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SUBJECT: Forwards responses to Geosciences Branch 810504 second round questions re neotectonic models or alternative models of Columbia Plateau.Final draft of FSAR Sections 2.5.1 & 2.5.2 will be submitted as Amend 18 on or about 811020.

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Washington Public Power Supply System

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U.S. NUCLEAR REGULATORY COMMISSION

Docket No. 50-397

Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Schwencer:

Subject: SUPPLY SYSTEM NUCLEAR PROJECT NO. 2
RESPONSES, GEOSCIENCES BRANCH TO ROUND TWO
QUESTIONS AND FINAL DRAFT OF FSAR SECTIONS 2.5.1 and 2.5.2

Reference: Letter, R. L. Tedesco to R. L. Ferguson, "WNP-2 FSAR - Request for Additional Informaion," dated May 4, 1981.

Enclosed are the responses to the Geosciences Branch questions transmitted to the Supply System by the referenced letter. Sixty (60) copies are being transmitted (ATTN: R. Auluck) under separate cover.

Also being transmitted under separate cover are sixty (60) copies of the final drafts of Sections 2.5.1 and 2.5.2 of the WNP-2 FSAR. This material will be submitted as Amendment 18 on or about October 20, 1981. The material consists of the following:

FSAR Subsection 2.5.1	Replacing Subsection 2.5.1
FSAR Subsection 2.5.2	Replacing Subsection 2.5.2
Figures 2.5-1 through 2.5-56	Replacing Figures 2.5-1 through 2.5-60
Appendix J	Added
Appendix K	Added
Appendix L	Added
Appendix N	Added
Appendix O	Added

Some of the figures used in this material are oversized and/or colored

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Mr. A. Schwencer, Chief
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Page 2

prints which require special processing for adequate reproduction. These figures will be submitted to the Commission with Amendment 18 by October 20, 1981.

Very truly yours,

G. D. BOUCHEY
Deputy Director,
Safety & Security

GDB:WWW:st

Enclosure

cc: W. S. Chin, BPA
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WNP-2 Files

360.6

Tectonic Framework and Mechanisms. Provide a neotectonic model or alternative models of the Columbia Plateau and adjacent provinces with emphasis on the possible seismic source zones in the Plateau under and around WNP-2.

RESPONSE

Neotectonic models for the development of the Columbia Plateau and adjacent provinces are described by Davis (Appendix 2.5N, WNP-2 FSAR, Amendment 18, October, 1981) and Laubscher (Appendix 2.5-O, WNP-2 FSAR Amendment 18, October, 1981). The alternative models of plateau deformation (Bruhn, 1981; Price, 1981; Bentley, 1977) and their implications to the definition of potential seismic sources are described in a seismic exposure analysis of the site by Woodward-Clyde Consultants (Appendix 2.5K, WNP-2 FSAR Amendment 18, October, 1981).

REFERENCES

Bentley, R.D., 1977, Stratigraphy of the Yakima Basalts and Structural Evolution of the Yakima Ridges in the Western Columbia Plateau: Geological Excursions of the Pacific Northwest, Department of Geology, Washington State University, Bellingham, WA, p. 339-389.

Bruhn, R. 1981, Preliminary Analysis of Deformation in Part of the Yakima Fold Belt, South-Central Washington: Report prepared for Washington Public Power Supply System, Richland, WA, 11 p.

Price, E.H., 1980, Strain Distribution and Model for Formation of Eastern Umtanum Ridge Anticline, South-Central Washington: Rockwell Hanford Operations, Report prepared for U.S. Department of Energy, RHO-BWI-SA-30, 27 p.

Price, E.H., 1981, Structural Geometry, Strain Distribution and Tectonic Evolution of Umtanum Ridge at Priest Rapids and a Comparison with Other Selected Localities within Yakima Fold Structures, South-Central Washington: Rockwell Hanford Operations, Richland, WA, RHO-BWI-138 in press.

360.7

Capable Faults. The following geologic or topographic features are faults or they are surface features that strongly suggest the presence of faults: the faults associated with Umtanum Ridge, Gable Mountain, Rattlesnake Mountain, Toppenish Ridge, Saddle Mountains, Yakima Ridge, "Alphabet Hills" in the Rattlesnake-Wallula linear zone; the straight course of the Columbia River east of the site and north of Richland; Trimble's lineaments; and other prominent lineaments in the region. Which of these features do you consider to be capable faults within the meaning of Appendix A, 10 CFR Part 100? Present the bases for eliminating those that you do not consider to be capable faults. Those that you consider to be capable faults, determine their lengths, their relationship to each other and their relationship to regional tectonic structures. Also, determine the nature and amount of movement, and the history of displacements along the faults, including the estimated maximum Quaternary displacement related to a single earthquake.

RESPONSE

The only fault in the vicinity of the site that is known to be capable within the meaning of Appendix A, 10 CFR 100 is the Central fault on Gable Mountain. The geology of the central fault is discussed in subsection 2.5.1.2.4.3 and its earthquake potential is discussed in subsection 2.5.2.4.2.2 (WNP-2 FSAR, Amendment 18, October, 1981). An additional discussion of the relationship to regional tectonic structures is presented in Appendixes 2.5K and 2.5N (WNP-2 FSAR, Amendment 18, October, 1981). This fault displaces 13,000 to 19,000 year old glaciofluvial deposits a maximum of 6 cm (Golder Associates, 1981). Although this fault is capable according to NRC criteria, alternative non-tectonic mechamisms are plausible for the origin of the displacement of the glaciofluvial deposits (Golder Associates, 1981).

The potential seismic sources in the region that are considered to be significant to the site are the Umtanum Ridge-Gable Mountain structural trend, the Rattlesnake-Wallula alignment (this includes Rattlesnake Mountain and the "Alphabet Hills"), Rattlesnake Hills, Saddle Mountains, Yakima Ridge, and Horse Heaven Hills (Section 2.5K.3, Appendix 2.5K, WNP-2 FSAR, Amendment 18, October, 1981). The capability of faults associated with these structures, possible fault rupture lengths, and alternative fault geometries based on alternative tectonic models are discussed in sections 2.5K.3 and 2.5K.4 of Appendix 2.5 K (WNP-2 FSAR Amendment 18, October, 1981). Additional detailed geologic information is presented in Woodward-Clyde Consultants, 1981a and 1981b.

Toppenish Ridge and Trimble's lineaments (as defined by Trimble (1950) near Palouse Falls) are not considered potential seismic sources significant to the site becuase they are too far from the site (greater than 50 km) to make a significant contribution to seismic exposure (Section 2.5K.3, Appendix 2.5K, WNP-2 FSAR, Amendment 18, October, 1981). Features similar to "Trimble's lineaments" proposed for the northwest-southeast oriented coulee drainages approximately 8 km southeast of the site are erosional features and do not appear to be structurally controlled. A continuity survey of the Ringold formation across these features show no signs of any deformation (Section 2.5.1.2.7.4, and Figures 2.5-36 and 2.5-37, WNP-2 FSAR, Amendment 18, October, 1981). The straight course of the Columbia River east of the site does not correlate with any lineaments interpreted from remote sensing imagery, gravity data, or aeromagnetic data that are considered to be a potential seismic source. In addition, based on analysis of well and gravity data, Rothe (1978) concludes that there is no vertical displacement of the basalts along the river in this area.

REFERENCES

Golder Associates, 1981, Gable Mountain: Structural Investigations and Analyses,: Report prepared for Northwest Energy Services Company, Kirkland, WA, 54 p.

Rothe, G. H., 1978, Earthquake swarms in the Columbia River basalts: Ph.D. dissertation, University of Washington, Seattle, 181 p.

Trimble, D. E., 1950, Joint Controlled Channeling in the Columbia River Basalt, Northwest Science, 24, pp. 84-88.

Woodward-Clyde Consultants, 1981a, Wallula Fault Trenching and Mapping: Report prepared for Washington Public Power Supply System, Richland, WA.

Woodward-Clyde Consultants, 1981b, Logs of Trenches at Finley Quarry: Field logs prepared for Washington Public Power Supply System, Richland, WA.

360.8

Surface Faulting. Provide an assesment of any surface fault potential at the site. Consider in this evaluation the Cold Creek Syncline, the hypothesized Wooded Island monocline (Rothe, 1978), thrust faults associated with anticlinorial ridges, the Gable Mountain faults, and faults discovered in nearly drill core, such as DB-10. The evaluation should consider the potential effects caused by man's activities.

RESPONSE

Surface faulting is not a factor in the design of the plant. There are no known capable faults within an 8-km (5-mi) radius of the site (Section 2.5.3, WNP-2 FSAR, Amendment 18, October, 1981). The closest known capable fault that might have the potential for surface-fault rupture is the Central fault on Gable Mountain, which is 18 km from the site. The Central fault is a northeast-striking, south-dipping reverse fault, which is interpreted to be a tear fault that formed in response to the growth of the east and west anticlines on Gable Mountain (Golder Associates, 1981). Other faults that are associated with folding along the Umtanum Ridge-Gable Mountain structural trend include a fault in boring DB-10, (Golder Associates, 1981) and a fault in boring 125 on the southwest side of the Southeast Anticline (Golder Associates, personal communication, 1981). The DB-10 fault is about 14 km from the site. At its closest approach, the Southeast Anticline fault is 6.7 km from the site Neither of these secondary faults strike towards the site and they are not known to be capable. Even if surface displacement is assumed to occur on these or other secondary faults associated with the Umtanum Ridge-Gable Mountain structural trend, the faulting would be restricted to the fold and the faults are too far from the site to pose a surface faulting hazard.

There are no known capable faults associated with the Cold Creek Syncline or the Yakima Ridge structure, which are approximately 10 and 20 km from the site respectively. Even if faults capable of producing surface faulting are assumed to exist along these structures, they are too far from the site to pose a surface faulting hazard.

There are no known faults in the vicinity of Wooded Island that appear capapable of producing surface faulting. The results of a continuity survey along White Bluffs (Section 2.5.1.2.7.4 and Figures 2.5-36 and 2.5-37 in WNP-2, FSAR Amendment 18, October, 1981) and detailed mapping of the area east of Wooded Island (Figure 2.5-36, WNP-2 FSAR Amendment 18, October 1981) indicate that the beds within the exposed upper Ringold Formation are essentially horizontal. No faulting was observed within the exposed part of this unit (Subsection 2.5.1.2.7.4, WNP-2 FSAR Amendment 18, October, 1981).

Detailed analysis of borehole geophysical data indicate that there are no discernable faults in the Ringold Formation (Miocene-Pliocene) at the site (Subsection 2.5.1.2.1, WNP-2 FSAR Amendment 18, October, 1981). A distinct structural high that is about 45 m above the surrounding gradient was encountered at the site in borehole BH-139A (Subsection 2.5.1.2.7.4, WNP-2 FSAR Amendment 18, October, 1981). Refraction seismic profiles (Appendix 2.5D, WNP-2 FSAR) also identify this high, but show no indications of other than a local fold structure. Detailed mapping of the excavations at the WNP-2 site (Subsection 2.5.H.2.1.1, Appendix 2.5H, WNP-2 FSAR Amendment 3, March, 1979) indicate there is no evidence of faulting in the foundation.

Man's future activities that could have an effect on the WNP-2 and WNP-1/4 site are the development of Ben Franklin dam, agricultural development with irrigation on the Hanford Reservation, discovery and production of commercial quantities of natural gas, and development of a mined cavern in basalt for the storage of radioactive waste.

Development of Ben Franklin dam is considered unlikely because of the unfavorable cost-benefit ratio. In order to develop this source (approximately 300 MW of energy), the last free-flowing stretch of the Columbia River within Washington State would need to be destroyed. In addition, the proposed dam location is in an area that shows incipient landsliding and is underlain by thick deposits of unconsolidated and highly permeable river gravels. The possible development of Ben Franklin dam and potential hydrologic effects are discussed in Section 2.4.13.1 and Figures 2.4-26, WNP-2 FSAR.

Recent activity by oil companies in the Columbia Plateau have indicated the probability of commercial quantities of natural gas on the west side of the Columbia Plateau between Yakima and Ellensberg. Limited quantities of natural gas was produced earlier in the 1920's and 1930's from a shallow field located on the north side of Rattlesnake Mountain within the present Hanford Reservation boundary. Current exploration is concentrated along major surface structures. Because there are no major structures within an 8 km (5 miles) distance of the site it is considered unlikely that the development of gas deposits would have any noticeable effect on the site.

Agricultural development with irrigation in the immediate vicinity of the site is considered unlikely because of the dedicated nature of the Hanford Reservation to nuclear power programs. The area to the east of the site, across the Columbia River, has been under irrigation for over 15 years. Essentially all of the available irrigatable land in this area is presently under cultivation. A discussion of the possible association between irrigation and seismicity is found in Appendix 2.5J, WNP-2 FSAR Amendment 18, October, 1981.

Underground mined cavities for the disposal of high level radioactive wastes are being considered by the Department of Energy for the Hanford Reservation. The depth of the proposed mined caverns at Hanford is approximately one kilometer within the Columbia River basalts. The closest approach of any potential mined cavern site to be under consideration is greater than 8 km (5 miles) to the west. Potential surface faulting that might be postulated due to an accident in the cavern construction would not likely pose a surface faulting hazard to the WNP-2 and WNP-1/4 sites.

<u>REFERENCE</u>

Golder Associates, 1981, Gable Mountain: Structural Investigations and Analyses: Report prepared for Northwest Energy Services Company, Kirkland, WA., 54 p.

360.9

Volcanic Hazards. Assess the potential volcanic hazards to WNP-2 in light of the effects of the 1980 eruptions of Mount St. Helens. What is the significance of the nearly three feet of 6000-year-old compacted ash discovered in 1980 near Richland?

GENERAL

There are two parts to Question 360.9 regarding potential volcanic hazards at WNP-2 and 1/4. The first part deals with effects of the 1980 eruptions at Mt. St. Helens and their potential impact on the volcanic hazard assessment at Hanford. The second part deals with the significance to the volcanic hazard assessment of nearly three feet of compacted ash (believed to be the 7,000 year old Mazama ash) found in Richland in 1980. The responses to each part are presented separately below.

Impact of 1980-1981 Mt. St. Helens Eruptions

The potential hazards from the 1980-1981 eruptions of Mt. St. Helens may be related to the volcanic processes (and their secondary effects) that occurred during the eruptions. Based on reports by Korosec and others (1980), Hammond (1980a, 1980b and 1981), Decker and Decker (1981) and Washington Divison of Geology and Earth Resources (1981) the major processes and secondary effects that have occurred in the 1980-1981 eruptions of Mt. St. Helens included:

- o dacite dome emplacement
- o mudflows or debris flows
- o pyroclastic flows
- o pyroclastic surges
- o landslides
- o earthquakes
- o explosion phenomena (air shock)
- o ground deformation (uplift, faulting, and tilting)
- o flooding
- o ashfall

Except for ashfall the above processes either occurred on or near the flanks of Mt. St. Helens (within 30 km) or were confined to the stream drainages that emanate from Mt. St. Helens. Flooding extended the farthest downstream and affected the Columbia River more than 80 km downstream of Mt. St. Helens.

Based on an examination of world-wide data regarding volcanic eruptions and processes, except for ashfall, the major volcanic processes (therefore hazards) generally occur within about 40 km of an explosive volcano. As the 40 km radius is approaced these process become more and more confined to the drainages. Beyond 40 km, the processes are almost completely confined to the drainages. Because WNP-2 and 1/4 lie about 165 km east of the closest Cascade composite volcano (Mt. Adams) and since these sties are not downstream on a drainage emanating from a Cascade composite volcano the major processes and secondary effects (except for ashfall) do not pose hazards to the sites.

The potential volcanic hazards to WNP-2 and 1/4 are the effects resulting from the downwind distribution of ash erupted from a Cascade composite volcano. The effects of a potential ashfall on the sites, developed from an evaluation of relevant data from Mt. St. Helens 1980 eruptions, from studies done for the Pebble Springs Nuclear Plant Site (Shannon & Wilson, 1976), and an examination of world-wide data are presented in Section 2.5.1.2.6.1 of the WNP-2 FSAR Amendment 18, October 1981. The elements of this potential ashfall are summarized:

- o Eruptive Sources: Mt. Adams or Mt. Rainier at a distance of 165 km and 180 km respectively.
- o Estimated Ash Eruptive Volume: Mt. St. Helens Layer Yn (4 km^3)
- o Duration of Ashfall: Approximately 20 hours.
- o Potential Thickness of Compacted Ashfall: 7.4 cm (3 inches)
- o Average Rate of Ashfall: 0.37 cm/hr (0.15 in/hr)
- o Average Density of Ash: 72 pcf (day, loose)
  96 pcf (dry, compacted)
  101 pcf (wet, compacted)
- o Estimated Compaction of Ash: 20-40%

Estimated Average Grain Size:		
	98%	0.5 mm
	91%	0.35 mm
	76%	0.25 mm
	57%	0.15 mm
	50%	0.075 mm
	40%	0.040 mm
	27%	0.010 mm
	20%	0.005 mm
	11%	<0.002 mm

Eight eruptions of Mt. St. Helens have occurred to date since renewed activity began on March 10, 1980 (Washington Division of Geology and Earth Resources, 1981). Of these only six produced large enough volumes of ash to be distributed at significant distances downwind. The dates of these eruptions and the direction of the dispersal axes are:

May 18, 1980	ENE
May 25, 1980	NW
June 12, 1980	SW
July 22, 1980	NE
August 6, 1980	NE
October 16-19, 1980	SW

The largest eruption occurred on May 18, 1980 and was the only one to deposit measureable amounts of ash at the site: less than 1 mm over a 9-hour period. However, the Hanford Site area was near the southern edge of the ash dispersal plume and did not receive the maximum effect of the ash fallout. If the axis of maximum downwind thickness had been centered over the site the effects of the May 18, 1980 ash fall would have been:

o Estimated Ash Eruptive Volume:	2.0 km^3
o Estimated Duration of Eruption:	12 hours
o Estimated Maximum Ash Thickness: (at site equivalent distance)	2.5 - 5.0 cm (1-2 inches)
o Estimated Rate of Ashfall: (ash thickness divided by eruption duration)	0.21 - 0.42 cm/hr (0.08 - 0.17 in/hr)

- o Estimated Density of Ash: 44-92 pcf (dry, loose)
  57-110 pcf (dry, compacted)
- o Estimated Grain Size: (at site equivalent distance) 65% 0.075 mm (75 microns)
  16% 0.005 mm (5 microns)

The five remaining significant ash eruptions of 1980 were of much less volume and have not affected the downwind areas to the extent of the May 18, 1980 eruption. As indicated by a comparison of the potential ashfall and the May 18, 1980 ashfall, the May 18 eruption would have produced less than 50% of the predicted maximum thickness at the site. In addition, the reamaining ashfall effect characteristics of May 18 fell reasonable within the predicted values of the potential ashfall.

The development of the potential ashfall was designed to represent what is reasonably considered to be a large volume, explosive Cascade composite volcano eruption and not a low probability catastrophic eruption such as Mt. Mazama (approximately 7,000 yr BP). The downwind ashfall thickness for the potential ashfall utilized data from the largest known (non-catastrophic) Cascade eruption: the Mt. St. Helens Yn ash that was deposited about 3,5000 yr BP. Thus the May 18, 1980 ash eruption could be considered a small to moderate eruption when compared to the potential ashfall. Crandell and Mullineaux (1978) indicate that such a small to moderate eruption would be expected to occur every 500 to 1000 years while the potential ashfall could be interpreted to occur every 2000 to 3000 years.

Because the efects of the May 18, 1980 Mt. St. Helens eruption were less than or were predicted by the potential ashfall, such an ashfall occurring at the site would not pose a hazard.

Three Feet Thick Ash Near Richland

In 1980 nearly three feet (90 cm) of volcanic ash were found in a building excavation in Richland, Washington (Fecht, 1981, oral communication). The ash was deposited in a low energy, backwater fluvial environment and consisted of three distinct units: thick lower and upper units of tuffaceous silt separated by a thin coarse glassy unit. The thin, coarse, glassy unit appeared to be associated with an unconformity between the lower and upper units. Fecht (1981, oral communication) believes that only about 10% of the total three-foot deposit appears to be reworked.

Although ash samples were collected for analysis they have not yet been analyzed; however, Fecht (1981, oral communication) believes this ash to be from Mt. Mazama (approximately 7,000 yr BP).

Richland lies about 425 km (265 mi) northeast from Crater Lake (Mt. Mazama), almost directly downwind along the main axis of maximum thickness of the Mt. Mazama ash deposited approximately 7000 yr.BP (Williams and Goles, 1968). Using isopach and ash thickness data developed for the Mazama eruption by Williams (1941) and Williams and Goles (1968) a maximum compacted thickness of Mt. Mazama ash of from 5 cm (2 in) to 7 cm (3 in) could be expected at Richland. This is considered to be a compacted free-air fall thickness. Fecht (1981, oral communication) indicated there are about seven localities on the Hanford Site where Mazama ash occurs in thicknesses less than 15 cm (6 in). In addition, he identified at least two localities where Mazama ash appears to be anomalously thick: at the Richland Landfill north of Richland and near Plymouth, Washington (approximately 32 km, south of Richland) where about 60 cm of Mt. Mazama (?) ash have been found in loessal material. Woodward-Clyde Consultants (1981) have reported an exposure of a lenticular deposit of Mt. Mazama ash up to 1.3 m thick in alluvium east of Pasco Basin and 30 cm of Mt. Mazama ash in eolian dune sand near Badger Mountain. They also report that near Priest Rapids Dam more than 1.5 m of Mt. Mazama ash occurs on a steep slope overlain by recent colluvium.

It appears that thicknesses of Mt. Mazama ash greater than those that would be expected from free-air (as taken from Williams, 1941 and William and Goles, 1968) are common within and in the region surrounding the Pasco Basin. The environments of deposition are both eolian and fluvial. The lenticular nature of the 1.3 m-thick Mazama ash observed east of Pasco Basin (Woodward-Clyde Consultants, 1981) and the 0.9 m of Mt. Mazama (?) ash in a low energy, backwater fluvial environment in Richland (Fecht, 1981, oral communication) suggest that these thicknesses are not primary free-air fall but may represent secondary concentration during deposition in lee or low energy areas of streams. Recent studies of subaerial deposition in Idaho of the May 18, 1980 Mt. St. Helens ash indicate that local thicknesses several tens of times thicker than that predicted by the free-air fallout distribution can occur (Othberg and Breckenridge, 1981). These anomalous thicknesses appear to occur in the lee of surface obstructions. In addition, the unconformity and the three distinct units noted at the thick deposit of Mt. Mazama (?) ash in Richland suggest that reworking may be involved in the deposition of that ash.

In conclusion, it is believed that the anomalously thick deposits of Mazama ash noted in and around the Pasco Basin are secondary concentrations of the ash which may be common in distal areas of volcanic ash deposition and do not represent free-air thicknesses.

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Othberg, K. L. and Breckenridge, R. M., 1981, Baseline depositional environments of Mount St. Helens ash in northern Idaho: Abstracts, Mount St. Helens One Year Later Symposium, Eastern Washington University, May 17 and 18, 1981.

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Woodward-Clyde Consultants, 1981, Black, J. H., Swan, F. H., III, and Hanson, K., Quaternary sediments study of the Pasco Basin and adjacent areas: Report prepared for Washington Public Power Supply System, May 22, 1981.

360.10

Work Plans. Provide details of your trenching program and geosciences work plan and the expected goals of these programs.

RESPONSE

The Supply System's field program has been completed. The trenching program was developed to investigate features along the southeastern portion of the Rattlesnake-Wallula alignment. Five trenches and two existing exposures were excavated and logged. The objective of the trenching program was to assess the capability of faults at localities along the Rattlesnake-Wallula alignment from Finley Quarry southeast to Warm Springs and, if possible, to gain information on the time of the most recent fault displacement, the amount and sense of displacement and slip rates. A trench at Finley Quarry, where the fault is exposed, was excavated parallel to the existing quarry face to expose the fault at greater depth and to provide additional structural and stratigraphic information. Additional exposures were provided by excavating the toe of the quarry face.

Capability of the Wallula fault has previously been inferred partly on the basis of Binghan's lineament and on evidence of late Quaternary faults near Warm Springs. Two trenches were excavated across Bingham's lineamant to determine if the lineament is fault controlled. The trench locality was selected based on a review of remote sensing and aerial and ground reconnaissance. Test pits were used to select the final trench locations.

Two trenches were excavated at Warm Springs to assess the conclusions of earlier investigators concerning faulting in this locality. The trenches were excavated close to the previous fault exposure in a stream bank and the stream bank was also further excavated. The results of the trenching program are contained in reports by Woodard-Clyde Consultants (1981a and 1981d).

Mapping of features along the Rattlesnake-Wallula alignment was conducted from Rattlesnake Mountain to Warm Springs. The objective of this work was to field check previous mapping and to obtain additional information needed to assess the seismic potential of the alignement. A remote sensing analysis was made to locate significant structures and to facilitate structural interpretation. Previously mapped faults were field-checked.

A study was conducted of the Quarternary sediments in the Pasco Basin to identify the straitigraphy and paleosols that may be used to date the most recent displacement on faults. The work also included an investigation of clastic dikes to assess their age and to evaluate their relationship to faults in the Basin. A comprehensive literature review and aerial and ground reconnaissance were conducted to identify deposits useful for assessing the capability of structures in the site region. Detailed descriptions of the deposits were made and ages were assessed where possible. The results of this study are contained in a report by Woodward-Clyde consultants (1981c).

A program was developed to investigate reported faults on Toppenish Ridge to assess if they are tectonic in origin or related to landsliding. Because ground access was not obtainable, the program consisted of aerial reconnaissance of Toppenish Ridge, interviews with previous workers, and a comparison of features observed there with features typical of both landsliding and faulting. The results of this study are in a report prepared by Woodward-Clyde Consultants (1981b).

REFERENCES

Woodward-Clyde Consultants, 1981a, Wallula Fault Trenching and Mapping: Report prepared for Washington Public Power Supply System, Richland, WA.

Woodward-Clyde Consultants, 1981b, Toppenish Ridge Study: Report prepared for Washington Public Power Supply System, Richland, WA.

Woodward-Clyde Consultants, 1981c, Quaternary Sediments Study of the Pasco Basin and Adjacent Areas: Report prepared for Washington Public Power Supply System, Richland, WA.

Woodward-Clyde Consultants, 1981d, Logs of Trenches at Finley Quarry: Letter Report prepared for Washington Public Power Supply System, Richland, WA.

360.11

What models of subsurface structure in the basalt pile are required or excluded by a detailed structural and kinematic analysis based on the fold and thrust geometry mapped at the ground surface, deep wells, seismic, and magnetics? These analyses should help explain:

a. Intersections of folds.

b. Cross structures.

c. Differences in fold spacing and trend.

d. Curving structures--Cleman Mountain anticline.

RESPONSE

The subsurface structure in the basalt pile below depths of approximately 1 to 2 km is uncertain. With the present data set, structural models have been inferred on the basis of detailed surface mapping of fold and thrust geometry combined with drilling. The available seismic reflection data (Myers and Price, 1979) is poor quality and has limited penetration (less than approxiamately 2 km); similary, magnetic data only provide information to shallow depths (Weston Geophysical, 1981a). Alternative structural models can be developed from the present data set and no model necessarily explains all the Columbia Plateau structures (Appendix 2.5K, WNP-2 FSAR, Amendment 18, October, 1981). Studies at Umtanum Ridge (Price, 1980, 1981; Golder Associates, 1981a, b) and Gable Mountain (Golder Associates, 1981b; Weston Geophysical, 1981b) indicate that observed reverse faults have narrow down-dip widths and developed secondarily to the folds as the folds grew progressively tighter. In contrast, the presence of scarps along the base of Toppenish Ridge suggests the possibility of a reverse fault having a significant area (Woodward-Clyde Consultants, 1981). These observations suggest that a range of styles of deformation and fault geometries may be associate with the Plateau folds. This range may reflect such factors as variations in the mechanical properties of different basalt units, local stress differences, and the possible influence of basement structures or irregularities on concentrating stress and deformation. The significance of alternative structural models to the evaluation of potential seismic sources in the site region is discussed in Section 2.5K.3.2 (Appendix 2.5K, WNP-2 FSAR Amendment 18, October, 1981).

REFERENCES

Golder Associates, 1981a, Geologic Structure of Umtanum Ridge -- Priest Rapids Dam to Sourdough Canyon: Report prepared for Northwest Energy Services Company, Kirkland, WA, 54 p.

Golder Associates, 1981b, Gable Mountain: Structural Investigations and Analyses: Report prepared for Northwest Energy Services Company, Kirkland, WA, 54 p.

Myers, C.W., and Price, S.M., 1979, Geologic Studies of the Columbia Plateau: A Status Report: Rockwell-Hanford Operations, Richland, WA, RHO-BWI-ST-4.

Price, E.H., 1980, Strain Distribution and Model for Formation of Eastern Umtanum Ridge Anticline, South-Central Washington: Rockwell Hanford Operations, Report prepared for U.S. Department of Energy, RHO-BWI-SA-30, 27 p.

Price, E.H., 1981, Structural Geometry, Strain Distribution and Tectonic Evolution of Umtanum Ridge at Priest Rapids and a Comparison with Other Selected Localities within Yakima fold Structures, South-Central Washington: Rockwell Hanford Operations, Richland, WA, RHO-BWI-FA-138 in press.

Weston Geophysical Corporation, 1981a, Geologic Interpretation of an Aeromagnetic Survey of the Central Columbia Plateau, Washington and Oregon: Report prepared for Washington Public Power Supply System, Richland, WA, 57 p.

Weston Geophysical Corporation, 1981b. Geophysical Investigations, Umtanum Ridge to Southeast Anticline, Hanford Reservation, WA: Prepared for Northwest Energy Services Company, Kirkland, WA.

Woodward-Clyde Consultants, 1981b, Toppenish Ridge Study: Report prepared for Washington Public Power Supply System, Richland, WA.

360.12

What are the merits of explaining the obvious structures and trends by vertical tectonics through the basalt pile or by horizontal tectonics within the basalt pile?

RESPONSE

Regional structural analyses (Appendixes 2.5N; 2.5-O, WNP-2 FSAR, Amendment 18, October, 1981; Price, written communication, 1981; Bruhn, 1981) and local structural studies (Golder Associates, 1981a, b; Price, 1980, 1981; Goff, 1981) indicate that the obvious structures and trends on the Columbia Plateau are the result of compressionsal (horizontal) tectonics. Post-basalt deformation occurred in response to regional north-south compression. Deformation may have occurred simply as folding within the basalt pile or as folding combined with reverse faulting. The reverse faults may be secondary to the folds or may represent detachment fault ramps that could have initiated along mechanical discontinuities within or beneath the Columbia River basalt. The alternative tectonic models and their implications to the site are discussed in Appendix 2.5K (WNP-2 FSAR, Amendment 18, October, 1981).

REFERENCES

Bruhn, R., 1981, Preliminary Analysis of Deformation in Part of the Yakima Fold Belt, South-central Washington: Report prepared for Washington Public Power Supply System, Richland, WA, 11 p.

Goff, F.E., 1981, Preliminary Geology of Eastern Umtanum Ridge, South-Central Washington: RHO-BWI-C-21, Rockwell Hanford Operations, Richland, WA, 100 p.

Golder Associates, 1981a, Geologic Structure of Umtanum Ridge -- Priest Rapids Dam to Sourdough Canyon: Report prepared for Northwest Energy Services Company, Kirkland, WA, 54 p.

Golder Associates, 1981b, Gable Mountain: Structural Investigations and Analyses: Report prepared for Northwest Energy Services Company, Kirkland, WA, 54 p.

Price, E.H., 1980, Strain Distribution and Model for Formation of Eastern Umtanum Ridge Anticline, South-Central Washington: Rockwell Hanford Operations, Report prepared for U.S. Department of Energy, RHO-BWI-SA-30, 27 p.

Price, E.H., 1981, Written communication to Woodward-Clyde Consultants, San Francisco, CA.

Price, E.H., 1981, Structural Geometry, Strain Distribution and tectonic Evolution of Umtanum Ridge at Priest Rapids and a Comparison with Other Selected Localities within Yakima Fold Structures, South-Central Washington: Rockwell Hanford Operations, Richland, WA, RHO-BWI-FA-138 in press.

360.13

What is the structural geometry below and between the anticlines of Frenchman Mountain, Saddle Mountain, Gable Mountain and Rattlesnake Ridge?

RESPONSE

The structural geometry below the Frenchman Hills, Saddle Mountains, Gable Mountain, and Rattlesnake Ridge anticlines is discussed in subsection 2.5.1.2.3 of the WNP-2 FSAR (Amendment 18, October, 1981) (see also response to question 360.11). The structural geometry between the anticlines of Frenchman Hills, Saddle Mountains, Gable Mountain and Rattlesnake Ridge is interpreted to generally consists of broad east-trending asymmetrical synclines. Although most of the synclines are broad and flat-bottomed, some have troughs that are rounded (Myers and Price, 1979).

The Frenchman Hills and Saddle Mountains anticlines are separated by an asymetric syncline referred to as the Othello Basin (Grolier and Bingham, 1978). Structural cross sections by Grolier and Bingham, (1971) indicate the axis of the syncline to be beneath Crab Creek just north of the north slope of Saddle Mountains. The north limb of the syncline is broad with low, southerly dipping basalt flows that appear to thicken slightly toward the synclinal axis. The southern flank dips slightly north and terminates on the south against the Saddle Mountains fault (Grolier and Bingham, 1971).

The Wahluke syncline occurs between the east-trending Saddle Mountains and Gable Mountain anticlines. The Wahluke syncline is a broad low-dipping, asymmetric fold having a steeper southern limb and the axis nearer the Gable Mountain anticline (Myers and Price, 1979). The syncline plunges from the east and west toward the Coyote Rapids depression. As in the Othello Basin, the basalt flows in the Wahluke syncline also appear to thicken toward the axis.

The Cold Creek syncline, the eastern extent of the Yakima Ridge anticline and the Benson Ranch syncline occur between the Gable Mountain and Rattlesnake Ridge anticlines. The Cold Creek syncline occurs between the Gable Mountain and Yakima Ridge anticlines. It is asymmetrical with a steeper southern limb and an axis nearer the Yakima Ridge anticline (Myers and Price, 1979). The Cold Creek syncline plunges eastward and appears to die out in the central Pasco Basin (Myers and Price, 1979) at a distance of more than 8 km (5-mi) from the site. Dips on the syncline are less than 10 degrees to the south on the north limb and less than 40 degrees to the north on the south limb.

The Benson Ranch syncline occurs between the Yakima Ridge and Rattlesnake Ridge anticlines. It is a subtle low dipping fold that plunges, gently southeastward into the Pasco Basin (Myers and Price, 1979). The syncline is interpreted to terminate to the southwest against the Rattlesnake Mountain fault Myers and Price, 1979).

REFERENCES

Golier, M. J., and Bingham, J.W., 1971, Geologic map and sections of parts of Grant, Adams and Franklin counties, Washington: U.S. Geological Survey, Miscellaneous Geologic Investigations, MAP I-589.

Grolier, M. J. and Bingham, J.W., 1978, Geology of parts of Grant, Adams, and Franklin counties, east-central Washington: Washington Department of Natural Resources, Division of Geology and Earth Resources, Bulletin No. 71, 91 p.

Myers, C.W., and Price, S.M., 1979, Geologic Studies of the Columbia Plateau: A Status Report: Rockwell-Hanford Operations, Richland, WA, RHO-BWI-ST-4.

361.1

Provide a discussion of possible ground motion from potential swarm earthquakes in the immediate vicinity of the site. What is the largest magnitude swarm earthquake which could occur close to the site? At what distance from the site is this event assumed to occur? Providing supporting bases. Compare the ground motion (including peaks and response spectra) from this potential earthquake to the SSE and actual design used.

RESPONSE

The potential occurrence of swarm earthquakes within the immediate vicinity of the site (considered to be a distance of less than 10 km) is discussed in Appendix 2.5J, (WNP-2 FSAR, Ammendment 18, October, 1981). The maximum magnitude value for swarm earthquakes near the site is conservatively estimated to be M_C 4.0. Earthquakes of such small magnitude are considered not to be of engineering significance to the plant because of the very short duration and very low energy content of ground motion associated with such earthquakes. Therefore, acceleration and response spectra are not estimated for these earthquakes.

361.2

As noted in the WNP-2 FSAR the peak acceleration was determined to be 0.25g by assuming an intensity MMI=VIII event occurred on the Rattlesnake structure and allowing for no attenuation. A report by Woodward-Clyde "Seismological Review of the July 16, 1936 Milton-Freewater Earthquake Source Region" states that the 1936 earthquake had a magnitude of M_L = 6.1. This earthquake is the largest magnitude earthquake (historical) within the Columbia Plateau Tectonic Province which has not been associated with a tectonic structure. Since magnitude may be a more realistic estimate of earthquake size than intensity, compare the ground motion (including peaks and response spectra) assuming that a magniutde M_L = 6.1 reoccurred in the vicinity of the WNP-2 site. One method of making such a comparison is to analyze accelerograms from similar magnitude earthquakes, recorded at appropriate distances, and site conditions. It has been the staff's position that the representation appropriate for use in comparing a "site specific spectra" with the SSE is the 84th percentile of the response spectra as derived directly from the real time histories.

RESPONSE

The July 16, 1936 Milton-Freewater Earthquake appears to have occurred in the basement beneath the Columbia Plateau volcanics at a depth of about 5 km (Woodward-Clyde Consultants, 1980). The after shock distribution and felt effects of the main shock suggest that the earthquake occurred on a northeast-trending zone parallel to the Hite fault. Although this earthquake has not been correlated with a known fault or structure (Section 2.5.2.3, WNP-2 FSAR, Amendment 18, October, 1981) an earthquake of this magnitude must have occurred on a tectonic structure. The possibility of earthquakes as large as, or larger than, the Milton-Freewater earthquake occurring on potential seismic source in the vicinity of the site is incorporated in the probabilistic analysis of ground motions conducted for the WNP-2 and WNP-1/4 site (Appendix 2.5K, WNP-2 FSAR, Amendment 18, October, 1981). Refer also to the response to Question 361.13.

REFERENCES

Woodward-Clyde Consultants, 1980b, Seismological review of the July 16, 1936 Milton-Freewater earthquake source region: Report prepared for the Washington Public Power Supply System, Richland, WA, 44 p.

361.3

Evaluate the maximum earthquake potential of faults which have been found to be capable within the meaning of appendix A, 10 CFR Part 100, and regional tectonic structures associated with the capable faults. Compare the ground motion (both peaks and response spectra) from potential earthquakes on these structures to the proposed SSE and actual design used. Include such consideration as: fault length, fault displacement, slip rate, magnitude or range of magnitude assumed for each structure, and the distance at which these events are assumed to occur from the site.

RESPONSE

Subsection 2.5.2.4 (WNP-2 FSAR Amendment 18, October, 1981) addresses the maximum earthquake potential at the site. The Central fault on Gable Mountain is the only fault that is known to be capable according to NRC criteria (Appendix A, 10 CFR 100). The maximum magnitude assessment for the Central fault is presented in Subsection 2.5.2.4.2.2 (WNP-2 FSAR, Amendment 18, October, 1981) and associated ground motions are given in Subsection 2.5.2.6.1.

361.6

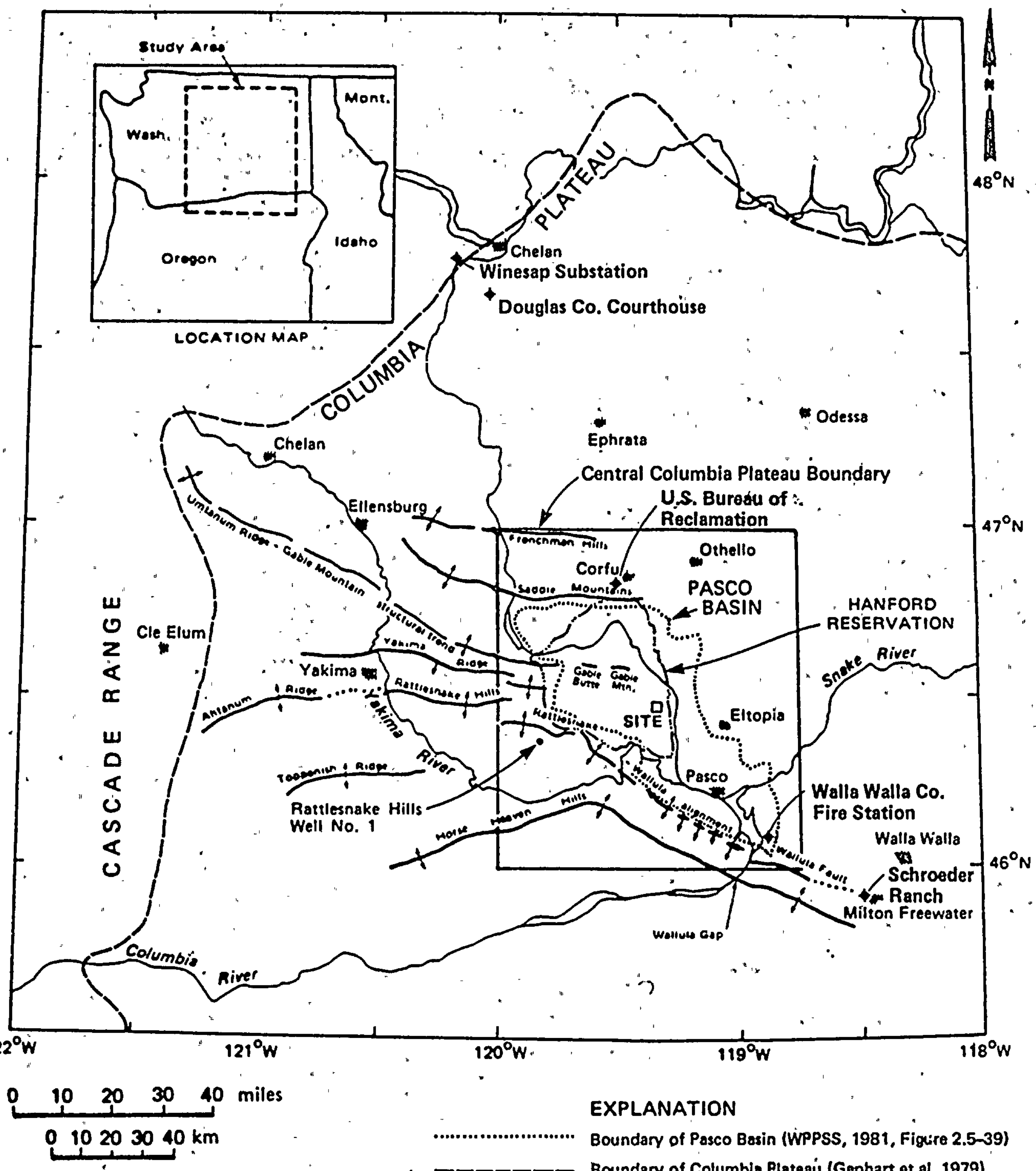
Provide the location and dates of operation of the strong motion instruments mentioned in your January 27, 1981, work plan.

RESPONSE

The location and dates of installation of the strong motion instruments mentioned in the Supply System's January 27, 1981, work plan are as follows:

Station	Latitude	Longitude	Date of Installation
Schroeder Ranch	45°57'	118°24'	September 3, 1981
Walla Walla Co. Fire Sta.	46°05'	118°54'	September 2, 1981
U.S. Bureau of Reclamation Communications Building	46°11'	119°33'	To be installed
Douglas County Courthouse	47°39'	120°04'	To be installed
Winesap Substation Chelan Co. P.U.D.	47°42'	120°13'	To be installed

These locations are shown on Figure 361.6-1.



EXPLANATION

Boundary of Pasco Basin (WPPSS, 1981, Figure 2.5-39)

Boundary of Columbia Plateau (Gephart et al, 1979)
Structure modified from WCC, 1981, Appendix 2.5K

Strong Motion Instrument Site

LOCATION MAP OF COLUMBIA PLATEAU SHOWING STRONG MOTION INSTRUMENT SITES	Figure 361.6-1

361.7

A report entitled "Fault and Earthquake Hazard Evaluation of Five U.S. Corps of Engineers Dams in Southeastern Washington" by David B. Slemmons and Peg O'Malley discusses potential earthquake hazard for Southwestern Washington. The authors estimate a magnitude of 6.3 to 6.8 (Richter) for the CLEW zone based on the Wallula Gap fault being probably active or capable and having a length of 40 km. Evaluate these findings and any impact they may have on the seismic design adequacy of the plant.

RESPONSE

The estimate of the maximum earthquake magnitude for the Wallula Gap fault by Slemmons and O'Malley (1980) is based on the assumption that the fault is a strike-slip or reverse-oblique fault and is probably capable. They assumed that the fault has a total length of about 40 km and the rupture length is taken as one-half of the total fault length. They estimate a magnitude of 6.3 to 6.8 for the Wallula Gap fault based on this assumed rupture length.

In the seismic exposure analysis, presented in Appendix 2.5K (WNP-2 FSAR, Amendment 18, October, 1981), the Wallula segment of the Rattlesnake-Wallula alignment (RAW) is essentially the same potential source as that considered by Slemmons and O'Malley (1980). The various tectonic models, segmentation models, and fault geometries presented in the seismic exposure analysis for the Wallula segment include the assumed parameters of Slemmons and O'Malley. In addition, the capability of the Wallula segment is assessed on the basis of recent field investigations of RAW (Woodward-Clyde Consultants, 1981a and 1981b). The development of the tectonic models, capability, segmentation, and fault width of RAW are given in Subsection 2.5K.3.3.2 of Appendix 2.5K (WNP-2 FSAR, Amendment 18, October, 1981). The fault rupture length, slip rate, and maximum magnitude are given in Subsections 2.5K.4.2 of this appendix.

REFERENCES

Slemmons, D.B., and O'Malley, P., 1980, Fault and Earthquake Hazard Evaluation of Five U.S. Corps of Engineers Dams of Southeastern Washington: Prepared for Seattle District, U.S. Corps of Engineers, 60 p.

Woodward-Clyde Constultants, 1981a, Wallula Fault Trenching and Mapping: Report prepared for Washington Public Power Supply System, Richland, WA.

Woodward-Clyde Consultants, 1981b, Logs of Trenches at Finely Quarry: Letter report prepared for Washington Public Power Supply System, Richland, WA.

361.8

Provide a discussion of the possible relationship of the earthquakes with depths greater than 9 km to the grabens whose bounding faults may extend for significant distances south under the Plateau, into the Pasco Basin.

RESPONSE

Analyses of the earthquake activity with depths greater than 9 km are discussed by Woodward-Clyde Consultants (1980), and in Appendix 2.5J (WNP-2 FSAR Amendment 18, October, 1981). There are no apparent alignments of hypocenters that suggest the presence of significant through-going faults. Based on these analyses, there is no apparent relationship between the deeper seismicity and the postulated southern extension of graben-bounding faults beneath the Columbia Plateau.

REFERENCES

Woodward-Clyde Consultants, 1980, Recent Seismicity of the Hanford Region, Report Prepared for Washington Public Power Supply System, Richland, WA.

361.12

If the assumptions of Davis (p. 2R-C-3, PSAR, Vol. 2A) that the 1872 earthquake "...almost certainly occurred within the North American plate..." and that "...the hypothesized Olympic-Wallowa lineament is not an expression of a fundamental change in crustal character..." (p. 2R C-4, PSAR. Vol. 2A) are correct, what is the justification for limiting the maximum magnitude earthquake within 100 km of the site to approximately magnitude 6?

RESPONSE

The maximum historical earthquake that has occurred in the Columbia Plateau is the 16 July 1936 Milton-Freewater earthquake, which had a maximum intensity of (MM) VII and occurred about 84 km southeast of the site (Subsection 2.5.2.1.1.1, WNP-2 FSAR, Amendment 18, October, 1981). The design basis ground motions for the WNP-2 plant are based on an intensity (MM) VIII. To evaluate the probability of exceeding the design basis, all potential sources in the site vicinity have been evaluated in terms of their maximum earthquake potential. These maximum magnitudes are not limited to magnitude 6. All of these potential sources extend to within 50 km of the site. Maximum earthquake potential is discussed in Subsection 2.5.2.4 (WNP-2 FSAR, Amendment 18, October, 1981) and in Section 2.5K.4 of Appendix 2.5K (WNP-2 FSAR, Amendment 18, October, 1981).

361.13

A great amount of geological and seismological data has been collected that is pertinent to evaluation of ground motion at the site. If these data were integrated into one or more possible tectonic models and these models were then used in a probabilistic analysis of ground motion, how would the ground motion at the site be affected? As an example, in the report "Factors Influencing Seismic Exposure of the southeast Washington Region" prepared by Woodward-Clyde Consultants for WPPSS, how would the levels of ground motion estimated at the site in this report be affected by the following parameter changes:

a. Modeling of the recently recorded seismicity near the site ("Recent Seismicity of the Hanford Region", Woodward-Clyde Consultants report for WPPSS) as discrete seismic sources rather than "random sources" and estimating maximum magnitude within these discrete sources according to several viable, but alternate, tectonic hypotheses.

b. Increasing the maximum magnitude of an earthquake in "random source" to an 1872 type earthquake to account for the possibility of a large event in this area.

c. Throughout the area, developing seismic source zones for probabilistic modeling through the consideration of several different tectonic hypotheses. For example, Sengor, Burke and Dewey (1978) have hypothesized "impactogens", rifts striking at high angles to orogenic belts behind an active subduction zone that accommodate both extensional and transcurrent crustal movements. The example they use is the Graben. Another possible example might be regional right lateral lineaments and faults zones existing in central and southern Oregon (Lawrence, 1976). These lineaments might possibly be considered analogous to the Olympic-Wallowa lineament, as they are in the same regional tectonic framework.

RESPONSE

A probabilistic analysis of ground motions at the site is presented in Appendix 2.5K (WNP-2 FSAR, Amendment 18, October, 1981). The significant parameters that affect the probability of exceedance of ground motions at the site include capability of potential seismic sources, tectonic models, source geometry, maximum earthquake magnitude, earthquake recurrence, and ground motion attenuation. The parameters are treated probabilistically in the seismic exposure analysis. The following paragraphs are in response to parts a), b), and c) of question 361.13.

a) Geologic structures that have a potential to be capable seismic sources are modeled in the seismic exposure analysis (Appendix 2K). Probabilistic distribution for maximum magniutdes on each source for viable, alternative tectonic models are included in the analysis.

b) Large earthquakes are considered to have the potential for occurring only on geologic structures. The possibility of such earthquakes occurring on geologic structures is incorporated in the seismic exposure analysis.

c) The development and use of alternative tectonic models is an integral part of the seismic exposure analysis. The alternative tectonic models that are incorporated in the analysis are discussed in Section 2.5K.3 of Appendix 2.5K (WNP-2 FSAR, Amendment 18, October, 1981).

361.14

Provide a discussion on any correlation of historic and recent earthquake activities and tectonic structures within the Columbia Plateau Tectonic Province. If any correlation exists, determine if an earthquake larger than that of the maximum historical earthquake should be assumed to occur on these structures. Provide supporting evidences. Compare the ground motion (including peaks and response spectra) from these potential earthquakes to the SSE and actual design used.

RESPONSE

As discussed in Section 2.5.2.3 of the WNP-2 FSAR (Amendment 18, October, 1981), there is no clearly defined correlation between specific mapped geologic structures, such as folds or faults, and the historical earthquake activity within the Columbia Plateau. The seismic exposure analysis that is presented in Appendix 2.5K (WNP-2 FSAR, Amendment 18, October, 1981) provides estimates of the probabilities of exceedance of the design-basis ground motions, including peak accelerations and response spectral values, at the plant site. The possibility of large earthquakes occurring on potential tectonic structures is incorporated in this analysis.