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and SAN DIEGO GAS & ELECTRIC COMPANY

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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| In the Matter of<br><br>SOUTHERN CALIFORNIA EDISON COMPANY, *et al.*, (San Onofre) Nuclear Generating Station, Units 2 and 3). | Docket Nos. 50-361 OL<br>50-362 OL<br><br>AFFIDAVIT OF JOHN A. BARNEICH IN SUPPORT OF MOTION FOR SUMMARY DISPOSITION OF FRIENDS OF THE EARTH, *ET AL.*'s CONTENTION 1a (DEWATERING WELLS). |

STATE OF CALIFORNIA, )
) ss.
COUNTY OF SAN FRANCISCO. )

JOHN A. BARNEICH, being first duly sworn, deposes and says that if called as a witness herein he can competently testify as follows:

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1. I am a geotechnical engineer employed by Woodward-Clyde Consultants (hereafter "WCC"). I am currently an Associate with WCC in their Orange/Los Angeles facility and am responsible for all earthquake engineering and soil dynamics work, for the development of the soil and rock testing laboratory, and for the management of projects with Southern California Edison Company (hereafter "SCE").

2. I received my Master of Science Degree in Geotechnical Engineering in 1966 and a Bachelor of Science Degree in structural engineering in 1964 from the University of California at Berkeley.

3. I have 16 years of experience in geotechnical engineering: 2 years as a field and laboratory technician; 2 years as an engineer-in-training California; and 12 years as a registered engineer in the State of California. My professional experience in geotechnical engineering has been primarily in the areas of soil dynamics and earthquake engineering, encompassing the geotechnical aspects of a wide variety of major civil projects, such as earth and concrete dams, buildings, bridges, pipelines, canals, roads, power facilities, underground structures, oil refineries, and airports.

4. I am a member of the American Society of Civil Engineers (hereafter "ASCE") and the current Chairman for

the Los Angeles Section, Energy Technical Group of the ASCE. I am also a member of the Earthquake Engineering Research Institute and have served on committees of other professional engineering organizations concerned with soil dynaimcs and earthquake engineering. I have given numerous lectures at technical conferences and was a guest lecturer at the Massachusets Institute of Technology on the seismic analysis of building foundations. I have authored eight published technical papers in geotechnical engineering and was a member of the arrangements committee for the 1978 National ASCE Specialty Conference on Soil Dynamics and Earthquake Engineering.

5. WCC (and its predecessor firm, Woodward-McNeill and Associates) has been engaged by SCE as geotechnical engineering consultants on the project known as San Onofre Nuclear Generating Station, Units 2 and 3 (hereafter "SONGS 2 and 3"). I have been involved in the SONGS 2 and 3 project since 1971 as the project manager for all WCC work in geotechnical engineering, including evaluation of soil-structure-interaction for earthquake response of structures, liquefaction of site soil, slope stability of the adjacent switch yard slopes, foundation design parameters for the support of structures, maximum earthquake design ground

motion parameters, and subsurface cavities created by construction dewatering wells at SONGS 2 and 3.

6. As WCC's project manager, I was responsible for all WCC's work between May 1977 and July 1979, on the investigation and demobilization of the construction dewatering wells at the SONGS 2 and 3 site (hereafter the "Site"). Specifically, I was at the Site when the first indication of a cavity at Well 6 was observed in May, 1977. Thereafter, I directed all of WCC's investigation and demobilization work on the wells from formulation of the initial plans for this work through the preparation of WCC's final report to SCE summarizing said work in July, 1979. I represented WCC in the Task Force set up by SCE at the request of the NRC Staff to fully investigate and demobilize any cavities beneath the Site. The key participants in the Task Force were WCC, Bechtel Power Corporation (hereafter "Bechtel"), and SCE. Lucien Hersch of Bechtel was named Chairman of the Task Force. The reports and significant documentation produced by the Task Force and submitted to the NRC STAFF are specified and given common reference numbers in the accompanying "List of Project References in Support of Motion for Summary Disposition of Intervenor Friends of the Earth, et al.'s Contention la (Dewatering Wells)" (hereafter the "Project Reference List").

7. In addition to directing WCC's efforts and participating in the planning and implementation of the investigation/demobilization of the Site construction dewatering wells, I have personally participated in the following field operations conducted by the Task Force: the initial drilling exploration at Wells 3, 6, 7, and 8; the initial part of the cross-hole seismic work at Wells 3, 4, 5, and 10; and of the well cleaning, television monitoring, and well bore or cavity surveying operations at Wells 1, 2, 3, 5, 6, 7, 8, and 9. These field operations are more fully described in the accompanying affidavit of Lucien Hersh.

I also coordinated planning for and was directly responsible for the Task Force's analysis of cavity stability (both statically and when subjected to seismic shaking associated with the Design Basis Earthquake) and for the evaluation of effects of cavities on the design soil stiffness parameters and on the estimated settlement of SONGS 2 and 3 Seismic Category I structures. The paragraphs that follow summarize some of the key observations and conclusions of the Task Force for which I am responsible, or with which I agree, based on my professional opinion after careful review of the work of other members of the Task Force.

8. One or more of three basic procedures were applied in the investigation and demobilization of each Site construction dewatering well: (1) drilling exploration and pressure grouting of the area around the well; (2) the airlift cleaning of the gravel pack and the removal of the well casing, followed by the placing of a measured volume of concrete in the wellbore; and (3) the exploration drilling of the area around the well, supplemented by crosshole seismic measurements to investigate areas between the various borings, followed by additional borings as required.

Procedure (3) above provided borings drilled to the full depth of the well from which a cross-hole seismic investigation was undertaken. The borings themselves provided data on the characteristics of the subsurface material. Seismic waves were then transmitted from one boring to another and their wave forms were analyzed to determine the nature of the material through which the waves passes. Where cross-hole seismic data could be interpreted to indicate the potential existence of a cavity, additional deep borings were drilled for the purpose of determining whether cavities in fact were present and to perform further cross-hole seismic investigation.

Application of procedures (1), (2) and (3) above led to the completion of the following investigation and demobilization work in the vicinity of the the wells: (1) drilling a total of 634 borings, some to the maximum depth of the wells (about 200 ft.); (2) removal of the well casing and filter gravel from the wellbore and subsequent filling of the wellbore with concrete at three of the wells; (3) exploration drilling and crosshole seismic surveys at four of the wells; (4) downhole inspection of 12 well casings by a bore-hole television camera; and, (5) pressure grouting with cement grout around four wells close to Seismic Category I structures where cavities were detected. Exhibit A (Reference No. 31), which is entitled "Summary of Investigation/Demobilization of Dewatering Wells," and is attached hereto and incorporated herein by this reference, presents a summary of how each well was investigated and demobilized. This work led to the demobilization of all wells and to the detection of cavities at Wells 6, 7, and 8; smaller cavities at Wells 3 and 5; and, perhaps, a small cavity at Well 10. The significant characteristics of these cavities are that they were sand-filled, limited in areal extent, rather lobate in shape, and are predominately located in the drawdown zone developed during construction. The mechanism of cavity formation is described in the accompanying affidavit of Robert L. McNeill. The implementation of procedures (1),

(2) and (3) above described, is more fully described in the accompanying affidavit of Lucien Hersh.

9. The cavities detected at Wells 6, 7, and 8 were found to be of controlling significance due to their size and proximity to Seismic Category I structures. The cavity at Well 6 is located to the east side of the north end of the Auxiliary Building and south of the Unit 2 Fuel Handling Building. The cavity does not extend beneath either structure and is small in plan area compared to the plan area of either adjacent structure. The cavity at Well 7 is located to the east of the south end of the Auxiliary Building (extending slightly under the Auxiliary Building) and north of the Unit 3 Fuel Handling Building. As was the case for Well 6, the cavity at Well 7 is small in plan area compared with the plan area of either adjacent structure. The cavity at Well 8 is located to the southeast of the Unit 3 containment Structure and extends slightly under the edge of the structure terminating at the tendon gallery. As was the case for the cavities at Wells 6 and 7, the plan area of the cavity is small compared to that of the adjacent Containment Structure. A portion of a tunnel structure is located over the cavity at Well 8. Contour maps of the cavity area and borings surrounding Wells 6, 7 and 8 are found in Exhibits E, H and K to the accompanying affidavit

of Lucien Hersh.. As more fully explained in the accompanying affidavit of Lucien Hersh, observations in the field indicate all detected cavities to be full of sand and/or grout.

10. The proximity to structure and size of all other cavities detected at the Site (small shallow cavity at Well 5, small shallow cavity at Well 3, and possible small cavity at Well 10) were not considered to have any measurable affects on adjacent structures for the reasons set forth in the accompanying affidavit of Lucien Hersh and further discussed below.

11. A mechanism may be postulated for the earthquake behavior of a subsurface cavity wherein the excess pore water pressure developed in the walls of the cavity due to seismic shaking could cause the wall material to collapse and simulate cavity-infill soil. In examining this mechanism, it is noted that the native soil in the San Mateo Formation underlying the Site is very dense (100% relative density) and is characterized by a very efficient grain packing. Further, experience in the field and the results of laboratory tests shows that the native soil fails by particulating grain-by-grain; and, in doing so, bulks and increased in volume by about 20%. Because the cavity is full of sand and/or grout, bulking is resisted by the

existing soil in the cavity and the expansion of the cavity by wall failure is self-stabilizing. From a conservative viewpoint, however, seismic shaking could conceivably cause liquefaction of the cavity-infill material, which could generate an excess pore pressure in the cavity-infill soil. The dissipation of this excess pore water pressure into the adjacent native soil could tend to reduce the stiffness of the native soil. This reduction in stiffness or local softening of native soils adjacent to cavities could lead to additional settlements and reduction in bearing capacity of adjacent structures.

12. The Task Force assigned WCC the task of quantitatively evaluating the effects of seismic shaking on the stability of the detected dewatering well cavities, which effects have been qualitatively described in Paragraph 11 above. This task included an evaluation of how the cavities in their most unstable configuration could affect the soil supporting adjacent SONGS 2 and 3 structures and thereby influence structural behavior.

To accomplish this assignment, I formulated the following 6-stage evaluation plan: STAGE ONE: characterize the cavity at well 8 in a finite-element model along with adjacent soil and structures; STAGE TWO: perform a dynamic response analysis of the model developed in STAGE ONE using the SONGS 2 and 3 design basis earthquake acceleration-time history and calculate the resulting stresses in the cavity infill soil and surrounding native soil; STAGE THREE: using the results of STAGE TWO, perform a time-sequenced analysis of dissipation of pore water pressure generated due to the liquefaction of the cavity infill soil; STAGE FOUR: from the results of STAGE THREE, determine the most critical configuration of instantaneous softening of the soil adjacent to the cavity and its effects on the supporting capacity of the soil beneath the adjacent Unit 3 Containment Structure; STAGE FIVE: extrapolate the results of the STAGE FOUR analysis to other cavities and structures; and STAGE SIX: quantify the effects on foundation soil stiffness parameters used in seismic design of SONGS 2 and 3 structures, as well as the effects on the bearing capacity of structures and allowable settlement of structures. This plan was presented to the Task Force, reviewed in detail, and subsequently adopted and implemented as described in Paragraphs 13 through 18 below.

13. The STAGE ONE through STAGE FOUR analyses and results for the cavity at Well 8 are presented in a report by WCC entitled "Report on the Results of Analyses Performed on Well 8 at SONGS Units 2 and 3 San Onofre, California." This report is attached hereto as Exhibit B (Reference

No. 7) and incorporated herein by this reference. The results of the analyses are also shown in plan for the cavity at Well 8 in Exhibit C (Reference No. 27), entitled "Plan Section of Cavity and Pore Pressure Ratios for De-watering Well 8", which is attached hereto and incorporated herein by this reference. These results, as documented in Exhibit B, are conservative because the analysis assumes the cavity to be more than 25 times greater in size than the known size of the cavity. The specific results, as summarized in Exhibit C, show the plan projection of the maximum extent of all cavity dimensions at Well 8, and the maximum extent of localized softening of the adjacent native soils defined by contours of equal pore pressure ratio (pore pressure/confining pressure) of 1.0 and 0.3 during or after the Design Basis Earthquake. The higher the pore pressure ratio, the lower the effective confining pressure. This is important because the stiffness of the soil is approximately proportional to the effective confining pressure (Figure 3.7-12, Final Safety Analysis Report, San Onofre Nuclear Generating Station, Units 2 and 3 [hereafter "FSAR"]). Thus, the soil within the 1.0 contour would exhibit very low stiffness, while the soil near the 0.3 contour would exhibit about 80% of its original stiffness. It should also be noted that these reductions were found to represent a transient condition, and the soil was found to stabilize to the pre-earthquake condition within about an hour after the Design Basis Earthquake.

14. The results of the analysis of the Well 8 cavity were extrapolated to the Well 6 and 7 cavities by the STAGE FIVE analysis described in Paragraph 12 above. Specifically, the Well 8 results were extrapolated by proportioning the size of the pore pressure ratio contours of 0.3 and greater for the cavity at Well 8 to the size of the cavities at Well 6 and 7 to obtain estimates of pore pressure ratio contours for these wells. The extrapolations were conservative because the relative proximity of the cavities at these wells to adjoining structures means less restriction to drainage of pore water pressure than existed at Well 8. However, no credit was taken for this condition. Typical results of this extrapolation for the cavities at Wells 6 and 7 at the elevation of the base of the Auxiliary Building are presented in Exhibit D (Reference No. 28) entitled "Plan Section of the Cavity and Pore Pressure Ratios for Dewatering Wells 6 and 7, which is attached hereto and incorporated by this reference.

15. The STAGE SIX analysis, described in Paragraph 12 above, to quantify the effects of cavities on structures was carried out in the format presented in Appendix E of

Exhibit B for structures located adjacent to the Wells 6, 7, and 8 cavities. Specifically, the following cases were assessed: the combined effects of the Wells 6 and 7 cavities on the adjacent Auxiliary Building; the individual effects of the Well 6 cavity on the adjacent Unit 2 Fuel Handling Building; the combined effects of the Wells 7 and 8 cavities on the adjacent Unit 3 Fuel Handling Building and, the effects of the Well 8 cavity on the adjacent Unit 3 Containment Structure. These assessments were made by calculating the potential reduction in soil stiffness or suport characteristics of the foundation material caused by an adjacent cavity. The calculation was facilitated by making conservative assumptions regarding the interrelationships between the geometry and spatial location of the cavity and the body of soil dominating the support of the structure. For the static analyses the geometric area enclosed within each cavity (described in the accompanying affidavit of Lucien Hersh), was conservatively assumed to have no soil stiffness at all. Likewise, for the seismic analysis, the soil within the 1.0 pore pressure contour, as mapped in Exhibit C for Well 8, and Exhibit D for Wells 6 and 7 was also assumed to have no soil stiffness and the soil between the 0.3 and 1.0 contours was assumed to have reduced soil stiffness approximately proportional to the reduction in confining pressure. The significant results of these analyses for Wells 6, 7, and 8 have been summarized in Exhibit E (Reference No. 37), entitled "Summary of Maximum Effects of Cavities on Structures, San Onofre Nuclear Generating Station, Units 2 and 3", which is attached hereto and incorporated herein by this reference.

16. The dynamic response analyses originally performed for the design of SONGS 2 and 3 Seismic Category I structures were made assuming ±30% variation in soil stiffness parameters. The maximum reduction in soil stiffness for any of these structures as calculated by the analyses of cavity effects, described in Paragraph 15 above, is 8%. This reduction is well within the ±30% margin of safety used in the design of these structures.

The static settlements of the Unit 3 Containment Structure, the Auxiliary Building, and the Units 2 and 3 Fuel Handling Buildings were estimated in the design of SONGS 2 and 3 to be less than 1/2 inch. It is conservative to assume settlement of a structure increases in direct proportion to the calculated maximum decrease in soil stiffness attributable to a subsurface cavity affecting the structure. Based on this conservative assumption, the change in settlement in the SONGS 2 and 3 structures affected by the detected cavities is calculated to be less than one-tenth of an inch. In my professional opinion, this change is well within acceptable settlement tolerances for SONGS 2 and 3 Seismic Category I structures.

A second confirming analysis of the effect of the cavities on the settlement of the structures was made by calculating the potential change in the volume of the soil beneath the Containment Structure due to the drainage of excess pore pressures. The details of this analysis are documented in Exhibit B. This analysis confirms that settlement attributable to the detected cavities to be less than 1/10-in. for all structures affected by the detected cavities at Wells 6, 7, and 8. As reported in Section 2.4.4.10.3 of the FSAR, the factor of safety against bearing failure for the structures is in excess of 100. The maximum 8% reduction in soil stiffness corresponds to about the same reduction in strength. Therefore, this factor was applied to calculated factors of safety against bearing failures for the various Seismic Catagory I structures at SONGS 2 and 3. The results of this calculation showed the factors of safety to remain in excess of 100 for all structures.

17. The effect of the cavity at Well 8 on the tunnel structure was based on the results of the pore-pressure dissipation analyses presented in Paragraph 15 above. This was done by conservatively assuming that the

tunnel would be unsupported in the area of the cavity within the maximum extent of the 0.5 pore pressure ratio contour at any point below the tunnel. A map of this area, entitled "Maximum Interpreted Effect of the Cavity on Tunnel Structure," is attached hereto as Exhibit F (Project Reference No. 29), and incorporated herein by this reference. The tunnel was then checked by Bechtel for its spanning capabilities. These calculations indicated tht the tunnel can span, unsupported, the cross-hatched area indicated in Exhibit F as more fully explained in the accompanying affidavit by Lucien Hersh.

18. Because of the small potential effects of the cavities at Wells 6, 7, and 8 on the adjacent structures, and because of the relatively small sizes and greater distances of cavities or possible cavities from major Seismic Category I structures at Wells 3, 5, and 10, no specific analyses were completed at the latter locations. These cavities or possible cavities, in fact, lie outside the soil dominating the support of the nearest major Seismic Category I structures and have no measurable effect on such adjacent structures.

19. Based on the foregoing information, it is my professional opinion that: (1) all significant subsurface

cavities at the Site were detected by the investigation carried out; (2) the measured size, location, and configuration of the cavities is accurate to the extent required for the evaluation of effects on structures; (3) the detected cavities will have no detrimental affect on SONGS 2 and 3 Seismic Category I structures; and (4) that all Site construction dewatering wells have been adequately demobilized by backfilling with sand, gravel, and/or grout.

John A. Barneich

JOHN A. BARNEICH

Subscribed and sworn to before me on June 3, 1980.

Sybil L. Boardman

NOTARY PUBLIC
for the County of San Francisco,
State of California.

SYBIL L. BOARDMAN
NOTARY PUBLIC-CALIFORNIA
CITY AND COUNTY OF
SAN FRANCISCO
My Commission Expires 11/19/80

## SUMMARY OF INVESTIGATION/DEMOBILIZATION OF DEWATERING WELLS

| Well Number | Description of Investigation/Demobilization |
|---|---|
| 1,2,9 | Annulus airlift cleaned, well casing removed, wellbore measured, and wellbore filled with concrete. |
| 3A | Test well--only operated a few days, casing inspected, and filled with concrete. |
| 3,10 | Shallow investigation at Well 3 by borings identified and delineated a small cavity. Borings and crosshole seismic measurements made to bottom of both wells. Results of investigations, and analyses considering the distance to Seismic Category I structures, show no cavities of structural significance at either well. Well casings filled and capped. |
| 4,5 | Shallow investigation at Well 4 by open excavation detected no cavity. Shallow investigation at Well 5 using borings and pressure grouting detected and delineated a small cavity. Deep drilling and cross-hole measurements made to bottom of both wells. Results of investigation show no cavities of structural significance exist at either well. Well casings filled and capped. |
| 6,7,8 | These wells primarily investigated by deep drilling and exploration/grouting in detected cavity areas. Filled cavities were detected and delineated for further evaluation of effects on adjacent structures. Well casings were filled. |
| 11,12 | Located outside plant area at considerable distance from Seismic Category I structures. Therefore, no investigation work carried out on these wells. |