SITAG Evaluation of the Sewell Report
on Tsunami Hazard at the Diablo Canyon Site

1.0 Introduction

This report documents the NRC staff evaluation of the report prepared by Dr. Sewell on the tsunami hazard at the Diablo Canyon site[1]. The evaluation was performed by the Seismic Issues Technical Advisory Group (SITAG) members of the U. S. Nuclear Regulatory Commission (USNRC).

2.0 Background

As a part of the technical review of the Diablo Canyon Independent Spent Fuel Storage Installation (ISFSI), Dr. Robert Sewell, a consultant for the Center for Nuclear Waste Regulatory Analysis (CNWRA), studied the tsunami hazard at the proposed ISFSI located at the existing site of the Diablo Canyon Power Nuclear Plant (DCNPP), and prepared a draft report (Sewell, 2003). The purpose of Dr. Sewell's study was to make a "preliminary assessment" of the tsunami hazard at the Diablo Canyon site based on current scientific understanding and analysis methods using a number of postulated tsunami scenarios. The study focused on locally generated tsunamis due to potential submarine landslides[2], which were not explicitly considered in the development of the DCNPP tsunami design basis.

2.1 Tsunamis

A tsunami is a complex natural phenomenon consisting of a series of waves generated by sudden displacements in the floor of an ocean, lake or a sea rapidly displacing massive amount of water. Earthquakes, landslides, volcanic eruptions and large meteorite impacts all have the potential to generate a tsunami. The effects of a tsunami can range from unnoticeable to devastating for people and facilities. The factors affecting tsunami wave heights include seismic fault displacement of ocean floor, fault attitude, and site terrain (both onshore and offshore). Lessons learned from the 2004 great Sumatra Tsunami in the Indian Ocean indicate that local submarine topography is instrumental in determining wave heights.

Submarine landslide tsunamis may also be triggered by various events including earthquakes, gas hydrate releases, wave action, explosions, or a combination of effects. Study of the potential for submarine landslides is challenging because of a lack of understanding about submarine geology and geomorphology. Studies indicate that most landslides occur along inclined areas of the sea floor, often in an environment where rapid deposition of unconsolidated, fine grain sediments or fractured rocks occurs.

2.2 Diablo Canyon Site

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[1]Sewell, R. T., *A Preliminary Numerical Study of the Hazard from Local Landslide Tsunami Scenarios at the Diablo Canyon Site in Central California*, Summary Report (Draft), R. T. Sewell Associates, Louisville, November 22, 2003.

[2]The term landslide is used to refer to the submarine landslides hereafter in this report.

The Diablo Canyon site is located on a shore area in central California, and is designed for a maximum combined wave run-up height of 34.6 ft (10.5 m), relative to the mean lower low water (MLLW) level[3], and maximum combined wave draw-down of 9.0 feet (2.7 m). These values were determined based on a deterministic probable maximum tsunami analysis that considered the enveloping effects of tsunamis generated by both distant and local sources. The record tsunami height in the area is in Crescent City, CA and was triggered by the1964 Alaska earthquake. Wave heights reached 17-20 ft (5.2- 6.1 m) in Crescent City, which is about 400 miles (667 km) from the Diablo Canyon site. The continental slope offshore of the Diablo Canyon site is very gentle. The sea floor drops 3283 ft (1000 m) over a distance of about 40 miles (67 km), which is equivalent to an average slope of less than 1 degree. As indicated in Dr. Sewell's report, there is not much detailed information pertaining to submarine features, geology, and potential slide areas offshore south-central California near the Diablo Canyon site. An example of a tsunami generated by a landslide is the 1812 event that produced estimated wave amplitudes of about 33 ft (10 m) at Goleta, California, located approximately 100 miles from the Diablo Canyon site. The results of scale model tests, which were performed after a severe storm occurred at the Diablo Canyon site during January 1981, were used to develop a combined wave run-up of 34.6 ft (10.5 m) for locally generated tsunamis.

3.0 Staff Evaluation

Based on deterministic analyses of a number of postulated landslide scenarios, the author attempts to show in the report that the DCNPP design basis wave heights may not be conservative, and that more detailed probabilistic tsunami hazard analysis should be performed to evaluate the DCNPP safety. The author developed 13 landslide scenarios using locations near potentially capable faults and considering regional bathymetry. The study used simple geometric parameters (slide area and volume) and physical parameters (average slide velocity) based on an analysis of bathymetry data. The study finds that all 13 scenarios produce a wave elevation that exceeds the DCNPP design basis for combined peak positive and peak negative wave amplitude. The study concludes that the existing tsunami design bases and perceptions of tsunami risk for the DCNPP site no longer reflect modern scientific understanding and methods. Based on this conclusion, the author recommends that the licensee justify or re-evaluate the tsunami design bases and perform a state-of-the-art assessment of tsunami hazard and risk for the DCNPP site.

Since information on submarine geology, geomorphology, and geotechnical properties affecting the slide potential were not readily available, the author was unable to (1) search for multiple failure surfaces, (2) compute factors of safety against sliding, and (3) select the most likely failure surface based on the lowest factor of safety. Recognizing the limitations of his study, the author states[4] that, "it is not the purpose of the study to develop final conclusions regarding the local landslide tsunami hazard, and final conclusions concerning such hazards should not be drawn from the 13 scenarios." A further key limitation of the study is that it is deterministic in that it examines a fixed set of scenarios and develops tsunami characteristics based on these scenarios. The author stated that the study considers tsunami events based on general return periods or recurrence intervals of interest to critical facilities such as nuclear power plants. The

[3]At the Diablo Canyon site, MLLW is 2.6 feet (0.79 m) below mean sea level (MSL).

[4] Page 14, section 7 of the Sewell report.

author estimated that recurrence intervals for the landslide scenarios vary from 750 years to 500,000 years[5] with an uncertainty of 1 to 2 orders of magnitude.

As a result of the numerous limitations described above, the NRC staff questions the usefulness of the study for making conclusions on the safety of DCNPP for the tsunami hazard. The study, however, points out the need for further investigation of the tsunami hazard for the Diablo Canyon site and other coastal plants. The major shortcomings of the study are that it is deterministic and that it uses very simplistic models due to the lack of information on submarine features and geology. Although the study placed the postulated landslides near capable faults, neither the magnitude nor the recurrence of earthquakes on these faults was included in the postulated displacement scenarios. The type of fault (i.e., thrusting mechanisms versus strike-slip) as well as the fault orientation relative to potential failure slopes also are important factors that were not considered in the study. In addition, without information on submarine geology and geotechnical properties, the study was unable to determine the likelihood of slope failures in the region. Therefore, the results of the study are not realistic, would have significant uncertainties, and cannot be relied on for making conclusions on tsunami hazard for the DCNPP site.

The author cites[6] recent tsunami events as evidence to suggest that submarine landslides may be an important contributor to the overall tsunami hazard for the DCNPP site. The events the author cited as evidence included: the locally generated 1998 Papua New Guinea tsunami event that produced a maximum local run-up of about 50 ft (15 m); the 1946 Aleutian earthquake in the vicinity of Scotch Cap, with estimated maximum local wave run-up of about 344 ft (105 m); volcanic flank collapses along the Hawaiian volcanic chain (in the Pacific); and the Canary Islands (in the Atlantic). It should be recognized, however, that the basic settings for these events are different from those of the DCNPP site. For example, there is a relatively steep slope near Papua New Guinea where that tsunami occurred, and in Hawaii the volcanic chain is surrounded by relatively deep ocean. Therefore, steeply inclined slopes naturally exist in both cases. In the offshore area near the DCNPP site, however, the offshore slope is very gentle, approximately 1 degree. Without a relatively large component of gravitational force along the potential sliding surface associated with steep slopes, submarine unlithified materials cannot easily slide. The author also cited another geographically closer example to address potential impact at the DCNPP site, that is, the submarine slide on December 21, 1812, that produced estimated wave amplitudes of about 33 ft (10 m) at Goleta, CA. The setting there is also different from the DCNPP due to the relatively steep slopes in the Santa Barbara Channel.

The author stated that although the slope is generally small in the vicinity of the Diablo Canyon, landslides can still be generated by local steep areas, and that significant slides on slopes of less than 3 percent, or 1.7 degrees, are not uncommon. However, to determine the likelihood of such a tsunami scenario, a relatively high-resolution bathymetric data would be necessary. This is even more problematic, since the author also did not have information with respect to submarine geology and geomorphology data, but purely depended on low-resolution bathymetric data to determine the slope distribution.

4.0 Summary/Conclusions

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[5] Page 27, section 10 of the Sewell report.

[6] Pages 2-3, section 2 of the report.

The report identifies the potential tsunami hazard at Diablo Canyon nuclear power plant based on a study of 13 postulated scenarios of landslides. The scenarios however, appear to be postulated based on the geometry alone without regard to the existing conditions affecting the slide potential (geotechnical properties, geology etc.) of the ocean floor. With respect to local tsunami studies, both relatively high-resolution bathymetric data and submarine geology and geomorphology data are necessary. In addition, we need to have fundamental understanding of the geotechnical properties of the underwater materials. Therefore, the author's simulation of local landslides with only low-resolution bathymetric data are speculatory with regard to the tsunami hazard at the site, and the results of the analyses in the report cannot be relied upon to make conclusions regarding the tsunami hazard for the Diablo Canyon site.

5.0 Recommendations

Even though the tsunami hazard study in the Sewell report is not realistic, and is based on unsupported assumptions, the NRC staff recognizes that there is a need to re-assess the tsunami hazard at the DCNPP site considering the recent developments in probabilistic hazards analysis methods in the seismic area, and the occurrence of the 2004 Indian Ocean tsunami. Therefore, it is recommended that further studies to realistically define the tsunami hazard at the DCNPP and other nuclear facilities located close to the coast, be undertaken.