Nuclear Development
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PSEG
Power LLC

ND-2011-0042
June 9, 2011

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Subject: **PSEG Early Site Permit Application**
Docket No. 52-043
Response to Request for Additional Information, RAI No. 26, Potential Dam Failures

References:
1) PSEG Power, LLC letter to USNRC, Application for Early Site Permit for the PSEG Site, dated May 25, 2010
2) RAI No. 26, SRP Section: 02.04.04 - Potential Dam Failures, dated May 12, 2011 (eRAI 5711)

The purpose of this letter is to respond to the request for additional information (RAI) identified in Reference 2 above. This RAI addresses Potential Dam Failures, as described in Subsection 2.4.4 of the Site Safety Analysis Report (SSAR), as submitted in Part 2 of the PSEG Site Early Site Permit Application, Revision 0.

Enclosure 1 provides our response for RAI No. 26, Questions No. 02.04.04-1 and 02.04.04-2. Our response to RAI No. 26, Question No. 02.04.04-1 will not result in a revision to the SSAR. Our response to RAI No. 26, Question No. 02.04.04-2 will result in a revision to the SSAR. Enclosure 2 provides proposed edits to the SSAR. Enclosure 3 provides new regulatory commitments created by the response to this RAI.

If any additional information is needed, please contact David Robillard, PSEG Nuclear Development Licensing Engineer, at (856) 339-7914.

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NRO

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 9th day of June, 2011.

Sincerely,

David P. Lewis
Director, Nuclear Development
PSEG Power, LLC

Enclosure 1: Response to NRC Request for Additional Information, RAI No. 26, Question Nos. 02.04.04-1 and 02.04.04-2, SRP Section: 02.04.04 - Potential Dam Failures
Enclosure 2: Proposed Revisions Part 2 – Site Safety Analysis Report Subsection 2.4.4
Enclosure 3: Summary of Regulatory Commitments

cc: USNRC Project Manager, Division of New Reactor Licensing, PSEG Site (w/enclosures)
USNRC, Environmental Project Manager, Division of Site and Environmental Reviews (w/enclosures)
USNRC Region I, Regional Administrator (w/enclosures)

PSEG Letter ND-2011-0042, dated June 9, 2011

ENCLOSURE 1

RESPONSE to RAI No. 26

QUESTIONS 02.04.04-1 and 02.04.04-2

Response to RAI No. 26, Question 02.04.04-1:

In Reference 2, the NRC staff asked PSEG for information regarding Potential Dam Failures, as described in Sections 2.4.4 of the Site Safety Analysis Report. The specific request for Question 02.04.04-1 was:

> *NUREG-0800, Standard Review Plan (SRP), Section 2.4.4, "Potential Dam Failures," establishes guidance that the NRC staff use to evaluate whether an applicant meets the NRC's regulations.*
>
> *For the analysis presented in Section 2.4.4 of the PSEG SSAR, the applicant used Stokes Law to analyze the effects of sediment transport in the event of dam failure instead of a fully calibrated sediment transport model. The conclusion of the analysis was that the sediment particles will drop out prior to reaching the site.*
>
> *Staff requests that the applicant provide a detailed description of the thought process that led to the decision that a Stokes Law analysis of sediment transport was sufficient. This discussion should include alternative analyses considered and the conceptual model that was used to justify this analysis.*

PSEG Response to NRC RAI:

Two primary factors contributing to the selection of the approach to address the potential impacts on safety-related structures, systems and components (SSC) from sedimentation or erosion resulting from dam failure(s) are (1) the distance from the nearest dams of concern to the plant location and (2) the effect of dam failures on the flow conditions in the reach of the Delaware River adjacent to the PSEG Site. While Stoke's Law may not be ideal due to turbulence in a tidally affected river, the concept of settling velocity, coupled with conservative assumptions, is valid. The results of this simplified analysis are corroborated against results of several detailed sediment transport models of the Delaware Estuary.

The reservoir nearest the plant location that has potential to generate increased flow rates and/or discharge large quantities of sediment with failure of the dam is the Edgar Hoopes Reservoir. This dam is located approximately 37 river miles upstream of the PSEG Site, including approximately 18.7 miles of the Delaware River and 18 miles of the Christina River. Consequently, this dam is relatively remote from the PSEG site.

The second factor relates to the hydraulic conveyance capacity of the 18.7 miles of the Delaware River reach and the lower 5 miles of the Christina River relative to the conservatively estimated maximum flow rate resulting from the Hoopes Reservoir dam failure and the volume of sediment potentially mobilized by the dam failure. Approximately 5 miles of the lower Christina River has a relatively flat slope and large conveyance resulting in lower flow velocities. The Delaware River has a large

conveyance capacity relative to the flow produced by a dam failure. Even a large watershed flood, accompanied by Hoopes Reservoir dam failure, does not produce velocities in the Delaware River reach from RM 52 to RM 70 greater than those that occur periodically as a result of high tides and storm surges. Normal maximum tidal flows in this reach are on the order of 800,000 cfs (Reference RAI-26-5). The peak discharge from the Christina River during the Hoopes Reservoir dam failure event combined with a 500-year flood was estimated with the HEC-RAS hydraulic model to be 22,400 cfs. The dam failure generated no significant increase in peak discharge to the Delaware River compared to the 500-year flood event without a dam failure. The Christina River flood event discharge is equivalent to less than 3% of the normal maximum tidal flow in this reach of the Delaware River.

The combination of distance and flow capacity result in the worst case dam failure producing no significant impact on Delaware River flow rate that would cause increased scour or deposition of river sediments beyond that which would occur naturally as a result of high flow events. Additionally, there would be no direct impact of bedload sediment produced by the dam failure at the plant location While some amount of bedload material would be generated by the dam failure that would be potentially discharged from the Christina River, the potential for that bedload material subsequently moving over 18 miles downstream and having an immediate, predictable and measurable impact along the New Jersey shoreline near the PSEG site is limited.

The suspended sediment, or wash load, potentially generated by the Hoopes Reservoir dam failure, consisting of smaller particles, would travel further and more quickly than bedload. The suspended load is analyzed by fall velocity in many detailed sediment transport models. Evaluation of the fall velocity was determined to be an appropriate and simplified means to assess potential for settling of fines (silt and clay particles) at relatively long distances from the source (Christina River). It is recognized that many other more complex processes impact the actual movement of suspended solids discharged to this Delaware River reach. Cook (Reference RAI 26-3), Cook et al (Reference RAI 26-2), Sommerfield (Reference RAI-26-6), and Celebioglu (Reference RAI-26-1) have described sediment dynamics in this river reach. Celebioglu applied a three dimensional hydrodynamic model and simulated a large flood event and its impacts on sediment transport. The results generally suggested some areas of preferred temporary deposition, although neither large scour depths nor deposition depths were suggested by the model. Sediment depth variations were generally in the range of millimeters.

As identified above, various researchers have completed sediment transport studies, including application of hydrodynamic models, to the Delaware Estuary (e.g., Reference RAI-26-1). There are numerous 2- and 3-dimensional hydrodynamic models with sediment transport capabilities. An intermediate modeling approach considered was to convert a 1-dimensional HEC-RAS hydraulic model to a sediment transport model for estimating longitudinal (1-dimensional) sediment transport characteristics. Analysis using Stokes Law, however, demonstrated that coarse particles, which comprise the bulk of the suspended sediment loads generated by the simulated dam failures, settle

out upon reaching the relatively quiescent waters of the Delaware River upstream of the PSEG Site. More complex models were not required to show that sediment transport to the Site would pose no threat to SSC.

It is noted that this discussion has addressed the potential for sediment deposition that could impair the operation of a plant SSC. Additional considerations of note are that the local velocities near the intake would prevent sediment deposition very near the intake. The plant is located within the estuary turbidity maximum where various physical conditions and processes combine to maintain a relatively high turbidity relative to upstream and downstream locations.

Sediment fall velocity is a specialized field of study and there are numerous methods/equations and variations along with estimates of various coefficients involved in these equations (Reference RAI-26-4). The approach used, applying Stokes Law along with a mass balance with conservative assumptions for the various parameters was determined to be an appropriate assessment of the potential impact of failure of the nearest significant dam on sedimentation at the PSEG plant, given the above mentioned historical analyses.

References:

RAI-26-1 Celebioglu, Tevfik, Kutay, November 2006. Simulation of Hydrodynamics and Sediment Transport Patterns in Delaware Bay.Doctoral Thesis, Drexel University.

RAI 26-2. Cook, Timothy L., Christopher K. Sommerfield, and Kuo-Chuin Wong, 2006. Observations of tidal and springtime sediment transport in the upper Delaware Estuary. ScienceDirect.com

RAI-26-3 Cook, Timothy L., 2004. Observations of Sediment Transport in the Delaware Estuary During Spring Runoff Conditions. Masters Thesis submitted to University of Delaware.

RAI-26-4 Dankers, P.J. T., 2002. The Behaviour of fines released due to dredging, A literature review. Delft University of Technology.

RAI-26-5 Harleman, D.R.F, One-Dimensional Models, In Estuarine Modeling: An Assessment, Capabilities and Limitations for Resource Management and Pollution Control, by Tracor, Inc. for the Water Quality Office, Environmental Protection Agency, February 1971.

RAI-26-6 Christopher K. Sommerfield, September 19, 2005. Observing Delaware River – Bay: University of Delaware Initiatives.Presentation at IOOS/NWQMN Workshop.

Associated PSEG Site ESP Application Revisions:

None

Response to RAI No. 26, Question 02.04.04-2:

In Reference 2, the specific request for Question 02.04.02-2 was:

> *NUREG-0800, Standard Review Plan (SRP), Section 2.4.4, 'Potential Dam Failures,' establishes guidance that the NRC staff use to evaluate whether an application meets the NRC's regulations.*
>
> *In the PSEG ESP application SSAR, the applicant looked at various scenarios for breach of dams and verified the time required for the flood wave to get to the site. In this analysis, flood waters from the nearest dam failure would have already receded by the time the next flood waters would arrive. The staff thinks that the time interval used to eliminate the initial flood threat may not be sufficiently conservative and that the combined events should be considered.*
>
> *The staff requests additional discussion of the conceptual model used to justify the method used to eliminate the risk of flooding due to the failure of multiple dams. Please include any historical data or information drawn upon to verify the results of this analysis.*

PSEG Response to NRC RAI:

Potential causes for dam failures as outlined in ANSI/ANS-2.8-1992 section 6 (SSAR Reference 2.4.4-1) include seismic dam failure. None of the major reservoirs in the Delaware River Basin are located in series therefore, there is no possibility of cascading dam failures impacting the Site. The only plausible event that could cause multiple dam failures would be seismic activity. Seismic events are evaluated in SSAR Subsection 2.5.2. Regionally, earthquakes are low to moderate individual events and their effects attenuate over distance; therefore, multiple dam failures from a seismic event are not likely. However, a conservative dam breach scenario was defined that would catastrophically breach two or more dams that are regionally grouped based upon their physiographic location.

Each dam breach modeled for the multiple dam failure scenarios described in SSAR Subsection 2.4.4.1 is timed so the combined maximum flood wave arrives at the PSEG Site simultaneously. Dams are not necessarily breached simultaneously (see SSAR Table 2.4.4-2), but rather were breached so that the maximum flood wave from each dam considered in the scenario peaks at the PSEG Site at the same time.

ANSI/ANS-2.8-1992 (SSAR Reference 2.4.4-1) section 9.2.1.2 Seismic Dam Failures provides guidance regarding the combination of events evaluated. Alternative I discusses evaluating a 25 year flood in conjunction with the Safe Shutdown Earthquake (SSE) and a 2 year wind speed. Alternative II discusses evaluating a 500 year flood in conjunction with the Operating Basis Earthquake (OBE) and a 2 year wind speed.

The SRP for Subsection 2.4.4 describes the first two areas of review as:

1. Flood waves from severe breaching of an upstream dam and
2. Domino-type or cascading dam failures.

To consider the potential for multiple hydrologically or seismically induced dam failures, four combinations of multiple dam failures located upstream of the PSEG plant are postulated as described in SSAR Subsection 2.4.4.1. These combinations are grouped geographically within the Delaware Basin. Starting at the northern end of the Delaware River Basin and moving downstream, the four combinations of dam breach scenarios modeled, based on physiography and proximity, are:

1. Cannonsville Reservoir and Pepacton Reservoir (Catskills)
2. Neversink Reservoir and Lake Wallenpaupack (Appalachian Plateau)
3. Francis E Walter Reservoir, Beltzville Reservoir, and Nockamixon Reservoir (Valley and Ridge transitioning into Piedmont)
4. Blue Marsh Reservoir, Marsh Creek Reservoir, Edgar Hoopes Reservoir, and Springton (Geist) Reservoir (Piedmont transitioning into coastal plain)

Results of the four dam failure scenario models described in SSAR Subsection 2.4.4 indicate that worst-case flooding at the PSEG site results from breaching both the Cannonsville and Pepacton dams during a seismic event. The exact timing of the dam breaches are conservatively set to occur at discrete times resulting in a single combined breach flood wave arriving at the PSEG Site coincident with the 10% exceedance high tide. In addition, the flood waves from the dam breaches are combined with the 500 year flood and 2 year wind-wave activity at the PSEG Site. By including the 10% exceedance high tide, the results of the dam breach scenario presented in Subsection 2.4.4 of the SSAR conservatively satisfy the requirements in the SRP and exceed combined events criteria in section 9.2.1.2 of ANSI/ANS 2.8.

Associated PSEG Site ESP Application Revisions:

SSAR Subsection 2.4.4.1 will be updated as specified in Enclosure 2 of this document to note that the exact timing of the dam breaches are conservatively set to occur at discrete times resulting in a single combined breach flood wave arriving at the PSEG Site.

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ENCLOSURE 2
Proposed Revisions
Part 2 – Site Safety Analysis Report

Subsection 2.4.4 – Potential Dam Failures

Marked Up Pages
2.4-54
2.4-55

RAI No. 26
Question 02.04.04-2

ADD:

The exact timing of the dam breaches in each scenario are conservatively set to occur at discrete times resulting in a single combined breach flood wave arriving at the PSEG Site.

e structure due to dam breach, as described in

e new plant location on the Delaware River. nstream dam failure is not considered in this ater considerations for the new plant.

2.4.4.1 Selection of Dams and Their Combinations for Failure Scenarios

According to the USACE National Inventory of Dams (NID) (Reference 2.4.4-11), the Delaware River Basin contains four dams with reservoir storage volumes greater than 6000 ac.-ft. within a 70 mi. radius of the new plant location. Due to their physiographic locations, coincident seismic failure of these four dams is modeled to determine effects at the new plant location. There are seven large (greater than 60,000 ac.-ft. of total storage) reservoirs in the basin, which are modeled to determine effects at the site (Figure 2.4.4-1). Combinations of seismic dam failures are discussed in RG 1.59 and ANSI/ANS-2.8-1992, Section 9.2.1.2 (Reference 2.4.4-1). None of the dams identified above are located in series relative to each other. Therefore, flood waves from failure of any of the dams (listed in Table 2.4.4-1) do not route through downstream dams. Consequently, a domino-type dam failure analysis is not considered in this model. Coincident dam failures, as a result of seismic activity, are used to calculate peak flows. Evaluation of simultaneous failures representing the worst case scenario is presented in the following subsections.

Replace with:
"during a single event."

Four scenarios are considered for the dam break analysis to determine the maximum water level elevation at the new plant location. These scenarios are based on the geographic locations of dams within the basin. These scenarios consist of two combinations of two large reservoirs, one combination of three reservoirs and one combination of the four largest reservoirs within 70 mi. of the plant failing simultaneously. Though failure of multiple reservoirs may be possible within a geographic region, the simultaneous failure of two large reservoirs or four smaller reservoirs due to a single seismic event is highly improbable because the reservoirs are not located within close proximity to each other. However, this approach is selected for conservatism. See Figure 2.4.4-1 for the location of the dams chosen for this analysis.

The first scenario is simultaneous failure of the Pepacton and Cannonsville dams. The flood waves due to failure of these dams are combined in the analysis because both dams are located in the Catskill Mountains in New York. The NID indicates these are the two largest reservoirs in the Delaware River Basin. The Pepacton and Cannonsville dams are earthfill, rock-faced dams, storing 460,000 ac.-ft. and 303,000 ac.-ft. of water, respectively. The Pepacton Dam is located on the East Branch Delaware River. The Cannonsville Dam is located on the West Branch Delaware River (Reference 2.4.4-25).

DELETE (typ):
"simultaneous"

The second scenario includes simultaneous failure of the Lake Wallenpaupack and Neversink dams. These two dams are combined in the dam breach analysis because they are both located in the transition between the Catskills and the Valley and Ridge physiographic provinces. The Lake Wallenpaupack and Neversink dams are both earthfill dams with concrete spillways, storing 209,000 ac.-ft. and 142,000 ac.-ft. of water, respectively. Lake Wallenpaupack Reservoir is located on Wallenpaupack Creek . Neversink Reservoir is located on the Neversink River. (References 2.4.4-20 and 2.4.4-11)

ADD (typ):
"such that their resultant flood waves reach the PSEG Site simultaneously."

ADD:
"such that their resultant flood waves reach the PSEG Site simultaneously."

RAI No. 26
Question 02.04.04-2

The third scenario consists of simultaneous failure of the F.E. Walter, Beltzville and Nockamixon dams. These dams are combined in the dam breach analysis because they straddle the Valley and Ridge physiography in the central part of the Delaware River Basin. These dams are constructed of earthfill with concrete spillways, storing 111,000 ac.-ft., 104,000 ac.-ft., and 66,500 ac.-ft. of water, respectively. The F.E. Walter Dam is located on the Lehigh River. The Beltzville Reservoir is located on Pohopoco Creek; a tributary to the Lehigh River. The Nockamixon Dam is located on Tohickon Creek. (References 2.4.4-21, 2.4.4-11, and 2.4.4-17)

The fourth scenario involves simultaneous failure of the Blue Marsh, Marsh Creek, Geist, and Edgar Hoopes dams; all located within 70 mi. of the new plant location (Figure 2.4.4-1). The Marsh Creek Reservoir stores 22,200 ac.-ft. of water. It is constructed of earthfill with a concrete spillway and is located on Marsh Creek (Reference 2.4.4-19). The Springton Reservoir (Geist Dam) stores 10,700 ac.-ft. of water and is located on Crum Creek (Reference 2.4.4-6). The Edgar Hoopes Reservoir stores 11,000 ac.-ft. of water and is located on Old Mill Stream-Red Clay Creek (Reference 2.4.4-11). The Blue Marsh Reservoir stores 50,000 ac.-ft. of water and is located on Tulpehocken Creek (Reference 2.4.4-22).

Combining the dam failures based on geographic regions is considered a worst case scenario for flooding at the new plant location. Discharge hydrographs from the dam breach analysis are used as input conditions into the hydraulic model. These hydrographs are used in combination with flooding, 10 percent exceedance high tide, and wave runup to calculate the maximum WSEL at the new plant location.

DELETE (typ):
"simultaneous"

2.4.4.2 Analysis of Potential Dam Failures

Modeling conducted to establish the maximum WSEL for the combined events dam failure analyses includes developing individual dam breach hydrographs, establishing the river model, 500-year flood modeling and adding wave effects.

Individual Dam Breach Hydrographs

Dam failure hydrographs are developed using the USACE HEC-HMS model to produce the dam breach hydrograph for each reservoir (Reference 2.4.4-8). All reservoirs are considered to be full prior to failure, and breach dimensions are conservatively assumed to be equal to the extent of the dam. Information obtained from the USACE NID includes dam height, dam length, spillway width, and maximum volume of storage (Reference 2.4.4-11). Bottom elevations of the dams are obtained from the USGS National Elevation Dataset (Reference 2.4.4-23). Dam break hydrographs are developed assuming complete dam failure within 0.2 hr., which is the equivalent of an instantaneous dam failure in the model (Reference 2.4.4-12). Table 2.4.4-2 provides a summary of tributary dam failure HEC-HMS input parameters.

The River Model

To route dam failure discharge through the respective stream reaches and the Delaware River to the new plant location, a TIN terrain model is prepared using the USGS National Elevation Dataset (Reference 2.4.4-23) DEM. The DEM uses the geometry of the tributary floodplain to route the flood waves. Geometry of the tributary floodplains is incorporated into the USACE HEC-RAS model (Reference 2.4.4-9).

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ENCLOSURE 3
Summary of Regulatory Commitments

ENCLOSURE 3

SUMMARY OF REGULATORY COMMITMENTS

The following table identifies commitments made in this document. (Any other actions discussed in the submittal represent intended or planned actions. They are described to the NRC for the NRC's information and are not regulatory commitments.)

COMMITMENT	COMMITTED DATE	COMMITMENT TYPE	
		ONE-TIME ACTION (Yes/No)	Programmatic (Yes/No)
PSEG will revise SSAR Section 2.4.4 to incorporate the changes in Enclosure 2 in response to NRC RAI No. 26.	This revision will be included in the next update of the PSEG Site ESP application SSAR.	Yes	No