconee and Fort Calhoun vulnerabilities were not apparent until after detailed investigations at the plants. The information needed for such investigations goes beyond what the NRC typically has for plants. Such an investigation should be tasked to acquire and use the necessary additional information.

However, the NRC's record on this issue is not encouraging. It knew about flooding hazards at Oconee since at least 1996 but did not take steps to address the situation for many years. (Duke Energy has reportedly begun to modify the Oconee plant to address consequences of a potential failure of Jocassee Dam, but completion of those modifications has reportedly slipped from 2013 to 2017.)

Moreover, the NRC's reaction to its staff's July 2011 study that warned of potential flooding risks was to black out sections of the report before releasing it publicly. The lead author of that report wrote to the NRC's Inspector General arguing that the information the NRC blacked out was related to reactor safety rather than security concerns—a charge supported by the fact that the Department of Homeland Security did not require any deletions before making the report public. He stated in his letter:

> "The Nuclear Regulatory Commission staff may be motivated to prevent the disclosure of this safety information to the public because it will embarrass the agency. The redacted information includes discussion of, and excerpts from, NRC official agency records that show the NRC has been in possession of relevant, notable, and derogatory safety information for an extended period but failed to properly act on it. Concurrently, the NRC concealed the information from the public."

Tokyo Electric Power Company (TEPCO), which owns the Fukushima plant, and Japan's nuclear power regulatory agency have been heavily criticized following the accident for not aggressively reevaluating safety precautions after obtaining evidence prior to the accident of tsunami threats greater than the plant was designed to withstand..

The NRC knows—and has known—about a similar hazard facing U.S. nuclear plants: flooding from upstream dam failures that can disable the emergency equipment needed to prevent reactor core meltdown. The NRC must aggressively address this issue to determine whether or not dam failures pose credible threats. If so, the NRC must compel plants to take the necessary protective measures to manage the risks. If not, the NRC should document its conclusions and have them peer-reviewed by the agency's Advisory Committee on Reactor Safeguards.

List of Reactors Potentially at High Risk of Flooding due to Dam Failure

Alabama:	Browns Ferry, Units 1, 2, 3
Arkansas:	Arkansas Nuclear, Units 1, 2
Louisiana:	Waterford, Unit 3
Minnesota:	Prairie Island, Units 1, 2
Nebraska:	Cooper
	Fort Calhoun
New Jersey:	Hope Creek, Unit 1
	Salem, Units 1, 2
New York:	Indian Point, Units 2, 3
North Carolina:	McGuire, Units 1, 2
Pennsylvania:	Beaver Valley, Units 1, 2
	Peach Bottom, Units 2, 3
	Three Mile Island, Unit 1
Tennessee:	Sequoyah, Unit 1
	Watts Bar, Unit 1
Texas:	South Texas, Units 1, 2
South Carolina:	H.B. Robinson, Unit 2
	Oconee, Units 1, 2, 3
Vermont:	Vermont Yankee
Virginia:	Surrey, Units 1, 2
Washington:	Columbia

(Source: Perkins, et al., "Screening Analysis," July 2011)

Related Links:

Cascadia Times, "Redacted NRC Report Says 35 Nuclear Power Plants in U.S. Threatened by Potential Upstream Dam Failures, Including One at Hanford," March 6, 2012.

Tom Zeller, Jr., *Huffington Post*, "Flood Threat to Nuclear Plants Covered Up by Regulators, NRC Whistleblower Claims," Sept. 14, 2012.

Tom Zeller, Jr., *Huffington Post*, "Leaked Report Suggests Long-Known Flood Threat To Nuclear Plants, Safety Advocates Say," Oct. 19, 2012.

Richard Perkins, et al., "Screening Analysis Report for the Proposed Generic Issue on Flooding of Nuclear Power Plant Sites Following Upstream Dam Failures," (redacted version), July 2011.

Richard Perkins, et al., "Screening Analysis Report for the Proposed Generic Issue on Flooding of Nuclear Power Plant Sites Following Upstream Dam Failures," (unredacted version), July 2011.

Perkins letter to NRC Inspector General, Sept. 14, 2012.

Dave Lochbaum, allthingsnuclear.org, "Is NRC Hiding an American Fukushima?" Sept. 19, 2012.

Notes:

[1] Duke Power Company, "Oconee Nuclear Station IPEEE Submittal Report," Dec. 21, 1995.
[2] References in the July 2011 report say that the 2009 letter is not publicly available; the quote here is taken from the unredacted version of the July 2011 NRC report.
[3] Duke Energy in its analysis uses a failure rate that is 20 times smaller. However, Duke's rate does not include overtopping, which is a major contributor to dam failures: http://www.damsafety.org/news/?p=e4cda171-b510-4a91-aa30-067140346bb2.

The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world.

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

National Headquarters
Two Brattle Square
Cambridge, MA 02238-9105
Phone: (617) 547-5552
Fax: (617) 864-9405

Washington, DC, Office
1825 K St. NW, Suite 800
Washington, DC 20006-1232
Phone: (202) 223-6133
Fax: (202) 223-6162

October 2012