EXHIBIT 2 – DECLARATION OF PETER BIRD

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE COMMISSION
AND BEFORE THE SECRETARY

In the matter of	
Pacific Gas and Electric Company	Docket Nos. 50-275-LR
Diablo Canyon Nuclear Power Plant	50-323-LR
Units 1 and 2	

DECLARATION OF PETER BIRD, Ph.D

Submitted to the U.S. Nuclear Regulatory Commission
By San Luis Obispo Mothers for Peace, Friends of the Earth,
and Environmental Working Group

March 4, 2024

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DECLARATION OF PETER BIRD, Ph.D

Under penalty of perjury, I, Peter Bird, declare as follows:

I. EXPERT QUALIFICATIONS

1. My name is Peter Bird. For over 46 years, I have been a Professor of Geophysics and Geology at the University of California at Los Angeles (UCLA). I now serve as Professor of Geophysics and Geology, Emeritus at UCLA. I am qualified by training and experience as an expert in the fields of geology and geophysics with a focus on tectonophysics and seismicity, including plate motion and plate deformation. A copy of my curriculum vitae is included here as Attachment 1.

2. I have a Ph.D. in Earth and Planetary Sciences from the Massachusetts Institute of Technology (1976) and a B.A. in Geological Sciences from Harvard College (1972). Over the past 48 years, I have published 76 academic papers, mostly about tectonics and seismicity, including the tectonics and seismicity of California. And I have authored or contributed to a number of academic papers on computer modeling methods and applications, including studies of the ongoing (neotectonic) deformation in California. I have also been a member or officer of several professional organizations relating to my expertise, including the Geological Society of America, the American Geophysical Union and the Southern California Earthquake Center. The former two organizations have recognized my work with two fellowships and an award.

3. In 2012, I participated in a Senior Seismic Hazards Analysis Committee (SSHAC) workshop sponsored by Pacific Gas & Electric Co. (PG&E) and run by Lettis Consultants International, regarding seismic hazard at the Diablo Canyon Power Plant. I presented results on both strike-slip and compressional deformation rates affecting the region, which were derived from my latest computer models of neotectonics. These models were prepared for the Southern California Earthquake Center's project Unified California Earthquake Rupture Forecast version 3, and also for the US Geological Survey's 2013 Update to the National Seismic Hazard Model.

4. On April 28, 2023, on behalf of San Luis Obispo Mothers for Peace (SLOMFP), I prepared a declaration setting forth my criticism of the seismic risk analysis for DCPP that was presented by the U.S. Nuclear Regulatory Commission (NRC) in its Draft Generic Environmental Impact Statement for License Renewal of Nuclear Plants (NUREG-1437, Rev. 2, Feb. 2023) (Draft GEIS) (NRC 2023). SLOMFP submitted my declaration with its comments on the Draft GEIS on May 2, 2023. My declaration can be accessed on the NRC's Agencywide Data Access and Management System (ADAMS) at ML23123A410. My declaration in that rulemaking proceeding is relevant to this DCPP license renewal proceeding because the NRC relied heavily on PG&E's seismic analyses for its conclusion that the environmental impacts of an earthquake-induced or related accident at DCPP are "SMALL." This matter is discussed in more detail below. I continue to stand by the facts and expert opinions expressed in my declaration.

II. PURPOSE AND DESCRIPTION OF MY DECLARATION

4. The purpose of my declaration is to explain why, in my expert opinion, the Environmental Report by applicant PG&E significantly underestimates the likelihood of a severe earthquake at DCPP, *i.e.*, an earthquake "that could cause substantial damage to the reactor core." [ER p. 4-61]. PG&E's 2018 estimate and 2023 revision of the long-term rate of seismic core damage as $2\sim3\times10^{-5}$ /yr fail to take into account current information or to deploy a technically-defensible seismicity model that show the seismic severe accident rate is about 47~70 times higher, or $\sim1.4\times10^{-3}$/ year.

5. The fundamental problem with PG&E's seismic risk analysis is not any error in computations, but the use of incomplete deformation models to support the 2015 Seismic Source Characterization (SSC). These incomplete deformation models also biased PG&E's 2018 seismic probabilistic risk assessment (SPRA). PG&E mistakenly decided that strike-slip faulting is the only important kind of neotectonic activity in the vicinity of DCPP.[1] As I have previously discussed, these deformation models do not meet basic scientific standards for objectivity and reliability because are not geometrically self-consistent, nor are they consistent with GPS and regional stress directions. Instead, they appear to be custom-built to minimize seismic hazard at DCPP.

6. In my expert opinion, thrust-faulting (due to horizontal compression of the crust) is an equal contributor to overall seismicity in this area. More importantly, it implies a far greater increase in expected SCDF at DCPP due to the extreme accelerations that occur in hanging-walls of thrust faults, especially near their tips.

7. The basis for my expert opinion is set forth below, first briefly, and then in detail, following a necessary Background section.

III. BACKGROUND REGARDING PG&E AND NRC SEISMIC STUDIES AND ENVIRONMENTAL DOCUMENTS

A. PG&E's Public Seismic Risk Studies

8. PG&E's public seismic risk studies are the post-Fukushima SSC (PG&E, 2015; 2015L) and the resulting SPRA (PG&E, 2018). According to the SPRA: *"The SPRA performed for DCPP shows that the point-estimate mean SCDF" [seismic core damage frequency] "is* 2.8×10^{-5} *per year…"* (page 52).

9. The seismic model presented in the SSC (PG&E, 2015 SSHAC Level-3) is notable for deformation models that focus almost exclusively on strike-slip faults, neglecting to consider thrust faults under DCPP as dangerous seismic sources.[1] This significant omission is addressed in (Bird, 2023) and will be discussed later in my declaration.

B. Environmental Documents

10. PG&E's SCDF estimate was accepted by NRC in the *Draft License Renewal GEIS* (NRC, 2023). *Table E.3-11*, entitled *Seismic (Full Power) Core Damage Frequency Comparison*, lists expected severe seismic accident rates for every nuclear plant in the country. In the row labeled *Diablo Canyon 1, 2* the value for the metric *SAMA SCDF(a)* is 1.3×10^{-5} /yr, and the value for the metric *SPRA Mean SCDF(b)* is 2.8×10^{-5} /yr. The mean of these two metrics is 2×10^{-5} /yr.

11. Both the *Draft License Renewal GEIS* and *Applicant's Environmental Report* (PG&E, 2023) describe the expected rate of severe accidents of external seismic origin as *"SMALL"*.[2] In the Draft GEIS, this characterization can be found at page E-34 ("*The NRC staff concludes that . . . external event risk is being effectively addressed and reduced by the various NRC Orders and other initiatives, and that, therefore external event risk is not expected to challenge the 1996 LR GEIS 95th percentile UCB [upper confidence bound] risk metrics during the initial LR [license renewal] . . . period.*") Also see page E-1 ("*The 1996 LR GEIS concluded that the probability-weighted consequences were small compared to other risks to which the populations surrounding nuclear power plants are routinely exposed.*")

12. In the Environmental Report, this characterization can be found in *Section 4.15 Postulated Accidents / Section 4.15.2 Severe Accidents*, on pages 4-61 (PDF page 455). The more specific statement of SCDF in PG&E (2023) is: *"As shown in Attachment G, Section G.2.1.17, the DCPP application model used for the SAMA analysis has an internal fire CDF of* 4.6×10^{-5} *and a seismic CDF of* 2.96×10^{-5} *which are less than the bounding CDFs in*

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[1] Technically, a few of PG&E's 2015 deformation models did include thrust faults; however, they were uniformly parameterized as steeply-dipping, slow-slipping, not passing below DCPP, limited to low maximum-magnitudes, and/or low-weighted on the logic tree(s). Thus, their net impact on PG&E's SSC and SCDF estimates was insignificant.

[2] In my understanding, the term "SMALL" is equivalent to "insignificant" from the standpoint of the severity of environmental impacts.

Tables E.3-10 and E.3-11. Consistent with NRC's conclusions, these lower fire and seismic CDFs are also not significant compared to the previous LR GEIS revisions." (page 4-62; PDF page 456).

13. For brevity in this Declaration, I will refer to this old estimate as a seismic core damage frequency of "$2{\sim}3\times10^{-5}$ /yr"; that is, one severe accident of seismic origin per 33,000~50,000 years.

IV. SCIENTIFIC ANALYSIS

A. Abstract

14. The following is an abstract of my scientific analysis:

(1) The Noto Peninsula earthquake in Japan (2024.01.01, *m*7.5, 10 km deep) produced peak ground accelerations (PGA) of 1.0~2.3 g (that is, 100~230% of gravity) at 5 modern digital strong-motion seismometers as far as 42 km from the rupture.

(2) This strong shaking occurred in the Noto Peninsula, which is part of the hanging-wall (upper block) of two en-echelon thrust faults that run parallel to its two coasts.

(3) The Irish Hills, San Luis Range, and DCPP site in California are at risk for similar earthquakes and similar shaking because they are underlain by similar thrust faults, including the inland Los Osos thrust fault and the Inferred Coastline thrust running along the shore by DCPP.[3]

(4) The expected recurrence interval between such events at DCPP can be roughly estimated by dividing the expected fault slip (averaging 2 m in the Noto earthquake, according to the USGS finite-fault solution) by the total heave rate of the thrust faults under DCPP, which is about 2.8 mm/year (as I will justify below). The result is 715 years. The inverse of this is the rate: 1.4×10^{-3} /yr.

(5) In the existing SSC (PG&E, 2015; 2015L), the intensity of shaking at this return period of 715 years has been underestimated by a factor of 3~7. This means that the chance of seismic core damage is much higher when thrust-faulting earthquake sources are included.

(6) Applying my analysis to these facts, the probability of a severe accident of earthquake origin at DCPP has been underestimated by a factor of (1.4×10^{-3} /yr) / ($2{\sim}3\times10^{-5}$ /yr) = 47~70. In other words, the severe accident that PG&E asserts will occur only once in 33,000~50,000 years may actually occur every ~715 years. That means that a license extension for 20 years would incur a ~2.8% probability of a severe accident.

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[3] "Inferred Coastline thrust" is my own term for a distinct fault surface whose trace follows the coastline opposite DCPP. Unlike the Shoreline fault in the same area, the Inferred Coastline thrust dips at a gentle angle beneath DCPP and has the up-dip rake of a thrust fault.

B. Detailed Scientific Argument

15. In the following pages, I will demonstrate that PG&E’s SCDF estimate is too low, by almost two orders of magnitude. PG&E’s error lies in the subjective [i.e., committee-based, not algorithm-based] creation of deformation models that served as the basis for the 2015 SSHAC Level-3 SSC, and their almost total exclusion of shallow thrust faults under DCPP as dangerous seismic sources. While my previous criticisms of PG&E’s seismic risk analyses (Bird, 2023) remain valid, it will not be necessary to evaluate every feature of the 2015 SSC here; rather, it will only be necessary to consider the kind of seismic source that was excluded.

(1) Accelerations in the 2024 Noto Peninsula earthquake

16. On 1 January 2024, at 07:10 UTC, a very large earthquake occurred beneath the Noto Peninsula on the northwest coast of Ishikawa Prefecture, Japan. Its magnitude was 7.6 on the moment-magnitude scale used by the Japan Meteorological Agency, and 7.5 on the moment-magnitude scale used by USGS. This thrust-faulting shock achieved a maximum JMA seismic intensity of Shindo 7 and Modified Mercalli intensity of IX (Violent) (Wikipedia, 2024). These intensities are very high.

17. Professor Shinji Toda of Tohoku University collected digital seismograms from the many strong-motion seismograph stations on and around the Noto Peninsula and reported them in Toda and Stein (2024). In their Figure 2, it can be seen that one station 42 km from the rupture experienced peak ground acceleration (PGA) of 230% of g; the next 4 highest PGA values observed were 150%, 140%, 120%, and 100% of gravity.[4] Toda & Stein noted that, in general, PGA values for this earthquake were about 4× greater than those anticipated by the well-known USGS ShakeMap algorithm at the same distances.

(2) Factors responsible for unusually strong shaking

18. According to the finite-fault solution computed by the U.S. Geological Survey (USGS, 2024), these high PGA sites were all located in the hanging-wall (upper block) of a thrust fault with SE dip. The reasons why unusually strong shaking should be expected in the hanging-wall of a thrust are well-understood, at least in qualitative terms:

19. First, it is common for thrust-fault ruptures to begin in the zone of highest stress-drop, near the base of the seismogenic zone at ~10 km depth. As the rupture expands up-dip, each

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[4] PGA, or Peak Ground Acceleration, is obtained from a seismogram either directly (if it is an accelerogram), or by taking the first time-derivative (if it is a velocity seismogram), or by taking the second time-derivative (if it is a displacement seismogram). Either way, it is a seismic acceleration in units of m/s^2. However, a common practice in this field of seismic hazard assessment is to normalize PGA by dividing it by the everyday (non-seismic) acceleration of gravity on the surface of the Earth, $g = 9.8$ m/s^2. After this normalization, PGA is expressed in units of “g”.

increment of slip adds its seismic energy to a directivity-pulse of strong shear (S) waves. Second, this shear-wave energy cannot escape into the atmosphere, because it is perfectly reflected by the free surface. Third, along the active fault at the base of the upper block, shear waves are also partially reflected upward by the low-velocity layer of fault gouge. Where the fault is actively slipping, higher reflection coefficients are caused by temporary coseismic increases of pore pressure in this gouge layer, and by the fact that the fault has left the elastic domain and is in a state of frictional plasticity. Thus, the shear-wave seismic energy propagating up-dip in the upper block is largely confined to a wedge whose thickness and mass decrease towards its tip (at the fault trace). Fourth, conservation of energy then requires seismic wave amplitude, velocity, and acceleration to increase to high values. In fact, there is a loose analogy to the behavior of shear waves in a whip, where the tip is intended to reach supersonic velocities.

20. A necessary step in every seismic source characterization probabilistic seismic hazard assessment study is the use of ground-motion prediction equations (GMPEs) to estimate shaking from earthquake magnitude, distance, and other geometric factors. One of the most respected sources of GMPEs in the "next-generation" literature is Campbell & Bozorgnia (2014). This source recognizes the special hazard in the hanging-wall of a thrust; the Abstract states (in part): *"In addition to those terms included in our now-superseded 2008 GMPE, we include a more-detailed hanging wall model, scaling with hypocentral depth and fault dip, …"*. Below, in their text: *"The hanging wall term was updated in part by empirically constraining the hanging wall model developed by Donahue and Abrahamson (2013, 2014) from ground motion simulations."* In their equation (1), term $\boldsymbol{f}_{\mathrm{hng}}$ describes additional intensity for observers in a hanging-wall location. This term is itself the product of 6 factors defined by equations (7-16). Thus, modern practice provides ways to estimate the hanging-wall effect, although these were apparently not used in the 2015 SSC study.

21. Notably, high PGA above a thrust-fault has been observed in California, in the 1971.02.09 San Fernando (or Sylmar) earthquake of m6.6, which had a maximum Mercalli intensity of XI (Extreme). A strong-motion seismogram installed on a bedrock base next to the Pacoima Dam observed PGA of 125% of g (Cloud & Hudson, 1975).

(3) Tectonic analogy between the Noto Peninsula and the Irish Hills of California

22. According to Japanese geological sources summarized by Toda & Stein (2024), the Noto Peninsula is a crustal block that is being uplifted from beneath the Sea of Japan by the joint action of conjugate SE-dipping thrust faults just offshore its NW coast and NW-dipping thrust faults just offshore its SE coast. The driving force comes from horizontal convergence (estimated as ~10 mm/yr) between the island of Honshu and the Eurasia plate (or, more precisely, between the Amur and Okhotsk plates in the PB2002 global model of Bird, 2003).

23. The Irish Hills, San Luis Range, and DCPP site in California occupy a closely analogous tectonic setting, with a SW-dipping active thrust fault (Los Osos thrust) on the NE side, and the NE-dipping Inferred Coastline thrust [my proposed name for purposes of this Declaration] on the southwest side. This basic structure was mostly ignored by PG&E in creating deformation models for the 2015 SSC (PG&E, 2015).

24. The Irish Hills and the San Luis Range are a dextral-transpressional orogen that has formed since ~3.5 million years (or mega annus, Ma) [*Page et al.*, 1998], or possibly since 7.8~6 Ma [*Atwater & Stock*, 1998; *Bird & Ingersoll*, 2022] when the motion of the Pacific plate changed its direction to become more compressional relative to North America. This means that the region can be expected to be cut by a number of both strike-slip and thrust (compressional) faults.

25. Evidence of compressional tectonic structures in the region includes the following eight significant elements:

    a. The Pismo syncline is the primary structural feature exposed in the Irish Hills [*Pacific Gas & Electric*, 2014]. Here beds have been rotated ~45°, which angle is supported by both mapped surface dips in outcrops (geologic map, *ibid*), and by the overall dip of unit Tmo Obispo Formation in the borehole-controlled cross-section of Figure 13-17 of the SSC for DCPP. This folding began after deposition of the youngest strata in the core of the fold (Tmpm), and prior to deposition of the Squire Member of the (Pliocene) Pismo Formation (Tpps), probably ~5 Ma. This folding implies upper-crustal strains of ~0.8, and mean strain-rates of ~0.8 / 5 Ma = 5×10^{-15} per second (/s). This is ~10× faster than rates of "off-modeled-fault" (or "continuum") deformation that are typical in the long-term neotectonics of the western US [5×10^{-16} /s per *Bird*, 2009]. This high rate of permanent straining implies a high rate of faulting and of earthquakes, even if the relevant thrust fault traces are not always exposed.

    b. According to the geologic map [PG&E, 2014] and associated cross-section C-C' in its Fig. 13-17, the apparent throw (vertical offset) of stratigraphic unit Tmo Obispo Formation is 1.6~2.2 km across the Shoreline fault trace. (This measurement is illustrated in my own Figure 1.) None of this can be explained by strike-slip on the Shoreline fault because its slip-rate is very low and because regional strikes of bedding are roughly parallel to it. Instead, the simplest explanation is thrust-faulting on the Inferred Coastline thrust that shares the complex, braided surface trace of the Shoreline fault. Assuming a typical thrust-fault dip of 25°, the amount of slip required to create this throw is (1.6~2.2 km) / sin(25°) = 3.8~5.2 km. Then, assuming this occurred since ~5 Ma, the mean rate of slip on the Inferred Coastline thrust has been 0.76~1.04 mm/a. To the northwest of section C-C' the throw of unit Tmo becomes much less, but the area of neotectonic uplift of the Irish Hills (Figure 7-4 in PG&E, 2015) continues to the northwest; so there the thrust fault probably does not terminate but merely deforms unit Tmo into a fault-initiation anticline above it. (In this area, complex older deformation associated with intrusions of Tmod diabase obscures the Pliocene-Quaternary structure, and makes balanced-section methods inapplicable.) In my professional judgment, this Inferred Coastline thrust fault continues, with the same rake and offset, northwest to the Hosgri fault.

    c. The neotectonic uplift rate of the whole Irish Hills region is uniform at 0.2 mm/a (Fig. 7-4 in PG&E, 2015). Because the Franciscan Complex basement is weak, and because there is no large isostatic gravity anomaly over the Irish Hills [*Simpson et al.*, 1986], this uplift process should be modeled with Airy isostasy. The implied rate of crustal thickening is then about 6 times larger, or about 1.2 mm/a. If this crustal thickening is occurring on a single thrust fault of dip 25°, then its rate of slip should be (1.2 mm/a) / sin(25°) = 2.8 mm/a. Or, if the crustal thickening is driven by two oppositely-vergent and overlapping thrust faults (as in my schematic section, Figure 1 at the end of this testimony), then each should have a slip-rate of ~1.4 mm/a. Obviously, more complex models with more thrust faults can be devised, but the implication for total strain and seismicity due to thrust-faulting will remain unchanged.

d. The southwestern front of the Irish Hills is a topographic scarp with a smooth arcuate shape, mirroring the slightly-lower scarp on the northeast which has been formed by slip on the Los Osos thrust fault. This suggests that the Inferred Coastline thrust is present under the southwestern front, at or near the coastline.

e. The 2003 San Simeon m6.6 and 1983 Coalinga m6.2 earthquake both had thrust mechanisms [Global Centroid Moment Tensor Catalog, *Ekström et al.*, 2012]. This is evidence of highly-compressive horizontal stresses in the Coast Ranges region, suggesting a likelihood of seismic thrust-faulting in other locations as well.

f. SSW-NNE directions of most-compressive stress shown by data in the World Stress Map [*Mueller et al.*, 1997; *Heidbach et al.*, 2008, 2016], and by interpolation of stress directions using the method of *Bird & Li* [1996], are almost perpendicular to the traces of the regional fault grain (Shoreline, Inferred Coastline, San Luis Bay, and Los Osos fault traces). This strongly suggests that currently these faults are either purely or dominantly thrust faults.

g. Closer to DCPP, two recent small earthquakes had thrust-faulting mechanisms with the expected SSW-NNE direction of maximum horizontal compression: 2023.12.27 m3.1 at 6.2 km depth under the Irish Hills, and 2024.01.01 m5.4 slightly offshore from the NW end of the Irish Hills (D. J. Weisman, pers. comm., 2024.01.02). This shows that the regional stress regime and orientation documented above also apply in the immediate vicinity of DCPP.

h. Models of neotectonic deformation, informed and guided by GPS velocity data, include such long-term compression. Specifically, *Shen & Bird* [2022] computed a suite of kinematic finite-element (F-E) models of neotectonics across the western US based on geodetic, geologic, & stress data with program NeoKinema. Their preferred model, which has been incorporated into the 2024 update of the USGS National Seismic Hazard Model, shows convergence of crustal blocks on both sides of the Irish Hills/San Luis Range region at velocities of ~1 mm/a, for a total of ~2 mm/a of local horizontal convergence rate.

(4) Thrust-fault slip-rates and earthquake recurrence intervals

26. The paragraphs above contain multiple arguments for horizontal convergence at ~2.0 mm/yr in the Irish Hills area, and for total thrust-fault slip rates of ~2.8 mm/yr. In addition, paragraph 25(b) shows that the slip-rate of the Inferred Coastline thrust must be 0.76~1.04 mm/yr. Therefore, deformation models like some of PG&E's in their 2015 SSC that attribute all uplift and shortening to the Los Osos fault are not defensible.

27. In SSC and PSHA studies that include fault seismic sources with very incomplete information, it is traditional to assume a periodic characteristic earthquake model. While this is only an approximation of the chaotic earthquake dynamics in the real Earth, it has the advantage of allowing simple arithmetical conversions between the triad of basic parameters: slip, slip-rate, and recurrence interval. For example, to compute the recurrence interval for large characteristic thrust-faulting earthquakes under the Irish Hills (either on the Los Osos or Inferred Coastline thrust), it is sufficient to divide the mean coseismic slip by the long-term tectonic slip-rate.

28. In the 2024 Noto Peninsula earthquake, we have the advantage of the finite-fault solution (USGS, 2024), which maps the amount of coseismic slip onto the active fault plane. This study showed maximum slip of 3.7 m under the center of the Noto Peninsula, with a mean slip that I visually estimate as 2.0 m (or 2000 mm) in the seismogenic depth range.

29. Dividing this mean slip of 2000 mm by the long-term tectonic slip-rate of 2.8 mm/a in the Irish Hills, the inferred recurrence rate for Noto-type earthquakes under the Irish Hills is 715 years. In other words, the inferred probability of Noto Peninsula-type earthquakes under the Irish Hills is the inverse of this, which is 1.4×10^{-3} /yr.

30. Again, reasonably presuming that the Noto Peninsula earthquake is a characteristic earthquake for this tectonic setting (shared by the Irish Hills in California), PGA values of 1.0~2.3 g (see section 1 above) must be expected with probability 1.4×10^{-3} /yr. However, in the 2015 SSC (specifically, in Figure 2.3.7-1 of PG&E, 2015L), we see that this outdated modeling associated this probability level with a PGA of only 0.32 g. Consequently, it appears that the 2015 SSC severely underestimated (by a factor of 3~7) the severity of shaking (PGA) that must be resisted every ~715 years.

(5) Susceptibility of DCPP to seismic core damage

31. This raises the question of whether PGA of 1.0~2.3 g will cause seismic core damage (SCD) at Diablo Canyon Units 1 & 2. Answering this question quantitatively becomes technical and difficult, given that spectral accelerations critical to individual component failures are typically twice as large as PGA; that is, perhaps 2.0~4.6 g at vibration frequencies of 5~10 Hz in the Noto Peninsula case.

32. The 2018 SPRA (PG&E, 2018) is the most recent available to me. Within this document, Table 5.4-4 (page 65) shows how the overall SCDF of 2.8×10-5 /yr was obtained. In principle, it should be possible to use this information to estimate the probability of SCD at

each level of shaking. My interpretation of the table is that the probability of SCD is ~6% at 2 g, rising to ~73% at 3 g and to >98% at 4 g. The problem is that the acceleration levels quoted in this table are not clearly identified; are they PGAs or (more likely) spectral accelerations? The context in this SPRA report suggests that they are spectral accelerations: the introductory section "3.1.3 Seismic Hazard Analysis Results and Insights" only discusses 5 Hz spectral accelerations, and the primary graphs that it refers to ("Figure 3-1 - Reference Rock Hazard by Source for 5 Hz Spectral Acceleration" and "Figure 3-4 - 5 Hz Control Point Mean and Fractiles Horizontal Hazard") are plots of 5 Hz spectral acceleration.

33. Therefore, my interpretation of these reports is that a PGA event of 1.0 g would produce 5 Hz spectral accelerations of ~2 g, and incur ~6% of SCD. However, a PGA event of 1.5 g would produce 5 Hz spectral accelerations of ~3 g, and incur a ~73% chance of SCD. And the peak Noto-earthquake observation of PGA of 2.3 g would produce spectral accelerations of ~4.6 g, and incur >98% chance of SCD.

34. It will probably be controversial exactly which of the Noto Peninsula seismograms give the median and worst-case forecasts of shaking at DCPP. The paragraph above shows that this is a critical point. Clearly these questions need to be resolved by independent experts, preferably in a revised SSC study followed by a revised SPRA study. In the meantime, for purposes of evaluating PG&E's Environmental Report, it is reasonable to assume that the levels of shaking seen in the Noto Peninsula earthquake will cause seismic core damage at DCPP if and when they occur in the Irish Hills of California.

(6) Risk of external seismic severe accidents at DCPP has been grossly underestimated

35. The combined implication of the above-cited facts and analysis is that the probability of a severe accident of earthquake origin at DCPP has been underestimated by a factor of $(1.4\times10^{-3}\ /\text{yr}) / (2\sim3\times10^{-5}\ /\text{yr}) = 47\sim70$. In other words, the severe accident that PG&E asserts will occur only once in 33,000~50,000 years may actually occur every ~715 years. That means that a license extension for 20 years would incur a ~2.8% probability of a severe accident.

C. Figure 1

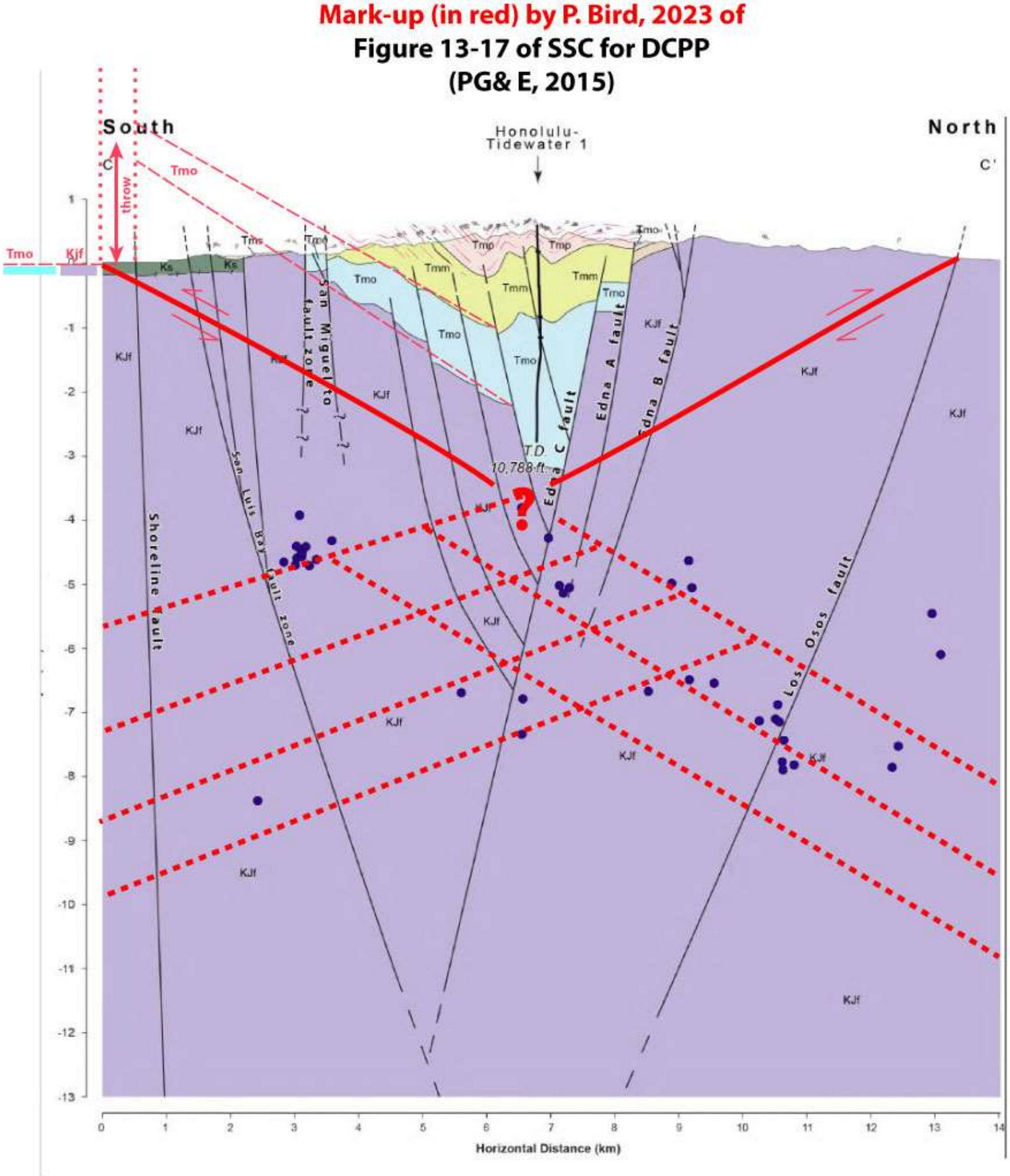

Figure 1. Revised geologic section through the Irish Hills near DCPP. The base for this figure is Figure 13-17 of the Seismic Source Characterization for DCPP (PG&E, 2015). Note that the fault dips suggested by black lines in their figure were not based on data, but were constrained by PG&E's (2015) *a priori* assumption that only strike-slip tectonics is active in the area. In red, I have suggested more plausible 25° dips for the Los Osos thrust (at right/North) and the Inferred Coastline thrust (at left/South). The upper-left portion of this figure is also edited to show the throw (vertical offset) of map unit Tmo across the Inferred Coastline thrust, discussed in my text paragraph IV.B.25(b).

V. ADDITIONAL OBJECTIONS TO APPLICANT'S ENVIRONMENTAL REPORT

A. Regarding adequacy of existing and planned deformation models

36. In my previous Declaration (2023.04.28) to NRC regarding their Draft Generic EIS (NRC, 2023), and in my Testimony (2023.06.30) to the California Public Utilities Commission regarding DCPP, I raised objections to the methodology of the SSC for DCPP (PG&E, 2015):

> *"The 2015 … SSC for … DCPP was deficient and biased in 3 ways: (1) Fault slip-rates were selected subjectively and in isolation, without modern deformation-modeling (as used by USGS) to guarantee that all fault slip-rates and rates of distributed permanent deformation are self-consistent, and also consistent with geodetic-velocity and stress-direction data; (2) Seismicity from unexpected, undetected, and/or subterranean ruptures between the known faults was modeled based on projection of a few decades of microseismicity, ignoring globally-calibrated relationships between long-term tectonic strain-rate and (typically higher) long-term-mean seismicity which includes seismic crises; and (3) Despite several arguments and proposals for a thrust fault at shallow depths under DCPP with slip-rate of ~1 mm/a, no such seismic source was included."*

Point (3) has been expanded in Section I of this Testimony, above.

37. However, I wish to restate my objections (1) and (2) above, because both systematic defects in deformation-modeling have the potential to seriously bias the estimated seismic hazard.

38. The response from PG&E appears in the following paragraph on page G-27 of Attachment G to Applicant's Environmental Report (PG&E, 2023):

> *"New or updated seismic methodologies and models developed since preparation of the SSC model will be considered as part of the SB-846-required seismic update. The DCPP seismic analyses, however, include a variety of well-established and vetted models rather than a single method. Therefore, additions or changes in data input from a single model typically result in slight to moderate changes in hazard calculations. If proposed new methods or models are determined to be viable and reliable, they will be integrated with other models so the impact of any single change is not expected to result in a significant change in the resulting seismic hazard."*

39. The strong implication here is that PG&E intends to keep their old deformation models from 2015, and perhaps add one or two alternative deformation models (probably with small logic-tree weights), so that there is no material change in net seismic hazard. Actually, in a public presentation to the Diablo Canyon Independent Safety Committee of the California Public Utilities Commission on 23 February 2024, the PG&E presenters indicated that there would be <u>no</u> new deformation models, and the geometry of the old deformation models would be <u>unchanged</u>. As discussed above, I consider this unscientific and unacceptable because the

old deformation models were not internally self-consistent, and were not consistent with GPS data, and also because they appeared to be custom-built to minimize seismic hazard at DCPP.

40. In this regard, I advise that NRC should apply strong scrutiny to this planned *"SB-846-required seismic update"* (if and when it is released), and also carefully consider the anticipated reviews offered by the 3 outside experts of UCLA's Garrick Risk Institute, and also the anticipated opinions of the Diablo Canyon Independent Safety Committee of the California Public Utilities Commission, informed by their Independent Peer Review Panel.

C. Regarding status of witness's models in the seismicity/hazard communities

41. Attachment G, page G-27 of Applicant's Environmental Report (PG&E, 2023) contains a description of how the Technical Integration (TI) Team and the Participatory Peer Review Panel (PPRP) of the SSHAC Level-3 SSC program (2012-2015) considered a presentation I made at the November 2012 San Luis Obispo workshop, and decided to use some elements (rates of strike-slip) and decided to exclude other elements (rates of horizontal compression; computer algorithms for objective creation of optimal deformation models; global calibrations for converting long-term strain-rates to seismicity). The paragraph I object to is this:

> *Dr. Bird's modeling of off-fault deformation and alternative methods to calculate seismicity rates were not considered mature enough by the Tl Team at the time of the SSHAC to include in the SSC model. This is consistent with exclusion of these models and model elements from the Uniform California Earthquake Rupture Forecast (ver. 3) which is the basis for the 2014 update to the United States Geological Survey Seismic National Seismic Hazard Map (References 111 & 113)*

42. The first problem is a misleading implication of the phrase, *"exclusion of these models."* My deformation model, obtained with my dynamic finite-element code NeoKinema, was used by the USGS in their 2014 Update to the National Seismic Hazard Model (Field et al., 2013). It was assigned a weight of 0.3 in the logic tree, and no other deformation model had a higher weight. The necessary distinction is that USGS finally decided to use only the computed fault slip-rates, and not the self-consistent off-fault deformation field.

43. Second, the repetition of this criticism, *"not .... mature enough"*, probably written in 2012, in the new Applicant's Environmental Report (PG&E, 2023) written 11 years later is also misleading. My NeoKinema code for creation of deformation models was used again in the 2024 Update to the National Seismic Hazard Model (Shen & Bird, 2022), with a logic-tree weight of 0.32. (Again, no other deformation model had a higher weight.)

44. Also, my global-calibration method (Bird & Kagan, 2004; Bird & Liu, 2007) for converting long-term strain-rates to shallow seismicity has been developed into 3 global seismicity models of increasing sophistication (Bird et al., 2010; Bird & Kreemer, 2015; Bird et al., 2015). These models have been registered with the Collaboratory for the Study of Earthquake Predictability (CSEP) and have proven successful in prospective tests by

independent experts (Strader et al., 2018; Bayona et al., 2023). The third of these models, named GEAR1, is currently the global standard.

Under penalty of perjury, I declare that the foregoing statements of fact are true and correct to the best of my knowledge and that the statements of opinion expressed above are based on my best professional judgment.

Executed in Accord with 10 CFR 2.304(d) by
Peter Bird

Date: March 4, 2024

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VII. CURRICULUM VITAE

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EDUCATION

Massachusetts Institute of Technology: Ph.D. in Earth and Planetary Sciences, 1976
Harvard College: B.A. in Geological Sciences, 1972

EMPLOYMENT

University of California, Los Angeles:
- Professor Emeritus, 2011-
- Professor of Geophysics and Geology, 1985-2011
- Vice-chairman, Dept. of Earth and Space Sciences, 1994-2002
- Associate Professor of Geophysics and Geology, 1981-85
- Assistant Professor of Geophysics and Geology, 1976-81

HONORS

Woollard Award, Geological Society of America, 2013
Fellow, American Geophysical Union, 1990
Fellow, Geological Society of America, 1989

RESEARCH AREAS (CHRONOLOGICAL FROM 1973)

Lateral refraction and attenuation of surface waves	1973-1977
Marine paleomagnetism and seafloor spreading	1974-1975
Thermal modeling with finite differences	1975-1977
Dynamic modeling with finite elements	1975-
Tectonophysics of continental collisions	1975-
Formation of marginal basins	1976-1977
Stress and temperature in subduction zones	1976-2009
Continental delamination	1977-1982
Neotectonic models of California	1978-
Hydration state and friction of montmorillonite clays	1979-1984
Mechanism of Laramide orogeny	1982-
Mechanism of Basin/Range taphrogeny	1986-
Solution transfer experiments on quartz	1986-1993
Lateral extrusion of lower crust	1987-1991
Regional neotectonic models: Africa, Alaska, Asia, Europe, ...	1989-
Global dynamic lithosphere models with plates & driving forces	1992-
Inverse or kinematic tectonic models from geologic & paleomag data	1994-
Global long-term seismicity forecasts from geodesy & plate tectonics	2000-
Long-term seismicity forecasts for Europe, especially Italy	2009-

CONSULTING EXPERIENCE ON SEISMIC HAZARD (FROM 2009 TO PRESENT)

GeoPentech, Lettis Consultants International, FM Global, Temblor, San Luis Obispo Mothers for Peace

UNPAID AFFILIATIONS

Southern California Earthquake Center (2000-present; Board member 2004-2012)
Collaboratory for the Study of Earthquake Predictability (model contributor, 2015)

VIII. PUBLICATIONS (CHRONOLOGICAL FROM 1975; OMITTING MOST ABSTRACTS)

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