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TABLE OF CONTENTS

Page

1 PURPOSE AND SCOPE 3

2 DESIGN INPUT 3

3 ASSUMPTIONS 6

4 METHODOLOGY AND ACCEPTANCE CRITERIA 8

5 CALCULATIONS 9

6 RESULTS 14

7 REFERENCES 14

1 PURPOSE AND SCOPE

The scope of this calculation is to determine the total annual doses to a construction worker during construction of a new unit, or units, at the PSEG Site, and the total annual collective dose to the construction workforce as a whole. The purpose of this calculation is to support the PSEG Early Site Permit Application (ESP) Environmental Report (ER) Subsection 4.5.

2 DESIGN INPUT

2.1 Doses from gaseous effluent releases from the Salem Generating Stations (SGS) and the Hope Creek Generating Station (HCGS) are obtained from the 2008 Annual Radioactive Effluent Release Report (RERR) for the Salem and Hope Creek Generating Stations (Reference 7.4), as tabulated below.

Gaseous Effluent Parameter	1Q2008	2Q2008	3Q2008	4Q2008	Annual
Maximum Gamma Air Dose (mrad)	1.06E-04	5.46E-05	2.15E-05	1.86E-05	2.01E-04
Maximum Beta Air Dose (mrad)	1.05E-04	6.13E-05	1.83E-05	9.49E-06	1.94E-04
Organ Dose (mrem) from I-131, I-133, Tritium, and particulate nuclides (>8 days half-life) - Site Boundary (N Sector)	3.89E-03	4.58E-03	5.50E-03	6.47E-03	2.04E-02

2.2 Direct radiation doses from the PSEG Site ISFSI are obtained from calculation number A-5-DCS-MDC-1957 (Reference 7.1). Doses are tabulated in terms of distance north from the ISFSI.

Dist (m)	Dose Rate (mrem/hr)	Annual Dose (mrem/yr)
1	1.55E+01	1.36E+05
10	5.67E+00	4.97E+04
25	2.14E+00	1.87E+04
50	8.05E-01	7.05E+03
100	2.22E-01	1.94E+03
200	4.10E-02	3.59E+02
300	1.07E-02	9.37E+01
400	3.16E-03	2.77E+01
500	1.12E-03	9.81E+00
750	1.01E-04	8.85E-01
1000	1.48E-05	1.30E-01

2.3 Annual doses from gaseous effluent releases from a single AP1000 reactor are obtained from Revision 17 of the AP1000 DCD (Reference 7.9), as tabulated below. These doses were given with a DCD specified χ/Q value, as shown below.

Gaseous Effluent Parameter	DCD Annual Dose(mrad)	DCD χ/Q (sec/m^3)
Gamma Air Dose	2.1	2.00E-05
Beta Air Dose	10.1	2.00E-05

2.4 A maximum site-specific χ/Q value of 1.60E-05 sec/m^3 corresponding to a distance of 0.17 miles [897.6 ft.] is obtained from Revision 0 of S&L calculation number 2009-08512 (Reference 7.5). This χ/Q value is the maximum value in any sector.

2.5 Annual direct radiation doses from normal operation of SGS and HCGS are listed in the 2008 RERR (Reference 7.4). The following table gives the direct radiation doses at the north sector site boundary TLD station. The 2008 RERR also gives the 1972-1976 pre-operational TLD data, which can be considered the background dose.

Average Reading (mrem/month)	Gross Annual Dose (mrem)	Annual Background Dose (mrem)
4.77	57.2	55

2.6 A maximum construction workforce of 4100 people is obtained from the response to PSEG RFI 066 R1 (Reference 7.3).

2.7 The limiting potential pathway for gaseous effluent doses to organs from SGS and HCGS is the thyroid (Reference 7.2), which has a weighting factor of 0.03, as specified in 10 CFR 20.

2.8 The minimum distance between dual unit AP1000 containment centerlines is 800 ft. as described in the Westinghouse siting guide (Reference 7.8).

2.9 The distance between the AP1000 containment centerline and the outside of the AP1000 shield building (i.e., the radius of the containment building) is 72.5 ft. (Reference 7.9).

2.10 The dose rate on the outside of the containment building wall is 0.25 mrem/hr (Reference 7.9).

2.11 Annual liquid effluent doses to members of the public from HCGS and SGS are obtained from the 2008 SGS and HCGS RERR, as shown below (Reference 7.4).

Liquid Effluent Parameter	Dose (mrem)
Whole Body Dose	6.69E-05
Organ Dose	1.58E-04

2.12 The annual liquid dose from a new AP1000 to members of the public is taken from S&L calculation 2009-10130, as shown below (Reference 7.10).

Liquid Effluent Parameter	Dose (mrem)
Whole Body Dose	1.57E-02
Organ Dose	1.77E-01

3 ASSUMPTIONS

3.1 It is assumed that workers will be present for 2400 hours per year. This is a 50 week, 40 hours a week work schedule (2000 hours per year) multiplied by an overtime factor of 1.2.

3.2 For conservatism, it is assumed that the ISFSI is fully loaded. This assumption makes this calculation independent of the cask loading schedule, which removes the need to consider and track the exact construction timeline.

3.3 The doses from 2008 are considered to be an acceptable basis for predicting releases during construction of new units. The SGS and HCGS units were operating normally, at or near rated power for most of 2008. SGS Unit 2 was shut down for a scheduled 57 day outage in the Spring and SGS Unit 1 was shut down for a scheduled 29 day outage in the Fall. Based on PSEG outage scheduling, two of the three SGS and HCGS units commonly have a scheduled outage in any given year. In addition, a 15 percent power uprate was implemented for Hope Creek in mid-2008, which increased the total power generation for the year (References 7.6 and 7.7).

3.4 The 2008 RERR lists gaseous effluent release doses, but does not specify if there is an occupancy factor of a person at the site boundary. It is assumed that doses are given for continuous occupancy (8760 hours per year).

3.5 It is assumed that the maximum number of workers on site will be present for the duration of construction. This conservative estimate eliminates the need to track changes in predicted work flow.

3.6 It is assumed that one mrad equals one mrem. This is because all the doses considered in this calculation are either gamma or beta, meaning that their quality factor is one. Since a rem is equal to a rad multiplied by this quality factor, one rem is the same as one rad.

3.7 It is assumed that construction workers will receive the same doses from the liquid effluent pathway as members of the public. This assumption is conservative because fish/invertebrate consumption and Delaware River recreational usage are independent of time spent working on-site.

3.8 The distance between containment building center lines for a dual unit AP1000 plant is comparable to the distance associated with the site-specific χ/Q value from Section 2.5 used in this calculation (Reference 7.8). Therefore, use of the minimum distance between the postulated release point and the nearest site boundary (i.e., the maximum χ/Q) provides a reasonable estimate of the effect on the construction workforce from the operating AP1000.

3.9 Gaseous effluent doses from SGS and HCGS are given at the site boundary. Construction workers may be located inside this boundary, since the new power block will straddle the current site boundary line. To account for this positional uncertainty, the doses are multiplied by a factor of ten to remain conservative.

3.10 Direct radiation doses from the ISFSI are obtained from a very conservative calculation, which considers an ISFSI fully loaded with fresh fuel casks in the worst possible arrangement. Workers standing at the south most portion of the construction site may receive an unacceptable dose under conditions described in the calculation. It is assumed that administrative controls will prevent doses exceeding 100 mrem/yr at the ISFSI fence, 10 m north of the ISFSI.

3.11 When considering direct radiation doses to construction workers from the ISFSI, it is assumed that the farthest south workers will be located is the north side of the E-W road just north of the ISFSI. This location corresponds to a distance of 25 m north of the ISFSI.

3.12 Since the two containment buildings for dual unit AP1000s are separated by 800 ft., direct radiation from the first unit can be considered a point source (using an inverse distance squared model) when calculating the direct radiation on workers building the second unit.

3.13 When considering workers constructing the second AP1000 unit, it is assumed that the second unit's containment building center is a good approximation of worker position over the duration of construction.

3.14 Doses from liquid effluents to members of the public are equivalent to those to construction workers. Since fish/invertebrate consumption and Delaware River recreational usages are independent of the time a construction worker spends on site, no occupancy factors are used when considering liquid effluent doses.

3.15 During normal operations of an AP1000, steam generator blowdown is returned to the condensate system, including the outdoor condensate storage tank. However, in the event that excessive radioactivity is detected, the blowdown is diverted to the liquid radwaste system for processing and disposal, as described in AP1000 DCD Subsection 11.2.1.2.3.3 (Reference 7.9). Therefore, it is assumed that direct radiation from the condensate storage tank is negligible.

4 METHODOLOGY AND ACCEPTANCE CRITERIA

Doses from liquid and gaseous effluents and direct radiation from a single AP1000 reactor during the construction of a second AP1000 reactor are analyzed. Furthermore, direct radiation contributions from the PSEG Site ISFSI are considered. Doses are not compared to regulations in this calculation.

4.1 All input doses were given for continuous occupancy (8760 hours per year), and needed to be scaled down to account for 2400 hours per year worker occupancy. This was done by multiplying doses by the ratio 2400/8760.

4.2 Gaseous effluent release doses for the AP1000 were given in the AP1000 DCD with a generic DCD χ/Q. These doses have been scaled to be site-specific by multiplying them by the site-to-DCD χ/Q ratio.

4.3 To calculate the total population dose for the workforce, the annual doses were multiplied by the maximum number of workers on site (4100 workers).

4.4 The doses considered in this calculation are given for different types of exposure and in different units. ER Subsection 4.5 requires that all doses be compared to the limits defined in 10 CFR 20. The dose limits in 10 CFR 20 are given as a total effective dose equivalent (TEDE). A TEDE is defined as the sum of the deep dose equivalent (DDE) and the committed effective dose equivalent (CEDE). For the purposes of this analysis, either the whole body dose or the sum of the gamma and beta doses is used to approximate the DDE. The organ dose multiplied by a weighting factor is the CEDE. In this case, the limiting potential pathway (critical organ) is the thyroid, which has a weighting factor of 0.03. For sources that are not tabulated in terms of an organ dose, the CEDE is zero.

4.5 Since direct radiation doses from the ISFSI are assumed to be no more than 100 mrem/yr at a distance of 10 m north of the ISFSI, doses at other distances are assumed to be equal to the calculated dose multiplied by a factor of 100/4.97E+04 (the ratio of the maximum possible dose to the calculated dose).

4.6 There are no acceptance criteria for this calculation. This calculation only determines the total doses to construction workers.

5 CALCULATIONS

5.1 Direct radiation doses to construction workers from an AP1000 while they build a second AP1000 are calculated by using an inverse distance squared model, using inputs from Sections 2.8 to 2.10, as seen below.

$$\text{DoseRate}(r) = \text{DoseRate}_i \times \frac{r_i^2}{r^2} \times \text{occupancy}$$

Where : r = distance from AP1000 containment center
DoseRate(r) = dose rate at “r”
DoseRate_i = known dose rate at “i"
Occupancy = number of hours per year a worker will be on site

$$\text{DoseRate} = 0.25\frac{\text{mrem}}{\text{hr}} \times \frac{(72.5\text{ft.})^2}{(800\text{ft.})^2} \times 2400\frac{\text{hr}}{\text{yr}} = 4.9\frac{\text{mrem}}{\text{yr}}$$

5.2 The following is the PSEG Site ISFSI direct radiation table. The table adjusts the calculated dose to reflect the maximum possible dose 10 m north of the ISFSI (100 mrem/yr), as described in Sections 3.11, 3.12, and 4.6. The table also scales the annual doses from continuous occupancy (8760 hours per year) down to worker occupancy (2400 hours per year). This is done by multiplying the annual dose by a factor of 2400/8760.

Dist (m)	Calculated Dose Rate (mrem/hr)	Calculated Annual Dose (mrem/yr)	Scaled Annual Dose (mrem/yr)	Scaled Annual Worker Dose (mrem/yr)
1	1.55E+01	1.36E+05	2.73E+02	74.90
10	5.67E+00	4.97E+04	100	27.40
25	2.14E+00	1.87E+04	3.77E+01	10.34
50	8.05E-01	7.05E+03	1.42E+01	3.89
100	2.22E-01	1.94E+03	3.92E+00	1.07
200	4.10E-02	3.59E+02	7.23E-01	0.20
300	1.07E-02	9.37E+01	1.89E-01	0.05
400	3.16E-03	2.77E+01	5.57E-02	0.02
500	1.12E-03	9.81E+00	1.98E-02	0.01
750	1.01E-04	8.85E-01	1.78E-03	0.00
1000	1.48E-05	1.30E-01	2.61E-04	0.00

5.3 The following table lists the gaseous effluent doses from SGS and HCGS. The doses are first scaled up by a factor of ten to account for workers being inside the site boundary. While the doses they could be exposed to would not be ten times the doses at the site boundary, the factor of ten was chosen to create a conservative value. The table then scales the annual doses from continuous occupancy (8760 hours per year) down to worker occupancy (2400 hours per year). This is done by multiplying the annual dose by a factor of 2400/8760.

Gaseous Effluent Parameter	Annual Dose	Annual Dose x10	Annual Worker Dose
Maximum Gamma Air Dose (mrad)	2.01E-04	2.01E-03	5.51E-04
Maximum Beta Air Dose (mrad)	1.94E-04	1.94E-03	5.32E-04
Organ Dose from I-131, I-133, Tritium, and particulate nuclides (>8 days half-life) - Site Boundary (N Sector) (mrem)	2.04E-02	2.04E-01	5.59E-02

5.4 The organ dose from gaseous effluents released from SGS and HCGS is converted from a general organ dose to a specific, limiting potential pathway (critical organ) dose. The limiting potential pathway is considered to be the thyroid. The thyroid has a weighting factor of 0.03 when converting from organ dose to CEDE. When the annual worker dose (5.59E-02 mrem) is multiplied by the weighting factor (0.03), a dose of 1.68E-03 mrem is found. This dose is the CEDE. The TEDE will be calculated in section 5.7.

5.5 The following table lists the gaseous release doses from a single unit AP1000. First, the annual DCD doses were localized by multiplying them by the ratio of the site-specific χ/Q value to the DCD χ/Q value. Then, doses were scaled down from continuous occupancy (8760 hours per year) to worker occupancy (2400 hours per year). This was done by multiplying the annual dose by a factor of 2400/8760.

Gaseous Effluent Parameter	DCD Annual Dose (mrad)	DCD χ/Q (sec/m^3)	Site χ/Q (sec/m^3)	χ/Q Ratio (Site/DCD)	Annual Dose (mrad)	Annual Worker Dose (mrad)
Gamma Air Dose	2.1	2.00E-05	1.60E-05	8.00E-01	1.68E+00	4.60E-01
Beta Air Dose	10.1	2.00E-05	1.60E-05	8.00E-01	8.08E+00	2.21E+00

5.6 The following table lists the direct radiation doses from SGS and HCGS. Background radiation was subtracted from the north site boundary TLD readings to calculate a continuous occupancy annual dose. This dose was then scaled down from continuous occupancy (8760 hours per year) to worker occupancy (2400 hours per year). This was done by multiplying the annual dose by a factor of 2400/8760.

Average Reading (mrem/month)	Gross Annual Dose (mrem)	Annual Background Dose (mrem)	Annual Dose (mrem)	Annual Worker Dose (mrem)
4.77	57.2	55	2.2	6.03E-01

5.7 The following table displays a summary of the various gamma, beta, whole body, and organ doses to a construction worker and shows their equivalent TEDE for all sources. The process used for determining an equivalent TEDE is specified in Section 4.4 of this calculation. As stated in Section 4.4, a TEDE is defined as the sum of the deep dose equivalent (DDE) and the committed effective dose equivalent (CEDE), and either the whole body dose or the sum of the gamma and beta doses is used to approximate the DDE. Note that that annual worker CEDE was calculated by multiplying the annual worker organ dose by the thyroid weighting factor (0.03). Also note that not all sources have doses listed for all dose types. This is because sources are defined differently (e.g., AP1000 gaseous releases are defined in terms of gamma and beta doses, while AP1000 liquid doses are defined in terms of whole body and organ/CEDE doses).

Source	Annual Worker Gamma Dose (mrad)	Annual Worker Beta Dose (mrad)	Annual Worker CEDE (mrem)	Annual Worker Whole Body Dose (mrem)	Annual Worker TEDE (mrem)
SGS & HCGS Gaseous	5.51E-04	5.32E-04	1.68E-03		2.76E-03
AP1000 Gaseous	4.60E-01	2.21E+00			2.67E+00
SGS & HCGS Direct			0.00E+00	6.03E-01	6.03E-01
ISFSI Direct				1.03E+01	1.03E+01
AP1000 Direct				4.90E+00	4.90E+00
SGS & HCGS Liquid			4.7E-06	6.69E-05	7.16E-05
AP1000 Liquid			1.77E-01	1.57E-02	1.93E-01

5.8 The following table displays a summary of annual doses for all the sources, as well as annual total population doses to the construction workforce as a whole. This conversion was done by multiplying the annual doses by the maximum number of construction workers on site (4100 workers).

Source	Annual Worker TEDE (mrem)	Annual Collective TEDE to Workforce (person-rem)
SGS & HCGS Gaseous	< 0.01	0.01
AP1000 Gaseous	2.67	10.95
ISFSI Direct	10.3	42.23
SGS & HCGS Direct	0.60	2.46
AP1000 Direct	4.90	20.09
SGS & HCGS Liquid	<0.01	<0.01
AP1000 Liquid	0.19	0.78
Total All Sources	18.66	76.51

6 RESULTS

The results of the calculation are tabulated below. The "total all sources" dose listed at the bottom of the table represents a worst case scenario. This bounding scenario is one in which the ISFSI is fully loaded, SGS and HCGS are operating normally during construction, an AP1000 has been built and is operating, and the number of construction workers stays constant at the maximum.

Source	Annual Worker TEDE (mrem)	Annual Collective TEDE to Workforce (person-rem)
SGS & HCGS Gaseous	< 0.01	0.01
AP1000 Gaseous	2.67	10.95
ISFSI Direct	10.3	42.23
SGS & HCGS Direct	0.60	2.46
AP1000 Direct	4.90	20.09
SGS & HCGS Liquid	<0.01	<0.01
AP1000 Liquid	0.19	0.78
Total All Sources	18.66	76.51

7 REFERENCES

7.1 "Direct Dose Rates in the Vicinity of the Salem & Hope Creek ISFSI," A-5-DCS-MDC-1957, Calculation, Revision 0.

7.2 "Offsite Dose Calculation Manual for PSEG Nuclear LLC – Salem Generating Station," Revision 21, 2008.

7.3 Public Service Enterprise Group Nuclear LLC, Response to RFI 066 R1 "TIA Data Requirements," 2009.

7.4 Public Service Enterprise Group Nuclear LLC, "2008 Annual Radioactive Effluent Release Report (RERR) for the Salem and Hope Creek Generating Stations," 2009.

7.5 Sargent & Lundy LLC, "Long-Term Diffusion Estimates for PSEG ESPA," 2009-08512, Calculation, Revision 0.

7.6 U.S. Nuclear Regulatory Commission, "Hope Creek Generating Station – Issuance of Amendment RE: Extended Power Uprate (TAC No. MD3002)," Letter, May 14, 2008.

7.7 U.S. Nuclear Regulatory Commission, "Operating Data Report," 2008.

7.8 Westinghouse, "AP1000 Dual Unit Siting (TR99)," APP-GW-GLR-099, Revision 0.

7.9 Westinghouse, Design Certification Document (DCD) for the Advanced Passive 1000 (AP1000) Reactor, Revision 17, 2008.

7.10 Sargent & Lundy, LLC, "Radiological Impact Analysis of Liquid Effluents for PSEG ESPA," 2009-10130, Calculation, Revision 0.