NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN 10 1983

Docket No.: 50-508

16.

MEMORANDUM FOR: Attached List

FROM: George W. Knighton, Chief, Licensing Branch No. 3, DL

SUBJECT: WNP-3 OL REVIEW SCHEDULE

Attached for your information and distribution to the appropriate technical reviewers is the approved schedule for review of the WNP-3 OL application.

The Division of Licensing project manager for WNP-3 Annette Vietti x24449 has received several phone calls over the past few weeks regarding scheduling dates. Therefore, to insure all the technical reviewers have a copy of the schedule it is being sent out again.

George W. Knighton

George W. Knighton, Chief
Licensing Branch No. 3
Division of Licensing

Attachment:
As stated

8301180502 XA

WNP-3 OL REVIEW SCHEDULE

Staff forwards Draft Environmental Statement (DES) questions to Division of Licensing (DL)	December 10, 1982
DL forwards DES questions to applicant	December 17, 1982
Environmental site visit and applicant responses to DES questions	*March 1983
Staff forwards Safety Evaluation Report (SER) questions to DL	April 5, 1983
DL forwards SER questions to applicant	April 12, 1983
Applicant rersponds to questions developed at the environmental site visit	May 2, 1983
Staff forwards DES input to DL	July 8, 1983
Applicant responds to SER questions	July 12, 1983
DL issues DES	September 7, 1983
Staff forwards draft SER input to DL	October 28, 1983
DL issues draft SER	December 1, 1983
Staff forwards Final Environmental Statement (FES) input to DL	January 31, 1984
DL issues FES	April 6, 1984
Staff forwards final SER input to DL	June 5, 1984
DL issues SER	August 9, 1984
ACRS meeting	September 20, 1984
Staff input to SSER forwarded to DL	November 6, 1984
DL issues SSER	December 13, 1984
Start hearings	May 1985
ASLB decision	November 1985
Commission decision	December 1985

*Specific date to be determined after coordination with participants

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

FEB 2 2 1984 11.

MEMORANDUM FOR: Gus C. Lainas, Assistant Director for Operating Reactors
Division of Licensing, NRR

FROM: James P. Knight, Assistant Director for Components & Structures Engineering

SUBJECT: GEOSCIENCES BRANCH SAFETY EVALUATION REPORT FOR THE TROJAN NUCLEAR PLANT

Plant Name: Trojan Nuclear Plant
Licensing Stage: Operating Reactor
Docket Number: 50-344
Responsible Branch: Operating Reactors Branch No. 3; C. Trammell, PM

On February 9, 1984 you requested that the Geosciences Branch (GSB) provide an appropriate input to the Trojan Spent fuel pool rerack SER addressing why it is acceptable to rerack Trojan today in light of ongoing investigations into the seismogenic potential of the subducting Juna de Fuca plate.

It was the understanding of the GSB at the February 3, 1984 meeting with you, that the SER would assess the appropriateness of the Safe Shutdown Earthquake (SSE). The acceptability of reracking the Trojan plant requires an integrated assessment and is beyond the purview of GSB.

The SER input from GSB is enclosed and we conclude that presently we see no reason to alter the seismic design basis approved for Trojan during the CP and OL reviews. This input was prepared by J. Kimball of GSB.

James P. Knight, Assistant Director for
Components & Structures Engineering
Division of Engineering

Enclosure:
As stated

cc: See next page

8402290448XA

2.5.2 Vibratory Ground Motion

As a result of regional research investigations performed since the issuance of the OL-SER for the Trojan site in October 1974, the knowledge of the seismicity and tectonics for this region has been greatly enhanced, and several issues are presently being debated. The most significant seismologic issue involves the seismogenic potential of the subducting Juan de Fuca plate beneath the Pacific Northwest, see for example, Heaton and Kanamori (1983, 1984) and Weaver and Michaelson (1983). These authors points out some of the features consistent and inconsistent with other subduction zones. They emphasize that there exists "sufficient evidence to warrant further study of the possibility of a great (magnitude greater than 8.0) subduction-zone earthquake in the Pacific Northwest" (Heaton and Kanamori, 1984).

The United States Geological Survey, National Science Foundation and the Nuclear Regulatory Commission are all supporting seismologic and geologic investigations to assess the possibility of whether or not a great earthquake is likely or even credible. The staff is well informed as to the progress of this ongoing research, and will continue through the NRC Office of Nuclear Regulatory Research sponsored research activities to maintain this awareness. This ongoing research is complex and incomplete and conclusions emanating from it are highly speculative at this time. As a result, we conclude that there is no reason to alter the seismic design basis for Trojan represented by a modified Housner response spectrum anchored at a zero period acceleration of 0.25g, approved during the CP and OL reviews. If and when in the course of these research activities substantial results are produced which lead to any modifications of this conclusion, appropriate notification will be made at that time. Until then, this information should be viewed in the context of ongoing research of a generic nature relative to the Pacific Northwest in general and should not be considered site-specific in any way.

References

Heaton, T. H., and K. Kanamori, 1983, Subduction in the Northwestern United States; Seismic or Aseismic? Transaction of the American Geophysical Union, N. 64, No. 45, p. 842.

Heaton, T.H. and H. Kanamori, 1984, Seismic Potential Associated with Subduction in the Northwestern United States, preprint, submitted to Seism. Soc. Amer. bull.

Weaver, C.S., and C.A. Michaelson, 1983, Segmentation of the Juan de Fuca Plate and Volcanism in the Cascade Range, Transactions of the American Geophysical Union, V. 64, No. 45, p. 886.

J. Kimball

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN 20 1984

MEMORANDUM FOR: Gus C. Lainas, Assistant Director for Operating Reactors
Division of Licensing, NRR

FROM: James P. Knight, Assistant Director for Components & Structures Engineering
Division of Engineering, NRR

SUBJECT: TRANSMITTAL OF INFORMATION TO TROJAN LICENSEE

PLANT NAME: Trojan Nuclear Plant
LICENSING STAGE: Operating Reactor
DOCKET NUMBER: 50-344
RESPONSIBLE BRANCH: Operating Reactors Branch No. 3;
C. Trammell, PM

At the American Geophysical Union meeting (December 12-16, 1983), a number of presentations were given regarding subduction of the Juan de Fuca Plate in the Pacific Northwest and the potential for a great (magnitude greater than 8.0) earthquake along the subduction interface. In particular, a paper presented by Weaver and Michaelson on the segmentation of the Juan de Fuca Plate would put the Trojan site near the potentially seismogenic segment, and a paper presented by Heaton concluded that the Juan de Fuca Plate shares many of the characteristics of subduction zones which have had great earthquakes.

Although at this time, conclusions regarding the seismogenic potential of the Juan de Fuca zone are not complete it appears as if this issue may eventually have to be addressed by utilities in the Pacific Northwest.

We recommend that the Trojan licensee be made aware of the current research activities regarding the subduction zone by sending them; 1) NRC staff questions on the Washington Nuclear Project #3 site; 2) NRC Draft Safety Evaluation report on the Washington Nuclear Project #3 site and; 3) the accepted NRC research proposal on the subduction zone which is being undertaken by the United States Geological Survey, which are attached.

Portland Gas and Electric should be advised to maintain a high state of knowledge of this issue and inform the staff of any significant findings relative to the Trojan site.

~~8401340162XA~~

JAN 20 1984

The Geosciences Branch is available to meet with the licensee to discuss the attached documents and any possible actions that the licensee may consider.

Robert E. Jackson for
James P. Knight, Assistant Director for
Components & Structures Engineering
Division of Engineering

Attachments:
As stated

cc: w/attachments
R. Vollmer
D. Eisenhut
J. Knight
G. Lainas
J. Miller
R. Jackson
G. Lear
C. Trammell
S. Brocoum
L. Reiter
J. Kimball
R. McMullen
H. Lefevre
L. Frank, Oregon DOE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 2 8 1983

MEMORANDUM FOR: George W. Knighton, Chief
Licensing Branch No. 3, DL

FROM: Robert E. Jackson, Chief
Geosciences Branch, DE

SUBJECT: SUPPLY SYSTEM NUCLEAR PROJECT NO. 3

Plant Name: Supply System Nuclear Project No. 3
Licensing Stage: OL
Docket Number: 50-508
Responsible Branch: Licensing Branch No. 3, Annette Vietti, LPM

We have reviewed Sections 2.5.1 through 2.5.3 of the Supply System Nuclear Project No. 3 Final Safety Analysis Report submitted by the Washington Public Power Supply System in support of their application for an Operating License. On the basis of this review we find that we require additional information and have enclosed questions prepared by the U. S. Geological Survey, Dr. David B. Slemmons, geological consultant, R. McMullen, Geology Section and J. King, Seismology Section, Geosciences Branch, Division of Engineering for your transmittal to the applicant. We recommend that a meeting be held to specifically discuss these questions.

Robert E. Jackson

Robert E. Jackson, Chief
Geosciences Branch
Division of Engineering

Enclosure:
As stated

cc: w/enclosure

T. Novak
J. Knight
L. Reiter
G. Lear
J. King
D. Gupta
D. Slemmons
D. Perkins, USGS
R. Morris, USGS
R. Wells, USGS
J. Knight
T. Sullivan
S. Brocoum
L. Heller
R. McMullen
A. Vietti
S. Algermissen, USGS
A. Tabor, USGS
J. Devine, USGS
O. Rothberg

8305090232

Geoscience Review Questions, WNP-3
Seismology

230.1 (SRP 2.5.2.2, 2.5.2.4, 2.5.2.6)

The work by Ruff and Kanamori (1980) and others appear to support the view that the subduction of the Juan de Fuca plate creates a potential for large magnitude earthquakes in the subduction zone beneath WNP-3. In addition:

a) Kanamori (1983) has published an equation relating the age of the subducting plate, convergence velocity, and the largest expected magnitude event. Does this equation apply to the Juan de Fuca plate and if not, why not? Alternatively are there other convincing models that allow the estimation of the magnitude of subduction zone earthquakes under the site to values lower than would be predicted by the Kanamori (1983) relationship?

b) Are there specific examples of aseismic subduction zones which share the following features with the Juan de Fuca subduction zone: young subducted lithosphere, low convergence rate, no back-arc basin, similar maximum depths of seismicity, shallow oceanic trench, low free-air gravity anomaly, small variation in surface topography of the subducted plate and, particularly, complete seismic quiescence down to the magnitude 5 level?

c) Crustal uplift rates of approximately 2mm/yr were observed in the region from 120 to 220 km inland of the Nankai Trough for the 50 years preceding the 1944, M=8.0 Tonankai and 1946, M=8.2 Nankaido earthquake. Why shouldn't the crustal uplift and NE-compressive strain reported by Savage (1981) for western Washington be considered consistent with a similar preseismic deformation? How is the Juan de Fuca subduction zone any different from the subduction zone in the Nankai Trough and the subduction zone associated with the Rivera plate?

d) What is the magnitude of the largest shock in the plate or along the plate interface that could occur beneath the site without exceeding the SSE acceleration? Specify the attenuation and distance used in the discussion. Assign a confidence level to your magnitude estimate, or estimate a range of magnitudes and corresponding confidence levels.

230.2 (SRP 2.5.2.2, 2.5.2.4)

a) What is the magnitude of the maximum credible earthquake that could occur on the subduction zone beneath the WNP-3 site? This magnitude may be described by a range of values with associated probabilities and a best-estimate value.

b) Estimate response spectra at the site assuming the occurrence of the maximum subduction zone earthquake beneath the site, for both vertical and horizontal components of motion. Specify all assumptions about hypocentral depth and attenuation. The spectra should be calculated on a deterministic basis. If, in addition, probabilistic response spectra are presented, describe the treatment of uncertainty in the magnitude of the maximum earthquake, the attenuation relation, and the hypocentral depth. Justify the SSE spectrum in light of your deterministic (and probabilistic) results, for both vertical and horizontal ground motion.

230.3 (SRP 2.5.2.1, 2.5.2.3)

The depth and configuration of the subducting Juan de Fuca plate is critical to the calculation of the effect of the Benioff zone earthquake at the site.

a) Attention is called to FSAR Figure 2.5-31. No location errors are specified for most of the earthquakes plotted thereon, especially for those occurring in a region which projects to the southwest of Olympia on section AA' and particularly for depth of focus. Referring to Crosson (1972), Figure 6, the site and most of the area in which these earthquakes occur is off-scale and the location errors are likely to be large. Several factors influence the accuracy in depth of focus, most important of which is station coverage which changed greatly during the time interval covered. The applicant is therefore asked to provide a number of diagrams similar to Crosson's Figure 6 for periods which reflect significant changes in network coverage and showing error bars that indicate the accuracy of hypocentral locations.

b) Figure 2.5-36C shows seismicity (for example in the vicinity of Mt. St. Helens) that does not appear to have been plotted in the sections shown in Figure 2.5-31. Yet Figure 2.5-31 states that earthquakes within 150 km of a line striking N60°E through the site have been included on the section. Two questions arise: (1) what earthquakes (if any) have been omitted from the section (Figure 2.5-31), and (2) why is the aperture for the section so wide since a width of 300 km results in earthquakes in the Willamette depression being projected to points west of the site into what may be an entirely different tectonic province?

c) Expand your explanation of the decrease in seismicity on the sections through the site west of point B in Figure 2.5-31.

d) The geometry and location of the flexure in the subducting plate is assumed to be the western boundary to down-dip tension earthquakes. Therefore, its position is critical. Clarify your reasoning for locating the position of the flexure.

e) The Puget Sound earthquake of February 15, 1946, is a large earthquake with uncertain depth (Rasmussen, Millard, and Smith, 1974). If this event was relocated at a shallower depth or farther to the west, it may significantly alter the applicant's conclusions about the earthquake potential of the subduction interface or the overriding plate. The International Seismological Summary for 1946 (1954) lists over 40 observations for this earthquake. The observations range in distance from as close as Seattle to as far as Lome in the Ivory Coast. Despite the existance of these data, the applicant chose not to do a computer relocation (FSAR p. 2.5-120). We request that the applicant relocate this earthquake using the published I.S.C. data and establish the relationship of this earthquake to the Juan de Fuca-North American plate interface.

230.4 (SRP 2.5.2.3, 2.5.2.4)

a) Estimate the maximum magnitude possible for a "random earthquake" in the shallow crust within a 32-km radius around the site.

b) Inasmuch as the 17 March 1904 earthquake has not been associated with a structure at any of its various hypothetical locations (pp. 2.5-127, 128, FSAR), show why the size of this earthquake should not be considered the size of the "random earthquake."

c) With respect to the 17 March 1904 earthquake, provide all references not in the public sector for the intensities shown in Figure 2.5-90, as well as for any other locations for which information is available which could be used to assess intensity. Provide the documentation for the relocation of the earthquake to "south of Port Townsend" and the assignment of a smaller size (both attributed to the Pacific Science Center, Victoria, B.C., as "Milne, 1981, private communication: and "Rogers 1981, private communication").

d) Identify the maximum historical earthquake, not associated with known geologic structure, in the tectonic province of the site. Following Appendix A to 10CFR100, assume this earthquake can occur in the vicinity of the site, estimate the resulting ground motion, and assess the adequacy of the SSE spectrum for this occurrence.

230.6 (SRP 2.5.2.4, 2.5.2.6)

Estimate the annual exceedance probability for the SSE, using as sources random earthquakes, subduction zone earthquakes, as well as earthquakes on significant, capable linears. Show the relative contribution of these sources to the annual exceedance probability. If an integrated assessment of exceedance probabilities is performed, assigning subjective weights to different tectonic models, the exceedance probabilities for each model should be presented separately.

230.5 (SRP 2.5.2.4, 2.5.2.6)

Estimate site-specific spectra for a range of percentiles for the maximum earthquake on the Olympia Lineament, using strong-motion data in the appropriate magnitude and distance range. Justify the SSE spectra in light of the site-specific spectra.

References

Crosson, R.W., (1972). Small earthquakes, structure and tectonics of the Puget Sound region, Bull. Seism. Soc. Am., vol. 62, no. 5, pp. 1133-1171.

International Seismology Summary for 1946 January to March (1954), Kew Observatory, Richmond, Surray.

Kanamori, H., (1983). Global Seismicity Preprint, California Institute of Technology.

Rasmussen, N.H., Millard, R.C., and Smith, S.W., 1974, Earthquake hazard evaluation of the Puget Sound region, Washington State: Seattle, Washington Univ. Press, 99 p.

Ruff, L., and Kanamori, H., (1980). Seismicity and the subduction process, Physics of the Earth and Planetary Interiors, vol. 23, pp. 240-252.

Savage, J. C., Lisowski, M., and Prescott, W. H., 1981, Geodetic strain measurements in Washington, J. Geoph. Res., vol. 86, pp. 4929-4940.

Geosciences Review Questions, WNP-3
Geology

231.1 Standard Review Plan (SRP) Sections 2.5.1.1, 2.5.3.1, 2.5.3.2 and 2.5.3.5

A major northwest-trending fault in the Humptulips River area (Tabor and Cady, 1978) projects northwestward under Quaternary deposits to an outcrop of steeply dipping Pleistocene deposits (op. cit) on the west Fork of the Humptulips River. The capability of this fault may be important to the site in light of the following. Offshore studies by Silver (1972) and Snavely and Wagner (1982) indicate a subduction tectonic style characterized by eastward (landward) dipping thrust faults that generally steepen westward (upwards) and that have offset sediments as young as Quaternary. Considering this structural framework, evaluate the possibility that the Humptulips fault, if capable, extends southeastward as a continuous fault or fault zone along the steepened west limb of the Wynoochee anticline (Rau, 1967) and on into the less well-defined Melbourne anticline (Gower and Pease, 1965) or alternatively to the southeast of these structures. Is the Humptulips fault throughgoing and capable? If so, evaluate the effects on the site. Vibroseis records along the Chehalis River might help evaluate the thrust fault hypothesis and reportedly have been obtained by AMOCO.

231.2 SRP Sections 2.5.1.1, 2.5.3.2 and 2.5.3.5

Assuming that a "....subduction tectonic style characterized by eastward dipping thrust faults that generally steepen westward (upwards)....", described in question 231.1 is correct for the site vicinity, would your conclusion regarding the non-capability of the "reverse" and "normal" faults remain the same? Would a thrust fault model allow the presence of undiscovered faults in the site vicinity? If thrust faults exist in the site vicinity what would be their effect on the site? Document and provide supporting bases for your responses.

231.3 SRP Sections 2.5.1-I and 2.5.1.2

Update the FSAR to include recent seismic reflection, remote sensing, and geophysical data that encompass the site area within a radius of about 25 miles. If any new suspect tectonic structures or lineaments of such size or proximity to the site are identified which would exceed the impact of the Olympia lineament on the site earthquake design basis, determine whether or not those features represent capable faults. Evaluate the impact on the site. Document and provide the bases for your responses.

231.4 SRP Sections 2.5.1-I and 2.5.1.2

Many of the natural drainage features in the site vicinity occur along projections of mapped faults although the faults are shown to terminate away from the stream valleys but along their trends. Also many drainages are oriented in a pattern that is parallel to to the NNW and NE striking fault pattern, yet the streams are not considered to be fault controlled by the applicant. Present the evidence that supports the conclusion that the drainage features are not fault controlled.

231.5 SRP Sections 2.5.1.1, 2.5.2.2, 2.5.3.1, 2.5.3.2 and 2.5.3.5

The applicant has dismissed offset magnetic anomalies KK and HH on the Juan de Fuca plate as probably due to episodic jumping of short transform faults connecting offset segments of the spreading ridge a la Hey 91977) (FSAR 2.5-44). Provided that successive jumps are in the same direction and occur after equal increments of spreading, the jumps should produce a V-shaped wake consisting of a pair of lineaments intersecting at the ridge. Although KK seems to form such a wake, mirrored in the Pacific plate, HH is less convincingly matched (c.f. Barr, 1974 and Elvers and others, 1973). Considering the difficulty of identifying the mirror image of HH, evaluate the hypothesis that HH is a fault as suggested by Pavoni (1966), and that the on-shore subcrustal extension of HH could be the source of deep-seated majc: earthquakes in the Puget Sound region (Fox, 1983). Evaluate the response at the site of a major earthquake on fault HH.

231.6 SRP Sections 2.5.1.1 & 2.5.1-IV

Provide the bases for reducing the assumed maximum downwind thickness of volcanic ash at the site from 6 inches to 1.75 inches as stated on FSAR page 2.5-81. What maximum thickness of tephra landfall, and what maximum rate of ashfall was used as the design basis for the WNP-3 plant.

231.7 SRP Sections 2.5.3.1, 2.5.3.5 and 2.5.2.2

Summarize the field geological, remote sensing, and geophysical data that have a bearing on the overall length and capability or non-capability of the Olympia lineament (including recent analyses by the U. S. Corps of Engineers Districts in Seattle and Portland).

References

Barr, S. M. 1974, Sea Mount formed near the crest of Juan de Fuca Ridge, NE Pacific Ocean; Marine Geology, vol. 17, p1-19.

Elvers, Douglas, Srivastava, S, P., Potter, Kenneth, Moorley, Joseph, Sdidel, Dean, 1973. A symetric spreading across the Juan de Fuca and Gorda rises as obtained from a detailed magnetic survey; Earth and Planetary Sciences Letters, vol. 20 p. 211-219.

Fox, Kenneth F., Jr., 1983, Northeast-trending subcrustal fault transects western Washington: U.S. Geological Survey Open-File Report 83-398.

Gower, H. P., and Pease, H., Jr., 1965, Geology of the Monteseno Quadrangle, Washington: U.S. Geological Survey GQ Map 374.

Hey, Richard, 1977, A new class of "pseudofaults" and their bearing on plate tectonics: a propagating rift model: Earth and Planetary Sciences Letters, v. 37, p. 321-325.

Pavoni, N., 1966, Tectonic interpretation of the magnetic anomalies southwest of Vancouver Island: Pure and applied geophysics, v. 63, p. 172-178.

Rau, W. W., 1967, Geology of the Wynoochee Valley Quadrangle, Washington: Washington State Division of Mines and Geology Bulletin no. 46, 51 p.

Silver, E. A., 1972, Pleistocene Tectonic Accretion of the Continental Slope off Washington: Marine Geology, v. 13, p. 239-249.

Snavely, P. D., Jr., and Wagner, H., 1982, Geologic cross section across the continental margin off Greys Harbor, southwestern Washington: U.S. Geological Survey Open-File Report 82-459, 11 p.

Tabor, R. W., and Cady, W. M., 1978, Geologic map of the Olympic Peninsula, Washington: U.S. Geological Survey Miscellaneous Field Investigations Map I-993.

Northwest U.S. Subduction Zone

Seismic Risk Assessment

Proposal to U.S.G.S. research

program for the U.S.N.R.C.

Project Chief: Thomas H. Heaton
U.S.G.S., Seismology Branch
Calif. Inst. Tech.
Pasadena, CA 91125
FTS 799-0267
Commercial 213-356-6822

Funding period: 01 October 1983 to 01 October 1984

1) Statement of Problem

Despite the fact that there is good evidence of present day convergence of the Juan de Fuca and North American plates, there has been remarkably little historic seismic activity along the shallow part of the Juan de Fuca subduction zone. Although it is impossible to rule out the possibility of aseismic creep, we find that the Juan de Fuca subduction zone shares many features with other subduction zones which both have been locked and have experienced great earthquakes (Heaton and Kanamori, 1983; included as an appendix). We propose to study the possible source characteristics and ensuing strong ground motions and Tsunami hazards for hypothetical great shallow subduction zone earthquakes off the coast of Washington and Oregon.

The first phase of the study will define the geometry and dimensions of potential rupture areas. We will also attempt to characterize the nature of rupture heterogeneity which can be expected. In the second phase, we will estimate the natue of ground motions which may result by comparing the northwestern U.S. with other subduction zones for which strong motion records are available. In the third phase, we will synthesize ground motions for hypothetical great earthquakes by summing the responses of individual segments of the proposed rupture surface. The responses of individual segments will be approximated both by actual recordings of moderate-sized earthquakes and also by numerical calculation of the theoretical response of layered crustal structure to point dislocations.

2) Importance of the Problem to Program Goals

This research is directly motivated by the licensing procedure for the Washington Public Power Supply System System Nuclear Project No. 3 located at Satsop, Washington. The possibility of large shallow subduction zone earthquakes was excluded in the design phase of this facility. However, new study of the nature of the Juan de Fuca subduction zone indicates that such events may be possible. EStimates of ground shaking from large subduction zones earthquakes are of central importance in the licensing review of this plant. Furthermore, due to the nature of this problem, this research is relevant to earthquake hazard estimation throughout the entire western parts of Washington and Oregon. This includes the currently operating Trojan nuclear plant in Oregon.

b) Work to be undertaken

Work on this project falls naturally into three catagories.

Characterization of the source In this phase of the work we will construct models of the feasible rupture parameters of shallow thrust earthquakes on the Juan de Fuca subduction zone. We will include parameters such as fault length, fault dip, fault width, average stress drop, and rupture heterogeneity. Constraints on these parameters will be investigated by studying other subduction zones. That is we will assume that rupture characteristics of Juan de Fuca subduction zone events will be similar to rupture characteristics seen for other subduction zones with similar physical characteristics. Physical characteristics which will be compared are; are of subducted lithosphere, rate of convergence, fault dip, topography of the subducted plate, geometry of the accretionary wedge, nature of marine terraces, and temporal and spatial patterns of seismicity. There are good reasons to suspect that these physical characteristics are closely related to the rupture parameters of shallow subduction earthquakes (see accompaning paper by Heaton and Kanamori). If subduction zones with similar physical characteristics can be found, then the nature of rupture heterogeneity for events on these zones will be characterized by studying the teleseismic body wave radiation from these events.

Earthquake recurrence rates will be estimated using estimates of the plate convergence rate together with estimates of rupture dimensions.

Estimation of strong ground motions We will use several procedures to estimate strong ground motion. The first procedure is described by Heaton et al. (1983). In this procedure a suite of strong motion records is constructed by collecting and scaling records taken at sites with similar tectonic conditions. Records are scaled with respect to site distance, earthquake size, and site conditions. However, it is desirable to collect records which require as little scaling as possible. Once a scaled suite of records has been constructed, we can calculate the statistical mean, median, standard deviation, etc. of various strong motion parameters. An example of this procedure is given in Table 1. In this example, records from strike-slip earthquakes have been scaled to a distance of 50 km and earthquake magnitude of 6½. Records were chosen so that little scaling was necessary. The suite of scaled response spectra is shown in Figure 1. The average spectrum, average plus one standard deviation spectrum, spectrum of the largest single record, and the spectrum which envelops all others are shown in Figure 2. Although the scatter may seem large, it is an accurate representation of the range of motions that have been observed at 50 km from magnitude 6½ strike-slip earthquakes.

This same procedure will be applied to construct suites of strong motion records from subduction zones. These records are principally from Japan. In Figure 3 we show a comparison of peak acceleration plotted as a function of distance and magnitude for ground motions recorded in Japan and the western U. S. We see that magnitude and distance scaling relationships seem to be similar in Japan and the western U.S. We also see that there is sufficient data to simulate subduction zone earthquakes with magnitudes up to about 7½, provided that the distance is greater than 50 km. However for larger earthquakes and smaller source distances, the procedure described above is not appropriate.

Although no records are available for earthquakes of M > 8, we can make synthetic ground motions by summing records from smaller earthquakes. This type of summation has been used with reasonable success by Hartzell (1978) and Kanamori (1979) on large strike-slip earthquakes. The technique has also been used by Heaton and also Kanamori to simulate ground motions for subduction zone earthquakes for use by Exxon Production Research Co.

The basic assumption in the synthesis procedure is that the motions from a large earthquake are a linear sum of the motions from smaller earthquakes. Enough smaller earthquakes are summed so that the sum of the seismic moments of the smaller events equals the moment of the large event. Timing delays due to rupture and travel time dealys are included in the summation process. The details of the timing assumptions in this summation process can, however, affect the nature of the final product. In order to discover appropriate timing assumptions, we will also construct synthetic teleseismic body waves for great earthquakes by summing body waves from smaller events. We will require that our models which produce strong motions also provide an adequate characterization of observed teleseismic body waves.

We will also investigate the feasibility of using the theoretical responses of point dislocation sources as Green's functions for three-dimensional finite fault simulations of very large earthquakes. This technique may be useful if observed records are not available at desired source-station geometries. Such Green's functions would be calculated assuming a horizontally-layered earth structure. The Green's functions would then be integrated over the fault surface in order to produce motions due to a finite rupture surface. These techniques have been used with considerable success to model records from moderate-sized earthquakes (Heaton, 1982; Hartzell and Helmberger, 1982; Hartzell and Heaton, 1983).

Evaluation of Tsunami hazard In order to obtain a rough estimate of the hazard due to local Tsunamis which may be generated by a great shallow subduction zone event, we will search for subduction zones with ocean bottom profiles and source geometries similar to that found in the Juan de Fuca subduction zone. Local Tsunamis generated by historic earthquakes in these other regions will be catalogued. These Tsunamis will then be scaled to account for differences in seismic moment to come up with estimates of the potential heights of Tsunamis that might be expected along the coast of Washington, Oregon, and British Columbia.

4) Strategy and timetable

Although the following work plan may evolve as we proceed into this project, we propose the following tasks and accompanying timetable.

Task I Characterization of source geometry. In this task, we compile physical characteristics of the Juan de Fuca subduction zone. Much of this background work has been done in the Final Safety Analysis Report of the WPPSS Nuclear Project Number 3 (October 1983)

Task II Comparison with other subduction zones. This will be primarily a literature search combined with interviews of knowledgeable colleagues. Cataloguing of physical features should allow us to select those zones with similar characteristics (October-November, 1983).

Task III Estimate source dimensions and geometry of shallow Juan de Fuca subduction zone event. Models of source geometry and size will be constructed (November 1983).

Task IV Characterize rupture heterogeneity. This task ventures into an area not yet studied. We intend to collect teleseismic time functions for large subduction zone events and to characterize the roughness of the time functions (December 1983 - Spring 1984).

Task V Construct suites of scaled strong ground motions. Catalogues of strong motion records will be searched to find records which may be similar to those expected from a Juan de Fuca subduction zone event. (January - March, 1984).

Task VI Construct synthetic strong motion records by summing records from smaller events. Models will be checked for consistency with teleseismic recordings of other great subduction zone events (Spring 1984).

Task VII Estimate local Tsunami hazard. A catalogue of local Tsunamis with source geometrics and ocean bottom profiles similar to the Juan de Fuca subduction zone will be constructed. Tsunami heights will then be scaled using the results of Task III (Summer 1984).

5) Location of proposed work

This project will be conducted at the Pasadena, California, field office of the Office of Earthquakes, Volcanoes, and Engineering USGS. This office is located on the campus of the California Institute of Technology.

6) Other commitments or anticipated difficulties that will affect progress or completion of the project

Most computer codes to manipulate data and compute synthetic ground motions are written and working. However, these codes must be updated. Furthermore, we expect to transfer our work from the Caltech Prime 750 computer to a new USGS VAX 11-750 computer in the Fall of 1983. Although we hope that this transition goes smoothly, there may be unanticipated delays caused by this. Digital recordings of ground motions from subduction zones are presently available, but if a larger catalogue becomes necessary, then collection of other records may delay our schedule.

Both principal investigators in this project are also 1/2 time committed to work in the Seismology Branch project entitled, Southern California Cooperative Seismic Network Project. Their research in this project covers several areas, with the main emphasis in FY1984 being research into possible new directions for seismic networks. Since the Pasadena Field Office is a small office having many responsibilities, the occurrence of local emergency situations, such as earthquakes, may affect work schedules on research projects.

7) Products

04/84 Preliminary report on nature of shaking from Juan de Fuca subduction zone earthquakes to the U.S.N.R.C.

10/84 Final report

10/84 Scientific paper on the nature of seismic hazards associated with the Juan de Fuca subduction zone.

Major facilities and equipment needed

The major requirement of this project is computer time. We presently purchase computer time from Caltech on a Prime 750 computer. However, it appears that a new USGS Vax 11-750 computer will become available for our use in Fall 1983. Thus our projected computer costs cover expenses for the Caltech computer which we feel will be necessary during the process of converting computers.

9) Expected interaction with other projects and workers

There will be strong interation with Hiroo Kanamori at Caltech who maintains strong interest in the nature of subduction zone earthquakes. He is presently working on similar studies under a research grant from Exxon Production Research Company. We also expect interaction from Doug Coats of Exxon Production Research Company and C.B. Crouse of Earth Technology Corporation. Caltech graudate students, in particular, Anne Mori, will be encouraged to participate in the research. Due to the far-ranging implications of this research, we expect to interact frequently about the nature of our preliminary conclusions with researchers at USGS-Menlo Park, Univ. of Washington, USGS-Denver, and the U.S. N.R.C.

10) Qualifications of principal investigators

The principal investigators in this project, Heaton and Hartzell, have considerable experience in the field of synthesizing both strong motions and teleseismic ground motions from complex realistic earthquake sources. They both also have experience in the problem of summing records of smaller earthquakes to simulate large ones. Both have experience in the commercial consulting field and Heaton has considerable experience in the field of estimating ground motions at subduction zones. A full summary of the qualifications of the principal investigators is contained in the resumes included with this proposal

M.Y. Effort	Funding Requested
0.4	40K

References

Hartzell, S.H. (1978). Earthquake aftershocks as Green's Functions, Geophys. Res. Letters, 5, 1-4.

Hartzell, S.H. and D.V. Helmberger (1982). Strong-motion modeling of the Imperial Valley earthquake of 1979, Bull. Seism. Soc. Am., 72, 571-596.

Hartzell, S.H. and T.H. Heaton (1983). Inversion of strong-ground motion and teleseismic waveform data for the fault rupture history of the 1979 Imperial Valley, California earthquake, Bull. Seism. Soc. Am., in press.

Heaton, T.H. (1982). The 1971 San Fernando earthquake: A double event?, Bull. Seism. Soc. Am., 72, 2037-2062.

Heaton, T.H., F. Tajima, and A.W. Mori (1983). Estimating ground motions using recorded accelerograms, manuscript.

Heaton, T.H. and H. Kanamori (1983). Seismic potential associated with subduction in the northwestern United States, manuscript.

Jennings, P.C. and H. Kanamori (1983). Effect of distance on local magnitudes found from strong-motion records, Bull. Seism. Soc. Am.,73, 1645-1670.

Kanamori, H. (1979). A semi-empirical approach to prediction of long-period ground motions from great earthquakes, Bull. Seism. Soc. Am., 69, 1645-1670.

Figure Captions

Figure 1. Response spectra (3% damped) for horizontal components of 15 records from strike-slip earthquakes which are scaled to a distance of 50 km and a magnitude of 6½. Records description and scaling parameters are given in Table 1. Figure is from Heaton et al. (1983).

Figure 2. a) average spectrum, b) average plus one standard deviation specturm, c) specturm of the largest single record, d) spectrum which envelopes all others; based on spectra shown in Figure 1 (taken from Heaton et al. 1983).

Figure 3. Comparison of peak ground accelerations recorded in the western U.S. and Japan. Distance is approximately the closest horizontal distance to the rupture. Dashed line is the modified local magnitude distance attenuation law of Jennings and Kanamori (1983). Figure is from Heaton et al. (1983).

TABLE 1

No.	Earthquake		Station	Magnitude M_w (if available)	Center of Energy Distance (km)	Soil Type	Calculated M_L	$-\log A_o$	C_s	A_I (m)	Scale Factor	Avg. Peak Horizontal Velocity (cm/sec)	Avg. Scaled Peak Velocity (cm/sec)
1	3/11/33	Long Beach	Vernon CMD Bldg.	6.3	36	0	6.23	2.28	+.15	12.59	.87	23.	20.
2	3/11/33	Long Beach	L.A. Subway Term.	6.3	42	0	6.23	2.38	+.15	10.0	1.10	20.5	22.6
3	12/30/34	L. California	El Centro	6.5	61	0	6.38	2.61	+.15	8.32	1.32	16.0	21.1
4	10/21/42	Borrego Valley	El Centro	6.5	46	0	6.38	2.44	+.15	12.3	.89	6.2	5.5
5	12/21/54	Eureka	Ferndale City Hall	6.5	40	1	6.38	2.35	0	10.72	1.02	31.	31.6
6	4/20/65	Japan	Site #CB002	6.1	50	0	6.08	2.43	+.15	6.31	1.74	7.8	7.8
7	4/20/65	Japan	Site #CB057	6.1	45	0	6.08	2.49	+.15	8.91	1.23	20.2	24.8
8	4/9/68	Borrego Mtn.	El Centro	6.6	65	0	6.45	2.65	+.15	8.91	1.23	20.2	24.8
9	10/15/79	Imperial Valley	Cerro Prieto	6.4	39	2	6.3	2.33	-.15	6.61	1.66	15.	24.9
10	10/15/79	Imperial Valley	Delta	6.4	50	0	6.3	2.49	+.15	9.12	1.2	29.2	35.1
11	10/15/79	Imperial Valley	Victoria	6.4	60	0	6.3	2.6	+.15	7.08	1.55	10.2	15.8
12	10/15/79	Imperial Valley	Calipatria	6.4	41	0	6.3	2.37	+.15	12.02	.91	13.7	12.4
13	10/15/79	Imperial Valley	Superstition	6.4	42	0	6.3	2.39	+.15	11.48	.95	6.9	6.6
14	10/15/79	Imperial Valley	Plaster City	6.4	38	0	6.3	2.32	+.15	13.49	.81	4.5	3.6
15	10/15/79	Imperial Valley	Niland	6.4	51	0	6.3	2.5	+.15	8.91	1.23	10.1	12.4
	Test Case			6.5	50	0	6.38	2.49	+.15	10.96		14.26 ± 8.5	17.87 ± 9.

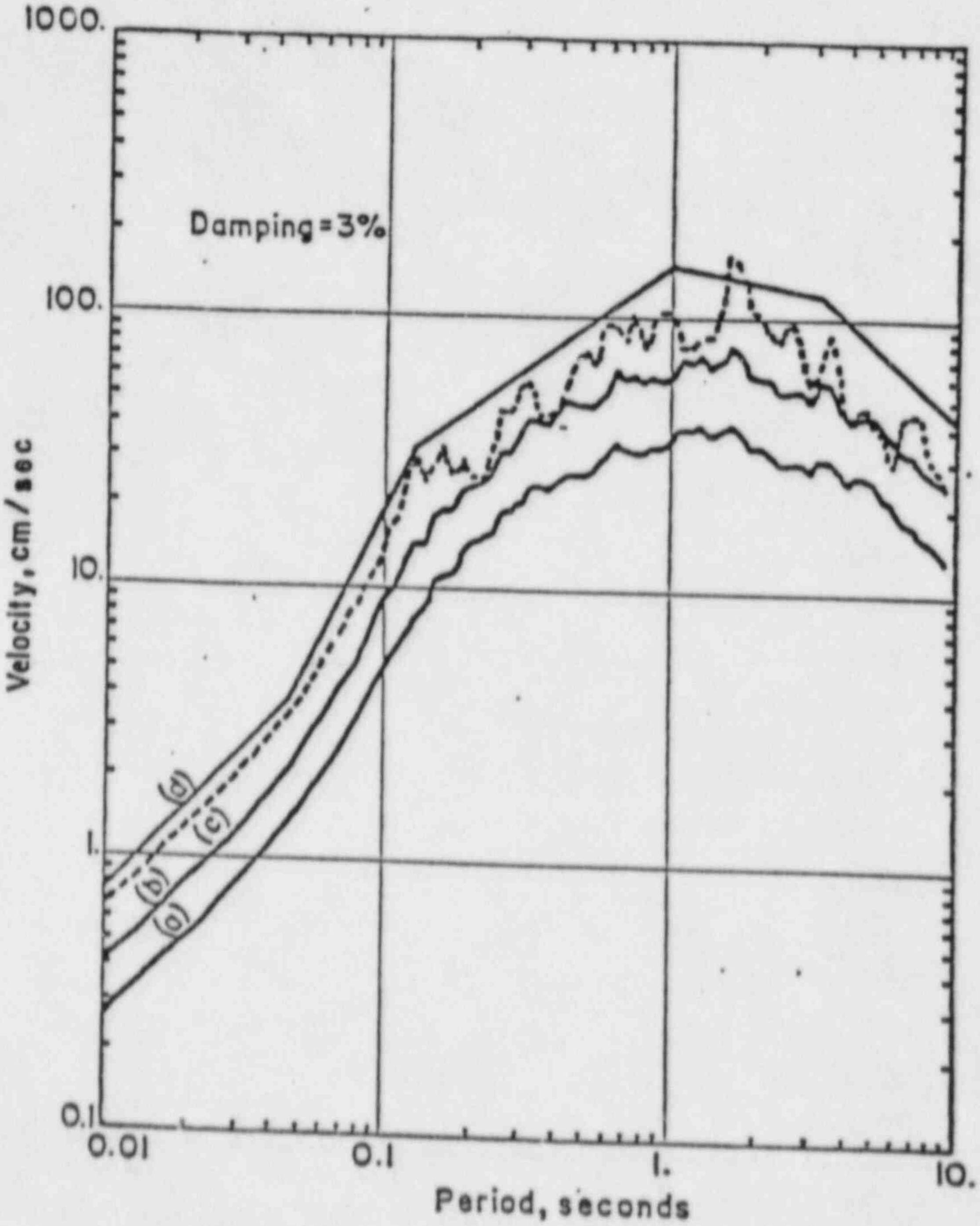
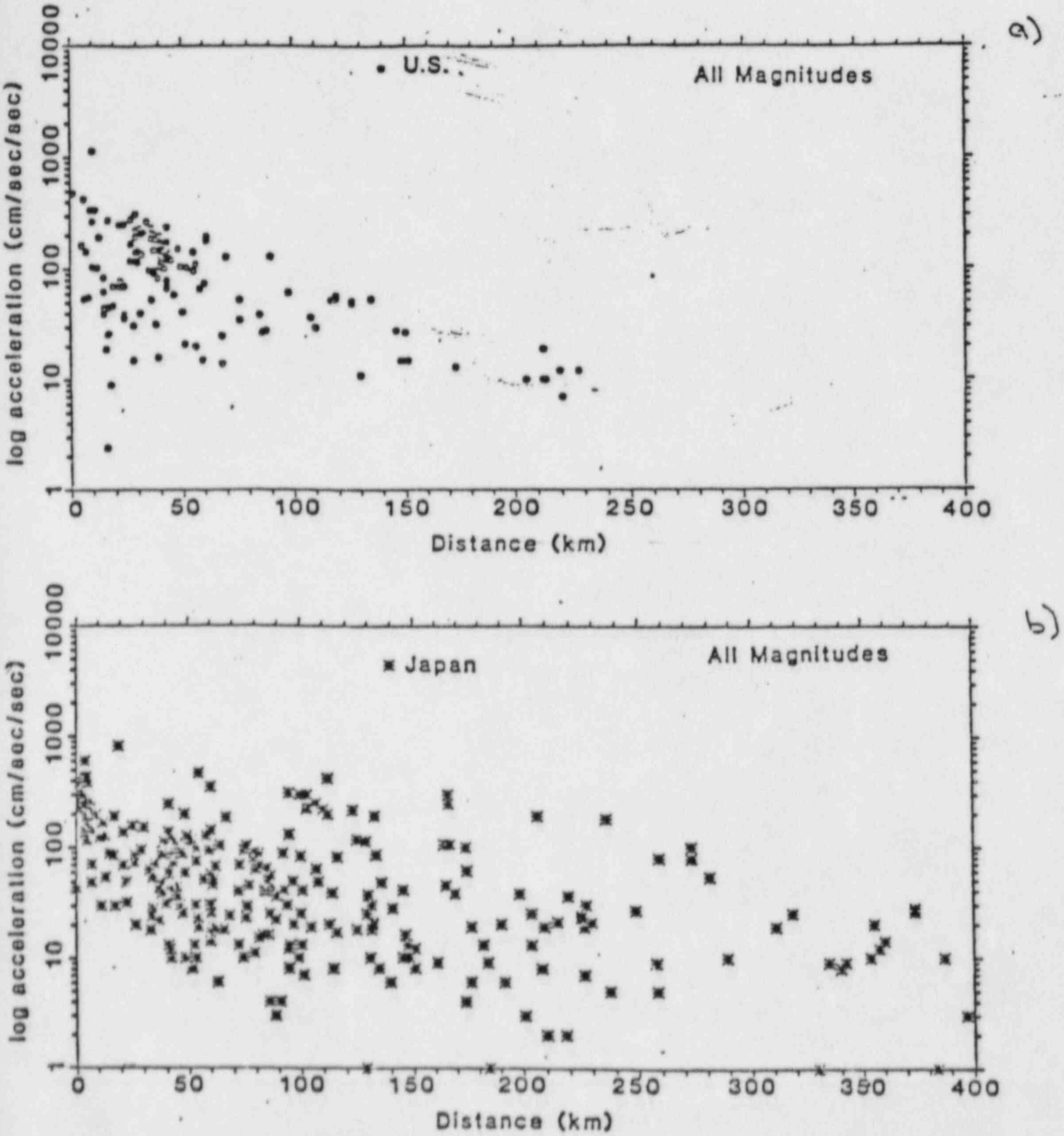

1000.
100.
10.
1.
0.1
0.01
0.1
1.
10.
Velocity, cm/sec
Period, seconds
Damping = 3%
(a)
(b)
(c)
(d)

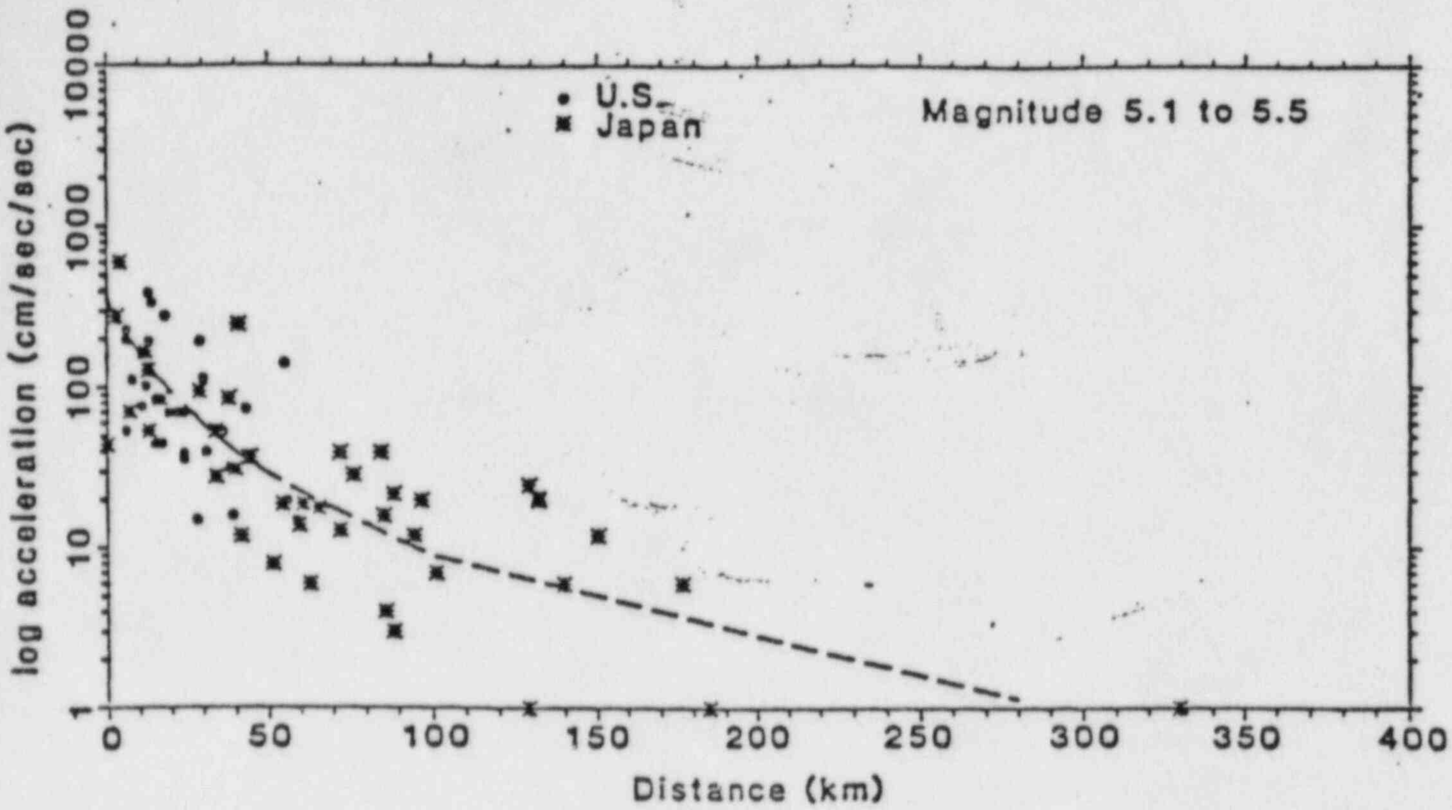
Fig. 3



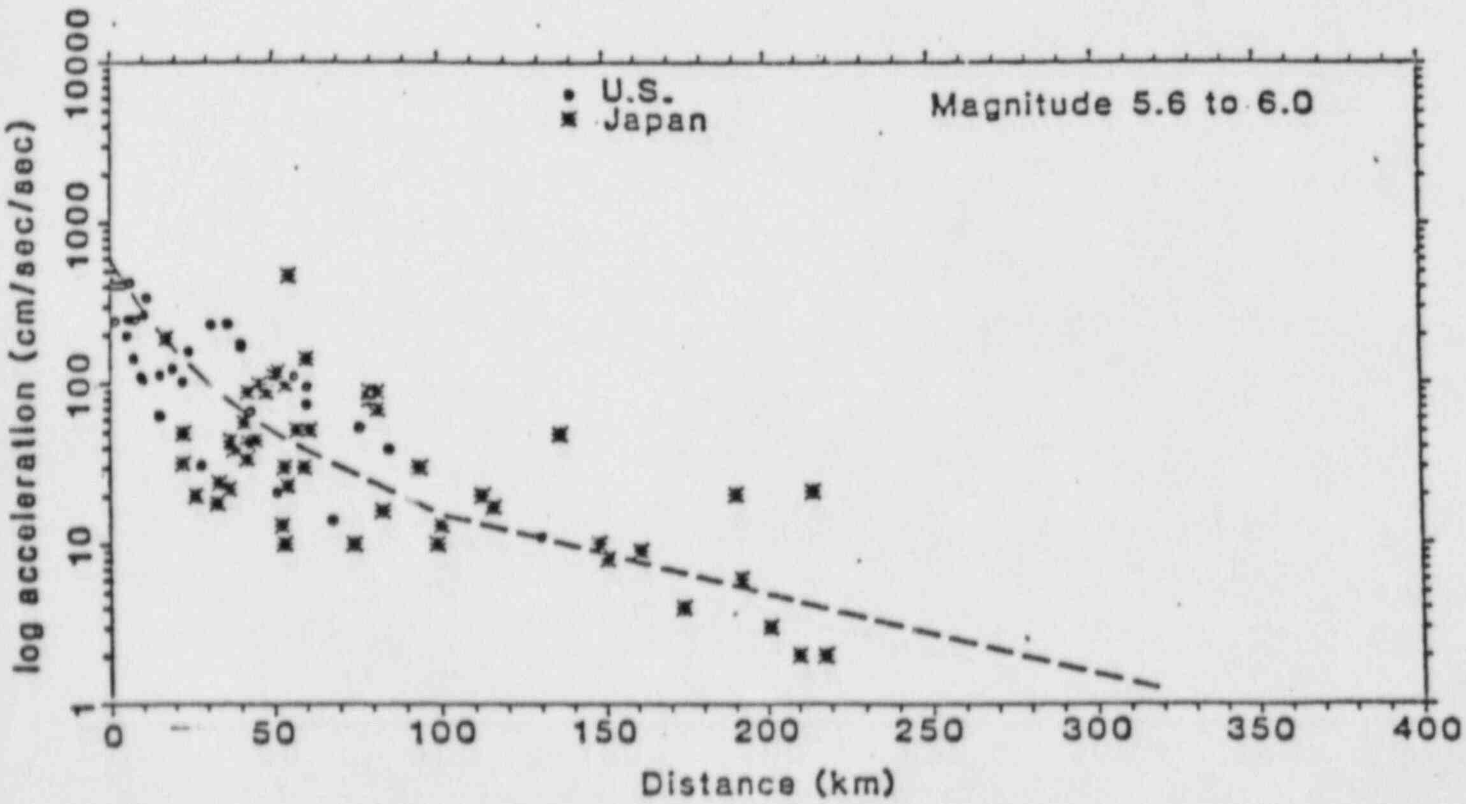
a)
log acceleration (cm/sec/sec)
1 10 100 1000 10000
• U.S.
All Magnitudes
0 50 100 150 200 250 300 350 400
Distance (km)
b)
log acceleration (cm/sec/sec)
1 10 100 1000 10000
* Japan
All Magnitudes
0 50 100 150 200 250 300 350 400
Distance (km)

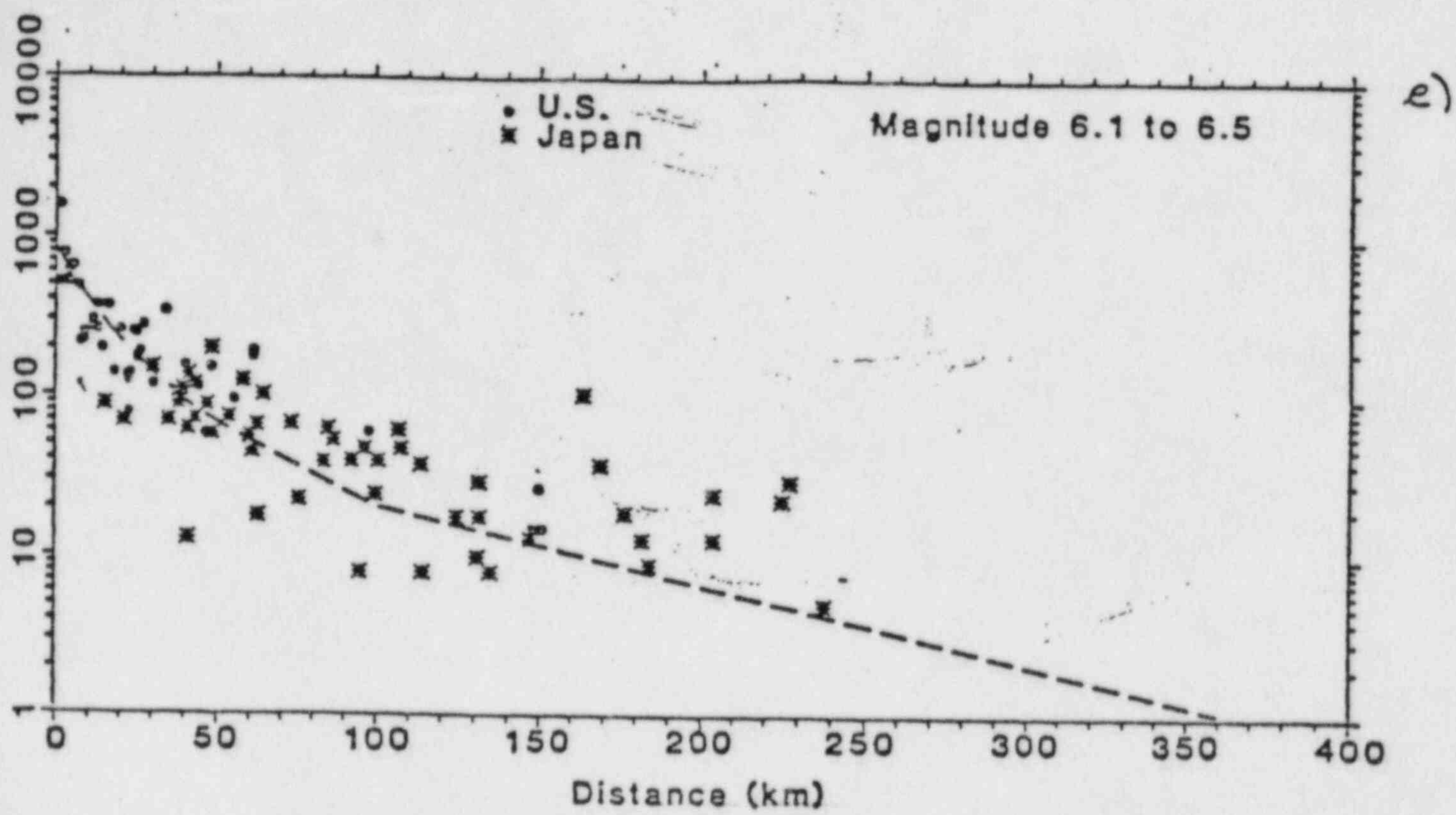
Fig. 3

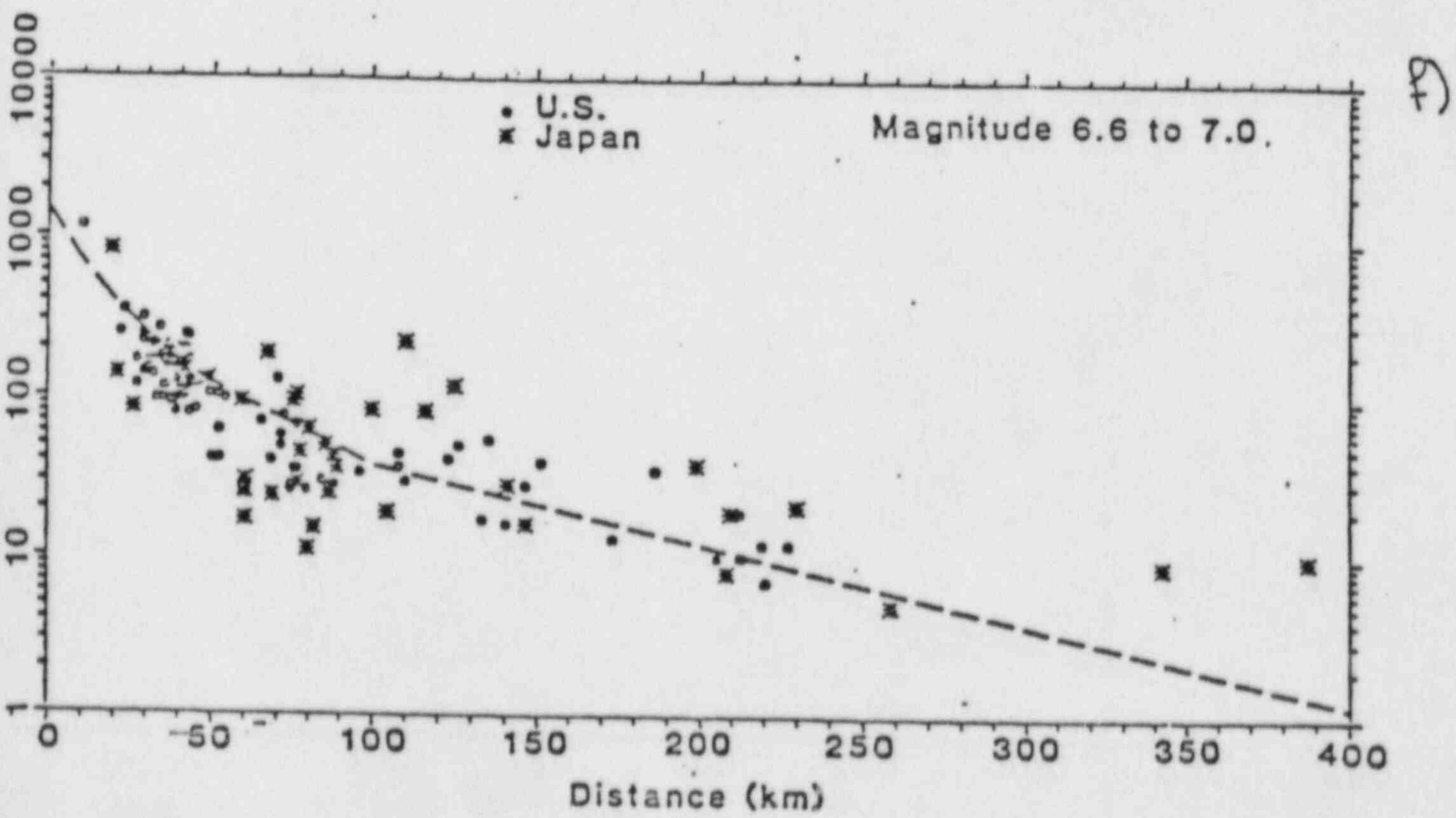
c)


U.S.
Japan
Magnitude 5.1 to 5.5
log acceleration (cm/sec/sec)
10000
1000
100
10
1
0
50
100
150
200
250
300
350
400
Distance (km)

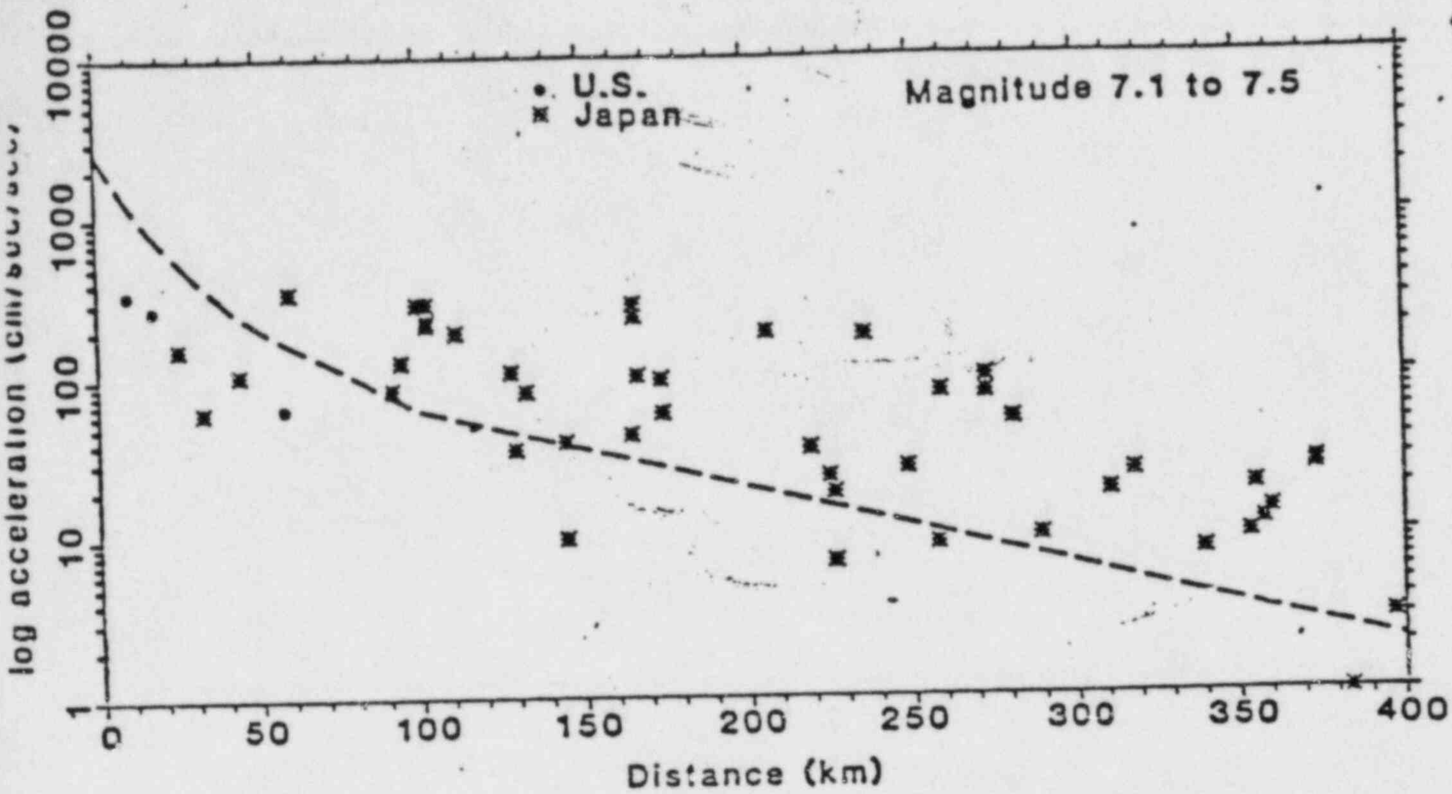
d)


U.S.
Japan
Magnitude 5.6 to 6.0
log acceleration (cm/sec/sec)
10000
1000
100
10
1
0
50
100
150
200
250
300
350
400
Distance (km)


e)
U.S.
Japan
Magnitude 6.1 to 6.5
10000
1000
100
10
1
0
50
100
150
200
250
300
350
400
Distance (km)

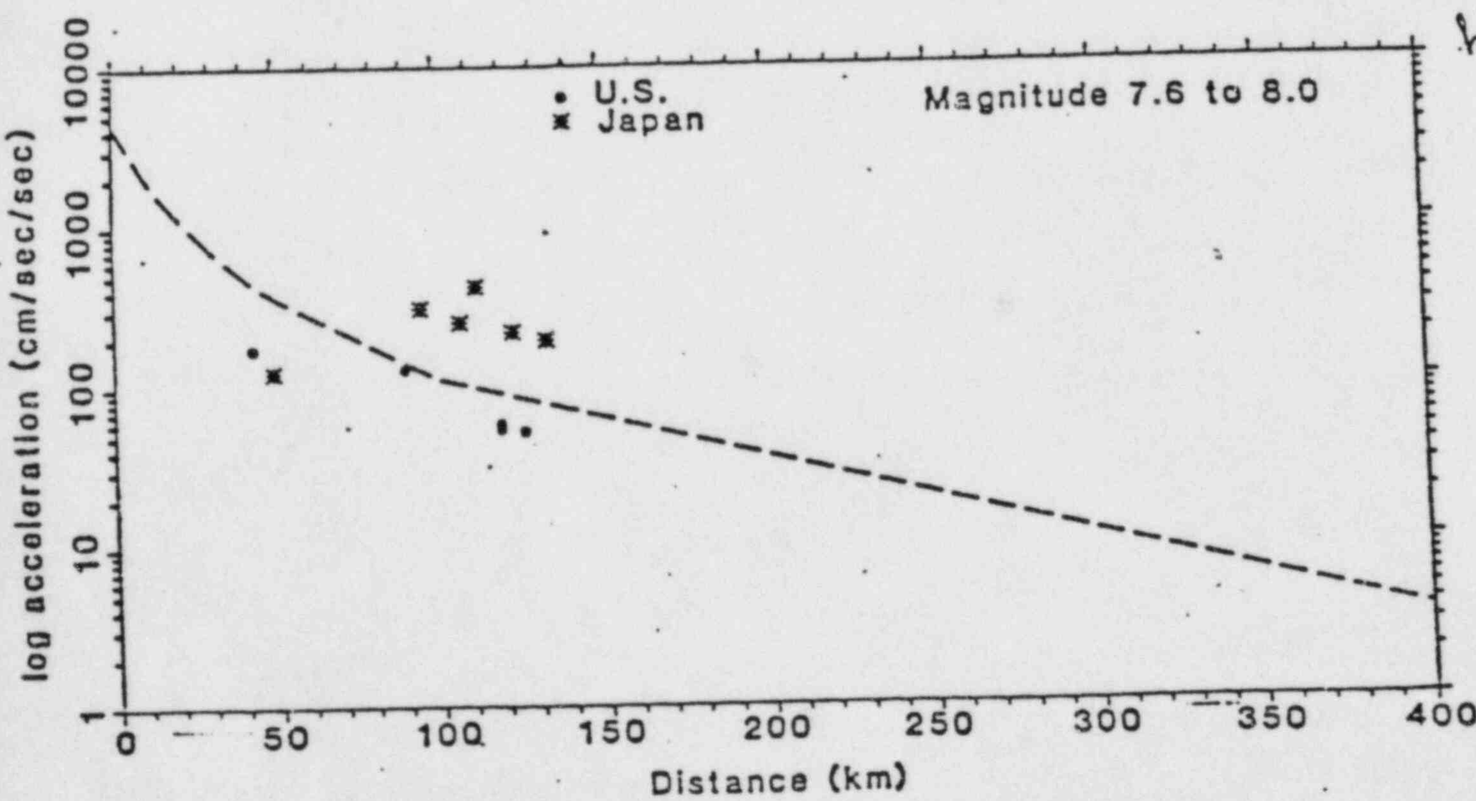

f)
U.S.
Japan
Magnitude 6.6 to 7.0
10000
1000
100
10
1
0
50
100
150
200
250
300
350
400
Distance (km)

g)



• U.S.
✱ Japan
Magnitude 7.1 to 7.5
log acceleration (cm/sec/sec)
10000
1000
100
10
1
0
50
100
150
200
250
300
350
400
Distance (km)

h)



• U.S.
✱ Japan
Magnitude 7.6 to 8.0
log acceleration (cm/sec/sec)
10000
1000
100
10
1
0
50
100
150
200
250
300
350
400
Distance (km)

Fig.3

Resume: Thomas H. Heaton

Title: Geophysicist - U. S. Geological Survey

Expertise: Seismology / Earthquake Engineering

Past Experience:

- 1979-1982 - Geophysicist with U.S. Geological Survey at Caltech office. Strong ground motion studies and earthquake prediction studies

- 1978-1979 - Senior Seismologist with Dames and Moore. Estimation of earthquake hazards for major energy facilities. Half-time visiting associate at the Seismological Laboratory at Caltech with emphasis on strong ground motion modeling

- 1977-1978 - Consultant to Dames & Moore--Seismic hazard studies

- 1974-1978 - Consultant to Converse, Davis, Dixon & Associates--Fault hazard studies

- 1974- Converse, Davis, Dixon & Associates--Engineering geology with emphasis on fault hazard studies

PROFESSIONAL AFFILIATIONS

Seismological Society of American
American Geophysical Union

ACADEMIC BACKGROUND

Chemistry and physics major, Bates College, 1968-1970
B.S. in physics with special interests in mathematics and geology, Indiana University, 1972
Ph.D. in Geophysics, minor in Applied Mechanics, California Institute of Technology, 1978

PUBLICATIONS

Alewine, R.W., and T.H. Heaton, Tilts associated with the Pt. Mugu earthquake, Proceedings, Conference on Tectonic Problems of the San Andreas Fault System, Geological Sciences, XIII, Stanford University, 94-103, 1973.

Heaton, T.H., Tidal triggering of earthquakes, Geophys. J.R. astr. Soc., 43, 307-326, 1975.

Heaton, T.H. and D.V. Helmberger, Predictability of strong ground motion in the Imperial Valley: Modeling the M4.9, November 4, 1976 Brawley earthquake, Bull. Seism. Soc. Am., 68, No. 1, 31-48, 1978.

Heaton, T.H. and D.V. Helmberger, A study of the strong ground motion of the Borrego Mountain, California, earthquake, Bull. Seism. Soc. Am., 67, No. 2, 315-330 1977.

Heaton, T.H., Generalized ray models of strong ground motion, Ph.D. Thesis, California Institute of Technology, 300 p., 1978.

Heaton, T.H. and D.V. Helmberger, Generalized ray models of the San Fernando Earthquake, Bull. Seism. Soc. Am., 69, No. 5, 1311-1341, 1979.

Anderson, J.G. and T.H. Heaton, Aftershock accelerogram recorded on a temporary array, in press U.S.G.S. Prof. Paper on October 1979 Imperial Valley Earthquake, 1980.

Heaton, T.H., J.G. Anderson, and P.T. German, Ground failure along the New-River, in preparation.

McNutt, M and T.H. Heaton, An evaluation of the seismic window theory, California Geology, January 1981, pp12-16.

Amini, A., K. Moslem, J.G. Anderson, and T.H. Heaton, Aftershock accelerograms from the May 1980 Mammoth earthquake sequence, in preparation.

Heaton, T.H., The 1971 San Fernando earthquake; A double event? BSSA, in Press, 1982.

Heaton, T. H., Tidal triggering of earthquakes, BSSA, in Press, 1982.

Heaton, T.H., F. Tajima, and A.W. Mori, Estimating ground motions using recorded accelerograms, BSSA, submitted.

Liu, H.L. and T.H. Heaton, Array analysis of the ground velocities and accelerations from the 1971 San Fernando earthquake, in preparation.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

NOV 1 1983

MEMORANDUM FOR: Thomas H. Novak, Assistant Director for Licensing, DL

FROM: James P. Knight, Assistant Director for Components & Structures Engineering, DE

SUBJECT: DRAFT SAFETY EVALUATION REPORT - GEOLOGY AND SEISMOLOGY - WASHINGTON NUCLEAR PLANT PROJECT NO. 3

Plant Name: Washington Nuclear Plant - Project No. 3
Docket Number: 50-508
Licensing Stage: OL Review
Responsible Branch: Licensing Branch No. 3
Responsible Project Manager: A. Vietti

Enclosed are the geology and seismology sections for the WNP-3 draft SER. This input applies to the SRP sections 2.5.1, 2.5.2 and 2.5.3. The report was prepared by Richard McMullen, Geologist and Jeff Kimball, Seismologist.

As stated in the attached draft SER, there are a number of open items (staff questions) which fall into two broad categories. First is the possibility of a large or great earthquake on the subduction zone beneath the site. Second is the possibility of unrecognized low angle thrust faults in the site vicinity that could cause large close - in earthquakes or surface faulting at the site. We anticipate that when these significant issues are addressed, that new information may require the reinterpretation of some previous positions of the staff, the USGS, and the applicant.

Except for the above discussed open items, the staff reaffirms its conclusions stated in the SER-CP that the applicant has adequately investigated and characterized the seismic and geologic hazards at the site, and with respect to those hazards, the site is acceptable.

Robert E. Jackson for
James P. Knight, Assistant Director for
Components & Structures Engineering
Division of Engineering

Enclosure:
As stated

cc: See next page

8410320463

cc: w/enclosure
G. Knighton
R. Jackson
L. Reiter
S. Brocoum
L. Heller
J. Kimball
R. McMullen
T. Sullivan
A. Vietti
D. Gupta
O. Rothberg
S. Algermissen, USGS
D. Perkins, USGS
J. Devine, USGS
R. Morris, USGS
R. Wells, USGS
A. Tabor, USGS
D. Slemmons

2.5 Geology and Seismology

The geology and seismology of the WNP-3 site were reviewed during the early and middle 1970's during the Construction Permit (CP) review.

As a result of the CP review the NRC staff concluded that:

(1) the inferred large deep seated fault blocks that have been associated with large earthquakes in the southern part of the Puget Sound are not present in the site area;

(2) movement of faults in the site vicinity most likely ceased in the late Tertiary, more than 2 million years before present (mybp), and are therefore not capable within the meaning of Appendix A, 10 CFR 100;

(3) there are no known structures in the immediate site vicinity that could be expected to localize earthquakes there;

(4) the applicant's assessment of the possible volcanic risks in the site region are adequate and that a problem of this type does not exist at the site; and

(5) the safe shutdown earthquake (SSE) with a maximum acceleration of 0.32, and the operation basis earthquake of 0.16g are conservative when applied to the foundation level.

During construction of the facility numerous minor faults were found in the excavation. The applicant investigated these faults and determined that they were at least 630,000 years old but most likely more than 2 million years old. The staff reviewed the applicant's data and made several visits to the site to examine the faults and concluded that the faults were not capable.

In 1974 through 1976, as a result of licensing activities for the Skagit Nuclear Power Plant, studies were initiated concerning the 1872 Earthquake

(MMI IX, magnitude 7.0). New data from these studies raised the question as to whether or not an event of that size could occur at the WNP-3 site. The applicant investigated that earthquake, mostly in regard to its Hanford sites, and determined that it was related to tectonic structure within a broad epicentral zone and therefore could not occur at the site. The NRC staff reviewed that data and data compiled by a panel of experts formed by Northwest US Utilities, and that of another panel of USGS and NOAA experts, and concluded that the 1872 Earthquake was centered in the region between Entiat, Washington and Chilliwack, British Columbia (NRC, 1978) and should not be expected to recur at the site. The most recent staff and USGS discussion of this earthquake can be found in the WNP-2 SSER.

On May 18, 1980, after several weeks of resurgent activity, Mount St. Helens erupted violently sending large quantities of ash several hundred miles downwind to the east. The NRC requested the applicant to reassess the volcanic hazards to the site based on the new data. The applicant concluded, based on that assessment, that the maximum potential ashfall that could be expected from such an eruption from the closest volcanoes during the worst meteorological conditions, would result in a maximum of 1.75 inches of ash at the site. They stated that the plant design could accommodate that kind of ashfall. The NRC staff reviewed the applicant's data and USGS data collected with partial NRC funding and concurred with the applicant's conclusion, but requested additional supporting data.

The staff has completed its review of the FSAR. It has held several meetings with its advisors, the U.S. Geological Survey and its geological consultant, Dr. David Slemmons, two technical meetings with the applicant and its consultants, and conducted a geological reconnaissance of the site and region around the site. On April 28, 1983 we transmitted questions, including those of our advisors to the applicant. Because of the June 1983 postponement of the WNP-3 site construction, those questions or outstanding issues have not been responded to. These open topics will be presented in Sections 2.5.1, 2.5.2, and 2.5.3.

Because of the extensive geologic and seismic information (mostly about subduction zones) that has come out since completion of the CP review, new staff concerns have arisen; however, the following CP conclusions of the staff are still valid:

(1) the inferred large deep-seated fault blocks that have been associated with large earthquakes in the southern part of Puget Sound are not present in the site area;

(2) movement on mapped faults in the site vicinity, including those in the excavation are ancient and are not capable; and

(3) The volcanic hazard to the site has been adequately addressed even in light of the recent eruption of Mt. St. Helens and has been appropriately considered in the design.

Based on new data since the CP, the adequacy of the SSE is in question for the following reasons which reflect our general concerns:

(1) The possibility of a large or great earthquake on a subduction zone beneath the site;

(2) the possibility of unrecognized low angle thrust faults in the site vicinity that could cause large close-in earthquakes or surface faulting at the site.

These issues will be addressed in greater detail in the following sections.

2.5.1 Basic Geologic and Seismic Information

2.5.1.1 Regional Geology

The WNP-3 site is located in the Pacific Border Physiographic Province of Washington State, about two miles south of the town of Satsop and 16 miles east of the city of Aberdeen. The site area lies in the Chenalis Lowlands, which comprise a physiographic zone separating the northern termination of the Oregon Coast Range from the Olympic Mountains.

The site and its environs are largely underlain by Cenozoic strata. Relative to more northern areas of the region, rocks of the site area are not highly deformed. Igneous rocks of Mesozoic and Cenozoic age, however, are more abundant than either sedimentary or metamorphic units throughout the region. The nearest outcrops to the site of Mesozoic and Paleozoic rocks (metamorphic, igneous, and sedimentary types) are found in the highly deformed area some miles to the north and northwest of the proposed plant area. Lithologically, the Cenozoic strata consists predominantly of marine clastic sediments deposited on a basement of Eocene oceanic basalts.

The tectonic history of the site region is complex, with eastward and westward directed low-angle thrusts, grabens, granitic plutons, and stratovolcanoes being best displayed and developed in the Northern Cascades. In the Northern Cascades, the Paleozoic Era is characterized by metamorphic and eugeosynclinal rocks. Eugeosynclinal sediments, granitic plutons, low-angle thrusts, and grabens were formed throughout the Mesozoic Era. During Cenozoic time, the formation of grabens, granitic plutons and basalt flows predominated tectonic activity. These events were followed by several orogenic periods which caused folding and faulting of the older formed rocks and general uplift of the region, and the stratovolcanoes of the Cascade range began to form. The structural features that were formed during these orogenies, and the region, were subsequently eroded during the Quarternary to produce the present day topography. While it appears that the last major period of deformation in the region ended in the Late Tertiary (Pliocene), evidence from Pleistocene deposits in the coastal areas west of the site, from 1100 year old fault dates in the Puget Sound area to the north, and from three active stratovolcanoes in the central part of the state to the east of the site, show that tectonism continued on a more minor scale through the Pleistocene into the Holocene.

The tectonic deformation of Western North America appears to be intimately related to the interaction of two major lithospheric plates, the North American Plate and the Pacific Plate. The interaction is principally along two major transcurrent faults, the San Andreas Fault in California and the Queen Charlotte Fault off Western Canada. However, in the area between Cape Mendocino in northern California and the southern extent of the Queen Charlotte Fault off the western tip of Vancouver Island, the two major plates named above are separated from one another by the small Juan de Fuca Plate.

The interaction between the Juan de Fuca Plate and the North American Plate is not presently understood. The magnetic anomaly pattern east and west of the Juan de Fuca Ridge indicates that part of the Juan de Fuca Plate has been subducted beneath the North American Plate. Also, the chain of stratovolcanoes which forms the axis of the Cascade Mountains is believed to have been produced by magma from a subducting plate (Atwater, 1970). Several other types of data indicate that an episode of late Cenozoic subduction occurred in this region of western North America. Seismic reflection surveys off the coast show a sediment-filled trench at the base of the continental slope (Hays and Ewing, 1970). Anomalously high gravity values on Vancouver Island are suggestive of a remnant subducting slab beneath the region (Stacey, 1973). Seismic wave velocities indicate that a high velocity slab exists beneath the Puget Sound Basin (McKenzie and Julian, 1971; Crosson, 1972) which is indicative of a subducting lithospheric plate.

The applicant has thoroughly reviewed the above-mentioned items and other types of data related to the current interaction of the lithospheric plate boundaries, including studies of plate kinematics (Silver, 1971; Atawater, 1970). While the available data are not clearly definitive, the applicant concludes that the data tends to support the interpretation that subduction is no longer occurring along the Juan de Fuca-North American Plate boundary or is occurring asseismically.

Available evidence examined during the CP review indicated that subduction along the Juan de Fuca Plate-North American Plate boundary was not currently occurring. In particular, earthquake activity indicative of a Benioff zone (a characteristic of subducting plates) was absent in this region. Also, the orientation of the present regional stress field was inconsistent with active subduction. Analysis of earthquake source mechanisms showed that the maximum principal stress is north-south compressional and the minimum principal stress varies from east-west to nearly vertical (Dehlinger and Couch, 1969; Couch and McFarlane, 1971; Crosson, 1972; Malone, et. al, 1975).

New information has been developed since publication of the CP SER and the FSAR, however, which may require a modification of the above conclusions. This new information may indicate that subduction is continuing and that the two plates may be coupled. That information and the NRC staff's concerns are presented in Sections 2.5.2 and 2.5.3.

Numerous reverse faults of a generally northwest or northeast trend, marking elongated basement uplifts, occur throughout the basaltic rocks of the region. These structural features are cut by east to northeast trending normal faults bounding areas showing different amplitudes of folding. Some of these faults significantly displace Tertiary strata in the region. The above described faults are thought to be the result of northeast compression of the crust, which was recurrent several times throughout the early Tertiary, until at least the middle Miocene. The basaltic basement complex shows the highest degree of faulting, with the intensity of faulting declining with the decreasing ages of the overlying rock units.

A line of stratovolcanoes extends along the Cascade Mountains from northern California to southern British Columbia. Eight of the valcanoes are within 200 miles of the Satsop site, the nearest being Mt. Rainier and Mt. St. Helens, each about 80 miles away. All of the volcanoes are believed to have been active within the past 15,000 years and three of them, Mt. St. Helens, Mt. Rainier, and Mt. Baker are considered active at the present time.

Prior to 1980 Mt. Rainier had received the most study. The studies show that it has been intermittently active during the last 10,000 years. This activity has been mainly of pyroclastic type, but includes at least one flow which extended nine miles from the mountain. Three of the tephra eruptions deposited about one inch of material up to 25 miles east of the mountain. The last major eruption occurred about 2000 years ago, but minor eruptive activity occurred 120 years and 150 years ago.

In addition to the eruptions of tephra, numerous mud flows have occurred at Mt. Rainier. The largest of these, the Osceola mud flow, occurred 5700 years ago. It extended about 70 miles down-valley from the volcano. None of the river valleys which could be potential mud flow pathways pass near the Satsop site. We conclude, therefore, that no mud flow hazard exists at the site.

A reassessment of the volcanic hazard was made after the May 18, 1980 eruption of Mt. St. Helens. It was found that downwind of the prevailing winds from the volcano at about 80 miles (plant's distance) there was an accumulation of 6 inches of tephra. The applicant reduced that value to 1.75 inches because the WNP-3 plant is upwind from the nearest Cascade volcanoes. This is a reasonable assumption but we require more data about the maximum thickness of tephra landfall and maximum rate of ash fall to support it.

In summary, it can be said that, while the geologic conditions of the Satsop site and its environs are very complex, and the area is still tectonically active, based on our review of the applicant's work to date, there are no known faults or other structures in the immediate vicinity of the site which could be expected to localize earthquakes; however, because of recent findings about the tectonics of the region, we require additional information to support that conclusion. The outstanding items concerning faulting in the region are discussed more fully in Section 2.5.3.

2.5.1.2 Site Geology

The WNP-3 site is located on a ridge in the Willapa Hills, 1 miles south of the intersection of the Satsop and Chehalis Rivers. The site elevation was +595 msl prior to excavation. Elevations rise to +1,768 msl at Minot Peak, 4 miles to the south. The floodplain of the Chehalis River Valley is about 1 miles wide and has a general elevation of +25 msl. Drainage patterns in the site area form a modified dendritic pattern that is structurally controlled to some extent by the regional Tertiary folding and jointing. Slopes are generally moderate, but range from nearly flat to vertical. The abundant weathering profiles, relict erosion surfaces and Pleistocene terraces in the area were used extensively to determine an upper limit to areal tectonic events.

The site vicinity is underlain by Quarternary deposits which consist of weathered gravels of the Wedekind Creek and Logan Hill formations of early to middle Pleistocene age; glacio-fluvial sands, silts, and gravels of middle to late Pleistocene age; loess of late Pleistocene age; colluvium and landslide deposits of late Pleistocene to Holocene age; and Holocene colluvium.

Approximately 15,000 feet of Tertiary rocks are present in the site vicinity, the oldest of which is the middle Eocene Crescent formation, a submarine basalt. Late Eocene Skookumchuck and McIntosh formations siltstones, tuffs, breccias, and sandstones overlie the basalt. The late Eocene to early Miocene Lincoln Creek formation of tuffaceous siltstone overlies the older four formations and is overlain by early to middle Miocene sandstones of the Astoria formation. The uppermost rocks in the site area are siltstones, sandstones, and conglomerates of the Montesano formation of late Miocene to early Pleistocene age. The plant site is founded on massively bedded sandstone of the Astoria formation.

Structurally the site is located on the nose of a broad poorly defined anticline, which is an extension of one of the areas several uplifts, the Minot Peak uplift. Typical of other anticlines in the region, the Minot Peak uplift has the basaltic basement rocks exposed in its core. Several significant faults (some with several thousand feet of displacement) in the site area can be shown by various means (e.g., terrace dating, saprolitization rates, erosion rates) to be associated with deformations no younger in age than Middle Quat ary (more than 630,000 years ago). Thus, they are not considered to be c pable faults within the meaning of 10 CFR Part 100, Appendix A.

Numerous landslides have been mapped on the site locality. Many of these, though not most commonly, have been identified in the Astoria formation, which is the foundation bedrock. These slides in the Astoria formation are related to slippage along weathered siltstone interbeds. Based on a detailed investigation of local landslides, the applicant determined the geologic and geomorphic conditions necessary for sliding to occur: strong weathering of the Astoria rock, the presence of siltstone beds in the Astoria, topographic slopes inclined in the direction of bedding dip, and undercutting of bedding beneath dip slopes. Site investigations showed that these conditions do not exist at the site. The staff concludes that landsliding does not represent a problem at the site.

2.5.2 Vibratory Ground Motion - WNP-3

As a result of regional and site investigations performed by the applicant and others since the issuance of the CP-SER for WNP-3 in February 1976, the knowledge of the area has been greatly enhanced. The applicant has, and is continuing to undertake numerous studies and investigations that will provide an extensive amount of new information and interpretation. The staff anticipates that our review of this new information will lead to an understanding and resolution of many issues relating to the site vibratory ground motion determination.

The increasing amount of new information, however, may require the reinterpretation of some previous positions of the staff, the USGS, and the applicant. Presently the open seismological items have been transmitted in the form of questions (0230.1 through 0230.6) to the applicant. The applicant and the staff have met to discuss these open issues, and it is anticipated that the applicant will undertake a rigorous program of investigations to collect the information which will allow the staff to resolve the open issues. A summary of these issues follows.

The most significant seismologic issue involves the seismogenic potential of the subducting Juan de Fuca plate beneath WNP-3. The staff concluded in the CP-SER for WNP-3 in February 1976 that "while the available data are not clearly definitive, we believe that they tend to support the interpretation that subduction is no longer occurring along the Juan de Fuca - North American Plate boundary." Since that time additional recordings of small earthquakes have revealed an inclined zone of seismicity dipping to the east-northeast (Crosson, 1980). In addition, based upon the work of Ruff and Kanamori (1980) and Kanamori (1983) regarding the seismogenic potential of subduction zones, a number of questions regarding the Juan de Fuca zone have been raised. It is the applicant's position as discussed in FSAR sections 2.5.1.1.4.2 and 2.5.2.4.2.2, that the interface between the Juan de Fuca and North American plates will not be the location of a large magnitude earthquake. The staff has indicated via the review questions that the applicant must document in greater detail their position.

In particular the staff has requested that the applicant document the following information regarding the Juan de Fuca plate. This includes the applicability of Kanamori (1983) relationship, and examples of aseismic subduction zones which share the same characteristics with the Juan de Fuca zone. The magnitude of the largest shock in the plate or along the plate interface that could occur without exceeding the SSE and ground motion attenuation from subduction zones that can be used for the WNP-3 site will also be documented. The magnitude of the maximum credible earthquake on the subduction zone, along with esitmates of vertical and horizontal response spectra, depth and configuration of the subducting plate based upon earthquake locations cross-sections, fault plane solutions, and historic earthquake re-locations will also be provided by the applicant and reviewed by the staff.

The staff has also requested that the applicant calculate site specific response spectra for the maximum historical earthquake, not associated with known geologic structure, in the tectonic province of the site, and for the maximum earthquake on the Olympia Lineament. The applicant has also been asked to estimate the annual exceedance probability for the SSE using all possible seismologic source including the subduction zone.

The staff, the USGS, and Dr. Slemmons will undertake and participate in meetings and probably several site visits to review the applicant's additional information and field investigations. Upon the applicant's submission and the staff's review of the new information, the staff will issue its Final SER. This SER will discuss in detail all the relevant geologic and seismic issues including the regional and site geology, capable faulting, seismicity, operating and safe shutdown earthquakes, and the vibratory ground motion. Reports by the USGS and Dr. Slemmons will be incorporated as appendices and will be discussed in the SER.

2.5.3 Surface Faulting

The applicant has determined that the structural geology of the site and region around the site is characterized by large uplifts and faults and folds related to those uplifts that were formed by regional northeast directed compression during the Tertiary period. Three of these uplifts are present within the site vicinity, the Minot Peak uplift, the Blue Mountain uplift, and the Black Hills uplift. The site is located on an anticline which is the northern extension of the Minot Peak uplift. All of the uplifts are bounded primarily on the southwest sides and southeast sides by high angle faults that strike north-northwest, and east-northeast, respectively, with offsets ranging from several thousand feet to several hundred feet. The closest faults of this kind to the site are the Weikswood fault on the southwest side of the Minot Peak uplift and the Gibson Creek fault on the southeast side of the uplift. Offsets on both faults exceed 2000 feet. The Weikswood fault is approximately 1 miles south of the site at its closest approach, and the Gibson Creek fault is about 5 3/4 miles south of the site.

The applicant investigated all of the faults in the site vicinity by means of a literature search, mapping, borings, trenching, and remote sensing techniques. The applicant determined an upper limit of age of last movement on the faults by analyzing cross-cutting relationships between faults and stratigraphic contacts, relict erosion surfaces, Quarternary deposits, paleosols and weathering profiles. By determining the ages of these features the applicant was able to show an upper limit of movement on these faults of at least 630,000 years before present and more likely 2 million years before present. The staff has reviewed the data that is the basis for the conclusion and concludes that the faults mapped in the site vicinity are not capable within the meaning of Appendix A. Numerous minor faults were encountered in excavations for the plant. Most of these faults are northwest to northeast striking reverse faults. The applicant has made a good case in the FSAR for relating these faults to the regional faults and to the Late Tertiary northeast directed compression. NRC staff geologists examined these faults on several occasions. The NRC concludes that the faults mapped on and around the site are not capable (Appendix A).

On the other hand, considerable new geological information regarding the tectonics of the site region has been developed since the FSAR was published. Although we hold to our position that the faults in the site locality are not capable, some of the new data raises some concern. For example, it is not clear what happens to the faults at depth. If they are indeed related to Late Tertiary tectonics which are no longer in existence that is one thing, but if they are tied to large eastward dipping thrust faults that flatten downward (eastward), which are related to an active subduction tectonic style of the Juan de Fuca plate, then additional analyses and possibly investigations, will have to be carried out. A major northwest-trending fault in the Humptulips River area (Tabor and Cady, 1978) is a possible fault of this kind. It projects northwestward under Quaternary deposits to an outcrop of steeply dipping Pleistocene deposits (op. cit) on the west Fork of the Humptulips River. The capability of this fault may be important to the site in light of the following. Offshore studies by Silver (1972) and Snavely and Wagner (1982) indicate a subduction tectonic style characterized by eastward (landward) dipping thrust faults that generally steepen westward (upwards) and that have offset sediments as young as Quaternary. Considering this structural framework, we have asked the applicant to evaluate the possibility that the Humptulips fault, if capable, extends southeastward as a continuous fault or fault zone along the steepened west limb of the Wynoochee anticline (Rau, 1976) and on into the less well-defined Melbourne anticline (Gower and Pease, 1965) or alternatively to the southeast of these structures. We have requested the applicant to determine whether or not the Humptulips fault is throughgoing and capable, and, if so to evaluate the effects on the site.

Recent seismic reflection, remote sensing, and geophysical data covering the area has been gathered that post dates the FSAR publication and therefore has not been evaluated with respect to the site. We have recommended that the applicant assess these data with respect to the site.

Many of the natural drainage features in the site vicinity occur along projections of mapped faults although the faults are shown to terminate away from the stream valleys but along projections of their trends. Also many drainages are oriented in a pattern that is paralled to the north-northwest and northeast striking fault pattern, yet the streams are not considered to be fault controlled by the applicant. Evidence that supports the conclusion that the drainage features are not fault controlled is needed before the staff can complete its review.

The applicant has dismissed offset magnetic anomalies KK and HH on the Juan de Fuca plate as probably due to episodic jumping of short transform faults connecting offset segments of the spreading ridge as suggested by Hey (1977) (FSAR 2.5-44). Provided that successive jumps are in the same direction and occur after equal increments of spreading, the jumps should produce a V-shaped wake consisting of a pair of lineaments intersecting at the ridge. Although KK seems to form such a wake, mirrored in the Pacific plate, HH is less convincingly matched (c.f. Barr, 1974 and Elevers and others, 1973). Considering the difficulty of identifying the mirror image of HH, the applicant has been requested to evaluate the hypothesis that HH is a fault as suggested by Pavoni (1966), and that the on-shore subcrustal extension of HH could be the source of deep-seated major earthquakes in the Puget Sound region (Fox, 1983), and to evaluate the response at the site of a major earthquake on fault HH.

REFERENCES

1. Atwater, T., 1970, Implications of Plate Tectonics for the Cenozoic Tectonic Evolution of Western North America; GSA, 81, pp 3513-3535.

2. Barr, S. M., 1974, Sea Mount formed near the crest of Juan de Fuca Ridge, NE Pacific Ocean; Marine Geology, vol. 17, p1-19.

3. Couch, R. W. and MacFarlane, W. T., 1971, A Fault Plane Solution of the October 1969 Mt. Rainier Earthquake and Tectonic Movements in the Pacific Northwest Derived from Fault Plane and First Motion Studies; EOS, AGU Trans, 52, 428 p.

4. Crosson, R. S., 1980, Review of Seismicity in the Puget Sound Region from 1970 through 1978; Report presented at the Puget Sound Earthquake Hazards Workshop, University of Washington, Maple Valley Center, Lake Wilderness, October 1980.

5. Crosson, R. S., 1972, Small Earthquakes, Structure, and Tectonics of the Puget Sound Region BSSA, 62, 5, pp 1133-1171.

6. Dehlinger, P. and Couch, R. W., 1969, Synthesis of Geophysical Results in the Juan de Fuca and Gorda Ridge Areas (NE Pacific Ocean), EOS, AGU Trans, 50, 186 p.

7. Elvers, D., Srivastava, S. P., Potter, K., Moorley, J., Sdidel, D., 1973, A symetric spreading across the Juan de Fuca and Gorda rises as obtained from a detailed magnetic survey; Earth and Planetary Sciences Letters, vol. 20 p. 211-219.

8. Fox, K. F., Jr., 1983, Northeast-trending subcrustal fault transects western Washington; U.S. Geological Survey Open-File Report 83-398.

9. Gower, H. P., and Pease, H., Jr., 1965, Geology of the Monteseno Quadrangle, Washington; U.S. Geological Survey GQ Map 374.

10. Hayes, D. E. and Ewing, M., 1970, Pacific Boundary Structure; in The Sea, A. E. Maxwell (ed), 4, Part II, pp 29-72.

11. Hey, R., 1977, A new class of "pseudofaults" and their bearing on plate tectonics: a propagating rift model; Earth and Planetary Sciences Letters, v. 37, p. 321-325.

12. Kanamori, H., 1983, Global Seismicity; Preprint, California Institute of Technology.

13. Malone, S. D., Rothe, G. H., and Smith, S. W., 1975, Details of microearthquake swarms in the Columbia Basin, Washington, BSSA, 65, 4, pp 855-865.

14. McKenzie, D. and Julian, B. 1971, Puget Sound, Washington - Earthquake and the Mantle Structure Beneath the Northwestern United States; GSA, 82, pp 3519-3524.

15. Pavoni, N., 1966, Tectonic interpretation of the magnetic anomalies southwest of Vancouver Island; Pure and applied geophysics, v. 63, p. 172-178.

16. Rau, W. W., 1967, Geology of the Wynoochee Valley Quadrangle, Washington; Washington State Division of Mines and Geology Bulletin no. 46, 51 p.

17. Ruff, L., and H. Kanamori, 1980, Seismicity and the Subduction Process; Physics of the Earth and Planetary Interiors, v 23, p. 240.

18. Silver, E. A., 1972, Pleistocene Tectonic Accretion of the Continental Slope off Washington; Marine Geology, v. 13, p. 239-249.

19. Silver, E. A., 1971c, Small Plate Tectonics in the Northeastern Pacific; GSA, 82, pp 3491-3496.

20. Snavely, P. D., Jr., and Wagner, H., 1982, Geologic cross section across the continental margin off Greys Harbor, southwestern Washington; U.S. Geological Survey Open-File Report 82-459, 11 p.

21. Stacey, R. A., 1973, Gravity Anomalies, Crustal Structure, and Plate Techtonics in the Canadian Cordillera; Can Jour Earth Sci., 10, pp 615-628.

22. Tabor, R. W., and Cady, W. M., 1978, Geologic map of the Olympic Peninsula, Washington; U.S. Geological Survey Miscellaneous Field Investigations Man I-993.

23. US NRC, 1983, Geosciences Review Questions, Memorandum from R. E. Jackson to G. W. Knighton, Supply System Nuclear Project No. 3, April 28, 1983.

24. UN NRC, 1982, Safety Evaluation Report related to the Operation of WPPSS Nuclear Project No. 2, Docket No. 50-397, Supplement No. 1, NUREG-0892, August, 1982.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

FEB 9 1984

MEMORANDUM FOR: J. P. Knight, Assistant Director for Components and Structures Engineering, DE

13.

FROM: G. Lainas, Assistant Director for Operating Reactors, DL

SUBJECT: TROJAN SPENT FUEL POOL AMENDMENT REQUEST AND JUAN DE FUCA PLATE MATTER

On February 3, 1984 we met with members of the Geosciences Branch to discuss the matter of the Trojan spent fuel pool rerack request and the new Juan de Fuca plate subduction issue. You were unable to attend.

The meeting was triggered by your memorandum to me of January 20, 1984, asking that we send documents to PGE regarding the Juan de Fuca plate matter.

At the meeting it was agreed that GSB would provide an appropriate input to the Trojan spent fuel pool rerack SE addressing why it is acceptable to rerack Trojan today in the face of this plate issue. This SE input would also serve as a "board notification" for the Trojan SFP Licensing Board.

When we receive the SE input, we will then send PGE a letter and the documents requested by your January 20th memo.

Since the Trojan spent fuel rerack is almost ready for issuance, we would appreciate receiving the GSB input by February 17.

G. C. Lainas, Assistant Director
for Operating Reactors
Division of Licensing

cc: R. Jackson
L. Reiter
J. Kimball
J. Gray
J. Goldberg
J. Miller
C. Trammell