Statement of
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United States Senate

Oversight Hearing
NRC's Implementation of the Fukushima Near-Term Task Force Recommendations and Other Actions to Maintain and Enhance Nuclear Safety

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Chairman Boxer, Ranking Member Vitter, and Members of the Committee,

Thank you for your invitation to appear before you today to address this critical matter.

The disaster at the Fukushima Daiichi reactors in 2011 had many causes, but at its core were two fundamental and inter-connected problems: a nuclear plant allowed to be designed, licensed, and constructed to only withstand an earthquake and tsunami far smaller than actually occurred; and a too-cozy relationship between the nuclear utility and its regulator that allowed weak safety requirements in the first place.

These problems plague the American nuclear regulatory system as well. My testimony will focus on an examination of one case study – Diablo Canyon – that suggests the Fukushima lessons have not been learned here. This is particularly important in light of the extraordinary and disturbing new seismic discoveries near the site and the inadequate response to them by the Nuclear Regulatory Commission. Unless the underlying dysfunctional nature of nuclear regulation in this country rapidly undergoes sweeping reform, a Fukushima-type disaster, or worse, may occur here, perhaps on the Central California coast.

The late environmentalist David Brower once defined a nuclear reactor as a complex technological device for locating earthquake faults in California. It seems that wherever a reactor was planned or built, earthquake faults were subsequently found, greater than the plant had been designed to withstand.

Arguably, Brower's definition applies nowhere better than Diablo Canyon. When Diablo was designed and granted its Construction Permit, PG&E and the Commission *asserted there were no active faults within thirty kilometers of the plant.* **We now know there are at least four.**

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Each time there was a new, belated seismic discovery at Diablo, the Commission gave PG&E a pass. Rules were relaxed, safety margins reduced, public hearings denied. The most recent revelations of increased seismic risk have met the same fate to date.

When the Hosgri Fault was revealed shortly after the construction permit had been granted, NRC waived the normal requirements of the license and granted an exception for the Hosgri. It did so assuring the public that the Hosgri was not connected to the nearby San Simeon Fault and that it was essentially impossible that there were any other nearby active faults waiting to be discovered.

A few years later, however, the San Luis Bay and Los Osos faults were found to be active nearby. And in 2008, USGS discovered the Shoreline Fault, coming within 600 meters of the plant. Faced with these embarrassing revelations, NRC and PG&E nonetheless asserted that these new faults were well within the license requirements.

However, the NRC's own senior resident inspector at Diablo, Dr. Michael Peck, soon discovered from PG&E's own estimates that the ground motion from those three new faults would exceed the ground motion permitted under the license. Rather than upgrade the plant, PG&E, at NRC urging, submitted a license amendment request to remove the license conditions they were violating. But the request failed to conform to NRC requirements in scores of instances, and was rejected from consideration. Rather than now require the plant to meet the license, however, NRC allowed it to keep operating in violation of the central seismic requirements.

Dr. Peck took the extraordinary step of submitting a Dissenting Professional Opinion, saying the plant should be shut down until it can demonstrate compliance with the license. After sitting on the DPO for a year, and only after the Associated Press had made its existence public, on September 10 of this year NRC issued its rejection. The DPO denial was neither unexpected nor persuasive.

But here is where the story gets most troubling, with developments essentially not reported to the public until today. On the very same day NRC issued to the news media its DPO denial, PG&E released its long-awaited new seismic study that had been required by the state. To no surprise, it received virtually no coverage, lost in the attention given to the NRC action.

Nonetheless, it is a stunning document. Buried in its more than 1800 pages are the following extraordinary findings:

- Despite longstanding claims that the Hosgri Fault is only 110 kilometers long and not connected to the San Simeon Fault, it is in fact connected, and a joint rupture is therefore possible; and the true length is at least 171 kilometers.
- The Shoreline Fault, which wasn't even known to exist a few years ago, is twice as long as previously thought.
- The Shoreline Fault also connects to the Hosgri, making possible a huge earthquake on both, coming within 600 meters of the plant.

- Despite the repeated claims by PG&E and NRC that the Hosgri Fault is the largest threat to Diablo, the new report estimates ground motions from the Shoreline and San Luis Bay Faults, and the San Simeon-Hosgri and Shoreline-Hosgri connected faults, all in excess of what would now be estimated for the Hosgri Fault alone.
- All of these are estimated to produce ground motion in excess of the Double Design Earthquake requirements in the license that apply to all faults except the Hosgri single fault.

It is *déjà vu* all over again. The PG&E and NRC response has been an almost exact repeat of the pattern evidenced from the beginning of the plant: discoveries of new seismic threats that had been claimed couldn't be possible; responding by sharpening pencils, to try to allow the plant to continue in the face of the new discoveries by removing the last remaining vestiges of conservatism in assumptions and reducing safety margins thereby; and avoiding public hearings where the discoveries and response thereto would be subject to serious scrutiny.

In this case, although the faults are longer, larger, more connected, and closer than previously assumed, PG&E and NRC have remarkably claimed that the seismic challenge to the plant would be lower. They have done so by applying dramatically weakened input assumptions, not allowed under the license and not subject to scrutiny in an evidentiary license hearing.

When the first nearby fault that wasn't supposed to be there was discovered, the Hosgri, the NRC gave PG&E an exception from the seismic conditions of its license that applied to all other faults. When the second, third, and now fourth active faults were discovered, after assurances they couldn't be there, the NRC has again in effect given further exceptions. And it has done so without license amendments and the right to a public hearing that the Atomic Energy Act requires.

As we have seen in the recent San Onofre matter, this pattern is endemic. The resistance to allowing adjudicatory hearings that would permit enhanced independent scrutiny and instead relying on backroom deals between the regulator and the regulated entity result in technically deficient safety decisions. In the Diablo case, the decisions have turned out to be erroneous, over and over again. And yet the pattern is repeated, over and over again. How many times do they get to be wrong before something changes?

If this dysfunctional regulatory system were responsible for relatively minor matters like, say, siting fast-food restaurants, the potential consequences would be marginal. But there are a thousand times the long-lived radioactivity of the Hiroshima bomb in each Diablo reactor, and approximately ten times that in its irradiated fuel pools. An earthquake larger than the plant is capable of withstanding can disrupt the essential cooling, causing massive release of radioactivity.

Unless we fix these problems—of regulated entities pressing for exceptions to and weakening of safety requirements and of regulators viewing themselves more as advocates for and allies of the industry they are to regulate rather than primarily protectors of public safety—we will not have learned the lessons of Fukushima. And a Fukushima-type disaster is just

waiting to occur here. All it takes is an earthquake larger than a plant like Diablo is capable of withstanding. It could happen tomorrow.

I explore these matters in more detail in what follows.

The Fukushima Lessons

The Japanese Diet passed legislation in October 2011 establishing the Fukushima Nuclear Accident Investigation Commission. The Fukushima Commission found:

> The direct causes of the accident were all foreseeable prior to March 11, 2011. But the Fukushima Daiichi Nuclear Power Plant was incapable of withstanding the earthquake and tsunami that hit on that day. The operator (TEPCO), the regulatory bodies (NISA and NSC) and the government body promoting the nuclear power industry (METI), all failed to correctly develop the most basic safety requirements....

The Fukushima Commission found that the accident was clearly "manmade" and preventable:

> The TEPCO Fukushima Nuclear Power Plant accident was the result of collusion between the government, the regulators and TEPCO, and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. Therefore, we conclude that the accident was clearly "manmade." We believe that the root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions, rather than issues relating to the competency of any specific individual.

They concluded that "The underlying issue is the social structure that results in 'regulatory capture,'" and that industry had "manipulated the cozy relationship with the regulators to take the teeth out of regulations." The nuclear industry must change, they said, and:

> The Commission has concluded that the safety of nuclear energy in Japan and the public cannot be assured unless the regulators go through an essential transformation process. The entire organization needs to be transformed, not as a formality but in a substantial way.

One could just as correctly make these diagnoses and prescriptions about the troubled U.S. nuclear power enterprise. These Fukushima "lessons learned" apply directly here as well. After all, the Fukushima accident involved American-designed reactors and a regulatory structure markedly similar to ours. The two fundamental problems at the heart of the Fukushima tragedy plague the American system as well: regulatory capture, resulting in weak regulations and enforcement, and the concomitant regulatory fiction of allowing reactors to be designed to only withstand challenges far less severe than they could actually face. We do not appear to have learned those lessons or in any serious way taken steps to repair the broken nuclear regulatory process here so as to avoid a Fukushima or worse occurring in this country.

Diablo Canyon as Case Study: A Potential Fukushima on the California Coast?

In my testimony today I will examine one case study, that of the Diablo Canyon Nuclear Plant in California.[2] The similarity of the Diablo history to the institutional problems that led to Fukushima are striking.

Each of the two Diablo reactors contains, when operating, about fifteen billion curies of radioactivity. To put that in perspective, we generally measure "permissible" concentrations of radioactivity in the environment in pico-curies, millionths of a millionth of a curie.[i] All told, many Chernobyls-worth of long-lived radioactivity reside at Diablo Canyon, in the heart of a seismically active region.

If a significant portion of that radioactivity were to be released to the environment, widespread damage could result--at high doses, close in, prompt death if there hasn't been effective and timely evacuation; at lesser doses, over wide areas, significantly increased rates of cancer and leukemia. Land can be contaminated for long periods of time, forcing relocation of people and cessation of activities such as agriculture. A major release of radioactivity in central California could be devastating.

The radioactivity only stays inside the fuel so long as it is continuously cooled. An atomic reactor is an extraordinary device. It cannot be turned off completely. Even after being "scrammed" (control rods inserted to stop the fissioning), a substantial amount of heat (initially about 7% of the amount when running) is still generated by decay of the fission products. Thus the fuel can, for weeks or months after the reactor is scrammed, melt and release its radioactivity if cooling is lost. An earthquake can trigger such a loss of cooling—e.g., by disrupting offsite power and onsite diesel generators, and/or breaching pipes or damaging pumps needed to circulate the coolant-- as well as the failure of backup systems and mitigation features.

The "Design Basis" Fiction

One would think that reactors would be required to be designed and constructed to safely withstand the greatest challenge (earthquake, terrorism, etc.) they could face. One would be wrong.

From the earliest days of the industry to the present, reactors have only been required to deal with a "design basis" event, which is often far less severe than the maximum challenge they could in fact experience. For example, reactor containments are only required to be designed to withstand the pressure from a break in a main pipe, not the pressures that could be generated from a meltdown. To save money, for instance, Mark I Boiling Water Reactor containments had been allowed to be very small, with backup pressure-reducing systems that could be quickly overwhelmed in a real accident. At Fukushima, the Mark I containments, based on the General Electric design, indeed failed to prevent massive release of radioactivity. U.S. pressurized water reactors (PWRs) likewise are not required to be designed to withstand pressures resulting from events involving major core damage. Recommendations to establish Containment Performance Design Objectives that would improve the situation went nowhere.[ii]

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[2] The research assistance of Cristine Peterson and Dorah Shuey is gratefully acknowledged.

Similarly, the "design basis threat" (DBT) regulations for establishing security provisions at reactors against a terrorist attack long required only protecting against a maximum of three external attackers, on foot, acting as a single team. In the Diablo Canyon operating license proceeding in the 1980s, experts appearing on behalf of Governor Jerry Brown testified that the security plan should be able to protect against a group of at least twelve attackers. PG&E and NRC argued that it wasn't "credible" there would ever be a terrorist attack in this country involving that many people and the design basis threat of three was sufficient.[iii] Of course, on 9/11, there were nineteen attackers, in four separate teams, and they weren't on foot. But the NRC's design basis threat regulations have only been modestly upgraded since, and proposals to increase the DBT to meet a 9/11-level threat have been rejected by NRC.[iv]

For years, evacuation plans were not required for areas surrounding nuclear plants, and environmental reviews did not have to consider accidents involving major releases of radioactivity, because the NRC had declared that Class IX accidents (those involving major core damage) were, in that remarkable phrase used so often, "non-credible." Then major core damage occurred at Three Mile Island, and the Governor of Pennsylvania, on the advice of the NRC, recommended an evacuation of pregnant women and children. The NRC had to admit Class IX accidents could in fact happen and change some of its regulations accordingly, though this was done grudgingly and in a limited fashion.

As seen from the above examples, the nuclear industry and compliant regulators have frequently decided, short-sightedly one must conclude, that it is cheaper to declare by fiat that serious safety or security challenges to nuclear plants are "non-credible" and don't need to be protected against, than to require that the atomic facilities be designed up front to handle the threats that can indeed occur. Over and over again, reality has risen up and bitten industry and regulator on the heels; optimistic assumptions dissolve when the "non-credible" ends up happening.

The Seismic Design Basis Fiction

For earthquakes, the design basis has been two-fold: a "Design Earthquake" or DE (now called the Operating Basis Earthquake, or OBE) and a "Double Design Earthquake" or DDE (now called the Safe Shutdown Earthquake). The first earthquake is the one that the reactor should be designed to be able to ride out without needing to shut down. The second, more serious earthquake is one in the face of which the reactor should be capable of safely shutting down and maintaining cooling and other safety functions thereafter. Despite definitions that indicate the safe shutdown earthquake is the maximum one deemed possible at the site, in practice, industry has pressed for and NRC granted approval for reactors to be designed to only withstand earthquakes and similar natural hazards such as tsunamis and floods far smaller than could indeed occur.

That is what happened at Fukushima. TEPCO and its regulators engaged in a regulatory fiction, establishing the design basis earthquakes (and ensuing tsunami) as considerably less than what turned out to be possible. It is expensive to design against these large challenges. The company instead pressed for, and the regulator acquiesced to, requiring the facility to be designed to a fictional earthquake and tsunami that were far less severe than could actually occur. It was this cutting of corners, in terms of safety, that produced the disaster at Fukushima. Nature

did not go along with the regulatory fiction. It is a similar regulatory pattern that has been evidenced in the long, troubled history of Diablo Canyon and its seismic design.

Nuclear Reactors: Complex Technological Devices for Locating Earthquake Faults in California

As indicated earlier, the late environmentalist David Brower once defined a nuclear reactor as a complex technological device for locating earthquake faults in California. Over and over again, nuclear plants have been planned and/or constructed in the state, only to be followed by the discovery of major faults nearby. These belated seismic discoveries led to the closure of PG&E's Humboldt Bay plant and General Electric's Vallecitos reactor and the abandonment of plans by the LA Department of Water and Power for an atomic power plant at Corral Canyon in Malibu and by PG&E at Bodega Head. Discovery of additional seismic hazard at San Onofre contributed to Unit 1's premature shutdown and cast a cloud over operations of Units 2 and 3, resolved only with their permanent closure last year, albeit for different reasons. For our purposes, however, let us look briefly at the track record of PG&E and the Commission leading up to the Diablo situation.

When PG&E applied in the early 1960s for permission for a nuclear plant at Humboldt Bay, it asserted that the nearby Little Salmon fault was not active and its presence need not be taken into account in designing the plant. In the early 1970s, however, oil company geologists doing studies in the area discovered that the fault was indeed active. (As we shall see, this pattern repeated itself at about the same time with Diablo Canyon.) Rather than upgrade the plant to meet the newly acknowledged seismic threat, it was permanently closed.[v]

In the early 1960s, PG&E applied to construct a nuclear plant at Bodega Head, a bit north of San Francisco. PG&E asserted that there were no serious seismic risks, despite being quite close to the San Andreas Fault, and in particular, that the plant would not be located over an active fault. The firm proceeded to dig a massive hole for the reactor containment foundation, which became known as the "Hole in the Head." Pierre Saint-Armand, a geophysicist at the China Lake naval base volunteered to help the community group concerned about the planned reactor. One weekend, when the excavation was unguarded, he crawled down a ladder into and examined the Hole in the Head and found an earthquake fault exposed therein. In other words, there was a fault directly below where PG&E was planning to construct a nuclear plant.[vi] His revelation led to the abandonment of the plant, and, ironically, PG&E turning its attention southward to Diablo Canyon as a prospective site.

Thus, PG&E and the Nuclear Regulatory Commission had two strikes against them already leading into the Diablo Canyon matter: Humboldt Bay and Bodega Head. In both cases, PG&E had claimed to have done thorough seismic evaluations beforehand; in both cases, someone other than PG&E or the regulator had subsequently revealed active faults nearby or indeed, at Bodega, directly beneath where the plant was to go. Both had to be abandoned.

Diablo Canyon: Hearing Denied on Possible Nearby Faults

Arguably, Brower's definition applies nowhere better than Diablo Canyon. When Diablo was designed and it obtained its Construction Permit, PG&E and the Atomic Energy

Commission asserted there were *no* active faults within thirty kilometers of the plant.[vii] We now know there are at least four major active faults nearby.

During the proceeding over PG&E's construction permit application for Diablo Canyon Unit 2 in 1970, the local intervenor in the hearing, the Scenic Shoreline Preservation Conference, requested a half day to present evidence of potential previously unidentified faults. PG&E and the Atomic Energy Commission staff opposed allowing any such evidence to be heard. By a two to one vote, the Atomic Safety and Licensing Board (ASLB) ruled with PG&E and the AEC staff and refused the request. The third ASLB member, Dr. Tom Pigford, who was for many years Chair of Nuclear Engineering at the University of California, Berkeley, vigorously dissented, saying in essence, shouldn't we find out before we pour concrete whether there are nearby earthquake faults? His concerns were overridden, the evidence of additional faults was not considered, and the construction permit was granted.[viii]

The plant was thus permitted and designed based on the premise put forward by PG&E and the AEC staff that there were no active faults within thirty kilometers.[ix] The Design Earthquake/Operating Basis Earthquake was set at 0.2 g peak ground acceleration. The Double Design Earthquake/Safe Shutdown Earthquake was set at double the DE/OBE, or 0.4 g.

Hosgri Fault Belatedly Discovered

The Construction Permit for Diablo Unit 2 was issued in December 1970, predicated on no active faults anywhere in the vicinity. Shortly thereafter, in 1971, the discovery of a massive offshore fault, the Hosgri, by two Shell Oil geologists, Hoskins and Griffiths, was published. By the time PG&E acknowledged the existence of the fault and NRC began to consider the ramifications, several years passed and the plant was already 80% constructed. The Construction Permit proceedings were not reopened to address the new discovery, something NRC Commissioners Victor Gilinsky and Peter Bradford more than a decade later stated was a mistake:[x]

> No hearings were held when the Hosgri fault was discovered. The persistence of litigation over these issues to this day suggests that it would have been wise policy, as well as good law, to reopen the construction permit at that time.

The U.S. Geological Survey estimated the Hosgri was capable of a 7.5 magnitude earthquake. It was clear that such an earthquake could produce ground motion considerably in excess of that for which the plant was designed. The staff of the Nuclear Regulatory Commission (which had, by this time, been formed after Congress broke up the AEC due to concerns about the conflict of interest in both being a regulator and advocate of nuclear power) urged that senior management attempt to pressure USGS to back off its estimate.[xi] USGS remained adamant.

Rather than abandon the plant because of the failure to characterize adequately the nearby seismic situation prior to construction, or undertake subsequent very expensive upgrades, PG&E reanalyzed the design using far less conservative (i.e., less protective) assumptions and argued that the plant could go forward without significant upgrades. PG&E did this by carving out

significant conservatisms from the seismic analysis that had been performed when the plant was designed, markedly reducing safety margins.

Pencil Sharpening Rather Than Significant Plant Upgrade

The central issue is translating earthquake magnitude and distance into acceleration (essentially the severity of shaking) at the plant. USGS recommended relying on its Circular 672, which estimated 1.15g peak acceleration for a M7.5 earthquake.[xii] If Diablo had to be retrofitted to withstand 1.15g peak acceleration, it is unclear that the facility could be upgraded to meet that requirement; in any case, the cost would be very high. Instead, PG&E, with NRC support, sharpened pencils and, by use of at least four modifications to normal practice at the time, dramatically reduced—alas, only on paper—the presumed ground motion that the plant should have to be retrofitted to withstand.

First, the NRC staff and PG&E argued that rather than use actual peak acceleration, they should use "effective" acceleration, i.e., employ a far lower value. They proposed 0.75 g, instead of 1.15 g, a large reduction. The "effective" acceleration figure of 0.75 g appeared arbitrary even to the Atomic Safety and Licensing Appeal Board which stated, "It is not entirely clear how the anchor point acceleration of 0.75g ultimately settled upon for the basic response spectrum was actually obtained."[xiii] Nonetheless, the Appeal Board upheld this and all the other reductions.

So, the first step taken by NRC staff and PG&E was to reduce the peak acceleration dramatically by putting forward a far smaller "effective" acceleration. They then reduced it even further by assuming a less conservative damping factor than had been used in the seismic design basis for the plant during construction (i.e., the methodology used for the DE and DDE). This second modification further reduced estimated acceleration and safety margins.

Third, PG&E proposed, and NRC allowed, the use of average estimates of as-built strength for components instead of code-allowable strengths, as normally required. This further reduced safety margins.

And finally, and most controversially, PG&E and NRC proposed a new reduction factor, never used before in nuclear licensing, which they called the "tau effect." They argued that peak acceleration should be reduced not just by their far smaller estimate of "effective" acceleration, weakened further by a less conservative damping factor, and relaxed further by use of average as-built strengths rather than code-allowable, but on top of all those reductions, one should further reduce significantly the acceleration by what was widely viewed as an arbitrary never-before-used fudge factor they called "tau." Their analogy was that a large ship is tossed about in the sea less than a small one, and therefore the reactor structures should be assumed to react less to an earthquake than normal structures. The "tau" factor thus resulted in about a 20% further reduction in presumed acceleration, on top of all of the other reductions.[xiv]

When added together, these cumulative relaxations of normal procedures for estimating ground motion from a large earthquake resulted in the new, far larger challenge to Diablo from the Hosgri Fault being estimated to produce little more acceleration than the far smaller quakes for which the plant was originally designed. For some frequencies of interest, indeed, the

estimated acceleration from the lesser quakes was in fact greater than that now estimated for the far more dangerous Hosgri event, because of the use of so many new non-conservative assumptions for the Hosgri analysis. As NRC Commissioners Victor Gilinksy and Peter Bradford noted in their opinion on the matter:[xv]

> With the changes and adjustments permitted by the [Atomic Safety and Licensing Appeal] Board it turns out that the post-Hosgri seismic response spectrum does not in all respects represent a more severe seismic standard than the one used before the discovery of the Hosgri fault. As the accompanying diagram illustrates, in the frequency range between 5 and 10 hertz (cycles per second), a range of particular interest in the analysis of the containment building surrounding the reactor, the two response spectra are quite close. [footnote omitted] For part of this range, in fact, the old spectrum shows a higher response. In other words, for that part of the range the original design conditions were more demanding than the new ones imposed after the discovery of the Hosgri fault. This new spectrum is the basis of the engineering reanalysis and ultimately determined the extent to which the containment was to be modified. Not surprisingly, in view of the above, only minor changes were required in this area.
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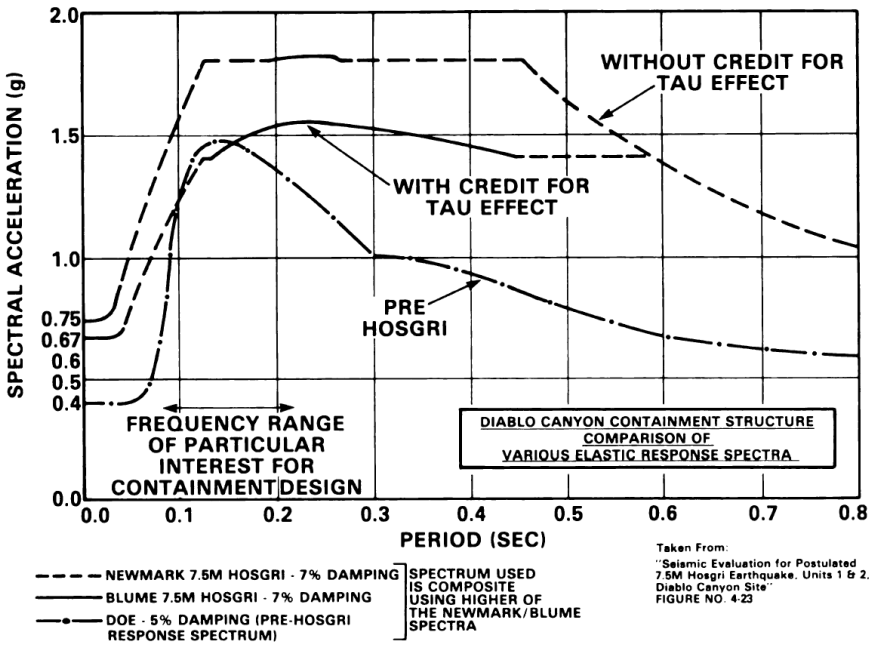
> (emphasis in original)



As the above graph taken from the Opinion of Commissioners Gilinsky and Bradford shows, the use of the "tau factor" permitted PG&E to presume far less acceleration from a Hosgri earthquake than would normally be presumed, and thus avoid having to do much upgrade at all of Diablo to deal with the far greater threat to the plant posed by the Hosgri compared to

the earthquake threat for which the plant was originally designed. The reduction resulting from the use of the tau factor, less conservative damping factors, etc. is so large that, in the frequency of concern for key structures, there is little difference between the assumed threat by the larger, closer Hosgri and the earlier lesser seismic challenge on which design was predicated. Indeed, at some frequencies, the old design requirements for the lesser earthquakes are greater than those for the far larger, new Hosgri.

Note that the graph only shows the large difference created by the use of the tau effect and the less conservative damping factors. Compare the dashed lines, which are presumed ground motion after having been reduced by the tau effect and the new protective damping assumptions, with the DDE line based on the pre-Hosgri input assumptions required by the existing permit. When the other factors are taken into account – the huge reduction of actual peak acceleration by instead assuming a far smaller "effective acceleration" and the use of average presumed as-built strengths instead of the normal requirement to assume code-tolerance strengths – the actual challenges to the structure could literally be off the chart, i.e., the challenge to the plant could be higher than the graph goes.[3]

In any case, these modifications, or fudge factors, depending on one's perspective, resulted in the extraordinary result that little upgrade to the plant ended up being required by NRC despite a vastly larger earthquake challenge quite close to the facility now being known to be possible. Indeed, because of the less conservative input assumptions, in some circumstances, the reductions were so large that the Hosgri was claimed to produce less risk than the far smaller quakes upon which the plant design had been originally based.

The Commission Refuses to Review; Commissioners Gilinsky and Bradford Dissent

The local community group that was the intervenor in the operating license proceeding, Mothers for Peace, and subsequently Governor Jerry Brown when he entered the case on behalf of the state, challenged these reductions in ground acceleration estimates. The Atomic Safety and Licensing Board ruled down the line for PG&E and the NRC Staff, as did the Atomic Safety and Licensing Appeal Board. The majority on the Commission itself did not agree to even undertake review of the rulings. Commissioners Gilinsky and Bradford issued a stinging opinion, faulting the Commission for not undertaking review and criticizing the Appeal Board's decision.

As they put it in their opinion, the central issue was what to do regarding the "discovery of the nearby Hosgri fault, which had not been taken into account in the original design of the plant." They said:

[3] Peak acceleration is "anchored" at 100Hz (essentially the vertical axis on the left in the Bradford-Gilinsky graph above), and then a response spectrum in constructed from that axis for other frequencies that are of interest for the seismic response of various kinds and elevations of structures. In the graph, the frequencies of special interest for containment design are marked, and for those, the Hosgri acceleration, modified by tau and other reductions, is not much different and in some cases lower than that presumed under the pre-Hosgri DDE for a smaller/further away earthquake.

> Since the plant was in large part already constructed at this point, the reanalysis and redesign understandably did not proceed as they would have in a plant yet to be built. Every advantage was taken of slack in safety margins left in the pre-Hosgri analysis, both in developing the response spectrum and in its application. To cite a couple of examples: a larger damping value was used in analyzing structures (7 percent instead of the earlier 5 percent), which reduced the effect of ground vibrations on the structures. At the same time, credit was taken for the actual – "as-built" -- strengths of materials (rather than the minimum required strengths, as is the usual practice) so that larger vibrations became tolerable....The point is that these further relaxations come on top of a redesign that has already shaved safety margins...."

They continued, "on top of all this trimming, the Board permitted a further substantial reduction, more-or-less across the board, in the response spectrum," by allowing the use of the so-called "tau effect," which they say reduced the acceleration response spectrum "by about 20 percent over the frequencies of interest." In accepting with virtually no basis the value proposed for the "tau effect," they say, the "Licensing Board's justification sounds almost mystical." They similarly criticize the Appeal Board's acceptance of the proposed tau factor, saying what isn't clear "is whether either Board had any idea what it was talking about." The tau value that was put forward, the Commissioners wrote, "is merely conjecture." They said, "The fact is that the tau effect has not been used in any other nuclear plant analysis. To our knowledge, it has not been used in the design of any other large building."

Commissioners Gilinsky and Bradford concluded, "Altogether, we cannot escape the impression that the Commission is declining review not because the opinion is essentially sound, but because it is unsound and the prospect of reviewing it is so unsettling."

Had there been one more vote on the Commission to review the Diablo matter, the present situation might not face us. But in the absence of Commission review, the approval of the operating licensing by the licensing board and the appeal board stood, and Diablo was allowed to commence operations without the significant upgrades that would have been required had the NRC not allowed the safety margins to be so dramatically eroded by use of these various reductions factors.

Upgrades Done Backwards, Erroneously Using Mirror-Image Blueprints

But the problems did not end at that point. Although PG&E was not required to do the full range of upgrades that would have been required without the use of the relaxed assumptions allowed, it still had to do some. And those it got astonishingly wrong.

The two Diablo units were built to mirror image blueprints of each other. When it came to making the modifications required, however, PG&E used the wrong set of blueprints for one of the units, i.e., the mirror-image blueprints for the other unit. It thus put the pipe supports and whip restraints and other upgrades in the wrong places. The error was revealed only a few days (!) after NRC had issued PG&E an operating license for low power testing, in part based on findings of adequate quality assurance controls. When the error was discovered, NRC had to

temporarily suspend the license, and PG&E had to go back and do the seismic retrofits all over again.

These errors—failing to do sufficient seismic characterization to identify the Hosgri before construction, and failing to have adequate quality assurance controls, resulting in putting the upgrades in the wrong locations due to use of the wrong blueprints—contributed to a plant that was supposed to cost $320 million ending up with more than a $5 billion cost overrun, much of which was passed on to the ratepayers.[xvi]

Errors Continue; New Seismic Discoveries Continue to Erupt, Disproving Past Claims

1. Los Osos and San Luis Bay Faults Found to Be Active Nearby Faults

Despite the embarrassment of not identifying or disclosing the Hosgri Fault before construction and the use of the wrong blueprints for the upgrades, PG&E and NRC assured the public that there were no other likely seismic problems yet to be addressed. PG&E and NRC staff all asserted, and the licensing board expressly ruled in the operating license proceeding, for example, that the Hosgri Fault was not connected to the San Simeon fault. If there were such a connection, there could be a larger quake, but they were sure there was no such link. PG&E and NRC staff also claimed, and the board so ruled, that there was essentially no chance that there were other active faults not yet discovered.[xvii]

A few years later, however, in its Long Term Seismic Program (LTSP), PG&E admitted there were at least two other active faults near the plant not previously identified in their original site characterization, the San Luis Bay and Los Osos Faults. These would turn out worrisome, as we shall see, because the subsequent estimates of ground motions possible from those new faults exceeded the limits in the license

2. Shoreline Fault Discovered

More than a decade after the LTSP, in 2008, USGS identified another new large active fault, this one the Shoreline Fault, coming within 300 meters of the plant intake and 600 meters from the reactor itself. This was deeply troubling, because its proximity to Diablo could result in an earthquake quite challenging for the plant to withstand. We were now up to four nearby active faults, whereas PG&E and the AEC had asserted at the time of the Construction Permit that there were none.

3. PG&E Analyses of Ground Motion from Shoreline, San Luis Bay, and Los Osos Faults Exceed the Double Design Earthquake/Safe Shutdown Earthquake in the Licensing Basis

In its subsequent Shoreline analyses, PG&E estimated ground motions for the Shoreline, San Luis Bay, and Los Osos Faults. PG&E asserted that these ground motions were below those spelled out as part of the license. However, Dr. Michael Peck, the NRC's Senior Resident Inspect at Diablo, noticed that in fact PG&E's ground motion estimates for these three faults all exceeded the DDE/SSE in the license. One will recall that the DDE/SSE is set at 0.4 g. To the extent that the Hosgri Exception was part of the licensing basis – and there appears question

whether it made its way into the license at all—it was an exception to the DDE/SSE and only applied to the Hosgri Fault. (PG&E took the position that the DDE of 0.4 g was the SSE and the Hosgri was not part of the SSE.[xviii])

PG&E estimated in its Shoreline analysis that the Shoreline Fault was capable of producing 0.62 g of ground motion, compared to the 0.4 g limit for the DDE/SSE. The Los Osos Fault was estimated as producing 0.60, also in excess of the 0.4 g limit. And the San Luis Bay Fault was estimated as producing 0.70 g, far above the 0.4 g level.

Dr. Peck pointed out that by PG&E's own estimates, these three new faults exceeded the DDE/SSE in the license. PG&E had two choices, he told them: come into compliance with the license by evaluating the capability of all the plant's safety components to withstand the higher levels of shaking and upgrading those that can't, or amend the license to remove the requirement they were violating.

License Amendment Sought, Then Withdrawn

PG&E chose the latter course. Rather than bring the plant into compliance with its license, it proposed amending the license so as to eliminate the provisions they weren't meeting.[xix] In particular, it proposed changing the Safe Shutdown Earthquake to be the Hosgri, with its far weaker assumptions and methodologies. The Hosgri exception would become the rule. The Shoreline, rather than have to meet the DDE/SSE, would be considered an "included case" of the far more lax Hosgri exception.

NRC staff requested PG&E provide a comparison table showing any deviations between the methodologies and acceptance criteria proposed in the license amendment request and NRC's Standard Review Plan. The subsequently provided comparison tables went on for hundreds of pages, identifying a vast number of deviations from NRC current requirements.[xx]

NRC concluded it could not accept the license amendment request for review (in part, apparently, because PG&E hadn't met the standards for a showing of "no significant hazards considerations" necessary for avoiding the opportunity for a prior public hearing if one was requested.) PG&E withdrew the application.

That should have been the end of the matter. Diablo should then have been shut down until it could be upgraded as necessary to meet the requirements of the license and the newly discovered and analyzed seismic threats. This was not to be.

Instead, NRC remarkably suggested to PG&E that it merely amend its Final Safety Analysis Report Update (FSARU) to include the Shoreline as an included case in the Hosgri evaluation. In essence, amend the license without amending the license; all to avoid the detailed scrutiny that would occur by NRC if there were a license amendment request and the transparency of a public license amendment hearing in which experts from parties other than NRC and PG&E could participate and testify. Without any public notice, PG&E quietly did so late last year.

Unfortunately, NRC regulations do not permit this. If the FSARU is to be amended to allow the use of methodologies and assumptions less conservative, i.e., with smaller safety margins, than those currently in the FSARU, a license amendment—and opportunity for public hearing—is required anyway. See 10 CFR §50.59.

Dr. Peck objected. He first filed a non-concurrence, and then a Dissenting Professional Opinion (DPO), a gutsy and rare move.[xxi] Peck asserted that under NRC's regulations, the plant needed to be shut down until it could be shown to be able to withstand the ground motions from the new faults, using the assumptions and methodologies in the license for the DDE/SSE.

Despite Dr. Peck's formal request that his DPO be made public, it remained hidden from public view for a year, until the Associated Press obtained a copy and published a major article about it. Shortly thereafter, the DPO denial was issued.

The Latest Embarrassment: the AB 1632 Seismic Study Findings

On the same day as the DPO denial was released, PG&E issued 1800+ pages of its AB1632 seismic study.[xxii] Required by California agencies in response to legislation authored by then-Assemblymember Sam Blakeslee in 2006, the study was to examine the earthquake faults that could potentially affect Diablo. Buried in it are following remarkable findings:

- PG&E now concedes that the Hosgri Fault is connected to the San Simeon Fault, making a joint rupture possible, and is thus much longer than previously assumed (61 kilometers longer).[4]
- They further admit that the Shoreline Fault is twice the length and capable of a larger earthquake than previously assumed.
- On top of that, the Shoreline appears to be connected to the Hosgri, thus allowing rupture on one to trigger rupture on the other, coming within a few hundred meters of the plant.
- Estimated ground motions for the Shoreline, San Luis Bay, and Los Osos Faults all continue to exceed the 0.4 g DDE/SSE of the license.
- Estimated ground motions for the Shoreline and the San Luis Bay Faults exceed those from the Hosgri (even when connected to the San Simeon). The Shoreline-Hosgri joint rupture produces ground motions greater than all of these.

When the plant was designed and got its construction permit, it was assumed, as indicated earlier, that there were no active faults within 30 kilometers and the plant was thus constructed to safely shutdown at ground motions up to 0.4 g. Now it is known there are at least four large, active faults close to the site, one coming to within a few hundred meters, and that all of them produce ground motions far in excess of 0.4 g.

After the Hosgri was discovered, PG&E and NRC argued it was not connected to any other major fault. After the San Luis Bay, Los Osos, and Shoreline Faults were discovered to be active near the plant, PG&E and NRC asserted that none could produce ground motion greater

[4] The Hosgri-San Simeon Fault could be considerably longer, but PG&E chose not to examine its potential connections with the San Gregorio Fault.

than the Hosgri. Now it is admitted that the Hosgri *is* connected to the San Simeon Fault Fault, making the Hosgri effectively much longer than previously presumed. It is also connected to the Shoreline, making possible a large joint rupture that occurs with the nearest approach a few hundred meters from the plant.

Most intriguingly the new report estimates ground motions for an earthquake on the San Luis Bay fault to be greater than the ground motion from an earthquake on the Hosgri-San Simeon. It similarly estimates that the Shoreline Fault can produce more ground motion than the Hosgri-San Simeon Fault. It estimates that a joint rupture on the Shoreline and Hosgri Faults would cause more ground motion than on the Hosgri-San Simeon. And presumably a joint Hosgri-San Simeon rupture would cause more ground motion than on the Hosgri alone.

In other words, the Hosgri Fault, long claimed to be unconnected to other major faults like the San Simeon, is now not necessarily the primary threat to Diablo. The new findings indicate these other, more recently identified faults, and recently admitted connected faults, can cause more damage to Diablo than the Hosgri.

The defense by NRC and PG&E for not taking action to deal with these increased potential challenges to Diablo is that the newly estimated ground motions, while larger than those now estimated for the Hosgri and the DDE/SSE, are smaller than they presumed long ago for the Hosgri. But that is dependent upon using the non-conservative, non-standard assumptions allowed only for the Hosgri exception, and then apparently using new, even less conservative assumptions on top of them. These new methodological presumptions are not allowed under the license. And there has been no license amendment, nor any vetting of these assumptions and their associated reduced safety margins in any adjudicatory hearing, where they may not withstand detailed scrutiny.

Once again, PG&E has commenced a process of sharpening its pencils, using new, even less conservative input assumptions to drive down estimated ground motions even as its studies identify longer, more connected faults capable of larger threats to the plant than the Hosgri. And PG&E and NRC have resisted licensing hearings to address these critical issues. The historical pattern seems to be repeating itself.

The Historical Pattern Continues

This has been the pattern throughout Diablo's troubled history. NRC and PG&E attempt to avoid public licensing hearings on the critical seismic issues. Overly optimistic assumptions are thus chosen, only to be, time and time again, disproven by newly discovered scientific facts. Rather than shut the plant down or require sufficient upgrades to address the newly revealed seismic challenges, NRC and PG&E carve more and more safety margins out of the design, using ever less conservative (i.e., less protective) assumptions and methodologies. And they try to do this behind closed doors, with the public locked out of their right to evidentiary hearings.

Right now there is an Atomic Safety and Licensing Board that is supposed to consider PG&E's application for extending the life of Diablo at least two decades beyond its original design life and license. The position of both the NRC staff and PG&E is that the new seismic

discoveries are forbidden to be considered in those hearings on the Atomic Energy Act license renewal matters.

Right now, NRC has allowed PG&E to eliminate the DDE/SSE requirements and methodologies in its license that it cannot meet, and to do so via amending its Final Safety Analysis Report but without a license amendment request that would trigger a public right to hearing. NRC and PG&E have taken the position that the public has no right to a hearing on those seismic issues either. Essentially, on the critical seismic new discoveries, NRC and PG&E want to be allowed to just work it out between themselves, behind closed doors, with the public and independent experts frozen out.

This has not worked very well in the past. The public has generally been right, and NRC and PG&E wrong, over all these years. In 1970, for example, the intervenor group alleged evidence of undiscovered faults; they were denied the right to present the evidence in the hearing. Then the Hosgri Fault was revealed. The construction permit proceeding wasn't reopened.

The intervenor group in the operating license proceeding, Mothers for Peace, alleged that the Hosgri Fault was connected to the San Simeon Fault, that PG&E hadn't done an adequate job studying the seismic situation in the area, that there could be more undiscovered faults, and that there were inadequate quality assurance controls. PG&E and NRC Staff argued to the contrary, and the licensing board and appeal board ruled with them. The group of mothers turned out to be right on each count, and PG&E and NRC wrong on each.

Now we face one more repetition of history. Newly released findings show longer, more connected faults, capable of more ground motion than the Hosgri. But once again the pencil sharpeners are out, trying to make the findings go away by using ever less conservative and protective assumptions, carving out more and more safety margin, and doing so without the scrutiny of public licensing hearings.

The problem is that nature may not go along with the regulatory fictions. As at Fukushima, an earthquake larger than the plant can withstand could occur at any moment. And as at Fukushima, it will not be an act of nature, but a manmade disaster, caused by the failure of our institutions.

Conclusion

When the application for the Diablo Canyon construction permit was being heard in 1970, PG&E and the Commission blocked a hearing on the prospect of additional, previously unidentified faults. They asserted that there were NO active faults within 30 kilometers.

A few years later, when the plant was almost complete, the first such active nearby fault was discovered, the Hosgri. Rather than upgrade to the full risk from the fault, they created an exception for the Hosgri from the normal requirements of the license, and modified the inputs in the calculation of ground motion to reduce the estimates and allow operation with minimal

upgrades. But they asserted there were no other significant undiscovered faults in the area, and that the Hosgri wasn't connected to the San Simeon Fault (or further, to the San Gregorio).

A few years later, however, the San Luis Bay and Los Osos Faults were identified as active and nearby. Again there confidence was expressed there were no other additional undiscovered faults.

Then the Shoreline Fault was discovered. At least four active faults have thus been found near the plant, after PG&E and the Commission had asserted that were none.

Now it is conceded that the Hosgri Fault is much longer than previously assumed and is connected to at least the San Simeon Fault. (PG&E did not look to see if it is also connected to the San Gregorio Fault, as many geologists believe, claiming that was "outside the study area." Not looking, of course, doesn't make a potential fault connection disappear.)

Now it is admitted that the Hosgri Fault is also connected to the Shoreline Fault, making possible a joint rupture coming within a few hundred meters of the plant.

Repeating past practice, in the face of all these troubling discoveries, PG&E has tried to downplay the challenge to the plant by use of new input assumptions that reduce, on paper, the ground motions expected from these larger seismic challenges. Even so, their own ground motion estimates show the Shoreline and San Luis Bay Faults individually produce more ground motion than the Hosgri, with the same situation for the Shoreline-Hosgri and San Simeon-Hosgri joint ruptures. The new information about the seismic threat shows these individual faults and connected faults to be more of a risk than the Hosgri alone.

In short, virtually every seismic claim about Diablo made by PG&E and the NRC over the years has proven erroneous and overly optimistic. The failure to allow these issues to be aired fully in public adjudicatory hearings has contributed to these problems, and is being repeated again. The barring of public hearings suggests a fear of not being able to withstand strict scrutiny.

Fukushima occurred because the reactor was designed for a smaller earthquake and tsunami than turned out to be possible. Reviews of the accident have suggested that a too-cozy relationship between regulator and industry contributed to allowing the selection of a fictional, small earthquake and tsunami as the design basis. Nature did not go along with the regulatory fiction. One can only hope that history does not repeat itself on the Central California Coast.

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[i] See NRC radiation protection regulations in 10 CFR 20 Appendix B; and EPA's Superfund cleanup preliminary remediation goals (PRGs) [http://epa-prgs.ornl.gov/radionuclides/]

[ii] See, e.g., NRC Commissioner James Asselstine to Victor Stello, Jr. NRC Executive Director for Operations, Subject: *NUREG/CO-0084, Proceedings of the Workshop on Containment Performance Design Objective,* April 13, 1987, transmitting attached paper by Daniel Hirsch,

Director, Stevenson Program on Nuclear Policy, University of California, Santa Cruz, *Minority Report: Assessing the Need for Containment Performance Design Objectives,* July 20, 1986.

[iii] Daniel Hirsch *et al.,* "Protecting Reactors from Terrorists," *The Bulletin of the Atomic Scientists*, Vol. 42, No. 3, March 1986; Daniel Hirsch, ""The Truck Bomb and Insider Threats to Nuclear Facilities," in Paul Leventhal (Ed.), *Preventing Nuclear Terrorism*, Lexington Books, Lexington, MA: 1987; Daniel Hirsch *et al., Nuclear Terrorism: A Growing Threat*, A Report to the Safeguards and Security Subcommittee, Advisory Committee on Reactor Safeguards, U.S. Nuclear Regulatory Commission; May 7, 1985. Reprinted in monograph series, Stevenson Program on Nuclear Policy, UC Santa Cruz, SPNP-85-F-1

[iv] Daniel Hirsch, "The NRC: What Me Worry?", *Bulletin of the Atomic Scientists,* January/February 2002; Daniel Hirsch, Edwin Lyman, and Dave Lochbaum, "The NRC's Dirty Little Secret: The Nuclear Regulatory Commission is Still Unwilling to Respond to Serious Security Problems," *Bulletin of the Atomic Scientists,* May/June 2003; Committee to Bridge the Gap, Petition to the Nuclear Regulatory Commission for Rulemaking**,** *PROPOSED AMENDMENTS TO 10 C.F.R. PART 73 (Upgrading the Design Basis Threat, Regulations for Protection Against Terrorist Attacks on Nuclear Reactors)*, July 23, 2004; NRC, SECY-05-0106, *Proposed Rulemaking to Revise 10 CFR 73.1, Design Basis Threat (DBT) Requirements.*

[v] David Lochbaum, *Seismic Shift: Diablo Canyon Literally and Figuratively on Shaking Ground,* Union of Concerned Scientists: November 2013

[vi] Gayle LeBaron, "Battle Over Bodega Head Nuclear Plant Set the Stage," April 15, 2011, *Press Democrat;* David Okrent, *Nuclear Reactor Safety: On the History of the Regulatory Process,* University of Wisconsin Press, 1981; Thomas Reymond Wellock, *Critical Masses: Opposition to Nuclear Power in California, 1958-1978,* University of Wisconsin Press, 1998.

[vii] U.S. Nuclear Regulatory Commission, *Safety Evaluation Related to the Operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2, Docket Nos. 50-275 and 50-323*, NUREG-0675, Supplement No. 34 (hereafter SSER 34), p. 2-39

[viii] Thomas H. Pigford, *Building the Fields of Nuclear Energy and Nuclear Waste Management, 1950-99,* University of California, Berkeley, University History Series, Regional Oral History Office, The Bancroft Library, 2001, pp. 144-150. Pigford reports that one of the factors involved in the ASLB refusing the request for a few hours to present evidence of nearby faults was that the ASLB chairman was running for election as County Manager of Montgomery County in Maryland and was in a hurry to return to the campaign.

[ix] The design was based on an earthquake more than 20 miles away on the Naciemento Fault, or a much smaller aftershock, not on an existing fault, arising from an earthquake on the San Andreas Fault, which is located 48 miles away. FSARU §2.5.2.9

[x] *Opinion of Commissioners Gilinsky and Bradford on Commission Review of ALAB-644 (Diablo Canyon Seismic Proceeding),* CLI-82-12A, 16NRC8,10

[xi] R.C. DeYoung, Assistant Director for Light Water Reactors Group 1, Division of Reactor Licensing, to Roger Boyd, Acting Director, Division of Reactor Licensing, USNRC, *Diablo Canyon Geology-Seismology,* January 5, 1976.

[xii] In these proceedings, peak acceleration is benchmarked at 100 Hz for comparison purposes. USGS did indicate one could modify the values from Circular 672, but did not recommend how or any other value.

[xiii] Atomic Safety and Licensing Appeal Board, *In the Matter of Pacific Gas and Electric Company, Diablo Canyon Nuclear Power Plant Units 1 and 2, Dockets No. 50-275 (OL) and 50-323 OL (Seismic Proceeding*), ALAB-644, 15 NRC 903, June 16, 1981
[xiv] Gilinsky-Bradford opinion at 12.
[xv] Gilinsky-Bradford Opinion at 13-14
[xvi] Barbara Byron, California Energy Commission, *California's Policies and Recommendations for Advanced Seismic Research at Diablo Canyon,* September 9, 2010.
[xvii] Atomic Safety and Licensing Board, *Partial Decision*, Diablo Canyon Units 1 and 2, September 27, 1979.
[xviii] PG&E took the position that the Hosgri analysis was not part of the Safe Shutdown Earthquake, that the SSE was the DDE at 0.4 g. See NRC SSER7, p. 2-3, citing a PG&E letter to NRC of April 11, 1978.
[xix] Pacific Gas & Electric, License Amendment Request 11-05, "Evaluation Process for New Seismic Information and Clarifying the Diablo Canyon Power Plant Safe Shutdown Earthquake," October 20, 2011.
[xx] Pacific Gas & Electric, Standard Review Plan Comparison Tables for License Amendment Request 11-05, "Evaluation Process for New Seismic Information and Clarifyinq the Diablo Canyon Power Plant Safe Shutdown Earthquake," December 6, 2011
[xxi] The Peck DPO, its Denial, the Appeal DPO Denial, and the Denial of the Appeal were released by NRC on September 10, 2014, available on the NRC ADAMS database at ML12452A743.
[xxii] available at http://www.pge.com/en/safety/systemworks/dcpp/seismicsafety/report.page