

# **FINAL SAFETY ANALYSIS REPORT**

## **CHAPTER 12**

### **RADIATION PROTECTION**

## **12.0 RADIATION PROTECTION**

This chapter of the U.S. EPR Final Safety Analysis Report (FSAR) is incorporated by reference with supplements as identified in the following sections.

## **12.1 ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES ARE AS LOW AS IS REASONABLY ACHIEVABLE**

This section of the U.S. EPR FSAR is incorporated by reference with the following supplements.

### **12.1.1 POLICY CONSIDERATIONS**

No departures or supplements.

### **12.1.2 DESIGN CONSIDERATIONS**

No departures or supplements.

### **12.1.3 OPERATIONAL CONSIDERATIONS**

The U.S. EPR FSAR includes the following COL Item in Section 12.1.3:

A COL applicant that references the U.S. EPR design certification will fully describe, at the functional level, elements of the ALARA program for ensuring that occupational radiation exposures are ALARA. This program will comply with provisions of 10 CFR Part 20 and be consistent with the guidance in RGs 1.8, 8.2, 8.7, 8.8, 8.9, 8.10, 8.13, 8.15, 8.27, 8.28, 8.29, 8.34, 8.35, 8.36, 8.38, and the applicable portions of NUREG-1736.

This COL Item is addressed as follows:

This section incorporates by reference NEI 07-08, "Generic FSAR Template Guidance for Ensuring that Occupational Radiation Exposures Are As Low As Is Reasonably Achievable (ALARA)" (NEI, 2008a) and NEI 07-03, "Generic FSAR Template Guidance for Radiation Protection Program Description" (NEI, 2008b).

### **12.1.4 REFERENCES**

{**NEI, 2008a.** Generic FSAR Template Guidance for Ensuring that Occupational Radiation Exposures Are As Low As Is Reasonably Achievable (ALARA), NEI 07-08, Revision 3, Nuclear Energy Institute, November 2008.

**NEI, 2008b.** Generic FSAR Template Guidance for Radiation Protection Program Description, NEI 07-03, Revision 7, Nuclear Energy Institute, November 2008.}

## **12.2 RADIATION SOURCES**

This section of the U.S. EPR FSAR is incorporated by reference with the following supplements.

### **12.2.1 CONTAINED SOURCES**

No departures or supplements.

#### **12.2.1.1 Reactor Core**

No departures or supplements.

#### **12.2.1.2 Reactor Coolant System**

No departures or supplements.

#### **12.2.1.3 Chemical and Volume Control System**

No departures or supplements.

#### **12.2.1.4 Primary Coolant Purification System**

No departures or supplements.

#### **12.2.1.5 Primary Coolant Degasification System**

No departures or supplements.

#### **12.2.1.6 Secondary Coolant System**

No departures or supplements.

#### **12.2.1.7 Component Cooling Water and Essential Service Water Systems**

No departures or supplements.

#### **12.2.1.8 Fuel Pool Cooling and Purification System**

No departures or supplements.

#### **12.2.1.9 Liquid Waste Management System**

No departures or supplements.

#### **12.2.1.10 Gaseous Waste Processing System**

No departures or supplements.

#### **12.2.1.11 Solid Waste Management System**

No departures or supplements.

#### **12.2.1.12 Post-LOCA ESF Filters**

No departures or supplements.

#### **12.2.1.13 Miscellaneous Sources**

The U.S. EPR FSAR includes the following COL Item in Section 12.2.1.13:

A COL applicant that references the U.S. EPR design certification will provide site-specific information for required radiation sources containing byproduct, source, and special nuclear material that may warrant shielding design considerations. This site-specific information will include a listing of isotope, quantity, form, and use of all sources in this latter category that exceed 100 millicuries.

This COL Item is addressed as follows:

The following radiation sources have been identified to be required.

| Isotope | Quantity                  | Form             | Geometry                       | Use                        | Location                                |
|---------|---------------------------|------------------|--------------------------------|----------------------------|---|
| Cf-252  | 0.5 Ci<br>(note a)        | Sealed<br>Source | Source Rod                     | Primary Start-up<br>Source | Reactor Core                            |
| Sb-Be   | 3E+06 Ci<br>(note b)      | Sealed<br>Source | Source Rod                     | Secondary<br>Source        | Reactor Core                            |
| Cs-137  | 400 Ci<br>(note c)        | Sealed<br>Source | Special form sealed<br>capsule | Calibration                | Elevation 0 feet of<br>Access Building  |
| {Cs-137 | 130 mCi<br>(note c)       | Sealed<br>Source | Special form sealed<br>capsule | Calibration                | Elevation 0 feet of<br>Access Building} |
| {Am-241 | 0.03 $\mu$ Ci<br>(note d) | Sealed<br>Source | Planchet                       | Calibration                | Elevation 0 feet of<br>Access Building} |
| {AmBe   | 3Ci (note e)              | Sealed<br>Source | Special form sealed<br>capsule | Calibration                | Elevation 0 feet of<br>Access Building} |

- As calculated, based on  $2\text{E}+09$  neutrons/sec at the beginning of life,  $2.3\text{E}+12$  neutron/sec-g spontaneous fission neutron emission rate, and 538 Ci/g specific activity for Cf-252.
- Based on an end of fuel cycle activation of  $5.95\text{E}+08$  Ci/ $\text{m}^3$  and  $4.22\text{E}-3$   $\text{m}^3$  volume for three secondary source rods.
- Based on data from box calibrator vendors.
- Based on data from source manufacturers.}
- Nominal size required to achieve proper dose rates for performing source checks of neutron detecting instruments.}

### 12.2.2 AIRBORNE RADIOACTIVE MATERIAL SOURCES

No departures or supplements.

### 12.2.3 REFERENCES

No departures or supplements.

**12.3 RADIATION PROTECTION DESIGN FEATURES**

This section of the U.S. EPR FSAR is incorporated by reference with the following supplements.

**12.3.1 FACILITY DESIGN FEATURES**

No departures or supplements.

**12.3.2 SHIELDING**

No departures or supplements.

**12.3.3 VENTILATION**

No departures or supplements.

**12.3.4 AREA RADIATION AND AIRBORNE RADIOACTIVITY MONITORING INSTRUMENTATION**

No departures or supplements.

**12.3.4.1 Area Radiation Monitoring Instrumentation**

No departures or supplements.

**12.3.4.2 Airborne Radioactivity Monitoring Instrumentation**

No departures or supplements.

**12.3.4.3 Portable Airborne Monitoring Instrumentation**

No departures or supplements.

**12.3.4.4 Criticality Accident Monitoring**

No departures or supplements.

**12.3.4.5 Implementation of Regulatory Guidance**

The U.S. EPR FSAR includes the following COL Items in Section 12.3.4.5:

A COL applicant that references the U.S. EPR design certification will describe the use of portable instruments, and the associated training and procedures, to accurately determine the airborne iodine concentration within the facility where plant personnel may be present during an accident, in accordance with requirements of 10 CFR 50.34(f)(2)(xxvii) and the criteria in Item III.D.3.3 of NUREG-0737. The procedures for locating suspected high-activity areas will be described.

A COL applicant that references the U.S. EPR design certification will provide site-specific information on the extent to which the guidance provided by RG 1.21, 1.97, 8.2, 8.8, and ANSI/HPS-N13.1-1999 is employed in sampling, recording and reporting airborne releases of radioactivity.

These COL Items are addressed as follows:

Procedures detail the criteria and methods for obtaining representative measurement of radiological conditions, including in-plant airborne radioactivity concentrations in accordance with applicable portions of 10 CFR Part 20 (CFR, 2008a) and consistent with the guidance in

Regulatory Guides 1.21 Appendix A (NRC, 1974), 1.97 (NRC, 2006), 8.2 (NRC, 1973), 8.8 (NRC, 1978), and 8.10 (NRC, 1977b) and ANSI/HPS-N13.1-1999 (ANSI, 1999). Additional discussion of radiological surveillance practices is included in the radiation protection program description provided in Section 12.5.

Surveillance requirements are determined by the {Radiation Protection and Chemistry Manager} based on actual or potential radiological conditions encountered by personnel and the need to identify and control radiation, contamination, and airborne radioactivity. These requirements are consistent with the operational philosophy in Regulatory Guide 8.10. Frequency of scheduled surveillances may be altered by permission of the {Radiation Protection and Chemistry Manager} or their designee. Radiation Protection periodically provides cognizant personnel with survey data that identifies radiation exposure gradients in areas resulting from identified components. This data includes recent reports, with survey data, location and component information.

The following are typical criteria for frequencies and types of surveys:

#### **Job Coverage Surveys**

- ◆ Radiation, contamination, and/or airborne surveys are performed and documented to support job coverage.
- ◆ Radiation surveys are sufficient in detail for Radiation Protection to assess the radiological hazards associated with the work area and the intended/specified work scope.
- ◆ Surveys are performed commensurate with radiological hazard, nature and location of work being conducted.
- ◆ Job coverage activities may require surveys to be conducted on a daily basis where conditions are likely to change.

#### **Radiation Surveys**

- ◆ Radiation surveys are performed at least monthly in any radiological controlled area (RCA) where personnel may frequently work or enter. Survey frequencies may be modified by the {Radiation Protection and Chemistry Manager} as previously noted.
- ◆ Radiation surveys are performed prior to or during entry into known or suspected high radiation areas for which up to date survey data does not exist.
- ◆ Radiation surveys are performed prior to work involving highly contaminated or activated materials or equipment.
- ◆ Radiation surveys are performed at least semiannually in areas outside the RCA. Areas to be considered include shops, offices, and storage areas.
- ◆ Radiation surveys are performed to support movement of highly radioactive material.
- ◆ Neutron radiation surveys are performed when personnel may be exposed to neutron emitting sources.

**Contamination Surveys**

- ◆ Contamination surveys are performed at least monthly in any RCA where personnel may frequently work or enter. Survey frequencies may be modified by the {Radiation Protection and Chemistry Manager} as previously noted.
- ◆ Contamination surveys are performed during initial entry into known or suspected contamination area(s) for which up to date survey data does not exist.
- ◆ Contamination surveys are performed at least daily at access points, change areas, and high traffic walkways in RCAs that contain contaminated areas. Area access points to a High Radiation Area or Very High Radiation Area are surveyed prior to or upon access by plant personnel or if access has occurred.
- ◆ Contamination surveys are performed at least semiannually in areas outside the RCA. Areas to be considered include shops, offices, and storage areas.
- ◆ A routine surveillance is conducted in areas designated by the {Radiation Protection and Chemistry Manager} or their designee likely to indicate alpha radioactivity. If alpha contamination is identified, frequency and scope of the routine surveillance is increased.

**Airborne Radioactivity Surveys**

- ◆ Airborne radioactivity surveys are performed during any work or operation in the RCA known or suspected to cause airborne radioactivity (e.g., grinding, welding, burning, cutting, hydrolazing, vacuuming, sweeping, use of compressed air, using volatiles on contaminated material, waste processing, or insulation).
- ◆ Airborne radioactivity surveys are performed during a breach of a radioactive system, which contains or is suspected of containing significant levels of contamination.
- ◆ Airborne radioactivity surveys are performed during initial entry (and periodically thereafter) into any known or suspected airborne radioactivity area.
- ◆ Airborne radioactivity surveys are performed immediately following the discovery of a significant radioactive spill or spread of radioactive contamination, as determined by the {Radiation Protection and Chemistry Manager}.
- ◆ Airborne radioactivity surveys are performed daily in occupied radiological controlled areas where the potential for airborne radioactivity exists, including containment.
- ◆ Airborne radioactivity surveys are performed any time respiratory protection devices, alternative tracking methods such as derived air concentration-hour (DAC-hr), and/or engineering controls are used to control internal exposure.
- ◆ Airborne radioactivity surveys are performed using continuous air monitors (CAMs) for situations in which airborne radioactivity levels can fluctuate and early detection of airborne radioactivity could prevent or minimize inhalations of radioactivity by workers. Determination of air flow patterns are considered for locating air samplers.
- ◆ Airborne radioactivity surveys are performed prior to use and monthly during use on plant service air systems used to supply air for respiratory protection to verify the air is free of radioactivity.



- ◆ Tritium sampling is performed near the spent fuel pit when irradiated fuel is in the pit and in other areas of the plant where primary system leaks occur and tritium is suspected.

Appropriate counting equipment is used based on the sample type and the suspected identity of the radionuclides for which the sample is being done. Survey results are documented, retrievable, and processed per site document control and records requirements consistent with Regulatory Guide 8.2. Completion of survey documentation includes the update of room/area posting maps and revising area or room postings and barricades as needed.

Air samples indicating activity levels greater than a procedure specified percentage of DAC are forwarded to the radiochemistry laboratory for isotopic analysis. Samples which cannot be analyzed onsite are forwarded to a contractor for analysis; or, the DAC percentage may be hand calculated using appropriate values from 10 CFR Part 20, Appendix B.

The responsible Radiation Protection personnel review survey documentation to evaluate if surveys are appropriate and obtained when required, records are complete and accurate, and adverse trends are identified and addressed.

An in-plant radiation monitoring program maintains the capability to accurately determine the airborne iodine concentration in areas within the facility where personnel may be present under accident conditions. This program includes the training of personnel, procedures for monitoring, and provisions for maintenance of sampling and analysis equipment consistent with Regulatory Guides 1.21 (Appendix A) and 8.8. Training and personnel qualifications are discussed in Section 12.5.

A portable monitor system meeting the requirements of NUREG-0737 (NRC, 1980), Item III.D.3.3, is available. The system uses a silver zeolite or charcoal iodine sample cartridge and a single-channel analyzer. The use of this portable monitor is incorporated in the emergency plan implementing procedures. The portable monitor is part of the in-plant radiation monitoring program. It is used to determine the airborne iodine concentration in areas where plant personnel may be present during an accident. Accident monitoring instrumentation complies with applicable parts of 10 CFR Part 50, Appendix A (CFR, 2008b).

Sampling cartridges are removed to a low background area for further analysis. These cartridge samples are purged of any entrapped noble gases, when necessary, prior to being analyzed.

### **12.3.5 DOSE ASSESSMENT**

No departures or supplements.

#### **12.3.5.1 Overall Plant Doses**

The U.S. EPR FSAR includes the following COL Item in Section 12.3.5.1:

A COL applicant that references the U.S. EPR design certification will provide site-specific information on estimated annual doses to construction workers in a new unit construction area as a result of radiation from onsite radiation sources from the existing operating plant(s). This information will include bases, models, assumptions, and input parameters associated with these annual doses.

This COL Item is addressed as follows:

{This section discusses the exposure of construction workers building Bell Bend Nuclear Power Plant (BBNPP).

#### **12.3.5.1.1 Site Layout**

The physical location of BBNPP relative to the existing SESS Units 1 and 2 is presented in Figure 12.3-1. BBNPP will be located approximately 5000 ft (1524 m) west of SSES. BBNPP and SSES will have separate protected areas (See Section 3.1).

#### **12.3.5.1.2 Radiation Sources at SSES Units 1 and 2**

During the construction of BBNPP, the construction workers will be exposed to radiation sources from the routine operation of SSES Units 1 and 2. Sources that have the potential to expose construction workers are listed in Table 12.3-1. They are characterized as to location, inventory, shielding, and typical local dose rates. They are also characterized in terms of potential to expose BBNPP construction workers. Only those with significant potential are analyzed in detail. Interior, shielded sources are not included. Figure 12.3-2 and Figure 12.3-3 show the locations of these sources.

These sources are discussed in the Offsite Dose Calculation Manual (ODCM), the annual Radiological Effluent Release Report, the Radiological Environmental Operating Report, and the Final Safety Analysis Report. The eight main sources of radiation to BBNPP construction workers are gaseous effluents, liquid effluents, the Independent Spent Fuel Storage Installation (ISFSI), the Condensate Storage Tanks (CSTs), the Low Level Radioactive Waste handling Facility (LLRWHF), the SEALANDS, the Steam Dryer Storage Vault, and the Turbine Building. These are discussed below.

Airborne effluents are release via four rooftop vents on the reactor building. The releases are reported annually to the NRC. Doses to the general population are also reported annually.

Effluents from the liquid waste disposal system produce small amounts of radioactivity in the discharge to the Susquehanna River. All waterborne effluents are released in batch mode and are sampled and analyzed prior to release. Waterborne effluents from the site are released into the cooling tower blowdown line for dilution prior to release in the Susquehanna River.

There are five sources of direct radiation that could contribute to construction workers dose: the Independent Spent Fuel Storage Facility (ISFSI), the Low Level Radioactive Waste Handling Facility (LLRWHRF), SEALAND containers, the Steam Dryer Storage Vault, and the Turbine Building. There are three sources identified that are not significant contributors to construction worker dose. These are listed in Table 12.3-1 along with a brief discussion.

There are five sources of skyshine radiation that could contribute to construction workers dose: the Condensate Storage Tanks (CSTs), the Low Level Radioactive Waste Handling Facility (LLRWHRF), SEALAND containers, the Steam Dryer Storage Vault, and the Turbine Building. They are also listed in Table 12.3-1.

#### **12.3.5.1.3 Historical Dose Rates**

The historical annual dose rates reported to the NRC are summarized in Table 12.3-2.

#### **12.3.5.1.4 Construction Worker Dose Estimates**

Annual doses from all sources combined were calculated for each 104 ft (32 m) by 97 ft (30 m) foot square on the plant grid. For purposes of dose calculation, a 100% occupancy is assumed.

(For purposes of collective dose calculations, the occupancy for construction workers is 2,200 hours per year.) The doses are the sum of the dose rates from the eight main sources; gaseous effluents, liquid effluents, the independent Spent Fuel Storage Facility (ISFSI), the Condensate Storage Tanks (CSTs), the Low Level Radioactive Waste handling Facility (LLRWHF), SEALAND containers, the Steam Dryer Storage Vault, and the Turbine Building. The annual doses are shown in Figure 12.3-4 for the year 2017, the last year of construction. It is this year that the dose rate will be greatest, primarily because the ISFSI will have the largest number of spent fuel storage casks.

The collective dose is the sum of all doses received by all workers. It is a measure of population risk. The number of workers (in terms of Full Time Equivalents) and their location by zone are given in Table 12.3-3. The zone locations are shown by squares in Figure 12.3-5. The details of the collective dose calculations are given in the following discussion. Dose rates from all sources combined were calculated for each square on the plant grid. The dose rates were the sum of the dose rate from the eight main sources and assume 100% occupancy.

The equation for dose rate during year  $t$  at location  $x,y$  on the plant grid is:

$$\dot{D}_{x,y} = \dot{D}_{\text{gas}} + \dot{D}_{\text{liq}} + \dot{D}_{\text{ISFSI},t} + \dot{D}_{\text{CST}} + \dot{D}_{\text{LLRWHF}} + \dot{D}_{\text{SEA}} + \dot{D}_{\text{SD}} + \dot{D}_{\text{TB}}$$

where the terms are explained in the ER subsections.

The equation for the average dose rate in a zone is:

$$\bar{\dot{D}}_z = \frac{1}{N_z} \sum_{(\text{all } x,y \text{ in } z)} \dot{D}_{x,y}$$

where  $N_z$  is the number of squares in the zone.

The equation for collective dose for the construction period is:

$$D = \frac{2200}{8760} \sum_t \sum_z \bar{\dot{D}}_z \text{FTE}_{z,t}$$

where  $\frac{2200}{8760}$  = fraction of work hours per year,  $\bar{\dot{D}}_z$  is defined as above, and  $\text{FTE}_{z,t}$  is the full time equivalent in zone  $z$  during year  $t$ , or

$$\text{FTE}_{z,t} = P_z C_t$$

The probability of a worker in each zone,  $P_z$ , reflects the average construction worker and is based on an approximation of how much time the average worker spends in each zone. The probability of a worker in each zone,  $P_z$ , results the average construction worker and is based on a rough idea of how much time the average worker spends in each zone, as shown in Table 12.3-13. The spatial distribution of zones on the site is shown (gold letters indicating a zone code in each square) in Figure 12.3-5. There are many locations where construction workers are not expected to perform work activities, so they are not marked in the figure. These squares that are marked are chosen because of planned activities at those locations.

### 12.3.5.1.5 Gaseous Dose Rates

The construction worker dose due to SSES gaseous effluents depends upon the airborne effluents release and the atmospheric transport to the worker. The releases, which flow out of the SSES Units 1 and 2 plant vents, are reported annually to the NRC. Doses to the general population are also reported annually. The releases are modeled as ground level releases, which is conservative as it does not take credit for the height of the releases. Although there are two reactor building and two turbine building vents, the Radioactive Effluent Release Reports only give a total release. The releases were conservatively modeled assuming the vent closes to the workers.

The annual dose rate from gaseous effluents to construction workers on the BBNPP site is bounded by the following equation:

$$\dot{D}_{(j), \text{ gas}} = c_{(j)} r^b \quad (\text{mrem/year})$$

where,

$c_{(j)}$  = dose type coefficient,

$j$  = dose type (TEDE, total body, organ, or thyroid),

$r$  = distance from the release point to the target =  $\sqrt{(N - N_s)^2 + (E - E_s)^2}$

$N, E$  = location of receptor on plant grid in feet,

$N_s, E_s$  = location of source on plant grid in feet, and

$b$  = fitting parameter for atmospheric dispersion model = -1.6925.

The  $c_{(j)}$  are documented in Table 12.3-4. The equation is based on annual average, undecayed, undepleted ground level  $\chi/Q$ s without credit for building wake from Susquehanna Steam Electric Station site meteorology for the years 2001 to 2006 (See ER Table 2.7-157) which are modeled as

$$\frac{\chi}{Q}(r) = 38.603r^{-1.6925}$$

where  $r$  is defined as above. The equation also assumes the most limiting gaseous effluent releases from the period 2001 to 2006. The model is based upon 100% occupancy.

The dose rates were calculated for an onsite location with a known  $\chi/Q$  for the years 2001 through 2006 according to the Regulatory Guide 1.109 (NRC, 1977a) method with Total Effective Dose Equivalent (TEDE) calculations according to Federal Guidance Reports 11 (EPA, 1988) and 12 (EPA, 1993). The gaseous releases are shown in Table 12.3-5. The 2006 releases gave the highest dose rates.

### 12.3.5.1.6 Liquid Dose Rates

The projected dose at the shoreline to a construction worker with a 2200 hours/year occupancy rate is 0.407 mrem/yr; for a person with a full-time occupancy (8760 hr/yr) the dose rate is 1.62 mrem/yr. This is based on releases and dilutions in Table 12.3-6 and Table 12.3-7. Table 12.3-8 lists the dose contributions by year.

### 12.3.5.1.7 ISFSI Dose Rates

For the purposes of this calculation the ISFSI is broken into north and south pieces. The north piece is assumed filled in 2010. Loading of the south piece is assumed to begin in 2009. The dose rate from the ISFSI is:

$$D_{\text{ISFSI},t} = k[f_N(t)\varpi_N e^{-\mu r_N} + f_S(t)\varpi_S e^{-\mu r_S}]$$

where, D = annual dose,

$$\varpi_i = \text{the solid angle between the ISFSI and receptor in steradians} = \pi \left( 1 - \frac{r_i}{\sqrt{R^2 + r_i^2}} \right)$$

k = fitting parameter = 1500 ft,

$f_i(t)$  = function describing loading with time dependence =  $a_i + b_i t$ ,

$\mu$  = effective removal coefficient in air in  $\text{ft}^{-1} = 0.002056 \text{ ft}^{-1}$ ,

$r_i$  = distance from ISFSI piece i to receptor in ft =  $\sqrt{(N - N_i)^2 + (E - E_i)^2}$

t = time in years (i.e., 2007),

$a_i$  = fitting parameter.

$$a_N = -233.88$$

$$a_S = -253.79$$

$b_i$  = fitting parameter,

$$b_N = 0.177 \text{ yr}^{-1}$$

$$b_S = 0.126 \text{ yr}^{-1}$$

R = effective source radius = 116.52 ft, and

$N_i, E_i$  = State plane coordinates of source and receptor

$$N_N = 341550 \text{ ft}$$

$$N_S = 341450 \text{ ft}$$

$$E_N = E_S = 2,440,600 \text{ ft.}$$

The equation is based upon TLD measurements in the vicinity of the ISFSI combined with historic loading data and a projected loading schedule. The incremental loading of the ISFSI is modeled as a linear function.

Figure 12.3-6 shows the effect of distance on dose and compares this to TLD measurements. Figure 12.3-7 shows a satellite image of the ISFSI, Figure 12.3-8 shows the locations of the TLDs.

The effect of time on dose is shown in Figure 12.3-9. And the basic input data to the time equation (the load history and projections) is shown in Table 12.3-9.

#### 12.3.5.1.8 Condensate Storage Tank Dose Rate

The Unit 1 Condensate Storage Tank (CST) is shielded on the west side by the Unit 1 Turbine Building, on the east by the Diesel Generator Building wall, on the north by the Refueling Water Storage Tank, and on the south by the Unit 1 Reactor Building (see Figure 12.3-2 and Figure 12.3-3). The Unit 2 CST is shielded on the west by the Unit 2 Turbine Building and on the north by the Unit 2 reactor Building. It is partially shielded on the east and south by an overflow berm which extends 10.5 ft (3.2 m) above grade, which means that 21.5 ft (6.6 m) is exposed above the berm height. When a line is projected from the top of the Unit 2 CST over the berm wall, it converges with grade 575 ft (175 m) from the CST, which means direct radiation is absorbed by the ground beyond that point. Since construction workers will spend the majority of their time on site west of SSES and the remaining time further than 575 ft (175 m) east or south of the SCTs, additional analysis for the direct dose from the CSTs is not required. The skyshine dose from the Condensate Storage Tank is represented by the equation

$$\dot{D}_{\text{CST}} = 2\text{E-}05e^{-0.0018r}$$

Where  $\dot{D}_{\text{CST}}$  is in mrem/yr (based on 8760 hr/yr occupancy) and  $r$  is in ft. This equation is based on the source terms listed in Table 12.3-10 and a source material of water with a density of 62 lb/ft<sup>3</sup> (1 g/cm<sup>3</sup>). The effect of distance on dose is shown in Figure 12.3-10.

#### 12.3.5.1.9 LLRWHF Dose Rate

The Low Level Radioactive Waste Handling Facility (LLRWHF) provides temporary storage for low level radioactive waste materials produced at SSES. It stores dry active waste, dewatered waste, and solidified waste. It is also used to temporarily store pieces of contaminated plant equipment and radioactive material. The LLRWHF source term, shown in Table 12.3-11, was conservatively developed based on 10,000 sq ft (283 m<sup>2</sup>) of storage in containers with a maximum dose rate of 100 µGy/hr (10 mR/hr) at 6.56 ft (2 m), the maximum allowable per 49CFR173.411, (CFR, 2008.) The storage containers are condensate demineralizer radwaste containers in linear storage modules. The facility has a 23 x 2 sq meters orientation to the east and a 7 x 2 sq meters orientation to the south. The more conservative 23 x 2 was used in calculating the direct dose to construction workers.

The direct dose from the LLRWHF is

$$\dot{D}_{\text{LLRWHF}} = 15068653r^{-2.3}$$

where  $\dot{D}_{\text{LLRWHF}}$  is in mrem/yr (based on 8760 hr/yr occupancy) and  $r$  is in ft. The effect of distance on dose is shown in Figure 12.3-11.

#### 12.3.5.1.10 Sealand Container Dose Rate

The area due west of the Unit 2 Cooling Tower was selected as an area to store actual or potentially contaminated material in containers such as SEALAND containers. The area is surrounded by dirt embankments to the west, north, and south. The Unit 2 cooling Tower lies

to the east. It is estimated that 80 SEALAND containers can be stored in the area. The direct dose from the SEALAND Containers is

$$\dot{D}_{SEA} = 5.7055e^{-0.0006r}$$

where  $\dot{D}_{SEA}$  is in mrem/yr (based on 8760 hr/yr occupancy) and  $r$  is in ft. The source term used to develop the equation is given in Table 12.3-12. It is based on the restriction that the dose rate on the exterior of each SEALAND container shall not exceed 20  $\mu$ Gy/hr (2 mR/hr). The dirt embankment is assumed to provide 3 ft (0.91 m) of shielding with a density of that for dry packed earth (i.e., 93.6 lb/ft<sup>3</sup> (1.5 g/cm<sup>3</sup>)). The effect of distance on dose is shown in Figure 12.3-12.

#### 12.3.5.1.11 STEAM DRYER STORAGE VAULT DOSE RATE

The original SSES Units 1 and 2 steam dryers, which have been replaced, are stored on site in a concrete storage facility located east of the LLRWLF. Prior to placement in storage, the steam dryers were cut into halves. Each half was placed inside its own steel box with one inch (2.54 cm) thick walls. The direct dose from the steam dryer storage vault is

$$\dot{D}_{SD} = 14.37e^{-0.003r}$$

where  $\dot{D}_{SD}$  is in mrem/yr (based on 8760 hr/yr occupancy) and  $r$  is in ft. This is based on 708.3 Ci of Co-60 which is based on surveys performed by SSES. The effect of distance on dose is shown in Figure 12.3-13.

#### 12.3.5.1.12 TURBINE BUILDING DOSE RATE

The N-16 present in the reactor steam in the primary steam lines, turbines, and moisture separators provides a dose contribution to locations outside the plant structure as a result of the high energy gamma rays which it emits as it decays. The following equipment components, located on or above the Turbine Building Operating Floor are considered in this analysis:

- ◆ High pressure turbine inlet piping
- ◆ High pressure turbines
- ◆ Moisture separators
- ◆ Low pressure turbines
- ◆ 42 inch cross-around piping from the moisture separators to the CIVs
- ◆ Combined intermediate valves and piping to low pressure turbines

Sources below the operating floor are not considered. Typically, these sources are pipes of smaller volume than the equipment above the Operating Floor, and hence, of smaller N-16 inventory. Their dose rate contributions are bounded by the equipment above the Operating Floor because the floor provides additional shielding to limit their contribution.

The dose from the turbine building is

$$\dot{D}_{TB} = 0.8744e^{-0.0009r}$$

where  $\dot{D}_{TB}$  is in mrem/yr (based on 8760 hr/yr occupancy) and  $r$  is in ft. This was developed using source terms based upon component volume, the density of the source within the volume (i.e., water or steam), and the N-16 concentration listed in Table 12.2-11 of the Susquehanna Steam Electric Station Final Safety Analysis Report. The effect of distance on dose for both direct and skyshine sources is shown in Figure 12.3-14.

#### **12.3.5.1.13 Collective Doses to BBNPP Workers**

The collective dose is the sum of all doses received by all workers. It is a measure of population risk. The total worker collective dose for the combined years of construction is 6.944 person-rem (6.944E-02 person-Sieverts). This is a best estimate based upon the worker census and occupancy projections shown in Table 12.3-3, and Table 12.3-13. The breakdown of collective dose by construction year and occupancy zone is given in Table 12.3-14. This assumes 2200 hours per year occupancy for each worker.}

#### **12.3.5.2 Post-Accident Access to Radiological Vital Areas**

No departures or supplements.

#### **12.3.5.3 Dose to the Public from Direct Radiation Exposure at the Exclusion Area Boundary**

No departures or supplements.

### **12.3.6 MINIMIZATION OF CONTAMINATION**

No departures or supplements.

### **12.3.7 REFERENCES**

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**SSES, 2007a.** Susquehanna Steam Electric Station Units 1 & 2, Offsite Dose Calculation Manual, ODCM-QA-001, Revision 3, PPL Susquehanna, LLC, November 2007.

**SSES, 2007b.** Susquehanna Steam Electric Station Units 1 & 2, Radioactive Effluent Release Report, 2006 Annual Report, PPL Susquehanna, LLC, April 2007.

**SSES, 2007c.** Susquehanna Steam Electric Station Units 1 & 2, Radioactive Environmental Operating Report, 2006 Annual Report, PPL Susquehanna, LLC, April 2007.}

Table 12.3-1—{Radiation Sources at SSES Units 1 and 2}

| Source   | Location on Plant Grid                                   | Radioactive Inventory  | Shielding  | Dose Rate  | Significance to BBNPP Workers  |
|--|--|--|--|--|--|
| Unit 1 and Unit 2 Reactor Building Vents       | U1 N341,185, E2,442,025<br>U2 N341,165, E2,442,025       | Gaseous effluents characterized in RETS                                    | N/A (Airborne)   | 150 $\mu$ Sv/yr/unit (15 mrem/yr/unit)   | The gaseous effluents from reactor building and turbine building vents are contributors to the dose to construction workers.                     |
| Unit 1 and Unit 2 Turbine Building Vents       | N 341, 175<br>E 2,441,833                                | Gaseous effluents characterized in RETS                                    | N/A (Airborne)   | 150 $\mu$ Sv/yr/unit (15 mrem/yr/unit)   | No impact because BBNPP is a substantial distance (i.e., over 3000 ft) from the body of water into which the SSES liquid effluents are released. |
| Liquid Waste Management System                 | N/A  | Liquid Effluents characterized in RETS                                     | N/A (waterborne)   | <30 $\mu$ Sv/yr (3 mrem/yr/unit) total body<br><100 $\mu$ Sv/yr (10 mrem/yr) organ | No impact because BBNPP is a substantial distance (i.e., over 3000 ft) from the body of water into which the SSES liquid effluents are released. |
| Refueling Water Storage Tank (RWST)            | N341,424, E2,442,000.5                                   | Liquid Waste   | Shielded by neighboring buildings  | <15 $\mu$ Gy/hr (1.5 mR/hr) contact  | No impact because shielded by Turbine building   |
| Condensate Storage Tanks (CSTs)                | U1 N341,371, E2,442,007.5<br>U2 N340,979.0, E2,442,007.5 | Liquid Waste   | Shielded by neighboring buildings  | Turbine Building shields direct dose to construction workers from the CSTs         | No impact because Turbine Building shields any dose to construction workers from the CSTs.   |
| Low Level Radwaste Handling Facility           | N341,400, E2,440,500                                     | Temporary storage for low level radioactive waste and radioactive material | Concrete walls   | <100 $\mu$ Sv/yr (10 mR/hr) at 6.6 ft (2 m)  | Direct source.   |
| Temporary Laundry Facility                     | Southwest of Unit 2 Turbine Building                     | Contaminated laundry   | Shielded by neighboring buildings  | 79.4 $\mu$ Gy/hr (7.94 mR/hr) at 1 ft (0.305 m) perimeter                          | No impact.   |
| ISFSI  | N341,500 E2,440,600                                      | Spent fuel   | Concrete walls   | <70 mrem/hr on surface   | Time dependent source.   |
| Turbine shine due to N-16 in the reactor steam | N 341,175<br>E 2,441,833                                 | N-16   | Shielding around each turbine train and a roof slab over each moisture separator | < 0.5 mrem/hr  | Direct and skyshine source.  |
| SEALAND Containers                             | N340,750, E2,441,050                                     | LSA boxes, barrels, shield blocks, turbine rotor stands, etc.              | Shielded by dirt embankment  | < 20 $\mu$ Gy/hr (2 mR/hr) at exterior surface                                     | Direct and skyshine source.  |
| Steam Dryers                                   | N341,060.3, E 2,440,653.5                                | Original steam dryers  | Concrete walls   | < 5 $\mu$ Sv/yr (0.5 mrem/hr)  | Direct and skyshine source.  |

**Table 12.3-2— {Historical All-Source Compliance for Offsite General Public}**

| <b>Maximum Offsite Doses for 40CFR190 Compliance from Gas and Liquid Releases as Reported to the NRC in Annual REMP Reports</b> |   |                        |                        |  |                |                        |
|---|---|------------------------|------------------------|--|----------------|------------------------|
| <b>Year</b>   | <b>Dose in mrem/year (<math>\mu</math>Sv/yr) from REMP Reports)</b> |                        |                        | <b>Dose as Percent of 40CFR190 Limit</b> |                |                        |
|   | <b>Thyroid</b>  | <b>WB</b>              | <b>Limiting Organs</b> | <b>WB</b>                                | <b>Thyroid</b> | <b>Limiting Organs</b> |
| 2006  | 5.27E-01<br>(5.27E+00)  | 5.27E-01<br>(5.27E+00) | 5.27E-01<br>(5.27E+00) | 2.11E-02                                 | 7.03E-03       | 2.11E-02               |
| 2005  | 8.38E-01<br>(8.38E+00)  | 8.38E-01<br>(8.38E+00) | 8.38E-01<br>(8.38E+00) | 3.35E-02                                 | 1.12E-02       | 3.35E-02               |
| 2004  | 1.22E+00<br>(1.22E+01)  | 1.22E+00<br>(1.22E+01) | 1.22E+00<br>(1.22E+01) | 4.88E-02                                 | 1.63E-02       | 4.88E-02               |
| 2003  | 1.21E+00<br>(1.21E+01)  | 1.21E+00<br>(1.21E+01) | 1.21E+00<br>(1.21E+01) | 4.84E-02                                 | 1.61E-02       | 4.84E-02               |
| 2002  | 1.31E+00<br>(1.31E+01)  | 1.31E+00<br>(1.31E+01) | 1.31E+00<br>(1.31E+01) | 5.24E-02                                 | 1.75E-02       | 5.24E-02               |
| 2001  | 2.20E-01<br>(2.20E+00)  | 2.20E-01<br>(2.20E+00) | 2.20E-01<br>(2.20E+00) | 8.80E-03                                 | 2.93E-03       | 8.80E-03               |
| 2000  | 1.73E-01<br>(1.73E+00)  | 1.73E-01<br>(1.73E+00) | 1.73E-01<br>(1.73E+00) | 6.92E-03                                 | 2.31E-03       | 6.92E-03               |
| 1999  | 9.82E-02 (9.82E-01)   | 9.82E-02 (9.82E-01)    | 9.82E-02 (9.82E-01)    | 3.93E-03                                 | 1.31E-03       | 3.93E-03               |
| 1998  | 1.38E-01<br>(1.38E+00)  | 1.38E-01<br>(1.38E+00) | 1.38E-01<br>(1.38E+00) | 5.52E-03                                 | 1.84E-03       | 5.52E-03               |
| 1997  | 1.63E-01<br>(1.63E+00)  | 1.63E-01<br>(1.63E+00) | 1.63E-01<br>(1.63E+00) | 6.52E-03                                 | 2.17E-03       | 6.52E-03               |
| 1996  | 5.64E-01<br>(5.64E+00)  | 5.64E-01<br>(5.64E+00) | 5.64E-01<br>(5.64E+00) | 2.26E-02                                 | 7.52E-03       | 2.26E-02               |
| 1995  | 2.31E-01<br>(2.31E+00)  | 2.31E-01<br>(2.31E+00) | 2.31E-01<br>(2.31E+00) | 9.24E-03                                 | 3.08E-03       | 9.24E-03               |
| 1994  | 1.41E-01<br>(1.41E+00)  | 1.41E-01<br>(1.41E+00) | 1.41E-01<br>(1.41E+00) | 5.64E-03                                 | 1.88E-03       | 5.64E-03               |
| Maximum   | 1.31E+00<br>(1.31E+01)  | 1.31E+00<br>(1.31E+01) | 1.31E+00<br>(1.31E+01) | 5.24E-02                                 | 1.75E-02       | 5.24E-02               |
| 2002  | 1.31E+00<br>(1.31E+01)  | 1.31E+00<br>(1.31E+01) | 1.31E+00<br>(1.31E+01) | 5.24E-02                                 | 1.75E-02       | 5.24E-02               |
| 2001  | 2.20E-01<br>(2.20E+00)  | 2.20E-01<br>(2.20E+00) | 2.20E-01<br>(2.20E+00) | 8.80E-03                                 | 2.93E-03       | 8.80E-03               |
| 2000  | 1.73E-01<br>(1.73E+00)  | 1.73E-01<br>(1.73E+00) | 1.73E-01<br>(1.73E+00) | 6.92E-03                                 | 2.31E-03       | 6.92E-03               |

**Table 12.3-3—{FTE for BBNPP Construction Workers}**

| <b>Zone</b> | <b>2012</b> | <b>2013</b> | <b>2014</b> | <b>2015</b> | <b>2016</b> | <b>2017</b> |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| B           | 0.5         | 2.3         | 4.0         | 4.0         | 4.0         | 3.2         |
| C           | 353.1       | 1516.9      | 2660.0      | 2660.0      | 2660.0      | 2138.0      |
| L           | 10.6        | 45.6        | 80.0        | 80.0        | 80.0        | 64.3        |
| O           | 85.0        | 365.0       | 640.0       | 640.0       | 640.0       | 514.4       |
| P           | 10.6        | 45.6        | 80.0        | 80.0        | 80.0        | 64.3        |
| R           | 10.6        | 45.6        | 80.0        | 80.0        | 80.0        | 64.3        |
| S           | 35.0        | 150.5       | 264.0       | 264.0       | 264.0       | 212.2       |
| T           | 35.0        | 150.5       | 264.0       | 264.0       | 264.0       | 212.2       |
| W           | 1.6         | 6.8         | 12.0        | 12.0        | 12.0        | 9.6         |
| By Year     | 542.2       | 2328.9      | 4084.0      | 4084.0      | 4084.0      | 3282.5      |

**Table 12.3-4—{Gaseous Dose Rate Type and Coefficients}**

| <b>Dose Type</b> | <b>Pathway</b> | <b>Methodology</b> | <b>c(j)</b> |
|------------------|----------------|--------------------|-------------|
| TEDE             | All            | ICRP26             | 1259244     |
| Total Body       | External       | ICRP2              | 692594.5    |
| Skin             | External       | ICRP2              | 845547.4    |
| Organ I & P      | I & P          | ICRP2              | 721931      |
| Total Body       | All            | ICRP2              | 813007.5    |
| Thyroid          | All            | ICRP2              | 812811.5    |
| Organ            | All            | ICRP2              | 826407      |

Table 12.3-5—{Historic Gaseous Releases For 2001 Through 2006}

| Nuclide   | 2001 Ci (Bq)        | 2002 Ci (Bq)        | 2003 Ci (Bq)        | 2004 Ci (Bq)        | 2005 Ci (Bq)        | 2006 Ci (Bq)        |
|-----------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| H 3       | 1.29E+02 (4.77E+12) | 1.37E+02 (5.07E+12) | 1.56E+02 (5.77E+12) | 1.60E+02 (5.92E+12) | 8.61E+01 (3.19E+12) | 5.87E+01 (2.17E+12) |
| Ar 41     |                     | 9.68E+00 (3.58E+11) | 3.37E-03 (1.25E+08) | 8.07E+00 (2.99E+11) |                     |                     |
| Cr 51     | 6.48E-03 (2.40E+08) | 3.31E-03 (1.22E+08) | 1.09E-03 (4.03E+07) | 2.52E-04 (9.32E+06) | 2.22E-04 (8.21E+06) | 2.07E-04 (7.66E+06) |
| Mn 54     | 5.96E-04 (2.21E+07) | 1.21E-03 (4.48E+07) | 2.61E-04 (9.66E+06) | 2.74E-04 (1.01E+07) | 2.33E-04 (8.62E+06) | 1.93E-04 (7.14E+06) |
| Co 57     |                     |                     |                     |                     | 3.11E-06 (1.15E+05) |                     |
| Co 58     | 4.43E-05 (1.64E+06) | 5.62E-05 (2.08E+06) | 9.42E-06 (3.49E+05) | 9.93E-06 (3.67E+05) | 2.43E-05 (8.99E+05) | 1.09E-05 (4.03E+05) |
| Co 60     | 2.27E-04 (8.40E+06) | 1.48E-03 (5.48E+07) | 8.83E-05 (3.27E+06) | 1.79E-04 (6.62E+06) | 2.54E-04 (9.40E+06) | 3.82E-04 (1.41E+07) |
| Fe 59     | 6.40E-05 (2.37E+06) | 2.32E-04 (8.58E+06) |                     |                     | 1.69E-05 (6.25E+05) |                     |
| Kr 85m    |                     |                     | 7.68E-04 (2.84E+07) | 6.02E-01 (2.23E+10) |                     |                     |
| Kr 87     |                     |                     | 5.44E-03 (2.01E+08) |                     |                     |                     |
| Kr 88     |                     |                     | 3.01E-01 (1.11E+08) | 2.48E-01 (9.18E+09) |                     | 6.94E-01 (2.57E+10) |
| Kr 89     |                     |                     | 6.03E-02 (2.23E+09) |                     |                     |                     |
| Sr 90     |                     | 2.95E-05 (1.09E+06) |                     |                     |                     |                     |
| Nb 95     | 5.39E-06 (1.99E+05) |                     |                     | 4.11E-06 (1.52E+05) | 6.43E-06 (2.38E05)  |                     |
| Ag 110m   | 1.18E-05 (4.37E+05) | 2.32E-06 (8.58E+04) |                     |                     |                     |                     |
| I 131     |                     |                     |                     |                     | 9.71E-06 (3.59E+05) | 1.41E+05 (5.22E+05) |
| I 133     |                     |                     |                     |                     | 1.28E-05 (4.74E+05) |                     |
| Xe 133    |                     |                     | 2.36E+04 (8.73E+06) | 6.04E-01 (2.23E+10) |                     |                     |
| Xe 133m   | 1.27E-01 (4.70E+09) |                     |                     |                     |                     |                     |
| Xe 135    | 6.65E+00 (2.46E+11) |                     | 2.84E-03 (1.05E+08) |                     |                     | 4.13E-02 (1.53E+09) |
| Xe 135m   |                     |                     | 1.52E-02 (5.62E+08) |                     |                     |                     |
| Xe 137    |                     |                     | 1.52E-01 (5.62E+09) |                     |                     |                     |
| Xe 138    |                     |                     | 6.73E-02 (2.49E+09) |                     |                     |                     |
| Cs 137    |                     | 3.23E-06 (1.20E+05) |                     |                     |                     |                     |
| Ce 141    | 1.76E-06 (6.51E+04) |                     |                     |                     |                     |                     |
| Ce 144    | 6.97E-06 (2.58E+05) |                     |                     |                     | 1.48E-05 (5.48E+05) |                     |
| Ba-La 140 |                     |                     |                     |                     | 8.73E-06 (3.23E+05) |                     |
| As 76     | 6.26E-03 (2.32E+08) | 1.86E-03 (6.88E+07) |                     |                     |                     |                     |
| Na 24     | 2.52E-04 (9.32E+06) | 8.08E-05 (2.99E+06) |                     |                     |                     |                     |
| Tc 99m    | 1.05E-03 (3.89E+07) | 1.78E-04 (6.59E+06) |                     |                     |                     |                     |

**Table 12.3-6—{Historical Liquid Releases for Input to LADTAPII}**

| <b>Isotope</b> | <b>2001 Ci (Bq)</b>    | <b>2002 Ci (Bq)</b>    | <b>2003 Ci (Bq)</b>     | <b>2004 Ci (Bq)</b>    | <b>2005 Ci (Bq)</b>    | <b>2006 Ci (Bq)</b>    |
|----------------|------------------------|------------------------|-------------------------|------------------------|------------------------|------------------------|
| Co-58          | 4.28E-04<br>(1.58E+07) | 2.92E-04<br>(1.08E+07) | 3.426E-04<br>(1.26E+07) | 2.03E-04<br>(7.51E+06) | 5.33E-05<br>(1.97E+06) | 3.25E-05<br>(1.20E+06) |
| Co-60          | 3.90E-03<br>(1.44E+08) | 3.27E-03<br>(1.21E+08) | 5.14E-03<br>(1.90E+08)  | 1.32E-03<br>(4.88E+07) | 9.01E-04<br>(3.33E+07) | 2.67E-04<br>(9.89E+06) |
| Cr 51          | 1.25E-02<br>(4.61E+08) | 1.15E-02<br>(4.27E+08) | 8.16E-03<br>(3.02E+08)  | 2.67E-03<br>(9.86E+07) | 8.43E-04<br>(3.12E+07) | 7.08E-04<br>(2.62E+07) |
| Cs 137         |                        |                        |                         | 6.57E-07<br>(2.43E+04) |                        | 4.45E-05<br>(1.64E+06) |
| F 18           | 1.82E-07<br>(6.72E+03) |                        |                         | 1.96E-07<br>(7.25E+03) |                        |                        |
| Fe 55          | 3.89E-03<br>(1.44E+08) | 6.45E-03<br>(2.39E+08) | 9.07E-03<br>(3.36E+08)  | 1.95E-02<br>(7.22E+08) |                        |                        |
| Fe 59          | 3.03E-05<br>(1.12E+06) | 6.12E-04<br>(2.26E+07) | 1.29E-04<br>(4.77E+06)  | 4.90E-05<br>(1.81E+06) | 4.63E-06<br>(1.71E+05) | 1.24E-05<br>(4.58E+05) |
| H 3            | 2.44E+01<br>(9.04E+11) | 6.61E+01<br>(2.45E+12) | 7.75E+01<br>(2.87E+12)  | 6.21E+01<br>(2.30E+12) | 7.40E+01<br>(2.47E+12) | 8.29E+01<br>(3.30E+12) |
| I 33           |                        |                        |                         |                        | 2.45E-07<br>(9.07E+03) |                        |
| Mn 54          | 3.44E-03<br>(1.27E+08) | 7.68E-03<br>(2.84E+08) | 5.34E-03<br>(1.98E+08)  | 1.29E-03<br>(4.77E+07) | 2.95E-04<br>(1.09E+07) | 1.40E-04<br>(5.17E+06) |
| Na 24          | 2.48E-06<br>(9.18E+04) |                        |                         |                        |                        |                        |
| Nb 95          |                        |                        | 6.81E-07<br>(2.52E+04)  | 2.66E-06<br>(9.84E+04) |                        |                        |
| P 32           | 1.18E-05<br>(4.36E+05) | 3.06E-05<br>(1.13E+06) |                         |                        |                        |                        |
| Sb 124         | 9.07E-07<br>(3.36E+04) |                        | 2.96E-06<br>(1.10E+05)  | 9.12E-07<br>(3.37E+04) | 3.32E-06<br>(1.23E+05) | 1.22E-05<br>(4.51E+05) |
| Tc 99m         |                        |                        |                         |                        |                        | 1.17E-06<br>(4.33E+04) |
| Zn 65          | 1.20E-04<br>(4.42E+06) | 4.28E-06<br>(1.58E+05) | 4.63E-05<br>(1.71E+05)  | 3.61E-06<br>(1.34E+05) | 1.88E-04<br>(6.96E+06) | 9.77E-05<br>(3.61E+06) |
| Xe 133m        | 1.27E-01<br>(4.70E+09) |                        |                         |                        |                        |                        |
| Xe 135         | 6.65E+00<br>(2.46E+11) |                        | 2.84E-03<br>(1.05E+08)  |                        |                        | 4.13E-02<br>(1.53E+09) |

**Table 12.3-7—{Historical Dilutions for Input to LADTAPII}**

| <b>Year</b> | <b>1<sup>st</sup> Quarter L<br/>(ft<sup>3</sup>)</b> | <b>2<sup>nd</sup> Quarter L<br/>(ft<sup>3</sup>)</b> | <b>3<sup>rd</sup> Quarter L<br/>(ft<sup>3</sup>)</b> | <b>4<sup>th</sup> Quarter L<br/>(ft<sup>3</sup>)</b> | <b>Total L (ft<sup>3</sup>)</b> | <b>Release<br/>Duration min</b> | <b>Flow Rate L/<br/>min (ft<sup>3</sup>/sec)</b> |
|-------------|--|--|--|--|---------------------------------|---------------------------------|--|
| 2001        | 6.84E+07<br>(2.42E+06)                               | 6.39E+07<br>(2.26E+06)                               | 3.36E+07<br>(1.19E+06)                               | 2.20E+07<br>(7.77E+05)                               | 1.88E+08<br>(6.64E+06)          | 6.28E+03                        | 2.99E+04<br>(1.76E+01)                           |
| 2002        | 7.70E+07<br>(2.72E+06)                               | 2.07E+08<br>(7.31E+06)                               | 1.58E+08<br>(5.58E+06)                               | 1.33E+08<br>(4.70E+06)                               | 5.75E+08<br>(2.03E+07)          | 1.90E+04                        | 3.03E+04<br>(1.78E+01)                           |
| 2003        | 9.05E+07<br>(3.20E+06)                               | 6.54E+07<br>(2.31E+06)                               | 2.13E+08<br>(7.52E+06)                               | 1.38E+08<br>(4.87E+06)                               | 5.07E+08<br>(1.76E+07)          | 1.49E+04                        | 3.40E+04<br>(2.00E+01)                           |
| 2004        | 1.04E+08<br>(3.67E+06)                               | 1.54E+08<br>(5.44E+06)                               | 1.17E+08<br>(4.13E+06)                               | 2.18E+07<br>(7.07E+05)                               | 3.97E+08<br>(1.40E+07)          | 1.15E+04                        | 3.45E+04<br>(2.03E+01)                           |
| 2005        | 8.91E+07<br>(3.15E+06)                               | 2.43E+08<br>(8.58E+06)                               | 1.63E+08<br>(5.76E+06)                               | 7.86E+07<br>(2.78E+06)                               | 5.74E+08<br>(2.03E+07)          | 1.81E+04                        | 3.17E+04<br>(1.87E+01)                           |
| 2006        | 1.43E+08<br>(5.05E+06)                               | 1.03E+08<br>(3.64E+06)                               | 9.69E+07<br>(3.42E+06)                               | 2.63E+08<br>(9.29E+06)                               | 6.06E+08<br>(2.14E+07)          | 1.88E+04                        | 3.22E+04<br>(1.90E+01)                           |



**Table 12.3-8—{Historical Shoreline Dose}**

| <b>Year</b> | <b>LADTAPII mrem/yr (<math>\mu</math>Sv/yr) with 12 hr/yr occupancy)</b> | <b>Worker mrem/yr (<math>\mu</math>Sv/yr) with 2200 hr/yr occupancy)</b> | <b>Full mrem/yr (<math>\mu</math>Sv/yr) with 8760 hr/yr occupancy)</b> |
|-------------|--|--|--|
| 2001        | 1.95E-03 (1.95E-02)  | 0.358 (3.58)   | 1.424 (14.24)  |
| 2002        | 1.71E-03 (1.71E-02)  | 0.314 (3.14)   | 1.248 (12.48)  |
| 2003        | 2.22E-03 (2.22E-02)  | 0.407 (4.07)   | 1.621 (16.21)  |
| 2004        | 5.61E-04 (5.61E-03)  | 0.103 (1.03)   | 4.10 (0.410)   |
| 2005        | 4.04E-04 (4.04E-03 )   | 0.074 (0.74)   | 0.295 (2.95)   |
| 2006        | 1.31E-04 (1.31E-03)  | 0.024 (0.24)   | 0.096 (0.96)   |

**Table 12.3-9—{Historic and Projected Loading of SSES ISFSI}**

| <b>Year</b> | <b>Bundles Added</b> | <b># of Bundles Total</b> |
|-------------|----------------------|---------------------------|
| 1999        | 208                  | 208                       |
| 2000        | 208                  | 416                       |
| 2001        | 468                  | 884                       |
| 2002        | 416                  | 1300                      |
| 2003        | 0                    | 1300                      |
| 2004        | 409                  | 1709                      |
| 2005        | 244                  | 1953                      |
| 2006        | 305                  | 2258                      |
| 2007        | 305                  | 2563                      |
| 2008        | 427                  | 2990                      |
| 2009        | 366                  | 3356                      |
| 2010        | 732                  | 4088                      |
| 2011        | 0                    | 4088                      |
| 2012        | 488                  | 4576                      |
| 2013        | 488                  | 5064                      |
| 2014        | 0                    | 5064                      |
| 2015        | 488                  | 5552                      |
| 2016        | 488                  | 6040                      |
| 2017        | 122                  | 6162                      |

**Table 12.3-10—{Condensate Storage Tank Source Terms}**

(Page 1 of 2)

| <b>Isotope</b> | <b>Curies (Bq)</b>  |
|----------------|---------------------|
| Br 83          | 2.75E-02 (1.02E+09) |
| Br 84          | 2.42E-02 (8.95E+08) |
| I 131          | 3.80E-02 (1.41E+09) |
| I 132          | 2.18E-01 (8.07E+09) |
| I 133          | 2.39E-01 (8.84E+09) |
| I 134          | 2.90E-01 (1.07E+10) |
| I 135          | 3.07E-01 (1.14E+10) |
| Cr 51          | 5.66E-05 (2.09E+06) |
| Mc 56          | 2.97E-03 (1.10E+08) |
| Co 58          | 5.67E-04 (2.10E+07) |
| CO 60          | 5.68E-05 (2.10E+07) |
| Sr 89          | 3.78E-04 (1.40E+07) |
| Sr 91          | 9.45E-03 (3.50E+08) |
| Sr 92          | 8.54E-03 (3.16E+08) |
| Mo 99          | 2.41E-03 (8.92E+07) |
| Tc 99m         | 2.35E-02 (8.70E+08) |
| Te 132         | 5.40E-03 (2.00E+08) |
| Cs 138         | 2.87E-02 (1.06E+09) |
| Ba 139         | 2.56E-02 (9.47E+08) |
| Ba 140         | 1.12E-03 (4.14E+07) |
| Ba 141         | 4.72E-03 (1.75E+08) |
| Ba 142         | 1.78E-03 (6.59E+07) |
| Np 239         | 2.62E-02 (9.69E+08) |
| Cs 140         | 9.75E-03 (3.61E+08) |
| Y 92           | 3.44E-03 (1.27E+08) |
| Cs 139         | 2.91E-02 (1.08E+09) |
| Sr 93          | 7.89E-04 (2.92E+07) |
| Y 93           | 1.71E-04 (6.33E+06) |
| La 141         | 1.89E-03 (6.99E+07) |
| Br 85          | 1.77E-03 (6.55E+07) |
| Tc 101         | 1.32E-03 (4.88E+07) |
| Cs 134         | 9.08E-05 (3.36E+06) |
| Cs 136         | 6.20E-05 (2.29E+06) |
| Cs 137         | 1.36E-04 (5.03E+06) |
| Na 24          | 1.97E-04 (7.29E+06) |
| Ni 65          | 1.77E-05 (6.55E+05) |
| W 187          | 3.11E-04 (1.15E+07) |
| Cs 141         | 4.44E-04 (1.64E+07) |
| Sr 94          | 1.09E-05 (4.03E+05) |
| Y 94           | 2.85E-05 (1.05E+06) |
| Y 95           | 1.06E-05 (3.92E+05) |
| Rb 91          | 1.05E-02 (3.89E+08) |
| Rb 90          | 2.03E-02 (7.51E+08) |
| Rb 89          | 1.42E-02 (5.25E+08) |
| Rb 88          | 2.13E-03 (7.88E+07) |
| La 142         | 1.23E-03 (4.55E+07) |
| Y 91m          | 5.11E-03 (1.89E+08) |
| Y 91           | 1.46E-05 (5.40E+05) |
| Sr 90          | 2.61E-05 (9.66E+05) |

**Table 12.3-10—{Condensate Storage Tank Source Terms}**

(Page 2 of 2)

| Isotope | Curies (Bq)         |
|---------|---------------------|
| La 140  | 6.12E-05 (2.26E+06) |

**Table 12.3-11—{LLRWHF Source Term}**

| <b>Isotope</b> | <b>Activity in Ci (Bq)</b> |
|----------------|----------------------------|
| Ba 137m        | 2.59E-02 (9.58E+08)        |
| Cr 51          | 3.17E-04 (1.17E+07)        |
| Fe 59          | 9.49E-04 (3.51E+07)        |
| Mn 54          | 1.66E-01 (6.14E+09)        |
| Co 58          | 3.49E-03 (1.29E+08)        |
| Cs 134         | 9.88E-03 (3.66E+08)        |
| I 129          | 1.09E-03 (4.03E+07)        |
| Sb 124         | 2.32E-05 (8.58E+05)        |
| Co 60          | 1.12E+00 (4.14E+10)        |
| Fe 55          | 1.40E+00 (5.18E+10)        |
| I 131          | 8.45E-06 (3.13E+05)        |
| Zn 65          | 5.67E-02 (2.10E+09)        |

**Table 12.3-12—{SEALAND Container Source Term}**

| <b>Isotope</b> | <b>Activity in Ci (Bq)</b> |
|----------------|----------------------------|
| Ba 137m        | 3.15E-04 (1.17E+07)        |
| Co 58          | 2.95E-03 (1.09E+08)        |
| Co 60          | 1.51E-01 (5.59E+09)        |
| Cs137          | 3.33E-04 (1.23E+07)        |
| Fe 55          | 4.00E+00 (1.48E+11)        |
| Fe 59          | 5.35E-03 (1.98E+08)        |
| I 129          | 1.30E-05 (4.81E+05)        |
| Mn 54          | 2.26E-01 (8.36E+09)        |
| Nb 95          | 3.10E-04 (1.15E+07)        |
| Ni 59          | 2.21E-04 (8.18E+06)        |
| Ni 63          | 1.33E-02 (4.92E+08)        |
| Sb 125         | 5.62E-04 (2.08E+07)        |
| Sr 89          | 4.74E-06 (1.75E+05)        |
| Sr 90          | 2.42E-06 (8.95E+04)        |
| Tc 99          | 7.07E-06 (2.62E+05)        |
| Y 90           | 2.42E-06 (8.95E+04)        |

**Table 12.3-13—{Occupancy by Construction Zone}**

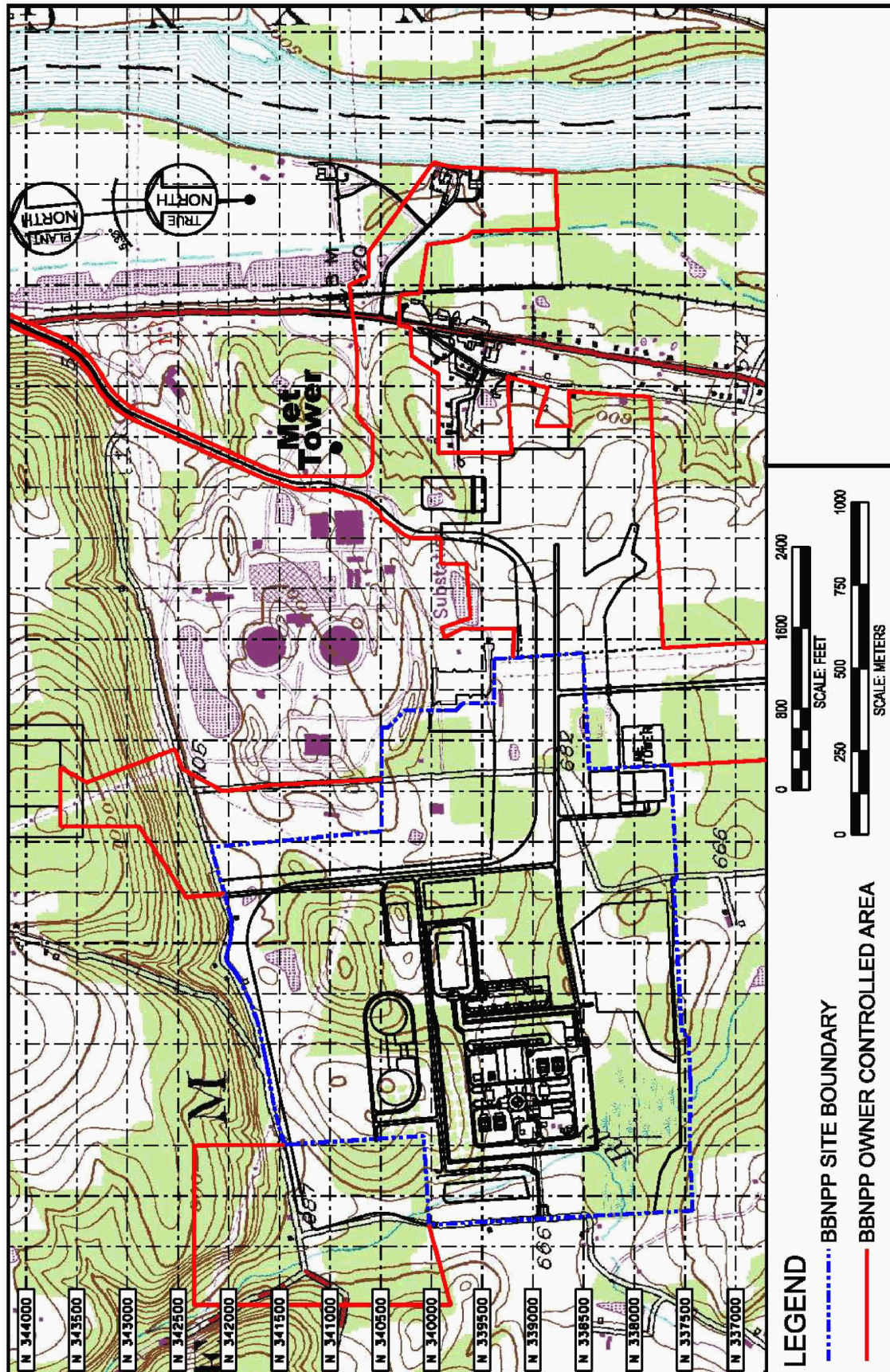
| <b>Zone Description</b>         | <b>Zone Code</b> | <b>Conservative<br/>Occupancy<br/>Fractions Used in<br/>Calculation</b> |
|---------------------------------|------------------|---|
| Batch Plant                     | B                | 0.001   |
| Construction on main structures | C                | 0.665   |
| Laydown                         | L                | 0.020   |
| Office/Trailer                  | O                | 0.160   |
| Parking                         | P                | 0.020   |
| Roads                           | R                | 0.020   |
| Shoreline                       | S                | 0.066   |
| Tower/Basin                     | T                | 0.066   |
| Warehouse                       | W                | 0.003   |
|                                 | TOTAL            | 1.021   |

**Table 12.3-14—{Collective Dose to BBNPP Construction Workers}**

| Zone    | Collective Dose by Zone person-Sievert (person-rem) |                        |                        |                        |                        |                        | Zone                   |
|---------|---|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
|         | 2012  | 2013                   | 2014                   | 2015                   | 2016                   | 2017                   |                        |
| B       | 4.82E-06<br>(4.82E-04)                              | 2.07E-05<br>(2.07E-03) | 3.63E-05<br>(3.63E-03) | 3.63E-05<br>(3.63E-03) | 3.64E-05<br>(3.64E-03) | 2.92E-05<br>(2.92E-03) | 1.64E-04<br>(1.64E-02) |
| C       | 9.71E-04<br>(9.71E-02)                              | 4.17E-03<br>(4.17E-01) | 7.32E-03<br>(7.32E-01) | 7.32E-03<br>(7.32E-01) | 7.32E-03<br>(7.32E-01) | 5.88E-03<br>(5.88E-01) | 3.30E-02<br>(3.30E+00) |
| L       | 4.31E-05<br>(4.31E-03)                              | 1.85E-04<br>(1.85E-02) | 3.26E-04<br>(3.26E-02) | 3.26E-04<br>(3.26E-02) | 3.27E-04<br>(3.27E-02) | 2.63E-04<br>(2.63E-02) | 1.47E-03<br>(1.47E-01) |
| O       | 4.85E-04<br>(4.85E-02)                              | 2.08E-03<br>(2.08E-01) | 3.65E-03<br>(3.65-01)  | 3.65E-03<br>(3.65-01)  | 3.65E-03<br>(3.65-01)  | 2.94E-03<br>(2.94E-01) | 1.65E-02<br>(1.65E+00) |
| P       | 5.29E-05<br>(5.29E-03)                              | 2.27E-04<br>(2.27E-02) | 3.98E-04<br>(3.98E-02) | 3.98E-04<br>(3.98E-02) | 3.98E-04<br>(3.98E-02) | 3.20E-04<br>(3.20E-02) | 1.80E-03<br>(1.80E-01) |
| R       | 9.18E-05<br>(9.18E-03)                              | 4.11E-04<br>(4.11E-02) | 7.84E-04<br>(7.84E-02) | 7.77E-04<br>(7.77E-02) | 8.05E-04<br>(8.05E-02) | 6.70E-04<br>(6.70E-02) | 3.50E-03<br>(3.50E-01) |
| S       | 2.47E-04<br>(2.47E-02)                              | 1.06E-03<br>(1.06E-01) | 1.86E-03<br>(1.86E-01) | 1.86E-03<br>(1.86E-01) | 1.86E-03<br>(1.86E-01) | 1.50E-03<br>(1.50E-01) | 8.40E-03<br>(8.40E-01) |
| T       | 1.29E-04<br>(1.29E-02)                              | 5.56E-04<br>(5.56E-02) | 9.76E-04<br>(9.96E-02) | 9.76E-04<br>(9.76E-02) | 9.77E-04<br>(9.77E-02) | 7.85E-04<br>(7.85E-02) | 4.40E-03<br>(4.40E-01) |
| W       | 8.12E-06<br>(8.12E-04)                              | 3.49E-05<br>(3.49E-03) | 6.12E-05<br>(6.12E-03) | 6.12E-05<br>(6.12E-03) | 6.12E-05<br>(6.12E-03) | 4.92E-05<br>(4.29E-03) | 2.76E-04<br>(2.76E-02) |
| By Year | 2.03E-03<br>(2.03E-01)                              | 8.75E-03<br>(8.75E-01) | 1.54E-02<br>(1.54E+00) | 1.54E-02<br>(1.54E+00) | 1.54E-02<br>(1.54E+00) | 1.24E-02<br>(1.24E+00) | 6.94E-02<br>(6.94E+00) |



Figure 12.3-1—{Site Layout}



**Figure 12.3-2—{CST and RWST Locations on Plant Grid}**  
(Background image for illustration purposes only. Pertinent information is labeled in red)

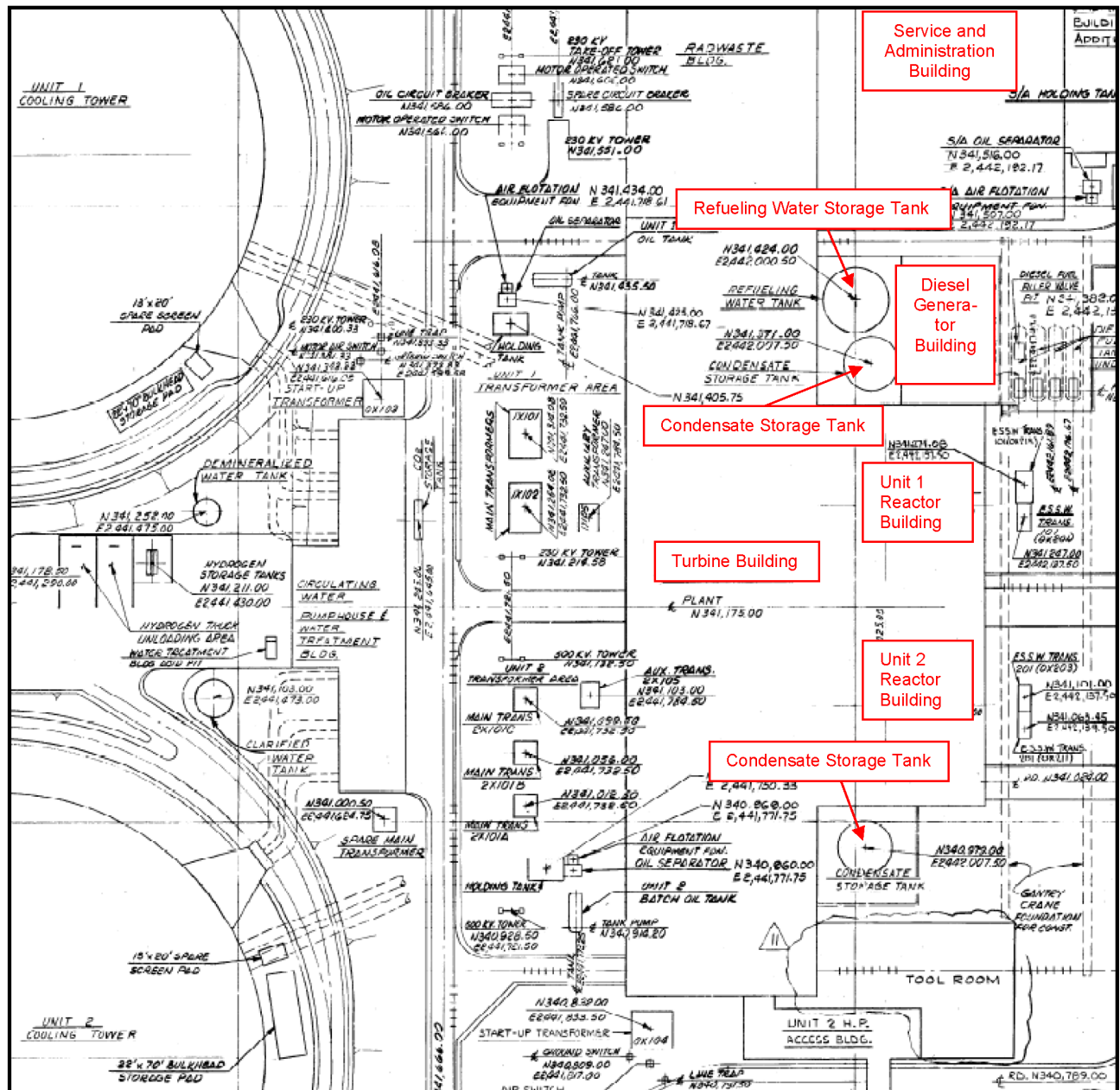
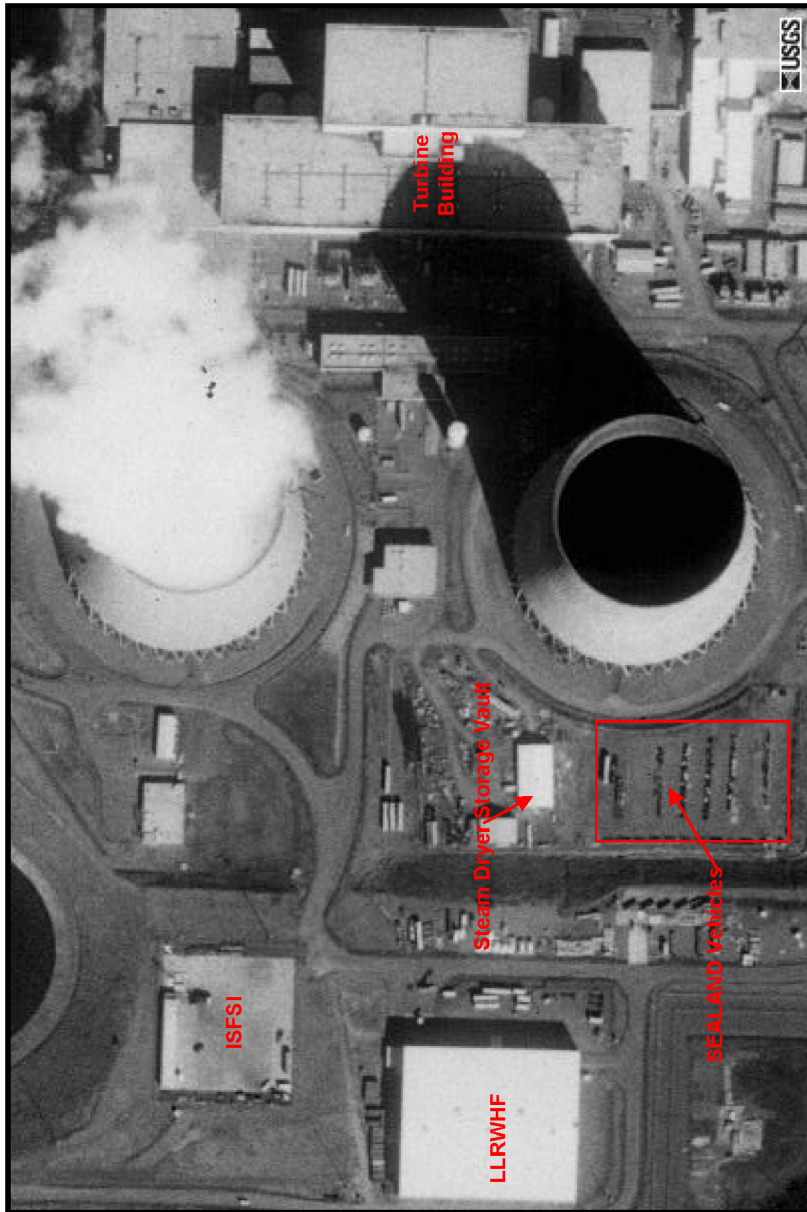




Figure 12.3-3—{Source Location}



**Figure 12.3-4—{Annual Dose Rate in 2017 in Units of mrem 8760 hours}**

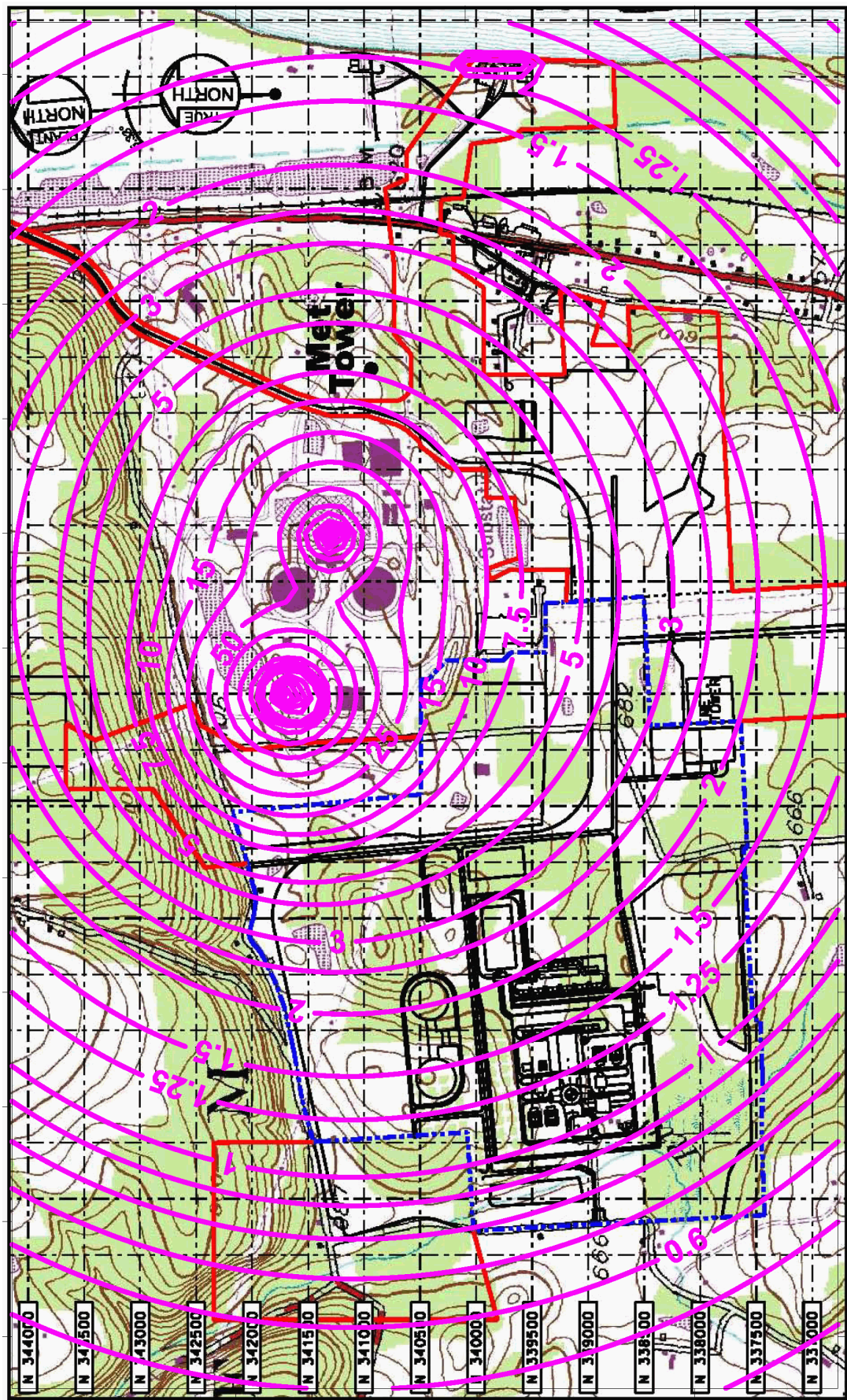
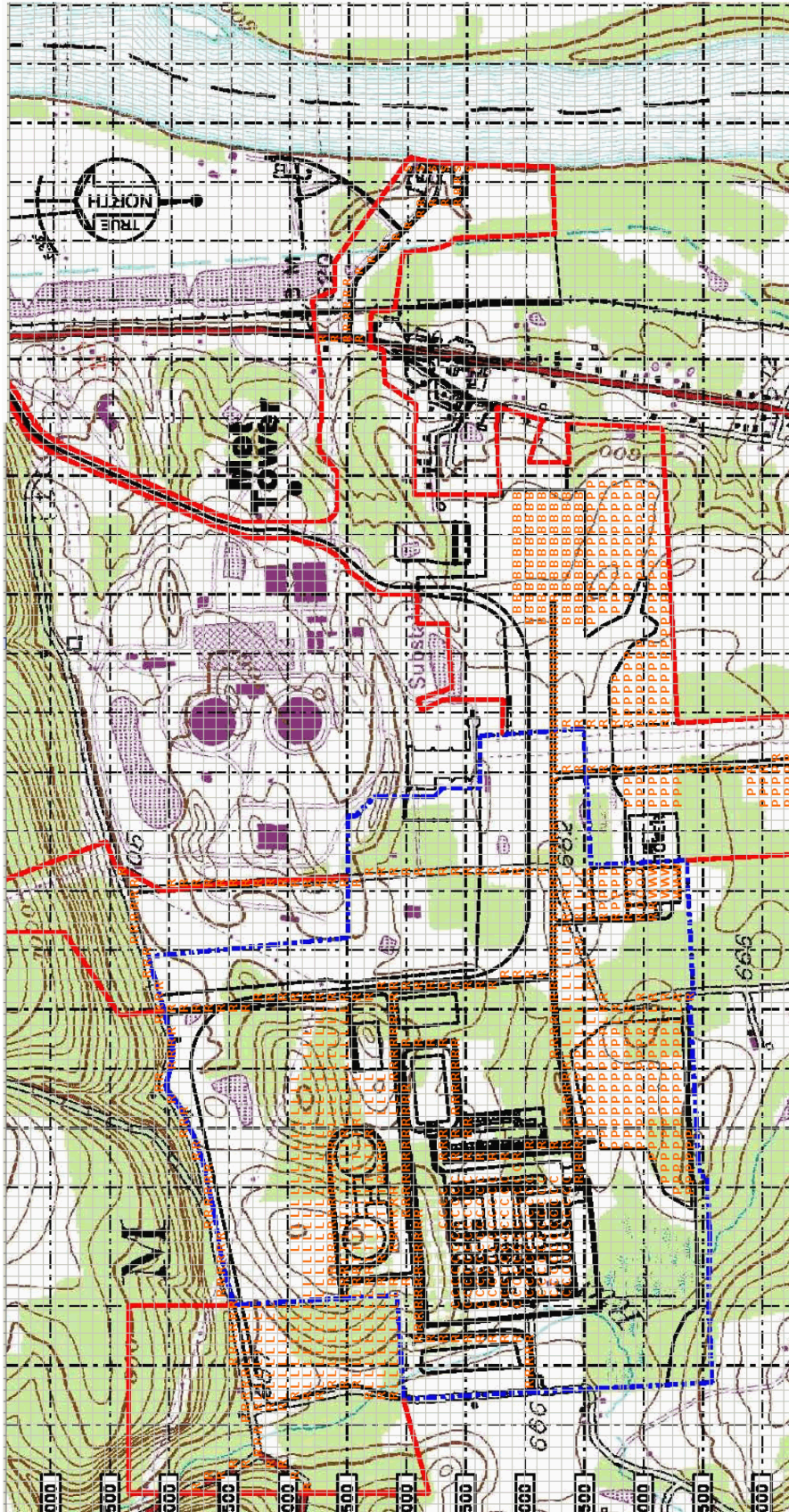




Figure 12.3-5—{Worker Zone Locations}

**Notes:**

Note 1 – the plant grid is in feet, there is a line every 500 feet and every other line is labeled at 1000 feet.

Note 2 – the following provides a key to the zones indicated in the figure:

| Zone | Description                     | Zone | Description    | Zone | Description                           |
|------|---------------------------------|------|----------------|------|---------------------------------------|
| B    | Batch Plant                     | O    | Office/Trailer | S    | Shoreline, tunnel, barge, in/out flow |
| C    | Construction on main structures | P    | Parking        | T    | Tower/Basin/De-salinization           |
| L    | Laydown                         | R    | Roads          | W    | Warehouse                             |

Figure 12.3-6—{ISFSI Distance Equation}

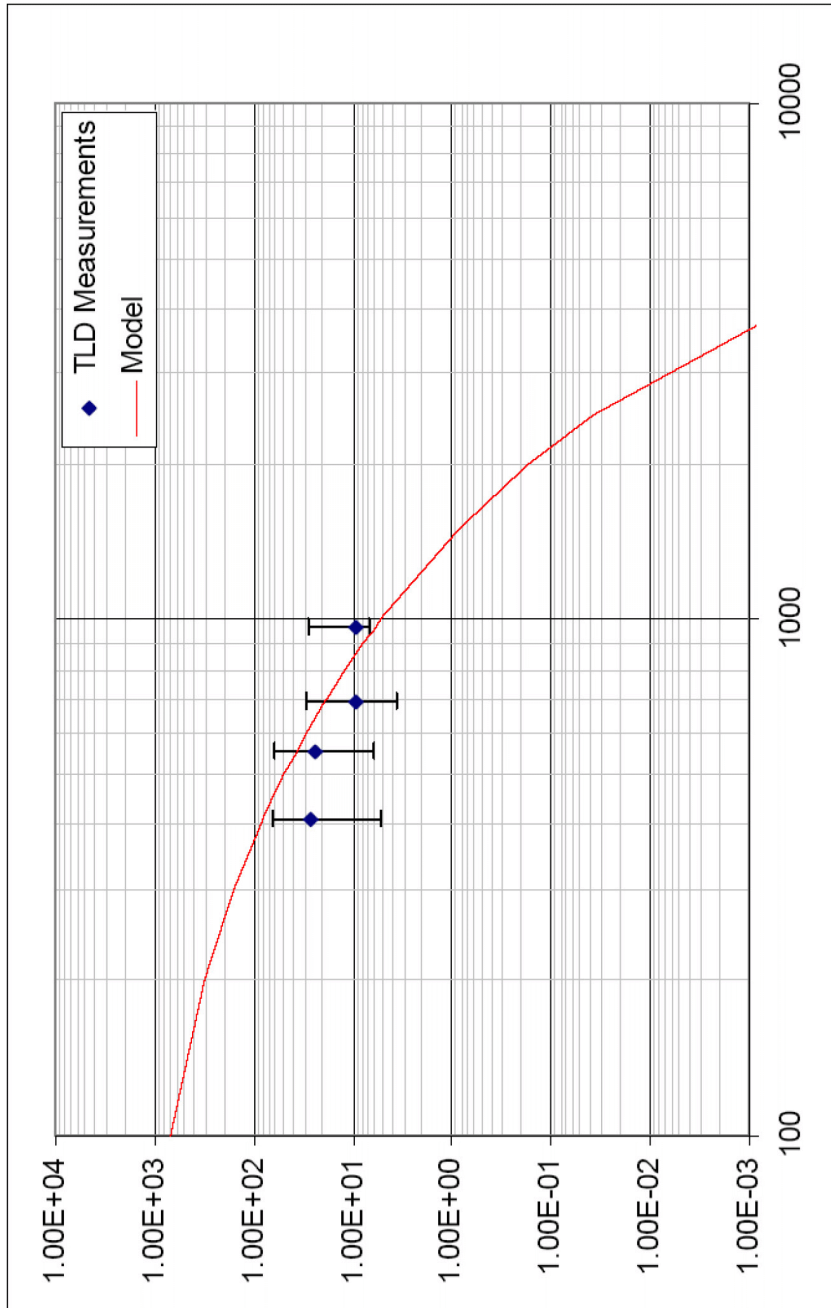




Figure 12.3-7—{ISFSI Satellite Image}

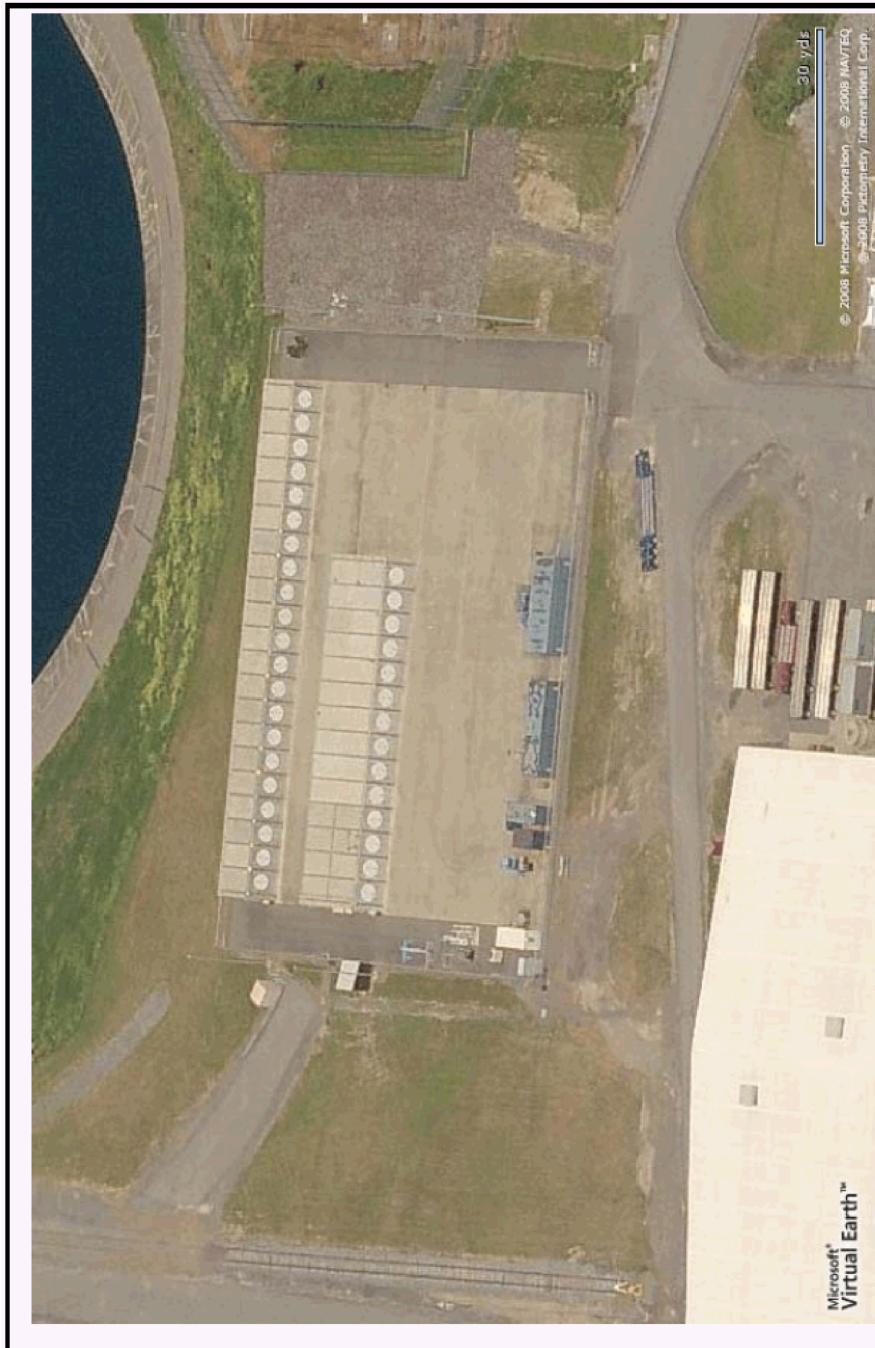


Figure 12.3-8—{SSES ISFSI (blue border) with TLDs and Grid}





Figure 12.3-9—{TLD (ID 13S2) Data Verifying Time Correlation Function}

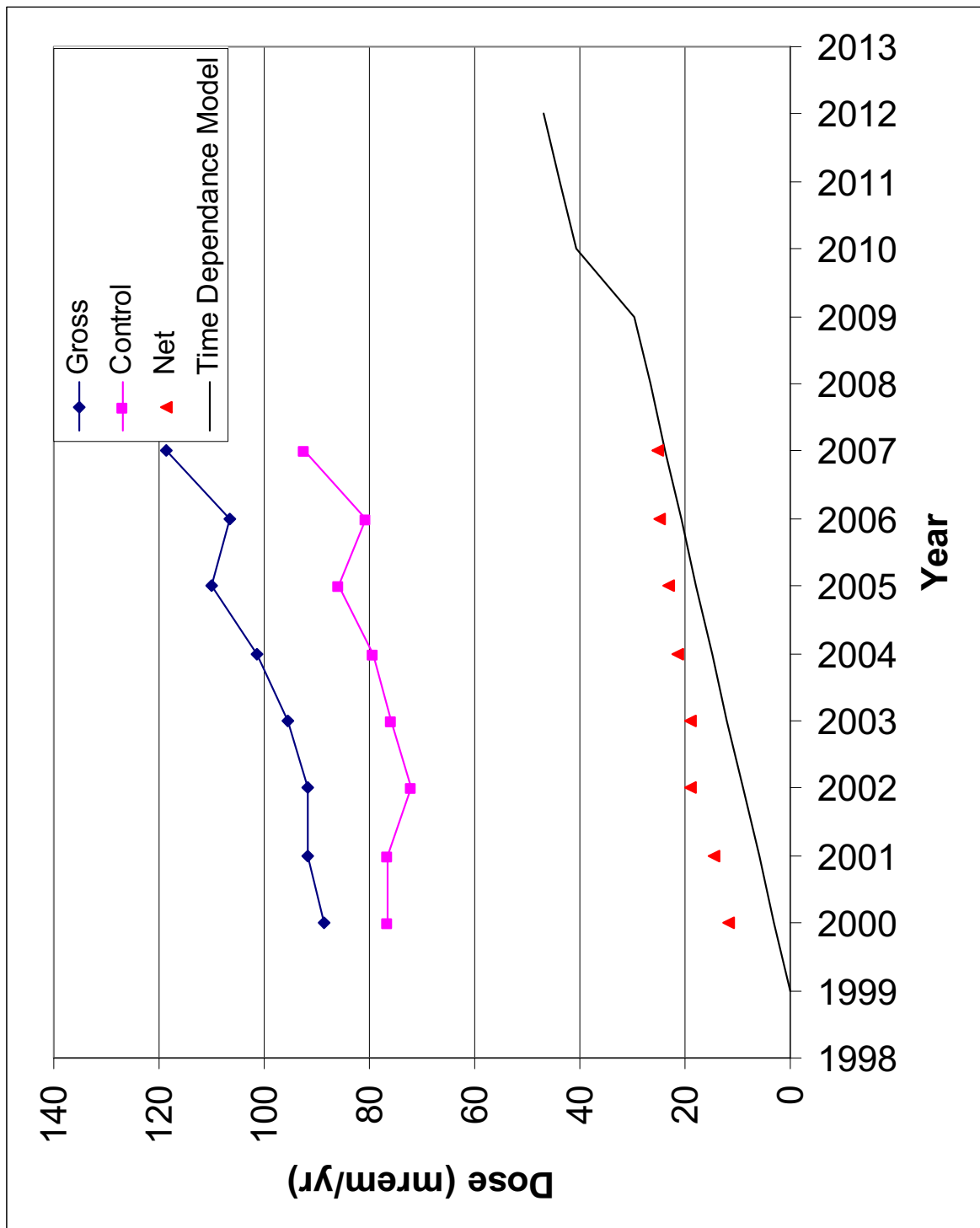


Figure 12.3-10—{Dose vs Distance for CSTs}

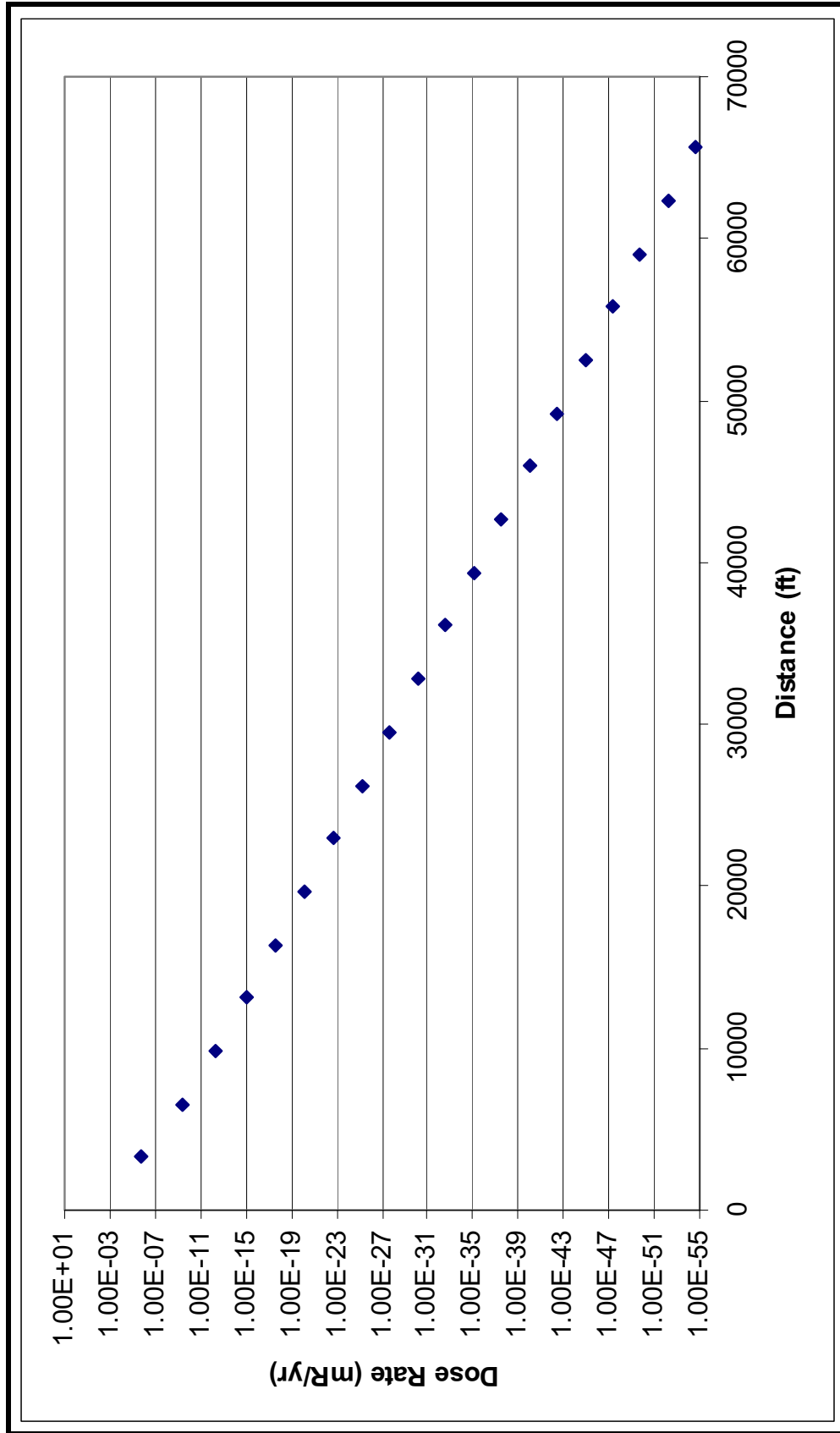


Figure 12.3-11 — {Dose vs Distance for LLRWHF}

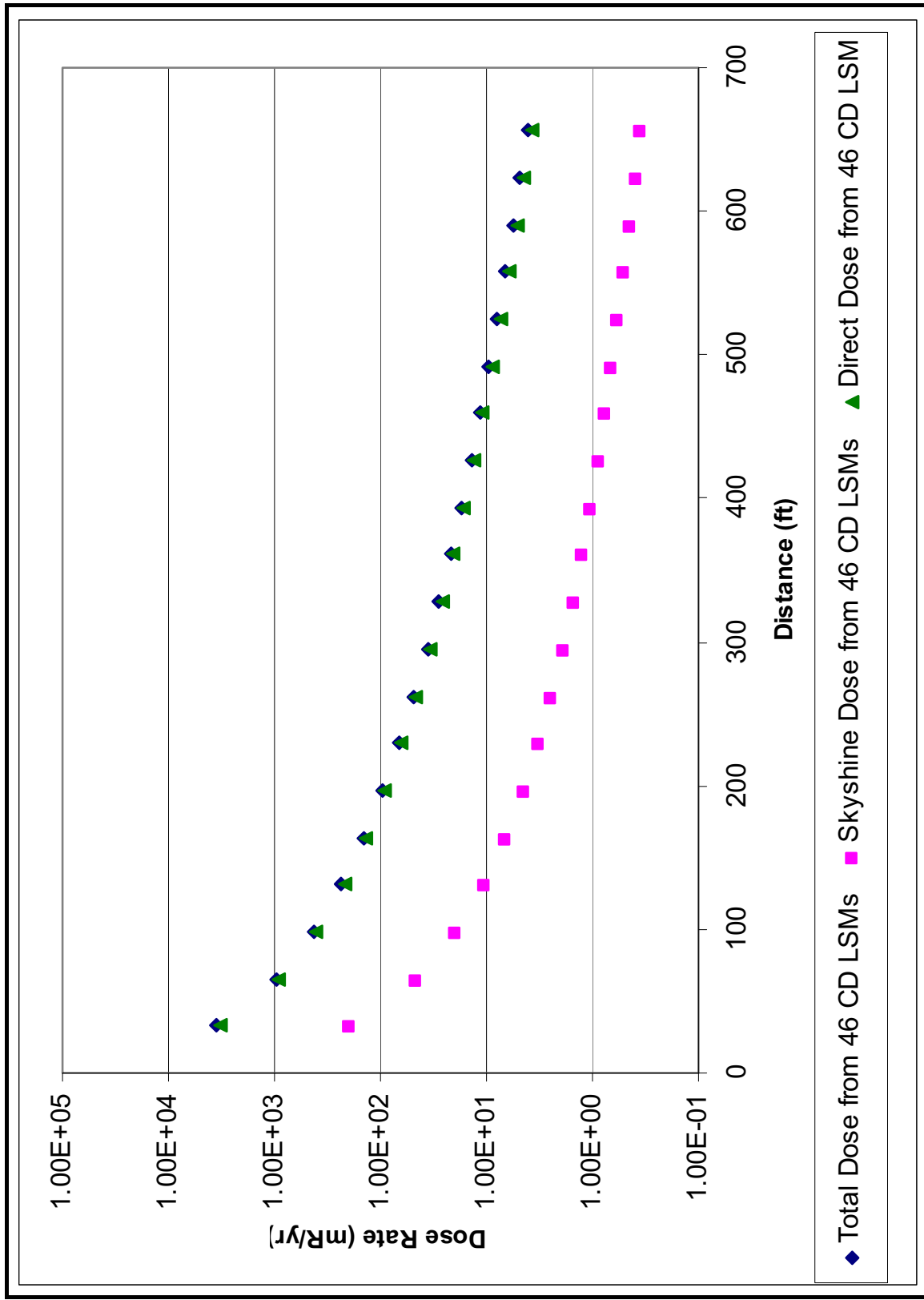


Figure 12.3-12—{Dose vs Distance for SEALAND Containers}

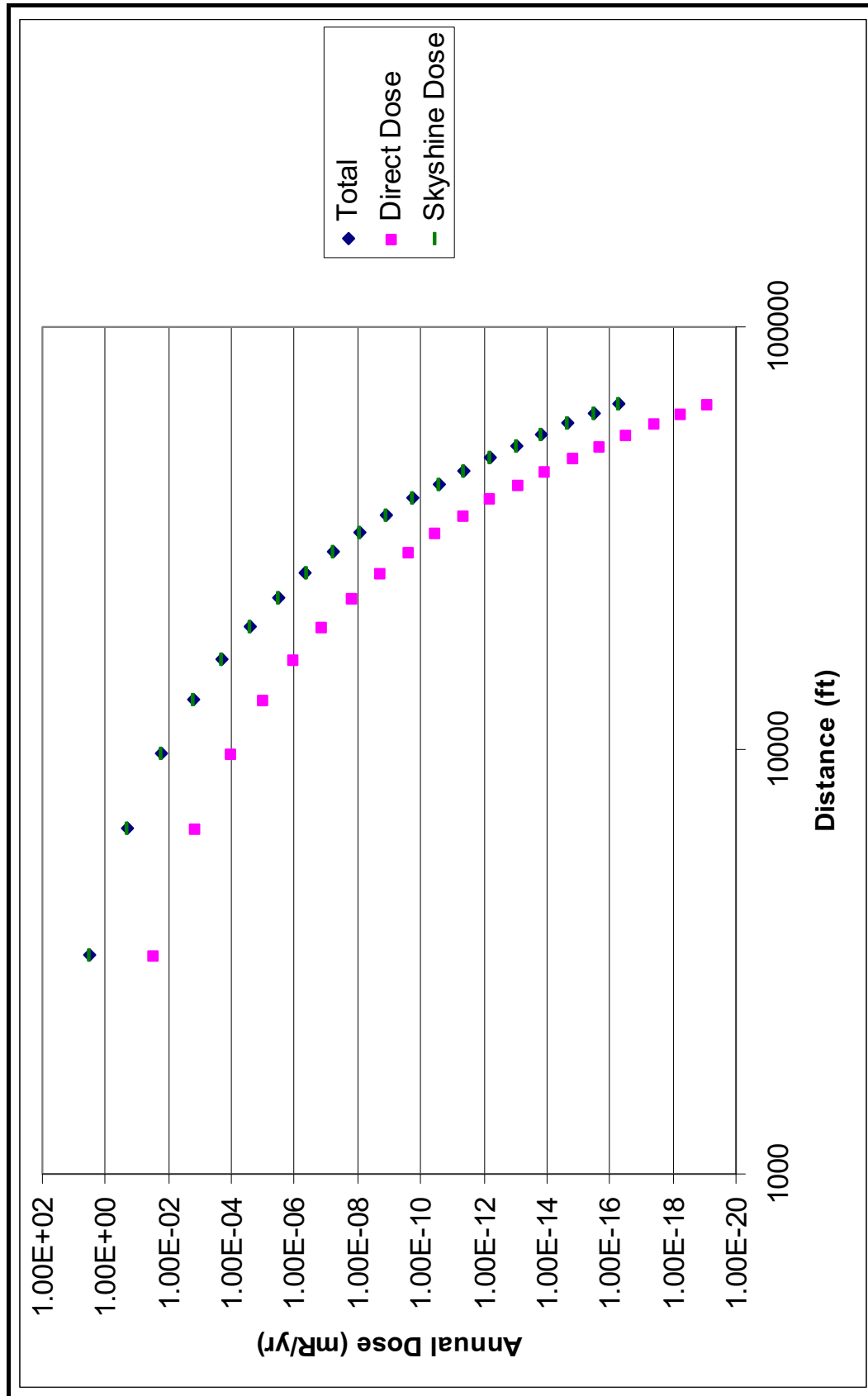


Figure 12.3-13—{Dose vs Distance for Steam Dryer Storage Vault}

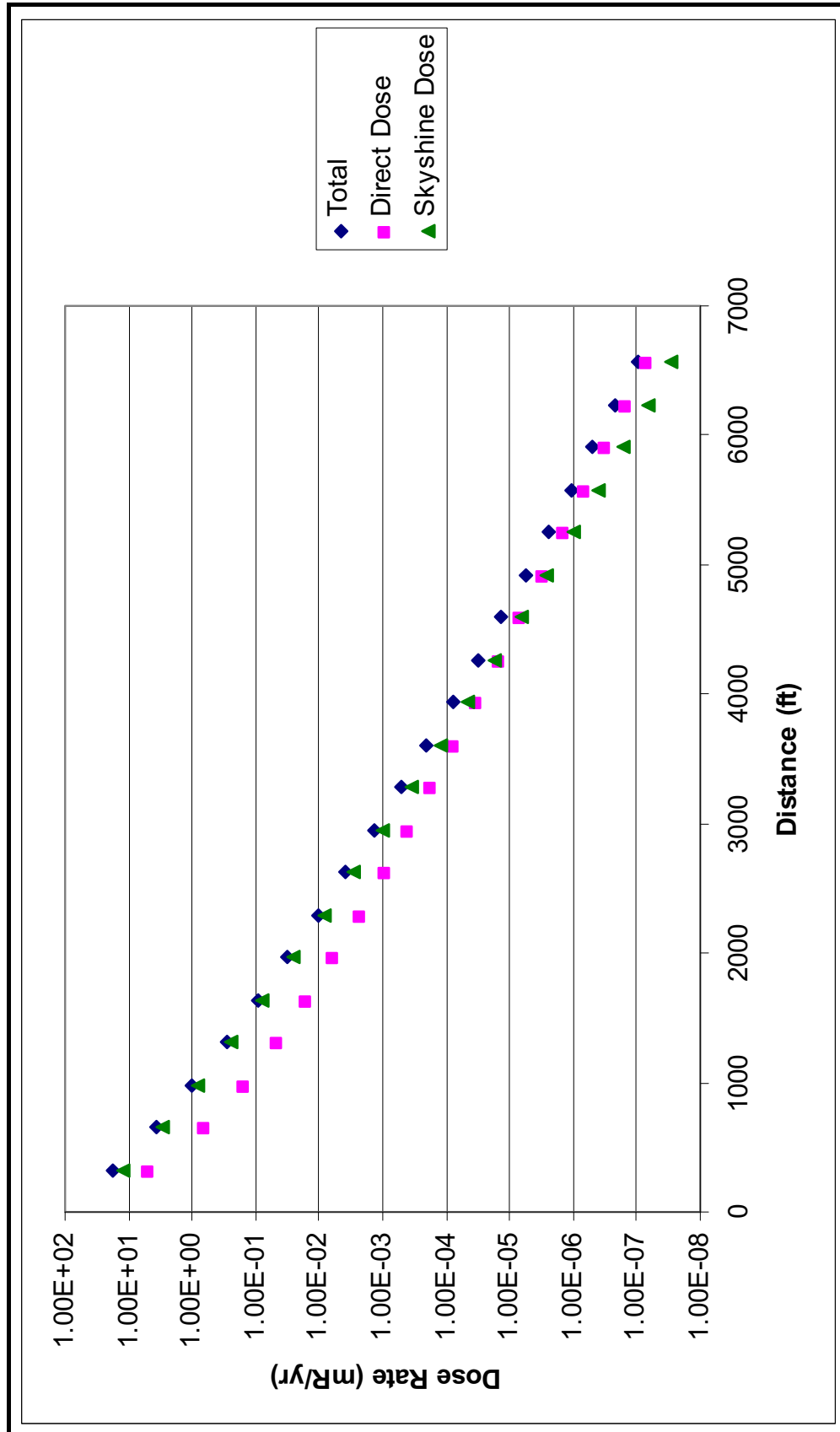
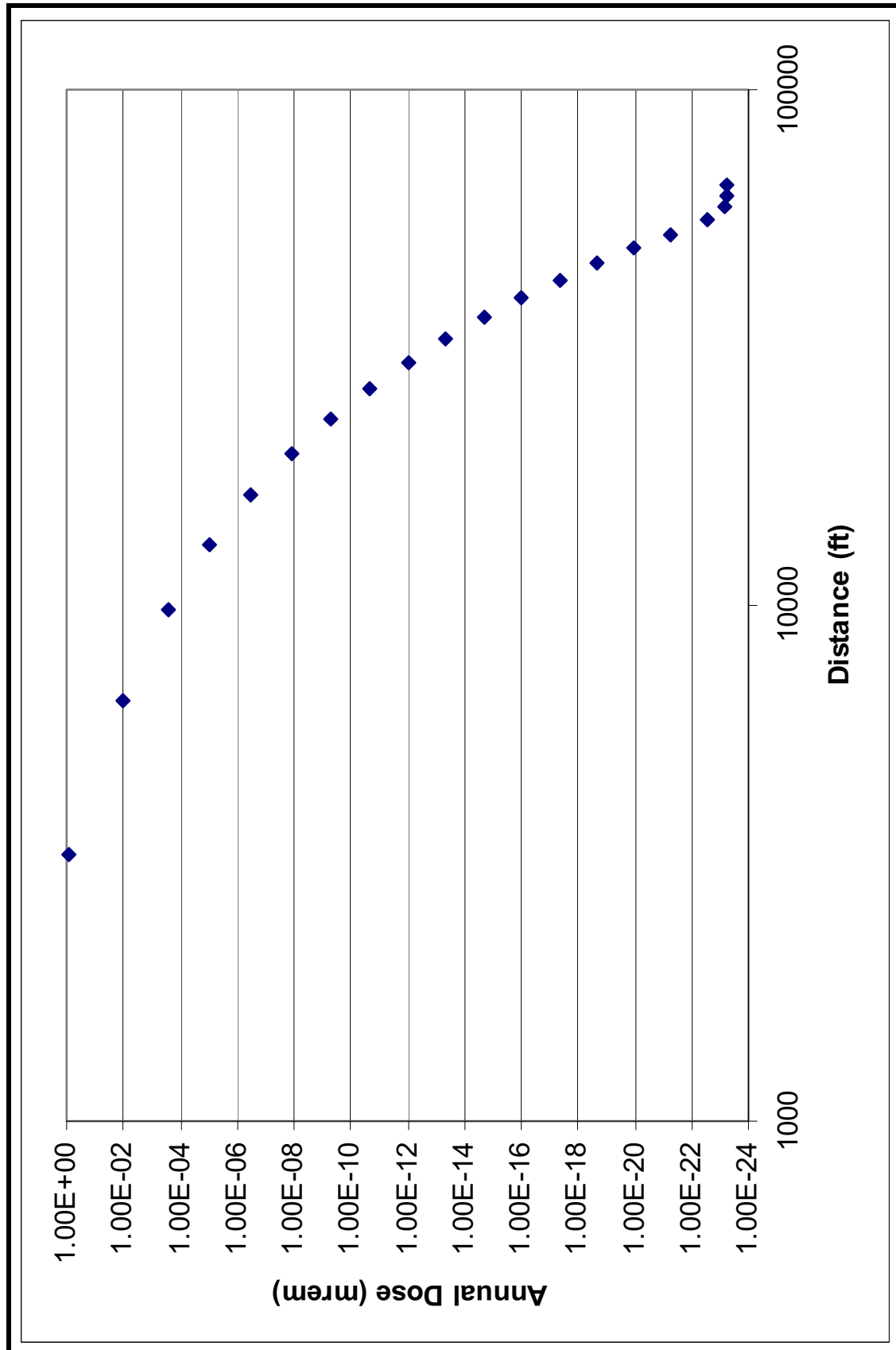


Figure 12.3-14—{Dose vs Distance for Turbine Building}



**12.4 DOSE ASSESSMENT**

This section of the U.S. EPR FSAR is incorporated by reference.

## 12.5 OPERATIONAL RADIATION PROTECTION PROGRAM

This section of the U.S. EPR FSAR is incorporated by reference with the following supplements.

The U.S. EPR FSAR includes the following COL Item in Section 12.5:

A COL applicant that references the U.S. EPR design certification will fully describe, at the functional level, elements of the Radiation Protection Program. The purpose of this Radiation Protection Program is to maintain occupational and public doses ALARA. The program description will identify how the program is developed, documented, and implemented through plant procedures that address quality requirements commensurate with the scope and extent of licensed activities. This program will comply with the provisions of 10 CFR Parts 19, 20, 50, 52, and 71 and be consistent with the guidance in RG 1.206, RG 1.8, RG 8.2, RG 8.4, RG 8.5, RG 8.6, RG 8.7, RG 8.8, RG 8.9, RG 8.10, RG 8.13, RG 8.15, RG 8.27, RG 8.28, RG 8.29, RG 8.34, RG 8.35, RG 8.36, RG 8.38, and the consolidated guidance in NUREG-1736.

This COL Item is addressed as follows:

This section incorporates by reference NEI 07-03A, "Generic FSAR Template Guidance for Radiation Protection Program Description" (NEI, 2009) with the following supplemental information:

NEI 07-03 Section 12.5.4.4, Access Control

The U.S. EPR FSAR Section 12.3.1.8 describes the Very High Radiation Areas (VHRAs) located in the Reactor and Fuel Buildings; their locations are shown in U.S. EPR FSAR Figures 12.3-1 through 12.3-9. VHRAs that are accessible will be controlled via physical barriers and positive access control, such as VHRA keys that are maintained under the control of the {Radiation Protection and Chemistry Manager}. These VHRAs are not routinely accessible during operations; access during special circumstances, such as outages, is via the radiation work control program.

NEI 07-03 Section 12.5.4.12, Quality Assurance

The Quality Assurance program is described in FSAR Section 17.5.

### 12.5.1 REFERENCES

{NEI, 2009. Generic FSAR Template Guidance for Radiation Protection Program Description, NEI 07-03A, Rev. 7, May 2009.}