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 07-08A, "Generic FSAR Template Guidance for Ensuring that Occupational Radiation Exposures Are As Low As Is Reasonably Achievable (ALARA)" (NEI, 2009A) and NEI 07-03A, "Generic FSAR Template Guidance for Radiation Protection Program Description" (NEI, 2009b).

12.1.4 References

{**NEI, 2009a.** Generic FSAR Template Guidance for Ensuring that Occupational Radiation Exposures Are As Low As Is Reasonably Achievable (ALARA), NEI 07-08A, Revision 0, Nuclear Energy Institute, October 2009.

NEI, 2009b. Generic FSAR Template Guidance for Radiation Protection Program Description, NEI 07-03A, Revision 0, Nuclear Energy Institute, May 2009.}

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 (note a)	Sealed Source	Source Rod	Primary Start-up Source	Reactor Core
Sb-Be	3E+06 Ci (note b)	Sealed Source	Source Rod	Secondary Source	Reactor Core
Cs-137	400 Ci (note c)	Sealed Source	Special form sealed capsule	Calibration	Elevation 0 feet of Access Building
{Cs-137	130 mCi (note c)	Sealed Source		Calibration	Elevation 0 feet of Access Building}
{Am-241	0.03 µCi (note d)	Sealed Source	Planchet	Calibration	Elevation 0 feet of Access Building}
{AmBe	3 Ci (note e)	Sealed Source	Special form sealed capsule	Calibration	Elevation 0 feet of Access Building}

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

12.2.1.14 Safety Injection System

No departures or supplements.

12.2.1.15 Normal Heat Removal System

No departures or supplements.

12.2.1.16 Aeroball Measurement System

No departures or supplements.

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.

12.3.1.1 Reactor Building

No departures or supplements.

12.3.1.2 Safeguard Building

No departures or supplements.

12.3.1.3 Fuel Building

No departures or supplements.

12.3.1.4 Nuclear Auxiliary Building

No departures or supplements.

12.3.1.5 Radioactive Waste Processing Building

No departures or supplements.

12.3.1.6 Access Building

The U.S. EPR FSAR includes the following conceptual design information in Section 12.3.1.6 for the Access Building:

> Access control facilities control the entrance and exit of personnel and materials into and from the radiologically controlled area (RCA) of the plant. [[Separate change areas for male and female personnel are located at the access control facility. These facilities are located at elevations -13 feet and 0 feet of the Access Building. The change areas are sufficiently sized to support routine operations, maintenance and typical refueling outage conditions.
>
> Radiation protection offices sufficient to support staff oversight of the radiological control program are located at elevation +39 feet of the Access Building. Space is provided for storage and issuance of radiation protection equipment, instrumentation, dosimetry, and supplies.
>
> Access control facilities are shown in Figures 12.3-14-[[Access Building at Elevation -31 Ft Radiation Zones]] through 12.3-20-[[Access Building at Elevation +54 Ft Radiation Zones.]]
>
> **Personnel Decontamination Area**
>
> [[Once a worker has entered the RCA within the Access Building, entrance to the portions of the connecting buildings in the RCA is at elevation 0 feet, where the worker enters Safeguard Building Division 4. From there, the worker can follow a passageway around the Reactor Building and enter the Fuel Building and Nuclear Auxiliary Building or access other divisions of the Safeguard Building.

Personnel decontamination areas are located near the exit side of the primary access control facility at elevation 0 feet of the Access Building near the control point. The personnel decontamination area is supplied with sinks and showers with drains that are routed to the liquid waste management system.]]

Portable Instrument Calibration Facility

[[A portable instrument calibration facility is located at elevation 0 feet of the Access Building and is designed so that radiation fields created during calibrations do not unnecessarily expose personnel and do not interfere with low-level monitoring or counting systems. This facility is in a low background radiation area so that ambient radiation fields from plant operation do not interfere with low-range instrument calibrations.]]

Respiratory Facility

[[A respirator facility is located with the laundry and consumables storage area at elevation 0 feet in the Access Building. Room is provided for respirator inspection, maintenance, repair, storage, inventory, control, and issuance.]]

Equipment Decontamination Facility

[[Decontamination and cleaning of personnel protective equipment, instrumentation, and small items are performed in a facility set up for that specific purpose at elevation 0 feet of the Access Building. The washdown area and sink drains are routed to the liquid waste management system, and positive air flow is maintained into the decontamination facility and exhausted into a monitored building ventilation system. The facility is provided with coated walls and floors to ease cleanup and decontamination.]]

Radioactive Materials Storage Area

[[A radioactive materials storage area is located at elevation 0 feet of the Access Building and provides for secure storage of calibration sources.]]

Facility for Dosimetry Processing and Bioassay

[[A bioassay room is located at elevation 0 feet of the Access Building outside of the radiological controlled area for dosimetry processing and bioassays collection. The facility is sufficiently shielded to maintain low background radiation levels.]]

The above conceptual design information is addressed as follows:

The reference Access Building designs are utilized. The design information as stated in the U.S. EPR FSAR is incorporated by reference.

12.3.1.7 Layout Design features for ALARA

No departures or supplements.

12.3.1.8 Access to Radiologically Restricted Areas

No departures or supplements.

12.3.1.9 Equipment Design Features and Shielding for ALARA

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 Section12.5.

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 CCNPP Unit 3

Site Layout

The physical location of CCNPP Unit 3 relative to the existing CCNPP Units 1 and 2 on the CCNPP site is presented on Figure 12.3-1. As shown, except for the CCNPP Unit 3 Makeup Water Intake Structure, CCNPP Unit 3 will be located southeast of the protected area from

CCNPP Units 1 and 2. Hence, the majority of construction activity will take place outside the protected area for the existing units, but inside the Owner Controlled Area for the CCNPP site.

Radiation Sources at CCNPP Units

During the construction of CCNPP Unit 3, the construction workers will be exposed to radiation sources from the routine operation of CCNPP Units 1 and 2. Sources that have the potential to expose CCNPP Unit 3 workers are listed in Table 12.3-1. They are characterized as to location, inventory, shielding, and typical local dose rates. 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) (CCNPP, 2005), the annual Radiological Effluent Release Report (CCNPP, 2007a), and the Radiological Environmental Operating Report (CCNPP, 2007b) for CCNPP Units 1 and 2. The four main sources of radiation to CCNPP Unit 3 workers are gaseous effluents, liquid effluents, the Independent Spent Fuel Storage Installation (ISFSI) and the Interim Resin Storage Area. These are discussed below.

All gaseous effluents flow out the CCNPP Units 1 and 2 plant stacks. The releases are reported annually to the NRC. For example, the annual gaseous releases from CCNPP Units 1 and 2 for 2006 were reported as 876 Ci (3.24E+13 Bq) of fission and activation gases, 3.28E-2 Ci (1.21E +09 Bq) of I-131, 1.62E-5 Ci (6.00E+05 Bq) of particulates with half-lives greater than eight days, and 4.79 Ci (1.77E+11 Bq) of tritium (CCNPP, 2007a). 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 Chesapeake Bay. The annual liquid radioactivity releases for 2006 were reported as 4.87E-02 Ci (1.80E+09 Bq) of fission and activation products, 1560 Ci (5.75E+13 Bq) of tritium, and 1.71 Ci (6.31E+10 Bq) of dissolved and entrained gases (CCNPP, 2007a).

There are two main direct radiation sources, the ISFSI and the Interim Resin Storage Area. This is because they are closer to CCNPP Unit 3 than all the other direct sources. There are radiation monitors at the perimeter of each. Radiation from minor direct sources from CCNPP Units 1 and 2 would be picked up by the ISFSI and Resin Storage Area monitoring programs, and thus, would be included in the dose estimates below.

Historical Dose Rates

The historical measured and calculated dose rates that were used to estimate worker dose are presented below.

Offsite Gaseous and Liquid Effluent Doses

The doses listed in Table 12.3-2 are to the maximally exposed member of the public due to the release of gaseous and liquid effluents from CCNPP Units 1 and 2 and are calculated in accordance with the existing units' ODCM (CCNPP, 2005). The maximum individual doses are from historical CCNPP Units 1 and 2 Annual Radiological Environmental Operating Reports and, prior to that, the Radiological Environmental Monitoring Program Annual Reports.

While these off-site doses provide perspective on the variation of effluent releases through the history of the operation of Units 1 and 2, on-site workers will be exposed to fewer pathways. For example, construction workers will not ingest food (edible plants or fish) grown in effluent streams as part of their work activity, therefore, only external and inhalation pathways will be considered.

ISFSI Historical Measurements

Figure 12.3-4 provides thermoluminescent dosimeter (TLD) measurements made adjacent to the ISFSI in 2005 as well as a conservative extrapolation of dose over distance. Table 12.3-3 contains the average monthly ISFSI TLD dose and the average monthly control location dose from 1990 to 2005. The locations used to determine the background are locations DR 1, 7, 8, 20, 21, 22, and 23 as described in the 2005 Radiological Environmental Monitoring Program (REMP) report (CCNPP, 2006b). Table 12.3-4 provides the time trend for the ISFSI net annual dose since spent fuel was initially placed into storage at the ISFSI in 1993.

Resin Storage Area Historical Measurements

Table 12.3-5 provides historical Resin Storage Area TLD readings from 2001 through 2005. Figure 12.3-5 provides the ISFSI and Resin Storage Area TLD readings, averaged over all detectors and over each year of data. Figure 12.3-6 extrapolates the 2005 dose rate over distance from the center of the Resin Area.

Projected Dose Rates at CCNPP Unit 3

Dose rates from all sources combined were calculated for each 100 x 100 foot square on the plant grid. These dose rates were in terms of mrem/year. For purposes of dose rate calculations, a 100% occupancy is assumed. (For purposes of collective dose calculations, the occupancy for construction workers is 2,200 hours per year.) The dose rates were the sum of the dose rate from the four main sources; gases, liquids (only on the shoreline), ISFSI, and Resin Storage Area. They are shown in Figure 12.3-7 for the year 2015, 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. In the calculations, no credit is taken for any additional shielding other than that present in measured doses.

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 12.3-13. The zone locations are shown by 100 x 100 foot squares in Figure 12.3-7. The details of the collective dose calculations are given in the following discussion.

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

$$\dot{D}_{x,y} = \dot{D}_{gas} + \dot{D}_{liq} + \dot{D}_{N,2005} + \dot{D}_{S,t} + \dot{D}_{resin}$$

where the terms are explained in the ER subsections.

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

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

where N_Z is the number of squares in the zone.

The equation for collective dose for the construction period is:

$$D = \frac{2200}{8760}\sum_{t}\sum_{Z}\overline{\dot{D}}_{Z}FTE_{Z,t}$$

where

$\frac{2200}{8760}$ = fraction of work hours per

$\overline{\dot{D}}_z$ = average dose rate in zone, Z.

$FTE_{Z,t}$ = Full Time Equivalents in zone Z during year t.

The equation for full time equivalents is:

$FTE_{Z,t} = P_Z \text{ Census}_t$

where P_Z = probability y of worker in zone, Z

Census_t = FTE of worker on site in year t.

The probability of a worker in each zone, P_Z, reflects the average construction worker and is based on a rough idea of how much time the average worker spends in each zone. For example, the time in the parking lot and road is low, in the construction areas is high, and in the offices is less. These are best estimates based on construction experience.

The spatial distribution of zones on the site is shown (red letters indicating a zone code in each square) in Figure 12.3-7. There are many locations where construction workers are not expected to be, so they are not marked in the figure. Those squares that are marked were chosen because of planned activities at those locations, for example, the parking lots are marked on site drawings, as are roads, and most importantly, the construction area.

Gaseous Dose Rates

The annual Total Effective Dose Equivalent (TEDE) dose rate from gaseous effluents to construction workers on the CCNPP Unit 3 site is bounded by the following equation:

$\dot{D}_{gas} = 220256\ r^{-1.8}$ (mrem/year)

where r is the distance from the stack to the worker location in feet

The skin dose rate equation bounds organ doses from iodines and particulates.

$\dot{D}_{skin} = 1066039\ r^{-1.8}$ (mrem/year)

where r is the distance from the stack to the worker location in feet

These parametric equations are based on annual average, undepleted, ground level χ/Qs that are based on CCNPP site specific meteorology for the years 2000 to 2006. Note that only those

wind directions which could carry gaseous effluents from the stacks to the CCNPP Unit 3 workers were included in the present analysis. Thus, the ENE through W sectors (clockwise) are included. The χ/Q data used are provided in Table 12.3-6. A bounding curve was then fitted to a power equation as shown in Figure 12.3-8.

The equation is:

$$\chi/Q\ (r) = 60\ r^{-1.8}$$

where r is the stack to target distance in feet

The dose rates were calculated for an onsite location with a known χ/Q for the years 2001 through 2006 according to the Regulatory Guide 1.109 (NRC, 1977a) method with TEDE calculations according to Federal Guidance Reports 11 (EPA, 1988) and 12 (EPA, 1993). The gaseous releases are shown in Figure 12.3-7. The 2006 releases gave the highest dose rates. This data was then used to establish the dose rate to χ/Q ratio which was used to derive a parametric equation to bound the dose rate from the 2006 releases.

These equations generate "TEDE" doses suitable for 10 CFR 20.1301 calculations.

Liquid Dose Rates

The dose from liquid effluents is conservatively calculated assuming all the exposure is from deposition on the shoreline. The historical liquid effluents and dilution rates for the years 2001 through 2006 are given in Figure 12.3-8. The maximum calculated dose at the shoreline during this interval is 0.32 mrem/yr (3.2 μSv/yr).

Thus,

$$\dot{D}_{liq} = 0.32\ (\text{mrem/year})\ \text{on shoreline}$$

$$= 0\ \text{not near the water}$$

The actual discharge from CCNPP Units 1 and 2 is 850 ft (259 m) away from shore. The dilution factor at the shore would provide a significant reduction but is conservatively ignored.

The LADTAPII computer code (NRC, 1986) was used to make these calculations. LADTAPII assumes a 12 hours/year occupancy rate which had to be scaled up by the factor 8760/12 for annual dose rate calculations.

ISFSI Dose Rates

The dose rate had to be calculated at various distances and directions from the ISFSI. The dose rate also had to be projected into the future as more spent fuel was loaded into storage canisters and stored at the ISFSI from CCNPP Units 1 and 2. TLD readings around the ISFSI as shown in Figure 12.3-9 were used to develop the following equation for 2005 dose rate as a function of location:

$$DR_{N,2005} = 76\omega e^{-0.00195x}\ (\text{mrem / year})$$

Where x = source surface to target distance (ft), and

ω = solid angle of the ISFSI source and equivalent air scattering volume above

The equation for solid angle is derived empirically from dosimetry and distance measurements at the ISFSI site. The height, H, and radius R, are effective values from the fit. They are 400 and 124 feet respectively. The equation is:

$$\omega = 2\arcsin\left(\left(\frac{H}{\sqrt{H^2 + r^2}}\right)\left(\frac{R}{\sqrt{R^2 + r^2}}\right)\right)$$

This is a reasonable approximation for the North end, i.e., ISFSI-N, which was about 72% loaded with spent fuel at the end of 2005. The exterior perimeter distance, x, to ISFSI-N is calculated assuming a source center at N9703, E7936. Then, it was assumed that all post-2005 spent fuel loading went into ISFSI-S whose source center was N9403, E7936. The source term for ISFSI-S was an extrapolation of the historic dose rate increase from ISFSI-N as shown in Figure 12.3-10. The dose rate from ISFSI-S as a function of calendar year after 2005 is:

$$\dot{D}_{s,t} = (-170.8456 + 0.08521\ t)\ \dot{D}_{N,2005}$$

where t is the absolute year (such as 2010).

Note that these provide annual average dose rates. There are significant temporal variations, for example, during ISFSI loading operations the dose rate will go up. These variations are included in the annual average.

Resin Area Dose Rates

The resin dose rate equation is given below where, r, the distance in feet from the effective center of the Resin Area, i.e., N 10100 E 7600 on the plant grid is given in feet.

$$\dot{D}_{resin} = \frac{2.23E6\ e^{-0.000951r}}{r^2} \text{ (mrem/year)}$$

This is independent of direction. The Cobalt-60 photon energy spectrum is assumed because it typically dominates or bounds the exterior distance dose rate from resin beds. In reality, there is expected to be significant variation in the sources and their strengths from quarter to quarter. There is also expected to be some azimuthal variation in dose rate. However, this is a best estimate, which is suitable for the purpose of ALARA calculations.

This equation was fitted to TLDs located as shown in Figure 12.3-11. The data for 2005 was used. All the data for the years 2001 through 2005 are in Table 12.3-5. There has been one year in which the dose rate was higher than is predicted by this equation. For this reason, future TLD dose rates will be monitored to assure that this equation and associated results remain valid.

Example Dose Rate Calculation

As an example the dose rate to the location N8050, E9150 is calculated. This location is at the center of the square that is nearest to the center of the containment of the new plant. The ISFSI will be at its maximum load for the construction period, i.e. as projected in 2015. The distances between the sources and the receptor are shown in the following table. Note that the first grid coordinate on the map is shown as N8050, but, mathematically is -8050. The distance, in feet, between the gas stack and the receptor is

$$r = \sqrt{(-10474 - -8050)^2 + (9996 - 9150)^2} = 2567$$

The other distances are similarly calculated

Location	N	E	r (ft)
Receptor	-8050	9150	
Gas Stack	-10474	9996	2567
ISFSI North Half	-9703	7936	1927
ISFSI South Half	-9403	7936	1694
Resin Area	-10100	7600	2570

The dose rate from gases released from the stack are

$$\dot{D}_{gas} = 220256 \cdot 2567^{-1.8} = 0.16064$$

The dose rate from liquids is zero because the receptor is not near the shoreline nor near any effluent liquids. The dose rate from ISFSI is calculated assuming the 2005 load at both the north and south halves. Both dose calculations depend upon the solid angles in streradians (sr) which are calculated as follows:

$$\omega_N = 2\arcsin\left(\left(\frac{400}{\sqrt{400^2 + 1927^2}}\right)\left(\frac{124}{\sqrt{124^2 + 1927^2}}\right)\right) = 0.02611sr$$

Similarly for the south half:

$$\omega_S = 2\arcsin\left(\left(\frac{400}{\sqrt{400^2 + 1694^2}}\right)\left(\frac{124}{\sqrt{124^2 + 1694^2}}\right)\right) = 0.03356sr$$

Note, that arcsin( ) calculates the planar angle in degrees or radians. Units of degree are converted by θ(degrees) = θ(radians)180/π(radians). The dose rate from the north half of the ISFSI is

$$\dot{D}_{N,2005} = 76 \cdot 0.02611 \cdot e^{-0.00195 \times 1927} = 0.04$$

From the south half the dose rate is calculated assuming it is loaded like the north half in 2005:

$$\dot{D}_{S,2005} = 76 \cdot 0.03356 \cdot e^{-0.00195 \times 1694} = 0.09381$$

Correcting for ISFSI loading out to the year 2015:

$$\dot{D}_{S,2015} = (-170.8456 + 0.08521 \cdot 2015)\ 0.09381 = 0.07998$$

The dose rate from resins is:

$$\dot{D}_{resin} = \frac{2.23E6\ e^{-0.000951\times 2570}}{2570^2} = 0.02931$$

Thus, the dose rate near the center of the containment in 2015 is:

$$\dot{D} = 0.16064 + 0 + 0.04631 + 0.07998 + 0.02931 = 0.316(\mathrm{mrem/y})$$

Compliance with Dose Rate Regulations

CCNPP Unit 3 construction workers are, for the purposes of radiation protection, members of the general public.

The regulations that govern dose rates to members of the general public are provided in 10 CFR 20.1301 (CFR, 2007a) and 10 CFR 20.1302 (CFR, 2007b).

10 CFR 20.1301

The 10 CFR 20.1301 (CFR, 2007a) limits annual doses from licensed operations to individual members of the public to 0.1 rem (1 mSv) TEDE (total effective dose equivalent.) In addition, the dose from external sources to unrestricted areas must be less than 0.002 rem (0.02 mSv) in any one hour. This applies to the public both outside of and within controlled areas. The maximum dose rates by zone are given in Table 12.3-9. For an occupational year, i.e., 2,200 hours onsite, the maximum dose would be on the road by the ISFSI or the Resin Storage Area, where the dose would be 0.0389 rem (0.389 mSv) and less than 0.002 rem (0.02 mSv) in any one hour. This assumes the worker stood on the road for 2,200 working hours in one year. This value is less than the limits specified above for members of the public.

Radiation Protection and ALARA Program

Due to the exposures from CCNPP Units 1 and 2 normal operations, the CCNPP Units 1 and 2 Radiation Protection and ALARA Program will be extended to include the CCNPP Unit 3 construction workers. This program meets the guidance of Regulatory Guide 8.8 (NRC, 1978) to maintain individual and collective radiation exposures ALARA. This program also meets the requirements of 10 CFR 20.1302.

Collective Doses to CCNPP Unit 3 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 4.6 person-rem (0.046 person-Sieverts). This is a best estimate and is based upon the worker census and occupancy projections shown in Table 12.3-11 and Table 12.3-12. The breakdown of FTE, average dose and collective dose by construction year and occupancy zone is given in Tables 12.3-13, Table 12.3-14, and 12.3-15. These assume 2,200 hours per year occupancy for each worker and are based on effluent release and meteorological data through 2006.}

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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NRC, 1986. LADTAP II – Technical Reference and User Guide, NUREG/CR-4013, U.S. Nuclear Regulatory Commission, April 1986.

NRC, 2006. Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants, Regulatory Guide 1.97, Revision 4, U.S. Nuclear Regulatory Commission, June 2006.}

Table 12.3-1— {Source List for CCNPP Units 1 and 2}

Source	Location	Radioactive Inventory	Shielding	Typical Dose Rates
CCNPP Unit 1 Stack	Side of CCNPP Unit 1 containment	There are two elevated vents, one for each of CCNPP Units 1 and 2. Their joint effluents are characterized in the annual RETS/REMP reports[(a)]	N.A., airborne effluent	Offsite doses generally less than few mrem/ year (few hundreths mSv/year)
CCNPP Unit 2 Stack	Side of CCNPP Unit 2 containment		N.A., airborne effluent	Offsite doses generally less than few mrem/ year (few hundreths mSv/year)
Circulating Water System Discharge	850 ft (259.1 m) from shore	Liquid effluents discharged to bay are characterized in annual RETS/REMP reports[(b)]	N.A., waterborne effluent	Offsite doses generally less than few mrem/ year (few hundreths mSv/year)
ISFSI	ISFSI Pad	Spent fuel characterized by TLD measurements listed in annual ISFSI REMP report	Vented concrete bunkers	Contact dose rates <20 mrem/hr (<0.2 mSv/hr)
Auxiliary Building	West of Turbine Building	Radwaste tanks and storage	Shielded building walls	Exterior contact <2.5 mrem/hr (<0.025 mSv/ hr)
Refueling Water Tanks (RWT)	Adjacent to Auxiliary Building on 45 ft (13.7 m) elevation	Maximum inventory occurs when tanks have reactor water	None	<5.0 mrem/hr (<0.05 mSv/hr) at 15 ft (4.6 m) distance
Interim Resin Storage Area, Lake Davies	300 ft (91.4 m) west of ISFSI	Interim storage of spent resin and filters	None	<0.5 mrem/hr (<0.005 mSv/hr) at the storage area fence
Materials Processing Facility (MPF)	South of Turbine Building	Interim storage of dry active waste, and liquids being processed for shipment	Variety of shields built into structure	Exterior contact <0.5 mrem/hr (<0.005 mSv/ hr)
Original Steam Generator Storage Facility	100 ft (30.5 m) north of north end of ISFSI	Lower assemblies of four original steam generators	Heavily shielded building	Exterior contact <0.5 mrem/hr (<0.005 mSv/ hr)
West Road Cage	On 45 ft (13.7 m) Elevation ~120 ft (~36.6 m) Auxiliary Building rollup doors	Interim storage of spent resins and filters	None	< 5.0 mrem/hr (<0.05 mSv/hr) at the cage fence

Notes:
(a) The gaseous releases reported for 2006 were 876 Ci (3.24E+13 Bq) of fission and activation gases, 3.28E-2 Ci (1.21E+09 Bq) of I-131, 1.62E-5 Ci (6.00E+05 Bq) of particulates with half-lives greater than eight days, and 4.79 Ci (1.77E+11 Bq) of tritium. These are typical compared to recent years.
(b) Liquid effluents from the liquid waste disposal produce small amounts of radioactivity in the discharge to the Chesapeake Bay. The annual liquid radioactivity releases for 2006 were reported as 4.87E-2 Ci (1.80E+09 Bq) of fission and activation products, 1560 Ci (5.75E+13 Bq) of tritium, and 1.71 Ci (6.31E+10 Bq) of dissolved and entrained gases. These are typical compared to the last five years.

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

	Historical Site Boundary Doses Reported to NRC (mrem/year)/(mSv/year)		
Limits	**75**	**25**	**25**
Year	**Thyroid**	**WB**	**Other Organs**
2006	0.052/0.00052	0.004/0.00004	0.010/0.00010
2005	0.006/0.00006	0.005/0.00005	0.095/0.00095
2004	0.007/0.00007	0.002/0.00002	0.006/0.00006
2003	0.006/0.00006	0.004/0.00004	0.023/0.00023
2002	0.003/0.00003	0.007/0.00007	0.174/0.00174
2001	0.005/0.00005	0.010/0.00010	0.351/0.00351
2000	0.018/0.00018	0.018/0.00018	0.211/0.00211
1999	0.011/0.00011	0.013/0.00013	0.686/0.00686
1998	0.005/0.00005	0.005/0.00005	0.302/0.00302
1997	0.005/0.00005	0.009/0.00009	0.235/0.00235
1996	0.005/0.00005	0.012/0.00012	0.245/0.00245
1995	0.007/0.00007	0.017/0.00017	0.132/0.00132
1994	0.024/0.00024	0.039/0.00039	0.473/0.00473
1993	0.099/0.00099	0.125/0.00125	0.466/0.00466
1992	0.125/0.00125	0.114/0.00114	0.420/0.00420
1991	0.167/0.00167	0.045/0.00045	0.292/0.00292
1990	0.070/0.00070	0.070/0.00070	0.370/0.00370
1989	0.526/0.00526	0.113/0.00113	0.674/0.00674
1988	1.130/0.01130	0.120/0.00120	0.500/0.00500
1987	0.381/0.00381	0.250/0.00250	1.360/0.01360
1986	0.685/0.00685	0.093/0.00093	0.643/0.00643
1985	0.800/0.00800	0.010/0.00010	0.030/0.00030
1984	0.710/0.00710	0.110/0.00110	0.020/0.00020
1983	0.150/0.00150	0.060/0.00060	0.030/0.00030
1982	0.220/0.00220	0.034/0.00034	0.080/0.00080
1981	0.100/0.00100	0.002/0.00002	0.080/0.00080
1980	0.170/0.00170	0.009/0.00009	N/A/N/A

Note:

Historically the receptors have been offsite; therefore, the dose is dominated by gaseous and liquid effluents.

Table 12.3-3— {Mean Historical ISFSI Exposures by Year}

Mean TLD Exposures by Year Digitized from Figure 7 of 2005 REMP Report (mRoentgen/30 days) (These are historical values and are listed as reported, in English units)		
Year	**ISFSI**	**Control**
1990	3.96	N/A
1991	3.95	4.11
1992	4.28	4.40
1993	3.99	4.19
1994	4.73	4.63
1995	5.14	4.69
1996	5.01	4.20
1997	5.56	4.31
1998	6.20	4.56
1999	6.07	4.47
2000	5.72	3.88
2001	6.88	4.15
2002	7.23	4.48
2003	8.46	4.60
2004	8.27	4.51
2005	8.14	4.02

Note: 1990 through 1992 provide baseline data before spent fuel stored at ISFSI in 1993.

Table 12.3-4— {Historical ISFSI Net Trend}

Annual Gamma Dose Rate based on ISFSI TLDs						
Year	ISFSI	Control[(a)]	Net ISFSI	ISFSI	Control[(a)]	Net ISFSI
	mrem/y	mrem/y	mrem/y	uSv/y	uSv/y	uSv/y
1991	48.06	47.54	(b)	480.6	475.4	(b)
1992	52.10	51.11	(b)	521.0	511.1	(b)
1993	48.53	48.54	0.00	485.3	485.4	0.0
1994	57.55	53.93	3.62	575.5	539.3	36.2
1995	62.59	54.67	7.92	625.9	546.7	79.2
1996	61.00	48.61	12.39	610.0	486.1	123.9
1997	67.69	50.02	17.68	676.9	500.2	176.8
1998	75.38	53.08	22.30	753.8	530.8	223.0
1999	73.80	52.00	21.79	738.0	520.0	217.9
2000	69.56	44.78	24.77	695.6	447.8	247.7
2001	83.71	48.02	35.69	837.1	480.2	356.9
2002	87.92	52.08	35.84	879.2	520.8	358.4
2003	102.90	53.49	49.41	1029.0	534.9	494.1
2004	100.65	52.41	48.24	1006.5	524.1	482.4
2005	99.07	46.52	52.55	990.7	465.2	525.5

Notes:

(a) Slightly adjusted such that 1993 net TLD dose is zero.

(b) 1991 and 1992 provide baseline before first spent fuel stored at ISFSI in 1993.

Table 12.3-5— {Historical Resin Storage Area TLD Readings for 2001 through 2005}

Quarter	RPDR05	RPDR06	RPDR07	RPDR08	RPDR09	RPDR10	RPDR11	RPDR12
1st Qtr 2001	16.07	16.88	27.94	16.66	32.02	29.56	11.82	21.36
2nd Qtr 2001	51.86	129.45	166.45	124.63	113.28	48.70	17.39	29.98
3rd Qtr 2001	38.54	50.32	154.74	146.91	122.34	52.91	16.91	32.08
4th Qtr 2001	17.54	20.19	23.16	19.72	19.62	21.49	12.68	21.98
1st Qtr 2002	20.91	23.04	38.04	37.08	28.29	28.45	13.96	24.30
2nd Qtr 2002	19.07	18.71	15.78	17.54	19.28	20.96	13.43	21.78
3rd Qtr 2002	15.83	16.20	19.20	18.68	21.08	23.75	16.27	27.98
4th Qtr 2002	16.87	17.04	23.38	18.94	18.91	21.48	17.89	29.63
1st Qtr 2003	16.48	17.21	23.87	18.31	18.11	22.52	18.06	19.73
2nd Qtr 2003	17.75	17.74	31.33	18.73	16.34	25.52	21.06	21.49
3rd Qtr 2003	15.44	15.87	20.96	20.52	16.98	19.31	17.58	24.81
4th Qtr 2003	18.01	16.93	18.63	17.39	19.97	21.78	17.29	26.26
1st Qtr 2004	16.32	16.75	17.88	17.64	18.75	20.89	17.38	25.82
2nd Qtr 2004	36.25	33.89	18.85	36.51	24.17	22.40	16.14	23.34
3rd Qtr 2004	30.26	30.32	24.27	50.34	28.67	30.49	14.84	32.10
4th Qtr 2004	59.47	72.37	74.41	77.07	43.09	46.48	21.50	48.46
1st Qtr 2005	33.37	42.40	34.46	37.28	31.26	33.52	17.03	52.83
2nd Qtr 2005	57.76	53.64	35.03	44.53	45.42	33.16	18.67	60.40
3rd Qtr 2005	30.16	33.09	23.84	42.11	25.38	24.47	15.03	46.03
4th Qtr 2005	17.97	16.71	20.91	38.71	20.81	18.56	14.62	39.27

Note:

(Exposure Rates to TLDs are expressed in milli-Roentgen/90 days. Note that for photons, a Roentgen is approximately equal to a rem.)

Table 12.3-6— {Historical Annual Average χ/Q (sec/m³) In CCNPP Unit 3 Directions}

Normal Effluent Annual Average, Undecayed, Undepleted ./Q Values for Ground Level Release Without Building Wake Using CCNPP Meteorological Data for Directions that Could Affect CCNPP Unit 3 Workers

	Distance from Stacks to CCNPP Unit 3 Location							
Downwind Direction	328 ft (100 m)	656 ft (200 m)	1640 ft (0.5 km)	0.5 mi (0.8 km)	0.62 mi (1.0 km)	0.75 mi (1.2 km)	0.93 mi (1.5 km)	1.24 mi (2.0 km)
ENE	1.43E-03	4.03E-04	7.76E-05	3.32E-05	2.24E-05	1.62E-05	9.19E-06	4.48E-06
E	1.08E-03	3.04E-04	5.86E-05	2.51E-05	1.69E-05	1.23E-05	6.95E-06	3.39E-06
ESE	9.72E-04	2.73E-04	5.26E-05	2.26E-05	1.53E-05	1.11E-05	6.27E-06	3.05E-06
SE	7.12E-04	1.96E-04	3.77E-05	1.63E-05	1.11E-05	8.07E-06	4.56E-06	2.21E-06
SSE	4.63E-04	1.27E-04	2.43E-05	1.05E-05	7.17E-06	5.21E-06	2.94E-06	1.42E-06
S	5.27E-04	1.43E-04	2.70E-05	1.16E-05	7.87E-06	5.71E-06	3.22E-06	1.55E-06
SSW	4.80E-04	1.30E-04	2.45E-05	1.05E-05	7.13E-06	5.17E-06	2.92E-06	1.40E-06
SW	4.63E-04	1.26E-04	2.38E-05	1.02E-05	6.92E-06	5.03E-06	2.84E-06	1.37E-06
WSW	4.03E-04	1.10E-04	2.08E-05	8.90E-06	6.06E-06	4.40E-06	2.49E-06	1.20E-06
W	3.64E-04	9.90E-05	1.88E-05	8.09E-06	5.52E-06	4.01E-06	2.27E-06	1.09E-06

	Distance from Stacks to CCNPP Unit 3 Location						
Downwind Direction	1.5 mi (2.4 km)	1.55 mi (2.5 km)	1.86 mi (3.0 km)	2.49 mi (4.00 km)	2.50 mi (4.02 km)	3.5 mi (5.6 km)	4.5 mi (7.2 km)
ENE	2.85E-06	2.61E-06	1.74E-06	9.29E-07	9.19E-07	4.85E-07	3.11E-07
E	2.15E-06	1.97E-06	1.32E-06	7.02E-07	6.94E-07	3.67E-07	2.35E-07
ESE	1.94E-06	1.78E-06	1.18E-06	6.29E-07	6.22E-07	3.27E-07	2.09E-07
SE	1.39E-06	1.28E-06	8.44E-07	4.44E-07	4.39E-07	2.28E-07	1.44E-07
SSE	8.96E-07	8.20E-07	5.41E-07	2.83E-07	2.80E-07	1.44E-07	9.07E-08
S	9.75E-07	8.93E-07	5.87E-07	3.06E-07	3.03E-07	1.55E-07	9.71E-08
SSW	8.81E-07	8.06E-07	5.30E-07	2.76E-07	2.72E-07	1.39E-07	8.70E-08
SW	8.60E-07	7.87E-07	5.17E-07	2.70E-07	2.67E-07	1.37E-07	8.55E-08
WSW	7.53E-07	6.89E-07	4.53E-07	2.36E-07	2.33E-07	1.19E-07	7.46E-08
W	6.86E-07	6.28E-07	4.13E-07	2.15E-07	2.13E-07	1.09E-07	6.82E-08

Table 12.3-7— {Historical Gaseous Releases for 2002 through 2006}

Nuclide	Release Ci (Bq)				
	2002	2003	2004	2005	2006
H-3	7.33E+00 (2.71E+11)	1.20E+01 (4.44E+11)	5.86E+00 (2.17E+11)	6.48E+00 (2.40E+11)	4.79E+00 (1.77E+11)
Ar-41	1.06E-02 (3.92E+08)	1.68E-02 (6.21E+08)	4.32E-01 (1.60E+10)	2.87E-03 (1.06E+08)	2.72E-03 (1.01E+08)
Fe-55	None Detected	None Detected	2.52E-04 (9.33E+06)	None Detected	None Detected
Co-58	None Detected	None Detected	1.24E-05 (4.59E+05)	7.09E-06 (2.62E+05)	8.99E-06 (3.33E+05)
Co-60	None Detected	None Detected	None Detected	None Detected	7.19E-06 (2.66E+05)
Br-82	None Detected	None Detected	1.10E-05 (4.07E+05)	None Detected	None Detected
Kr-85 m	1.78E-02 (6.60E+08)	6.67E-02 (2.47E+09)	5.48E-02 (2.03E+09)	2.18E-02 (8.06E+08)	8.60E-02 (3.18E+09)
Kr-85	3.33E+01 (1.23E+12)	2.99E+01 (1.11E+12)	2.31E+01 (8.54E+11)	2.22E+01 (8.23E+11)	1.88E+02 (6.94E+12)
Kr-87	3.09E-04 (1.14E+07)	2.87E-03 (1.06E+08)	7.08E-05 (2.62E+06)	None Detected	None Detected
Kr-88	6.65E-04 (2.46E+07)	9.07E-03 (3.36E+08)	4.90E-03 (1.81E+08)	9.06E-03 (3.35E+08)	2.33E-02 (8.61E+08)
Sr-89	None Detected	None Detected	None Detected	1.24E-07 (4.59E+03)	9.08E-09 (3.36E+02)
Sr-90	None Detected	None Detected	4.48E-10 (1.66E+01)	9.43E-07 (3.49E+04)	None Detected
I-131	5.75E-04 (2.13E+07)	1.82E-03 (6.72E+07)	1.54E-03 (5.71E+07)	1.36E-03 (5.03E+07)	3.28E-02 (1.21E+09)
I-132	None Detected	None Detected	None Detected	None Detected	4.28E-03 (1.58E+08)
I-133	2.96E-03 (1.10E+08)	3.80E-03 (1.41E+08)	1.42E-03 (5.25E+07)	3.06E-03 (1.13E+08)	2.32E-02 (8.57E+08)
I-135	None Detected	None Detected	None Detected	None Detected	3.87E-03 (1.43E+08)
Xe-131 m	1.00E-01 (3.71E+09)	9.53E-01 (3.53E+10)	8.35E-01 (3.09E+10)	6.57E-01 (2.43E+10)	1.51E+01 (5.60E+11)
Xe-133 m	2.84E-01 (1.05E+10)	1.83E+00 (6.78E+10)	1.75E+00 (6.49E+10)	6.11E-01 (2.26E+10)	6.49E+00 (2.40E+11)
Xe-133	6.03E+01 (2.23E+12)	1.12E+02 (4.15E+12)	1.22E+02 (4.52E+12)	1.55E+02 (5.72E+12)	2.58E+02 (9.53E+12)
Xe-135 m	6.12E-04 (2.26E+07)	5.29E-03 (1.96E+08)	1.29E-04 (4.77E+06)	None Detected	None Detected
Xe-135	2.75E+00 (1.02E+11)	5.77E+00 (2.13E+11)	9.23E+00 (3.41E+11)	1.29E+01 (4.77E+11)	2.67E+01 (9.87E+11)
Xe-138	1.34E-04 (4.96E+06)	3.71E-04 (1.37E+07)	7.15E-09 (2.64E+02)	None Detected	None Detected

Table 12.3-8— {Historical Liquid Releases 2001 through 2006}
(Page 1 of 2)

Isotope	Release Ci (Bq)					
	2001	2002	2003	2004	2005	2006
Ag-110M	3.45E-02 (1.28E+09)	2.03E-02 (7.49E+08)	2.22E-03 (8.22E+07)	2.65E-04 (9.81E+06)	9.78E-06 (3.62E+05)	1.77E-04 (6.55E+06)
Ba-140	None Detected	2.88E-05 (1.07E+06)	None Detected	None Detected	None Detected	None Detected
Be-7	None Detected	3.94E-04 (1.46E+07)	None Detected	None Detected	None Detected	None Detected
Ce-144	1.19E-03 (4.40E+07)	None Detected	2.25E-04 (8.33E+06)	None Detected	None Detected	None Detected
Co-57	1.19E-03 (4.39E+07)	3.50E-04 (1.30E+07)	7.61E-05 (2.82E+06)	1.62E-05 (5.99E+05)	1.39E-06 (5.14E+04)	1.79E-05 (6.64E+05)
Co-58	3.04E-01 (1.13E+10)	4.29E-02 (1.59E+09)	1.44E-02 (5.33E+08)	5.90E-03 (2.18E+08)	2.39E-03 (8.85E+07)	3.23E-03 (1.19E+08)
Co-60	1.95E-02 (7.22E+08)	1.94E-02 (7.19E+08)	3.64E-03 (1.34E+08)	1.77E-03 (6.53E+07)	5.94E-04 (2.20E+07)	1.43E-03 (5.31E+07)
Cr-51	5.64E-02 (2.09E+09)	1.09E-02 (4.03E+08)	1.54E-03 (5.71E+07)	6.88E-04 (2.55E+07)	3.89E-04 (1.44E+07)	5.01E-04 (1.85E+07)
Cs-134	3.30E-03 (1.22E+08)	2.35E-04 (8.68E+06)	7.95E-05 (2.94E+06)	2.78E-04 (1.03E+07)	7.55E-05 (2.79E+06)	4.48E-04 (1.66E+07)
Cs-136	None Detected	None Detected	None Detected	None Detected	None Detected	1.09E-05 (4.03E+05)
Cs-137	9.39E-03 (3.48E+08)	4.44E-04 (1.64E+07)	3.17E-04 (1.17E+07)	7.34E-04 (2.71E+07)	1.32E-04 (4.89E+06)	5.60E-04 (2.07E+07)
Eu-154	6.99E-04 (2.59E+07)	3.32E-04 (1.23E+07)	2.03E-04 (7.51E+06)	None Detected	None Detected	None Detected
Eu-155	2.23E-04 (8.25E+06)	3.63E-04 (1.34E+07)	1.47E-04 (5.44E+06)	None Detected	None Detected	None Detected
Fe-55	1.07E-01 (3.96E+09)	1.19E-01 (4.41E+09)	2.71E-02 (1.00E+09)	1.51E-02 (5.59E+08)	8.67E-02 (3.21E+09)	2.27E-02 (8.39E+08)
Fe-59	5.02E-03 (1.86E+08)	2.25E-03 (8.33E+07)	5.80E-05 (2.14E+06)	5.35E-06 (1.98E+05)	1.66E-05 (6.13E+05)	5.15E-05 (1.90E+06)
I -131	1.42E-03 (5.26E+07)	3.51E-04 (1.30E+07)	6.04E-04 (2.24E+07)	2.93E-04 (1.08E+07)	1.58E-04 (5.86E+06)	4.10E-03 (1.52E+08)
I -132	None Detected	2.40E-04 (8.88E+06)	None Detected	None Detected	None Detected	None Detected
I -133	8.97E-05 (3.32E+06)	4.95E-05 (1.83E+06)	1.57E-05 (5.80E+05)	3.55E-05 (1.31E+06)	1.59E-05 (5.86E+05)	8.91E-05 (1.90E+06)
La-140	None Detected	9.69E-05 (3.59E+06)	None Detected	None Detected	None Detected	None Detected
Mn-54	5.75E-03 (2.13E+08)	4.66E-03 (1.72E+08)	7.45E-04 (2.76E+07)	1.81E-04 (6.68E+06)	4.11E-05 (1.52E+06)	2.21E-04 (8.18E+06)
Na-24	4.66E-03 (1.72E+08)	None Detected	2.49E-06 (9.21E+04)	None Detected	None Detected	None Detected
Nb-95	5.96E-02 (2.20E+09)	2.16E-02 (7.98E+08)	2.65E-03 (9.82E+07)	3.06E-04 (1.13E+07)	1.60E-04 (5.93E+06)	2.89E-04 (1.07E+07)

Table 12.3-8— {Historical Liquid Releases 2001 through 2006}
(Page 2 of 2)

Isotope	Release Ci (Bq)					
	2001	2002	2003	2004	2005	2006
Nb-97	3.54E-05 (1.31E+06)	None Detected	None Detected	None Detected	None Detected	None Detected
Ni-63	None Detected	None Detected	None Detected	2.17E-03 (8.03E+07)	6.16E-03 (2.28E+08)	7.47E-04 (2.76E+07)
Ru-103	5.42E-04 (2.01E+07)	7.10E-05 (2.63E+06)	None Detected	None Detected	None Detected	None Detected
Sb-124	3.42E-03 (1.26E+08)	6.43E-05 (2.38E+06)	5.50E-04 (2.04E+07)	None Detected	None Detected	None Detected
Sb-125	2.15E-02 (7.96E+08)	1.70E-02 (6.30E+08)	8.85E-03 (3.27E+08)	1.44E-04 (5.33E+06)	8.57E-06 (3.17E+05)	6.83E-05 (2.53E+06)
Sn-113	5.45E-03 (2.02E+08)	2.18E-03 (8.06E+07)	5.27E-05 (1.95E+06)	None Detected	None Detected	None Detected
Sn-117M	3.77E-04 (1.40E+07)	3.86E-04 (1.43E+07)	1.08E-03 (3.98E+07)	3.20E-05 (1.18E+06)	1.28E-04 (4.74E+06)	None Detected
Sr-89	7.63E-04 (2.82E+07)	9.51E-06 (3.52E+05)	4.84E-04 (1.79E+07)	None Detected	3.83E-04 (1.42E+07)	None Detected
Sr-90	2.12E-05 (7.84E+05)	None Detected	1.89E-06 (7.00E+04)	None Detected	None Detected	None Detected
Te-125M	None Detected	None Detected	None Detected	None Detected	1.27E-02 (4.70E+08)	1.38E-02 (5.11E+08)
Te-132	None Detected	1.44E-04 (5.33E+06)	None Detected	None Detected	None Detected	None Detected
W -187	None Detected	7.15E-06 (2.65E+05)	None Detected	None Detected	None Detected	None Detected
Zn-65	1.54E-06 (5.70E+04)	None Detected	None Detected	None Detected	None Detected	None Detected
Zr-95	3.59E-02 (1.33E+09)	1.12E-02 (4.15E+08)	1.46E-03 (5.41E+07)	1.59E-04 (5.88E+06)	1.17E-04 (4.34E+06)	1.58E-04 (5.84E+06)
Zr-97	5.61E-05 (2.08E+06)	None Detected	None Detected	None Detected	None Detected	None Detected
Total	6.82E-01 (2.52E+10)	2.75E-01 (1.02E+10)	6.65E-02 (2.46E+09)	2.81E-02 (1.04E+09)	1.10E-01 (4.08E+09)	4.86E-02 (1.80E+09)
Dilution Flow ft^3/sec (L/sec)	3,705.3 (104,922)	2,738.4 (77,543)	4,924.0 (139,431)	5,147.8 (145,769)	5147.8 (145,769)	5003.4 (141,681)

Table 12.3-9— {Projected Dose Rates from all Sources by Construction Zone}

Maximum Construction Zone Dose Rates (mrem/year) Assuming 2,200 Hours Per Year Occupancy			
Zone	Zone Description	Dose Rate mrem/2200 hours (mSv/2200 hours)	Effluents Only mrem/2200 hours (mSv/2200 hours)
B	Batch Plant	0.02 (0.0002)	0.01 (0.0001)
C	Construction on main structures	1.35 (0.0135)	0.08 (0.0008)
L	Laydown/Spoils	21.67 (0.2167)	0.12 (0.0012)
O	Office/Trailer	2.42 (0.0242)	0.03 (0.0003)
P	Parking	19.65 (0.1965)	0.04 (0.0004)
R	Roads	38.89 (0.3889)	0.13 (0.0013)
S	Shoreline, tunnel, barge, in/out flow	0.47 (0.0047)	0.47 (0.0047)
T	Tower/Basin/Desalinization	0.02 (0.0002)	0.01 (0.0001)
W	Warehouse	0.65 (0.0065)	0.03 (0.0003)
	Maximum, not roads	21.67 (0.2167)	0.47 (0.0047)
	Maximum, all zones	38.89 (0.3889)	0.47 (0.0047)

Note: The 39 mrem assumes worker occupancy of 2200 hours per year on the highest dose location on the road, converted assuming 8760 hours per year. The ALARA program will prevent this. In fact, workers will spend very little time at that location. Occupancy is expected to be 2%, or 44 hours per year at any road location. Taking credit for 2% occupancy the road dose drops to 0.78 mrem. This and all other doses meet the criterion.

Table 12.3-10— {Projected Construction Worker Census 2010 to 2015}

Year	Construction Workers on Site
2010	531
2011	2,281
2012	4,000
2013	4,000
2014	4,000
2015	3,215

Table 12.3-11— {Projected Construction Worker Occupancy by Zone}

Zone Description	Zone Code	Occupancy Fraction
Batch Plant	B	0.001
Construction on Main Structures	C	0.665
Laydown/Spoils	L	0.020
Office/Trailer	O	0.160
Parking	P	0.020
Roads	R	0.020
Shoreline, Tunnel, Barge, In/Out Flow	S	0.066
Tower/Basin/Desalinization	T	0.066
Warehouse	W	0.003
	Total	1.021

Note: Total of occupancy fractions is greater than 1 because the "Laydown/Spoils" zone fraction was conservatively increased to match the occupancy fraction for parking and roads.

Table 12.3-12— {FTE for CCNPP Unit 3 Construction Workers}

	FTE (Number of Workers by Zone)						
Zone	**Count**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
B	41	0.5	2.3	4.0	4.0	4.0	3.2
C	232	353.1	1516.9	2660.0	2660.0	2660.0	2138.0
L	451	10.6	45.6	80.0	80.0	80.0	64.3
O	87	85.0	365.0	640.0	640.0	640.0	514.4
P	172	10.6	45.6	80.0	80.0	80.0	64.3
R	170	10.6	45.6	80.0	80.0	80.0	64.3
S	69	35.0	150.5	264.0	264.0	264.0	212.2
T	65	35.0	150.5	264.0	264.0	264.0	212.2
W	38	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**

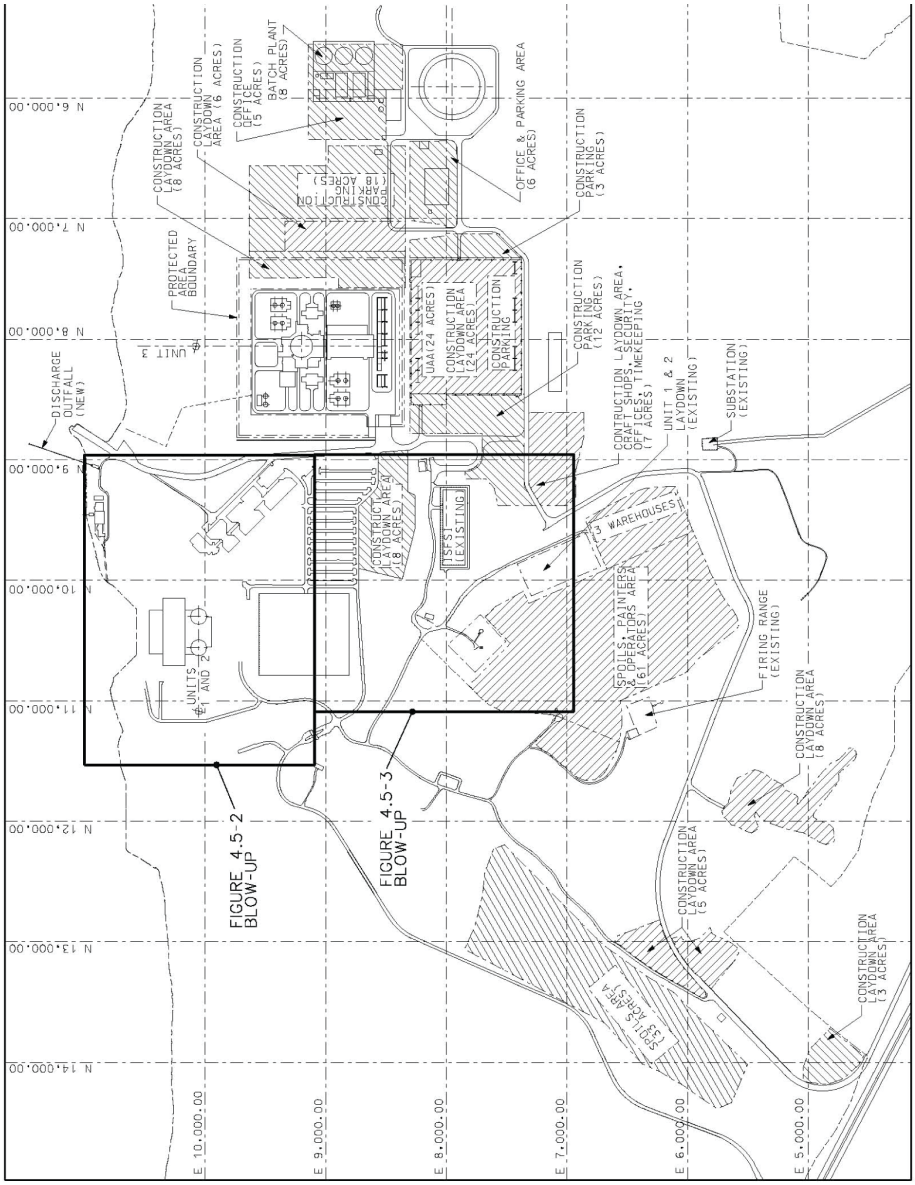
Table 12.3-13— {Average Dose Rates to CCNPP Unit 3 Construction Workers}

Average Dose Rate (mrem/year (mSv/year)) by Zone							
Zone	Count	2010	2011	2012	2013	2014	2015
B	41	0.054 (0.00054)	0.054 (0.00054)	0.054 (0.00054)	0.054 (0.00054)	0.054 (0.00054)	0.054 (0.00054)
C	232	0.493 (0.00493)	0.523 (0.00523)	0.553 (0.00553)	0.582 (0.00582)	0.612 (0.00612)	0.642 (0.00642)
L	451	3.218 (0.03218)	3.311 (0.03311)	3.404 (0.03404)	3.496 (0.03496)	3.589 (0.03589)	3.682 (0.03682)
O	87	1.059 (0.01059)	1.128 (0.01128)	1.196 (0.01196)	1.264 (0.01264)	1.332 (0.01332)	1.400 (0.01400)
P	172	2.383 (0.02383)	2.632 (0.02632)	2.881 (0.02881)	3.130 (0.03130)	3.379 (0.03379)	3.628 (0.03628)
R	170	10.757 (0.10757)	11.262 (0.11262)	11.767 (0.11767)	12.273 (0.12273)	12.778 (0.12778)	13.283 (0.13283)
S	69	0.731 (0.00731)	0.732 (0.00732)	0.732 (0.00732)	0.732 (0.00732)	0.732 (0.00732)	0.733 (0.00733)
T	65	0.054 (0.00054)	0.054 (0.00054)	0.054 (0.00054)	0.054 (0.00054)	0.055 (0.00055)	0.055 (0.00055)
W	38	0.929 (0.00929)	0.952 (0.00952)	0.975 (0.00975)	0.999 (0.00999)	1.022 (0.01022)	1.045 (0.01045)

Table 12.3-14— {Projected Collective Dose for Construction Worker by Zone}

Collective Dose (person-rem) (person-sievert) by Zone								
Zone	**Zone Description**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**By Zone**
B	Batch Plant	0.0000 (0.0000)	0.0000 (0.0000)	0.0001 (0.000001)	0.0001 (0.000001)	0.0001 (0.000001)	0.0000 (0.0000)	0.0002 (0.000002)
C	Construction on main structures	0.0437 (0.000437)	0.1992 (0.001992)	0.3691 (0.003691)	0.3889 (0.003889)	0.4087 (0.004087)	0.3445 (0.003445)	1.7541 (0.017541)
L	Laydown/ Spoils	0.0086 (0.000086)	0.0379 (0.000379)	0.0684 (0.000684)	0.0702 (0.000702)	0.0721 (0.000721)	0.0595 (0.000595)	0.3167 (0.003167)
O	Office/ Trailer	0.0226 (0.000226)	0.1033 (0.001033)	0.1922 (0.001922)	0.2031 (0.002031)	0.2141 (0.002141)	0.1809 (0.001809)	0.9162 (0.009162)
P	Parking	0.0064 (0.000064)	0.0302 (0.000302)	0.0579 (0.000579)	0.0629 (0.000629)	0.0679 (0.000679)	0.0586 (0.000586)	0.2837 (0.002837)
R	Roads	0.0287 (0.000287)	0.1290 (0.001290)	0.2364 (0.002364)	0.2466 (0.002466)	0.2567 (0.002567)	0.2145 (0.002145)	1.1119 (0.011119)
S	Shoreline, tunnel, barge, in/ out flow	0.0064 (0.000064)	0.0277 (0.000277)	0.0485 (0.000485)	0.0485 (0.000485)	0.0486 (0.000486)	0.0390 (0.000390)	0.2188 (0.002188)
T	Tower/ Basin/ Desalinization	0.0005 (0.000005)	0.0021 (0.000021)	0.0036 (0.000036)	0.0036 (0.000036)	0.0036 (0.000036)	0.0029 (0.000029)	0.0163 (0.000163)
W	Warehouse	0.0004 (0.000004)	0.0016 (0.000016)	0.0029 (0.000029)	0.0030 (0.000030)	0.0031 (0.000031)	0.0025 (0.000025)	0.0136 (0.000136)
	By YEAR	0.1173 (0.001173)	0.5310 (0.005310)	0.9791 (0.009791)	1.0270 (0.010270)	1.0749 (0.010749)	0.9024 (0.009024)	**4.6316** (0.046316)

Figure 12.3-1— {Site Layout of CCNPP Units 1, 2, and 3}



See Figure 1.1-3 and Figure 1.2-1 for Site and Powerblock layout

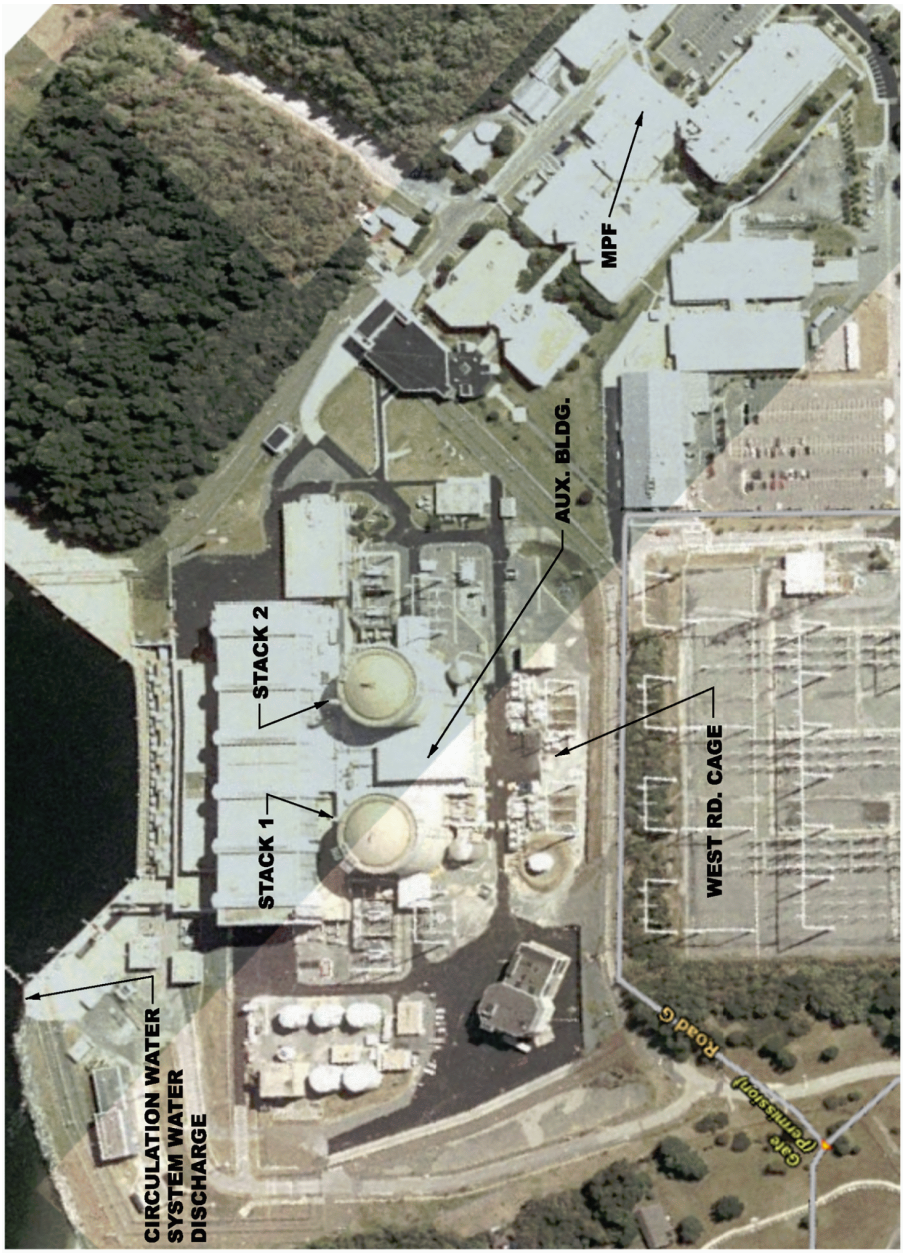


Figure 12.3-2— {Sources on CCNPP Units 1 and 2 (Part 1 and 2)}

Figure 12.3-3— {Sources on CCNPP Units 1 and 2 (Part 2 of 2)}

Figure 12.3-4— {Historical ISFSI 2005 TLD Doses Versus Distance}

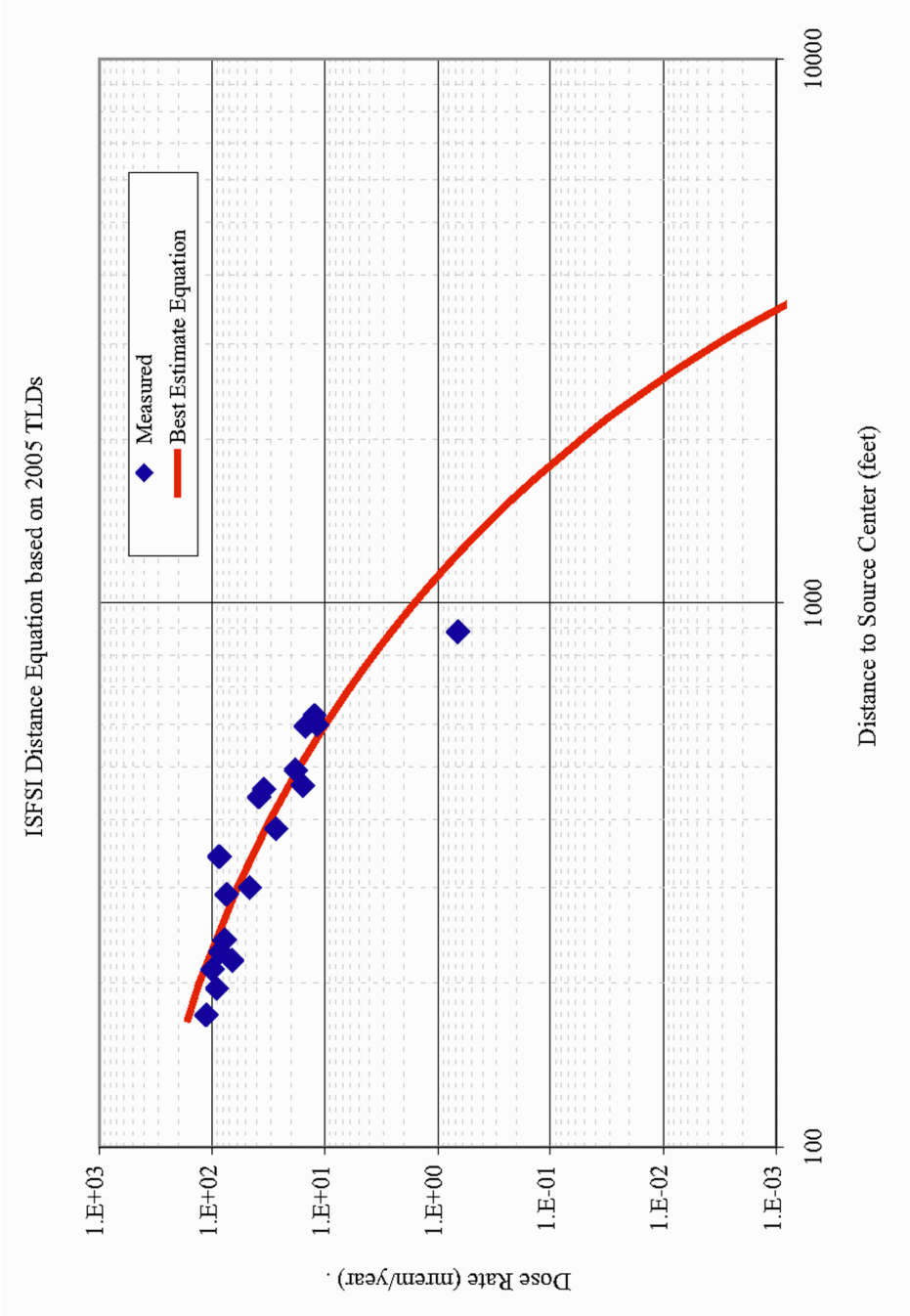


Figure 12.3-5— {Resin Area and ISFSI Historical TLD Readings}

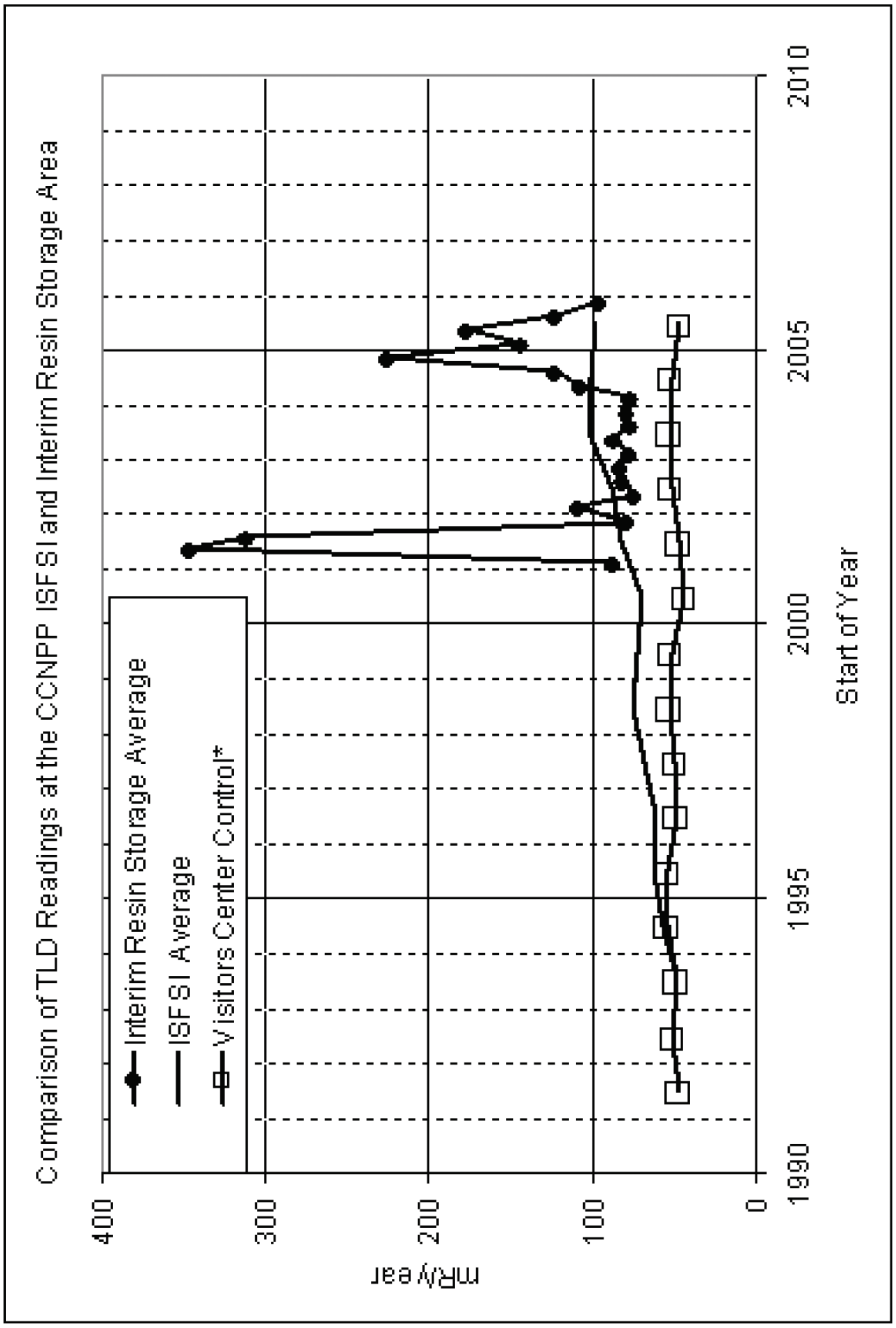
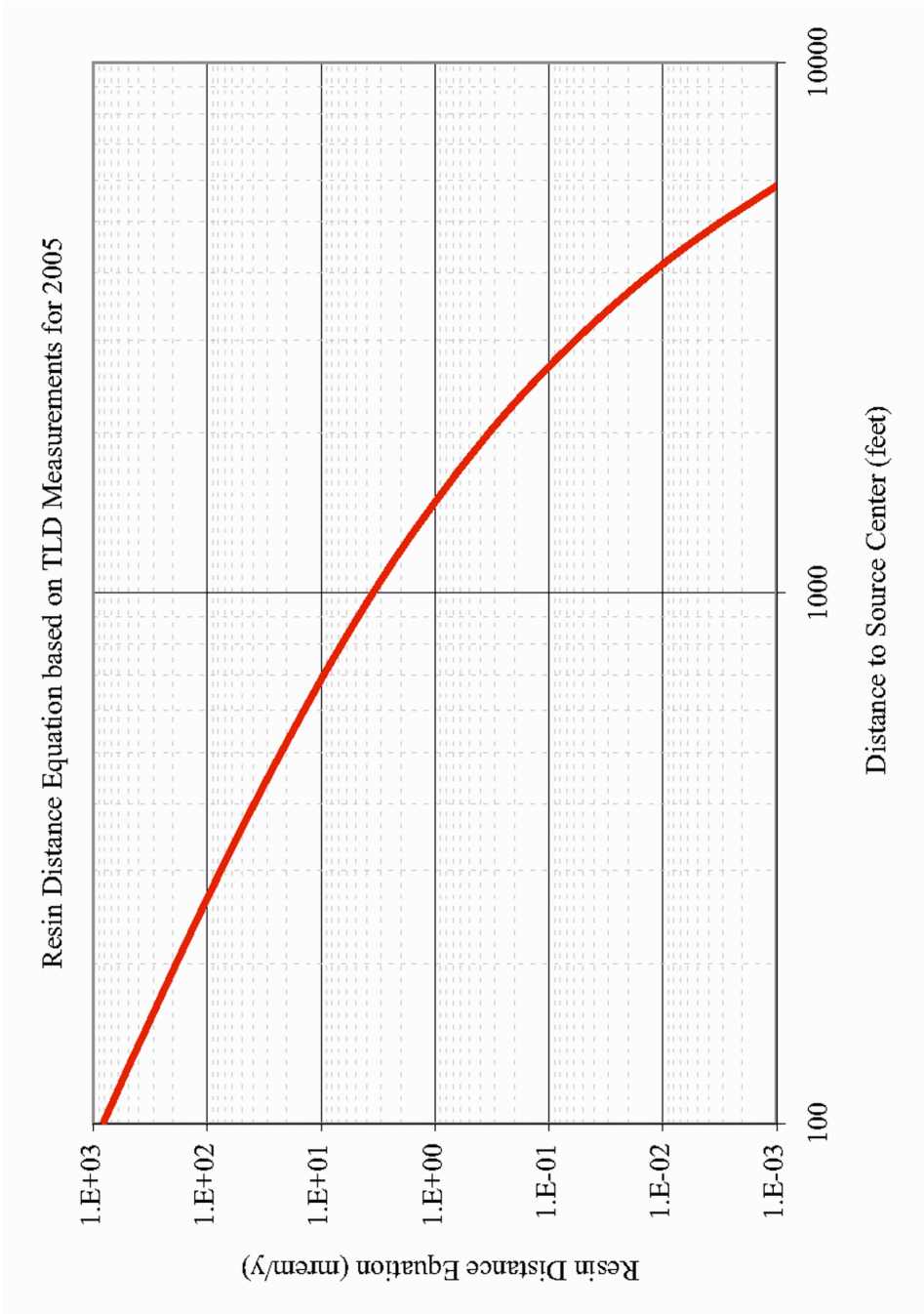


Figure 12.3-6— {Resin Area Dose Rate for 2005}



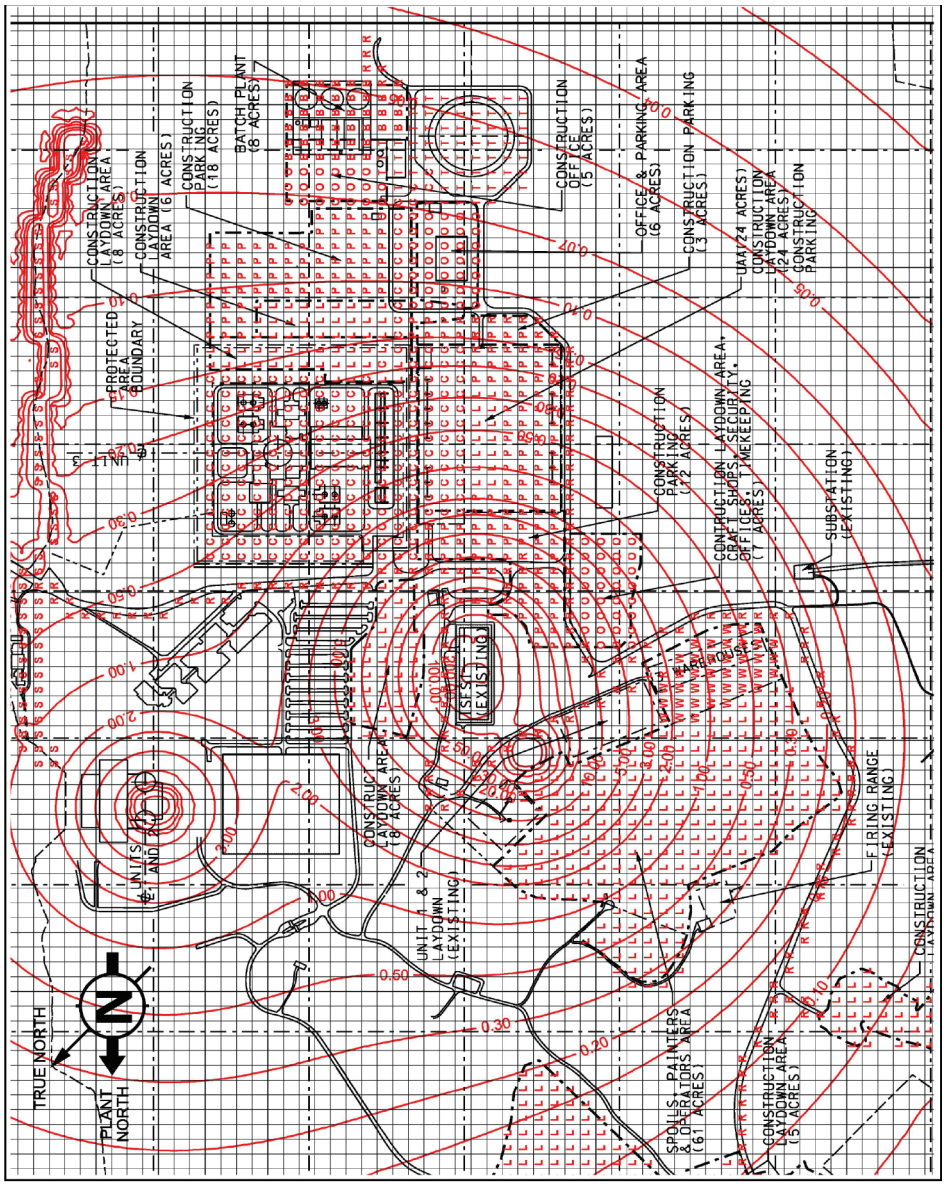


Figure 12.3-7— {Dose Rate Estimated in 2015}

Note 1 - The plant grid on this figure is shown in 100-foot by 100-foot squares.

Note 2 - The following provides a key to the zones indicated in the figure.

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

Note 3 - See Figure 1.1-3 and Figure 1.2-1 for Site and Powerblock layout

Figure 12.3-8— {Bounding Annual Average X/Q in CCNPP Unit 3 Direction}

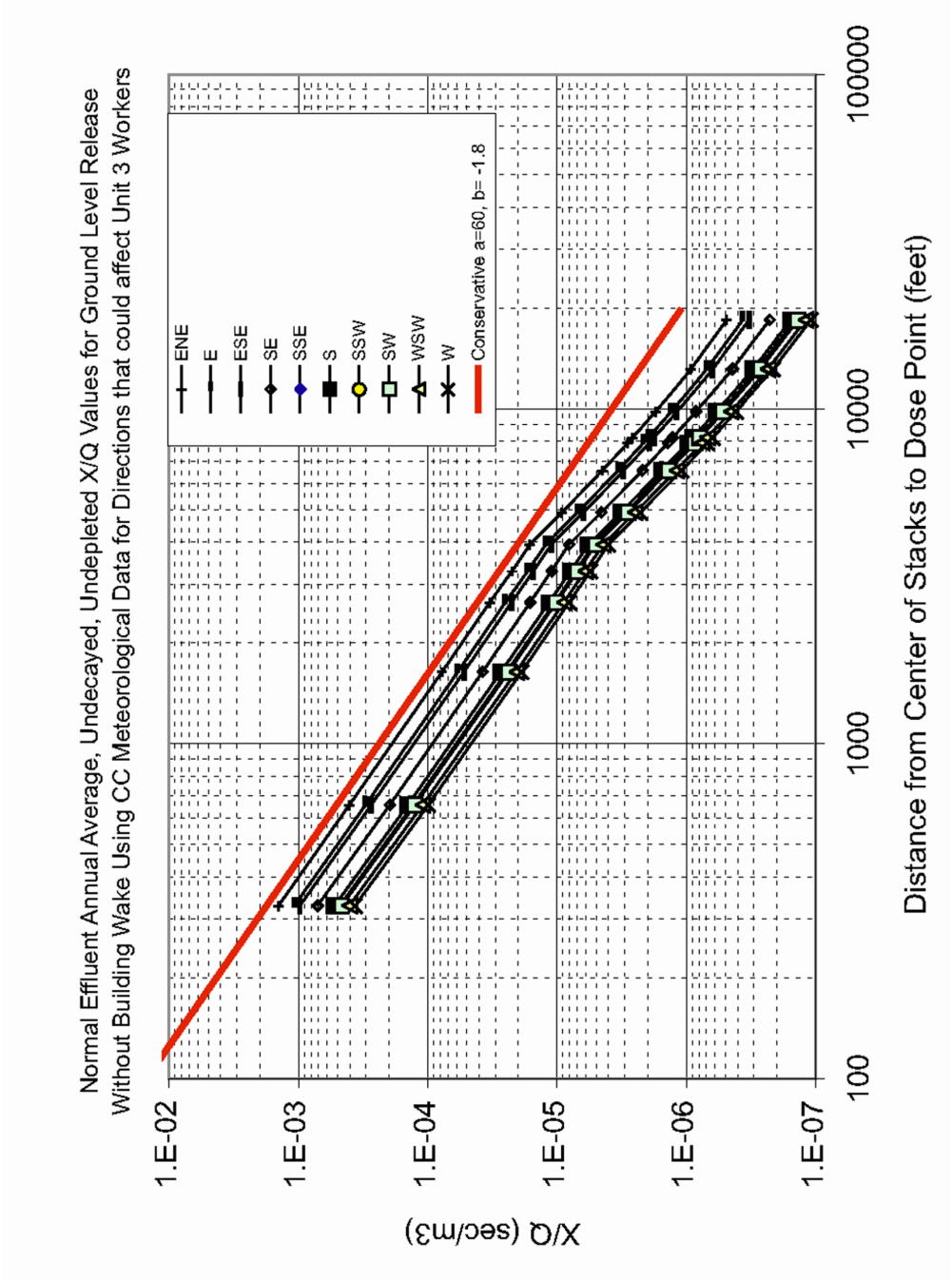
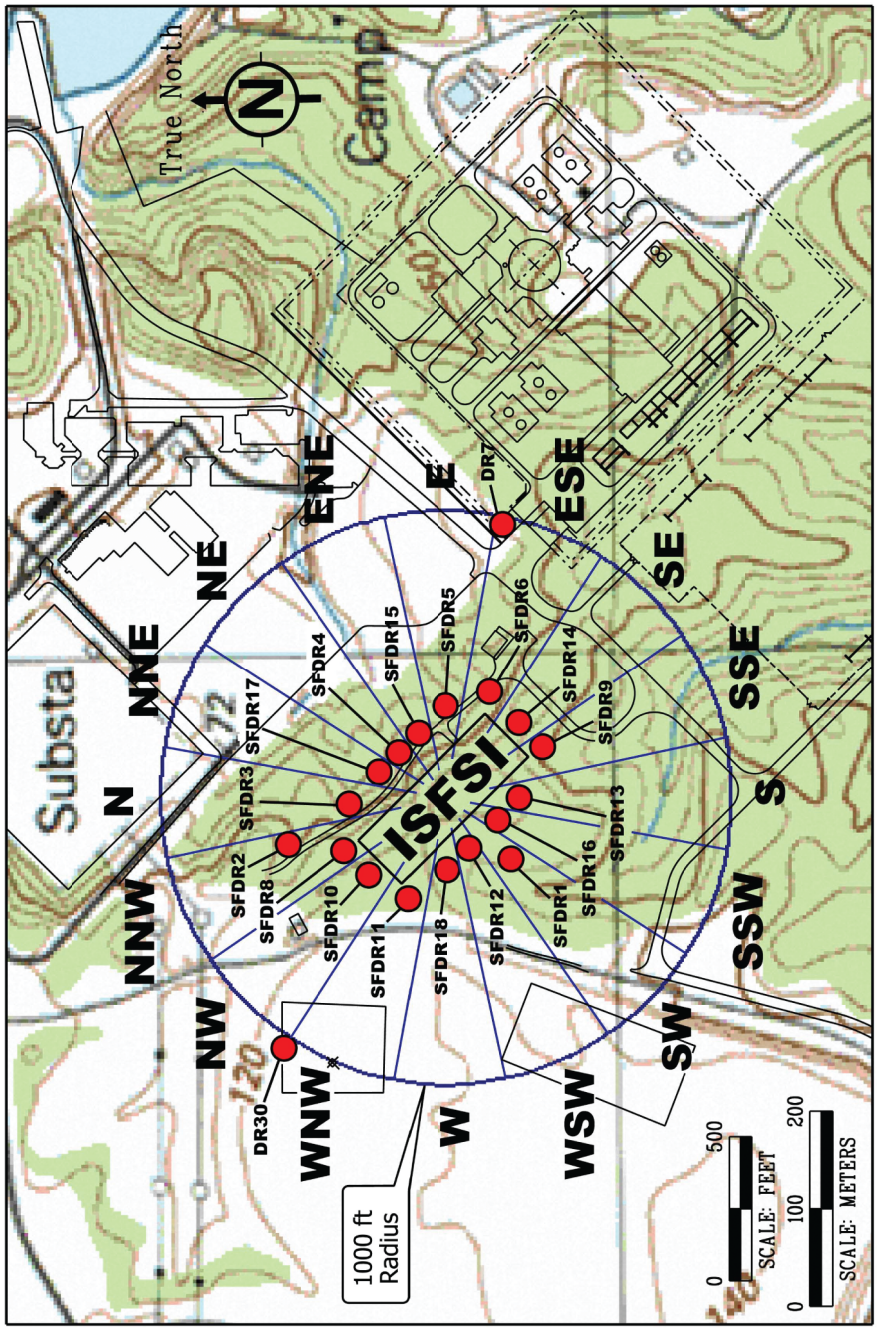
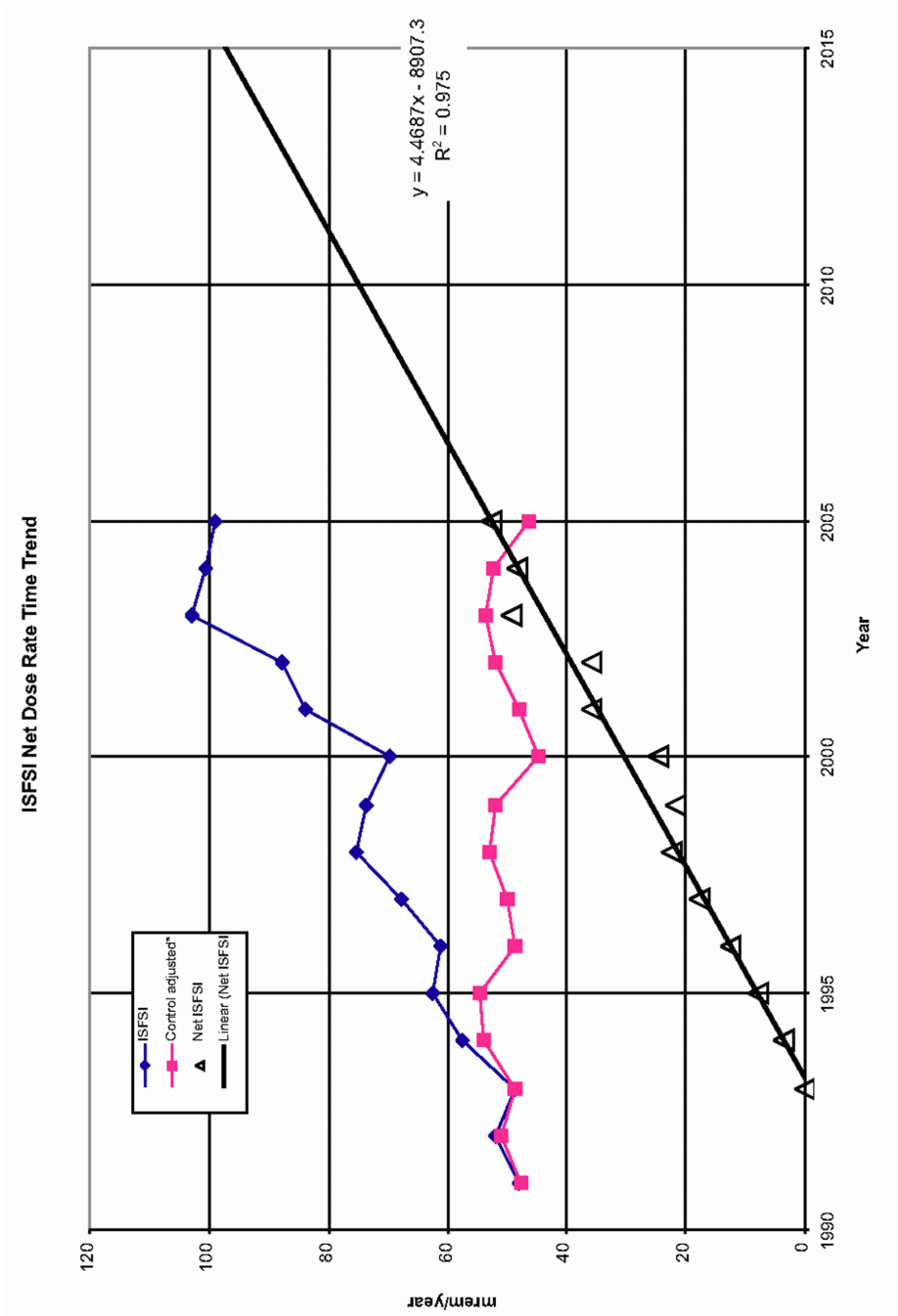


Figure 12.3-9— {SFSI TLD Locations}



See Figure 1.1-3 and Figure 1.2-1 for Site and Powerblock layout

Figure 12.3-10— {Annual Gamma Net ISFSI Dose Rate}



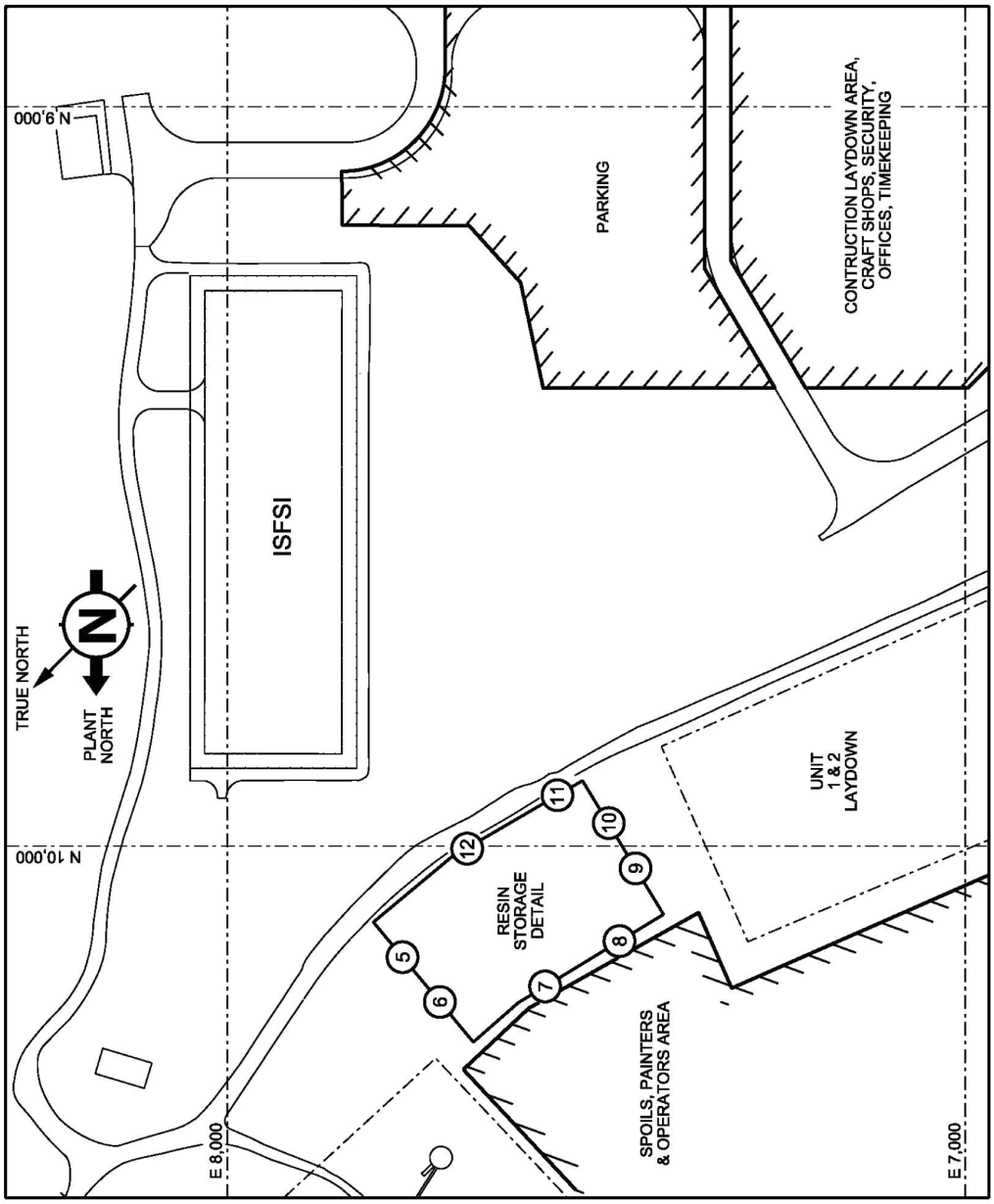


Figure 12.3-11— {Resin Area TLD Locations}

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 07-03A 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 07-03A 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, Revision 0, Nuclear Energy Institute, May 2009.}