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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of SOUTHERN CALIFORNIA EDISON COMPANY, *et al*. (San Onofre Nuclear Generating Station, Units 2 and 3).	)	Docket Nos. 50-361 OL 50-362 OL AFFIDAVIT OF ROBERT L. McNEILL IN SUPPORT OF MOTION FOR SUMMARY DISPOSITION OF INTERVENOR FRIENDS OF THE EARTH *ET AL*. CONTENTION 1a (DEWATERING WELLS).
STATE OF NEW MEXICO COUNTY OF BERNALILLO	)	ss.

ROBERT L. McNEILL, being first duly sworn, deposes and says that if called as a witness herein he can competently testify as follows:

8006110 046

1. I am presently employed as a member of the Technical Staff at Sandia National Laboratory, located in Albuquerque, New Mexico. I am also self-employed as a geotechnical engineering consultant to Southern California Edison Company (hereafter "SCE") for matters related to San Onofre Nuclear Generating Station, Units 2 and 3 (hereafter "SONGS 2 and 3").

The opinion expressed herein is solely my own, and does not represent the views or the position of Sandia National Laboratory, or the United States Department of Energy.

2. I hold a Doctor of Science Degree in engineering mechanics (minors: mathematics and physics) from the University of New Mexico, and a Master of Science Degree in geotechnical engineering and a Bachelor of Science Degree in structural engineering from the University of California (Berkeley).

3. I have 27 years experience in geotechnical engineering: two years as a field and laboratory technician, three years as an engineer in-training in California, and twenty-two years as a registered professional engineer in the States of California, Nevada, Arizona, New Mexico, and New York. My experience encompasses the geotechnical, dynamic, and seismic design aspects of almost every kind of heavy construction: dams, buildings, bridges, roads, power

facilities, mining facilities, tunnels, subways, pipelines, offshore structures, and hardened defense structures.

4. I have taught geotechnical engineering at the University of New Mexico, the University of California at Los Angeles, and the California State University at Long Beach and at San Diego. I have given guest lectures on geotechnical engineering topics at the University of California at Berkeley and at Los Angeles, the University of New Mexico, the Texas A. and M. University, and the University of Colorado at Boulder. I have authored approximately twenty published professional papers on geotechnical engineering. I have been awarded the Clement T. Wiskocil Prize for Outstanding Engineering Graduate by the University of California at Berkeley, and the Thomas Fitch Rowland Prize for Best Paper on Construction in 1960 by the American Society of Civil Engineers. I have been a guest "State-of-the-Art" speaker at two world conferences on geotechnical engineering. I have served on many professional and technical committees, and am a Past President of the Institute for the Advancement of Engineering.

5. From 1970 until 1975, I was President of Woodward-McNeill & Associates (hereinafter "WMA"). WMA was retained by SCE for geotechnical engineering work associated with the analysis, design, and construction of SONGS 2 and 3. In that capacity I was the Principal in charge of said

work, and personally accomplished a substantial amount of the geotechnical work on the project, in addition to my management duties. Since 1975, I have been an independent consultant to Woodward-Clyde Consultants (hereafter "WCC") and to SCE, providing advice and consultation to WCC as they continued the work of WMA at SONGS 2 and 3, and providing technical advice and review to SCE on many other aspects of that project.

6. In the foregoing capacities, I have become completely familiar with the design and operation of the construction dewatering well system at SONGS 2 and 3. At all pertinent times I have been directly involved with the investigation and demobilization of this system and have actively participated in the decision-making process regarding the investigation and demobilization of this system. I have authored or reviewed the various reports and documentation regarding the investigation and demobilization of the cavities formed by operation of this system, which are identified 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 1a (Dewatering Wells) hereafter "Project Reference List"). I have also engaged in research for new data and related engineering experiences to augment said investigation, reports and documentation. I have relied in

part on the 15 engineering references listed in the document entitled "List of References", which is attached hereto as Exhibit A and incorporated herein by this reference.

7. In May, 1977, I was present at the SONGS 2 and 3 site (hereafter the "Site") when the annular gravel filter pack around Dewatering Well 6 was observed to have dropped under the vibratory action of local compaction. I inspected the situation with my colleague from WCC, John A. Barneich. At that time, Mr. Barneich requested that I proceed at once to assemble a working hypothesis as to how and why the filter gravel could have dropped, so that a rational investigative program could be designed to detect what, if any, subsurface features might have been associated with the drop of the filter gravel.

8. In May, 1977, a few days after the events in Paragraph 7 above, after studying the problem I formulated a working hypothesis for the phenomena described in Paragraph 7 above. The hypothesis postulated a mechanism for the formation of subsurface cavities by operation of the SONGS 2 and 3 construction dewatering well system. This mechanism for cavity formation was formulated in the following way.

Comparison of the measured gradations of the filter gravel and the San Mateo sand, using a standard work on filter design (Terzaghi K., and R. Peck: Soil Mechanics in Engineering Practice, Wiley, N.Y., 1948), indicated that

the filter gravel would act as an effective filter for the San Mateo sand, if the filter gravel were present. This was subsequently confirmed by laboratory experiments conducted under my guidance. However, the gravel would not be present: (1) if it arched across the annulus between the dewatering well casing (14 inches in diameter) and the well bore (30 inches in diameter) and therefore did not completely fill the annulus; or (2) if it were loosely placed, and subsequently compacted under the stress of the hydraulic pumping gradient; or (3) if the filter gravel migrated through the fluted louvres in the well casing because, for example, the well casing corroded during operation. Items (1) and (2) can easily happen in practice. Subsequent television surveys of Dewatering Wells 2, 4, 5, 6, 7, 8 and 9 at the Site showed casing corrosion and zones which were missing gravel, so item (3) is known to have happened.

It was further recognized that there was a possibility of subsurface erosion if there existed locally high hydraulic gradients in a zone where the filter gravel was not present. By applying standard principles of subsurface flow and erosion, I formulated the mechanism of cavity formation which predicted that: (a) cavities would most likely form in the drawdown zone around the dewatering well because this is the area experiencing highest hydraulic gradients; (b) cavity formation would be enhanced if the

pumping were intermittent; (c) the cavities would likely be funnel-shaped, decreasing in size with depth; (d) the cavities would likely be filled with sand attrited from the roof and walls; and (e) that the width of such cavities would likely be smaller than the length or the height. This mechanism of cavity formation is more fully described in the paper entitled "Mechanisms of Cavity Formation", which is attached hereto as Exhibit B (Reference No. 9, Appendix A) and incorporated herein by this reference.

9. Based upon my prediction of narrow cavity width, I recommended to SCE, WCC, and Bechtel Power Corporation (hereafter "Bechtel") that it would be necessary to have surface borings closely spaced if there was to be confidence that all cavities could be detected. My prediction of sand infill led to my second recommendation to SCE, WCC, and Bechtel that it would be necessary to monitor all aspects of the boring operation (rate of advance, feed pressure, mud inventory, etc.) carefully if there was to be confidence that infill, and therefore cavity, could be detected. I personally supervised the first few exploratory borings, and established the boring and monitoring procedures, which were subsequently carried on by WCC and Bechtel throughout the program to investigate and demobilize the SONGS 2 and 3 construction dewatering well system.

10. In May, 1977, I was present at the Site shortly after infill sand was first discovered in a borehole indicating the presence of a subsurface cavity near Dewatering Well 6. To determine the configuration of the subsurface cavity so that it could be analyzed for its possible effects on the facilities, I considered two points: (1) the hypothesized mechanism, described in Paragraph 8 above, postulated that the cavity should be narrow; and (2) the San Mateo Sand Formation in its native state is quite cohesive, supporting vertical cliffs about 100 ft. high. Based on these points, it was decided by SCE, WCC, and Bechtel, upon my recommendation, that the most positive way to define the configuration of such a cavity at this site would be to empty it and measure it directly by surveying methods.

In order to implement this recommendation it was necessary to remove the steel dewatering well casings. After the in-place condition of the casings was recorded on video tape, several casings were removed. I personally supervised the removal of casings at Wells 1, 2, 6, 7 (inner casing, and attempt on outer casing), and 9. Wells 1, 2, and 9 were emptied of their filter gravel, surveyed by television and/or mechanical or sonar calibration techniques, and found to have no cavities.

Subsequent emptying and surveying of Wells 6, 7 and 8, revealed that each of these wells had a cavity and

that these cavities extended into adjacent backfills made of recompacted San Mateo sand. Because the San Mateo sand when recompacted, is very dense, strong, and stiff, but does not have the cohesion of the native material and will not stand vertically below the water table, the emptying operations were at this point abandoned in favor of a program of closely-spaced deep and shallow borings around each of these wells. This borings program was thereafter conducted by Bechtel under the direct supervision and control of Lucien Hersh.

Based upon my personel knowledge of the professional execution and thoroughness of the emptying and surveying programs, as well as the borings program, the operations of which I reviewed on a weekly basis, and having carefully analyzed the extensive logs and other data produced by these investigative programs, as more fully described in the accompanying affidavit of Lucien Hersh, it is my professional opinion that no subsurface cavities exist at Dewatering Wells 1, 2 and 9, and that no subsurface cavities other than those more fully described in the accompanying affidavit of Lucien Hersh exist at Dewatering Wells 3, 6, 7 and 8.

11. On or about September 25, 1977, I was personally supervising the boring operation when a small cavity was detected at Dewatering Well 5, which at that time was in

an excavation about 30 feet below plant grade. The top of the small cavity was a foot or so below the floor of that excavation. I personally observed the driving of a large steel casing around Well 5, using a vibratory hammer. I observed and recorded the resulting depression in the ground surface caused by the collapse of the cavity roof due to the vibratory forces.

Motivated in part by the observation that this cavity at Well 5 was very small it was decided to implement other techniques of detecting possible cavities, to complement and guide the planning of the boring efforts for the remaining wells to be explored on the Site, which at that time were Dewatering Wells 4 and 5. A small cavity had been detected at Well 3 by borings, and it was decided to use this cavity to try out the complementary techniques. Two such techniques were tried: micro-gravity and cross-hole seismic. The micro-gravity technique proved to be too sensitive to cultural and other background noise, so it was abandoned. The cross-hole seismic technique, however, proved to be effective in detecting cavities at this site because it clearly identified, in a distinct pattern of seismic-waves, the known cavity at Well 3. I personally supervised the calibration of the technique at the known cavity at Well 3, and participated in the application of the technique as part of the borings programs at Wells 4 and 5.

I have reviewed in detail the logs of the borings and the cross-hole seismic data produced in investigating the subsurface area around Wells 4 and 5. Based on this review and my knowledge of the professional execution and thoroughness of the borings program and the cross-hole seismic program, the operations of which I reviewed on a weekly basis, it is my professional opinion that no significant cavities other than those more fully described in the accompanying affidavit of Lucien Hersh exist at Dewatering Wells 4 and 5.

12. All of the detected cavities, described in Paragraphs 10 and 11 above, were grouted. I participated in the planning of that program, observed typical operations in the field, made weekly reviews of the progress, and analyzed the results. Based on these and on the verification borings which were advanced, it is my professional opinion that no open voids exist in the five detected dewatering well cavities, and that all of these cavities have been completely filled and demobilized with grout and bulked San Mateo sand.

13. At the request of SCE, analyses have been made by myself and WCC to estimate the effects of the detected cavities on the structures and equipment of SONGS 2 and 3 both statically and dynamically in the event of the Design Basis Earthquake. I participated in the planning of these analyses, reviewed their progress, and analyzed the results.

For the static case, the supporting capacity of the cavity infill materials was ignored, and the resulting effects on the bearing capacity and settlement was then analyzed. The results showed a safety factor on bearing capacity in excess of 100, and settlements of only a fraction of an inch. These results are not surprising given the small relative size of the detected cavities when compared to the immense size of the structures associated with each detected cavity. In my professional opinion, the foregoing assumptions and analyses for the static effects, more fully described in the accompanying Affidavit of John A. Barneich, are adequately conservative as a representation of the behavior of SONGS 2 and 3 structures and equipment in the event of a Design Basis Earthquake.

For the dynamic case, the supporting capacity of the cavity infill material was discounted and it was assumed that the infill would liquefy and become the source of high-pressure water propagating pore pressures into the adjacent San Mateo sand. Laboratory tests show that the San Mateo sand will not liquify even under high pore pressures, so it was assumed that the effects of the postulated high pore pressures would be to decrease the stiffness of the San Mateo sand. The size of the zone of decreased stiffness was calculated, and its dynamic capacity was conservatively reduced in calculations of structural earthquake response in

translation and rocking. The results of these calculations are set forth in a document entitled "Summary of Maximum Effects of Cavities on Structures," which is attached hereto as Exhibit C (Reference No. 37) and incorporated herein by this reference. These results show a maximum effect of 8%, well within the ± 30% tolerance used for conservatism in the original structural analyses and design of SONGS 2 and 3. In my professional opinion, the foregoing assumptions and analyses for the dynamic effects, more fully described in the accompanying affidavit of John A. Barneich, are adequately conservative as a representation of the behavior of SONGS 2 and 3 structures and equipment in the event of Design Basis Earthquake.

14. During the period May, 1979 through August, 1977, I have been a member of a task force comprised of representatives from SCE, WCC, and Bechtel (hereafter the "Task Force"). Lucien Hersh of Bechtel was the chairman of the Task Force. The Task Force reported to Kenneth P. Baskin, Manager of Generation Engineering Services for SCE.

The sole purpose of the Task Force was to thoroughly investigate and demobilize the construction dewatering well system at SONGS 2 and 3 with the goal of providing assurance that all cavities with a potentially adverse effect on SONGS 2 and 3 structures and equipment were discovered, defined, and filled in such a way as to have no

unacceptable effect on SONGS 2 and 3 structures in the event of the Design Basis Earthquake.

I have personal knowledge of the Task Force's efforts. I have been directly involved with each of the Task Force programs for investigation and demobilization of this system and the decision-making process involved with the formulation and implementation of these programs. I have authored or reviewed all of the various reports which document the data produced and the results obtained by the Task Force. My hypothesis for the mechanism of subsurface cavity formation has been proven correct by the results of the extensive borings and excavation program conducted by Bechtel pursuant to conservative drilling and monitoring procedures I either recommended or concurred in. The results of the borings and seismic-cross hole investigative programs confirm that a total of five cavities were formed on the Site by the operation of Dewatering Wells 3, 5, 6, 7 and 8 due to the absence of filter gravel. These cavities were sand-filled, limited in areal extent, rather lobate in shape, and predominately located in the drawdown zones of these dewatering wells.

15. During the period November, 1977 through August, 1979, the Task Force held seven meetings with the NRC Staff. Two of these meetings which I attended included a site tour of the SONGS 2 and 3 construction dewatering

well system and were also attended by representatives of Intervenor Friends of the Earth, et al. The last of these meetings was held on August 10, 1979 and involved a comprehensive six-hour presentation of the steps taken by the Task Force to investigate and demobilize the SONGS 2 and 3 construction dewatering well system. At the above-mentioned meeting of August 10, I personally expressed my professional opinions to the NRC Staff which are reiterated herein.

16. In sum, based upon my direct involvement and supervision of the Task Force effort to investigate and demobilize the SONGS 2 and 3 construction dewatering well system, my extensive review of the documentation produced by these programs, (including, but not limited to the documents listed in the Project Reference List), and my review of the engineering references in Exhibit A, it is my professional opinion that all subsurface cavaties which could adversely effect Seismic Category I structures at SONGS 2 and 3 have been detected, defined and filled, and that these cavities can have no unacceptable adverse effect on

The capability of SONGS 2 and 3 structures and equipment to withstand the Design Basis Earthquake.

Robert L. McNeill

Subscribed and sworn to before me on June 4, 1980.

Mary K. Smith
NOTARY PUBLIC
For the County of Bernalillo,
State of New Mexico.

My Commission Expires:
MAY 29, 1983

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MECHANISMS OF CAVITY FORMATION

A-1 INTRODUCTION

The extent, size, and configuration of the cavities have been determined, and are presented in the text of this report. This appendix has been prepared to summarize the likely mechanisms of the formation of the cavities. The sections that follow discuss the mechanisms and present the results of piping tests performed in the laboratory.

A-2 DISCUSSION OF THE MECHANISM OF CAVITY FORMATION

The dewatering wells were designed to prevent subsurface erosion, if all components of the well remained intact: the louvers were sized to retain the filter gravel; and, the filter gravel was adequately graded to retain the native sand. It therefore appears likely that, for some of the wells, the components did not remain intact. The key component is the filter gravel: test data presented in Appendix D show that if the gravel were present and intact, erosion of the native sand would not occur. The filter gravel could be missing due to the following three causes: (1) arching in the annulus between the casing and the wellbore during placement of the gravel; (2) compaction and settlement of the gravel under the hydraulic gradient of the pumping; and/or (3) removal of the casing through corrosion. There are no records available to evaluate the likelihood of causes (1) and (2). Some of the casings on the landward side of the site were found to be corroded when inspected by television or when pulled from the ground. It is possible that a seawater/freshwater interface could have caused corrosion of some of the casings, or that galvanic current could have been generated by the dissimilar casing and weld metals (the welds on the recovered casing on the landward side were seriously corroded). Though the largest

cavities were encountered at well locations where casing corrosion was significant (Wells 6, 7 and 8), a small cavity was also found at Well 3 where the well casing was found to be relatively unaffected by corrosion, indicating that causes (1) and/or (2) may have been contributory to the forming of a cavity at this well. Thus it is not possible to state definitively which of causes (1), (2) or (3), or what combination of them, may be responsible for the absence of the gravel. The discussion that follows describes a mechanism consistent with site conditions and the laboratory piping tests discussed in Section A-3.

The flow field around a well is sketched in Figure A-1, along with some approximate dimensions for these wells. The flow net shown depicts the intensity of the hydraulic gradient: where the mesh is closely spaced, the hydraulic gradient is expected to be high. The gradient could also be locally high in the uniform flow zone if there is a perturbation in the smooth wall of the well, as shown in Figure A-2: the flow line can concentrate at the peturbation, to cause a locally high gradient. If that local gradient is sufficiently high, and if the filter gravel is absent, then erosion can start at the perturbation, and propagate from that point, as shown on Figure A-3.

It is expected that the erosion feature of Figure A-3 will propagate until the gradient at the end, point a, diminishes to less than the value which will erode the soil in question. For the native sands, which have cohesion due to their gradation and efficient packing, the gradient which will erode them is probably much greater than for truly cohesionless sands. This is supported by the observation that the native sands stand in near-vertical cliffs 100 ft high and vertical cuts have been noted to stand vertically underwater. Thus, subsurface erosion features in the native sand are expected to have a limiting stable size. The erosion feature is not, however, expected to

propagate as a cylinder. Instead, because the gradient in the roof of the hole (e.g., point b), can also exceed the critical gradient, the roof is expected also to erode. The infill sand will probably be partially removed by erosion in the absence of a gravel filter, leaving a sloping wedge of infill sand within the erosion feature, as shown in the upper left sketch of Figure A-4. Because the permeabilities of the native and the infill sands are not grossly dissimilar (permeability of infill sand is about 0.1 cm/sec compared to 0.015 cm/sec for the native sand; see Appendix D), the flow for this condition can be estimated from the rough sketch presented in the upper-right of Figure A-4; This flow is expected to lead to further erosion at the end and upper part of the erosion hole until it reaches a size such that the gradient at that eroding end is less than the critical gradient. This then is the hypothesized configuration of the erosion cavities likely to develop adjacent to dewatering wells in sand.

Based on these considerations, it is expected that the cavities formed will be rather lobate, as shown in the lower-right sketch of Figure A-4, and they will have a finite stable size. Similar considerations also lead to the expectation that the cavities would be tabular in the vertical direction. The effect described would be expected to be most severe in the upper drawdown zone, where the gradients are likely to be most severe (see Figure A-5). In addition, in the drawdown zone, the cavity is subjected to wetting and dewatering as the well goes through pumping cycles. The effect of this is to further pull down the roof, accentuating the effects described above. Because the native San Mateo sand is very dense (mean dry density of 123 pcf) and because the infill sand will achieve a lower density (estimated maximum dry density of 105 pcf consistent with a relative density of between 50 and 60%), it is expected that 15 to 20% bulking will be associated with the above described phenomenon. Therefore, it is expected that the stabilized cavity will be full

or nearly full of infill sand. This expectation has been corroborated by observations during the field investigations.

Some of the cavity sand is removed during pumping. Because the louvered section starts at about Elev. -60 ft and the most likely location of cavity formation is in the drawdown zone, the cavity should develop a funnel-shape at the base, as shown in Figure A-5. The cavity, therefore, is expected narrow to about the well diameter below the drawdown zone where gradients become small.

A-3 PIPING TEST RESULTS

To simulate the initiation and progression of piping in San Mateo sand, laboratory tests were conducted on a hand-carved block sample of San Mateo sand. Two oblong thumb-like cavities were created in the sample by using a minute air nozzle to blow the sand from the block at the desired locations. One of the cavities was located near the center of the sample and the other at one edge of the sample. The sample, with a layer of glass beads at the inlet and outlet ends, was cast in resin inside a lucite cylinder to provide confinement and to prevent disintegration during saturation. Penetration of the resin was prevented by a cellophane wrap around the sample.

A photograph of the laboratory setup and a sketch describing the apparatus is presented in Figure A-6. Because the resin, the glass beads, and the lucite containers are all transparent, the laboratory apparatus provided a visual observation of the sample throughout the test.

Three tests were run on the sample as follows:

1. The two cavities were plugged with inflated bladders to simulate San Mateo sand without cavities; the inlet water pressure was gradually increased to about 18 psi (about 35 minutes).

2. Same as (1) above, except that the inlet pressure was raised relatively quickly to about 15 psi (5 minutes).

3. The bladders were omitted; the inlet pressure was increased relatively quickly to about 12 psi (5 minutes).

The results of the three tests described above are presented in Figures A-7 and A-8. Two additional tests were run, Nos. 4 and 5, to observe the effect of partial and total removal of glass beads. The observations during these tests provided an estimate of what might happen if there were no gravel packing around the well screens.

During Test No. 1 some of the fines in the San Mateo sand appear to have been washed out: the permeability of the sample increased from 0.13 to 0.24 cm/sec. This is similar to the development stage of well pumping, when some turbidity is expected in the pumped water. The sample remained stable during Test No. 2. The bladders were removed and Test No. 3 was conducted. During this test, sand particles were seen being dislodged and transported from the cavity surface into the cavity. A slight upward progression of the cavity was noted. However, a stable mode was soon reached and the sample remained essentially the same during the remainder of the test when the inlet pressures were increased to as much as 15 psi.

To simulate the condition of pump shutdown and restarting, the laboratory sample was allowed to free-drain by decreasing the gradient and then restarting the flow. Minor but discernable amounts of sand were dislodged from the cavity walls during this hydraulic cycling process.

Next the glass beads were removed from the discharge end of the apparatus to simulate total absence of gravel pack adjacent to the dewatering well screen. Minor scaling and surface

degradation was observed, but an equilibrium was reached when no further material was seen being dislodged.

The observations from the above tests lead to the following conclusions:

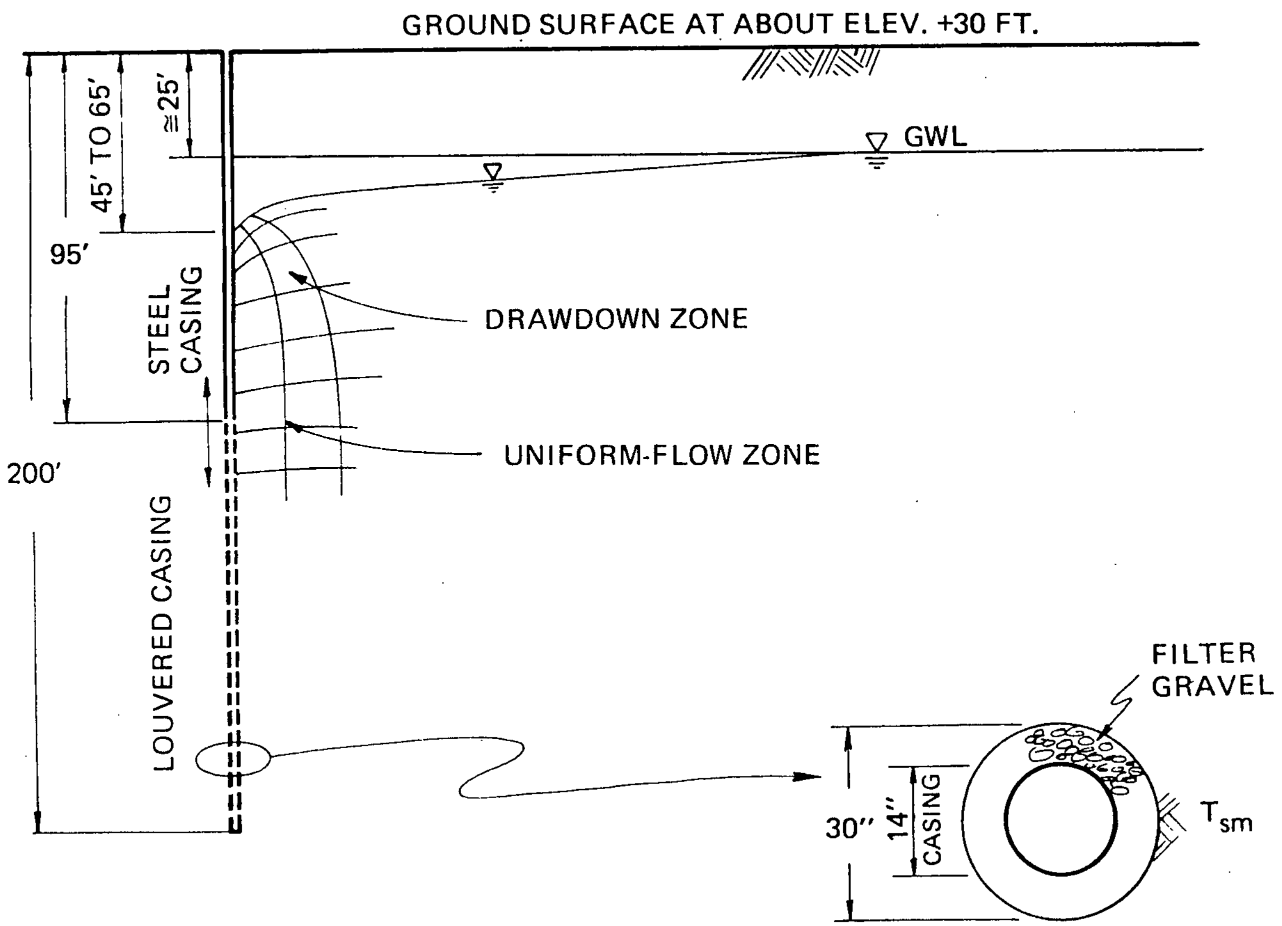
1. Cavity formation is not possible if the gravel pack is in place.

2. A trigger mechanism, such as a missing gravel pack, initiates the loss of sand and starts the cavity formation process.

3. Discernable amounts of sand are dislodged from the cavity walls during each hydraulic cycling event.

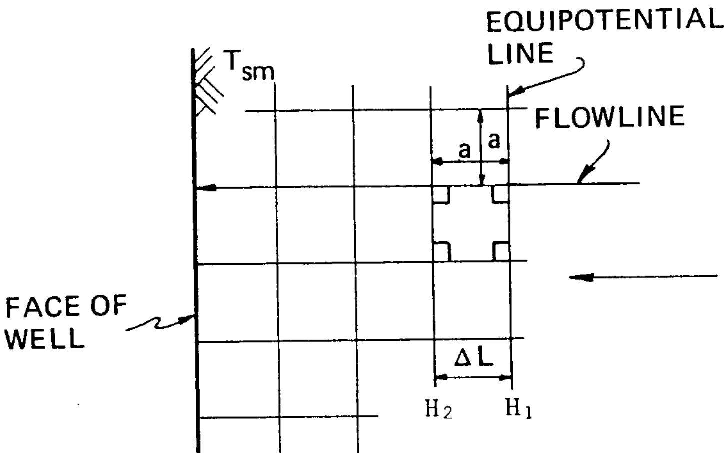
4. The simulated cavities in the laboratory always stablized and, for the flow rates and gradients applied, no contiguous pipe developed through the sample.

These results are consistent with and support the hypothesized mechanism of cavity formation described in Section A-2 above.



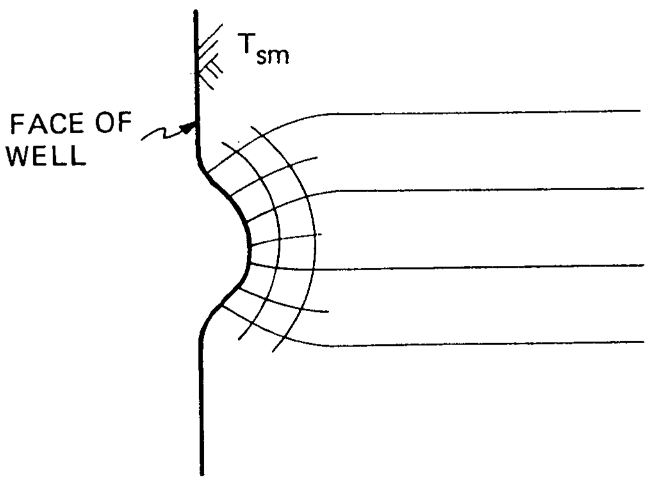
Project: SONGS 2 & 3 Project No. 411301	TYPICAL DEWATERING WELL AND FLOW FIELD DURING OPERATION (SCHEMATIC)	Fig. A-1

WOODWARD-CLYDE CONSULTANTS



$$i = \frac{\Delta H}{\Delta L} = \frac{H_1 - H_2}{\Delta L} = \text{HYDRAULIC GRADIENT}$$

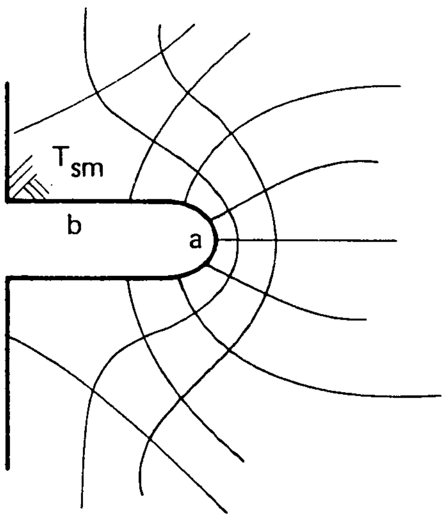
a) UNIFORM WELL FACE



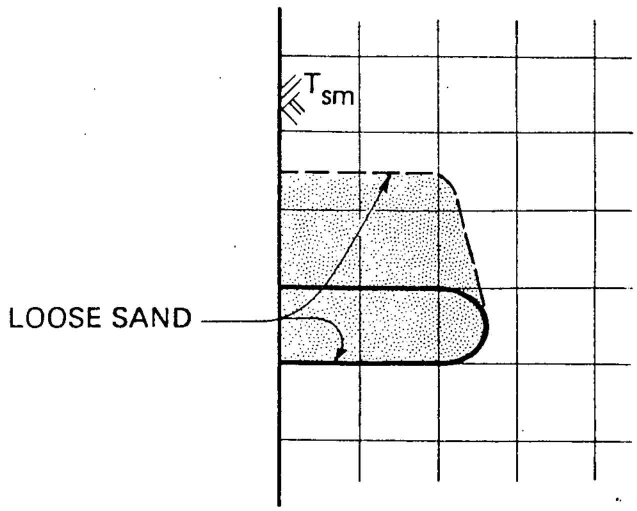
b) INITIAL PERTURBATION AT WELL FACE

Project:	SONGS 2 & 3	SCHEMATIC PRESENTATION OF FLOW FIELDS AT THE WELL FACE	Fig. A-2
Project No.	411301		

WOODWARD–CLYDE CONSULTANTS



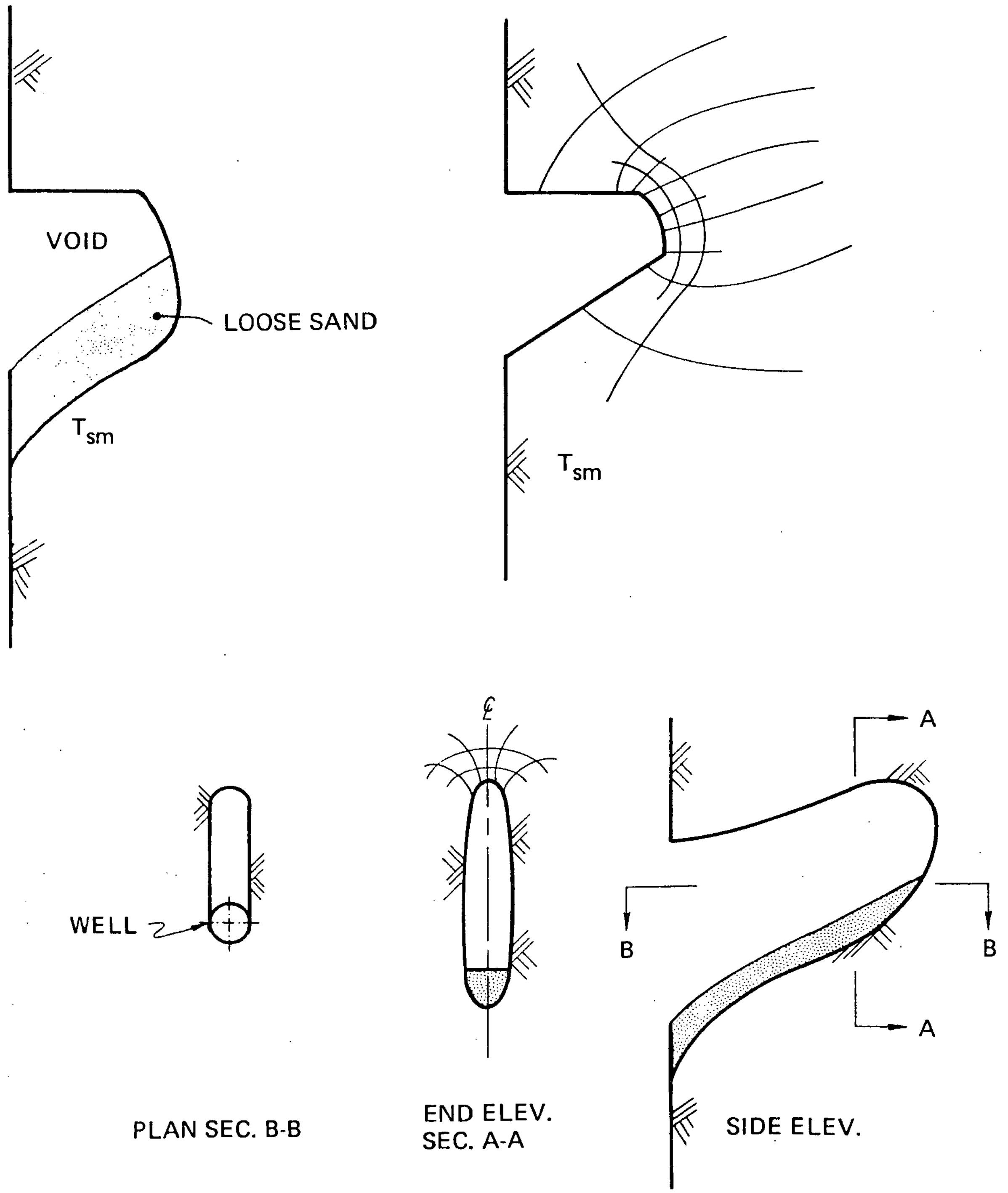
a) IDEALIZED PIPING



b) PROBABLE CAVITY FORMATION

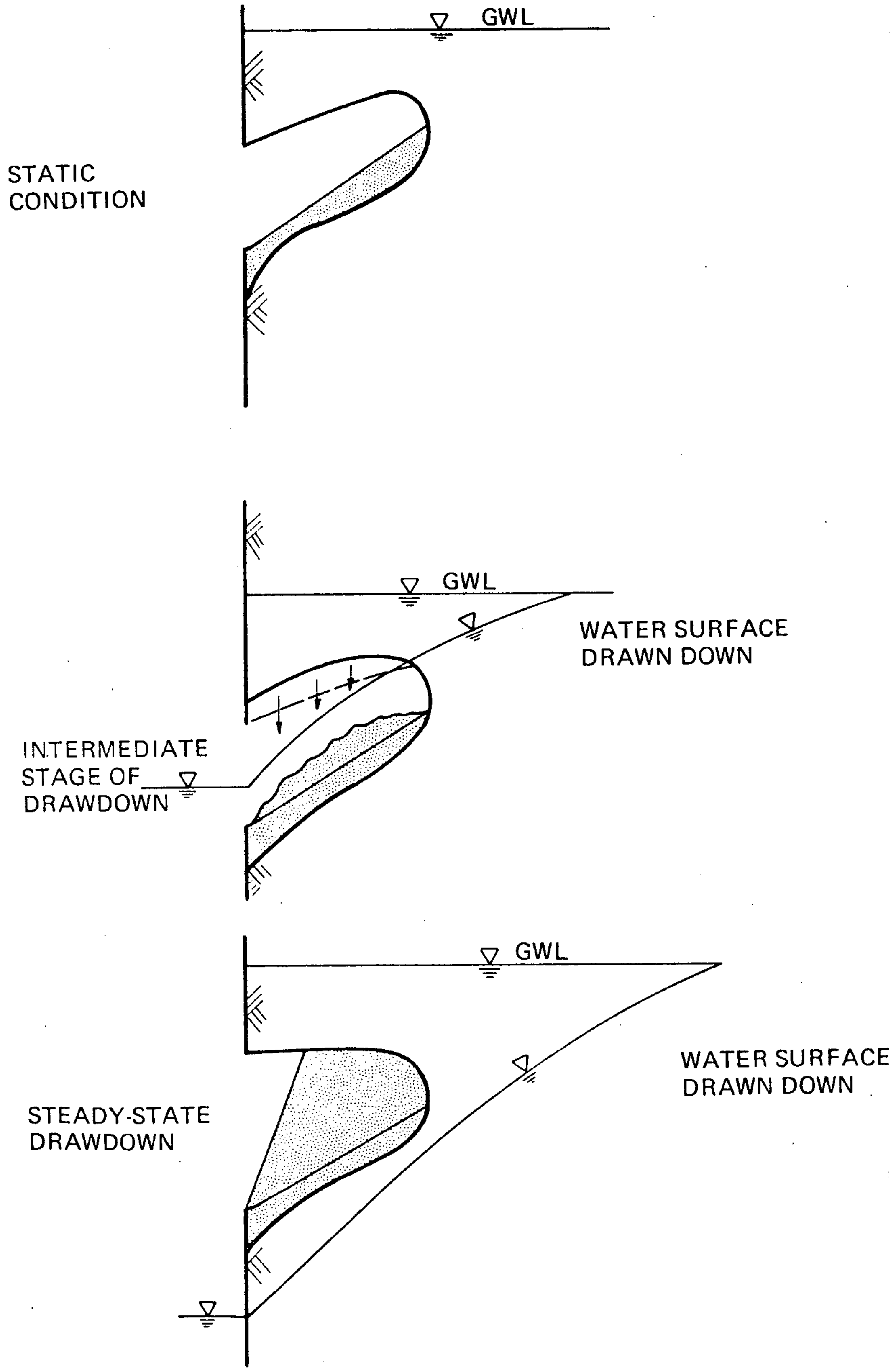
Project: SONGS 2 & 3 Project No. 411301	INITIAL PROGRESSION OF EROSION FEATURE	Fig. A-3

WOODWARD–CLYDE CONSULTANTS



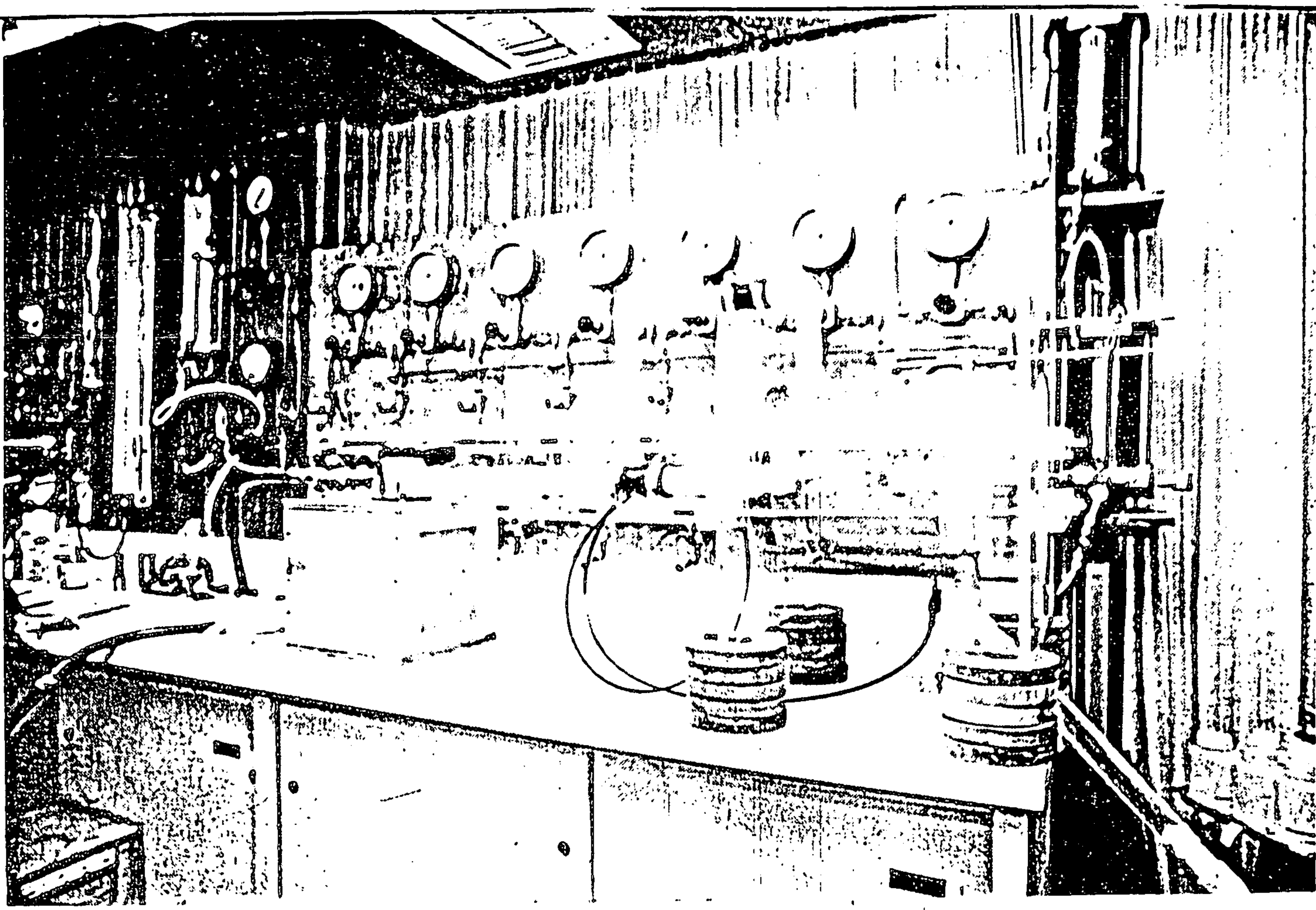
Project:	SONGS 2 & 3	LIKELY FINAL DEVELOPMENT OF EROSION FEATURE	Fig. A-4
Project No.	411301		

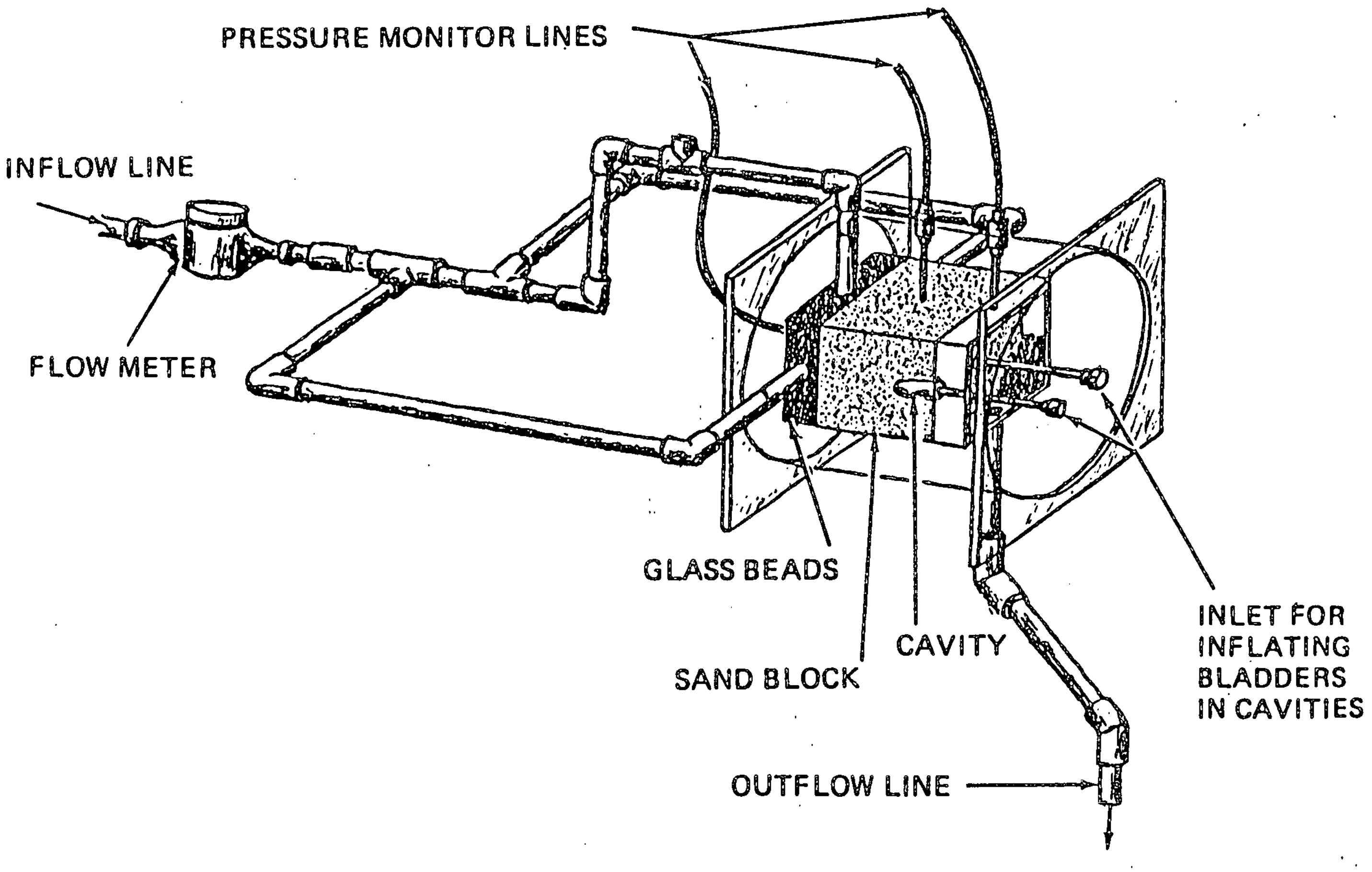
WOODWARD-CLYDE CONSULTANTS



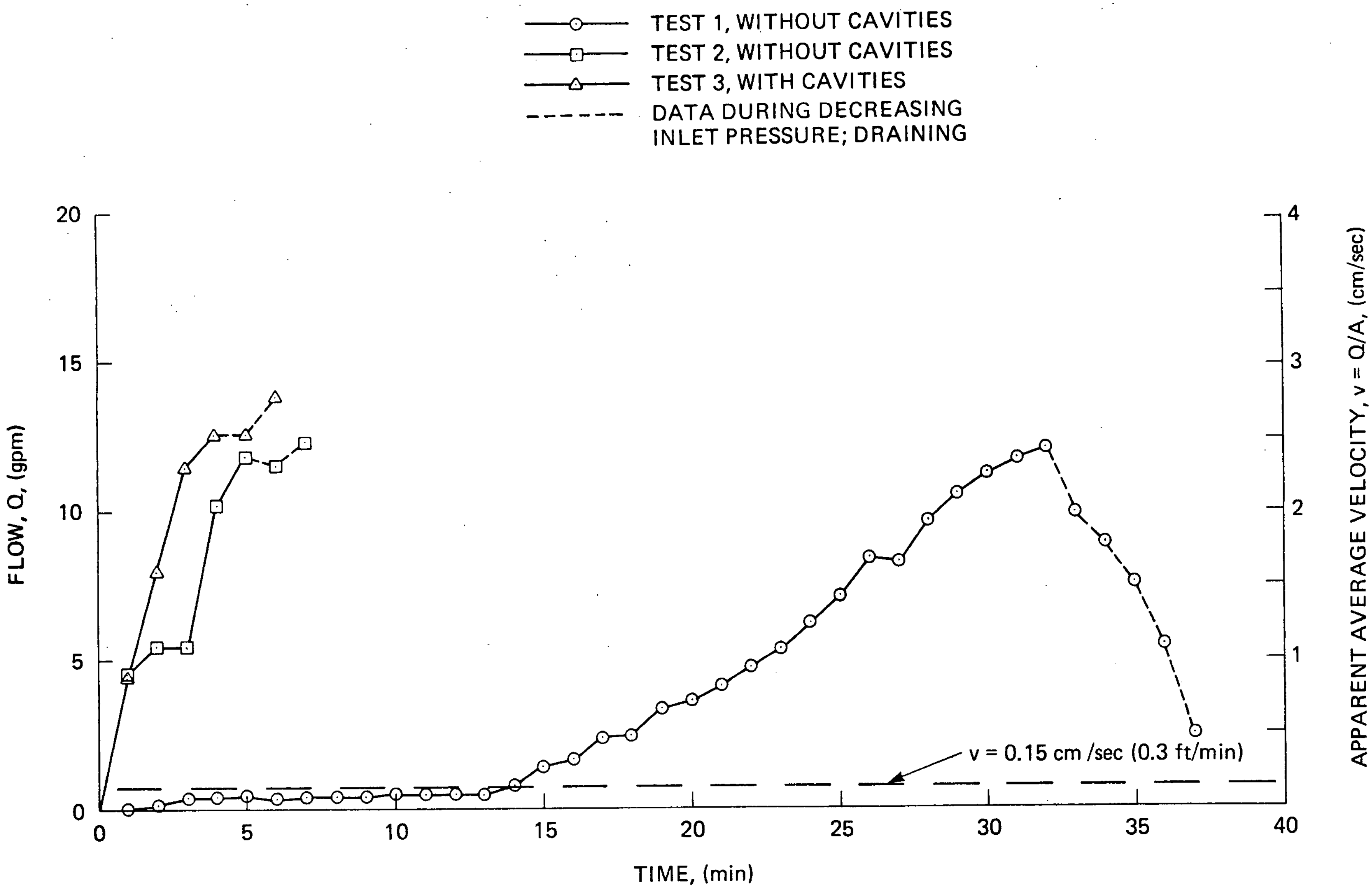
Project:	SONGS 2 & 3	LIKELY CONFIGURATION OF CAVITY	Fig. A-5
Project No.	411301		

WOODWARD–CLYDE CONSULTANTS



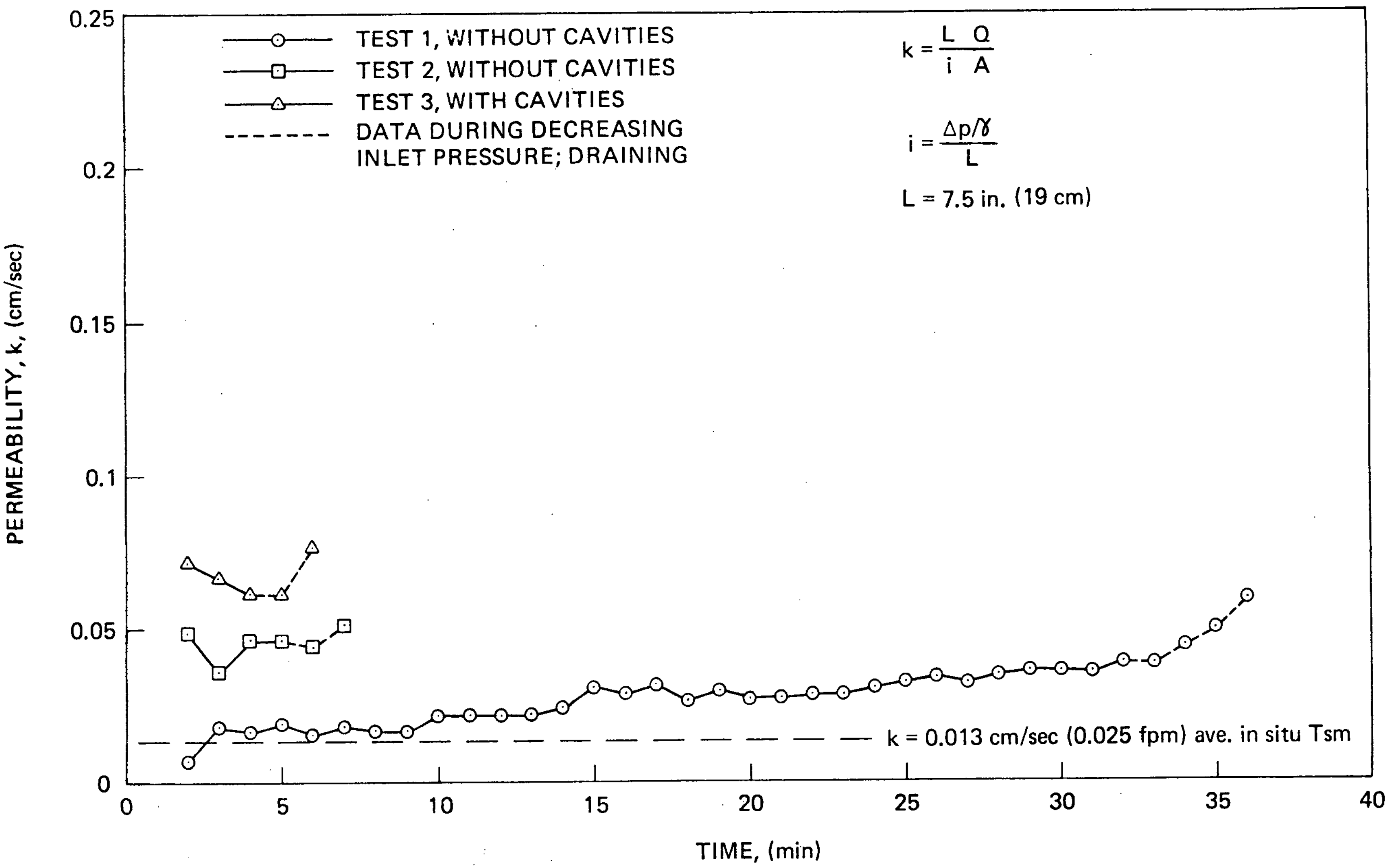


Project:	SONGS 2 & 3	LABORATORY APPARATUS TO STUDY INITIATION AND PROGRESSION OF PIPING	Fig.
Project No.	411301		A-6



Project: SONGS 2 & 3 Project No. 411301	TIME VARIATION OF MEASURED FLOWRATE AND AVERAGE VELOCITY	Fig. A-7

WOODWARD-CLYDE CONSULTANTS



Project: SONGS 2 & 3 Project No. 411301	TIME VARIATION OF PERMEABILITY OF SAN MATEO SAND	Fig. A-8

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SUMMARY OF MAXIMUM EFFECTS OF CAVITIES ON STRUCTURES

Structure	Well No.	Maximum Decrease of Dynamic Stiffness* (percent)		Maximum Increase in Settlement of Structure (percent)	
		Translation	Rocking	Total Vertical	Differential
Containment Unit 3	8	4	5	4	5
Auxiliary Units 2 and 3	6,7	2	2	2	2
Fuel Handling Unit 2	6	<1	3	<1	3
Fuel Handling Unit 3	7,8	<1	8	<1	8

* Affecting dynamic response of the structure during earthquake shaking.

EXHIBIT C (REFERENCE 37)