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Decision 82 10 022 OCT 6 1982

ORIGINAL

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Investigation on the Commission's own motion into the matter of the adoption of regulations governing the safety and construction of a liquefied natural gas terminal in the State of California.	OII 1 (Filed October 18, 1977)
In the Matter of the Application of Western LNG Terminal Associates, a general partnership, and of a Joint Application of Western LNG Terminal Associates, Pacific Gas and Electric Company and Pacific Lighting Service Company, California corporations, for a permit authorizing the construction and operation of an LNG terminal pursuant to Section 5550 et sec, of the Public Utilities Code.	Application 57626 (Filed October 14, 1977)
In the Matter of the Application of PACIFIC GAS and ELECTRIC COMPANY, AND PACIFIC LIGHTING SERVICE COMPANY, California corporations, for a Certificate that Public Convenience and Necessity require the construction, operation, and maintenance of a 34" Pipeline from the Point Conception area, Santa Barbara County, California to Gosford, Kern County, California, and related facilities.	Application 57792 (Filed January 9, 1978)
Investigation on the Commission's own motion into the impact of the decline in natural gas available to California from traditional sources and the need for and timing of deliveries from supplemental supply projects.	Case 10342 (Filed June 1, 1977; amended August 23, 1977)

I N D E X

(See Decisions 89177, 90372, and 92552 for appearances.)

SEISMIC OPINION

Summary

By this decision the Commission finds that the site proposed for a liquefied natural gas (LNG) terminal at Little Cojo Bay near Point Conception, Santa Barbara County, is seismically and geologically suitable for the construction and operation of such a terminal.

The Commission orders that the design and construction of such a terminal shall be consistent with provisions adopted in this decision.

The Commission concludes that the employment of a panel of experts to conduct the initial review of the seismic evidence considered in the decision was a proper procedure and adopts most of the findings of the panel.

The Commission finds that reliability of public utility service and the maintenance of the financial integrity of utility investment, in addition to public safety considerations, should be factors, and the seismic, geologic, and engineering design criteria adopted here are consistent with all three concepts.

The Commission's Executive Director is instructed to formulate a proposal for the establishment of a technical advisory committee to assist the Commission in carrying out its responsibilities in connection with the design and construction of the LNG terminal in accordance with the criteria established by this decision.

The large trenches dug at the terminal site to identify faulting, which are offensive to the religious beliefs of a group of Native Americans, are ordered to be closed and the land surface is to be restored to its original condition as required by the Phase I Archeological Plan.

The seismic phase of the proceeding is concluded.

Recent Procedural History

By Decision (D.) 89177 dated July 31, 1978, the Commission granted a conditional permit to Western LNG Terminal Associates (Western Terminal) authorizing Western Terminal to construct and operate an LNG terminal at Little Cojo Bay, about three miles east of Point Conception, in Santa Barbara County.

The Commission was charged by the Liquefied Natural Gas Terminal Act of 1977, Chapter 10, Division 2 of the Public Utilities (PU) Code (LNG Act) with the responsibility for issuing a decision on an application filed for a permit to construct and operate an LNG terminal. Construction and operation of an LNG terminal in California without obtaining a permit was prohibited. The issuance of a permit by the Commission was declared to be

> "...in lieu of any other permit, license, certificate, or other entitlement for use required by any agency of state or local government for the construction or operation of an LNG terminal, to the extent permitted by federal statute or regulation of any federal-state agreement relating to water discharge permits. . . ." (PU Code § 5581.)

PU Code § 5632 directed that:

> "The commission shall not issue a permit for construction and operation at any site unless it finds to do so is consistent with public health, safety, and welfare and may impose such conditions on the issuance of a permit as may be necessary or appropriate to ensure the public health, safety, and welfare."

Acting according to § 5632, the Commission attached 41 conditions to the permit granted by D.89177.

This decision concerns Condition 36, Geological and Geotechnical Investigations, and Condition 37, Subsurface Exploration.

During the investigations preceding the issuance of D.89177, it was shown that the Little Cojo Bay site was located near a number of geologic faults that could constitute seismic risks to the proposed LNG facility. One fault, the Arroyo Fault,[1] was discovered within the boundaries of the site. The Commission concluded in D.89177, on the basis of then currently available data, that the Arroyo Fault exhibited 1-1/2 to 2-1/2 feet of displacement, its latest mapped movement occurring between 5,000 and 8,000 years ago.

Evidence of the Arroyo Fault's existence was first submitted to the Commission on April 28, 1978. The Commission's Executive Director immediately requested Western Terminal to undertake geological and geotechnical[2] investigations, including trenching, respecting the Arroyo Fault. Subsequently, on June 16, 1978 the assigned Administrative Law Judge (ALJ) John J. Doran issued an order directing Western Terminal to conduct further geological investigations to determine the significance of the Arroyo Fault and also of other identified geological anomalies.

The LNG Act required the Commission to issue its decision on the permit application by July 31, 1978. Although on-site excavation and trenching commenced promptly after the Executive Director's request, the evidence necessary for a definitive disposition of the seismic safety issues could not possibly be developed by the July 31 deadline so the Commission's order in D.89177 reserved a determination of the question by prescribing Conditions 36 and 37, as follows:

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[1] The Arroyo Fault was originally designated the "Arroyo Central" Fault because it was discovered in the gully known as the Arroyo Central.

[2] The term "geotechnical" as used in this proceeding was understood as applying to soil creep, landslides, flooding, erosion, and liquefaction during an earthquake.

"36. Geological and Geotechnical Investigations

"Condition:

"Western Terminal shall undertake the further geological and geotechnical investigations outlined in ALJ Doran's June 16, 1978, order to Western Terminal. At a minimum, additional trenching to the east and west side of Arroyo Central is required to further evaluate the significance of the fault identified as the Arroyo Fault. Additionally, two trenches on seismic line 'C' as shown on Plate 1.DC of Exhibit O-106 are required to analyze the significance of geological anomalies identified to the north of Arroyo Central. Any further trenching and investigation, as required, will be the subject of future Commission directives.

"37. Subsurface Exploration

"Condition:

"Due to the recognition of secondary faults within the site, e.g. Arroyo fault, Beach fault, if subsequent investigation confirms the site's suitability, Western Terminal is directed to undertake detailed subsurface exploration to insure that no critical LNG component will be located within the distance of 100 feet (30 m.) from any fault trace."

Ordering Paragraph 16 of D.89177 provided for further hearings in the LNG proceedings to consider, together with other unresolved issues, the additional seismic evidence required by Conditions 36 and 37. Hearings were held on other loose ends of the proceeding and they were tied up by D.90372 dated June 5, 1979, and D.92552 dated December 30, 1980, leaving only Conditions 36 and 37 requiring disposition.

Panel Procedures

The firm of Dames and Moore had been retained by Western Terminal to perform geological studies in support of Western Terminal's original permit application. Western Terminal therefore commissioned Dames and Moore to conduct the further investigations required by Conditions 36 and 37.

As the investigations proceeded, they revealed the existence of other faults within the proposed terminal area. The Commission realized that the interpretation of these faults, their relationship to one another, and determination of the risk they would present to safe and reliable construction and operation of an LNG terminal would require the resolution of highly technical and complex geologic, seismic, and structural issues. It was obvious that the various parties in these proceedings would be presenting a broad range of interpretations and recommendations on these issues.

In the first phase of these proceedings, leading to D.89177, the California Coastal Commission (CCC) had proposed that Western Terminal fund the operation of two independent terminal design and construction review panels to assure that the geological hazards be thoroughly quantified, that the construction drawings and calculations be thoroughly reviewed, and that construction be inspected. The geological hazards panel would be comprised of seven experts, including two seismologists, two engineering geologists, two geotechnical engineers, and a structural engineer.

The structural panel would be comprised of seven experts, including two structural engineers, one geotechnical engineer, one engineering geologist, one mechanical engineer, one electrical engineer, and one engineer expert in fire protection and safety engineering. The members of each panel were to be appointed as

follows: two each by the Public Utilities Commission, CCC, and Division of Mines and Geology, and one by the Seismic Safety Commission. The geological hazards panel was to provide Western Terminal, the Public Utilities Commission, and the structural panel with its best judgment on the character of the geotechnical hazards that might affect the terminal. The structural panel was to make recommendations to Western Terminal and the Public Utilities Commission on any modifications to Western Terminal's proposed terminal design. configuration, and construction and operation methods that the panel felt, in its best judgment, would minimize risks to life and property from geologic hazards.

Although this Commission rejected, in D.89177, the CCC's proposals for expert panels, the seed had been planted. The Commission expressed informally to the staff a desire to create a seismic review panel composed of highly qualified geological, seismic, geotechnical, and structural experts to advise the Commission. The staff agreed that such an advisory panel was necessary and proceeded with the development of such a panel.

The first task undertaken by staff was to define the scope of review for the panel. In order to assure an unbiased panel review, staff believed the panel should be able to review the entire evidentiary record in these proceedings, and if necessary, critique the geologic, seismic, and structural findings and conclusions of the pertinent Commission LNG decisions. The scope of the panel investigation, moreover, should set forth general areas of panel inquiry to assure the panel the breadth to delve into areas it deemed necessary in order to resolve the seismic issues put before it. The staff, therefore, believed that the panel, after review of the pertinent geologic, seismic, and engineering evidence, should submit to the Commission its answers to the following questions:

1. What are the seismic hazards associated with the construction of an LNG terminal at Little Cojo Bay, including an analysis of the maximum credible earthquake which would produce the greatest ground shaking and surface faulting at the site? This analysis should be based upon the maximum earthquake (or earthquakes) that can be postulated to be capable of occurring under the presently known tectonic framework of the site. The postulated earthquake should be a rational and believable event that is in accord with all the known geologic and seismic data about the site.

2. Taking into account the answer to question 1 above, and also taking into account the state of the art of engineering design and construction of large installations in active seismic areas, can an LNG system - especially those structures, components, and systems which perform vital safety-related functions, such as LNG storage containers, their impounding systems, and hazard protection systems - be designed and built to safely withstand a maximum credible earthquake?

3. If the answer to question 2 should be yes, what engineering criteria should be established for the design of the proposed LNG terminal?

The staff believed that the panel should be composed of experts in the fields of engineering geology, seismology, geotechnical engineering, and structural engineering.

An engineering geologist would be needed to evaluate the engineering geology reports and mappings pertaining to local and regional geologic settings, stratification, schistosity, features, evidences, and influences of earthquake faults and dating within the

site and in the vicinity of the site. A seismologist would be required to analyze reports of the location of faults and displacements, fault classification, estimated earthquake recurrence intervals, seismic wave propagation, seismic acceleration, attentuation through geologic settings, and the estimated maximum seismic activity that might ultimately affect the site.

A geotechnical engineer would evaluate the evidence on overall site geology, cavernous rocks, soil conditions, potential for liquefaction, landslides, ground subsidence, slope stability, propagation of earthquake-induced motions through underlying deposits, and other seismically related hazards. The geotechnical specialist would also analyze the parameters of bearing capacity of foundation materials, shear failure, settlement of foundations, and tilting of structures.

The structural engineers would use the geologic and seismic evidence to evaluate horizontal and vertical response spectra together with critical damping ratio of structures, and to evaluate dynamic analyses of structures, soil-structure interaction, liquid-structure interaction, etc., to establish design criteria for the structures.

The process of selecting a list of recommended panel members began with discussions with the staff of the CCC and the Department of Water Resources, the State Geologist, Public Utilities Commission consultants, and other scientists. From these discussions, the staff compiled a list of nearly 40 qualified engineering geologists, seismologists, geotechnical engineers, and structural engineers. Upon completion of the list, the staff contacted those structural engineers, engineering geologists, and the geotechnical engineers who seemed to be held in highest esteem by their colleagues. Staff sought the input of these individuals on the composition of the panel and ascertained their availability to serve on the panel.

The Commission had no history of using an advisory panel of this nature. It was necessary, therefore, to adopt procedures to integrate the functioning of the panel within the traditional Commission hearing process. There were various procedures the Commission could adopt to achieve this end, but the staff advised that the primary focus should be on due process considerations. The staff, therefore, recommended that the Commission direct the Executive Director to prepare, and to submit to all parties for comment, proposed procedures for integrating the functioning of the panel into the Commission's decision-making process. All parties would be given 21 days to comment on these proposed procedures, and the Executive Director would be authorized to adopt final procedures.

The staff recommended the following panel to the Commission:

Name	Affiliation	Discipline
Clarence R. Allen, Ph.D.	Calif. Inst. of Technology	Engineering Geol.-Seismologist
Lloyd S. Cluff, CEG	Woodward-Clyde Associates	Engineering Geologist
Henry J. Degenkolb, P.E.	Degenkolb & Associates	Structural Engineer
Paul G. Jennings, Ph.D.	Calif. Inst. of Technology	Structural Engineer
Roy G. Johnston, P.E.	Brandow and Johnston Assoc.	Structural Engineer
H. Bolton Seed, Ph.D.	Univ. of California, Berkeley	Geotechnical Engineer

The Commission, by Resolution L-217 dated July 15, 1980, approved the establishment of a panel comprised of the persons recommended by the staff. Resolution L-217 directed the Commission's Executive Director to prepare proposed procedures for the panel and notify all of the interested parties of the Commission's intentions. On August 15, 1980, a staff coproject manager directed a letter transmitting the Executive Director's proposed procedures. Parties desiring to comment on the procedures were required to file their responses by September 15, 1980.

The panel procedures proposed by the Executive Director were patterned after a procedure found in the California Water Code. Section 2000 of the Water Code authorizes the Superior Court to refer a water appropriation suit to the State Water Resources Control Board (Board) for "advice." The report prepared by the Board becomes prima facie evidence of the facts reported (Water Code § 2019). These reports can be prepared ex parte or with hearings and testimony. Usually one person from the Board sponsors the report at the court trial and is subject to cross-examination on that report. The California Supreme Court has upheld this procedure, pointing out that parties cannot argue due process denials or denial of any constitutional rights since they are given, at the trial, an opportunity to be heard in opposition to the report and to introduce evidence contrary to the facts presented in the report. (City of Pasadena v City of Alhambra et al. (1949) 33 Cal 2d 908, 919. Followed in City of Pasadena v City of Alhambra et al. (1949) 33 Cal 2d 956. 957, cert. denied, 339 US 937, 94 L ed 1354.)

Similarly here the Commission referred the seismic, geologic, geotechnical, and structural engineering issues related to the siting of an LNG terminal at Little Cojo Bay to the LNG seismic panel for its advice.

The panel was charged with the conduct of workshops to review and analyze the reports, testimony, and arguments of the various parties in these proceedings. It was then to prepare a final report setting forth its "advice." This report would be introduced at a formal hearing; panel members would sponsor the report and would be subject to cross-examination. Parties would have an opportunity to present evidence in rebuttal to the panel's final report. The ALJ conducting the formal hearing would then prepare a decision draft for the Commission's consideration.

Four parties filed comments on the proposed LNG seismic panel review procedures: The Fred H. Bixby Ranch Company (Bixby Ranch), Hollister Ranch Owners' Association (Hollister Ranch),[3] Sierra Club, and Western Terminal. In general, the comments contended that the proposed panel procedures deprived the parties of their right to due process.

In response to the comments, the staff prepared a recommended final version of the panel procedures. By Resolution L-218 dated November 18, 1980, the Commission adopted the recommended final version.

Dr. Seed's participation as a panel member was challenged by Hollister Ranch in a January 5, 1981 motion. Although his continued participation was supported by the staff, Dr. Seed resigned from the panel and recommended that he be replaced by Izzat M. Idriss, Ph.D. Acting upon the recommendation of the other panel members and the staff, the Commission, by Resolution L-220 dated February 18, 1981, appointed Dr. Idriss to the panel.

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[3] The Bixby Ranch is adjacent to the site on the west. The Hollister Ranch is a ranchette-type real estate development bounding the site on the north and east (the south boundary being the Santa Barbara Channel of the Pacific Ocean).

Data Input to Panel

Copies of the adopted LNG Seismic Panel Procedures were mailed to all parties on November 24, 1980. On December 22, 1980, the Executive Director notified the parties that public hearings would be held in San Francisco on January 29 and 30, 1981, to receive direct testimony and reports or oral presentations on the geologic, seismic, geotechnical, and structural issues in accordance with the panel procedures. Western Terminal had submitted its evidence on October 31, 1980. This filing was in compliance with Conditions 36 and 37 of D.89177. Evidence from other parties was due January 19, 1981.

The January 29 and 30 hearings were held before ALJ James F. Haley. At that time the technical reports and expert testimony that the panel was charged with evaluating were received.

The work product of 21 experts was identified and received into evidence. Ten of the 21 were presented by Western Terminal and were associated with an eight-volume report entitled "Final Geoseismic Investigation, Proposed LNG Terminal, Little Cojo Bay, California, For Western LNG Terminal Associates," produced by Dames and Moore and submitted to Western Terminal on October 29, 1980 (and filed with the Commission on October 31, 1980). The staff presented four consultants and also sponsored the testimony of three experts from the California Division of Mines and Geology (CDMG). Hollister Ranch presented three witnesses and the Sierra Club one.

The expert witnesses were subjected to examination by the five panel members present (Dr. Seed being absent). Consistent with the adopted panel procedures, questioning of the experts was limited to panel members.

The Santa Barbara Indian Center and Hollister Ranch objected to the panel procedures, saying that they were deprived of an effective opportunity to cross-examine the technical witnesses.

Counsel for Hollister Ranch stated that his objection would "stand for all witnesses that appear before this Commission and before this panel, unless provision is ultimately made for such cross-examination." (Tr. 8538.)

After the technical evidence was formally placed in the record at the January hearings, the panel and the parties' experts proceeded to conduct the workshops. The table below shows the dates, locations, and subjects of those workshops:

Date	Location	
March 4, 1981	Los Angeles	Ground Motion
March 31, 1981 and April 1, 1981	San Francisco	Geology and Seismicity
April 14 & 15, 1981	Los Angeles	Structural Engineering
May 12, 1981	San Francisco	Geotechnical Engineering
June 25 & 26, 1981	Los Angeles	Geology and Seismicity
July 7 & 8, 1981	San Francisco	Concluding Workshops

Legal and procedural issues were not addressed at the workshops, but were, instead, considered at brief formal hearings conducted by ALJ Ealey immediately before each workshop session. The workshops were conducted in an informal manner, free of procedural objections and legalisms. No written transcripts were made of the workshop sessions; instead, when a consensus was reached among the panel members, or among the workshop participants, the panel recorded a summary on a tape recorder. The tape recordings were transcribed and transmitted to the parties by the staff coproject manager's letter of September 22, 1981.

At the workshops all participants were given an opportunity to present their views to the panel. They were permitted to refer to written material and maps. They also commented upon, and disagreed with, the positions taken by other workshop participants.

No workshop participant was denied a full opportunity to discuss and present his position. The panel chairman described the method by which the parties presented their positions at the workshops as follows:

> "The Panel asked all of the parties individually to summarize the most important conclusions and present the supporting arguments to support their conclusions and also to make reference to their agreements or disagreements with other participants in the workshops.
>
> "What we wanted to do was not spend a great deal of time focusing on unimportant issues, but to allow the participants of the workshops to help the Panel identify those issues that were most relevant and then find out the facts and various interpretations that relate to those issues so that we could address those important issues which are spelled out in the Panel's report." (Tr. vol. CH-2, page 59.)

In addition to the informal public workshops, the panel made several visits to the Little Cojo Bay site and inspected two operational east coast LNG terminal facilities. (Tr. vol. CH-1, page 57.) During the four months following the final workshop on June 8, 1981, the panel prepared its report based upon a review of the data presented at the public hearings and the workshops, as well as upon pertinent published literature and the collective expertise and experience of individual panel members. (Tr. vol. CH-1, pages 59-60.) The panel issued its report on November 9, 1981, and it was served on all parties and participants active in the seismic proceedings. As specified in our comments to Section 7.e. of the adopted LNG Seismic Panel Procedures, we intended the panel's report to become "the prima facie evidence of the physical facts therein found," and that unless the panel's findings were rebutted by subsequent testimony, cross-examination, or persuasion, we would rely on the panel's report to resolve the geologic, seismic, and

geotechnical issues surrounding Western Terminal's request for a permit to construct and operate an LNG terminal at Little Cojo Bay. We note that in reaching our findings and decision on the seismic issues of the Little Cojo Bay site we have not relied on this provision. In other words, we have not considered the panel's report as prima facie evidence, but simply as evidence considered in our decision-making process. We have aligned and balanced the panel's report, the responses to that report, and cross-examination that took place on the panel's report and the responses to that report. The findings we make are based upon those materials and reflect the clear preponderance of the evidence submitted in this proceeding.

Concurrent FERC-CPUC
Hearing Procedures

The Federal Energy Regulatory Commission (FERC) on October 12, 1979, issued an order granting applications to transport LNG from Alaska and Indonesia into California and to construct and operate an LNG terminal at the Little Cojo Bay site. On December 12, FERC issued an order on rehearing modifying and clarifying its previous order. Hollister Ranch, Bixby Ranch, and the Santa Barbara Indian Center petitioned for review of those orders in the United States Court of Appeals for the District of Columbia Circuit. On April 17, 1980, the court issued an order remanding the proceeding to FERC "in order to provide the Commission the opportunity to consider in the first instance new evidence presented by the U.S. Geological Survey Report and any other relevant new information."

The U.S. Geological Survey (USGS) report, referred to above, was "Open-File Report 80-299" by Yerkes and others. This open-file report was superseded by a final report entitled "Seismotectonic Setting of the Santa Barbara Channel Area, Southern California" and written by R. F. Yerkes, H. G. Greene, J. C. Tinsley, and D. R. Lajoie.

FERC, by an order issued March 2, 1981, remanded the proceedings to ALJ Samuel Z. Gordon for the purpose of holding hearings on evidence of seismic conditions at the Little Cojo Bay site that may be new and material. FERC specified that the evidence should include the geological reports and other new seismic information described by the petitioners in their motion to the court, as well as other evidence developed by the project sponsors during their seismic investigations. The sponsor of the LNG terminal project had a continuing obligation under the FERC orders to conduct seismic investigations at the Little Cojo Bay site, and to report to FERC on the status of these investigations.

FERC was aware that this Commission was engaged in proceedings considering essentially the same subjects. FERC sought to avoid the massive regulatory duplication that would otherwise be inevitable if the Commission and FERC were to hold simultaneous protracted proceedings to consider the same eight-volume seismic report submitted by the project sponsors to both agencies, as well as the USGS report and other data submitted in support of or in opposition to the project sponsors' conclusions. The FERC also had a strong desire to avail itself of the expertise of the LNG seismic review panel assembled by the Commission.

FERC wished to avoid the necessity for the same witnesses to travel back and forth across the country, presenting the same evidence on the same subject, and being cross-examined by the same parties. The FERC, ALJ, and the parties were requested to suggest procedures by which relevant portions of the Commission's record, including in particular the LNG seismic review panel's expertise, could be made a part of the FERC record in a manner that would be legally sufficient, fair to all interested parties, and efficient and convenient for all of the participants.

ALJ Gordon held a prehearing conference on March 11, 1981, and, advised in his report to FERC, that the most effective way to achieve the objectives of the March 2 order would be to hold concurrent hearings with the Commission on the phase of this Commission's proceedings in which the panel report is received in evidence, along with the testimony of sponsoring panel witnesses, cross-examination of the panel witnesses, rebuttal testimony to the report, and cross-examination on the rebuttal. At the prehearing conference ALJ Gordon directed the FERC counsel to arrange for a concurrent hearing, subject to the acceptance of his proposal by FERC.

ALJ Gordon's March 2 report, and a supplemental report issued March 19, 1981, presented two alternative methods to concurrent hearings, one method making use of depositions and the other the incorporation of the Commission's record on the panel report into the FERC proceedings by reference.

At the March 11 FERC prehearing conference views were expressed that § 1.37(e)(7)[4] of FERC's Rules of Practice and Procedure might stand in the way of the recommended concurrent hearing. ALJ Gordon did not believe this section should be a bar. Clearly, neither FERC nor the Commission was in a position of an advocate or litigant respecting the forthcoming panel report and the cross-examination and rebuttal evidence which might be adduced. Both Commissions were in the posture of seeking to adduce relevant facts and expert opinion evidence on these matters. That either or both Commissions may later, after their decisions are issued, be in the position of advocate or litigant should not be a bar to their holding a concurrent hearing at which such relevant facts and expert opinion evidence could be adduced, thus avoiding any further massive regulatory duplication. ALJ Gordon noted that massive regulatory duplication had occurred in the past since the proceedings leading to FERC's previous initial LNG decisions were largely paralleled by simultaneous or nearly simultaneous proceedings conducted before the Commission.

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[4] Section 1.37(e)(7) provides: Cooperation between two or more commissions in a concurrent hearing shall preclude either from taking the position of an advocate or a litigant. If a commission wishes to take such a position, it will not be appropriate for that commission to be a cooperating participant in that proceeding. In such situations the appropriate method of procedure will be intervention under § 1.8.

Bixby Ranch did not object to concurrent hearings, but opposed waiver of § 1.37(e)(7). Hollister Ranch adopted Bixby Ranch's comments, and expressed additional concerns that the panel procedures might curtail Hollister Ranch's right to cross-examine witnesses and that the Commission might be predisposed to accept the conclusions of the panel's report.

FERC, by an order issued April 28, 1981, adopted ALJ Gordon's recommendation for concurrent hearings before ALJ Gordon and a Commission counterpart. FERC waived § 1.37(e)(7) of its Rules of Practice and Procedure, and also § 1.37(e)(4)(v), to the extent necessary to hold a concurrent hearing and to manage it efficiently. FERC was concerned that § 1.37(e)(4)(v) might be misconstrued to require detailed technical compliance with FERC's hearing practices and procedures, even in situations where no party's federal statutory or constitutional rights would be infringed, by resort to modified procedures that might be mandated by California law or that might be more appropriate and efficient for concurrent hearings jointly managed by representatives of two sovereign independent commissions. In those circumstances, FERC felt that ALJ Gordon ought to have a legal flexibility to agree with his counterpart Commission presiding officer to the use of the most efficient hearing practices and procedures that are consistent with the respective legal mandates of applicable federal and California statutes and constitutional provisions. FERC contemplated that ALJ Gordon and his California counterpart would independently control the separate records being compiled for each commission, including separate and independent rulings on admissibility of evidence and separate and independent decisions on that evidence.

Inasmuch as the Commission had been in the posture of an advocate and litigant before FERC for several years in these proceedings, the practical effect of § 1.37(e)(7), absent a waiver, would be to preclude use of a concurrent hearing, resulting in the regulatory duplication FERC sought to avoid.

The Commission, desiring to cooperate with FERC in minimizing regulatory duplication, by Resolution L-223 dated August 18, 1981, agreed to conduct concurrent hearings and authorized ALJ Haley to work out the procedural details.

Concurrent Hearings and Record

This Commission, in accordance with FERC, held formal public hearings in Los Angeles on January 12 and 13, 1982, and on January 18, 1982, to receive into evidence the panel report and all additional reports or rebuttal evidence filed by the parties to these proceedings. ALJ Gordon presided for FERC and ALJ Parke L. Boneysteele represented this Commission's assigned presiding officer, Commissioner Richard D. Gravelle (In re Southern Pacific Transportation Company (1978) 83 CPUC 680, 684 f.n.).

The proceedings were submitted on January 18, 1982, subject to receipt of opening and reply briefs. Although the agreed concurrent hearing procedures provided for each agency's compiling its own record, the ALJs were in complete agreement on procedure and an identical record was compiled for both agencies. To distinguish the concurrent record, transcript volumes and exhibits were identified by the prefix "CH" for "concurrent hearings."

At the hearings, the panel report was received into evidence and the six-panel members were cross-examined by counsel for Hollister Ranch and examined by the ALJs. Two witnesses sponsored by Hollister Ranch testified, one of whom was subjected to very limited cross-examination by one of the project sponsors.

Counsel for Western Terminal moved that the entire FERC remand record be incorporated into this Commission's record of these

proceedings so that the FERC record could be made available to be used by the parties as they desire. This motion was granted by the Commission's ALJ.

Counsel for Hollister Ranch emphasized that his participation in the cross-examination of the panel was not a waiver of his earlier objection that the reports and testimony of the expert witnesses had not been subject to cross-examination. Finally, in his opening brief, Hollister Ranch's counsel reiterated that:

> "Hollister has consistently objected, both orally and in writing, to the admission of testimony without opportunity to cross-examine the sponsoring witnesses. The arguments will not be repeated here other than to note again that the proceedings are defective as a matter of procedural due process and that a full and proper hearing on these issues has been denied the parties."

Due Process Issue

Before proceeding to evaluate the evidence before us and to formulate a decision based upon that evidence, it is obvious that it is incumbent upon the Commission to consider and dispose of the question of whether the evidence is adequate and meets due process requirements, including, as well as constitutional requirements, those of PU Code § 1701 and Rule 64 of the Commission's Rules of Practice and Procedure.[5]

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[5] "1701. All hearings, investigations, and proceedings shall be governed by this part and by rules of practice and procedure adopted by the commission, and in the conduct thereof the technical rules of evidence need not be applied. No informality in any hearing, investigation, or proceeding or in the manner of taking testimony shall invalidate any order, decision or rule made, approved, or confirmed by the commission. (Former § 53.)" "64. (Rule 64) Form and Admissibility. Although technical rules of evidence ordinarily need not be applied in hearings before the Commission, substantial rights of the parties shall be preserved."

Earlier in this opinion the Commission has related the circumstances which led the Executive Director to propose, and the Commission to adopt, employment of the procedures available to the courts of this State to refer water right determination suits to the Board as referee. The legality and constitutionality of the use of this procedure by the courts is well-established as our earlier citation shows. Before undertaking the panel procedure, the Commission was convinced that, so long as the parties "were afforded full opportunity to be heard in opposition to the report as evidence, and to introduce evidence contrary to the facts appearing therein," they were not being deprived of any constitutional right. "Constitutional mandates are observed where such facts are not made incontrovertible and opportunity is given to refute them in court." (Fleming v Bennett (1941) 18 Cal 2d 518, 527.)

The only remaining question is whether the Commission regularly pursued its authority by referring the initial evaluation of seismic evidence to an expert panel.

It is settled that the Legislature has the power to prescribe that the report of a referee shall be prima facie evidence of the facts reported. (People v Buckley (1904) 143 Cal 375, 393; Miller & Lux, Inc., v Secara (1924) 193 Cal 755, 766; and Pacific Live Stock Co. v Lewis (1915) 241 US 454, 455 (36 Sup. Ct. 637, 60 L ed 1084, 1089).) It follows that, if the people of the State or the Legislature has properly delegated this power to the Commission, then the Commission has regularly pursued its authority by using the referee procedure.

Article XII of the Constitution of California establishes the Public Utilities Commission and provides the constitutional base for regulation of public utilities. Section 2 confers upon the Commission the power, subject to statute and due process, to

establish its own procedures. Section 5 gives the Legislature plenary power, unlimited by the other provisions of the Constitution, but consistent with Article XII, to confer additional authority and jurisdiction upon the Commission. The Legislature, acting under Article XII and its predecessor, has empowered the Commission, by PU Code § 1701, to adopt rules of procedure. By PU Code § 701, the Commission was authorized to do all things, whether specified in the applicable part of the PU Code or not, which are necessary and convenient in the exercise of the Commission's power and jurisdiction. Acting on the authority thus granted, the Commission decided, and proceeded, to implement the panel procedures used to resolve these proceedings.

It is thus abundantly clear that the adoption of the panel procedures rests on constitutional and statutory bedrock. The procedures were adopted after due notice and opportunity for comment, and after adequate consideration by the Commission; they provide for preservation of the substantial rights of the parties.

It could be argued, indeed, that failure by the Commission to devise a flexible and efficient method for evaluating the most complex issues in these proceedings would be cause for questioning and criticism. Academic critics fault the typical American regulatory commission for relying to an excessive extent on judicial procedures to accomplish its delegated legislative functions. They consider that these commissions have failed to develop techniques required for administering novel, experimental, and complex regulatory policies, regarding themselves instead as merely tribunals for the adjudication of disputes between private parties, rather than as aggressive promoters of the public interest.[6]

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[6] Marver H. Bernstein, Regulating Business by Independent Commission, Princeton University Press (1955), p. 29. Also see pages 28, 34, 61, 72, 89, 97, 101, 134, 174, 179-182, 192-195, 209, 210, 289, 290, 293, and 296. Irston R. Barnes, The Economics of Public Utility Regulation, F. S. Crofts & Co. (1942) pages 191-194.

The Commission is convinced that the employment of a panel procedure is a legal, sound, and practical method for evaluating the technical evidence available to the Commission in these proceedings. The LNG terminal siting process is clearly a legislative process and the Legislature has expressly, in PU Code § 5581, conferred upon the Commission legislative authority normally exercised by county planning commissions and boards of supervisors. Meticulous adherence to ancient judicial procedures was not intended, nor is it constitutionally required.

Having determined that the procedural methods are legal, proper, correct, and under the circumstances essential, the Commission shall proceed to examine the panel's report and the refutations and rebuttals.

Evidence - Panel Report and Rebuttal

Presentation of Panel Report

The panel's report consisted of two sections. The first section was a letter of transmittal which set out the panel's findings and conclusions and its recommendations to the Commission. The second section, the body of the report, consisted of 31 pages, divided into six chapters, as follows:

1.0 The LNG Seismic Review Panel
2.0 Seismic Geology and Seismicity
3.0 Ground Motion Characteristics
4.0 Geotechnical Considerations
5.0 Earthquake Engineering Considerations
6.0 Technical Review Board.

The letter of transmittal, which we interpret as part of the panel's report sets forth the following recommendations:

1. The panel agrees with D.89177 of July 31, 1978, wherein the Commission found that the strict application of NRC siting criteria to

LNG facilities is inappropriate. The panel recommends design earthquakes corresponding to levels of earthquake recurrence, and does not use the terms capable fault, maximum credible earthquake, operating-basis earthquake, and safe-shutdown earthquake, which are concepts developed for nuclear power plant siting.

2. The panel believes that a definition of fault capability based on a specified time criterion arbitrarily tends to classify a capable fault as dangerous and a fault that is not capable as safe. In particular, the panel believes that the time criterion of 100,000 to 140,000 years, as applied to the evaluation of seismic safety at this facility, is unduly conservative.

3. The panel recommends the likely maximum earthquake having a recurrence interval of hundreds of years, Level A, be used as a basis for design for continued, essentially uninterrupted operation of the facility.

4. The panel recommends the likely maximum earthquake having a recurrence interval of thousands of years, Level B, be used as a basis for design for seismic safety of Category I and Category II structures.

5. The panel recommends Level C earthquakes, those that have likely recurrence intervals of tens of thousands of years, not be considered.

6. The panel judges that likely maximum magnitudes for Level A earthquakes are 4-3/4 at 5 km, 5-1/2 at 12 km, 7 at 50 km, and 8-1/4 at 100 km.

7. The panel judges that likely maximum magnitudes for Level B earthquakes are 5-3/4 at 5 km, 6-1/2 at 12 km, including 12 km vertically beneath the site, and 8-1/4 at 100 km.

8. The panel believes the likelihood of surface fault displacements at the proposed tank site to be so low that the tank foundations need not be specially designed to accommodate surface faulting.

9. The panel recommends that the site faults outside the tank site that have evidence of displacements within the past few thousands of years be considered likely to experience surface faulting within the life of the facility; where it can be shown that materials a few thousands of years old are unfaulted, the panel recommends surface fault displacement not be considered in design.

10. The panel recommends that the design single-event displacement on recent site faults be 30 cm of vertical displacement, with 10 cm of strike slip, and a component of horizontal compression.

11. The panel has recommended design spectra to accommodate ground motions associated with Levels A, B, and C earthquakes. It is the intent of the panel that the recommended spectra for Levels A and B be used in the design process in the way in which applicant has proposed to use the operating-basis earthquake and the safe-shutdown earthquake. The Level C spectra are included only in case the Commission decides not to adopt the Level B earthquakes recommended by the panel.

12. The panel foresees no unusual geotechnical design problems posed by soil creep, landsliding, flooding, erosion, or liquefaction at the proposed site.

13. The panel has made specific recommendations on load factors, allowable stresses, permissible ductility, damping values, materials, and other parameters required for engineering design consistent with the earthquake levels recommended.

14. The panel recommends that the LNG tanks be placed on concrete mat foundations.

15. The panel recommends that an independent Technical Review Board be appointed by, and report to, the CPUC to oversee the engineering concepts and to monitor the adequacy of the design and design-checking

> process, and the quality control system. The panel also recommends this Technical Review Board be given the authority to arbitrate and resolve differences that may arise on whether proposed design or construction techniques carry out the intent of the safety regulations adopted for this facility.

The categories of structures referred to in the letter are those defined by the Commission's General Order (GO) 112-D, § 193.105(a) as follows:

> Category I: All structures, components, and systems which perform a vital safety-related function, including the LNG storage containers, their impounding systems, and hazard protection systems, shall be classified Category I.
>
> Category II: All structures, components, and systems not included in Category I which are required to maintain continued safe plant operation shall be classified Category II.
>
> Category III: All structures, components, and systems not included in Categories I and II, but which are essential for maintaining support of normal plant operations, shall be classified Category III.

The letter of transmittal was signed by all six panel members. All were in agreement and there was no minority report nor were there any reservations expressed by any of the panel members.

In drafting the report proper, the panel members assigned themselves primary responsibility for the chapters according to their fields of expertise. Mr. Cluff and Dr. Allen were the key participants in producing Chapter 2, Seismic Geology and Seismicity. Chapter 3, Ground Motion Characteristics, resulted from a combined effort by Drs. Jennings and Idriss. Dr. Idriss provided primary leadership for Chapter 4, Geotechnical Considerations, with assistance from Dr. Allen and Mr. Cluff. Earthquake Considerations,

Chapter 5 had, as its primary authors, the two construction engineers, Messrs. Degenkolb and Johnston, with participation of Drs. Jennings and Idriss.

Although the first drafts of the chapters were written by their primary authors, all members of the panel participated in making comments, suggestions, and modifications, and in evolving the final product, which was supported and written by the panel collectively.

Issues and Concepts as Identified and Viewed by Panel

The panel identified its charge as rendering independent advice on whether an LNG terminal can be designed and constructed at the proposed site in a manner consistent with public safety. The panel noted that it was not obligated to accept earlier criteria and definitions related to the seismic safety of LNG facilities, including those described in GO 112-D. The panel supported, in principle, the requirements of geologic, seismic, and engineering studies, procedures, and evaluations, as described in GO 112-D, to assess seismic hazards and ways to accommodate them in design.

The panel did not adopt several major concepts outlined in the GO. In particular, the panel did not agree with the definition of fault capability based on a 100,000-to-140,000-year time limit, especially insofar as the panel felt that this definition arbitrarily tends to categorize a capable fault as dangerous and a fault that is not capable as safe. The panel believed that this criterion is a scientific oversimplification and is unduly conservative for this facility.

The Commission had asked the panel to analyze the maximum credible earthquake and to determine whether or not the LNG system can be built to withstand it. The panel recommended that an event as infrequent as the maximum credible earthquake not be used as a basis for design of the proposed facility.

Dr. Clarence Allen succinctly set forth the panel's reasoning for rejecting this term:

> "The definition of maximum credible earthquake has been the subject of a great debate among geologists and seismologists for many years, particularly within the time of the nuclear plant controversies, ...
>
> "Because clearly what is credible to one person may not be credible to another ...
>
> "That is the very reason why we have tried to go over to earthquakes that we think are likely at various time intervals rather than specifying one earthquake that, so to speak, conforms to a definition that is not well posed." (Tr. CH-1, p. 58.)

In his answer to the next question, he notes, "I have often used the example that it is certainly perfectly possible that a meteor will hit this room in the next five seconds and we'll be killed. We can compute statistically how often that might happen. It is [un]likely. We don't consider it credible." As Dr. Allen further explained later in the hearing:

> "Indeed, we had tried to face up to this realistically by presenting alternative earthquakes that might occur with different occurrence levels to allow the Public Utilities Commission to make the final decision of what is an acceptable level of risk." (Tr. CH-1, p. 101.)

Rather than specifying a single design earthquake, or a single design earthquake for each of several earthquake sources, the panel presented likely maximum earthquakes for three different recurrence intervals.[7]

The panel observed that most dictionaries define safe as a condition that is free from danger or risk. The panel considered no facility to be absolutely free from risk; therefore, no facility could be said to be absolutely safe. There are degrees of risk and, consequently, degrees of safety. The panel said that three separate

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[7] A recurrence interval is the average time period between earthquakes of a given magnitude.

thought processes are involved in judging seismic safety: the assessment of the earthquake hazard; the assessment of the ability of the facility to accommodate the earthquake hazard; and the judgment of the acceptability of the risk. In the panel's view, failure to distinguish among these discrete activities is at the root of many controversies over decisions on seismic safety.

The panel viewed seismic safety as a judgment of the acceptability of the degree of earthquake risk; a facility is adequately earthquake-safe if the risks associated with earthquakes are judged to be acceptable. Judging the acceptability of the risk is a value judgment that involves some considerations other than those of science and engineering alone; therefore, throughout most of the report, the panel gave alternative criteria that might be used should the Commission decide to use a design level different from that recommended by the panel.

The panel reported that numerous technical issues were raised during the workshops. The workshop process, because of the open and active participation by all parties, allowed the panel to sort out from the many issues that had been argued and debated the critical few scientific and engineering issues that have direct bearing on the seismic safety of the proposed LNG facility. The panel determined that the issues requiring resolution were:

> The locations, sizes, and likelihood of occurrence of earthquakes that must be considered in design.
>
> The ground motion characteristics associated with the selected design earthquakes.
>
> The potential for surface fault displacement along faults that traverse the site.
>
> The structural design considerations required to accommodate the design earthquakes and potential surface faulting.

Recognizing that many of the earlier criteria considered in these proceedings were originally developed in nuclear power plant siting processes, the panel stated that it felt that LNG terminals and nuclear power plants fall into different categories in terms of risk to the public because the consequences of a failure are radically different. The panel did not feel it appropriate to evaluate the proposed LNG terminal on the same bases as used to evaluate a proposed nuclear facility.

Reception of the Panel Report

By the receipt of the panel's report into evidence the panel has answered its charge, and we have come into possession of an analysis of the seismic risks at the proposed terminal site that we were seeking. The scientific and technical qualifications and prestige of the panel members compel that their report be given great weight.

The first paragraph of the letter states that:

> "In the judgment of the Panel, an LNG facility can be designed and constructed at the Little Cojo Bay site, Santa Barbara County, California, in such a manner as to be consistent with public safety."

Obviously the panel members were not comfortable with the Commission's choice of the wording of the three questions the Commission posed. They did not like the term "maximum credible earthquake." Indeed, their aversion to this term was such, in the panel's words, that use of the term was "shunned"[8] by the panel. The reasons for that shunning are set out in the previous section.

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[8] Shun, v.t.; To avoid deliberately and esp. habitually. Webster's Seventh Collegiate Dictionary (1966) G & C. Merriam Co.

The Commission infers the shunning to be a tactful suggestion that perhaps the questions could have been more expertly framed to elicit the expert opinion, judgment, conclusions, and advice that the Commission requires for resolution of the seismic issues of these proceedings. Indeed, Dr. Allen, in explaining the shunning to Hollister Ranch's counsel, referred to the "maximum credible earthquake" as "a definition that is not well posed." (Tr. 68.)

Accordingly, the Commission finds the panel's unqualified statement that an LNG facility can be safely designed and constructed as responsive to its question 2 and the engineering criteria recommended by Chapter 5 as responsive to question 3. The construction of a definitive response to the complex components of question 1, however, requires analysis of the report.

Seismic Geology and Seismicity-
Assessment of Maximum Earthquakes

In evaluating the seismic hazards, the panel considered seismic geology and seismicity before it took up surface faulting.

The Commission had asked the panel to analyze the maximum credible earthquake and to determine whether or not the LNG system could be built to withstand it. The panel replied that, although the state of the art of engineering design and construction of large installations in active seismic areas is such that the plant could be designed and built to safely withstand such an earthquake, the panel believed that to do so would be overly conservative. The panel recommended that an event as infrequent as the maximum credible earthquake not be used as a basis for design of the proposed facility. Rather than specifying a single design earthquake, or a single design earthquake for each of several earthquake sources, the panel presented likely maximum earthquakes for three different recurrence intervals. The largest earthquake that is likely to recur on specific faults was given for: A, the recurrence interval of a few hundreds of years; B, the recurrence interval of a few thousands

of years; and C, the recurrence interval of a few tens of thousands of years.

The panel identified four off-site earthquake sources that it believes will govern seismic design: the F-1 faults, the near regional faults, the far regional faults, and the San Andreas Fault. The likely Richter scale maximum earthquake magnitudes that the panel believes could result from movement of these faults, for the three-recurrence levels, are shown in Table I of the panel report, and are reproduced here:

LIKELY MAXIMUM EARTHQUAKES FOR DIFFERENT RECURRENCE INTERVALS

Earthquake Source	Distance From Site (km)	(A) 100s of years	(B) 1000s of years	(C) 10s of 1000s of years
F-1 faults	5	4-3/4	5-3/4	6-3/4
Near regional faults	12	5-1/2	6-1/2	7-1/2
Far regional faults	50	7	N/A	N/A
San Andreas Fault	100	8-1/4	8-1/4	8-1/2

The term N/A, in the table, indicates "not applicable" because the panel judged that earthquakes on faults at about this distance will not control design parameters.

The panel's explanation for its concept of the three earthquake levels and recurrence intervals is quoted below:

> "The first level of earthquakes, A, has a recurrence interval that has sometimes been attributed to the operating-basis earthquake ---a reasonably likely event during the life of a structure, and one for which continued operation of a facility following an earthquake is expected. Ordinary building codes for non-critical structures are often based on design earthquakes of this level of recurrence, or much less.
>
> "The second level of earthquakes, B, corresponds to maximum events that might occur with recurrence intervals of a few thousands of years. Critical structures whose failure could have a major impact on

public safety are often designed on the assumption of the occurrence of such an earthquake during the life of the structure.

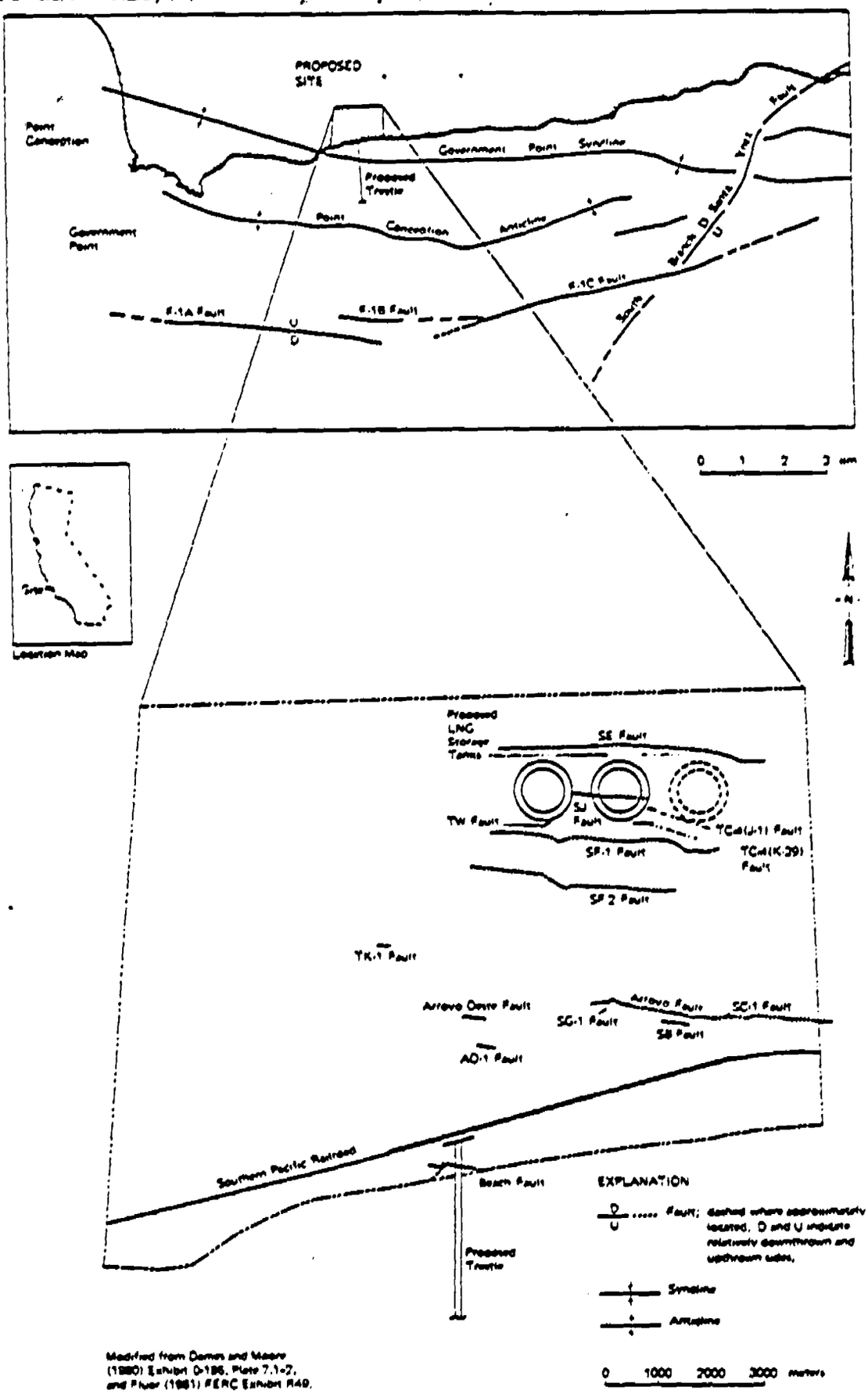
"The third of these recurrence levels, C, approaches what has sometimes been attributed to the safe-shutdown or maximum credible earthquake---the largest rationally conceivable event that might occur in the present tectonic environment. The recurrence interval of a few tens of thousands to a few hundreds of thousands of years corresponds to levels of acceptable risk that typically have been associated with nuclear reactors and large dams above populated areas. Events that might occur even less often are not considered credible in planning. This hypothetical maximum earthquake is interpreted as one that should not cause a failure of a structure in such a way as to seriously endanger public safety, even though the structure may be put out of operation and cause significant economic loss to the operator. In most areas, it is an exceedingly unlikely event. It is so unlikely, in fact, that earthquakes of this rarity usually are not considered in the design of structures.

"In the opinion of the Panel, the second level of earthquake recurrence, B, is more appropriate for the design for seismic safety of the proposed LNG facility than is Level C. Level A is a more frequent recurrence level that is recommended for design for continued, essentially uninterrupted, operation of the facility. Considering the consequences of failure of an LNG facility during an earthquake, and considering the actions that can be taken to mitigate the effects of failure, it is the Panel's judgment that the largest earthquake that might be expected during a period of a few thousands of years is an adequately conservative event to be used in the design of critical elements of the proposed LNG facility; these elements should not fail during the earthquake in such a way as to

> seriously endanger public safety. In the highly unlikely event that the Level C earthquake occurred, the Panel feels that the engineering design and precautionary measures incorporated to accommodate the Level B earthquake will protect the facility to an acceptable degree and prevent catastrophic failure. In other words, even the occurrence of a Level C earthquake is not likely to endanger public safety."

The panel thus concluded that the Level B earthquake should be used as a basis of design for seismic safety.

Figure I of the panel's report, Exhibit (Exh.) CE-1, shows a map of the site and the location of the significant faults located on or near the site. This map has been reproduced below.



Modified from Dames and Moore (1980) Exhibit D-186, Plate 7.1-2, and Fluor (1981) FERC Exhibit R49.

Figure 1 - MAP OF SITE AND SELECTED FAULTS

In justifying its conclusions, the panel discussed each source separately:

1. On-Site Faults

   The panel did not consider any of the faults that cross the site itself to be sufficiently seismogenic to cause vibratory ground motions at the site more severe than those from off-site faults at greater distances. The panel recognized that one or more of these on-site faults might experience a small amount of displacement during a large nearby earthquake; however, these displacements would be subsidiary to the principal break on more distant faults and would not be the centers of primary energy release themselves.

2. F-1 Faults

   The panel considers the offshore F-1 fault system to be seismogenic and the nearest geologic structure capable of producing significant vibratory ground motions at the site. The marine geophysical data presented to the panel suggest that the F-1 faults do not connect with other regional faults and do not collectively extend beyond 24 km in length. Only one of the fault segments has evidence of activity within the past 11,000 years, Holocene time, and that has been limited to the central 8 km portion of that segment. Other fault segments have no evidence of displacement during the past 11,000 years.

   As the geologic history of displacement on the F-1 faults shows that only one of the segments has been active within the past 11,000 years, and only for an 8 km length, the past behavior of the faults strongly suggests to the panel that all segments are not likely to experience displacement simultaneously. The panel believed that it is more reasonable to expect that a single segment will rupture along only a portion of its

total length. This suggested to the panel a lower magnitude for these faults than would be associated with a 24 km rupture length.

In addition, the panel concluded that the degree of activity of the F-1 faults, based on slip rates averaged from borehole data, can be said to be low. For example, when the average slip rate is calculated for a highly active fault such as the San Andreas, the rate is 40 mm per year: for the Wasatch Fault in Utah, the rate is 2 mm per year; and for the F-1 faults, it is .07 mm per year. In the case of the fault that caused the 1971 magnitude 6-1/2 San Fernando earthquake, the slip rate is 1 to 2 mm per year. This fault, which is in the same broad tectonic environment as are the F-1 faults, ruptured for a length of 15 km during the 1971 event.

Based on applications by the workshop participants of the various methods for estimating earthquake magnitude, and comparison with worldwide experience of fault behavior, the panel judged that the largest earthquake likely to recur on any of the F-1 faults within a period of a few hundred of years, Level A, is of magnitude 4-3/4. The panel judged a Level B likely maximum earthquake to be a magnitude 5-3/4 event once every few thousands of years. The Level C maximum earthquake along the F-1 faults was not expected to exceed magnitude 6-3/4 every few tens of thousands of years. The panel assumed that these earthquakes would occur at 5 km horizontal distance from the site.

3. Near Regional Faults

The panel stated that the western Transverse Ranges[9] are transected by numerous east-trending faults of regional extent; these are typically but not exclusively thrust faults reflecting north-south tectonic[10] compression. Among such faults near the site are the north and south branches of the Santa Ynez Fault, the Pacifico Fault, and the Mid-Channel Fault. Each of these faults can be the subject of debate as to its seismogenic capability, but there can be little doubt that the dominant structure of the Transverse Ranges is that of east-trending thrust faults, nor can there be doubt, based on the geologic evidence and the local earthquake history, that many of these faults are seismogenic. Furthermore, because of the uniqueness of this tectonic environment, the panel was of the opinion that there are probably shallow-dipping thrust faults beneath the western Transverse Ranges that are not clearly related to particular faults breaking the ground surface. Based on the collective experience of the panel, and the data presented during the course of its review, the panel judged that the maximum near regional earthquake likely every few hundreds of years, Level A, is a magnitude 5-1/2 event at 12 km from the site, including the possibility that this distance could be measured vertically downward to a shallowly

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[9] In Santa Barbara County the Western Transverse Ranges are locally known as the Santa Ynez Mountains. The Channel Islands are considered to be submerged peaks of the Transverse Ranges as well.

[10] Tectonic. Of, pertaining to, or designating the rock structure and external forms resulting from the deformation of the earth's crust. American Geological Institute, Dictionary of Geological Terms. (1962) Dolphin Books, Doubleday & Company.

dipping rupture surface 12 km depth. A similar event recurring every few thousands of years, Level B, would be of magnitude 6-1/2, and a magnitude 7-1/2 event is likely for Level C every few tens of thousands of years.

As the panel declared in its letter of transmittal, the panel believed that the largest earthquake that might be expected during a period of a few thousands of years is the appropriate one to be used in the design of this LNG facility. The panel recognized that this hypothetical magnitude 6-1/2 event at 12 km on near regional faults would probably be the controlling earthquake for the design of many elements of the proposed LNG facility.

4. Far Regional Faults

The far regional faults include such faults as the Hosgri Fault (to the northwest and possibly west of Pt. Conception) and those near Santa Barbara and the Channel Islands. The panel judged that the likely maximum earthquake having a recurrence interval of hundreds of years is of magnitude 7 on a far regional fault assumed to be at a nominal distance of 50 km. The panel noted that a larger event, of magnitude 7.3 to 7.5, occurred at about this distance as recently as 1927, but the panel judged this to be a relatively rare event that is not statistically representative of Level A earthquakes. Magnitudes for Levels B and C earthquakes were not considered because the panel judged that at no spectral frequencies[11] will earthquakes on these faults control design parameters.

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[11] The design spectrum will be defined later in this opinion in footnote 14.

5. San Andreas Fault

The panel believes that the San Andreas Fault, which is about 100 km northeast from the site at its closest point, may rupture and cause a great earthquake during the life of the facility. The Level A and Level B events are both judged to be of magnitude 8-1/4, whereas the Level C event is judged to be of magnitude 8-1/2. These earthquakes are expected to control the design parameters at very low frequencies.

Seismic Geology and Seismicity-
Surface Faulting

The panel believed that much of the near surface faulting at the site may have taken place by slow creep processes, rather than by sudden displacements during earthquakes. The panel feels, nevertheless, that a conservative approach requires that these faults be assumed to have experienced sudden displacements.

The parties had, in the earlier phases of the proceeding, widely varying contentions on the maximum amount of vertical displacement that could be expected from a single on-site fault event. For example, Western Terminal claimed that the maximum single-event displacement that has occurred in the S-J Fault (the fault underlying the LNG tank sites), over the last few hundreds of thousands of years was only 4 cm. On the other hand, Hollister Ranch claimed it was at least 20 cm, and that future movement on the fault could cause an offset of 161 cm.

The panel concluded that the geologic evidence showed that there has been no fault displacement along the S-J Fault for at least 100,000 years, and possibly for as long as 180,000 years.

Based on the evidence presented to the panel during the course of its deliberations and its visit to the site to examine this fault, the panel concluded the amount of displacement along the S-J Fault during a single event is most likely closer to 20 cm. In the

panel's judgment, however, differences of opinion on past displacements are irrelevant, because the likelihood of future displacement on the S-J and other tank site faults is so low it does not warrant engineering consideration. Because displacements on some of the other site faults, such as the Arroyo Fault, can be shown to have taken place within the past few thousands of years, the recurrence interval of Level B earthquakes, the panel considered that they should be considered likely to occur again within the life of the proposed facility.

The panel reasoned that since some site faults have convincing geologic evidence for multiple fault-slip events, the maximum observed cumulative displacement on these faults did not, therefore, occur in one slip event. Although there are various interpretations on the number of events, and some geologic exposures are poor, the good exposures have evidence of multiple displacements and the panel saw no reason to believe that this is not the case for the poor exposures. Based on the geologic evidence presented to the panel, and a comparison with the behavioral characteristics of other active faults, especially slip rates, the panel recommended that the Commission consider the design single-event vertical displacement on recent site faults to be 30 cm.

The site faults are mainly thrust faults, and are essentially parallel to the east-striking, south-dipping bedding in the Sisquoc Formation. Therefore, the panel said, a component of horizontal compression should be included in the design of structures required to accommodate the 30 cm of vertical displacement. The amount of compression will depend on the dip of the fault. In addition, there is evidence that a component of strike slip has occurred on some site faults; therefore, future fault slip events may have a strike-slip component. Based on the data presented to the

panel, it is recommended that a design strike-slip displacement of 10 cm be required.[12]

Seismic Geology and Seismicity-Design for Surface Displacement

As noted in the preceding discussion, the panel believed the likelihood of future displacements along the S-J Fault to be so low that the tank foundations need not be specially designed to accommodate surface fault displacement. Should the highly unlikely event of fault displacement occur, the panel believed that the remote location of the site, in addition to the engineering design and safety measures being planned in the design of the facility, minimize the risk and render the consequences acceptable. In the panel's judgment, it would be unreasonable to require additional design to accommodate such unlikely surface faulting, given the backup safety measures planned.

For site faults on which displacements can be shown to have taken place within the past few thousand years, the panel recommended

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[12] Thrust fault. A reverse fault that is characterized by a low angle of inclination with reference to a horizontal plane. Reverse fault. A fault along which the hanging wall has been raised relatively to the footwall. Dip. The angle at which a stratum or any planar feature is inclined from the horizontal. The dip is at a right angle to the strike. Strike. The course or bearing of the outcrop of an inclined bed or structure on a level surface; the direction or bearing of a horizontal line in the plane of an inclined stratum, joint, fault, cleavage plane, or other structural plane. It is perpendicular to the direction of the dip. Strike slip. The component of the slip parallel with the fault strike, or the projection of the net slip on a horizontal line in the fault surface. (Dictionary of Geological Terms, op. cit.)

that the design single-event vertical displacement should be 30 cm. It recommended a design strike-slip displacement of 10 cm for these faults, as noted above.

In those areas where recent displacements can be precluded, as in places where materials that are a few thousands of years old are demonstrably unfaulted, the panel recommended that the Commission not require consideration of surface fault displacement.

The panel recommended that Category I buildings and other structures be sited so they will not be astride faults that have evidence of displacement within the past few thousands of years. In particular, the fire station and the control building should be sited where it can be shown that there are no such faults. Other Category I structures, such as LNG pipelines, that must cross recent faults should be specifically designed to accommodate the recommended 30 cm of vertical displacement and 10 cm of strike-slip displacement. In the case of the Category II structures, the panel recommended that the loading platform and trestle, and LNG pipelines outside the tank site area be designed to accommodate 30 cm of vertical displacement and 10 cm of strike-slip displacement on a bedding-plane fault anywhere beneath these structures. This recommendation allowed for the possibility that a fault similar to the Arroyo Fault might exist somewhere along the length of the pipeline, or offshore, where there are no recent deposits directly along the proposed trestle location for evaluating fault displacement history. The panel recommended that Category III structures not be required to be designed for surface fault displacement.

The panel further recommended that, during excavation and foundation preparation, field review continue and any newly discovered faults be documented and evaluated. Earthquake safety measures consistent with the intent of the recommendations described in the panel report should be applied to any newly discovered faults.

Although the panel did not believe that the tank foundations should be designed to accommodate surface displacement, the panel did give its attention to design of tank foundations. Exh. O-231, prepared by Western Terminal at the panel's request, had recommended a ring wall type foundation. The panel did not concur and recommended a mat foundation, as was required by D.89177. In cross-examination, Degenkolb said that, while he did not calculate any offsets, his preliminary calculation of reinforcing was such that the mat would be ductile and would be capable of taking deformations with damage but without failure. He stated the mat would function to absorb an offset and thus help prevent tank failure. He did not believe that there would be a leak from the tanks even with three feet (91 cm) of offset.

Ground Motion Characteristics

By D.90372, dated June 5, 1979, in these proceedings, the Commission promulgated GO 112-D, Rules Governing Design, Construction, Testing, Maintenance and Operation of Utility Gas Gathering, Transmission, and Distribution Piping Systems (GO 112-D). GO 112-D was a revision of a previous general order, GO 112-C. D.90372 modified parts of Parts I and II of GO 112-C and added Part III to establish LNG safety standards. The procedure used to establish GO 112-D is recounted in pages 2 and 8 of D.90372.[13]

In the record leading to D.90372 and GO 112-D, Western Terminal had presented design criteria recommended by Thomas L. Anderson, Ph.D., of Fluor Engineers and Constructors, Inc. Dr. Anderson's criteria used recommended elastic response spectra provided by Jeffrey A. Johnson, Ph.D., then of Dames and Moore. Dr. Johnson, in turn, relied on the work of Nathan M. Newmark, Ph.D., a preeminent seismic design expert. The exhibits presenting Dr. Anderson's design criteria were identified and admitted as Exhs. O-122 through O-126 in these proceedings.

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[13] D.90372 was not printed. A typed copy is available in the Commission's files (1 CPUC 2d 587).

The seismic criteria prescribed by GO 112-D were generally consistent with Exhs. O-122 through O-126, except for three specific differences. These differences were in the level of the design acceleration used to scale the Safe Shutdown Earthquake (SSE) and Operating Basis Earthquake (OBE) response spectra, in the use of ductility factors and in the allowable stresses and load factors for Category I structures when subjected to SSE loads.

Drs. Johnson and Anderson were among the witnesses who were presented at the January 29 and 30, 1981 kick-off panel hearings. Dr. Newmark had previously testified, on November 1, 1978, in support of the seismic design standards then being prepared by Western Terminal and by the State's larger gas utilities.

Dr. Newmark had distributed prepared testimony for the January 29-30 hearings but died before the time of the hearings. Testimony was given in his stead by William J. Hall, Ph.D., a long-time colleague and associate of Dr. Newmark, who adopted Dr. Newmark's testimony as his own.

At panel Workshop 3, held at Los Angeles on April 14 and 15, 1981, panel member Jennings requested Western Terminal to compile a single document that included Western Terminal's proposed design data and specifications and to indicate where Western Terminal was in disagreement with GO 112-D. In response to this request, Western Terminal, at the July 7, 1981 hearing opening Workshop 6, presented a document entitled "WLNG/Newmark-Hall Recommended Seismic Design Criteria Little Cojo Bay LNG Receiving Terminal." This document was identified and received as Exh. O-231.

Exh. O-231 was a revision of Exhs. O-122 through O-126, and reflected the changes discussed in Exh. 180, the compiled prepared testimony of Western Terminal's witnesses for the January 29 and 30, 1981 panel kick-off hearings. The changes were mainly to add GO 112-D criteria with which Western Terminal agreed. The differences

between GO 112-D and Exh. O-231 were essentially the three specific differences above as explained by Dr. Anderson.

After considering the mass of information available to it, the panel reached a general agreement, but with some exceptions, with the performance requirements of the three design categories given in Exh. O-231. As stated in its letter of transmittal, the panel recommended design spectra[14] to accommodate ground motions associated with its Levels A, B, and C earthquakes.

The panel observed that, in addition to the recommended design spectra, design analyses may require values of ground acceleration and velocity. The panel's recommended values for these parameters were presented in Table 2 of the report and are shown below:

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14 Design Response Spectrum: A smooth plot of the maximum response (acceleration, velocity, and relative displacement) of a continuous spectrum of single-degree freedom oscillators subjected to the SSE or OBE. The maximum response of these oscillators is plotted against their vibration frequency for a specific damping ratio. The design response spectra are used to compute the maximum response of a structure to the SSE and OBE. Frequency: Natural frequency of vibration of a structure measured in Hertz (cycles/second). Structures exhibit natural frequencies for both horizontal and vertical vibrations. Damping Ratio: The damping ratio is an inherent property of a structure. It is a measure of the rate of decay, with time, of free vibration amplitude, expressed as a percentage of critical damping. Also known as damping or the damping factor. Critical Damping: The level of damping at which a structure, when released from a deflected position less than the elastic strain limit, will return to its neutral position without oscillation. (Exh. O-231, p. 1-A.)

RECOMMENDED VALUES FOR GROUND ACCELERATIONS AND VELOCITIES

Source	Level	Magnitude	Distance	Acceleration
F-1 faults	A	4-3/4	5 km	0.40 g
F-1 faults	B	5-3/4	5 km	0.60 g
F-1 faults	C	6-3/4	5 km	0.75 g
Source	**Level**	**Magnitude**	**Distance**	**Velocity**
Far Regional faults	A	7	50 km	25 cm/sec
Near Regional faults	B	6-1/2	12 km	45 cm/sec
Near Regional faults	C	7-1/2	12 km	85 cm/sec

The design accelerations for Levels A, B, and C are controlled by earthquakes on the F-1 faults at a distance of 5 km. Design velocities, however, are controlled by earthquakes on the near regional faults at a distance of 12 km for Levels B and C. The magnitude 7 earthquake at a distance of 50 km controls the design velocity for Level A. The Level A earthquake on the near regional faults, at a distance of 12 km, is judged to have a magnitude of -1/2; the velocity associated with such an earthquake is approximately 15 to 20 cm/sec.

The purpose and use of design spectra will be explained in more detail when the panel's design spectra recommendations are evaluated.

Geotechnical Considerations

Geotechnical considerations pertain to the physical ability of a site to conform to the intended use. In the past it was more commonly known as "engineering geology." The subject was discussed in D.89177, under the side heading "Geologic Hazards," at pages 226 and 227. Specific considerations included soil creep, landslides and slope failure, flooding and erosion, seismic settlement and differential compaction, and liquefaction. In D.89177 the Commission determined, on the basis of the limited information then available to it, that none of the listed hazards posed a significant risk to the operation of the LNG facility.

The panel report, Exh. CE-1, stated that the panel foresaw no unusual geotechnical design problems, based on the data presented during the course of its review. The panel recognized that the geotechnical evaluations at the site have been mainly preliminary, and the panel understood that further evaluations will be conducted for final design and construction.

The geotechnical portion of the panel's report provided mostly cautionary comments that the panel felt should be taken into account in the final design.

The panel, in the final chapter of its report, recommended the establishment of a technical review board. The panel recommended that the final geotechnical aspects be evaluated by the technical review board.

Design Categories

Western Terminal's consultants, Fluor Engineers and Constructors, classified the plant components into the three design categories specified by GO 112-D, § 193.105.

The panel concurred with the design category designations, except the panel recommended that those portions of the control building that house the controls, instrumentation, and communications equipment, and the main control panel and components, be in Category I. The panel also recommended that those portions of the fire station that house fire equipment and monitoring devices for the control and detection equipment be in Category I.

The panel stated that it was in general agreement with the performance requirements of the three design categories for the facility given in Exh. O-231, with certain exceptions as described below. In its report, the panel stated that the earthquake design spectra termed OBE and SSE in Exh. O-231 are replaced by earthquake spectra A and B, respectively.

It was the panel's understanding that the elements of the terminal in Categories I and II would be designed to accommodate the earthquakes represented by the earthquake design spectra, and in any case for not less than the requirements of the Uniform Building Code, 1979 Edition. For Category III structures, the panel considered the requirements of the Uniform Building Code to be adequate. In all cases where the Uniform Building Code is a basis for design, the panel recommended that the zone factor, Z, be 1, corresponding to Zone 4, which, the panel thought, appropriate for this site. The panel also recommended that the importance factor, I, be 1.5 for Category I and II elements and be 1.0 for Category III elements. No parties took exception to these recommendations of the panel.

Earthquake Engineering Considerations-Allowable Working Stresses, Load Factors, Analytical Procedures, and Damping

The panel recommended that the Commission require values for allowable working stress and load factors as given in Tables 3 and 4 of Exh. CH-1.

GO 112-D specifies working stress not to exceed 90% of yield stress. Exh. O-231 proposed that the load used to calculate stress be reduced to take advantage of ductility. The panel agreed but specified the working stress determined from the reduced load should not exceed the yield stress.

Exh. O-231 proposed modifications to GO 112-D load factors[15] for reinforced concrete design to allow use of test data. The panel recommended several modifications of the load factor combinations in Exh. O-231.

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[15] Load Factors are the constants used in equations for determining the total load used to proportion a structural element. The equations combine the effect of live, dead, wind, earthquake, and other loads.

Exh. O-231 proposed more detailed analytical procedures than GO 112-D. The panel modified the O-231 analytical procedures to conform to the 1979 Uniform Building Code specifications. The damping values recommended by the panel are set forth in Table 5 of Exh. CE-1, and are generally the GO 112-D values, with minor revisions to make the values for design more specific to an LNG terminal.

Earthquake Engineering Considerations-Ductility

GO 112-D, § 193.133(c) III required components of Category I plant be designed to behave elastically, without any permanent deformation, at the SSE level.

The panel recommended that ductility[16] be considered in the design of many of the structures of the proposed facility and that the use of ductility factors be permitted in the seismic analysis of the facility. The panel noted that experience in earthquake performance, as well as laboratory tests and theoretical studies, indicates that to be earthquake-resistant, even in the theoretically elastic range, the materials chosen and the proportions and details provided must be ductile. The panel recommended that the Commission require that whenever a member is subject to bending or shear caused by earthquake forces, it be detailed to the requirements of the Uniform Building Code for ductile moment-resisting frames. Shear walls should also be detailed as defined by Uniform Building Code requirements. The panel recommended that the use of ductilities be permitted as given in Table 6 of Exh. CE-1, and that where direct stresses are concentrated at discontinuities, the member sizes and details be provided for the actual (not code-derived nor reduced) forces, as would be required for a ductility factor of 1.0. The ductile structural elements used in the construction should be of types whose behavior has been substantiated by cyclical tests carried into the ductile range. The panel recommended that no ductility be permitted in precast concrete systems.

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[16] Ductility is the property of a structure which permits it to resist loads resulting in stresses beyond its elastic limit without failure or collapse. However, a ductile structure loaded beyond its elastic limit may require some repair. The ratio of the total amount of deflection which a structure is permitted to deflect during a given earthquake relative to the elastic deflection is termed the "allowable ductility factor." The allowable ductility of an individual structure depends on many factors including the level of earthquake, type of structural system, materials of construction, type of connections, level of acceptable damage, and cost of repair. (Exh. O-231, § 5.5.5.) Ductility Factor: The value of deformation or strain which a structure can sustain without failure or collapse relative to the value from which it departs appreciably from elastic conditions. (Exh. O-231, p.1-A.)

Should the Commission choose to be more conservative than the panel recommends in § 2.1 and require that the design be based on the Level C earthquakes, it was the opinion of the panel that higher ductility factors should be allowed than those tabulated for the Level B earthquakes. If Level C is chosen, the ductility factors should be increased 25% for Category I and II structures, except for the tanks, and used in the analysis as proposed by Western Terminal on page 14 of Exhibit O-231, with the reference frequency of 2.5 Hz replaced by 1.8 Hz. For the tanks, the ductility should be increased by 10% for compression and sloshing and 25% for impulsive response.

The panel also supported its ductility recommendation during cross-examination on its report. Both panel members Johnson and Degenkolb asserted their belief that by requiring a ductile structure, the panel was adding an additional level of conservatism to the design of the facility. They specifically recommended certain materials that would respond elastically during an earthquake to provide an additional safety margin. Their recommendation, they pointed out, was more conservative than applicant's proposal to use ductility in its seismic analysis, but not as conservative as the existing ductility requirements in GO 112-D. Degenkolb also pointed out that the cost of designing to avoid an interruption of service must be balanced against the risk of incurring damage from an earthquake having a long recurrence interval.

Earthquake Engineering Considerations-Other Earthquake Design Considerations

The panel made other general design and material recommendations concerning spillage, the LNG tanks (including reiteration of the recommendation for mat, rather than ring wall foundation), and for the trestle and platform. The panel recommended that the details of administration of its recommendations be entrusted to a technical review board to be established by the Commission.

Technical Review Board

The panel concluded its report, Exh. CH-1, by saying that it can be seen from the discussions and recommendations in many parts of the report that there are many areas in the earthquake-resistant design of the LNG facility where professional judgment and specialized knowledge and skills are required. The panel recommended that an independent technical review board be appointed by, and report to, the Commission to oversee the engineering concepts. This would be consistent, the panel said, with procedures for other major projects such as dams, bridges, and facilities where the welfare and safety of the public are concerned.

The responsibilities of the technical review board would include monitoring the adequacy of the design and the design-checking process, and the quality control system. The panel also recommended that the technical review board be given the authority to arbitrate and resolve differences that might arise on whether proposed design or construction techniques carry out the intent of the safety regulations adopted for the facility.

Comments by Commission's Consulting Geologists and of the California Division of Mines and Geology

The adopted panel procedures, § 6.e., provided that parties had the right to file exceptions to the panel's report within 45 days of the issuance of the final panel report. The Commission received two sets of comments. One set, which was filed by the staff, had been prepared by James Slosson, Ph.D., and Robert L. Kovach, Ph.D., consulting geologists who had been retained by the Commission. Another set was filed by the CDMG. The CDMG comments were prepared by James F. Davis, Ph.D., the state geologist.

Dr. Slosson, a former state geologist, had participated throughout the length of the proceedings. Dr. Kovach became active in the workshop phase only and testified for the first time at the January 29-30, 1981 initial panel hearings. CDMG has been involved throughout the LNG siting process, although it became more active during the additional geologic investigations undertaken by Western Terminal in compliance with Conditions 36 and 37.

The procedural status of the comments was a matter of concern to both Western Terminal and Hollister Ranch. Both parties believed the authors of the comments should be available for cross-examination. Western Terminal had no objection to their being treated as briefs. Hollister Ranch reserved the right to object to their consideration until after reviewing the CDMG comments, which document had not been received by Hollister Ranch. Since both sets of comments are consistent with the positions taken by the sponsors before the panel, the Commission will treat them as briefs based upon positions as taken before the panel.

ature of Commission's Geologists' Comments

The Commission staff's consulting geologists' comments, summarized below, are that:

1. The panel's earthquake recurrence levels be explained as:

Level A (100s of years)	occurrence very likely*
Level B (1,000s of years):	occurrence likely*
Level C (10,000s of years):	occurrence unlikely but possible*

*During the lifetime of the proposed terminal.

2. Should the Commission believe that the remoteness and low population density of the site cannot be guaranteed for the life of the terminal, the Commission

should then adopt Level C design criteria in lieu of the Level B criteria recommended by the panel.

If the Commission adopts the panel's recommendations, it should mandate that the site must continue to meet the population requirements of PU Code § 5582.

3. It would be more reasonable for the Commission to adopt magnitude 7.5 as the most likely maximum earthquake for the far regional faults for the Level A recurrence interval.

4. The Commission should increase the likely maximum earthquake magnitudes on the F-1 and associated faults, Level A to 5.5, Level B to 6.5, and Level C to 7.5.

5. Should the Commission adopt a more conservative stance than the panel such as by selecting the Level C design earthquake criteria, increased on-site fault displacements should be adopted. (20 cm vertical beneath tank sites; greater than 30 cm vertical on recent faults, with proportional strike slip components.)

6. A safety and construction monitoring system including on-site geologic inspection would work well with the independent technical review board recommended by the panel.

7. Public interest would be served by continuing to use the 100,000-to-140,000-year time criteria set forth in GO 112-D as the prime ingredient of siting studies such as those evaluated by the panel for the proposed LNG terminal site.

In support of their recommendations, staff's consultants state that the occurrence of a 7+ magnitude earthquake in 1812 and a 7.3 to 7.5 magnitude earthquake in 1927, both probably centered within 50 kilometers of the site, and suggest that earthquakes associated with far regional faults and exceeding a magnitude of 7.0 may recur within several hundred years. In addition, seismicity records may well lack data for relatively large magnitude events, merely because no such earthquakes have occurred during the relatively short time that California has been settled and reporting earthquake magnitudes.

The consultants believe that the slip rate of 0.07 mm/year and likely rupture of 8 km assigned to the F-1 and associated faults by the panel are the minimum estimates allowed by the data. The slip rates for the F-system fault complex are, however, similar to those of the San Fernando Fault. Since there are so many seismic unknowns, especially in the marine environment, they argued that it is their opinion that the Commission should recognize these unknowns by increasing the likely maximum earthquake levels to those recommended by the consultants. The consultants are of the opinion their higher numbers are more in accord with historic events from reasonably similar faults in southern California.

The staff, in its opening brief, noted that the consultants' comments were in disagreement with several of the panel's recommendations and that the positions taken by the consultants were similar in some respects to the positions taken by Dr. Luyendyk and Dr. Asquith. The staff did not endorse the consultants' views. The staff did, however, request that the Commission consider carefully the consultants' comments before reaching a decision on the seismic issues.

Nature of CDMG Comments

Dr. Davis' recommendations were transmitted under the signature of Jan Denton, director of the Department of Conservation, and thus became those of the department of which CDMG is a division.

The CDMG favored the use of the panel as providing a direct and thorough opportunity for the technical issues to be explored and, in its opinion, is a superior way to proceed with such matters.

The CDMG summarized its participation in the panel process, noting that it had, in January 1981, provided a critical review to the Commission of the geotechnical reports of the applicant and other parties. The CDMG developed conclusions regarding the seismic potential of faults on the site and in the adjoining region, the recurrence intervals of major earthquakes on these structures, and the peak accelerations which might be expected as a result of these events at the proposed LNG site. Following submittal of this document, the CDMG participated in all of the geology and seismology sessions of the LNG seismic review panel.

The CDMG and the Department of Conservation concurred in general with the findings of the panel, which were similar to the recommendations made by CDMG in its January report. CDMG was concerned that its general concurrence not constitute a precedent that would automatically apply to other sites. Dr. Davis' report concluded:

> "In our opinion, the surface faulting criterion of movement during the 'last few thousand' years proposed by the LNG panel is a satisfactory procedure in which to frame design conclusions for an LNG facility, if it is applied in the context of the geologic and tectonic framework of the site location. If the CPUC is to apply this criterion for LNG siting which may take place at other than Pt. Conception, it must require extensive geologic and seismic history analyses at any future LNG site locations, similar to those performed at Pt. Conception, in order to assure appropriate design conclusions."

This concern was repeated by the director in the Department's transmittal letter, which concluded with this paragraph:

> "Flexibility should be provided in subsequent site evaluations of other prospective LNG locations. This would permit consideration of age of faulting in surface fault movement design requirements which are appropriate to other geologic circumstances. In any case, extensive geologic and seismologic investigations similar to those conducted at Point Conception are appropriate."

Rebuttal to Panel Report-
Luyendyk and Asquith

The only active rebuttal to the panel's evidence was presented by Hollister Ranch. As mentioned above, the Commission's consultants, Drs. Slosson and Kovach, had submitted comments, but Hollister Ranch diligently cross-examined the panel members for the better part of three days, and presented two witnesses in rebuttal; Bruce P. Luyendyk, Ph.D., and Donald O. Asquith, Ph.D., the discoverer of the Arroyo Fault. Drs. Luyendyk and Asquith had testified in the earlier phases of these proceedings, and they testified again before the panel at the January 1981 hearings. They also participated in the panel workshops.

Drs. Luyendyk and Asquith each submitted prepared testimony which was received as exhibits. Dr. Luyendyk also had surrebuttal concerning comments made earlier by Dr. Allen concerning his rebuttal testimony. There was virtually no cross-examination of Dr. Luyendyk and none at all of Dr. Asquith.

Hollister Ranch presented no witness to rebut the panel's design and geotechnical conclusions.

Luyendyk's Testimony

Dr. Luyendyk is an associate professor in the Department of Geological Sciences, University of California, Santa Barbara.

According to Dr. Luyendyk, the panel underestimated the seismic hazard at the LNG terminal site by a simplistic interpretation of the seismic capability of the P-1 and some of the regional faults. He felt that the panel failed to recognize the existence and significance of a major seismic plate boundary zone which runs through the Santa Barbara Channel and passes only a few kilometers south of the site. As a consequence, the panel lumped and split faults in the seismic zone into categories such as "P-1 and associated faults," "near regional faults," and "far regional faults." This pigeonholing is a result of the panel's view, which Dr. Luyendyk believed to be incorrect, that these various sets of faults are unrelated and unconnected. By disassociating the seismic zone faults from one another, Dr. Luyendyk believes that the panel has, by implication, isolated the faults and therefore distributed the regional seismicity onto many alleged small faults; these small faults, if unrelated, presumably pose less risk than the seismic zone taken as a whole.

Dr. Luyendyk would modify the panel's interpretation of the significance of the P-1 fault by classifying it as part of the near regional fault zone, rather than as a separate local fault. He described the seismic plate boundary zone as running from the San Gabriel Fault in the east through the San Fernando Valley, the Ventura basin, the Santa Barbara Channel, to Point Conception, where it turns north and parallels the coast north to San Francisco. The zone is not expressed as a single fault in the Santa Barbara

Channel. Because they are reverse faults, they appear discontinuous in outcrop and often in en-echelon[17] sets. In a reverse fault tectonic environment, very few faults can be traced along a continuous line in outcrop. This is particularly true in the Channel and western Transverse Ranges region. Also, in a reverse fault environment, a moderate earthquake can occur at depth without causing a surface break.

Dr. Luyendyk agreed that the south branch of the Santa Ynez Fault should be classified as a near regional fault, but he would, by applying GO-112-D, III, Appendix B, § (d)(6)(i), place it 7 or 8 km south of the site, rather than 12 km as recommended by the panel on Table I of its report, Exh. CH-1.

He saw no justification for stipulating different recurrence intervals for near regional versus regional faults and would modify Table I by substituting values found by the analysis of CPUC consultants George Young and Armen Der Kiureghian in their January 19, 1981 report. Dr. Luyendyk believed that Appendix C of their report presents a very logical and clear analysis with generous error limits. Using their Figure C-1 and Tables C-1 and C-2 of this report, the Category A earthquake for the F-1 fault would be magnitude 5.0 to 5.5 or greater, the Category B earthquake would be magnitude 6.0 to 6.5 or greater, and the Category C earthquake would be magnitude 7 to 7.5. Dr. Luyendyk emphasized that these values are much higher than those assigned in Table I of the panel report.

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[17] Echelon faults. Separate faults having parallel but steplike trends; the group having one more or less general direction but with the individuals parallel to each other and at an angle to that direction. Thought to be the result of torsion in a region of differential diastrophism. From term en echelon, the original derivation of which was the Latin scala, ladder. (Dictionary of Geological Terms, op. cit.)

Dr. Luyendyk said that while uncertain of the methods used by the panel, he suspected that the panel underestimated both the regional seismicity (the regional recurrence rate) and the length of the F-1 fault. Dr. Luyendyk considered the separating of the F-1 fault as a local minor feature to be a very nonconservative decision on the part of the panel.

Dr. Luyendyk speculated that the 1812 earthquake may have occurred in the F-1 fault zone. This event, of an estimated magnitude of 7 to 7.5, occurred in the Santa Barbara Channel. Although data do not exist to locate the 1812 event precisely, Dr. Luyendyk stated that the known fact of its occurrence in the channel must be considered in the seismic design criteria for the site. He referred to GO 112-D, Appendix B, § (d)(6)(i)(A)b, which reads:

> "Where epicenters or locations of highest intensity of historically reported earthquakes cannot be reasonably related to known faults but are recognized as being within a tectonic structure and/or tectonic province in which the site is located, the accelerations at the site shall be determined assuming that those earthquakes occur on the fault (zone) closest to the site which is capable of producing an earthquake of that magnitude."

Dr. Luyendyk said that, based on this criterion, with which he agreed, the 1812 earthquake[18] is required to be located in the F-1 and associated faults. He noted that CDMG placed the 1812 earthquake on the F-1 fault and the USGS placed both the 1812 event and the 1977 Lompoc earthquake on the F-1 fault.

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[18] A detailed description of the larger earthquakes in Santa Barbara County can be found in Appendix 1 to CDMG Exh. 0-207.

Asquith's Testimony

Dr. Asquith is a registered geologist, engineering geologist, and geophysicist in California. Prior to his work as a consulting geologist he had been employed for a number of years as a geologist for one of the "seven sister" oil companies.

Dr. Asquith did not concur with the panel report in four significant areas, as follows:

1. The determination of likely maximum earthquakes.
2. The determination of the likelihood of future displacement under the tank sites.
3. The practical application and policy implications of recommendations 9 and 10 in the panel's letter.
4. The reliability of the data on which the panel has based its judgments.

In regard to his first concern, the likely maximum earthquakes, Dr. Asquith testified that the likely maximum earthquakes presented in Table 1 of the report, Exh. CE-1, and used in the panel's recommendations have presumably been derived from estimates by workshop participants and judgments based on the panel's collective experience. The latter are not presented in the report. The estimates presented by workshop participants are known, however, and are worthy of some discussion.

Dr. Asquith said that the estimates of recurrence intervals for the F-1 fault system presented by the various workshop participants were based primarily on displacements on this fault as interpreted from the offshore well data. Based on varying interpretations of displacement along the fault, and the displacement-magnitude relationships that were used by all the participants, recurrence intervals for a magnitude 6.5 ranged from 5,000 years for the Western LNG's consultant, to 2,000 years for the Commission's consultant, to 1,400 years for the intervenor's consultant (Dr. Asquith).

Dr. Asquith recommended a B-level earthquake of 7, and said that the B-level earthquake recommended by the panel would appear to be the least conservative of all possible choices. That is, it is the lowest earthquake magnitude that can be derived from the range considered during the workshop sessions, and, assuming that this lowest value is appropriate, it is the lowest value that can be attributed to the range inherent in the panel's general description of recurrence intervals. As an alternative, he recommended magnitudes of 6.0, 7.0, and 7.5 for Levels A, B, and C for the P-1 faults. Were he to take into account the views of the other participants in the panel workshop, in particular those of the Western LNG's consultant, he would temper these values by 1/2 magnitude to 5.5, 6.5, and 7.0. In no case did it appear to him to be reasonable or prudent, however, even when all viewpoints are considered, to adopt magnitudes as low as those recommended by the panel.

Dr. Asquith concurred in the likelihood of a magnitude 8 or 8-1/2 event on the San Andreas Fault but, as to the "near regional faults" since he believed that the earthquake magnitude potential of the P-1 fault system equals or exceeds that of the near regional faults, and at a closer distance, he felt that category was superfluous.

Not only did Dr. Asquith disagree with the panel's evaluation of the off-site faults, he also disagreed with the panel report as regards potential fault rupture beneath the proposed tank sites. He said that the panel, in approaching the problem of potential rupture under the tanks, apparently used conventional precepts in geological analysis that dictate that future fault displacements will occur only along older faults in the same area and that future displacements will not exceed the previous maximum single event displacement on that fault. Yet, he said, the panel report

readily acknowledges that on-site faults are not conventional. That is, despite a massive program of on-site subsurface investigations and off-site reconnaissance, neither Western Terminal's hypothesis of flexural slip nor Hollister Ranch's alternative of master fault control has been established as "proven." Given the obviously unconventional nature of the pattern of faulting at the site, Dr. Asquith said that "unconventional interpretations" should at least be considered in the light of on-site evidence rather than experience with conventional fault zones.

In this regard, Dr. Asquith said, new evidence introduced by Western Terminal late in the sequence of workshop sessions has proved to be crucial in an understanding of the sequence of faulting in this unconventional fault zone. Specifically, Western LNG's consultants introduced a highly improved log of a shallow exposure of the Arroyo Fault that clearly establishes two episodes of movement on this fault. Dr. Asquith thought the same data also clearly establish that these movements could not have occurred as creep, and also that both episodes occurred very late in the overall fault sequence, probably within the last 10,000 years.

Taken by itself, this evidence clearly belied, to Dr. Asquith, contentions on the part of some workshop participants that "creep" is a viable explanation of on-site fault mechanisms. More important, however, is the indicated sequence of faulting, including the Arroyo Fault and the nearby SB-1 Fault. The latter is an "almost forgotten" fault located only 60 feet south of the Arroyo Fault at trench SB. This fault displaces only a marine sand sequence of age approximately 80,000 years which clearly predates the first recognizable movement on the nearby Arroyo Fault by approximately 70,000 years. Thus, in the only area of the site in which the sequence of movements of two nearby faults can be deduced, a modest movement of 20 cm on one fault has been followed by a displacement of approximately 160 cm on a "new fault," i.e. the Arroyo Fault, only 60 feet away.

The sequence of events involving the Arroyo Fault, Dr. Asquith said, is significant, because the panel, in concluding that design for any amount of rupture under the proposed tanks is unnecessary "because the likelihood of future displacement on the SJ and other tank site faults is so low it does not warrant engineering consideration," has apparently chosen to disregard the potential for "new faulting" even though it can be deduced that "new faulting" must have occurred many times on the site in the past and, more importantly, that it has occurred under circumstances very similar to those that we now observe at the tank sites.

To explain this in a different way, Dr. Asquith said, if we could "push back" the sequence of events in the area of the Arroyo Fault at trench SB approximately 10,000 years, we would observe only one Quaternary fault,[19] the SB. We could also note that this fault is very similar to the S-J Fault at the tank sites in that it has approximately 20 cm of displacement at the uncomformity and that the displacement dies out in the overlying marine sand layer. From this we could deduce that this fault has not moved since very soon after the platform was cut and the overlying marine sand was deposited, that is about 70,000 years before this hypothetical time of observation. Given the logic employed by the panel, he surmised, it would have been recommended that design for fault rupture would be unnecessary astride the SB Fault and in the unfaulted area nearby. Yet we know that in the ensuing 10,000 years, a single-event displacement of up to 160 cm occurred on a "new fault," the Arroyo, located only 60 feet from the SB Fault. Dr. Asquith speculated that,

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[19] Quaternary The younger of the two geologic periods or systems in the Cenozoic era. Quaternary is subdivided into Pleistocene and Recent [Holocene] epochs or series. It comprises all geologic time and deposits from the end of the Tertiary until and including the present. (Dictionary of Geological Terms, op. cit.)

although he could not so demonstrate, other examples at the site of major "new faults" that post-date smaller faults may be located nearby.

He believes additional investigations to be necessary. He recommended additional work in his report to the panel of January 14, 1981 aimed at resolving these and other questions. Of particular concern are the areas on-trench with the proposed tank sites, and also the untrenched area near the center of the site located generally between trenches SA and SF. He noted also that the extent of the investigations that he has recommended is patterned after those ordered by the Commission in 1978 in response to questions raised about the nature and extent of the Arroyo Fault. If the Commission's adopted criteria for LNG site investigations were implemented, a much more extensive program would be required.

Beside his concerns over the panel's recommendations 9 and 10 which relate to the design for fault rupture for components of the facility other than the tanks, Dr. Asquith had major concerns about these recommendations relating to the feasibility of their implementation, the design value that has been recommended, and the policy implications involved. As to the feasibility of implementing these recommendations, he noted that the data now available indicate that the only earth unit at the site that can possibly be considered as "a few thousand years old" is the modern soil. Further, examination of the data now available for the many Quaternary faults at the site indicates to him that the only fault that is now known to cut the modern soil, and which would on these assumptions apparently require design for surface faulting, is the Arroyo. It should also be noted, however, that of the eight exposures of the Arroyo Fault at which a determination of this type could be made, only one has been logged as cutting the modern soil. Thus, of the known Quaternary faults at the site, only one, the Arroyo, falls into the category recommended by the panel as requiring design for surface rupture.

Several of the other faults at the site may actually fall into this category, Dr. Asquith said, but he really did not know because, based on experience gained from the multiple exposures of the Arroyo Fault, there is only a one-in-eight chance of knowing if a fault has moved in the last "few thousand years" based on a single exposure of that fault. Since the Arroyo is the only fault that has been investigated to this extent, Dr. Asquith argues that it is not known which of the faults now identified at the site actually fall into the panel's category as requiring design for surface faulting.

As to the outlook for the adequate evaluation of any new Quaternary faults that may be discovered in construction excavations, Dr. Asquith considered the picture to be even more questionable. The panel provided for ongoing review of the design process, but did not address further geologic investigations that would be required to implement their recommendations, even the normally required engineering geologic inspection of all construction excavations. According to Dr. Asquith, such recommendations are standard procedure in the ongoing evaluation of even noncritical facilities. Their absence in the panel's report on a critical facility is, to Dr. Asquith, a major omission, particularly in the light of very significant problems that he believes can be expected to arise in implementing of the panel's recommendations.

Regarding the design fault displacement value recommended by the panel, Dr. Asquith noted that the recommended 30 cm displacement is not at all conservative in that the previous displacements on the only affected fault, the Arroyo, based on his measurements, are 30 cm and 160 cm. Since the panel recommends 30 cm of design displacement, this is, he said, again, the lowest possible level of conservatism that can be applied given the data presented to the panel.

On the subject of safety, it was Dr. Asquith's contention that the Commission should be aware that the recommended design criteria as related to the proposed critical facility are substantially less than those now in effect for noncritical facilities in California. Specifically, the proposed criteria require design for fault rupture only where previous rupture can be shown to have occurred within the last "few thousands of years." Alternatively, he said guidelines adopted for implementing the Alquist-Priolo Special Studies Zones Act, which represent adopted policy in California as regards fault-rupture hazards, require that even noncritical facilities not be placed astride faults that have moved in the last 11,000 years. He said that this value provides a safety factor of about one order of magnitude, ten times larger than the panel's recommendation.

The Alquist-Priolo Special Studies Zones Act is found at California Public Resources Code §§ 2621 et seq. Its purpose is set out in § 2621.5:

"§ 2621.5 Purpose

"It is the purpose of this chapter to provide for the adoption and administration of zoning laws, ordinances, rules and regulations by cities and counties in implementation of the general plan that is in effect in any city or county. The Legislature declares that the provisions of this chapter are intended to provide policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to prohibit the location of developments and structures for human occupancy across the trace of active faults as defined by this board.

"This chapter is applicable to any project, as defined in Section 2621.6, upon issuance of the official special studies zones maps to affected local jurisdictions, but does not apply to any development or structure in existence prior to May 4, 1975. The implementation of this chapter shall be

pursuant to policies and criteria established and adopted by the State Mining and Geology Board."

Dr. Asquith added that the purpose of this segment of his testimony was not to argue the pros or cons of adopted state policy for the siting of facilities astride active or potentially active faults. Rather, it was intended to inform the Commission that the panel's recommendations 9 and 10 are in substantial conflict with existing state policy regarding fault rupture hazards and that adoption of such recommendations would result in inconsistencies in the treatment of these hazards among various agencies of the State.

Dr. Asquith had other concerns regarding the panel's report. He had an overall concern related to the reliability of the data on which the panel based its judgment. The report makes it very clear that the panel members believe that they have a sound basis for making the judgments submitted in their report. Dr. Asquith believed that, on the critical issues particularly, the basis for the panel's conclusions is not as clear-cut as the report would suggest. For example, on the issue of rupture under the tanks, the panel report states that the likelihood of future displacement on the tank site faults is "so low as to not warrant engineering consideration." The report does not, Dr. Asquith said, indicate how low is "so low," but presumably this judgment is based on workshop discussions indicating general agreement that the observed displacements on tank site faults probably occurred soon after deposition of the marine sand that is the basal unit of the terrace deposits. This is apparently the basis for the statement in the report that: "Geologic evidence shows that there has been no fault displacement along the S-J fault for at least 100,000 years, and possibly for as long as 180,000 years."

In actuality, Dr. Asquith testified, the "geologic evidence" does not show this. The most reliable dating of the oldest terrace units not cut by the S-J Fault indicates these sediments are approximately 30,000 years old. Since there is no dating of the marine sands cut by the S-J Fault, the only conclusion that can be

drawn from the "geologic evidence" and for which there is a "sound basis" is that there has been no displacement on the S-J Fault for at least 30,000 years. The extension of this value to 100,000 years or to 180,00 years is a judgment of the panel based on only one interpretation of the meaning of certain evidence.

There were other interpretations of this evidence, in Dr. Asquith's opinion.

The biggest problem with the panel's interpretation of the data was, Dr. Asquith said, that it leaves the vast majority of the time span since the cutting of Platform V, the platform under the tanks, completely unaccounted for. That is, whether Platform V is 120,000 years old as he contended, or 180,000 years old as Western Terminal contends; and if the alluvial terrace deposits are 30,000 years old, Dr. Asquith concluded that this leaves 90,000 to 150,000 years of time to be accounted for in the very thin to, in places, nonexistent, marine sand deposits. If this long period of time, 75% to 85% of the span under consideration, is represented by these sand deposits, then it is illogical to assume that the faulting occurred soon after initial deposition and was preserved in deposits only a few feet thick for 90,000 to 150,000 years. It is more likely, in his opinion, that the faulting occurred much later in the history of this unit, probably in the time frame of 30,000 to 40,000 years ago.

Dr. Asquith concluded by saying that, while the panel has adopted a different interpretation of this evidence, it is misleading to qualify this interpretation by a mode of presentation that indicates that "geologic evidence" indicates there is a "sound basis for judgment" in this and other critical questions. In actuality, he said, there is a rather limited basis for most of the panel's conclusions regarding the geologic and seismic environment of the site. According to Dr. Asquith, their conclusions, in most instances, are based on only one of several interpretations of the data, and the basis for the choices among these interpretations are not described in the report.

Evaluation of Panel Report and Rebuttal Evidence and Commission Consultants' Advice

Seismic Geology and Seismicity- Definitions of Earthquake Levels

As noted previously, the panel rejected the use of the term "maximum credible earthquake." Obviously, the panel members were not comfortable with our choice of the wording of the initial questions posed. They did not like the term "maximum credible earthquake." Indeed their aversion to this term was such that its use was "shunned" by the panel. We infer the shunning to be a tactful suggestion that perhaps the question could have been more expertly framed to solicit the expert opinion, judgment, conclusions, and advice we require to resolve these seismic issues.

Rather than focusing on the largest earthquake imaginable on any given fault potentially affecting the site, the panel presented an analysis of the likelihood of different magnitude earthquakes occurring on faults at specified distances from the site. In reflecting on this transposition, we find the panel's refocusing of the issue eminently reasonable, since it centers our attention upon the probabilities of seismic events and acceptable levels of safety and reliability.

We also note that the panel stated that its Level C earthquake "approaches" what has sometimes been attributed to the safe shutdown earthquake (as defined in GO 132-D) or the definition of maximum credible earthquake. However, it was the panel's view that a Level B earthquake, the largest earthquake that might be expected during a period of a few thousands of years, was an

adequately conservative event to be used in design of critical elements of the proposed LNG facility. The panel further stated in Exh. CE-1 that in the highly unlikely event that a Level C earthquake occurred, the panel feels that the engineering design and precautionary measures incorporated to accommodate the Level B earthquake will protect the facility to an acceptable degree and prevent catastrophic failure.

We therefore adopt as a finding the panel's unqualified statement that an LNG facility can be safely designed and constructed at Little Cojo Bay in such a manner as to be consistent with public health and safety.

For our purposes, then, the important question is, "For what level or levels of earthquakes should the various LNG facilities at the Little Cojo Bay site be designed?" To determine the answer to that question, it is first necessary to determine the earthquake-generating capability of sources having seismic influence on the site, and the associated recurrence intervals.

Seismic Geology and Seismicity-Selection of Design Earthquake Recurrence Interval

Perhaps the most important facet of our seismic decision regards the level of seismic hazard that is appropriate to consider in determining the safety and engineering design considerations associated with the proposed terminal. The selected level of seismic design will ultimately determine the degree of public safety and reliability that is built into this terminal. The panel has strongly recommended that the Level B earthquake be used as the basis for design. That is, they recommend that the maximum earthquake that is expected to occur every 3,000 to 7,000 years, or on the average of once in 5,000 years, is an adequately conservative standard to adopt for design of this terminal.

We adopt the panel's recommendations for the design levels for this facility. Our reasons for this action are set forth below.

Although we are aware that the panel's recommendation is less conservative than Finding 101 of D.89177, we also are fully cognizant of a critical fact related to our fact-finding process underlying that finding - namely, that in 1978 we lacked detailed site specific information (and scientific and engineering evaluation of that information) and therefore were constrained to adopt the most conservative posture. In other words, viewed against the wealth of information now before us, information which was subject to searching cross-examination by opponents of this project, Finding 101 was and must be seen as a preliminary indication of the possible magnitude of the risks to be assessed - not as a final statement of what the risks actually were or are.

The panel's recommendation is based on several considerations:

(1) The Level C earthquake is so unlikely that, with the exception of nuclear power plants, it is usually not considered for the design of structures.

(2) Engineering design and precautionary measures incorporated in the design for a Level B earthquake will protect the facility to an acceptable degree and prevent catastrophic failure of the facility should a Level C event occur.

(3) Redundant safety features, such as installing the tanks in containment basins below grade, exist to mitigate the effects of possible tank failure.

(4) The proposed site is remote from population concentrations.

We find these considerations compelling.

In reaching our conclusion that the Level B earthquake is the appropriate design level for the critical structures of this facility, we are very cognizant of the eminent qualifications of the panel members. In the areas of geology, seismology, and earthquake engineering, they are nationally recognized leaders of their fields.

they are experienced in all aspects of earthquake hazard assessment and risk mitigation, and their experience encompasses substantial work on other major energy facilities, including nuclear facilities, in diverse geographic and tectonic environments throughout the world. In preparing its recommendations, the panel has been able to rely upon the entire seismic record of this proceeding, and it had the opportunity to visit two East Coast LNG receiving terminals. It has also visited the proposed site on several occasions. Moreover, in conducting its analysis and in making its recommendations, the panel has, through the workshop process, conducted an open dialogue with other eminent geologists, seismologists, and earthquake engineers who conducted their own analysis and evaluation of the seismic hazards of the proposed site. A review of the record demonstrates that this arrangement provided a direct and thorough opportunity for the geologic, seismic, and engineering issues to be explored. The end result of this process is a report which we find to be carefully written, and it addresses the issues that need to be resolved. It is logical in its presentation and analysis and it is comprehensive. Moreover, the panel ably and candidly supported its expert views and recommendations during three days of cross-examination. A review of the record convinces us that their findings and conclusions are supported by the record and that we should give them considerable weight in this proceeding.

We are also persuaded by the overall philosophy of the panel that construction of a seismically safe facility, such as an LNG terminal, indeed perhaps the safety and reliability of the entire facility, is a total process that begins with selection of the design criteria, continues during design, and is completed during construction by assuring that the selected criteria and design are in fact built into the facility. This philosophy was best expressed by panel member Johnson:

> "We are particularly recommending that there be quality control all the way through the operation, both the checking of the design, the observation, inspection of the materials; and also, we are recommending that there be a technical review board to see that when special questions, questions in dispute arise during the design process, there will be technical expertise to answer those questions and to be able to solve the problems that might occur.
>
> "So, all in all as a Panel, we are recommending a total process, not only a conservative level of earthquake shaking and a design based on a spectra, but the recommendations of the structural engineers, plus the carrying out of the total operation from the beginning to end in a very safe and orderly and regulated and inspected manner." (Tr. p. 96.)

We are also mindful that the panel's recommendation is a team effort that has produced a composite report reflecting the input of various experts. No persuasive evidence or argument has been produced that would cause us to reject the panel's recommendation that we adopt the Level B earthquake. In our initial LNG decision, D.89177, and in our decision on LNG safety standards, D.90372, in the interest of conservatism, we adopted findings such as Findings 101 and 102 of D.89177. We then required Western Terminal to undertake additional seismic investigations that would allow us to further evaluate the seismic risks of the proposed site. We also formed the Seismic Review Panel to assist and advise us in evaluating those risks. The results of this undertaking are now available to us for our review. We should not tie our hands and place ourselves in such an inflexible position that we could not take advantage of the additional geologic, seismic, and design information and evaluation that has been generated.

After due consideration of all factors and the residual concern over the public safety consequences, we will amend our original decision, reached after careful consideration of the mass of evidence, and select Level B, which has the earthquake recurrence level of one every 3,000 to 7,000 years as the appropriate recurrence interval for the design of Category I plant components, the critical and vulnerable elements of the LNG terminal. Level A, with recurrence interval of from 300 to 700 years will be selected as the OBE for the design of Category II plant. This interval is shorter than the 2,000 years specified in GO 112-D, § 193.119(5)(b)(2) but is consistent with the design acceleration set forth in that rule. We note, however, that our adoption of the Level B earthquake, and our other findings here, reflect the fact that the seismic risk analysis and our seismic design criteria are site specific to the Little Cojo Bay site. We thus concur in the State Geologist's emphasis that these design considerations are specific to this particular site.

Seismic Geology and Seismicity-
Determination of Design Magnitude

Having selected a recurrence interval, the next step is a determination of the design seismic magnitudes consistent with that recurrence interval. Although little new evidence regarding off-site faults was presented in this phase of the case, the workshop sessions provided an opportunity for a direct and thorough reexamination and reevaluation of the significant off-site faults.

There is no question that the massive San Andreas Fault, one of the earth's very largest earthquake faults, is capable of producing great earthquakes at geologically frequent intervals. The panel assigned an 8-1/4 magnitude to its Levels A & B, and raised the value to 8-1/2 for Level C. The Commission will adopt these magnitudes. Fortunately the fault is 100 km away at its closest point and an earthquake on the fault would affect the design parameters only at very low frequencies of vibration.

The panel concluded, for the far regional faults, at no spectral frequencies will Levels B or C earthquakes on these faults control design parameters. It therefore did not estimate magnitudes for these earthquakes. The Commission concurs with this approach.

The Commission adopts the panel'c conclusion that a 6-1/2 magnitude earthquake at 12 km on a near regional fault, namely a Level B earthquake, will probably be the controlling earthquake for the design of many elements of the proposed LNG facility.

As described earlier in this opinion, the panel concluded that the peak design accelerations for Levels A, B, and C earthquakes are controlled by earthquakes on the F-1 faults at a distance of 5 km. Design velocities, however, are controlled by earthquakes on the near regional faults at a distance of 12 km for Levels B and C. A magnitude 7 earthquake at a distance of 50 km controls the design velocity for Level A.

The panel also concluded that Level C maximum earthquakes along the F-1 faults are not expected to exceed a magnitude of 6.75. The Commission, in D.89177, found that the possibility existed of a 7.5 magnitude earthquake on the F-1 and on the north and south branches of the Santa Ynez. (Finding 99.) The panel found that, for the north and south branches of the Santa Ynez Fault, "near-regional" faults, a magnitude 7.5 event is likely for Level C earthquakes.

In reaching its recommendations on the seismic potential of faults on the site and in the adjoining region, the panel relied upon the wealth of information relating to the physical characteristics of the faults. For the F-1 fault, the panel indicated it began its analysis by evaluating what it considered to be the maximum earthquake that might occur every few tens of thousands of years. That analysis was based on the length of the fault, the segmentation of the fault, and the Holocene (last 11,000 years) history of fault, during which period only one segment was broken. The panel concluded

that the past behavior of the F-1 faults strongly suggests that all segments are not likely to experience displacement simultaneously. It concluded that a 6.75 magnitude earthquake could occur every few tens of thousands of years 5 km from the site. The panel then determined the magnitude of each quake with recurrence intervals of a few hundreds of years (Level A) and a few thousands of years (Level B) based on seismologic and geologic considerations. During cross-examination it noted that its analysis did not preclude the possibility of a 7.5 magnitude earthquake occurring on the F-1 12 km from the site, but that at 5 km, much closer to the site, the physical characteristics of the F-1 fault would not support an earthquake greater than 6.75 magnitude every few tens of thousands of years.

The panel reviewed geological evidence for consistency with these deductions. For instance, during its testimony, the panel noted that if, as suggested by Dr. Asquith, earthquakes in the range of magnitude 6 had occurred on the F-1 fault 5 km from the site every few hundreds of years, the ocean floor topography, for which good quality data exist, should show evidence of such activity. However, the evidence demonstrates that the nature of the sea floor extension of the F-1 is not compatible with the level of activity of the F-1 urged by Dr. Asquith. Nor did the panel think that the evidence would support Dr. Luyendyk's theory that the F-1 fault system is part of a master shear zone through the channel. The panel also pointed out that if a 7.5 magnitude was assigned to the F-1 fault, one would expect to discover a rupture length of 48 km. This latter distance is contrasted by the panel to the 24 km total length of the combined three segments of the F-1 fault system. We are convinced by the panel's careful evaluation of the foregoing geologic evidence that its conclusions concerning the F-1 fault are eminently reasonable and should be adopted. For design purposes we adopt the Level B earthquake on the F-1 at 5 km from the site.

We are also persuaded by the panel's presentation that it is unreasonable to place a 7.5 Richter magnitude earthquake on the south branch of the Santa Ynez Fault 7 to 8 km from the site. The persuasive geologic evidence presented during these proceedings shows the south branch of the Santa Ynez Fault dying out at 7 to 8 km from the site. We agree with the panel that it is more reasonable to assume that if there were a major energy release of a 7.5 magnitude earthquake on this fault, it would not occur at the point where the fault is dying out, but at a point at least 12 km from the site.

Seismic Geology and Seismicity-
Evaluation of Surface Faulting

The question of surface faulting is the most controversial of the entire proceeding. Indeed, as described earlier, it was the discovery of the Arroyo Fault and the subsequent revelation of the existence of other on-site faults that led to the establishment of the panel.

The panel's conclusions regarding surface faulting were set out in the review of the panel report. Hollister Ranch controverted the panel's findings at length in its brief. The panel's position was, in turn, staunchly defended by the Commission staff and by Western Terminal in their replies. It was also supported by CDMG in their reply to the panel report.

To resolve such highly technical questions was precisely why the Commission established the panel. Geology is by its nature a highly controversial science. Expert judgment requires years of education and professional experience. The Commission accepts the panel's conclusion that there has been no fault displacement along the S-J Fault for at least 100,000, and possibly for as long as 180,000 years, and that the most likely maximum single event vertical displacement is about 20 cm. The Commission accepts the panel's advice that single event design displacement on other on-site faults

should be 30 cm, with a component of compression depending on the dip of the fault, and that a strike-slip displacement of 10 cm. should be required. Despite the concerns of Dr. Asquith and the Commission staff's consultants, the Commission considers the panel's displacement estimates to be reasonable.

The Commission accepts the panel conclusion that none of the on-site faults are sufficiently seismogenic to cause vibratory ground motions at the site more severe than such motions from off-site faults at greater distances.

Seismic Geology and Seismicity-
Design for Surface Displacements

The S-J Fault lies directly under the LNG tank site. Condition 37 of D.89177, directed Western Terminal to "insure that no critical LNG component will be located within the distance of 100 feet (30 m.) from any fault trace." GO 112-D states, "In no case may an LNG tank be sited within 100 feet of a capable fault." The term "capable fault" is defined at length in Appendix B(c)(6) as a fault which has exhibited one or more of several specified characteristics, one of which is "Faulting at or near the ground surface within the past 100,000 to 140,000 years..." The S-J Fault thus meets the Commission's definition of a capable fault.

The panel was quite emphatic in its rejection of the term "capable fault" in the context of this proposed facility. In particular, the panel did not agree with the definition of fault capability based on a 100,000-to-140,000-year time limit, especially insofar as this definition arbitrarily tends to categorize a "capable" fault as dangerous and a fault that is "not capable" as safe. The panel believed that this criterion is a scientific oversimplification and is unduly conservative for this facility.

Rather than using a concept of active faults having moved during the last 140,000 years, and describing these as capable faults, the panel concluded that the potential for surface faulting should be used in design only for faults where there is evidence of movement during the last few thousand years. We accept this recommendation with the notation urged upon us by CDMG that the criterion of movement during the "last few thousand" years is a satisfactory procedure in which to frame design conclusions for an LNG facility as long as this criterion is only applied in the context of the geologic and tectonic framework of the Little Cojo Bay site.

Both the panel, Western Terminal, and CDMG believe that fault displacements of the site have been predominantly aseismic and that certain of the faults have had less frequent episodes of activity than others.

We cannot accept the panel's recommendation that the S-J Fault be ignored. We understand the panel's argument that the S-J Fault evidences no fault activity during the past 100,000 to 180,000 years, and therefore, in the panel's view, the likelihood of surface displacement in the future is so low that no surface displacement design is required for the tanks. The tanks, however, are a most vital component of the facility. A displacement under the tanks could have a devastating effect on the operational capability of the tanks. In keeping with the conservative stance the Commission is taking, considering system reliability and maintenance of the financial integrity of the utility enterprise, in addition to safety alone, we will require the tanks to be designed for 20 cm of offset. The Commission cannot ignore the existence under the tank site of a fault, of the type the Commission had, after much consideration, deemed to be "capable".

The Commission will accept the panel's recommendation of the continuation of the D.89177 requirement for a reinforced concrete mat design for the tank foundation.

Ground Motion Characteristics-
Design Spectra

Every structure has a "natural frequency of vibration". When disturbed by some external force the structure will vibrate at the natural frequency, measured in hertz (Hz), the modern term for cycles per second. The vibration will be resisted by other forces caused by internal or external friction and resistance of the fluid (liquid or gas) in which the object is vibrating. This resistance is called "damping": the most common example is provided by an automobile shock absorber. If the external force consists of a vibration at or near the natural frequency, a condition called resonance is caused, and the amplitude of vibration is limited only by the amount of damping present.[20] It is therefore important in seismic design that the frequency of vibrations caused by an earthquake be considered in design.

The concept of a design spectrum[21] was proposed by Drs. Newmark and Hall in 1969 and refined in a 1976 paper.[22] Appendix B of Exhibit 199, prepared by George A. Young, Ph.D., late consultant to the Commission, contains an explanation of the concept.

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[20] The best known and most dramatic example of this phenomenon was the self-destruction of the Tacoma Narrows Bridge.

[21] A formal definition of design spectrum and associated terms can be found at footnote 14.

[22] N.M. Newmark, and W. Hall, Earthquake Resistant Design of Nuclear Power Plants, Proceedings, Intergovernmental Conference on Assessment and Mitigation of Earthquake Risk, UNESCO, Paris, France (1975).

Response spectra may be prepared which display the peak response separately for acceleration, velocity, or displacement, but, because the differing peak influences of the three different factors, response spectra are now customarily prepared on a single tripartite plot. There is one independent variable frequency, shown on the horizontal axis, and three dependent variables; velocity, shown on the vertical axis, acceleration on a positive sloping diagonal axis, and displacement, on a negative sloping diagonal axis. The concept is difficult to visualize but illustrations are readily available on pages III-B-15 and 16 of GO 112-D.

Damping influences the magnitude of the response, so curves for several damping values are customarily shown on one chart, thus producing "spectra".

The Newmark and Hall procedure assumes that response values can be estimated at each specific site. Thus the effect of earthquake magnitude, source distance, and local site conditions can be introduced into the estimate of these values. Newmark and Hall indicated that when no other data are available, values given for a "standard earthquake" could be used. Values for the standard earthquake were taken as values 50% greater than estimated for the 1940 El Centro earthquake, which was the strongest earthquake of record at that time. Values proposed for the standard earthquake for the peak ground acceleration, velocity, and displacement were 0.5g, 24 in./sec, and 18 in., respectively. It was further indicated that for other values of peak ground acceleration, the peak ground velocity and displacement should be scaled proportionately. As a result, few users of the procedure have bothered to estimate peak ground velocities and displacements as a function of magnitude, source distance, and site conditions but have used the standard earthquake values. Therefore, the procedure is identified as a "site-independent" procedure.

In 1973, the United States Atomic Energy Commission, predecessor of the Nuclear Regulatory Commission (NRC), adopted Regulatory Guide 1.60 which was based on procedures summarized in a 1973 paper by Drs. Newmark, Blume, and Kapur. The Regulatory Guide 1.60 spectra were based on two separate statistical analyses, one by Dr. Newmark and one by Dr. Blume. The Regulatory Guide 1.60 procedures are probably the most widely used procedures for developing design response spectra for nuclear power plants and are also used for other important facilities. The procedures are considered applicable to rock or soil sites, but the regulation states that the procedures do not apply to sites that are relatively close to the epicenter of the expected earthquake or to sites that are underlain by poor soil conditions. It is not stated exactly what distance is close and what soil conditions are poor.

GO 112-D adopted both the Newmark-Hall and Regulatory Guide 1.60 as acceptable spectra. A discussion of the pros and cons of each of these spectra is to be found at pages 44 to 46 of D.90372.

The panel, as briefly mentioned earlier, presented separate site specific spectra at 5% spectral damping, for its Level A, B, and C earthquakes. The approach of the panel was to choose reasonably conservative design earthquakes and to select the level of design spectra to exceed the average level of response associated with the design earthquakes. This approach, plus other conservatisms in design and construction, provided, in the opinion of the panel, adequate protection against the conceivable, but highly unlikely, event of peak responses exceeding the level of the design spectrum.

The panel stated that its intent was that its recommended spectrum for Level A be used in the design process in the way Western Terminal has proposed to use the OBE spectrum. The panel's recommended spectrum was higher than Western Terminal's spectrum,

except in the frequency range 0.7 to 2 Hz. The panel's recommended spectrum for Level B is intended for use in the design process in the same way as applicant has proposed to use the SSE spectrum.

The panel prepared a design spectrum for Level C earthquakes, which it indicated was included only in case the Commission decided not to adopt the Level B earthquakes recommended by the panel for design purposes. For frequencies higher than approximately 2 Hz, the Level C spectral ordinates are controlled by the magnitude 6-3/4 earthquake at a distance of 5 km. In the frequency range of 0.25-2 Hz, they are controlled by the 7-1/2 magnitude at 12 km, and below 0.25 Hz, by the 8-1/2 magnitude earthquake on the San Andreas, 100 km away.

With regard to the Level C earthquakes, the panel report states that in the middle and high frequency ranges, the design earthquakes are large thrust events on faults that dip northward toward or under the site; these are judged by the panel to be capable of generating stronger motions than the Newmark-Hall GO-112-D spectra proposed in Exh. O-231. In particular, a magnitude 6-3/4 event on the P-1 fault at 5 km includes the implication of a major energy release at a depth of 10 to 15 km under the site, with attendant strong shaking at high and middle frequencies. A magnitude 7-1/2 earthquake at 12 km would not be expected to generate high frequency motion of the levels of the nearer, smaller event, but could generate strong motions at middle frequencies (approximately 0.3 to 5 Hz). The panel repeated, however, that it considered these Level C earthquakes to be exceedingly unlikely and not recommended as design events for the proposed facility.[23]

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[23] Dr. T. L. Anderson of Fluor stated that the LNG storage tanks would have frequencies in the range 6 to 9 Hz. (Exh. O-180, p. 5.)

GO 112-D, in § 193.119(b)(4), specifies vertical design spectra for the SSE and OBE as two-thirds of the amplitude of the recommended horizontal design spectra at all frequencies. This specification was adopted by Western Terminal in Exh. O-231.

The panel adopted this practice only in part. The panel stated that the strong-motion data from recent earthquakes indicate that, in the near-field, the high-frequency components of motion in the horizontal and vertical directions are comparable. The panel, therefore, recommended that the design spectra for vertical motions be two-thirds the horizontal spectra only for frequencies from 0.1 Hz to 3 Hz. The vertical and horizontal design spectra should be equal for frequencies of 10 Hz and higher. In the transitional region between 3 and 10 Hz, the design spectra for vertical motions can be determined by drawing straight lines on a logarithmic plot of the design spectra, joining the points for a particular value of damping at frequencies of 3 and 10 Hz.

The panel's recommended design spectra to accommodate ground motions associated with A and B earthquakes are adopted. The recommended spectra for Levels A and B should be used in the design process in the way in which Western Terminal has proposed to use OBE and SSE. The panel's recommendation concerning vertical motions will also be adopted.

Ground Motion Characteristics-
Design Accelerations

The panel prepared a recommended acceleration value for Level C earthquake on the F-1 fault. This Level C value of 0.75g exceeded the Commission's D.89177, Finding 102 (as clarified by D.90372, p. 88) value of 0.70g. However, the panel's recommended acceleration for Level B of 0.60g is within the range set forth in Finding 99. Our adoption in D.89177 of the very conservative 0.7g acceleration level for critical structures was based partly on the

unknown risks of the on-site faults. Western Terminal, at our direction, has conducted an extensive evaluation of the on-site faults. This issue was openly discussed and evaluated during the panel's workshops. We now have the additional input of the panel, CDMG, and USGS. Only Hollister contends that the design maximum acceleration for the F-1 fault should be at least .85g and not the .6g recommended by the panel. Basic to Hollister Ranch's contention is its argument that the F-1 fault at 5 km from the site must be assigned a maximum credible event magnitude of 7.5. However, we have already rejected this argument; therefore, Hollister Ranch's contentions as to the appropriate design acceleration level are also rejected.

In its report, the panel stressed that peak ground acceleration of the design earthquakes plays a minor part in the process of selecting the complete design criteria because its effects are confined generally to very high frequencies and because many factors not relevant to the overall strength of ground motion can affect the peak acceleration recorded by an instrument. The panel also stated that characterizing a complex wave form by its single peak value can lead to a serious oversimplification. As noted earlier, the panel has recommended, and we have adopted, design spectra that characterize the ground motion in such a way that structures and components at all natural frequencies are subjected to comparably conservative levels of forces in design. We will therefore adopt the panel's recommendation of a peak acceleration of .6g for the Category I structures, recognizing the context of this recommendation.

GO 112-D, § 193.119(5)(b)(1) permits an OBE design maximum acceleration of half the SSE. For a SSE acceleration of 0.6g this would be 0.3g. The panel recommends 0.40g for its Level A. Since the panel's recommendation is more conservative, we will adopt 0.40g

acceleration level for design of Category II structures. The panel's recommendations concerning Category III plant and the 1979 Uniform Building Code are reasonable and will be adopted.

Evaluation of Geotechnical Considerations

The panel and other parties in this proceeding do not foresee any unusual geotechnical design problems (landsliding, flooding, erosion, or liquifaction) at the site. The panel's cautionary comments on geotechnical problems pertain to technical design considerations, rather than to the public policy questions posed by the major fundamental design decisions that the Commission is required to resolve in the siting process for an LNG terminal. This order therefore will not concern itself with detailed geotechnical specifications; insofar as they are not contrary to GO 112-D or D.89177, the panel's recommendations will be required.

Evaluation of Earthquake Engineering Considerations-Design Categories

The final classification of plant components into design categories is a function for which the panel is eminently qualified. The panel's classification will be accepted.

Evaluation of Earthquake Engineering Considerations-Allowable Stress, Ductility, Analytical Procedures, Damping, and other Design Considerations

Two of the panel's recommendations are major departures from GO 112-D, namely, allowable stress and use of ductility factors. These were considered in detail and discussed at length in D.90372, the decision that established GO 112-D. The determinations made at that time were not adopted casually nor are they to be discarded lightly. Reference is made to pages 50 through 52a of D.90372 for that discussion.

GO 112-D requires all Category I plant to behave elastically, that is, to survive a design force without permanent deformation, at the SSE level. Category II plant is required to be designed to behave elastically at the OBE, but could behave inelastically, and suffer structural damage and permanent deformation, at the SSE. Category III plant must behave elastically at earthquakes specified by "applicable codes" (in the case of the subject LNG terminal the Uniform Building Code) but would suffer structural damage at both the OBE and SSE levels.

In adhering to all-elastic design, the Commission stressed safety. The panel, drawing on its experience, responded to this concern by urging the adoption of a ductile design for the facility. It was the panel's contention that a ductile design adds an additional margin of safety to accommodate the many unknowns that are not calculated in design analysis. It pointed out that plastic deformation was not the equivalent of catastrophic failure, and a structure could suffer deformation without undue risk to public safety. Moreover, a plant that had undergone plastic failure would be repairable.

As noted earlier, acceptance of the panel's allowable working stress and ductility recommendations would be more conservative than those proposed by Western Terminal but less conservative than those set forth in GO 112-D. We believe the overall package of criteria recommended by the panel will assist us in achieving a high level of service reliability and also assist in protecting the investment of the utility. We again stress, as we did in our adoption of the panel's seismic design standard, that we are acting now on the basis of detailed site specific information and evaluation, which we did not have when we adopted GO 112-D standards as being applicable to this project. Each member of the panel has had considerable experience in investigating damages of earthquakes and looking at the performance of various types of facilities that have experienced large earthquakes. Indeed, this is one of the

primary reasons they were chosen as members of the panel. Degenkolb in responding to a question about the performance of the structure in response to a large earthquake underlined the importance of a ductile structure when he stated, "Secondly we have pushed very strongly for redundancy and ductility. You could be off, you could be wrong by a factor of 50 to 100 percent on your forces. And that is not as important on a performance of the structure as the ductility of the material, its ability to stretch and still hang together, its anchorage. the details, things of that nature." We will therefore heed both Degenkolb's and the panel's advice and adopt their allowable working stress and ductility recommendations.

The panel's proposed analytical procedures will also be authorized. The panel's recommended load factors also appear reasonable and we will adopt them.

The panel made a number of other detailed specific design recommendations. They do not appear to require any special detailed consideration and, insofar as they are not contrary to GO 112-D or D.89177, they will be found to be reasonable and will be required.

Answer to Commission's Second Question-Safe Siting

The Commission's second question, as reproduced on page 8 of this decision, can best be answered last. We have evaluated questions 1 and 3, the seismic hazards being designed for and the engineering criteria to withstand those hazards, first.

The panel devotes but a single sentence, and that in the first paragraph of the letter of transmittal, to the answer of question 2. The question could have been answered by a single word - yes.

The Commission, after considering both panel report and panel testimony, the advice of the Commission staff's own consultants and of the CDMG, and the testimony of Hollister Ranch's rebuttal witnesses, concurs with the panel and expands the answer, given the

design criteria adopted by the Commission, to assure investment protection and to include the ability to maintain a reasonably reliable level of service with minimal interruption by a maximum credible earthquake. The Commission believes that the conservative design posture consistently maintained by it during the entire course of this proceeding will provide such ability.

Dr. Asquith contended that the LNG terminal would be contrary to state policy as expressed by the Alquist-Priolo Act. Western Terminal contends that that legislation is irrelevant to this proceeding and the Commission agrees. The Commission here is concerned with conscientiously discharging its responsibilities under the LNG Act. It submits that this decision is responsive to that charge. The Legislature set out the considerations that led it to enact the LNG Act in the Act's preamble and it is not incumbent upon the Commission to question the Legislature's purpose in specifying differing criteria for the LNG terminal and for general siting by local governmental agencies.

The Commission will find that an LNG terminal can be safely and reliably sited at the Point Conception site.

Evaluation of Proposal for Technical Review Board

The LNG Act in PU Code § 5637, requires that the Commission, among other things,

> "...shall establish a monitoring system to ensure that any terminal authorized pursuant to this chapter is constructed and operated in compliance with all applicable regulations adopted and terms and conditions established pursuant to this chapter."

A technical review board would be helpful to the Commission in carrying out this charge. The Commission cannot, however, delegate its authority to an independent board as contemplated by the panel. Any such board would have to operate as an extension of the Commission staff and the ultimate authority and responsibility must of necessity remain with the Commission.

The Commission's experience in this proceeding has shown the value of being able to draw on the combined expertise of a highly qualified group of professionals. The proceeding has also shown that it is imperative that any advisory body have a continuing understanding of the Commission's function and of its powers and its constraints. It is also desirable that there be continuing two-way feedback between the Commission and the advisory body as to the requirements of each. This can be best accomplished by having two staff members, one legal and one technical, each with at least 5 years' Commission staff experience, serving as committee members. As members, these staff people would have equal stature with the other committee members, and better communication could be established and maintained than could be accomplished through mere liaison contact staff persons. The staff members could report informally to the Commission at its regular scheduled conferences and receive informal guidance back from the Commission. Matters requiring formal action by vote of the Commission could be presented to the Commission by memorandum and the Commission could act by resolution.

The Commission will conclude that use of a technical advisory committee is a reasonable method of maintaining ongoing technical supervision of the LNG terminal project and will conclude that such a committee should be established. The Executive Director will be directed to formulate a proposal for the establishment of a technical advisory committee and to submit the proposal to the Commission at an appropriate time. Establishment of the committee will be by Commission resolution.

Conclusion of Geologic and Seismic Phase

The proposed Little Cojo terminal site has been intensively studied. The staff recommends that there be no further investigation. Dr. Asquith disagrees and believes that the technical

review board process should include geologic investigations necessary to implement the panel's recommendations. He said that engineering geologic inspection of all construction excavations is standard procedure in the ongoing evaluation of even noncritical facilities.

The Commission does not consider these two positions inconsistent. Extensive continuing geologic and seismologic investigations would not be productive. However, the Commission considers the more routine-type of inspection contemplated by Dr. Asquith as part of the technical advisory committee's normal function. The Commission also accepts the panel's recommendation that during excavation and foundation preparation, field review shall continue and any newly discovered faults be documented and evaluated, and that earthquake safety measures consistent with the intent of the panel's recommendations shall be applied to any newly discovered faults. The Commission expects the Executive Director to so specify when the charge of the advisory panel is drafted.

The Commission considers the geologic and seismic phase to be completed, absent dramatic new discoveries or developments. The Commission will find that Western Terminal has complied with Conditions 36 and 37 of D.89177 and no further site investigations are required.

Site Specific Criteria

As contrasted to D.90372 and GO 112-D, this decision pertains specifically to the LNG terminal being proposed by Western Terminal at the Point Conception site. Where the criteria and standards of this decision differ from GO 112-D or other Commission orders, they are intended to be in the nature of variances from prior orders, and not as amendments or modifications having general applicability.

Motion of Santa Barbara Indian Center to Close Trenches and Restore Land Surface

At the first day of hearing counsel for the Santa Barbara Indian Center made the following motion:

"Please, gentlemen, don't delay any further.

"When you have concluded your investigation, order these trenches to be covered and the land restored; in that way this sacred land can go on for generations to come being used in the way that the Great Spirit intended."

The religious significance to the Chumash group of Native Americans of the Point Conception area was touched upon briefly in D.89177. Subsequently, the LNG terminal site has been dissected by the massive trenches required for the geologic investigations by Condition 36 of D.89177. The trenching is considered by the local Native Americans as a desecration of a holy site and an affront to their religious beliefs. Accordingly they have, by formal motion on their behalf by counsel for the Santa Barbara Indian Center, requested the Commission to order closure of the trenches and restoration of the land surface.

The trenches have served their purpose. The Commission is closing the geologic and seismic investigations concerning the LNG terminal. The trenches should be closed and the land surface restored. The Commission will so order.

Findings and Conclusions

Findings of Fact

1. Conditions 36 and 37 of D.89177 required that Western Terminal undertake further geologic and geotechnical investigations to evaluate the significance of the Arroyo Fault and possibly other faults located in or near the site. Western Terminal has conducted extensive trenching and geologic and geotechnical investigations, extensive evidence and exhibits have been developed in the record, and all interested parties have developed their exhibits in the record. The Commission finds that the investigations conducted by Western Terminal fully meet and satisfy Conditions 36 and 37.

2. Western Terminal's compliance with Conditions 36 and 37 and the LNG Seismic Panel procedures have generated additional detailed site specific data and a more thorough evaluation of the seismic and geologic risks than were presented to us in D.89177 and D.90372. Those decisions indicated the magnitude of the risks to be assessed, but did not constitute a final statement of what the seismic and geologic risks are.

3. The panel's opinion that likely maximum magnitudes for Level A earthquakes are 4-3/4 at 5 km, 5-1/2 at 12 km, 7 at 50 km, and 8-1/4 at 100 km is reasonable.

4. The panel's opinion that likely maximum magnitudes for Level B earthquakes are 5-3/4 at 5 km, 6-1/2 at 12 km, including 12 km vertically beneath the site, and 8-1/4 at 100 km is reasonable.

5. The likely maximum earthquakes having a recurrence interval of hundreds of years, Level A, should be used by applicant as a basis for design for continued, essentially uninterrupted operation of the facility.

6. The likely maximum earthquakes having a recurrence interval of thousands of years, Level B, should be used by applicant as a basis for design for seismic safety of Category I and II structures.

7. The panel's recommended values for ground accelerations and velocities are reasonable as follows:

Accelerations

Source	Level	Magnitude	Distance	Acceleration
P-1 faults	A	4-3/4	5 km	0.40g
P-1 faults	B	5-3/4	5 km	0.60g
P-1 faults	C	6-3/4	5 km	0.75g

Velocities

Far Regional Faults	A	7	50 km	25 cm/sec
Near Regional Faults	B	6-1/2	12 km	45 cm/sec
Near Regional Faults	C	7-1/2	12 km	85 cm/sec

8. The panel's recommended response spectra to accommodate ground motions associated with Levels A and B earthquakes are reasonable. Applicant should use those response spectra for Levels A and B earthquakes in the design of components, equipment, and systems of the LNG facility.

9. The panel's specific recommendations on load factors, allowable stresses, permissible ductility, damping values, materials, and other parameters required for engineering design consistent with the earthquake levels are reasonable and should be used for the design of components, equipment, and systems of the LNG facility.

10. The site faults outside the tank site that have evidence of displacements within the past few thousands of years should be considered likely to experience surface faulting within the life of the facility; where it can be shown that materials a few thousands of years old are unfaulted, surface fault displacement should not be considered in design.

11. The panel's recommendations that the design single-event displacement on recent site faults be 30 cm of vertical displacement, with 10 cm of strike slip, and a component of horizontal compression should be adopted.

12. There has been no fault displacement on the S-J Fault for 100,000 to 140,000 years.

13. Storage tanks sited over the S-J Fault should be designed to accommodate 20 cm of offset.

14. The panel's recommendation that the LNG tanks be placed on concrete mat foundations is supportive of previous Commission D.89177, Condition 38 and Finding 106.

15. No party in this phase of hearing foresees any unusual geotechnical design problems posed by soil creep, landsliding, flooding, erosion, or liquefaction at the proposed site. This conclusion is in agreement with previous Commission D.89177, Finding 93.

16. The panel has recommended that during excavation and foundation preparation, any newly discovered faults should be evaluated, and earthquake safety measures consistent with the panel's recommendations should be applied to such faults. This recommendation is reasonable and should be adopted.

17. The panel has recommended that an independent technical review board be appointed by, and report to, the CPUC to oversee the engineering concepts and to monitor the adequacy of the design and design checking process, and the quality control system. The panel also recommends this technical review board be given the authority to arbitrate and resolve differences that may arise on whether proposed design or construction techniques carry out the intent of the safety regulations adopted for this facility. The above recommendation will work well with the Safety, Construction, and Environmental Monitoring Programs adopted by D.90372. The recommendation to appoint an independent technical review board should be adopted.

18. The Little Cojo Bay site presents no unusual geotechnical problems.

19. The panel's geotechnical recommendations, insofar as they are not contrary to GO 112-D and D.89177, are reasonable and should be required.

20. The panel's classification of plant components into design categories is reasonable and should be adopted.

21. The use of ductility factors is authorized.

22. The analytical procedures proposed by the panel should be permitted.

23. The panel's damping values should be authorized.

24. The panel's recommended load factor combinations are reasonable and should be adopted.

25. The engineering design recommendations made by the panel in Chapter 5 of Exh. CE-1 are reasonable and should be adopted.

26. The Little Cojo Bay site is seismically and geologically suitable for the construction and operation of an LNG terminal.

27. An LNG system - especially those structures, components, and systems which perform vital safety-related functions, such as LNG storage containers, their impounding systems, and hazard protection systems - can be designed and built in a manner consistent with public health, safety, and welfare.

28. Because some of the nomenclature and the terminology used in the panel's report, Exh. Ch-1, are different from GO 112-D, for the purpose of avoiding conflict and confusion, the terminology, definitions, and requirements applied to capable fault, maximum credible earthquake, operating basis earthquake, safe shutdown earthquake, and any other terms used in Exh. CH-1 are exempted from GO 112-D, for the LNG facilities to be located at Little Cojo Bay, Santa Barbara County.

Conclusions of Law

1. The LNG terminal siting process is a legislative process.

2. The Legislature has conferred upon the Commission, in PU Code § 5581, legislative authority normally exercised by other state and local governmental agencies.

3. The reference of the initial evaluation of the seismic evidence relative to the siting of the LNG terminal to a panel of experts is in accordance with all constitutional and legal requirements.

4. The Commission has regularly pursued its authority in employing an expert panel for the initial review of the seismic evidence considered in this decision.

5. The holding of concurrent hearings and compilation of a concurrent record with the Federal Energy Regulatory Commission is a proper exercise of the Commission's authority.

6. All parties to this proceeding have been given an opportunity to be heard at the concurrent hearings in opposition to the panel's report and to present evidence contrary to the facts presented in the report.

7. The substantial rights of the parties to this proceeding have been preserved.

8. The procedures employed in reaching this decision are legal, proper, correct, and, under the circumstances, essential.

9. The Alquist-Priolo Act is not applicable to this proceeding.

10. The Commission has no statutory authority to delegate its decision-making authority to a technical review board.

11. Use of a technical advisory committee is a reasonable method of assisting the Commission in carrying out its responsibilities in connection with the design and construction of the LNG terminal, and such a technical advisory committee should be established.

12. The technical advisory committee should function as an extension of the Commission staff.

13. The Executive Director should be directed to formulate a proposal for the establishment of a technical advisory committee and to submit the proposal to the Commission at an appropriate time. Establishment of the committee would be by a resolution of the Commission. The technical advisory committee shall include two members of the Commission staff as discussed in the foregoing opinion.

14. The trenches opened for the geologic and seismic investigations of the LNG terminal site should be closed and the land surface restored as set forth in the Commission's Phase I Archeological Plan.

15. The seismic phase of this proceeding should be concluded.

16. The design and construction specifications established by this order, insofar as they differ from prior orders of the Commission specifically including GO 112-D, should be considered as variances from those orders and not as amendments having general applicability. Except as specifically authorized by this decision, or by subsequent Commission resolution, the requirements of prior orders, including GO 112-D, should apply.

SEISMIC ORDER

IT IS ORDERED that:

1. The proposed site at Little Cojo Bay is seismically and geologically suitable for the construction and operation of a liquefied natural gas (LNG) terminal.

2. The design and construction of an LNG terminal shall be consistent with the findings and conclusions of this decision.

3. This decision constitutes the establishment of variances, applicable to the Little Cojo Bay LNG terminal site only, to the requirements of D.89177 and GO 112-D. Except as specifically otherwise permitted by the findings and conclusions of this decision, the provisions of D.89177 and GO 112-D shall apply to the design and construction of the Little Cojo Bay LNG terminal.

4. The Executive Director is directed to formulate a proposal for the establishment of a technical advisory committee as contemplated by this decision and to submit a proposal for the establishment of such a committee to the Commission at an appropriate time. Establishment of the committee will be by resolution of the Commission. The technical advisory committee shall include one technical and one legal person from the Commission staff, each having at least 5 years' Commission staff experience.

5. Western LNG Terminal Associates is ordered and directed to close the trenches opened for the geologic and seismic investigations of the LNG terminal site and to restore the land surface to its original condition.

6. The seismic phase of this proceeding is concluded.

This order becomes effective 30 days from today.

Dated OCT 6 1982, at San Francisco, California.

JOHN E. BRYSON
President
RICHARD D GRAVELLE
LEONARD M. GRIMES, JR.
VICTOR CALVO
PRISCILLA C. GREW
Commissioners

I CERTIFY THAT THIS DECISION WAS APPROVED BY THE ABOVE COMMISSIONERS TODAY.

Joseph E. Bodovitz, Executive Director

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