**NRC RAI Letter No. PTN-RAI-LTR-072 Dated February 20, 2013**

**SRP Section: 11.02 – Liquid Waste Management System**

**Supplemental Staff RAI to RAI 11.02-1, 11.02-2, 11.02-3, and 11.02-4.**

**NRC RAI Number: 11.02-6 (eRAI 6985)**

**Background**

In FSAR Rev. 4, Section 11.2.3.5, PTN COL 11.2-2, the applicant proposes a disposal method for liquid radioactive effluents using deep well injection into the Boulder Zone. When compared to routine effluent discharges in surface waters, the radioactivity injected in the Boulder Zone is expected to be isolated from the surface environment and out of reach of traditional radiation exposure scenarios and pathways considered by NRC regulations and guidance. Traditional effluent discharge methods dilute and disperse the radioactivity in the environment, but this disposal method confines the radioactivity into a slow moving and expanding plume with the total inventory of long-lived radionuclides increasing over the operating life of the plant. As a result, radiological assessment methods and assumed exposure scenarios used to quantify radiological impacts and compliance with NRC regulations for effluents discharged in surface water bodies are not directly applicable.

The deep well injection method involves technical and regulatory considerations that are not explicitly addressed under 10 CFR 50.34a, and 50.36a, and 10 CFR Part 50, Appendix I design objectives and ALARA provisions in controlling radioactive effluent releases. Similarly, the requirements of 10 CFR 20.1301 and 20.1302 and 40 CFR Part 190 [under Part 20.1301(e)] in complying with effluent concentration limits and doses to members of the public also do not explicitly address deep well injection. However, the applicant must still meet applicable requirements under these regulations in applying the deep well injection method for waste disposal.

Accordingly, the applicant has performed and provided an analysis in its current application under the provisions of 10 CFR 20.2002, "Method for obtaining approval of proposed disposal procedures." However, the results are presented in a manner that excludes a demonstration of compliance with some NRC requirements and associated guidance on the assumption that the discharge method offers complete isolation of the radioactivity with no radiation exposures to the public. The applicant has not included information sufficient to determine if it meets the requirements of 10 CFR 20.1301, 10 CFR 20.1302, and 10 CFR 20.1406; and numerical guides, design objectives, and ALARA provisions of 10 CFR Part 50, Appendix I for liquid effluents.

10 CFR 20.2002 provides an applicant with a method to obtain approval for proposed procedures, not otherwise authorized in the regulations, for disposal of licensed material generated in the licensee's activities. Under 10 CFR Part 20.2002, an applicant has to provide (a) a description of the waste, including the chemical and physical properties important to risk evaluation and the proposed manner and conditions of disposal; (b) an analysis of the environment in which wastes will be disposed; (c) the nature and location of other potentially affected licensed and unlicensed facilities; and (d) analyses and procedures to ensure that doses are maintained ALARA and within the dose limits of 10 CFR Part 20. The NRC typically approves Part 20.2002 requests that will result in a dose to a member of the public (including all exposure groups) that is no more than "a few millirem/year" (see SECY-07-0060, Attachment 1, and NUREG-1757, Vol. 1, Rev. 2, Section 15.12). As is noted in the SECY paper, the NRC selected this criterion because it is a fraction of the dose associated with naturally occurring background radiation, a fraction of the annual public dose limit, and an attainable objective in the majority of cases.

In this context, the staff considers its well-established Part 50 light-water-reactor criteria (including those prescribed by Appendix I) in determining whether all releases of radioactive material to the environment are ALARA and what monitoring, design criteria, and other conditions apply. As a result, the staff's evaluation of this disposal method under Part 20.2002 does not preclude the staff from considering the substantial technical requirements, design criteria, technical specifications, monitoring, and annual reporting called for by other provisions of Part 20 and Part 50.

Moreover, the staff notes that there is a need to ensure that NRC and Florida Department of Environmental Protection (FLDEP) requirements, when issued, are not conflicting and do not impose duplicative requirements, such as for radiological monitoring, periodic inspections and testing in confirming the mechanical integrity of the injection and monitoring wells, and requirements for well abandonment and closure at the end of their operational cycles or in the event of well failures and migration of radioactive materials in Upper Floridan aquifers.

As a result, there are a number of issues that the staff needs to consider in bridging and integrating these regulatory requirements and NRC acceptance criteria. The issues involve the resolution of geo-hydrological characteristics of the Boulder Zone; use of information described in the construction and testing of the first exploratory and monitoring wells (see FPL reports of Sept. 2012); development of an appropriate radioactive source term confined within an amorphous plume; development of an approach and method for modeling potential exposure scenarios that consider well failures and intrusion scenarios as expected operational occurrences using current land-use practices for this part of Florida; identification of surrogate criteria in achieving the same regulatory objectives since some of current regulatory requirements do not apply to this disposal method; identification of FLDEP permit conditions that would fulfill or supplement NRC requirements on installation, testing, operation, and environmental monitoring; and insertion of specific license conditions on the design features of injection and monitoring wells whose construction would not be completed before the issuance of the combined license.

**RAI Questions on Proposed Deep Well Injection Disposal Method**

The information provided in FSAR Rev. 4, Sections 9.2, 10.4.5, and 11.2 and responses to staff RAIs presented in FPL correspondence (May 22, 2012 and July 13, 2012) are not sufficient for the staff to validate and verify the estimated doses of the assumed exposure doses in the FSAR are bounding and acceptable. Without this information, the staff is unable to make a determination that the applicant meets the acceptance criteria in SRP 11.2 and complies with the requirements of 10 CFR 20.2002, 20.1301, 20.1302, and 20.1406, and 10 CFR Part 50, Appendix I numerical guides, design objectives, and ALARA provisions. This supplemental RAI on the proposed deep well injection method consolidates and subsumes the issues identified in prior staff RAIs. As a result, the following RAIs are closed: RAI 11.02-1, 11.02-2, 11.02-3, and 11.02-4.

1. The proposed discharge method for the disposal of treated liquid radioactive waste by injection into the Boulder Zone (about 2800 to 3500 feet below grade) represents a waste management approach that is not practiced by any other nuclear power plant in the U.S. While deep well injection provides the means to isolate liquid radioactive waste over the long-term, complete isolation is not assured because of the potential for human intrusion via drilling into the Boulder Zone, and unknown hydraulic connections between the Lower and Upper Floridan aquifers through the middle confining unit. Thus, the applicant is requested to consider radiological impacts of the disposal method should radioactivity be brought up to the surface by (1) drilling activities undertaken at a location beyond the control of the applicant (licensee) and expose well drillers to radioactive materials, (2) failure of a well casing or packing that could contaminate the Upper Floridan Aquifer and expose water users to radioactive materials, and (3) upward migration of the injectate from the Boulder Zone into the base of the Upper Floridan Aquifer and expose water users to radioactive materials. Based on a review of the literature, the staff notes that there have been instances where contaminants have migrated upward out of the Boulder Zone. In some studies, this was not attributed to improper well construction. As is noted in FSAR Rev. 4, Section 2.4.12.2.1.2 and Figure 2.4.12-214 and in the FPL report on the construction of the dual-zone monitoring well,

the Upper Floridan Aquifer has been designated as an underground source of drinking water (USDW).

2. In assessing radiological impacts, the applicant is requested to address the following exposure scenarios and pathways in bracketing the range of events and doses to members of the public that could result if exposed to the injectate. The scenarios assume that these events would take place offsite with the applicant (licensee) not being aware of these events during plant operation. The scenarios may include, but are not limited to the following:

    i. a drilling scenario, taking place offsite, involving contaminated drilling mud and cuttings being brought to the surface and exposing workers during drilling activities and nearby members of the public.
    ii. the failure of injection well packings and joints after closure and abandonment, with the assumption that the failed wells become conduits connecting the radioactive plume within the Boulder Zone to the Upper Floridan aquifer from which contaminated water would be used at the surface. Some reported uses of water include landscaping and nursery irrigation, agriculture, aquaculture, and industrial applications. The applicant should present a detailed analysis of potential exposure pathways and doses from this scenario and describe all supporting assumptions. The applicant should discuss the effects and expiration of institutional controls, if any, on deep well injection activities and use of the land and groundwater in the vicinity of the plant site.
    iii. a U-tube scenario where offsite well drilling activities and differential pressures associated with injection would result in the radioactive plume, within the Boulder Zone, being hydraulically pushed into the Upper Floridan aquifer. The analysis should consider the potential migration of fluids and radioactivity through offsite wells or formation/fissures, and well penetrations to USDW as well as natural migration into overlying aquifers.
    iv. Alternatively, the applicant could develop a single bounding scenario (from the above scenarios or equivalent variations of these scenarios) in defining and characterizing types of activities or natural processes leading to radiation exposures, and assumed exposure pathways and potential doses to offsite drilling crew workers and members of the public. Should this alternative be selected, the applicant is requested to provide the appropriate justification and supporting information in identifying such a bounding scenario for the staff to conduct an independent evaluation of

the applicant's approach and results in concluding that regulatory requirements have been met.

3. In developing the radioactive source terms for any of the above scenarios, the applicant is requested to consider the cumulative inventories of long-lived radionuclides expected to be present after 40 years of operations for both reactor units. The applicant should present a detailed analysis, identify long-lived radionuclides of importance to dose modeling, describe the physical and chemical properties important to the dose assessment, and describe the expected behavior of each radionuclide in the Boulder Zone based, in part, on their deposition and adsorption characteristics if assumed. This analysis should include the accumulation, radial distribution, and movement of radioactivity within and out of the Boulder Zone. Sources of radioactivity include long-lived radionuclides, such as H-3, C-14, Sr-90, Tc-99, I-129, and Cs- 137, among others, and transuranics. The analysis should provide radionuclide specific estimates of their concentrations in and around the injection point and in radial directions of the plume within the Boulder Zone after 40 years of plant operation. The source term should consider whether the injectate results in a plume (depending on the use of reclaimed municipal waste water or seawater) that is buoyant or readily miscible within the 200-foot thick Boulder Zone formation brine. The applicant should consider geochemical effects associated radionuclide chemical speciation and absorption within the rock formation.
4. In modeling the movement of radioactivity in groundwater, the traditional approach applies distribution coefficients (Kd) and retardation factors. The Kd approach works best for radionuclides that are in contact with very small soil particles, where the Kd lumps the effects of number of complex chemical processes into a single value. However, currently published Kd values used in modeling the movement of radioactivity in groundwater may not apply to this type of environment. The applicant is requested to indicate if in modeling the movement of radioactivity in the Boulder Zone, the evaluation considered the application of retardation factors, and, if so, describe how Kd values were modified and assigned to radionuclides. The applicant is requested to indicate whether the presence of residual concentrations of organic compounds in reclaimed municipal waste water were considered in developing distribution coefficients and retardation factors.

**FPL RESPONSE:**

A performance assessment (PA) was performed to assess the environmental fate and transport of Turkey Point Units 6 & 7 liquid effluent releases by deep well injection. The PA coupled numerical groundwater modeling techniques with a liquid pathway analysis to identify the maximum exposed members of the public (maximally exposed individual – MEI) in unrestricted areas as a result of the Turkey Point Units 6 & 7 liquid effluent releases. The MEI is a hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible radiological dose attributed to each of two postulated deep well injection operation modes (i.e., normal and off-normal) and a third special case, inadvertent intrusion. MEI dose is assigned using Regulatory Guide 1.109 (RG 1.109) dose contribution calculations for the radionuclides retained in the PA; where necessary, independent recognized technical approaches are used to validate RG 1.109 results. The groundwater modeling portion of the PA was conducted independent of RG 1.109 since that NRC guidance solely addresses surface water transport. The regulatory criteria applied in interpreting the MEI dose assignments are the single reactor 10 CFR Part 50, Appendix I, calendar year design objectives: less than or equal to 3 mrem to the total body and less than or equal to 10 mrem to the critical organ. MEI dose assignments attributable to the calendar quarter Appendix I numerical guidance on technical specifications defining limiting conditions for operation are not explored in the PA because this guidance is specifically provided to allow operational flexibility in response to actual, as opposed to estimated, releases from the plant under unusual conditions. Doing so would require unreasonable speculation about in-plant liquid effluent generation or processing upsets.

The response to Questions 1 through 4 is organized as follows:

1. Background-Units 6 & 7 Liquid Effluent Releases
    1.1. Effluent Composition
    1.2. Deep Well Injection System Features
2. Groundwater Modeling [Questions 3 and 4]
    2.1. Radial Transport In the Boulder Zone Model
    2.2. Vertical Transport Model [Questions 1 and 3]
    2.3. Questions 3 and 4 Response Summary
3. Liquid Effluent Pathway Analysis [Questions 1 and 2]

For ease of referenceability, the response is presented in section and subsection levels, with each level designated by outline notation. In the following sections, where a specific portion of the response directly addresses a question, the question number is provided in brackets. At the end of the groundwater modeling discussion, a summary response for Questions 3 and 4 is provided. Similarly, at the end of the liquid pathway analysis discussion, a summary response for Questions 1 and 2 is provided.

## 1. Background-Units 6 & 7 Liquid Effluent Releases

Liquid effluent from Turkey Point Units 6 & 7 operation is released to the highly permeable zone in the Lower Floridan aquifer (known as the Boulder Zone) using the deep well injection system (DIS). A description of the anticipated effluent composition and principal natural subsurface DIS features is provided below.

### 1.1. Effluent Composition

Liquid waste other than radwaste, including wastewater from the main condenser cooling system (blowdown), wastewater retention basin, and sanitary waste treatment system, will be collected in a common blowdown sump and injected to the Boulder Zone using the DIS. The liquid radwaste will be mixed into the blowdown sump pump discharge (ER Figures 3.3-1 and 3.4-1 illustrate liquid stream flow diagrams for Turkey Point Units 6 & 7). The activity concentration of the radwaste portion of the effluent would be controlled to 10 CFR Part 20, Appendix B, effluent concentration limits (ECLs) at the blowdown sump discharge by specifying and maintaining flow rates corresponding to at least the minimum dilution factor (DF). The required minimum DF is calculated and applied prior to the release of liquid radwaste (batch is the only release mode anticipated) to ensure the activity concentration of the mixture complies with 10 CFR Part 20, Appendix B, ECLs. Implementation of the liquid radwaste effluent control program will be in accordance with the Turkey Point Units 6 & 7 Offsite Dose Calculation Manual (ODCM), which will be available for inspection prior to initial fuel load as shown in FSAR Table 13.4-201.

The selected main condenser cooling system makeup water supply (reclaimed water or saltwater) determines the bulk DIS injection flow rate and injectate composition. Specifically, the reclaimed water injectate will be considerably lower in total dissolved solids (TDS) concentration than the saltwater injectate and will be injected at a lower total flow rate because the cycles-of-concentration operational limits are higher. These two main condenser cooling system makeup water supply sources are described below; makeup water composition for each is discussed in ER Sections 3.4 and 3.5.

#### 1.1.1. Reclaimed Water

Reclaimed water provided from the Miami-Dade Water and Sewer Department will be the primary source of makeup water to the circulating water system. As discussed in ER Subsection 3.4.1.1.1, the maximum reclaimed water makeup rate to the circulating water system would be approximately 19,200 gpm per unit. This is based on maintaining four cycles of concentration in the cooling towers. The normal operating blowdown rate to the common blowdown sump at four cycles of concentration would be approximately 4860 gpm per unit, representing the dominant source of discharge to the DIS; other contributors to the effluent stream in the common blowdown sump, in addition to the cooling tower blowdown, are wastewater retention basin effluents and raw water required for liquid radwaste dilution.

#### 1.1.2. Saltwater

Saltwater would be used as makeup from the radial collector wells for the circulating water system when a sufficient quantity and/or quality of reclaimed water is not available. As discussed in ER Subsection 3.4.1.1.1, the maximum saltwater makeup rate to the circulating water system would be approximately 43,200 gpm per unit. This is based on maintaining 1.5 cycles of concentration in the cooling towers. The normal operating blowdown rate to the common blowdown sump for saltwater at 1.5 cycles of concentration would be approximately 28,860 gpm per unit.

### 1.2. Deep Well Injection System Features

#### 1.2.1. Deep Well Injection System Description

As described in FSAR Subsection 9.2.12 and ER Section 3.9, 12 deep injection wells (10 primary and 2 backup) will be installed in the Plant Area to provide a means of disposal of treated wastewater, sanitary waste, blowdown, and treated liquid radioactive waste effluent. The deep injection wells will have a 24-inch diameter final casing with an

18-inch injection tube installed within the final casing and will extend approximately 2900 to 3500 feet below ground surface (bgs).

1.2.2. Subsurface Description

Figure 1 depicts a hydrogeologic cross section showing representative depths and thicknesses of the hydrogeologic units penetrated by the DIS. In order of increasing depth, the hydrogeological units include the following:

- Surficial Aquifer (Biscayne Aquifer)
- Intermediate Confining Unit
- Upper Floridan Aquifer
- Middle Confining Unit (Upper and Lower)
- Lower Floridan Aquifer (Boulder Zone)

A summary description is included in the paragraphs below adapted from FSAR Subsection 2.4.12.

1.2.2.1. Surficial Aquifer (Biscayne Aquifer)

The surficial aquifer system comprises all the rocks and sediments from the land surface downward to the top of the intermediate confining unit. These lithologic materials consist primarily of limestones and sandstones with sands, shells, and clayey sand with minor clays and silts. Site-specific boring data indicate that the maximum thickness of the Biscayne aquifer is approximately 115 feet at the Turkey Point Units 6 & 7 site. Biscayne aquifer groundwater use in the vicinity of the Turkey Point Property Area is limited as the freshwater/saltwater interface within this aquifer is located approximately 6 miles (9.6 kilometers) inland from the Property Area. Regional groundwater flow in the Biscayne aquifer is generally toward the east-southeast, with a hydraulic gradient of approximately 2E-05 ft/ft.

1.2.2.2. Intermediate Confining Unit

The intermediate confining unit (upper confining unit for the Upper Floridan aquifer) extends from the base of the surficial aquifer system to the top of the Floridan aquifer system and is characterized by the complex interbedded lithologies of the Hawthorn Group. These lithologies consist primarily of silty clay, calcareous sands, silts, calcareous wackestones, limestones, sandstones, and sands, and obtain a thickness of approximately 600 to 1050 feet in the vicinity of the Turkey Point Units 6 & 7 site. Site information suggests a thickness of approximately 700 feet just to the north of the Turkey Point Units 6 & 7 site to approximately 1000 feet southwest of the site.

#### 1.2.2.3. Upper Floridan Aquifer

The topmost hydrogeologic unit of the Floridan aquifer system is the Upper Floridan aquifer. This unit is overlain by the surficial aquifer system and the intermediate confining unit, of which the latter acts as a confining layer to the Upper Floridan aquifer. The Upper Floridan aquifer consists of several thin water-bearing zones of high permeability interlayered with thick zones of low permeability. The hydrogeology of the Upper Floridan aquifer varies throughout Florida. In southeastern Florida, the aquifer has been interpreted to include a thinner Suwannee Limestone and extends down into the Avon Park Formation. Confinement between flow zones is typically better in southwestern Florida than in southeastern Florida. In southeastern Florida, estimates of the thickness of the Upper Floridan aquifer vary. Reference 1 suggests a range from 100 to greater than 400 feet in thickness in southern Florida, with a thickness of approximately 200 feet in the immediate vicinity of the Turkey Point Units 6 & 7 site. Reference 2 suggests the Upper Floridan aquifer is 500 to 600 feet thick in the region.

Regional groundwater flow in the Upper Floridan aquifer is generally toward the east. The apparent hydraulic gradient in the vicinity of the Turkey Point Units 6 & 7 site is approximately 6E-05 ft/ft (Reference 3).

The Upper Floridan aquifer is a source of potable groundwater in much of Florida. However, in southeastern Florida the water quality in the Upper Floridan aquifer is brackish and variable.

#### 1.2.2.4. Middle Confining Unit (Upper and Lower)

The middle confining unit of the Floridan aquifer system underlies the Upper Floridan aquifer, separating it from the Lower Floridan aquifer. In many places the middle confining unit is divided into upper and lower units separated by the Avon Park permeable zone. The middle confining unit contains beds of micritic limestone (wackestone to mudstone), dolomitic limestone, and dolomite (dolostone) that are distinctly less permeable than the strata of the Upper and Lower Floridan aquifers. The elevation of the top of the middle confining unit is approximately –1200 feet National Geodetic Vertical Datum of 1929 (NGVD 29), and the thickness is greater than 1000 feet in the vicinity of Turkey Point (Reference 1). At the Turkey Point Units 6 & 7 site, observations from the installation of the Class V exploratory well EW-1 indicate that the lower portion of the middle confining unit has an approximate thickness of 1000 feet, which serves as the primary confinement for the Boulder Zone (Reference 4).

1.2.2.5. Lower Floridan Aquifer (Boulder Zone)

The Lower Floridan aquifer in southern Florida consists of a thick sequence of low permeability rocks separated by relatively thin permeable zones. The aquifer underlies the middle confining unit and extends from a depth of approximately 2400 feet bgs to a depth that is undetermined but thought to be greater than 4000 feet bgs in the Miami-Dade County area. Observations recorded during the construction of the Class V exploratory well EW-1 at the Turkey Point Units 6 & 7 site indicate that the depth to the top of the Lower Floridan aquifer is approximately 2900 feet below pad level (bpl) (Reference 4).

A highly permeable zone in the Lower Floridan aquifer (the Boulder Zone) occurs in southern Florida. Here, the Lower Floridan aquifer contains thick confining units above the Boulder Zone. These confining units are similar in lithology to the middle confining unit of the Floridan aquifer system. Determination of groundwater flow directions and hydraulic heads in the Boulder Zone has been unreliable due to the lack of good head data and the transitory effects of ocean tides, Earth tides, and atmospheric tides.

Based on samples taken during the installation of exploratory well EW-1, the Boulder Zone contains saltwater with an approximate TDS concentration of 36.2 kilograms per cubic meter (Reference 4).

2. Groundwater Modeling [Questions 3 and 4]

To support the evaluation of potential impacts to members of the public and doses to the MEI due to operation of the Turkey Point Units 6 & 7 DIS, the following models were developed:

- Radial Transport in the Boulder Zone Model: a two-dimensional (2D) axisymmetric model created to evaluate injectate migration within the Boulder Zone under the assumption of confined aquifer conditions.
- Vertical Transport Model: a three-dimensional (3D) model created to evaluate vertical migration out of the Boulder Zone due to buoyancy-driven flow under the assumption of leaky confined aquifer conditions.

Each analysis/model is described in detail below and is available in the Turkey Point Units 6 & 7 COLA Online Reference Portal.

2.1. Radial Transport In the Boulder Zone Model

A variable-density numerical groundwater model was developed to evaluate the fate and transport of radionuclides within the Boulder Zone under the assumption of confined conditions, with particular interest in the radial extent of the injectate plume throughout and beyond the operational life of the plant. A variable-density model was selected because density differentials between the injectate (cycled reclaimed water or saltwater) and the in situ groundwater are expected to have an impact on the flow and transport regimes in the DIS disposal horizon.

This model considers the Boulder Zone (i.e., injection zone) only; other aquifer and/or confining units are not taken into account. The Boulder Zone is modeled as a confined (non-leaky) aquifer, neglecting other aquifer and/or confining units, which is conservative with respect to modeling radial transport because solutes (radionuclides) cannot leave the system by vertical leakance.

The elements of the numerical model for the base case, including the development of the input parameters and predicted radionuclide activity concentrations at potential receptor locations, are described in the following subsections. A base-case scenario was first developed, followed by a series of sensitivity analyses.

### 2.1.1. Numerical Model Description and Development of Model Input Parameters

#### 2.1.1.1. Radioactive Source Term Selection [Question 3]:

Development of the radioactive source terms for purposes of this response takes into consideration the entire DCD Table 11.2-7 inventory. Radionuclide-specific activity concentrations are then determined on a basis consistent with that upon which DCD Table 11.2-8 has been developed. Specifically, the injectate activity concentrations presented in Table 1 are based upon the release of the average daily discharge for 292 days per year (i.e., 292 effective full power days per year, averaged over the operating life of the plant) while utilizing the site-specific dilution flow rate (e.g., 6230 gpm per unit when the reclaimed makeup water source is used). Note that the number of units operating affects the rate of injection but not the injectate activity concentration. Illustrative of this is the calculation of the tritium injectate activity concentration:

$$\frac{(1010\ Ci/yr)(1E06\ \mu Ci/Ci)}{292\ day/yr} = 3.46E06\ \mu Ci/day \qquad \text{Eqn. 1}$$

Dividing by the per-unit reclaimed water dilution flow of 6230 gpm or 3.40E10 ml per day yields:

$$\frac{3.46E06\ \mu Ci/day}{3.40E10\ ml/day} = 1.02E-04 \mu Ci/ml = 1.02E05\ pCi/L \qquad \text{Eqn. 2}$$

The activity concentrations of the other 48 radionuclides listed in DCD Table 11.2-7 are computed in the same manner.

While injectate radionuclide activity concentrations are determined on a basis consistent with that used to develop DCD Table 11.2-8 (i.e., based upon the release of the average daily discharge for only 292 days per year), it is otherwise conservatively assumed for purposes of the PA that both units operate continuously (i.e., for 365 days per year) throughout the life of the plant and therefore continuously release their average daily discharge. Making such a simplifying assumption eliminates the modeling complexity required to reflect a transient operating regime. This assumption of continuous operation and release is conservative because it increases both the rate of plume expansion and the radioactive source term.

A screening analysis was then performed using the LADTAP II computer code (NUREG/CR-4013) to identify the DCD Table 11.2-7 radionuclides that are the most significant potential dose contributors considering the assumed ingestion pathways of drinking water and irrigated milk, meats, and vegetables for effluent decay times ranging from 5 to 100 years. This analysis determined that tritium, strontium-90, cesium-134, and cesium-137 contribute over 99 percent of the dose to the total body and the organs of a child (the most conservative receptor) after a decay time of 10 years or more. As discussed further in Section 2.1.1.5 of this response, the injectate plume (for the base case) is not projected to reach the receptor location until more than 10 years after initiation of injection. These four radionuclides are therefore retained for further fate and transport modeling and subsequent dose analysis. The injectate activity concentrations of these four radionuclides are presented in Table 1.

The cumulative inventory present in the Boulder Zone at the end of Turkey Point Units 6 & 7 plant operations for both units was also determined. This analysis reflects the DCD Table 11.2-7 inventory continually injected into the Boulder Zone for 61 years, with radioactive decay being the only removal mechanism, thereby conservatively maximizing the inventory. The results of this analysis are presented in Table 2. However, as noted above, only tritium, cesium-134, cesium-137, and strontium-90 were retained for purposes of the fate and transport modeling and subsequent dose analyses as they contribute over 99 percent of the dose to the MEI. The spatial extent of the plume is discussed below in Section 2.1.1.5 of this response and illustrated in Figures 6, 9, 11, and 13.

#### 2.1.1.2. Numerical Model Description

Depending on the source of cooling water makeup (reclaimed water or saltwater), the deep well injectate drawn from the common blowdown sump may be less or more dense than the in situ Boulder Zone groundwater. When reclaimed water is used for cooling water makeup, the injectate is less dense, and when saltwater is used the injectate is more dense than the in situ groundwater.

To account for these density differences and their impact on radionuclide transport, SEAWAT, a finite-difference, variable-density groundwater code (Reference 5), is used to model the fate and transport of radionuclides injected into the Boulder Zone. SEAWAT solves the 3D variable-density groundwater flow and multi-species transport equations by coupling MODFLOW (Reference 6) and MT3DMS (References 7 and 8). SEAWAT is widely used to simulate variable-density groundwater flow and is maintained by the U.S. Geological Survey. Groundwater Vistas (Reference 9) was used as a preprocessor and postprocessor to facilitate the development of the model and interpretation of model results.

#### 2.1.1.3. Modeling Approach

The DIS injection field is simulated utilizing an axisymmetric approach, which represents a radially symmetric 3D system as a 2D model (Figure 2 presents a general schematic) (Reference 10). With this approach, the DIS injection field is represented as a single well and provides a computationally efficient alternative to a full 3D model (Reference 10). This approach is appropriate given the absence of a strong regional hydraulic gradient in the Boulder Zone (Reference 3) relative to that likely to be induced by the injection. The center of the injection field is used to represent the long-term average injection location.

Axisymmetric flow and transport are simulated using a vertical cross-section model by adjusting several model parameters (horizontal and vertical hydraulic conductivity, specific storage and porosity) to account for the increase in cross-sectional flow area with radial distance from the injection well. Equation 3, presented below (Reference 10), illustrates the parameter adjustment for horizontal hydraulic conductivity. The other parameters that require adjustment are modified in the same manner. Note that the dimensions of this equation do not, and are not intended to, balance.

$$K^*_{x,j} = r_j \theta \cdot K_x \qquad \text{Eqn. 3}$$

where:

$K_x$ = horizontal hydraulic conductivity for the aquifer (length/time)
$K^*_{x,j}$ = horizontal hydraulic conductivity of the cell in column j entered into the model (length/time)
$r_j$ = radial distance from the injection well to the center of the cell in column j (length)
$\theta$ = angle open to flow (radians) (equal to $2\pi$ when flow is in all radial directions)

2.1.1.4. Model Domain, Boundary/Initial Conditions, and Parameters [Question 3]

The following subsections provide a brief description of the model domain, boundary and initial conditions, and parameters along with the bases for each, as summarized in Table 3.

2.1.1.4.1. Domain

The model domain extends approximately 15 miles radially from the point of injection. This distance is selected to fully encompass the anticipated radial extent of the injectate plume over the life of the facility. A uniform horizontal grid spacing of 45 meters is used throughout the model domain, resulting in 537 model columns. The selected aquifer thickness (152 meters based on Reference 11) is modeled using 76 layers, resulting in a 2-meter vertical grid resolution. Figure 3 shows the model grid with the injection well located on the extreme left side of the domain; this represents the center of the radially symmetric system.

2.1.1.4.2. Boundary and Initial Conditions

The boundary and initial conditions for the radial transport model are described below.

- Boundary Conditions:
    - Injection Well: Injection into the Boulder Zone is simulated with a single well placed at the edge of the model domain, consistent with the axisymmetric approach. The length of the simulated injection well is 74 meters, based on the penetration into the Boulder Zone achieved in exploratory well EW-1 (Reference 4). Section 2.1.1.4.4 of this response describes the injection parameters (flow rates and dissolved concentrations).
    - Distal Boundary: The distal boundary of the model (i.e., cells in all layers of the column farthest from the injection point) is assigned as a constant head and constant concentration boundary. The head along this boundary is assigned a value of 1.9 meters North American Vertical Datum of 1988 (NAVD 88), the measured head in the Boulder Zone at the site (Reference 4). The TDS concentration in the Boulder Zone was estimated to be 36.2 kilograms per cubic meter based on measurements taken during the installation of EW-1 (Reference 4); this value is used as the TDS concentration at the distal boundary. The radionuclide activity concentrations are assigned a value of 0 at the distal boundary.

- Initial Conditions: Throughout the model domain, the following initial conditions were assigned:

- Head: 1.9 meters NAVD 88
- TDS concentration: 36.2 kg/cubic meter
- Radionuclide activity concentrations: 0 for all species

2.1.1.4.3. Aquifer and Transport Parameters

The Boulder Zone is assumed to be homogeneous for the purpose of assigning groundwater flow and transport parameters. These parameters include the horizontal and vertical hydraulic conductivity, specific storage, effective porosity, and longitudinal and vertical dispersivity. The bases for assigning values to each of these parameters are provided below.

- Hydraulic Conductivity and Specific Storage: An analysis of available Boulder Zone hydraulic tests was conducted. The available data were from 11 injection and withdrawal test locations within the Turkey Point Units 6 & 7, Florida Keys Aqueduct, and Miami-Dade Water and Sewer Department South District Wastewater Treatment Plant sites. The approximate mean aquifer transmissivity (~23,000 square meters per day) and mean storativity (3.6E-04) values from this analysis are used in the model. Detailed data regarding the hydraulic conductivity anisotropy ratio (i.e., $K_z/K_x$) in the Boulder Zone are not available. A ratio of 1/3 was selected. This value is within the range for limestone and dolomite (Reference 12), the rock types present in the Boulder Zone.
- Effective Porosity and Longitudinal and Vertical Dispersivity: The selected effective porosity value of 20 percent is based on the literature value presented in Reference 11. The longitudinal dispersivity value of 15 meters is based on the Eckstein and Xu equation presented in Reference 13 and a transport distance of approximately 2.2 miles (the distance to the nearest potential receptor [member of the public] as described in Section 3 of this response). The selected longitudinal dispersivity and horizontal grid spacing values result in a grid Peclet number (grid spacing/longitudinal dispersivity) of 3. Several sources indicate that when the grid Peclet number is smaller than 4, the standard finite-difference method, which is used in these simulations, can be used reliably (References 7 and 14). A vertical dispersivity value of 0.3 meter was selected; the resulting ratio of longitudinal to vertical dispersivity ($\alpha_L/\alpha_V$) is within the range described in Reference 15.
- Solubility and Adsorption/Retardation Factor [Question 4]: The geochemical effects associated with radionuclide chemical speciation can play an important role in radionuclide migration in groundwater by limiting radionuclide solubility and affecting their distribution between the aqueous and solid phases in the subsurface. In this analysis, solubility constraints and solid phase adsorption/desorption of radionuclides are not considered (i.e., the distribution coefficient, $K_d$, is assumed to be 0 ml/g). These assumptions

result in conservative predictions of aqueous radionuclide activity concentrations at the receptor locations of interest.

#### 2.1.1.4.4. Operational Parameters and Assumptions

The base case operating scenario incorporates reclaimed water as the makeup water source, which constitutes the majority of the injectate composition. The intermittent use of saltwater as a makeup water source and its effect on radionuclide transport was assessed as a sensitivity analysis case as discussed in Section 2.1.1.7 of this response.

- Modeled Time Period: With a projected 60-year operational life (40-year license and 20-year renewal period) per unit and a 1-year interval between the startup of Unit 6 and Unit 7, the total time period spanned by the operation of both units is 61 years. The groundwater model simulation duration is 100 years, which includes 61 years of DIS operation followed by 39 years without injection. This 39-year period is simulated to evaluate radionuclide migration after injection ceases.
- Injection Regime: Cycled reclaimed water is the principal injectate component for the base case and all but one of the sensitivity analyses. The estimated annual reclaimed water flow rates reflect the following operational phases:

  - Turkey Point Unit 6 alone operates in model year 1
  - Turkey Point Units 6 & 7 operate in model years 2 through 60
  - Turkey Point Unit 7 alone operates in model year 61
  - No units operate during model years 62 to 100

  The planned 30-day unit outage every 18 months is not modeled, and both units are assumed to continuously operate 365 days per year for 60 years. This assumption of continuous operation is conservative because it maximizes radionuclide activity concentrations at receptor locations of interest due to the increased rates of liquid radwaste generation, release, and plume expansion. Because the plume is expanding at a more rapid rate, there is less time available for radionuclide decay prior to reaching a potential receptor location.

  With these assumptions, the approximate average annual injection rate is 6230 gpm for a single unit, or approximately 12,460 gpm for two units. These injection rates are based, in part, on the minimum dilution flow rate of 6000 gpm per unit used in the DCD to demonstrate compliance with the ECLs of 10 CFR Part 20, Appendix B (DCD Subsection 11.2.3.3).

- TDS Concentration: The TDS concentration of the injectate for the base case modeling scenario is approximately 2.7 kg/cubic meter, which is the estimated injectate TDS concentration when reclaimed water is used as the source of cooling water makeup.
- Receptor Locations: Two potential receptor locations at which members of the public could potentially be exposed have been identified: one location approximately 2.2 miles from the point of injection and a second location approximately 7.7 miles away from the injection point (Figure 4). The location at 2.2 miles represents the distance to the nearest privately owned land parcel in the vicinity of the Turkey Point Property Area that could potentially serve as an exposure point for a member of the public. The second location, the Ocean Reef Club community, represents the distance to the nearest existing offsite water-supply well in the Upper Floridan aquifer. This location serves as another potential exposure point for a member of the public. Additional rationale for the selection of these locations is presented in Section 3 of this response. The receptors are assumed to be exposed to the predicted radionuclide activity concentrations in model layer 1, the uppermost model layer, at their respective distances from the injection point. Model layer 1 is located approximately 915 meters (3000 feet) bgs. Assuming receptors are exposed to model layer 1 concentrations is conservative because model layer 1 contains the highest radionuclide activity concentrations of any model layer due to the buoyant nature of the cycled reclaimed water injectate as described in the following section.

2.1.1.5. Model Simulation and Results [Question 3]

The base case simulation was conducted using the numerical model described above. The transport of radionuclides is governed by the flow field, which for this system, is largely driven by the TDS concentration distribution in the aquifer. As such, the behavior of the TDS plume is described below, followed by a description of radionuclide transport.

2.1.1.5.1. TDS

Figure 5 presents the simulated TDS concentrations in the aquifer at 10-year intervals throughout the simulation. As shown in Figure 5, the injection of reclaimed water results in a buoyant, low salinity injectate plume. Several physical processes govern the behavior of the plume. The two that dominate the flow and transport regimes are injection pressure, which pushes the injectate radially outward and downward from the injection well, and buoyant forces arising from density differentials, which are determined by TDS concentration. The injectate is buoyant due to its low TDS concentration (approximately 2.7 kg/cubic meter) relative to that of the in situ Boulder Zone water (approximately 36 kg/cubic meter). Dispersion also mixes the plume radially and vertically. Although the well is only partially penetrating, the injection pressure is sufficient to push the injectate to the bottom of the modeled aquifer at small radial distances from the injection well. The low salinity plume continues to expand radially throughout the duration of injection; however, the rate of expansion decreases because the aquifer volume available for flow increases by the square of the radial distance from the injection well. After injection ceases at model year 61, the injection pressure is removed, and buoyant forces cause the low salinity injectate to rise to the top of the aquifer while slowly expanding radially. Modeling the Boulder Zone as a confined aquifer results in a conservative estimate of radial spreading as solutes cannot leave the system due to vertical leakance through the overlying middle confining unit. As shown in Figure 5, the radial extent of the low salinity plume does not reach the nearest potential receptor location until more than 10 years after the inception of injection and does not reach the receptor location 7.7 miles from the point of injection at any time during the 100-year simulation.

2.1.1.5.2. Tritium

Figure 6 shows the evolution of the tritium injectate plume from model year 1 to model year 100. In addition to radioactive decay, the same physical processes that govern the behavior of the low salinity injectate plume (i.e., injection pressure, dispersion, and buoyancy) govern the behavior of the tritium plume. As shown in Figure 6, the rate of radial expansion decreases and stabilizes after approximately 20 years of injection. At this time, a balance is achieved between continued injection and the combined effects of dispersion, buoyancy, and radioactive decay, resulting in a relatively constant radial extent until the end of plant operations at year 61. After injection ceases, radioactive decay and buoyancy-driven migration and mixing rapidly decrease tritium activity concentrations as shown in Figure 6. Figure 7 presents an isocontour map of tritium activity concentrations at the end of plant operations (i.e., model year 61) in model layer 1, which yields the highest radionuclide activity concentrations of any model layer.

In order to give context to the concentrations, a dose has been calculated using the methodology presented in Section 4 of this response. This dose is calculated assuming child exposure (the most conservative receptor) due to the ingestion of water and irrigated foods (vegetables, meat, and milk). Figure 7 also includes these doses corresponding to each of the tritium activity concentrations presented; peak doses at the hypothetical receptor locations are discussed in Section 4 of this response. Figure 8 presents the tritium relative activity concentration (simulated concentration, C, divided by the as-injected concentration, $C_0$) breakthrough curve for a hypothetical receptor location 2.2 miles from the injection well. This figure illustrates that the peak tritium activity concentration occurs at approximately model year 25. After year 25, the concentration slowly decreases until year 61, when the concentration decreases sharply due to the cessation of injection. The decreasing concentrations from model years 25 to 61 are due to the increasing vertical thickness of the low salinity injectate plume as shown in Figure 5. As fluid injection continues over time, the vertical thickness of the low salinity injectate plume at a given radial distance from the injection well increases. This results in increased average travel time to the receptor location, allowing for more radioactive decay and thus a lower tritium concentration. The peak tritium activity concentration at the receptor location 2.2 miles from the injection location is 3.1E04 pCi/L (approximately 30 percent of the as-injected concentration) as presented in Table 4. As illustrated in Figure 6, the tritium injectate plume does not reach the receptor location 7.7 miles from the point of injection at any time during the 100-year simulation.

#### 2.1.1.6. Other Radionuclides

The behavior of the other modeled radionuclides (cesium-134, cesium-137 and strontium-90) are governed by the same processes as those described above. Note that the process of retardation is not simulated for any radionuclide (i.e., $K_d = 0$ ml/g).

##### 2.1.1.6.1. Cesium-134

Figure 9 shows the evolution of the cesium-134 injectate plume from model year 1 to model year 100. The evolution of the cesium-134 plume is similar to that of the tritium plume, though with a smaller radial extent due to its lower radioactive half-life, which causes the cesium-134 activity concentration to undergo significant decay before reaching the receptor location at locations far from the injection well. Figure 10 presents an isocontour map of the model layer 1 cesium-134 activity concentrations at the end of plant operations (i.e., model year 61). As described previously, Figure 10 also includes the dose corresponding to each of the cesium-134 activity concentration isocontours presented; peak doses at the hypothetical receptor locations are discussed in Section 4 of this response.

Figure 8 presents the cesium-134 relative concentration breakthrough curve for a receptor location 2.2 miles from the injection well. Note that relative concentrations for cesium-134 are represented on the secondary (right side) vertical axis, which is required due to the extremely low cesium-134 relative activity concentrations at the simulated receptor location. This figure illustrates that the peak cesium-134 activity concentration occurs at approximately model year 15, earlier than that of tritium. Furthermore, the decrease in the concentration after the peak is more pronounced, due to the shorter half-life of cesium-134. The peak cesium-134 activity concentration at the receptor located 2.2 miles from the injection location is 7.7E-03 pCi/L (approximately 1 percent of its injectate concentration) as presented in Table

4. The cesium-134 injectate plume does not reach the receptor located 7.7 miles from the point of injection at any time during the 100-year model simulation time.

2.1.1.6.2. Cesium-137

Figure 11 shows the evolution of the cesium-137 injectate plume from model year 1 to model year 100. The evolution of the cesium-137 plume is similar to that of tritium, but the cesium-137 plume has a larger radial extent due to its longer radioactive half-life. A longer half-life allows cesium-137 to travel longer and therefore farther than tritium before it decays to insignificant levels relative to the as-injected concentration. Figure 12 presents an isocontour map of the model layer 1 cesium-137 activity concentrations at the end of plant operations (i.e., model year 61). As described previously, Figure 12 also includes the dose corresponding to each of the cesium-137 activity concentrations presented; peak doses at the hypothetical receptor locations are discussed in Section 4 of this response. Figure 8 presents the cesium-137 relative concentration breakthrough curve for a receptor location 2.2 miles from the injection well. This figure illustrates that the peak cesium-137 activity concentration occurs at approximately model year 42, later than that of tritium. Furthermore, the concentration decrease after the peak is not as pronounced as that for tritium, due to the longer half-life of cesium-137. As half-life increases, the sensitivity to the increase in average travel time decreases. The peak cesium-137 activity concentration at the receptor location 2.2 miles from the injection location is 7.6E-01 pCi/L (approximately 55 percent of its as-injected concentration) as presented in Table 4. The cesium-137 injectate plume does not reach the receptor location 7.7 miles from the point of injection at any time during the 100-year model simulation time.

2.1.1.6.3. Strontium-90

Figure 13 shows the evolution of the strontium-90 injectate plume from model year 1 to model year 100. The strontium-90 plume evolution is nearly identical to that of cesium-137 due to their similar half-lives (29 and 30.1 years, respectively). Figure 14 presents an isocontour map of simulated strontium-90 activity concentrations in model layer 1 at the end of plant operations (i.e., model year 61). As described previously, Figure 14 also includes the dose corresponding to each of the strontium-90 activity concentrations presented; peak doses at the hypothetical receptor locations are discussed in Section 4 of this response. Figure 8 presents the strontium-90 relative concentration breakthrough curve for a receptor location 2.2 miles from the injection well. This figure illustrates that the peak strontium-90 activity concentration occurs at approximately model year 41. The peak strontium-90 activity concentration at the receptor location 2.2 miles from the injection location is 5.6E-04 pCi/L (approximately 55 percent of the as-injected concentration) as presented in Table 4. The strontium-90 injectate plume does not reach the receptor located 7.7 miles from the point of injection at any time during the 100-year model simulation time.

2.1.1.7. Sensitivity Analyses

Twelve additional simulations were performed to evaluate how the predicted peak radionuclide activity concentrations change when key input parameters are varied over plausible ranges. The varied parameters include transmissivity, effective porosity, aquifer thickness, anisotropy ratio, longitudinal and vertical dispersivity, storativity, and injectate regime (i.e., cycled saltwater makeup, as described below under Section 2.1.1.7.1 of this response). With the exception of injectate fluid and transmissivity, the selection of these parameter values is based primarily on engineering judgment and literature values. The transmissivity value is based on an analysis of available data.

Sensitivity analyses were conducted by varying a single input parameter value with the exception of the saltwater makeup case, which required adjustment of all the injection parameters during the 60-day saltwater makeup cycle as previously described. Table 4 summarizes the sensitivity analyses performed, the predicted peak radionuclide activity concentrations at the receptor location 2.2 miles from the point of injection for each case, and the percentage change relative to the base case value. The injectate plume does not reach the receptor location at 7.7 miles from the point of injection at any time during the 100-year simulation for any of the sensitivity cases evaluated.

With the exception of the saltwater makeup case, the following description focuses on the tritium results. Tritium is the focus because it is the dominant dose contributor, as described in Section 3.1.1 of this response, but the description of the relevant physical processes given below applies to all the radionuclides modeled. Variations in radionuclide behavior are due to differences in half-life; simulation results (Table 4) indicate that shorter-lived species (e.g., cesium-134) generally exhibit greater sensitivity.

2.1.1.7.1. Saltwater Makeup Sensitivity Case

In the event that reclaimed water is not available in sufficient quality or quantity, Turkey Point Units 6 & 7 will use saltwater provided by the radial collector wells as a backup water source. The use of saltwater is limited to a maximum of 60 days in any consecutive 12-month period (References 16 and 17). While using saltwater as the source of cooling water makeup, the injection flow rate (58,175 gpm) is approximately five times greater than the reclaimed water injection flow rate, and the resulting radionuclide activity concentrations are approximately five times lower. At approximately 57 kg/cubic meter, the TDS concentration of the saltwater makeup injectate is much higher than that of the in situ groundwater in the Boulder Zone (approximately 36 kg/cubic meter, Reference 4).

In the saltwater makeup injection case, the injectate fluid alternates between reclaimed water and saltwater. The reclaimed water is buoyant relative to the in situ Boulder Zone water while the saltwater injectate is negatively buoyant, leading to a distinctly different injectate plume behavior from that of the base case. For this case, it is assumed that for the last 60 days of the year, every year, saltwater rather than reclaimed water is the source of makeup water. This results in changes to the flow rate and composition of the injectate during the use of saltwater makeup as summarized in Table 1.

The same physical processes that govern the behavior of the base case low salinity plume also apply to the saltwater makeup case high salinity plume. Figure 15 shows the cyclic nature of the reclaimed and saltwater injection. For the first 10 months of each year, low salinity reclaimed water is injected, while during the last 60 days of each year, high salinity saltwater is injected. Because the saltwater is more dense than the in situ water, it is negatively buoyant and flows to the bottom of the aquifer rather than rising to the top as the reclaimed water does. This behavior is illustrated in Figure 16, which shows the evolution of the injectate TDS plume from model year 1 to model year 100. Due to these density variations, a low salinity plume develops at the top of the aquifer and a high salinity plume develops at the bottom of the aquifer.

Figure 17 shows the evolution of the tritium injectate plume from model year 1 to model year 100. The saltwater makeup case results in a 23 percent lower peak tritium activity concentration at the 2.2-mile receptor location as compared to the base case (Table 4). The lower peak concentration is due primarily to two factors. First, the saltwater injectate has a tritium activity concentration that is about one-fifth of the reclaimed water injectate. Therefore, as the saltwater is injected, it dilutes the reclaimed water plume near the injection well. Second, the saltwater injectate's higher fluid density causes it to flow to the bottom of the aquifer. This transports some of the tritium to the bottom of the aquifer with the sinking plume (Figure 17). It also reduces the radial spreading of the reclaimed water plume at the top of the aquifer when compared to the base case, in which the constant injection of buoyant water continually adds to the plume at the top of aquifer. This increases the reclaimed water plume's travel time to the hypothesized receptor locations, allowing for additional radioactive decay and a lower peak concentration compared to the base case.

2.1.1.7.2. Other Sensitivity Cases

The remaining 11 sensitivity simulations were performed with reclaimed water as the injectate fluid. Figure 18 presents the tritium activity concentration distributions at model year 25 for all 13 model simulations (base case plus 12 sensitivity cases). Model year 25 is selected for comparison as this is the time at which the base case tritium peak occurs at the receptor location 2.2 miles from the injection point. Figure 19 presents the tritium breakthrough curves at the hypothesized receptor location at 2.2 miles from the injection well for all 13 cases, and Table 4 summarizes the peak concentrations in each simulation at the same location. Selected simulations for which peak concentrations at the hypothesized receptor location exhibit sensitivity are described below.

2.1.1.7.3. Effective Porosity

Decreasing the effective porosity from 20 to 15 percent (i.e., a 25 percent decrease) results in a 29 percent increase in the peak tritium activity concentration. Effective porosity represents the volume of interconnected pore space per unit volume of aquifer material (Reference 12). This case behaves as expected since, in general, decreasing the effective porosity increases groundwater velocity, resulting in a lower travel time and less radioactive decay. Figure 18 indicates that at model year 25, the shape of the tritium plume for this case is very similar to that of the base case; however, the increased flow velocity allows for faster radial migration and, thus, higher tritium activity concentrations at any given location in the top layer of the model. Figure 19 confirms that reducing the effective porosity results in earlier breakthrough and a higher peak concentration at the hypothesized receptor location compared to the base case.

2.1.1.7.4. Aquifer Transmissivity

Increasing the aquifer transmissivity to 55,736 square meters per day (600,000 square feet/day, 240 percent of the base case transmissivity) results in a 19 percent increase in the peak tritium activity concentration, while decreasing the transmissivity to 5573 square meters/day (60,000 square feet/day, 24 percent of the base case) results in a 35 percent decrease in the peak tritium activity concentration. For these cases, the aquifer thickness and anisotropy ratios are held constant, which results in changes to both the horizontal and vertical conductivity values throughout the model domain. Transmissivity is defined as the aquifer hydraulic conductivity times its thickness and is, therefore, proportional to groundwater flow velocity for a given hydraulic head gradient. As such, increasing the transmissivity increases the groundwater velocity, which reduces travel and decay time, resulting in earlier breakthrough and higher peak tritium activity concentrations at any given location at the top of the aquifer. A higher transmissivity also results in less downward flow of injectate and, thus, less vertical distribution of tritium at a given radial distance (Figure 18). This is due to the increased radial flow as a result of the higher hydraulic conductivity, which requires a lower injection pressure. As expected, the decreased transmissivity case exhibits the opposite effects, including a later breakthrough and lower peak concentrations at the hypothesized receptor location (Figure 19).

2.1.1.7.5. Vertical Dispersivity

Increasing the vertical dispersivity to 1 meter (roughly three times the base case) results in a 26 percent decrease in the peak tritium activity concentration at the simulated observation point, while decreasing the vertical dispersivity to 0.1 meter (one-third of the base case) results in a 26 percent increase in the peak concentration. Vertical dispersivity represents the effect of heterogeneity on contaminant spreading in the vertical direction. A larger vertical dispersivity enhances vertical mixing, while using a lower vertical dispersivity results in a much sharper interface between the in situ water and the injectate. Figure 19 indicates that decreasing the vertical dispersivity results in earlier breakthrough and a higher peak concentration, which occurs at approximately model year 21. Conversely, increasing the vertical dispersivity results in later arrival times and a lower peak concentration, which occurs at approximately model year 33.

2.1.1.7.6. Longitudinal Dispersivity

Two simulations were also conducted to evaluate the impact of longitudinal dispersivity on the model results. Longitudinal dispersivity represents the effect of heterogeneity on contaminant spreading in the horizontal direction. Larger longitudinal dispersivity values result in more mixing in the horizontal direction. This mixing is due to local differences around the mean flow velocity. The peak concentration at the receptor 2.2 miles away is relatively insensitive to longitudinal dispersivity because the duration of injection (61 years) is long compared to the mean travel time (approximately 15 to 20 years) and, therefore, significant concentration decreases are only realized at the plume edges. The minimal impact of longitudinal dispersivity on transport is evident in Figures 18 and 19, which show no appreciable differences from the base case.

2.1.1.7.7. Vertical Thickness of the Domain

A simulation was developed to evaluate the impact of reducing the vertical thickness of the model domain. For this case, the total vertical thickness of the domain is reduced from 152 to 92 meters, while the transmissivity and storativity values are consistent with those in the base case. Holding transmissivity (T) constant while reducing the aquifer thickness (b) requires an increase in the hydraulic conductivity (K = T/b). Note that because $K_z = 1/3\ K_x$, the vertical conductivity also increases relative to the base case. Similarly, specific storage ($S_s$ = S/b) is increased relative to the base case due to the decrease in aquifer thickness. The model was revised for this case by removing the bottom 30 model layers and altering the parameters described above. Reducing the aquifer thickness to 92 meters (i.e., approximately by 40 percent) results in a 16 percent increase in the peak tritium activity concentration at the simulated 2.2-mile receptor location. This increase is a result of the higher hydraulic conductivity, which increases the groundwater velocity, reducing travel and decay time as described above. Additionally, the reduced thickness forces the plume radially rather than allowing it to propagate downward as shown in Figure 18. Figure 19 indicates that decreasing the aquifer thickness results in earlier breakthrough and a higher peak concentration that occurs at approximately model year 27.

2.1.1.7.8. Storativity and Anisotropy

The three remaining cases, which alter storativity and anisotropy ($K_x/K_z$), result in minor or negligible changes in the peak concentrations at the receptor location 2.2 miles from the injection point (Table 4 and Figures 18 and 19).

2.1.1.7.9. Sensitivity Analysis Summary

Twelve sensitivity analyses were performed to evaluate how the predicted peak radionuclide activity concentrations change when key input parameters are varied over plausible ranges. The parameters varied include transmissivity, effective porosity, aquifer thickness, anisotropy ratio, longitudinal and vertical dispersivity, storativity, and injection regime.

As summarized in Table 4, changes to anisotropy ratio, longitudinal dispersivity and storativity result in only minor changes (5 percent or less) to the peak radionuclide activity concentrations. Three sensitivity cases produced lower peak activity concentrations at the hypothesized receptor locations (saltwater makeup injection regime, increased vertical dispersivity, and decreased transmissivity), with the shorter-lived species (i.e., cesium-134 and tritium) exhibiting more sensitivity than the longer-lived species (i.e., cesium-137 and strontium-90).

Four sensitivity cases resulted in higher peak activity concentrations at the hypothesized receptor location: increased aquifer transmissivity, decreased effective porosity, decreased vertical dispersivity, and decreased aquifer thickness. Tritium, the dominant dose contributor, is most sensitive to a decrease in the effective porosity. However, the increase in the peak activity concentration resulting from changing the effective porosity from 0.20 to 0.15 (i.e., a 25 percent decrease) is less than 30 percent. Due to its low radioactive half-life, cesium-134 exhibits greater sensitivity than that of tritium; the peak concentration at the receptor location increased by 173 percent for the decreased porosity case. However, cesium-134 is not a significant dose contributor; subsequent dose analysis for the base case shows that the total dose due to tritium was over 100 times greater than that due to cesium-134 for all exposure scenarios at the hypothesized receptor location as discussed below and summarized in Tables 8, 9, and 10. Increases in the peak activity concentrations of cesium-137 and strontium-90 are less than 15 percent for all cases.

## 2.2. Vertical Transport Model [Questions 1 and 3]

The principal mechanism for migration of injectate out of the Boulder Zone is upward seepage through the confining layer due to the injection pressure and the density differential between the injected fluid and the in situ groundwater. Cooling water makeup sourced from reclaimed water has the potential for upward migration due to the relatively low TDS concentration and correspondingly low density compared to groundwater in the Boulder Zone, while cooling water makeup derived from saltwater (radial collector wells) will tend to sink due to a high TDS concentration and, therefore, does not pose a risk of upward vertical migration. While TDS concentration is the primary determinant of fluid density for the expected range of conditions, temperature can also contribute to density differentials.

### 2.2.1. Model Description and Approach

The normal confined (i.e., absent a natural or man-made failure such as an improperly abandoned well or naturally occurring conduit) upward migration from the Boulder Zone through the middle confining unit was simulated with a 3D groundwater model developed to simulate injection of reclaimed water into the Boulder Zone. The modeling was also performed using SEAWAT (Reference 5) and includes consideration of fluid density variations due to both TDS concentration and temperature. Solute transport modeling was performed for TDS concentration, which serves as a non-decaying radionuclide surrogate. Some parameter values described below are different than those used in the axisymmetric model of radial migration due to differences in modeling objectives (e.g., transmissivity as discussed below).

#### 2.2.1.1. Model Domain

The model domain was discretized as 23 layers representing depths of 1350 feet to 3175 feet bgs. The bottom layer, 260 feet thick, represents the injection zone. Two injection wells were simulated near the center of the model domain, which measures 12 miles by 12 miles laterally and is discretized into 150 rows and 150 columns.

2.2.1.2. Aquifer Parameters

Each layer was assigned uniform thickness and aquifer properties. Throughout the domain, typical longitudinal, horizontal transverse, and vertical transverse dispersivity values of 30 feet, 3 feet, and 3 feet, respectively, were used. The effective porosity was set at 0.2, a reasonable default value for the limestone and dolomite limestone that constitute the confining strata encountered in EW-1 (Reference 4).

The strata above the top of the injection zone (2915 feet bgs) were conceptualized as six confining zones based on general confining properties as indicated in the geophysical logs (Reference 4). Laboratory core tests provide measurements of total porosity, horizontal hydraulic conductivity, and vertical hydraulic conductivity, which were used to develop regression equations for horizontal and vertical conductivity as a function of total porosity. Core data from the Florida Keys Aqueduct Authority (FKAA) J. Robert Dean Water Treatment Plant injection well IW-1, which is located less than 12 miles from the Turkey Point Units 6 & 7 site, were also used in this study in order to increase the number and range of porosity and hydraulic conductivity data points in the regression analysis. The resulting regression equations were applied to total porosity measurements derived from sonic travel time logs (Reference 4) to yield hydraulic conductivity values for each model layer above the injection zone.

The first confining unit above the Boulder Zone extends from 2600 to 2915 feet bgs, and was conceptualized as seven layers in the model. Using the regression analysis described above, the resulting equivalent vertical hydraulic conductivity of this unit is 7.37E-03 feet per day. This confining zone represents the deepest part of the middle confining unit. The middle confining unit extends upward to a depth of approximately 1200 feet bgs.

The transmissivity in the Boulder Zone was assigned a value of 51,000 square feet per day, which is lower than typical estimates. Using a low value effectively increases the potential for vertical migration by increasing pressure in the injection zone and limiting lateral movement of the injectate. This transmissivity equates to a horizontal hydraulic conductivity of 196.2 feet per day in the Boulder Zone (51,000 square feet per day per 260 feet). The vertical hydraulic conductivity of the Boulder Zone was assigned a value of 20 feet per day, based on testing performed during installation of EW-1 (Reference 4).

The temperatures of the in situ groundwater and injectate were set to 50°F (10°C) and 64.4°F (18°C), respectively, giving a temperature differential of 14.4°F (8°C), which is approximately equal to the maximum expected differential. The maximum expected injection temperature is 91°F, while the in situ temperature as measured during the installation of EW-1 was approximately 77°F (Reference 4), yielding a difference of 14°F. An extreme differential, 50°F, was used in the sensitivity analysis to evaluate the impact on vertical migration.

#### 2.2.1.3. Operational Parameters

The simulation duration is 100 years, which includes, in the case of this model, 60 years of plant operation (i.e., injection) followed by 40 years without injection. The expected maximum flow of 18.6 MGD (approximately 12,900 gpm) is divided equally between the two pumping wells. A TDS concentration of approximately 2.7 kg/cubic meter, based on use of reclaimed water for makeup water, is used for the injectate.

### 2.2.2. Model Simulation Results

Results of the base case simulation show that the low salinity plume migrates upward but is contained below a depth of 2600 feet bgs, or approximately 300 feet into the middle confining unit, at the end of the 100-year simulation. Given that the top of the middle confining unit is at approximately 1200 feet bgs, the plume would have to vertically migrate an additional 1000 feet or more to reach the Upper Floridan aquifer. The time to transit this additional distance and reach the Upper Floridan aquifer is expected to be greater than 100 years, by which time radionuclide concentrations are expected to have fallen to non-consequential levels even if only radioactive decay is taken into consideration.

### 2.2.3. Sensitivity Analyses

Sensitivity analyses were conducted to evaluate the effects of varying model parameters. With the exception of injection zone transmissivity, parameter values are varied to increase vertical migration of the low salinity plume. The following parameters are varied in separate model runs:

- Effective porosity (reduced to 0.1 from 0.2)
- Dispersivity (longitudinal, transverse horizontal, and transverse vertical dispersivities increased to 100 feet, 10 feet, and 10 feet, respectively, from 30 feet, 3 feet, and 3 feet, respectively)
- Injection zone transmissivity (increased to 510,000 square feet per day from 51,000 square feet per day)
- Vertical hydraulic conductivity (increased by a factor of 2 for all confining layers above the injection zone)
- Temperature differential (increased to 50°F from 14.4°F by increasing injectate temperature)

2.2.4. Sensitivity Analyses Summary

Results of the sensitivity analyses show that altering the vertical hydraulic conductivity and effective porosity produces the greatest increase in upward migration. In these cases, the front of the low salinity plume reaches the bottom of the second confining zone, or 2600 feet bgs. Note that this is well within the bounds of the middle confining unit.

2.2.5. Vertical Transport Model Summary

As noted above, the base case value of transmissivity chosen for the injection zone is lower than most estimates and adds conservatism by limiting the lateral spreading of the low salinity plume, thus increasing the potential for buoyancy-induced upward migration. Sensitivity analyses confirm that increasing the transmissivity of the injection zone reduces vertical migration. A second measure of conservatism was added to the analysis by simulating only two injection wells, while the as-designed system uses up to 12 injection wells. Over the period of operations, the wells used for injection would change over time, which would lessen near-field pressure and reduce vertical migration. Outages and periods of using saltwater for cooling water makeup are not simulated; including these periods would further limit the potential for vertical migration, since the injectate, when saltwater is used for cooling water makeup, will be denser than the existing water in the Boulder Zone. Any injected radioactive species dissolved in the low salinity plume would undergo significant radioactive decay in the confining zones over the simulated 100 years.

Based on the modeling results, the migration of radioactive species out of the Boulder Zone by density-driven vertical migration is expected to be contained below a depth of 2600 feet bgs, or approximately 300 feet into the middle confining unit, at the end of the 100-year simulation. Further, due to the transit time required for the plume to continue to vertically migrate and reach the Upper Floridan aquifer, it is expected that the radionuclide concentrations will have fallen to non-consequential levels.

2.3. Questions 3 and 4 Response Summary

For ease of review, Questions 3 and 4 of NRC RAI 11.02-6 (eRAI 6985) are again presented below, followed by a summary with references to the specific sections in this response where each question is addressed.

2.3.1. Question 3

In developing the radioactive source terms for any of the above scenarios, the applicant is requested to consider the cumulative inventories of long-lived radionuclides expected to be present after 40 years of operations for both reactor units. The applicant should present a detailed analysis, identify long-lived radionuclides of importance to dose modeling, describe the physical and chemical properties important to the dose assessment, and describe the expected behavior of each radionuclide in the Boulder Zone based, in part, on their deposition and adsorption characteristics if assumed. This analysis should include the accumulation, radial distribution, and movement of radioactivity within and out of the Boulder Zone. Sources of radioactivity include long-lived radionuclides, such as H-3, C-14, Sr-90, Tc-99, I-129, and Cs- 137, among others, and transuranics. The analysis should provide radionuclide specific estimates of their concentrations in and around the injection point and in radial directions of the plume within the Boulder Zone after 40 years of plant operation. The source term should consider whether the injectate results in a plume (depending on the use of reclaimed municipal waste water or seawater) that is buoyant or readily miscible within the 200-foot thick Boulder Zone formation brine. The applicant should consider geochemical effects associated radionuclide chemical speciation and absorption within the rock formation.

2.3.2. Question 3 Response Summary

As described in Section 2 of this response, a detailed analysis of the fate and transport of the radionuclides injected into the Boulder Zone using the DIS was performed. To account for the buoyant nature of the reclaimed water injectate and negatively buoyant behavior of the saltwater injectate, a variable-density flow and transport model was developed (Section 2.1 of this response).

The radioactive source term considered in the analysis is based on a screening analysis of the entire DCD Table 11.2-7 inventory. This screening analysis identified four long-lived radionuclides (tritium, cesium-134, cesium-137, and strontium-90) that are the most significant potential dose contributors. The behavior of each of these radionuclides in the Boulder Zone is assessed using the radial transport model (Section 2.1 of this response).

The expected behavior of the effluent plume as well as the physical and chemical properties controlling plume behavior are described in Section 2.1.1.5 of this response. The geochemical processes that could reduce aqueous radionuclide activity concentrations (i.e., solubility constraints and sorption) are neglected, resulting in conservative predictions of aqueous radionuclide activity concentrations at the potential receptor locations (Section 2.1.1.4.3 of this response).

Specific estimates of tritium, cesium-134, cesium-137, and strontium-90 concentrations present in the Boulder Zone are provided at various radial distances and times, including at the end of plant operations (Section 2.1.1.5 of this response along with Figures 6 through 14).

The analyses conducted indicate that the receptor located 7.7 miles from the point of injection will not be impacted by radionuclides from the operation of the DIS at any time during or after plant operations. Additionally, the cumulative radionuclide inventory expected to be present in the Boulder Zone at the end of plant operations is presented (Section 2.1.1.1 of this response).

Finally, the vertical migration of injectate out of the Boulder Zone was also modeled (Section 2.2 of this response). These results indicate that there is expected to be some limited vertical migration of effluent, but it is contained below a depth of 2600 feet bgs, approximately 300 feet into the middle confining unit.

2.3.3. Question 4

In modeling the movement of radioactivity in groundwater, the traditional approach applies distribution coefficients (Kd) and retardation factors. The Kd approach works best for radionuclides that are in contact with very small soil particles, where the Kd lumps the effects of number of complex chemical processes into a single value. However, currently published Kd values used in modeling the movement of radioactivity in groundwater may not apply to this type of environment. The applicant is requested to indicate if in modeling the movement of radioactivity in the Boulder Zone, the evaluation considered the application of retardation factors, and, if so, describe how Kd values were modified and assigned to radionuclides. The applicant is requested to indicate whether the presence of residual concentrations of organic compounds in reclaimed municipal waste water were considered in developing distribution coefficients and retardation factors.

2.3.4. Question 4 Response Summary

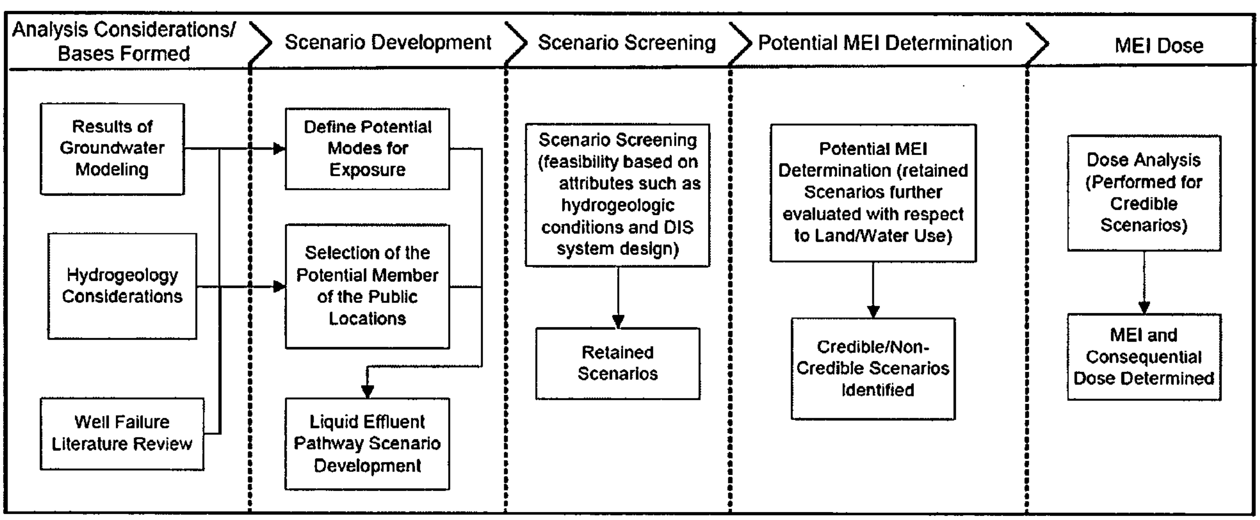
The retardation factor describes how many times faster the groundwater is traveling relative to the contaminant being sorbed (Reference 12). Retardation due to adsorption of radionuclides onto the solid phase or other chemical processes is not considered in this analysis (i.e., $K_d$ = 0 ml/g for all radionuclides)(Section 2.1.1.4.3 of this response). This assumption results in conservative predictions of aqueous contaminant concentrations at the potential receptor locations as retardation slows the transport of radionuclides, allowing for more decay and, therefore, lower concentrations. Tritium, the radionuclide with the largest dose contribution, is commonly assumed to be non-sorbing.

3. Liquid Effluent Pathway Analysis [Questions 1 and 2]

FPL proposes to use a non-traditional disposal method for NRC licensed radioactive material in liquid effluents, i.e., deep well injection into the Boulder Zone (about 2900 feet bgs). At depths this great, coupled with the presence of the confining units, it is not anticipated, under normal operating conditions, that any radioactivity injected into the Boulder Zone would reach either an underground source of drinking water (USDW) or the surface environment—primarily due to confinement, slow movement, and decay. This disposal method differs from that of traditional liquid effluent releases in that traditional disposal methods involve the direct discharge into surface waters where the liquid effluent is diluted and dispersed in the receiving waters and is immediately available for member-of-the-public exposure. Injection provides the means to isolate liquid radioactive waste over the long-term minimizing the exposure since the activity concentrations would be reduced (decayed) during that time. A liquid effluent pathway analysis was conducted to assess these and other effects as they relate to credible and non-credible MEI exposures.

FPL designed the liquid effluent pathway analysis to identify any appropriate member-of-the-public receptors, and ultimately determine the MEI through a process in which postulated exposure scenarios were screened for feasibility/credibility. It should be noted that, in many cases, in determining such exposure scenarios, extraordinary events/assumptions had to be postulated in order for the scenario to result in a member of the public being exposed to radioactive effluents and, therefore, an MEI could be identified. This liquid effluent pathway analysis culminates in an assessment of the doses potentially delivered to the MEI as a result of the injection of effluent to the Boulder Zone (Section 4 of this response). The liquid effluent pathway analysis followed by FPL is illustrated below.

Liquid Effluent Pathway Analysis




As illustrated, FPL designed the liquid effluent pathway analysis as a multi-phase process. Initially, prior to development of the postulated exposure scenarios, a definition of the exposure modes and selection of the member-of-the-public locations were formulated in the context of the anticipated liquid effluent exposure pathway modes and were delineated based on such inputs as the hydrogeology local to the site and the results of the groundwater modeling. The liquid effluent pathway scenarios were then developed whereby each scenario was comprised of a conceptual model based upon the identified effluent exposure pathway with respect to the defined member-of-the-public locations and modes.

The identified liquid effluent pathway scenarios then went through a screening process that included assessing whether a liquid effluent pathway scenario should be retained for further analysis (i.e., determination of the consequential doses to the associated member-of-the-public receptors and identification of the MEI). This screening again considered relevant background information, such as the hydrogeology local to the site, and the results of the groundwater modeling, particularly the radial extent of injectate travel in the Boulder Zone, the relevant time-dependent radionuclide concentrations at potential member-of-the-public receptor locations, along with potential for vertical effluent migration out of the Boulder Zone (provided in Sections 1 and 2 of this response). Lastly, the retained scenarios were further evaluated based on parameters important to member-of-the-public determination—current and projected land and water use—to determine credible/non-credible scenarios for ultimate determination of the MEI and consequential dose analysis (Section 4 of this response).

## 3.1. Considerations/Bases for Liquid Effluent Pathway Analysis

### 3.1.1. Radial Transport—Boulder Zone

In order to determine the greatest relevant radial extent of radionuclide propagation, within which a potential liquid effluent pathway exposure to a member of the public must be assessed, a PA coupling an initial dose screening analysis with the results of the radial transport in the Boulder Zone model was conducted.

As presented in Section 2.1.1.1 of this response, an initial dose screening analysis was first performed using the LADTAP II computer program to identify the DCD Table 11.2-7 radionuclides that are the most significant potential dose contributors considering the assumed ingestion pathways of drinking water and irrigated milk, meats, and vegetables for effluent decay times ranging from 5 to 100 years. This analysis determined that, while the percentage of each of the radionuclide's contribution to the total annual dose varies over time due to each of their respective half-lives, tritium, strontium-90, cesium-134, and cesium-137 contribute more than 99 percent of the annual dose to the total body and the organs of a child (the most conservative receptor) after a decay time of 10 years or more (as previously noted, the injectate plume is not expected to reach the receptor locations until more than 10 years after initiation of injection). The modeled radial extents of tritium, cesium-134, cesium-137, and strontium-90, along with the corresponding concentrations in their respective plumes, are illustrated in Figures 6, 9, 11, and 13, respectively.

To give some context to the potential dose contribution from each radionuclide during the modeled time period, there is a limited duration, i.e., over a decay period of about 30 years or less, in which the sum of the per-unit radionuclide doses is expected to be at least 1 mrem per year. During this period, tritium contributes more than 90 percent of the total dose, (i.e., the contribution to the total body dose for a child from radionuclides other than tritium is a small fraction of 1 mrem per year for any period greater than 5 years). Based on the most limiting 10 CFR Part 50, Appendix I, design objective of 3 mrem per year for the total body per unit, or 6 mrem per year for both units, the tritium concentration yielding this dose to a child (i.e., the 6 mrem per year derived activity concentration) was determined to be 37,000 pCi/L (two-unit source term and two-unit deep well injection rate; the two-unit case is more limiting as it results in a greater extent of plume expansion at any given point in time as well as a higher cumulative radionuclide inventory).

To provide an indication of the area of consequence for this analysis, this 37,000 pCi/L derived tritium activity concentration was then used as a basis for ascertaining the farthest radial extent of a tritium concentration capable of producing doses at the level of the 10 CFR Part 50, Appendix I, design objectives during the modeled timeframe. Based on the model described in Section 2.1 of this response, Figure 20 depicts the extent of the 37,000 pCi/L tritium activity concentration profile at 5, 10, 25, 50, and 75 years. Tritium concentrations are below the 37,000 pCi/L derived activity concentration at all locations at 100 years and, therefore, no contour is shown in Figure 20 for this simulation time. As Figure 20 indicates, the farthest radial extent of the 37,000 pCi/L derived tritium activity concentration during the modeled timeframe is between approximately 1.9 and 2 miles from the injection zone. As further described in Section 2.1.1.5.2 of this response, the radial extent of the 37,000 pCi/L tritium activity concentration profile begins to retract after year 25 due to the increasing thickness of the low salinity injectate plume and the resultant increase in the travel time to any given radial distance from the injection point. After injection ceases at year 61, the tritium plume diminishes due to radioactive decay and the lack of continued injection, and as a result, the 37,000 pCi/L tritium activity concentration contour retracts more rapidly toward the injection location.

3.1.2. Vertical Transport Model

As detailed in Section 2.2 of this response, in order to determine the potential for upward vertical migration of the effluent out of the Boulder Zone absent some failure of the middle confining unit (e.g., a conduit created by a mechanical well failure), a 3D vertical transport model was developed to simulate the behavior of the injected effluent plume in this regard. Results of this vertical transport model simulation show that there is some upward migration of the low salinity plume, but it is contained below a depth of 2600 feet bgs, well within the middle confining unit and well below the base of any USDW.

3.1.3. Horizontal Gradient Analysis of Upper Floridan Aquifer

A horizontal gradient analysis of the Upper Floridan aquifer was also performed to determine if potential consequences may arise as a result of a postulated scenario under off-normal operations in which the radioactive plume in the Boulder Zone were to become hydraulically connected to the Upper Floridan aquifer (e.g., due to mechanical well failure), a designated USDW.

As described in Section 1.2.2.3 of this response, the gradient in the Upper Floridan aquifer is generally toward the east. The apparent hydraulic gradient in the vicinity of Turkey Point is approximately 6E-05 ft/ft (Reference 3). This gradient is not expected to be significantly increased by the presence of pumping wells because, as discussed below, current offsite water use in the Upper Floridan aquifer is limited to three wells located at distances from the site so that they will not cause significant disruption to the local flow field. Further, on-site pumping wells used to supply water to Turkey Point Unit 5 would serve to slow migration away from the site and will be monitored for contamination as described below. Based on an estimated transmissivity of 50,000 square feet per day (Reference 3), aquifer thickness of 200 feet (Reference 1), and an effective porosity of 0.3 (Reference 3), the velocity, v, in the Upper Floridan aquifer is calculated using equation 4 (Reference 3):

$$V = \frac{TI}{b\varphi_e} \qquad \text{Eqn. 4}$$

where:

T = transmissivity (50,000 square feet per day)
I = hydraulic gradient (6E-05 ft/ft)
b = aquifer thickness (200 feet)
$\varphi_e$ = effective porosity (0.3)

The resulting estimate of the flow velocity in the Upper Floridan aquifer is 0.05 feet per day. Groundwater traveling at this velocity would require about 300 years to traverse 1 mile.

As such, any hypothetical exposure scenario that involves significant travel in the Upper Floridan aquifer, illustrated as Pathway B in Figure 23, can be dismissed because the time required for significant lateral travel would constitute many half-lives for the radionuclides of interest (Table 1). Significant lateral travel is more likely to take place in the Boulder Zone under the gradient induced by injection, as modeled in the radial transport model described in Section 2.1 of this response. Therefore, the postulated bounding exposure scenario is the extraction and use of water from directly above a hypothetical failure of the middle confining unit after injection and flow through the Boulder Zone, illustrated as Pathway A in Figure 23.

3.1.4. Mechanical Well Failure

The failure of injection well packings and joints after closure and abandonment, with the assumption that the failed wells may become conduits connecting the liquid effluent plume within the Boulder Zone to the Upper Floridan aquifer, thereby resulting in the use of contaminated water at the surface, was investigated for inclusion in the liquid effluent pathway analysis.

Mechanical well failure can typically result from:

- The development of a hole in the final casing or injection tubing
- The development of a fluid leak at the packer that seals the annular space between the final casing and the injection tubing
- A failure in the cement seal at the base of the final casing

The development of a hole in the final casing of an injection well is not common but when it does occur, it typically occurs during casing installation. Data obtained from Florida Department of Environmental Protection (FDEP) records and institutional knowledge were used to identify Class I injection wells in Florida that have had a mechanical well failure. FDEP records revealed that three Class I injection wells in Florida have or have had a hole in the final casing. In each case, the hole was identified during pressure testing. A hole was identified in the final casing of Boynton Beach IW-1 following installation of the casing and prior to placing the well into service. The hole was successfully patched prior to installing the injection tubing inside the final casing. A tear in the final casing of IW-2 at Miami-Dade Water and Sewer Department South District Wastewater Treatment Plant and IW-5 at the East Central Regional Water Reclamation Facility have also been identified. In both cases, the casing tear was located near the base of the Boulder Zone primary confining unit, and therefore, did not threaten a USDW. Therefore, no repair was performed to eliminate the tear in casing.

Review of FDEP records also revealed that 3 of approximately 188 Class I injection wells in Florida have developed a leak at the packer that seals the annular space between the final casing and the injection tubing. In each case, the leak resulted in annular fluid leaking from the annular space into the injection zone. The leak at the packer of each of the facilities (Lee County North IW-1, Martin County North IW-2, and Zemel Road Landfill IW-1) was subsequently sealed. None of the mechanical failures resulted in injected fluids impacting a USDW, and most involved the development of a hole(s) in steel injection tubings that were ultimately replaced with fiberglass-reinforced plastic injection tubing.

The DIS will be constructed with fiberglass-reinforced plastic injection tubing to prevent the development of corrosion holes in the injection tubing. Additionally, the final casing of each well will undergo pressure testing and video inspection prior to installation of the fiberglass-reinforced plastic injection tubing to demonstrate there are no holes in the final casing. Each injection well will also undergo annular pressure testing after the fiberglass-reinforced plastic injection tubing has been seated into the packer at the base of the final casing to demonstrate the absence of leaks in the final casing, fiberglass-reinforced plastic injection tubing, packer seals, and the annular space. Continuous pressure monitoring of the annular space then allows instantaneous detection of the development of a leak in the final casing, fiberglass-reinforced plastic injection tubing, or packer. These injection well construction standards are mandated by FDEP in Chapter 62-528 of the Florida Administrative Code (F.A.C.).

In the unlikely event that a deep injection well is suspected of having a failure that evidences effluent migration to the Upper Floridan or Biscayne aquifers, it will be removed from service for further investigation. If the deep injection well cannot be repaired, it will be permanently removed from service. Given that the as-designed DIS is configured to provide spare well capacity, the need to install any additional deep injection wells is not anticipated.

3.1.5. Institutional Controls [Question 2]

Improper plugging and abandonment of injection wells was investigated for inclusion in the liquid effluent pathway analysis. An assumption was made that the failed wells may become conduits connecting the liquid effluent plume within the Boulder Zone to the Upper Floridan aquifer, thereby resulting in use of or contact with contaminated water at the surface. The DIS proposed for Turkey Point Units 6 & 7 is considered a Class I injection well under Chapter 62-528 of the F.A.C., and, pursuant to this code, will be regulated by FDEP.

Rule 62-528.435(2), F.A.C., requires that any Class I injection well permit issued by FDEP include provisions to ensure that well plugging and abandonment activities would not allow the movement of fluids either into a USDW or from one USDW to another. These requirements include that an underground injection control permit applicant "submit a plan for plugging and abandonment, which shall address post-closure monitoring of the injection operation." Requirements for post-closure monitoring are addressed in Rule 62-528.425(1)(k), F.A.C. The post-closure requirements include monitoring the attenuation of any pressure effects and for water quality changes caused by the underground injection operation both in the injection zone and in overlying aquifers. The FDEP requirements also include identifying well(s) to be used for post-closure monitoring, parameters to be monitored, sampling frequency, proposed duration of post-closure monitoring, and total estimated cost of post-closure monitoring.

FPL submitted, and FDEP approved, a plugging and abandonment plan that includes proposed post-closure monitoring as part of the permit authorizing the construction and operation of the first Class I injection well system for Turkey Point Units 6 & 7. The plugging and abandonment plan submitted to FDEP includes 2 years of monitoring of the associated dual-zone monitor well (DZMW-1) following plugging and abandonment of deep injection well number 1 (DIW-1). The proposed post-closure monitoring plan consists of continued monthly sampling of both monitoring zones of DZMW-1 for the same water quality parameters that were required for DZMW-1 during operation of DIW-1.

Post-closure monitoring would begin upon completion of plugging and abandoning DIW-1 with neat cement and would continue for 2 years. If after the 2 years of post-closure monitoring of DZMW-1 there is no indication of fluid migration associated with DIW-1, a request to cease monitoring and plug and abandon DZMW-1 will be submitted to FDEP for consideration. The request will include a summary of the post-closure monitoring data. FDEP would review this information and approve the DZMW-1 plugging and abandonment if FDEP's review confirms no fluid migration has occurred. If the post-closure monitoring were to indicate that fluid migration associated with DIW-1 were occurring, it is anticipated that continued post-closure monitoring or remedial action would be required. A similar plugging and abandonment plan would need to be reviewed and approved by FDEP for the remainder of the wells installed as part of the DIS.

The plugging and abandonment of the deep injection wells, plugging and abandonment of the associated dual-zone monitor wells, and the associated post-closure monitoring will ensure that current and future groundwater use in the vicinity of the plant is not impacted. This is because the 2-year period of monitoring after successful plugging and abandonment will confirm that the injected fluids are not migrating out of the injection zone. Moreover, the plugging of the injection wells with neat cement eliminates the possibility of injected fluid movement because all pathways for fluid movement through the injection well are sealed by cement. In addition, the plugging and abandonment process will be overseen by FDEP until monitoring information confirms conclusively that no fluid migration has occurred.

### 3.1.6. Land/Water Use/Ownership in Areas Beyond the Turkey Point Property Boundary

To identify opportunities where members of the public could potentially be exposed to injectate at points beyond the Property Boundary, an examination of current and projected land use/ownership and groundwater use in the vicinity of Turkey Point was conducted. This examination provides the rationale for both eliminating, if possible, scenarios from further consideration and for selecting the associated member-of-the-public locations and exposure pathways (e.g., ingestion, irrigation) for those scenarios that are retained. Figure 22 depicts the available information related to current land ownership and water supply well location and type. For reference, the maximum areal extent in which a tritium activity concentration at or above 37,000 pCi/L derived activity concentration might exist is also depicted. A description of the current and future land/water use is provided in the paragraphs below. This information will be verified during the annual land use census required by the Turkey Point Units 6 & 7 ODCM. Changes to the liquid effluent pathway analysis as a result of the land use census will be incorporated in an ODCM and/or ODCM-implementing procedure revision.

#### 3.1.6.1. Current Land Use/Ownership

The land parcels immediately adjacent to the west of the Property Area (Figure 22) are within an area of agricultural use that is owned predominantly by FPL, Miami-Dade County, South Florida Water Management District (SFWMD), and other private entities. Land parcels owned by private entities are within an area of agricultural use, and only a few houses are located on these parcels to the west. The land parcels immediately adjacent to and north of the Property Area are categorized as parks and recreation land use, environmentally protected parks land use, undeveloped land, or agriculture use. FPL, SFWMD, and Miami-Dade County are the predominant land owners in the region. There are land parcels owned by private entities and members of the public, but these parcels are again within areas classified non-residential land use categories only.

Within the city limits of Homestead, the only permitted uses for land parcels designated for agriculture include agriculture and related uses supportive of local agricultural production and residential use not to exceed one dwelling unit per 5 gross acres (Reference 18). Therefore this designation encompasses any land devoted to subsistence farming. However, based upon a review of current aerial imagery, there does not appear to be any subsistence farming taking place on any of the parcels designated for agriculture within the city limits of Homestead in the vicinity of Turkey Point.

#### 3.1.6.2. Projected Land Use/Ownership

Miami-Dade County has adopted a future land use plan that discourages urban sprawl and instead sets forth a smart growth plan that encourages growth within the county's previously determined Urban Development Boundary and Urban Expansion Area. The boundaries of both are north and northwest of the Property Area. This allows the county to provide public services within optimal levels for the protection of the South Miami-Dade Watershed located between Biscayne Bay and the Everglades National Park (References 19 and 20).

It is the intent and objective of the Comprehensive Development Master Plan (CDMP) for Miami-Dade County to protect and preserve the biological and hydrological functions of the lands categorized as future wetlands as identified in the land use element of the plan. Future impacts to the biological functions of publicly and privately owned wetlands are to be mitigated. All privately owned wetlands identified by the South Florida Regional Planning Council as Natural Resources of Regional Significance and wetlands on federal, state, or county land acquisition lists are to be given a high priority for public acquisition. Under the plan, publicly acquired wetlands are to be restored and managed for their natural resource, habitat, and hydrologic values (Reference 19). Figure 22 depicts the area of planned property acquisitions.

According to the Miami-Dade County CDMP, the majority of the land west of the Property Area will have a land use category of Environmental Protection, a non-residential use category (Reference 19). Two parcels of land located west of the Property Area (one south of Homestead and another between U.S. Highway 1 and Card Sound Road) and one parcel of land northwest of the Property Area (west of Biscayne Bay Park) will have a land use category of Open Land, also a non-residential land category (Reference 19).

According to the Future Land Use Map for Homestead, the closest parcels of land to the Property Area are designated as either a Planned Regional Activity Center or for agriculture (AU) (Reference 18). A Planned Regional Activity Center is defined as a flexible, mixed-use designation available to developments of regional impact within the city. It can include any mixture of the land use designations defined in approved development orders and integrated into a coordinated and self-contained master plan of development for the designated area as approved pursuant to Chapter 380, Florida Statutes, and amended from time to time. Potential residential uses include single-family (average density 4.5 units per acre), townhouse (average density 10 units per acre), and multi-family (average density 20 units per acre) development areas. The average density of all residential parcels in any Planned Regional Activity center project area cannot exceed 10 units per gross acre. Non-residential uses include light industrial and office uses, conservation uses, hotels and motels, recreational facilities, schools and other public facilities and utilities, country club and related facilities, sports stadiums and related facilities, and motorsports parks and related facilities. Land designated as AU is limited to agriculture and related uses supportive of local-agricultural production and residential use not to exceed one dwelling unit per 5 gross acres. This land use designation will be implemented through the AU zoning district in the city's land development code.

According to the future land use map for Florida City, the closest parcels of land to the Property Area are designated as commercial and open land and lie outside the permitted urban development boundary for Miami-Dade County. They, therefore, are not to be developed for any residential use (Reference 21). Furthermore, the land parcels both north and west of the Property Area that are outside of the city limits of Homestead and Florida City have been acquired or are planned for acquisition by state or federal agencies for proposed Comprehensive Everglades Restoration Plan (CERP) projects, specifically the C-111 Spreader Canal project and the Biscayne Bay Coastal Wetlands project (Reference 19).

Finally, to further discourage urban sprawl, the Miami-Dade County has adopted policies mandating that new water supply or wastewater collection lines not be extended to provide service to land within areas designated agriculture, open land, or environmental protection on the future land use map. New water or wastewater lines to serve land within these areas are to be approved or permitted only where the absence of the facility would result in an imminent threat to public health or safety. The use of onsite facilities (e.g., wells) are to be given priority consideration. In all cases, facilities are to be sized as required to only service the area where the imminent threat exists to avoid facilitating additional urban development in the area. This policy is not intended to preempt federal, state, or local long-range planning or the development of facilities to serve areas within the urban development boundary or urban expansion area. Public health and safety determinations are to be made in accordance with Chapter 24 (Environmental Protection) and Section 2-103.20, et seq., (Water Supply for Fire Suppression) of the Code of Miami-Dade County (Reference 20).

#### 3.1.6.3. Current Water Use

Figure 22 depicts current permitted wells in the vicinity of Turkey Point. According to the SFWMD (Reference 22), Miami-Dade County has 22 well fields designated for public water service. The closest well field to the Turkey Point Unit 6 & 7 site is the Newton well field, with two pumps located within the city limits of Homestead (approximately 7 miles from the Turkey Point Units 6 & 7 site) (Reference 22). All other well fields are located more than 7 miles from the Turkey Point Units 6 & 7 site. The primary drinking water source for all of Miami-Dade County is the Biscayne aquifer. According to the Miami-Dade County 20 Year Water Use Permit, Exhibit 27D, monitoring wells have been placed along the 2008 USGS salt front line to monitor the Biscayne aquifer for saltwater intrusion (Reference 22). These monitoring wells are depicted as water supply wells on Figure 22.

Current users of the Upper Floridan aquifer within the vicinity of the Turkey Point Units 6 & 7 site include Turkey Point Unit 5 (cooling system makeup water), Card Sound Golf Club (irrigation use), the Ocean Reef Club (irrigation use), and the FKAA (drinking water) (Reference 22). Ocean Reef Club is the only Upper Floridan aquifer user beyond the Property Area depicted in Figure 22. Table 5 summarizes current water use in Miami-Dade County from all sources (Reference 22).

#### 3.1.6.4. Future Water Use

Miami-Dade County has policies within their CDMP that are designed to protect the integrity of groundwater within well field protection areas by strict adherence to the well field protection ordinances, rigorous enforcement of sanitary sewer requirements, hazardous waste disposal prohibitions, land use restrictions, and other applicable regulations and by supporting system improvements that are designed to protect or enhance the raw water supply (Reference 20).

The CDMP also states that individual potable water supplies, including private wells, are to be considered interim facilities to be utilized only where no alternative public water supply is available and land use and water resources are suitable for an interim water supply. Such interim water supply systems are to be phased out as service becomes available from a municipal or county supply.

Wherever the use of existing private wells, interim wastewater treatment plants, or septic tanks pose a threat to public health or the environmental integrity of Miami-Dade County, the county is to assert its authority to create a special taxing district to finance connections to the public water supply or to the public sewer system, thereby continuing to discourage any private wells for drinking water and private waste water disposal (Reference 20).

Miami-Dade County is to continue to use, expand, and pursue the development of new potable water well fields and alternative water supplies to meet the county's existing and future water supply needs. After 2013, Miami-Dade County is to meet all water supply demands associated with new growth from alternative water supply sources, which may include: withdrawals from the Upper Floridan aquifer, implementation of water conservation methods, and development of reclaimed and wastewater reuse strategies (Reference 20).

Florida City plans to build a reverse osmosis (RO) plant/brine treatment plant that will increase capacity by 5 MGD starting in 2020 to offset the population growth within the service area (Reference 23). Homestead has opted to increase bulk water purchases from Miami-Dade Water and Sewer Department rather than adding any additional capacity (Reference 23). Miami-Dade Water and Sewer Department plans to build the South Miami Heights well field and water treatment plant by 2014. These facilities are approximately 10.5 miles from the Turkey Point Units 6 & 7 site. This new South Miami Heights plant will treat brackish water from the Upper Floridan aquifer to provide a proposed 17.45 MGD in additional drinking water capacity between 2020 and 2030. The department also plans to complete phases 2 and 3 of the Hialeah Floridan aquifer RO water treatment plant (located approximately 30 miles from the Turkey Point Unit 6 & 7 site) by 2026, which will add 5 MGD (phase 2) and 2.5 MGD (phase 3) in capacity to the existing facility completed in 2012 (Reference 23). However, none of these planned additional municipal water supply facilities that are intended to use brackish and/or water from the Upper Floridan aquifer will be located near the Turkey Point Units 6 & 7 site.

### 3.1.6.5. Summary of Current and Projected Land/Water Use in the Area of Turkey Point and Beyond Property and Members-of-the-Public Identification

The following paragraphs summarize current and projected land/water use in the area of Turkey Point based on data obtained from several sources, including SFWMD, county, and local municipal planning documents (References 18 through 23), and discuss the consequential implications with regard to the identification of the members of the public.

The land parcels immediately adjacent to the west of the Property Area consist of agriculture land that is owned predominantly by FPL, Miami-Dade County, and SFWMD as well as other private entities or individuals. Land parcels owned by private entities or individuals are within an area of agricultural use, and based on aerial photography, only a few houses are located on these parcels to the west. The land parcels immediately adjacent to the north of the Property Area are categorized as parks and recreation land use, environmentally protected parks land use, undeveloped land, or agriculture use. FPL, SFWMD, and Miami-Dade County are the predominant land owners in this area. There are land parcels owned by private entities and individuals, but these parcels are also designated for non-residential use. Based on current land use records and aerial photography, no large scale or individual subsistence farming is currently occurring near Turkey Point. Current land use near Turkey Point does not include large-scale farming or livestock raising that could potentially impact the population through the ingestion of food products.

Future land use near Turkey Point will be influenced by planning and policies enacted by Miami-Dade County as well as state and federal agencies. Areas designated as resources of regional significance and wetlands on federal, state, or county land acquisition lists have been given a high priority for public acquisition. Additionally, lands may be acquired as part of CERP projects in the area. Urban sprawl is to be discouraged by not providing new water supply or wastewater collection service to land within areas designated Agriculture, Open Land, or Environmental Protection. Potentially, all land near Turkey Point is to be removed from private ownership and designated as publicly protected land during the operational lifetime of Turkey Point Units 6 & 7. More importantly, the proposed land use will not induce large-scale farming or livestock raising that could potentially impact the population through the ingestion of food products.

Current water use indicates that there are no current public users of any groundwater in the immediate vicinity of the Property Area. There are only three current users of the Upper Floridan aquifer within Miami-Dade County, all of whom are located beyond the maximum extent of the 37,000 pCi/L derived tritium activity concentration contours. Future water use policy mandates that individual potable water supplies, including private wells, are to be considered interim facilities to be utilized only where no alternative public water supply is available and land use and water resources are suitable for an interim water supply. Such interim water supply systems are to be phased out as service becomes available from municipal or county supplies.

Miami-Dade County future water use planning includes development of new potable water well fields and alternative water supplies to meet the county's existing and future water supply needs. After 2013, Miami-Dade County will meet all water supply demands associated with new growth from alternative water supply sources, which may include withdrawals from the Upper Floridan aquifer. However, the planned points of withdrawal for these potential additional sources of water are located 10 miles or more from the Turkey Point Units 6 & 7 site.

Current and future land and water use impacts the selection of members of the public/populations that could potentially be exposed to the DIS effluent. These populations could be impacted through the use of groundwater and through the ingestion of animals and crops exposed to this same groundwater. Current and future land use in the area would indicate that large-scale farming or livestock production is not expected. Although several municipalities may in the future utilize additional groundwater resources such as water from the Upper Floridan aquifer, these potential well fields would be located well beyond the maximum extent of the 37,000 pCi/L derived tritium activity concentration contours. Based on current and projected future land and water use policy and trends as described above, population exposure to effluent is not anticipated.

### 3.2. Exposure Pathway Modes for Liquid Effluent Pathway Analysis

Two operating modes—normal operation and off-normal operation—and a special case—inadvertent intrusion—are considered for purposes of the liquid effluent pathway analysis.

<u>Normal Operation</u> – Operation within specified operational limits and conditions. This condition assumes that the DIS and subsurface hydrogeological units operate as designed or expected, i.e., with no system failures such as deep injection well seal failure or subsurface confining unit fracture/failure.

<u>Off-Normal Operation</u> – An operational process beyond specified operational limits or conditions that, while not expected, may occur during the operating lifetime of a facility, e.g., deep injection well seal failure or subsurface confining unit fracture/failure.

<u>Inadvertent Intrusion</u> – This is a special case mode whereby, while highly unexpected, a member of the public is unknowingly exposed to injectate while otherwise engaging in normal activities.

### 3.3. Member-of-the-Public Location Selection Process and Bases

RG 1.109 provides guidance for the determination of doses to members of the public as a result of routine releases of reactor effluents. Specifically, RG 1.109 provides guidance related to the selection of member-of-the-public locations. Per RG 1.109, the point of dose evaluation for the liquid effluent pathway analysis is to be the location of the highest offsite dose. It is evaluated:

- "At a location that is anticipated to be occupied during the operating lifetime of the plant, or
- With respect to such potential land and water usage and food pathways as could actually exist during the term of plant operation."

With regard to the latter evaluation consideration, RG 1.109 states:

> "*...the applicant may take into account any real phenomena or actual exposure conditions. Such conditions could include actual values for agricultural productivity, dietary habits, residence times, dose attenuation by structures, measured environmental transport factors (such as bioaccumulation factors), or similar values actually determined for a specific site.*"

The above guidance is applied first to identify locations in unrestricted areas beyond the Turkey Point Units 6 & 7 site where liquid effluent pathway exposure to a member of the public might occur. The dose delivered to each identified member of the public is estimated through the application of the MEI approach regarding lifestyle and dietary habits as implemented in the NRC-endorsed computer program LADTAP II.

The locations at which exposure to treated liquid radioactive injectate disposed of through deep well injection may potentially occur have been assigned to three areas based on their placement relative to Turkey Point Units 6 & 7. These areas, which are depicted in Figure 21, are defined as follows:

Plant Area – This area includes the location of Turkey Point Units 6 & 7 and includes the DIS. No current or future member of the public or populations have access to effluent at this location. Plant workers, however, may have exposure to effluent.

Property Area – This area includes all FPL-owned property between the Plant Area and the Turkey Point Property Boundary. No current or future member of the public or populations have access to effluent at this location. Plant workers, however, may have exposure to effluent.

Beyond Property Area – This area includes the area beyond the Turkey Point Property Boundary. Members of the public and populations that are part of the general public may access effluent at these locations. The land ownership in this area includes private, government, and significant FPL ownership (Figure 22).

## 3.4. Liquid Effluent Pathway Screening Analysis

### 3.4.1. Scenario Identification

An initial liquid effluent pathway screening analysis was conducted to identify potential scenarios under which members of the public could possibly be exposed to the liquid effluent. The scenarios are categorized by location (Plant Area, Property Area, Beyond Property Area) and mode (normal, off-normal, inadvertent intrusion). An analysis was then performed to determine if the postulated scenario will be retained for detailed liquid effluent pathway analysis or, alternatively, will be eliminated from further consideration. This screening analysis is described in the subsections below.

#### 3.4.1.1. Plant Area

##### 3.4.1.1.1. Normal Operation

A postulated scenario was assumed in which a plant worker may become exposed to effluent during normal operations mode. The normal operation mode for purposes of potential member-of-the-public exposure scenario determination assumes that no system failures such as injection well failure or subsurface loss of confinement occur within the bounds of the Plant Area or elsewhere. As detailed in Section 3.1.2 of this response, as part of the normal operation of the DIS, there is expected to be some limited vertical migration of the effluent from the Boulder Zone into the middle confining unit, primarily as a result of injection pressure and buoyancy. However, based on the vertical transport modeling results discussed in Section 2.2.5 of this response, any upward migration of effluent that might occur is expected to be contained below a depth of 2600 feet, or approximately 300 feet into the middle confining unit, at the end of the 100-year simulation. Given that the top of the middle confining unit is at approximately 1200 feet bgs, the plume will have to vertically migrate an additional 1000 feet or more to reach the Upper Floridan aquifer. The time to transit this additional distance and reach the Upper Floridan aquifer is expected to be greater than 100 years under this normal operation scenario (i.e., no unanticipated vertical flow conduit is encountered in the middle confining unit), by which time radionuclide concentrations are expected to have fallen to non-consequential levels even if only radioactive decay is taken into consideration. Because the Upper Floridan aquifer is, therefore, not anticipated to be impacted, no member-of-the-public exposure pathway is expected, and this scenario is not retained for further liquid effluent pathway analysis.

#### 3.4.1.1.2. Off-Normal Operation

Five postulated scenarios were screened in which an off-normal event occurs within the plant area. The first three postulated scenarios involve scenarios in which a plant worker is exposed as a result of an off-normal event with the exposure location occurring within the Plant Area, as follows:

- Deep injection well failure at site
- Worker exposure at leaking pipe
- Worker exposure to Biscayne aquifer

The remaining two postulated scenarios involve exposure to a member of the public as a result of an off-normal event within the Plant Area where the injectate release travels to a location within the Property Area and Beyond Property Area, respectively, as follows:

- Middle confining unit failure and injectate travel to the Turkey Point Unit 5 Upper Floridan aquifer water supply wells
- Middle confining unit failure and injectate travel to the Beyond Property Area.

Each scenario along with the associated screening analysis is detailed below.

Deep Injection Well Failure at Site. This scenario involves a subsurface mechanical failure of one or more deep injection wells that is undetected by plant operators, resulting in the injection of effluent into the Upper Floridan or Biscayne aquifers. This scenario is not considered feasible for the following reasons:

- The construction materials, installation, and testing for the deep injection wells are both rigorous and thorough (see response to eRAI 6985 Question No. 5).
- Pressure and flow into the deep injection wells are continuously monitored for fluctuations, which could indicate a well failure.
- The operational history of deep injection wells in Florida indicates such a failure is unlikely as discussed in Section 3.1.4 of this response.

Worker Exposure at Leaking Pipe. This postulated scenario involves a leak in the deep well injection piping whereby a plant worker is exposed to the effluent from the leak. A section of the deep injection well piping is anticipated to be located above grade. There is a possibility that a temporary leak could occur in that piping, resulting in a localized release of effluent. However, any consequential plant worker exposure is suitably controlled through the appropriate implementation of the plant's occupational radiation control program as described in FSAR Appendix 12AA in applying engineering controls, ALARA practices, and other exposure avoidance/reduction measures to maintain each radiation worker's resultant dose below the applicable annual occupational limit of 5 rem. Additionally, since FPL maintains positive access control of the Plant Area, there is no potential for member-of-the-public exposure. Therefore, this scenario is not retained for further liquid effluent pathway analysis.

Worker Exposure to Biscayne Aquifer. This exposure pathway is a worker at the site who may be exposed to effluent from the Biscayne aquifer during any type of earth-moving work (e.g., trenching) that may be conducted over the operational lifetime of Turkey Point Units 6 & 7. Normal operation assumes some limited vertical migration of effluent into the middle confining unit above the Boulder Zone, but as described in Section 3.4.1.1.1 of this response, it will be contained well below the top of the middle confining unit over the plant's operational lifetime and beyond. This scenario, however, assumes vertical migration of effluent through both the middle and the intermediate confining units into the Biscayne aquifer and discounts the dispersion and dilution that will occur in the intervening Upper Floridan aquifer. Therefore, this scenario is not considered feasible and is not retained for further liquid effluent pathway analysis.

Middle Confining Unit Failure and Injectate Travel to the Turkey Point Unit 5 Upper Floridan Aquifer Water Supply Wells. This scenario assumes travel of injectate through a fracture in the middle confining unit and then to one or more of the Unit 5 water supply wells, which are screened in the Upper Floridan aquifer. As discussed above, geological, seismological, and geophysical investigations performed for the site (FSAR Subsection 2.5.3) as well as geologic results from EW-1 indicate there are no known or suspected faults or other geological features at the Turkey Point Units 6 & 7 site that would allow vertical fluid movement through the middle confining layer. As also discussed above, monitoring of Upper Floridan aquifer and dual-zone monitoring well conditions is to be conducted to alert plant operators of possible injectate incursions to the Upper Floridan aquifer. Response actions are to include, as appropriate, confirmatory Upper Floridan aquifer/dual-zone well monitoring, removal of affected DIS components from service, and other actions protective of members of the public and plant workers. The DIS off-normal operations prompt detection and mitigative strategies program will be part of the Turkey Point Units 6 & 7 ODCM/REMP to be made available for inspection prior to fuel load (FSAR Table 13.4-201).

This scenario, therefore, is not considered feasible and is not retained for further liquid effluent pathway analysis.

Middle Confining Unit Failure and Travel to Beyond Property Area. This scenario postulates a failure of the middle confining unit within the Plant Area with consequential member-of-the-public exposure to injectate in the Beyond Property

Area. Geological failures resulting in a failure of the middle confining unit were first considered. Geological, seismological, and geophysical investigations performed for the site (FSAR Subsection 2.5.3) as well as geologic results from EW-1 indicate there are no known or suspected faults or other geological features at the Turkey Point Units 6 & 7 site that would allow vertical fluid movement through the middle confining unit. The borehole-compensated sonic geophysical log performed on the interval from 1475 to 3230 feet bpl of EW-1 was reviewed for evidence of a fracture(s) within the logged interval. Based on this data, no features were observed in EW-1 suggesting that the confining strata above the Boulder Zone has been compromised by vertical fractures or other features.

Although not evidenced through the geophysical investigation, a failure in the middle confining unit (lower unit) above the Boulder Zone within the bounds of the Plant Area, should one occur, may lead to a U-Tube type scenario where Boulder Zone water containing effluent travels vertically through an improperly abandoned well, naturally formed conduit, etc., and was, therefore, postulated. This effluent could conceivably travel laterally through the Upper Floridan aquifer to Beyond Property Area locations to potentially be accessed by members of the public/populations for use (e.g., in plant nurseries).

However, the potential radiological impacts of this scenario are bounded by those of the Beyond Property Area–Off-Normal Operation middle confining unit failure-related scenario described below (Section 3.4.1.3.2 of this response). Specifically, in being transported to a potential Beyond Property Area member-of-the-public receptor location, the effluent would undergo dilution and dispersion in the Upper Floridan aquifer, and as discussed in Section 3.1.3 of this response, the gradient in the Upper Floridan aquifer would tend to impede the flow of the effluent plume inland toward the Beyond Property Area location.

Further, as part of the prompt detection and mitigative strategies program prepared for DIS off-normal operations, monitoring of the Upper Floridan aquifer and dual-zone monitoring well conditions are to be conducted to alert plant operators of possible effluent incursions into the Upper Floridan aquifer. Response actions are to include, as appropriate, confirmatory Upper Floridan aquifer/dual-zone well monitoring, removal of affected DIS components from service, and other actions protective of members of the public and plant workers. The DIS off-normal operations prompt detection and mitigative strategies program will be part of the Turkey Point Units 6 & 7 ODCM/Radiological Environmental Monitoring Program (REMP) to be made available for inspection prior to fuel load (FSAR Table 13.4-201). This scenario is, therefore, not considered a feasible off-normal operation scenario and is not retained for further liquid effluent pathway analysis.

3.4.1.1.3. Inadvertent Intrusion

No inadvertent intrusion scenarios relating to exposure and subsequent dose from the operation of the DIS have been identified at the Plant Area since FPL maintains positive access control to the Plant Area.

3.4.1.2. Property Area

3.4.1.2.1. Normal Operation

As described in the Plant Area–Normal Operation discussion in Section 3.4.1.1.1 of this response, the normal operation mode for purposes of the potential member-of-the-public exposure scenario assumes that no such system failures, e.g., injection well failure or subsurface loss of confinement, occur within the bounds of the Property Area. As part of the normal operation of the DIS, there is expected to be some limited vertical migration of the effluent from the Boulder Zone into the middle confining unit. However, as further described in Section 3.4.1.1.1 of this response, the Plant Area–Normal Operation scenario, the Upper Floridan aquifer is not anticipated to be impacted, no member-of-the-public exposure pathway is expected, and therefore, this scenario is not retained for further liquid effluent pathway analysis.

3.4.1.2.2. Off-Normal Operation

Two postulated scenarios were screened in which an off-normal event occurs within the Property Area. The postulations involve scenarios where a member-of-the public is exposed as a result of an off-normal event and exposure occurs beyond the Plant Area, as follows:

Middle Confining Unit Failure and Travel to Beyond Property Area. As previously discussed in Section 3.4.1.1.2 of this response, a failure in the middle confining unit above the Boulder Zone within the bounds of the Property Area, should one occur, could create a U-Tube type scenario where Boulder Zone water could be introduced into the Upper Floridan aquifer to potentially be accessed by Beyond Property Area members of the public/populations for use. However, as also discussed in Section 3.4.1.1.2 of this response, such a failure within the Property Area is unlikely, the effluent would undergo dilution and dispersion in the Upper Floridan aquifer in being transported to a potential Beyond Property Area member-of-the-public receptor location, and the gradient in the Upper Floridan aquifer would tend to impede the flow of the effluent plume inland toward the Beyond Property Area location. Therefore, this scenario is not considered a feasible off-normal operation scenario and is not retained for further liquid effluent pathway analysis.

Migration Through the Middle and Intermediate Confining Units. The potential exposure pathway is a member of the public who may be exposed to surface water that is in connection with the Biscayne aquifer. This scenario is similar to the Worker Exposure to Biscayne aquifer scenario discussed above in Section 3.4.1.1.2 of this response as it also assumes the vertical migration of effluent through both the middle and the intermediate confining units into the Biscayne aquifer. However, as further described for the Plant Area–Normal Operation scenario in Section 3.4.1.1.2 of this response, any upward migration of effluent is expected to be contained well below the top of the middle confining unit over the plant's operational lifetime and beyond and thus, it is not anticipated that any radionuclides will travel through the middle confining unit absent some failure in that stratum. This scenario, however, requires the postulation of a failure in the intermediate confining unit as well as the middle confining unit in order for the effluent to enter the Biscayne aquifer and discounts the dilution and dispersion that will occur in the intervening Upper Floridan aquifer. Therefore, this scenario is not considered feasible and is not retained for further liquid effluent pathway analysis.

3.4.1.2.3. Inadvertent Intrusion

No inadvertent intrusion scenarios relating to exposure and subsequent dose from the operation of the DIS have been identified at the Property Area since FPL maintains positive access control to the Property Area.

3.4.1.3. Beyond Property Area

3.4.1.3.1. Normal Operation

As described in the Plant Area–Normal Operation discussion in Section 3.4.1.1.1 of this response, the normal operation mode for purposes of the potential member-of-the-public exposure scenario assumes no system failures, e.g., injection well failure or subsurface loss of confinement, occur beyond the Property Area. As part of the normal operation of the DIS, there is expected to be some limited vertical migration of the effluent from the Boulder Zone into the middle confining unit. However, as further described for the Plant Area–Normal Operation scenario in Section 3.4.1.1.1 of this response, because the Upper Floridan aquifer is not anticipated to be impacted, no member-of-the-public exposure pathway is expected, and therefore this scenario is not retained for further liquid effluent pathway analysis.

3.4.1.3.2. Off-Normal Operation

Two postulated scenarios were screened in which an off-normal event occurs in the Beyond Property Area. The postulated scenarios involve instances where a member of the public is exposed as a result of an off-normal event, with exposure occurring in the Beyond Property Area, as follows:

Migration Through the Middle and Intermediate Confining Units. The potential exposure pathway is a member of the public who may become exposed to effluent that is in connection with the Biscayne aquifer. This scenario is similar to the Plant Area–Off-Normal Worker Exposure to Biscayne aquifer scenario discussed in Section 3.4.1.1.2 of this response as it also assumes the vertical migration of effluent through both the middle and the intermediate confining units into the Biscayne aquifer. This aquifer could then potentially be accessed by a member of the public or population for potable water use, farming, etc. However, as further described in Section 3.4.1.1.1 of this response, the Plant Area–Normal Operation scenario, any upward migration of effluent is expected to be contained well below the top of the middle confining unit over the plant's operational lifetime and beyond, and, thus, it is not anticipated that any radionuclides will travel through the middle confining unit absent some failure in that stratum. This scenario, however, requires the postulation of a failure in the intermediate confining unit as well as the middle confining unit in order for the effluent to enter the Biscayne aquifer and discounts the dilution and dispersion that will occur in the intervening Upper Floridan aquifer. Therefore, this scenario is not considered feasible and is not retained for further liquid effluent pathway analysis.

Middle Confining Unit Failure. A failure in the middle confining unit above the Boulder Zone could create a U-Tube type scenario where Boulder Zone injectate containing effluent travels vertically up into the Upper Floridan aquifer through an improperly abandoned well, naturally formed conduit, etc., at a location where it could potentially be accessed by a member of the public/populations for use (e.g., in plant nurseries). This scenario is considered a feasible off-normal scenario and is retained for further liquid effluent pathway analysis.

3.4.1.3.3. Inadvertent Intrusion

A member of the public located at or near the Property Boundary could drill a water supply well directly into the Boulder Zone and use its groundwater for ingestion, irrigation, and livestock. While possible, this scenario is highly improbable given the Boulder Zone's extreme depth, high TDS concentration, and the classification by the FDEP as a Class G-IV aquifer not suitable for potable use and not subject to the minimum groundwater criteria. (See rules 62-520.410 and 62-520.440, F.A.C.). A more plausible scenario is for a member of the public to drill a well into the Upper Floridan aquifer immediately above a failure in the middle confining unit then unknowingly use the contaminated Upper Floridan groundwater for both ingestion and subsistence irrigation. This hypothetical scenario is, therefore, retained for further dose consideration.

### 3.4.2. Summary of Scenarios Retained for Further Liquid Effluent Pathway Analysis

The following postulated scenarios are retained for further screening (member-of-the-public assignment):

- Beyond Property Area–Off-Normal Operation (Middle Confining Unit Failure)
- Beyond Property Area–Inadvertent Intrusion

Table 6 summarizes the scenarios retained for further detailed consideration (as indicated by shading). The members of the public are listed where they have been identified.

## 3.5. Member-of-the-Public Identification, Retained Liquid Effluent Pathway Scenarios, and Selection of Locations for Dose Analyses

A more detailed analysis of the liquid effluent pathway scenarios considered feasible was performed to determine which liquid effluent pathway scenarios (location and mode) potentially constituting exposure to the MEI are to be assigned a member-of-the-public location and used for detailed dose analysis purposes. As part of this analysis, current and projected land and water usage in the vicinity of Turkey Point are taken into consideration in selecting member-of-the-public location(s) at and beyond the Property Boundary and the associated members of the public/populations that may potentially be impacted.

### 3.5.1. Member-of-the-Public Identification

As noted in Section 3.1.6 of this response, potential member-of-the-public exposure is influenced by current land/water use and future land and water use policy and trends. Individual ownership of Beyond Property Area land in the vicinity of Turkey Point is limited; future land use planning would indicate that individual ownership in this area will only decrease. Additionally, there is no current subsistence farming or the raising of livestock in the area; based on future planning and trends, this is expected to remain the case throughout the operational life of Turkey Point Units 6 & 7. There are no current individual users of groundwater from any aquifer either within or within the approximate vicinity of the maximum extent of the 37,000 pCi/L derived tritium activity concentration contour; future water use planning would discourage individual long-term groundwater use in favor of water provided by municipalities drawing on water sources at points significantly beyond the maximum extent of the 37,000 pCi/L derived tritium activity concentration contour.

Although the likelihood of individual land ownership and groundwater use in the vicinity of the Turkey Point Units 6 & 7 site is low, radiological exposure to members of the public as a consequence of underground injection of effluent is a possibility, albeit remote, particularly within an extended timeframe (e.g., 100 years), as influenced by such factors as changes in public policy, climate, or population trends. Therefore, in order to bound this uncertainty, member-of-the-public locations have been selected based on their placement relative to the Property Area. Specific event scenarios potentially involving members of the public sited at these locations have been categorized as follows:

- Credible – Such a scenario may be expected to occur during the operational lifetime of the plant (or beyond)
- Non-Credible – Such a scenario is not likely to occur during the operational lifetime of the plant or beyond; however, it is included to provide a bounding dose for the off-normal event category

Identification of the Member of the Public for the Beyond Property Area Off-Normal Scenario. The only current users of water from the Upper Floridan aquifer in the vicinity of Turkey Point are located at the Ocean Reef Club community, approximately 7.7 miles southeast of the Turkey Point Units 6 & 7 site. Although the current use of this water is for landscape irrigation, potable water use could occur at this location. Therefore, such use by the Ocean Reef Club community is retained as a credible Beyond Property Area member-of-the-public exposure scenario.

As noted previously, there are no members of the public currently residing within or in the near proximity of the maximum extent of the 37,000 pCi/L derived tritium activity concentration contour. The nearest privately owned land parcel to the Property Area, located 2.2 miles from the effluent injection point (Figure 24), constitutes the nearest Beyond Property Area location that could potentially serve as an exposure point for a member of the public. The U-tube or conduit constituting failure of the middle confining unit is assumed to occur beneath this land parcel since as discussed above, the eastward gradient in the Upper Floridan aquifer would cause the effluent introduced by a failure occurring closer to the effluent injection point to flow away from the member-of-the-public's location. The effluent-containing water is then assumed to instantaneously travel to the Upper Floridan aquifer, where it is then available for access by a member of the public. It is assumed that a production well is placed exactly over the middle confining unit failure; dilution in the Upper Floridan aquifer is therefore not considered. Furthermore, no credit is taken for travel time from the Boulder Zone through the middle confining unit to the Upper Floridan aquifer. Therefore, this location has been selected as the location for the non-credible member of the public.

Identification of the Member of the Public for the Inadvertent Intrusion Scenario. As noted above, the nearest privately owned land parcel to the Property Area, located 2.2 miles from the effluent injection point (Figure 24), constitutes the nearest Beyond Property Area location that could potentially serve as an exposure point for a member of the public. A subsistence driller is assumed to drill a well into the Upper Floridan aquifer directly above a conduit in the middle confining unit overlaying the Boulder Zone and withdraw this groundwater for drinking water ingestion, irrigation, and livestock. In addition to exposure through these pathways, it is assumed that the subsistence driller also incurs inhalation, immersion, and deposition exposure during the actual drilling operations. Therefore, the location for this member of the public is the same as the Beyond Property Area–Off-Normal Operation non-credible member of the public.

#### 3.5.2. Retained Liquid Effluent Pathway Scenarios and Selection of Locations for Dose Analysis

Table 7 provides a summary of the scenarios retained for detailed dose analysis purposes, including the location of the members of the public. Figure 24 depicts the location of the members of the public. Specific source terms, methods/pathways of exposure, etc., are summarized in the next section.

- Off-Normal Operation
  - Middle confining unit failure located 2.2 miles from the effluent injection point and member-of-the-public Upper Floridan aquifer use resulting in exposure through drinking water ingestion (non-credible)
  - Middle confining unit failure and individual member-of-the-public Upper Floridan aquifer use at Ocean Reef Club community for drinking water only (credible)
- Inadvertent Intrusion – Member-of-the-public drilling of a well into the Upper Floridan aquifer immediately above a failure in the middle confining unit located 2.2 miles from the effluent injection point then unknowing use of the contaminated Upper Floridan groundwater thereby made available for drinking water ingestion, irrigation, milk animals, and livestock (subsistence driller)

## 4. Dose Analyses

As delineated in Section 3 of this response, three scenarios were moved forward as potential liquid effluent exposure pathways leading to the identification of the MEI and its associated consequential dose. The doses determined for the retained members of the public and associated scenarios are based on the source term, exposure duration, and exposure pathways. The dose analyses are summarized in the following paragraphs.

### 4.1. Beyond Property Area Off-Normal Operation

#### 4.1.1. Middle Confining Unit Failure and Member-of-the-Public Exposure (Credible)

The Ocean Reef Club community, as depicted on Figure 24, is approximately 7.7 miles from the effluent injection point. As summarized in Table 5, this community represents the nearest members of the public in the near vicinity of the Turkey Point Units 6 & 7 site that currently use Upper Floridan aquifer water for any application. While Upper Floridan aquifer water is currently only being used by Ocean Reef Club for irrigation purposes, the most credible off-normal receptor was identified as a member of the public in the Ocean Reef Club community. This scenario assumes the water supply well is directly over the middle confining unit failure and takes no credit for further dilution, resulting in the same radionuclide concentrations in the Upper Floridan aquifer as those observed in the Boulder Zone. Based upon the radial transport model's simulation results, the Boulder Zone groundwater radionuclide activity concentration at this location for all radionuclides of interest is expected to remain at non-consequential levels for the full 100-year simulation duration. Therefore, no dose has been calculated.

#### 4.1.2. Middle Confining Unit Failure and Member-of-the-Public Exposure (Non-Credible)

The nearest privately owned land parcel to the Property Boundary, which is located 2.2 miles from the centroid of the DIS (Figure 24), has been selected as the location for the non-credible member of the public. It is assumed that a production well is directly connected to a conduit or other failure in the middle confining unit occurring at this location such that no mixing occurs in the Upper Floridan aquifer. The member of the public is assumed to use the Upper Floridan aquifer water for ingestion only.

The expected radionuclide activity concentrations are required at this location. Figure 8 presents the tritium, cesium-134, cesium-137 and strontium-90 relative concentration profiles at this location over the 100-year simulation, as calculated by the radial transport model. As discussed in Section 2.1.1.1 of this response, these are the radionuclides which have been retained for fate and transport modeling and subsequent dose analysis. The maximum radionuclide activity concentrations and corresponding times of occurrence following start of plant operation are as follows:

- Tritium: 3.1E04 pCi/L (25 years)
- Cesium-134: 7.7E-03 pCi/L (15 years)
- Cesium-137: 7.6E-01 pCi/L (42 years)
- Strontium-90: 5.6E-04 pCi/L (41 years)

These maximum concentrations are conservatively assumed to occur concurrently and, therefore, are used collectively as the source term for the dose analyses conducted at this location. For these further analyses, a separate LADTAP II run is made for each radionuclide (tritium, strontium-90, cesium-134, and cesium-137) to calculate the dose to an offsite receptor 2.2 miles from the modeled effluent injection point.

For tritium, as an example, the LADTAP II input parameters are as follows:

- Discharge to impoundment per unit = 6230 gpm = 3.40E07 L per day
- Annual release per unit = 1.3E03 Ci per year
- LADTAP II transit (decay) time = 21 years

The annual release per unit is calculated as follows:

- Injectate concentration = 1.0E05 pCi/L, as calculated in Section 2.1.1.1 of this response, Radioactive Source Term Selection
- Annual release = (1.0E05 pCi/L)(3.40E07 L per day)(365 days per year)(Ci/1E12 pCi) = 1.3E03 Ci per year

Note that this annual release value exceeds the corresponding DCD Table 11.2-7 value by a factor of 1.25. This reflects the impact of having determined the plant-specific injectate concentrations on a basis consistent with that used to develop DCD Table 11.2-8, i.e., based upon the release of the average daily discharge for only 292 days per year (Section 2.1.1.1 of this response), while otherwise conservatively assuming that both units operate continuously (i.e., for 365 days per year throughout the life of the plant) and, therefore, continuously release their average daily discharge. It must be emphasized that these are simplifying assumptions made solely for the purposes of performing a conservatively bounding analysis in response to this RAI, and that, in making these assumptions, there is no intent to convey that the plant is expected to actually be operated in a way that is different from the certified design.

LADTAP II uses the transit time parameter to calculate the effective decayed radionuclide activity concentration at the receptor location. To assign transit time values, a two-step approach is necessary. First, as further described above, the radial transport model is used to determine activity concentrations at the receptor location that account for advection, dispersion, buoyancy effects, and chemical processes that include first-order radioactive decay. For tritium, the calculated peak activity concentration at the offsite receptor is 3.1E04 pCi/L based on the injection concentration of 1.0E05 pCi/L and the dilution flow of 6230 gpm per unit.

Second, the LADTAP II transit time input parameter value is determined by calculating the duration that would be required for the as-injected tritium activity concentration of 1.0E05 pCi/L to decay to the peak concentration at the receptor location of 3.1E04 pCi/L as predicted by the radial transport model. This duration, i.e., the transit time value, is solved for using a variation of the general equation for radioactive decay, equation 5:

$$C_{rec} = C_{inj}\, e^{-\lambda t} \qquad \text{Eqn. 5}$$

$$t = [\ln(C_{inj}/C_{rec})][t_{1/2}/\ln(2)]$$

$$t = [\ln(1.0E05/3.1E04)][12.33/0.693]$$

$$t = 21 \text{ years}$$

In this tritium example, $C_{inj}$ and $C_{rec}$ are the tritium activity concentrations at the injection and receptor locations, respectively; λ is the tritium decay constant, defined as ln(2) divided by the tritium half-life, $t_{1/2}$, of 12.33 yr; and t is the decay time, i.e., the value of the LADTAP II transit time input parameter to be solved for.

Based on this and the other required inputs as noted above, LADTAP II calculates the doses to the offsite receptor corresponding to a peak tritium activity concentration of 3.1E04 pCi/L. Source terms, peak activity concentrations, and receptor doses for the other three radionuclides retained for further analysis are similarly calculated.

Table 8 summarizes the resultant doses (for conservatism, a child was considered as the member of the public). The total body dose is lower than the 10 CFR Part 50, Appendix I, annual design objective of 3 mrem per unit. The organ dose (dose to child's liver as maximum organ) is lower than the 10 CFR Part 50, Appendix I, annual limit of 10 mrem per unit. As can be seen, tritium is the dominant dose contributor.

### 4.1.3. Beyond Property Area–Inadvertent Intrusion

The doses associated with the inadvertent intrusion scenario represent a non-credible worst case bounding estimate for annual dose. As previously described, farming and the raising of milk animals and livestock are not currently performed and are not anticipated to be performed in the region adjacent to Turkey Point. However, to present this worst case dose, a subsistence driller is assumed to be exposed through these pathways as well as through effluent ingestion subsequent to the inhalation, immersion, and deposition exposure which occurs during the actual drilling operations. This scenario assumes that a water supply well is installed in the Upper Floridan aquifer directly above the conduit in the middle confining unit at the 2.2 mile location which allows deep well injectate to instantaneously travel to the Upper Floridan aquifer from the Boulder Zone. Therefore, the location as well as the radionuclide concentrations for this member of the public are the same as those for the Beyond Property Area Off-Normal Operation non-credible member of the public, as previously described.

#### 4.1.3.1. Duration of Exposure Bases

A summary of the drilling operation for such a water supply well is provided for insight regarding the exposure pathways, durations, etc., as follows:

- An Upper Floridan aquifer water supply well in Miami-Dade County is typically drilled to a depth of approximately 1500 feet below grade.
- A drilling crew typically consists of three to four individuals who wear standard safety equipment, including hard hats, gloves, safety glasses, and safety shoes; these drill crews typically work a 12-hour day.
- The first 1000 feet of drilling typically utilizes a mud rotary method. This method involves the use of drilling mud which is pumped into the borehole.

The mud is forced upward and carries the drill cuttings, which are then pumped into a slurry pit where they are separated from the mud, which is then re-circulated for continued drilling. This drilling methodology generates very little mist or spray.

- Below a depth of 1000 feet, reverse-air drilling methodology is used. In this application, air is forced down the boring drill pipe and is used to bring drill cuttings to the ground surface, where the cuttings are pumped to the slurry pit and separated (the cuttings at this point are mixed with groundwater assumed to contain effluent). The water is then re-circulated down the borehole. Geophysical logging and packer testing are also typically performed during the pilot borehole installation.
- Once the pilot borehole is completed to 1000 feet using mud rotary methodology, the hole is reamed and casing is installed and cemented in place. The pilot borehole is then completed to approximately 1500 feet using reverse-air methodology. The hole is also then reamed and casing is installed and cemented in place.
- The water supply well is then developed using both pump and air development. The development water is typically containerized, and its disposal is regulated by Miami-Dade County due to its high chloride content.

Based on the above description of pilot borehole installation, well installation, and well development, there is little opportunity for exposure to water, mist, or drill cuttings. However, incidental daily exposure is likely. It is assumed that a worker would be exposed to the radioactive constituents present in the drilling mud and groundwater as a result of inhalation, immersion, and deposition.

The total time duration of exposure is calculated as follows:

- A water supply well in the Upper Floridan aquifer typically requires 75 days to complete. The Upper Floridan aquifer, which is assumed to contain the radionuclides, is not encountered until 1000 feet have been completed (or 66 percent of the 75 days). Therefore, exposure due to drilling is assumed to be for 25 days.
- The time to complete and develop a water supply well in the Upper Floridan aquifer is 20 days. Exposure is assumed to occur during this entire time period.

Therefore, the exposure time for the driller is 45 days total. A 12-hour shift is assumed for each day.

4.1.3.2. Calculation of Doses

Doses to the total body and maximum organ (liver) due to inhalation, air immersion, and deposition acquired during the drilling activity by the member-of-the-public age group receiving the maximum doses are first calculated. These doses were then conservatively combined with the annual doses to the maximum dose age group from ingestion of drinking water and irrigated foods to arrive at total annual doses for the "subsistence driller."

The LADTAP II computer program is used to calculate doses to the member of the public from ingestion of drinking water and milk, meats, and vegetables irrigated with Upper Floridan groundwater. Drilling-related doses to the total body and maximum organ (liver) due to inhalation, immersion, and deposition are determined using the appropriate RG 1.109 methodology, with the exception that immersion-related dose conversion factors are obtained from Federal Guidance Report No. 12 (Reference 25).

In order to determine the inhalation and immersion pathway doses resulting from a driller standing in an evaporating puddle of liquid effluent brought to the surface by the drilling operations, the resultant concentration of radionuclides in the air must first be determined. As RG 1.109 does not provide guidance on establishing airborne activity due to puddle evaporation, an empirical relationship for determining puddle evaporation rates developed by the EPA is used. In all cases, values for the various parameters used in determining the doses due to inhalation, immersion, and deposition are conservatively selected. Finally, for comparison purposes, a comparative surrogate dose was also calculated using drinking water ingestion as a surrogate—that is, the amount of water ingested per day needed to yield double the driller dose for inhalation and immersion was calculated.

The specific steps for calculating the subsistence driller doses are as follows:

1. Driller Air Dose – Calculate airborne activity due to evaporation of puddle. Use this to calculate inhalation and immersion doses.
2. Driller Ground Dose – Calculate deposition doses from puddle.
3. Driller Total Dose – Add inhalation, immersion, and deposition doses to arrive at total doses from drilling.
4. Surrogate Driller Dose – Double the driller doses from Step 3 and consider these as the surrogate driller doses, then calculate the amount of contaminated water needing to be ingested that yield these doses.
5. Subsistence Driller Total Doses – Add the surrogate driller dose to the annual child (maximum dose age group) doses from ingestion of drinking water and irrigated foods to arrive at the total annual doses for the "subsistence driller."

6. Demonstrate that this falls below 10 CFR Part 50, Appendix I, design objectives per reactor of 3 mrem for total body and 10 mrem for any organ.

4.1.3.2.1. Driller Doses from Inhalation and Immersion

The drilling action causes contaminated liquid effluent from the boulder zone to come to the surface and form an evaporating puddle. It is assumed that the puddle evaporates into a fixed volume of air. Wind removes contamination from the air volume. For each radionuclide, the time-dependent concentration in the air volume can be expressed as follows in equation 6:

$$\frac{dC_{air}}{dt} = \frac{Q_{pud}C_{pud} - Q_{air}C_{air}}{V_{air}} \qquad \text{Eqn. 6}$$

where:

$C_{pud}$ = Concentration in puddle (Ci per cubic meter), calculated using the radial transport model based on the operation of two units
$C_{air}$ = Concentration in air (Ci per cubic meter)
$Q_{pud}$ = Evaporation rate from puddle to air volume (cubic meters per second), calculated using EPA guidance in Report EPA 550-B-99-009 (Reference 26)
$Q_{air}$ = Removal rate from air volume (cubic meters per second) due to wind
$V_{air}$ = Volume of air (cubic meters)
t = Time (seconds)

Under equilibrium conditions, there is no change in the concentration in air. Setting equation 6 equal to zero and solving for the air concentration yields the following equation, equation 7.

$$C_{air} = C_{pud}\left(\frac{Q_{pud}}{Q_{air}}\right) \qquad \text{Eqn. 7}$$

It is assumed that the puddle is 1 centimeter deep (Reference 26) and spreads out over an area of 100 square meters. Such a large area is selected because it yields a large evaporation rate.

The evaporation rate is determined from the following empirical formula (Reference 26), equation 8:

$$Q_{pud} = \frac{V_{pud}(WSF)(LFA)(DF)(TCF)}{60 \text{ seconds per minute}} \qquad \text{Eqn. 8}$$

Where:

$V_{pud}$ = Volume of puddle (cubic meters), based on depth of 1 centimeter and area of 100 square meters
WSF = Wind speed factor, based on wind speed
LFA = Liquid factor ambient, based on ambient water temperature of 25°C
DF = Density factor of water, based on ambient water temperature of 25°C
TCF = Temperature correction factor, calculated assuming a conservative puddle temperature of 103°F

In equation 7, $Q_{pud}$ in the numerator and $Q_{air}$ in the denominator are both dependent on wind speed. $Q_{pud}$ is proportional to parameter WSF, which is equal to the wind speed raised to the power of 0.78. Hence, a lower wind speed yields a conservative air concentration as long as it is greater than or equal to 1 meter per second. For a worst-case accident analysis, the EPA stipulates a wind speed of 1.5 meters per second in 10 CFR 68.22. For conservatism, an even more stable wind speed of 1 meter per second is assumed. Furthermore, the extent of the air volume in the lateral and vertical dimensions is assumed to be conservatively small such that the cross-sectional area affected by the wind speed is 1 square meter. The product of the wind speed and the cross-sectional area yields $Q_{air}$ of 1 cubic meter per second.

For each nuclide, the dose to an organ due to air inhalation is calculated as follows, equation 9:

$$D_{inh} = (C_{air})(BR)(t)(DCF_{inh}) \qquad \text{Eqn. 9}$$

Where:

$D_{inh}$ = Inhalation dose (mrem)
BR = Breathing rate of 8000 cubic meters per year for adult/teen and 3700 cubic meters per year for child [RG 1.109, Table E-4]
t = Exposure duration of 1.94E06 seconds (12 hours per day for 45 days)
$DCF_{inh}$ = Inhalation dose conversion factor (mrem/Ci) [RG 1.109, Table E-7]

For each nuclide, the dose to an organ due to immersion in the air is calculated as follows, equation 10:

$$D_{imm} = (C_{air})(t)(DCF_{imm}) \qquad \text{Eqn. 10}$$

Where:

$D_{imm}$ = Immersion dose (mrem)
t = Exposure duration of 1.94E06 seconds (12 hours per day for 45 days)
$DCF_{imm}$ = Immersion dose conversion factor (mrem-cubic meter per Ci per second) (Reference 25)

4.1.3.2.2. Driller Doses from Deposition

For each nuclide, the dose to an organ due to ground deposition is calculated as follows:

$$D_{dep} = (C_{pud})(h_{pud})(t)(DCF_{dep}) \qquad \text{Eqn. 11}$$

Where:

$D_{dep}$ = Deposition dose (mrem)
$h_{pud}$ = Puddle depth (meters), assumed to be 1 centimeter (Reference 26)
t = Exposure duration of 1.94E6 seconds (12 hours per day for 45 days)
$DCF_{dep}$ = Deposition dose conversion factor (mrem-square meters per Ci per second) [RG 1.109, Table E-6]

4.1.3.2.3. Driller Total Dose

The age group that receives the maximum doses is the teen. The resulting doses based on the operation of two units are 0.082 mrem for total body and 0.083 mrem for liver. The doses per unit are 0.041 mrem for total body and 0.041 mrem for liver.

4.1.3.2.4. Comparative Surrogate Driller Doses

For further conservatism, the doses calculated above for the driller based on the operation of two units are doubled to arrive at the comparative surrogate driller doses. The amount of water ingestion needed to yield the resulting two-unit teen surrogate driller doses of 0.16 mrem for total body and 0.17 mrem for liver is approximately 49 L. Based on the drilling duration of 45 days, this corresponds to an average intake of 1.1 L per day. The doses per unit are 0.082 mrem for total body and 0.083 mrem for liver.

4.1.3.2.5. Overall Subsistence Driller Dose

Tables 9, 10, and 11 summarize the resultant doses to the subsistence driller (the maximum dose age group for drilling-related doses is the teen, while for conservatism, a child was considered as the member of the public for purposes of determining the ingestion-related doses). The member of the public's total body and total organ doses are both determined to be lower than the associated 10 CFR Part 50, Appendix I, annual design objectives of 3 mrem and 10 mrem, respectively, for a single unit. Table 12 summarizes the doses for all retained scenarios.

## 4.2. Question 1 and 2 Response Summary

For ease of review, Questions 1 and 2 of NRC RAI 11.02-6 (eRAI 6985) are presented below followed by a summary response with references to the specific sections above where each question is addressed.

### 4.2.1. Question 1

The proposed discharge method for the disposal of treated liquid radioactive waste by injection into the Boulder Zone (about 2800 to 3500 feet below grade) represents a waste management approach that is not practiced by any other nuclear power plant in the U.S. While deep well injection provides the means to isolate liquid radioactive waste over the long-term, complete isolation is not assured because of the potential for human intrusion via drilling into the Boulder Zone, and unknown hydraulic connections between the Lower and Upper Floridan aquifers through the middle confining unit. Thus, the applicant is requested to consider radiological impacts of the disposal method should radioactivity be brought up to the surface by (1) drilling activities undertaken at a location beyond the control of the applicant (licensee) and expose well drillers to radioactive materials, (2) failure of a well casing or packing that could contaminate the Upper Floridan aquifer and expose water users to radioactive materials, and (3) upward migration of the injectate from the Boulder Zone into the base of the Upper Floridan aquifer and expose water users to radioactive materials. Based on a review of the literature, the staff notes that there have been instances where contaminants have migrated upward out of the Boulder Zone. In some studies, this was not attributed to improper well construction. As is noted in FSAR Rev. 4, Section 2.4.12.2.1.2 and Figure 2.4.12-214 and in the FPL report on the construction of the dual-zone monitoring well, the Upper Floridan aquifer has been designated as an USDW.

### 4.2.2. Question 1 Response Summary

A liquid effluent pathway analysis was conducted to assess the radiological impacts of utilizing a non-traditional approach to waste management for a U.S. nuclear power plant—the disposal of treated liquid radioactive waste by injection into the Boulder Zone. Specifically, the liquid effluent pathway analysis provided a means, although not anticipated, for determining the impacts should an event occur where the injectate does not remain isolated. A description of the analysis undertaken by FPL is provided in Section 3 of this response.

The liquid effluent pathway analysis postulated various scenarios where a member of the public may become exposed to the liquid effluent (Section 3 of this response). Amongst the set of postulated exposure scenarios, consideration of the following were included:

- Drilling activities undertaken at a location beyond the control of the applicant (licensee) and expose well drillers to radioactive materials (Section 3.4.1.3.3)
- Failure of a well casing or packing that could contaminate the Upper Floridan aquifer and expose water users to radioactive materials (Sections 3.1.4 and 3.4.1.1)
- Upward migration of the injectate from the Boulder Zone into the base of the Upper Floridan aquifer and expose water users to radioactive materials (Sections 3.1.2, 3.4.1.1, 3.4.1.2, and 3.4.1.3)

These exposure scenarios were initially screened for feasibility/credibility (Section 3 of this response). Finally, the liquid effluent pathway analysis culminated in an assessment of the doses potentially delivered to the MEI (Section 4 of this response). The results of this assessment showed that, even with the conservative assumptions and implausible events postulated for purposes of the analysis, the dose to the MEI remain below the 10 CFR Part 50, Appendix I, design objectives.

4.2.3. Question 2

In assessing radiological impacts, the applicant is requested to address the following exposure scenarios and pathways in bracketing the range of events and doses to members of the public that could result if exposed to the injectate. The scenarios assume that these events would take place offsite with the applicant (licensee) not being aware of these events during plant operation. The scenarios may include, but are not limited to the following:

i. a drilling scenario, taking place offsite, involving contaminated drilling mud and cuttings being brought to the surface and exposing workers during drilling activities and nearby members of the public.

ii. the failure of injection well packings and joints after closure and abandonment, with the assumption that the failed wells become conduits connecting the radioactive plume within the Boulder Zone to the Upper Floridan aquifer from which contaminated water would be used at the surface. Some reported uses of water include landscaping and nursery irrigation, agriculture, aquaculture, and industrial applications. The applicant should present a detailed analysis of potential exposure pathways and doses from this scenario and describe all supporting assumptions. The applicant should discuss the effects and expiration of institutional controls, if any, on deep well injection activities and use of the land and groundwater in the vicinity of the plant site.

iii. a U-tube scenario where offsite well drilling activities and differential pressures associated with injection would result in the radioactive plume, within the Boulder Zone, being hydraulically pushed into the Upper Floridan aquifer. The analysis should consider the potential migration of fluids and radioactivity through offsite wells or formation/fissures, and well penetrations to USDW as well as natural migration into overlying aquifers.

iv. Alternatively, the applicant could develop a single bounding scenario (from the above scenarios or equivalent variations of these scenarios) in defining and characterizing types of activities or natural processes leading to radiation exposures, and assumed exposure pathways and potential doses to offsite drilling crew workers and members of the public. Should this alternative be selected, the applicant is requested to provide the appropriate justification and supporting information in identifying such a bounding scenario for the staff to conduct an independent evaluation of the applicant's approach and results in concluding that regulatory requirements have been met.

4.2.4. Question 2 Response Summary

In performing the liquid pathway assessment analysis, specifically assessing radiological impacts, several exposure scenarios and pathways were postulated to bracket the range of events and doses to members of the public that could result if exposed to the injectate (Section 3 of this response). Amongst the postulated scenarios considered were the following:

- A drilling scenario, taking place offsite, involving contaminated drilling mud and cuttings being brought to the surface and exposing workers during drilling activities and nearby members of the public (Section 3.4.1.3.3 of this response)
- The failure of injection well packings and joints after closure and abandonment, with the assumption that the failed wells become conduits connecting the radioactive plume within the Boulder Zone to the Upper Floridan aquifer from which contaminated water would be used at the surface (Sections 3.1.4 and 3.4.1.1 of this response)
- A U-tube scenario where offsite well drilling activities and differential pressures associated with injection would result in the radioactive plume, within the Boulder Zone, being hydraulically pushed into the Upper Floridan aquifer (Sections 3.1.2, 3.4.1.1, 3.4.1.2, and 3.4.1.3 of this response)

Prior to the development of these scenarios, exposure modes and locations for the member of the public were defined in Sections 3.2 and 3.3 of this response, respectively. The liquid effluent pathway scenarios were then developed with consideration of developed inputs, e.g., groundwater modeling and investigation of well failure modes (Section 3.4 of this response). The postulated scenarios were then screened for feasibility/credibility (Section 3.4 and 3.5 of this response). Lastly, the retained scenarios were screened for potential MEI determination and the resultant dose analyses performed (Section 4 of this response).

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**Table 1 Injectate Concentrations**

| Component | Half-life (yrs)[a] | Annual Releases (Ci/year)[b] | Injectate Water Concentration (reclaimed water source) | Injectate Water Concentration (saltwater source) |
|---|---|---|---|---|
| TDS | Not applicable | Not applicable | 2.7 kg/m$^3$ | 57.0 kg/m$^3$ |
| H-3 | 12.4 | 1.01E3 | 1.0E5 pCi/L | 2.2E4 pCi/L |
| Cs-134 | 2.1 | 9.93E-3 | 1.0E0 pCi/L | 2.1E-1 pCi/L |
| Cs-137 | 30.1 | 1.332E-2 | 1.3E0 pCi/L | 2.9E-1 pCi/L |
| Sr-90 | 29.0 | 1.0E-5 | 1.0E-3 pCi/L | 2.2E-4 pCi/L |

[a] Reference 24
[b] Source: DCD Table 11.2-7 (based on 292 days per year operation of a single unit)

**Table 2 Cumulative Isotopic Inventory at the End of Plant Operations**

| Isotope | Release per Unit (Ci/yr)[1] | Subsurface Activity at 61 years (Ci) |
|---|---|---|
| H-3 | 1.26E3 | 2.17E4 |
| Na-24 | 2.04E-3 | 5.02E-6 |
| Cr-51 | 2.31E-3 | 2.53E-4 |
| Mn-54 | 1.63E-3 | 2.01E-3 |
| Fe-55 | 1.25E-3 | 4.93E-3 |
| Fe-59 | 2.50E-4 | 4.40E-5 |
| Co-58 | 4.20E-3 | 1.18E-3 |
| Co-60 | 5.50E-4 | 4.18E-3 |
| Zn-65 | 5.13E-4 | 4.95E-4 |
| Br-84 | 2.50E-5 | 2.18E-9 |
| Rb-88 | 3.38E-4 | 1.65E-8 |
| Sr-89 | 1.25E-4 | 2.50E-5 |
| Sr-90 | 1.25E-5 | 4.00E-4 |
| Sr-91 | 2.50E-5 | 3.97E-8 |
| Y-91m | 1.25E-5 | 1.71E-9 |
| Y-93 | 1.13E-4 | 1.89E-7 |
| Zr-95 | 2.88E-4 | 7.28E-5 |
| Nb-95 | 2.63E-4 | 3.63E-5 |
| Mo-99 | 7.13E-4 | 7.74E-6 |
| Tc-99m | 6.88E-4 | 6.81E-7 |
| Ru-103 | 6.17E-3 | 9.57E-4 |
| Ru-106 | 9.20E-2 | 1.36E-1 |
| Rh-103m | 6.17E-3 | 9.50E-7 |
| Rh-106 | 9.20E-2 | 1.25E-7 |
| Ag-110m | 1.31E-3 | 1.30E-3 |
| Ag-110 | 1.75E-4 | 1.97E-10 |
| Te-129m | 1.50E-4 | 1.99E-5 |
| Te-129 | 1.88E-4 | 3.58E-8 |
| Te-131m | 1.13E-4 | 5.56E-7 |
| Te-131 | 3.75E-5 | 2.58E-9 |
| Te-132 | 3.00E-4 | 3.80E-6 |
| I-131 | 1.77E-2 | 5.59E-4 |

**Table 2 Cumulative Isotopic Inventory at the End of Plant Operations (Cont'd)**

| Isotope | Release per Unit (Ci/yr)[1] | Subsurface Activity at 61 years (Ci) |
|---|---|---|
| I-132 | 2.05E-3 | 7.75E-7 |
| I-133 | 8.38E-3 | 2.87E-5 |
| I-134 | 1.01E-3 | 1.46E-7 |
| I-135 | 6.22E-3 | 6.73E-6 |
| Cs-134 | 1.24E-2 | 3.70E-2 |
| Cs-136 | 7.88E-4 | 4.10E-5 |
| Cs-137 | 1.67E-2 | 5.45E-1 |
| Ba-137m | 1.56E-2 | 1.10E-7 |
| Ba-140 | 6.90E-3 | 3.48E-4 |
| La-140 | 9.29E-3 | 6.16E-5 |
| Ce-141 | 1.13E-4 | 1.45E-5 |
| Ce-143 | 2.38E-4 | 1.29E-6 |
| Ce-144 | 3.95E-3 | 4.45E-3 |
| Pr-143 | 1.63E-4 | 8.72E-6 |
| Pr-144 | 3.95E-3 | 1.87E-7 |
| W-187 | 1.63E-4 | 6.35E-7 |
| Np-239 | 3.00E-4 | 2.80E-6 |
| **Total** | | **4.35E4[2]** |

Notes:

[1]Release per unit values are escalated from AP1000 DCD Table 11.2-7 (as described in the Section 2.1.1.1 of this response).
[2]The 'Total' value represents the sum of all isotopes, multiplied by 2 to account for two units.

**Table 3 Model Parameter Summary**

| Parameter | Value |
|---|---|
| Transmissivity (T) | 23,223 $m^2$/day<br>(250,000 $ft^2$/day) |
| Anisotropy ratio ($K_z/K_x$) | 1/3 |
| Effective Porosity ($\phi_e$) | 0.2 |
| Storativity (S) | 3.6E-4 |
| Longitudinal Dispersivity ($\alpha_L$) | 15 m (49 ft) |
| Vertical Dispersivity ($\alpha_V$) | 0.3 m (1 ft) |
| Injection well length | 74m (243 ft) |
| Boulder Zone TDS concentration | 36.2 kg/$m^3$ |
| Boulder Zone aquifer thickness | 152 m (500 ft) |
| Horizontal grid spacing | 45 m (uniform) (148 ft) |
| Vertical grid spacing | 2 m (uniform) (6.5 ft) |
| Distribution Coefficient ($K_d$) | 0 ml/g (all species) |
| Initial head in Boulder Zone | 1.9 m (6.2 ft) NAVD 88 |

**Table 4 Peak Activity Concentrations at the 2.2 Mile Location**

| Case | Peak Activity Concentrations at 2.2 mi from Injection Point (pCi/L)[1] | | | |
|---|---|---|---|---|
| | H-3 | Cs-134 | Cs-137 | Sr-90 |
| Base case | 3.1E4 | 7.7E-3 | 7.6E-1 | 5.6E-4 |
| Sensitivity Cases | | | | |
| $\Phi_e$ = 15 % (decreased $\Phi_e$) | 4.0E4 (+29%) | 2.1E-2 (+173%) | 8.6E-1 (+13%) | 6.4E-4 (+14%) |
| $\alpha_V$ =0.1 m (decreased $\alpha_V$) | 3.9E4 (+26%) | 1.2E-2 (+56%) | 8.6E-1 (+13%) | 6.3E-4 (+13%) |
| T = 55,736 $m^2$/day (increased T) | 3.7E4 (+19%) | 2.2E-2 (+186%) | 8.1E-1 (+7%) | 6.0E-4 (+7%) |
| b = 92 m (decreased b) | 3.6E4 (+16%) | 1.5E-2 (+95%) | 8.2E-1 (+8%) | 6.0E-4 (+7%) |
| $K_z$=0.1$K_x$ (decreased $K_z/K_x$) | 3.1E4 (0%) | 7.8E-3 (+1%) | 7.6E-1 (0%) | 5.6E-4 (0%) |
| $\alpha_L$= 5 m (decreased $\alpha_L$) | 3.1E4 (0%) | 7.5E-3 (-3%) | 7.6E-1 (0%) | 5.6E-4 (0%) |
| $\alpha_L$= 30 m (increased $\alpha_L$) | 3.1E4 (0%) | 8.1E-3 (+5%) | 7.6E-1 (0%) | 5.6E-4 (0%) |
| S = 1E-3 (increased S) | 3.1E4 (0%) | 7.7E-3 (0%) | 7.6E-1 (0%) | 5.6E-4 (0%) |
| S = 1E-4 (decreased S) | 3.1E4 (0%) | 7.7E-3 (0%) | 7.6E-1 (0%) | 5.6E-4 (0%) |
| Saltwater injection 60 days per year | 2.4E4 (-23%) | 3.5E-3 (-55%) | 6.5E-1 (-14%) | 4.8E-4 (-14%) |
| $\alpha_V$= 1.0 m (increased $\alpha_V$) | 2.3E4 (-26%) | 4.0E-3 (-48%) | 6.3E-1 (-17%) | 4.6E-4 (-18%) |
| T = 5,573 $m^2$/day (decreased T) | 2.0E4 (-35%) | 5.6E-4 (-93%) | 6.4E-1 (-16%) | 4.7E-4 (-16%) |

Notes
T = transmissivity
b = aquifer thickness (note that in this simulation the transmissivity value is the same as that of the base case and therefore hydraulic conductivity increases)
$\Phi_e$ = effective porosity
$\alpha_V$ = vertical dispersivity
$\alpha_L$ = longitudinal dispersivity
$K_z$ = vertical hydraulic conductivity
$K_x$ =horizontal hydraulic conductivity
S = storativity

[1]Values in parentheses represent changes in peak concentration relative to the base case on a percentage basis.

Concentrations are from a simulated observation well in model layer 1.

**Table 5 Summary of Water Use in Miami-Dade County**

| Water User | Water Source | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Biscayne Aquifer | Floridan Aquifer | Surficial Aquifer | Onsite Lake | Tamiami Aquifer | County Water | Canals | Borrow Pits |
| FPL (Unit 5) | - | 3 | - | - | - | - | - | - |
| Public[1] | 173 | 1 | 8 | 1 | - | - | - | - |
| Agricultural[1] | 723 | 2 | 15 | 2 | 1 | 20 | - | - |
| Aquaculture | 20 | - | - | - | - | - | - | - |
| Golf Course | 60 | - | - | 30 | - | 22 | - | - |
| Industrial | 284 | - | 16 | 3 | - | 2 | 7 | 8 |
| Landscape | 762 | - | 19 | 93 | - | 9 | 33 | - |
| Livestock | 5 | - | - | - | - | - | - | - |
| Nursery | 673 | - | 6 | 2 | - | 16 | 1 | - |

[1]Floridan Aquifer use includes public usage (Florida Keys Aqueduct Authority) and irrigation usage (Card Sound Golf Club and Ocean Reef Club).

## Table 6 Results of Initial Exposure Pathway Scenario Screening

| Location | DIS Operation Mode | Description | Retained for Further Analysis | Member-of-the-public Type/Location |
|---|---|---|---|---|
| Plant Area | Normal Operation | Migration through the middle confining unit | No – injectate contained in middle confining unit | Not Applicable |
| | Off-Normal Operation | Worker exposure at leaking pipe | No – controlled by occupational radiation control program | Not Applicable |
| | | Worker exposure to Biscayne aquifer | No – not considered feasible | Not Applicable |
| | | Middle confining unit failure | No – not considered feasible | Not Applicable |
| | | Migration through the middle and intermediate confining units | No – not considered feasible | Not Applicable |
| | | Catastrophic failure of deep injection well | No – not considered feasible | Not Applicable |
| | | Middle confining unit failure and injectate travel to Unit 5 Upper Floridan wells | No – not considered feasible | Not Applicable |
| | Inadvertent Intrusion | Not Applicable | Not Applicable | Not Applicable |
| Property Area | Normal Operation | Migration through the middle confining unit | No – Injectate contained in middle confining unit | Not Applicable |
| | Off-Normal Operation | Middle confining unit failure | No – not considered feasible | Not Applicable |
| | | Migration through the middle and intermediate confining units | No – not considered feasible | Not Applicable |
| | Inadvertent Intrusion | Not Applicable | Not Applicable | Not Applicable |
| Beyond Property Area | Normal Operation | Migration through the middle confining unit | No – injectate contained in middle confining unit | Not Applicable |
| | Off-Normal Operation | Middle confining unit failure | Yes | Refer to Table 7 |
| | | Migration through the middle and intermediate confining units | No – not considered feasible | Not Applicable |
| | Inadvertent Intrusion | Middle confining unit failure and member-of-the-public drilling and ingestion exposure | Yes (worst case) | Refer to Table 7 |

**Table 7 Retained Dose Scenarios**

| Location | Exposure Pathway Mode | Description | Member-of-the-Public Type/Location |
|---|---|---|---|
| Plant Area | None Retained | | |
| Property Area | None Retained | | |
| Beyond Property Area | Off-Normal Operation | Middle confining unit failure and member-of-the-public ingestion exposure (Non-Credible) | Beyond Property Boundary at closest private parcel |
| | | Middle confining unit failure and member-of-the-public ingestion exposure (Credible) | Beyond Property Boundary at Ocean Reef Club Community |
| | Inadvertent Intrusion | Middle confining unit failure and member-of-the-public drilling and ingestion exposure (Worst Case) | Beyond Property Boundary at closest private parcel |

**Table 8 Member-of-the-Public Injectate Ingestion Dose Summary**

| Radionuclide | Total Body Dose for 2 Units (mrem/year) | Liver[1] Dose for 2 Units (mrem/year) |
|---|---|---|
| Tritium | 1.8E0 | 1.8E0 |
| Cesium-134 | 3.1E-4 | 1.5E-3 |
| Cesium-137 | 1.8E-2 | 1.2E-1 |
| Strontium-90 | 1.5E-4 | 0 |
| **Total** | **1.8** | **1.9** |

[1]Liver is the organ receiving the maximum dose

**Table 9 Inadvertent Intrusion Dose Summary – Total Body**

| Radionuclide | Total Body Dose for 2 Units (mrem/year) | | |
|---|---|---|---|
| | Drinking | Irrigation | Total |
| Tritium | 1.8E0 | 3.3E0 | 5.1E0 |
| Cesium-134 | 3.1E-4 | 5.6E-3 | 5.9E-3 |
| Cesium-137 | 1.8E-2 | 3.5E-1 | 3.7E-1 |
| Strontium-90 | 1.5E-4 | 1.7E-3 | 1.8E-3 |
| **Total** | **1.8** | **3.6** | **5.5** |

**Table 10 Inadvertent Intrusion Dose Summary – Maximum Organ**

| Radionuclide | Liver Dose for 2 Units (mrem/year) | | |
|---|---|---|---|
| | Drinking | Irrigation | Total |
| Tritium | 1.8E0 | 3.3E0 | 5.1E0 |
| Cesium-134 | 1.5E-3 | 2.7E-2 | 2.8E-2 |
| Cesium-137 | 1.2E-1 | 2.4E0 | 2.5E0 |
| Strontium-90 | 0 | 0 | 0 |
| **Total** | **1.9** | **5.7** | **7.6** |

**Table 11 Inadvertent Intrusion Subsistence Driller Dose Summary**

| Pathway | Dose (mrem) per Unit | |
|---|---|---|
| | Total Body | Liver[1] |
| Annual Ingestion of Water and Irrigated Foods | 2.7 | 3.8 |
| Inhalation During Drilling | 8.2E-02 | 8.3E-02 |
| Air Immersion During Drilling | 2.6E-06 | 2.6E-06 |
| Deposition During Drilling | 1.8E-05 | 0 |
| Total | 2.8 | 3.9 |
| 10 CFR Part 50, Appendix I Design Objectives | 3 | 10 |

[1]Liver is the organ receiving the maximum dose

**Table 12 Dose Summary**

| Location | Exposure Pathway Mode | Description | Location | Dose (peak airborne concentration) |
|---|---|---|---|---|
| Beyond Property Area | Off-Normal Operation | Middle confining unit failure and member-of-the-public ingestion exposure (Non-Credible) | Beyond Property Boundary at closest private parcel | 1.8 mrem/year total body dose for 2 units |
| | | Middle confining unit failure and member-of-the-public exposure – Ocean Reef Club Community (Credible) | Ocean Reef Club Community | 0 mrem/year total body dose |
| | Inadvertent Intrusion | Middle confining unit failure and member-of-the-public drilling and ingestion exposure (Worst Case) | Beyond Property Boundary at closest private parcel | 5.6 mrem/year total body dose for 2 units |

**Figure 1 Deep Injection Well, Dual-zone Monitoring Well and Hydrogeologic Units at Turkey Point (typical)**

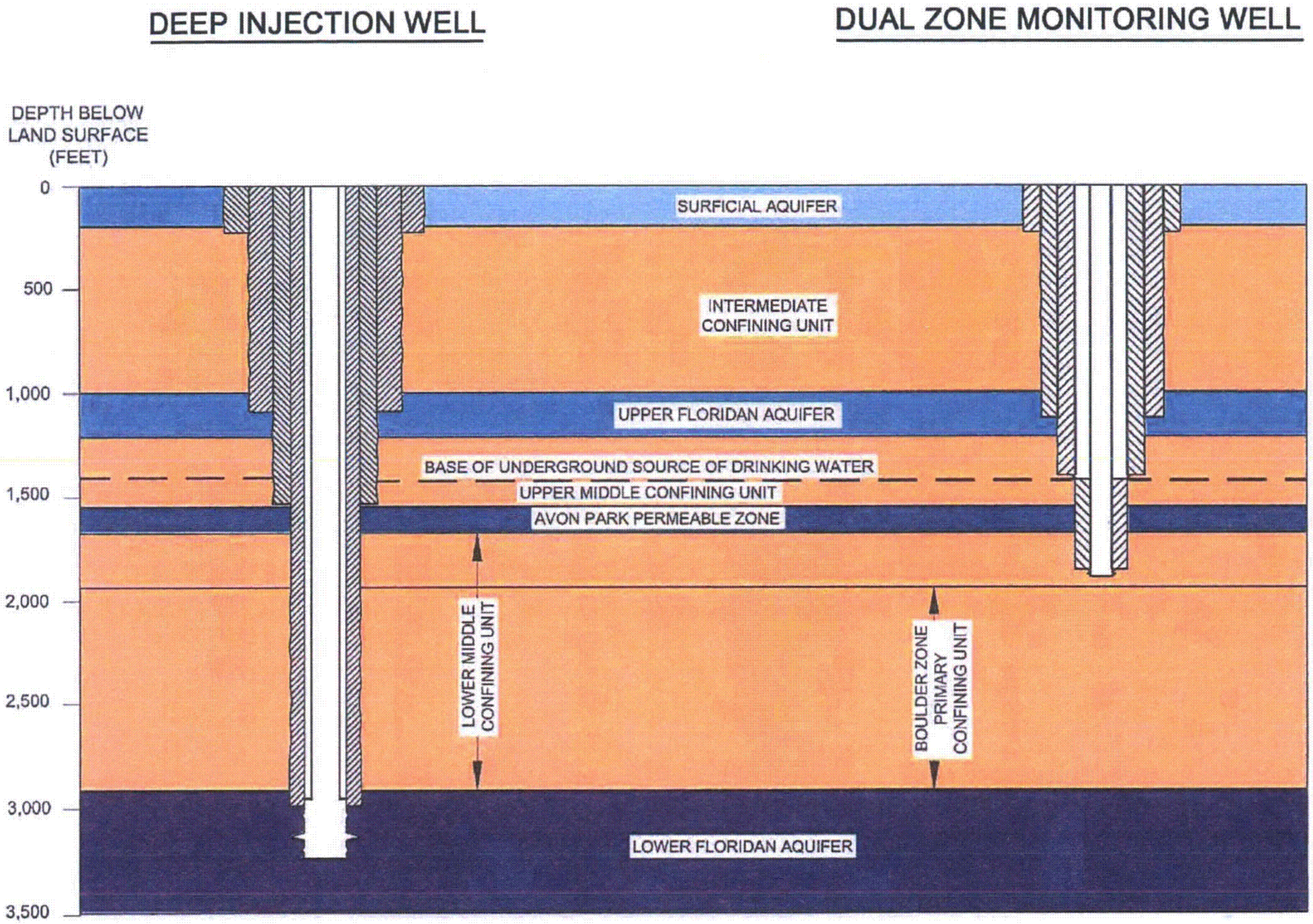


**Figure 2 Schematic of an Axially Symmetric Model**

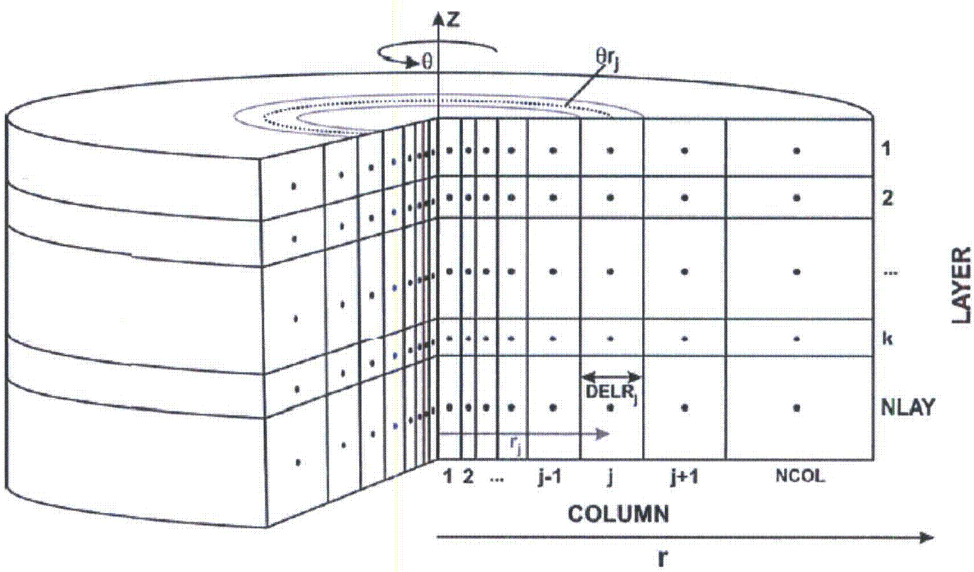


**Figure 3 Model Grid**

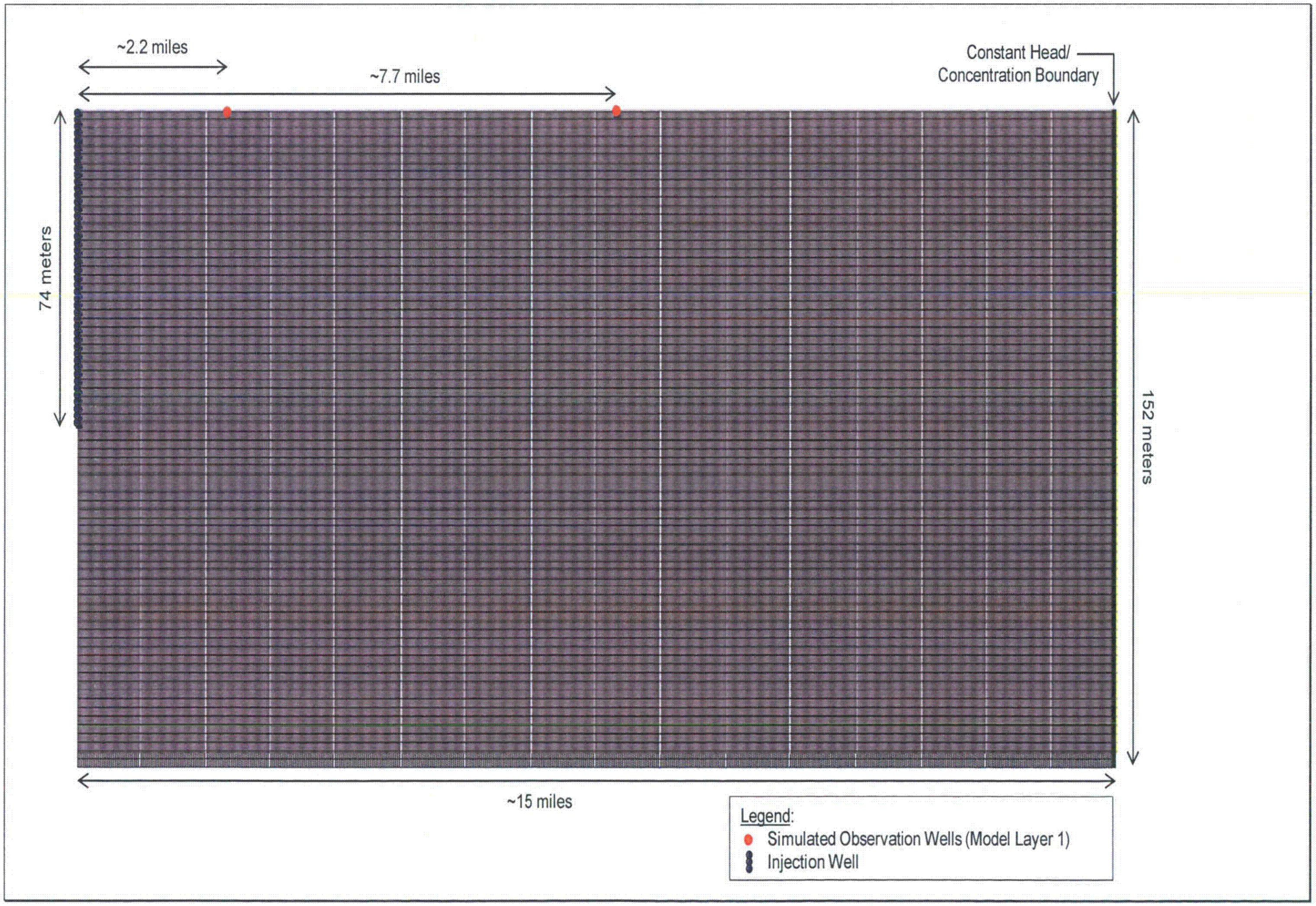
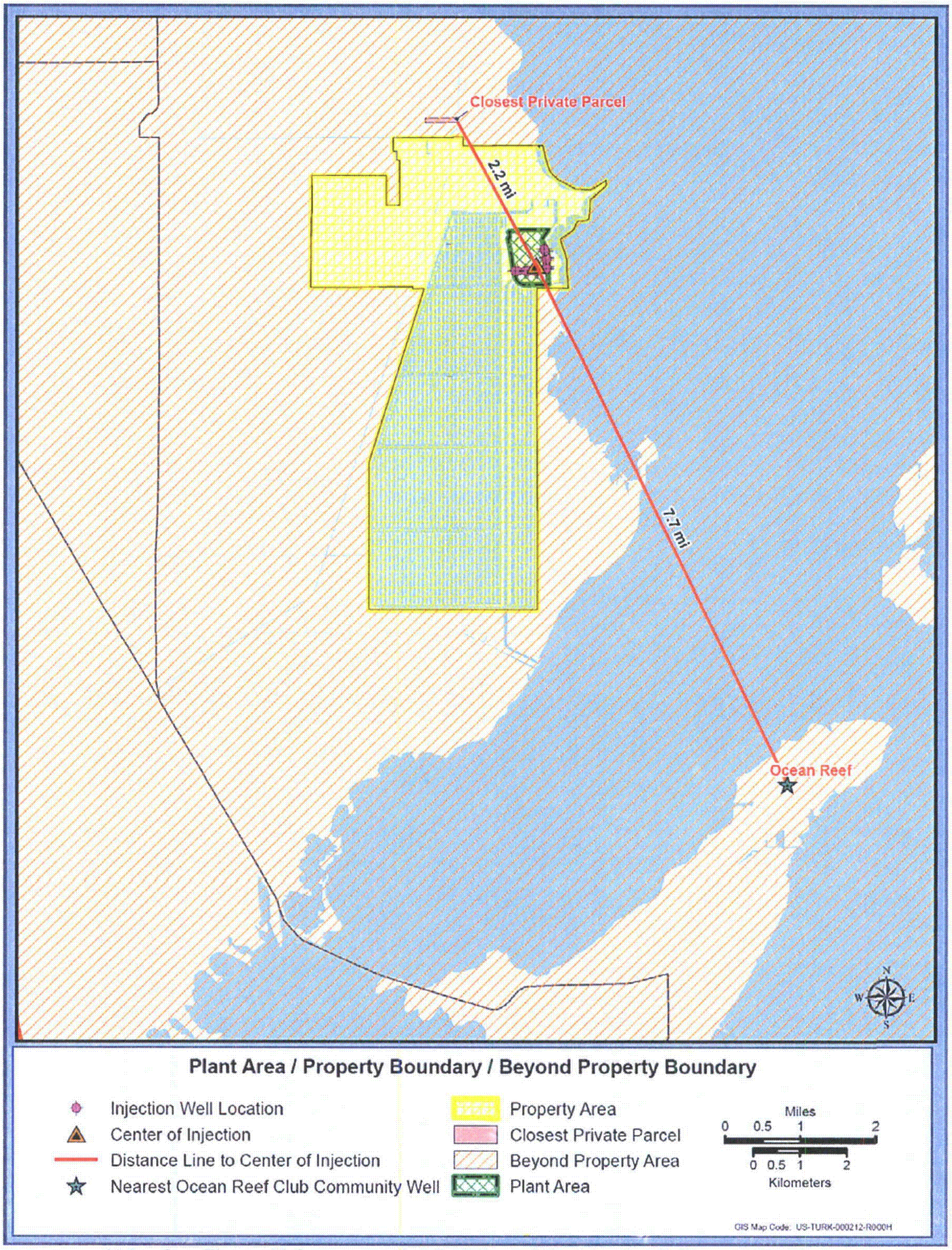
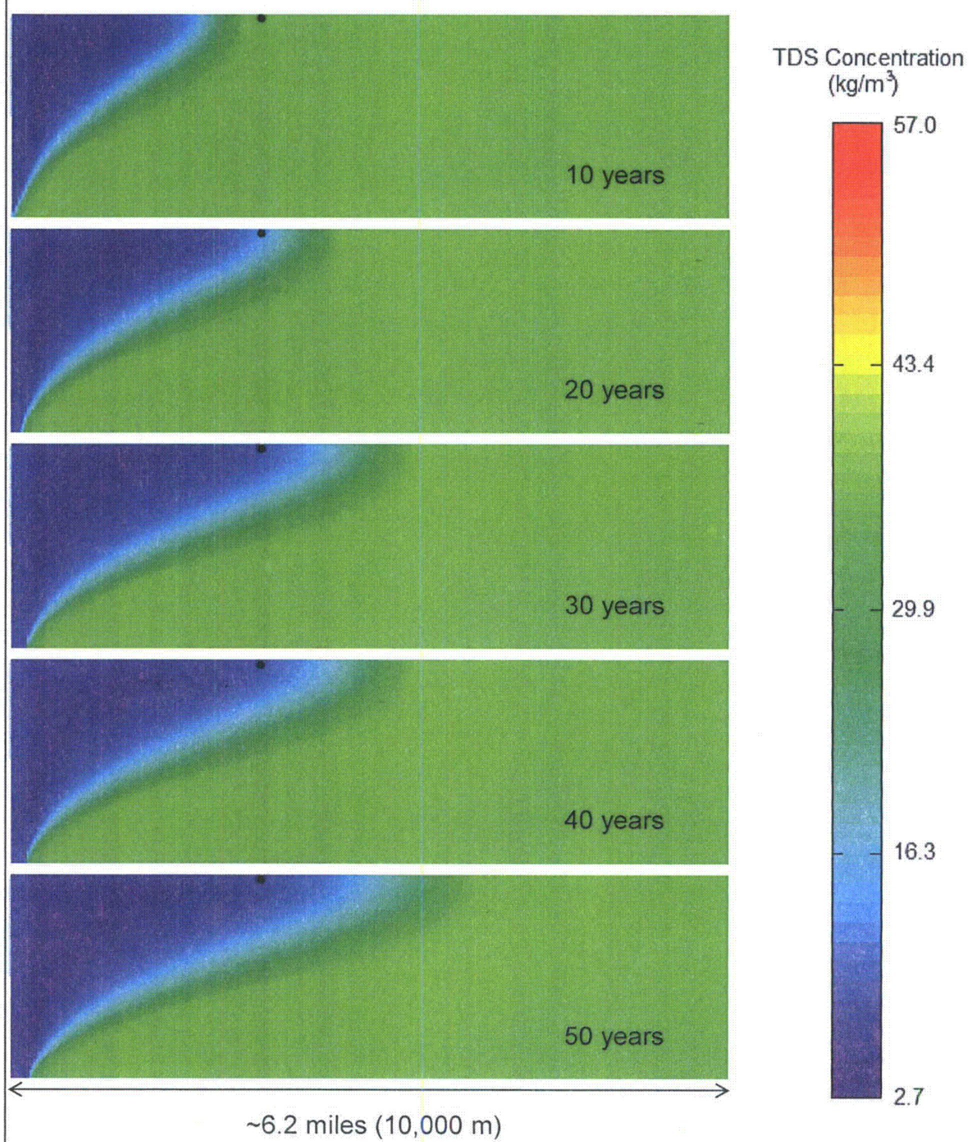


**Figure 4 Proposed Injection Well Field and Hypothesized Receptor Locations**




Note: See Figure 10 for a more detailed view of the injection field.

**Figure 5 Base Case Boulder Zone TDS Concentrations (Sheet 1 of 2)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 5 Base Case Boulder Zone TDS Concentrations (Sheet 2 of 2)**

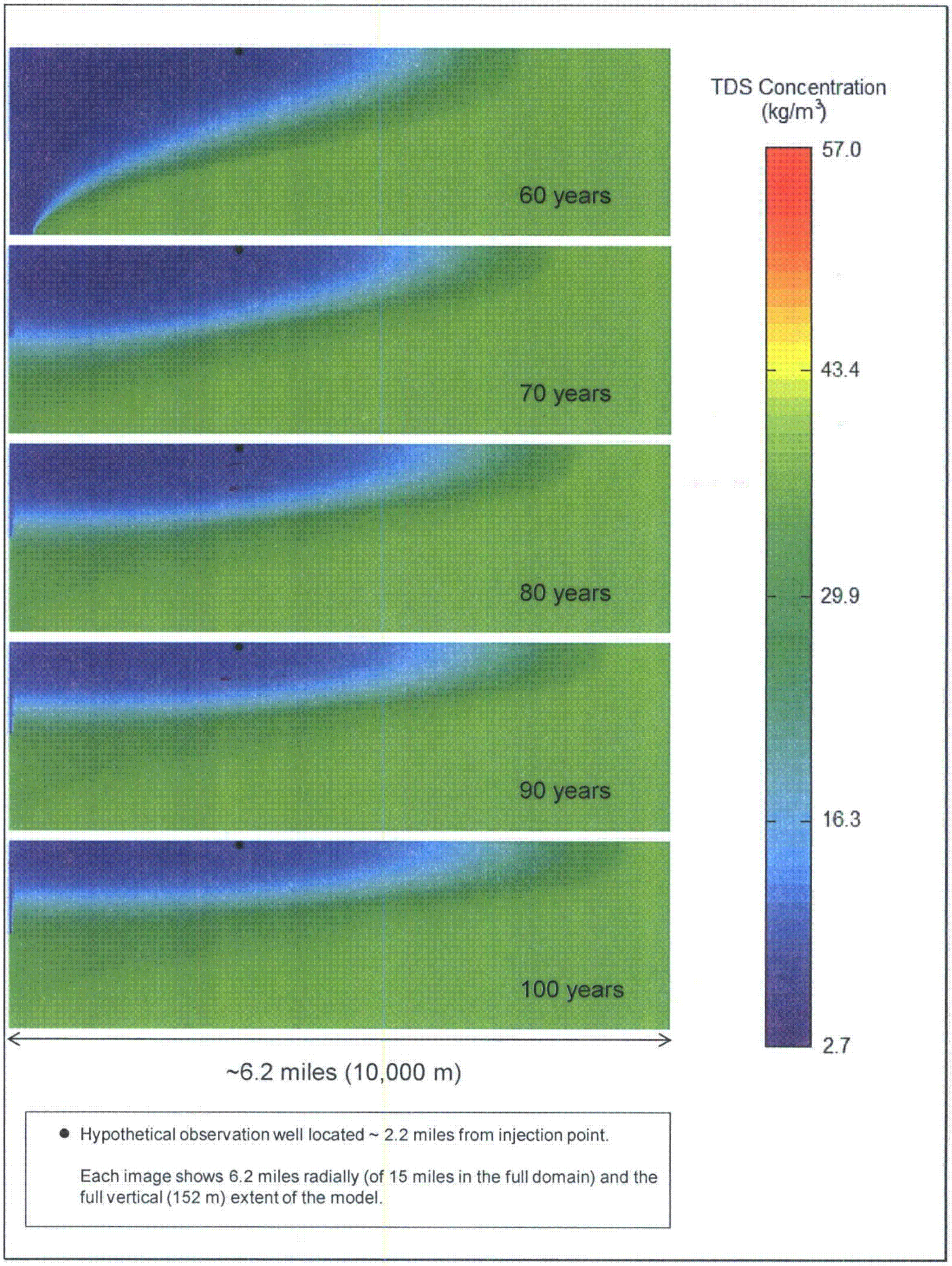
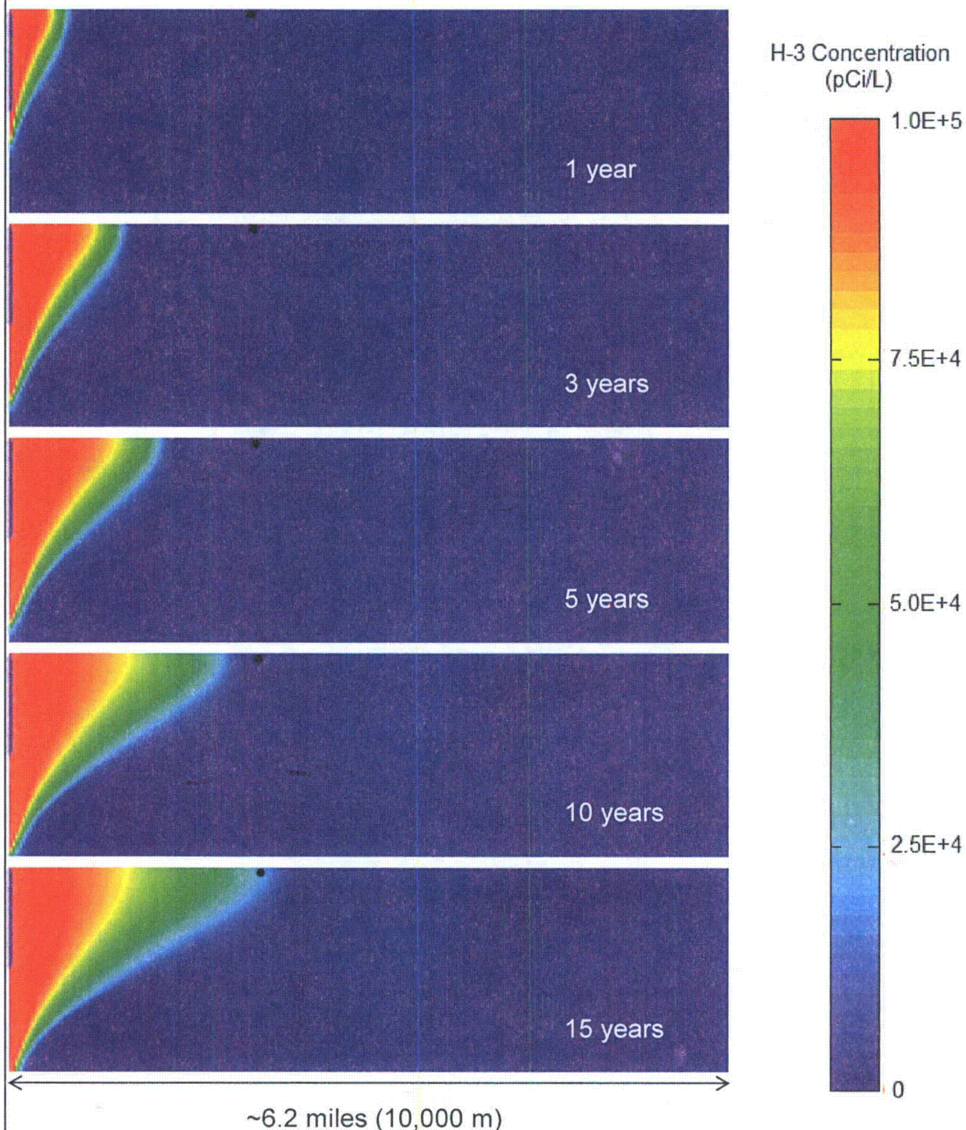


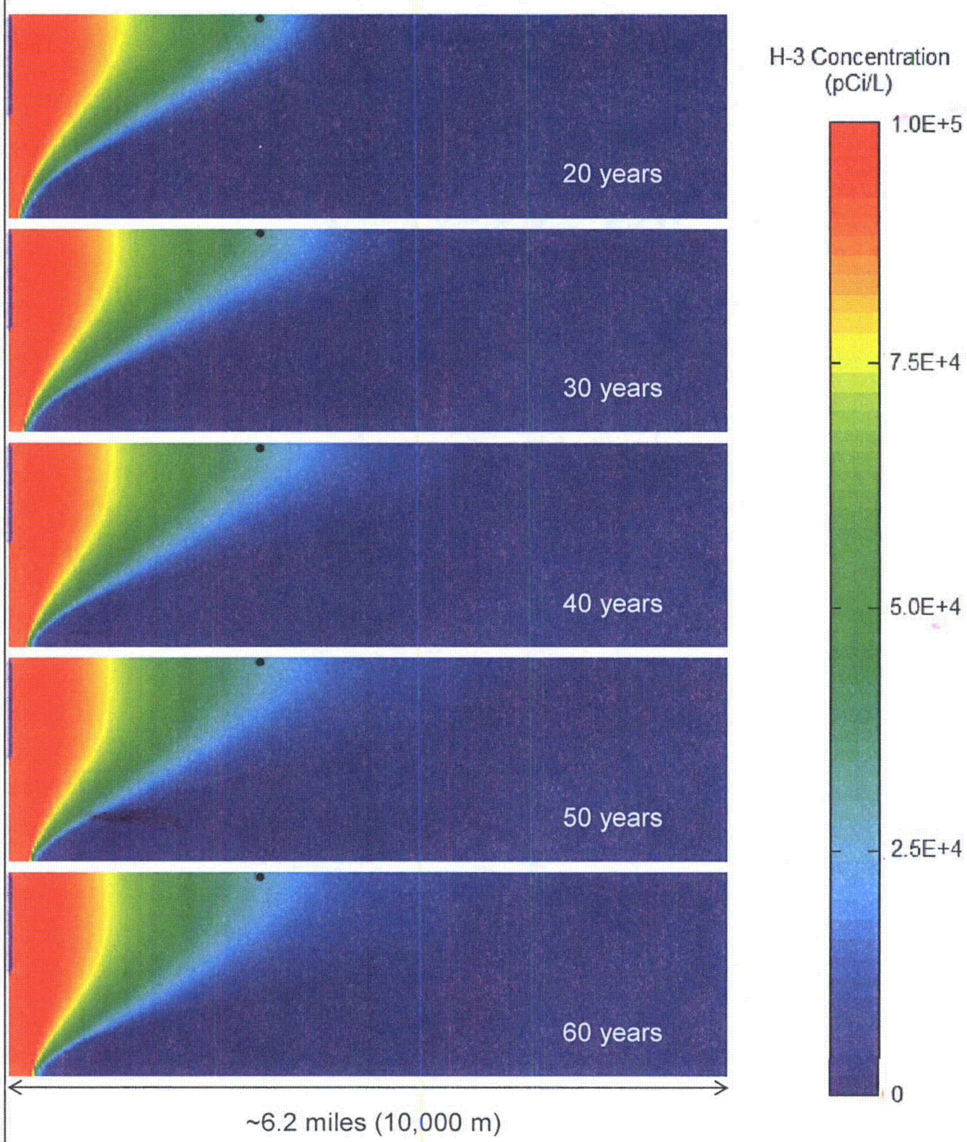
**Figure 6 Base Case Boulder Zone Tritium Concentrations (Sheet 1 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

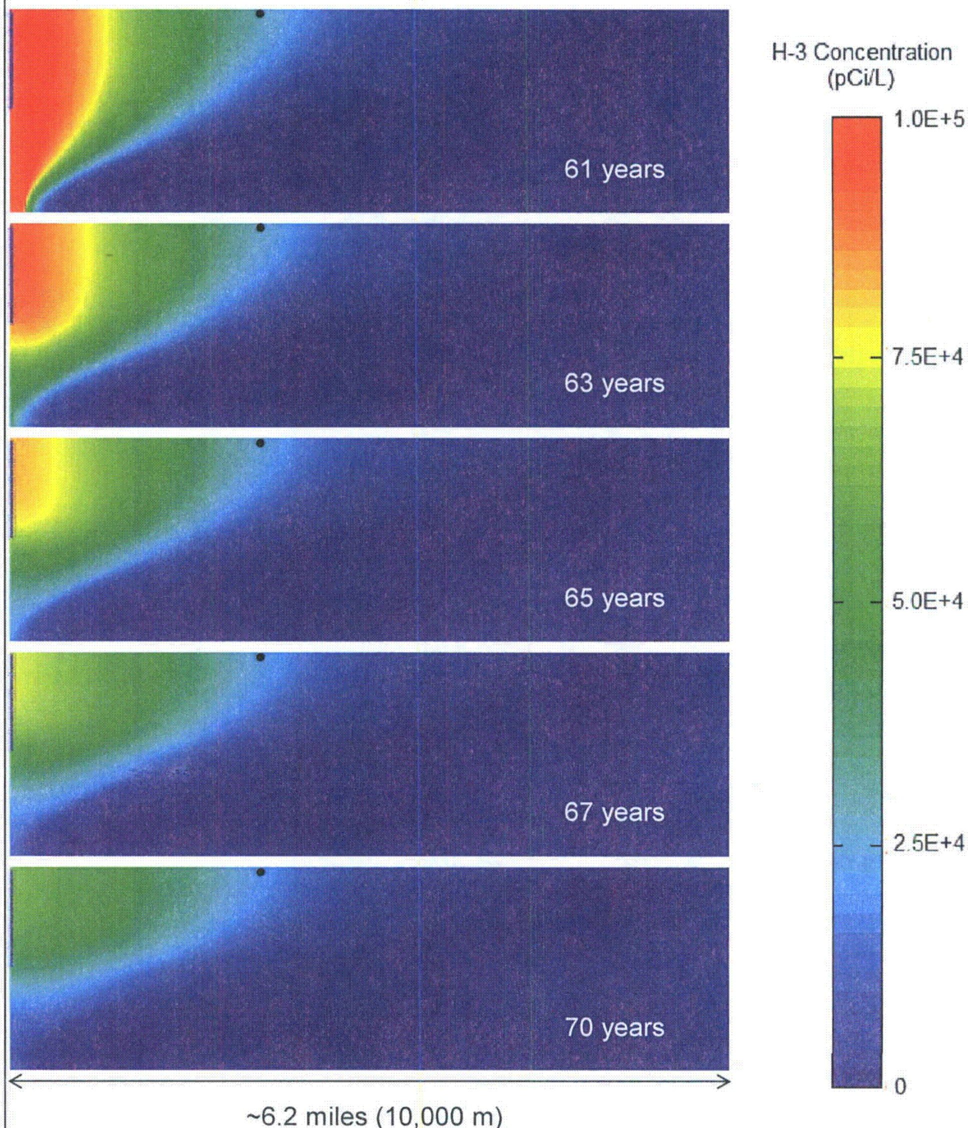
**Figure 6 Base Case Boulder Zone Tritium Concentrations (Sheet 2 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

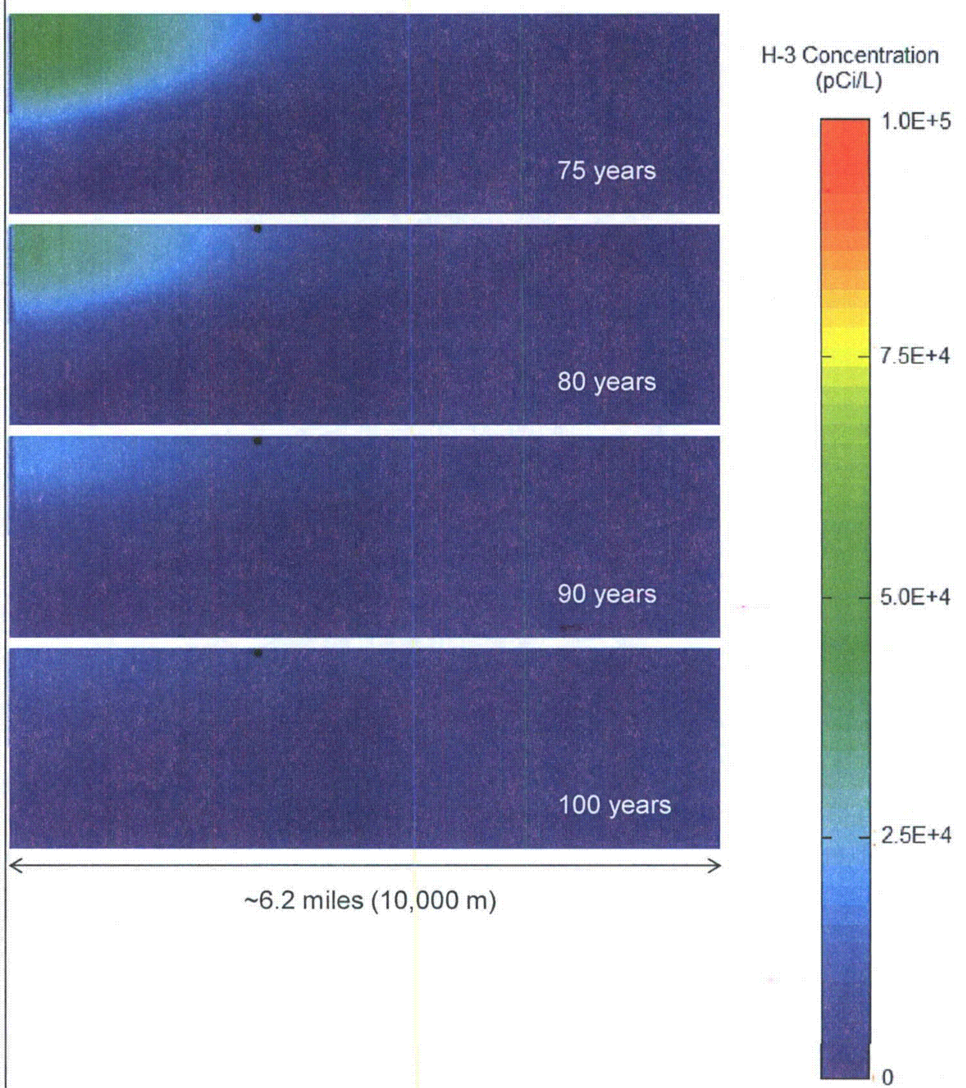
**Figure 6 Base Case Boulder Zone Tritium Concentrations (Sheet 3 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 6 Base Case Boulder Zone Tritium Concentrations (Sheet 4 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 7 Model Layer 1 Distribution of Tritium in the Boulder Zone for the Base Case Simulation at the End of Plant Operations**

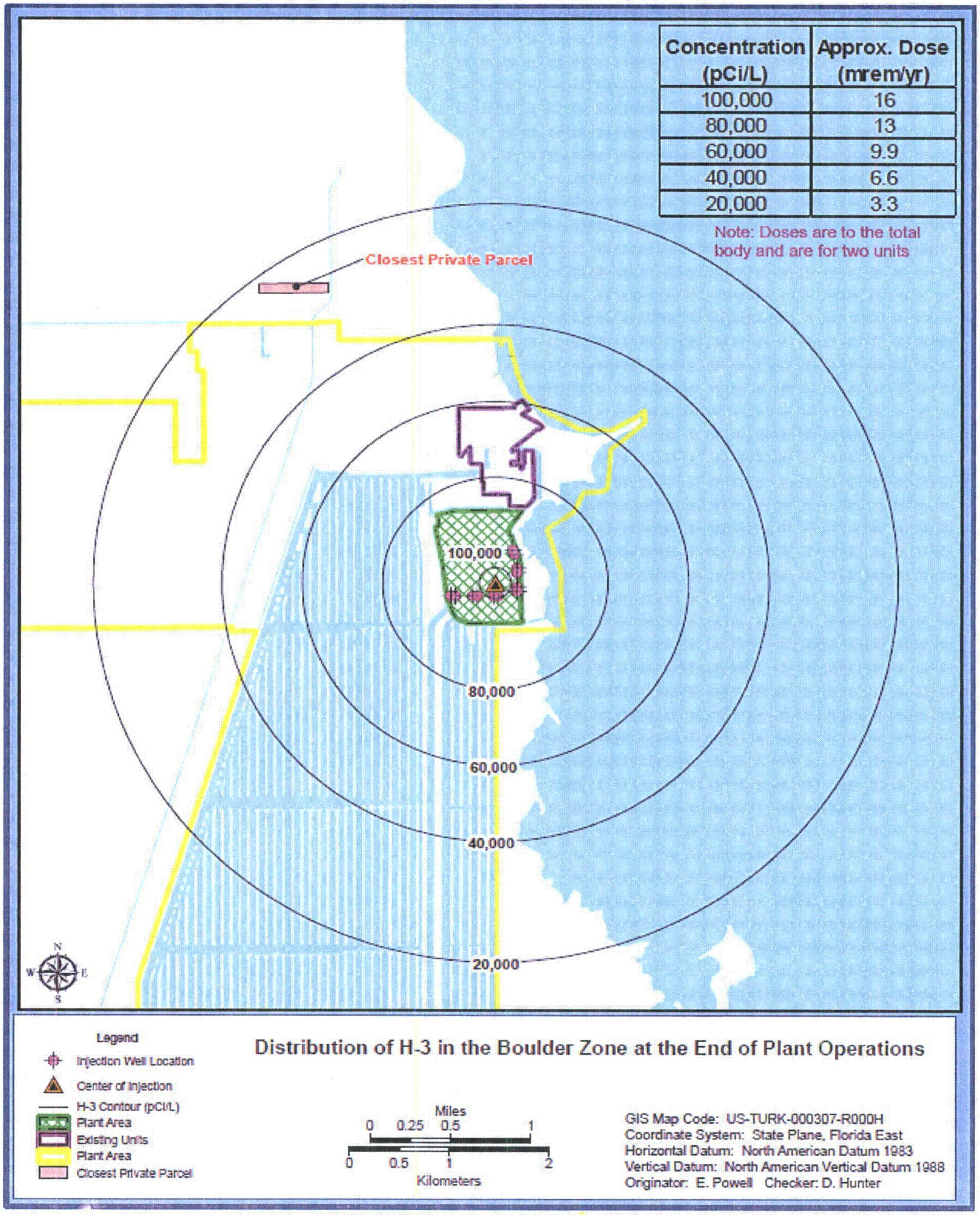


**Figure 8 Model Layer 1 Base Case Relative Concentration Breakthrough Curves at 2.2 mile Receptor Location**

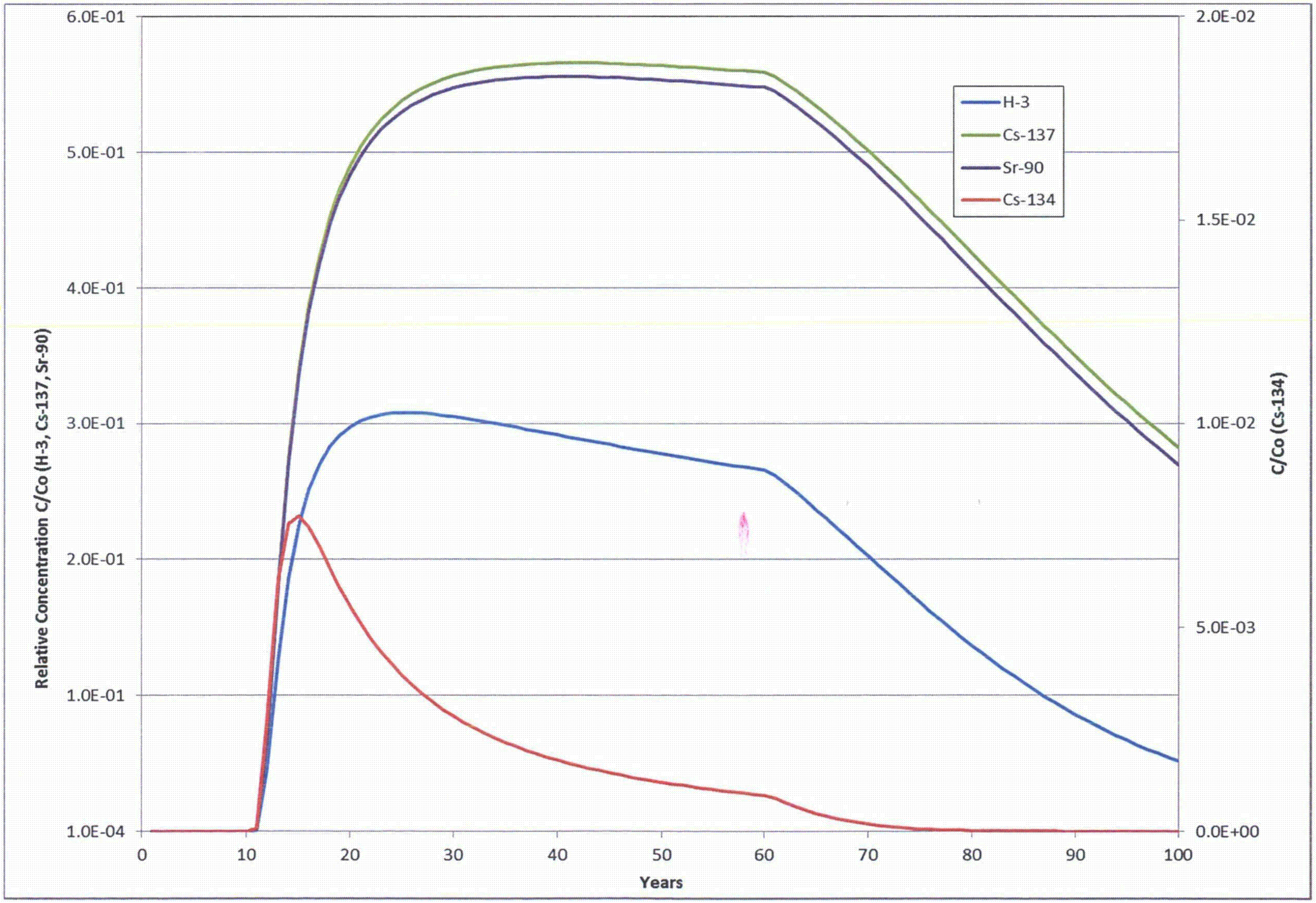
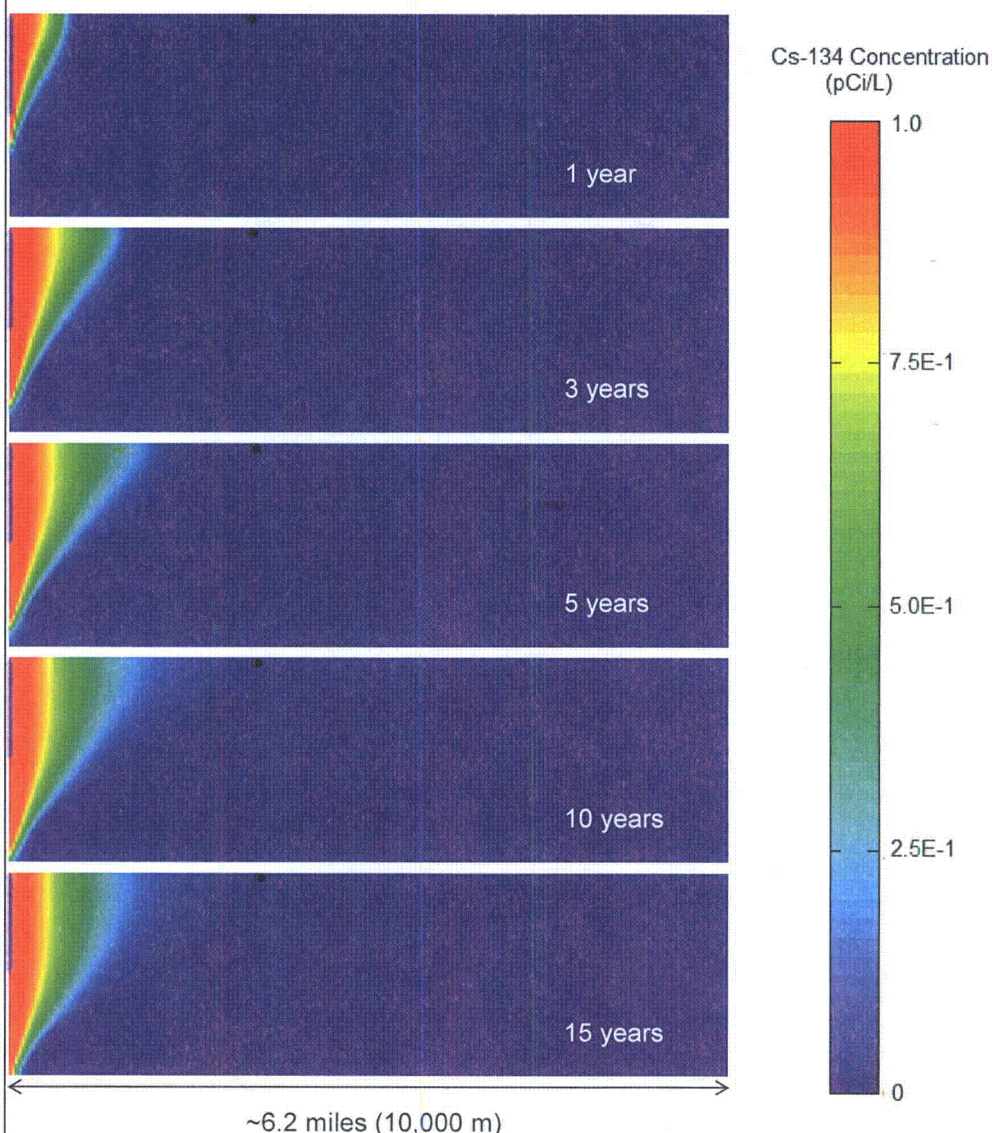


**Figure 9 Base Case Boulder Zone Cesium-134 Concentrations (Sheet 1 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 9 Base Case Boulder Zone Cesium-134 Concentrations (Sheet 2 of 4)**

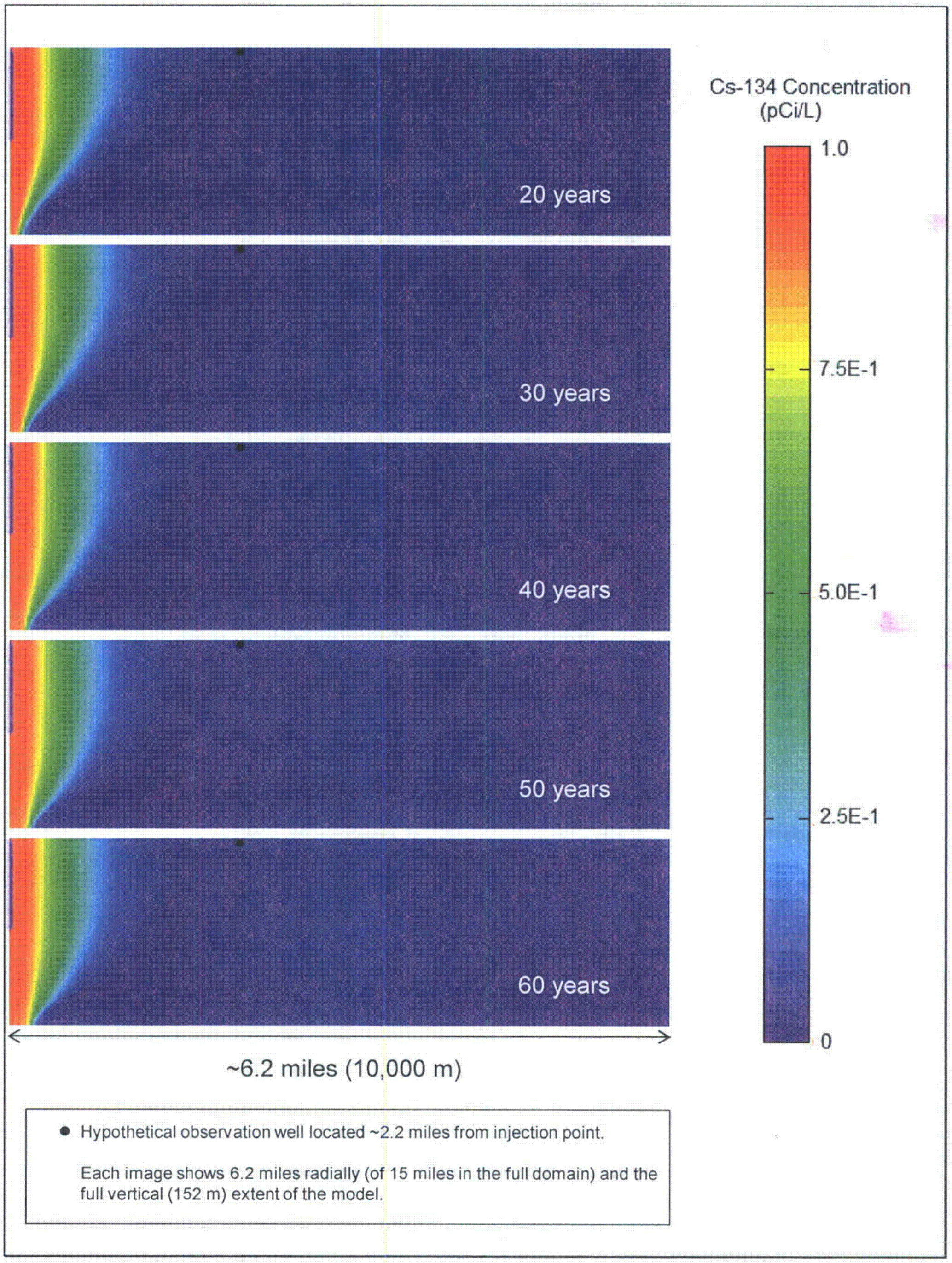
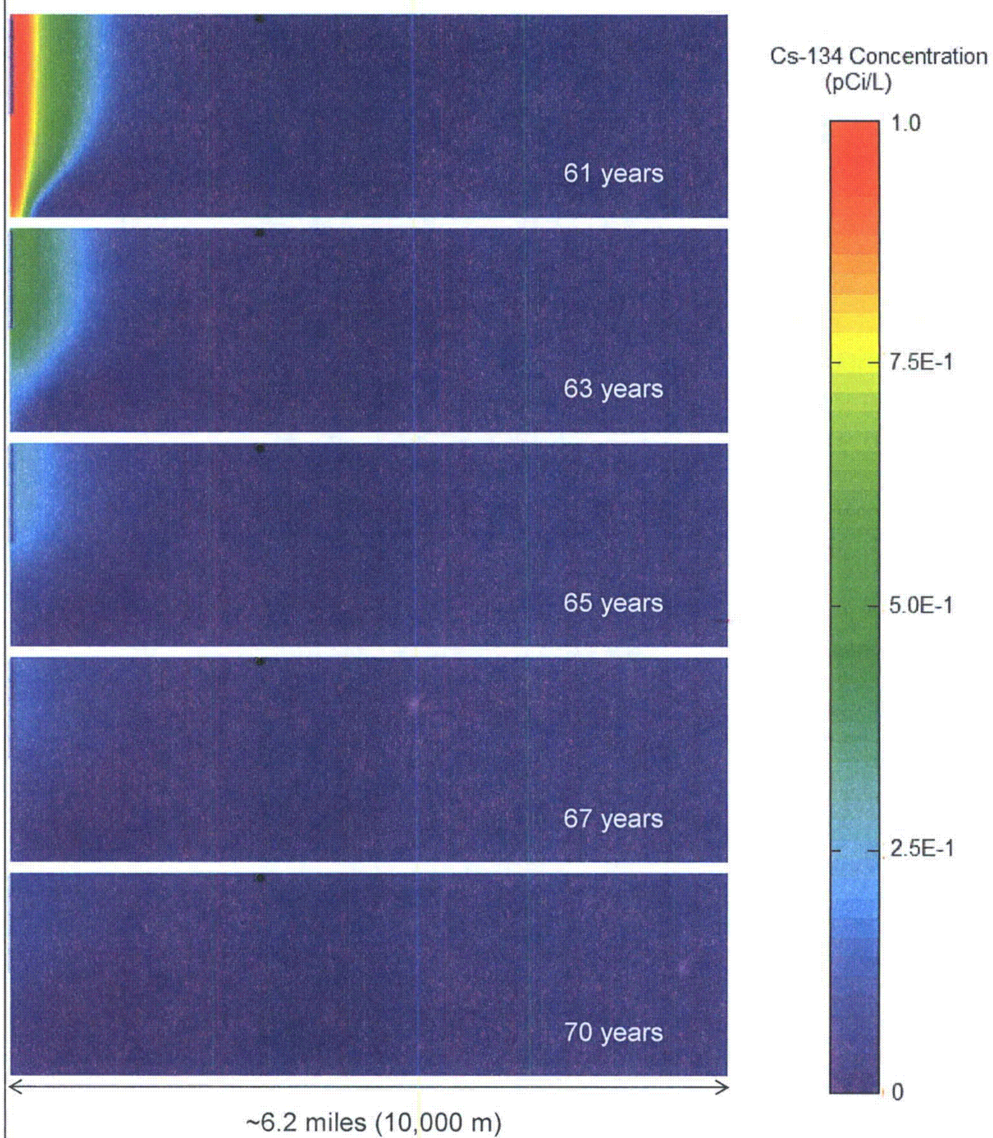


**Figure 9 Base Case Boulder Zone Cesium-134 Concentrations (Sheet 3 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 9 Base Case Boulder Zone Cesium-134 Concentrations (Sheet 4 of 4)**

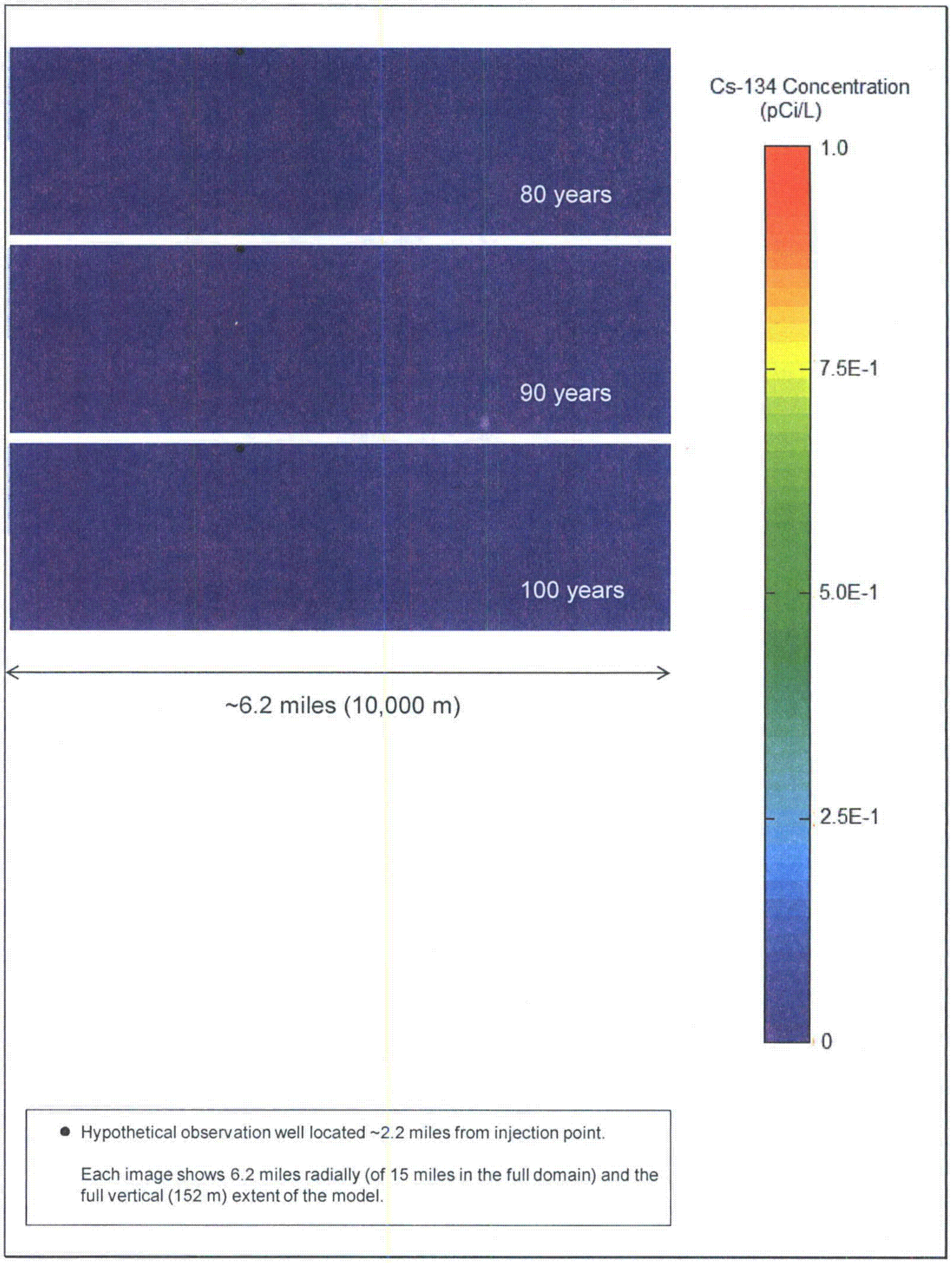


**Figure 10 Model Layer 1 Distribution of Cesium-134 in the Boulder Zone for the Base Case Simulation at the End of Plant Operations**

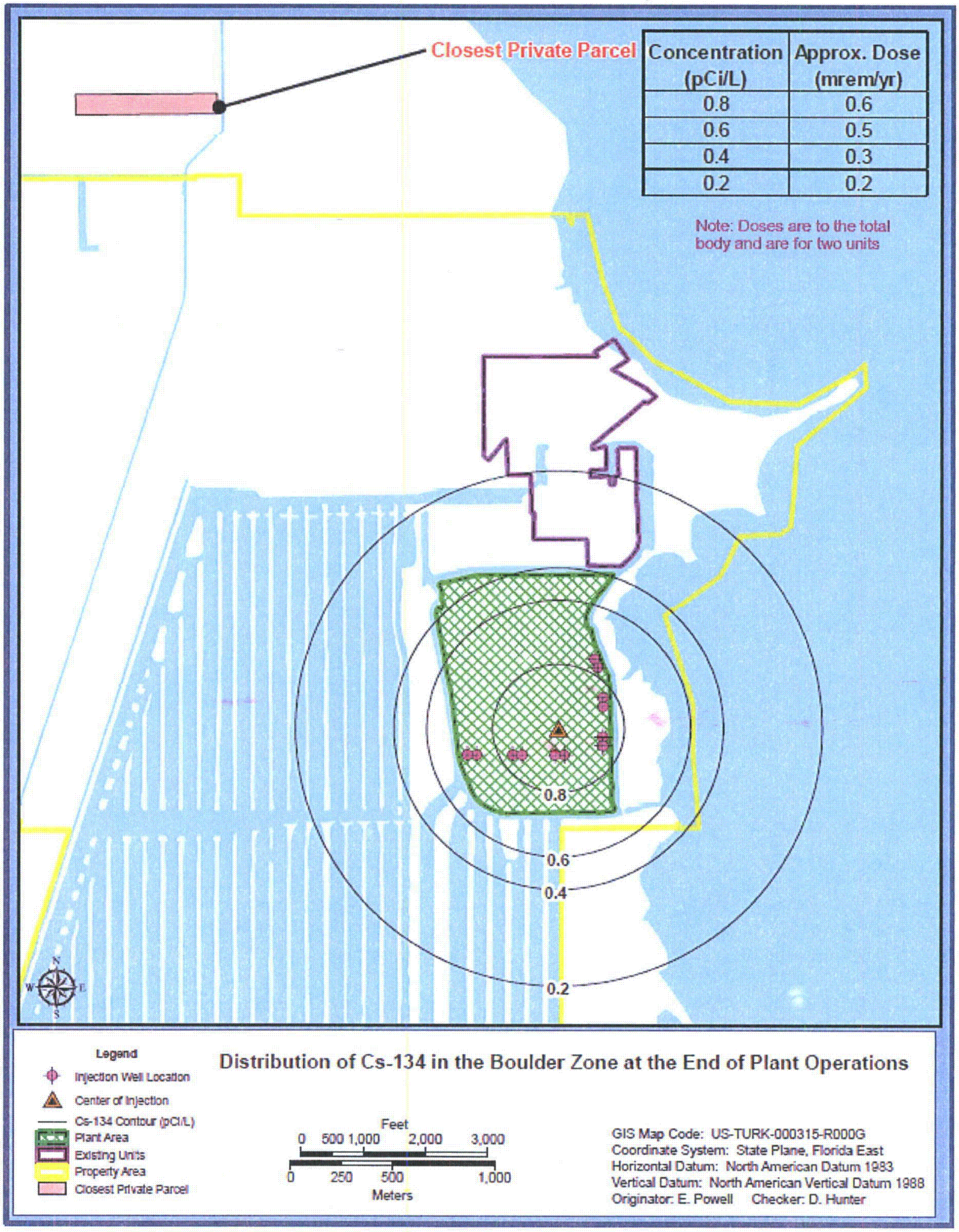


**Figure 11 Base Case Boulder Zone Cesium-137 Concentrations (Sheet 1 of 4)**

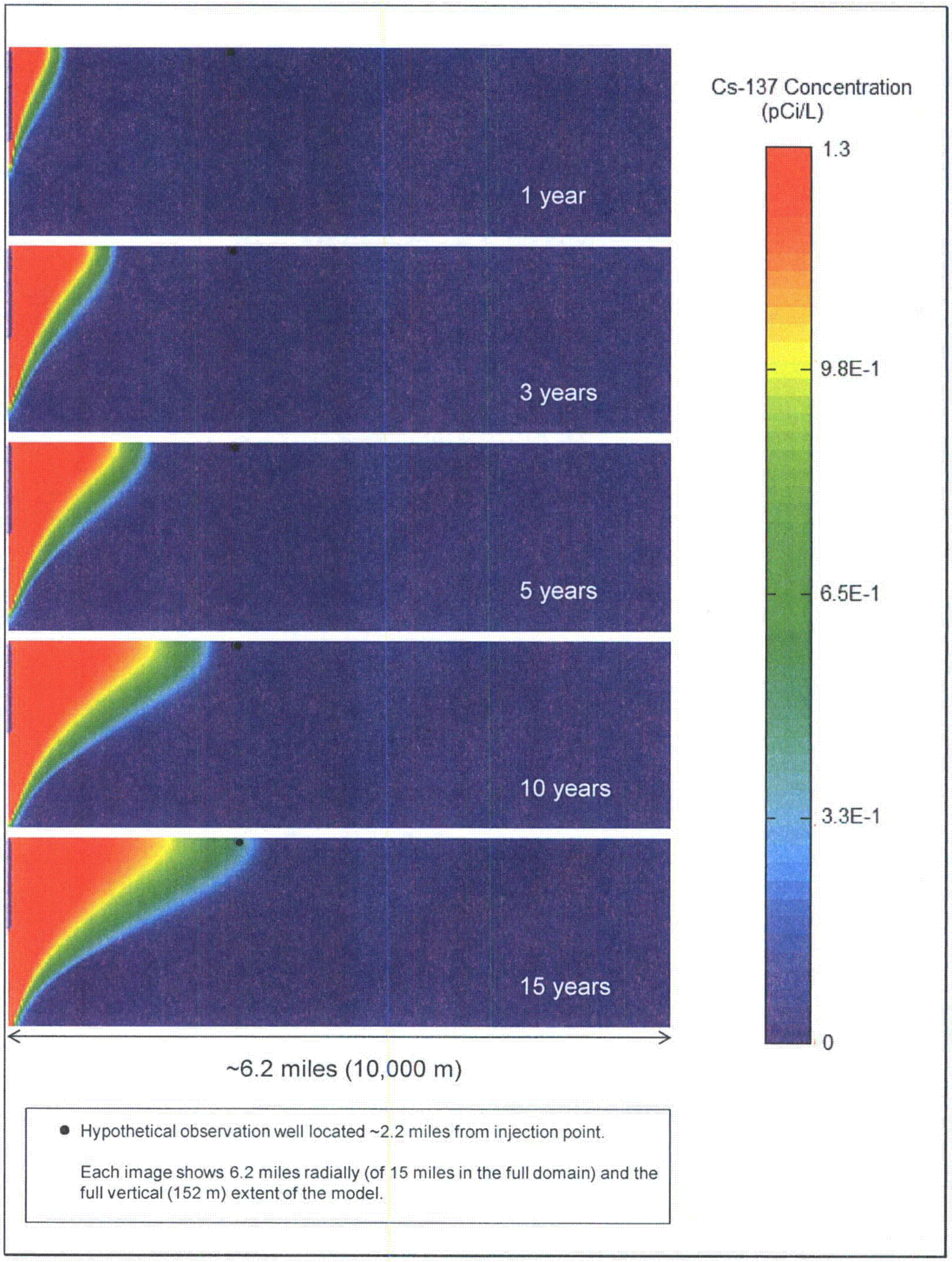


**Figure 11 Base Case Boulder Zone Cesium-137 Concentrations (Sheet 2 of 4)**

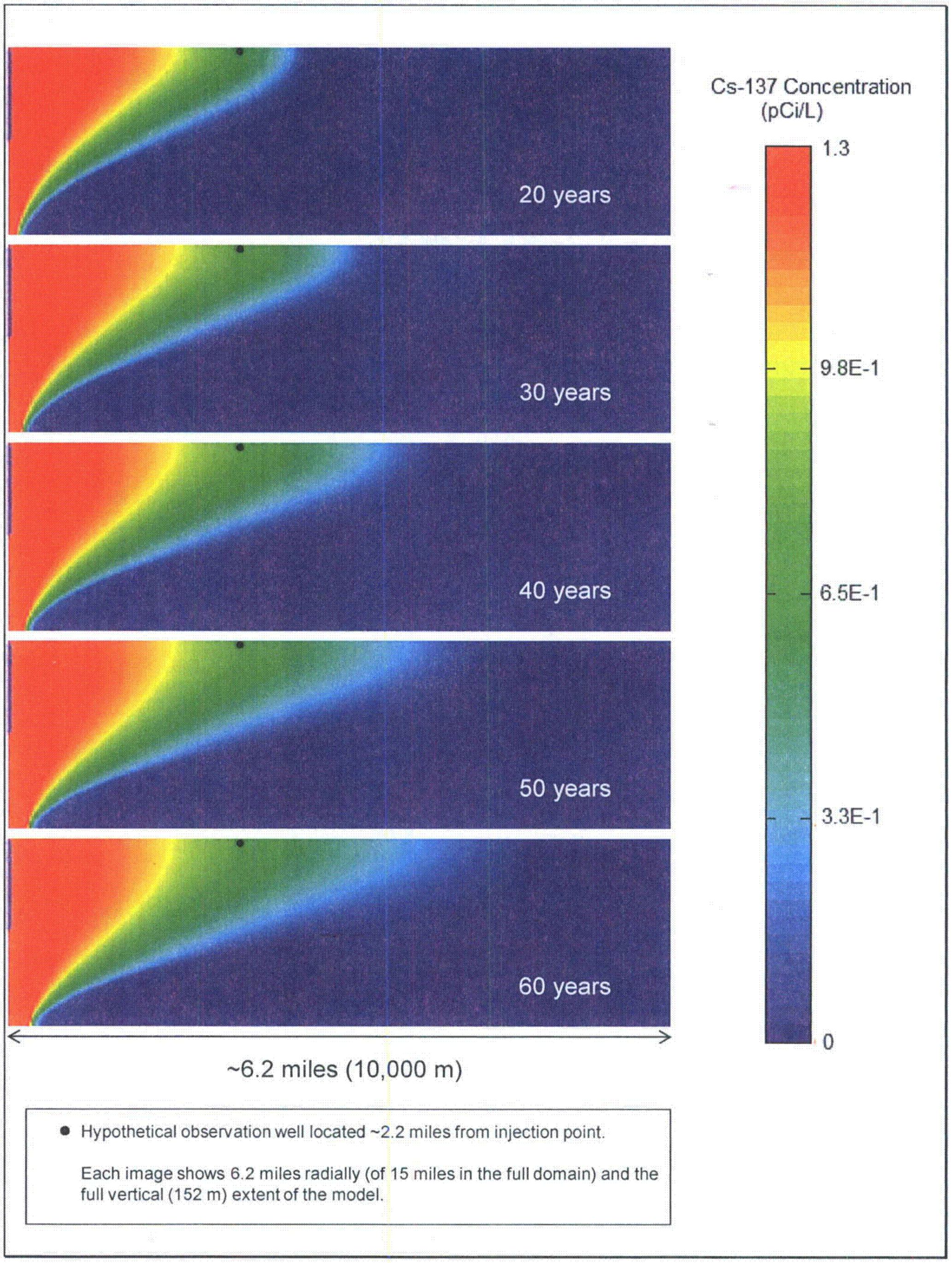
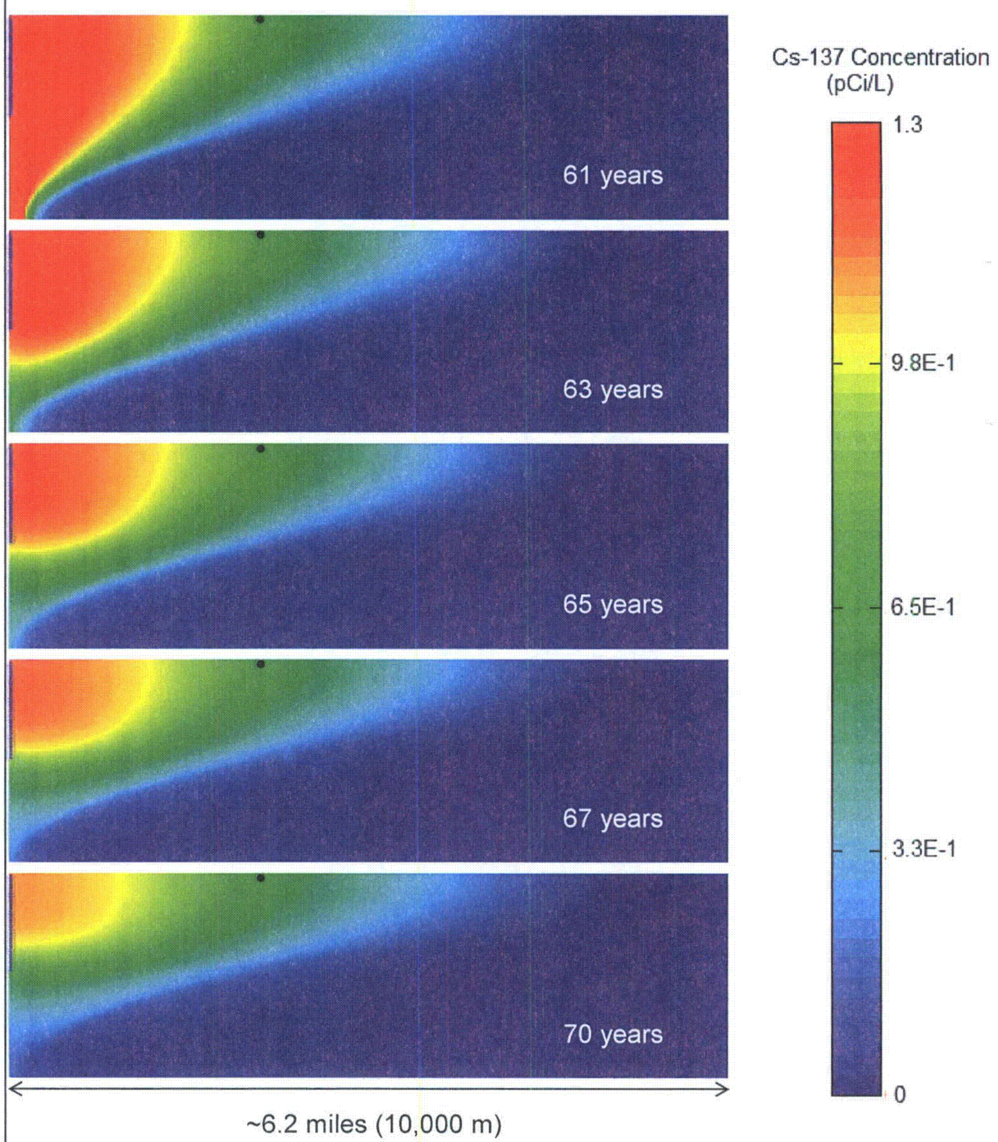


**Figure 11 Base Case Boulder Zone Cesium-137 Concentrations (Sheet 3 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 11 Base Case Boulder Zone Cesium-137 Concentrations (Sheet 4 of 4)**

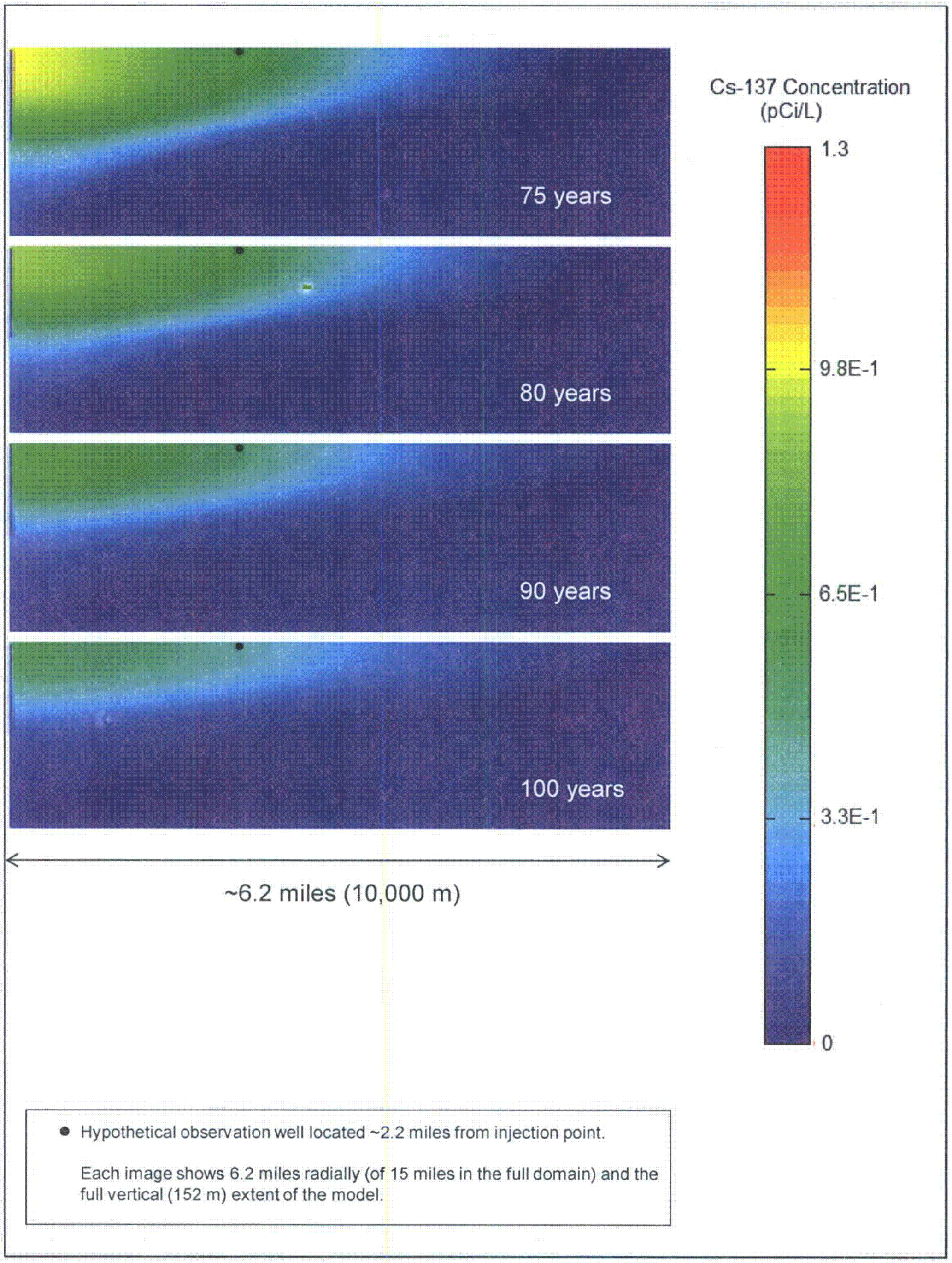


**Figure 12 Model Layer 1 Distribution of Cesium-137 in the Boulder Zone for the Base Case Simulation at the End of Plant Operations**

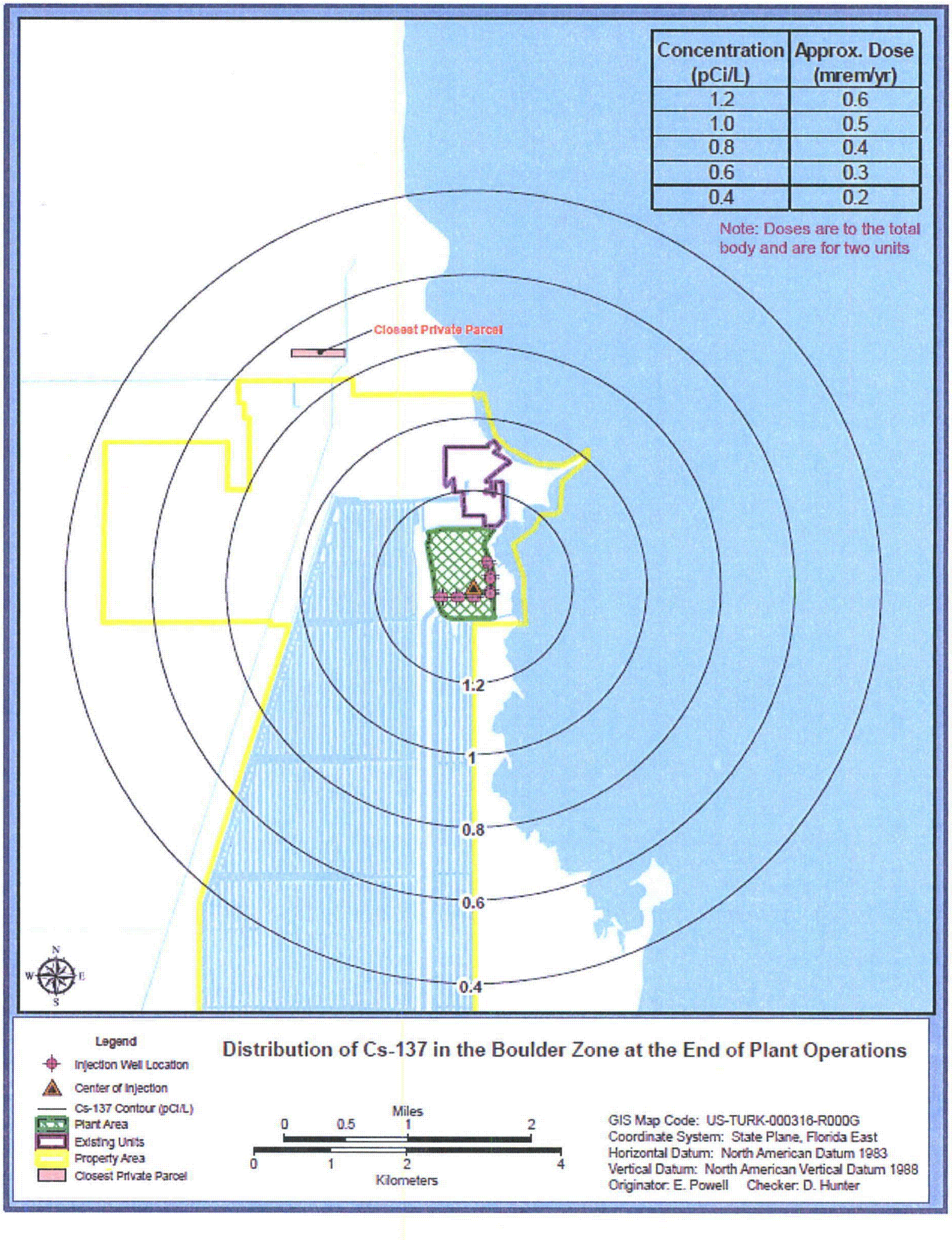
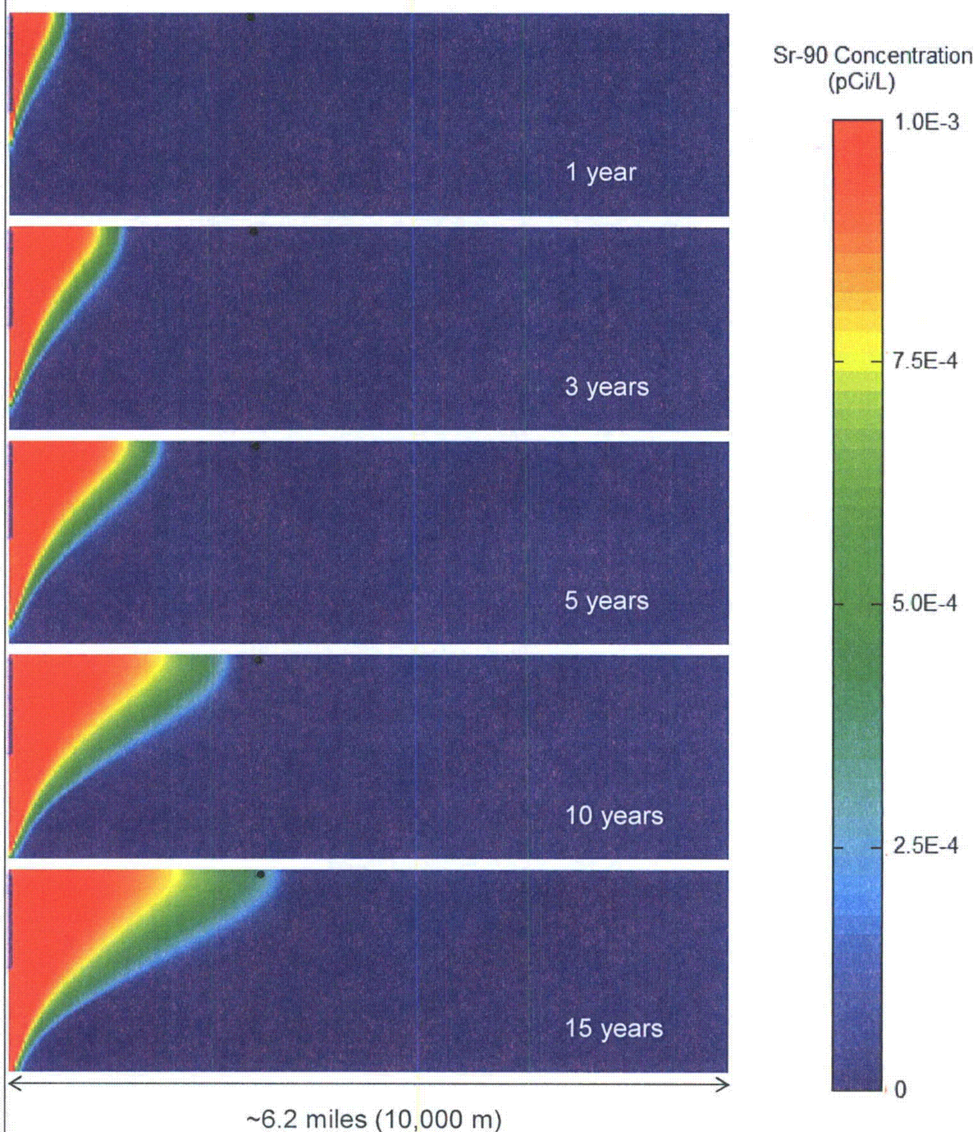


**Figure 13 Base Case Boulder Zone Strontium-90 Concentrations (Sheet 1 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 13 Base Case Boulder Zone Strontium-90 Concentrations (Sheet 2 of 4)**

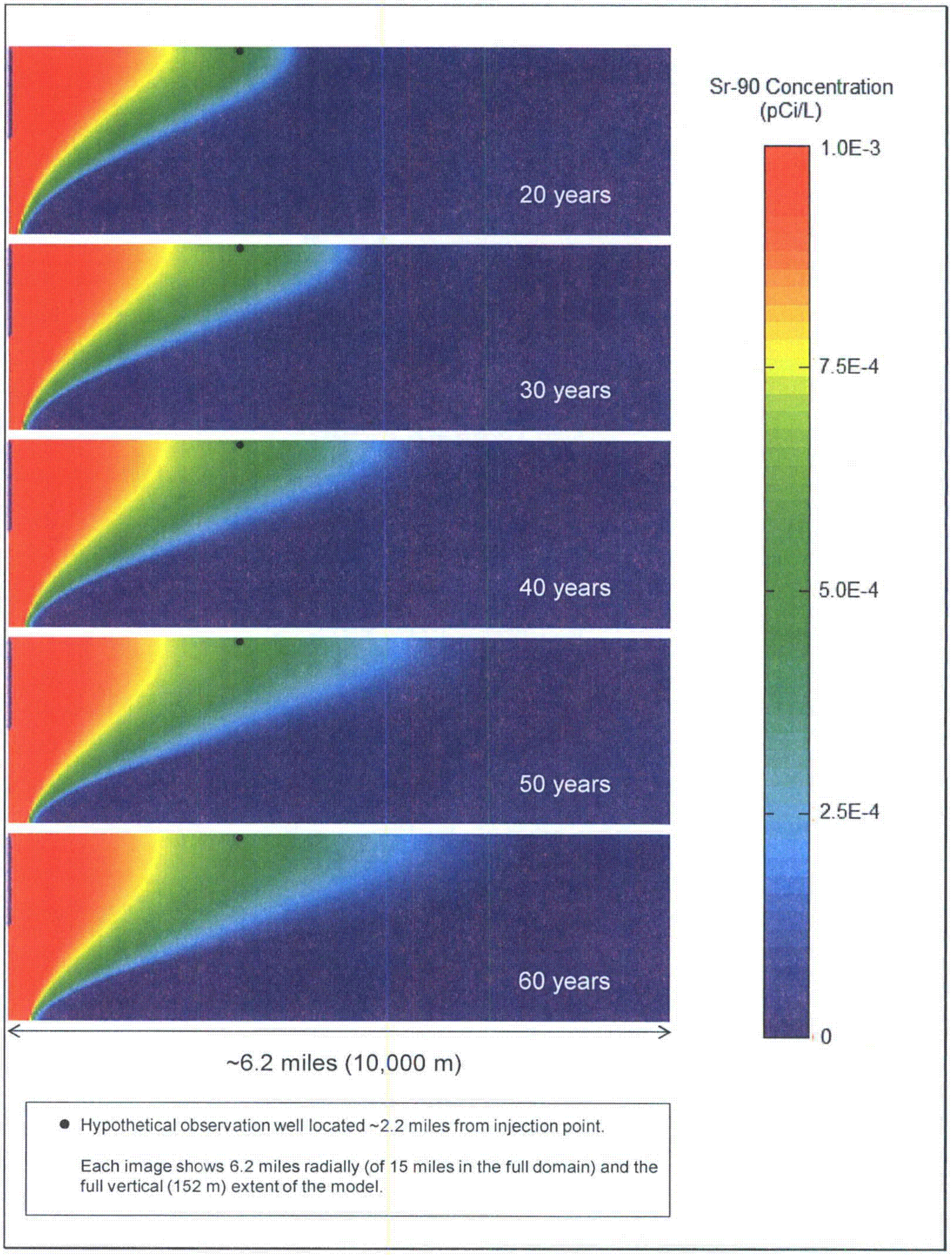
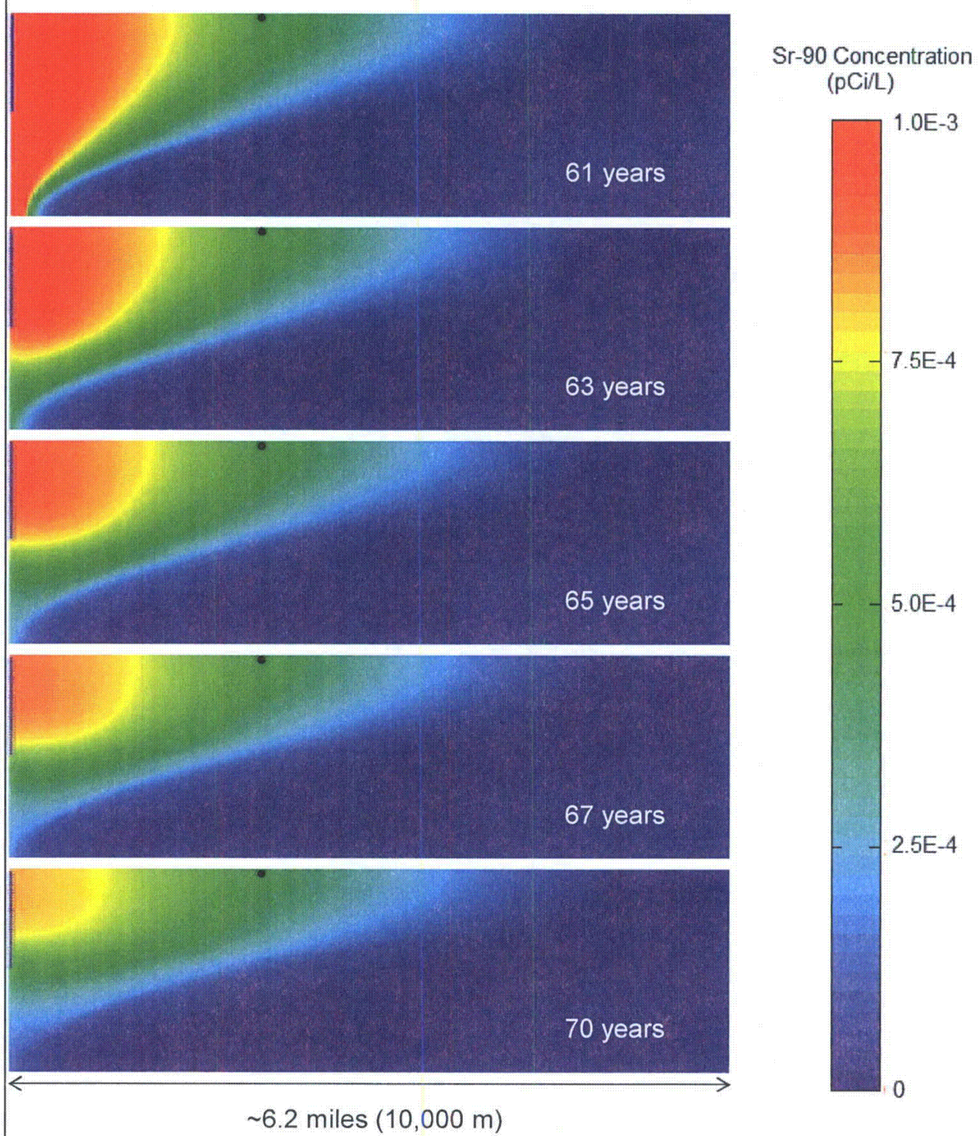


**Figure 13 Base Case Boulder Zone Strontium-90 Concentrations (Sheet 3 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 13 Base Case Boulder Zone Strontium-90 Concentrations (Sheet 4 of 4)**

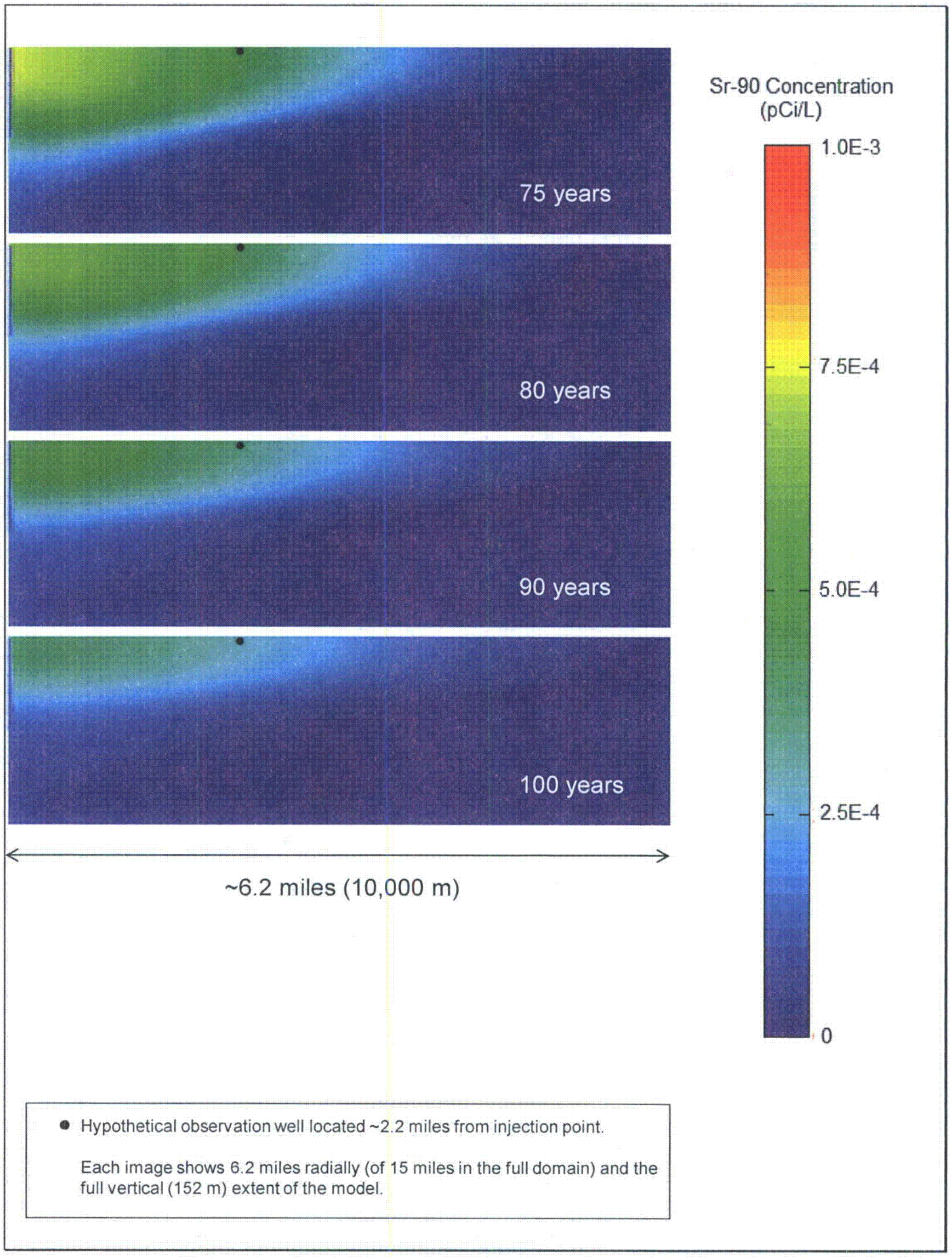


**Figure 14 Model Layer 1 Distribution of Strontium-90 in the Boulder Zone for the Base Case Simulation at the End of Plant Operations**

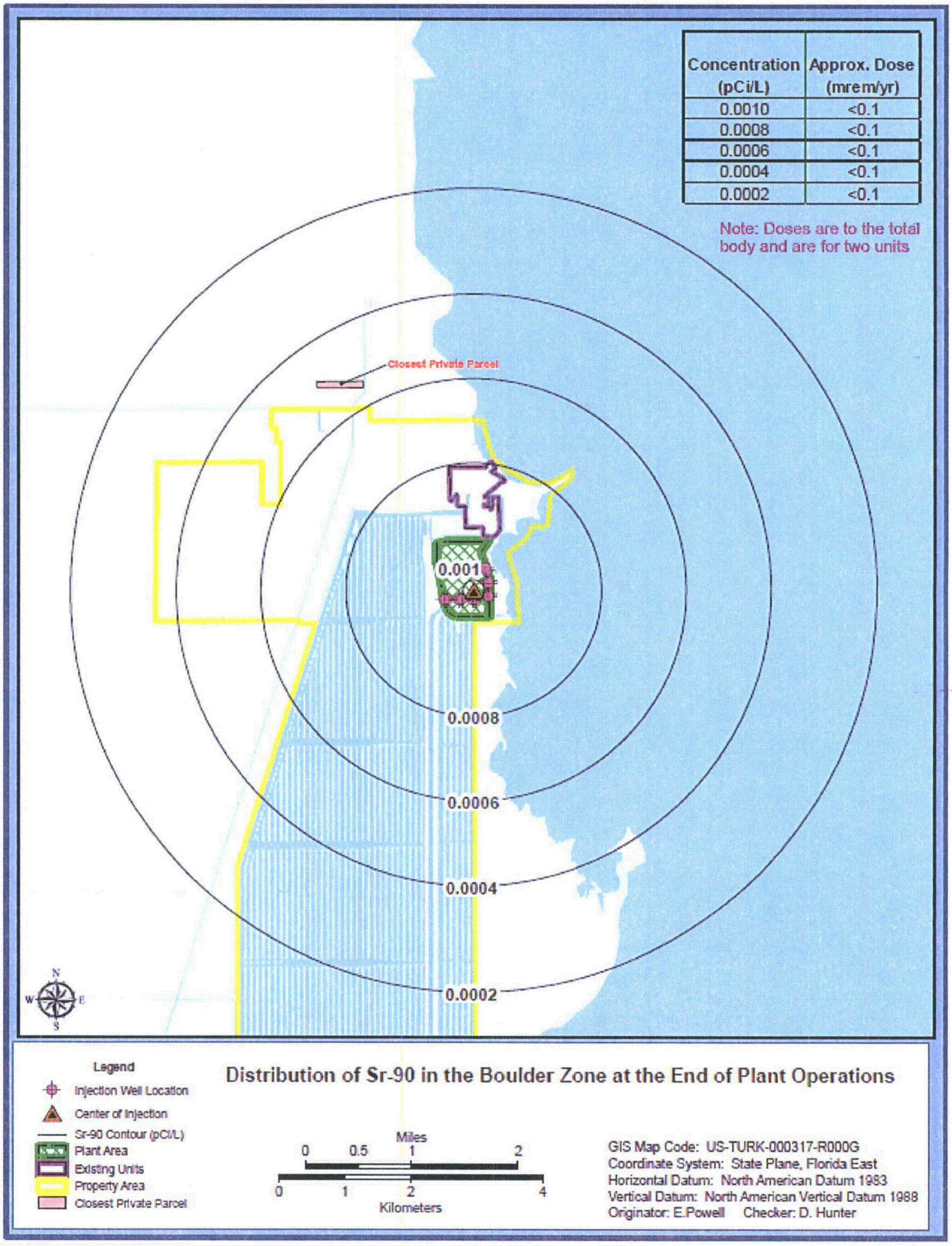


**Figure 15 Saltwater Injection Case Boulder Zone TDS Concentrations – Cycled Injection**

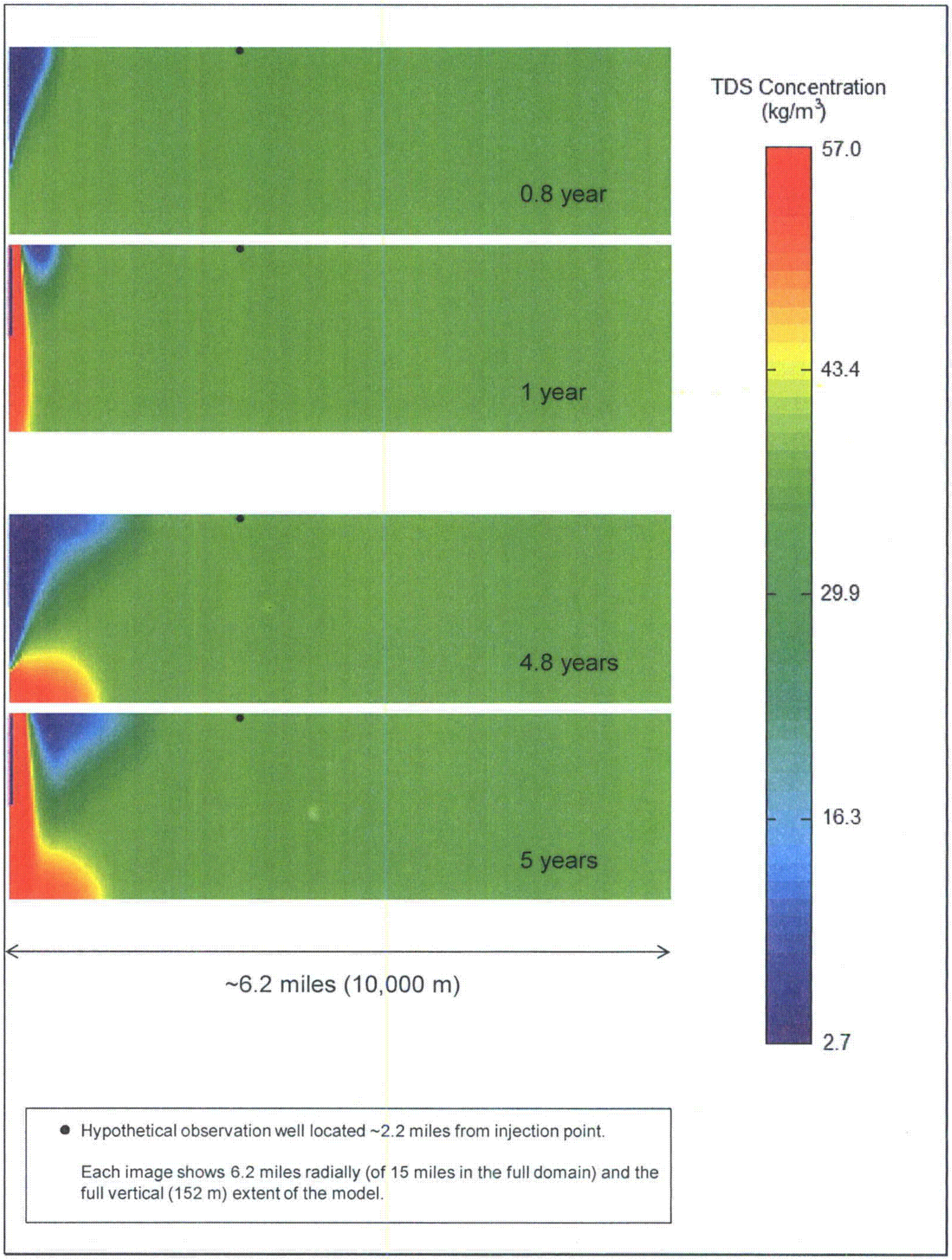
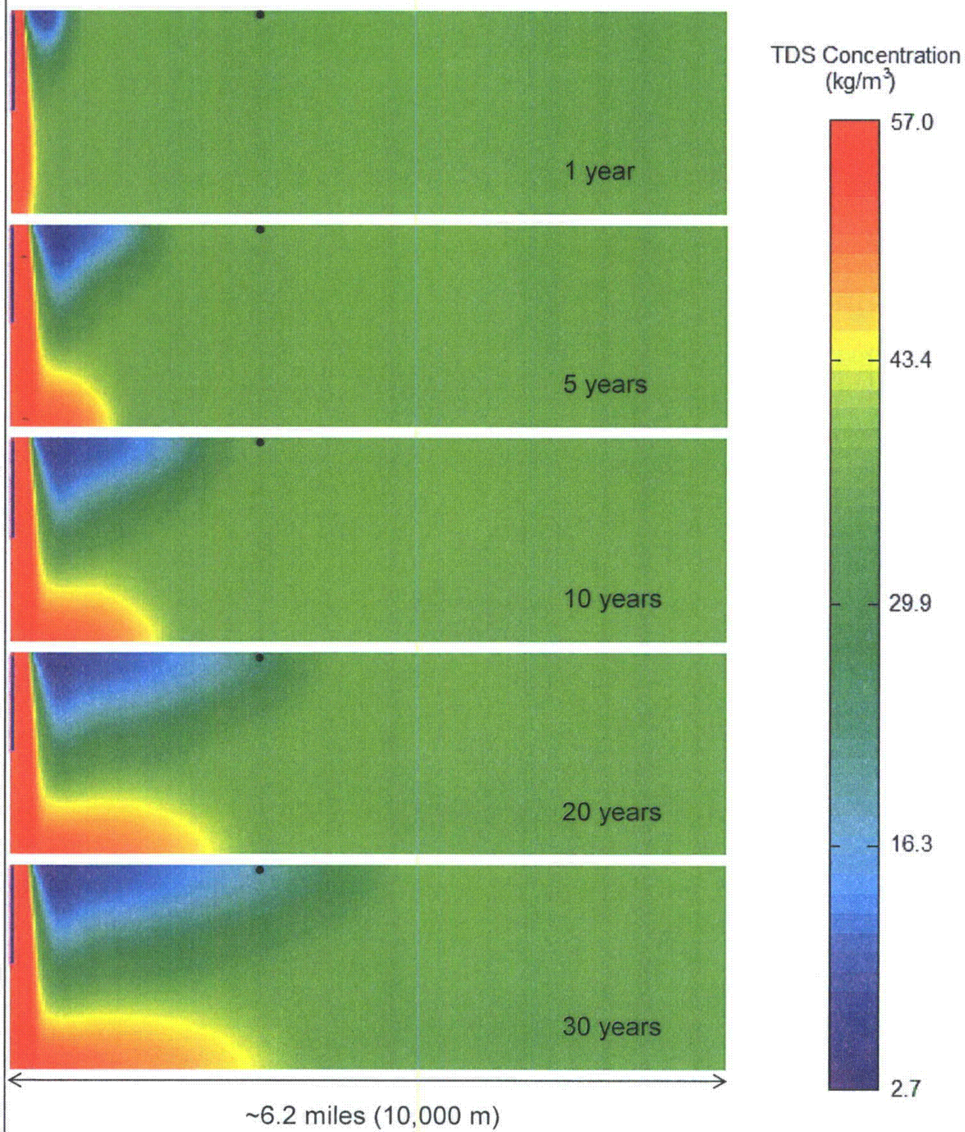


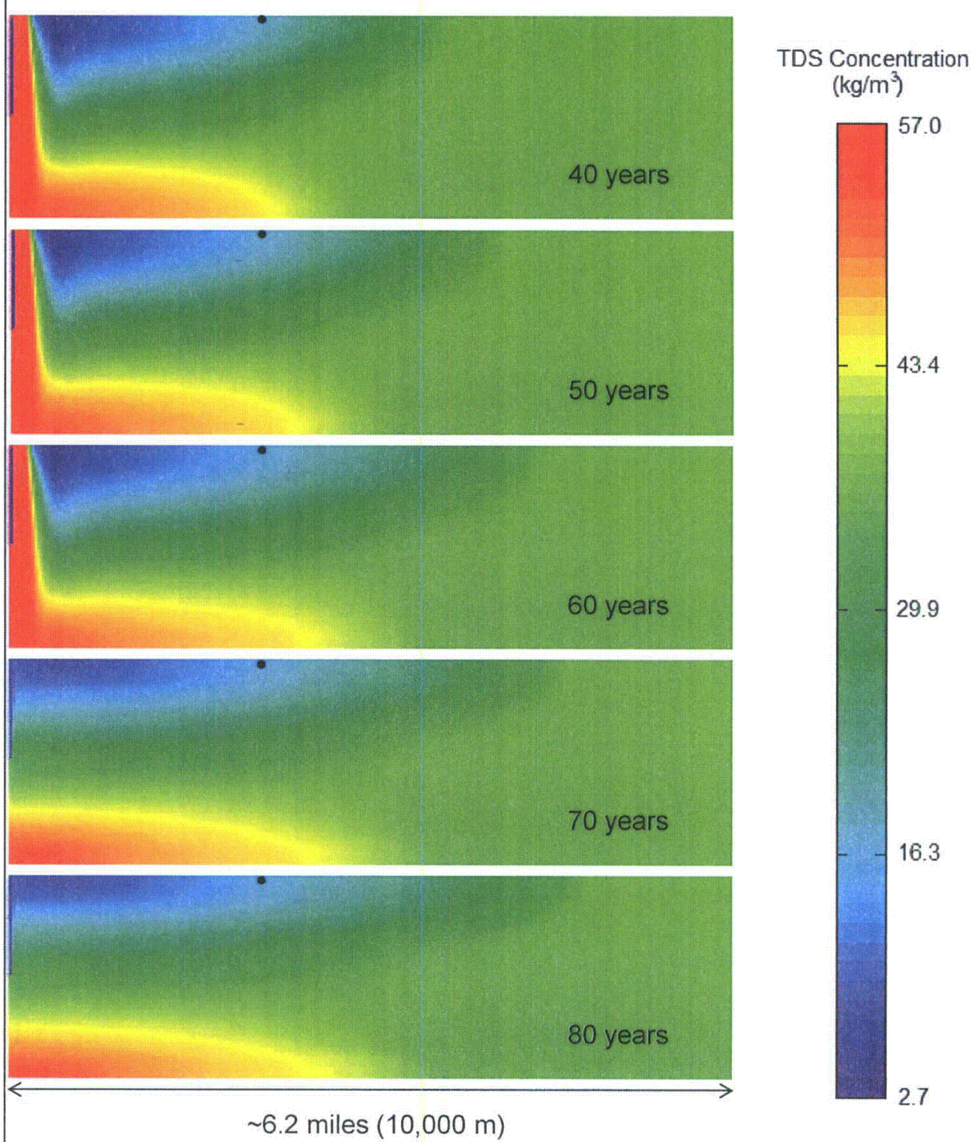
**Figure 16 Saltwater Injection Case Boulder Zone TDS Concentrations (Sheet 1 of 3)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 16 Saltwater Injection Case Boulder Zone TDS Concentrations (Sheet 2 of 3)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 16 Saltwater Injection Case Boulder Zone TDS Concentrations (Sheet 3 of 3)**

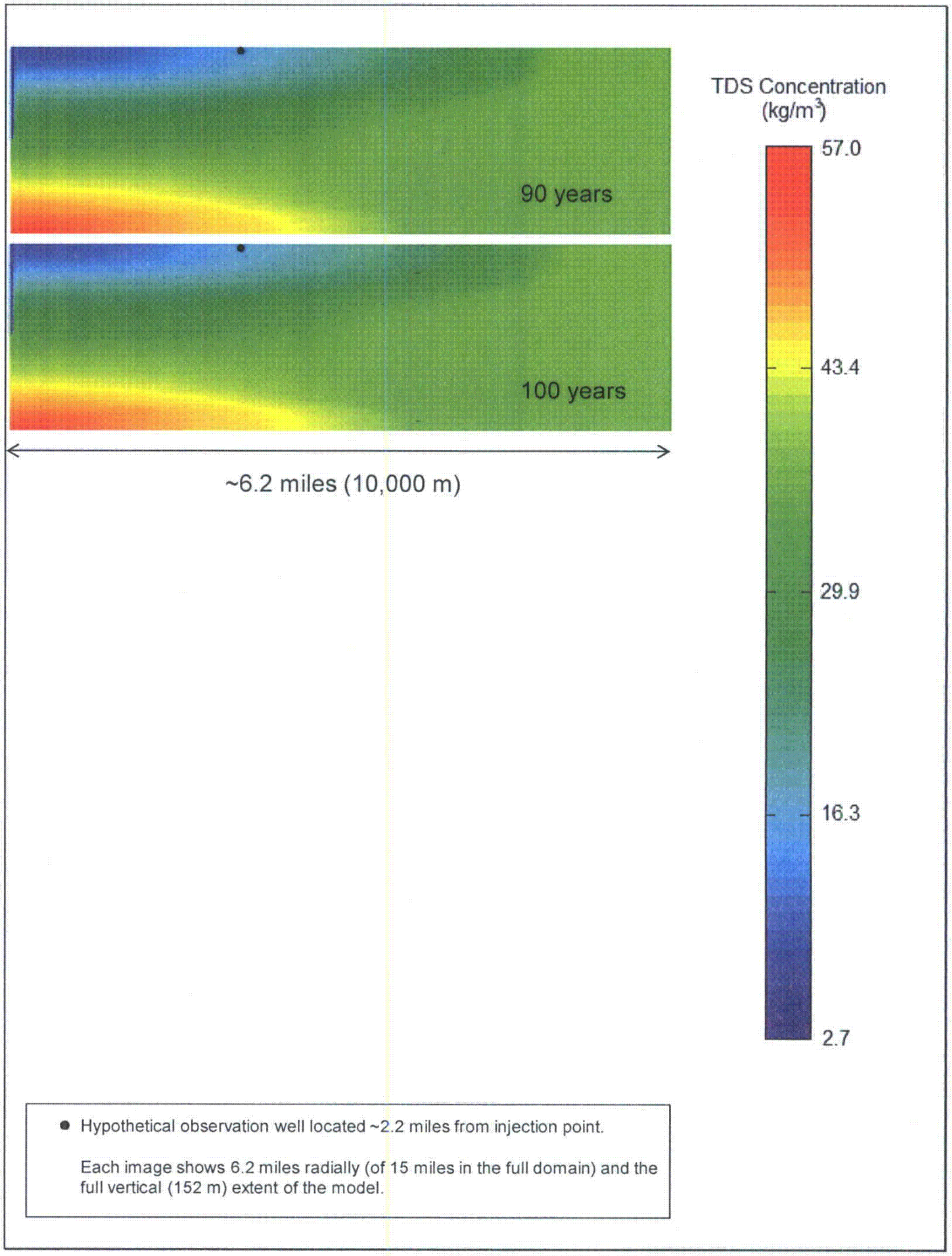
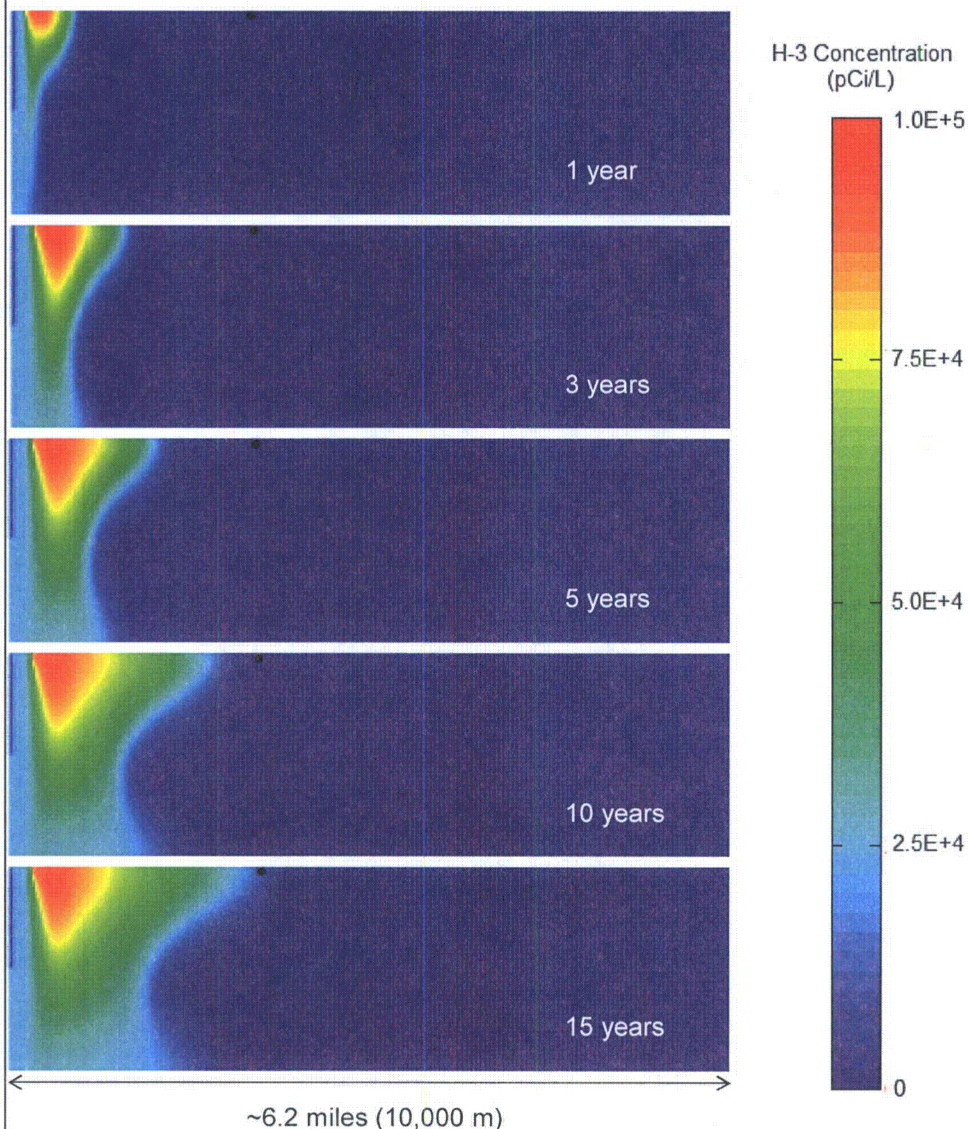


**Figure 17 Saltwater Injection Case Boulder Zone Tritium Concentrations (Sheet 1 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 17 Saltwater Injection Case Boulder Zone Tritium Concentrations (Sheet 2 of 4)**

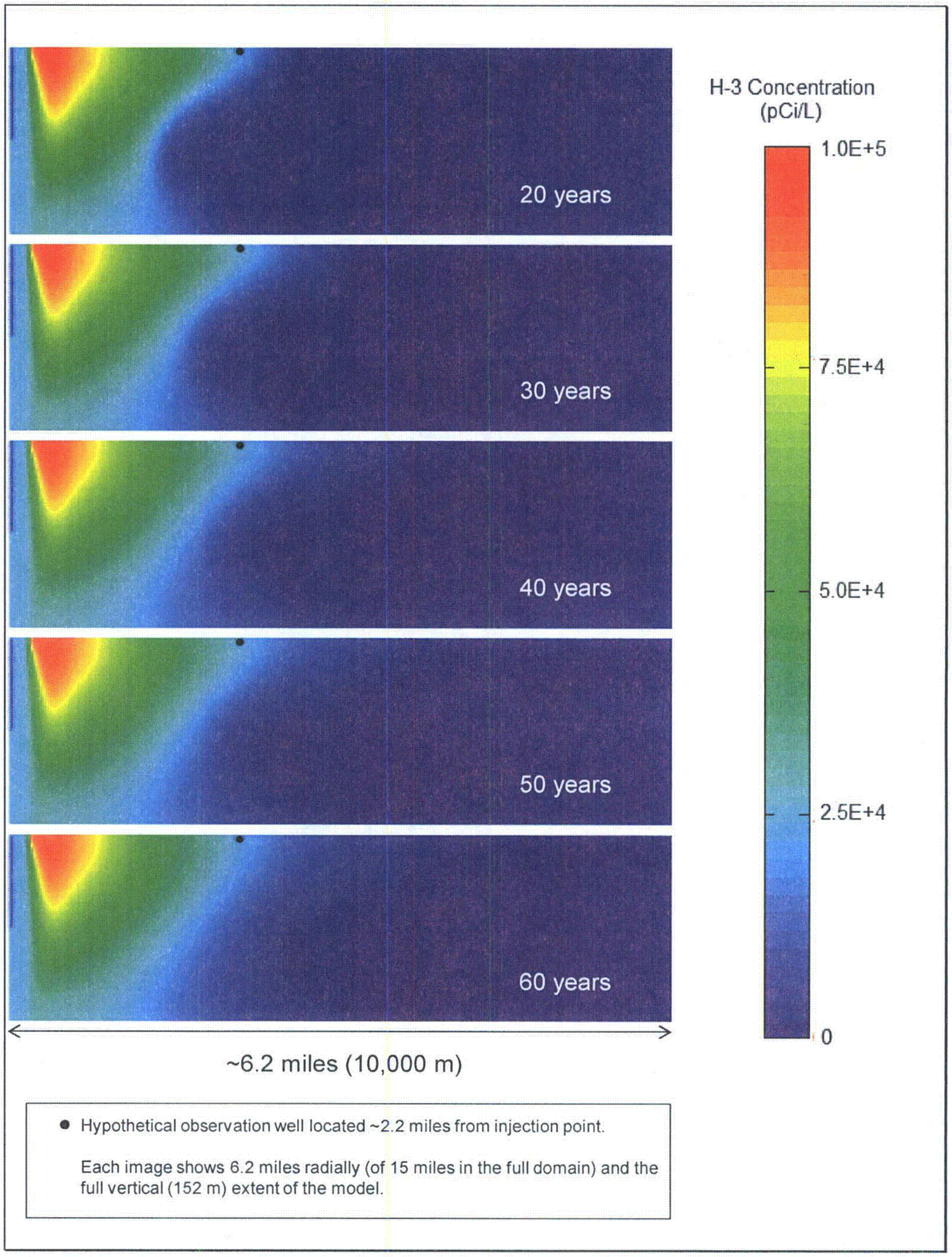


**Figure 17 Saltwater Injection Case Boulder Zone Tritium Concentrations (Sheet 3 of 4)**

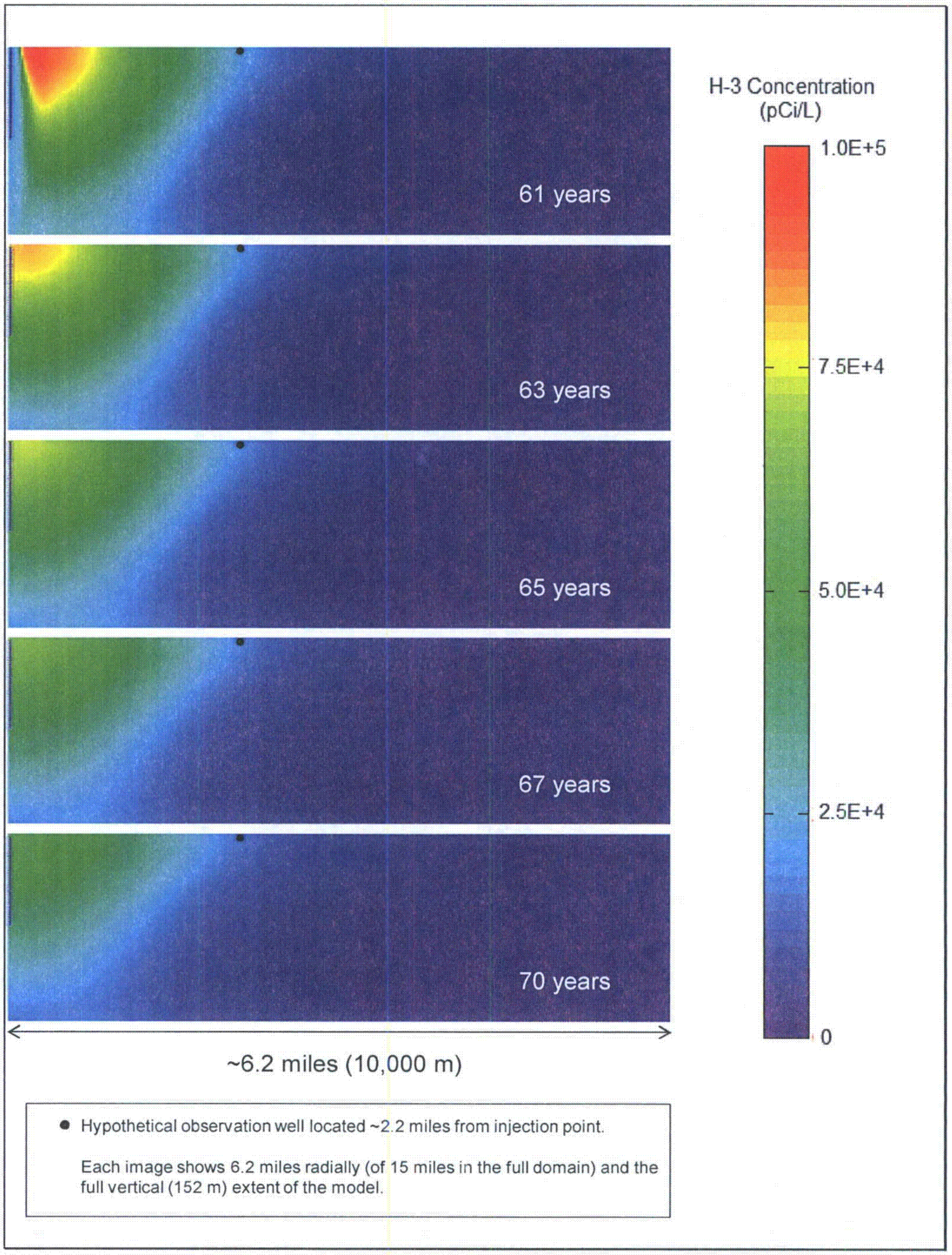
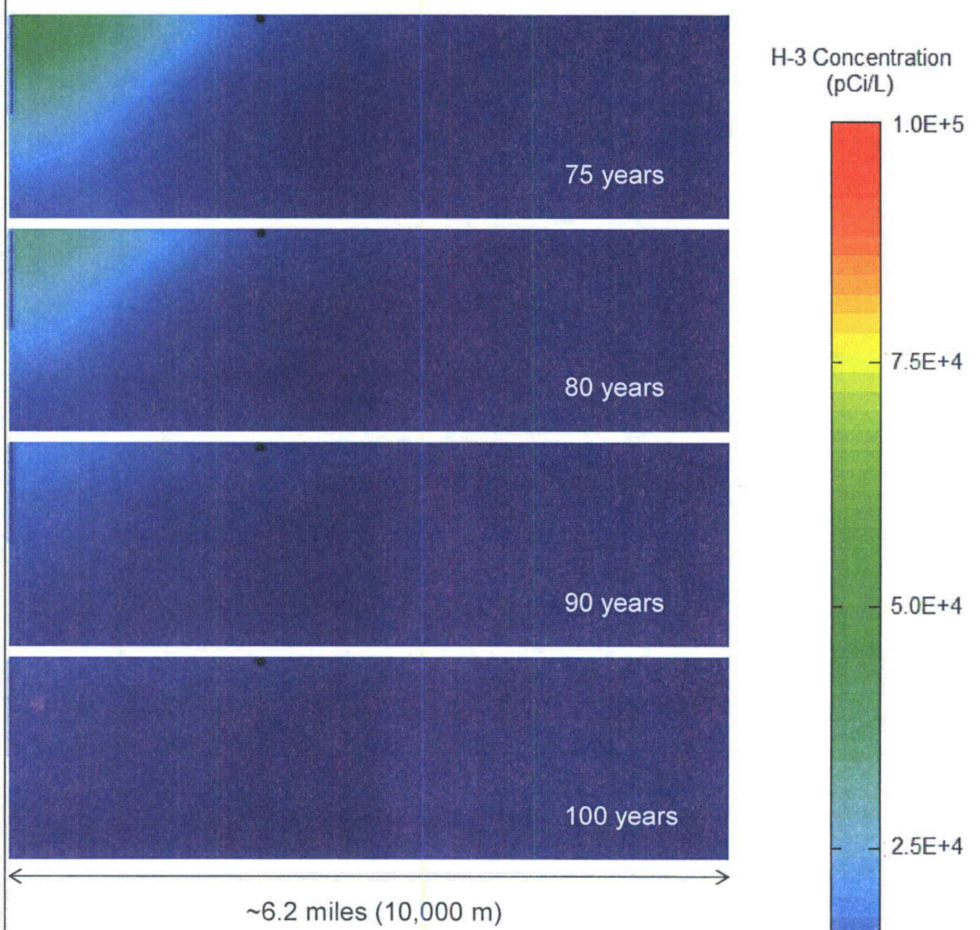


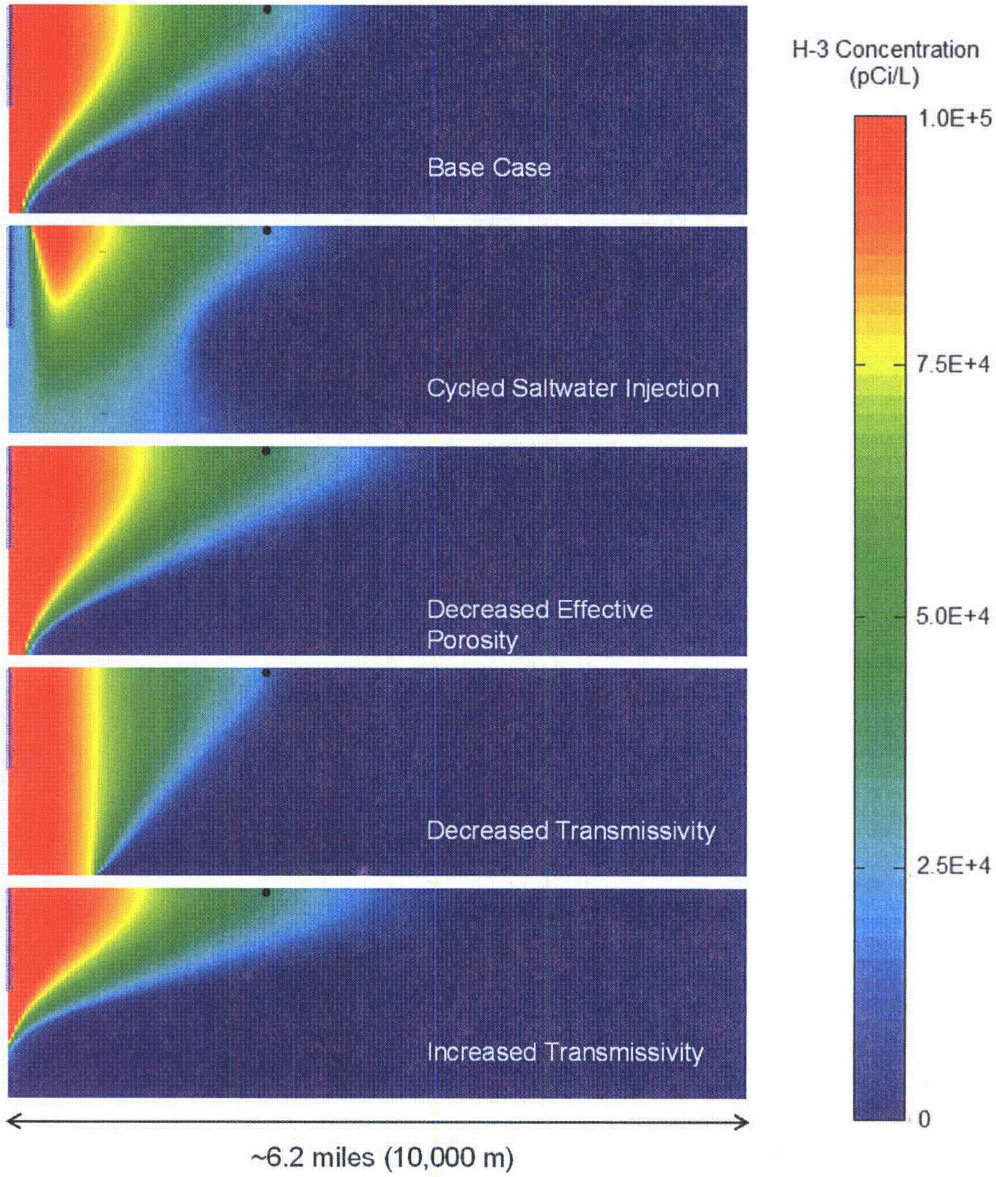
**Figure 17 Saltwater Injection Case Boulder Zone Tritium Concentrations (Sheet 4 of 4)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

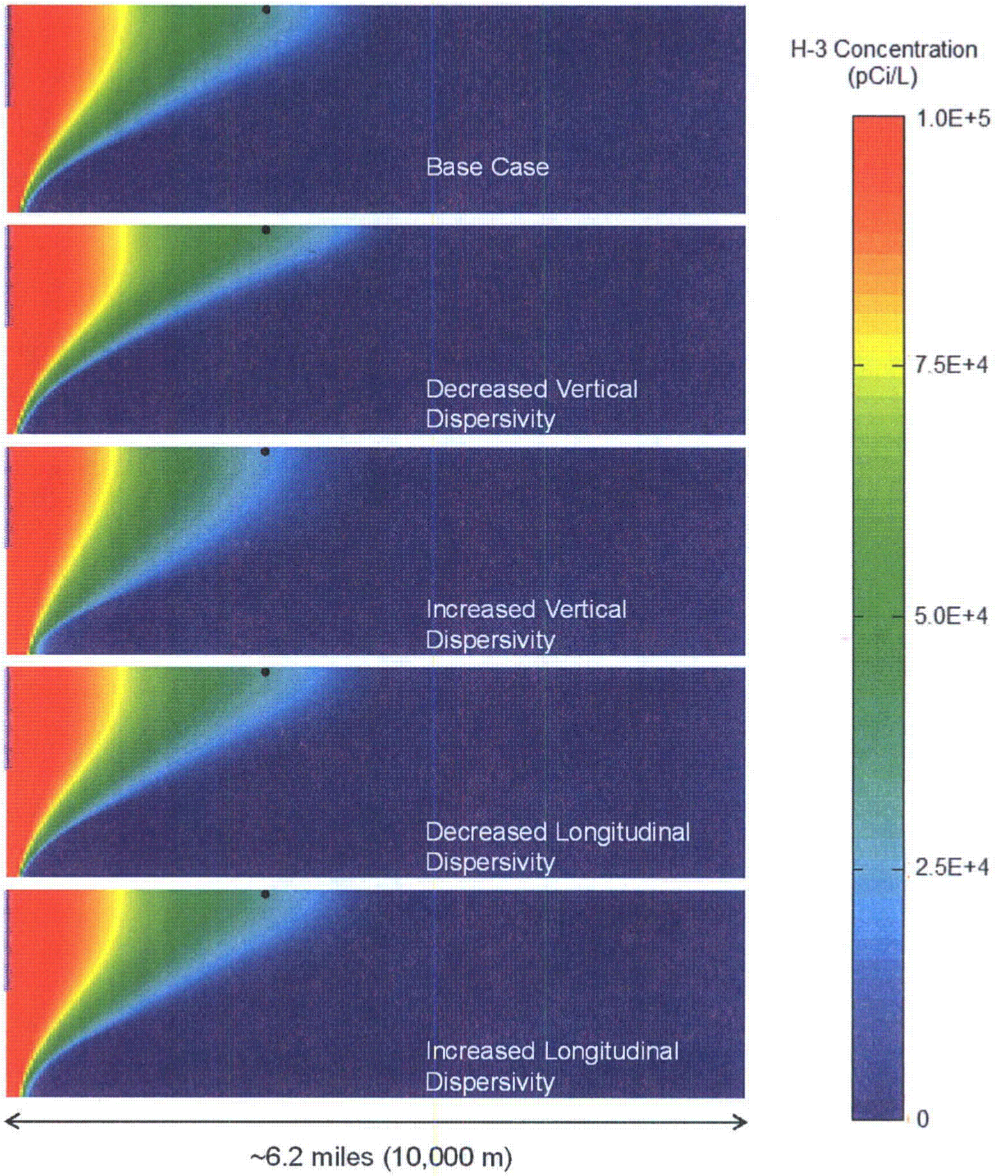
**Figure 18 Boulder Zone Tritium Concentrations at Model Year 25 (Sheet 1 of 3)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

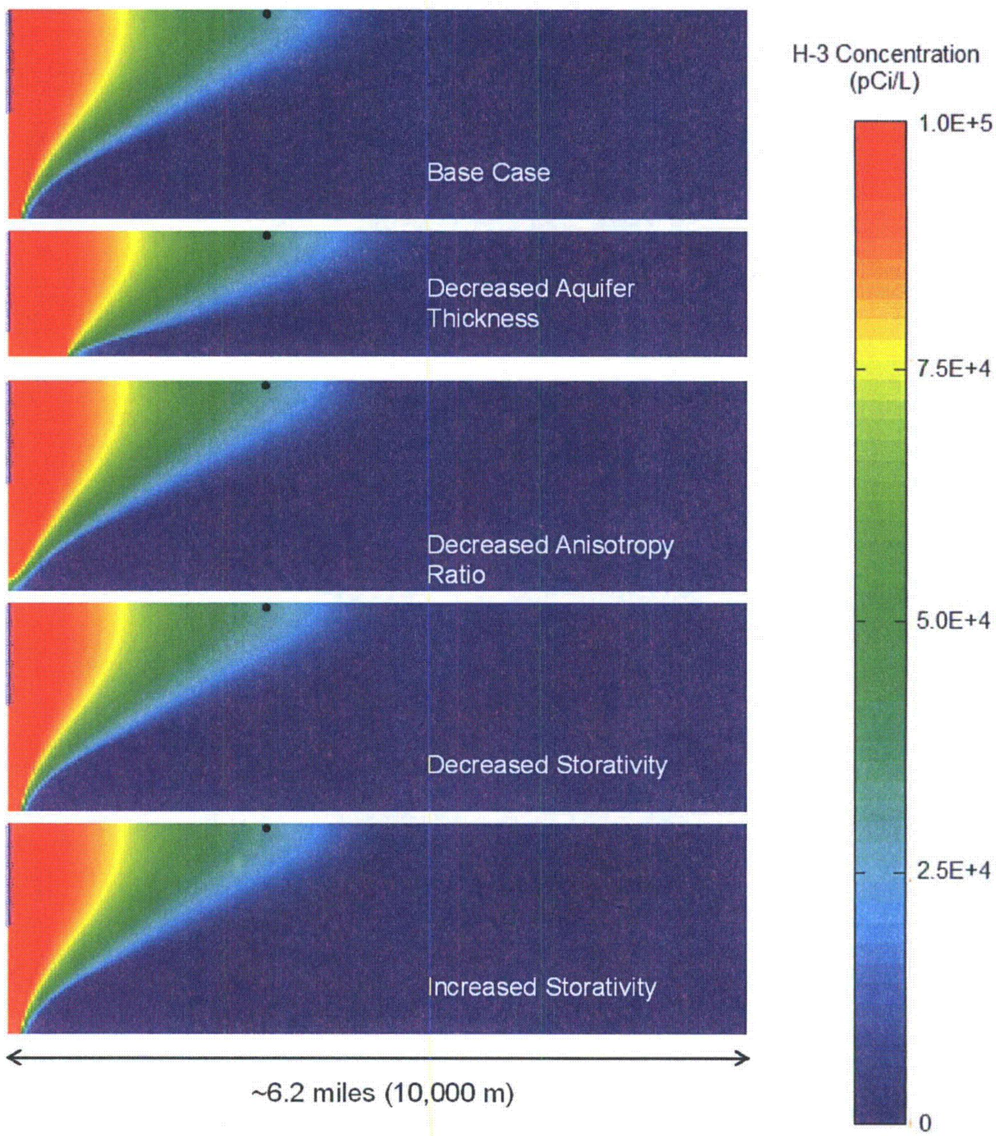
**Figure 18 Boulder Zone Tritium Concentrations at Model Year 25 (Sheet 2 of 3)**




● Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical (152 m) extent of the model.

**Figure 18 Boulder Zone Tritium Concentrations at Model Year 25 (Sheet 3 of 3)**




- Hypothetical observation well located ~2.2 miles from injection point.

Each image shows 6.2 miles radially (of 15 miles in the full domain) and the full vertical extent of the model (152 m for all cases except the decreased thickness case [92 m]).

**Figure 19 Boulder Zone Tritium Breakthrough Curves in Model Layer 1 at 2.2 mile Receptor Location**

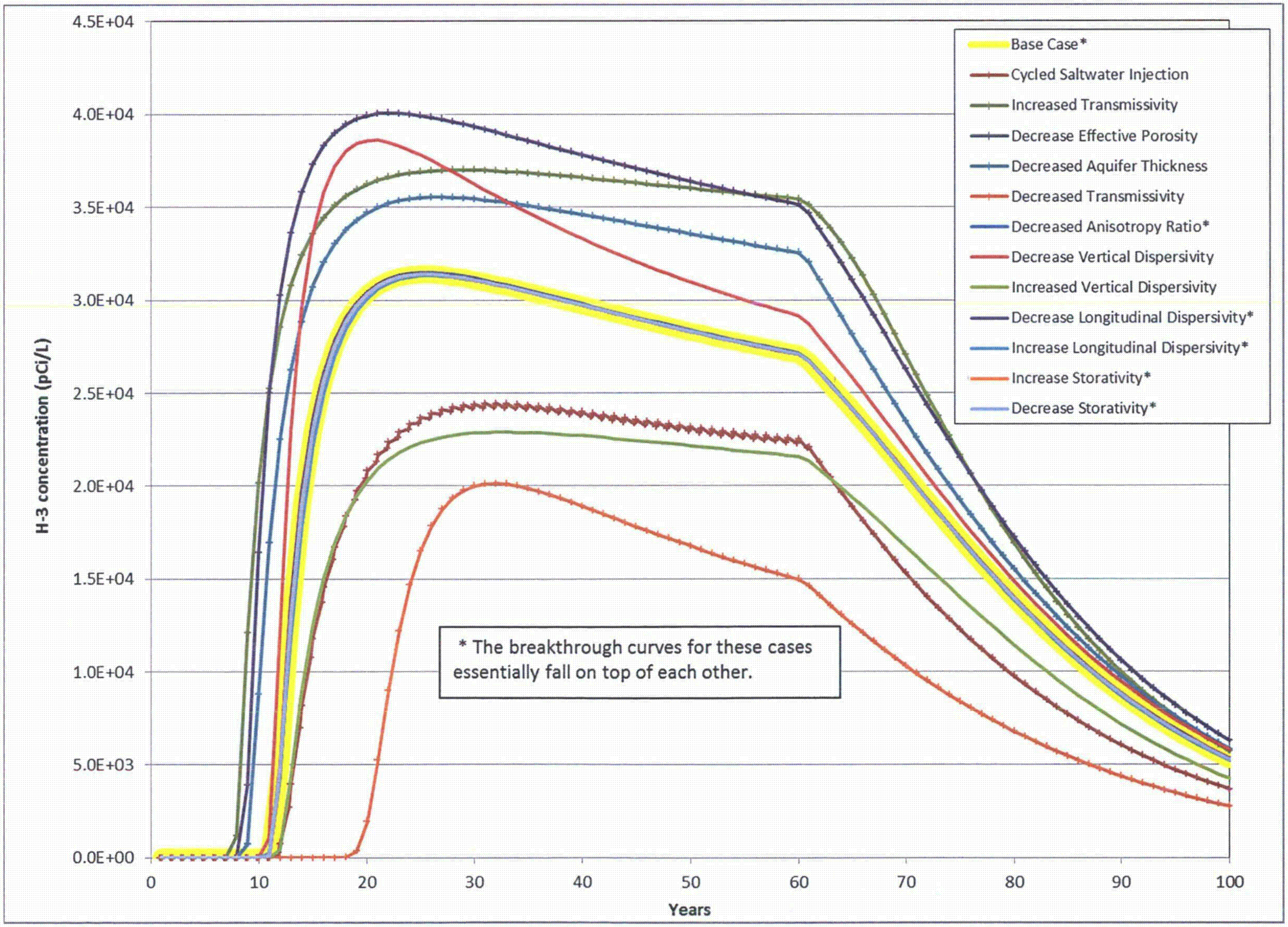


**Figure 20 Six mrem Derived Tritium Activity Concentration Profiles in the Boulder Zone Base Case Simulation**

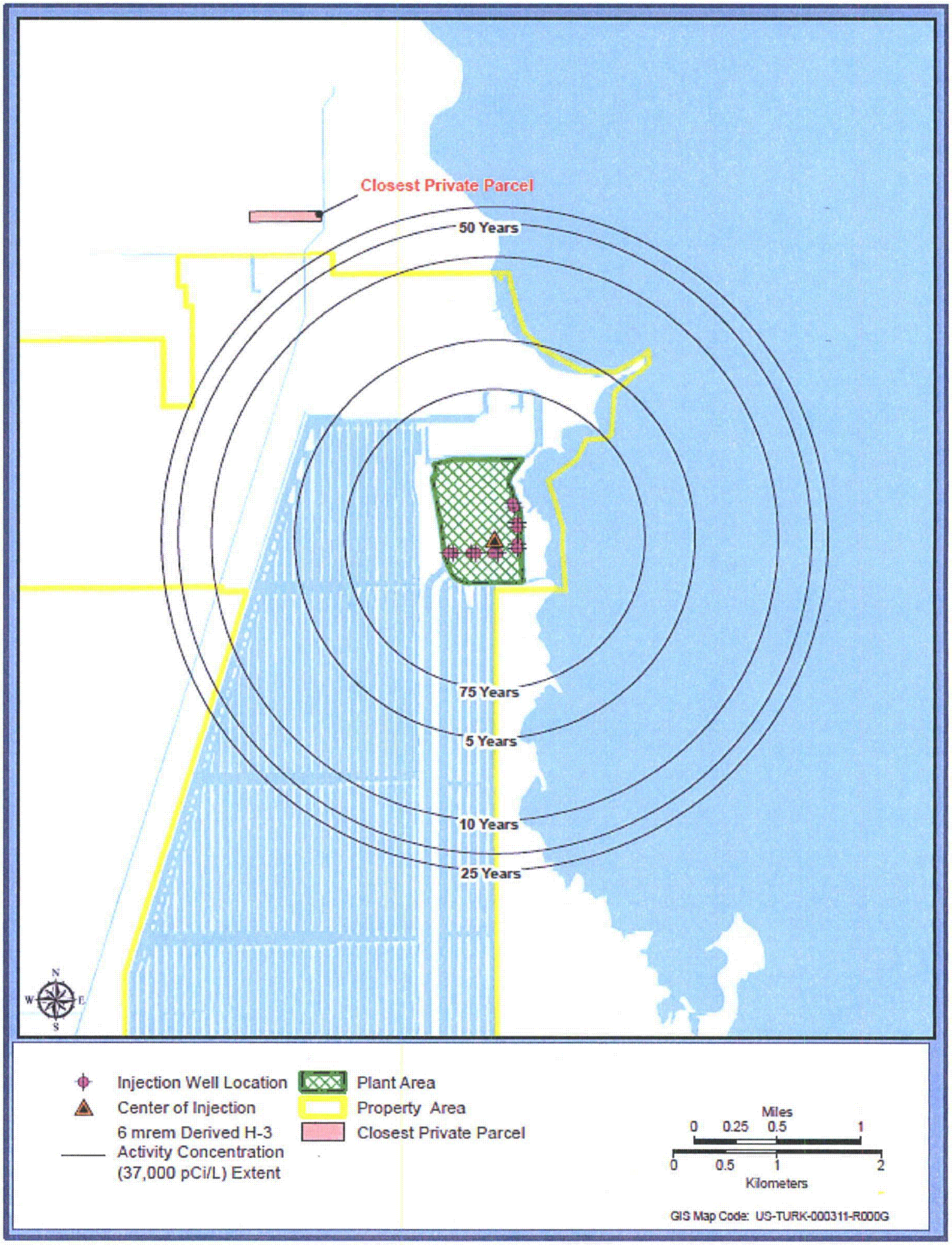


**Figure 21 Potential Exposure Location Areas**

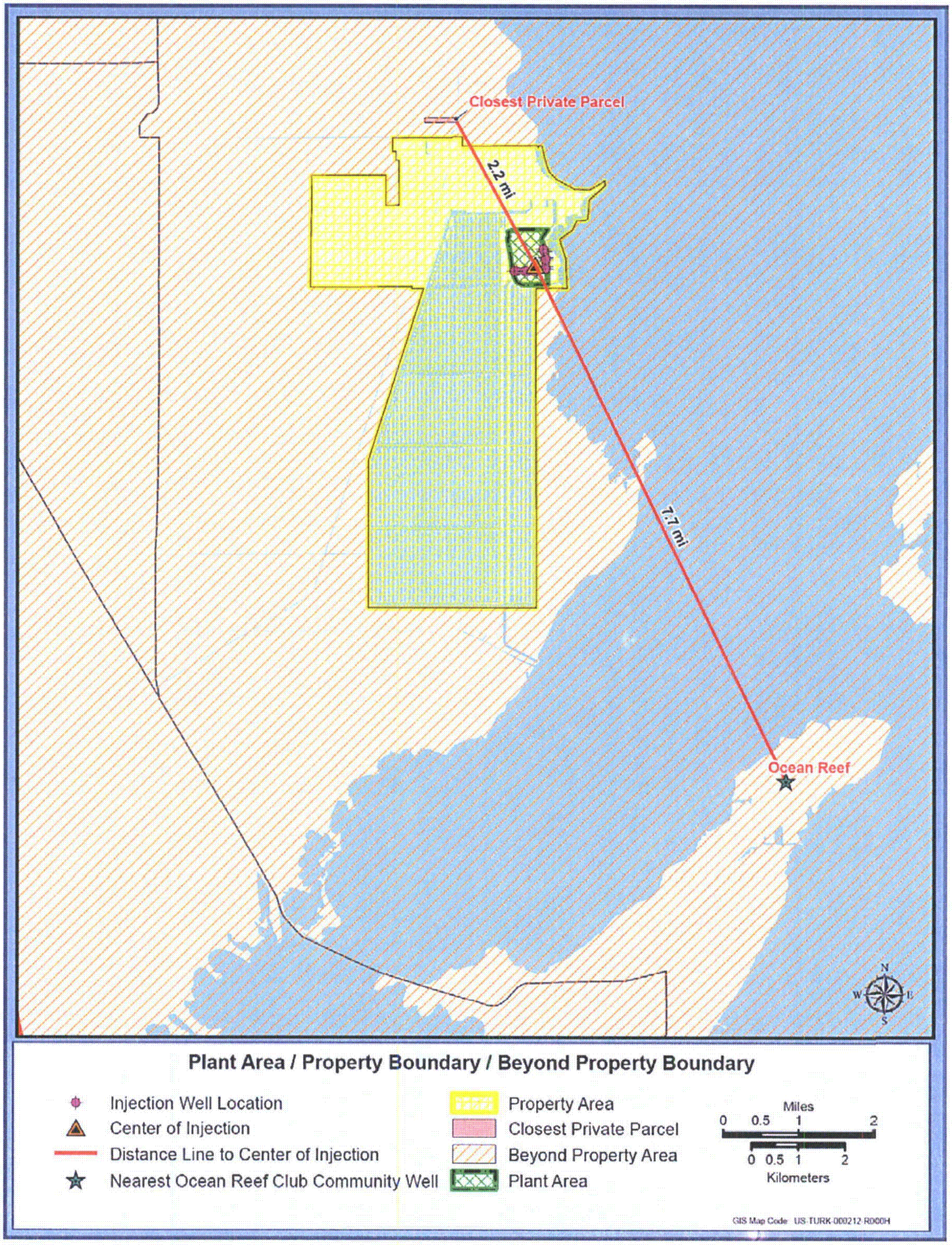


**Figure 22 Land Ownership and Water Supply Well Locations in the Area of Turkey Point**

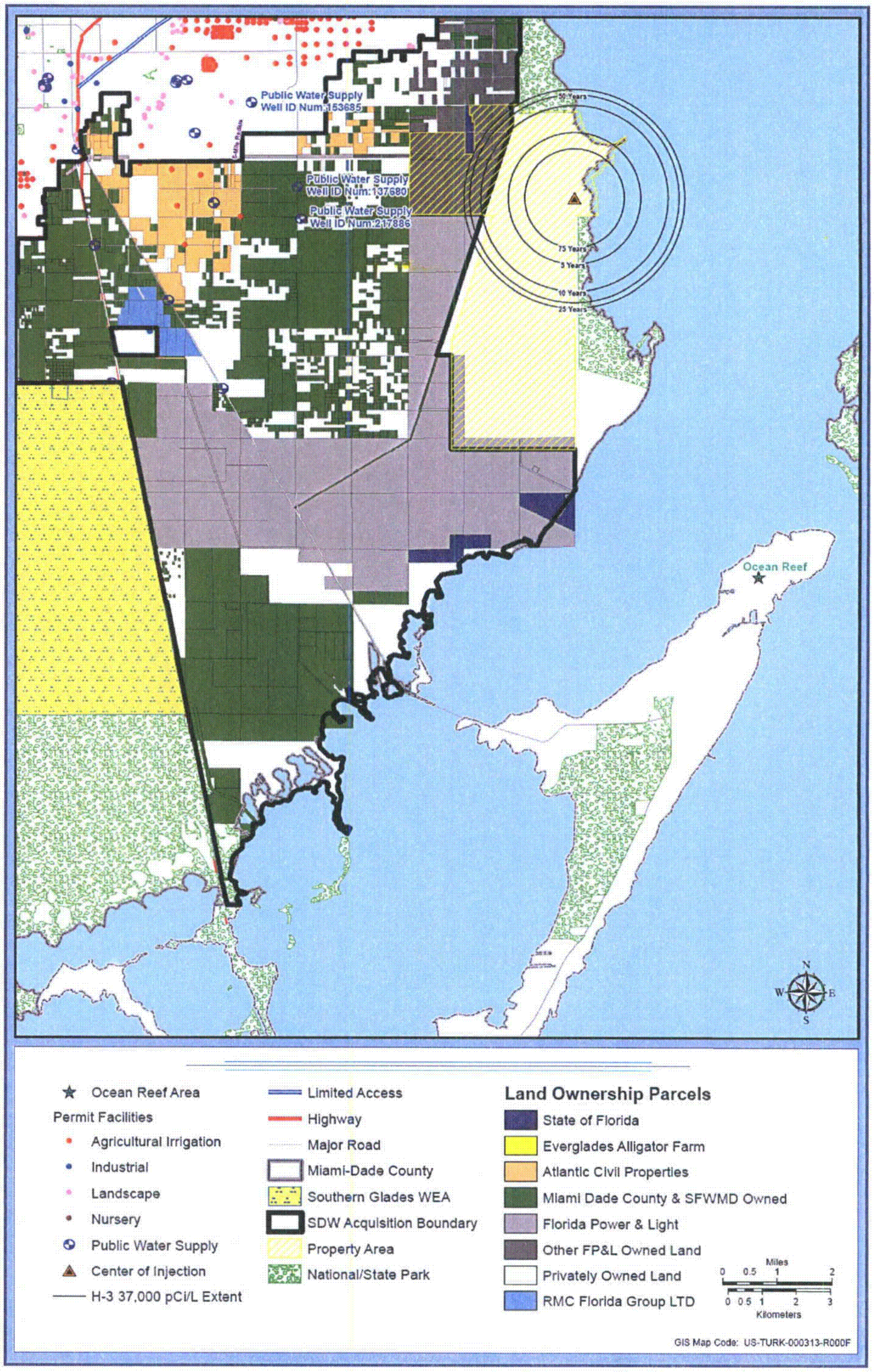
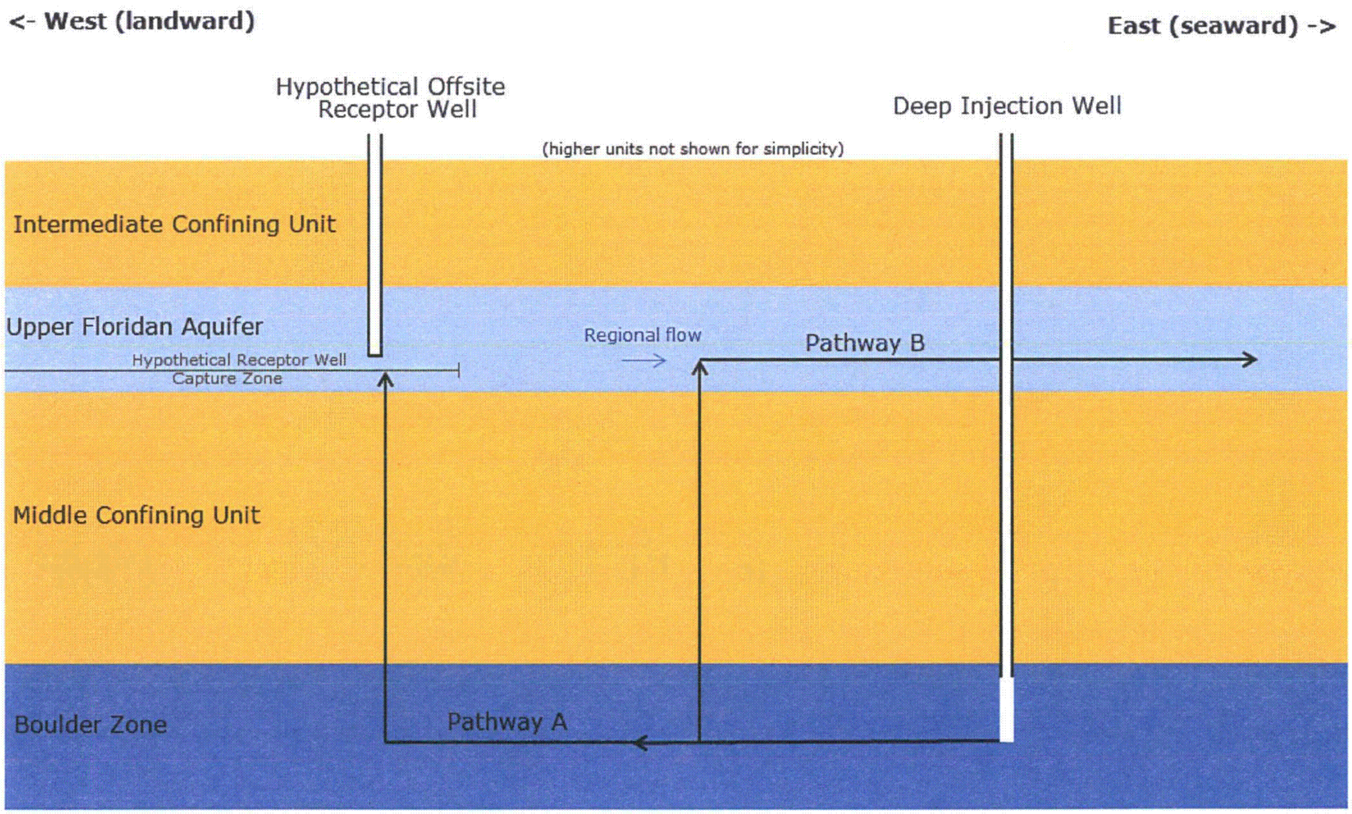


**Figure 23 Conceptual Schematic of Pathways to Hypothetical Offsite Receptor Accessing the Upper Floridan Aquifer**




Schematic illustration of potential pathways. Not to scale.

**Figure 24 Retained Member-of-the-Public Locations**