Draft Supplemental Environmental Impact Statement

for the Production of Tritium in a Commercial Light Water Reactor

Watts Bar Nuclear Plant

Sequoyah Nuclear Plant

U.S. Department of Energy
National Nuclear Security Administration

DOE/EIS-0288-S1

August 2014

ACRONYMS AND ABBREVIATIONS

CFR	*Code of Federal Regulations*
CLWR	commercial light water reactor
CO2e	carbon dioxide equivalent
DOE	U.S. Department of Energy
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
FR	*Federal Register*
NEPA	*National Environmental Policy Act of 1969*
NNSA	National Nuclear Security Administration
NRC	U.S. Nuclear Regulatory Commission
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
SEIS	supplemental environmental impact statement
TPBAR	tritium-producing burnable absorber rod
TVA	Tennessee Valley Authority
U.S.C.	*United States Code*

UNDERSTANDING SCIENTIFIC NOTATION

NNSA has used scientific notation in this SEIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number and a positive or negative power of 10. Examples include the following:

Positive powers of 10	Negative powers of 10
$10^1 = 10 \times 1 = 10$	$10^{-1} = 1 \div 10 = 0.1$
$10^2 = 10 \times 10 = 100$	$10^{-2} = 1 \div 100 = 0.01$
and so on, therefore,	and so on, therefore,
$10^6 = 1,000,000$ (or 1 million)	$10^{-6} = 0.000001$ (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are 3 chances in 1 million that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.

METRIC PREFIXES

Prefix	**Symbol**	**Multiplication factor**		**Scientific notation**
tera-	T	1,000,000,000,000	=	1×10^{12}
giga-	G	1,000,000,000	=	1×10^{9}
mega-	M	1,000,000	=	1×10^{6}
kilo-	k	1,000	=	1×10^{3}
deca-	D	10	=	1×10^{1}
deci-	d	0.1	=	1×10^{-1}
centi-	c	0.01	=	1×10^{-2}
milli-	m	0.001	=	1×10^{-3}
micro-	μ	0.000001	=	1×10^{-6}
nano-	n	0.000000001	=	1×10^{-9}
pico-	p	0.000000000001	=	1×10^{-12}

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CONVERSION FACTORS

Metric to English			English to Metric		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
square kilometers	247.1	acres	acres	0.0040469	square kilometers
square kilometers	0.3861	square miles	square miles	2.59	square kilometers
square meters	10.764	square feet	square feet	0.092903	square meters
Concentration					
kilograms/square meter	0.16667	tons/acre	tons/acre	0.5999	kilograms/square meter
milligrams/liter	1[a]	parts/million	parts/million	1[a]	milligrams/liter
micrograms/liter	1[a]	parts/billion	parts/billion	1[a]	micrograms/liter
micrograms/cubic meter	1[a]	parts/trillion	parts/trillion	1[a]	micrograms/cubic meter
Density					
grams/cubic centimeter	62.428	pounds/cubic feet	pounds/cubic feet	0.016018	grams/cubic centimeter
grams/cubic meter	0.0000624	pounds/cubic feet	pounds/cubic feet	16,025.6	grams/cubic meter
Length					
centimeters	0.3937	inches	inches	2.54	centimeters
meters	3.2808	feet	feet	0.3048	meters
micrometers	0.00003937	inches	inches	25,400	micrometers
millimeters	0.03937	inches	inches	25.40	millimeters
kilometers	0.62137	miles	miles	1.6093	kilometers
Temperature					
Absolute					
degrees Celsius × 1.8	+32	degrees Fahrenheit	degrees Fahrenheit−32	×0.55556	degrees Celsius
Relative					
degrees Celsius	1.8	degrees Fahrenheit	degrees Fahrenheit	0.55556	degrees Celsius
Velocity or Rate					
cubic meters/second	2,118.9	cubic feet/minute	cubic feet/minute	0.00047195	cubic meters/second
meters/second	2.237	miles/hour	miles/hour	0.44704	meters/second
Volume					
cubic meters	264.17	gallons	gallons	0.0037854	cubic meters
cubic meters	35.314	cubic feet	cubic feet	0.028317	cubic meters
cubic meters	1.3079	cubic yards	cubic yards	0.76456	cubic meters
cubic meters	0.0008107	acre-feet	acre-feet	1,233.49	cubic meters
liters	0.26418	gallons	gallons	3.78533	liters
liters	0.035316	cubic feet	cubic feet	28.316	liters
liters	0.001308	cubic yards	cubic yards	764.54	liters
Weight/Mass					
grams	0.35274	ounces	ounces	28.35	grams
kilograms	2.2046	pounds	pounds	0.45359	kilograms
kilograms	0.0011023	tons (short)	tons (short)	907.18	kilograms
metric tons	1.1023	tons (short)	tons (short)	0.90718	metric tons
English to English					
acre-feet	325,850.7	gallons	gallons	0.000003046	acre-feet
acres	43,560	square feet	square feet	0.000022957	acres
square miles	640	acres	acres	0.0015625	square miles

a. This conversion factor is only valid for concentrations of contaminants (or other materials) in water.

COVER SHEET

RESPONSIBLE AGENCY: U.S. Department of Energy (DOE), National Nuclear Security Administration (NNSA)

COOPERATING AGENCY: Tennessee Valley Authority (TVA)

TITLE: *Draft Supplemental Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (DOE/EIS-0288-S1) (SEIS)

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ABSTRACT: In March 1999, DOE published the *Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (DOE/EIS-0288; the 1999 EIS). The 1999 EIS addressed the production of tritium in TVA reactors using tritium-producing burnable absorber rods (TPBARs) and analyzed the potential environmental impacts of irradiating up to 3,400 TPBARs per reactor operating on an 18-month fuel cycle. The 1999 EIS included TPBAR irradiation scenarios using multiple reactors to irradiate a maximum of 6,000 TPBARs every 18 months. On May 14, 1999, DOE published the Record of Decision for the 1999 EIS, in which it announced its decision to enter into an agreement with TVA to produce tritium in the Watts Bar Unit 1 reactor (Watts Bar 1) in Rhea County, Tennessee, near Spring City, and Sequoyah Units 1 and 2 reactors (Sequoyah 1 and 2) in Hamilton County, Tennessee, near Soddy-Daisy. In 2002, TVA received license amendments from the U.S. Nuclear Regulatory Commission (NRC) to produce tritium in those reactors. Since 2003, TVA has been producing tritium for the NNSA by irradiating TPBARs only in Watts Bar 1. However, irradiation of TPBARs in the Sequoyah reactors has remained a viable option. TVA has never irradiated TPBARs in the Sequoyah reactors. After irradiation, NNSA transports the TPBARs to the Tritium Extraction Facility at the DOE Savannah River Site in South Carolina. NNSA has prepared this SEIS because there is new information about the amount of tritium required to support the nation's requirements (see Section S.3) and because TVA's experience in irradiating TPBARs has produced new information relevant to the potential environmental impacts at irradiation reactor sites that was not available when the 1999 EIS was prepared (see Section S.1). This SEIS does not revisit DOE's tritium extraction activities because the actions described in this SEIS would result in the extraction of tritium from fewer TPBARs at the Tritium Extraction Facility with subsequently fewer environmental impacts at the Savannah River Site than the 1999 EIS analyzed.

During irradiation of TPBARs in a reactor, while the great majority of tritium is captured inside the TPBARs, a small amount diffuses through the TPBAR cladding into the reactor coolant; this is called permeation. Based on several years of production experience at Watts Bar 1, NNSA has determined that tritium permeation through the cladding occurs at a higher rate than the 1999 EIS projected and analyzed; nevertheless, tritium releases to the environment have been below regulatory limits. NNSA has prepared

this SEIS to analyze the potential environmental impacts from TPBAR irradiation at TVA sites based on a high and thus conservative estimate of the tritium permeation rate and NNSA's revised estimate of the maximum number of TPBARs necessary to support the current tritium supply requirements.

The proposed action this SEIS evaluates is to irradiate up to a total of 2,500 TPBARs every 18 months in one or more TVA reactors. There are two reactors at both the Watts Bar site and the Sequoyah site. However, in the event of a reactor outage, there is a potential that more than 2,500 TPBARs would need to be irradiated every 18 months for some period of time after the outage to compensate for the temporary shortfall in tritium supply. Therefore, this SEIS also evaluates a maximum production scenario of irradiating 5,000 TPBARs every 18 months. The SEIS evaluates the potential environmental impacts from TPBAR irradiation for seven alternatives:

- The No-Action Alternative assumes irradiation of up to a total of 2,040 TPBARs every 18 months using the reactors identified in the 1999 ROD (Watts Bar 1, Sequoyah 1, and Sequoyah 2) to keep permeation levels under currently approved NRC license and regulatory limits.

- Alternative 1 assumes use of the Watts Bar site only to irradiate up to a total of 2,500 TPBARs every 18 months with no TPBAR irradiation at the Sequoyah site.

- Alternative 2 assumes use of the Sequoyah site only to irradiate up to a total of 2,500 TPBARs every 18 months with no TPBAR irradiation at the Watts Bar site.

- Alternative 3 assumes use of both the Watts Bar and Sequoyah sites to irradiate up to a total of 2,500 TPBARs every 18 months.

- Alternative 4 assumes use of the Watts Bar site only to irradiate up to a total of 5,000 TPBARs every 18 months with no TPBAR irradiation at the Sequoyah site.

- Alternative 5 assumes use of the Sequoyah site only to irradiate up to a total of 5,000 TPBARs every 18 months with no TPBAR irradiation at the Watts Bar site[1].

- Alternative 6 assumes use of both the Watts Bar and Sequoyah sites to irradiate up to a total of 5,000 TPBARs every 18 months.

The maximum number of TPBARs analyzed in this SEIS for irradiation in a single reactor (as opposed to a single site) is 2,500 TPBARs per fuel cycle versus the 3,400 TPBARs analyzed in the 1999 EIS. NNSA has identified Alternative 1 as its Preferred Alternative for this SEIS.

The results of the analyses presented in this SEIS indicate there would be no significant increase in radiation exposure associated with TPBAR irradiation for facility workers or the public. For all analyzed alternatives, estimated radiation exposures would remain well below regulatory limits (see Table C-1 in Appendix C for a list of regulatory limits). The calculated estimated exposures for normal reactor operation[2] with the maximum number of TPBARs would remain comparable to those for normal reactor operation without TPBARs.

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1. Alternative 4, 5, and 6 are considered mutually exclusive to any other alternative, meaning that NNSA would not select any one of those alternatives in addition to another alternative in the Record of Decision, as that would exceed the maximum production scenario of irradiating 5,000 TPBARs every 18 months.
2. The term "normal operations" refers to a reactor operating as designed and in accordance with the parameters associated with its operating license. Normal operations can include operations with or without TPBARs inserted into the reactor core.

PUBLIC INVOLVEMENT: NNSA published a Notice of Intent to prepare the SEIS in the *Federal Register* (76 FR 60017) on September 28, 2011, to invite comments and suggestions on the proposed scope of the SEIS. NNSA requested public comments by mail, facsimile, or e-mail by the close of the scoping period on November 14, 2011. A public scoping meeting took place on October 20, 2011, at the Southeast Tennessee Trade and Conference Center in Athens, Tennessee. NNSA considered all scoping comments it received in the preparation of this Draft SEIS.

NNSA will accept comments by mail, facsimile, or e-mail on this Draft SEIS for a period of 45 days after publication of the U.S. Environmental Protection Agency's Notice of Availability in the *Federal Register*. Comments should be addressed to Mr. Curtis Chambellan using the contact information above. NNSA will consider all comments received or postmarked by the close of the comment period in the preparation of the Final SEIS. To the extent practicable, NNSA will consider comments it receives after the end of the comment period. NNSA will announce the time and location of a public hearing at a later date. This document is available on DOE's NEPA website at http://energy.gov/nepa/nepa-documents and NNSA's NEPA website at http://nnsa.energy.gov/nepa/tritiumseis.

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CHAPTER 1. INTRODUCTION AND PURPOSE AND NEED FOR ACTION

Chapter 1 provides an overview of this National Nuclear Security Administration (NNSA) Supplemental Environmental Impact Statement (SEIS) for production of tritium in a commercial light water reactor (CLWR). This chapter includes background information on the production of tritium in a CLWR (Sections 1.1 and 1.2) and describes the purpose and need for agency action (Section 1.3). The proposed action and tritium requirements are discussed in Section 1.4. This chapter also discusses the scope of the SEIS (Section 1.5) and the relationship of the SEIS to other *National Environmental Policy Act of 1969* 42 U.S.C. §§ 4321 *et seq*. (NEPA) documents (Section 1.6). In addition, this chapter discusses the scoping process NNSA used to obtain input on the issues it should address in the SEIS (Section 1.7). The chapter concludes with a section on the organization of the SEIS (Section 1.8).

This Draft SEIS will be available for review for a minimum of 45 days following publication of the U.S. Environmental Protection Agency's (EPA's) Notice of Availability in the *Federal Register*. During the comment period, NNSA will hold at least one public meeting to solicit comments on the Draft SEIS. NNSA will publish information about the date, time, and location of all public meetings in local newspapers. All comments NNSA receives during the comment period will be considered by NNSA during preparation of the Final SEIS. Late comments will also be considered to the extent practicable.

1.1 Introduction

NNSA, which was established in March 2000 as a separately organized, semi-autonomous agency within the U.S. Department of Energy (DOE), is responsible for maintaining the safety, security, and effectiveness of the U.S. nuclear weapons stockpile. Tritium, a radioactive isotope of hydrogen, is an essential component of every weapon in the U.S. nuclear weapons stockpile. Unlike long half-life nuclear materials in nuclear weapons, tritium decays at a rate of about 5.5 percent per year. Therefore, NNSA must replenish the tritium in each nuclear weapon periodically.

Tritium

Tritium is a radioactive isotope of hydrogen. It has two neutrons and one proton in the nucleus (ordinary hydrogen contains one proton and no neutrons in the nucleus). Tritium is chemically identical to hydrogen and deuterium. Both "H-3" and "T" are used as symbols to designate tritium. Tritium has a half-life of 12.3 years, meaning that every 12.3 years half of the tritium atoms decay to another nuclear form. As a result of this relatively short half-life, an amount of tritium will reduce by about 11 percent in 2 years, 25 percent in 5 years, 50 percent in 12.3 years, and 90 percent in 42 years.

In March 1999, DOE published the *Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (DOE 1999a; referred to in this document as the 1999 EIS). That EIS analyzed the production of tritium in Tennessee Valley Authority (TVA) reactors using tritium-producing burnable absorber rods (TPBARs) (see Section 2.1 of this SEIS for a description of TPBARs), and assessed the potential impacts of irradiating up to 3,400 TPBARs per reactor operating on an 18 month fuel cycle. The 1999 EIS included TPBAR irradiation scenarios using multiple reactors to irradiate a maximum of 6,000 TPBARs every 18 months. On May 14, 1999, DOE published the Record of Decision for the 1999 EIS, in which it announced its decision to enter an agreement with TVA to produce tritium in the Watts Bar Unit 1 reactor (Watts Bar 1) and Sequoyah Units 1 and 2 reactors (Sequoyah 1 and 2) (64 FR 26369). In 2002, TVA received license amendments from the U.S. Nuclear Regulatory Commission (NRC) to produce tritium in those reactors (NRC 2002a); Section 1.2 discusses the amendments.

NNSA has an Interagency Agreement with TVA to irradiate TPBARs that is in effect until November 30, 2035. Since 2003, TVA has been producing tritium for NNSA by irradiating TPBARs in Watts Bar 1 in Rhea County, Tennessee, near Spring City. Table 1-1 lists the numbers of TPBARs TVA has irradiated in Watts Bar 1 per fuel cycle. Each fuel cycle covers a period of about 18 months. After irradiation, NNSA transports the TPBARs to the Tritium Extraction Facility at the DOE Savannah River Site in South Carolina. Figure 1-1 shows the tritium production process. To date, TVA has not produced tritium at Sequoyah 1 or 2, but that remains a viable option.

Table 1-1. TPBARs irradiated in Watts Bar 1 per fuel cycle.

Approximate fuel cycle dates	Number of TPBARs irradiated
Fall 2003–Spring 2005	240
Spring 2005–Fall 2006	240
Fall 2006–Spring 2008	240
Spring 2008–Fall 2009	368
Fall 2009–Spring 2011	240
Spring 2011–Fall 2012	544

Source: NRC 2011a.
Note: See Sections 3.1.3.2 and 3.1.5.1.3 of this SEIS for a discussion of the tritium releases that have been associated with TPBAR irradiation.

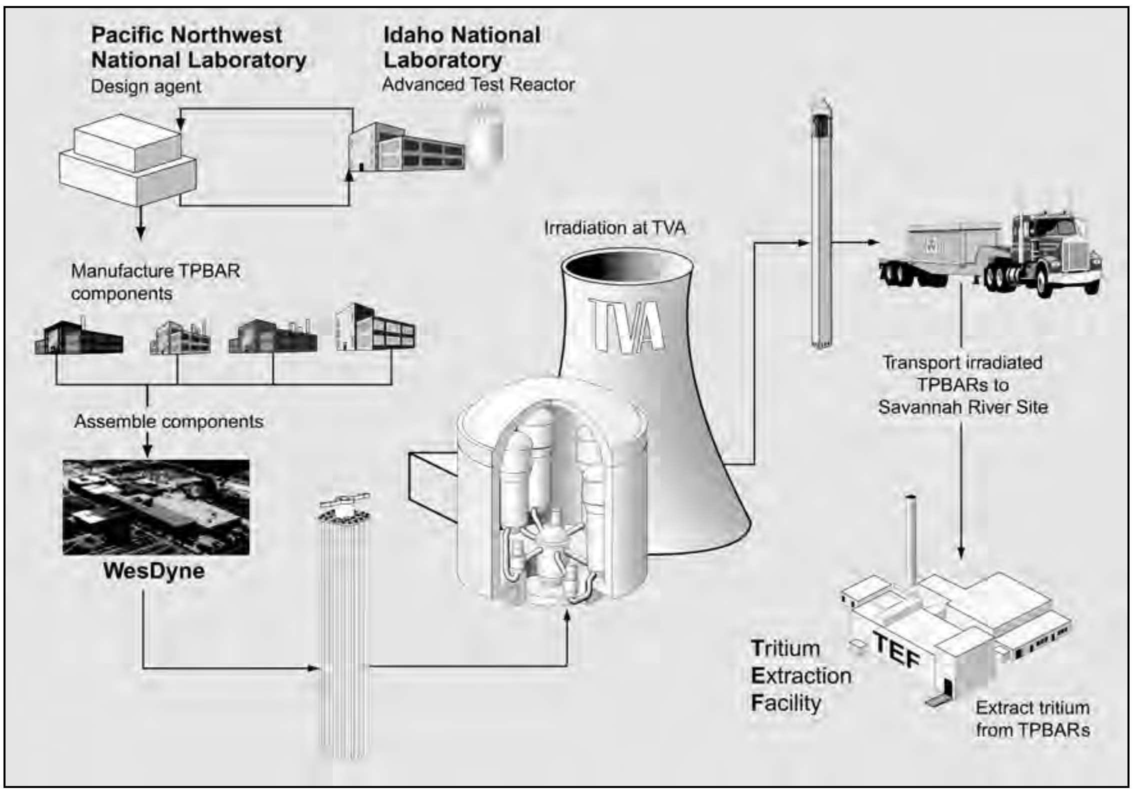

Figure 1-1. Tritium production process (GAO 2010).

During irradiation of the TPBARs in a reactor, a small amount of tritium diffuses through the TPBAR cladding into the reactor coolant; this is called permeation. After several years of production experience at Watts Bar 1, NNSA has determined that tritium permeation through the cladding is about three to four times higher than the 1999 EIS projected and analyzed (PNNL 2013a); nevertheless, tritium releases to the environment have been below regulatory limits (see Table C-1 for a list of regulatory limits). NNSA has prepared this SEIS to update the information provided in 1999 EIS to include: (1) the analysis of the potential environmental impacts associated with TPBAR irradiation based on a more conservative estimate of the tritium permeation rate, (2) NNSA's revised estimate of the maximum number of TPBARs necessary to support the current tritium supply requirements, and (3) a maximum production scenario of irradiating 5,000 TPBARs every 18 months, which NNSA might require as a contingency capability to compensate for potential future shortfalls in the event of a reactor outage.

> **Tritium Releases and Regulatory Limits**
>
> Although there are no specific regulatory limits on tritium releases, there are regulatory limits to which tritium releases are *applicable.* For example, regulations implemented under the *Safe Drinking Water Act* require the tritium concentration at any drinking water intake to be below 20,000 picocuries per liter (40 CFR Part 141). Consequently, tritium releases that would result in tritium concentrations above 20,000 picocuries per liter at any drinking water intake would violate this regulatory limit.
>
> Another example concerns public doses from radiation. The most stringent regulatory limits for public doses from normal operations are 10 millirem per year from all pathways, 3 millirem per year from the liquid pathway, and 5 millirem per year from the air pathway (see Table C-1 in Appendix C). Because tritium releases contribute to public doses, these releases are applicable to the overall dose limits. Sections 4.1.15 and 4.2.15 of this SEIS present a detailed analysis of applicable regulatory limits and tritium releases.

1.2 Background

The United States requires a reliable source of tritium to support its nuclear weapons systems (DOE 1999a). Although tritium occurs naturally, it is so rare that useful quantities must be manufactured. DOE constructed and operated more than a dozen nuclear reactors for the production of nuclear materials at the Savannah River Site in Aiken, South Carolina, and the Hanford Site in Richland, Washington, starting in the early part of the Manhattan Project during World War II. Those reactors are no longer operational. DOE shut down the last one, K-Reactor at the Savannah River Site, in 1988. Between 1988 and 2005, DOE and then NNSA met tritium demands largely by recycling tritium gas from the dismantlement of nuclear weapons. However, NNSA determined that recycling could not meet tritium demands even with the reduction in requirements. Therefore, since 2003, TVA has been producing tritium for NNSA by irradiating TPBARs but, to date, has done this only in Watts Bar 1.

Tritium cannot be used by itself to construct a nuclear weapon. Tritium is, however, a key component of all nuclear weapons in the nation's current stockpile. Tritium enables weapons to produce a larger fission yield while reducing the overall size and weight of the warhead. This process, called boosting, has enabled the development of sophisticated delivery systems. The production of tritium in a CLWR is technically straightforward. Most CLWRs use 12-foot-long rods that contain an isotope of boron (boron-10) in ceramic form. These rods are generally referred to as burnable absorber rods. The rods are inserted in reactor fuel assemblies to absorb excess neutrons from the fission process in the uranium fuel, which controls power levels at the beginning of an operating cycle. The NNSA tritium program has developed another type of burnable absorber rod—the TPBAR—in which a lithium aluminate ceramic, rather than a boron ceramic, absorbs neutrons. TPBARs are placed in the same locations in the reactor core as the standard burnable absorber rods. There is no fissile material (uranium or plutonium) in TPBARs (DOE 1999a).

While the two types of rods function in a similar manner to absorb excess neutrons in the reactor core, there is one notable difference: when neutrons strike the lithium aluminate ceramic material in a TPBAR, the reaction produces tritium. The tritium is held in the rod in a solid form. Heating the TPBAR at an extraction facility, in a vacuum and at much higher temperatures than normally occur in a reactor, releases the tritium. Chapter 2 discusses the production of tritium in a CLWR in more detail.

The Tennessee Valley Authority

TVA was established by an Act of Congress in 1933 (16 U.S.C. §§ 831 to 831dd) as a Federal corporation to improve the navigability of and provide flood control for the Tennessee River, to provide reforestation and ensure the proper use of marginal lands in the Tennessee Valley, to provide agricultural and industrial development of the Tennessee Valley, to provide for the national defense, and for other purposes. Today, TVA is the largest public power producer in the United States; it generates 174 billion kilowatt-hours of electricity for communities and businesses. The TVA power system serves almost 9 million people in 196 counties in Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia. The TVA power system, which is self-financed, consists of 11 fossil-fuel plants, 3 nuclear plants, 29 hydroelectric plants, 1 pumped-storage plant, 9 combustion turbine sites, 3 combined-cycle sites, 2 diesel generator sites, 14 solar energy sites, 1 wind energy site, 1 digestor gas site, and 1 biomass cofiring site. The fossil fuel plants account for 51 percent of electricity generation, nuclear plants for 36 percent, and hydroelectric plants for 8 percent; the other sources account for the remaining 5 percent. TVA employs about 12,500 people (TVA 2011a). A network of 155 power distributors, including municipally owned utilities and electric cooperatives, distributes the electricity. In addition, TVA sells power directly to 56 large industrial customers and Federal facilities (TVA 2011a). The production of tritium in TVA reactors is consistent with the Congressional purposes that established TVA—that is, to provide for the industrial development of the Tennessee Valley and for national defense. TVA is a cooperating agency on this SEIS.

NRC Licensing for TPBAR Irradiation

Before TPBARs could be irradiated in any of its reactors, TVA was required to apply for and receive amendments to its existing operating licenses for each affected Watts Bar and Sequoyah unit from the NRC. Commercial nuclear power plants must operate in accordance with their NRC operating licenses and regulations. NRC licenses contain technical specifications that result from a nuclear power plant's safety analysis and NRC regulations. Technical specifications impose safety limits on nuclear power plant operations and require certain surveillance activities, design features, and administrative controls to ensure safe operation of the plant. Changes to technical specifications require NRC approval through the license amendment process (NRC 2011a).

In August 2001, TVA filed an application to amend the Watts Bar 1 operating license to allow irradiation of up to 2,304 TPBARs in the reactor core each fuel cycle. The NRC issued License Amendment 40 on September 23, 2002, which addressed the changes necessary for the production of tritium in Watts Bar 1. The amendment stated that the number of TPBARs TVA could irradiate in Watts Bar 1 would be determined for each cycle, but would be less than or equal to 2,304. For the Sequoyah reactors, on September 30, 2002, the NRC issued License Amendment 278 for Sequoyah 1 and License Amendment 269 for Sequoyah 2, which allow for the irradiation of up to 2,256 TPBARs in each reactor. To date, TVA has not irradiated TPBARs in Sequoyah 1 and 2. As discussed in Section 2.3.1, TVA has concluded that it will not use the Sequoyah reactors for tritium production until it prepares new license amendment applications and the NRC issues new license amendments for those reactors (Krich 2011a).

As listed in Table 1-2, after the original license amendment in September 2002, the Watts Bar 1 operating license has been amended three times in relation to TPBAR irradiation. In 2003, based on technical issues in relation to accident analyses, TVA determined that the number of TPBARs it could irradiate in Watts Bar 1 would be limited to 240 rather than the previously approved limit of 2,304 (NRC 2008a). Therefore, the NRC issued License Amendment 48 on October 8, 2003, to authorize the irradiation of 240 TPBARs in Watts Bar 1 during the operating cycle scheduled for the Fall of 2003 through the Spring of 2005 (NRC 2003).

Because it found tritium permeation from TPBARs to be greater than expected in the Watts Bar 1 operating cycle from the Fall of 2003 through the Spring of 2005, TVA stated in a March 22, 2005, letter

Table 1-2. NRC license amendments for TPBAR irradiation in Watts Bar 1 since 2002.

Date	Amendment number	Maximum TPBARs per fuel cycle	Applicable period
September 23, 2002	40	2,304	Fall 2002–Fall 2003
October 8, 2003	48	240	Fall 2003–Spring 2008
January 18, 2008	67	400	Spring 2008–Fall 2009
May 4, 2009	77	704	Fall 2009–current

Source: NRC 2011a.

to the NRC that the number of TPBARs it would irradiate in Watts Bar 1 would remain at 240 until the permeation issue was understood and resolved (NRC 2008a). Therefore, TVA irradiated only 240 TPBARs during the Watts Bar 1 operating cycles between the Fall of 2003 and the Spring of 2008. Design changes (see Section 2.3.2.2) to the TPBARs resulted in a TVA request to increase the number of TPBARs to 400 for the Watts Bar 1 operating cycle scheduled for the Spring of 2008 through the Fall of 2009. As a result, NRC issued License Amendment 67 on January 18, 2008, to authorize irradiation of 400 TPBARs in Watts Bar 1 (NRC 2008a). In response to increased NNSA tritium production goals, NRC increased the number of TPBARs TVA could irradiate at Watts Bar 1 to 704 by issuing License Amendment 77. In issuing License Amendment 77, NRC concluded that “there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, and such activities will be conducted in compliance with the Commission's regulations” (NRC 2009).

Nonproliferation

Nuclear nonproliferation refers to preventing the spread of nuclear weapons, nuclear weapons materials, and nuclear weapons technology to countries that do not have them. The 1999 EIS (DOE 1999a) discussed nonproliferation in relation to the use of commercial reactors to make tritium for national security purposes. That discussion included a summary of an interagency review of nonproliferation issues by the NRC, the U.S. Department of Defense, and the U.S. Department of State, the *Interagency Review of the Nonproliferation Implications of Alternative Tritium Production Technologies Under Consideration by the Department of Energy, A Report to the Congress* (DOE 1998). In support of this SEIS, NNSA has recently reassessed the relevance of U.S. nonproliferation policy to current programmatic needs and concluded that the interagency assessment from 1998 is still valid and that there have been no changes in U.S. nonproliferation policy or regulations that would affect the conclusions of the 1998 assessment and the 1999 EIS (Mendelsohn 2011).

1.3 Purpose and Need for Action

U.S. strategic nuclear systems are based on designs that use tritium gas. Because tritium decays at a rate of about 5.5 percent per year (i.e., every 12.3 years one-half of the tritium has decayed), periodic replacement is required as long as the United States relies on a nuclear deterrent. The nation, therefore, requires a reliable source of tritium to maintain its nuclear weapons stockpile. In the 1999 EIS, DOE assumed that up to 3 kilograms of tritium per year would need to be produced in CLWRs (DOE 1999a). Since completion of the 1999 EIS, the projected need for tritium has decreased. Considering the design of the TPBARs and the efficiency of the tritium extraction process, NNSA has determined that irradiation of a maximum of 2,500 TPBARs every 18 months would produce enough tritium to meet current requirements (NNSA 2013). However, in the event of a reactor outage, there is a potential that more than 2,500 TPBARs would need to be irradiated every 18 months for some period of time after the outage to compensate for the temporary shortfall in tritium supply. Therefore, this SEIS also evaluates the potential environmental impacts associated with a maximum production scenario of irradiating 5,000 TPBARs every 18 months.

Chapter 2 of the 1999 EIS discussed the purpose and need for DOE action to produce tritium in one or more CLWRs (DOE 1999a). That purpose and need remains the same today even though current tritium requirements are smaller than they were in 1999. Even with this reduced need, however, a higher-than-previously-expected tritium permeation rate has resulted in limitations on the number of TPBARs that the NRC has permitted TVA to irradiate in its reactors. As a result, TVA cannot currently irradiate enough TPBARs in its reactors to meet NNSA's projected tritium production requirements (NNSA 2013). NNSA and TVA are supplementing applicable environmental analyses in the 1999 EIS to analyze the potential environmental impacts of the higher tritium permeation to support the proposed action of increasing tritium production quantities to meet requirements. This SEIS has been prepared in accordance with Section 102(C) of NEPA, the Council on Environmental Quality regulations (40 CFR Parts 1500 to 1508) and the DOE NEPA implementing regulations (10 CFR Part 1021), and follows DOE NEPA guidance.

The 1999 EIS estimated that the permeation of tritium through the TPBAR cladding into the reactor coolant systems would be less than or equal to 1 curie per TPBAR per year (DOE 1999a). Based on tritium production experience at Watts Bar 1, NNSA has determined that tritium permeation through the cladding is about 3 to 4 times higher than this estimate; nevertheless, tritium releases have been below regulatory limits (TVA 2013). To put this permeation rate into perspective, this represents less than 0.1 percent of the total tritium each TPBAR produces during irradiation. Based on estimates from Pacific Northwest National Laboratory, the design agency, the 1999 EIS estimated that each TPBAR would contain about 1 gram of tritium after irradiation. The operational experience with TPBAR irradiation at Watts Bar 1 since 2003 (see Table 1-1, which shows TPBAR loadings of 240 to 544 TPBARs) has shown that each TPBAR has produced, on average, about 1 gram of tritium. However, as the number of TPBARs in a reactor increases, tritium production efficiency is expected to decrease such that each TPBAR would produce less than 1 gram of tritium (PNNL 2013b).[1] Tritium contains 9,640 curies per gram.[2] The 1999 EIS assumed that 1 curie of tritium would permeate through the cladding per TPBAR per year, which is a capture rate of 9,639 of 9,640 curies of tritium (a capture efficiency of 99.989 percent). For a permeation rate of 5 curies per TPBAR per year, the capture rate is 9,635 of 9,640 curies of tritium, a capture efficiency of 99.948 percent. For a permeation rate of 10 curies per TPBAR per year, the capture rate is 9,630 of 9,640 curies of tritium, a capture efficiency of 99.896 percent.

National defense support has been one of TVA's historic multipurpose missions. TVA could adopt the SEIS and apply its analysis to update its environmental record for both Watts Bar and Sequoyah. Figure 1-2 shows the locations of the Watts Bar and Sequoyah Nuclear Plants.

1.4 Proposed Action and NNSA Tritium Requirements

The 1999 EIS assessed the potential environmental impacts of irradiating up to 3,400 TPBARs per reactor per fuel cycle (a fuel cycle lasts about 18 months). The 1999 EIS included TPBAR irradiation scenarios using multiple reactors to irradiate a maximum of 6,000 TPBARs every 18 months (DOE 1999a). Since DOE prepared the 1999 EIS, the projected need for tritium has decreased (NNSA 2013). Based on the *Fiscal Year 2014 Stockpile Stewardship and Management Plan* (NNSA 2013), NNSA needs a capability to irradiate up to 2,500 TPBARs every 18 months to meet current requirements (see Table 5-1 of NNSA 2013). The proposed action in this SEIS is to irradiate up to a total of 2,500 TPBARs every 18 months in one or more TVA reactors. In addition, as explained in Section 1.3, this SEIS also analyzes the potential environmental impacts associated with a maximum production scenario of irradiating 5,000 TPBARs every 18 months.

1. The expected reduction in tritium production efficiency in individual TPBARs is a secondary reason why NNSA is evaluating a maximum production scenario of irradiating 5,000 TPBARs every 18 months.
2. The radioactivity of a radionuclide per unit mass is known as "specific activity."

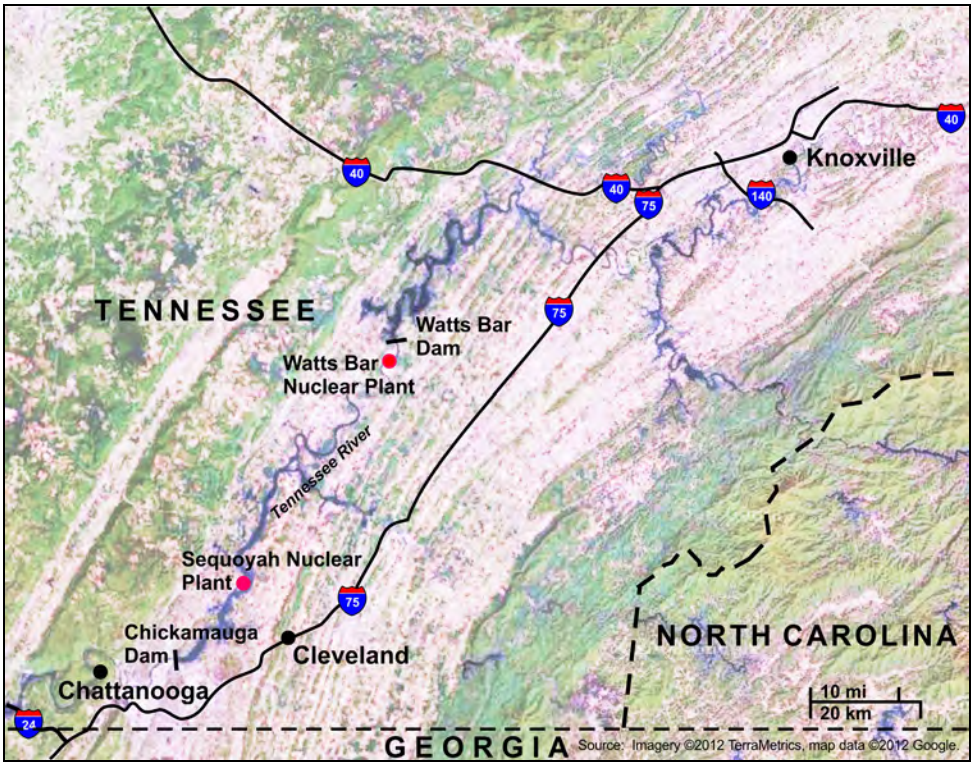

Figure 1-2. Locations of TVA reactors.

1.5 Scope

The SEIS analyzes the potential environmental impacts of seven alternatives, as described below. Chapter 2 provides a more detailed discussion of these alternatives.

- No-Action Alternative. The No-Action Alternative is based on the analysis in the 1999 EIS, the Record of Decision for the 1999 EIS, and analyses for NRC license applications and license amendment actions (see Section 1.2). Consistent with the analysis in the 1999 EIS, the No-Action Alternative in this SEIS assumes that TVA would operate Watts Bar 1 and Sequoyah 1 and 2 to maintain tritium releases that would meet NRC license and regulatory limits. Under the No-Action Alternative, the total number of TPBARs TVA could irradiate every 18 months would be 2,040 if TVA used all three currently available reactors for tritium production (that is, 680 TPBARs each in Watts Bar 1 and Sequoyah 1 and 2).

- Alternative 1 (Preferred Alternative). Use only the Watts Bar site to irradiate a maximum of 2,500 TPBARs every 18 months. This could involve use of both Watts Bar units. TVA is completing construction of Watts Bar 2 and that reactor is expected to begin operations in about 2015 (TVA 2007a) (see Section 1.6).

- Alternative 2. Use only the Sequoyah site to irradiate a maximum of 2,500 TPBARs every 18 months. This could involve use of both Sequoyah units.

- Alternative 3. Use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. This would provide the ability to supply tritium requirements at either site independently or to use both sites, with each supplying a portion of the tritium required. For the analysis of Alternative 3, NNSA assumed that each site would irradiate 1,250 TPBARs.

- Alternative 4. Use only the Watts Bar site to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this would involve use of both Watts Bar reactors.

- Alternative 5. Use only the Sequoyah site to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this would involve use of both Sequoyah reactors.

- Alternative 6. Use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this could involve the use of one or both reactors at each of the sites. For the analyses in this SEIS, NNSA assumed for Alternative 6 that each site would irradiate 2,500 TPBARs every 18 months.

Alternative 4, 5, and 6 are considered mutually exclusive to any other alternative, meaning that NNSA would not select any one of those alternatives in addition to another alternative in the Record of Decision, as that would exceed the maximum production scenario of irradiating 5,000 TPBARs every 18 months.

Chapter 2 also discusses other courses of action NNSA considered but rejected from detailed analysis because they were considered unreasonable.

Chapter 3 presents the affected environment for the Watts Bar and Sequoyah sites, and also represents current operating conditions. At the Watts Bar site, those current operating conditions include the impacts associated with ongoing TPBAR irradiation operations at Watts Bar 1.

Chapter 4 discusses potential direct and indirect impacts of the alternatives in the following resource areas: land use, aesthetics (visual and noise), climate and air quality, geology and soils, water resources, biological resources, cultural resources, infrastructure (such as utilities), socioeconomics (employment and income, population and housing, and community services), waste and spent nuclear fuel management, human health and safety (including accidents and intentional destructive acts), transportation, and environmental justice. The analysis of potential impacts is based on an assumed high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year. In the Notice of Intent to prepare this SEIS, NNSA stated that it would assess the impacts associated with tritium production in CLWRs based on a permeation rate of about 5 curies of tritium per TPBAR per year (76 FR 60017; September 28, 2011). Although the observed tritium permeation through the cladding has been less than 5 curies of tritium per TPBAR per year, the current permeation rate does not take into account potential uncertainties about operating cycle length, tritium production per TPBAR, and future operational changes that could occur at the TVA reactors, all of which could affect the permeation rate. Given these potential uncertainties in operational parameters, and after consultation with TVA and the Pacific Northwest National Laboratory (the TPBAR design agency), NNSA decided to evaluate an even higher and thus more conservative tritium permeation rate (10 curies of tritium per TPBAR per year) in this SEIS instead of 5 curies of tritium per TPBAR per year (TVA 2013, PNNL 2013a). NNSA, the Laboratory, and TVA have determined that a tritium permeation rate of 10 curies of tritium per TPBAR per year is the best estimate to ensure that the analyses in this SEIS would reasonably be expected to bound uncertainties in relation to future operations. By analyzing this higher tritium permeation rate, NNSA is confident that the SEIS provides a reasonable, but conservative and bounding, analysis of the potential environmental impacts from tritium production in the Watts Bar and Sequoyah reactors.

Chapter 5 discusses cumulative impacts in these resource areas as appropriate.

1.6 Other Related National Environmental Policy Act Reviews

This section discusses other related NEPA documents.

- *Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (DOE 1999a). The 1999 EIS addressed the production of tritium in TVA reactors using TPBARs. In the Record of Decision for the 1999 EIS, DOE selected TVA's Watts Bar 1 and Sequoyah 1 and 2 for tritium production (64 FR 26369; May 14, 1999). This SEIS supplements the 1999 EIS and focuses on new information relevant to environmental concerns.

- *Watts Bar Nuclear Plant, Unit 1; Environmental Assessment and Finding of No Significant Impact* (NRC 2002b). In response to TVA's license application, on August 26, 2002, the NRC published this environmental assessment and Finding of No Significant Impact to allow TVA to irradiate up to 2,304 TPBARs in Watts Bar 1. On the basis of the environmental assessment, the NRC concluded that the proposed action will not have a significant effect on the quality of the human environment.

- *Sequoyah Nuclear Plant, Units 1 and 2; Environmental Assessment and Finding of No Significant Impact* (NRC 2002c). In response to TVA's license application, on September 23, 2002, the NRC published this environmental assessment and Finding of No Significant Impact to allow TVA to irradiate up to 2,256 TPBARs in each of the Sequoyah reactors. On the basis of the environmental assessment, the NRC concluded that the proposed action will not have a significant effect on the quality of the human environment. TVA has never irradiated TPBARs in the Sequoyah reactors.

- *Final Supplemental Environmental Impact Statement for the Sequoyah Nuclear Plant Units 1 and 2 License Renewal* (TVA 2011b). TVA published a Final SEIS in June 2011 to assist in the decision on whether to submit an application to the NRC to extend the operating licenses of the two units for an additional 20 years beyond their current license terms. The document supplements *Sequoyah Nuclear Plant: Final Environmental Impact Statement, Units 1 and 2* (TVA 1974). In the Record of Decision (76 FR 55723, September 8, 2011), TVA decided to proceed with the license extension application. The current licenses will expire in 2020 for Unit 1 and in 2021 for Unit 2. License extension would involve continuation of normal operations,[3] maintenance, and refueling. The No-Action Alternative in the TVA Final SEIS was to end operation of the Sequoyah reactors when the current licenses expire. TVA expects to submit the license extension application to the NRC in the first quarter of 2013 (Krich 2011b).

  TVA has not produced tritium for NNSA at the Sequoyah site but could in either or both reactors. If the NRC approved the license renewals, Sequoyah 1 and 2 would be available to produce tritium for NNSA through 2040 and 2041, respectively.

- *Final Supplemental Environmental Impact Statement for the Completion and Operation of Watts Bar Nuclear Plant Unit* 2 (TVA 2007a). TVA completed an SEIS in June 2007 to assess the environmental impacts of completing and operating Watts Bar 2 to meet the need for additional electricity for the TVA system and to maximize the use of existing assets. In an August 15, 2007,

3. The term "normal operations" refers to a reactor operating as designed and in accordance with the parameters of its operating license. Normal operations can include operations with or without TPBARs inserted into the reactor core.

Record of Decision, TVA decided to complete and operate Watts Bar 2; construction began soon after (72 FR 45859). TVA is building the reactor as originally designed alongside Watts Bar 1, which has been operating since 1996. In the SEIS, TVA proposed minimal new construction with no need to expand the existing site. TVA prepared the SEIS to update the extensive previous environmental record pertinent to that proposed action. Producing tritium for NNSA in Watts Bar 2 was not part of this proposed action, and would require a license amendment from the NRC if TVA determined it should do so to meet NNSA requirements.

- *Final Environmental Impact Statement: Accelerator Production of Tritium at the Savannah River Site* (DOE/EIS-0270) (DOE 1999b). In March 1999, DOE completed this EIS, which presents the environmental impacts of constructing and operating a linear accelerator that would produce tritium. In the "Consolidated Record of Decision for Tritium Supply and Recycling" (64 FR 26369, May 14, 1999), DOE decided that "the Accelerator Production of Tritium technology will be developed as the backup tritium supply. Engineering development and demonstration, preliminary design, and detailed design of key elements of the system will be completed to permit expeditious initiation of accelerator facility construction at the preferred location on the Savannah River Site should it be needed." Section 2.3.2.1 discusses the reasons why accelerator production of tritium technology is not a reasonable alternative for this SEIS.

- *Draft Surplus Plutonium Disposition Supplemental Environmental Impact Statement* (NNSA 2012). On July 19, 2010, DOE issued an amended Notice of Intent to prepare an SEIS to analyze potential environmental impacts of alternatives to dispose of about 13 metric tons of weapons-grade plutonium (75 FR 41850). The Draft Supplemental EIS was published in July 2012, and supplements the *Surplus Plutonium Disposition Environmental Impact Statement*, which DOE issued in November 1999 (DOE 1999c). Among other things, that EIS analyzed the impacts of using mixed-oxide fuel in domestic commercial reactors to generate electricity. Mixed-oxide fuel is a mixture of plutonium and uranium. DOE and TVA have entered into an interagency agreement to evaluate the use of mixed-oxide fuel in the TVA Browns Ferry and Sequoyah reactors, and the Draft Surplus Plutonium Disposition SEIS analyzes the potential impacts of such use. TVA is a cooperating agency for that SEIS. TVA has not made a decision to use mixed-oxide fuel in its reactors. If TVA decided to use mixed-oxide fuel, it would have to submit a license amendment application to the NRC. The NRC has not evaluated or approved use of this fuel in TVA reactors.

  TVA would not irradiate TPBARs and use mixed-oxide fuel in a TVA reactor at the same time. Therefore, if TVA adopts the *Surplus Plutonium Disposition Supplemental Environmental Impact Statement* and decides to use mixed-oxide fuel in one or both of the Sequoyah reactors, TVA would not operate a Sequoyah reactor with mixed-oxide fuel and TPBARs at the same time.

- *Categorical Exclusion for the Watts Bar Tritiated Water Storage Tank System* (TVA 2011c). On October 4, 2011, TVA determined that the construction and operation of a 500,000-gallon tritiated water tank and associated pumps and piping at Watts Bar qualified for a categorical exclusion under Section 5.2.1 of its NEPA procedures. TVA documented this determination in a Categorical Exclusion (TVA 2011c). This tank system, which will store treated tritiated water from Watts Bar 1 and 2, will have enough capacity to store and release this water at appropriate times to enable TVA to better manage releases and continue to stay well within NRC and EPA regulatory limits. TVA recently completed construction of the

Categorical Exclusion

A categorical exclusion is a NEPA determination an agency can make about an action it has determined would not individually or cumulatively have a significant impact on the human environment.

stainless-steel tank system in the protected area at Watts Bar. In March 2012 and April 2012, TVA issued two additional categorical exclusions related to the tritiated water tank system; the first categorical exclusion addressed the placement of construction trailers and the second addressed the disposal of soil and concrete (TVA 2012). A summary of the impacts associated with construction and operation of the Watts Bar tritiated water tank system, as considered in the Categorical Exclusion, follows.

Construction of the tank system will affect less than 1 acre of land. The stainless-steel tank will be about 45 feet in diameter and 45 feet tall. Secondary containment will be provided by setting the storage tank into a larger diameter, open tank with a rain shield (about 55 feet in diameter and 30 feet tall) to provide full capacity retention. Due to the small area of construction and use of previously disturbed land, impacts to soils and cultural resources from construction activities are unlikely. Some minor emissions could occur during construction of the 500,000-gallon tank from the use of cranes and other construction equipment. Such emissions will be temporary and under the levels generally experienced at the site. The construction workforce, about 100 skilled and general laborers, will be on site for about 15 weeks. Operation of the tritiated water tank system would have no impact on the quantity of or management of wastes. TVA has estimated that the maximum tritium concentration in the 500,000-gallon tritiated water storage tank will be 88 million picocuries per milliliter. The anticipated average tritium concentration in the tank will be about 20 million picocuries per milliliter. The worst-case accident scenario would occur if the entire contents of the tank accidently discharged instantaneously to the river. This event would not exceed the maximum permissible EPA drinking water limit of 20,000 picocuries per liter downstream at the closest drinking water intake (TVA 2012).

- *Waste Confidence Generic Environmental Impact Statement, NUREG-2157 (Draft for Public Comment)* (NRC 2013). On September 9, 2013, NRC published this Draft EIS to examine the potential environmental impacts that could occur as a result of the continued storage of spent nuclear fuel at at-reactor and away-from-reactor sites until a repository is available. The Draft Generic EIS is intended to improve the efficiency of the NRC's licensing processes by (1) providing a generic evaluation of the environmental impacts that could occur as a result of continuing to store spent fuel after the end of a reactor's licensed life for operation and before disposal in a repository, and (2) providing the regulatory basis for the NRC's proposed amendments to its regulations in 10 CFR Part 51. TVA operations in relation to spent nuclear fuel would be required to comply with any regulatory requirements resulting from the Record of Decision(s) that occurs as a result of the Generic EIS.

1.7 Public Scoping

Although scoping is not required for an SEIS, NNSA published its Notice of Intent to prepare this SEIS in the *Federal Register* on September 28, 2011 (76 FR 60017), and invited stakeholders and the public to contribute to scoping the SEIS. The Notice announced the date, time, and location of a public scoping meeting NNSA held, which NNSA also announced on its project website (see the Cover Sheet) and in a newspaper advertisement. NNSA ran the notice in the following newspapers on the indicated dates:

- *The Daily Post-Athenian*, Athens, Tennessee, October 13 and 19;
- *The Herald News*, Dayton, Tennessee, October 12 and 19;
- *Advocate and Democrat*, Monroe County, Tennessee, October 12 and 20;
- *Chattanooga Times Free Press*, Chattanooga, Tennessee, October 13, 14, and 19;
- *Knoxville News Sentinel*, Knoxville, Tennessee, October 14 and 18;
- *The Oak Ridger*, Oak Ridge, Tennessee, October 14 and 19;

- *Crossville Chronicle*, Crossville, Tennessee, October 14 and 19; and
- Roane County News, Roane County, Tennessee, October 14 and 19.

A public scoping meeting took place on October 20, 2011, at the Southeast Tennessee Trade and Conference Center in Athens, Tennessee. The meeting began at 7:00 p.m. and adjourned at 10:00 p.m. During an open house before the scoping meeting, NNSA and TVA personnel were available to answer questions and discuss this SEIS. Information packages were available that included background information about the project and the NEPA process. A court reporter recorded and transcribed all oral comments. Twelve people attended the meeting. NNSA invited all attendees to provide comments, either written or oral, on the proposed project. Attendees who wished to speak had an opportunity to register. Comment sheets were available for attendees who wished to provide written comments. Four individuals presented oral comments at the meeting. The comment period closed on November 14, 2011. In addition to oral comments received at the scoping meeting, NNSA received a total of 25 comment documents (via hand-in at the scoping meeting, e-mail, and letter), from which NNSA identified 180 comments. This section summarizes the range of topics raised by commenters and how NNSA considered those comments.

- <u>Water resources</u>. Commenters expressed concern about increased pollution and contamination of the Tennessee River and the Chattanooga drinking water supply.

  Sections 4.1.5 and 4.2.5 assess the potential impacts to the Tennessee River and drinking water supplies as a result of TPBAR irradiation.

- <u>Infrastructure</u>. Commenters requested that the SEIS consider modification or enhanced physical protection of reactors as a result of the NRC report on earthquake- and tsunami-related damage at the Fukushima Dai-ichi Nuclear Power Plant in Japan.

  TVA works closely with the NRC to ensure its reactors meet all safety requirements. Sections 4.1.12 and 4.2.12 discuss the current readiness to respond to natural or man-made disasters and efforts by the NRC and TVA to identify possible gaps, vulnerabilities, or enhancements; and to provide short-, intermediate-, and long-term recommendations to improve overall ability to respond to such events. Those sections also present the potential human health consequences of a range of accident scenarios, including those initiated by natural phenomena. TPBAR irradiation does not affect safety requirements or response readiness. As discussed in Sections 4.1.12 and 4.2.12, because Watts Bar and Sequoyah have sufficient existing response readiness, NNSA concluded that additional discussions about augmenting readiness were unnecessary in this SEIS.

- <u>Waste management</u>. Commenters requested that the SEIS address the wastes associated with TPBAR irradiation and consider the increased storage requirements for spent nuclear fuel and disposition of the TPBARs.

  Sections 4.1.10 and 4.2.10 discuss the potential waste management impacts from TPBAR irradiation, including increases in low-level radioactive waste and spent nuclear fuel generation.

- <u>Human health and safety</u>. Commenters expressed concern about increases in radiation releases from increased tritium production and stated the SEIS should analyze the safety of the Savannah River Site tritium facilities and potential accident impacts to workers at the Watts Bar and Sequoyah sites and the public.

Sections 4.1.12 and 4.2.12 discuss the potential impacts to public and worker health from both normal operations and accidents at Watts Bar and Sequoyah. The new information about changes to potential environmental impacts is specific to the function of the TPBARs in TVA reactors that produce tritium. The actions described in this SEIS would result in extraction of tritium from fewer TPBARs and fewer potential environmental impacts at the Savannah River Site than the 1999 EIS analyzed. In addition, there have been no significant changes at the Savannah River Site that would change the potential environmental impacts at the site from TPBAR tritium extraction. As a result, this SEIS does not revisit the potential environmental impacts for tritium extraction activities at DOE's Savannah River Site.

- <u>Human health and safety</u>. Commenters expressed concern that application of current radiological criteria to a "standard man" results in an under-assessment of impacts to women, children, infants and human embryos. Commenters requested the SEIS consider the impacts to women, children, infants, and human embryos specifically using more applicable criteria.

  Sections 4.1.11 and 4.2.11 discuss the potential impacts to human health and safety from TPBAR irradiation. The analysis methods are based on factors from the Interagency Steering Committee on Radiation Standards (ISCORS 2002). As shown in those sections, the potential annual dose to the maximally exposed individual would be less than 0.86 millirem at any site. Such an annual dose would be less than 0.2 percent of the 620 millirem average annual dose that an individual receives from natural and man-made radiation. Because the dose from TPBAR irradiation would be insignificant in comparison with natural and man-made radiation, a more detailed analysis is not warranted.

- <u>Intentional destructive acts and accidents</u>. Commenters identified several accident scenarios they believe that the SEIS should analyze including a catastrophic event beyond the foreseeable such as a major earthquake (on the scale of that which caused the Fukushima accident), loss of cooling systems and backup power, waste gas decay tank rupture, and increased likelihood of terrorist events due to tritium production.

  The SEIS analyses address the potential consequences of the scenarios identified by the commenters. Sections 4.1.12 and 4.2.12 present the potential human health consequences of a range of accident scenarios, including those initiated by natural phenomena such as earthquakes. In addition, Sections 4.1.12.8 and 4.2.12.8 address the potential impacts from intentional destructive acts, such as terrorism events. Unlike accident analysis, the analysis of intentional destructive acts provides an estimate of potential consequences without attempting to estimate the frequency or probability of a successful destructive act.

- <u>Opposition to project</u>. Commenters expressed opposition to continued or increased production of tritium.

  NNSA tritium production activities are carried out to meet requirements established in concert with the U.S. Department of Defense in accordance with national security policy. Therefore, NNSA has determined that policy questions about whether tritium should be produced will not be addressed in this SEIS.

- <u>Nuclear weapons policy and treaties, purpose and need</u>. Commenters expressed concern about continued weapons maintenance or production in light of the reduced stockpile levels the New Strategic Arms Reduction Treaty identified.

The purpose and need discussed in the 1999 EIS remains valid today even though tritium requirements are smaller today than in 1999. Section 1.3 of this SEIS provides additional information about current tritium requirements. National security requirements are the programmatic driver for NNSA's continued need for TPBAR irradiation to supply tritium.

- Nonproliferation impact assessment, use of civilian reactors for weapons purposes. Commenters expressed opposition to use of TVA commercial reactors for production of weapons materials, stating it was in breach of the no-dual-use principle and contrary to nonproliferation efforts.

  Nonproliferation issues, which include the no dual-use principle, were addressed in detail during the 1999 EIS process, including the specific issue of using commercial reactors for tritium production. Section 1.2 of this SEIS provides additional information in relation to nonproliferation. As discussed in that section, NNSA has reassessed the relationship between the proposed action and U.S. nonproliferation policy and has concluded that the interagency assessment from 1998 is still valid and that there have been no changes in U.S. nonproliferation policy or regulations that would affect the conclusions presented during the 1999 EIS process.

- Environmental policy and permits. Commenters questioned the need for the original license amendment and requested that the SEIS address new or updated licensing requirements for the Sequoyah site.

  Section 1.2 of this SEIS addresses the license amendment process and history for the Watts Bar and Sequoyah reactors in relation to TPBAR irradiation. For interested readers, general information on the NRC licensing process can be found at http://www.nrc.gov/reactors/new-reactor-op-lic/licensing-process.html (for new reactor licenses) and http://www.nrc.gov/reactors/operating/licensing/renewal/process.html (for amendments to existing reactor licenses).

- Cost. Commenters requested that the SEIS provide an accurate accounting of costs and explain why TVA has not recovered fees from DOE.

  Costs are usually beyond the scope of NEPA documents such as this SEIS. The cost agreements between DOE and TVA would not affect the potential environmental impacts of the alternatives analyzed in the SEIS. The Record of Decision will discuss costs if NNSA/TVA decisionmakers determine that they are a relevant consideration in making any decision informed by this SEIS.

- Cumulative impacts. Commenters requested that the SEIS address cumulative impacts including the TVA coal ash spill, radiological and mercury releases from the DOE Oak Ridge Reservation, and increased releases from commercial electricity production at the Watts Bar and Sequoyah sites.

  Chapter 5 of this SEIS presents the potential cumulative impacts from the proposed action and other current and reasonably foreseeable actions such as operations associated with the Oak Ridge Reservation and TVA operations at Watts Bar and Sequoyah.

- Technological aspects of tritium leakage. Commenters expressed concern about ongoing unresolved problems due to tritium leakage and questioned if NNSA planned to address the technical aspects of the leakage.

  Section 2.3.2.2 discusses engineering efforts to address TPBAR tritium permeation. As discussed in that section, the Pacific Northwest National Laboratory has redesigned several TPBAR *components in an attempt to reduce tritium permeation into the reactor coolant. For example, Laboratory researchers modified the TPBAR to increase tritium capture efficiency. Despite this redesign, there was no discernible improvement in getter performance and tritium still permeates from the TPBARs at higher-than-previously-expected rates. The scientists and engineers continue to seek a technical solution. Even with this higher tritium permeation, the new analyses do not indicate that there would be any significant increase in radiation exposure associated with TPBAR irradiation for facility workers or the public. For all analyzed alternatives, estimated radiation exposures would remain well below regulatory limits. The calculated estimated exposures for normal reactor operations with the maximum number of TPBARs would remain comparable to those for normal reactor operation without TPBARs.*

- <u>Transportation</u>. Commenters requested that the SEIS address transportation issues, risks, and dangers along the route between Athens, Tennessee, and the Savannah River Site in South Carolina.

  Sections 4.1.13, 4.2.13, and Appendix E address potential transportation impacts associated from tritium production, including the potential impacts of transportation between Tennessee and SRS.

1.8 Organization

This Draft SEIS consists of two volumes: a standalone Summary and this volume, which contains the analyses, technical appendixes that support the analyses, and additional project information. The following list discusses the components of this volume:

- Chapter 1, Introduction and Purpose and Need for Agency Action, presents an overview of this SEIS, background information about tritium and tritium production in a CLWR, the NNSA purpose and need, the scope of the SEIS, and other related NEPA documents. It includes an overview of the public involvement process and summarizes the range of comments NNSA received during scoping.

- Chapter 2, Alternatives, describes the SEIS alternatives in detail and includes a discussion of alternatives NNSA considered and eliminated from detailed analysis. It includes a summary comparison of potential environmental impacts of the alternatives and identifies the Preferred Alternative for the SEIS.

- Chapter 3, Affected Environment, describes the environments at the Watts Bar and Sequoyah sites that each alternative could affect.

- Chapter 4, Environmental Impacts, presents potential environmental impacts from the alternatives and discusses unavoidable adverse impacts and management and mitigation measures.

- Chapter 5, Cumulative Impacts, presents potential impacts of the alternatives that could result in combination with impacts of other past, present, and reasonably foreseeable future projects.

- Chapters 6, 7, and 8 provide information about the relationship between short- and long-term uses of resources, irreversible and irretrievable commitment of resources, and regulatory requirements, respectively.

- Chapters 9 to 11 provide the list of preparers, glossary, and references.

The appendixes include technical information that supports the environmental analyses and documentation of the NEPA process NNSA followed in preparing this SEIS:

- Appendix A contains copies of public notices about the SEIS.
- Appendix B is the distribution list.
- Appendix C discusses the analysis of human health effects from normal operations.
- Appendix D discusses the analysis of human health effects from facility accidents; the discussion includes intentional destructive acts.
- Appendix E discusses the tritium plume modeling for the analysis of impacts from tritium discharges to water.
- Appendix F discusses the analysis of radiological human health effects of overland transportation.

CHAPTER 2. ALTERNATIVES AND COMPARISON OF ENVIRONMENTAL IMPACTS

This chapter describes the physical process for producing tritium in a commercial light water reactor (CLWR) (Section 2.1) and the planning assumptions and basis the National Nuclear Security Administration (NNSA) developed for the environmental impact analysis (Section 2.2). It details the reasonable alternatives this NNSA Supplemental Environmental Impact Statement (SEIS) evaluates, including the No-Action Alternative, and describes the alternatives NNSA considered but eliminated from detailed analysis (Section 2.3). This chapter describes the TVA reactor sites previously selected for tritium production, which are further analyzed in this SEIS (Section 2.4), provides a summary comparison of the environmental impacts that could result from implementation of each alternative and the No-Action Alternative (Section 2.5), and identifies NNSA's Preferred Alternative (Section 2.6).

2.1 Production of Tritium in a Commercial Light Water Reactor

In March 1999, the U.S. Department of Energy (DOE) issued the *Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (1999 EIS; DOE 1999a). The 1999 EIS included a detailed description of the production of tritium in a CLWR. This section summarizes that description.

TVA built the Watts Bar and Sequoyah reactors to produce electricity for commercial sale. The reactors use fuel that consists of pellets of uranium dioxide stacked in 12-foot-long tubes called fuel rods. Fuel rods are grouped together as fuel assemblies, in which metal grids hold the rods side by side at fixed distances from each other. A typical fuel assembly for a CLWR is an array with 17 rows and 17 columns; it holds 264 fuel rods and has positions for 25 nonfuel tubes (see Figure 2-1). The nonfuel positions are for moveable control rods, neutron source rods, or fixed burnable absorber rods (in this context, "burnable" means "capable of being consumed or altered by neutron absorption" rather than "flammable."), and instrumentation.

During the fission process, uranium atoms split and release energy. Some of this energy becomes heat, which the power plant uses to generate electricity. Two types of nonfuel rods, movable and fixed, control the fission process. The movable control rods start or stop the reactor. The fixed burnable absorber rods control the distribution of heat and extend the duration of the fuel cycle.

As Section 1.2 discusses, a CLWR can be operated to produce tritium while at the same time generating electric power. The process uses tritium-producing burnable absorber rods (TPBARs), which are specially fabricated rods that replace fixed burnable absorber rods in the reactor core. TPBARs are long, thin tubes that contain lithium-6. When neutrons in the reactor core strike a lithium-6 nucleus, the nuclear reaction produces tritium. The exterior dimensions of the TPBARs are similar to those of the boron-containing burnable absorber rods so they fit in the fuel assemblies in place of the boron-containing burnable absorber rods. To facilitate their insertion and removal from fuel assemblies, TPBARs are attached to a base plate. Figure 2-2 shows the typical structure of a TPBAR. In addition to producing tritium, TPBARs fill the same role as burnable absorber rods in the operation of the reactor.

During the reactor's normal fuel cycle (about 18 months), TPBARs are irradiated and the tritium gas is captured in the getter. (A getter is a material that absorbs free tritium gas and chemically binds it within its own structure). At the end of the fuel cycle, some fuel rods are depleted, which means they no longer contain enough uranium-235 to power the reactor as designed, and must be replaced. During the refueling period, these fuel assemblies, as well as fuel assemblies that contain TPBARs, are removed from the reactor core and transferred to the spent fuel pool. TPBAR assemblies are then removed from

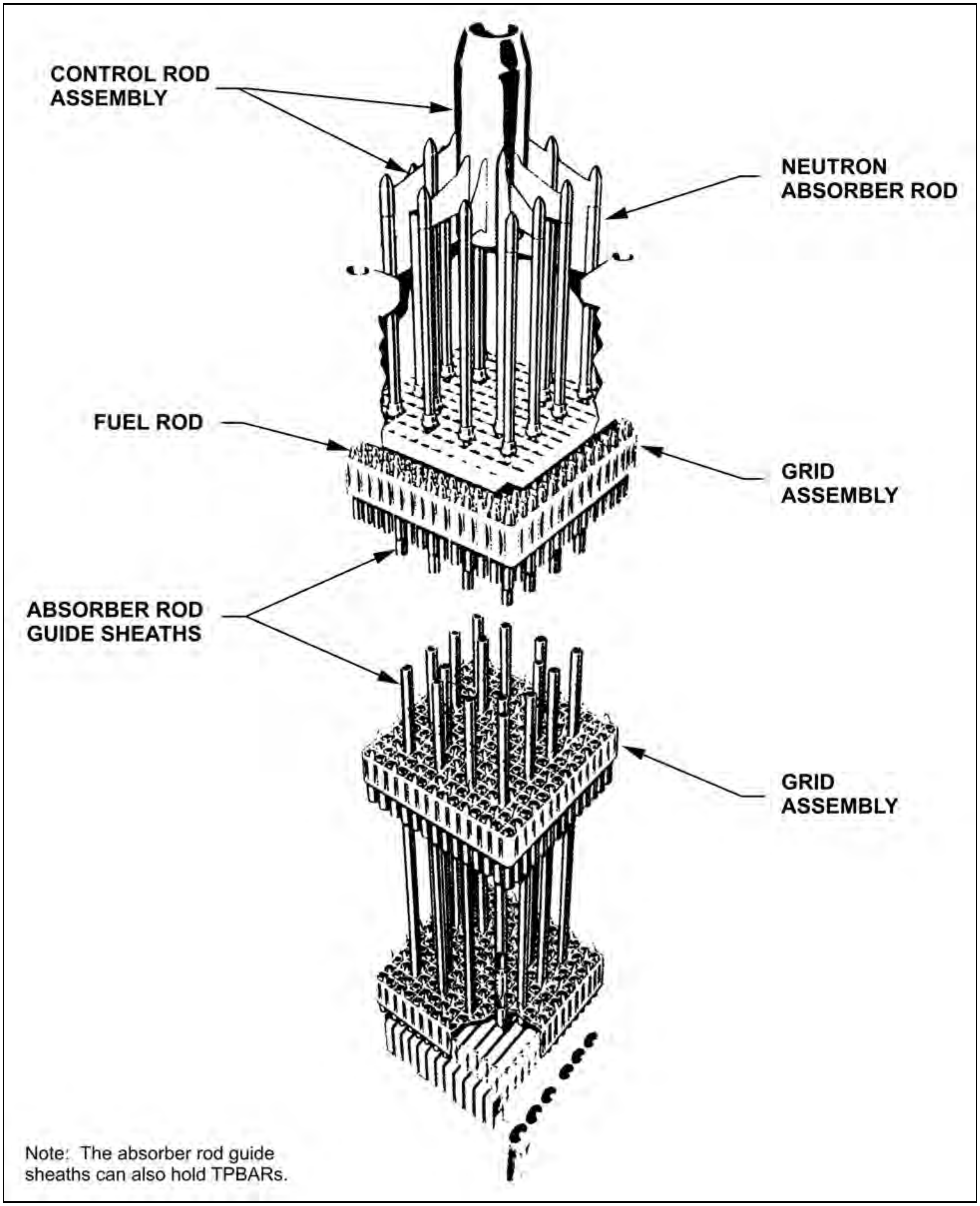

Figure 2-1. Typical fuel assembly cross-sections (DOE 1999a).

the fuel assemblies, mechanically separated from the base plate, and placed in a consolidation container. The consolidation container with the TPBARs is placed in a shipping cask, sealed, placed on a truck, and transported to the Tritium Extraction Facility at the Savannah River Site. Figure 1-1 in Chapter 1 shows

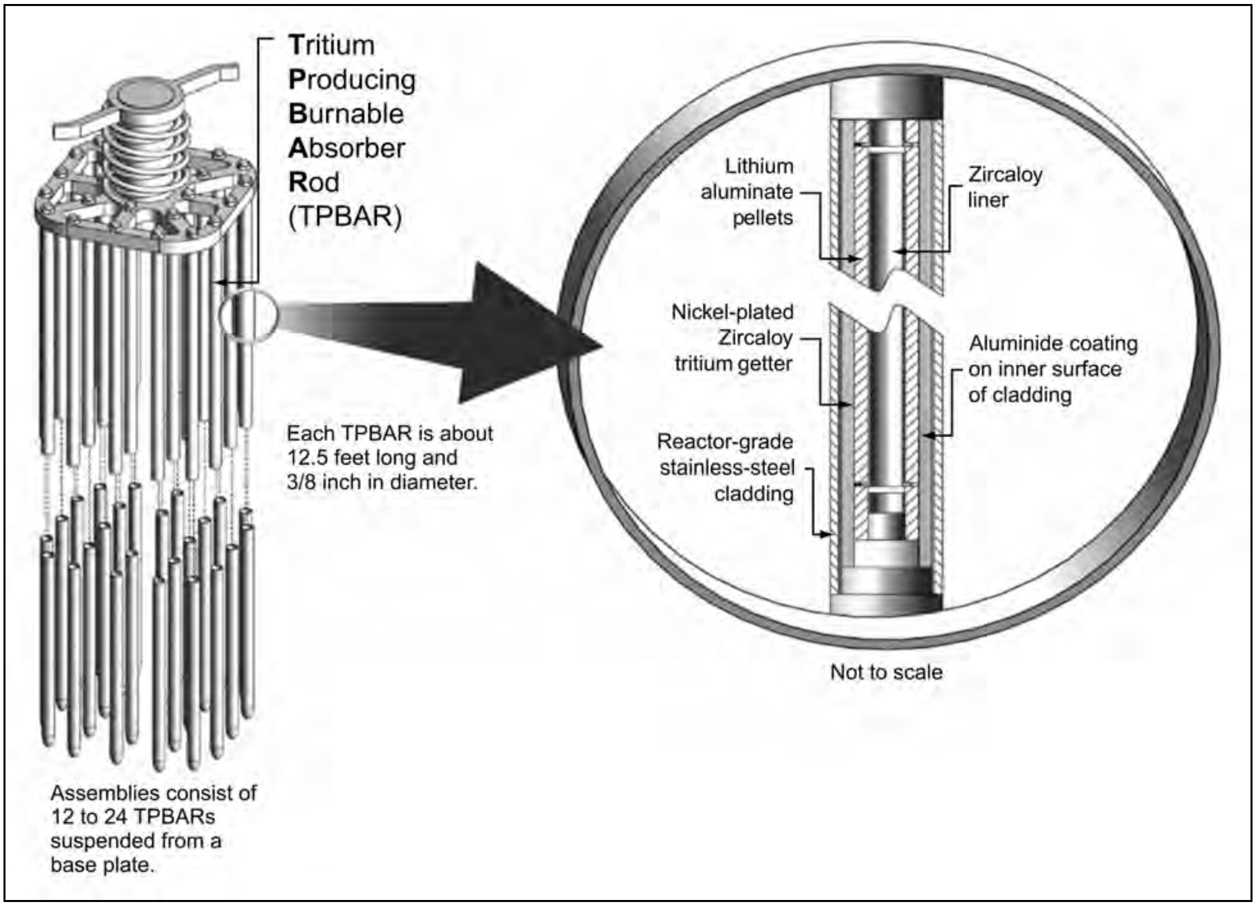

Figure 2-2. A typical TPBAR (GAO 2010).

the process from TPBAR fabrication and assembly through reactor irradiation and shipment to the Tritium Extraction Facility.

The tritium is extracted in a high-temperature heating and vacuum process, after which it is purified.

Impacts of Tritium Production on Reactor Operations

The replacement of burnable absorber rods with TPBARs has little effect on the normal operation of the reactor. The normal power distribution in the core, and reactor coolant flow and its distribution in the core, remain within the limits of the technical specifications for a reactor without TPBARs. A small amount of tritium permeates through the TPBARs during operation, which increases the quantity of tritium in the reactor coolant water system in comparison with a reactor that is not being used to produce tritium (DOE 1999a). Because tritium is an isotope, or type, of the hydrogen atom, it can combine with oxygen in the coolant water to become part of a water molecule (tritiated water). Tritiated water in the reactor coolant can reach the environment via several mechanisms, including (1) operations that refresh the reactor coolant to maintain the correct system parameters, (2) refueling operations, and (3) normal leakage and diffusion from the primary system into secondary systems. Tritium is released to the environment through the normal operations of the radioactive waste system or in steam system blowdown or condensing cooling water.

Once in the environment, tritium can enter the human body when people swallow tritiated water or breathe tritium gas. Exposure to tritium increases the risk of developing cancer. However, because tritium emits low-energy ionizing radiation and leaves the human body relatively quickly, it is one of the least dangerous radioactive isotopes (NRC 2011a).

Based on the operational experience from producing tritium in Watts Bar Unit 1 (Watts Bar 1), NNSA has determined that tritium permeation through TPBAR cladding is three to four times higher than DOE projected and analyzed in the 1999 EIS (GAO 2010). Therefore, as discussed in Section 1.5, this SEIS conservatively[1] analyzes potential environmental impacts that would occur as a result of tritium permeation levels that are higher than the observed increased tritium permeation levels in order to bound those impacts.

The following points provide a qualitative summary of the operational differences between a tritium production reactor and a nuclear power reactor without tritium production.

- Tritium releases. The amount of tritium in liquid effluents and gaseous emissions increases due to the presence of TPBARs in the reactor.

- Public and worker radiation exposure. The increased levels of tritium released to the environment and the additional handling and processing of TPBARs result in a slight increase in radiation exposure for the public and workers.

- Accident conditions. The physical changes to the reactor core involve replacing some burnable absorber rods with TPBARs. This change slightly increases the estimated amount of radionuclides that certain accidents could release.

- Waste. The additional handling, processing, and shipping of TPBAR assemblies slightly increases low-level radioactive waste generation rates.

- Spent nuclear fuel. Operating a reactor in a tritium-producing mode can produce additional spent nuclear fuel. This occurs because more fresh fuel is necessary to produce the design power level throughout the reactor's 18-month fuel cycle in comparison with reactors that only use burnable absorber rods. More fresh fuel assemblies are added during refueling, which results in additional spent nuclear fuel. Without tritium production, more fuel assemblies can stay in the reactor for more than one cycle during operations. Irradiation of 2,500 TPBARs in a single reactor would increase spent nuclear fuel generation by about 24 percent per fuel cycle (see Sections 4.1.10.2 and 4.2.10.3). Irradiation of 5,000 TPBARs at a single site would increase spent nuclear fuel generation at either Watts Bar or Sequoyah by about 48 percent per fuel cycle (see Sections 4.1.10.5 and 4.2.10.6). However, TVA has an infrastructure in place or has a plan to manage the increased volume of spent nuclear fuel assemblies.

- Transportation and handling. Irradiated TPBAR assemblies are packaged and transported from the reactor site to the Savannah River Site for tritium extraction and purification. In addition, low-level radioactive waste is packaged and transported for disposal at a low-level waste disposal facility, which entails expected small increases in radiological exposures and accident risks.

- Personnel requirements. TPBAR irradiation creates a small number of additional jobs at the reactor facility and for transportation.

1. The SEIS analysis is considered conservative because it evaluates a tritium permeation rate of 10 curies of tritium per TPBAR per year even though the observed tritium permeation rate has been less than 5 curies of tritium per TPBAR per year.

Chapter 4 describes the impacts for each analyzed tritium production alternative in this SEIS in each of these areas. Chapter 4 also includes an assessment of tritium mitigation and management measures to treat tritiated effluents to minimize the impacts of tritium releases.

2.2 Planning Assumptions and Basis for Analysis

This SEIS updates the evaluation in the 1999 EIS of the potential environmental impacts of the irradiation and handling of the TPBARs at the reactor facilities, and the transportation of unirradiated and irradiated materials including wastes to and from the various facilities. The following paragraphs describe the planning assumptions and considerations NNSA used as the basis for the impact analyses in the SEIS.

Tritium Requirements

Maintenance of the nation's nuclear weapons stockpile requires tritium. In the 1999 EIS, DOE assumed that the CLWR program would be required to produce up to 3 kilograms of tritium per year. Since completion of the 1999 EIS, the projected need for tritium has decreased. Considering the design of the TPBARs and the efficiency of the tritium extraction process, NNSA has determined that irradiation of a maximum of 2,500 TPBARs every 18 months would produce enough tritium to meet current requirements (NNSA 2013). However, in the event of a reactor outage, there is a potential that more than 2,500 TPBARs would need to be irradiated every 18 months for some period of time after the outage to compensate for the temporary shortfall in tritium supply. Therefore, this SEIS also evaluates a maximum production scenario of irradiating 5,000 TPBARs every 18 months.

Agreement Period

The Interagency Agreement between DOE and the Tennessee Valley Authority (TVA) to irradiate TPBARs is in effect until November 30, 2035 (TVA 2012). Consistent with that agreement, the SEIS assesses the environmental impacts of TPBAR irradiation in TVA CLWRs until 2035.

Reactors

In the Record of Decision for the 1999 EIS, DOE decided to use Watts Bar 1 and Sequoyah 1 and 2 for tritium production (64 FR 26369; May 14, 1999). Since that time, TVA has decided to complete construction of Watts Bar 2. In light of that decision, although TVA has no current plans to use Watts Bar 2 to produce tritium, this SEIS, which supplements the 1999 EIS, considers tritium production using one or both reactors at either or both the Watts Bar and Sequoyah sites as reasonable alternatives. These reactor alternatives provide flexibility for NNSA in deciding how to meet future tritium supply requirements.

Reactor Operating Licenses

The NRC licenses CLWRs to operate for 40 years. The operating licenses for the CLWRs considered in this SEIS expire or will expire as follows (NRC 2011b):

- Watts Bar 1 in November 2035,
- Watts Bar 2 in 2055 (if the NRC licensed it to begin operations in 2015),[2]
- Sequoyah 1 in September 2020, and
- Sequoyah 2 in September 2021.

2. Watts Bar Unit 2 was scheduled to begin operation in December 2012. However, on September 6, 2012, the NRC directed its staff to conduct a 2-year environmental study on the Waste Confidence Rule; the NRC will not issue licenses until the study has been completed (NRC 2012a). Therefore, this SEIS assumes that the earliest Watts Bar 2 could receive an operating license is 2015.

The Sequoyah reactors would not continue operating through 2035 without NRC approval to relicense the reactors to extend their operating periods (life extension). If the NRC approved the license renewals, Sequoyah 1 and 2 would continue to operate through 2040 and 2041, respectively, and would be available to produce tritium for NNSA through the current expiration date of the Interagency Agreement.

Tritium Releases

For purposes of analysis in this SEIS, NNSA assumed a high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year could potentially occur. This is a conservative assumption based on operational experience at Watts Bar 1, which has shown that tritium permeates from the TPBARs at levels of about three to four times higher than the 1 curie of tritium per TPBAR per year that was estimated in the 1999 EIS (PNNL 2013a). In accordance with NRC guidance, NNSA assumes that 10 percent of this tritium would be released to the atmosphere as tritiated water vapor (air emissions) and 90 percent would be released in the liquid effluent (Chandrasekaran et al. 1985) (Appendix C of this SEIS contains additional information about tritium release pathways). Table 2-1 lists tritium release estimates based on these assumptions for irradiation of 680, 1,250, 2,500, and 5,000 TPBARs every 18 months.

Table 2-1. Assumed tritium releases (curies per year) from TPBAR irradiation for analysis in this SEIS.

Number of TPBARs[a]	Air emissions	Liquid effluents	Total tritium releases
680[b]	680	6,120	6,800
1,250[c]	1,250	11,250	12,500
2,500[d]	2,500	22,500	25,000
5,000[e]	5,000	45,000	50,000

a. Every 18 months.
b. Under the No-Action Alternative, 680 TPBARs would be irradiated at each of Watts Bar 1, Sequoyah 1, and Sequoyah 2.
c. Under Alternative 3, Watts Bar and Sequoyah would both irradiate 1,250 TPBARs using one or both reactors at each site.
d. Under Alternatives 1 or 2, Watts Bar or Sequoyah (but not both) would irradiate up to a total of 2,500 TPBARs using one or both reactors.
e. Under Alternatives 4 or 5, Watts Bar or Sequoyah (but not both) would irradiate up to a total of 5,000 TPBARs using two reactors at a single site. Under Alternative 6, Watts Bar and Sequoyah would both irradiate 2,500 TPBARs using one or both reactors at each site. No more than 5,000 TPBARs would be irradiated under Alternatives 4, 5, or 6.

Radiological Impacts

In this SEIS, NNSA analyzes the potential radiological impacts to the public and the workers at the reactor sites from normal operations with TPBARs, accidents, and intentional destructive acts for the tritium production alternatives based on a high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year. In addition, for workers, additional radiological impacts would occur as a result of TPBAR consolidation activities. Consolidation means inserting the irradiated TPBARs from several fuel assemblies into a container in preparation for shipment to the Tritium Extraction Facility.

Two TPBAR Failures

The design of the TPBARs and the required TPBAR cladding quality assurance essentially preclude TPBAR failure during irradiation (DOE 1999). Nonetheless, the 1999 EIS assumed that two TPBARs could fail during the 40-year operational period and analyzed the release of all of the tritium in two failed TPBARs to the environment. For conservatism, the 1999 EIS assumed that all of the tritium from the two failed TPBARs would be released during one operating cycle. This SEIS similarly includes an analysis of 2 TPBAR failures during one operating cycle and updates the potential impacts associated with such a tritium release to the environment. These potential impacts are presented in Chapter 4 for all relevant resources under subheadings entitled “TPBAR Failure Scenario.”

Transportation

For analysis of transportation impacts, NNSA assumed that 2,500 to 5,000 irradiated TPBARs every 18 months would be transported from the tritium production site(s) to the Savannah River Site. Trucks would transport the irradiated TPBARs in casks similar to those for transporting spent nuclear fuel. In addition to the transportation of irradiated TPBARs, NNSA evaluates the transportation of the irradiated TPBAR hardware, which would be separated from the rods at the reactor site, and other low-level radioactive waste directly attributable to tritium production. NNSA would transport this low-level waste in separate packages to the Nevada National Security Site (formerly the Nevada Test Site). Sections 4.1.13 and 4.2.13 describe the potential environmental impacts of the transportation of these materials from the Watts Bar and Sequoyah sites, respectively.

Spent Nuclear Fuel

As discussed in Section 2.1, tritium production increases the amount of spent nuclear fuel a reactor produces in a fuel cycle. TVA is planning to build dry cask storage at Watts Bar regardless of whether it produces additional tritium at the site. Additional tritium production would increase the necessary dry cask storage capacity. For the SEIS, NNSA assumed TVA would store the additional spent nuclear fuel from tritium production on the reactor site in a generic dry cask independent spent fuel storage installation until the availability of a suitable national repository. Section 5.2.6 of the 1999 EIS (DOE 1999a) discusses the potential environmental impacts of constructing and operating this storage installation. That discussion is still applicable, and the SEIS does not revisit it. In addition, the *Final Supplemental Environmental Impact Statement for the Completion and Operation of Watts Bar Nuclear Plant Unit 2* (TVA 2007a) discusses the potential environmental impacts of constructing and operating such a storage installation. Construction and operation of the installation would require a site-specific evaluation under the *National Environmental Policy Act of 1969* (NEPA; 42 U.S.C. §§ 4321 *et seq*.), and TVA will not make a decision to construct or operate it as a result of this SEIS. The Sequoyah site has an operational dry cask facility. TVA operations in relation to spent nuclear fuel would be required to comply with any regulatory requirements resulting from the Record of Decision(s) that occurs as a result of the *Waste Confidence Generic Environmental Impact Statement, NUREG-2157* (NRC 2013).

2.3 Alternatives

Section 2.3.1 identifies the alternatives that NNSA evaluates in this SEIS, and Section 2.3.2 discusses the alternatives NNSA considered but eliminated from detailed analysis. The impact discussions in Chapter 4 assume that TVA would receive either licenses or license amendments to:

- Complete and operate the Watts Bar Unit 2 reactor,
- Irradiate the required number of TPBARs at Watts Bar (Alternatives 1, 3, 4, and 6),
- Irradiate the required number of TPBARs at Sequoyah (Alternatives 2, 3, 5, and 6), and
- Continue operations at Watts Bar and Sequoyah through 2035.

2.3.1 SEIS TRITIUM PRODUCTION ALTERNATIVES

To supply tritium to meet stockpile requirements, NNSA could potentially use one or more of four TVA CLWR units at the Watts Barr and Sequoyah sites. The SEIS evaluates the impacts of seven alternatives. Table 2-2 summarizes these alternatives and provides information about the number of TPBARs analyzed per site as well as the maximum number of TPBARs that could be irradiated every 18 months for each alternative.

In the Notice of Intent to prepare this SEIS, NNSA stated that it would assess the impacts associated with tritium production in CLWRs based on a permeation rate of about 5 curies of tritium per TPBAR per year (76 FR 60017; September 28, 2011). Although the observed tritium permeation through the cladding has been less than 5 curies of tritium per TPBAR per year, the current permeation rate does not take into account potential uncertainties about operating cycle length, tritium production per TPBAR, and future operational changes that could occur at the TVA reactors, all of which could affect the permeation rate.

Given these potential uncertainties in operational parameters, and after consultation with TVA and the Pacific Northwest National Laboratory (the TPBAR design agency), NNSA decided to evaluate an even higher and thus more conservative tritium permeation rate (10 curies of tritium per TPBAR per year) in

Table 2-2. SEIS tritium production alternatives.

	Alternatives									
	No-Action		**1**	**2**	**3**		**4**	**5**	**6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor Units	1	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs analyzed per site	680	1,360	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	2,040		2,500	2,500	2,500		5,000	5,000	5,000	

this SEIS instead of 5 curies of tritium per TPBAR per year (TVA 2013; PNNL 2013a). NNSA, the Laboratory, and TVA have determined that a tritium permeation rate of 10 curies of tritium per TPBAR per year is the best estimate to ensure that the analyses in this SEIS would reasonably be expected to bound uncertainties in relation to future operations. By analyzing this higher tritium permeation rate, NNSA is confident that the SEIS provides a reasonable, but conservative and bounding, analysis of the potential environmental impacts from tritium production in the Watts Bar and Sequoyah reactors.

In addition, the SEIS includes a standalone analysis of the potential impacts associated with a permeation rate of 5 curies of tritium per TPBAR per year at Watts Bar 1 to provide the most realistic estimate of the potential impacts (Section 4.4).

No-Action Alternative

The No-Action Alternative for the SEIS is based on the analysis in the 1999 EIS, the Record of Decision for the 1999 EIS, and analyses for NRC license applications and license amendment actions (see Section 1.3). The 1999 EIS analyzed the irradiation of up to 3,400 TPBARs in Watts Bar 1 and Sequoyah 1 and 2 with an assumed permeation rate of 1 curie of tritium per TPBAR per year. As such, the 1999 EIS analyzed the potential impacts associated with the release of 3,400 curies of tritium per year from each of those reactors. In the Record of Decision for the 1999 EIS, DOE selected Watts Bar 1 and Sequoyah 1 and 2 as the specific reactors to produce tritium for national security purposes [64 FR 26369; May 14, 1999]). Following the Record of Decision, TVA prepared applications to amend the Watts Bar 1 and Sequoyah 1 and 2 operating licenses to allow the irradiation of TPBARs in Watts Bar 1 and Sequoyah 1 and 2, and the NRC issued applicable license amendments (see Section 1.2). Since 2003, TVA has irradiated TPBARs at Watts Bar 1 but has not irradiated TPBARs at Sequoyah 1 and 2.[3]

Consistent with the analysis in the 1999 EIS, the No-Action Alternative in this SEIS assumes that TVA would operate Watts Bar 1 and Sequoyah 1 and 2 to maintain tritium releases that would meet NRC license and regulatory limits. This means that each of these reactors could release no more than 3,400 curies of tritium to the environment per year. Based on a conservatively assumed permeation rate

3. TVA has concluded that it will not use the Sequoyah reactors for tritium production until it prepares new license amendment applications and the NRC issues new license amendments for those reactors (Krich 2011a).

of 5 curies of tritium[4] per TPBAR per year, TVA could irradiate 680 TPBARs in each of the Watts Bar 1 and Sequoyah 1 and 2 reactors and stay within the maximum annual release of 3,400 curies of tritium analyzed in the 1999 EIS. Under the No-Action Alternative, the total number of TPBARs TVA could irradiate every 18 months would be 2,040 if TVA used all three currently available reactors for tritium production. This would be 460 TPBARs fewer than the maximum of 2,500 TPBARs that NNSA has determined it needs every 18 months to meet current requirements (NNSA 2013).

NNSA has defined the No-Action Alternative to represent the approach that would be taken to supply tritium in the TVA-operated Watts Bar 1 and Sequoyah 1 and 2 reactors within the bounds of the 1999 EIS and reasonably foreseeable NRC license amendments. Although the No-Action Alternative does not represent current operations at Watts Bar and Sequoyah, the impacts associated with current operations are presented in Chapter 3.

Alternative 1: Watts Bar Only (Preferred Alternative)
Under Alternative 1, TVA would irradiate up to a total of 2,500 TPBARs every 18 months at the Watts Bar site and would not irradiate TPBARs for tritium production at the Sequoyah site. TVA is currently completing construction of Watts Bar 2 and that reactor is expected to begin operations in about 2015 (TVA 2007a). Although TVA has no current plans to apply for a license amendment to allow Watts Bar 2 to produce tritium, the SEIS evaluates the potential environmental impacts associated with the use of Watts Bar 2 to provide the flexibility to use it in the future.

Alternative 2: Sequoyah Only
Under Alternative 2, TVA would irradiate up to a total of 2,500 TPBARs every 18 months at the Sequoyah site and would not irradiate TPBARs for tritium production at the Watts Bar site. TVA proposes to construct a 500,000-gallon tritiated water tank system, similar to the tank system TVA constructed at Watts Bar, to facilitate effluent water management to minimize potential impacts from tritium releases. This SEIS evaluates the potential impacts of constructing and operating such a tank system at the Sequoyah site for Alternatives 2, 3, 5, and 6.

Alternative 3: Watts Bar and Sequoyah
Under Alternative 3, TVA would irradiate up to a total of 2,500 TPBARs every 18 months using both the Watts Bar and Sequoyah sites. This would provide NNSA and TVA the ability to supply requirements at either site independently or to use both sites, with each supplying a portion of the necessary tritium. For the analyses in this SEIS, NNSA assumed for Alternative 3 that each site would irradiate up to 1,250 TPBARs every 18 months.

Alternative 4: Watts Bar Only (5,000 TPBARs)
Under Alternative 4, TVA would irradiate up to a total of 5,000 TPBARs every 18 months at the Watts Bar site using Watts Bar 1 and 2. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this would involve use of both Watts Bar reactors. TVA is currently completing construction of Watts Bar 2. Under this alternative, TVA would not irradiate TPBARs for tritium production at the Sequoyah site. Although TVA has no current plans to apply for a license amendment to allow Watts Bar 2 to produce tritium, the SEIS evaluates the potential environmental impacts associated with the use of Watts Bar 2 to provide the flexibility to use it in the future.

4. The permeation rate of 5 curies of tritium per TPBAR per year represents a rounding up of the 3 to 4 curies of tritium per TPBAR per year that has been observed at Watts Bar 1 since the inception of TPBAR irradiation at that reactor.

Alternative 5: Sequoyah Only (5,000 TPBARs)
Under Alternative 5, TVA would irradiate up to a total of 5,000 TPBARs every 18 months at the Sequoyah site using Sequoyah 1 and 2. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this would involve use of both Sequoyah reactors. Under this alternative, TVA would not irradiate TPBARs for tritium production at the Watts Bar site.

Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)
Under Alternative 6, TVA would irradiate up to a total of 5,000 TPBARs every 18 months using both the Watts Bar and Sequoyah sites. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this could involve the use of one or both reactors at each of the sites. For the analyses in this SEIS, NNSA assumed for Alternative 6 that each site would irradiate 2,500 TPBARs every 18 months.

Alternative 4, 5, and 6 are considered mutually exclusive to any other alternative, meaning that NNSA would not select any one of those alternatives in addition to another alternative in the Record of Decision, as that would exceed the maximum production scenario of irradiating 5,000 TPBARs every 18 months.

2.3.2 ALTERNATIVES CONSIDERED BUT ELIMINATED FROM DETAILED ANALYSIS

This section discusses alternatives that NNSA considered but eliminated from detailed study in this SEIS. Section 2.3.2.1 discusses alternatives previously considered by NNSA that have been reconsidered in this SEIS. Section 2.3.2.2 discusses alternatives not previously considered by NNSA that have been considered in this SEIS.

NNSA considered and ultimately dismissed the following alternatives in relation to tritium production in either the *Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE/EIS-0161, October 1995) (DOE 1995) and/or the 1999 EIS:

- Redesign weapons to use less or no tritium,
- Purchase tritium from foreign sources,
- Exclusively recycling tritium, and
- Use non-TVA reactors.

The *Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE/EIS-0161, October 1995) (DOE 1995) and/or the 1999 EIS explain the reasons why these alternatives were eliminated from detailed analysis. NNSA has reviewed the discussion of these alternatives in the previous documents and has concluded that the reasons for eliminating these alternatives remain valid. Therefore, NNSA is not revisiting them in this SEIS.

2.3.2.1 Alternatives Considered Previously and Reconsidered in this SEIS

Produce Tritium in an Accelerator
DOE evaluated this as a reasonable alternative in the *Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE 1995) and as part of the No-Action Alternative in the 1999 EIS. In the Record of Decision for the 1999 EIS, DOE selected the CLWR as the primary tritium supply technology and designated accelerator production of tritium as the backup technology (64 FR 26369; May 14, 1999). DOE concluded that CLWR production of tritium would have the best chance of meeting all national security requirements. NNSA does not believe the higher tritium permeation rate from TPBAR irradiation (in comparison with the rate DOE evaluated in the 1999 EIS) changes this conclusion. In addition, since 1999, DOE has not pursued development or implementation of the technology to produce tritium using accelerators. It would take many years and would be much more costly to initiate a

program to do so than to increase tritium production using TPBARs. For these reasons, accelerator production of tritium is not a reasonable alternative.

Use the TVA Bellefonte Reactors

TVA previously proposed the Bellefonte reactors for TPBAR irradiation, and DOE assessed those reactors as a reasonable alternative in the 1999 EIS. The 1999 EIS Record of Decision did not select the TVA Bellefonte reactors for TPBAR irradiation (64 FR 26369; May 14, 1999), and those reactors remain uncompleted. On August 18, 2011, the TVA Board of Directors approved the completion of Bellefonte Unit 1, a 1,260-megawatt-electric nuclear reactor near Scottsboro in northern Alabama. The timeline for the completion of construction of Bellefonte Unit 1 is uncertain, and TVA is not proposing the use of the Bellefonte reactors for TPBAR irradiation. As a result, using the Bellefonte reactors for TPBAR irradiation is not a reasonable alternative.

2.3.2.2 Alternatives Not Considered Previously but Considered in this SEIS

Redesign TPBARs To Decrease the Tritium Permeation Rate

The Pacific Northwest National Laboratory has redesigned several TPBAR components in an attempt to reduce tritium permeation into the reactor coolant. For example, Laboratory researchers modified the nickel-plated getter in the TPBAR to increase tritium capture efficiency. (A getter is a material that absorbs free tritium gas and chemically binds it within its own structure.) Despite this redesign, there was no discernible improvement in getter performance and tritium still permeates from the TPBARs at higher-than-previously-expected rates. However, the scientists and engineers continue to seek a technical solution (GAO 2010). Because redesign activities have not resolved the issue, TPBAR redesign is not a reasonable alternative at this time.

Use of a Tritium Removal System for Effluent Management

NNSA considered alternatives that could remove tritium from the reactor coolant rather than releasing the tritium to the environment. Researchers have conceived technologies for tritium removal including separation processes based on water distillation, catalytic exchange of hydrogen isotopes, combined electrolysis and catalytic exchange, palladium metal membrane/reactor separation, gas adsorption/desorption, gaseous diffusion, and thermal diffusion (EPRI 2002a; DOE 2009).

While it would be technologically feasible for TVA to use a tritium removal system, the analysis in this SEIS demonstrates that tritium concentrations in TVA reactor coolant are very small and associated releases to air and liquid pathways would remain very small even with tritium permeation of as much as 10 curies per TPBAR per year for either 2,500 TPBARs or 5,000 TPBARs. TVA can maintain tritium releases from its reactors well below applicable regulatory limits without implementing a tritium removal system. While NNSA and TVA continue to monitor the development of tritium removal technologies, they have concluded that TVA can use a large holding tank to manage tritium releases effectively. A large holding tank will enable TVA to better control the timing of releases of coolant containing tritium to continue to stay well within NRC and U.S. Environmental Protection Agency (EPA) limits. Section 1.6 of the SEIS includes a discussion of the Watts Bar tritiated water tank system that has been constructed. As discussed in Section 2.4.2, TVA proposes to construct and operate a tritiated water tank system at Sequoyah if there was a decision to irradiate TPBARs at that site or to facilitate routine tritium management. It should be emphasized that because of the very low concentrations of tritium in TVA reactors, any tritium removal system, no matter how effective, would not yield enough tritium to eliminate the need to irradiate TPBARs to meet tritium production requirements.

2.4 Reactor Sites

Sections 2.4.1 and 2.4.2 provide overviews of the TVA Watts Bar and Sequoyah sites and reactors, respectively. Chapter 3 provides detailed descriptions of the environmental baselines for these sites in relation to each resource area that this SEIS evaluates.

2.4.1 WATTS BAR

The Watts Bar site occupies about 1,000 acres in Rhea County, Tennessee, on the Tennessee River at River Mile 528 about 50 miles northeast of Chattanooga (DOE 1999a). Section 3.1.1 describes the main land-use activities of the surrounding area. Figure 2-3 shows the general arrangement of the site.

TVA received a construction permit from the NRC for each unit in 1973, and Watts Bar 1 began commercial power operation in May 1996. TVA suspended construction of Watts Bar 2 in 1985 after completing the major structures and installing some equipment including the reactor coolant system piping. On August 3, 2007, TVA informed the NRC of its plan to resume construction of Watts Bar 2 after completing the *Final Supplemental Environmental Impact Statement for the Completion and Operation of Watts Bar Nuclear Plant Unit* 2 (TVA 2007a). On July 7, 2008, the NRC extended the Watts Bar 2 construction permit completion date to December 2015. The NRC review of the Watts Bar 2 operating license application is in progress (NRC 2011c). If the NRC approves the operating license, TVA expects to begin operations at Watts Bar 2 in 2015.

Watts Bar 1 and 2 are Westinghouse-designed pressurized water reactors. Facilities include reactor containment buildings, turbine buildings, an auxiliary building, a service building, a water pumping station for circulating water in the condenser, a diesel generator building, a river intake pumping station, a natural-draft cooling tower, a transformer yard, a 500-kilovolt switchyard, a 161-kilovolt switchyard, a spent nuclear fuel cooling pool, and sewage treatment facilities (DOE 1999a). Each reactor containment building houses a pressurized water reactor. Table 2-3 lists the general design specifications of the Watts Bar 1 and 2 reactors. The Watts Bar Nuclear Plant currently has a workforce of about 572 people to operate Watts Bar 1. Once Watts Bar 2 becomes operational, the workforce at the Watts Bar site would be approximately 1,150 workers (TVA 2012).

Table 2-3. General design specifications of Watts Bar 1.[a]

Criteria	Value per reactor
Core thermal power level	3,459 megawatts-thermal
Plant capacity factor	More than 90 percent
Total steam flow rate	15.1 million pounds per hour
Electrical generation (net)	1,200 megawatts-electric
Normal operating cycle	18 months
Size of full core fuel load	193 fuel assemblies (89.5 metric tons of uranium)

Source: DOE 1999a.

a. Data are for Watts Bar 1, which is operational. Design specifications for Watts Bar 2 are similar to those for Watts Bar 1.

During operation, the reactor coolant water transfers the heat from the fissioning fuel to the steam generators. After the steam passes through the turbines, it flows to a condenser that removes the remaining heat and turns it into water again. This recirculated condenser water is cooled further by passing through a natural-draft evaporative cooling tower (without fans). Although the cooling system is called the closed mode, it requires makeup water from the Tennessee River to replace water losses due to evaporation and blowdown (a process that removes excess dissolved solids from the system). The Watts Bar site also employs a supplemental condenser cooling water system that TVA placed in service in 1999.

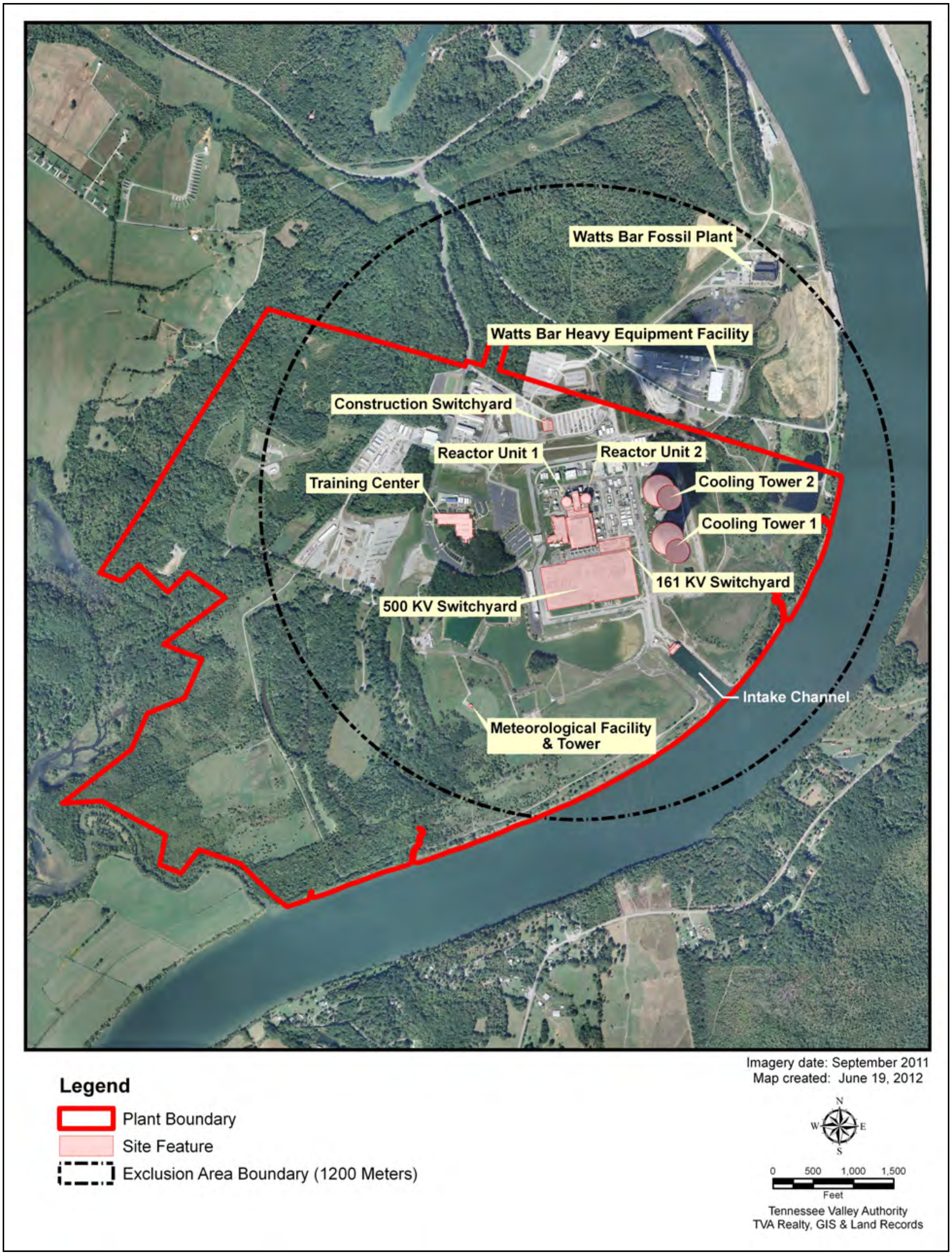

Figure 2-3. Watts Bar site (TVA 2012).

The system provides additional water to the reactor cooling towers and condensers by gravity flow from an intake structure immediately upstream of the Watts Bar Dam (TVA 2007a).To replace the lost water (mainly from cooling tower operation) from Watts Bar 1 operations, the pumping station withdraws about 41,000 gallons per minute from the Tennessee River. Blowdown from the natural-draft cooling tower discharges to the river at a normal rate of about 28,000 gallons per minute. A diffuser system disperses the blowdown into the river water and limits the rise in temperature to meet the requirements of a National Pollutant Discharge Elimination System permit. Once Watts Bar 2 becomes operational, it would have a system similar to that for Watts Bar 1.

The operation of Watts Bar 1 produces radioactive fission products and activates corrosion products in the reactor coolant system. A chemical water treatment system removes radionuclides from the coolant water. The gases and liquids are processed and monitored to minimize the release of radioactive nuclides to the atmosphere and the Tennessee River. The treatment system produces radioactive waste that TVA disposes of in accordance with its operating license.

Normal operations involve regular use of hazardous substances and chemicals. This results in the generation of hazardous waste, which TVA controls, stores, and manages in accordance with the regulations (40 CFR Parts 260 to 265) that implement the *Resource Conservation and Recovery Act of 1976, as amended* (42 U.S.C. §§ 6901 *et seq.*). TVA sends this waste for disposal at permitted treatment and disposal facilities. Operations at Watts Bar do not generate mixed wastes (that is, wastes that contain both hazardous and radioactive materials).

Operations involve regular generation of solid waste such as uncontaminated clothing, rags, waste paper, boxes, and filters; TVA disposes of this waste in accordance with State of Tennessee and local regulations.

To refuel and maintain the reactor, TVA must shut it down as part of the normal fuel cycle about every 18 months. During this period, the irradiated TPBARs and spent nuclear fuel assemblies are removed from the reactor and placed in the spent fuel pool for cooling. After about 1 month, the TPBARs are removed from the fuel assemblies, loaded into transportation casks, and sent to the Tritium Extraction Facility at the Savannah River Site.

TVA has recently constructed a 500,000-gallon tritiated water tank and associated pumps and piping at the Watts Bar site. Section 1.6 discusses the Categorical Exclusions TVA prepared for this action, and how it determined that no extraordinary circumstances exist and that no significant environmental impacts will result from construction and operation of this tank system.

2.4.2 SEQUOYAH

Sequoyah 1 and 2 are on a 525-acre site (not including a southern peninsula training center that occupies about 105 acres) in Hamilton County, Tennessee, along the Tennessee River at River Mile 484.5, about 7.5 miles northeast of Chattanooga (DOE 1999a). Section 4.2.2.1 describes the main land use activities of the surrounding area. Figure 2-4 shows the general arrangement of the site.

Sequoyah 1 and 2 are Westinghouse-designed pressurized water reactors. Sequoyah 1 began operations in July 1981 and Sequoyah 2 in June 1982. The nuclear steam supply systems include the reactor vessels, steam generators, and associated piping and pumps. These are housed in two reactor containment buildings. The rest of the plant includes a turbine building, an auxiliary building, a service and office building, a control building, a condenser circulating water pumping station, a diesel generator building, a river intake pumping station, two natural-draft cooling towers, a transformer yard, a 500-kilovolt

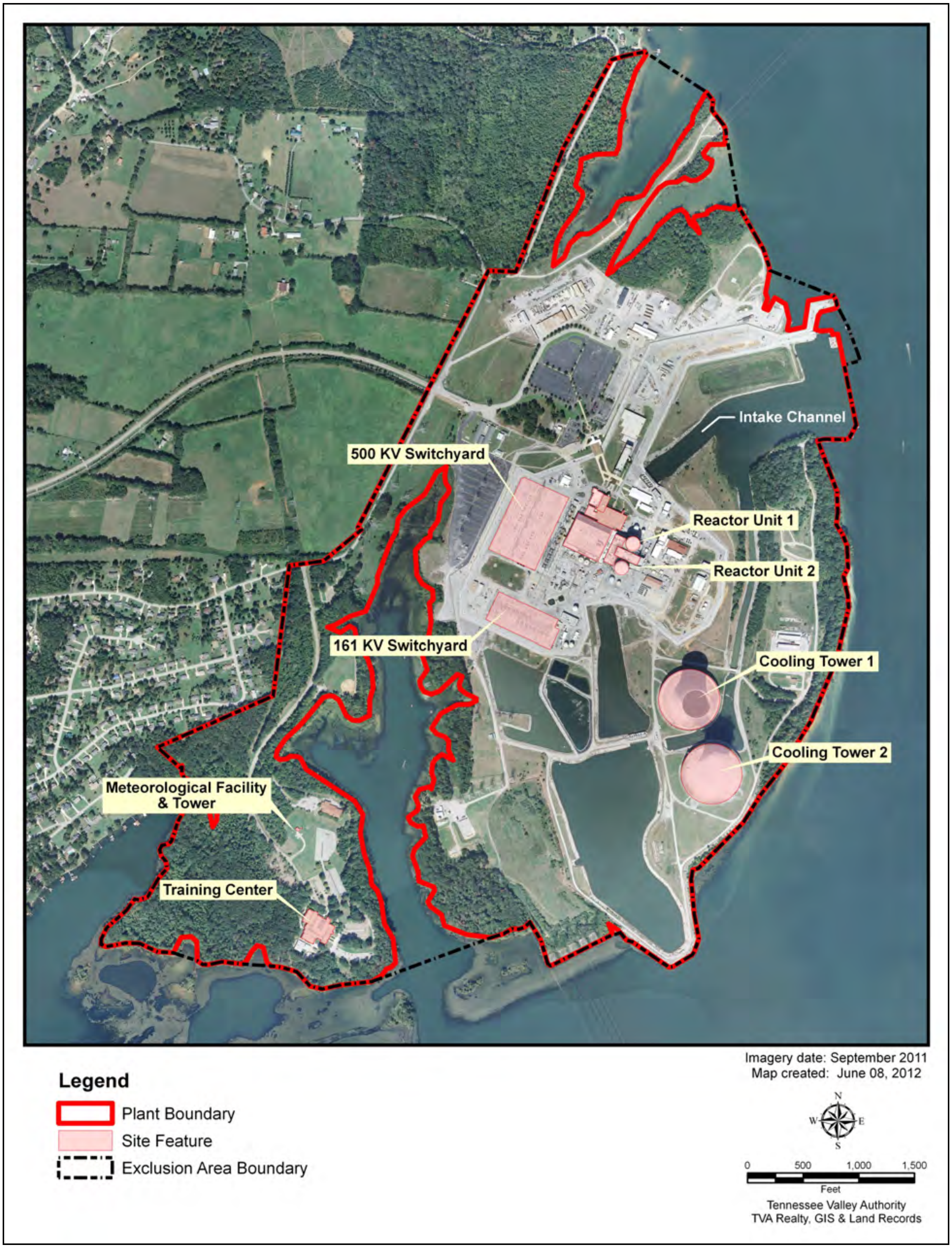

Figure 2-4. Sequoyah site (TVA 2012).

switchyard, a 161-kilovolt switchyard, a spent nuclear fuel cooling pool, a dry cask storage facility, and sewage treatment facilities (TVA 2012).

During normal operations without tritium production, TVA employs about 1,150 workers at the Sequoyah site (TVA 2012). Tritium production could require the addition of fewer than 10 new workers per unit (DOE 1999a). Table 2-4 lists the general design specifications of the Sequoyah 1 and 2 reactors.

Table 2-4. General design specifications of Sequoyah 1 and 2.

Criteria	Value per reactor
Core thermal power level	3,455 megawatts-thermal
Plant capacity factor	More than 90 percent
Total steam flow rate	14.9 million pounds per hour
Electrical generation (net)	1,198 megawatts-electric
Normal operating cycle	18 months
Size of full core fuel load	193 fuel assemblies (89.5 metric tons of uranium)

Source: DOE 1999a.

During operations at Sequoyah 1 or Sequoyah 2, the reactor coolant water transfers the heat from the fissioning fuel to the steam generators. After the steam passes through the turbines, it flows to a condenser that removes the remaining heat and turns it into water again. The overall thermal efficiency of each unit is about 35 percent. The condenser is cooled by a direct open cooling system (or mode) using diffusers supplemented by a helper or closed system (or mode) that uses natural-draft, evaporative cooling towers. TVA does not use the cooling towers, but they are available if necessary to meet thermal discharge limits (TVA 2012).

Cooling towers can be used in the helper mode, in which they discharge water through the diffuser pipes into the river, or in the closed mode. In the closed mode, makeup water from the Tennessee River is necessary to replace water losses from evaporation and blowdown. When one of the reactors is at full power, the temperature of the water flowing through each condenser rises about 30°F. The open cooling mode using the diffuser pipes withdraws and returns about 1.2 million gallons per minute with both units operating. In the cooling tower closed-cycle cooling mode, water lost through evaporation, small leaks, and blowdown is made up by withdrawing about 66,000 gallons per minute from the Tennessee River. Blowdown from a cooling tower is discharged to the river at a normal rate of nearly 32,000 gallons per minute (DOE 1999a). Diffusers mix the blowdown with river water and limit the temperature rise to meet the requirements of a National Pollutant Discharge Elimination System permit. Tritium production would not affect the thermal discharge characteristics of the plant (DOE 1999a).

Operation of the plant produces radioactive fission products and activates corrosion products in the reactor coolant system. Small amounts of these radioactive products enter the reactor coolant water. A chemical water treatment system removes radionuclides from the cooling water. The gases and liquids are processed and monitored on site to minimize the release of radioactive nuclides to the atmosphere and the Tennessee River. The treatment system produces radioactive waste that TVA disposes of in accordance with its operating license.

Normal operations involve regular use of several hazardous substances and chemicals. This results in the generation of hazardous waste, which TVA controls, stores, and manages in accordance with the regulations that implement the *Resource Conservation and Recovery Act of 1976, as amended*. TVA sends this waste for disposal at a permitted treatment and disposal facility. Operations at Sequoyah do not generate mixed wastes. Operations also involve regular generation of solid waste such as uncontaminated clothing, rags, waste paper, boxes, and filters; TVA disposes of this waste in accordance with State and local regulations.

Tritiated Water Tank System

TVA is proposing to build a 500,000-gallon tritiated water tank and associated pumps and piping at the Sequoyah site. TVA would use this tank to store tritiated water from Sequoyah 1 and 2 after it passes through the existing liquid radioactive waste processing system. TVA would release the stored tritiated water to the Tennessee River—as it currently does without the tank—by the existing pathway.[5] The tank system would have sufficient capacity to store and release the water at appropriate times (that is, TVA would release water from the tank during times of higher river flow for better dilution), and it would enable TVA to minimize the potential impacts of tritiated water releases. The system would allow TVA to plan fewer releases each year and to ensure that effluents from Sequoyah would continue to remain well below the regulatory concentration limits in Appendix B of 10 CFR Part 20 and in 40 CFR Part 141 (TVA 2011c).

The tank would be in an area that has been in industrial use since construction began at the Sequoyah site, and it would be outside the 100-year floodplain (TVA 2011c). The tank would be stainless steel and about 45 feet in diameter and 45 feet tall. It would have a domed roof and an internal membrane bladder at the top to prevent evaporation. It would have a secondary containment consisting of a larger diameter open tank with a rain shield (about 55 feet in diameter and 30 feet high) to capture 100 percent of the stored liquid in case the main tank failed. There would be about 5 feet of space between the inner and outer tank walls, which TVA would use for maintenance and inspection activities. There would be a rain shield (roof) between the outside and inside tank to keep rainwater from entering the annular space between the tanks. TVA would conduct tests for radioactivity of the water that would collect in the sump area between the tanks to ensure there would be no unmonitored radioactive releases from the sump (TVA 2011c).

TVA expects construction would take about 24 weeks: 6 weeks for foundation work and 18 weeks to build the tank itself. The foundation would be about 60 feet in diameter with a 2-foot-thick rebar-reinforced foundation with piles. The 18 weeks for tank construction would include preparation, onsite fabrication of the stainless-steel inner tank and the carbon-steel outer tank, and cleanup. TVA would schedule piping and electrical work in parallel with the foundation and tank construction. Work activities would not interrupt other activities at the plant except for final interconnections to station operating systems. TVA estimates the construction workforce would be about 100 workers (TVA 2011c).

Construction of the tank would involve minor emissions from cranes and other construction equipment, but TVA expects emission levels would remain generally within those normally experienced on the site and would not require special equipment to control emissions. The disturbed area is likely to be less than 1 acre at one time. Once operational, the tritiated water tank system would affect less than 1 acre of land in the existing protected area.

Construction could result in small amounts of runoff that TVA would control using best management practices. The project would generate some construction and solid waste that TVA would dispose of in accordance with State of Tennessee and local regulations. TVA does not expect construction to generate radioactive waste, but there is a potential that excavation activities could encounter legacy contamination. Therefore, TVA would monitor all excavation for radioactivity (TVA 2011c).

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5. See Section 3.2.5.1.3 for a discussion of the Sequoyah cooling water system. As explained in that section, during most of the year, the system operates in a once-through, or open, mode in which the cooling water from the reservoir picks up heat from the condenser, discharges to the diffuser pond within the plant boundaries, and returns to the reservoir through diffuser pipes. In this mode, the cooling towers do not operate and there is essentially no loss of cooling water; the withdrawn amount is the same as the discharged amount.

The piping for the new tank would connect with the existing waste disposal system to allow the existing monitor tank pumps to fill the tank. TVA would install two new pumps in the waste packaging area of the site and use them to pump the tritiated water to the current station effluent system, which would dilute the water with normal cooling water discharges. Preliminary evaluations indicate that the existing monitor tank pumps would have the capacity to pump the water at about 150 gallons per minute from the monitor tank to the new tritiated water tank (TVA 2011c).

The piping design includes features to protect groundwater from potential piping leaks in conjunction with the nuclear industry's voluntary groundwater protection initiative. The design includes a leak-proof trench or tunnel to hold the pipes with a monitored sump to detect any leaks. TVA does not expect the new tritiated water tank system to increase worker dose estimates within the restricted area boundary and does not anticipate a need for a license amendment for its construction and operation (TVA 2011c).

2.5 Comparison of Potential Environmental Impacts of Alternatives

To aid the reader in understanding the differences among the alternatives, this section compares the environmental impacts of the alternatives. Section 2.5.1 discusses the key analyses and findings in the SEIS. Sections 2.5.2 through 2.5.8 summarize the environmental impacts of the alternatives. The impacts of the No-Action Alternative, which are presented in Section 2.5.2, are a baseline for comparison with the impacts of the action alternatives. Table 2-5 at the end of this chapter supports this comparison. In addition to the data for the alternatives, Table 2-5 includes data that reflect current operating conditions for the Watts Bar and Sequoyah sites. Section 2.5.9 discusses differences between this SEIS and the 1999 EIS. Lastly, Section 2.5.10 summarizes the cumulative impact analysis and Section 2.5.11 discusses proposed mitigation measures.

2.5.1 KEY ANALYSES AND FINDINGS

This SEIS analyzes the potential environmental impacts of irradiating TPBARs and the resulting release of tritium. The key analyses are:

- The potential impacts of tritium releases on the health of workers and the public,
- The potential impacts of tritium releases on the Tennessee River, and
- The potential impacts of TPBAR irradiation on the operation and safety of the TVA reactor facilities.

The key SEIS findings are:

- The tritium releases from normal operations with TPBAR irradiation would have an insignificant impact on the health of workers and the public.
  - For the average worker, irradiation of 2,500 TPBARs could increase the annual dose by a maximum of 8.3 millirem in comparison with not irradiating TPBARs (see Tables 4-8 and 4-22 of the SEIS). A dose increase of 8.3 millirem would result in an additional latent cancer fatality risk of about 5×10^{-6}, or 1 chance in 200,000. Irradiation of 5,000 TPBARs at one site could increase the average worker's annual dose by a maximum of 16.5 millirem in comparison with not irradiating TPBARs (Sections 4.1.11.6 and 4.2.11.6). A dose increase

of 16.5 millirem would result in an additional latent cancer fatality risk of about 1×10^{-5}, or 1 chance in 100,000.

– For the hypothetical member of the public who received the highest dose from irradiation of 2,500 TPBARs, the annual dose could increase by a maximum of 0.33 millirem in comparison with not irradiating TPBARs (Section 4.1.11, Table 4-7). A dose increase of 0.33 millirem would result in an additional latent cancer fatality risk of 2×10^{-7}, or 1 chance in about 5 million. Irradiation of 5,000 TPBARs at one site could increase the annual dose by a maximum of 0.67 millirem in comparison with not irradiating TPBARs (Section 4.1.11, Table 4-7). A dose increase of 0.67 millirem as a result of TPBAR irradiation would result in an additional latent cancer fatality risk of 4×10^{-7}, or 1 chance in about 2.5 million.

- The tritium releases from TPBAR irradiation would increase tritium concentrations in the Tennessee River in comparison with not irradiating TPBARs. However, the tritium concentration at any drinking water intake would remain well below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter identified in 40 CFR Part 141. Even at the conservative permeation levels NNSA analyzed for this SEIS, the analyses determined that the average tritium concentration at any drinking water intake would be no more than about one-tenth the 20,000-picocurie-per-liter limit (Sections 4.1.5 and 4.2.5).

Radiation, Dose Units, and Latent Cancer Fatalities

Radiation dose is the amount of energy in the form of ionizing radiation absorbed per unit mass of any material. For people, radiation dose is the amount of energy absorbed in human tissue. In the United States, radiation dose is commonly measured in units called rem; a smaller fraction of the rem is the millirem (1/1,000 of 1 rem). Person-rem is a unit of collective radiation dose applied to populations or groups of individuals; it is the sum of the doses received by all the individuals of a specified population.

Numerical fatal cancer estimates presented herein were obtained using a linear no-threshold extrapolation from the nominal risk estimated for lifetime total cancer mortality that results from a large dose of radiation. Use of this approach is the basis for current radiation protection regulations to protect the public and workers. According to the extrapolation, if a certain radiation dose has an associated risk of a cancer, one-tenth of that dose would have one-tenth of the risk. Thus, the cancer risk is not 0, however small the dose. In accordance with DOE guidance, a risk factor of 0.0006 latent cancer fatality per rem was used in this SEIS as the conversion factor for all radiological exposures up to 20 rem per individual. A risk factor of 0.0012 was used for individual doses of 20 rem or greater.

- TPBAR irradiation would not have a significant adverse impact on the operation and safety of TVA reactor facilities. Potential risks from accidents would remain essentially the same whether TPBARs were irradiated in a TVA reactor or not. Irradiation of 2,500 TPBARs in a single reactor would increase spent nuclear fuel generation by about 24 percent per fuel cycle (see Sections 4.1.10.2 and 4.2.10.3). Irradiation of 5,000 TPBARs at a single site could increase spent nuclear fuel generation at either Watts Bar or Sequoyah by about 48 percent per fuel cycle (see Sections 4.1.10.5 and 4.2.10.6). However, TVA has an infrastructure in place or has a plan to manage the increased volume of spent nuclear fuel assemblies.

- As discussed in Sections 4.1.14 and 4.2.14, for all alternatives, TPBAR irradiation would not cause any disproportionately high and adverse consequences to minority or low-income populations.

Additional Low-Level Radioactive Waste

Any reactor that irradiated TPBARs would generate more low-level radioactive waste than one that did not. Much of the low-level waste would consist of TPBAR base plates and other irradiated hardware that would remain after the TPBARs were separated from their assemblies in preparation for shipping to the Savannah River Site. In the 1999 EIS, DOE and TVA estimated that low-level waste would increase by about 15 cubic feet per year for irradiation of 3,400 TPBARs (DOE 1999a), which would represent less than 0.1 percent of the low-level waste the Watts Bar site generates annually. Because this is such a small percentage, DOE and TVA do not think a more precise estimate is needed for irradiation of fewer TPBARs (a maximum of 2,500 under the proposed action in this SEIS). Therefore, this SEIS, like the 1999 EIS, estimates an additional 15 cubic feet of low-level waste annually for all reactors that irradiate TPBARs, regardless of the number of irradiated TPBARs, recognizing that this number is conservatively high for the alternatives discussed in this SEIS. For Alternatives 4, 5, and 6, an additional 30 cubic feet of low-level waste would be generated annually.

2.5.2 POTENTIAL IMPACTS OF THE NO-ACTION ALTERNATIVE

Under the No-Action Alternative, TVA would irradiate as many as 680 TPBARs every 18 months in each of the following reactors: Watts Bar 1, Sequoyah 1, and Sequoyah 2. The total number of TPBARs TVA would irradiate every 18 months could be up to 2,040 if TVA used all three reactors for tritium production.

Watts Bar

Tritium releases would result from normal reactor operations, without TPBARs, of Watts Bar 1 and 2 (even though Watts Bar 2 would not irradiate TPBARs under this alternative, it would nonetheless produce and release some tritium during normal reactor operations without TPBARs[6]) as well as from tritium production in Watts Bar 1. TVA is currently completing construction of Watts Bar 2 (TVA 2007). TVA recently constructed a 500,000-gallon tritiated water tank system to facilitate effluent water management to mitigate impacts on the river. With this system in place, normal operations at the levels analyzed for this alternative could potentially release an estimated 10,440 curies of tritium a year to the Tennessee River. Of this tritium released, 6,120 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium. Tritium concentrations in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter within about 30 feet of the diffuser that returns water to the river (the nearest drinking water intake is 23 miles away). Annual radioactive releases to the air from Watts Bar could potentially total 1,196 curies, with tritium making up 1,160 curies. As discussed in Sections 3.1.3 and 4.1.3.1, greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. The continued TPBAR irradiation in Watts Bar 1 would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from Watts Bar normal operations if TPBARs were not irradiated (see the text box above). TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation. Operation of the tritiated water tank system would have no impact on the quantities or management of wastes. Once Watts Bar 2 becomes operational, the two reactors at the site would generate about 115 assemblies of spent nuclear fuel per year, which would include about 3 additional spent nuclear fuel assemblies associated with TPBAR irradiation at Watts Bar 1.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 116 millirem per year. Of this dose, about 114 millirem per year would be from normal operations unrelated to TPBAR

6. Tritium is produced in all U.S. commercial nuclear reactors from fission of uranium in the reactor fuel and neutron activation of boron in burnable absorber rods.

irradiation. Statistically, if a worker received a dose of 116 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 14,400. The total annual workforce dose would be about 102 person-rem. Of this dose, about 100 person-rem would be from normal operations unrelated to TPBAR irradiation. The collective dose to facility workers would result in 0 (0.06)[7] latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations with TPBARs would also be well within the NRC regulatory limit of 25 millirem per year. At Watts Bar, the total annual dose to the population within 50 miles (about 1.45 million people in 2025) during normal operations would be about 7.6 person-rem per year, which equates to 0 (0.005) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.28 millirem. For comparison, the average annual dose from natural and man-made radiation is about 620 millirem.

Based on the analyzed design-basis accidents, the highest dose to the maximally exposed individual would be well below the NRC regulatory limit (25 rem) and the average individual dose to the 50-mile population would be much less than 1 rem. Based on the analyzed beyond-design-basis accidents, the early containment failure accident would represent the highest dose to the maximally exposed individual, with an estimated frequency of about 1 chance in 3 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident. The analysis of intentional destructive acts indicates that potential consequences would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

Tritium Concentrations in Discharge Plumes

The analysis for this SEIS modeled the tritium concentration in the Tennessee River after discharge from the reactors to determine at what point the concentration would be below the EPA-established drinking water limit of 20,000 picocuries per liter.

For Watts Bar, under Alternatives 1, 3, 4, and 6, tritium concentrations would be below the limit after dilution occurred, no more than 140 feet downstream after exiting the diffuser. Under Alternatives 2 and 5, Watts Bar would not irradiate TPBARs and the tritium concentration would be below the limit soon after exiting the diffuser.

For Sequoyah, under Alternatives 2, 3, 5, and 6, tritium concentrations would be below the limit after dilution occurred, no more than 18 feet downstream after exiting the diffuser. Under Alternatives 1 and 4, Sequoyah would not irradiate TPBARs and the tritium concentration would be below the limit before exiting the diffuser.

The reason for the difference between Watts Bar and Sequoyah release concentrations is that the cooling systems for the two plants are different. Watts Bar is basically a closed system that recycles most of its cooling water and has a relatively low discharge rate (about 80 cubic feet per second). Sequoyah operates primarily in an open mode in which cooling water is pumped through the heat exchanging system and discharged to the river without recycling. The typical average discharge rate is 2,333 cubic feet per second. As a result of recirculation and a lower discharge rate, tritium is concentrated in the effluent and disperses more slowly at Watts Bar compared to Sequoyah. This is why the tritium concentration in Sequoyah effluent would be less than the tritium concentration in Watts Bar effluent.

7. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Additional Spent Nuclear Fuel

The amount of additional spent nuclear fuel from TPBAR irradiation depends on the number of irradiated TPBARs. As TPBARs are irradiated, they absorb neutrons, which reduces the plant's power levels. In order to maintain design power levels during TPBAR irradiation, TVA would need to increase the number of fresh fuel assemblies. The increase in fresh fuel assemblies generates additional spent nuclear fuel. Irradiation of 680 TPBARs per cycle would generate about 4 additional spent nuclear fuel assemblies every 18 months (which would equate to about 3 additional spent nuclear fuel assemblies annually) in comparison with operations without TPBARs. As the number of TPBARs were increased, they would absorb an increasingly higher percentage of neutrons, which would reduce the plant's power levels. TVA would then need to increase the number of fresh fuel assemblies to maintain design power levels. The increase in fresh fuel assemblies would generate additional spent nuclear fuel.

The relationship between the number of irradiated TPBARs and the amount of additional spent nuclear fuel is not linear. For example, irradiation of 1,250 TPBARs in a reactor would generate 8 to 12 additional spent nuclear fuel assemblies every 18 months. At twice the number of TPBARs (2,500), the number of spent nuclear fuel assemblies would increase to 41 (about 3 to 5 times more than for 1,250). This nonlinearity occurs because, as more TPBARs are added to the reactor, fewer neutrons are available to initiate fission in uranium atoms, and increasingly greater quantities of fresh fuel are needed to maintain the design power level for the reactor.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Watts Bar operations would be 0 (0.003) for crew, 0 (3×10^{-4}) for members of the public, and 0 (5×10^{-6}) for radiological accidents, along with 0 (0.004) traffic fatality.

Sequoyah

Tritium releases would occur as a result of tritium production as well as normal reactor operations without TPBARs. Normal operations would release 16,560 curies of tritium to the Tennessee River each year. Of this tritium released, 12,240 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium. Tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter after leaving the diffusers. Annual radioactive releases to the air would total 1,867 curies, including about 1,840 curies of tritium. As discussed in Sections 3.2.3 and 4.2.3.1, greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste from current Sequoyah operations. TPBAR irradiation would have no impact on nonradioactive hazardous or nonhazardous waste generation. Sequoyah would generate spent nuclear fuel at a rate of about 113 spent nuclear fuel assemblies annually, which would include about 6 spent nuclear fuel assemblies associated with TPBAR irradiation at Sequoyah 1 and 2.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 109 millirem per year. Of this dose, about 105 millirem per year would be from normal operations unrelated to TPBAR irradiation. Statistically, if a worker received a dose of 109 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 15,300. The total annual workforce dose would be about 132 person-rem. Of this dose, about 128 person-rem would be from normal operations unrelated to TPBAR irradiation. The collective dose to facility workers would result in 0 (0.08) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles (about 1.29 million people in 2025) during normal operations would be about 10.8 person-rem per year, which equates to 0 (0.006) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.24 millirem. For comparison, the average annual dose from natural and man-made radiation is about 620 millirem.

Based on the analyzed design-basis accidents, the highest dose to the maximally exposed individual would be well below the NRC regulatory limit (25 rem) and the average individual dose to the 50-mile population would be much less than 1 rem. Based on the analyzed beyond-design-basis accidents, the early containment failure accident would represent the highest dose to the maximally exposed individual, with an estimated frequency of approximately 1 chance in 1.5 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident. The analysis of intentional destructive acts indicated that potential consequences would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Sequoyah operations would be 0 (0.005) for crew, 0 (6×10^{-4}) for members of the public, and 0 (1×10^{-5}) for radiological accidents, along with 0 (0.005) traffic fatality.

2.5.3 POTENTIAL IMPACTS OF ALTERNATIVE 1 (PREFERRED ALTERNATIVE)

Under Alternative 1, TVA would irradiate up to a total of 2,500 TPBARs every 18 months in Watts Bar 1, Watts Bar 2, or both, which would represent an increase of 1,820 TPBARs at Watts Bar in comparison with the No-Action Alternative. At Sequoyah, no TPBARs would be irradiated under this alternative, which would represent a decrease of 680 TPBARs for each of the Sequoyah reactors in comparison with the No-Action Alternative.

Watts Bar

During normal operations, the two reactors could potentially release about 26,820 curies of tritium (of which 22,500 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium) to the Tennessee River each year, which would be an increase in comparison with the 10,440 curies of tritium assumed to be released under the No-Action Alternative. Tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter within about 70 feet of the diffuser. Annual radioactive releases to the air from Watts Bar could potentially total 3,016 curies, including 2,980 curies of tritium, which would be an increase in comparison with the total release of 1,196 curies, including 1,160 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from normal operations if TPBARs were not irradiated. TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation. Irradiation of 2,500 TPBARs would generate no more than 41 additional spent nuclear fuel assemblies every 18 months over the No-Action Alternative if TVA irradiated all 2,500 TPBARs in a single reactor. On an annual basis, this would increase spent nuclear fuel generation at Watts Bar by about 24 percent in comparison with the No-Action Alternative. TVA has an infrastructure in place or has a plan at Watts Bar to manage the increased volume of spent nuclear fuel assemblies.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 122 millirem per year, which would be an increase in comparison with the 116 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 122 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 13,700. The total annual workforce dose would be about 107 person-rem, which would be an increase in comparison with the 102 person-rem the worker population would receive each year under the No-Action Alternative. Of this dose, about 100 person-rem would be from normal operations unrelated to TPBAR irradiation. The collective dose to facility workers would result in 0 (0.06) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations with TPBARs would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 16.7 person-rem per year, which would be an increase in comparison with the 7.6 person-rem annual dose under the No-Action Alternative. A collective dose of about 16.7 person-rem per year equates to 0 (0.001) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.52 millirem, which would be an increase in comparison with the 0.28 millirem that individual would receive each year under the No-Action Alternative. An annual dose of 0.52 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Based on the analyzed design-basis accidents, the highest dose to the maximally exposed individual would be well below the NRC regulatory limit (25 rem) and the average individual dose to the 50-mile population would be much less than 1 rem. Based on the analyzed beyond-design-basis accidents, the early containment failure accident would represent the highest dose to the maximally exposed individual, with an estimated frequency of about 1 chance in 3 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident. The analysis of intentional destructive acts indicates that potential consequences would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Watts Bar operations would be 0 (0.01) for crew, 0 (0.001) for members of the public, and 0 (2×10^{-5}) for radiological accidents, along with 0 (0.004) traffic fatality.

Sequoyah

Under this alternative, no irradiation of TPBARs would take place using the Sequoyah nuclear reactors. Therefore, there would be no impacts attributable to TPBAR irradiation. The following discussion describes the impacts of normal operations at Sequoyah without TPBARs. During normal operations without TPBARs, the reactors would release 4,320 curies of tritium to the Tennessee River each year, which is the same as current conditions and would be a reduction in comparison with the 16,560 curies of tritium assumed to be released under the No-Action Alternative. Tritium concentrations in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter after leaving the diffusers. Annual radioactive releases to the air would total 507 curies, including about 480 curies of tritium, which would be a reduction in comparison with the total release of 1,867 curies, including 1,840 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation with TPBAR irradiation. Without TPBAR irradiation, low-level radioactive waste generation would decrease by about 15 cubic feet per year in comparison with the No-Action Alternative. There would be no changes to nonradioactive hazardous and nonhazardous waste generation. The reactors would generate about 107 spent nuclear fuel assemblies per year, which is the same quantity the site currently generates.

Worker exposure to radiation during normal operations without TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 105 millirem per year, which would be a reduction in comparison with the 109 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 105 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 15,900. The total annual workforce dose would be about 128 person-rem, which would be a reduction in comparison with the 132 person-rem the worker population would receive under the No-Action Alternative. The collective dose to facility workers would result in 0 (0.08) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 4.4 person-rem per year, which would be a reduction in comparison with the 10.8 person-rem that the population would receive each year under the No-Action Alternative. A collective dose of about 4.4 person-rem per year equates to 0 (0.003) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.13 millirem, which would be a reduction in comparison with the 0.24 millirem that this individual would receive each year under the No-Action Alternative. An annual dose of 0.13 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Potential impacts from onsite accidents and intentional destructive acts would be essentially identical to those analyzed for the No-Action Alternative. Under Alternative 1, there would be no irradiation of TPBARs at Sequoyah and no transportation in relation to tritium production taking place at the Sequoyah site.

2.5.4 POTENTIAL IMPACTS OF ALTERNATIVE 2

Under Alternative 2, TVA would irradiate up to a total of 2,500 TPBARs every 18 months in Sequoyah 1, Sequoyah 2, or both, which would represent an increase of 1,140 TPBARs at Sequoyah in comparison with the No-Action Alternative. At Watts Bar, no TPBARs would be irradiated, which would represent a decrease of 680 TPBARs in Watts Bar 1 in comparison with the No-Action Alternative.

Watts Bar

Under this alternative, no irradiation of TPBARs would take place using the Watts Bar nuclear reactors. Therefore, there would be no impacts attributable to TPBAR irradiation. The following discussion describes the impacts of normal operations at Watts Bar without TPBARs. During normal operations without TPBARs, the reactors would release 4,320 curies of tritium to the Tennessee River each year, which would be a reduction in comparison with the 10,440 curies of tritium assumed to be released under the No-Action Alternative. The tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter soon after leaving the diffuser. Annual radioactive releases to the air would total 514 curies, including 480 curies of tritium, which would be a decrease in comparison with the total 1,196 curies, including 1,160 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation with TPBAR irradiation. Without TPBAR irradiation, low-level radioactive waste generation would decrease by about 15 cubic feet per year in comparison with the No-Action Alternative. Nonradioactive hazardous and nonhazardous waste generation would not change. Because Watts Bar would no longer irradiate TPBARs, about 3 less spent nuclear fuel assemblies would be generated annually in comparison with the No-Action Alternative. The reactors would generate about 112 spent nuclear fuel assemblies per year when Watts Bar 2 becomes operational.

Worker exposure to radiation during normal operations without TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 114 millirem per year, which would be a decrease in comparison with the 116 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 114 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 14,600. The total annual workforce dose would be about 100 person-rem, which would be a decrease in comparison with the 102 person-rem the worker population would receive each year under the No-Action Alternative. All of this dose would be from normal operations unrelated to TPBAR irradiation. The collective dose to facility workers would result in 0 (0.06) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 4.2 person-rem per year, which would be a decrease in comparison with the 7.6 person-rem dose received each year under the No-Action Alternative. A collective dose of about 4.2 person-rem per year equates to 0 (0.003) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.19 millirem, which would be a decrease in comparison with the 0.28 millirem that this individual would receive each year under the No-Action Alternative. An annual dose of 0.19 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Potential impacts from onsite accidents and intentional destructive acts would be essentially identical to those analyzed for the No-Action Alternative. Under Alternative 2, there would be no irradiation of TPBARs at Watts Bar and no transportation in relation to tritium production taking place at the Watts Bar site.

Sequoyah

NNSA analyzed irradiation of 2,500 TPBARs every 18 months using one or both reactors at the Sequoyah site. In addition, TVA proposes to construct and operate a 500,000-gallon tritiated water tank system to facilitate effluent water management. The stainless-steel tank, which would be about 45 feet in diameter and 45 feet tall, would disturb less than 1 acre of land in the existing protected area. Due to the small area of construction and use of previously disturbed land, impacts to soils and cultural resources from construction activities would be unlikely. Some minor emissions could occur during construction of the 500,000-gallon tank from the use of cranes and other construction equipment. Such emissions would be temporary and similar to the levels generally experienced at the site from on-going operations. The construction workforce, about 100 skilled and general laborers, would be on site for about 15 weeks. The operational impacts of that tritiated water tank system are included in the discussion below.

During normal operations, the Sequoyah reactors could potentially release 26,820 curies of tritium (of which 22,500 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium) to the Tennessee River each year, which would be an increase in comparison with the 16,560 curies of tritium assumed to be released under the No-Action Alternative. The tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter after leaving the diffusers. Annual radioactive releases to the air from Sequoyah could potentially total about 3,007 curies, including about 2,980 curies of tritium, which would be an increase in comparison with the total 1,867 curies, including 1,840 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from normal operations if TPBARs were not irradiated. TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation.

Operation of the tritiated water tank system would have no impact on the quantities or management of wastes. Irradiation of 2,500 TPBARs would generate no more than 41 additional spent nuclear fuel assemblies every 18 months if all 2,500 TPBARs were irradiated in a single reactor. On an annualized basis, this would increase spent nuclear fuel generation at Sequoyah by about 24 percent in comparison with the No-Action Alternative. TVA has an infrastructure in place at Sequoyah to manage the increased volume of spent nuclear fuel assemblies.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 111 millirem per year, which would be an increase in comparison with the 109 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 111 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 15,000. The total annual workforce dose would be about 135 person-rem, which would be an increase in comparison with the 132 person-rem the worker population would receive under the No-Action Alternative. The collective dose to facility workers would result in 0 (0.08) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 16.2 person-rem per year, which would be an increase in comparison with the 10.8 person-rem that the population would receive each year under the No-Action Alternative. A collective dose of about 16.2 person-rem per year equates to 0 (0.01) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.33 millirem, which would be an increase in comparison with the 0.24 millirem that this individual would receive each year under the No-Action Alternative. An annual dose of 0.33 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Based on the analyzed design-basis accidents, the highest dose to the maximally exposed individual would be well below the NRC regulatory limit (25 rem) and the average individual dose to the 50-mile population would be much less than 1 rem. Based on the analyzed beyond-design-basis accidents, the early containment failure accident would represent the highest dose to the maximally exposed individual, with an estimated frequency of about 1 chance in 1.5 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident. The analysis of intentional destructive acts indicates that potential consequences would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Sequoyah operations would be 0 (0.01) for crew, 0 (0.002) for members of the public, and 0 (2×10^{-5}) for accidents, along with 0 (0.005) traffic fatality.

2.5.5 POTENTIAL IMPACTS OF ALTERNATIVE 3

Under Alternative 3, TVA would irradiate up to a total of 2,500 TPBARs every 18 months using both the Watts Bar and Sequoyah sites. This would provide NNSA and TVA the ability to supply requirements at either site independently or to use both sites, with each supplying a portion of the tritium required. For the analyses in this SEIS, NNSA assumed for Alternative 3 that each site would irradiate 1,250 TPBARs.

Watts Bar

During normal operations, the reactors could potentially release 15,570 curies of tritium (of which 11,250 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium) to the Tennessee River per year, which would be an increase in comparison with the 10,440 curies of tritium assumed to be released under the No-Action Alternative. Tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter within about 30 feet of the diffuser. Annual radioactive releases to the air could potentially total about 1,766 curies, including 1,730 curies of tritium, which would be an increase in comparison with the total 1,196 curies, including 1,160 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from normal operations if TPBARs were not irradiated. TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation. Irradiation of 1,250 TPBARs in a single reactor would generate from 8 to 12 additional spent nuclear fuel assemblies every 18 months. On an annualized basis, this would increase spent nuclear fuel generation at Watts Bar by 5 to 7 percent in comparison with the No-Action Alternative.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 118 millirem per year, which would be an increase in comparison with the 116 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 118 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 14,100. The total annual workforce dose would be about 104 person-rem, which would be an increase in comparison with the 102 person-rem the worker population would receive each year under the No-Action Alternative. Of this dose, about 100 person-rem would be from normal operations unrelated to TPBAR irradiation. The collective dose to facility workers would result in 0 (0.06) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 10.5 person-rem per year, which would be an increase in comparison with the 7.6 person-rem dose received each year under the No-Action Alternative. A collective dose of about 10.5 person-rem per year equates to 0 (0.04) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.36 millirem, which would be an increase in comparison with the 0.28 millirem that this individual would receive each year under the No-Action Alternative. An annual dose of 0.36 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Based on the analyzed design-basis accidents, the highest dose to the maximally exposed individual would be well below the NRC regulatory limit (25 rem) and the average individual dose to the 50-mile population would be much less than 1 rem. Based on the analyzed beyond-design-basis accidents, the early containment failure accident would represent the highest dose to the maximally exposed individual, with an estimated frequency of about 1 chance in 3 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident. The analysis of intentional destructive acts indicates that potential consequences would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Watts Bar operations would be 0 (0.005) for crew, 0 (4×10^{-4}) for members of the public, and 0 (1×10^{-5}) for radiological accidents, along with 0 (0.004) traffic fatality.

Sequoyah

TVA proposes to construct and operate a 500,000-gallon tritiated water tank system to facilitate effluent water management. The impacts from constructing that system would be the same as those for Alternative 2. During normal operations, the reactors could potentially release 15,570 curies of tritium (of which 11,250 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium) to the Tennessee River each year, which would be a decrease in comparison with the 16,560 curies of tritium assumed to be released under the No-Action Alternative. The tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter after leaving the diffusers. Annual radioactive releases to the air could potentially total about 1,757 curies, including about 1,730 curies of tritium, which would be a decrease in comparison with the total 1,867 curies, including 1,840 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from normal operations if TPBARs were not irradiated. TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation. Irradiation of 1,250 TPBARs in a single reactor would generate from 8 to 12 additional spent nuclear fuel assemblies every 18 months. On an annualized basis, this would increase spent nuclear fuel generation at Sequoyah by 5 to 7 percent in comparison with the No-Action Alternative.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 108 millirem per year, which would be a slight decrease in comparison with the 109 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 108 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 15,400. The total annual workforce dose would be about 132 person-rem, which would be essentially the same as the 132 person-rem the worker population would receive under the No-Action Alternative. The collective dose to facility workers would result in 0 (0.08) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 10.3 person-rem per year, which would be a slight decrease in comparison with the 10.8 person-rem that the population would receive each year under the No-Action Alternative. A collective dose of about 10.3 person-rem per year equates to 0 (0.006) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.23 millirem, which would be a slight decrease in comparison with the 0.24 millirem that this individual would receive each year under the No-Action Alternative. An annual dose of 0.23 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Based on the analyzed design-basis accidents, the highest dose to the maximally exposed individual would be well below the NRC regulatory limit (25 rem) and the average individual dose to the 50-mile population would be much less than 1 rem. Based on the analyzed beyond-design-basis accidents, the early containment failure accident would represent the highest dose to the maximally exposed individual, with an estimated frequency of about 1 chance in 1.5 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident. The analysis of intentional destructive acts indicates that potential consequences would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Sequoyah operations would be 0 (0.005) for crew, 0 (5×10^{-4}) for members of the public, and 0 (1×10^{-5}) for accidents, along with 0 (0.005) traffic fatality.

2.5.6 POTENTIAL IMPACTS OF ALTERNATIVE 4

Under Alternative 4, TVA would irradiate up to a total of 5,000 TPBARs every 18 months at Watts Bar (2,500 in each of Watts Bar 1 and 2), which would represent an increase of 4,320 TPBARs at Watts Bar in comparison with the No-Action Alternative. At Sequoyah, no TPBARs would be irradiated under this alternative, which would represent a decrease of 680 TPBARs for each of the Sequoyah reactors in comparison with the No-Action Alternative.

Watts Bar

During normal operations, the two reactors could potentially release about 49,320 curies of tritium (of which 45,000 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium) to the Tennessee River each year, which would be an increase in comparison with the 10,440 curies of tritium assumed to be released under the No-Action Alternative. Tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter within about 140 feet of the diffusers. Annual radioactive releases to the air from Watts Bar could potentially total 5,516 curies, including 5,480 curies of tritium, which would be an increase in comparison with the total release of 1,196 curies, including 1,160 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 30 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from normal operations if TPBARs were not irradiated. TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation. Irradiation of 5,000 TPBARs would generate no more than 82 additional spent nuclear fuel assemblies every 18 months over the No-Action Alternative if TVA irradiated 2,500 TPBARs in each of the Watts Bar reactors. On an annual basis, this would increase spent nuclear fuel generation at Watts Bar by about 48 percent in comparison with the No-Action Alternative. TVA has an infrastructure in place or has a plan at Watts Bar to manage the increased volume of spent nuclear fuel assemblies.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 130.5 millirem per year, which would be an increase in comparison with the 116 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 130.5 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 12,800. The total annual workforce dose would be about 114.7 person-rem, which would be an increase in comparison with the 102 person-rem the worker population would receive each year under the No-Action Alternative. Of this dose, about 100 person-rem would be from normal operations unrelated to TPBAR irradiation. The collective dose to facility workers would result in 0 (0.07) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations with TPBARs would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 29.4 person-rem per year, which would be an increase in comparison with the 7.6 person-rem annual dose under the No-Action Alternative. A collective dose of about 29.4 person-rem per year equates to 0 (0.02) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.86 millirem, which would be an increase in comparison with the 0.28 millirem that individual would receive each year under the No-Action Alternative. An annual dose of 0.86 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Potential impacts from accidents at a reactor would be the same as for Alternative 1 because TVA would not irradiate more than 2,500 TPBARs in any one reactor. The analysis of intentional destructive acts would be the same as for Alternative 1. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Watts Bar operations would be 0 (0.02) for crew, 0 (0.002) for members of the public, and 0 (4×10^{-5}) for radiological accidents, along with 0 (0.008) traffic fatality.

Sequoyah

Under this alternative, no irradiation of TPBARs would take place using the Sequoyah nuclear reactors and the impacts would be the same as discussed for Sequoyah under Alternative 1.

2.5.7 POTENTIAL IMPACTS OF ALTERNATIVE 5

Under Alternative 5, TVA would irradiate up to a total of 5,000 TPBARs every 18 months at Sequoyah (2,500 in each of Sequoyah 1 and 2), which would represent an increase of 3,640 TPBARs at Sequoyah in comparison with the No-Action Alternative. At Watts Bar, no TPBARs would be irradiated under this alternative, which would represent a decrease of 680 TPBARs in comparison with the No-Action Alternative.

Watts Bar

Under this alternative, no irradiation of TPBARs would take place using the Watts Bar nuclear reactors and the impacts would be the same as discussed for Watts Bar under Alternative 2.

Sequoyah

NNSA analyzed irradiation of 5,000 TPBARs every 18 months using both reactors at the Sequoyah site. In addition, TVA proposes to construct and operate a 500,000-gallon tritiated water tank system to facilitate effluent water management. The impacts from constructing that system would be the same as those for Alternative 2.

During normal operations, the Sequoyah reactors could potentially release 49,320 curies of tritium (of which 45,000 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium) to the Tennessee River each year, which would be an increase in comparison with the 16,560 curies of tritium assumed to be released under the No-Action Alternative. The tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter within about 18 feet of the diffusers (the nearest drinking water intake is 10 miles away). Annual radioactive releases to the air from Sequoyah could potentially total about 5,507 curies, including about 5,480 curies of tritium, which would be an increase in comparison with the total 1,867 curies, including 1,840 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 30 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from normal operations if TPBARs were not irradiated. TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation. Operation of the tritiated water tank system would have no impact on the quantities or management of wastes. Irradiation of 5,000 TPBARs would generate no more than 82 additional spent nuclear fuel assemblies every 18 months if TVA irradiated 2,500 TPBARs in each of the Sequoyah reactors. On an annualized basis, this would increase spent nuclear fuel generation at Sequoyah by about 48 percent in comparison with the No-Action Alternative. TVA has an infrastructure in place at Sequoyah to manage the increased volume of spent nuclear fuel assemblies.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 117.4 millirem per year, which would be an increase in comparison with the 109 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 117.4 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 14,200. The total annual workforce dose would be about 142.4 person-rem, which would be an increase in comparison with the 132 person-rem the worker population would receive under the No-Action Alternative. The collective dose to facility workers would result in 0 (0.09) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 28.1 person-rem per year, which would be an increase in comparison with the 10.8 person-rem that the population would receive each year under the No-Action Alternative. A collective dose of about 28.1 person-rem per year equates to 0 (0.02) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.55 millirem, which would be an increase in comparison with the 0.24 millirem that this individual would receive each year under the No-Action Alternative. An annual dose of 0.55 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Potential impacts from accidents at a reactor would be the same as for Alternative 2 because TVA would not irradiate more than 2,500 TPBARs in any one reactor. The analysis of intentional destructive acts would be the same as for Alternative 2. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Sequoyah operations would be 0 (0.02) for crew, 0 (0.004) for members of the public, and 0 (4×10^{-5}) for radiological accidents, along with 0 (0.01) traffic fatalities.

2.5.8 POTENTIAL IMPACTS OF ALTERNATIVE 6

Under Alternative 6, TVA would irradiate up to a total of 5,000 TPBARs every 18 months using both the Watts Bar and Sequoyah sites. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this could involve the use of one or both reactors at each of the sites. For the analyses in this SEIS, NNSA assumed for Alternative 6 that each site would irradiate 2,500 TPBARs every 18 months. At Watts Bar, this would represent an increase of 1,820 TPBARs in comparison with the No-Action Alternative. At Sequoyah, this would represent an increase of 1,140 TPBARs in comparison with the No-Action Alternative.

Watts Bar

During normal operations, the two reactors could potentially release about 26,820 curies of tritium (of which 22,500 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium) to the Tennessee River each year, which would be an increase in comparison with the 10,440 curies of tritium assumed to be released under the No-Action Alternative. Tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter within about 70 feet of the diffuser. Annual radioactive releases to the air from Watts Bar could potentially total 3,016 curies, including 2,980 curies of tritium, which would be an increase in comparison with the total release of 1,196 curies, including 1,160 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from normal operations if TPBARs were not irradiated. TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation. Irradiation of 2,500 TPBARs would generate no more than 41 additional spent nuclear fuel assemblies every 18 months over the No-Action Alternative if TVA irradiated all 2,500 TPBARs in a single reactor. On an annual basis, this would increase spent nuclear fuel generation at Watts Bar by about 24 percent in comparison with the No-Action Alternative.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 122 millirem per year, which would be an increase in comparison with the 116 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 122 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 13,700. The total annual workforce dose would be about 107 person-rem, which would be an increase in comparison with the 102 person-rem the worker population would receive each year under the No-Action Alternative. Of this dose, about 100 person-rem would be from normal operations unrelated to TPBAR irradiation. The collective dose to facility workers would result in 0 (0.06) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations with TPBARs would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 16.7 person-rem per year, which would be an increase in comparison with the 7.6 person-rem annual dose under the No-Action Alternative. A collective dose of about 16.7 person-rem per year equates to 0 (0.001) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.52 millirem, which would be an increase in comparison with the 0.28 millirem that individual would receive each year under the No-Action Alternative. An annual dose of 0.52 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Based on the analyzed design-basis accidents, the highest dose to the maximally exposed individual would be well below the NRC regulatory limit (25 rem) and the average individual dose to the 50-mile population would be much less than 1 rem. Based on the analyzed beyond-design-basis accidents, the early containment failure accident would represent the highest dose to the maximally exposed individual, with an estimated frequency of about 1 chance in 3 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident. The analysis of intentional destructive acts indicates that potential consequences would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Watts Bar operations would be 0 (0.01) for crew, 0 (0.001) for members of the public, and 0 (2×10^{-5}) for radiological accidents, along with 0 (0.004) traffic fatality.

Sequoyah

NNSA analyzed irradiation of 2,500 TPBARs every 18 months using one or both reactors at the Sequoyah site. In addition, TVA proposes to construct and operate a 500,000-gallon tritiated water tank system to facilitate effluent water management. The impacts from constructing that system would be the same as those for Alternative 2.

During normal operations, the Sequoyah reactors could potentially release 26,820 curies of tritium (of which 22,500 curies would be from TPBAR irradiation and 4,320 curies would be from non-TPBAR tritium) to the Tennessee River each year, which would be an increase in comparison with the 16,560 curies of tritium assumed to be released under the No-Action Alternative. The tritium concentration in the discharge plume would be below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter after leaving the diffusers. Annual radioactive releases to the air from Sequoyah could potentially total about 3,007 curies, including about 2,980 curies of tritium, which would be an increase in comparison with the total 1,867 curies, including 1,840 curies of tritium, assumed to be released under the No-Action Alternative. Greenhouse gas emissions (7,100 tons of carbon dioxide annually) would be essentially the same as from normal operation without TPBAR irradiation. TPBAR irradiation would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the low-level waste that would occur from normal operations if TPBARs were not irradiated. TPBAR irradiation would have no impact on nonradioactive hazardous and nonhazardous waste generation. Operation of the tritiated water tank system would have no impact on the quantities or management of wastes. Irradiation of 2,500 TPBARs would generate no more than 41 additional spent nuclear fuel assemblies every 18 months if all 2,500 TPBARs were irradiated in a single reactor. On an annualized basis, this would increase spent nuclear fuel generation at Sequoyah by about 24 percent in comparison with the No-Action Alternative.

Worker exposure to radiation during normal operations with TPBARs would remain well below the NRC regulatory limit of 5,000 millirem per year, with an average worker dose of about 111 millirem per year, which would be an increase in comparison with the 109 millirem an average worker would receive each year under the No-Action Alternative. Statistically, if a worker received a dose of 111 millirem, the estimated probability of that worker developing a fatal cancer sometime in the future from 1 year of normal operations would be about 1 in 15,000. The total annual workforce dose would be about 135 person-rem, which would be an increase in comparison with the 132 person-rem the worker population would receive under the No-Action Alternative. The collective dose to facility workers would result in 0 (0.08) latent cancer fatality per year of normal operation.

Radiation exposure of the public from normal operations would also remain well within the NRC regulatory limit of 25 millirem per year. The total annual dose to the population within 50 miles during normal operations would be about 16.2 person-rem per year, which would be an increase in comparison with the 10.8 person-rem that the population would receive each year under the No-Action Alternative. A collective dose of about 16.2 person-rem per year equates to 0 (0.01) latent cancer fatality per year of normal operation. The annual dose to the maximally exposed offsite individual would be about 0.33 millirem, which would be an increase in comparison with the 0.24 millirem that this individual would receive each year under the No-Action Alternative. An annual dose of 0.33 millirem would be less than 1 percent of the average annual dose of 620 millirem that an individual receives from natural and man-made radiation.

Based on the analyzed design-basis accidents, the highest dose to the maximally exposed individual would be well below the NRC regulatory limit (25 rem) and the average individual dose to the 50-mile population would be much less than 1 rem. Based on the analyzed beyond-design-basis accidents, the early containment failure accident would represent the highest dose to the maximally exposed individual, with an estimated frequency of about 1 chance in 1.5 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident. The analysis of intentional destructive acts indicates that potential consequences would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Under normal or accident conditions, within the same 50-mile radius, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified.

For transportation impacts, over the life of the project (until 2035), the estimated numbers of latent cancer fatalities from Sequoyah operations would be 0 (0.01) for crew, 0 (0.002) for members of the public, and 0 (2×10^{-5}) for accidents, along with 0 (0.005) traffic fatality.

2.5.9 DIFFERENCES IN IMPACTS FROM 1999 EIS

The 1999 EIS analyzed the potential environmental impacts from irradiation of a maximum of 3,400 TPBARs in any one of the Watts Bar and Sequoyah reactors, assuming a tritium permeation rate of 1 curie per TPBAR per year. This was assumed to result in an annual release of a total of 3,400 curies of tritium per reactor to the air and water surrounding the Watts Bar and Sequoyah reactors. This SEIS analyzes the potential environmental impacts from irradiation of 2,500 to 5,000 TPBARs in the Watts Bar and Sequoyah reactors, assuming a high and thus conservative tritium permeation rate of 10 curies per TPBAR per year, which is more than double the tritium permeation rate that has been observed at Watts Bar 1. This is assumed to result in a maximum annual release of a total of 25,000 to 50,000 curies of tritium to the air and water surrounding the Watts Bar and Sequoyah reactors. Both the 1999 EIS and this SEIS demonstrate that the potential environmental impacts from irradiation of TPBARs (whether 3,400, 2,500, or 5,000) in the Watts Bar and Sequoyah reactors would be small, regardless of whether the permeation rate is 1 curie or 10 curies of tritium per TPBAR per year. While the resultant potential impacts are small in either case, the differences between the two analyses are described below.

Water Resources

The 1999 EIS estimated TVA would release a maximum of 3,060 curies of tritium from TPBAR irradiation each year to the Tennessee River from any reactor as a result of TPBAR irradiation. This SEIS estimates a maximum potential release to the river of 26,820 curies of tritium each year for irradiation of 2,500 TPBARs and 49,320 curies of tritium each year for irradiation of 5,000 TPBARs. These totals include both non-TPBAR tritium releases and those attributed solely to TPBAR irradiation. The results indicate that tritium concentrations at any drinking water intake would remain well below the maximum permissible EPA drinking water limit of 20,000 picocuries per liter. As discussed in Sections 4.1.5 and 4.2.5 of this SEIS, the average tritium concentration at any drinking water intake would be no more than about one-tenth of the limit of 20,000 picocurie per liter.

Air Resources

The 1999 EIS estimated a reactor would release a maximum of 340 curies of tritium from TPBAR irradiation each year to the air. This SEIS estimates maximum potential releases to the air of 2,500 curies of tritium each year for irradiation of 2,500 TPBARs and 5,000 curies of tritium each year for irradiation of 5,000 TPBARs. There are no explicit regulatory limits for tritium releases to the air[8]; however, tritium releases to the air are considered in human health radiation doses, which are regulated, as discussed below.

Human Health

The 1999 EIS estimated the dose to the maximally exposed individual would be 0.34 millirem per year at Watts Bar and 0.11 millirem per year at Sequoyah. For the analyzed tritium production alternatives, this SEIS conservatively estimates that the highest doses to the maximally exposed individual would be 0.52 millirem per year at Watts Bar and 0.33 millirem per year at Sequoyah for irradiation of 2,500 TPBARs and 0.86 millirem per year at Watts Bar and 0.55 millirem per year at Sequoyah for irradiation of 5,000 TPBARs. The results indicate that potential exposure of the public to radiation from normal operations would remain well within the NRC regulatory limit of 25 millirem per year. The 1999 EIS estimated the average annual dose to workers would increase by a maximum of about 1.1 millirem per year as a result of TPBAR irradiation (see Table 5-5 of the 1999 EIS). This SEIS estimates the average annual dose to workers would increase by no more than about 8.3 millirem per year for irradiation of 2,500 TPBARs (see Tables 4-8 and 4-22 of the SEIS) and by no more than about 16.5 millirem per year for irradiation of 5,000 TPBARs (Sections 4.1.11.5 and 4.2.11.6). In all cases, worker exposure to radiation would remain well below the NRC regulatory limit of 5,000 millirem per year.

Spent Nuclear Fuel Generation

The 1999 EIS estimated TPBAR irradiation would generate a maximum of 60 additional spent nuclear fuel assemblies every 18 months for irradiation of 3,400 TPBARs in a single reactor. This SEIS estimates a maximum of 41 additional spent nuclear fuel assemblies every 18 months for irradiation of 2,500 TPBARs in a single reactor and 82 additional spent nuclear fuel assemblies every 18 months for irradiation of 5,000 TPBARs at one site. Both Watts Bar and Sequoyah have infrastructure in place or a plan to manage the increased spent nuclear fuel assemblies.

Accidents and Intentional Destructive Acts

This SEIS confirms that TPBAR irradiation would not substantially affect the types of accidents that could potentially occur or the potential impacts from those accidents. The 1999 EIS did not analyze intentional destructive acts. NNSA estimates through the analysis in this SEIS that the potential consequences of such acts would be no worse than those of the most conservative beyond-design-basis accident NNSA analyzed. Tritium releases from TPBAR irradiation in a beyond-design-basis accident or intentional destructive act would be an extremely small contributor to the consequences of such events.

2.5.10 CUMULATIVE IMPACTS

Based on the analysis in Chapter 4 of this SEIS, the cumulative impact analysis focused on the resources with the greatest potential to experience meaningful effects from the irradiation of TPBARs. These resource areas include human health, biological resources, and air and water quality, which have the potential to be impacted by releases of radiological materials into the environment. As discussed in Chapter 5, this SEIS concludes that the potential proposed action, when considered along with other nearby current and reasonably foreseeable activities, would not have any cumulatively significant environmental impact.

8. See also Section 8.2.2. The National Emission Standards for Hazardous Air Pollutants for radionuclides (40 CFR Part 61, Subparts H and I) are not applicable to NRC-licensed facilities such as TVA reactors. As cited in an EPA Final Rule (60 FR 46206), compliance with NRC regulations constitutes compliance with 40 CFR Part 61, Subparts H and I.

2.5.11 MITIGATION MEASURES

To mitigate potential impacts from tritium releases, TVA proposes to construct and operate a 500,000-gallon tritiated water tank system at Sequoyah in the event of a decision to irradiate TPBARs at that site or to facilitate routine tritium management (see Section 2.4.2). Such a system would be the same as the system that TVA is currently building at the Watts Bar site (see Section 1.6). TVA would use the Watts Bar and Sequoyah tank systems to store tritiated water after it passed through the liquid radioactive waste processing system. TVA would release the stored tritiated water to the Tennessee River by the existing pathways. The tank systems that TVA would potentially have in place at both the Watts Bar and Sequoyah sites would have sufficient capacity to store and release the water at appropriate times (that is, TVA will release the water from the tank during times of higher river flows for better dilution), and it will enable TVA to minimize the potential impacts of tritiated water releases. The systems would enable TVA to plan fewer releases each year and to ensure that site effluents would continue to remain well below regulatory concentration limits.

2.6 Preferred Alternative

Council on Environmental Quality regulations require that an agency identify its Preferred Alternative(s), if one or more exists, in a draft EIS or SEIS [40 CFR 1502.14(e)]. The Preferred Alternative is the alternative the agency believes would fulfill its statutory mission, giving consideration to environmental, economic, technical, and other factors. NNSA has identified the irradiation of up to 2,500 TPBARs every 18 months at the Watts Bar site (Alternative 1) as the Preferred Alternative for this SEIS. Alternative 1 is preferred because TPBAR irradiation operations could be conducted entirely at the site at which tritium irradiation operations currently occurs, and potentially in the one reactor that has successfully supported NNSA's tritium production program.

Table 2-5. Comparison of impacts of alternatives.

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Land use	Occupies about 1,000 acres.	Occupies 525 acres.	Occupies about 1,000 acres.	Occupies 525 acres.	No change compared with No-Action Alternative.	Less than 1 acre disturbed at one time for tritiated water tank system.	No change compared with No-Action Alternative.	Less than 1 acre disturbed at one time for tritiated water tank system.	No change compared with No-Action Alternative.	Less than 1 acre disturbed at one time for tritiated water tank system.	No change compared with No-Action Alternative.	Less than 1 acre disturbed at one time for tritiated water tank system.
Aesthetics and noise	Rural setting.	Rural setting.	Rural setting.	Rural setting.	No change.	No change.	No change.	No change.	No change.	No change.	No change.	No change.
Air resources[b]	*Radioactive releases in 2010 in curies:* Tritium: 25 Other: 18 Total: 43 Greenhouse gas emissions: 3,200 tons of carbon dioxide per year.	*Radioactive releases in 2010 in curies:* Tritium: 89[c] Other: 27 Total: 116 Greenhouse gas emissions: 7,100 tons of carbon dioxide per year.	*Annual radioactive releases in curies:* Tritium: 1,160 Other: 36 Total: 1,196 Greenhouse gas emissions would increase to 7,100 tons of carbon dioxide per year once Watts Bar 2 becomes operational.	*Annual radioactive releases in curies:* Tritium: 1,840 Other: 27 Total: 1,867 Greenhouse gas emissions would be essentially the same as from reactor operations without TPBARs.	*Annual radioactive releases in curies:* Tritium: 2,980 Other: 36 Total: 3,016 Greenhouse gas emissions would be essentially the same as No Action Alternative.	*Annual radioactive releases in curies:* Tritium: 2,980 Other: 27 Total: 3,007 Greenhouse gas emissions would be essentially the same as No Action Alternative.	*Annual radioactive releases in curies:* Tritium: 1,730 Other: 36 Total: 1,766 Greenhouse gas emissions would be essentially the same as No Action Alternative.	*Annual radioactive releases in curies:* Tritium: 1,730 Other: 27 Total: 1,757 Greenhouse gas emissions would be essentially the same as No Action Alternative.	*Annual radioactive releases in curies:* Tritium: 5,480 Other: 36 Total: 5,516 Greenhouse gas emissions would be essentially the same as No Action Alternative.	*Annual radioactive releases in curies:* Tritium: 5,480 Other: 27 Total: 5,507 Greenhouse gas emissions would be essentially the same as No Action Alternative.	*Annual radioactive releases in curies:* Tritium: 2,980 Other: 36 Total: 3,016 Greenhouse gas emissions would be essentially the same as No Action Alternative.	*Annual radioactive releases in curies:* Tritium: 2,980 Other: 27 Total: 3,007 Greenhouse gas emissions would be essentially the same as No Action Alternative.
Geology and soils	Typical of Eastern Tennessee.	Typical of Eastern Tennessee.	Typical of Eastern Tennessee.	Typical of Eastern Tennessee.	No change.	No change.	No change.	No change.	No change.	No change.	No change.	No change.

Table 2-5. Comparison of impacts of alternatives (continued).

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Water resources	605-2,070 curies of tritium released to Tennessee River per year (see Table 3-9). Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) soon after leaving the diffuser.	1,270–2,190 curies of tritium[c] released to Tennessee River per year (see Table 3-33). Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) after the diffusers.	10,440 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) within about 30 feet of the diffusers.	16,560 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) after the diffusers.	26,820 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) within about 70 feet of the diffusers.	26,820 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) after leaving the diffusers.	15,570 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) within about 30 feet of the diffusers.	15,570 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) after leaving the diffusers.	49,320 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) within about 140 feet of the diffusers.	49,320 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) within about 18 feet of the diffusers.	26,820 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) within about 70 feet of the diffusers.	26,820 curies of tritium released to Tennessee River per year. Tritium concentration in the discharge plume would be below the EPA drinking water limit (20,000 picocuries per liter) after leaving the diffusers.
Biological resources	Typical of Eastern Tennessee.	Typical of Eastern Tennessee.	Typical of Eastern Tennessee.	Typical of Eastern Tennessee.	No change.	No change.	No change.	No change.	No change.	No change.	No change.	No change.
Cultural resources	No major resources.	No major resources.	No major resources.	No major resources.	No change.	No change.	No change.	No change.	No change.	No change.	No change.	No change.
Infrastructure	In place, supports demands.	In place, supports demands.	No change.	No change.	No change.	No change.	No change.	No change.	No change.	No change.	No change.	No change.

Table 2-5. Comparison of impacts of alternatives (continued).

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Socio-economics	Workforce of about 572 people.	Workforce of about 1,150 people.	Workforce would increase to about 1,150 once Watts Bar 2 becomes operational.	Operational workforce for tritium production requires up to 20 additional workers compared with operations without tritium production.	No change in operational workforce compared with No-Action Alternative.	Construction workforce of about 100 people for tritiated water tank system. No change in operational workforce.	No change in operational workforce compared with No-Action Alternative.	Construction workforce of about 100 people for tritiated water tank system. No change in operational workforce.	Operational workforce for tritium production in 2 reactors requires up to 20 additional workers compared with operations without tritium production.	Operational workforce for tritium production in 2 reactors requires up to 20 additional workers compared with operations without tritium production.	No change in operational workforce compared with No-Action Alternative.	Construction workforce of about 100 people for tritiated water tank system. No change in operational workforce.

Table 2-5. Comparison of impacts of alternatives (continued).

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Waste management	Annual wastes: Hazardous: 9,059 pounds Nonhazardous solid: 1,882 tons LLW: 11,060 cubic feet	Annual wastes: Hazardous: 1,063 pounds Nonhazardous solid: 778 tons LLW: 4,697 cubic feet	Wastes would double once Watts Bar 2 becomes operational. TPBAR irradiation at Watts Bar 1 generates about 15 cubic feet per year of LLW, which is less than 0.1 percent of the total LLW generated from Watts Bar operations. TPBAR irradiation has no impact on hazardous waste and nonhazardous waste generation.	TPBAR irradiation would generate about 15 cubic feet per year of LLW, which is less than 0.1 percent of the total LLW generated from Sequoyah operations. TPBAR irradiation would have no impact on hazardous waste and nonhazardous waste generation.	No change compared with No-Action Alternative.	No change compared with No-Action Alternative. Operation of the tritiated water tank system would have no impact on the quantity of wastes generated or the management of wastes.	No change compared with No-Action Alternative.	No change compared with No-Action Alternative. Operation of the tritiated water tank system would have no impact on the quantity of wastes generated or the management of wastes.	TPBAR irradiation at Watts Bar 1 and 2 would generate about 30 cubic feet per year of LLW, which is less than 0.1 percent of the total LLW generated from Watts Bar operations. TPBAR irradiation has no impact on hazardous waste and nonhazardous waste generation.	TPBAR irradiation at Sequoyah 1 and 2 would generate about 30 cubic feet per year of LLW, which is less than 0.1 percent of the total LLW generated from Sequoyah operations. TPBAR irradiation has no impact on hazardous waste and nonhazardous waste generation.	No change compared with No-Action Alternative.	No change compared with No-Action Alternative. Operation of the tritiated water tank system would have no impact on the quantity of wastes generated or the management of wastes.

Table 2-5. Comparison of impacts of alternatives (continued).

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Spent nuclear fuel generation	Watts Bar 1 generates spent nuclear fuel at a rate of about 59 fuel assemblies each year, including about 3 spent nuclear fuel assemblies associated with TPBAR irradiation at Watts Bar 1.	Sequoyah generates spent nuclear fuel at a rate of about 107 fuel assemblies each year.	Watts Bar would generate spent nuclear fuel at a rate of about 115 fuel assemblies each year once Watts Bar 2 becomes operational. This would include about 3 spent nuclear fuel assemblies associated with TPBAR irradiation at Watts Bar 1.	Sequoyah would generate spent nuclear fuel at a rate of about 113 fuel assemblies each year. This would include about 6 spent nuclear fuel assemblies associated with TPBAR irradiation at Sequoyah 1 and 2	Irradiation of 2,500 TPBARs would generate no more than 41 additional spent nuclear fuel assemblies every 18 months, assuming all 2,500 TPBARs were irradiated in a single reactor. This could increase annual spent nuclear fuel generation at Watts Bar by about 24 percent.	Irradiation of 2,500 TPBARs would generate no more than 41 additional spent nuclear fuel assemblies every 18 months, assuming all 2,500 TPBARs were irradiated in a single reactor. This could increase annual spent nuclear fuel generation at Sequoyah by about 24 percent.	Irradiation of 1,250 TPBARs would generate 8 to 12 additional spent nuclear fuel assemblies every 18 months. This could increase annual spent nuclear fuel generation at Watts Bar by about 5 to 7 percent.	Irradiation of 1,250 TPBARs in a single reactor would generate 8 to 12 additional spent nuclear fuel assemblies every 18 months. This could increase annual spent nuclear fuel generation at Sequoyah by about 5 to 7 percent.	Irradiation of 5,000 TPBARs would generate no more than 82 additional spent nuclear fuel assemblies every 18 months. This could increase annual spent nuclear fuel generation at Watts Bar by about 48 percent.	Irradiation of 5,000 TPBARs would generate no more than 82 additional spent nuclear fuel assemblies every 18 months. This could increase annual spent nuclear fuel generation at Sequoyah by about 48 percent.	Irradiation of 2,500 TPBARs would generate no more than 41 additional spent nuclear fuel assemblies every 18 months, assuming all 2,500 TPBARs were irradiated in a single reactor. This could increase annual spent nuclear fuel generation at Watts Bar by about 24 percent.	Irradiation of 2,500 TPBARs would generate no more than 41 additional spent nuclear fuel assemblies every 18 months, assuming all 2,500 TPBARs were irradiated in a single reactor. This could increase annual spent nuclear fuel generation at Sequoyah by about 24 percent.

Table 2-5. Comparison of impacts of alternatives (continued).

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Human health and safety (normal operations)	*Maximally exposed individual:* Dose: 0.28 millirem Risk of LCF: 2×10^{-7} *Population:* Dose: 1.29 person-rem LCFs: 0 (0.0008) *Total worker:* Dose: 101 person-rem LCFs: 0 (0.06)	*Maximally exposed individual:* Dose: 0.18 millirem Risk of LCF: 1×10^{-7} *Population:* Dose: 2.54 person-rem LCFs: 0 (0.002) *Total worker:* Dose: 128 person-rem LCFs: 0 (0.08)	*Maximally exposed individual:* Dose: 0.28 millirem Risk of LCF: 2×10^{-7} *Population:* Dose: 7.6 person-rem LCFs: 0 (0.005) *Total worker:* Dose: 102.2 person-rem LCFs: 0 (0.06)	*Maximally exposed individual:* Dose: 0.24 millirem Risk of LCF: 1×10^{-7} *Population:* Dose: 10.8 person-rem LCFs: 0 (0.006) *Total worker:* Dose: 131.9 person-rem LCFs: 0 (0.08)	*Maximally exposed individual:* Dose: 0.52 millirem Risk of LCF: 3×10^{-7} *Population:* Dose: 16.7 person-rem LCFs: 0 (0.01 *Total worker:* Dose: 107.4 person-rem LCFs: 0 (0.06)	*Maximally exposed individual:* Dose: 0.33 millirem Risk of LCF: 2×10^{-7} *Population:* Dose: 16.2 person-rem LCFs: 0 (0.01) *Total worker:* Dose: 135.2 person-rem LCFs: 0 (0.08)	*Maximally exposed individual:* Dose: 0.36 millirem Risk of LCF: 2×10^{-7} *Population:* Dose: 10.5 person-rem LCFs: 0 (0.006) *Total worker:* Dose: 103.8 person-rem LCFs: 0 (0.06)	*Maximally exposed individual:* Dose: 0.23 millirem Risk of LCF: 1×10^{-7} *Population:* Dose: 10.3 person-rem LCFs: 0 (0.006) *Total worker:* Dose: 131.6 person-rem LCFs: 0 (0.08)	*Maximally exposed individual:* Dose: 0.86 millirem Risk of LCF: 5×10^{-7} *Population:* Dose: 29.4 person-rem LCFs: 0 (0.02) *Total worker:* Dose: 114.7 person-rem LCFs: 0 (0.07)	*Maximally exposed individual:* Dose: 0.55 millirem Risk of LCF: 3×10^{-7} *Population:* Dose: 28.1 person-rem LCFs: 0 (0.02) *Total worker:* Dose: 142.4 person-rem LCFs: 0 (0.09)	*Maximally exposed individual:* Dose: 0.52 millirem Risk of LCF: 3×10^{-7} *Population:* Dose: 16.7 person-rem LCFs: 0 (0.01) *Total worker:* Dose: 107.4 person-rem LCFs: 0 (0.06)	*Maximally exposed individual:* Dose: 0.33 millirem Risk of LCF: 2×10^{-7} *Population:* Dose: 16.2 person-rem LCFs: 0 (0.01) *Total worker:* Dose: 135.2 person-rem LCFs: 0 (0.08)
Design-basis accident (reactor)	*Maximally exposed individual:* Dose: 9.5×10^{-3} rem *Population:* Dose: 8.7 person-rem *Average Individual* Dose: 7.2×10^{-6} rem	*Maximally exposed individual:* Dose: 9.5×10^{-3} rem *Population:* Dose: 15.4 person-rem *Average Individual* Dose: 1.5×10^{-5} rem	*Maximally exposed individual:* Dose: 9.5×10^{-3} rem *Population:* Dose: 10.5 person-rem *Average Individual* Dose: 7.2×10^{-6} rem	*Maximally exposed individual:* Dose: 1.3×10^{-3} rem *Population:* Dose: 20 person-rem *Average Individual* Dose: 1.5×10^{-5} rem	*Maximally exposed individual:* Dose: 3.4×10^{-3} rem *Population:* Dose: 40 person-rem *Average Individual* Dose: 2.8×10^{-5} rem	*Maximally exposed individual:* Dose: 4.8×10^{-3} rem *Population:* Dose: 70 person-rem *Average Individual* Dose: 5.4×10^{-5}rem	*Maximally exposed individual:* Dose: 1.8×10^{-3} rem *Population:* Dose: 20 person-rem *Average Individual* Dose: 1.4×10^{-5} rem	*Maximally exposed individual:* Dose: 2.4×10^{-3} rem *Population:* Dose: 36 person-rem *Average Individual* Dose: 2.7×10^{-5} rem	*Maximally exposed individual:* Dose: 3.4×10^{-3} rem *Population:* Dose: 40 person-rem *Average Individual* Dose: 2.8×10^{-5} rem	*Maximally exposed individual:* Dose: 4.8×10^{-3} rem *Population:* Dose: 70 person-rem *Average Individual* Dose: 5.4×10^{-5}rem	*Maximally exposed individual:* Dose: 3.4×10^{-3} rem *Population:* Dose: 40 person-rem *Average Individual* Dose: 2.8×10^{-5} rem	*Maximally exposed individual:* Dose: 4.8×10^{-3} rem *Population:* Dose: 70 person-rem *Average Individual* Dose: 5.4×10^{-5}rem

Table 2-5. Comparison of impacts of alternatives (continued).

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Design-basis accident (nonreactor)	*Maximally exposed individual:* Dose: 4.4×10^{-2} rem *Population:* Dose: 650 person-rem *Average individual:* Dose: 5.4×10^{-4} rem	*Maximally exposed individual:* Dose: 1.1×10^{-2} rem *Population:* Dose: 850 person-rem *Average individual:* Dose: 8.5×10^{-4} rem	*Maximally exposed individual:* Dose: 4.4×10^{-2} rem *Population:* Dose: 780 person-rem *Average individual:* Dose: 5.4×10^{-4} rem	*Maximally exposed individual:* Dose: 1.1×10^{-2} rem *Population:* Dose: 1,100 person-rem *Average individual:* Dose: 8.5×10^{-4} rem	*Maximally exposed individual:* Dose: 0.16 rem *Population:* Dose: 2,900 person-rem *Average individual:* Dose: 2.0×10^{-3} rem	*Maximally exposed individual:* Dose: 4.0×10^{-2} rem *Population:* Dose: 4,000 person-rem *Average individual:* Dose: 3.1×10^{-3} rem	*Maximally exposed individual:* Dose: 8.4×10^{-2} rem *Population:* Dose: 1,400 person-rem *Average individual:* Dose: 9.6×10^{-4} rem	*Maximally exposed individual:* Dose: 2.0×10^{-2} rem *Population:* Dose: 1,900 person-rem *Average individual:* Dose: 1.5×10^{-3} rem	*Maximally exposed individual:* Dose: 1.6×10^{-1} rem *Population:* Dose: 2,900 person-rem *Average individual:* Dose: 2.0×10^{-3} rem	*Maximally exposed individual:* Dose: 4.0×10^{-2} rem *Population:* Dose: 4,000 person-rem *Average individual:* Dose: 3.1×10^{-3} rem	*Maximally exposed individual:* Dose: 0.16 rem *Population:* Dose: 2,900 person-rem *Average individual:* Dose: 2.0×10^{-3} rem	*Maximally exposed individual:* Dose: 4.0×10^{-2} rem *Population:* Dose: 4,000 person-rem *Average individual:* Dose: 3.1×10^{-3} rem
Beyond-design-basis accident	*Maximally exposed individual:* Dose: 19.7 rem *Population:* Dose: 4.2×10^{5} person-rem *Average Individual:* Dose risk: 4×10^{-7} rem/yr	*Maximally exposed individual:* Dose: 25 rem *Population:* Dose: 7.1×10^{5} person-rem *Average Individual:* Dose risk: 1×10^{-6} rem/yr	*Maximally exposed individual:* Dose: 19.7 rem *Population:* Dose: 5.1×10^{5} person-rem *Average Individual:* Dose risk: 5×10^{-7} rem/yr	*Maximally exposed individual:* Dose: 25 rem *Population:* Dose: 9.2×10^{5} person-rem *Average Individual:* Dose risk: 1×10^{-6} rem/yr	*Maximally exposed individual:* Dose: 19.7 rem *Population:* Dose: 5.1×10^{5} person-rem *Average Individual:* Dose risk: 5×10^{-7} rem/yr	*Maximally exposed individual:* Dose: 25 rem *Population:* Dose: 9.2×10^{5} person-rem *Average Individual:* Dose risk: 1×10^{-6} rem/yr	*Maximally exposed individual:* Dose: 19.7 rem *Population:* Dose: 5.1×10^{5} person-rem *Average Individual:* Dose risk: 5×10^{-7} rem/yr	*Maximally exposed individual:* Dose: 25 rem *Population:* Dose: 9.2×10^{5} person-rem *Average Individual:* Dose risk: 1×10^{-6} rem/yr	*Maximally exposed individual:* Dose: 19.7 rem *Population:* Dose: 5.1×10^{5} person-rem *Average Individual:* Dose risk: 5×10^{-7} rem/yr	*Maximally exposed individual:* Dose: 25 rem *Population:* Dose: 9.2×10^{5} person-rem *Average Individual:* Dose risk: 1×10^{-6} rem/yr	*Maximally exposed individual:* Dose: 19.7 rem *Population:* Dose: 5.1×10^{5} person-rem *Average Individual:* Dose risk: 5×10^{-7} rem/yr	*Maximally exposed individual:* Dose: 25 rem *Population:* Dose: 9.2×10^{5} person-rem *Average Individual:* Dose risk: 1×10^{-6} rem/yr

Table 2-5. Comparison of impacts of alternatives (continued).

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Trans-portation[d]	Crew LCFs: 0 (0.003) Public LCFs: 0 (3×10^{-4}) Radiological accident LCFs: 0 (5×10^{-6}) Traffic fatalities: 0 (0.004)	Crew LCFs: 0 (0.005) Public LCFs: 0 (6×10^{-4}) Radiological accident LCFs: 0 (1×10^{-5}) Traffic fatalities: 0 (0.005)	Crew LCFs: 0 (0.003) Public LCFs: 0 (3×10^{-4}) Radiological accident LCFs: 0 (5×10^{-6}) Traffic fatalities: 0 (0.004)	Crew LCFs: 0 (0.005) Public LCFs: 0 (6×10^{-4}) Radiological accident LCFs: 0 (1×10^{-5}) Traffic fatalities: 0 (0.005)	Crew LCFs: 0 (0.01) Public LCFs: 0 (0.001) Radiological accident LCFs: 0 (2×10^{-5}) Traffic fatalities: 0 (0.004)	Crew LCFs: 0 (0.01) Public LCFs: 0 (0.002) Radiological accident LCFs: 0 (2×10^{-5}) Traffic fatalities: 0 (0.005)	Crew LCFs: 0 (0.005) Public LCFs: 0 (4×10^{-4}) Radiological accident LCFs: 0 (1×10^{-5}) Traffic fatalities: 0 (0.004)	Crew LCFs: 0 (0.005) Public LCFs: 0 (5×10^{-4}) Radiological accident LCFs: 0 (1×10^{-5}) Traffic fatalities: 0 (0.005)	Crew LCFs: 0 (0.02) Public LCFs: 0 (0.002) Radiological accident LCFs: 0 (4×10^{-5}) Traffic fatalities: 0 (0.008)	Crew LCFs: 0 (0.02) Public LCFs: 0 (0.004) Radiological accident LCFs: 0 (4×10^{-5}) Traffic fatalities: 0 (0.01)	Crew LCFs: 0 (0.01) Public LCFs: 0 (0.001) Radiological accident LCFs: 0 (2×10^{-5}) Traffic fatalities: 0 (0.004)	Crew LCFs: 0 (0.01) Public LCFs: 0 (0.002) Radiological accident LCFs: 0 (2×10^{-5}) Traffic fatalities: 0 (0.005)
Intentional destructive acts	NRC safety and security studies show that radiological release affecting public health and safety is unlikely from a terrorist attack.	NRC safety and security studies show that radiological release affecting public health and safety is unlikely from a terrorist attack.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.	Consequences no worse than those of most conservative beyond-design-basis accident analyzed.

Table 2-5. Comparison of impacts of alternatives (continued).

Alternative	**Current conditions**		**No-Action Alternative**		**Alternative 1**	**Alternative 2**	**Alternative 3**		**Alternative 4**	**Alternative 5**	**Alternative 6**	
Site	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah	Watts Bar	Sequoyah
Reactor units	1[a]	1 and 2	1[a]	1 and 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and/or 2	1 and 2	1 and 2	1 and/or 2	1 and/or 2
Number of TPBARs irradiated per site every 18 months	240 to 544	0	680	680 per reactor (total 1,360)	2,500	2,500	1,250	1,250	5,000	5,000	2,500	2,500
Maximum TPBARs irradiated every 18 months for alternative	544	0	2,040		2,500	2,500	2,500		5,000	5,000	5,000	
Resource	**Environmental impacts**											
Environ-mental justice	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.	No disproportion-ately high and adverse consequences to minority or low-income populations.

LLW = low-level radioactive waste; LCF = latent cancer fatality; N/A = not applicable; yr = year.

a. Watts Bar 1 is the only reactor at the Watts Bar site that would irradiate TPBARs under current conditions and the No-Action Alternative. However, the No-Action Alternative also includes the operation of Watts Bar 2 (without TPBARs) while the current conditions do not reflect Watts Bar 2 operation.

b. The annual radioactive releases from current conditions are based on actual measured values using 2010 data. The tritium releases for the alternatives are based on an assumed high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year, with 10 percent released to the air. For Watts Bar, the "other" radiological releases are assumed to increase from 18 curies per year (current conditions) to 36 curies per year (for the alternatives) because Watts Bar 2 is assumed to become operational, which would double the "other" radiological releases.

c. Tritium is produced in all U.S. commercial nuclear reactors from fission of uranium in the reactor fuel and neutron activation of boron in burnable absorber rods.

d. The values presented for transportation are not annualized; instead they reflect the total impacts expected over the entire period evaluated in this SEIS (that is, until 2035).

CHAPTER 3. AFFECTED ENVIRONMENT

In accordance with Council on Environmental Quality regulations, the affected environment is "interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment" (40 CFR 1508.14). Descriptions of the affected environment provide a comparison for understanding the potential direct, indirect, and cumulative impacts of the alternatives (Chapter 4). To analyze potential environmental impacts that could result from the implementation of each of the alternatives, the National Nuclear Security Administration (NNSA), with assistance from TVA, compiled information about the Watts Bar and Sequoyah Nuclear Plant environments.

As noted in Chapter 1, this Supplemental Environmental Impact Statement (SEIS) supplements the U.S. Department of Energy (DOE) March 1999 *Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (DOE 1999a; the 1999 EIS). Therefore, this chapter focuses specifically on describing the affected environment to support the analyses in Chapter 4, which evaluates the potential environmental impacts based on (1) a bounding level of tritium permeation in recognition of the higher-than-expected permeation levels since 2004, and (2) the decrease in the maximum number of tritium-producing burnable absorber rods (TPBARs) necessary to supply reasonably foreseeable tritium requirements.

The scope of the affected environment discussions varies with each resource to ensure inclusion of relevant issues. The level of detail in the description of each resource varies with the likelihood of a potential impact to the resource. For example, the descriptions of land resources, geology and soils, and archaeological and historic resources contain less detail because there would be little or no impacts that have not already occurred due to the presence of the nuclear plants. On the other hand, this chapter describes ambient conditions for water resources in greater detail because of the potential for environmental impacts from the higher tritium permeation levels from TPBARs.

Section 3.1 describes the affected environment for the following resource areas for the Watts Bar Nuclear Plant, and Section 3.2 describes them for the Sequoyah Nuclear Plant:

- Land use. Land use practices and land ownership information.
- Aesthetics. Visual resources in terms of land formations, vegetation, and color, and the occurrence of unique natural views, and ambient noise levels.
- Climate and air quality. Climatic conditions such as temperature and precipitation, the quality of the air, and greenhouse gas emissions.
- Geology and soils. The geologic characteristics of the area at and below the ground surface, the frequency and severity of seismic activity, and the kinds and quality of soils.
- Water resources. Surface-water and groundwater features, water quality, floodplains, and wetlands.
- Biological resources. Plants and animals that live in the area, particularly aquatic life in the Tennessee River, and the occurrence of special-status species.
- Cultural resources. Historic and archaeological resources and the importance of those resources.
- Infrastructure and utilities. Utilities, energy, and site services including site demands.

- Socioeconomics. The labor market, population, housing, some public services, and personal income.

- Waste and spent nuclear fuel management. Ongoing solid, hazardous, and radioactive waste generation and management practices, the kinds of waste from current activities, the means by which TVA disposes of its waste, and pollution prevention practices.

- Human health and safety. The existing public and occupational safety conditions and estimates of radiation dose to the public and workers from existing radiological sources.

- Transportation. The existing transportation systems in the area of each plant along with traffic volumes for local roadways.

- Environmental justice. The locations of low-income and minority populations and income levels among low-income populations.

3.1 Watts Bar Site

This section describes the affected environment for the Watts Bar Nuclear Plant.

3.1.1 LAND USE

The Watts Bar site is in Rhea County, Tennessee, and occupies about 1,000 acres on the west bank of the Chickamauga Reservoir along the Tennessee River at River Mile 528 (see Figure 1-2 in Chapter 1). (River Mile refers to the distance up a river from its mouth.) Figure 2-3 in Chapter 2 shows the layout of the site, which is about 50 miles northeast of Chattanooga, Tennessee, and 31 miles north-northeast of the Sequoyah Nuclear Plant.

Rhea County is between the Cumberland Mountains and the Tennessee River. The county is generally rural with several small towns. The largest is Dayton, about 16 miles southwest of the site. Spring City, the second largest, is about 8 miles northwest of the site. About 28 percent of Rhea County is farmland. Other land uses in the area include scattered residential, forest, and recreational uses. There is forested land along the north and west sides of the site, and the Tennessee River flows along the east and south sides. Recreation lands include the Meigs County Park about 2 miles to the northwest across the river. Watts Bar Reservoir and Chickamauga Reservoir provide water-based recreation.

The Watts Bar site is part of the lands TVA manages through its Watts Bar Reservoir Land Management Plan, which covers about 16,000 acres of public land around the Watts Bar Reservoir in Loudon, Meigs, Rhea, and Roane Counties. TVA has allocated the land into broad use categories or zones that include project operations, sensitive resource management, natural resources conservation, industrial, developed recreation, and shoreline access (TVA 2009a). The Watts Bar site is part of the Watts Bar Reservation in the project operations category. In addition to the nuclear plant, the Watts Bar Reservation contains the Watts Bar Dam and Hydroelectric Plant and the TVA Central Maintenance Facility. TVA formerly operated the Watts Bar Fossil Plant on the Reservation; it ceased operations in 1983, and TVA deconstructed it and recycled most of the materials in 2011 (TVA 2011d; Brickhouse 2012).

Although Dayton and Spring City have municipal zoning, Rhea County does not zone its unincorporated areas and, therefore, the Watts Bar site does not have a municipal zoning designation.

3.1.2 AESTHETICS

3.1.2.1 Visual

Visual resources include natural and manmade physical features that provide the landscape its character and value as an environmental resource. The potentially affected area for visual resources encompasses those lands from which the site is visible.

The site is in a rural area along the Tennessee River, which flows along the east and south sides. There are scattered residences around the plant and across the river. The predominant visual features of the plant include the cooling towers, containment structures, turbine building, and transmission lines. The tallest buildings are the cooling towers at about 500 feet. From residences to the north and west, forest screens the plant from sight. A wooded area east of the plant partially screens it from traffic passing on the river. The plant is distantly and partially visible from coves and hollows along the river and from some area roads such as State Route 68 (SR 68) (DOE 1999a). Trees along the eastern shoreline shield the view of the plant buildings from further inland, but the cooling towers are visible from a portion of SR 304 across the river and from residences along this road.

The vapor plume from the cooling towers can be visible as far as 10 miles away from nearby residential areas and from SR 68 and other nearby roads. Plume height, length, and frequency of occurrence vary with atmospheric conditions; it is most visible during cooler months and after a weather front has moved through the area. The plume is less visible during the summer months when hazy conditions and morning fog are more common (DOE 1999a).

3.1.2.2 Noise

Noise Measurement

Noise is unwanted sound that interferes with normal activities or otherwise diminishes the quality of the environment. Noise can be intermittent or continuous, steady or impulsive, stationary or transient. Stationary sources normally result from specific land uses such as housing tracts or industrial plants. Transient noise sources (for example, trains) move through the environment, either along established paths or randomly.

Noise is measured in decibels, a logarithmic unit, which means a 50-decibel noise is twice as loud as a 40-decibel noise (an increase of 10 decibels). The human ear does not respond equally to all frequencies of sound. Low frequencies (below 250 hertz) and very high frequencies (above 10,000 hertz) are less audible than the frequencies in between. The A-weighted decibel scale approximates the response of the human ear by giving less weight to low and very high frequencies; it corresponds with subjective judgment of how loud a noise is (FTA 2006).

A characteristic of environmental noise is that it is not steady; it varies in loudness from one moment to the next. To account for these variations in the sound level over time, and to assess environmental noise in a consistent and practical manner, a statistical approach reduces several different noise levels (at different times) to one level. Two commonly used measurements are the equivalent sound level and the day-night average sound level (FTA 2006). The equivalent sound level describes cumulative exposure

Noise Terms

A-weighted decibels:
A measurement of sound that approximates the sensitivity of the human ear, which is used to characterize the intensity or loudness of sound.

Day-night average sound level:
The energy average of the A-weighted sound levels over a 24-hour period. It includes an adjustment factor for noise between 10 p.m. and 7 a.m. to account for the greater sensitivity of most people to noise during the night.

from all sources of noise over a specified period (such as an hour). The day-night average sound level describes cumulative exposure from all sources of noise over 24 hours. This measurement includes an increase of 10 A-weighted decibels in noise between 10 p.m. and 7 a.m. to account for greater nighttime sensitivity to noise.

A judgment of a community noise impact typically depends on the magnitude of the increase above existing background sound levels. There are no Federal, State of Tennessee, or local industrial noise statutes for the communities immediately around the Watts Bar Nuclear Plant. Noise can interrupt ongoing activities and can result in community annoyance, especially in residential areas. In general, most residents become highly annoyed when noise interferes significantly with activities such as sleeping, talking, noise-sensitive work, and listening to radio, television, or music (FTA 2006). Sound levels that cause annoyance in people vary greatly by individual and background conditions. The U.S. Environmental Protection Agency (EPA) recommends indoor and outdoor sound levels of no more than 45 A-weighted decibels and 55 A-weighted decibels, respectively, to avoid annoyance (EPA 1978). The U.S. Department of Housing and Urban Development considers areas with day-night average sound levels of 65 A-weighted decibels or less to be acceptable for residential development (Schomer 2005).

A one-time exposure to a very brief, very loud sound such as an explosion, or to continuous loud sounds over an extended period, can cause hearing loss. Long or repeated exposure to sounds at or above 85 A-weighted decibels can cause such loss. The louder the sound, the shorter the time before hearing loss can occur. Sounds less than 75 A-weighted decibels, even after long exposure, are unlikely to cause hearing loss (NIDCD 2008). The National Institute of Occupational Safety and Health recommends a maximum 8-hour time-weighted average sound level of less than 85 A-weighted decibels for protection of human hearing. The Institute considers exposures at or above this level hazardous (NIOSH 1998). The Occupational Safety and Health Administration requires a hearing conservation program in workplaces when sound levels equal or exceed this level [29 CFR 1910.95(c)(1)].

Noise Sources in the Area

Noise sources in the area include river and lake traffic, road traffic, and plant equipment including transformers, cooling towers, air-blast circuit breakers, steam venting, and emergency sirens. Average noise levels in rural areas are typically about 40 A-weighted decibels during the day (TVA 2011e). The plant is an industrial facility, and average sound levels are higher on the site.

Estimated day-night average sound levels at the three residences nearest the site boundary (between 3,000 and 6,000 feet away), including the noise from the plant and background noise, are between 53 and 63 A-weighted decibels. Intermittent sound levels at these locations range from 84 to 103 A-weighted decibels from air-blast circuit breakers and steam venting (DOE 1999a). The sound levels at these residences are generally below a day-night average sound level of 65 A-weighted decibels (DOE 1999a), which is the U.S. Department of Housing and Urban Development acceptable maximum for residential areas (Schomer 2005). Watts Bar 1 is a licensed, operating nuclear power reactor. Testing of the emergency warning siren system occurs on a regular basis and results in outdoor sound levels of about 60 A-weighted decibels within a radius of about 10 miles (DOE 1999a). TVA typically tests siren systems once a month at noon (TVA 2011e). Emergency sirens are designed to be very loud and easily heard in the community. These sirens provide a warning as part of the local community emergency plans for various emergencies, such as tornado warnings, as well as their primary function to warn of an emergency at the Watts Bar site (TVA 2011e). These sirens would probably continue to serve the community even if the plant closed.

3.1.3 CLIMATE AND AIR QUALITY

3.1.3.1 Climate

The Watts Bar Nuclear Plant is in the Great Tennessee Valley between the Cumberland Plateau to the west and the Appalachian Mountains to the east, and is an area of complex local terrain. This results in localized variations in temperatures and winds. As a whole, the area experiences a moderate climate with cool winters averaging 2 to 4 degrees Fahrenheit (°F) warmer than plateau areas to the west. In winter, severe storms are rare. Appreciable accumulations seldom last more than a few days. Occasional ice storms can be severe enough to cause damage (DOE 1999a).

The summer temperature rises as high as 95°F. Thunderstorms frequently reduce afternoon temperatures by 10°F to 15°F. Data collected over a 30-year period (1981 to 2010) at the Chattanooga airport indicate the average annual temperature is 61°F. The average daily maximum temperature in July is 90°F, and the average daily minimum temperature in January is 30.7°F (TCS 2011). The average annual precipitation is about 52 inches, with the minimum monthly average in October (about 3.3 inches) and the maximum monthly average in November (5 inches) (TCS 2011). Severe thunderstorms occasionally produce hail and damaging winds. The prevailing winds are from the south-southwest, and the average annual wind speed at the Chattanooga airport (using data through 2002) is 6 miles per hour (NCDC 2008).

Severe Weather

Windstorms generally occur several times a year at the Watts Bar site. High winds can accompany thunderstorms, which occur about 56 days a year (NOAA 2011). Between 1950 and 2009, the highest recorded wind speed in Chattanooga, Tennessee, was 63 miles per hour on June 11, 2009 (TVA 2011b).

The 1999 EIS estimated that the probability of a tornado occurrence at the Watts Bar site would be about once in 5,400 years, a probability of 0.00018 (18 chances in 100,000 in a given year) (DOE 1999a). In 2007, the TVA EIS reported this estimated probability as 0.00027 (about once in every 3,700 years or 27 chances in 100,000 in a given year) using data through 2005 (TVA 2007a).

These probabilities are being reconsidered based on a historic outbreak of tornadoes that occurred in Rhea County, Tennessee, on April 27, 2011. Based on preliminary National Weather Service information, two tornadoes with strengths of EF1 and EF4 on the Enhanced Fujita Scale struck the county that day near Spring City (NWS 2011a). Spring City is about 7 miles northwest of the Watts Bar site. The analysis of the April 27 event is not yet complete and the National Weather Service has not yet updated the tornado frequency calculations using the April 2011 information. However, the increase in number of tornadoes would translate to an increase in tornado frequency at the Watts Bar site, with a new probability of 0.00096 and a recurrence interval of 1,041 years (TVA 2012).

Enhanced Fujita (EF) Scale

A scale that rates the strength of tornadoes in the United States based on the damage that they cause. It is a set of wind estimates (not measurements) based on damage; there are six categories from zero to 5. The scale was implemented in February 2007 and updated the original Fujita Scale that was introduced in 1971. The EF scale and associated wind estimated wind speeds in miles per hour are:

EF0	65 to 85
EF1	86 to 110
EF2	111 to 135
EF3	136 to 165
EF4	166 to 200
EF5	over 200

3.1.3.2 Air Quality

The *Clean Air Act* (42 U.S.C. §§ 7401 *et seq.*) requires EPA to set standards for pollutants considered harmful to public health and the environment. National primary ambient air quality standards define

> **Ambient Air**
>
> The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in immediate proximity to an emission source.

levels of air quality EPA has determined as necessary to provide an adequate margin of safety to protect public health, including the health of sensitive populations such as children and the elderly. National secondary ambient air quality standards define levels of air quality EPA deems necessary to protect the public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. EPA has established National Ambient Air Quality Standards for six criteria pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter [which includes particulate matter with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) and less than or equal to 2.5 micrometers ($PM_{2.5}$)], and sulfur dioxide. Table 3-1 lists the primary and secondary standards for each criteria pollutant. The State of Tennessee has similar standards, which are also addressed in Table 3-1. EPA designates regions in compliance with the standards as attainment areas. Areas where the applicable standards are not being met are nonattainment areas. Rhea County, Tennessee, is in attainment for all criteria pollutants.

Prevention of Significant Deterioration regulations restrict criteria pollutant emissions and protect national parks and wilderness areas that are Class I air quality areas. Class I areas include national wilderness areas, memorial parks larger than 5,000 acres, and national parks larger than 6,000 acres. The Class I areas closest to Watts Bar are the Joyce Kilmer-Slickrock National Wilderness Area in Tennessee and North Carolina and the Great Smoky Mountains National Park. These areas are about 50 miles from Watts Bar (DOE 1999a).

Air Emission Sources

Sources of criteria air pollutant emissions at the Watts Bar site include emergency diesel generators, diesel fire pumps, two auxiliary boilers, two cooling towers, lubricating oil systems, fuel oil storage tanks, sandblasting and surface coating operations, and vehicular traffic (TVA 2012). Heavy equipment and vehicles generate exhaust emissions from fuel combustion, and vehicles on unpaved roads generate fugitive dust emissions (PM_{10}). Watts Bar holds a Conditional Major Operating Permit from the Tennessee Department of Environment and Conservation for these sources (TVA 2012). In addition, Watts Bar holds a Tennessee permit for a large diesel generator. Current Watts Bar air emissions include minor amounts of nitrogen oxides, carbon monoxide, sulfur oxides, and PM_{10}. For 2010, Watts Bar reported annual emissions of 0.22 ton of sulfur dioxide and about 9.4 tons of nitrogen oxides (TVA 2012). When Watts Bar 2 becomes operational, it will produce similar air emissions from sources such as emergency diesel generators. The plant would require an amended air emissions operating permit to add new emissions sources for Watts Bar 2 (TVA 2007a).

Gaseous Radioactive Emissions

The Watts Bar site has three primary sources of gaseous radioactive emissions (DOE 1999a):

- Discharges from the gaseous waste management system,
- Discharges from the exhaust of noncondensable gases in the main condenser, and
- Gaseous discharges from ventilation systems including those at the reactor building, reactor auxiliary building, and fuel-handling building.

The gaseous waste management system collects fission product gases (mainly noble gases) that accumulate in the primary coolant. A portion of the primary coolant diverts continually to the primary coolant purification, volume, and chemical control system to remove contaminants and adjust the chemistry and volume. Noncondensable gases flow to the gaseous waste management system, which is a

Table 3-1. National and Tennessee Ambient Air Quality Standards.

Pollutant	National Primary standards[a]	National Secondary standards[a]	National: Form	Tennessee Primary standards[b]	Tennessee Secondary standards[b]
Carbon monoxide					
8-hour average	9 ppm	None	Not to be exceeded more than once per year	9.0 ppm	Same as Primary
1-hour average	35 ppm	None	Not to be exceeded more than once per year	35.0 ppm	Same as Primary
Lead					
Rolling 3-month average	0.15 $\mu g/m^3$	Same as Primary	Not to be exceeded	None	None
Calendar quarter	None	None		1.5 $\mu g/m^3$	Same as Primary
Nitrogen dioxide					
Annual arithmetic mean	0.053 ppm	Same as Primary	Annual mean	0.05 ppm	Same as Primary
1-hour	0.10 ppm	None	98th percentile, averaged over 3 years	None	None
Ozone					
8-hour average (2008 standard)	0.075 ppm	Same as Primary	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years	None	None
1-hour (daily maximum)	None	None		0.12 ppm	Same as Primary
PM_{10}					
Annual (arithmetic mean)	None	None		50 $\mu g/m^3$	Same as Primary
24-hour average	150 $\mu g/m^3$	Same as Primary	Not to be exceeded more than once per year on average over 3 years	150 $\mu g/m^3$	Same as Primary
$PM_{2.5}$					
Annual arithmetic mean	15 $\mu g/m^3$	Same as Primary	Annual mean, averaged over 3 years	None	None
24-hour average	35 $\mu g/m^3$	Same as Primary	98th percentile, averaged over 3 years	None	None
Total suspended particulates					
24-hour average	None	None		None	150 $\mu g/m^3$
Sulfur dioxide					
Annual (arithmetic mean)	None	None		0.03 ppm	None
24-hour average	None	None		0.14 ppm	None
3-hour average	None	0.5 ppm	Not to be exceeded more than once per year	None	0.5 ppm
1-hour average	0.075 ppm	None	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years	None	None
Hydrogen fluoride					
30-day average	None	None	Not to be exceeded more than once per year	None	1.5 ppb
7-day average	None	None	Not to be exceeded more than once per year	None	2.0 ppb
24-hour average	None	None	Not to be exceeded more than once per year	None	3.5 ppb
12-hour average	None	None	Not to be exceeded more than once per year	None	4.5 ppb

ppm = parts per million; $\mu g/m^3$ = micrograms per cubic meter.

a. Source: National Ambient Air Quality Standards, 40 CFR Part 50 (as of October 2011).

b. Source: Tennessee Ambient Air Quality Standards, *Rules of Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Air Pollution Control*; Chapter 1200-3-3, "Ambient Air Quality Standards" (October 2006 Revised) (http://tn.gov/sos/rules/1200/1200.htm).

series of gas storage tanks that allows short half-life radioactive gases to decay, leaving only a small quantity of long half-life radionuclides for release to the atmosphere. Table 3-2 lists the 2010 nontritium gaseous radioactive emissions in curies from Watts Bar 1. Table 3-3 lists the gaseous tritium emissions from Watts Bar 1 for 2002 to 2010. When Watts Bar 2 becomes operational, it should produce similar annual radioactive gaseous emissions.

Table 3-2. Nontritium radioactive gaseous emissions at the Watts Bar site, 2010.

Emission	Curies
Fission gases (including carbon-14)	18.01

Sources: Woods 2012; TVA 2012.

Table 3-3. Tritium gaseous emissions (curies) at Watts Bar 1, 2002 to 2010.

Emission	2002	2003	2004	2005	2006	2007	2008	2009	2010
Tritium	50.20	102.80	13.90	24.80	22.12	36.40	48.3	53.60	25.30

Sources: Woods 2012; TVA 2012.

3.1.3.3 Greenhouse Gases

The burning of fossil fuels such as coal, diesel, and gasoline emits carbon dioxide, which is a greenhouse gas. Greenhouse gases can trap heat in the atmosphere, similar to the glass walls of a greenhouse, and have been associated with global climate change. Climate change refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). The Intergovernmental Panel on Climate Change, in its Fourth Assessment Report, stated that warming of the Earth's climate system is unequivocal, and that most of the observed increase in globally averaged temperatures since the mid-20th Century is very likely due to the observed increase in concentrations of greenhouse gases from human activities (IPCC 2007). These gases are well mixed throughout the lower atmosphere, so emissions would add to cumulative regional and global concentrations of carbon dioxide. The effects from an individual source therefore cannot be determined quantitatively.

The global carbon cycle consists of large carbon sources and sinks. Billions of tons of carbon in the form of carbon dioxide are absorbed by oceans and living biomass (called carbon sinks) and are emitted to the atmosphere through natural and manmade processes (called carbon sources). When in equilibrium, carbon flow between these reservoirs is roughly balanced. Over the last 250 years, global atmospheric concentrations of carbon dioxide have risen about 36 percent, most of which is from burning fossil fuels (TVA 2011b).

The primary greenhouse gas emitted by electric utilities is carbon dioxide from the burning of coal and other fossil fuels. Carbon dioxide emissions from fossil-fuel combustion by electricity generation in the United States totaled about 2.4 billion tons in 2009 (EPA 2011a). Nuclear electric plants do not directly produce any measurable carbon dioxide during the electricity generation process (TVA 2011b).

EPA has promulgated regulations for emissions of greenhouse gases under the *Clean Air Act* (EPA 2011b):

- On March 13, 2010, EPA issued the final Greenhouse Gas Tailoring Rule. This rule raised the thresholds for greenhouse gas emissions that define when permits under the Prevention of Significant Deterioration and Title V Operating Permit programs are required for new and existing industrial facilities.

- Starting on January 2, 2011, large industrial facilities that must already obtain Clean Air Act permits for nongreenhouse gases must include greenhouse gas requirements in the permits if they are newly constructed and have the potential to emit 75,000 tons or more per year of carbon dioxide equivalent (CO2e) or if they make changes at the facility that increase greenhouse gas emissions by that amount. (CO2e is a measure for comparison of greenhouse gases based on their global warming potential, using the functionally equivalent amount or concentration of carbon dioxide as the reference value.)

- Starting on July 1, 2011, in addition to the facilities described above, all new facilities emitting greenhouse gases in excess of 100,000 tons per year of CO2e and facilities making changes that would increase greenhouse gas emissions by at least 75,000 tons per year of CO2e must obtain permits that address greenhouse gas emissions.

- Also beginning in July 2011, operating permits will be required for all sources that emit at least 100,000 tons per year of CO2e. Sources that emit less than 50,000 tons per year of CO2e will not be required to obtain permits for greenhouse gases before 2016 (EPA 2011b).

TVA does not monitor or estimate greenhouse gas emissions from its nuclear sites. However, Watts Bar does compile annual diesel fuel use for its combustion emission sources. This burning of diesel fuel is the primary source of greenhouse gases at Watts Bar. Table 3-4 lists annual diesel fuel use and estimated carbon dioxide emissions at Watts Bar from 2008 to 2010.

Table 3-4. Annual diesel fuel use and estimated carbon dioxide emissions at the Watts Bar site, 2008 to 2010.

Fuel/emissions	2008	2009	2010
Diesel fuel (gallons)	270,000	130,000	63,000
Carbon dioxide emissions (tons)[a]	3,000	1,500	700

Source: TVA 2012.

a. Based on 22 pounds of carbon dioxide per gallon of burned diesel fuel (DOE 2012).

Greenhouse gases are also generated by vehicle traffic of the workers commuting between Watts Bar and their residences. The Watts Bar site has a current workforce of about 572 persons (TVA 2011c), including 10 workers attributable to the tritium production activities, who live primarily in Rhea County and neighboring counties in the area (TVA 2012). A typical passenger car emits 5.6 tons of carbon dioxide every 12,000 miles (EPA 2011c). Therefore, if each of the 572 workers drove 12,000 miles per year during their commutes, the amount of carbon dioxide produced per year would be about 3,200 tons.[1] Once Watts Bar 2 becomes operational, the Watts Bar site will employ about 1,150 workers and the amount of carbon dioxide per year from worker commutes would be about twice its current level. Once that occurred, the total amount of carbon dioxide from Watts Bar activities (diesel fuel use and worker commuting) would be about 7,100 tons annually.

Estimated greenhouse gas emissions from the existing facility are relatively small in comparison with the 111 million tons of Tennessee CO2e emissions in 2009 and the estimated 7.3 billion tons (EPA 2011a) of U.S. CO2e emissions in 2009. Emissions from the facility, in combination with past and future emissions from all other sources, would contribute incrementally to climate change impacts.

1. This calculation of greenhouse gases includes consideration of greenhouse gases from transportation of TPBARs and low-level radioactive wastes. The greenhouse gases from these transportation activities represent less than 1 percent of the greenhouse gases from worker transportation.

3.1.4 GEOLOGY AND SOILS

3.1.4.1 Geology

The Watts Bar Nuclear Plant is in the Tennessee section of the Valley and Ridge Province of the Appalachian Highlands. This province consists of a series of folded and faulted mountains and valleys that formed during the late Paleozoic Era about 250 million years ago. These strata were folded westward, and forced over massive thrust faults with little metamorphism or igneous intrusion. Long narrow ridges and somewhat broader intervening valleys with a northeast-southwest trend characterize this province. The ridges are roughly parallel and fairly evenly topped and have developed in areas underlain by resistant sandstones and the more siliceous limestones and dolomites. The valleys have formed through erosion in the areas underlain by easily weathered shales and the more soluble limestone formations (USGS 2011a; TVA 2008a). Near the Watts Bar site, the Tennessee River (before the impoundment of Chickamauga Reservoir) had entrenched its course to an elevation of 670 feet above mean sea level. The small tributary valley floors slope from the river up to around 800 feet above mean sea level, while the crests of the intervening ridges range between 900 and 1,000 feet above mean sea level (TVA 2008a).

The Watts Bar site is on unconsolidated alluvial and terrace deposits the Tennessee River laid down when it flowed at a higher level. Drilling has shown that the deposits are about 40 feet thick and consist of sandy, silty clay in the upper half, and pebbles, cobbles with small boulders of quartz or quartzitic sandstone embedded in a sandy clay matrix in the lower half. The underlying bedrock consists of the Conasauga Shale Formation (of Middle Cambrian Age), which consists predominantly of shale with interbedded limestone. Based on rock core data, the Conasauga Formation provides a satisfactory and competent foundation for the plant structures. Cores from drill holes in the area indicate no evidence of weathering below the upper 5 feet of rock. Physical testing, both static and dynamic, has shown that the unweathered rock can support loads that are greater than the loads from the site structures (TVA 1972). The shales and limestones are generally of low permeability, and the majority of the groundwater flows through the overlying terrace deposits (DOE 1999a). The Conasauga Formation at the site contains few fossils and has no known areas of unique paleontological significance (TVA 1972).

3.1.4.2 Seismicity

The Kingston thrust fault is about a mile northwest of the Watts Bar site and is traceable to the northeast and the southwest. The fault dips to the southeast at an angle of 30 degrees or more, which carries the plane of the fault at least 2,000 feet below the surface of the Watts Bar site. This fault developed about 250 million years ago but has been inactive for many millions of years; recurrence of movement is unlikely (TVA 2008a).

TVA based the design of Watts Bar 1 on the largest historic earthquake to occur in the Southern Appalachians—the 1897 Giles County, Virginia, earthquake magnitude of 5.9 (Modified Mercalli intensity of VIII). The safe-shutdown earthquake is defined as the earthquake that produces the maximum ground vibration for which structures, systems, and components important to safety will remain functional (DOE 1999a). TVA established the safe-shutdown earthquake for Watts Bar 1 at a maximum horizontal acceleration of 0.18 *g* (*g* is the acceleration due to gravity) and a simultaneous maximum vertical acceleration of 0.12 *g* (DOE 1999a).

The largest earthquake in the southern Appalachians since 1973 occurred in Fort Payne, Alabama, on April 29, 2003; it had a magnitude of 4.6 and Modified Mercalli intensity of IV to V, which is lower than the design-basis earthquake (Modified Mercalli intensity of VIII). Therefore, the Fort Payne earthquake has no significant impact on previous findings. TVA completed the Individual Plant Examination for

External Events in 1998, which included an examination of seismic effects, and concluded that the seismic capacity of the Watts Bar site exceeds 0.3 *g*, the minimum level required by the NRC for a Review Level Earthquake. Therefore, seismic design change recommendations were not necessary (TVA 2007a).

From 1973 to 2011, there have been 218 recorded earthquakes with an average magnitude of 3 within a 200-mile radius of the Watts Bar site (USGS 2011b).

3.1.4.3 Soils

The unconsolidated deposits that overlie bedrock are primarily alluvial and terrace deposits consisting of fine-grained, finely sorted soils and clays with micaceous sand and some quartz gravel. TVA made extensive evaluation of the soils on the Watts Bar 1 site and devised foundation requirements for all plant structures in relation to the specific location and safety classification of each. The general requirements for Safety Category I structures involve use of in situ soil, compacted granular fill, or in situ rock as foundation material (DOE 1999a).

3.1.5 WATER RESOURCES

3.1.5.1 Surface Water

3.1.5.1.1 Surface-Water Hydrology

The Watts Bar site is at the northern end of the Chickamauga Reservoir, an impoundment on the Tennessee River and TVA's sixth largest reservoir. Figure 3-1 shows the relative location of the Chickamauga Reservoir in the TVA system of 49 active dams and reservoirs on the Tennessee River and its primary tributaries (TVA 2010a). TVA operates the reservoir system for flood control, navigation, power generation, water supply, recreation, and economic growth. In relation to flood control, TVA places particular emphasis on protection of Chattanooga (DOE 1999a), which is 40 miles downstream from the Watts Bar site.

The main body of the Chickamauga Reservoir extends 59 miles along the run of the Tennessee River from Chickamauga Dam at Tennessee River Mile 471 going upstream to Watts Bar Dam at River Mile 530. In a straight line, the two dams are about 44 miles apart. The reservoir, which also extends about 32 miles up the Hiwassee River, covers an area of 35,400 acres at the normal maximum water elevation of 682.5 feet above mean sea level, and contains a volume of 628,000 acre-feet (TVA 2010a). Its flood storage capacity is 345,000 acre-feet (TVA 2011f).

The Chickamauga Reservoir ranges in width from about 900 feet to 2.5 miles. At the Watts Bar Nuclear Plant, the reservoir is about 1,100 feet wide, with cross-sectional depths that range between 18 and 26 feet. Over the last 30 years, TVA has released an average flow from the Watts Bar Dam of 27,000 cubic feet per second (TVA 2007a). TVA has released an average flow at the Chickamauga Dam of 32,000 cubic feet per second (TVA 2010a) because tributaries (primarily the Hiwassee River) add flow between the two dams. The Watts Bar site is at River Mile 528; about 2 river miles below the Watts Bar Dam. Although average flow from the dam is 27,000 cubic feet per second, daily releases can average as little as 3,300 to as much as 150,000 cubic feet per second. On an hourly basis, the amount of water TVA releases from the dam can drop to zero because of peaking operations at the dam's hydroelectric plant (TVA 2007a).

The Chickamauga Reservoir has a drainage area of 20,800 square miles. The Tennessee River is the primary contributor of water to the reservoir, but the Hiwassee River, which enters at Tennessee River

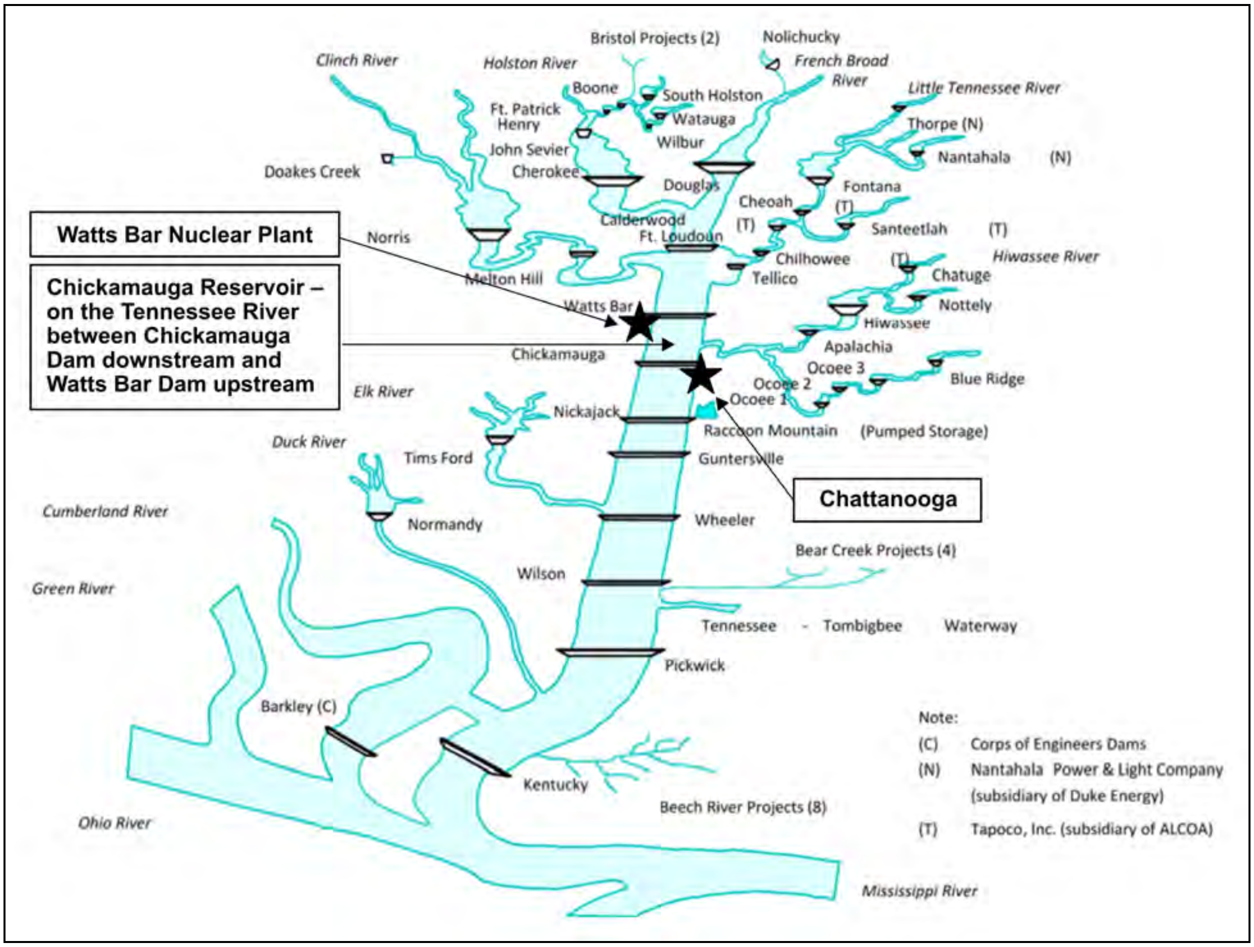

Figure 3-1. TVA water control system and the Chickamauga Reservoir (not to scale; TVA 2010a).

Mile 499.5, is a significant contributor. The Tennessee Department of Environment and Conservation identifies more than 50 creeks and drainage channels (most unnamed) that enter the Tennessee River portion of the Chickamauga Reservoir and more than 20 additional creeks and drainage channels that enter the portion of the reservoir that backs up into the Hiwassee River drainage (count obtained from the State of Tennessee online water quality assessment tool at http://www.tn.gov/environment/water.shtml).

In the discussion that follows, reference to the Tennessee River is interchangeable with the Chickamauga Reservoir for those portions of the reservoir that overlie the bed of the Tennessee River; the same applies for the Hiwassee River.

3.1.5.1.2 Surface-Water Quality

The *Clean Water Act* (33 U.S.C. §§ 1251 *et seq.*) established a framework for regulating quality standards for surface waters and discharges into those waters. Under that framework, the states evaluate their surface waters, determine applicable beneficial uses, set water quality criteria to support those uses, and then implement rules and regulations to achieve or maintain applicable water quality criteria. In Tennessee, water quality criteria applicable to the beneficial uses are in State of Tennessee Rules Chapter 1200-4-3, "General Water Quality Criteria" (http://tn.gov/sos/rules/1200/1200.htm). Criteria for beneficial uses for specific surface waters, and sometimes for segments of specific surface waters, are in Chapter 1200-4-4, "Use Classifications for Surface Waters" (http://tn.gov/sos/rules/1200/1200.htm). Section 305(b) of the *Clean Water Act* requires states to develop and periodically update an inventory of the water quality of all water bodies in the state. These inventories, which states report to EPA and the public, identify whether the water quality supports the applicable designated uses. Section 303(d) of the *Clean Water Act* requires states to develop, periodically update, and report an inventory of water bodies that do not meet water quality standards.

Table 3-5 identifies designated uses and general water quality status for the surface waters in the immediate vicinity of the Watts Bar site. The water quality status comes from Tennessee's 2010 Section 303(d) report (TDEC 2010a) as well as other State information. Changes identified in the State's draft 2012 report (TDEC 2012a) have also been incorporated in Table 3-5, but because of the report's draft status at the time of the preparation of this SEIS, the changes are identified with explanations in the footnotes. The table focuses on the status of the Tennessee River, which includes the Chickamauga Reservoir where the Watts Bar site is, and the Watts Bar Reservoir just upstream on the other side of Watts Bar Dam. Chapter 1200-4-4 of the Tennessee Rules identifies designated uses by primary river basins in the state. The Watts Bar site is in the Upper Tennessee River Basin. Within this basin, Chapter 1200-4-4 divides the Tennessee River into several segments to show changes in designated uses and to support listing of side streams that enter the river within those segments. The portion of the river that Table 3-5 describes is the southernmost segment (the one farthest downstream) of the Upper Tennessee River Basin. The table lists the river segment in three parts to show changes in water quality designations.

Table 3-5 also provides information on side streams that enter the Tennessee River reservoirs within about 3 miles of the Watts Bar site (that is, for a 6- to 7-mile stretch along the river with the site near the center). The 3-mile distance has no specific regulatory significance; the hydrology analysis used it as a representative distance to show the characteristics of the smaller streams and drainages near the site. Considering the larger, 68-mile segment of the Tennessee River in the table, other side streams have been evaluated for water quality but, consistent with those identified within 3 miles, most are in the category of having insufficient data for a water quality assessment. Tennessee Rules Chapter 1200-4-4 specifies use classifications for each stream it identifies by name; for "all other surface waters named and unnamed in the Upper Tennessee River Basin," the Chapter specifies applicable uses as fish and aquatic life, recreation, livestock watering and wildlife, and irrigation.

As the information in Table 3-5 indicates, water quality in the Tennessee River or Chickamauga Reservoir in the area of the Watts Bar site supports all designated uses for this water. Just upstream on the other side of Watts Bar Dam, however, the Tennessee River or Watts Bar Reservoir is an impaired water under Section 303(d); water quality in this area does not support all designated uses as a result of polychlorinated biphenyl contamination in the sediments. Because of the contamination, Tennessee has issued a Fish Tissue Advisory for the Tennessee River portion of the Watts Bar Reservoir, which advises against eating certain types of fish and taking precautions in eating others (TDEC 2010b). The table shows that the State of Tennessee considers the roughly 16-mile stretch of the river below Watts Bar Dam to be an exceptional Tennessee water due to its habitat for several Federally listed endangered mussels. By Tennessee Rules (Chapter 1200-4-3-.06), the Department of Environment and Conservation cannot authorize degradation in exceptional waters unless (1) there is no alternative that would render the proposed activity nondegrading and (2) the activity is in the economic or special interest of the public (TDEC 2011b).

The 1999 EIS (DOE 1999a) reported that surface-water quality measurements since the Watts Bar Nuclear Plant began operating, in comparison with previous measurements, show that plant operations have no significant effect on surface-water quality. The 1999 EIS provided a table of water quality data to demonstrate that conclusion. Table 3-6 is an update of that information. It lists the data from the earlier document and results from more recent water quality monitoring to represent current conditions. The table indicates that the values have not changed dramatically and are still within levels set for

Table 3-5. Surface-water quality and designations near the Watts Bar site.

Water body	Location	Designated use classifications[a,b]							Water quality assessment results[c,d] and other assigned designations[e]
		DOM	IWS	FAL	REC	LWW	IRR	NAV	
Side channels and creeks entering Tennessee River/Chickamauga Reservoir/Watts Bar Reservoir within about 3 miles (river centerline miles) of the Watts Bar Nuclear Plant[c]									
Sewee Creek[f]	Draining into Tennessee River/Chickamauga Reservoir from the east at about River Mile 525			X	X	X	X		• Impaired water – does not fully meet designated uses due to *E. coli* contamination and pasture grazing
Yellow Creek[f]	Draining into Tennessee River/Chickamauga Reservoir from the west at about River Mile 526-			X	X	X	X		• Impaired water – does not fully meet designated uses due to *E. coli* contamination and alteration of vegetation cover from pasture grazing
Various creeks and drainage channels	4 creeks and channels draining (2 from the west and 2 from the east) into Tennessee River/Chickamauga Reservoir between River Mile 525– and River Mile 532+			X	X	X	X		• Water quality not assessed – insufficient data.
Wolf Creek	Draining into south side of the Piney River bay area of Watts Bar Reservoir			X	X	X	X		• Impaired water – does not fully meet designated uses due to *E. coli* contamination and alteration of vegetative cover from pasture grazing.
Town Creek	Draining into west end of the Piney River bay area of Watts Bar Reservoir			X	X	X	X		• Water quality supports all designated uses.
Piney River	Draining into west end of the Piney River bay area of Watts Bar Reservoir			X	X	X	X		• Water quality supports all designated uses.
Various creeks and drainage channels[g]	8 creeks and channels draining (all from the west) into Tennessee River/Watts Bar Reservoir between River Mile 525– and River Mile 532+			X	X	X	X		• Water quality not assessed – insufficient data.

a. DOM = domestic water supply; IWS = industrial water supply; FAL = fish and aquatic life; REC = recreation; LWW = livestock watering and wildlife; IRR = irrigation; NAV = navigation. The State has two other designations—TS = trout stream and NRTS = naturally reproducing trout stream—that do not apply to this area of the Tennessee River.

b. Source: TDEC 2011a.

c. Source: TDEC 2010b, 2012a.

d. Source: State of Tennessee online water quality assessment tool at http://www.tn.gov/environment/water.shtml.

e. Sources for Exceptional Tennessee Waters: TDEC 2011b, 2010b.

f. Yellow Creek and Sewee Creek were added as assessed streams in the Draft 2012 303(d) List (TDEC 2012a).

g. Of the eight creeks or channels considered here, two (Muddy Creek and Toestring Branch) were assessed as supporting designated uses in the 2010 assessment, but were identified as not assessed in the 2012 report.

Table 3-6. Surface-water quality monitoring near the Watts Bar site.

Parameter	Unit of measure	Water quality criteria	Average water body concentration: 1999 EIS	Recent sampling[a,b]	
Radiological					
Alpha (gross)	picocuries per liter	15[c,d]	0.433	NA[e]	
Beta particles and photon emitters	millirem per year	4[c,d]			
Beta (gross)	picocuries per liter	Varies by nuclide	3.75	2.79	
Tritium	picocuries per liter	20,000[c,d]	<300[f]	378	
Nonradiological				Downstream (TRM 503.3)	Upstream (TRM 529.5)
Manganese	milligrams per liter	0.05[d,g]	0.060	0.043	<0.056
Nitrate (as N)	milligrams per liter	10.0[c,d]	0.253	NR	NR
Arsenic	milligrams per liter	0.010[c,d]	0.001	ND (<0.00099)	<0.0010
Barium	milligrams per liter	2.0[c,d]	0.142	NR	NR
Cadmium	milligrams per liter	0.005[c,d]	0.00014	ND (<0.00095)	ND (<0.00097)
Chromium	milligrams per liter	0.1[c,d]	0.0012	<0.0011	<0.0011
Lead	milligrams per liter	0.015[c,d] action level	0.0046	<0.001	<0.00096
Mercury	milligrams per liter	0.002[c,d]	0.00021	ND (<0.00019)	ND (<0.00044)
Nickel	milligrams per liter	0.1[d]	NR	ND (<0.0091)	ND (<0.0095)
Selenium	milligrams per liter	0.05[c,d]	NR	ND (<0.0019)	ND (<0.0019)
pH (acidity/alkalinity)	pH units	6.5–8.5[d,g]	7.8	8.2	7.8

NA = not available; ND = not detected; NR = not reported; < = less than; TRM = Tennessee River Mile.

a. Radiological results from TVA (2010b, 2011i) for beta and tritium at two sampling locations. (1) Beta (gross) and tritium results are averages of the values reported in the 2009 and 2010 annual reports. (2) Consistent with the manner reported in the source documents, beta (gross) and tritium results are averages of only those results above detection limits. For the beta (gross) results, 37 of 52 samples over 2 years had results over the detection limit of 1.9 picocuries per liter. For the tritium results, only 3 of 52 samples over 2 years had results over the detection limit of 270 picocuries per liter. There were no results over detection limits for the 2009 sampling year.

b. Nonradiological results from the EPA STORET Database (EPA 2011d) listing data collected between December 2003 and October 2008. (1) In instances where both positive detections and nondetections were reported over the various sampling events, the average value (in the table) was calculated using the reported detection limits for the nondetections and the result is a less-than (<) value. (2) In instances where no positive detections were reported, the entry is ND for not detected and the value in parentheses is the average detection limit shown with a less-than symbol (<).

c. National Primary Drinking Water Regulations (40 CFR Part 141).

d. Rules of Tennessee, Department of Environment and Conservation, Bureau of Environment, Division of Water Supply – Chapter 1200-05-01, “Public Water Systems” (http://tn.gov/sos/rules/1200/1200.htm).

e. Updated results for ambient levels of this parameter were not found, but during the last 5 years of record (2006 through 2010), TVA reported that no detected quantities of gross alpha radioactivity were in the Watts Bar liquid effluents (TVA 2007b, 2008b, 2009b, 2010c, 2011j).

f. Below lower limit of detection of 300 picocuries per liter.

g. National Secondary Drinking Water Regulations (40 CFR Part 143).

drinking water. Data in the table show an increase in tritium concentration between what the 1999 EIS reported and the results of recent sampling. However, as indicated in the table’s footnote a, the recent sampling data included only 3 of 52 samples over 2 years at levels greater than the detection limit; whereas the 1999 EIS reported all tritium results during the reporting period as less than the detection limit. The more current sampling shows slightly higher tritium levels, but it might be that tritium levels remained relatively consistent at about the detection limit over all sampling events. The positive detections might also be the result of unusual conditions at the time of the sampling event, such as low river flow or nonuniform wastewater releases.

The recent, nonradiological sampling data in Table 3-6 is from routine monitoring by the Tennessee Department of Environment and Conservation at two locations: one downstream of the Watts Bar site and one upstream. The Department enters the results of its water sampling activities into the EPA STOrage and RETreival (STORET) Database (EPA 2011d). The sampling location at River Mile 503.3, about 25 miles from the Watts Bar site, is the closest downstream monitoring site. NNSA queried the EPA STORET database for sampling data from 2000 and beyond, but it only contained data from 2003 through 2008 for this sampling location. The EPA STORET database also includes results from routine sampling of the Tennessee River just upstream of the Watts Bar site but still below Watts Bar Dam. One of two sites for this sampling is just downstream of the site's Outfall 113 discharge location (see Section 3.1.5.1.3); the few samples from this location might have included contributions from plant discharge, but none of the metals in Table 3-6 were present in detectable quantities in those samples. Table 3-6 lists the results from the other upstream location, at River Mile 295.5 (only about 1 mile from the Watts Bar plant). This monitoring location included data from 2000 through 2008. As the data show, the downstream and upstream sample results were very similar. The biggest differences between the two sets of samples were that the average manganese level was slightly higher in the upstream samples, even though one of the upstream samples had no detectable manganese, and the average pH of the downstream samples was higher at 8.2 in comparison with 7.8 for the upstream samples.

As an additional measure of surface-water quality, TVA evaluates and rates its reservoirs in relation to their ecological health. The rating system is based on five ecological indicators: (1) level of dissolved oxygen, (2) amount of chlorophyll as a measure of algae in the water, (3) number and variety of healthy fish, (4) variety of animal life on the reservoir bottom, and (5) concentrations of metals and other contaminants such as pesticides and polychlorinated biphenyls in the reservoir sediments (TVA 2011g, 2011h). TVA samples the reservoirs at several locations on a 2-year cycle unless results show notable changes that require verification on a shorter schedule. TVA scores and compiles these results to generate a composite rating of the reservoir's overall ecological health. Figure 3-2 shows the results of the rating system from 1994 to 2010 for the Watts Bar Reservoir and from 1994 to 2009 for the Chickamauga Reservoir.

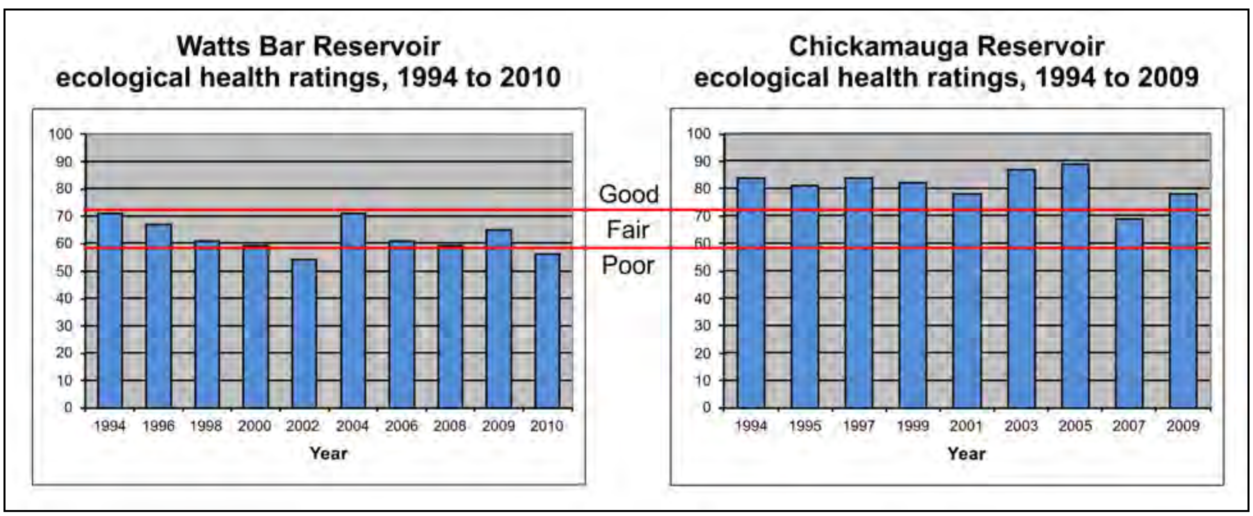

Figure 3-2. Ecological health ratings of the Watts Bar and Chickamauga Reservoirs (Data source: TVA 2011g, 2011h).

As the figure shows, the ecological health rating of the Watts Bar Reservoir has varied between fair and poor since 1994. These ratings have generally followed flow conditions in the reservoir, with the ratings being lower when flow is also low. For example, 2010 had low flow conditions due to a generally dry weather pattern. Dissolved oxygen is the ecological indicator most responsive to low-flow conditions and was a primary driver in the reservoir's overall score for 2010. TVA has added aeration equipment to the reservoir to add oxygen to the water and to improve conditions immediately downstream of Watts Bar Dam (TVA 2011g). Ecological health ratings for the Chickamauga Reservoir have consistently been in the good range. The single exception in 2007 was due to low flow in the reservoir; that year was the driest in 118 years of record (TVA 2011h).

3.1.5.1.3 Surface-Water Use and Rights

Regional Surface-Water Use

TVA and the U.S. Geological Survey compiled water use data for the area that makes up the TVA water control system (TVA 2008c). The data, from 2005, are presented in multiple groupings and water use categories. Two of the groupings are Reservoir Catchment Areas and Water Use Tabulation Areas. Under the method TVA and the Geological Survey used, the Catchment Areas are land areas centered on a primary TVA-operated reservoir and the Tabulation Areas are groupings of one or more Reservoir Catchment Areas. As appropriate, multiple Catchment Areas were grouped together when there were notable water-use transactions between them. Of significance to this discussion, the Watts Bar Reservoir Catchment Area and the Chickamauga Reservoir Catchment Area are grouped together into a Water Use Tabulation Area. TVA and the Geological Survey used this approach to compile cumulative water use figures starting with the Reservoir Catchment Areas farthest upstream and ending with those near the junction with the Ohio River (see Figure 3-1). In addition, water use results were presented in terms of categories of water users (specifically, thermoelectric, industrial, public supply, and irrigation), and water source (that is, as a surface-water or groundwater withdrawal). The report addressed one other water use element significant to the cumulative water demand in the surface-water system, namely return flow, which returns to the system after being withdrawn for a beneficial purpose. Return flow includes discharges from industrial or publicly owned wastewater treatment plants and cooling water TVA returns to the stream or reservoir after use. The U.S. Geological Survey compiles water use data every 5 years, but data are not yet available for 2010.

Table 3-7 summarizes water use in the Watts Bar and Chickamauga Reservoir Catchment Areas. Both include large surface areas that extend into multiple Tennessee counties. The table lists average values for 2005 in millions of gallons per day. The data show that the primary water use in both catchment areas is thermoelectric. The Kingston (coal-fired) Thermoelectric Plant is in the Watts Bar Reservoir Catchment Area, and both the Watts Bar and Sequoyah Nuclear Plants are in the Chickamauga Reservoir Catchment Area. The data also show that, by far, surface-water withdrawals meet most water demand in both areas. TVA data show that almost 99 percent of the withdrawn water returns to the water flow system. The return rate of almost 106 percent for the Chickamauga Reservoir Catchment Area is the result of water that comes from the Watts Bar Reservoir system but returns to the Chickamauga Reservoir system.

Public water systems downstream from the Watts Bar site include three primary users that withdraw water from the Tennessee River. The City of Dayton, Tennessee, about 14 miles southwest of the site (or about 23 River Miles), serves a population of about 20,500 and withdraws water from the Chickamauga Reservoir (Dayton 2011). The two water providers (one utility district and one water company) for the City of Chattanooga, about 38 miles southwest of the site (or about 58 River Miles), serve a combined population of about 220,000 with withdrawals from the river (EPA 2011e). In addition, public recreation is a significant, nonconsumptive use of the Chickamauga Reservoir and one of its designated use classifications (see Table 3-5).

Local Surface-Water Use

Consistent with the information in Table 3-7, the Watts Bar Nuclear Plant is the largest user of surface water in the upstream (northern) portion of the Chickamauga Reservoir. The plant withdraws water from

Table 3-7. Average water use (millions of gallons per day) in the Watts Bar and Chickamauga Reservoir Catchment Areas in 2005.

Reservoir catchment area	Water source	Water use	Water use by category: Thermo-electric	Industrial	Public Supply	Irrigation	Returned to surface water
Watts Bar	Surface water	1,443	1,431	0	11.9	0.34	NA
	Groundwater	1	0	0.02	0.9	0.03	NA
	Totals	**1,444**	**1,431**	**0.02**	**12.9**	**0.37**	**1,303**
	(percent of total)		(99%)	(<0.1%)	(0.9%)	(<0.1%)	(90.2%)
Chickamauga	Surface water	1,678	1,577	74.5	25.0	1.8	NA
	Groundwater	25	0	0.6	24.0	0.8	NA
	Totals	**1,703**	**1,577**	**75.1**	**49.0**	**2.6**	**1,804**
	(percent of total)		(92.6%)	(4.4%)	(2.9%)	(0.1%)	(105.9%)
Watts Bar and Chickamauga combined	Surface water	3,121	3,008	74.5	36.9	2.1	NA
	Groundwater	26	0	0.6	25.0	0.8	NA
	Totals	**3,147**	**3,008**	**75.1**	**61.9**	**2.9**	**3,107**
	(percent of total)		(95.6%)	(2.4%)	(2.0%)	(<0.1%)	(98.7%)

Source: TVA 2008c.
NA = not available.

the adjacent river or reservoir system to supply service water, makeup water for the steam generator and, the largest demand, cooling water. In the plant's steam cycle, steam is condensed after passing through the turbine generator and a separate cooling water loop is used to remove heat from the condenser. This water is then cooled by a natural-draft evaporative cooling tower. Although the cooling system is designated as a closed type, makeup water from the Tennessee River is needed continuously to replace water losses from evaporation, drift, and blowdown. In the original configuration of the plant, all cooling water came from the Intake Pump Station on the southeast side of the site on an inlet connecting to the main river body. In 1999, TVA modified the cooling system to include the Supplemental Condenser Cooling Water System (supplemental system) to improve the performance of the heat removal system.

Drift
Cooling water that is lost as mist or spray carried into the atmosphere from cooling towers.

Blowdown
Water drained from a cooling system to control mineral buildup. Evaporative cooling, such as occurs in cooling towers, increases mineral levels in the remaining water. Draining a portion of the circulating water and replacing it with fresh (makeup) water is a method used to keep mineral concentrations at an acceptable level.

Figure 3-3 is a diagram of the Watts Bar Nuclear Plant's water flows and discharges, focusing on the cooling system. The shaded area represents the supplemental system, which basically is another source of water for the cooling system, added at the cooling tower basins. The new source of water is via a line that at one time supplied water from the Watts Bar Reservoir to the old Watts Bar Fossil Plant, just upstream from the current nuclear plant. TVA extended this line from the old fossil plant to the cooling tower basins and modified the basins with an overflow weir that takes water back toward the fossil plant and the old discharge point into the river. The line from the Watts Bar Reservoir now provides gravity flow of water to the cooling tower basins; because the basin capacities and operating parameters were not changed, a similar volume of water overflows the basins and discharges to the river. In the process, the added water mixes with that in the cooling system and, because it is generally cooler than the water from the cooling tower, it picks up and removes heat when it is discharged. Because the supplemental system is gravity-fed, its flow rate varies with the water level in Watts Bar Reservoir. At high water levels, TVA has calculated that a flow of 365 cubic feet per second could go through the system; the average flow has been about 200 cubic feet per second (TVA 2007a).

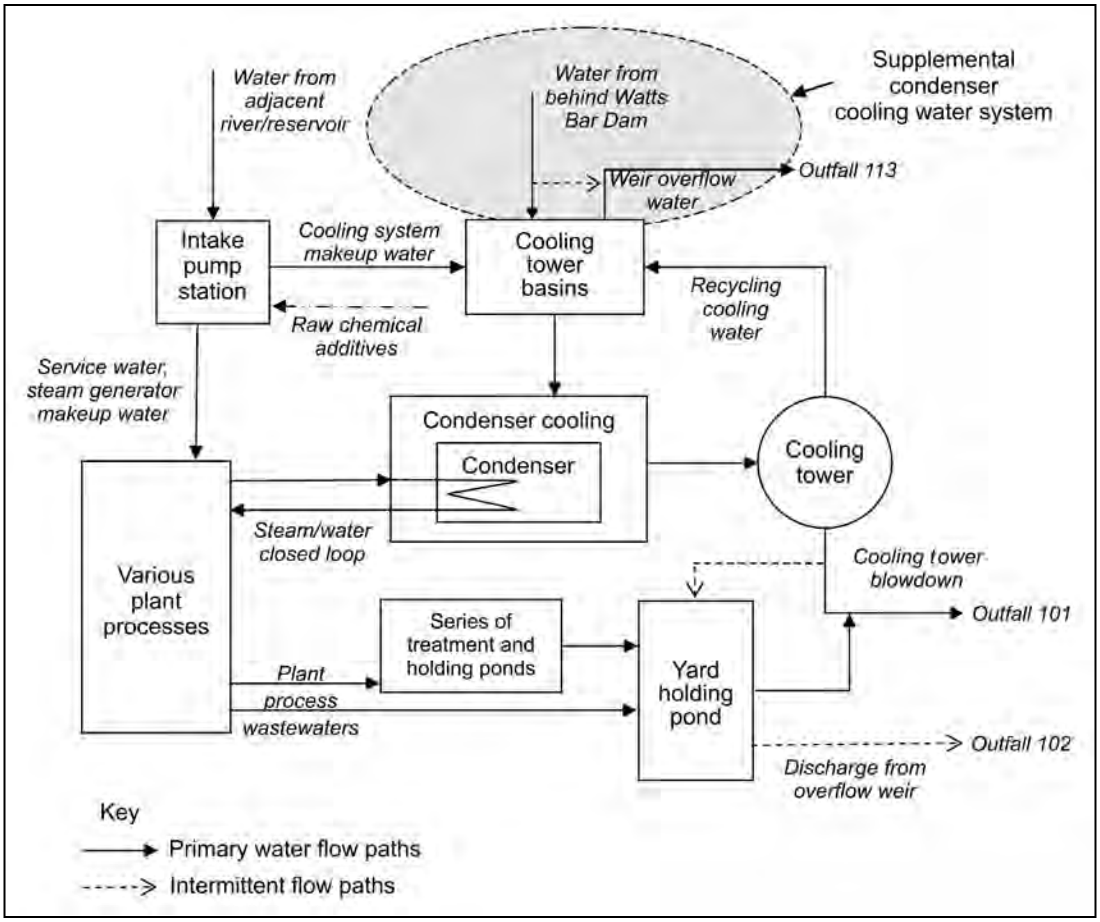

Figure 3-3. Process and cooling water flows and discharges at the Watts Bar site.

When Watts Bar 2 becomes operational, the supplemental condenser cooling water system will supply water to the cooling systems of both units. Incoming water will enter the Unit 2 cooling tower basin through the existing supplemental system inlet line. The water will pass through the Unit 2 cooling tower basin to reach the intake for the Unit 2 condenser cooling water. An existing crossover weir, in the divider wall between the Unit 1 and Unit 2 condenser cooling water intake plumes, will allow a portion of the water to the reach the Unit 1 intake. To balance the inflow from the supplemental system, the existing overflow weir in the Unit 1 cooling tower basin will return flow to the river through the supplemental condenser cooling water discharge line (Outfall 113 in Figure 3-3). The amount of water coming in from the Watts Bar Reservoir (which will still depend on the depth of the water upstream behind Watts Bar Dam) and the amount of water returned to the river by the supplemental system will not exceed existing amounts (Hopping 2012), which includes water going back to the river at an average rate of about 200 cubic feet per second (TVA 2007a). The supplemental system is a discretionary system; that is, TVA does not need it to operate the Watts Bar reactor safely (TVA 2007a). However, with the system in service, the plant's power production is more efficient. The tritiated water tank system would be connected to the plant's liquid radioactive waste discharge system (not shown on Figure 3-3). The tritiated water tank system would discharge to the cooling tower blowdown piping that leads to either Outfall 101 or the yard holding pond.

The other water source Figure 3-3 shows is the river, or reservoir, that flows past the Watts Bar site. The Intake Pump Station supplies the site with its nonpotable service water and provides makeup water for the steam generator system and the condenser cooling system. The station is on the south side of the site at the end of an 800-foot inlet that joins the river at River Mile 528 (TVA 2007a). Operation of Watts Bar 1 has shown an average need of about 80 cubic feet of water per second from the pump station, with the majority of that flow going to the condenser cooling system. When Watts Bar 2 becomes operational, TVA estimates it will need to increase withdrawals at the pump station by 33 percent (TVA 2007a) to about 106 cubic feet per second.

As Figure 3-3 shows, the water in the supplemental system that overflows the weir of the cooling tower basin discharges at Outfall 113 at River Mile 529.2, which is upstream of the Watts Bar site and about 0.7 mile below the dam (TVA 2007a). This outfall is a shoreline release slightly below the surface of the river and is regulated under a National Pollutant Discharge Elimination System permit, which establishes temperature limits for the discharge. If the discharge approaches the permit limits, the Watts Bar plant has the ability to divert water from above the dam directly to the discharge line (dashed line in Figure 3-3), mixing it with the water going to Outfall 113 and reducing the temperature of the discharge. The aerial view in Figure 3-4 shows the location of this outfall as well as other permitted outfalls and key components of the cooling system. The permit identifies two mixing zones for Outfall 113: an active mixing zone when there is flow in the river and a passive mixing zone when there is no flow. The active mixing zone is defined as having a width represented by the right half of the river (facing downstream) and extending 2,000 feet downstream from the outfall. The passive mixing zone is the entire width of the river (about 1,100 feet in this area) and extending 1,000 feet downstream. The entire width of the river is allowed as the mixing zone because modeling has shown that the near-surface discharge does not affect bottom-dwelling species and there is ample room at depth for fish to pass (TDEC 2011c).

The other means of heat removal from the condenser cooling system are the cooling tower and the blowdown that is continuously removed from the system to control the level of dissolved solids in the recirculating water. The blowdown removes heat from the system as it is replaced with cooler makeup water from the river and what is mixed from the supplemental system. As Figures 3-3 and 3-4 show, the blowdown discharges back to the Tennessee River at Outfall 101. Process wastewater from the yard holding pond also discharges to Outfall 101. This outfall is at River Mile 527.9 on the south side of the site (just downstream of the inlet for the Intake Pumping Station), and the discharge is through two multiport diffusers on the bottom of the river (TVA 2007a). Discharge from this outfall is regulated under the site's National Pollutant Discharge Elimination System permit, which defines the mixing zone for this outfall as an area with the width of the diffusers (240 feet) and that extends downstream 240 feet (TDEC 2011c).

To ensure adequate dilution of the effluent at Outfall 101, discharge is permitted only when flow in the river (controlled by the release rate from Watts Bar Dam) is at least 3,500 cubic feet per second. This requirement is facilitated by an interlock between the dam and the Watts Bar site that automatically closes the Outfall 101 diffusers when flow from the hydroturbines at the dam drops below 3,500 cubic feet per second (TVA 2007a). When the diffusers are closed, the discharge automatically diverts to the yard holding pond (dashed line in Figure 3-3) until river flow increases. As noted in Section 3.1.5.1.1, the long-term average water release rate from Watts Bar Dam is 27,000 cubic feet per second, but daily averages can be as little as 3,300 cubic feet per second and, on an hourly basis, flows can drop to zero. As a result, routing of blowdown water to the yard holding pond, although not a normal condition, occurs periodically. Over a typical year, discharges from Outfall 101 average about 43 cubic feet per second; when Watts Bar 2 becomes operational, TVA estimates the average will increase to about 80 cubic feet per second. On an hourly basis, these values range from zero when flow in the river is too low to allow the discharge to flows that are more than double the average when high flow from the yard holding pond (after periods of zero discharge to the outfall) is added to the blowdown discharge (TVA 2007a).

The Watts Bar site has a third outfall for process wastewaters, Outfall 102 (Figure 3-4). This outfall is intended only for emergency conditions to protect plant property from the consequences of an overflow of

ERCW = essential raw coolant water; NPDES = National Pollutant Discharge Elimination System; RCW = raw cooling water; SCCW = supplemental condenser cooling water; TRM = Tennessee River Mile.

Figure 3-4. Locations of outfalls and key components of the Watts Bar cooling system (TVA 2007a).

the yard holding pond. The pond's overflow weir drains overland to a local stream channel that discharges to the Tennessee River at River Mile 527.2, a little more than a half-mile downstream of Outfall 101. Outfall 102 is regulated under the plant's National Pollutant Discharge Elimination System permit, but TVA reports that the only time discharges have occurred at this outfall have been when Outfall 101 required maintenance. TVA also reports that operation of Watts Bar Dam and the blowdown system are carefully coordinated to avoid risk of overflowing the yard holding pond (TVA 2007a). When

Unit 2 is operational, the amount of water diverted to the holding pond will roughly double during periods of low flow in the river. While this will increase the potential for a pond overflow, TVA believes that operational controls will keep the risk of such an occurrence very low (TVA 2007a).

To summarize local water use, the Watts Bar site currently withdraws water from the Tennessee River system at a rate of about 280 cubic feet per second and discharges water back to the system at about 240 cubic feet per second. These values equate to approximately 180 million and 160 million gallons per day, respectively, for comparison with the values in Table 3-7. When Watts Bar 2 becomes operational, TVA estimates the water withdrawal will increase to about 310 cubic feet per second and the amount discharged to the river system will increase to about 280 cubic feet per second. Under average flow conditions, the withdrawal rate of 310 cubic feet per second represents about 1.1 percent of the total flow of the Tennessee River past the site. The net consumptive use of about 30 cubic feet per second represents about 0.11 percent of the total flow.

Consistent with its use for cooling water, a primary concern for discharges to the reservoir is the temperature of the effluent and its effects on the temperature of the receiving water. Table 3-8 summarizes the temperature limits from the National Pollutant Discharge Elimination System permit for the Watts Bar outfalls.

Table 3-8. Temperature limits for Watts Bar site outfalls to the Tennessee River.

Outfall	Parameter	Application	Limit
101	Effluent temperature	Daily average	95°F
102	Effluent temperature	Grab	95°F
113	Instream temperature at downstream edge of mixing zone	Maximum hourly average	86.9°F
	Instream temperature rise from upstream ambient to downstream edge of mixing zone	Maximum hourly average	5.4°F
	Instream temperature rate-of-change at downstream edge of mixing zone	Maximum hourly average	±3.6°F
	Instream temperature receiving stream bottom at mussel relocation zone	Maximum hourly average	92.3°F

Source: TVA 2007a.

Water for cooling is treated with chemicals to maximize cooling effectiveness and to minimize adverse impacts on plant components. These chemicals consist primarily of (1) corrosion inhibitors to prevent rusting of component surfaces and (2) various additives to keep heat exchange surfaces clean. This latter group of chemicals includes materials such as biocides, surfactants, and dispersants to keep the surfaces clean of mineral or biological buildup (such as mollusks or other biota). TVA identifies these chemical additives, and any proposed changes to their makeup, to the State of Tennessee along with toxicological data for approval. TVA tightly controls the use of approved chemicals to comply with Tennessee water quality criteria and applicable National Pollutant Discharge Elimination System permit conditions when the cooling water is discharged. Under terms of the permit, TVA uses a biocide and corrosion treatment plan that requires, among other things, that it submit an annual report to the State that identifies specific chemical use and monitoring results. When Watts Bar 2 is operational, TVA estimates that the amount of water treatment chemicals will increase by about one-third to accommodate the increased amount of cooling water. These increased amounts of chemical additives will be within the original design basis of the plant and will be subject to the review and approval requirements of the existing permit.

Low-level radioactive wastewater is mixed with the water that flows from the yard holding pond and later discharges to the reservoir. Table 3-9 summarizes the radiological constituents in the discharged liquid from 2006 to 2010. The 1999 EIS reported similar information, which the table provides for comparison.

Table 3-9. Annual radioactive liquid effluents released to the reservoir (curies).

Material	1999 EIS	2006 through 2010[a]		
		Minimum	Maximum	Average
Tritium	639	605	2,070	1,570
Other radionuclides	1.32	0.08	4.67	1.14

a. Sources: DOE 1999a; TVA 2007b, 2008b, 2009b, 2010c, 2011j.

The "Other radionuclides" row in the table includes (1) fission and activation products, (2) dissolved and entrained gases, and (3) gross alpha activity. However, each of the annual reports for the last 5 years indicated that gross alpha activity was below detection limits in all of the analyses. Because TVA has irradiated only a limited number of TPBARs in Watts Bar 1 since late 2003, the typical ongoing tritium releases from the 1999 EIS did not include tritium from TPBARs, but rather represent baseline releases from normal reactor operations. Tritium releases over the last 5 years include quantities from TPBARs as well as baseline quantities. TVA estimates that when Watts Bar 2 becomes operational, the quantity of baseline radioactive constituents discharged to the reservoir will be about double current baseline values (TVA 2007a).

At the river's average flow rate of 27,000 cubic feet per second at Watts Bar, the radionuclide discharges in Table 3-9 are diluted by more than 800 billion cubic feet of water over the course of a year, so concentrations are very low. The TVA annual reports for 2006 to 2010 data describe the liquid effluents as being within applicable concentration limitations set by the NRC in 10 CFR Part 20, "Standards for Protection Against Radiation," and within the dose limits set by EPA in 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations." TVA has indicated that the applicable liquid discharge limits will be met when Watts Bar 2 becomes operational (TVA 2007a).

Surface-Water Rights

Tennessee water law has been based historically on common law riparian doctrine under which landowners adjacent to surface waters have use rights but not property rights to the water, which is common property. As a result of increasing water demand, Tennessee has modified this traditional approach to "regulated riparianism" in which the water is public property and its use is controlled through regulatory permit systems (TACIR 2010). These permit systems incorporate concepts such as "reasonable use" or "beneficial use," which provides the State the ability to protect water quantity and quality for a variety of uses and users. The *Tennessee Water Quality Act of 1977* (Tennessee Code Annotated 69-3-101) requires anyone that would change the character of the water to obtain a permit from the Tennessee Department of Environment and Conservation (Tennessee 2002), and the implementing regulations specify that an Aquatic Resource Alteration Permit is required for water-altering activities including withdrawal (TACIR 2010). Construction or modification of intake structures for withdrawing water from the TVA water system could require permits from the U.S. Army Corps of Engineers and TVA.

3.1.5.2 Groundwater

3.1.5.2.1 Groundwater Hydrology

The region of the Watts Bar site is in the Valley and Ridge Physiographic Province of the eastern United States. This province is characterized by a sequence of folded and faulted, northeast-trending sedimentary rocks that form a series of alternating valleys and ridges. The principal aquifers in this province are the carbonate rocks that typically underlie the valleys and connect directly to sources of recharge such as rivers or lakes. Once water reaches the consolidated, carbonate rocks, movement is along fractures, bedding planes, and solution openings. Because the rocks are so heavily folded and faulted, groundwater movement is generally localized; most movement takes place in a series of adjacent, isolated, shallow groundwater flow systems within 300 feet of the land surface. Most groundwater discharges directly to local springs or streams (Lloyd and Lyke 1995).

Groundwater at Watts Bar comes principally from infiltration of local precipitation and from lateral underflow from the area north of the site. All groundwater flow from the site is toward Chickamauga Reservoir, either directly or via Yellow Creek, just to the southwest of the site. The site is above the Conasauga Formation, which is about 84-percent shale and 16-percent limestone. This formation generally has low permeability (Haugh 2002), so the majority of groundwater flows through the terrace deposits that overlie the bedrock (DOE 1999a). The Conasauga Formation does, however, allow water movement through local fracture zones (Lloyd and Lyke 1995) and, as indicated above, the underlying carbonate rocks, when present, provide the principal aquifers.

3.1.5.2.2 Groundwater Quality

In relation to water quality, the groundwater of the area is hard due to the presence of dissolved minerals; the longer the water travels underground, the higher the concentration of minerals. In places where the overlying alluvial materials are thin, the aquifers are susceptible to contamination by human activities (Lloyd and Lyke 1995).

At the Watts Bar site, TVA performed preoperational monitoring of groundwater by analyzing data from six wells in the Conasauga Formation to verify that the flow gradient was toward the Chickamauga Reservoir. Through 2002, the operational groundwater monitoring program for the site used two wells in the Conasauga Formation, one upgradient and one downgradient of the site. TVA took quarterly samples to monitor for the consistency of groundwater constituents.

In 2002, TVA detected a low level of tritium (just above detection limits) in one of its groundwater monitoring locations. TVA notified the NRC and the State of Tennessee and started action to install additional monitoring wells on the site and to determine the source of the contamination. By late 2004, TVA determined the source of the tritium contamination was leakage from an underground radioactive effluent pipe and a bellows for the Unit 2 fuel transfer tube. By the end of 2005, TVA corrected the problem by replacing the effluent pipe with a new line, sealing the Unit 2 fuel transfer tube, and coating the fuel transfer canal. Samples from 2005 from two of the new monitoring locations had tritium levels greater than the NRC 30-day reporting level of 30,000 picocuries per liter; the highest result was 550,000 picocuries per liter. However, TVA did not identify additional sources of contamination (TVA 2007a). Since that time, tritium levels in the groundwater monitoring wells have decreased. Monitoring results for 2009 and 2010 show the highest detected levels of tritium in the onsite monitoring wells were 3,420 and 2,860 picocuries per liter, respectively (TVA 2010b, 2011i). Figure 3-5 shows the locations of the groundwater monitoring wells TVA used in the tritium monitoring efforts. Well #5 in the figure is an upgradient well TVA used as a control in evaluating results from the other wells. TVA reported that some residual tritium will remain in the groundwater until it either decays or is diluted and will eventually migrate to the river where concentrations will be further reduced and pose no public health hazard (TVA 2007a). As points of reference for the detected tritium levels, the EPA limit for tritium in drinking water is 20,000 picocuries per liter (40 CFR Part 141), and surface waters (and therefore groundwater recharge) naturally contains tritium levels of about 10 to 30 picocuries per liter (ANL 2005), well below the detection limit for normal water quality sampling and analysis efforts. Testing of water from public drinking water intakes from the Chickamauga Reservoir occasionally shows detectable amounts of tritium. For example, in 2010 TVA reported that 6 of 34 samples from drinking water system intakes had tritium levels that ranged roughly from 300 to 600 picocuries per liter (TVA 2011j); the lower limit of detection was 270 picocuries per liter (that is, the laboratory reported it could not reliably detect levels lower than that value).

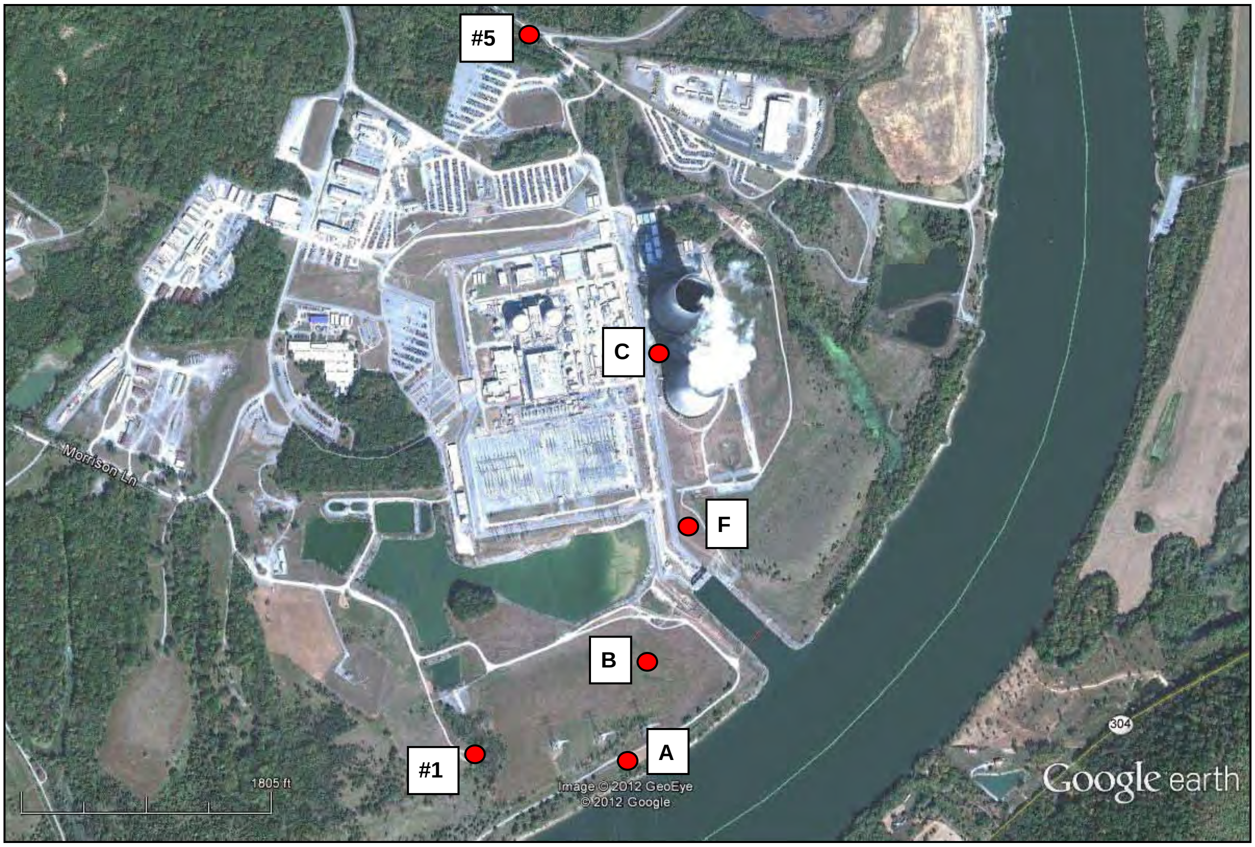

Figure 3-5. Approximate locations of groundwater monitoring wells (#5, #1, A, B, C, and F) used in tritium monitoring (Source of well locations: TVA 2011j).

3.1.5.2.3 Groundwater Use and Rights

As Table 3-7 shows, groundwater use in both the Watts Bar and Chickamauga Catchment Areas is minor in comparison to uses of surface water; groundwater use from these areas accounts for less than 0.1 percent and about 1.5 percent, respectively, of the total water use. In both areas, the primary use for groundwater is public water supplies. In the Chickamauga Catchment Area, groundwater use for public water supplies basically equals that of surface water.

The Watts Bar Utility District provides potable water to the Watts Bar site, which is in Rhea County. The water is from three wells about 2.5 miles northwest of the site (DOE 1999a). Private wells are common in rural areas that public water supply systems do not serve. However, in a 2005 report on rural water needs in Tennessee, the State estimated there were only 307 residences without water service in all of Rhea County and only 270 in all of Meigs County across the river from the plant.

Tennessee's groundwater law evolved from a doctrine called, among other names, the "rule of capture," which allowed landowners to withdraw an unlimited quantity of water from groundwater under their properties, regardless of injury to other landowners, unless it could be proven that the groundwater was part of an underground stream, in which case it was treated as a surface water for legal purposes. As with surface water, the law shifted to a "reasonable use rule" that restricted groundwater use to the overlying land and required that it be noninjurious to other landowners; groundwater became more like common property than private property. Actions that would change the character of groundwater would require an Aquatic Resource Alteration Permit as described above for surface-water actions (TACIR 2010).

3.1.5.3 Floodplains and Wetlands

3.1.5.3.1 Floodplains

Figure 3-6 is a segment from the Flood Insurance Rate Map from the Federal Emergency Management Agency for the area of the Watts Bar site. The reactor buildings are within the roughly square area (formed by road lines) in the center of the map portion of the figure. The map area with dark shading represents the extent of the water level under conditions of a 100-year flood (FEMA 2008). Because of the nature of the facility, TVA has performed detailed flood analyses for the site and identifies the water level of the 100-year flood as ranging from 697.3 feet above mean sea level at Tennessee River Mile 528.4 to 697.6 feet above mean sea level slightly farther upstream at River Mile 529.0 (TVA 2007a). (The site is between River Mile 528.0 and River Mile 528.6.) The “697” in the figure in the Tennessee River south of the site is the flood elevation at that location. The small areas on Figure 3-6 with lighter shading and designated as Zone X represent areas that would be covered by water in the event of a 500-year flood. TVA identifies specific water elevations for the 500-year flood as 701.1 feet above mean sea level at River Mile 528.4 and 701.4 feet at River Mile 529.0. In the area of the Watts Bar site, TVA uses the level of the 500-year flood to control residential and commercial development on TVA lands and, for TVA projects, to designate if a development should be considered flood damageable (TVA 2007a).

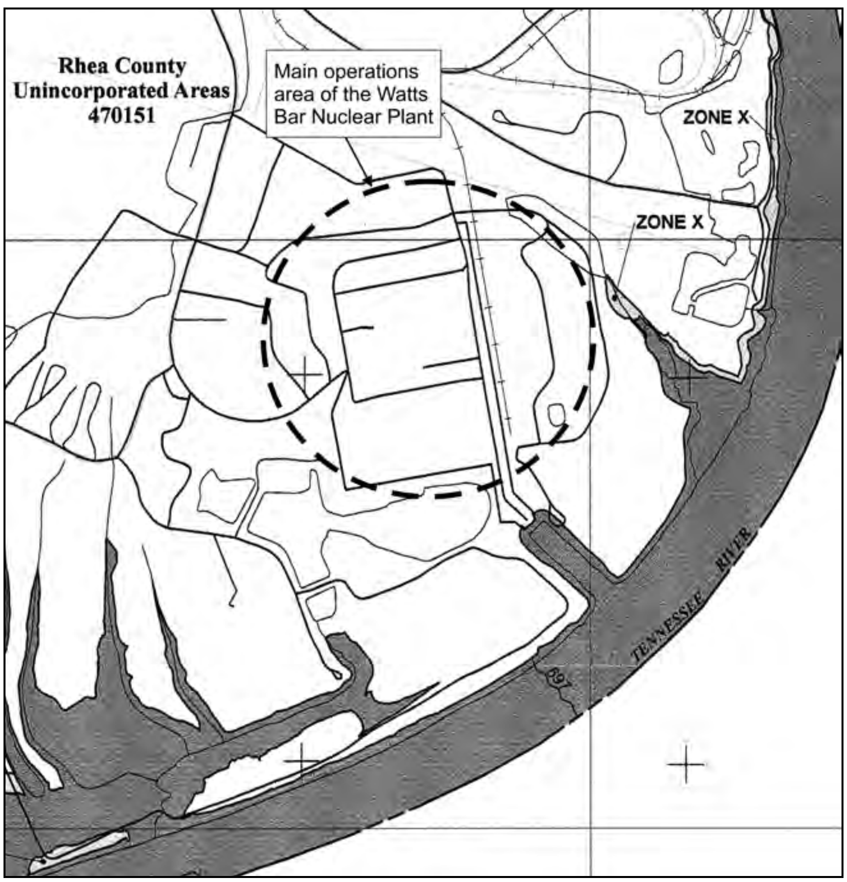

Figure 3-6. Segment from the Flood Insurance Rate Map for the area of the Watts Bar site (FEMA 2008).

Because Watts Bar is a nuclear facility, TVA has analyzed the potential effects of a probable maximum flood, which is defined as the most severe flood that can reasonably be predicted to occur at a site as a result of meteorological conditions and hydrologic factors of the specific watershed (TVA 2007a). Calculated flood levels for the probable maximum flood are higher than those for the 100- and 500-year floods on the Federal Emergency Management Agency map (Figure 3-6). TVA's ability to protect safety-related facilities, systems, and equipment at the site, and if necessary to shut down the plant, are evaluated against the much more rigorous standard of the probable maximum flood. That is, having facility locations, barriers, and procedures in place to prepare for and respond to the probable maximum flood level ensures protection from adverse impacts from lesser flood levels.

3.1.5.3.2 Wetlands

Figure 3-7 is from the U.S. Fish and Wildlife Service National Wetlands Inventory online mapper tool (http://www.fws.gov/wetlands/Data/Mapper.html). It shows potential wetlands near the Watts Bar site. These areas are described as forested wetlands, emergent wetlands that have developed in ash disposal sites, and emergent wetlands in containment ponds in the southwest portion of the site; scattered areas of fringe emergent wetlands along the shoreline of the site; and small areas of forested scrub-shrub, which are emergent wetlands along the streams on the site. A wetlands field survey in October 2006 identified a forested wetlands area next to the north side of the site between the road and the rail line (TVA 2007a). Figure 3-7 shows the approximate location of this 1-acre wetlands area.

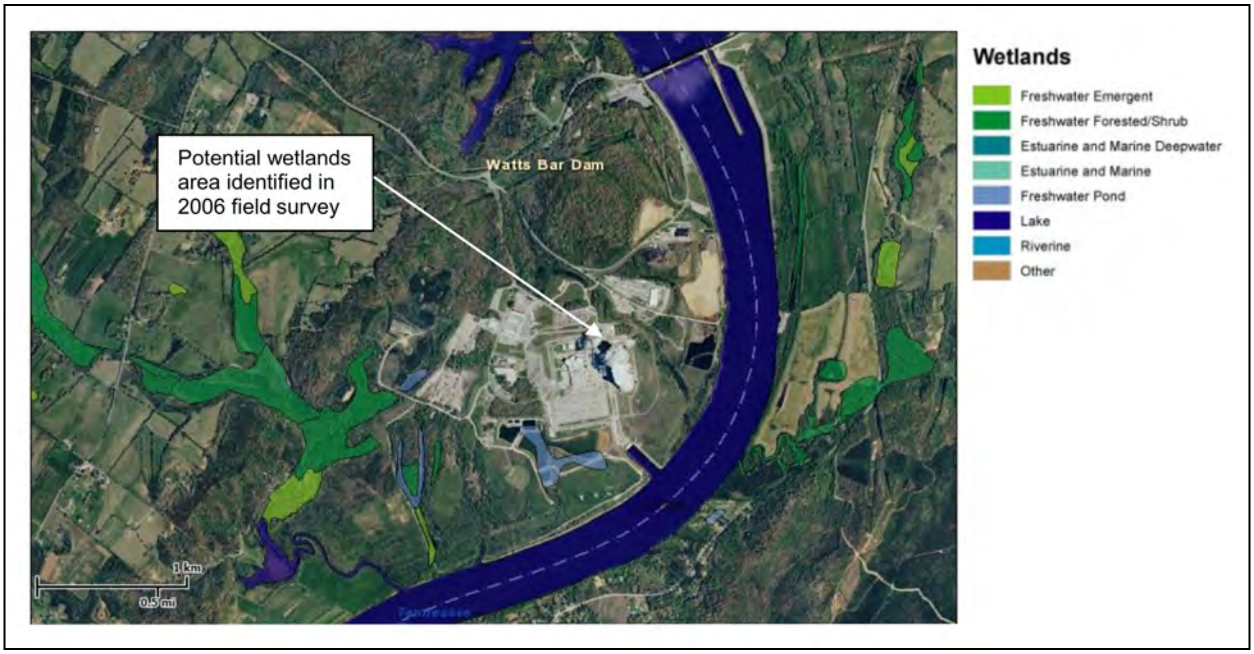

Figure 3-7. Potential wetlands areas on and near the Watts Bar site.

3.1.6 BIOLOGICAL RESOURCES

The Watts Bar site is in the Central Ridge and Valley Section of the Eastern Broadleaf Forest Physiographic Province (McNab et al. 2005). Prominent, southwest-northeast trending ridges and adjacent valleys characterize this Section, which lies between the Blue Ridge Mountains and the Cumberland Plateau. The Tennessee River flows through this Section, roughly paralleling the alignment of the valleys. The natural cover types consist of oak-hickory and oak-pine forests, although agricultural activities have had heavy impacts on the region. The TVA conversion of the Watts Bar site to an industrial site caused additional alterations.

There have been several reviews and evaluations of the biological resources, both terrestrial and aquatic, on the Watts Bar site during the construction and operation of the nuclear facilities. The first comprehensive environmental review occurred before construction of Watts Bar 1 (TVA 1972). Subsequent reviews occurred in 1993 and 1995 for the completion of Unit 1, in 1999 during the evaluation for tritium production at Watts Bar, in 2005 for the replacement of steam generators in Unit 1, and in 2007 for the completion and operation of Watts Bar 2 (NRC 1995; DOE 1999a; TVA 1993, 2005, 2007a). Monitoring of the operation of Watts Bar 1 has produced additional data, particularly on aquatic resources. These environmental reviews are the primary sources for information on biological resources.

3.1.6.1 Flora

The terrestrial plant communities of the Watts Bar site have changed very little over the past 40 years (TVA 2007a). The majority of the area (more than 70 percent) consists of herbaceous vegetation types that occur in old fields, gravel parking areas, roadside rights-of-way, and industrial sites. Deciduous forest and evergreen-deciduous forest cover about 30 percent of the site (TVA 2007a). The deciduous forest consists of oak-hickory forest and bottomland hardwood forest. Most of the remaining forested land lies to the west and southwest of the site. Common tree species include Virginia pine (*Pinus virginiana*), shortleaf pine (*P. echinata*), white oak (*Quercus alba*), post oak (*Q. stellata*), southern red oak (*Q. falcata*), black oak (*Q. velutina*), sweet gum (*Liquidambar styraciflua*), yellow poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), and a variety of hickories (*Carya* spp.) (TVA 1972). Common shrub and understory species include black gum (*Nyssa sylvatica*), Japanese honeysuckle (*Lonicera japonica*), flowering dogwood (*Cornus florida*), Carolina buckthorn (*Rhamnus caroliniana*), highbush blueberry (*Vaccinium corymbosum*), common hazel (*Corylus avellana*), and alder (*Alnus serrulata*) (TVA 1972, 2005). Past disturbances and available moisture influenced by soil characteristics determine the composition of the plant communities. For example, the evergreen-deciduous forest occurs on moist upland topographic sites with well-drained soils; Virginia pine, shortleaf pine, sweet gum, and oak dominate this forest. In contrast, sweet gum, black gum, and oak dominate moist bottomland sites that flood seasonally. Invasive species present on the Watts Bar site include Japanese stilt grass (*Microstegium vimineum*), Japanese honeysuckle (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), and Russian olive (*Elaeagnus angustifolia*) (TVA 2007a).

3.1.6.2 Fauna

The industrial facilities on the Watts Bar site have greatly modified wildlife habitats (TVA 2005, 2007a), but habitats have changed little from those described in earlier environmental reviews. However, because of access control for the nuclear plant, the remaining undisturbed habitat continues to support a variety of animal communities. Wildlife habitat on the site is contiguous with forested and agricultural lands along the Tennessee River. Game species in the vicinity of the site include white-tailed deer (*Odocoileus virginianus*), gray squirrel (*Sciurus carolinensis*), raccoon (*Procyon lotor*), wild turkey (*Meleagris gallopavo*), ruffed grouse (*Bonasa umbellus*), cottontail rabbit (*Sylvilagus floridanus*), and bobwhite quail (*Colinus virginianus*). Good squirrel populations occur in large stands of hardwoods, while raccoons and cottontail rabbits are most common in the wide rolling valleys between the ridges (DOE 1999a). Smaller mammals likely to occur in habitats on or adjacent to the Watts Bar site include a variety of rodents and carnivores. Hardwood and stream habitat adjacent to the Watts Bar site provide potential habitat for a variety of bat species including the little brown bat (*Myotis lucifugus*), big brown bat (*Eptesicus fuscus*) eastern red bat (*Lasiurus borealis*), hoary bat (*L. cinereus*), and eastern pipistrelle (*Pipistrellus subflavus*). The diverse habitats around the site also support varied and abundant populations of amphibians and reptiles including snakes, frogs, salamanders, and lizards.

The mixture of forest and open vegetation, and the proximity of wetlands and open water, create a variety of habitats for a diverse bird population. Some common year-round resident species include the crow

(*Corvus brachyrhynchos*), blue jay (*Cyanocitta cristata*), American kestrel (*Falco sparverius*), mourning dove (*Zenaida macroura*), screech owl (*Otus asio*), belted kingfisher (*Ceryle alcyon*), pileated woodpecker (*Dryocopus pileatus*), downy woodpecker (*Picoides pubescens*), tufted titmouse (*Baeolophus bicolor*), and field sparrow (*Spizella pusilla*) (TVA 1972). Other species that might be locally or seasonally common are the eastern meadowlark (*Sturnella magna*), American goldfinch (*Carduelis tristis*), eastern bluebird (*Sialia sialis*), and song sparrow (*Melospiza melodia*) (TVA 2007a). Observations of osprey (*Pandion heliaetus*) are common in the vicinity near lakes, reservoirs, and ponds. A variety of waterfowl including Canada geese (*Branta canadensis*) and mallards (*Anas platyrhynchos*) have been observed near ponds on the Watts Bar site and adjacent Yellow Creek area to the southwest. Although some shorebirds, spotted sandpiper (*Actitis macularia*), and killdeer (*Charadrius vociferus*), have been observed near settling ponds at the site, most ponds are lined with riprap and provide poor shorebird habitat.

3.1.6.3 Aquatic Environments

The Watts Bar site (at Tennessee River Mile 528) is along the riverine portion of Chickamauga Reservoir, about 2 miles downstream of Watts Bar Dam. The quality of the water at the Watts Bar 1 intake is generally satisfactory, but negatively influenced, particularly in summer and fall, by water releases from the Watts Bar Reservoir, 2 miles upstream (DOE 1999a). Water standing at the face (the forebay) of Watts Bar Dam becomes stratified, particularly in warmer weather and consequently becomes oxygen deficient. An aerator installed in the forebay of the Watts Bar Reservoir in 1996 reduced stratification and provided higher dissolved oxygen levels in reservoir releases. Other aquatic environments on or adjacent to the Watts Bar site include emergent wetlands, forested-shrub wetlands, and natural and manmade ponds (see Section 3.1.5.3.2).

The 1972 Final Environmental Impact Statement (TVA 1972) and later environmental reviews described the characteristics of the aquatic environment and biota in and around the Watts Bar site. Additional information is available from aquatic monitoring that has occurred during construction and operation of the Watts Bar facilities. The following sections identify relevant later reviews and additional information.

3.1.6.3.1 Plankton

Plankton communities consist of microscopic and macroscopic algae (phytoplankton) and animals (zooplankton, bacteria, and larval forms of free-living and sessile organisms). Similar to terrestrial vascular plants, planktonic algae use energy from the sun and elemental nutrients in the water to transform carbon dioxide into the organic material of their cells. These organisms provide the basis for the food web of aquatic systems and are the principal food of most of the zooplankton and some fish species. In general, plankton densities in the Chickamauga Reservoir increase from upstream to downstream under normal flow conditions (TVA 2011b). However, occasionally lower counts occur at the diffuser location; these are thought to be a result of the mixing of the plankton-rich upper and plankton-poor lower strata the diffuser action causes in warmer months, when stratification is evident in the reservoir, rather than a true reduction in plankton cells (TVA 2011b).

The water entering Chickamauga Reservoir through Watts Bar Dam contains a moderate concentration of suspended phytoplankton and zooplankton (TVA 1972). Recent studies indicate that the majority of planktonic organisms (including fish eggs, larval fish, microinvertebrates, algae, etc.) in the vicinity of the Watts Bar site originate in the Watts Bar Reservoir above Watts Bar Dam and pass through its turbines (TVA 2007a). Plankton density varies greatly from day to day. Sampling surveys from 1973 to 1985 indicate that plankton populations decrease rapidly as distance from Watts Bar Dam increases due to the swift-flowing riverine nature of the upper portions of Chickamauga Reservoir. In additional surveys to determine the hydrothermal effects on ichthyoplankton (fish eggs and larvae), TVA documented a decrease in population densities from above the Watts Bar Dam to Tennessee River Mile 528.0 (TVA 2011k). As water enters the reservoir pool of Chickamauga Reservoir (25 to 30 miles downstream of the Watts Bar site), velocities decrease and plankton densities gradually increase to levels comparable to those in the Watts Bar Dam forebay (TVA 2007a). Because the Watts Bar Dam influences the flow of water in the Tennessee River past the Watts Bar site, these observations continue to be valid (NRC 2011d).

Evaluation of the entrainment of ichthyoplankton during the first year of operation of Watts Bar 1 revealed the presence of only a few varieties at low densities (DOE 1999a). Eggs and larvae passing the Watts Bar 1 water intake are primarily spawned in the Watts Bar Reservoir and exposed to passage through the hydroelectric generation turbines at Watts Bar Dam. Collection of very few eggs or larvae of species known to spawn in tailwaters (the downstream side of the dam) indicates that most spawning in Chickamauga Reservoir occurs downstream of the Watts Bar site (DOE 1999a). TVA characterizes the entrainment of eggs and larvae at the Watts Bar 1 water intake as extremely low with seasonal estimates similar between historic sampling in 1996 (eggs 0.29% and larvae 0.57%) and recent sampling in 2010 (eggs 0.12% and larvae 0.40%) (TVA 2011l). These low levels are largely attributable to the small TVA use of the water (0.6 percent) that passes the site (TVA 1997).

3.1.6.3.2 Fish Communities

Fish community sampling results after Watts Bar 1 began operation were consistent with preoperational results (DOE 1999a). The slight differences were attributable to differences in the sample design. Data collections from 1977 to 1985 occurred on a monthly basis throughout the year, and those from 1990 to 1995 occurred only once during the fall of each year. Important species evaluated in the comparison of preoperational and operational conditions were largemouth bass (*Micropterus salmoides*), spotted bass (*M. punctulatus)*, redear sunfish (*Lepomis microlophus*), white bass (*Morone chrysops*), emerald shiner (*Notropis atherinoides*), common carp (*Cyprinus carpio*), brook silversides (*Labidesthes sicculus*), log perch (*Percina caprodes*), bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieui*), spotted sucker (*Minytrema melanops*), and yellow bass (*Morone mississippiensis*). A comparison of the first year's monitoring results with preoperational data indicated that operation of Watts Bar 1 has not adversely affected the tailwater fish population below Watts Bar Dam (DOE 1999a). Table 3-10 shows that subsequent monitoring through the Vital Signs Monitoring Program (Reservoir Fish Assemblage Index) has documented a consistent rating of "good" for the quality of the fish community in the vicinity of the Watts Bar site (TVA 2007a; Simmons 2010a). Before Watts Bar 1 operation (1993 to 1995), TVA collected 39 fish species at the Chickamauga Reservoir inflow station (River Mile 529), within the thermal discharge zone of the plant; during later years (1999 to 2009) TVA collected 45 fish species at this site (Simmons 2010a). Data from several sampling methods in the Chickamauga Reservoir from 1947 to 2009 resulted in the collection of 83 valid species records. The results were similar to the observed trends at the inflow station: some historical fish species were absent in more recent surveys and new native species have been recently sampled that were not historically present (Simmons 2010b). TVA samples have not contained 22 native species since the 1970s; since 2000, TVA has collected three new native and two nonnative species that it had not previously collected from the Chickamauga Reservoir (Simmons 2010b). The bluegill, gizzard shad, and redear sunfish tended to be consistently dominant in terms of numbers in the fish community below and above the dam (NRC 2011d).

Fish impingement on the Watts Bar 1 water intake traveling screens appears to have increased since a sampling effort in 1996 and 1997. Gizzard shad were predominant in the samples (60.4%) followed by threadfin shad (39.5%) and inland silverside (0.1%) in the 2010 and 2011 sampling period (TVA 2011m). The timing of this peak impingement period, January through March 2011, and species composition of impinged fish suggests stress and cold-shock was a factor. This is a commonly observed natural phenomenon during colder winter months at fossil and nuclear facilities in TVA and other southeastern

Table 3-10. Summary of Reservoir Fish Assemblage Index scores[a] directly upstream and downstream of the Watts Bar Nuclear Plant in the Chickamauga Reservoir, 1993 to 2009.

Station	Location	1993	1996	2000	2005	2009	1993–2009 average
WBN Upstream Forebay	TRM 531.0	44	43	44	46	45	**42**
WBN Downstream Inflow	TRM 529.0	52	42	44	42	44	**45**
Transition	TRM 490.5	51	44	46	46	41	**45**
Forebay	TRM 482.0	NR	47	48	39	37	**42**
Forebay	TRM 472.3	43	NR	45	46	42	**44**

Source: Simmons 2010a.

NR = not reported; TRM = Tennessee River Mile; WBN = Watts Bar Nuclear Plant.

a. Reservoir Fish Assemblage Index scores: 12–21 (very poor), 22–31 (poor), 32–40 (fair), 41–50 (good), 51–60 (excellent).

reservoirs (TVA 2011m). During the 2010 and 2011 sampling period, daily water temperatures were 1.4 to 3.2 degrees Fahrenheit cooler than the 1996 and 1997 sampling period, and the large and rapid decrease in water temperatures could have caused cold stress on the shad population and thereby increasing impingement.

Before 1978, fisheries biologists thought the tailwaters of Watts Bar Dam contained favorable spawning habitat for several species including sauger (*Stizostedion canadense*), smallmouth bass, white bass, and possibly yellow perch (*Perca flavescens*) (TVA 1972). However, the evaluation of information in the 1978 NRC EIS discounted this theory (NRC 1978). Since 1978, studies have confirmed that the reach between the Watts Bar Dam and the Watts Bar site is a staging area, not an area of significant spawning activity for these species (NRC 1995).

3.1.6.3.3 Aquatic Macrophytes

Aquatic plants in the Watts Bar Reservoir covered 10 acres during the late 1970s. Coverage increased to about 691 acres during the 1980s, but decreased back to the 1970s levels by the early 1990s (DOE 1999a). An extended drought in the mid- to late 1980s enhanced conditions for growth of aquatic macrophytes. A return to more normal rainfall and runoff conditions resulted in a return to early 1980s densities. Eurasian watermilfoil (*Myriophyllum spicatum*) and spiny-leafed naiad (*Najas minor*) remain the dominant species. Populations of aquatic macrophyte species in the Chickamauga Reservoir fluctuated similarly over the same period, primarily in response to river flow conditions (NRC 1995). Aquatic macrophytes have difficulty establishing in the faster current velocity near the Watts Bar site and, therefore, have not caused nuisance problems (TVA 2007a).

3.1.6.3.4 Mussel and Clam Communities

A relatively diverse native mussel community inhabits the Tennessee River downstream from Watts Bar Dam. Sampling in the 1990s indicated that 31 species are present; however, the 5 most abundant species account for 90 percent of the total (DOE 1999a). Many of the mussels in this part of the river are quite old, and most species might not have reproduced successfully in the last 30 or more years (DOE 1999a). Surveys along three reaches of the Tennessee River in the vicinity of the Watt Bar Nuclear Plant documented 17 species of which four of the species appear to have recruitment (recruitment occurs when juvenile organisms survive to be added to a population) (Third Rock Consultants 2010). The long-term trend is a reduction in abundance and species richness (NRC 1995). The State of Tennessee has designated the 9.9-mile reach of the river from Watts Bar Dam (River Mile 529.9) downstream to Hunter Shoal (River Mile 520) as a mollusk sanctuary. In addition to the native mussels, a large population of the Asiatic clam (*Corbicula fluminea*) and an increasing population of the zebra mussel (*Dreissena polymorpha*) inhabit this part of the river. The Asiatic clam has been present in the Watts Bar Dam tailwater for at least 25 years, but TVA first found the zebra mussel there in 1993 (TVA 1997).

TVA began a program for systematic monitoring of the ecological condition of its reservoirs in the early 1990s. One aspect of this program is the benthic index that assesses the quality of the benthic communities. Since the initiation of this program, the quality of the benthic community near the Watts Bar site has remained relatively constant (TVA 2007a). The riverine tailwater reach downstream of the site was rated good in 2001 and excellent from 2003 to 2005 (TVA 2007a). The program has documented an average number of 6.8 taxa in the Watts Bar site vicinity (River Mile 527.4) with two taxa making up 75 percent of the total abundance (TVA 2007a).

3.1.6.4 Special-Status Species

Under the provisions of Section 7 of the *Endangered Species Act of 1973* [16 U.S.C. § 1536(a)(2)], Federal agencies must ensure that any action authorized, funded, or carried out by an agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat.

Special-Status Species

This section focuses on special-status species. For this project, those include Federally listed threatened, endangered, and candidate species as well as species the State of Tennessee recognizes as of special concern in the area of the proposed project.

The U.S. Fish and Wildlife Service and the State of Tennessee list several terrestrial and aquatic species that occur in the vicinity of the Watts Bar site as endangered, threatened, or candidates for listing as endangered or threatened (Table 3-11). The Biological Assessment in the 1995 NRC Final EIS (NRC 1995), which is incorporated here by reference, described the status and biology of Federally listed species in the vicinity of the site. The NRC concluded in the Biological Assessment, and the Fish and Wildlife Service concurred in its Biological Opinion, that the commercial operation of Watts Bar 1 would have no effect on Federally listed species. Several later environmental reviews (DOE 1999a; TVA 2005, 2007a; Third Rock Consultants 2010) evaluated threatened and endangered species (Federal and State) in the vicinity of the site with similar conclusions of no effects on listed species.

Table 3-11. Federally and state-listed threatened and endangered animal species potentially on or near the Watts Bar site (Rhea and Meigs Counties).

Common name	Scientific name	Federal	State
Mollusks			
Dromedary pearlymussel	*Dromus dromas*	Endangered	Endangered
Pink mucket	*Lampsilis abrupta*	Endangered	Endangered
Rough pigtoe	*Pleurobema plenum*	Endangered	Endangered
Fanshell	*Cyprogenia stegaria*	Endangered	Endangered
Orangefoot pimpleback	*Plethobasus cooperianus*	Endangered	Endangered
Sheepnose	*Plethobasus cyphyus*	Endangered	
Fish			
Blue sucker	*Cyprogenia stegaria*	Not listed	Threatened
Snail darter	*Percina tanasi*	Threatened	Threatened
Spotfin chub	*Erimonax monachus*	Threatened	Candidate
Laurel dance	*Phoxinus saylori*	Endangered	
Reptiles			
Northern pinesnake	*Pituophis melanoleucus*	Not listed	Threatened
Birds			
Bald eagle	*Haliaeetus leucocephalus*	Recovery	Threatened
Osprey	*Pandion haliaetus*	Not listed	Threatened
Bachman's sparrow	*Aimophila aestivalis*	Not listed	Endangered
Mammals			
Gray bat	*Myotis grisescens*	Endangered	Endangered
Indiana bat	*Myotis sodalis*	Endangered	Endangered

Sources: NRC 1995; DOE 1999a; TVA 2005, 2007a; TDEC 2011d; USFWS 2012a, 2012b.

3.1.6.4.1 Aquatic Animals

Nine aquatic species that occur in the Tennessee River near the Watts Bar site are on the Federal list of endangered or threatened wildlife (Table 3-11). Six of these are endangered mussel species, of which four (dromedary pearlymussel, pink mucket, rough pigtoe, and fanshell) occur in mussel beds in the vicinity of the site (TVA 2007a). The others are fish species—the threatened snail darter, the threatened spotfin chub, and the endangered laurel dance. The snail darter occurs downstream of Watts Bar Dam (CBD 2011). To protect the mussel beds, the State has established a mussel sanctuary extending almost 10 miles from River Mile 520 to River Mile 529.9. Figure 3-8 shows the location of the mussel sanctuary in relation to the Watts Bar site (TVA 2007a).

Figure 3-8. Location of mussel sanctuary in Chickamauga Reservoir below Watts Bar Dam (Source: TVA 2007a).

Mollusk surveys downriver of the Watts Bar site documented two Federally listed endangered species, the pink mucket and sheepnose mussel, and one candidate species, the bullhead (*Plethobasus cyphyus*), in a 2010 study (Third Rock Consultants 2010). Preimpoundment surveys of nearby portions of the Tennessee River found three other aquatic species, all Federally listed as endangered. These species are the birdwing pearlymussel (*Conradilla caelata*), white wartyback pearlymussel (*Plethobasus cicatricosus*), and the Cumberland monkeyface pearlymussel (*Quadrula intermedia*). They inhabit gravel riffles in medium to large rivers and have not been found in the Watts Bar tailwater or in Chickamauga Reservoir for 25 years; they are not listed in Rhea or Meigs County. In addition to the Federally listed species, the State of Tennessee lists the blue sucker as a threatened species (TVA 2005, 2007a).

3.1.6.4.2 Terrestrial Animals

The U.S. Fish and Wildlife Service delisted bald eagles in 2007 in the lower 48 states under the Endangered Species Act because of recovery throughout its range. Bald eagles visit the Watts Bar site during the winter, where they roost on trees near the reservoirs and forage for fish. The nearest reported eagle nest is about 4 miles south-southwest of the plant. Eagles first used this nest site in 1994; it has been inactive since 1996 (DOE 1999a). At least five bald eagle nests occur in the vicinity of Watts Bar along the Tennessee River, within 10 miles of the site, but no nests have been reported recently closer than 2 miles from the facility (Somershoe 2012).

Gray bats roost in caves throughout the year and feed primarily over water on adult insects. Small numbers (fewer than 500) of gray bats continue to roost in a cave about 3.3 miles from the site (TVA 2007a). Because of frequent human visitation, bats do not regularly occupy this cave. In addition, gray bats have occurred in three other caves between 10 and 20 miles from the site; at present, they regularly occupy only one of these caves. Gray bats might forage over the reservoir adjacent to and downstream from the site. Indiana bats hibernate in caves or abandoned mines, often in large groups, from October through April. Summer habitat consists of wooded areas where bats roost under loose bark of dying or dead trees as well as forage for insects in areas along rivers or lakes and in uplands. The Indiana bat hibernates in caves in other areas of eastern Tennessee and in northeast Alabama, and periodic sightings occur in riparian forests along the Chickamauga Reservoir. Limited maternal colony habitat occurs at the site, and there have been no documented occurrences of the species at the Watts Bar site (LeGrand 2012).

The State of Tennessee lists the osprey as threatened. Ospreys feed primarily on fish and regularly occur along the Tennessee River adjacent to the Watts Bar site (NRC 1995). In addition, ospreys have recently nested in the immediate vicinity of Watts Bar Reservoir (Osprey Watch 2012).

3.1.6.4.3 Terrestrial Plants

There are no reports of Federally or State-listed plants on or in the immediate vicinity of the Watts Bar site (DOE 1999a; TVA 2005, 2007a). Six state-listed species occur within 5 miles of the site (Table 3-12). In addition, there are no known designated critical habitats for plant species within 5 miles of the site or in Rhea County (TVA 2007a).

Table 3-12. State-listed plant species reported within 5 miles of the Watts Bar site.

Common name	Scientific name	State status	Habitat description
Appalachian bugbane	*Cimicifuga rubrifolia*	Threatened	Rich woods
Heavy sedge	*Carex gravida*	Special concern	Rocky river bluffs
Prairie goldenrod	*Solidago ptarmicoides*	Endangered	Barrens
Northern bush honeysuckle	*Diervilla lonicera*	Threatened	Rocky woodlands and bluffs
Spreading false foxglove	*Aureolaria patula*	Threatened	Oak woods and edges
Slender blazing star	*Liatris cylindracea*	Threatened	Barrens

Source: TVA 2007a.

3.1.7 CULTURAL RESOURCES

Historic Preservation

Cultural resources are archaeological sites, historic structures and objects, and traditional cultural properties. Historic properties are cultural resources that are listed in or eligible for listing in the *National Register of Historic Places* because they meet one or more criteria and retain integrity (36 CFR § 60.4). Section 106 of the *National Historic Preservation Act* (16 U.S.C. §§ 470 *et seq.*) requires that Federal agencies take into account the effects of their actions on historic properties. Section 101(b)(4) of the

> **National Register**
>
> The *National Register of Historic Places* is the official listing of historic resources established and maintained by the Federal government to foster the preservation of particular cultural resources.

National Environmental Policy Act of 1969 (42 U.S.C. §§ 4321 *et seq*.) requires Federal agencies to coordinate and plan their actions to identify unique historic or cultural characteristics of the geographic area (40 CFR § 1508.27) of the proposed project and act accordingly. The first step of the process is for an agency to determine if an action is an "undertaking" (36 CFR § 800.3(a)). The proposed action in this SEIS is an undertaking because it is "a project, activity, or program funding in whole or in part under the direct or indirect jurisdiction of a Federal agency, including those carried out by or on behalf of a Federal agency; those carried out with Federal financial assistance; and those requiring a Federal permit, license, or approval" (36 CFR § 800.16(y)).

The regulations at 36 CFR Part 800, "Protection of Historic Properties," describe the process for compliance with Section 106 of the *National Historic Preservation Act*, including defining the area of potential effect, steps to identify resources and evaluate effects, and consultation with interested parties including the State Historic Preservation Officer and other concerned parties. The regulations state, "If the undertaking is a type of activity that does not have the potential to cause effects on historic properties, assuming such historic properties are present, the agency official has no further obligations under section 106, or this part" (36 CFR § 800.3(a)(1)). By definition, an "effect" is an "alteration to the characteristics of a historic property qualifying it for inclusion in or eligibility for the National Register" (36 CFR § 800.16(i)).

According to regulations on the protection of historic properties (36 CFR § 800.5(a)(2)(v)), an adverse effect can include "introduction of visual, atmospheric, or audible elements that diminish the integrity of the property's significant historic features." A project can have adverse visual effects by involving either a negative aesthetic or obstructive effect on historic properties. An obstructive effect is one that diminishes the historic property's integrity by blocking the property from view or by blocking the view from the property.

Background of the Tennessee River Valley

It is likely that people have inhabited the area encompassing the Tennessee River Valley, including the Watts Bar and Sequoyah sites, continuously for at least 12,000 years. Archaeological investigations over the past 150 years and records for the Tennessee River Valley document four major prehistoric occupational periods with some overlap of cultural markers: the Paleo-Indian from 10,500 to 8000 B.C., the Archaic from 8000 to 600 B.C., the Woodland from 1000 B.C. to 1000 A.D., and the Mississippian from 1000 to 1600 A.D. (TVA 2011b).

As Euro-American settlers moved westward across Tennessee in the late 18th and early 19th centuries, the many mounds and earthworks they encountered became a focus of speculative interpretation. By the 1870s, more systematic excavations clearly demonstrated that American Indians constructed mounds and villages and that the occupants might have been ancestors of historic tribes of the Southeast. Several mounds in the Tennessee River Valley, including areas in the vicinity of the Watts Bar and Sequoyah sites, are associated with human burials. After European contact and settlement, much of the river valley and surrounding areas was used for timber harvesting and agriculture. With the creation of the Tennessee Valley Authority in 1933, an extensive archaeological recovery program using Federal relief workers in valleys to be inundated for TVA projects dramatically increased knowledge of the prehistoric American Indian presence (TVA 2011b).

Historic and Cultural Resources at the Watts Bar Site

The area of potential effect for the proposed action is that within the Watts Bar site boundary. During the development, construction, and operation of the Watts Bar Nuclear Plant, several environmental reviews have considered the potential for impacts to historic and archaeological resources at the plant site. There are four archaeological sites in this area (40RH6, 40RH7, 40RH8, and 40RH64). The Watts Bar Basin Survey identified the first three sites in the mid-1930s, and a survey of the reservoir after inundation recorded the fourth. Early in the history of the plant, surveys determined plant construction would adversely affect two of the sites (40RH6 and 40RH7) and resulted in a decision to conduct data recovery (TVA 2007a). While portions of the sites have been excavated, all four remain eligible or potentially eligible for listing in the National Register (TVA 2007a). It should be noted that the Tennessee State Historic Preservation Office determined that tritium production at Watts Bar would have no effect upon properties listed or eligible for listing in the National Register (DOE 1999a).

The historic Leuty Cemetery was located on the site before plant construction; two graves were removed in 1974 and placed in another local cemetery northwest of the site (TVA 2007a). The Watts Bar Fossil Plant was adjacent to the Watts Bar Nuclear Plant Site. TVA built the fossil plant in the 1940s, originally the Watts Bar Steam Plant and the first of the TVA coal-fired power plants, and operated it until 1957. TVA restarted the plant in 1970 and operated it until 1982, then again ceased operations. In a 1998 review of the Watts Bar Nuclear Plant for condenser unit upgrades (TVA 1998), TVA determined that the Watts Bar Fossil Plant was eligible for listing in the National Register. However, TVA determined in a 2011 environmental assessment that the plant and some associated structures were deteriorating, that some structures had been dismantled, and that the brick exterior walls of the plant were distressed and likely to collapse without extensive refurbishment. In addition, the fossil plant contained environmental hazards including asbestos, lead, mercury, and polychlorinated biphenyls (TVA 2011d). TVA dismantled the Watts Bar Fossil Plant in 2011 (Brickhouse 2012).

Although a majority of the area of potential effect has experienced extensive disturbance over the years from plant construction, maintenance, and upgrades, the cultural resource literature for the region and along the river valley (TVA 2007a, 2011b) indicates a strong potential for additional unidentified archaeological resources on the site, especially in undisturbed areas.

TVA has conducted interactions and consultations for a variety of undertakings with 14 American Indian tribes and groups that have cultural ties or interests in the Watts Bar site and surrounding region. These tribes and groups include the Cherokee Nation, Eastern Band of Cherokee Indians, United Keetoowah Band of Cherokee Indians in Oklahoma, The Chickasaw Nation, Muscogee (Creek) Nation of Oklahoma, Alabama-Coushatta Tribe of Texas, Alabama-Quassarte Tribal Town, Kialegee Tribal Town, Thlopthlocco Tribal Town, Seminole Tribe of Florida, Choctaw Nation of Oklahoma, Absentee Shawnee Tribe of Oklahoma, Eastern Shawnee Tribe of Oklahoma, and Shawnee Tribe of Oklahoma (TVA 2007a, 2011b). A letter requesting tribal participation and input in this SEIS was sent to the 14 tribal organizations in January 2013.

3.1.8 INFRASTRUCTURE AND UTILITIES

Electricity

The Watts Bar site includes one currently operating reactor (Watts Bar 1) capable of producing about 1,200 megawatts of electricity (TVA 2012). Once Watts Bar 2 becomes operational, it would have a similar electrical output as Watts Bar 1.

Water

The Watts Bar site used about 52.1 million gallons of potable water in 2010 (TVA 2012). The site takes in raw water from the bank of the Chickamauga Reservoir and transfers used water to holding tanks before releasing it back to the reservoir. TVA transports potable water to support facilities not connected to the potable water system.

Steam

At full output, Watts Bar 1 produces about 15.1 million pounds of steam per hour (TVA 2012). Once Watts Bar 2 becomes operational, it would have a similar steam output as Watts Bar 1.

Sanitary Sewer

The Watts Bar site is connected to the municipal sewer system in Spring City, Tennessee. The municipality has sufficient capacity to handle the effluent from the plant (TVA 2012).

Industrial Gas

Large-volume industrial gases (more than 10,000 pounds) at the Watts Bar site include the following (TVA 2012):

- Carbon dioxide for fire protection systems and for generator purge during outages (about 60,000 pounds),

- Nitrogen as a cover gas for the cold-leg accumulators, in radioactive waste, and in other locations (about 21,000 pounds), and

- Refrigerants including R-22, R-12, R-11, R-502, and possibly others (about 35,000 pounds).

Smaller volumes of gases include the following (TVA 2012):

- Hydrogen for generator cooling (about 800 to 1,000 pounds),
- Propane for the meteorological tower backup generator (about 4,000 pounds), and
- Acetylene, argon, and oxygen for welding (no estimate available).

3.1.9 SOCIOECONOMICS

Watts Bar is near the Town of Spring City in Rhea County in eastern Tennessee. Spring City is about 17 miles northeast of Dayton, Tennessee, and 50 miles northeast of Chattanooga, Tennessee. Highway access to Spring City is by U.S. Highway 27 (US 27) and nearby State Route 68 (SR 68). US 27 links the town to Dayton (the Rhea County seat) and SR 68, both to the south; to Chattanooga in the southwest; and to Interstate Highway 40 (I-40), about 25 miles north. SR 68 links Spring City to I-75.

> **Socioeconomics**
>
> The study of the interrelation between social and economic factors. For analysis under the *National Environmental Policy Act of 1969* (NEPA), these factors include income, employment, housing, community services, education, public safety, and health care.

Demography

The socioeconomic region of influence is Meigs and Rhea Counties, Tennessee. Meigs County is just east of Rhea County; the two counties are defined by the Tennessee River. In 2010, about 1.2 million people lived within 50 miles of the Watts Bar site (USCB 2012). About 76 percent of the jobs in Rhea County are held by residents of Rhea or Meigs County (USCB 2003). The region of influence had an estimated overall population of about 43,600 in 2010, an increase of about 4,100 or 10.4 percent since 2000 (USCB 2000a, 2011a, 2011b). In 2010, the population per square land mile was 85, about half the density of the State of Tennessee (USCB 2011a, 2011b). The number of households in the region was about 17,000 in 2010, while the number of families was about 12,100 (USCB 2010a, 2010b). Table 3-13 lists general demographic characteristics data for the two counties, the region of influence as aggregate and, for comparison, Tennessee.

Table 3-13. General demographic characteristics in Meigs County, Rhea County, and Tennessee, 2010.

Demographic measure	Meigs County	Rhea County	Totals	Tennessee
Population, 2010	11,753	31,809	43,562	6,346,105
Percent change from 2000	6.0%	12.0%	10.4%	11.5%
Families	3,386	8,680	12,066	1,679,177
Households	4,686	12,276	16,962	2,493,552
Male	5,847	15,568	21,415	3,093,504
Female	5,906	16,241	22,147	3,252,601

Sources: USCB 2000a, 2010a, 2010b, 2010o, 2011a, 2011b.

For Spring City, the 2010 population of 1,981 represents a decrease of 44 or 2.2 percent, from 2000 and a small decrease from the 1990 count of 2,199 (USCB 1990, 2000a, 2010c, 2011c). The population in the region of influence is projected to continue growing. The projected population will be about 47,800 in 2020, 50,400 in 2030, and 52,000 in 2040 (CBER 2012). The decennial rates of growth, 9.7, 5.4, and 3.3 percent, respectively, are well below the projected rate of growth in the State by about 3 percent for 2030 and 2040. For 2020, the projected region of influence population is greater than the projected rate of growth in the State (CBER 2012).

Income

Total personal income in the region of influence was $1,102 million in 2009, up from $770 million in 2000 (BEA 2011a). Rhea County is the larger contributor with $795.1 million in personal income in 2009.

Per capita personal income in Meigs County ($25, 404) was slightly higher than in Rhea County ($25,228) in 2009, both about 75 percent of the state per capita personal income of $34,277. Median family income and median household income were also notably smaller than the statewide level. The 2009 median value of an owner-occupied house in Meigs County and Rhea County were similar, differing by less than 10 percent. Table 3-14 summarizes income data for the region of influence and, for comparison, Tennessee.

Table 3-14. Income and housing value[a] data for Meigs County, Rhea County, and Tennessee, 2009.

Characteristics	Meigs County	Rhea County	Tennessee
Per capita personal income	$25,404	$25,228	$34,277
Median household income	$32,096	$34,830	$42,943
Median family income	$43,938	$40,160	$52,910
Median housing value[b]	$106,700	$99,100	$128,500

Sources: BEA 2011a, 2011b, 2011c; USCB 2010d, 2010e, 2010f.

a. Owner-occupied units.

b. 2009 inflation adjusted values.

Employment

Employment by sector over the last decade has changed slightly, as shown in Table 3-15. In 2009, the manufacturing, government and government enterprises, retail trade, and administrative and waste management industries were the region on influence’s largest employment sectors. Despite a shift in employment since 2001, the manufacturing industry remains an important source of employment in the region of influence accounting for nearly 21 percent of employment in 2009, a decrease of about 8 percent. Government and government enterprise accounted for 16 percent of all jobs in 2009, an increase of 1 percent. Retail trade accounted for nearly 10 percent of all jobs in 2009, an increase of 1 percent from 2001. The administrative and waste management industry accounted for nearly 5 percent of all jobs in 2009.

Table 3-15. Employment by sector (number of jobs).

Industry sector	Meigs County		Rhea County		ROI	
	2001	2009	2001	2009	2001	2009
Total employment	5,308	6,060	13,742	13,994	19,050	20,054
Farm employment	385	335	506	421	891	756
Forestry, fishing, and related activities	(a)	(a)	95	(a)	(a)	(a)
Mining	(a)	30	40	52	(a)	82
Utilities	(a)	(a)	(a)	(a)	(a)	(a)
Construction	722	(a)	767	1,077	1,489	(a)
Manufacturing	785	726	4,804	3,472	5,589	4,198
Wholesale trade	92	(a)	81	112	173	(a)
Retail trade	568	598	1,141	1,354	1,709	1,952
Transportation and warehousing	(a)	(a)	(a)	(a)	(a)	(a)
Information	26	(a)	52	80	78	(a)
Finance and insurance	(a)	(a)	233	299	(a)	(a)
Real estate and rental and leasing	(a)	(a)	261	404	(a)	(a)
Professional, scientific, and technical services	187	(a)	279	(a)	466	(a)
Management of companies and enterprises	(a)	(a)	0	(a)	(a)	(a)
Administrative and waste management services	(a)	453	275	503	(a)	956
Educational services	25	55	(a)	(a)	(a)	(a)
Health care and social assistance	149	284	(a)	(a)	(a)	(a)
Arts, entertainment, and recreation	(a)	(a)	84	109	(a)	(a)
Accommodation and food services	(a)	(a)	816	724	(a)	(a)
Other services, except public administration	582	(a)	747	874	1,329	(a)
Government and government enterprises	474	511	2,407	2,728	2,881	3,239

Sources: BEA 2011b, 2011c.
ROI = region of influence
a. Not listed to avoid disclosure of confidential information, but the estimates for this item are included in the total employment numbers.

The number of jobs in the region of influence has grown by 5.7 percent since 2001. Since 2001, the rate of growth in the number of jobs in the region, particularly in Rhea County, has lagged behind the rate of growth in the population. The current rate suggests an ample-sized labor pool of people available for work. Table 3-16 lists information about the unemployment rate in the region and, for comparison, Tennessee and national unemployment rates.

Table 3-16. Unemployment rates in Meigs County, Rhea County, Tennessee, and the United States, June 2007 to June 2011.

Period	Meigs County	Rhea County	ROI	Tennessee	United States
June 2007	6.2	5.8	5.9	4.8	4.7
June 2008	8.8	8.4	8.5	6.8	5.7
June 2009	15.5	14.7	14.9	11.3	9.7
June 2010	12.5	12.9	12.8	9.7	9.6
June 2011	13.2	13.4	13.4	10.2	9.3

Sources: BLS 2011a, 2011b.
ROI = region of influence.

Housing

The region of influence has about 19,500 housing units. The housing vacancy rate in the region is a relatively high 15.8 percent. Rental units make up about 30 percent of the occupied units. Table 3-17 contains data about housing characteristics in the region and, for comparison, Tennessee.

Table 3-17. Housing characteristics in Meigs County, Rhea County, and Tennessee, 2009.

Characteristic	Meigs County	Rhea County	ROI	Tennessee
Total housing units	5,698	13,777	19,475	2,721,019
Occupied units	4,656	11,747	16,403	2,412,567
Owner-occupied	3,576	8,713	12,289	1,682,052
Renter-occupied	1,080	3,034	4,114	730,515
Vacant units	1,042	2,030	3,072	308,452
Percent vacant units	18.3%	14.7%	15.8%	11.3%

Sources: USCB 2010d, 2010e, 2010f.
ROI = region of influence.

Community Services

NNSA examined education, public safety, and health care to determine the level of community services for the region of influence:

- Education. During the 2009–2010 school year, there were 7,012 children in public schools in the three school districts in the region of influence. Meigs County School District had 1,913 students in four schools (NCES 2011a), the Dayton School District in Rhea County had 777 students in one school, and the Rhea County School District had 4,322 students in six schools (NCES 2011b). The State of Tennessee had an average pupil-to-teacher ratio of 15 to 1; the Meigs County ratio was 15.1 to 1; Dayton was 14.3 to 1; and Rhea County School District was 14.7 to 1 (NCES 2011c).

- Public safety. Four municipal (Decatur, Dayton, Graysville, and Spring City Police Departments) and two county law enforcement agencies provide police protection to residents in the region of influence (USACOPS 2012). The average officer-to-population ratio is 2.3 to 1,000 residents (FBI 2010a, 2010b; USCB 2011a, 2011b). Volunteer firefighters are the primary providers of fire protection services in the communities of the region. The Dayton Fire Department employs paid firefighters. The ratio of firefighters to the population is 7.6 to 1,000 (USFA 2011; USCB 2010g, 2010h).

- Health care. The region of influence includes one general/surgical hospital with 114 staffed beds. The hospital operates well below capacity (AHA 2006).

3.1.10 WASTE AND SPENT NUCLEAR FUEL MANAGEMENT

Activities at the Watts Bar site generate wastes from normal reactor operations. The wastes fall into three broad categories: hazardous, nonhazardous, and low-level radioactive waste. The site generates no high-level radioactive waste as defined by the *Nuclear Waste Policy Act of 1982* (42 U.S.C. §§ 10101 *et seq.*). Table 3-18 summarizes the annual amount of waste Watts Bar generates. The data in the table reflect actual wastes from Watts Bar 1 and expected wastes from Watts Bar 2, once that plant begins operation.

Table 3-18. Annual waste generation at the Watts Bar site.

Category	Amount
Hazardous waste	9,059 pounds
Nonhazardous solid waste	1,882 tons
Low-level radioactive waste	11,060 cubic feet

Source: TVA 2012.

Hazardous Waste

Hazardous wastes at the Watts Bar site typically include paints, solvents, acids, oils, radiographic film and development chemicals, and degreasers. Neutralization is the only waste treatment TVA performs on site. The site normally stores hazardous wastes in polyethylene containment systems during accumulation. TVA uses an approved storage building for hazardous wastes for 90 or 180 days, depending on the generator status at the time (that is, small-quantity or large-quantity hazardous waste generator). TVA transports this waste to an offsite hazardous waste storage facility for disposal before it exceeds the 90- or 180-day storage limit.

Nonhazardous Waste

Nonhazardous wastes at the Watts Bar site typically include construction materials, municipal solid waste (that is, paper, plastics, garbage, and other items), and sanitary wastes. With the exception of sanitary wastes, TVA sends nonhazardous wastes to a permitted offsite disposal facility. The Town of Spring City manages sanitary waste in its waste treatment system.

Low-Level Radioactive Waste

During the fission process, radioactive fission and activation products build up in the reactor (in the fuel and the structural materials). A small fraction of these materials escape and contaminate the reactor coolant. The gaseous waste processing system removes fission product gases from the Nuclear Steam Supply System with periodic discharges of small quantities of gases through the monitored plant vent.

TVA handles solid low-level radioactive waste from the operation of Watts Bar through a Solid Radwaste Disposal System that processes and packages dry and wet waste for offsite shipment and disposal. Dry waste consists of compactable and uncompactable material. Contaminated protective clothing, paper, rags, glassware, compactable and uncompactable trash, and reactor components and equipment constitute most of the solid low-level waste at Watts Bar. Uncompactable wastes include tools, pumps, motors, valves, piping, and other large radioactive components. Wet wastes consist of spent resins and filters. Table 3-19 lists the categories and amounts of low-level waste the Watts Bar site generates.

Waste Types

Hazardous waste:
Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment. Hazardous wastes appear on special EPA lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity (40 CFR 261.3).

Nonhazardous waste:
Nonhazardous waste consists of materials that are neither radioactive nor hazardous. Examples include normal household garbage, sanitary waste, and construction waste (EPA 2012).

Low-level radioactive waste:
Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. Low-level radioactive waste includes personal protective clothing, air filters, solids from the liquid low-level waste treatment process, and radiological control and survey waste (10 CFR 62.2).

Table 3-19. Annual low-level radioactive waste generation at the Watts Bar site.

Waste type	Amount (cubic feet)
Spent resins and filter sludges	720
Filter cartridges	240
Compactable and uncompactable trash	10,000
Contaminated oil	100
Total	**11,060**

Source: TVA 2007a.

Low-level radioactive waste is classified as A, B, or C, with Class A being the least hazardous and Class C being the most hazardous. Class A includes dry and wet active waste. Classes B and C are normally wet waste. Units 1 and 2 will share the Solid Radwaste Disposal System. The sharing will not inhibit the safe shutdown of one unit if the other unit experiences an accident. TVA transports its Class A low-level waste to the Energy Solutions licensed disposal facility in Clive, Utah. It ships Class B and C low-level waste to the Sequoyah site for storage in the waste vault.

Waste Minimization Practices

The Watts Bar site has an active waste minimization program with the following practices:

- Salvaging useful portions of construction and demolition materials for resale.
- Maintaining segregated storage areas for each type of recoverable material.
- Selling scrap treated lumber or placing it in dumpsters for disposal by the solid waste disposal contractor at an offsite permitted landfill.
- Collecting inert construction and demolition wastes for disposal at the onsite permitted landfill.
- Placing waste paper in bins or dumpsters and selling it to an offsite recycling facility.
- Recycling and selling aluminum cans.
- Placing nonrecoverable solid wastes in dumpsters for disposal by the solid waste disposal contractor.
- Collecting and storing special wastes (for example, desiccants, oily wastes, insulation) and then disposing of them by incineration.
- Sending asbestos to an approved special waste landfill for disposal.
- Collecting and storing used oil, fluorescent tubes, and antifreeze in drums and tanks and recycling them.
- Collecting medical wastes and disposing of them in accordance with the medical waste disposal procedure for TVA medical facilities.
- Routing plant sanitary wastewater to the sanitary wastewater treatment plant and then treating it for release in accordance with the National Pollutant Discharge Elimination System permit.

- Discharging metal-cleaning wastewater (trisodium phosphate, acetic acid, etc.) to approved storage ponds for future disposal in accordance with the National Pollutant Discharge Elimination System permit.

- Routing wastewater from floor and equipment drains in nonradiation areas through sumps to the turbine building sump for discharge in accordance with the National Pollutant Discharge Elimination System permit.

- Selling surplus chemicals, recycling lead acid batteries, recovering and recycling refrigerant, and using solvent recovery equipment for painting operations.

- Incorporating steps to use biodegradable solvents and cleaners to replace hazardous chemicals in cleaning operations to the extent practical.

Spent Nuclear Fuel Management

When TVA irradiates nuclear reactor fuel to the point that it no longer contributes to the operation of the reactor, or if the fuel has cladding leaks that allow radioactive gaseous emissions, the fuel assembly becomes "spent nuclear fuel" and TVA removes it from the reactor core and stores it in the spent nuclear fuel storage pool or basin. *The Nuclear Waste Policy Act of 1982* gave the Secretary of Energy responsibility for the development of a repository for the disposal of high-level radioactive waste and spent nuclear fuel. When a repository became available, DOE would transport spent nuclear fuel for disposal from nuclear power reactors to the repository. Until a repository becomes available, utilities will store spent nuclear fuel in reactor pools or in other NRC-licensed storage locations. Because of the uncertainty about the opening a repository, NNSA assumed that TVA will continue to store spent nuclear fuel in onsite facilities for the duration of the proposed action (that is, until about 2035). The Watts Bar spent nuclear fuel storage pool has the capacity to hold 1,386 assemblies. Watts Bar is currently planning a dry cask storage facility to increase its onsite storage capacity.

Storage Capacity

A reserve spent nuclear fuel pool storage capacity is required for a full-core discharge (193 fuel assemblies) in the event it became necessary to remove all fuel from a reactor vessel. The remaining pool storage capacity can hold 1,177 fuel assemblies, because 16 storage cells might not be usable for various reasons. Once Watts Bar 2 is operational, the site will discharge about 115 spent nuclear fuel assemblies annually, which would include about 3 spent nuclear fuel assemblies annually from TPBAR irradiation at Watts Bar 1. As of July 2011, the spent nuclear fuel inventory at Watts Bar was 807 fuel assemblies, leaving a usable pool storage capacity of 563 fuel assemblies (TVA 2012). To supplement spent nuclear fuel pool storage capacity, TVA is planning the construction and operation of a dry cask storage facility (independent spent fuel storage installation) at the Watts Bar site. Under the current schedule for Watts Bar 1, such a facility will be necessary by 2018. Assuming Watts Bar 2 begins operation in 2015, the facility will be necessary by about 2017.

3.1.11 HUMAN HEALTH AND SAFETY

Routine operations at the Watts Bar site have the potential to affect worker and public health. Air emissions from the site can lead to exposure to radioactive and nonradioactive materials. Liquid effluent discharges to nearby water bodies could affect downstream populations that use the water for drinking or recreation. In addition, workers are exposed to occupational hazards similar to those at most industrial work sites. The following discussion characterizes human health impacts from the natural environment as well as current releases of radioactive and nonradioactive materials from the Watts Bar site.

3.1.11.1 Radiation Environment

Public

Table 3-20 lists the average annual radiation exposure to people in the vicinity of the Watts Bar site. As listed, the average annual dose to an individual from natural and manmade radiation is about 620 millirem (NCRP 2009). Based on a 2010 population of 1,179,099 people (USCB 2012) within 50 miles of the site, the natural and manmade dose to the population is about 731,000 person-rem per year.

Table 3-20. Average annual dose from natural and manmade radiation in the United States.

Source	Dose (millirem)[a]
Natural	
Cosmic	33
Terrestrial	21
Radon	228
Internal	29
Manmade	
Medical	300
Consumer products	13
Other	0.3
Average annual total	**620[b]**

Source: NCRP 2009.

a. Values are based on average national data.

b. The actual value is 624.3 millirem. NNSA has rounded this value to 620 millirem in this SEIS.

Members of the public could be exposed to released emissions and effluents from the Watts Bar site that would be in addition to the natural and manmade dose. TVA calculates radiation doses to individuals and populations each year using radiological monitoring points around the site and conservative assumptions about exposure. Table 3-21 lists these doses.

Table 3-21. Annual public doses from normal operations at the Watts Bar site during 2010.

Affected environment	Airborne releases[a]	Liquid releases[a]	Totals[a]	Regulatory limit
Maximally exposed offsite individual (millirem)	0.013	0.015	0.028[b]	25[c]
Population within 50 miles (person-rem)[d]	0.671	0.680	1.287[b]	None
Average dose to an individual within 50 miles (millirem)	0.000569	0.00228	0.00279	None

Source: TVA 2011j.

a. NNSA based these calculations on actual measurements of releases, which includes irradiation of 240 TPBARs.

b. NNSA based the total doses in this table on Watts Bar 1 operation (TVA 2011j). Section 4.1.11 discusses additional doses that could result once Watts Bar 2 becomes operational.

c. The standard for the maximally exposed offsite individual (25 millirem per year for the total body from all pathways) is in 40 CFR Part 190.

d. NNSA based population data for airborne releases on the total 50-mile population around the site, which is 1,179,099 people. It based population data for liquid releases on people using public water supplies downstream of the site within 50 miles, projected from data in TVA (2011j), which is 298,447 people.

Workers

Nuclear power plant environments produce radiation fields as a result of radioactivity in the reactor and its associated components. Design features and operating practices ensure that individual occupational radiation doses are within the limits in 10 CFR Part 20. In addition, TVA maintains individual and total worker population doses as low as is reasonably achievable. Table 3-22 lists radiation doses to onsite workers.

Table 3-22. Average annual worker doses from normal operations of Watts Bar 1, 2005 to 2010.

Affected environment	Standard[a]	Dose[b]
Average worker (millirem)	None	114.9[c]
Maximally exposed worker (millirem)	5,000	1,289
Total workers (person-rem)	None	101

a. NRC regulatory limit from 10 CFR Part 20.
b. Source: TVA 2012.
c. Average annual worker dose was determined by dividing the average total worker dose over the six years from 2005 to 2010 by the average number of exposed workers over that period.

3.1.11.2 Chemical Environment

Nonradioactive chemical wastes from Watts Bar 1 include boiler blowdown water treatment wastes (sludges and high-saline streams with residues that TVA disposes of as solid wastes and biocides), boiler metal-cleaning solvents, floor and yard drain wastes, and storm water runoff. Regeneration (chemical removal of radioactive waste) of ion exchange resins produces neutralized sulfate and sodium salts. Other water purification processes produce phosphate and aluminum hydroxide residue. Processes for defouling facility piping produce organic residue byproducts and halites (oxygenated chlorine and bromine ions).

The operation of Watts Bar 1 includes controls on the storage of process chemicals and disposal of waste products. TVA minimizes adverse health impacts to the public through administrative and design controls to decrease hazardous chemical releases to the environment and achieve compliance with permit requirements (such as air emissions and National Pollutant Discharge Elimination System permit requirements). TVA verifies the effectiveness of these controls by monitoring information about and inspecting compliance with mitigation measures.

3.1.11.3 Emergency Preparedness

The NRC based the license for the operation of Watts Bar 1 in part on a finding that there is reasonable assurance that TVA can and will take adequate protective measures in the event of a radiological emergency. The NRC based this finding on (1) a review of Federal Emergency Management Agency findings, (2) determinations that State and local emergency plans are adequate and give reasonable assurance of implementation, and (3) the assessment that TVA onsite emergency plans are adequate and give reasonable assurance of implementation.

The Watts Bar 1 emergency plan establishes that evacuation is the most effective protective action to cope with radiological incidents. The plan provides the details of an evacuation plan, which tasks risk counties, identified as McMinn, Meigs, and Rhea, with preparing evacuation plans for citizens within the 10-mile emergency planning zone and determining the number of people to be evacuated from the zone. The plan assigns host counties, identified as Hamilton, Roane, Cumberland, and McMinn, responsibility to identify suitable shelters for evacuees. A State Emergency Operation Center would provide the focus for emergency reaction (for example, notifications, protective action, and evacuation implementation). Fixed sirens would alert residents and transients within the 10-mile emergency planning zone with backup, if needed, from emergency vehicle sirens and loudspeakers. The State Emergency Operation Center Director would involve county Emergency Management Directors as necessary. The Emergency Alert System and the National Oceanic and Atmospheric Administration Weather Radio would provide emergency information and instructions. The evacuation would be ordered and accomplished by designated sectors. Traffic assistance teams would patrol designated evacuation routes. The American Red Cross would operate mass care shelters in the host counties. Shelter information points on each evacuation route would help direct evacuees to their assigned shelters. Evacuation planning requires considerable effort; training, education, and practice runs further the probability of successful evacuation if it is ever necessary (DOE 1999a).

3.1.12 TRANSPORTATION

The Watts Bar Nuclear Plant is on the Tennessee River, near Spring City, Tennessee, about midway between Chattanooga and Knoxville. The Tennessee River is navigable past the site and is a major barge route.

A main line of the Cincinnati, New Orleans and Texas Pacific Railroad (a division of Norfolk Southern) runs from Cincinnati to Chattanooga and passes through Spring City about 7 miles west of the site and parallel to U.S. Highway 27 (US 27). A TVA railroad spur connects the main line at Spring City to the Watts Bar plant. The spur would require refurbishment before use.

Figure 3-9 shows that US 27 parallels the river on the northwest, and State Route 58 (SR 58) parallels the river on the southeast. SR 68 runs roughly east-west a mile north of the plant and provides access to the plant and connects US 27, SR 58, and Interstate Highway 75 (I-75). Similarly, SR 30 connects US 27, SR 58, and I-75 south of the plant. I-75 runs between Chattanooga and Knoxville about 15 miles east of the plant.

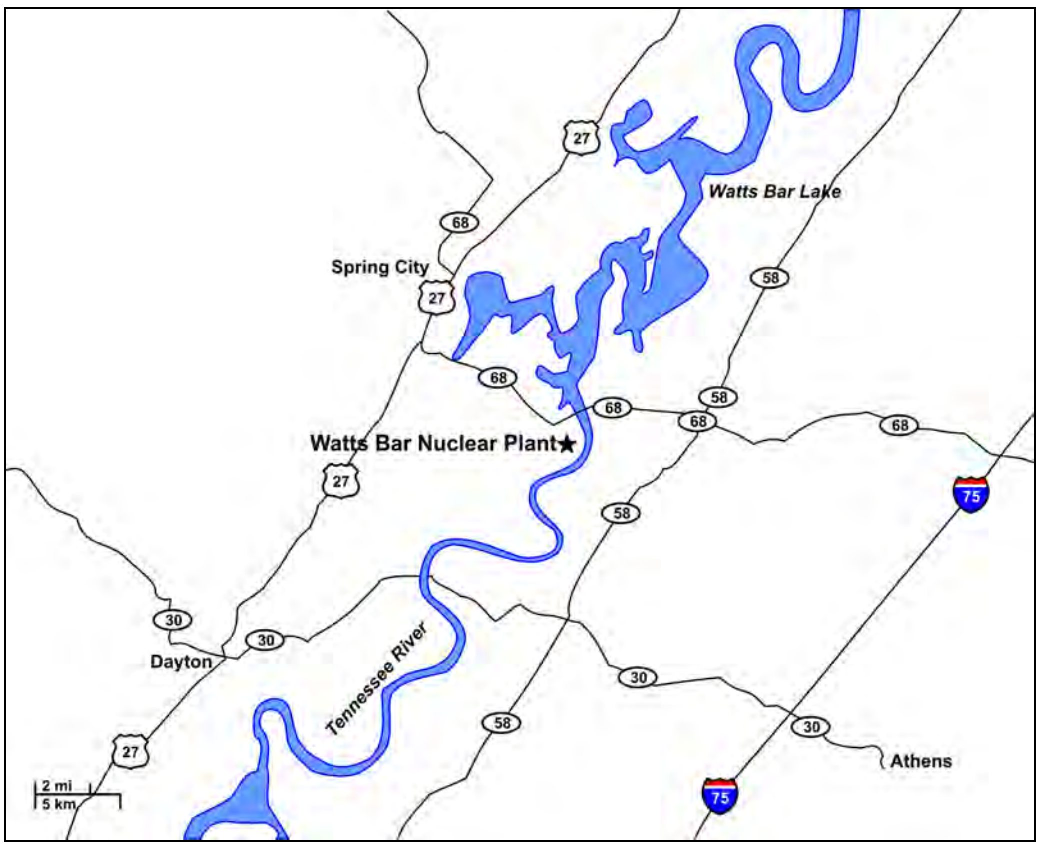

Figure 3-9. Transportation routes near the Watts Bar site (Source: Imagery ©2012 TerraMetrics, Map data ©2012 Google).

About 570 permanent employees commute to Watts Bar Unit 1 on a daily basis. Commuting employees approach Watts Bar from the west on US 27 and SR 68. Commuters from the east use SR 58 and SR 68.

Those from more distant locations to the east (for example, Lenoir City, Loudon, or Athens) travel on I-75 and then SR 68. Most truck shipments arrive in the area on I-75 and then take SR 68 to the plant. Other roads in the vicinity are available to commuting workers. Tritium production employees are integrated into the workforce; that is, there are no employees who work exclusively on tritium production. Two to four trucks per 18-month refueling cycle (one to three trucks per year) transport irradiated TPBARs to the Tritium Extraction Facility at the Savannah River Site. Table 3-23 lists 2010 two-way annual average daily traffic volumes near the plant.

Table 3-23. Annual average daily traffic volumes near the Watts Bar Site, 2010.

Station and description	Traffic volume
Rhea County	
11 – SR 302 north of SR 68	2,899
13 – US 27 south of SR 68 intersection	9,641
14 – SR 68 east of US 27	5,330
16 – SR 302 south of SR 68	1,122
18 – SR 68 west of plant entrance	4,938
Meigs County	
12 – SR 58 south of SR 68	1,196
13 – SR 58 north of SR 68	2,091
14 – SR 68 west of SR 58	5,657
16 – SR 304 north of SR 68	2,100
18 – SR 304 south of SR 68	980
52 – SR 68 at Watts Bar Dam	4,521
McMinn County	
78 – I-75 north of SR 68 exit	40,346
91 – I-75 south of SR 68 exit	38,134

Source: TDOT 2011.

3.1.13 ENVIRONMENTAL JUSTICE

EPA has defined “environmental justice” as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies” (EPA 2005). Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” signed in February 1994, directs Federal agencies to address environmental and human health conditions in minority and low-income communities. The evaluation of impacts to environmental justice is dependent upon determining if there would be disproportionately high and adverse impacts from the proposed action on any low-income or minority group in the affected community.

NNSA used demographic information from the U.S. Census Bureau to identify minority and low-income populations in the region of influence. It obtained information on locations and numbers of minority and low-income populations from the 2010 Census. “Minority” refers to people who classified themselves in the 2010 Census as Black or African American, Asian or Pacific Islander, American Indian or Alaskan Native, Hispanic of any race or origin, or other non-White races (CEQ 1997a). Environmental justice guidance defines “low-income” using statistical poverty thresholds from the U.S. Census Bureau. NNSA developed information on low-income populations using 2009 incomes from the 2010 Census.

In general, the racial and ethnic characteristics of the region of influence population differ from those in Tennessee. As a percentage, the region has a larger White population, smaller Black or African American population, and smaller Hispanic or Latino population. Table 3-24 lists data about the racial and ethnic composition of residents in the region of influence and, for comparison, Tennessee.

Table 3-24. Racial and ethnic composition in Meigs County, Rhea County, and Tennessee, 2010.

Characteristic	Meigs County	Rhea County	ROI total	Percent, ROI[a]	Tennessee	Percent, Tennessee[a]
Total population	11,753	31,809	43,562	100%	6,346,105	100%
One race[b]	11,606	31,307	42,913	98.5%	6,236,096	98.3%
White	11,341	29,695	41,036	94.2%	4,921,948	77.6%
Black or African American	116	616	732	1.7%	1,057,315	16.7%
American Indian and Alaska Native	64	141	205	0.5%	19,994	0.3%
Asian	18	130	148	0.3%	91,242	1.4%
Native Hawaiian and other Pacific Islander	0	23	23	0.1%	3,642	0.1%
Two or more races	147	502	649	1.5%	110,009	1.7%
Hispanic or Latino (of any race)	176	1,187	1,363	3.1%	290,059	4.6%
White, not Hispanic or Latino	11,261	29,303	40,563	93.1%	4,800,782	75.6%
Minority population	492	2,506	2,998	6.8%	1,545,323	24.4%

Sources: USCB 2010a, 2010b, 2010i.
ROI = region of influence.
a. Totals might not equal sums due to rounding.
b. Does not include racial data for some populations, but the totals include these people.

The Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who is in poverty. If a family's total income is less than that family's threshold, that family, and every individual in it, is considered to be in poverty. The poverty thresholds do not vary geographically, but they are updated annually for inflation with the Consumer Price Index. The official poverty definition counts money income before taxes but excludes capital gains and noncash benefits (such as public housing, Medicaid, and food stamps). In 2009, the poverty threshold for an individual was $10,956; for a family of four it was $21,954 (USCB 2010j).

In 2009, residents of the region of influence experienced a higher rate of poverty than those in the State as a whole; 20.4 percent of the people in Meigs County were living in poverty, as were 21.9 percent of those in Rhea County, in comparison with 17.2 percent of the people in the State of Tennessee (USCB 2010j).

3.2 Sequoyah Site

This section describes the affected environment for the Sequoyah Nuclear Plant.

3.2.1 LAND USE

The Sequoyah site occupies 525 acres near the center of Hamilton County, Tennessee, on a peninsula on the western shore of Chickamauga Reservoir at Tennessee River Mile 484.5 (see Figure 1-2 in Chapter 1). Figure 2-3 in Chapter 2 shows the layout of the site. The site is about 7.5 miles northeast of Chattanooga, Tennessee, 18 miles from the center of Chattanooga, and about 6 miles from the center of Soddy-Daisy, Tennessee.

Hamilton County has a well-developed land use and zoning plan. The two primary land use types are residential (37 percent) and farm-agriculture (23 percent). Zoning in Hamilton County is primarily agricultural (60 percent), with areas of residential (31 percent), manufacturing and industrial (7 percent), commercial (2 percent), special zoning (0.6 percent), and office uses (0.1 percent)[2] (CHCRPA 2005).

Land uses near the Sequoyah site include agricultural, forest, residential, and recreational. There is forested land along the north side with a residential area beyond, and the Tennessee River flows along the east and south sides of the Sequoyah site. There are agricultural and residential lands west of the site. The Chickamauga Reservoir supports water-based recreation. Recreational lands include Skull Island Recreation Area across the river about a mile to the north, the Chester Frost County Park about 4 miles to the south, and the Harrison Bay State Park across the river about 4 miles to the south.

The Chattanooga-Hamilton County Regional Planning Agency *Comprehensive Plan 2030* identifies the land use of the Sequoyah site as utilities and the zoning as agricultural (CHCRPA 2005). The site is industrial in character.

3.2.2 AESTHETICS

3.2.2.1 Visual

Visual resources include natural and manmade physical features that provide the landscape its character and value as an environmental resource. The potentially affected area for visual resources encompasses those lands from which the site is visible.

The Sequoyah site is in a rural area along the Tennessee River. Nearby residential subdivision growth has increased over recent years within a 10-mile radius of the plant. Some small-scale farming and at least one dairy farm are within 5 miles of the plant. The nearest residence is about a half-mile north-northwest of the plant, and others to the north, northwest, west, west-southwest, and west-northwest are less than a mile from the plant (TVA 2011b).

The predominant visual features of the plant include the reactors, powerhouse, cooling towers, and transmission lines and associated structures that are visible from as far as 4 miles away along the Tennessee River to the north and south. The tallest buildings are the cooling towers at about 460 feet (TVA 2011b). The towers are visible from Harrison Bay State Park south of the plant. Motorists have broad horizontal views of the site from the east along State Route 312 (SR 312) (Birchwood Pike), including from the Skull Island Recreation Area and a Tennessee Wildlife Resources Agency boat ramp south of Skull Island. People on the water have similar views from the eastern side of the Tennessee River. These views become less dominant closer to the west side of the river near the plant. An observer can typically distinguish the plant features at distances as far as 4 miles, but the details are obscure and tend to merge into larger patterns. Very close to the site, the bank becomes very steep and dense; mature hardwood and evergreen trees screen the site from view (TVA 2011c). From the north, an arm of the Chickamauga Reservoir with a border of trees on both sides screens the plant from view.

The vapor plume from the cooling towers can be visible as far as 10 miles away from nearby residential areas, U.S. Highway 27 (US 27), SR 58, and County Highway 5550. The cooling towers operate about 2 percent of the time, usually during periods of low river flow or peak summer temperatures. The plume height, length, and frequency of occurrence vary with atmospheric conditions; it is most visible during cooler months and after a weather front has moved through (DOE 1999a).

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2. Due to rounding, the percentages total slightly more than 100 percent.

3.2.2.2 Noise

Section 3.1.2.2 describes noise measurement methods and terms.

Noise Sources in the Area

Noise sources in the area include river and lake traffic, road traffic, power-line hums, and plant equipment including fans, turbine generators, transformers, cooling towers, compressors, emergency diesel engines, main steam safety relief valves, and emergency sirens. The main steam safety relief valves produce loud noise and visible steam for a few hours, usually less than five times a year, but are clearly audible to nearby residents. Under some atmospheric conditions, the 500-kilovolt power lines produce a light humming audible underneath them, but this noise is rarely heard outside the right-of-way (TVA 2011b).

Noise Terms

A-weighted decibels:
A measurement of sound that approximates the sensitivity of the human ear, which is used to characterize the intensity or loudness of sound.

Day-night average sound level:
The energy average of the A-weighted sound levels over a 24-hour period. It includes an adjustment factor for noise between 10 p.m. and 7 a.m. to account for the greater sensitivity of most people to noise during the night.

Emergency sirens are designed to be very loud and easily heard in the community. These sirens provide a warning as part of the local community emergency plans for various emergencies, such as tornado warnings, as well as their primary function to warn of an emergency at the Sequoyah site. These sirens would probably continue to serve the community even if the plant closed (TVA 2011b).

Estimated sound levels in rural areas near the Sequoyah site are typically about 40 A-weighted decibels during the day (TVA 2011b). Because the plant is an industrial facility, sound levels are higher on the site itself but those at the site boundary are consistent with a rural residential area (TVA 2011b). Testing of the emergency warning sirens occurs on a regular basis and results in outdoor sound levels of about 60 A-weighted decibels within a radius of about 10 miles of the site (DOE 1999a). TVA typically tests the sirens once a month at noon (TVA 2011n).

3.2.3 CLIMATE AND AIR QUALITY

3.2.3.1 Climate

The Sequoyah Nuclear Plant is in the eastern Tennessee portion of the Southern Appalachian region. The circulation pattern over the southeastern United States is most pronounced in the autumn and is accompanied by extended periods of fair weather and widespread atmospheric stagnation. In winter, the normal circulation pattern becomes more varied as the eastward-moving migratory high- and low-pressure systems, associated with the mid-latitude westerly current, bring alternating cold and warm air masses into the area with changes in wind direction, wind speed, atmospheric stability, precipitation, and other meteorological elements. In summer, the migratory systems are less frequent and less intense with a warm moist air influx from the Atlantic Ocean and the Gulf of Mexico (TVA 2011b). In comparison with the rest of the United States, the climate in the southeast is warm and wet with high humidity and mild winters. Data collected over a 30-year period (1981 to 2010) at the Chattanooga airport indicate the average annual temperature is 61°F, the average daily maximum temperature in July is 90°F, and the average daily minimum temperature in January is 30.7°F. The average annual precipitation is about 52 inches with the minimum monthly average in October (3.3 inches) and the maximum monthly average in November (5 inches) (TCS 2011).

The terrain features of the region have some effect on the general climate. The mountain ridge and valley terrain is aligned northeast-southwest over eastern Tennessee and that creates a bimodal upvalley-downvalley wind flow in the lower 500 to 1,000 feet during much of the year. Differential surface heating between land and water is rare because of the relatively narrow width of the Tennessee River as it flows southwestward through the valley area (TVA 2011b).

Severe Weather

Windstorms can occur several times a year at the Sequoyah site, particularly during winter, spring, and summer, with winds over 35 miles per hour and on occasion over 60 miles per hour. Between 1950 and 2009, the highest recorded wind speed in Chattanooga, Tennessee, was 63 miles per hour on June 11, 2009. High winds can accompany thunderstorms, which occur about 56 days per year with a maximum frequency in July (TVA 2011b). The estimated probability of a tornado at the Sequoyah site is about once in 6,000 years. The probability of a tornado striking any point within the site area is 0.000044, or 4.4 chances per 100,000 in a given year (TVA 2011b).

These probabilities are being reconsidered based on a historic outbreak of tornadoes that occurred in Hamilton County on April 27, 2011. Based on preliminary National Weather Service information, 10 tornadoes from EF1 to EF4 on the Enhanced Fujita Scale struck the county that day (NWS 2011b). However, only three tornadoes (one preliminarily classified as EF1 and two preliminarily classified as EF0, but which have subsequently been reclassified as EF1) appeared to have tracks within 10 miles of the Sequoyah site (TVA 2011b). The analysis of the April 27 event is not yet complete and the National Weather Service has not yet updated the tornado frequency calculations using the April 2011 information (TVA 2012).

Enhanced Fujita (EF) Scale

A scale that rates the strength of tornadoes in the United States based on the damage that they cause. It is a set of wind estimates (not measurements) based on damage; there are six categories from zero to 5. The scale was implemented in February 2007 and updated the original Fujita Scale that was introduced in 1971. The EF scale and associated wind estimated wind speeds in miles per hour are:

EF0	65 to 85
EF1	86 to 110
EF2	111 to 135
EF3	136 to 165
EF4	166 to 200
EF5	over 200

3.2.3.2 Air Quality

The *Clean Air Act* (42 U.S.C. §§ 7401 *et seq.*) requires EPA to set standards for pollutants considered harmful to public health and the environment. National primary ambient air quality standards define levels of air quality EPA has determined as necessary to provide an adequate margin of safety to protect public health, including the health of sensitive populations such as children and the elderly. National secondary ambient air quality standards define levels of air quality EPA deems necessary to protect the public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. EPA has established National Ambient Air Quality Standards for six criteria pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter (which includes particulate matter with an aerodynamic diameter less than or equal to 10 micrometers [PM_{10}] and less than or equal to 2.5 micrometers [$PM_{2.5}$]), and sulfur dioxide. Table 3-25 lists the primary and secondary standards for each criteria pollutant. The State of Tennessee has similar standards, which are also addressed in Table 3-25.

Ambient Air

The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in immediate proximity to an emission source.

EPA designates regions in compliance with the standards as attainment areas. Areas where the applicable standards are not being met are nonattainment areas. Hamilton County is a nonattainment area for annual

Table 3-25. National and Tennessee Ambient Air Quality Standards.

Pollutant	National Primary standards[a]	National Secondary standards[a]	National: Form	Tennessee Primary standards[b]	Tennessee Secondary standards[b]
Carbon monoxide					
8-hour average	9 ppm	None	Not to be exceeded more than once per year	9.0 ppm	Same as Primary
1-hour average	35 ppm	None	Not to be exceeded more than once per year	35.0 ppm	Same as Primary
Lead					
Rolling 3-month average	0.15 μg/m^3	Same as Primary	Not to be exceeded	None	None
Calendar quarter	None	None		1.5 μg/m^3	Same as Primary
Nitrogen dioxide					
Annual arithmetic mean	0.053 ppm	Same as Primary	Annual mean	0.05 ppm	Same as Primary
1-hour	0.10 ppm	None	98th percentile, averaged over 3 years	None	None
Ozone					
8-hour average (2008 standard)	0.075 ppm	Same as Primary	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years	None	None
1-hour (daily maximum)	None	None		0.12 ppm	Same as Primary
PM_{10}					
Annual (arithmetic mean)	None	None		50 μg/m^3	Same as Primary
24-hour average	150 μg/m^3	Same as Primary	Not to be exceeded more than once per year on average over 3 years	150 μg/m^3	Same as Primary
$PM_{2.5}$					
Annual arithmetic mean	15 μg/m^3	Same as Primary	Annual mean, averaged over 3 years	None	None
24-hour average	35 μg/m^3	Same as Primary	98th percentile, averaged over 3 years	None	None
Total suspended particulates					
24-hour average	None	None		None	150 μg/m^3
Sulfur dioxide					
Annual (arithmetic mean)	None	None		0.03 ppm	None
24-hour average	None	None		0.14 ppm	None
3-hour average	None	0.5 ppm	Not to be exceeded more than once per year	None	0.5 ppm
1-hour average	0.075 ppm	None	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years	None	None
Hydrogen fluoride					
30-day average	None	None	Not to be exceeded more than once per year	None	1.5 ppb
7-day average	None	None	Not to be exceeded more than once per year	None	2.0 ppb
24-hour average	None	None	Not to be exceeded more than once per year	None	3.5 ppb
12-hour average	None	None	Not to be exceeded more than once per year	None	4.5 ppb

ppm = parts per million; ppb = parts per billion; μg/m^3 = micrograms per cubic meter

a. Source: National Ambient Air Quality Standards, 40 CFR Part 50 (as of October 2011).

b. Source: Tennessee Ambient Air Quality Standards, *Rules of Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Air Pollution Control*; Chapter 1200-3-3, "Ambient Air Quality Standards" (October 2006 Revised) (http://tn.gov/sos/rules/1200/1200.htm).

$PM_{2.5}$ based on the 1997 standards (TVA 2011b). Hamilton County is in an attainment area for 8-hour ozone.

Prevention of Significant Deterioration regulations restrict criteria pollutant emissions and protect national parks and wilderness areas that are Class I air quality areas. Class I areas include national wilderness areas, memorial parks larger than 5,000 acres, and national parks larger than 6,000 acres. The Class I areas closest to the Sequoyah site are the Cohutta National Wilderness Area in Georgia and the Joyce Kilmer-Slickrock National Wilderness Area in Tennessee and North Carolina (DOE 1999a). These areas are about 37 miles and 60 miles, respectively, from Sequoyah.

Air Emission Sources

Sources of criteria air pollutant emissions at the Sequoyah site include emergency diesel generators, auxiliary boilers, cooling towers, vehicular traffic, and some heavy machinery for normal operations and planned refueling periods (TVA 2011b). Heavy equipment and vehicles generate exhaust emissions from fuel combustion, and vehicles on unpaved roads generate fugitive dust emissions (PM_{10}). Current air emissions from the operation of the Sequoyah reactors include minor amounts of nitrogen oxides, carbon monoxide, sulfur oxides, PM_{10}, and volatile organic compounds in gaseous form (TVA 2011b).

The Sequoyah Nuclear Plant is a minor source as defined by air quality regulations. All agencies and companies in Hamilton County that have the potential to emit air pollutants must obtain an air pollution permit from the Chattanooga/Hamilton County Air Pollution Control Bureau. The following emissions sources at Sequoyah require air permits: the cooling towers, the auxiliary steam boilers for heating and other uses, the diesel-powered auxiliary emergency generators, and other small sources such as insulation saws and abrasives operations (TVA 2011b).

Gaseous Radioactive Emissions

The Sequoyah site has three primary sources of gaseous radioactive emissions (DOE 1999a):

- Discharges from the gaseous waste management system,
- Discharges from the exhaust of noncondensable gases in the main condenser, and
- Gaseous discharges from ventilation systems including those at the reactor building, reactor auxiliary building, and fuel-handling building.

The gaseous waste management system collects fission product gases (mainly noble gases) that accumulate in the primary coolant. A portion of the primary coolant diverts continually to the primary coolant purification, volume, and chemical control system to remove contaminants and adjust the chemistry and volume. Noncondensable gases flow to the gaseous waste management system, which is a series of gas storage tanks that allows short half-life radioactive gases to decay, leaving only a small quantity of long half-life radionuclides for release to the atmosphere. Table 3-26 lists the 2010 nontritium gaseous radioactive emissions in curies from Sequoyah (Units 1 and 2). Table 3-27 lists the gaseous tritium emissions from the Sequoyah site for 2002 to 2010.

Table 3-26. Nontritium radioactive gaseous emissions at Sequoyah 1 and 2, 2010.

Emission	Curies
Fission gases (including carbon-14)	26.8

Source: TVA 2011o.

Table 3-27. Tritium gaseous emissions (curies) at Sequoyah (Units 1 and 2), 2002 to 2010.

Emission	2002	2003	2004	2005	2006	2007	2008	2009	2010
Tritium	141.69	48.60	107.55	69.36	111.93	131.17	59.79	45.33	88.8

Source: Kimsey 2012.

3.2.3.3 Greenhouse Gases

The burning of fossil fuels such as coal, diesel, and gasoline emits carbon dioxide, which is a greenhouse gas. Greenhouse gases can trap heat in the atmosphere, similar to the glass walls of a greenhouse, and have been associated with global climate change. Climate change refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). The Intergovernmental Panel on Climate Change, in its Fourth Assessment Report, stated that warming of the Earth's climate system is unequivocal, and that most of the observed increase in globally averaged temperatures since the mid-20th Century is very likely due to the observed increase in concentrations of greenhouse gases from human activities (IPCC 2007). These gases are well mixed throughout the lower atmosphere, so emissions would add to cumulative regional and global concentrations of carbon dioxide. The effects from an individual source therefore cannot be determined quantitatively.

The global carbon cycle consists of large carbon sources and sinks. Billions of tons of carbon in the form of carbon dioxide are absorbed by oceans and living biomass (called carbon sinks) and are emitted to the atmosphere through natural and manmade processes (called carbon sources). When in equilibrium, carbon flow between these reservoirs is roughly balanced. Over the last 250 years, global atmospheric concentrations of carbon dioxide have risen about 36 percent, most of which is from burning fossil fuels (TVA 2011b).

The primary greenhouse gas emitted by electric utilities is carbon dioxide from the burning of coal and other fossil fuels. Carbon dioxide emissions from fossil-fuel combustion by electricity generation in the United States totaled about 2.4 billion tons in 2009 (EPA 2011a). Nuclear electric plants do not directly produce any measurable carbon dioxide during the electricity generation process (TVA 2011b). EPA has promulgated regulations for emissions of greenhouse gases under the *Clean Air Act* (EPA 2011b):

- On March 13, 2010, EPA issued the final Greenhouse Gas Tailoring Rule. This rule raised the thresholds for greenhouse gas emissions that define when permits under the Prevention of Significant Deterioration and Title V Operating Permit programs are required for new and existing industrial facilities.

- Starting on January 2, 2011, large industrial facilities that must already obtain *Clean Air Act* permits for nongreenhouse gases must include greenhouse gas requirements in the permits if they are newly constructed and have the potential to emit 75,000 tons or more per year of carbon dioxide equivalent (CO2e) or if they make changes at the facility that increase greenhouse gas emissions by that amount. (CO2e is a measure for comparison of greenhouse gases based on their global warming potential, using the functionally equivalent amount or concentration of carbon dioxide as the reference value.)

- Starting on July 1, 2011, in addition to the facilities described above, all new facilities emitting greenhouse gases in excess of 100,000 tons per year of CO2e and facilities making changes that would increase greenhouse gas emissions by at least 75,000 tons per year of CO2e must obtain permits that address greenhouse gas emissions.

- Also beginning in July 2011, operating permits will be required for all sources that emit at least 100,000 tons per year of CO2e. Sources that emit less than 50,000 tons per year of CO2e will not be required to obtain permits for greenhouse gases before 2016 (EPA 2011b).

TVA does not monitor or estimate greenhouse gas emissions from its nuclear sites. However, at Watts Bar, TVA compiles annual diesel fuel use for its combustion emission sources. This burning of diesel fuel is the primary source of greenhouse gases at nuclear sites. Sequoyah's diesel fuel use and greenhouse gas emissions are estimated to be similar to those of Watts Bar because, due to plant design considerations, Watts Bar uses all four diesel generators, as does Sequoyah. The only significant use of diesel fuel is for testing, which is the same at each plant (McGuire 2011). Table 3-28 lists annual estimated diesel fuel use and estimated carbon dioxide emissions for 2008 to 2010.

Table 3-28. Annual diesel fuel use and estimated carbon dioxide emissions at the Sequoyah site, 2008 to 2010.

Fuel/emissions	2008	2009	2010
Diesel fuel (gallons)	270,000	130,000	63,000
Carbon dioxide emissions (tons)[a]	3,000	1,500	700

Source: TVA 2012.

a. Based on 22 pounds of carbon dioxide per gallon of burned diesel fuel (DOE 2012).

Greenhouse gases are also generated by vehicle traffic of the workers commuting between Sequoyah and their residences. The Sequoyah Nuclear Plant has a workforce of about 1,150 employees who live primarily in Hamilton County and neighboring counties in the area. A typical passenger car emits 5.6 tons of carbon dioxide over 12,000 miles of travel (EPA 2011c). Therefore, if each of the 1,150 workers drove 12,000 miles per year during their commutes, the amount of carbon dioxide produced per year would be about 6,400 tons.[3] The total amount of carbon dioxide from Sequoyah activities (diesel fuel use and worker commuting) would be about 7,100 tons annually.

Estimated greenhouse gas emissions from the existing facility are relatively small in comparison with the estimated 111 million tons of Tennessee CO2e emissions in 2009 and the 7.3 billion tons (EPA 2011a) of U.S. CO2e emissions in 2009. Emissions from the facility, in combination with past and future emissions from all other sources, would contribute incrementally to climate change impacts.

3.2.4 GEOLOGY AND SOILS

3.2.4.1 Geology

The Sequoyah Nuclear Plant is in the Tennessee section of the Valley and Ridge Province of the Appalachian Highlands. This province consists of a series of folded and faulted mountains and valleys that formed during the late Paleozoic Era about 250 million years ago. Long narrow ridges and somewhat broader intervening valleys with a northeast-southwest trend characterize this province. The ridges are roughly parallel and fairly evenly topped, and have developed in areas underlain by resistant sandstones and the more siliceous limestones and dolomites. The valleys have formed through erosion in the areas underlain by easily weathered shales and the more soluble limestone formations. In the vicinity of the Sequoyah site (before the impoundment of Chickamauga Reservoir), the Tennessee River had entrenched its course to an elevation of 640 feet above mean sea level. The crests of the intervening ridges range between 900 and 1,000 feet above mean sea level (TVA 2008a).

3. This calculation of greenhouse gases would also include consideration of greenhouse gases from transportation of TPBARs and low-level radioactive wastes if Sequoyah irradiated TPBARs. The greenhouse gases from these transportation activities would represent less than 1 percent of the greenhouse gases from worker transportation.

The Conasauga Formation, which is of Middle Cambrian age, underlies the Sequoyah site, providing the foundation bedrock for the plant. Unconsolidated alluvial, terrace, and residual deposits overlie the Formation at the site. The Chickamauga Reservoir covers more recent alluvial deposits that were associated with the floodplain of the Tennessee River (TVA 2011b).

The Conasauga Formation at the Sequoyah site consists of several hundred feet of interbedded limestone and shale in varying proportions. The shale, where fresh and unweathered, is dark gray and banded, and can be split along its parallel thin layers. The limestone is predominantly light gray, medium-grained to coarse crystalline to oolitic, with many shaly partings. A statistical analysis of cores from the site indicates a ratio of 56 percent shale to 44 percent limestone. Farther to the southeast and higher in the geologic section, the amount of limestone increases in exposures along the shore of the Chickamauga Reservoir (TVA 2011b).

The Conasauga Formation provides a satisfactory and competent foundation for Sequoyah site structures. Cores from holes drilled in the area indicate no evidence of weathering below the upper 5 feet of rock. Physical testing, both static and dynamic, has shown that the unweathered rock can support loads that are greater than the loads from site structures (DOE 1999a).

3.2.4.2 Seismicity

The Kingston thrust fault trends about a mile northwest of the Sequoyah site and is traceable for 75 miles northeastward and 70 miles southwestward. The fault dips to the southeast at an angle of 30 degrees or more, which carries the plane of the fault at least 2,000 feet below the surface of the Sequoyah site. This fault developed about 250 million years ago but has been inactive for many millions of years; recurrence of movement is unlikely (TVA 2008a).

The known seismic history of the southeastern United States suggests that the earthquake hazard is relatively minor at the Sequoyah site. There are no active faults in the vicinity of the site, and there is no physical evidence of seismic activity (TVA 2011b). The maximum historic quake reported in the Southern Appalachian Tectonic Province – in Giles County, Virginia, in 1897 – had a magnitude of 5.9 and Modified Mercalli intensity of VIII. Although this earthquake occurred 285 miles northeast of the site, TVA assumed this intensity occurred at the site to define the safe-shutdown earthquake. TVA designed the Sequoyah Nuclear Plant such that all structures, systems, and components important to safety will remain functional when subjected to a safe-shutdown earthquake with a maximum horizontal acceleration of 0.18 g (g is the acceleration due to gravity) and maximum vertical ground acceleration of 0.12 g.

The NRC, in its review for the original Sequoyah Nuclear Plant operating license, requested additional information on the seismic design basis. This resulted in the development of a site-specific response spectrum, which represents the 84th percentile of 13 actual earthquake recordings and has a peak acceleration of 0.22 g. As a result of the development of the site-specific response spectrum, the NRC considered a safe-shutdown earthquake of 0.22 g in its design evaluation. However, TVA presented data and analysis to justify its design based on a safe-shutdown earthquake of 0.18 g, and the NRC later approved the design and operating license (TVA 2011b).

From 1973 to 2011, there have been 218 recorded earthquakes with an average magnitude of 3 within a 200-mile radius of the Sequoyah site (USGS 2011b). Since 1973, the most significant earthquake near the site was the Fort Payne earthquake on April 29, 2003, about 60 miles southeast of the site in northeastern Alabama, near the Georgia border. This earthquake had a magnitude of 4.6 and a Modified Mercalli intensity of IV to V, and is one of the larger earthquakes to have occurred within 200 miles of the site. However, that earthquake was well below the magnitude of the maximum historical earthquake in the southern Appalachians, which was the 1897 Giles County, Virginia, earthquake with a magnitude of 5.9 and a Modified Mercalli intensity if VIII. TVA designed the Sequoyah Nuclear Plant based on an earthquake of this magnitude (TVA 2011b).

3.2.4.3 Soils

At the Sequoyah site, unconsolidated alluvial, terrace, and residual deposits overlie the Conasauga Formation. The Chickamauga Reservoir covers more recent alluvial deposits associated with the floodplain of the Tennessee River. In the main plant area, TVA removed alluvium during construction, and only residual soils remain (silt and clay from weathering of the underlying shale and limestone). In other areas of the site, either terrace deposits or varying thicknesses of residual soils, which grade downward into saprolitic shale of the Conasauga Formation, overlie the Formation. In a few localized areas, weathered shale is exposed at the ground surface. However, in most exploratory drilling, the depth to shale residuum ranged from 3 to 34 feet. Grain-size analyses show that soils across the site range from fat clay residual material to sand and gravel terrace deposits (TVA 2011b).

3.2.5 WATER RESOURCES

3.2.5.1 Surface Water

3.2.5.1.1 Surface-Water Hydrology

The Sequoyah site is in the southern portion of the Chickamauga Reservoir, an impoundment on the Tennessee River and TVA's sixth largest reservoir. Figure 3-10 shows the relative location of the reservoir in the TVA system of 49 active dams and reservoirs on the Tennessee River and its primary tributaries (TVA 2010a). TVA operates the reservoir system for flood control, navigation, power generation, water supply, recreation, and economic growth. In relation to flood control, TVA places particular emphasis on protection of Chattanooga, which is 8 miles downstream from the Sequoyah site.

The main body of the Chickamauga Reservoir extends 59 miles along the Tennessee River, from Chickamauga Dam at Tennessee River Mile 471 to Watts Bar Dam at River Mile 530. In a straight line, the two dams are about 44 miles apart. The Chickamauga Reservoir also extends about 32 miles up the Hiwassee River. The reservoir covers about 35,400 acres at the normal maximum water elevation of 682.5 feet above mean sea level and contains a volume of 628,000 acre-feet (TVA 2010a). Its flood storage capacity is 345,000 acre-feet (TVA 2011f).

The Chickamauga Reservoir ranges in width from about 900 feet to 2.5 miles. At the Sequoyah site, the reservoir varies in width from roughly 4,000 feet on the north side of the site to about 1,800 feet on the south, but there are many inlets and coves in this portion of the reservoir that effectively increase the width in places. At the site, the Chickamauga Reservoir is about 3,000 feet wide with cross-sectional depths up to 50 feet at normal water elevation (DOE 1999a). The navigational channel within the reservoir is 900 feet wide. Over the 33 years from 1976 through 2008, the average flow at Chickamauga Dam was 32,000 cubic feet per second (TVA 2010a). The Sequoyah site is at River Mile 484.5 about 14 miles above Chickamauga Dam as the river flows. The average flow at that location was essentially the same as through the dam. River flow in the vicinity of the Sequoyah site is governed by hydropower operations at the upstream Watts Bar Dam (River Mile 529.9), the downstream Chickamauga Dam (River Mile 471) and, to a lesser extent, by dams in the Hiwassee River and its tributaries. Peaking hydropower operation at the two Tennessee River hydroprojects can cause short periods of zero or reverse flow near the Sequoyah site (DOE 1999a). The average surface elevation of the reservoir varies over a normal operating year by 6.5 feet from a high of 682.5 feet above mean sea level in summer to a low of 676 feet above mean sea level during winter (TVA 2010a).

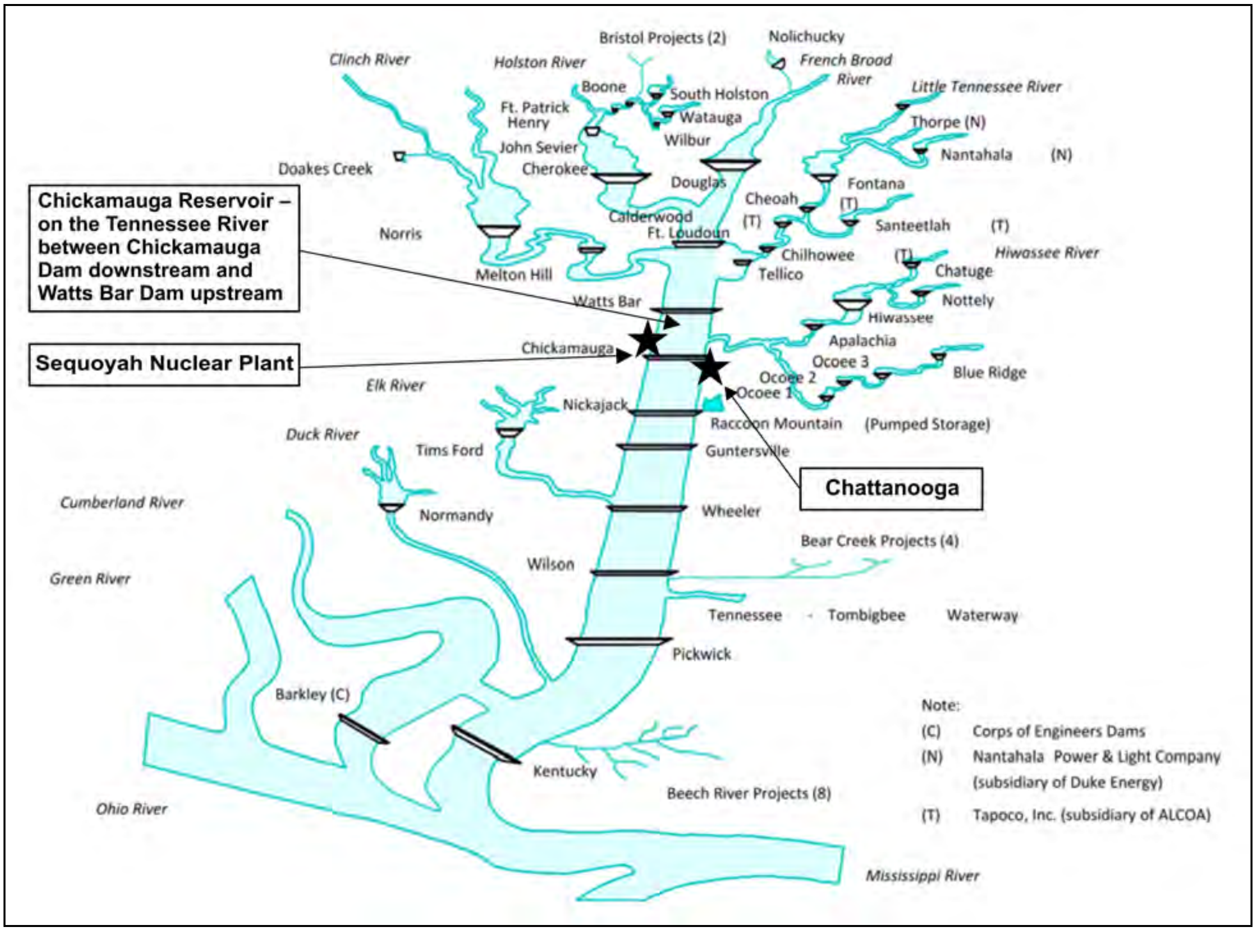

Figure 3-10. TVA water control system and the Chickamauga Reservoir (not to scale; TVA 2010a).

The Chickamauga Reservoir has a drainage area of 20,800 square miles. The Tennessee River is the primary contributor of water to the reservoir, but the Hiwassee River, entering at River Mile 499.5, is a significant contributor. The Tennessee Department of Environment and Conservation identifies more than 50 creeks and drainage channels (most unnamed) that enter the Tennessee River portion of the Chickamauga Reservoir and more than 20 creeks and drainage channels that enter the portion of the reservoir that backs up into the Hiwassee River drainage (count obtained from the State of Tennessee online water quality assessment tool at http://www.tn.gov/environment/water.shtml). In the discussion that follows, reference to the Tennessee River is interchangeable with the Chickamauga Reservoir for those portions that overlie the bed of the Tennessee River; the same applies for the Hiwassee River.

3.2.5.1.2 Surface-Water Quality

The *Clean Water Act* (33 U.S.C. §§ 1251 *et seq.*) established a framework for regulating quality standards for surface waters and discharges into those waters. Under that framework, the states evaluate their surface waters, determine applicable beneficial uses, set water quality criteria to support those uses, and then implement rules and regulations to achieve or maintain applicable water quality criteria. In Tennessee, water quality criteria applicable to the beneficial uses are in State of Tennessee Rules Chapter 1200-4-3, "General Water Quality Criteria" (http://tn.gov/sos/rules/1200/1200.htm). Criteria for beneficial uses for specific surface waters, and sometimes for segments of specific surface waters, are identified in Chapter 1200-4-4, "Use Classifications for Surface Waters" (http://tn.gov/sos/rules/1200/1200.htm). Section 305(b) of the *Clean Water Act* requires states to develop and periodically update an inventory of the water quality of all water bodies in the state. These inventories, which states report to EPA and the public, identify whether the water quality supports the applicable designated uses. Section 303(d) of the *Clean Water Act* requires states to develop, periodically update, and report an inventory of water bodies that do not meet water quality standards.

Table 3-29 identifies designated uses and general water quality status for the surface waters in the immediate vicinity of the Sequoyah site. The water quality status comes from Tennessee's 2010 Section 303(d) report (TDEC 2010a) as well as other State information. Changes identified in the State's draft 2012 report (TDEC 2012a) have also been incorporated in Table 3-29, but because of the report's draft status at the time of the preparation of this SEIS, the changes are identified with explanations in the footnotes. The table focuses on the status of the Tennessee River, which includes the Chickamauga Reservoir at the Sequoyah site. Chapter 1200-4-4 of the Tennessee Rules identifies designated uses by primary river basins in the State. The Sequoyah site is in the Lower Tennessee River Basin; within this basin, Chapter 1200-4-4 divides the Tennessee River into several segments to show changes in designated uses and to support listing of side streams that enter the river within those segments. Table 3-29 lists information about the northernmost segment (the one farthest upstream) of the Lower Tennessee River Basin. The table shows the river segment broken into three parts to show changes in water quality designations.

Table 3-29 also provides information on side streams that enter the Tennessee River within about 3 miles of the Sequoyah site (that is, for a 6- to 7-mile stretch along the river with the site near the center). The 3-mile distance has no specific regulatory significance; the hydrology analysis used it as a representative distance to show the characteristics of the smaller streams and drainages near the site. Considering the larger, 39-mile segment of the Tennessee River in the table, other side streams have been evaluated for water quality but, consistent with those identified within 3 miles, many are in the category of having insufficient data for a water quality assessment. In addition, in general terms, assessed streams reaching the Tennessee River through the built-up areas of Chattanooga are more often identified as impaired in comparison with side streams to the north of Chattanooga. Tennessee Rules Chapter 1200-4-4 specifies use classifications for each stream it identifies by name; for "all other surface waters named and unnamed in the Lower Tennessee River Basin" the Chapter specifies applicable uses as fish and aquatic life, recreation, livestock watering and wildlife, and irrigation.

As the information in Table 3-29 indicates, water quality in the Tennessee River or Chickamauga Reservoir in the area of the Sequoyah site supports all designated uses for this water. Downstream on the other side of Chickamauga Dam, however, the Tennessee River or Nickajack Reservoir is an impaired water under Section 303(d) of the *Clean Water Act*; water quality in this area does not support all designated uses because of polychlorinated biphenyl and dioxin contamination in the sediments. Because of the contamination, Tennessee has issued a Fish Tissue Advisory for the Nickajack Reservoir portion of the Tennessee River advising taking precautions in eating catfish (TDEC 2010b). The table indicates that Tennessee considers the roughly 3-mile stretch of the river below Chickamauga Dam to be an exceptional Tennessee water to be protected due to its habitat for the Federally listed threatened snail darter. By Tennessee Rules (Chapter 1200-4-3-.06), the Department of Environment and Conservation cannot authorize degradation in exceptional waters unless (1) there is no alternative that would render the proposed activity nondegrading and (2) the activity is in the economic or special interest of the public (TDEC 2011b). Although not shown in Table 3-29 because of its distance from the Sequoyah site, portions of the Hiwassee River embayment are also impaired waters on the Tennessee Section 303(d) list. The impaired segment closest to the Tennessee River has a mercury contamination issue from atmospheric deposition from an industrial point source (TDEC 2010a).

The 1999 EIS (DOE 1999a) reported monitoring data for surface water near the Sequoyah site. Table 3-30 lists the data from the earlier document along with results from water quality monitoring from 2000 to 2008. The table indicates that the values have not changed dramatically and are still within levels

Table 3-29. Surface-water quality and designations near the Sequoyah site.

Water body	Location description	Designated use classifications[a,b] DOM	IWS	FAL	REC	LWW	IRR	NAV	Water quality assessment results[c,d] and other assigned designations[e]
Tennessee River from River Mile 460.6 to 499.4 – the northernmost section of the Lower Tennessee River Basin per Tennessee Rules Chapter 1200-4-4									
1. Tennessee River/ Nickajack Reservoir	River Mile 460.6 (Chattanooga Creek) to River Mile 468.3 (South Chickamauga Creek)	X	X	X	X	X	X	X	• Impaired water – does not fully meet designated uses due to polychlorinated biphenyl and dioxin contamination in sediments.
2 Tennessee River/ Nickajack Reservoir	River Mile 468.3 (South Chickamauga Creek) to River Mile 471 (Chickamauga Dam)	X	X	X	X	X	X	X	• Impaired water – does not fully meet designated uses due to polychlorinated biphenyl and dioxin contamination in sediments. • Exceptional Tennessee Water – for Federally listed threatened snail darter.
3. Tennessee River/ Chickamauga Reservoir	River Mile 471 (Chickamauga Dam) to River Mile 499.4 (Hiwassee River)	X	X	X	X	X	X	X	• Water quality supports all designated uses. • Sequoyah Nuclear Plant is at River Mile 484.5.
Side channels and creeks entering Tennessee River/Chickamauga Reservoir within about 3 miles (river centerline miles) of the Sequoyah Nuclear Plant[c]									
Unnamed tributary	Tributary, near Daisy Dallas Road, enters Tennessee River/Chickamauga Reservoir from west side near River Mile 481			X	X	X	X		• Impaired water – does not fully meet designated uses due to biological integrity loss from an undetermined cause.
Soddy Creek and Little Soddy Creek[f]	Enters Tennessee River/Chickamauga Reservoir from west side near Mile 487.5			X	X	X	X		• Water quality supports all designated uses.
Various creeks and drainage channels	18 creeks and channels draining (13 from the west and 5 from the east) into Tennessee River/Chickamauga Reservoir between River Mile 481 and River Mile 488			X	X	X	X		• Water quality not assessed – insufficient data.

a. DOM = domestic water supply; IWS = industrial water supply; FAL = fish and aquatic life; REC = recreation; LWW = livestock watering and wildlife; IRR = irrigation; NAV = navigation. The State has two other designations—TS = trout stream and NRTS = naturally reproducing trout stream—that do not apply to this area of the Tennessee River.

b. Source: TDEC 2011a.

c. Source: TDEC 2010a, 2012a.

d. Source: State of Tennessee online water quality assessment tool at http://www.tn.gov/environment/water.shtml.

e. Sources for Exceptional Tennessee Waters: TDEC 2011b, 2010b.

f. The draft 2012 assessment changes Little Soddy Creek, which enters the reservoir near Soddy Creek, from “not assessed” to “supports all designated uses.”

Table 3-30. Surface water quality monitoring near the Sequoyah site.

Parameter	Unit of measure	Water quality criteria	Average water body concentration	
			1999 EIS	Recent sampling[a,b]
Radiological				
Alpha (gross)	picocuries per liter	15[c,d]	1.9	N/A[e]
Beta particles and photon emitters	millirem per year	4[c,d]		
– Beta (gross)	picocuries per liter	Varies by nuclide	2.67	2.36
– Tritium	picocuries per liter	20,000[c,d]	<300[f]	398
Nonradiological				
Manganese	milligrams per liter	0.05[d,g]	0.000956	0.058
Nitrate (as N)	milligrams per liter	10.0[c,d]	0.245	NR
Arsenic	milligrams per liter	0.010[c,d]	0.00233	< 0.0011
Barium	milligrams per liter	2.0[c,d]	<1	NR
Cadmium	milligrams per liter	0.005[c,d]	0.000117	ND (<0.001)
Chromium	milligrams per liter	0.1[c,d]	0.00333	ND (<0.001)
Lead	milligrams per liter	0.015[c,d] action level	0.00142	<0.00096
Mercury	milligrams per liter	0.002[c,d]	0.0002	ND (<0.0002)
Nickel	milligrams per liter	0.1[d]	NR	ND (<0.0096)
Selenium	milligrams per liter	0.05[c,d]	NR	ND (<0.0018)
pH (acidity/alkalinity)	pH units	6.5–8.5[d,g]	7.52	7.8

N/A = not available; ND = not detected; NR = not reported; < = less than.

a. Radiological results from TVA (2010d, 2011q) for beta and tritium results at one sampling location. (1) Beta (gross) and tritium results are averages of the values reported in the 2009 and 2010 annual reports. (2) Consistent with the manner reported in the source documents, beta (gross) and tritium results are averages of only those results reported as being above detection limits. For the beta (gross) results, 9 of 26 samples over 2 years had results over the detection limit of 1.9 picocuries per liter. For the tritium results, only 2 of 8 samples over 2 years had results over the detection limit of 270 picocuries per liter and that included no results over detection limits for the 2009 sampling year.

b. Nonradiological parameters from the EPA STORET Database (EPA 2011d) showing data collected between January 2000 and July 2008. (1) In instances where both positive detections and nondetections were reported over the various sampling events, the average value (shown in the table) was calculated using the reported detection limits for the nondetections and the result is shown as a less-than (<) value. (2) In instances where no positive detections were reported, the entry is ND for not detected and the value in parentheses is the average detection limit shown with a less-than (<) value.

c. National Primary Drinking Water Regulations (40 CFR Part 141).

d. Rules of Tennessee, Department of Environment and Conservation, Bureau of Environment, Division of Water Supply – Chapter 1200-05-01, "Public Water Systems" (http://tn.gov/sos/rules/1200/1200.htm).

e. Updated results for ambient levels of this parameter were not found, but during the last 5 years of record (2006 through 2010), TVA reported that no detected quantities of gross alpha radioactivity were in the Sequoyah liquid effluents (TVA 2007c, 2008d, 2009d, 2010e, 2011o).

f. Below lower limit of detection of 300 picocuries per liter.

g. National Secondary Drinking Water Regulations (40 CFR Part 143).

set for drinking water. Data in the table show an increase in tritium concentration between what the 1999 EIS reported and the results of recent sampling. However, as indicated in the table's footnote a, the recent sampling data included only 2 of 8 samples over 2 years at levels greater than the detection limit, whereas the 1999 EIS reported all tritium results during the reporting period as less than the detection limit. This could indicate the average tritium concentrations fluctuate at levels near the detection limit, or that a few of the recent samples were collected near the time when TVA released a batch of wastewater.

The more recent nonradiological sampling data in Table 3-30 is from routine monitoring by the Tennessee Department of Environment and Conservation at a location about 7 miles downstream of the Sequoyah site. The Department enters the results of its water sampling activities into the EPA STOrage and RETreival (STORET) Database (EPA 2011d). The location at River Mile 477 is the closest monitoring site downstream of the site. The STORET database includes results from routine sampling of the Tennessee River upstream at River Mile 503.3. Table 3-6 in Section 3.1.5 lists the results from the River Mile 503.3 sampling station as the closest downstream sampling location to the Watts Bar site. This location also serves as an upstream location for comparison with the results in Table 3-30. As the data in the table show, current nonradiological water quality parameters often vary from those the 1999 EIS reported. Manganese levels are a primary example. The references that provided the data do not indicate why levels of certain parameters changed over time but, because the constituents are at low values (within the National Primary Drinking Water Standards), NNSA assumes these are normal fluctuations that vary depending on the nature of the runoff that makes its way to the surface water during the time of sample collection.

As an additional measure of surface-water quality, TVA evaluates and rates its reservoirs in relation to their ecological health. The rating system is based on five ecological indicators: (1) level of dissolved oxygen, (2) amount of chlorophyll as a measure of algae in the water, (3) number and variety of healthy fish, (4) variety of animal life on the reservoir bottom, and (5) concentrations of metals and other contaminants such as pesticides and polychlorinated biphenyls in the reservoir sediments (TVA 2011g, 2011h). TVA samples the reservoirs at several locations on a 2-year cycle unless results show notable changes that require verification on a shorter schedule. TVA scores and compiles these results to generate a composite rating of the reservoir's overall ecological health. Figure 3-11 shows the results of the rating system from 1994 to 2009 for the Nickajack and Chickamauga Reservoirs.

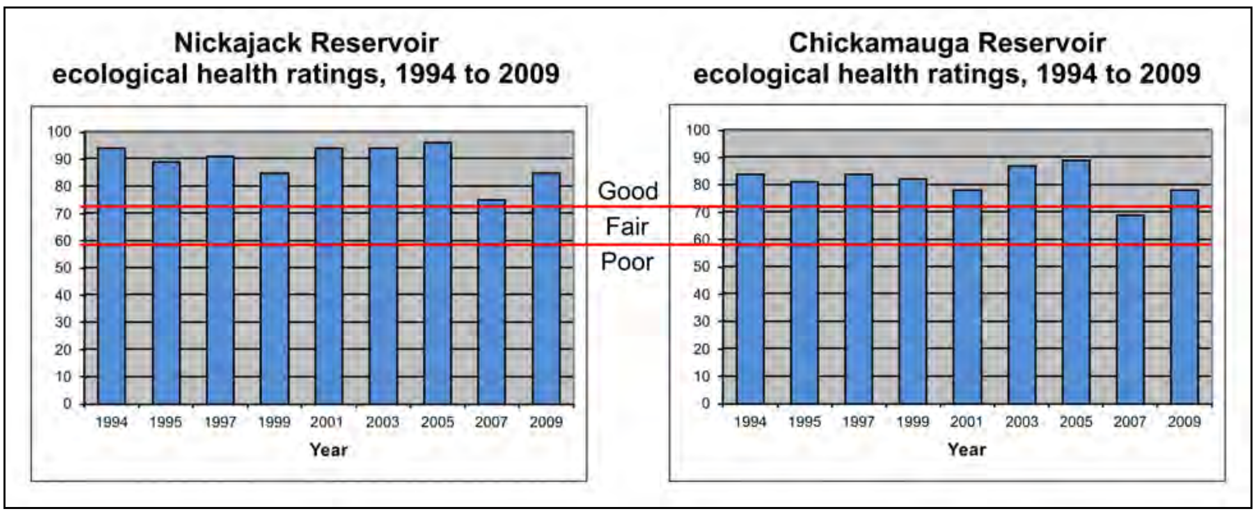

Figure 3-11. Ecological health ratings of the Nickajack and Chickamauga Reservoirs (Data sources TVA 2011p, 2011h).

As the figure shows, the ecological health rating of the Nickajack Reservoir has been consistently good since 1994. TVA attributes these high ratings to the fact that this reservoir is small and narrow with a short retention time, which prevents it from stratifying during summer. This keeps oxygen levels up in the lower water column and limits algal growth (TVA 2011p). These ratings often follow flow conditions in the reservoir, with the ratings being lower when flow is also low; dissolved oxygen is the ecological indicator most responsive to low flow. This is also evident in the ecological health ratings for the Chickamauga Reservoir, which have consistently been in the good range with the single exception in 2007. Ratings for both reservoirs dipped in 2007 due to low flows; it was the driest in 118 years of record (TVA 2011h).

3.2.5.1.3 Surface-Water Use and Rights

Regional Surface-Water Use

TVA and the U.S. Geological Survey compiled water use data for the area that makes up the TVA water control system (TVA 2008c). The data, from 2005, are presented in multiple groupings and water use categories. Two of the groupings are Reservoir Catchment Areas and Water Use Tabulation Areas. Under the method TVA and the Geological Survey used, the Catchment Areas are land areas centered on a primary TVA-operated reservoir and the Tabulation Areas are groupings of one or more Reservoir Catchment Areas. As appropriate, multiple Catchment Areas were grouped together when there were notable water-use transactions between them. Of significance to this discussion, the Watts Bar Reservoir Catchment Area and the Chickamauga Reservoir Catchment Area are grouped together into a Water Use Tabulation Area. The Nickajack Reservoir Catchment Area, the next area in a line to the south, is in its own Water Use Tabulation Area. TVA and the Geological Survey used this approach of Reservoir Catchment Areas to compile cumulative water use figures starting with the areas farthest upstream and ending with those near the junction with the Ohio River (Figure 3-10). In addition, water use results were presented in terms of categories of water users (specifically, thermoelectric, industrial, public supply, and irrigation), and water source (that is, as a surface-water or groundwater withdrawal). The report addressed one other water use element significant to the cumulative water demand in the surface-water system, namely return flow, which returns to the system after being withdrawn for a beneficial purpose. Return flow includes discharges from industrial or publicly owned wastewater treatment plants and cooling water TVA returns to the stream or reservoir after use. The U.S. Geological Survey compiles water use data every 5 years, but data are not yet available for 2010.

Table 3-31 summarizes water use in the Watts Bar, Chickamauga, and Nickajack Reservoir Catchment Areas. Each Catchment Area includes large surface areas that extend into multiple Tennessee counties, and the Nickajack area extends into the northeast corner of Georgia. The table lists average values for 2005 in millions of gallons per day. As the data show, the primary water use in both the Watts Bar and Chickamauga Reservoir Catchment Areas is thermoelectric. The Kingston (coal-fired) Thermoelectric Plant is in the Watts Bar Reservoir Catchment Area, and both the Watts Bar and Sequoyah sites are in the Chickamauga Reservoir Catchment Area. There are no thermoelectric plants in the Nickajack Catchment Area. The data also show that surface-water withdrawals meet most water demand in all three areas. TVA data show that almost 99 percent of the withdrawn water returns to the water flow system. The return rate of almost 106 percent for both the Chickamauga and Nickajack Reservoir Catchment Areas is the result of water that comes from one system but returns to another. The primary example of this (involving the most water) is the Watts Bar site, which withdraws water from the Watts Bar Reservoir and puts it back into the Chickamauga Reservoir.

Public water systems downstream of the Sequoyah site include two primary users. The City of Chattanooga, about 8 miles (10 River Miles) southwest and downstream of the plant, has one utility district and one water company that provide water. The utility district withdraws water from the Chickamauga Reservoir, and the water company withdraws from the Nickajack Reservoir a couple of miles below Chickamauga Dam (TVA 2010a). The two providers serve a combined population of 223,000 with water from the Tennessee River (EPA 2011e). In addition, public recreation is a significant nonconsumptive use of the Chickamauga and Nickajack Reservoirs and one of their designated use classifications (Table 3-29).

Local Surface-Water Use

Consistent with the information in Table 3-31, the Sequoyah Nuclear Plant is the largest user of surface water in the southern portion of the reservoir. The Sequoyah site obtains its potable water and fire suppression water from the Hixson Utility District, which uses groundwater as its source. All other plant water comes from the Chickamauga Reservoir through the condenser cooling water and essential raw

Table 3-31. Average water use (millions of gallons per day) in the Watts Bar, Chickamauga, and Nickajack Reservoir Catchment Areas in 2005.[a]

Reservoir catchment area	Water source	Water use	Water use by category				Returned to surface water
			Thermo-electric	Industrial	Public supply	Irrigation	
Watts Bar	Surface water	1,443	1,431	0	11.9	0.34	NA
	Groundwater	1	0	0.02	0.9	0.03	NA
	Totals	**1,444**	**1,431**	**0.02**	**12.9**	**0.37**	**1,303**
	(percent of total)		(99%)	(<0.1%)	(0.9%)	(<0.1%)	(90.2%)
Chickamauga	Surface water	1,678	1,577	74.5	25.0	1.8	NA
	Groundwater	25	0	0.6	24.0	0.8	NA
	Totals	**1,703**	**1,577**	**75.1**	**49.0**	**2.6**	**1,804**
	(percent of total)		(92.6%)	(4.4%)	(2.9%)	(0.1%)	(105.9%)
Nickajack	Surface water	47	0	5.4	41.6	0.2	NA
	Groundwater	8	0	6.7	0.8	0.1	NA
	Totals	**55**	**0**	**12.1**	**42.4**	**0.3**	**58**
	(percent of total)		(0%)	(22.0%)	(77.2%)	(0.5%)	(105.5%)
Watts Bar, Chickamauga, and Nickajack combined	Surface water	3,168	3,008	79.9	78.5	2.3	NA
	Groundwater	34	0	7.3	25.7	0.9	NA
	Totals	**3,202**	**3,008**	**87.2**	**104.3**	**3.2**	**3,165**
	(percent of total)		(93.9%)	(2.7%)	(3.3%)	(<0.1%)	(98.8%)

a. Source: TVA 2008c.
NA = not available; > = less than.
Note: Sums might not equal total values due to rounding.

cooling water pumping stations. Both stations take water from the reservoir on the north (upstream) side of the plant. The condenser cooling water pumping station is at the end of a 1,650-foot-long intake channel that links it to the main body of the reservoir. A skimmer wall on the reservoir side of the intake channel prevents floating debris from getting into the channel and supports removal of water from subsurface areas where the water is cooler. The pumping station for the essential raw cooling water is at the reservoir's edge on the upstream end of the skimmer wall. This pumping station maintains contact with water during any reservoir level fluctuation, including loss of the downstream dam and during a probable maximum flood (TVA 2010a).

Figure 3-12 is a diagram of the Sequoyah Nuclear Plant's water flows and discharges, focusing on the cooling system. Most of the water from the Chickamauga Reservoir comes into the Sequoyah site through the condenser cooling water pumping station and its six pumps, each with a maximum capacity of almost 420 cubic feet per second. Each of four pumps in the essential raw cooling water pumping station has a capacity of about 25 cubic feet per second. In 2005, the two pumping stations provided an average of about 2,380 cubic feet per second (or 1,540 million gallons per day for comparison with the values in Table 3-30).

The Sequoyah site's condenser cooling water system operates in several modes:

- <u>Open mode</u>. During most of the year, the system operates in a once-through, or open, mode in which the cooling water from the reservoir picks up heat from the condenser, discharges to the diffuser pond within the plant boundaries, and returns to the reservoir through diffuser pipes. In this mode, the cooling towers do not operate and there is essentially no loss of cooling water; the withdrawn amount is the same as the discharged amount.

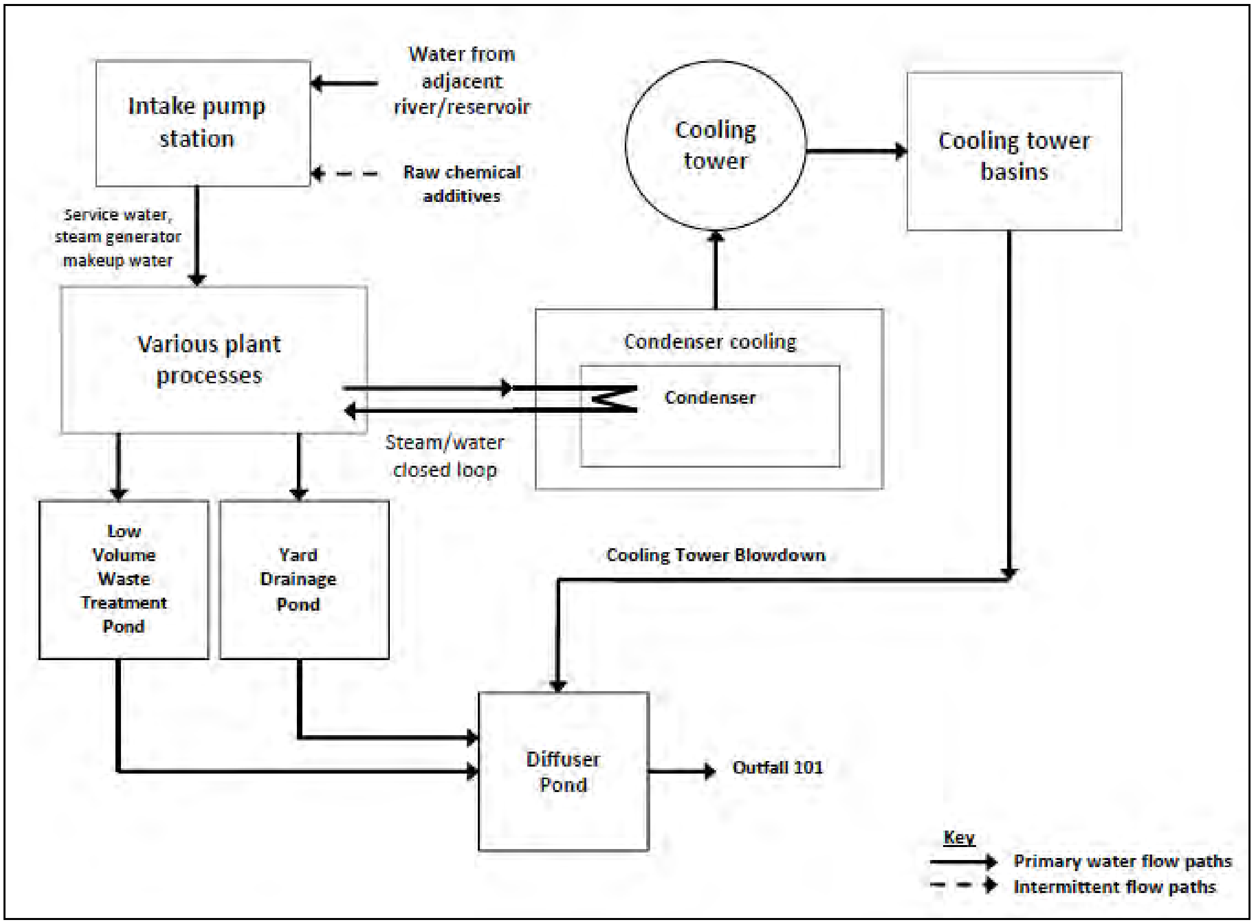

Figure 3-12. Process and cooling water flows and discharges at the Sequoyah site.

Drift

Cooling water that is lost as mist or spray carried into the atmosphere from cooling towers.

Blowdown

Water drained from a cooling system to control mineral buildup. Evaporative cooling, such as occurs in cooling towers, increases mineral levels in the remaining water. Draining a portion of the circulating water and replacing it with fresh (makeup) water is a method used to keep mineral concentrations at an acceptable level.

- Helper mode. When the temperature of the condenser cooling water that returns to the reservoir approaches a permit limit, the system operates in helper mode. In this mode, the cooling water goes through the cooling towers before discharge to the diffuser pond and return to the reservoir. There is loss of cooling water in this mode from evaporation and drift that can be as much as 57 cubic feet per second. From 2006 through 2009, the Sequoyah Nuclear Plant operated in the helper mode for an average of about 113 days per year (TVA 2010a).

- Closed mode. In this rarely used mode the condenser cooling water goes through the cooling towers, but rather than discharging to the diffuser pond and the reservoir, it discharges to the intake channel for recycling through the cooling system. Only blowdown from the system discharges to the diffuser pond and the reservoir in this mode. The pumps must add water from the reservoir to make up for the water losses from evaporation, drift, and blowdown.

The essential raw cooling water system removes heat from process locations in both the primary (radioactive) and secondary (nonradioactive) portions of the reactors. This is a once-through system, so the amount of intake water is basically the same as the amount of discharge back to the reservoir. In 2005 the condenser cooling system withdrew and discharged water at an average rate about 2,380 cubic feet per second. This represents about 7.4 percent of the average flow in the reservoir. During times when the condenser cooling system was in helper mode, the pumps withdrew water at the same rate but the discharge was about 57 cubic feet per second less, which is less than 0.2 percent of the average flow through the Chickamauga Reservoir.

The Sequoyah site operates several discharge outfalls for returning water to the Chickamauga Reservoir under the terms of its National Pollutant Discharge Elimination System permit (TN0026450) (TVA 2011d). The primary discharge point is Outfall 101 (Figure 3-13) where the cooling water returns to the reservoir. The permit also regulates several discharge points that are internal to the plant as water moves from one holding or treatment pond to another. The following discussion deals only with those outfalls where water discharges or might discharge to the reservoir:

- Outfall 101. This outfall is the line that drains the diffuser pond and is the primary outfall for the plant. The line consists of a two-pipe multiport diffuser on the bottom of the Tennessee River straight out from the diffuser pond on the south side of the site at River Mile 483.65. The upstream pipe extends 1,300 feet into the reservoir; the last 350 feet is a 17-foot-diameter diffuser section (the section with outlets). The downstream pipe parallels the first, is 16 feet in diameter, and is 350 feet shorter. The last 350 feet is the diffuser section. The outlets on the diffuser sections of both lines point downstream. In combination, the two diffuser lines discharge through a 700-foot band that begins 600 feet from the shore. This point on the shore juts into the reservoir about 500 feet. Each of the diffuser lines has a flow of about 1,190 cubic feet per second with an average pressure head of 7 feet in the diffuser pond. The mixing zone for this discharge (defined in the National Pollutant Discharge Elimination System permit) is an area 750 feet wide that extends 1,500 feet downstream and 275 feet upstream of the diffusers. The diffuser pond receives cooling water from the condenser cooling water system, the essential raw cooling water system, wastewater from several process water holding and treatment ponds, and storm water runoff from the site. TVA mixes low-level radioactive liquid waste with waste cooling water before it goes to the diffuser pond (TVA 2010a).

- Outfall 110. A surface-water channel runs north from the area of the cooling towers to the forebay area of the intake channel. When the condenser cooling water system is operating in the closed mode, this surface-water channel is the means of recycling the cooling water back to the beginning of the water system. The point where the channel meets the forebay is Outfall 110. When the condenser cooling water system is in open or helper mode, gates close off the channel to the forebay and the water flows to the diffuser pond through another set of gates. Because the condenser cooling water system seldom operates in the closed mode, the plant rarely uses Outfall 110. In a 2010 document, TVA reported that it had been inactive for about 14 years (TVA 2010a).

- Outfall 116. Wastewater from backwashing of the condenser cooling water intake system discharges through Outfall 116, a reservoir inlet on the north side of the site.

- Outfall 117. Wastewater from backwashing the screen and strainer on the essential raw cooling water intake system discharges through Outfall 117, next to the system intake pumps on the reservoir.

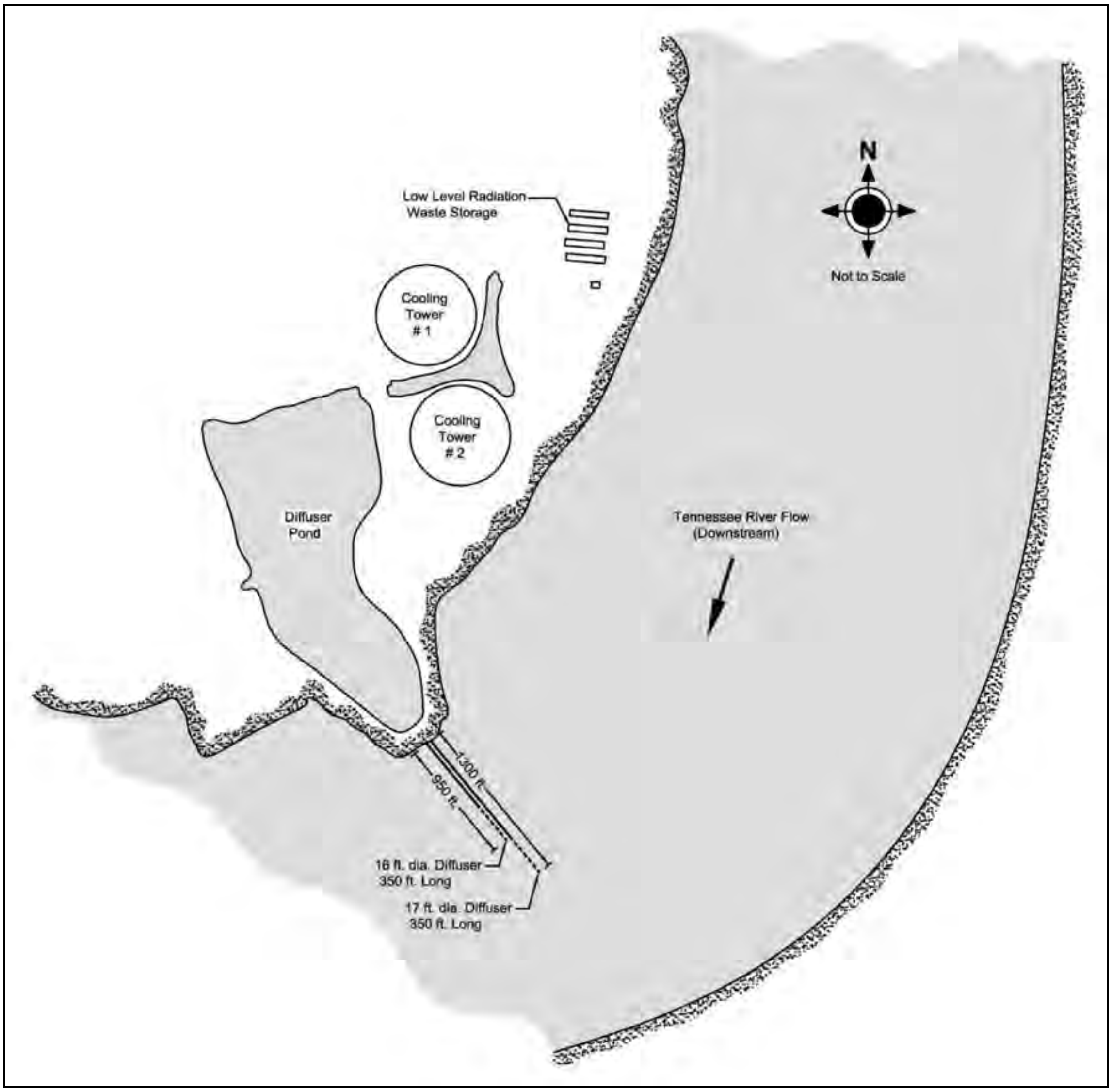

Figure 3-13. Location of submerged diffusers at Sequoyah Outfall 101 (TVA 2010a).

- Outfall 118. On the forebay area of the intake channel, this outfall is for water from the dredge pond TVA occasionally operates in conjunction with the essential raw cooling water system. The dredge pond has been inactive since 1997. Outfall 118 is also inactive, receiving only storm water falling on the dredge pond and the adjacent vegetated areas (TVA 2010a).

Consistent with its use as cooling water, a primary concern for discharges back to the reservoir is the temperature of the effluent and its effects on the temperature of the receiving water. Table 3-32 summarizes the temperature limits from the National Pollutant Discharge Elimination System permit for Sequoyah Outfall 101.

TVA treats water for cooling with various chemicals to maximize cooling effectiveness and to minimize adverse impacts on plant components. These chemicals consist primarily of (1) corrosion inhibitors to prevent rusting of component surfaces and (2) materials to keep heat exchange surfaces clean. This latter group of chemicals includes biocides, surfactants, and dispersants to keep the surfaces clean of mineral or biological buildup (such as mollusks or other biota). TVA identifies these chemical additives, and any proposed changes to their makeup, to the State along with toxicological data for approval. TVA tightly

Table 3-32. Temperature limits for Sequoyah Outfall 001 to the Tennessee River (TVA 2010a).

Outfall	Parameter	Averaging period (hours)	Limit
101	Maximum temperature at downstream end of diffuser mixing zone[a]	24	86.9°F
	Maximum temperature at downstream end of diffuser mixing zone	1	93.0°F
	Maximum temperature rise at downstream end of diffuser mixing zone		
	April through October	24	5.4°F
	November through March	24	9.0°F
	Maximum temperature rate of change	1	±3.6°F

Source: TVA 2010a.

a. When the 24-hour ambient temperature exceeds 84.9°F, the 24-hour downstream temperature can exceed 86.9°F, if there are at least three cooling tower lift pumps in service for each operating unit. In all cases, the hourly average temperature at the downstream end of the mixing zone shall not exceed 93.0°F.

controls the use of approved chemicals to ensure that discharges comply with the State water quality criteria and applicable permit conditions. Under the terms of the permit, TVA has developed and implements a biocide and corrosion treatment plan that requires, among other things, that the site submit an annual report to the State that identifies specific chemical use and monitoring results.

TVA mixes low-level radioactive wastewater with the water the Sequoyah site discharges to the diffuser pond and later to the reservoir. The tritiated water tank system would be connected to the plant's liquid radioactive waste discharge system (not shown on Figure 3-12) and would discharge to the cooling tower blowdown piping that leads to the diffuser pond and then to Outfall 101. Table 3-33 summarizes the radiological constituents in the discharged liquid from 2006 to 2010. The 1999 EIS reported similar information, which the table provides for comparison purposes. The "Other radionuclides" row in Table 3-32 includes (1) fission and activation products, (2) dissolved and entrained gases, and (3) gross alpha activity. However, each of the annual reports for this period indicated that gross alpha activity was below detection limits in all the analyses. The tritium discharges in the table are representative of typical, baseline conditions because TVA has not irradiated TPBARs at the Sequoyah site.

Table 3-33. Annual radioactive liquid effluents released to the environment from the Sequoyah site (curies).

		2006 through 2010[a]		
Material	1999 EIS	Minimum	Maximum	Average
Tritium	715	1,270	2,190	1,740
Other radionuclides	1.15	0.028	2.73	0.64

a. Sources: TVA 2007c, 2008d, 2009d, 2010e, 2011o.

At the river's average flow rate of 32,000 cubic feet per second at the Sequoyah site, the radionuclide discharges in Table 3-33 are diluted by about 1 trillion cubic feet of water over the course of a year, so concentrations are very low. The TVA annual reports for 2006 through 2010 (see table footnote) describe the radiological constituents of the liquid effluents as being within applicable NRC concentration limits in 10 CFR Part 20, "Standards for Protection Against Radiation," and within EPA dose limits in 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations."

Surface-Water Rights

Tennessee water law has been based historically on common law riparian doctrine under which landowners adjacent to surface waters have use rights but not property rights to the water, which is common property. As a result of increasing water demand, Tennessee has modified this traditional approach to "regulated riparianism" in which the water is public property and its use is controlled through regulatory permit systems (TACIR 2010). These permit systems incorporate concepts such as "reasonable use" or "beneficial use," which provides the State the ability to protect water quantity and quality for a variety of uses and users. The *Tennessee Water Quality Act of 1977* (Tennessee Code Annotated 69-3-101) requires anyone that would change the character of the water to obtain a permit from the Tennessee Department of Environment and Conservation (Tennessee 2002), and the implementing regulations specify that an Aquatic Resource Alteration Permit is required for water-altering activities including withdrawal (TACIR 2010). Construction or modification of intake structures for withdrawing water from TVA water systems could require permits from the U.S. Army Corps of Engineers and TVA.

3.2.5.2 Groundwater

3.2.5.2.1 Groundwater Hydrology

The region of the Sequoyah site is in the Valley and Ridge Physiographic Province of the eastern United States. This province is characterized by a sequence of folded and faulted, northeast-trending sedimentary rocks that form a series of alternating valleys and ridges. The principal aquifers in this province are the carbonate rocks that typically underlie the valleys and connect directly to sources of recharge such as rivers or lakes. Once water reaches the consolidated carbonate rocks, movement is along fractures, bedding planes, and solution openings. Because the rocks are so heavily folded and faulted, groundwater movement is generally localized; most movement takes place in a series of adjacent, isolated, shallow groundwater flow systems within 300 feet of the land surface. Most groundwater discharges directly to local springs or streams (Lloyd and Lyke 1995).

The Conasauga Formation underlies the peninsula on which TVA built the Sequoyah Nuclear Plant; it consists of several hundred feet of interbedded limestone and shale. The Conasauga is a poor water-bearing formation with groundwater occurring primarily in small openings along fractures and bedding planes, which decrease in size with depth. Groundwater at the site comes from infiltration of precipitation; the water table is 10 to 25 feet below ground. Groundwater movement is to the northeast and southwest into the Chickamauga Reservoir (TVA 2010a).

3.2.5.2.2 Groundwater Quality

In relation to water quality, the groundwater of the area is hard due to the presence of dissolved minerals; the longer the water travels underground, the higher the concentration of minerals. In places where the overlying alluvial materials are thin, the aquifers are susceptible to contamination by human activities (Lloyd and Lyke 1995).

TVA has monitored groundwater quality over the years at the Sequoyah site to obtain background concentrations, to examine the effect of onsite disposal practices, and in response to specific incidents. The remainder of this section addresses monitoring findings specific to tritium and fuel oil contamination.

Monitoring for tritium began in 1977. At first, TVA used four wells around the perimeter of the site (wells W-1, -2, -4, and -5 in Figure 3-14). In 1980, TVA reduced the monitoring to one well (W-5). Test results in this well in 1989 showed a tritium concentration of 379 picocuries per liter. The next detection of tritium was in 1998. From then until 2001 TVA detected tritium consistently at concentrations between 401 and 2,120 picocuries per liter. Monitoring has not shown tritium in that well since 2001.

TVA expanded groundwater monitoring at the site in 2002 and 2004 in areas of known tritium contamination with 12 new monitoring wells (wells 24 to 35 in Figure 3-14). In 2007, the monitoring program again increased with almost 30 new geoprobe borings and monitoring wells. Results from these investigations suggest the tritium contamination in the groundwater is from past inadvertent releases of radioactive liquids. TVA has been able to link the results to specific events, locations, and timeframes. During the monitoring, there have been no results in excess of the tritium drinking water standard of

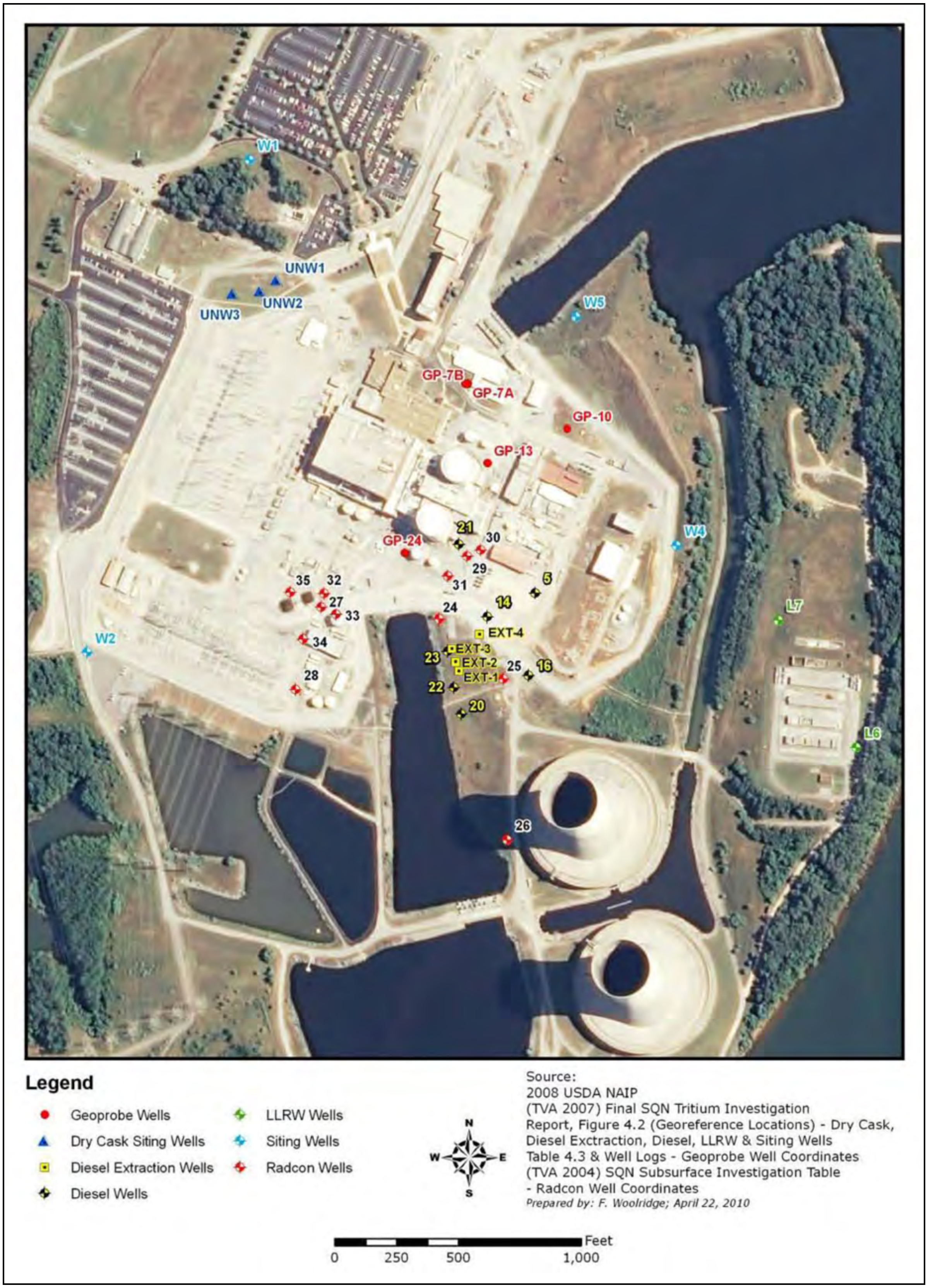

Figure 3-14. Geoprobe and monitoring well locations for tritium and diesel fuel investigations (TVA 2010a).

20,000 picocuries per liter. TVA has recently detected tritium in only four of the monitoring wells (GP-1, -21, -29, and -31); since 2008 the trend of observed tritium concentrations has been flat or downward.

TVA no longer engages in the activities it has linked to the contamination. Because of this, the stabilization or reduction of detected concentrations, and the fact that concentrations are less than drinking water standards, no active remediation has been started or recommended. TVA will continue to evaluate groundwater conditions (TVA 2010a).

In the early 1990s, TVA discovered two leaks in an underground diesel fuel transfer line at the Sequoyah site. TVA repaired the leaks and installed nine groundwater monitoring wells to assess the incident. The results indicated a free product plume extending from the leak location to the discharge channel for the condenser cooling water system. TVA installed an interceptor trench and four extraction wells (Figure 3-14). A 1993 risk assessment concluded there was no significant risk to human health or the environment. In mid-2009, a section of pipe that supplied diesel fuel oil to underground storage tanks failed a pressure test. TVA took the system out of service and removed about 200 cubic yards of diesel-contaminated soil for offsite disposal. Results from testing of the underlying remaining soil were all below detection levels, and the Tennessee Department of Environment and Conservation formally closed the spill incident as of August 5, 2010 (TVA 2010a). There was no evidence that this second incident contributed to groundwater contamination.

3.2.5.2.3 Groundwater Use and Rights

As Table 3-31 indicates, groundwater use in the combined Watts Bar, Chickamauga, and Nickajack Reservoir Catchment Areas is minor in comparison with uses of surface water, about 1.1 percent of total water use. Groundwater use in the Nickajack Reservoir Catchment Area is a much higher percentage of the total (about 15 percent), but overall water use in this area is much less than in the other two. In both the Watts Bar and Chickamauga areas, the primary use for groundwater is public water supplies; in the Chickamauga area, groundwater use for public water supplies nearly equals that of surface water. Industry is the primary groundwater user in the Nickajack Reservoir Catchment Area.

The Hixson Utility District provides potable and fire protection water for the Sequoyah Nuclear Plant and the residential areas nearest to the site in Hamilton County. The district obtains its water from wells in the Cave Springs area about 8 miles southwest of the site and withdraws an average of about 8 million gallons per day (TVA 2010a). There are no groundwater supply wells on the Sequoyah site. Private wells are common in rural areas that public water supply systems do not serve. However, in a 2005 report on rural water needs in Tennessee, the State estimated there were only 355 residences without water service in all of Hamilton County.

Tennessee’s groundwater law evolved from a doctrine called, among other names, the “rule of capture,” which allowed landowners to withdraw an unlimited quantity of water from groundwater under their properties, regardless of injury to other landowners, unless it could be proven that the groundwater was part of an underground stream, in which case it was treated as a surface water for legal purposes. As with surface water, the law shifted to a “reasonable use rule” that restricted groundwater use to the overlying land and required that it be noninjurious to other landowners; groundwater became more like common property than private property. Actions that would change the character of groundwater would require an Aquatic Resource Alteration Permit as described above for surface-water actions (TACIR 2010).

3.2.5.3 Floodplains and Wetlands

3.2.5.3.1 Floodplains

Figure 3-15 is a segment from the Flood Insurance Rate Map from the Federal Emergency Management Agency for the area of the Sequoyah site. The reactor and turbine buildings are within the oval overlay in the center of the figure. The map area with dark shading represents the extent of the water level under conditions of a 100-year flood (FEMA 2002). Because of the nature of the facility, TVA has performed detailed flood analyses for the site and identifies the water level of the 100-year flood as 687 feet above mean sea level at River Mile 484.5 (TVA 2010a), which is next to the central area of the site. The "686" in the figure on inlets in the Tennessee River south of the plant is the flood elevation at those locations. There are similar "687" values on the north side of the site (not shown). TVA identifies the water elevation for the 500-year flood as 688.5 feet above mean sea level at River Mile 484.5 and identifies its flood risk profile at this location as 689 feet above mean sea level. In the area of the Sequoyah site, TVA uses the flood risk profile elevation to control residential and commercial development on TVA lands and, for TVA projects, to designate if a development should be considered flood damageable (TVA 2010a). To be conservative, TVA uses this 689-foot flood risk profile elevation to protect critical activities and facilities at the site rather than the normally required 500-year flood elevation, which would be lower.

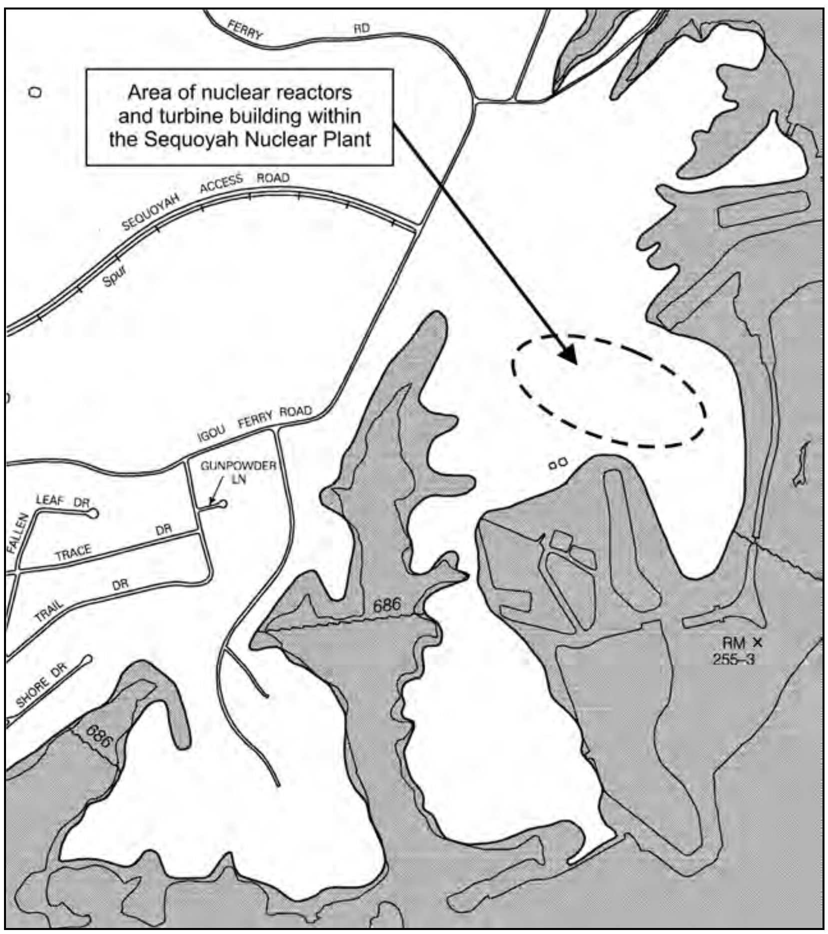

Figure 3-15. Segment from the Flood Insurance Rate Map for the area of the Sequoyah site (FEMA 2002).

Because Sequoyah is a nuclear facility, TVA has analyzed the potential effects of a probable maximum flood, which is defined as the most severe flood that can reasonably be predicted to occur at a site as a result of meteorological conditions (including a probable maximum precipitation event) and hydrologic factors of the specific watershed (TVA 2010a). Calculated flood levels for the probable maximum flood are higher than those for the 100- and 500-year floods on the Federal Emergency Agency map (Figure 3-15). TVA's ability to protect safety-related facilities, systems, and equipment at the site, and if necessary to shut down the plant, are evaluated against the much more rigorous standard of the probable maximum flood. That is, having facility locations, barriers, and procedures in place to prepare for and respond to the probable maximum flood level ensures protection from adverse impacts from lesser flood levels.

3.2.5.3.2 Wetlands

Figure 3-16 is from the U.S. Fish and Wildlife National Wetlands Inventory online mapper tool (http://www.fws.gov/wetlands/Data/Mapper.html). It shows potential wetlands on and near the Sequoyah site. The wetlands areas of the Chickamauga Reservoir and its bay or inlet areas are lacustrine (lake-related) wetlands, either permanently or semipermanently flooded (for areas with shoreline fluctuations).

Figure 3-16. Potential wetlands areas on and near the Sequoyah site.

The onsite ponds are permanently flooded palustrine (marsh-type) wetlands because they are not associated with flowing water. The green-colored area on the north side of the plant is a palustrine wetlands area that floods seasonally. In addition to these wetlands areas, TVA indicates there are likely to be woody wetlands in some areas that border the reservoir (TVA 2010a).

3.2.6 BIOLOGICAL RESOURCES

The Sequoyah site is in the Ridge and Valley ecoregion, which is also known as the Great Valley of East Tennessee. The Ridge and Valley ecoregion is a relatively low-lying region between the Blue Ridge Mountains to the east and the Cumberland Plateau on the west (TVA 2011b). As a result of extreme folding and faulting events, the roughly parallel ridges and valleys come in a variety of widths, heights, and geologic materials, including limestone, dolomite, shale, siltstone, sandstone, chert, mudstone, and marble. Springs and caves are relatively numerous. The Tennessee River flows through this region, roughly paralleling the alignment of the valleys. The Sequoyah site is near the center of Hamilton County, Tennessee, about 7.5 miles northeast of the Chattanooga city limits. The area immediately around the site is primarily open agricultural lands with scattered forests. Forests cover about 50 percent of the region. The ecoregion has great aquatic habitat diversity and supports a diversity of fish (Arnwine et al. 2000).

The Sequoyah site is an industrial facility of which about 40 percent is developed; it includes a mix of barren land, urbanized open space, and low-, medium-, and high-intensity improvements. In addition, the site includes other areas such as open water, forests, grasslands, pastures, and wetlands.

3.2.6.1 Flora

Decades of agricultural activities and land development (residential, light commercial, infrastructure, farming, etc.) have disturbed the vegetation at the Sequoyah site and in the general vicinity. Construction of the Sequoyah plant converted about 525 acres of mixed hardwood forest, pine forest, pasture, and old field into buildings, parking lots, landscaped areas, and other industrial uses (TVA 2011b). TVA assessed terrestrial plant communities during the initial environmental review for the construction of Sequoyah 1 and 2 (TVA 1974).

A January 2010 Sequoyah site walkover identified plant populations of various lawn and weedy species such as crab grass (*Digitaria* spp.) and herbaceous vegetation along fencerows and roadsides (TVA 2011b). Wooded areas are adjacent to Chickamauga Reservoir, around the training center, west of the ponds, along the reservoir between the intake channel and cooling towers, northwest of the old steam generator storage facility, and in the northern portion of the site. Common tree species included shortleaf pine and Virginia pine. Common invasive nonnative plant species in and around the site include Chinese privet (*Ligustrum sinense*), Japanese honeysuckle, trumpet creeper (*Campsis radicans*), Japanese stilt grass, multiflora rose, and Chinese bush clover (*Sericea lespedeza*). All of these species have the potential to affect the native plant communities adversely because they can spread rapidly and displace native flora (TVA 2009c).

3.2.6.2 Fauna

Hamilton and Bradley Counties, Tennessee, which are in the vicinity of the Sequoyah site, provide habitat for seven upland game species: white-tailed deer, gray squirrel, raccoon, wild turkey, ruffed grouse, cottontail rabbit, and bobwhite quail. Squirrel populations occur in large stands of hardwoods, while raccoons and rabbits are most common in the wide rolling valleys between the ridges (TVA 1974). Flooded areas in and around the site provide habitat for beavers (*Castor canadensis*) and common amphibians such as the American toad (*Bufo americanus*), Fowler's toad (*B. woodhousii fowleri*), upland chorus frog (*Pseudacris triseriata feriarum*), and northern cricket frog (*Acris crepitans crepitans*) (TVA 2009c). Common reptiles include eastern garter snake (*Thamnophis sirtalis sirtalis*), black racer (*Coluber constrictor*), and rat snake (*Elaphe obsoleta*) (TVA 2009c).

A variety of waterfowl and wading bird species such as great blue herons (*Ardea herodias*) and gulls (*Larus* spp.) use the Chickamauga Reservoir shorelines extensively (TVA 2011d). Some shoreline areas have eroded and are covered in riprap, preventing those areas from providing suitable habitat to terrestrial wildlife (TVA 2009c). There is a heron rookery, identified in 2010, along the eastern shoreline of the Sequoyah site near the intake structure in the Chickamauga Reservoir. About 15 to 20 herons were seen nesting in pine trees. Two additional heron colonies occur within 3 miles of the site (TVA 2009c, 2011b).

The bald eagle is a fairly common winter resident and occasional summer resident on the Chickamauga Reservoir. Several bald eagle nests occur along the Chickamauga Lake area, more than 10 miles from the plant. In addition, one nest was found in close proximity to the Sequoyah facility in 2011, and another currently active nest is directly across the river from the facility (Somershoe 2012). Ospreys feed primarily on fish and regularly occur on the Chickamauga Reservoir. One osprey nest has been documented just north of the Sequoyah site (Osprey Watch 2012). The peregrine falcon (*Falco peregrinus*) formerly nested on the Cumberland Escarpment in Hamilton County and very recently nested on a bridge spanning the Chickamauga Dam tailwater. Suitable nest habitat does not occur in the vicinity of the site. The peregrine falcon is, however, a rare migrant in the area. Peregrine falcons feed mostly on waterfowl, shorebirds and, in urban areas, pigeons.

3.2.6.3 Aquatic Environments

The Chickamauga Reservoir includes areas of varying depth, blind nonflowing embayments, tributary streams, peninsulas, inundated reservoir shallows (overbank areas), and the navigation channel or old riverbed (DOE 1999a). The area is characterized by embayments and shallow overbanks that alternate between the right and left banks as the channel changes course. There are extensive shallow areas in the stretch about 2 to 4 miles downstream from the Sequoyah site (TVA 1974; DOE 1999a). TVA has routinely studied aquatic conditions in the Tennessee River, including the Chickamauga Reservoir, as part of its Vital Signs Monitoring Program since 1990 (TVA 2011b).

3.2.6.3.1 Plankton Communities

The plankton community includes ichthyoplankton, which are eggs and larvae of fish that occur mainly in the upper reaches of the water column. The eggs are passive and drift with the water currents. Most fish larvae have a temporary free-floating stage before they develop the ability to swim effectively. Eggs of some fish species float possibly as a dispersal mechanism and to improve the survival rate of the larvae. Other fish eggs are demersal (that is, suspended on and or just above the bottom), and some are attached to various substrates. The free-floating eggs are more susceptible to entrainment because they are subject to the currents. TVA sampled fish eggs from four locations next to the Sequoyah site in 1985; it collected 35,257 eggs in 685 samples. Freshwater drum (*Aplodinotus grunniens*) eggs made up 99.5 percent of the total (TVA 2011b). Fish larvae from 685 samples in 1985 near the site totaled 121,370. Species of shad dominated at 61 percent of the total followed by sunfish (*Lepomis* spp.) at 17 percent.

3.2.6.3.2 Fish Communities

Preoperational monitoring for the Sequoyah site occurred from 1971 to 1977. Operational monitoring occurred from 1980 to 1986. Species designated as important to the Chickamauga Reservoir [sauger, crappie (*Perciformis annularis*), white bass, and channel catfish (*Ictalurus punctatus*)] were monitored from 1986 to 1995. Gizzard shad (*Dorosoma cepedianum*) and threadfin shad (*D. petenense*) dominate the fish community of the Chickamauga Reservoir, as in most main stream Tennessee River impoundments. Rough fish, especially carp (*Cyprinus* spp.), drum, and smallmouth buffalo (*Ictiobus bubalus*), contribute significantly to standing crop (biomass) estimates. Among the sport fish, largemouth and spotted bass, bluegill, redear sunfish, longear sunfish (*Lepomis megalotis*), crappie, and sauger are abundant, but smallmouth bass and walleye (*Sander vitreus*) are rare.

Differences are likely in the fish community along the longitudinal gradient with a more riverine community at the upper end of inflow of a reservoir and a more lacustrine (similar to a lake) community in the pool near the dam. Other factors to consider in evaluating biotic communities in reservoirs include characteristics such as water depth, fluctuation, drawdown, retention time, stratification, bottom anoxia, substrate type, and stability. The location of the Sequoyah site is where reservoir characteristics shift from the transitional zone to the forebay (lacustrine). TVA has routinely monitored the aquatic conditions in the Tennessee River, including the Chickamauga Reservoir, since 1993. It uses fish communities to evaluate ecological conditions because of their role in the aquatic food web, and because fish life cycles are long enough to integrate conditions over time. Scores and sums of 12 factors determine an overall Reservoir Fish Assemblage Index score for each sample collection site (TVA 2011b). Average scores have remained in the "good" range and scores from 1993 to 1999 (Table 3-34) are similar to those from 2000 to 2009 (Table 3-35), indicating stability over time.

Table 3-34. Reservoir Fish Assemblage Index scores[a] in Chickamauga Reservoir, 1993 to 1999[a].

Station	Location	1993	1994	1995	1997	1999	1993–1999 average
Inflow	TRM 529.0	52	52	48	44	42	**48**
Transition SQN upstream	TRM 490.5	51	40	48	39	45	**45**
Forebay SQN downstream	TRM 482.0	NR	NR	NR	NR	41	**41**
Forebay	TRM 472.3	43	44	47	40	45	**44**
Hiwassee River embayment	HiRM 8.5	46	39	39	40	43	**41**

Source: TVA 2011b.
HiRM = Hiwassee River Mile; NR = not reported; SQN = Sequoyah Nuclear Plant; TRM = Tennessee River Mile.
a. Reservoir Fish Assemblage Index scores: 12–21 (very poor), 22–31 (poor) 32–40 (fair), 41–50 (good), 51–60 (excellent).

Table 3-35. Reservoir Fish Assemblage Index scores[a] in Chickamauga Reservoir, 2000 to 2009.

Station	Location	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2000–2009 average
Inflow	TRM 529.0	44	46	48	48	42	42	42	42	44	44	**45**
Transition SQN upstream	TRM 490.5	46	45	51	42	49	46	47	44	34	41	**45**
Forebay SQN downstream	TRM 482.0	48	46	43	45	41	39	35	38	38	37	**41**
Forebay	TRM 472.3	45	48	46	43	43	46	43	41	41	34	**43**
Hiwassee River embayment	HiRM 8.5	43	47	NR	36	42	45	NR	41	NR	42	**42**

Source: TVA 2011b.
HiRM = Hiwassee River Mile; NR = not reported; SQN = Sequoyah Nuclear Plant; TRM = Tennessee River Mile.
a. Reservoir Fish Assemblage Index scores: 12–21 (very poor), 22–31 (poor), 32–40 (fair), 41–50 (good), 51–60 (excellent).

3.2.6.3.3 Aquatic Macrophytes

In the reach of the Chickamauga Reservoir above the Sequoyah site (toward the Watts Bar site), some embayments support colonies of coontail (*Ceratophyllum* spp.), potamogetons or pond weeds (*Potamogeton* spp.), and cattails (*Typha* spp.) (DOE 1999a). There has been use of a chemical control program to suppress a Eurasian watermilfoil (*Myriophyllum spicatum*) invasion. Only a few submerged or emergent macrophytes occur in the immediate area of the Sequoyah site (TVA 1974; DOE 1999a).

3.2.6.3.4 Mussel and Clam Communities

Very few native mussels persist in the impounded river habitat next to the Sequoyah site (DOE 1999a). Sampling in this part of the Chickamauga Reservoir produced a few individuals that represent eight wide-ranging species. Large numbers of native mussel species occur in seminatural reaches of the Tennessee River not far downstream from Chickamauga Dam (at River Mile 471) and in an approximate 15-mile reach downstream from Watts Bar Dam (at River Mile 529). These areas are at least 13 miles downstream and 19 miles upstream, respectively, from the Sequoyah site (River Mile 483). There have been no commercial harvests of native mussels from the downstream part of the Chickamauga Reservoir in the last 20 to 25 years (DOE 1999a).

An important factor contributing to the decline in native mussel populations was the loss of habitat after impoundment of the river. Dam construction slowed the flow of the river, thereby permitting silt to settle and alter bottom conditions. Mussels generally prefer gravel or a mixture of sand, mud, and gravel, but do not survive in deep silt. While habitat for native mussels is scarce in this impounded part of the Tennessee River, suitable habitat supports large populations of the exotic Asiatic clam and a few native snails. The Asiatic clam has been present in the Chickamauga Reservoir for at least 30 years (DOE 1999a). In addition, the zebra mussel has been found in this area in the last few years.

In 2010, TVA conducted a survey of the Tennessee River near the Sequoyah site to document the existing mollusk community (unionid mussels, aquatic snails, and zebra mussel infestation) and habitat conditions in areas that site operations might affect and outside such areas (TVA 2011b). TVA studied four sites in the river adjacent to the site in areas that plant operations might affect and four sites in areas that site activities would not affect. Areas most likely to be affected by Sequoyah operations include the water intake and associated skimmer wall, coolant water diffusers and the associated mixing zone, and a submersed dam in the historical river channel downstream of the intake site that TVA uses to help retain colder deep water near the plant intake.

The survey showed that the sites near the Sequoyah site support relatively low-diversity, low-abundance mussel and snail communities. It found 280 mussels representing 10 species and 281 snails representing 4 species. The survey collected no Federally listed mussel or snail species (live or dead) (TVA 2011b). Mussel species richness and density in the study area are very low in comparison with other areas of the Tennessee River that still support viable mussel communities (since impoundment), particularly those with listed species like pink mucket. In areas of the mainstem river that still retain quality mussel habitat, species richness typically exceeds 15 species and can exceed 25 species (TVA 2011b).

3.2.6.4 Special-Status Species

> **Special-Status Species**
>
> This section focuses on special-status species. For this project, those include Federally listed threatened, endangered, and candidate species as well as species the State of Tennessee recognizes as of special concern in the area of the proposed project.

Under the provisions of Section 7 of the Endangered Species Act [16 U.S.C. § 1536(a)(2)], Federal agencies must ensure that any action authorized, funded or carried out by an agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat. TVA evaluated threatened and endangered species in the EIS for the relicensing of Sequoyah 1 and 2 (TVA 2011b). In March 2011, TVA completed a Natural Heritage Database query for a 6-mile radius around the Sequoyah site. Table 3-36 lists the threatened or endangered species with a known occurrence and other species of concern within the 6-mile range. There are no identified listed species on the Sequoyah site (TVA 2011b). In addition to the Natural Heritage Database list, determination of potential occurrence of Federally listed species is from the U.S. Fish and Wildlife Service listing for Hamilton County (USFWS 2012c).

3.2.6.4.1 Plants

The large-flowered skullcap (also known as the mountain skullcap) is a perennial herb in the mint family; it is Federally listed as a threatened species. It is restricted to three counties in southeast Tennessee and four counties in northwest Georgia, and occurs on rocky, relatively dry forested slopes and ravines and along forested streams with gravelly, fine sandy loam soils. The Fish and Wildlife Service first listed it in 1986, when it was known to exist at 10 different locations (DOE 1999a). Since then, it has been found at more locations and is presently known to exist at 36 sites with a minimum total population of 48,000

Table 3-36. Endangered, threatened, and other species of concern identified or potentially occurring near the Sequoyah site.

Common name	Scientific name	Federal status	State status[a]	State rank[b]	Habitat	Notes
Plants						
Gibbous panic-grass	*Sacciolepis striata*	NL	S	S1	Floodplains and shallow pools	Identified in 1985 (amount unknown) within about 1.5 miles of Sequoyah site.
Pink lady-slipper	*Cypripedium acaule*	NL	S-CE	S4	Piney woods	Two clumps identified in 2007 within about 6 miles of Sequoyah site.
Ovate-leaved arrowhead	*Sagittaria platyphylla*	NL	S	S2S3	Swamps and emergent wetlands	Identified in 1980 (amount unknown) within about 6 miles of Sequoyah site.
Fragrant bedstraw	*Galium uniflorum*	NL	S	S1	Dry woods	Identified in 1997 (amount unknown) within about 6 miles of Sequoyah site.
Tall larkspur	*Delphinium exaltatum*	NL	E	S2	Glades and barrens	Identified in 1938 (amount unknown) within about 5.75 miles of Sequoyah site.
American ginseng	*Panax quinquefolius*	NL	S-CE	S3S4	Rich woods	Identified in 2007 within about 6 miles of Sequoyah site.
Large-flowered skullcap	*Scutellaria montana*	T	T	S2	Escarpments and dry woods	Between 3 and 136 plants identified at 27 different locations from 1986 to 2006; locations were between 0.75 mile and 6 miles from Sequoyah site.
Small whorled pogonia	*Isotria medeoloides*	T	E	S1	Mid-elevation dry woods	Identified by Fish and Wildlife Service as occurring in Hamilton County.
Virginia spiraea	*Spiraea virginiana*	T	E	S2	Stream bars and ledges	Identified by Fish and Wildlife Service as occurring in Hamilton County.

Table 3-36. Endangered, threatened, and other species of concern identified or potentially occurring near the Sequoyah site (continued).

Common name	**Scientific name**	**Federal status**	**State status[a]**	**State rank[b]**	**Habitat**	**Notes**
Birds						
Appalachian's Bewick's wren	*Thryomanes bewickii atlus*	NL	E	S1	Brushy areas, scrub, and thickets in open country, open and riparian woodland	Small number (amount unknown) of this bird spotted in 1908 within about 6 miles of Sequoyah site.
Bald eagle	*Haliaeetus leucocephalus*	Recovery	D	S3	Areas close to large bodies of water	From 1975 through 2005, between five and seven individuals, a pair, and a nest observed along Chickamauga Reservoir between about 1 and 6 miles from Sequoyah site.
Bachman's sparrow	*Aimophila aestivalis*	NL	E	S3B, S4N	Dry open pine or oak woods	One to two individuals spotted in 1969 within about 3 miles of Sequoyah site.
Great egret	*Ardea alba*	NL	D	S2B, S3N	In and around marshes, swampy woods, streams, lakes, ponds; fields, and meadows	Nest identified in 1991 within about 5.9 miles of Sequoyah site.
Fish						
Highfin carpsucker	*Carpiodes velifer*	NL	D	S2S3	Large rivers, mostly in Tennessee River drainage	One individual identified in 1994 during an electrofishing survey within about 5.75 miles of Sequoyah site.
Snail darter	*Percina tanasi*	T	T	S2S3	Sand and gravel shoals of moderately flowing, vegetated, large creeks; upper Tennessee River watershed	Identified by Fish and Wildlife Service as occurring in Hamilton County.

Table 3-36. Endangered, threatened, and other species of concern identified or potentially occurring near the Sequoyah site (continued).

Common name	**Scientific name**	**Federal status**	**State status[a]**	**State rank[b]**	**Habitat**	**Notes**
Mussels						
Dromedary pearly mussel	*Dromus dromas*	E	E	S1	Medium to large rivers with riffles and shoals and relatively firm rubble, gravel, and stable substrates	One individual identified in 1978 (date might not be accurate) within about 3 miles of Sequoyah site.
Pink mucket	*Lampsilis abrupta*	E	E	S2	Sand-gravel or rocky substrates with moderate-to-strong currents	More than one individual identified (exact amount unknown) in 1963 (date might not be accurate) within about 5.5 miles of Sequoyah site.
Orange pimpleback	*Plethobasus cooperianus*	E	E	S1	Large rivers in sand-gravel-cobble substrates in riffles and shoals in deep flowing water; Cumberland and Tennessee River systems	Identified by Fish and Wildlife Service as occurring in Hamilton County.
Indiana bat	*Myotis sodalis*	E	E	S1	Caves and abandoned mines in winter. Wooded areas for spring/summer roosting.	Identified by Fish and Wildlife Service as occurring in Hamilton County.

Sources: TVA 2011b; USFWS 2012c.

a. Status information
NL = not listed.
Federal abbreviations: E = endangered; T = threatened; C = candidate.
State abbreviations: E = endangered; T = threatened; D = deemed in need of management; S = special concern; S-CE = special concern, commercially exploited.

b. Rank information
S1: Extremely rare and critically imperiled in the state.
S2: Very rare and imperiled within the state.
S3: Rare and uncommon in the state.
S4: Widespread, abundant, and apparently secure within the state, but with cause for long-term concern.
_N: Occurs in Tennessee in a nonbreeding status (mostly applies to vertebrates).
_B: Breeds in Tennessee.

individuals. It was down-listed in 2002 to threatened status (USFWS 2002). A population of large-flowered skullcap occurs on a steep bluff across the Tennessee River from the Sequoyah site, and several other skullcap populations occur within a few miles of the site. There is no suitable habitat for this species on the site (DOE 1999a).

A population of the small whorled pogonia, Federally listed as threatened and State-listed as endangered, occurs on Walden Ridge about 15 miles southwest of the Sequoyah site. This widespread species occurs in open, dry deciduous woods with acid soil (USFWS 1992). Little suitable habitat occurs on the Sequoyah site, and field surveys of the site have not found this species (DOE 1999a).

Virginia spiraea is Federally listed as threatened and State-listed as endangered. The plant is limited to a seven-state distribution and typically occurs along stream banks where scouring from periodic flooding makes these areas inhospitable to other plants (USFWS 2009). According to the Natural Heritage Database, there has been no documentation of the Virginia spiraea near the Sequoyah site (TVA 2011b).

3.2.6.4.2 Terrestrial Animals

TVA is not aware of any Federally listed threatened or endangered terrestrial animal species on the Sequoyah site or in the immediate area. There are no known caves that gray bats might inhabit near the site; it is likely, however, that gray bats forage over adjacent portions of the Chickamauga Reservoir. There have been no observations of the Indiana bat at the Chickamauga Reservoir or elsewhere in Hamilton County. This bat hibernates in caves in other areas of east Tennessee and in northeast Alabama and periodic sightings occur in riparian forests along the Chickamauga Reservoir. There is little suitable habitat on the Sequoyah site (DOE 1999a).

The bald eagle was removed from the Federal list of endangered and threatened species on August 9, 2007. However, the bald eagle remains protected under the *Bald and Golden Eagle Protection Act*, which prohibits disturbance of bald and golden eagles, as well as the *Migratory Bird Treaty Act*. Bald eagle populations in the state of Tennessee have slowly been increasing. In the last 2 years, two active bald eagle nests have been reported near the Sequoyah site. One directly across the river from the site was active in 2012 (Somershoe 2012).

Two State-listed species, Bachman’s sparrow and Appalachian’s Bewick’s wren, might occur in the region based on old observations (Table 3-36).

3.2.6.4.3 Aquatic Animals

There are no known endangered or threatened aquatic species in the impounded part of the Chickamauga Reservoir adjacent to the Sequoyah site (DOE 1999a; TVA 2011b); however, the Fish and Wildlife Service lists a few species as potentially occurring in Hamilton County (Table 3-36). Conditions in this part of the reservoir are quite unlike the flowing-water, rocky-bottom habitats in which nearly all Tennessee River endangered and threatened species normally occur. Four protected aquatic species occur in the river not far downstream from Chickamauga Dam, 13 miles downstream from the Sequoyah site. Of these species, only the endangered pink mucket and the threatened snail darter have been encountered in the Chickamauga Dam tailwater within the last decade.

3.2.7 CULTURAL RESOURCES

Section 3.1.7 discusses Federal responsibility for historic preservation and the historical background of the Tennessee River Valley.

Historic and Cultural Resources at the Sequoyah Site

The area of potential effect for the proposed action is that within the Sequoyah site boundary. An archaeological contractor conducted a literature and records search of State of Tennessee archaeological files as part of operating license renewal activities for the plant (McKee et al. 2010). According to the literature review, there are two recorded and mapped mound complexes (40HA20 and 40HA22) along the shoreline of the Chickamauga Reservoir in the area of potential effect. Impoundment of the reservoir inundated a third recorded site (40HA21).

When TVA began developing assessments for continued production at Sequoyah, it conducted two cultural resource surveys at the site. The first was a 2009 survey (Jones and Karpynec 2009) for the preparation of an environmental assessment for a proposed project to replace a steam generator. The survey did not find additional cultural resources or historic properties nearby.

The second investigation was a Phase 1 archaeological survey of the entire Sequoyah site in February 2010 in preparation for the plant's operating license renewal application (McKee et al. 2010). The area of potential effect for that survey was also that within the site boundary. Archaeological surveyors found widespread disturbance across the site, even where there had been no development. These disturbances included debris, transmission line construction, and recreational use disturbances along the river shoreline. The survey identified and recorded three lithic scatters: one archaeological site (40HA549) and two isolated finds.

McKee et al. (2010) documented two historic cemeteries (McGill and Igou Cemeteries) within the Sequoyah site boundaries. Although historical records indicate the cemeteries were on the site, a goal of the survey was to identify their locations and evaluate their condition. The survey found that the McGill Cemetery was covered with pavement near an equipment warehouse. TVA records indicate that it relocated the burials from the cemetery to another local cemetery in the area. The Igou Cemetery is undisturbed and contains 44 graves; TVA maintains this cemetery (TVA 2011b).

TVA determined that none of the archaeological and historic sites the two surveys identified for the license renewal application were eligible for inclusion in the National Register (TVA 2011b); the Tennessee State Historic Preservation Officer concurred (TVA 2011b).

TVA has conducted interactions and consultations for a variety of undertakings with 14 American Indian tribes and groups that have cultural ties or interests in the Sequoyah site and surrounding region. These tribes and groups include the Cherokee Nation, Eastern Band of Cherokee Indians, United Keetoowah Band of Cherokee Indians in Oklahoma, The Chickasaw Nation, Muscogee (Creek) Nation of Oklahoma, Alabama-Coushatta Tribe of Texas, Alabama-Quassarte Tribal Town, Kialegee Tribal Town, Thlopthlocco Tribal Town, Seminole Tribe of Florida, Choctaw Nation of Oklahoma, Absentee Shawnee Tribe of Oklahoma, Eastern Shawnee Tribe of Oklahoma, and the Shawnee Tribe (TVA 2007a, 2011b). A letter requesting tribal participation and input in this SEIS was sent to the 14 tribal organizations in January 2013.

3.2.8 INFRASTRUCTURE AND UTILITIES

Electricity

The Sequoyah site includes two reactor units, each capable of producing about 1,198 megawatts of electricity (TVA 2012).

Water

The Sequoyah site used about 36.6 million gallons of potable water in 2010 (TVA 2012). The site receives its water from and returns it to the Chickamauga Reservoir. TVA transports potable water to support facilities that are not connected to the potable water system.

Steam

At full output, each Sequoyah reactor produces about 14.9 million pounds of steam per hour (TVA 2012).

Sanitary Sewer

The Sequoyah site is connected to the municipal sewer system in Soddy-Daisy, Tennessee (TVA 2012), and pumped offsite to the Moccasin Bend sewage treatment system. In 2011, the treatment system was functioning at only 75 percent of its available capacity and has sufficient capacity to handle the effluent from Sequoyah (SETDD 2012).

Industrial Gas

Large volume industrial gases (more than 10,000 pounds) at the Sequoyah site include the following (TVA 2012):

- Carbon dioxide for fire protection systems and generator purge during outages (about 60,000 pounds),

- Nitrogen as a cover gas for the cold-leg accumulators, in radioactive waste, and other locations (about 21,000 pounds), and

- Refrigerants including R-22, R-12, R-11, R-502 and possibly others (about 35,000 pounds).

Smaller volumes of gases include the following (TVA 2012):

- Hydrogen for generator cooling (about 800 to 1,000 pounds),
- Propane for the meteorological tower backup generator (about 4,000 pounds),
- Acetylene, argon, and oxygen for welding (no estimate available), and
- Laboratory gases for analyses and calibrations (no estimate available).

3.2.9 SOCIOECONOMICS

The Sequoyah site is near the Town of Soddy-Daisy in Hamilton County, in south-central Tennessee. Chattanooga is about 18 miles southwest of Soddy-Daisy. Highway access to Soddy-Daisy is by U.S. Highway 27.

> **Socioeconomics**
>
> The study of the interrelation between social and economic factors. For analysis under the *National Environmental Policy Act of 1969* (NEPA), these factors include income, employment, housing, community services, education, public safety, and health care.

Demography

The socioeconomic region of influence is Hamilton County, Tennessee. In 2010, about 1 million people lived within 50 miles of the Sequoyah site (USCB 2012). About 78 percent of the workforce at the site live in Hamilton County (TVA 2011b). Hamilton County had a population of about 336,500 in 2010, an increase of about 28,600 or 9.3 percent since 2000 (USCB 2000b, 2011d). In 2010, the county population per square land mile was 620, about 4 times the density per square mile of the State (USCB 2011d). The number of households in the county was about 136,700 in 2010, while the number of families was about 88,100 (USCB 2010k). Table 3-37 lists general demographic characteristics data for the county and, for comparison, the State of Tennessee.

Table 3-37. General demographic characteristics of Hamilton County and Tennessee, 2010.

Demographic measure	Hamilton County	Tennessee
Population, 2010	336,463	6,346,105
Percent change from 2000	9.3%	11.5%
Families	88,149	1,679,177
Households	136,682	2,493,552
Male	161,906	3,093,504
Female	174,557	3,252,601

Sources: USCB 2000b, 2010k, 2011d.

In Soddy-Daisy, the 2010 population of 12,714 represents an increase of 1,184 or 10.3 percent from 2000 and a large increase, 54.3 percent, from the 1990 count of 8,240 (USCB 2010l, 2011e). The projected population in the county will continue to grow, although rather slowly. The county's projected population will be about 352,200 in 2020, 355,600 in 2030, and 353,100 in 2040 (CBER 2012). The decennial rates of growth, 4.7, 1.0, and 0.7 percent, respectively, are substantially lower than the projected rate of growth in the State (CBER 2012).

Income

Total personal income in the county was $12.5 billion in 2009, up from $9.4 billion in 2000 (BEA 2011a). In 2009, per capita personal income in Hamilton County of $36,941 was about 7.8 percent higher than the statewide average of $34,277 (BEA 2012). Hamilton County median family income and median household income also exceed the State levels (USCB 2010m). The 2009 median value of an owner-occupied house in Hamilton County was about 111 percent of the median value of houses in the State that year (USCB 2010m). Table 3-38 summarizes income data for Hamilton County and, for comparison, Tennessee.

Table 3-38. Income and housing value[a] data for Hamilton County and Tennessee, 2009.[a]

Characteristic	Hamilton County	Tennessee
Per capita personal income	$36,941	$34,277
Median household income	$45,557	$42,943
Median family income	$58,045	$52,910
Median housing value[b]	$142,500	$128,500

Sources: BEA 2011a, 2011d, 2012; USCB 2010f, 2010m, 2011d.

a. 2009 inflation-adjusted values.

b. Owner-occupied units.

Employment

Employment by sector over the last decade has changed, as shown in Table 3-39. In 2009, the government and government enterprises, health care and social assistance, retail trade, and manufacturing sectors were Hamilton County's largest employers. Since 2001, there has been a slight employment shift from manufacturing and retail trade sectors towards the health care and social assistance and government and government enterprises sectors. Health care and social assistance accounted for almost 11 percent of all jobs in 2009, an increase of nearly 4 percent from 2001. Retail trade accounted for nearly 10 percent of all jobs in 2009, a decrease nearly 2 percent from 2001. The manufacturing industry also experienced a decrease, accounting for 9 percent of all jobs in 2009, a decrease of nearly 4 percent from 2001.

The rate of growth in the number of new jobs since 2001 lagged behind the rate of growth in the county population. The unemployment rate in the county has routinely and broadly reflected the unemployment rate in the United States and has been healthier than the unemployment rate in the State of Tennessee.

Table 3-39. Employment by sector (number of jobs).

Industry sector	Hamilton County	
	2001	2009
Total employment	235,076	233,131
Farm employment	751	647
Forestry, fishing, and related activities	718	(a)
Mining	309	(a)
Utilities	324	297
Construction	12,586	12,202
Manufacturing	30,632	21,703
Wholesale trade	8,438	8,124
Retail trade	27,220	22,823
Transportation and warehousing	20,647	15,807
Information	3,139	3,977
Finance and insurance	15,581	18,197
Real estate and rental and leasing	6,077	7,690
Professional, scientific, and technical services	11,235	13,346
Management of companies and enterprises	3,710	1,033
Administrative and waste management services	14,403	14,699
Educational services	2,973	3,505
Health care and social assistance	16,669	25,104
Arts, entertainment, and recreation	3,160	3,656
Accommodation and food services	15,302	17,998
Other services, except public administration	13,024	13,739
Government and government enterprises	28,178	28,266

Source: BEA 2011d.

a. Not listed to avoid disclosure of confidential information, but the estimates for this item are included in the total employment numbers.

The June 2011 unemployment rate of 9.2 percent suggests an ample labor pool of people available for work in Hamilton County (BLS 2011a). Table 3-40 lists information about the unemployment rate in the county and, for comparison, unemployment rates in Tennessee and the United States.

Table 3-40. Unemployment rates[a] in Hamilton County, Tennessee, and the United States, 2007 to 2011.

Period	Hamilton County	Tennessee	United States
June 2007	4.2%	4.8%	4.7%
June 2008	6.0%	6.8%	5.7%
June 2009	9.7%	11.3%	9.7%
June 2010	8.7%	9.7%	9.6%
June 2011	9.2%	10.2%	9.3%

Sources: BLS 2011a, 2011b.

a. Not seasonally adjusted

Housing

Hamilton County has about 148,400 housing units. Rental units make up a relatively high 33 percent of the occupied units. There are about 15,200 vacant housing units in the county. Table 3-41 contains data about housing characteristics in the county and, for comparison, Tennessee.

Table 3-41. Housing characteristics in Hamilton County and Tennessee, 2009.

Characteristic	Hamilton County	Tennessee
Total housing units	148,424	2,721,019
Occupied units	133,211	2,412,567
Owner-occupied	89,199	1,682,052
Renter-occupied	44,012	730,515
Vacant units	15,213	308,452
Percent vacant units	10.2%	11.3%

Sources: USCB 2010f, 2010m.

Community Services

NNSA examined education, public safety, and health care to determine the current level of community services for the county:

- Education. In the 2009–2010 school year, there were about 42,000 children in 80 public schools in the single school district in the county (NCES 2011d). The State of Tennessee had an average pupil-to-student ratio of 15 to 1; Hamilton County had an average 14.5-to-1 ratio (NCES 2011c).

- Public safety. Seven municipal (Chattanooga, Collegedale, East Ridge, Lookout Mountain, Red Bank, Signal Mountain, and Soddy-Daisy Police Departments) and one county law enforcement agencies provide police protection to residents in the county (USACOPS 2012). The average officer-to-population ratio was 2.1 to 1,000 residents (FBI 2010a, 2010b; USCB 2010n). Career, volunteer, and paid-per-call firefighters operating from 47 stations provide fire protection services in the communities of the county (USFA 2011). The ratio of firefighters to the county population is 2.7 to 1,000 (USFA 2011; USCB 2010n).

- Health care. There are eight hospitals in Hamilton County, all in Chattanooga (AHA 2006). Hospitals include general/surgical, psychiatric, rehabilitation, and long-term acute care facilities with a total of 1,869 staffed beds (AHA 2006).

3.2.10 WASTE AND SPENT NUCLEAR FUEL MANAGEMENT

The Sequoyah site generates wastes as a consequence of normal reactor operations. The wastes fall into three broad categories: hazardous, nonhazardous, and low-level radioactive waste. The site generates no high-level radioactive waste, as defined by the *Nuclear Waste Policy Act of 1982* (42 U.S.C. §§ 10101 *et seq.*). Table 3-42 summarizes the annual amount of waste in each category.

Table 3-42. Annual waste generation at the Sequoyah site.

Category	Amount
Hazardous waste[a]	1,063 pounds
Nonhazardous solid waste[a]	778 tons
Low-level radioactive waste[b]	4,697 cubic feet

Source: TVA 2011b.
a. Based on data from 2009.
b. Based on data from 2010.

Hazardous Waste

Hazardous wastes at Sequoyah typically include paints, solvents, acids, oils, radiographic film and development chemicals, and degreasers. Neutralization is the only waste treatment that occurs on site.

The site normally stores hazardous wastes in polyethylene containment systems during accumulation. TVA uses an approved storage building to store hazardous wastes for either 90 or 180 days, depending on the site's hazardous waste generator status at the time (that is, small quantity or large quantity). TVA transports waste to an offsite hazardous waste storage or disposal facility before it exceeds the 90- or 180-day storage limit.

Sequoyah's designation as a small quantity generator or as a conditionally exempt small quantity generator changes based on routine operating conditions and episodic waste generating activities at the site. The site was a conditionally exempt generator in 2006 and 2007, when it generated 220 pounds or less of waste in any calendar month in a year. It was a small quantity generator in 2008, 2009, and 2010, when it generated more than 220 pounds but less than 2,200 pounds in any calendar month in a year. Sequoyah has a permit for hazardous waste (TN 5640020504) under the *Resource Conservation and Recovery Act of 1976* (42 U.S.C. §§ 7901 *et seq.*) (TVA 2011b).

Waste Types

Hazardous waste:
Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment. Hazardous wastes appear on special EPA lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity (40 CFR 261.3).

Nonhazardous waste:
Nonhazardous waste consists of materials that are neither radioactive nor hazardous. Examples include normal household garbage, sanitary waste, and construction waste (EPA 2012).

Low-level radioactive waste:
Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. Low-level radioactive waste includes personal protective clothing, air filters, solids from the liquid low-level waste treatment process, and radiological control and survey waste (10 CFR 62.2).

TVA operates the hazardous waste storage facility in Muscle Shoals, Alabama, which has a Resource Conservation and Recovery Act Part B permit (AL2640090005) for temporary storage of hazardous wastes. The hazardous waste storage facility is a central collection point for most Sequoyah-generated hazardous wastes. TVA ships most of the hazardous waste from the Sequoyah site to the storage facility for consolidation, storage, and eventual disposal at approved and licensed facilities. The site generates used oil from maintenance activities on plant equipment, collects it, stores it on site, and ships it to an approved recycling center for recovery (TVA 2011b).

Nonhazardous Waste

Nonhazardous wastes at the Sequoyah site typically include construction materials, municipal solid waste (paper, plastics, garbage, and other items), and sanitary wastes. With the exception of sanitary wastes, TVA sends nonhazardous wastes from Sequoyah to the permitted Sand Valley Landfill in Collinsville, Alabama, which has an estimated remaining lifespan of about 30 years (TVA 2011b).

Low-Level Radioactive Waste

During the fission process, radioactive fission and activation products build up in the reactor in the fuel and the materials of construction. A small fraction of these materials escapes and contaminates the reactor coolant. The primary coolant system also receives radioactive contaminants. A radioactive waste treatment system removes these contaminants from the coolant. Sequoyah 1 and 2 use separate radioactive waste treatment systems for gaseous, liquid, and solid waste treatment. TVA combines residues from the gaseous and liquid waste treatment systems (filters, resins, and dewatered solids) and disposes of them with the solid low-level radioactive waste. Contaminated protective clothing, paper, rags, glassware, compactable and uncompactable trash, and reactor components and equipment constitute the majority of solid low-level radioactive waste at the Sequoyah site. Table 3-43 lists the low-level waste the site generates.

Table 3-43. Annual low-level radioactive waste generation at the Sequoyah site in 2010.

Waste type	Volume per year (cubic feet)
Spent resins, filter sludges, evaporator bottoms	318
Dry active waste, compressible waste, contaminated equipment	4,273
Mechanical filters and tank residue	106
Total	**4,697**

Source: TVA 2011b.

Low-level radioactive waste is classified as A, B, or C, with Class A the least hazardous and Class C the most hazardous. TVA transports its Class A low-level waste to the Energy Solutions licensed disposal facility in Clive, Utah. To provide storage for low-level waste TVA cannot ship, it has built an onsite storage facility. This facility is on a 16-acre site. The grade elevation is about 730 feet, which is above the probable maximum flood elevation. The facility consists of individual buildings called modules; each module contains packaged radioactive waste from Sequoyah and Watts Bar, and has four compartments. The modules are aboveground structures of reinforced concrete. The modules are designed to resist loads from extreme environmental events such as high winds, tornadoes, and seismic events. The structural characteristics of the onsite storage facility meet or exceed the criteria applicable to Sequoyah. The facility is inside an access-controlled security fence. Class B and C wastes constitute a low percentage by volume of the total of low-level waste in this facility. The facility has enough capacity to store the anticipated volume of Class B and C wastes that Sequoyah and Watts Bar would produce through 2035 (TVA 2011b).

Waste Minimization Practices

The Sequoyah site has an active waste minimization program that consists of the following practices:

- Salvaging useful portions of construction and demolition materials for resale.
- Maintaining segregated storage areas for each type of recoverable material.
- Selling scrap treated lumber or placing it in dumpsters for disposal by the solid waste disposal contractor at an offsite permitted landfill.
- Collecting inert construction and demolition wastes for disposal at the onsite permitted landfill.
- Placing waste paper in bins or dumpsters and selling it to an offsite recycling facility.
- Recycling and reselling aluminum cans.
- Placing nonrecoverable solid wastes in dumpsters for disposal by the solid waste disposal contractor.
- Collecting special wastes (for example, desiccants, oily wastes, insulation), storing them, and disposing of them by incineration.
- Sending asbestos to an approved special waste landfill for disposal.
- Collecting used oil, fluorescent tubes, and antifreeze, storing them in drums or tanks, and recycling them.

- Collecting medical wastes and disposing of them in accordance with the disposal procedure for TVA medical facilities.
- Discharging all plant sanitary wastewater directly to the Hamilton County Public Operated Treatment Works.
- Discharging metal-cleaning wastewater (for example, trisodium phosphate, acetic acid) to approved storage ponds for future disposal in accordance with the National Pollutant Discharge Elimination System permit.
- Routing wastewater from floor and equipment drains in nonradiation areas through sumps to the turbine building sump for discharge in accordance with the National Pollutant Discharge Elimination System permit.
- Selling surplus chemicals, recycling lead acid batteries, recovering and recycling refrigerant, and using solvent recovery equipment for painting operations.
- Incorporating steps to use biodegradable solvents and cleaners to replace hazardous chemicals in cleaning operations to the extent practical.

Spent Nuclear Fuel Management

When TVA irradiates nuclear reactor fuel to the point that it no longer contributes to the operation of the reactor, or if the fuel has cladding leaks that allow radioactive gaseous emissions, the fuel assembly becomes spent nuclear fuel and TVA removes it from the reactor core and stores it in the spent nuclear fuel storage pool or basin. *The Nuclear Waste Policy Act of 1982* gave the Secretary of Energy responsibility for the development of a repository for the disposal of high-level radioactive waste and spent nuclear fuel. When a repository became available, DOE would transport spent nuclear fuel for disposal from nuclear power reactors to the repository. Until a repository becomes available utilities will store spent nuclear fuel in reactor pools or in other NRC-licensed storage locations. Because of the uncertainty about opening a repository, NNSA assumed that TVA will continue to store spent nuclear fuel in onsite facilities for the duration of the proposed action (that is, until about 2035). The Sequoyah spent nuclear fuel pool has the capacity to hold 2,089 fuel assemblies.

Storage Capacity

A reserve spent nuclear fuel pool storage capacity is required for a full-core discharge (193 fuel assemblies) in the event it became necessary to remove all fuel from a reactor vessel. The remaining pool storage capacity can hold 1,884 fuel assemblies, because 12 storage cells might not be usable for various reasons. The Sequoyah site discharges about 107 spent nuclear fuel assemblies each year. As of July 2011, the spent nuclear fuel inventory at Sequoyah was 1,833 fuel assemblies, leaving a usable pool storage capacity of 246 fuel assemblies (TVA 2012). TVA will use dry cask storage to ensure the necessary capacity for a full-core discharge in the spent nuclear fuel pool. Sequoyah is currently using 26 dry cask storage containers to ensure the capacity to store a full core (TVA 2012).

3.2.11 HUMAN HEALTH AND SAFETY

Routine operations at the Sequoyah site have the potential to affect worker and public health. Air emissions from the site can lead to exposure to radioactive and nonradioactive materials. Liquid effluent discharges to nearby water bodies can affect downstream populations that use the water for drinking or recreation. In addition, workers are exposed to occupational hazards similar to those experienced at most industrial work sites. The following discussion characterizes human health impacts from the natural environment as well as current releases of radioactive and nonradioactive materials from the site.

3.2.11.1 Radiation Environment

Public

Table 3-44 lists average annual background radiation exposure to people in the vicinity of the Sequoyah site. The average annual dose to an individual from natural and manmade radiation is about 620 millirem (NCRP 2009). Based on a 2010 population of about 983,000 people (USCB 2012) within 50 miles of the site, the natural and manmade dose to the population is about 610,000 person-rem per year.

Table 3-44. Average annual dose from natural and manmade radiation in the United States.

Source	Dose (millirem)[a]
Natural	
Cosmic	33
Terrestrial	21
Radon	228
Internal	29
Manmade	
Medical	300
Consumer products	13
Other	0.3
Average annual total	**620[b]**

Source: NCRP 2009.

a. Values are based on average national data.

b. The actual value is 624.3 millirem. NNSA has rounded this value to 620 millirem in this SEIS.

Members of the public might be exposed to released emissions and effluents from the Sequoyah site that would be in addition to the background dose. TVA calculates radiation doses to individuals and populations each year using radiological monitoring points around the site and conservative assumptions about exposure. Table 3-45 lists these doses.

Table 3-45. Annual public doses from normal operations of the Sequoyah site in 2010.

Affected environment	Airborne releases[a]	Liquid releases[a]	Totals[a]	Regulatory limit
Maximally exposed offsite individual (millirem)	0.00406	0.0135	0.0176[b]	25[c]
Population within 50 miles (person-rem)[d]	1.662	0.903	2.535[b]	None
Average dose to an individual within 50 miles (millirem)	0.00169	0.00264	0.00430	None

Source: TVA 2011q.

a. NNSA based these calculations on actual measurements of releases.

b. NNSA based population data for airborne releases on the total 50-mile population around the site, which is about 983,000 people; it based population data for liquid releases on people using public water supplies downstream of the site within 50 miles, projected from data in TVA (2011q), which is 340,904 people.

c. The standard for the maximally exposed offsite individual (25 millirem per year for the total body from all pathways) is in 40 CFR Part 190.

d. Doses based on 2010 operations at the Sequoyah site (TVA 2011q).

Workers

Nuclear power plant environments produce radiation fields as a result of radioactivity in the reactor and its associated components. Design features and operating practices ensure that individual occupational radiation doses are within the limits in 10 CFR Part 20. In addition, TVA maintains individual and worker population doses as low as is reasonably achievable. Table 3-46 lists radiation doses received by onsite workers.

Table 3-46. Average annual worker doses from normal operations of the Sequoyah site, 2005 to 2010.[a]

Affected environment	Standard[a]	Dose[b]
Average worker (millirem)	None	105.4[c]
Maximally exposed worker (millirem)	5,000	1,425
Total workers (person-rem)	None	128

a. NRC regulatory limit from 10 CFR Part 20.
b. Source: TVA 2012.
c. Average annual worker dose was determined by dividing the average total worker dose over the 6-year period from 2005 to 2010 by the average number of exposed workers over that period.

3.2.11.2 Chemical Environment

Nonradioactive chemical wastes from Sequoyah 1 and 2 include boiler blowdown, water treatment wastes (sludges and high-saline streams with residues that TVA disposes of as solid wastes and biocides), boiler metal-cleaning solvents, floor and yard drain wastes, and stormwater runoff. Processes for defouling facility piping produce organic residue byproducts and halites (oxygenated chlorine and bromine ions). The operation of Sequoyah 1 and 2 includes controls on the storage of process chemicals and disposal of the waste products. TVA minimizes adverse health impacts to the public through administrative and design controls to decrease hazardous chemical releases to the environment and to achieve compliance with permit requirements (such as air emissions and National Pollutant Discharge Elimination System permit requirements). TVA verifies the effectiveness of these controls by monitoring information about and inspecting compliance with mitigation measures.

3.2.11.3 Emergency Preparedness

The NRC based the license it issued for the operation of Sequoyah 1 and 2 in part on a finding that there is reasonable assurance that TVA can and will take adequate protective measures in the event of a radiological emergency. The NRC based this finding on (1) a review of the Federal Emergency Management Agency findings, (2) determinations that State and local emergency plans are adequate and give reasonable assurance of implementation, and (3) the assessment that TVA onsite emergency plans are adequate and give reasonable assurance of implementation.

The Sequoyah Nuclear Plant emergency plan establishes that evacuation is the most effective protective action TVA can take to deal with radiological incidents. The plan provides the details of the evacuation plan, which tasks risk counties, identified as Bradley and Hamilton Counties, with preparing evacuation plans for citizens within the 10-mile emergency planning zone and determining the number of people to be evacuated from the zone. The plan assigns host counties, identified as Meigs, Rhea, and Sequatchie, responsibility to identify suitable shelters for evacuees. A State Emergency Operation Center would provide the focus for emergency reaction (for example, notifications, protective action, and evacuation implementation). Fixed sirens would alert residents and transients within the 10-mile emergency planning zone with backup, if needed, from emergency vehicle sirens and loudspeakers. The State Emergency Operation Center Director would involve county Emergency Management Directors as required. The Emergency Alert System and the National Oceanic and Atmospheric Administration Weather Radio would provide emergency information and instructions. The evacuation would be ordered and accomplished by designated sectors. Traffic assistance teams would patrol designated evacuation routes. The American Red Cross would operate mass care shelters. Shelter information points on each evacuation route would help direct evacuees to their assigned shelters. Evacuation planning requires considerable effort; training, education, and practice runs further the probability of successful evacuation if it is ever required (DOE 1999a).

3.2.12 TRANSPORTATION

The Sequoyah Nuclear Plant is on the Tennessee River (on Chickamauga Lake), near Soddy-Daisy, Tennessee, about 15 miles northeast of Chattanooga and 31 miles southwest of the Watts Bar Nuclear Plant. The Tennessee River is navigable past the site and is a major barge route.

A main line of the Cincinnati, New Orleans and Texas Pacific Railroad (a division of Norfolk Southern) runs from Cincinnati to Chattanooga and passes through Soddy-Daisy, parallel to U.S. Highway 27 (US 27), about 5 miles northwest of the plant. A TVA railroad spur connects the main line north of Soddy-Daisy to the Sequoyah plant. The spur would require refurbishment before use.

Figure 3-17 shows that US 27 parallels the river on the northwest, and State Route 58 (SR 58) parallels the river on the southeast. SR 60 provides the nearest upstream river crossing about 13 miles northeast of the plant. SR 153 provides the nearest downstream river crossing (on Chickamauga Dam) about 11 miles southwest of the plant. The Sequoyah Access Road (County Road 2158) connects the plant to US 27 just north of Soddy-Daisy. Interstate Highway 75 (I-75) runs between Chattanooga and Knoxville about 8 miles southeast of the plant, but access is limited to one of the two previously mentioned river crossings.

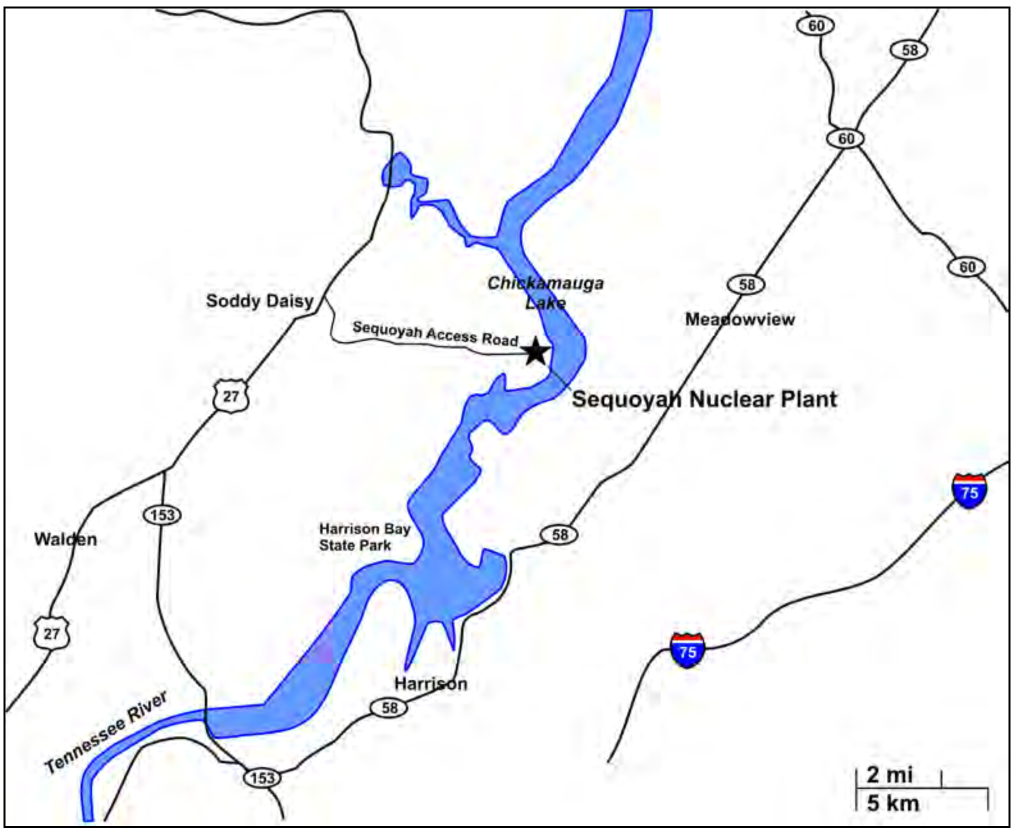

Figure 3-17. Transportation routes near the Sequoyah site (Source: Imagery ©2012 TerraMetrics, NASA, Map data ©2012 Google, Europa Technologies).

About 860 permanent employees commute daily to the Sequoyah Nuclear Plant. Commuters approach Sequoyah from the northwest on US 27 or SR 319. Most truck shipments arrive in the area on I-75 and then take either SR 153 or SR 60 to US 27 depending on the cargo and the origin. Other roads in the vicinity are available to commuting workers. Table 3-47 lists 2010 two-way annual average daily traffic volumes near the plant.

Table 3-47. 2010 annual average daily traffic volumes near the Sequoyah site.

Station and description	Traffic volume
Hamilton County	
19 – SR 319 north of Sequoyah Access Road (County Road 2158)	2,420
31 – SR 319 south of Sequoyah Access Road (County Road 2158)	6,986
60 – I-75 south of SR 60 exit	47,109
101 – SR 60 at river crossing	3,856
164 – I-75 south of SR 153 exit	96,259
167 – I-75 north of SR 60 exit	44,341
209 – SR 153 at Chickamauga Dam	49,235
229 – I-75 north of SR 153 exit	81,183
273 – US 27 south of Soddy-Daisy	32,488
304 – Sequoyah Access Road	2,452
336 – US 27 north of Soddy-Daisy	27,768

Source: TDOT 2011.

3.2.13 ENVIRONMENTAL JUSTICE

EPA has defined "environmental justice" as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA 2005). Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," issued in February 1994, directs Federal agencies to address environmental and human health conditions in minority and low-income communities. The evaluation of impacts to environmental justice is dependent on determining if there would be disproportionately high and adverse impacts from the proposed project on any low-income or minority group in the affected community.

NNSA used demographic information from the U.S. Census Bureau to identify minority and low-income populations in the region of influence. "Minority" refers to people who classified themselves in the 2010 U.S. Census as Black or African American, Asian or Pacific Islander, American Indian or Alaskan Native, Hispanic of any race or origin, or other non-White races (CEQ 1997a). Environmental justice guidance defines "low-income" using statistical poverty thresholds used by the U.S. Census Bureau. NNSA developed information on low-income populations using 2009 incomes from the 2010 Census.

Racial and ethnic characteristics of the Hamilton County population are similar to those of the residents of Tennessee as a whole. Table 3-48 summarizes the racial and ethnic characteristics of the Hamilton County population and, for comparison, Tennessee.

The Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who is in poverty. If a family's total income is less than that family's threshold, that family, and every individual in it, is considered to be in poverty. The poverty thresholds do not vary geographically, but they are updated annually for inflation with the Consumer Price Index. The official poverty definition counts money income before taxes but excludes capital gains and noncash benefits (such as public housing, Medicaid, and food stamps). In 2009, the poverty threshold for an individual was $10,956, and for a family of four it was $21,954 (USCB 2010j). In 2009, residents of Hamilton County experienced a slightly higher rate of poverty (18.1 percent) than those in the State as a whole (17.2 percent) (USCB 2011d).

Table 3-48. Racial and ethnic composition of Hamilton County and Tennessee, 2010.

Characteristic	Hamilton County	Percent, Hamilton County[a]	Tennessee	Percent, Tennessee[a]
Total population	336,463	100%	6,346,105	100%
One race[b]	330,786	98.3%	6,236,096	98.3%
White	248,716	73.9%	4,921,948	77.6%
Black or African American	67,900	20.2%	1,057,315	16.7%
American Indian and Alaska Native	1,165	0.3%	19,994	0.3%
Asian	5,912	1.8%	91,242	1.4%
Native Hawaiian and Other Pacific Islander	296	0.1%	3,642	0.1%
Two or more races	5,677	1.7%	110,009	1.7%
Hispanic or Latino (of any race)	14,993	4.5%	290,059	4.6%
White, not Hispanic or Latino	242,154	72.0%	4,800,782	75.6%
Minority population	94,309	28.0%	1,545,323	24.4%

Sources: USCB 2010i, 2010k.

a. Totals might not equal sums due to rounding.

b. Does not include racial data for some populations, but the totals include these people.

CHAPTER 4. ENVIRONMENTAL IMPACTS

This chapter discusses potential impacts to the resource areas described in Chapter 3 in relation to the No-Action Alternative and Alternatives 1 to 6, which are described in Chapter 2. It focuses specifically on describing the potential environmental impacts based on (1) a more conservative tritium permeation level of 10 curies per tritium-producing burnable absorber rod (TPBAR) per year in recognition of the higher-than-expected permeation levels since 2003[1], (2) a revised estimate of the number of TPBARs necessary to support the current tritium supply requirements in comparison with the number the U.S. Department of Energy (DOE) analyzed in the 1999 Environmental Impact Statement (DOE 1999a, the 1999 EIS), and (3) a maximum production scenario of irradiating 5,000 TPBARs every 18 months, which NNSA might require as a contingency capability to compensate for potential future shortfalls in the event of a reactor outage. The National Nuclear Security Administration (NNSA) has organized this chapter by site: Section 4.1 discusses the potential impacts of the alternatives for the Watts Bar site, and Section 4.2 discusses the potential impacts of the alternatives for the Sequoyah site. The complete impacts of any particular alternative would be the combination of the impacts from both sites; Section 2.5 in Chapter 2 summarizes the complete impacts of each alternative at both sites. Sections 4.1 and 4.2 have subsections that detail:

- Land use. Changes in land use.
- Aesthetics. Effects to visual resources and the perception of them and changes in noise levels.
- Climate and air quality. Changes to local air quality and greenhouse gas emissions.
- Geology and soils. Impacts to soils.
- Water resources. Impacts to surface-water and groundwater features, water quality, floodplains, and wetlands.
- Biological resources. Impacts to terrestrial and aquatic plants and animals, and special-status species.
- Cultural resources. Impacts to historic and archaeological resources.
- Infrastructure and utilities. Impacts associated with infrastructure demands.
- Socioeconomics. Impacts to population, income, employment, housing, and community services.
- Waste and spent nuclear fuel management. Impacts from solid, hazardous, and radioactive waste generation including spent fuel management.
- Human health and safety. Impacts to public and worker human health from normal plant operations.

1. Although the observed tritium permeation through the cladding has been less than 5 curies of tritium per TPBAR per year, after consultation with TVA, NNSA has decided to evaluate an even higher, and thus conservative, tritium permeation rate (10 curies of tritium per TPBAR per year) in this SEIS (TVA 2013; PNNL 2013a). By analyzing this higher tritium permeation rate, NNSA is confident that the SEIS provides a reasonable, but conservative and bounding, analysis of the potential environmental impacts from tritium production in the Watts Bar and Sequoyah reactors.

- Accidents and intentional destructive acts. Impacts to the public and workers from accidents and intentional destructive acts.

- Transportation. Impacts to the transportation systems in the area, including radiological impacts from the transportation of nuclear materials.

- Environmental justice. The potential for disproportionately high and adverse impacts to low-income and minority populations.

Where there are differences from the 1999 EIS analysis, the sections describe those differences.

Section 4.3 summarizes unavoidable adverse impacts at each site under the alternatives. For comparison, NNSA analyzed an expected case using actual current conditions at the Watts Bar site; Section 4.4 provides details. Section 4.5 discusses mitigation measures the Tennessee Valley Authority (TVA) could use to reduce impacts.

4.1 Watts Bar Site

This section describes potential impacts for the Watts Bar site (Section 4.2 discusses impacts at the Sequoyah site for Alternatives 2, 3, 5, and 6). Each subsection discusses estimated impacts for:

- No-Action Alternative. TVA would irradiate TPBARs at Watts Bar Unit 1 reactor (Watts Bar 1) and Sequoyah Units 1 and 2 reactors (Sequoyah 1 and 2) in numbers that would keep permeation levels under U.S. Nuclear Regulatory Commission (NRC) license and regulatory limits. TVA would irradiate a maximum of 680 TPBARs every 18 months at Watts Bar 1 and 680 TPBARs every 18 months at each of Sequoyah 1 and Sequoyah 2 for a total of 1,360 TPBARs every 18 months at Sequoyah. TVA will operate Watts Bar 2, which the NRC has not authorized to produce tritium, to produce electricity if it receives an NRC operating license, but would not irradiate any TPBARs at that unit.

- Alternative 1. Use only the Watts Bar site to irradiate a maximum of 2,500 TPBARs every 18 months. This could involve use of both Watts Bar units. TVA is completing construction of Watts Bar 2 (Section 1.6). As discussed in Section 2.6, Alternative 1 is the preferred alternative.

- Alternative 2. Use only the Sequoyah site to irradiate a maximum of 2,500 TPBARs every 18 months. This could involve use of both Sequoyah units.

- Alternative 3. Use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. This would provide the ability to supply stockpile tritium requirements at either site independently or to use both sites with each supplying a portion of the supply. For the analyses in this Supplemental Environmental Impact Statement (SEIS), NNSA assumed for Alternative 3 that each site would irradiate 1,250 TPBARs every 18 months.

- Alternative 4. Use only the Watts Bar site to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this would involve use of both Watts Bar reactors.

- Alternative 5. Use only the Sequoyah site to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this would involve use of both Sequoyah reactors.

- Alternative 6. Use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this could involve the use of one or both reactors at each of the sites. For the analyses in this SEIS, NNSA assumed for Alternative 6 that each site would irradiate 2,500 TPBARs every 18 months.

The impact discussions in Section 4.1 assume that TVA would receive either licenses or license amendments to:

1. Complete and operate the Watts Bar Unit 2 reactor,
2. Irradiate the required number of TPBARs at Watts Bar (Alternatives 1, 3, 4, and 6),
3. Irradiate the required number of TPBARs at Sequoyah (Alternatives 2, 3, 5, and 6), and
4. Continue operations at Watts Bar and Sequoyah through 2035.[2]

4.1.1 LAND USE

4.1.1.1 No-Action Alternative

Under the No-Action Alternative, TVA would irradiate 680 TPBARs at Watts Bar 1 every 18 months. Because the necessary facilities are in place or being completed, there would be no changes or impacts to land use. As described in Section 2.4.1, TVA has completed construction of a 500,000-gallon tritiated water tank system to facilitate effluent water management. TVA addressed the potential impacts from the tritiated water tank system in three Categorical Exclusions, as discussed in Section 1.6.

4.1.1.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. Alternative 1 would not require additional lands, and the necessary facilities are in place or being completed, so there would be no changes or impacts to land use in comparison with the No-Action Alternative.

4.1.1.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use the Sequoyah site to irradiate a maximum of 2,500 TPBARs every 18 months. Under Alternative 2, TVA would not use Watts Bar 1 to irradiate TPBARs. The site would only generate power, and there would be no changes or impacts to land use in comparison with the No-Action Alternative.

4.1.1.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 1,250 TPBARs every 18 months. At Watts Bar, Alternative 3 would not require additional lands, and the necessary facilities are in place or being completed, so there would be no changes or impacts to land use in comparison with the No-Action Alternative.

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2. Section 2.2 discusses the current status of reactor operating licenses.

4.1.1.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Alternative 4 would not require additional lands, and the necessary facilities are in place or being completed, so there would be no changes or impacts to land use in comparison with the No-Action Alternative.

4.1.1.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as discussed in Section 4.1.1.3.

4.1.1.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.1.2.

4.1.2 AESTHETICS

4.1.2.1 No-Action Alternative

Under the No-Action Alternative, TVA would irradiate 680 TPBARs at Watts Bar 1 every 18 months.

Visual

The prominent features of the plant are already in place (cooling towers, containment structures, turbine building, and transmission lines). The tallest buildings would continue to be the cooling towers. Vapor plumes would continue to be visible up to 10 miles away but at no greater frequency than under current conditions. The stainless-steel tritiated water storage tank being constructed at the Watts Bar site is about 45 feet in diameter and 45 feet tall with a domed roof. It has a secondary containment consisting of a larger diameter open tank with a rain shield (about 55 feet in diameter and 30 feet high) to capture 100 percent of the stored liquid in case the main tank failed. There would be about 5 feet of space between the inner and outer tank walls, which TVA would use for maintenance and inspection activities (TVA 2011c). The tritiated water storage tank is visually consistent with the industrial character of the site. Therefore, there would be no significant impacts to visual resources associated with TPBAR irradiation.

Noise

Intermittent noise from operating the air-blast circuit breakers and steam venting as well as from emergency sirens would continue. Noise levels at the nearest residences would generally continue to be below a day-night average sound level of 65 A-weighted decibels (TVA 2011b). Testing of emergency sirens would continue to occur 1 day a month (TVA 2011e).

4.1.2.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months.

Visual

The prominent visual features of the plant are already in place (cooling towers, containment structures, turbine building, and transmission lines). The tallest buildings would continue to be the cooling towers. Vapor plumes would continue to be visible up to 10 miles away but at no greater frequency than under existing conditions. There would be no changes or impacts to visual resources in comparison with the No-Action Alternative.

Noise

Irradiation of 2,500 TPBARs would not change the existing noise environment. Site-generated noise would still be heard off site from operating air-blast circuit breakers and steam venting. Testing of the emergency sirens would continue to occur 1 day a month. Noise levels at the nearest residences would remain the same and would generally continue to be below a day-night average sound level of 65 A-weighted decibels (TVA 2011b). There would be no changes in noise levels or impacts in comparison with the No-Action Alternative.

4.1.2.3 Alternative 2: Sequoyah Only

Under Alternative 2, TVA would not use Watts Bar to irradiate TPBARs. The site would only generate power. Visual and noise resources would be unaffected whether or not TPBARs were irradiated in a reactor. Therefore, there would be no change in impacts to these resources in comparison with the No-Action Alternative.

4.1.2.4 Alternative 3: Watts Bar and Sequoyah

Under Alternative 3, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months.

Visual

The prominent visual features would remain the cooling towers, containment structures, turbine building, and transmission lines. The tallest buildings would continue to be the cooling towers. Vapor plumes would continue to be visible up to 10 miles away but at no greater frequency than under existing conditions. There would be no changes or impacts to visual resources in comparison with the No-Action Alternative.

Noise

Site-generated noise would still be heard off site from operating air-blast circuit breakers and steam venting. Testing of the emergency sirens would continue to occur 1 day a month. Noise levels at the nearest residences would generally continue to be below a day-night average sound level of 65 A-weighted decibels (TVA 2011b). There would be no changes in noise levels or impacts in comparison with the No-Action Alternative.

4.1.2.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. The impacts at Watts Bar would be the same as discussed in Section 4.1.2.2.

4.1.2.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under Alternative 5, TVA would not use Watts Bar to irradiate TPBARs. The site would only generate power. The impacts at Watts Bar would be the same as discussed in Section 4.1.2.3.

4.1.2.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.2.2.

4.1.3 CLIMATE AND AIR QUALITY

The following sections discuss environmental consequences for climate and air quality for the No-Action Alternative and Alternatives 1 through 6. The impacts refer to the site as a whole and not to separate units at the site. This SEIS uses a high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year; it also conservatively assumes release of 10 percent of this tritium to the environment as gaseous emissions[3] (Chandrasekaran et al. 1985).

4.1.3.1 No-Action Alternative

The No-Action Alternative assumes the continuation of current plans and currently permitted tritium irradiation activities at each site. Under the No-Action Alternative, TVA would continue to produce tritium at Watts Bar 1, irradiating 680 TPBARs every 18 months. TVA would operate Watts Bar 2, which the NRC has not authorized to produce tritium, to produce electricity if it receives an NRC operating license, but would not irradiate any TPBARs in that unit.

Nonradioactive gaseous emissions

No additional air pollutant emission sources would occur beyond those described in Section 3.1.3.2, which discusses the quantity of these emissions once Watts Bar 2 is operational. The plant would require an amended air emissions operating permit to add new emissions sources for Watts Bar 2 (TVA 2007a).

Greenhouse Gases

Greenhouse gas emissions would be no different from existing conditions at Watts Bar, until Watts Bar 2 becomes operational. No additional air pollutant emission sources that create greenhouse gases would occur beyond those described in Section 3.1.3.2. Once Watts Bar 2 becomes operational, the total amount of carbon dioxide from Watts Bar activities (diesel fuel use and worker commuting) would be about 7,100 tons annually. As Section 3.1.3.3 discusses, the carbon dioxide emissions from the Watts Bar activities would be much less than 1 percent of carbon dioxide emissions from other activities in the state of Tennessee. Additional significant air quality impacts from greenhouse gases would be unlikely.[4]

Climate

As mentioned earlier and discussed in Chapter 3, nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change significantly from emissions under existing conditions at Watts Bar. As a result, significant additional contributions to changes to climate would be unlikely.

Radioactive gaseous emissions

Table 4-1 lists estimated radioactive gaseous emissions for the No-Action Alternative. Under the No-Action Alternative, TVA would irradiate 680 TPBARs at Watts Bar and the nontritium radioactive

3. As indicated in Section 4.4, the actual percent of tritium released through gaseous emissions is about 3 percent.
4. This calculation of greenhouse gases includes consideration of greenhouse gases from transportation of TPBARs and low-level radioactive wastes. The greenhouse gases from these transportation activities represent less than 1 percent of the greenhouse gases from worker transportation.

Table 4-1. Annual radioactive gaseous emissions (curies) at Watts Bar – No-Action Alternative.

Release	No-Action Alternative (680 TPBARs)
Tritium from TPBARs	680[a]
Non-TPBAR tritium	480[b]
Other radioactive	36[c]
Totals	**1,196**

a. Under the No-Action Alternative, TVA would irradiate 680 TPBARs at Watts Bar. Based on a high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year and the potential release of 10 percent to the environment as gaseous tritium, the total tritium emissions from irradiation of 680 TPBARs would be 680 curies.
b. Based on the bounding assumption of 4,800 curies of non-TPBAR tritium releases from reactor operations per two-unit site (TVA 2012) and the assumption that 10 percent of the tritium emissions would be gaseous air releases (Chandrasekaran et al. 1985).
c. Based on TVA's measurement of actual annual radioactive gaseous emissions to the environment for 2010 at Watts Bar 1 (TVA 2011j). For this analysis, NNSA assumed that the same gaseous emission rate would occur at Watts Bar 2 when that reactor begins operations.

gaseous emissions would be similar to those under existing conditions. Based on operational experience and system performance information, TVA has estimated that a maximum of 2,400 curies of non-TPBAR tritium is released from reactor operations per reactor (4,800 curies total) (TVA 2012). Conservatively assuming that 10 percent of the tritium would be released to the air (Chandrasekaran et al. 1985), the two Watts Bar units would release 480 curies of tritium during reactor operations from non-TPBAR sources. Based on a high and thus conservative assumed permeation rate of 10 curies of tritium per TPBAR per year and the potential release of 10 percent to the environment as gaseous tritium, the total tritium emissions from irradiation of 680 TPBARs would be 680 curies. Section 4.1.11 discusses impacts to human health from radioactive gaseous emissions.

TPBAR Failure Scenario

Even though the design of the TPBAR essentially precludes the potential for TPBAR failure during irradiation, for this SEIS, NNSA conservatively assumed that two TPBARs could fail in a single reactor operating cycle and release all tritium from the failed TPBARs to the reactor coolant system. Gaseous tritium emissions from the two failed TPBARs would be about 2,315 curies. This value is based on the following assumptions:

- Each TPBAR would generate a maximum design limit of 1.2 grams of tritium over an operating cycle; the specific activity of tritium is 9,640 curies per gram (DOE 1999a).
- Two failed TPBARs could release about 23,150 curies of tritium to the reactor coolant system during the operating cycle.
- Ten percent of the released tritium would be gaseous and 90 percent would be liquid (Chandrasekaran et al. 1985).

Section 4.1.11.8 presents the potential human health impacts for releases from the two failed TPBARs.

4.1.3.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months.

Nonradioactive gaseous emissions

Nonradioactive gaseous emissions would be no different from such emissions under the No-Action Alternative at Watts Bar. Additional air pollutant emission sources would not occur beyond those described in Section 3.1.3.2, which discusses the quantity of these emissions once Watts Bar 2 is operational. The plant would require an amended air emissions operating permit to add new emissions sources for Watts Bar 2 (TVA 2007a). As a result, emissions of criteria pollutants should not change during operations at the site. Therefore, NNSA anticipates no significant additional air quality impacts from nonradioactive emissions.

Greenhouse Gases

Greenhouse gas emissions would be essentially the same as discussed in Section 4.1.3.1.

Climate

Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change significantly from existing conditions at Watts Bar. As a result, significant additional contributions to changes to climate would be unlikely.

Radioactive gaseous emissions

Table 4-2 lists annual estimated radioactive gaseous emissions during tritium production at Watts Bar for Alternative 1. The calculations in this table assume a high and thus conservative tritium permeation rate of 10 curies of tritium per TPBAR per year and a potential release of 10 percent of this tritium to the environment as gaseous emissions.

Table 4-2. Annual estimated radioactive gaseous emissions (curies) at Watts Bar – Alternative 1.

Release	No-Action Alternative (680 TPBARs)	Alternative 1 (2,500 TPBARs)
Tritium from TPBARs	680	2,500
Non-TPBAR tritium[a]	480	480
Other radioactive	36	36
Totals	**1,196**	**3,016**

a. Based on the bounding assumption of 4,800 curies of non-TPBAR tritium releases from reactor operations per two-unit site (TVA 2012) and the assumption that 10 percent of the tritium emissions would be air releases (Chandrasekaran et al. 1985).

Section 4.1.11 discusses the impacts to human health from radioactive gaseous emissions.

TPBAR Failure Scenario

Even though the design of the TPBAR essentially precludes the potential for failure during irradiation, for this SEIS NNSA conservatively assumed that two TPBARs could fail in a single reactor operating cycle and release all tritium from the failed TPBARs to the reactor coolant system. Gaseous tritium emissions from the two failed TPBARs would be about 2,315 curies. This value is based on the assumptions described above for the No-Action Alternative. Section 4.1.11.8 presents the potential human health impacts for releases from the two failed TPBARs.

4.1.3.3 Alternative 2: Sequoyah Only

Under Alternative 2, TVA would use the Sequoyah site to irradiate a maximum of 2,500 TPBARs every 18 months. As described above, TVA has completed construction of a 500,000-gallon tank system at Watts Bar; under Alternative 2, TVA proposes to construct and operate such a tank system at Sequoyah to facilitate effluent water management (TVA 2011c). TVA would not irradiate TPBARs at Watts Bar, which could change the impacts to air resources in comparison with the No-Action Alternative. This section discusses those potential changes.

Nonradioactive gaseous emissions

Nonradioactive gaseous emissions would not be different from such emissions under existing conditions at Watts Bar. Additional air pollutant emission sources would not occur beyond those described in Section 3.1.3.2, which discusses the quantity of these emissions once Watts Bar 2 is operational. The plant would require an amended air emissions operating permit to add new emissions sources for Watts Bar 2 (TVA 2007a). As a result, emissions of criteria pollutants should not change significantly. Therefore, NNSA anticipates no significant additional air quality impacts for nonradioactive emissions.

As indicated in Section 4.2.3.3, some minor emissions could occur at the Sequoyah site during construction of the 500,000-gallon tank from the use of cranes and other construction equipment. The emissions would be temporary and within the levels generally experienced at the Sequoyah site (TVA 2011c).

Greenhouse Gases

Greenhouse gas emissions would be essentially unaffected regardless of TPBAR irradiation. Therefore, greenhouse gas emissions would be essentially the same as discussed in Section 4.1.3.1.

Climate

Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change significantly from existing conditions at Watts Bar. As a result, significant additional contributions to changes to climate would be unlikely.

Radioactive gaseous emissions

Table 4-3 lists annual estimated radioactive gaseous emissions at Watts Bar during tritium production for Alternative 2. The calculations in this table assume that tritium production would occur only at the Sequoyah site. Because TVA would not irradiate TPBARs at Watts Bar, no additional tritium emissions would occur beyond those from plant operation without TPBARs. Section 4.1.11 discusses impacts to human health from radioactive gaseous emissions.

Table 4-3. Annual estimated radioactive gaseous emissions (curies) at Watts Bar – Alternative 2.

Release	No-Action Alternative (680 TPBARs)	Alternative 2 (0 TPBARs)
Tritium from TPBARs	680	0
Non-TPBAR tritium[a]	480	480
Other radioactive	36	36
Totals	**1,196**	**516**

a. Based on the bounding assumption of 4,800 curies of non-TPBAR tritium releases from reactor operations per two-unit site (TVA 2012) and the assumption that 10 percent of the tritium emissions would be air releases (Chandrasekaran et al. 1985).

4.1.3.4 Alternative 3: Watts Bar and Sequoyah

Under Alternative 3, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. As described in Chapter 2, the analyses assumed that the Watts Bar and Sequoyah sites would each irradiate 1,250 TPBARs using one or both reactors at each site. As described above, TVA has completed construction of a 500,000-gallon tank system at Watts Bar; under Alternative

3, TVA proposes to construct and operate such a tank system at Sequoyah to facilitate effluent water management at both sites (TVA 2011c).

Nonradioactive gaseous emissions

Nonradioactive gaseous emissions would not be different from such emissions under existing conditions. Additional air pollutant emission sources would not occur beyond those described in Section 3.1.3.2. As a result, emissions of criteria pollutants should not change during operations at the sites. Therefore, NNSA anticipates no significant additional air quality impacts for nonradioactive emissions.

As indicated in Section 4.2.3.3, some minor emissions could occur at the Sequoyah site during construction of the 500,000-gallon tank from the use of cranes and other construction equipment. The emissions would be temporary and within the levels generally experienced at the Sequoyah site (TVA 2011c).

Greenhouse Gases

Greenhouse gas emissions would be essentially the same as discussed in Section 4.1.3.1.

Climate

Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change significantly from existing conditions. As a result, NNSA anticipates no significant additional contributions to changes to climate.

Radioactive gaseous emissions

Tritium emissions for Watts Bar from TPBAR irradiation under Alternative 3 would be about half of those under Alternative 1. Table 4-4 lists estimated annual radioactive gaseous emissions during tritium production at Watts Bar. Section 4.2.3.4 discusses radioactive gaseous emissions from Sequoyah under Alternative 3. Section 4.1.11 discusses impacts to human health from radioactive gaseous emissions.

Table 4-4. Annual estimated radioactive gaseous emissions (curies) at Watts Bar – Alternative 3.

Release	No-Action Alternative (680 TPBARs)	Alternative 3 (1,250 TPBARs)
Tritium from TPBARs	680	1,250
Non-TPBAR tritium[a]	480	480
Other radioactive	36	36
Totals	**1,196**	**1,766**

a. Based on the bounding assumption of 4,800 curies of non-TPBAR tritium releases from reactor operations per two-unit site (TVA 2012) and the assumption that 10 percent of the tritium emissions would be air releases (Chandrasekaran et al. 1985).

TPBAR Failure Scenario

Even though the design of the TPBAR essentially precludes the potential for TPBAR failure during irradiation, for this SEIS NNSA conservatively assumed that two TPBARs could fail in a single reactor operating cycle and release all tritium from the failed TPBARs to the reactor coolant system. Gaseous tritium emissions from the two failed TPBARs would be about 2,315 curies. This value is based on the assumptions described above for the No-Action Alternative. Section 4.1.11.8 presents the potential human health impacts for the releases from the two failed TPBARs.

4.1.3.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months.

Nonradioactive gaseous emissions

Nonradioactive gaseous emissions would be no different from such emissions under the No-Action Alternative at Watts Bar. Additional air pollutant emission sources would not occur beyond those described in Section 3.1.3.2, which discusses the quantity of these emissions once Watts Bar 2 becomes operational. The plant would require an amended air emissions operating permit to add new emissions sources for Watts Bar 2 (TVA 2007a). As a result, emissions of criteria pollutants should not change during operations at the site. Therefore, NNSA anticipates no significant additional air quality impacts from nonradioactive emissions.

Greenhouse Gases

Greenhouse gas emissions would be essentially the same as discussed in Section 4.1.3.1.

Climate

Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change significantly from existing conditions at Watts Bar. As a result, significant additional contributions to changes to climate would be unlikely.

Radioactive gaseous emissions

Table 4-5 lists annual estimated radioactive gaseous emissions during tritium production at Watts Bar for Alternative 4. The calculations in this table assume a high and thus conservative tritium permeation rate of 10 curies of tritium per TPBAR per year and a potential release of 10 percent of this tritium to the environment as gaseous emissions.

Table 4-5. Annual estimated radioactive gaseous emissions (curies) at Watts Bar – Alternative 4.

Release	No-Action Alternative (680 TPBARs)	Alternative 4 (5,000 TPBARs)
Tritium from TPBARs	680	5,000
Non-TPBAR tritium[a]	480	480
Other radioactive	36	36
Totals	**1,196**	**5,516**

a. Based on the bounding assumption of 4,800 curies of non-TPBAR tritium releases from reactor operations per two-unit site (TVA 2012) and the assumption that 10 percent of the tritium emissions would be air releases (Chandrasekaran et al. 1985).

Section 4.1.11 discusses the impacts to human health from radioactive gaseous emissions.

TPBAR Failure Scenario

Even though the design of the TPBAR essentially precludes the potential for failure during irradiation, for this SEIS NNSA conservatively assumed that two TPBARs could fail in a single reactor operating cycle and release all tritium from the failed TPBARs to the reactor coolant system. Gaseous tritium emissions from the two failed TPBARs would be about 2,315 curies. This value is based on the above-described assumptions for the No-Action Alternative. Section 4.1.11.8 presents the potential human health impacts for releases from the two failed TPBARs.

4.1.3.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as described in Section 4.1.3.3.

4.1.3.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.3.2.

4.1.3.8 Differences from 1999 EIS

- The 1999 EIS assumed (1) TVA would irradiate 3,400 TPBARs every 18 months at the Watts Bar site, and did not consider the use of Watts Bar 2 for tritium production, (2) that an average of 1 curie of tritium per TPBAR per year could permeate to the reactor coolant, and (3) that 10 percent of this tritium would be released to the environment as gaseous air emissions. The annual tritium gaseous emissions under these assumptions would be 340 curies.

- For this SEIS, NNSA assumed (1) TVA would irradiate up to a maximum of 5,000 TPBARs every 18 months at Watts Bar using both reactors, (2) that an average of 10 curies of tritium per TPBAR per year could permeate to the reactor coolant, and (3) that 10 percent of this tritium would be released to the environment as gaseous air emissions. The annual tritium gaseous emissions under these assumptions would be 5,000 curies.

Non-TPBAR Tritium Releases

- The 1999 EIS estimated annual non-TPBAR tritium air releases from normal reactor operations would be 5.6 curies at Watts Bar. DOE based the estimate on estimated emissions at that time.

- For this SEIS, NNSA estimated annual non-TPBAR tritium air releases from normal reactor operations would be 480 curies at Watts Bar. NNSA based the estimate on 4,800 curies of total non-TPBAR tritium releases per two-reactor site (which is a bounding estimate provided by TVA) and the release of 10 percent of that tritium to the air. Since the preparation of the 1999 EIS, TVA has gathered additional data about tritium releases from its operations. The differences between the values in the 1999 EIS and this SEIS reflect this additional data.

Other Radioactive Releases (Nontritium)

- The 1999 EIS estimated radioactive nontritium air emissions from normal reactor operations would be 283 curies at Watts Bar based on emission estimates at that time.

- For this SEIS, NNSA estimated radioactive nontritium air emissions from normal reactor operations would be 36 curies at the Watts Bar site (once Watts Bar 2 becomes operational) based on current emission estimates. Since the preparation of the 1999 EIS, TVA has gathered additional information about nontritium gaseous releases from its operations. The differences between the value in the 1999 EIS and this SEIS reflect this additional data.

Greenhouse Gas Emissions

- The 1999 EIS did not assess greenhouse gas emissions.

- For this SEIS, NNSA assessed greenhouse gas emissions from existing facilities at the Watts Bar site. The irradiation of TPBARs would have essentially no impact on the quantity of greenhouse gas emissions.

4.1.4 GEOLOGY AND SOILS

4.1.4.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at Watts Bar 1. Watts Bar 2, which is not authorized to produce tritium, would produce electricity if the NRC issued an operating license but would not irradiate TPBARs. Because all plant facilities and infrastructure necessary to support plant operations with tritium production are in place, under construction, or planned independent of TPBAR irradiation (such as a dry cask storage facility), significant impacts to geology and soil beyond the current conditions reflected in the discussion in Section 3.1.4 would be unlikely.

As Section 2.4.1 describes, TVA has completed construction of a 500,000-gallon tritiated water tank system to facilitate effluent water management. TVA addressed the impacts from that construction in three Categorical Exclusions (see Section 1.6). Operation of the tritiated water tank system will have no impact on geology and soils.

4.1.4.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both reactors at the Watts Bar site to irradiate a maximum of 2,500 TPBARs every 18 months. Additional impacts to geology and soils at the Watts Bar site, beyond those of current conditions (Section 3.1.4), would be unlikely under this alternative.

4.1.4.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use only the Sequoyah site to irradiate up to 2,500 TPBARs. Geology and soil resources in the area of the Watts Bar site would be unaffected whether or not TPBARs were irradiated in a reactor at the Sequoyah site. Therefore, there would be no change in the impacts to these resources in comparison with the current conditions discussed in Section 3.1.4.

4.1.4.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analysis for this alternative assumed that each site would irradiate 1,250 TPBARs every 18 months. Additional impacts to geology and soils at the Watts Bar site, beyond current conditions (Section 3.1.4), would be unlikely under this alternative.

4.1.4.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Additional impacts to geology and soils at the Watts Bar site, beyond those of current conditions (Section 3.1.4), would be unlikely under this alternative.

4.1.4.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. Therefore, there would be no change in impacts to these resources in comparison with the current conditions discussed in Section 3.1.4.

4.1.4.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. Additional impacts to geology and soils at the Watts Bar site, beyond those of the current conditions (Section 3.1.4), would be unlikely under this alternative.

4.1.5 WATER RESOURCES

The primary impact to water resources from any of the alternatives would be a change in the amount of tritium Watts Bar would release in liquid effluents. The use of TPBARs in the Watts Bar reactors would not change the thermal or chemical characteristics of the water the plant discharged to the Chickamauga Reservoir or Tennessee River, and it would not affect the quantities or types of radionuclides other than tritium in the discharges. Appendix E describes the evaluations of the effects of added tritium discharges to the Tennessee River from Watts Bar. This section summarizes those evaluations and describes the impacts for each alternative.

NNSA evaluated the effects of tritium discharges using the U.S. Environmental Protection Agency (EPA) set of computer programs called Visual Plumes (Frick et al. 2003). EPA and contributors from private industry, academia, and a state agency developed Visual Plumes under a cooperative agreement; its purpose is to simulate surface and subsurface water jets and plumes to assist, among other uses, in mixing zone analyses. The NNSA evaluation involved the use of two models from Visual Plumes, UM3 (for the “three-dimensional Updated Merge model”) and DKHW (for the “Davis, Kannberg, Hirst model for Windows”). Both are three-dimensional plume models for simulating single- and multi-port submerged discharges. As described in Appendix E, both models are designed for applications such as the Watts Bar discharge but, because there are no actual plume data available to determine which model better simulates the site-specific conditions, NNSA used both models in the evaluations. In relation to actual plume data, the practical limitations of measuring plume characteristics, particularly in a water body like the Tennessee River under varying flow and discharge conditions, is the reason site-specific data is unavailable and why models are routinely used in such instances to provide plume simulations.

This section describes impacts based on comparisons between in-stream tritium concentrations predicted by the plume models and applicable regulatory standards. Nonradiological constituents in liquid effluents from Watts Bar Outfall 101 are regulated under the plant’s National Pollutant Discharge Elimination System permit, but the permit does not regulate the discharge of radionuclides in liquid effluents from the plant. Radionuclide discharge is regulated under the plant’s operating license with the NRC and NRC regulations, which require that the total effective dose equivalent to individual members of the public from each licensed operation not exceed 0.1 rem (100 millirem) in a year (10 CFR Part 20). According to the regulation, the licensee can demonstrate compliance with this requirement by measuring or calculating the dose to the individual likely to receive the highest dose, or by demonstrating that the annual average concentrations of radioactive materials in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed values specified in Table 2 of Appendix B to 10 CFR Part 20. That table specifies a concentration limit for tritium of 1 million picocuries per liter in water effluents to unrestricted areas. The Technical Specifications appended to the Watts Bar operating license (Sections 5.7.2.7.b and c) specify that liquid effluents to unrestricted areas are limited to 10 times the concentration values in Appendix B to 10 CFR Part 20; that is, the site-specific limit for tritium is 10 million picocuries per liter.

Another regulatory limit indirectly applicable to tritium levels in the Watts Bar effluent is in the EPA National Primary Drinking Water Regulations (40 CFR Part 141). In these regulations, EPA sets a maximum contaminant level for beta particle and photon radioactivity in drinking water as one that would produce an annual dose equivalent of 4 millirem per year to the total body or any internal organ. The regulation further specifies that a tritium concentration of 20,000 picocuries per liter meets this limit. In application, if there were other beta particle- or photon-emitting radionuclides present, the limit for tritium would have to be reduced accordingly. For example, if both tritium and strontium-90 were present in drinking water and the strontium-90 was at a concentration that would result in a dose of 2 millirem per year (half the allowable limit), the limit for tritium would be cut in half to 10,000 picocuries per liter.[5] This regulation is not directly applicable to the discharge area of the Tennessee River because it is not used as drinking water, but the river is a drinking water source (before treatment) at locations downstream.

The evaluations in Appendix E address several variables to encompass the expected range of discharge and river conditions at the Watts Bar site. These include three variables for one parameter and two variables for each of two other parameters as follows:

- Tritium in liquid effluents:
    - 15,570 curies per year from normal plant operations and deployment of 1,250 TPBARs under Alternative 3, resulting in an average tritium concentration of 218,000 picocuries per liter in the discharge to Outfall 101 (see Appendix E);
    - 26,820 curies per year from normal plant operations and deployment of 2,500 TPBARs under Alternatives 1 and 6, and potentially Alternative 3, resulting in an average tritium concentration of 376,000 picocuries per liter in the discharge to Outfall 101 (see Appendix E); and
    - 49,320 curies per year from normal plant operations and deployment of 5,000 TPBARs under Alternative 4, resulting in an average tritium concentration of 691,000 picocuries per liter in the discharge to Outfall 101 (see Appendix E).
- Water discharge rate to Outfall 101:
    - 80 cubic feet per second under normal plant operations, and
    - 175 cubic feet per second for periods after instances of curtailed discharges due to low river flow.
- River flow:
    - 3,500 cubic feet per second, the lowest river flow under which discharges can be made, and
    - 27,000 cubic feet per second, the average river flow condition at Watts Bar.

The NNSA evaluations for the Watts Bar nuclear power plant site included modeling of 12 scenarios to address the combinations posed by the above variables. Appendix E provides further detail on the development of these and other model parameters. Table 4-6 summarizes the modeling results in terms of the tritium concentration as the discharge plume moves downstream, away from the diffusers. The table

5. Other beta particle- and photon-emitting radionuclides typically in the Watts Bar liquid effluents are identified in Appendix E (Table E-4), where they are evaluated for their impacts on the tritium limit. The results of the evaluation indicate that none are present in sufficient concentrations to affect the use of 20,000 picocuries per liter as the limit for tritium.

lists results for each of the 12 scenarios and for the UM3 and DKHW models. To present a more conservative evaluation, the concentrations in the table are the maximum plume concentrations that would

Table 4-6. Watts Bar modeling of tritium concentration in the discharge plume.

Evaluated scenarios[a]	Distance (ft) for plume centerline to decrease to 20,000 pCi/L		Centerline concentration (pCi/L) at boundary of mixing zone (240 ft from diffusers)		Centerline concentration (pCi/L) where plume surfaces and distance from the diffusers	
	UM3	**DKHW**	**UM3**	**DKHW**	**UM3**	**DKHW**
Scenarios with the typical effluent discharge of 80 cubic feet per second to the river						
1. Low tritium and low river flow	25	14	NM[b]	NM	16,800 at 32 ft	8,770 at 53 ft
2. Low tritium and typical river flow	17	13	4,480	4,510	3,830 at 317 ft	1,410 at 1,106 ft
3. Middle tritium and low river flow	Surf[c] (≈51)	35	NM	NM	29,000 at 32 ft	15,100 at 53 ft
4. Middle tritium and typical river flow	48	42	7,730	7,780	6,610 at 317 ft	2,420 at 1,106 ft
5. High tritium and low river flow	Surf[c] (≈110)	Surf[c] (≈80)	NM	NM	53,300 at 32 ft	27,800 at 53 ft
6. High tritium and typical river flow	142	146	14,200	14,300	12,100 at 317 ft	4,450 at 1,106 ft
Scenarios with the maximum, short-term effluent discharge of 175 cubic feet per second to the river						
7. Low tritium and low river flow	Surf[c] (≈30)	19	NM	NM	20,700 at 28 ft	14,300 at 32 ft
8. Low tritium and typical river flow	19	12	NM	4,660	7,830 at 102 ft	2,700 at 595 ft
9. Middle tritium and low river flow	Surf[c] (≈65)	Surf[c] (≈43)	NM	NM	35,800 at 28 ft	24,600 at 32 ft
10. Middle tritium and typical river flow	51	38	NM	8,030	13,500 at 102 ft	4,660 at 595 ft
11. High tritium and low river flow	Surf[c] (≈130)	Surf[c] (≈90)	NM	NM	65,700 at 28 ft	45,200 at 32 ft
12. High tritium and typical river flow	Surf[c] (≈140)	136	NM	14,800	24,800 at 102 ft	8,560 at 595 ft

ft = feet; NM = not modeled; pCi/L = picocuries per liter; Surf = surfaces; ≈ = approximately.

a. Scenarios:
   Low tritium = effluent with a tritium concentration of 218,000 picocuries per liter.
   Middle tritium = effluent with tritium concentration of 376,000 picocuries per liter.
   High tritium = effluent with tritium concentration of 691,000 picocuries per liter.
   Low river flow = 3,500 cubic feet per second (the lowest river flow during which effluent discharges still take place).
   Typical river flow = 27,000 cubic feet per second (average flow over the course of a year).

b. The plume reached the water surface before leaving the mixing zone, and modeling stopped at that point.

c. The model predicts the plume would reach the surface before the centerline concentration reduced to 20,000 picocuries per liter. The value in parentheses is a rough estimate of the distance at which the concentration would be reached.

with three variables and only one other parameter with two variables, so there are only six evaluated scenarios. The evaluation for the Sequoyah plant did not include two variables for discharge rate to the river. Because the Sequoyah plant is not restricted from discharging to the river during periods of low flow (as is the Watts Bar plant), a single average discharge rate was appropriate for the Sequoyah evaluation. In addition, it should be noted that the water discharge rate from the Sequoyah plant (Section 4.2.5) is much greater than that above for the Watts Bar plant and, as a result, the tritium concentrations in the Watts Bar discharge (with less dilution water) are much greater. This is a direct reflection of the difference in the cooling systems for the two nuclear plants. Watts Bar has a closed system that recycles much of its cooling water, so blowdown from the system is the primary discharge to the river. Sequoyah, be present at the centerline of the plume. The Sequoyah analysis (Section 4.2.5) includes one parameter on the other hand, has the flexibility to operate in several modes, but it operates predominantly in the open mode, in which cooling water passes only once through the system to pick up heat before discharge. In addition to the 12 modeled scenarios in Table 4-6, Appendix E describes estimated tritium releases under the No-Action Alternative, which would include irradiation of a smaller number of TPBARs.

As the results show, both models predict that maximum tritium concentrations would reduce to drinking water levels very quickly, before the plume surfaced, for each of the different tritium concentrations when both the effluent discharge and river flow were at typical conditions (that is, scenarios 2, 4, and 6 in Table 4-6). The models show that the "low river flow" and "maximum effluent discharge" parameters act to cause the plume to surface closer to the diffusers and at higher concentrations. In five of the low-river-flow scenarios, for example, one or both of the models predicted the plume would surface before the centerline concentration reduced to 20,000 picocuries per liter and, as a result, the models stopped at that point.

Table 4-6 also lists predicted concentrations of tritium at other locations of potential interest including the mixing zone boundary and the point at which the plume would first reach the water surface. As noted in the table, the models often did not compute concentrations at the boundary of the mixing zone because they stopped once the plume reached the surface.

The nearest drinking water intake is for the City of Dayton, Tennessee, which is southwest of the Watts Bar site and about 23 miles downstream as the river flows. Tritium concentrations are already monitored at this drinking water intake. As further discussed in Appendix E, at this downstream distance it is reasonable to assume the tritium would be well mixed into the river flow. At the maximum tritium discharge and typical river flow, the average tritium concentration at the downstream drinking water intake would be about 2,050 picocuries per liter, well below the drinking water limit of 20,000 picocuries per liter. The middle tritium discharge evaluated above is roughly half of the maximum quantity, so the average concentration under that discharge scenario would be roughly half of that for the maximum scenario. Section 4.1.11 discusses impacts to human health from tritium releases.

4.1.5.1 No-Action Alternative

4.1.5.1.1 Surface Water

Under the No-Action Alternative, there would be no impacts to surface water resources in the area of the Watts Bar Nuclear Power Plant with the possible exception of a relatively small increase in the amount of tritium in the liquid effluents from the Watts Bar site. As Table 1-1 in Chapter 1 shows, TVA has irradiated TPBARs in Watts Bar 1 during the past 8 years, but the average TPBAR use over that period has been about 310 in comparison with the 704 that the NRC has authorized and the 680 TPBARs for which NNSA conducted the No-Action Alternative analysis.

When Watts Bar 2 is operating, the two reactors would result in an estimated annual baseline release of about 4,320 curies of tritium in the liquid effluents without TPBARs and about 6,120 curies per year from both reactors with a full authorized loading of 680 TPBARs at Watts Bar 1. This total curie release is two-thirds of the lowest amount evaluated in the preceding section (that is, the Low Tritium scenario component in Table 4-6); therefore, the impacts would be less than the predicted results of the plume models. The estimated average tritium concentration of 146,000 picocuries per liter (see Table E-1, Appendix E) in the discharge to the river would be well under the limit of 10 million picocuries per liter in the Watts Bar operating license and, although greater than the drinking water limit of 20,000 picocuries per liter, the tritium concentration in the discharge plume would be below the drinking water limit within less than 30 feet of the diffusers (from the results for the low tritium scenarios in Table 4-6). Assuming the 10,440 (4,320 plus 6,120) curies of tritium would be completely mixed into the average river flow of 27,000 cubic feet per second [about 24.1 trillion (2.41×10^{13}) liters per year], the average tritium concentration at the nearest downstream drinking water intake would be about 433 picocuries per liter. Section 4.1.11 discusses impacts to human health from tritium releases.

As noted in the plant's National Pollutant Discharge Elimination System permit, stormwater runoff from the site is currently authorized under the Tennessee Storm Water Multi-Sector General Permit for Industrial Activities (Permit Number TNR051343) and is subject to the requirements and controls in the stormwater pollution prevention plan the General Permit requires (TDEC 2011d). As Section 2.4.1 discusses, TVA has completed construction of a tritiated water tank to minimize potential impacts of tritiated water releases. This tank system will give TVA the flexibility to reduce the number of batch releases during the year and target them to periods of higher river flow, which would minimize impacts. TVA will use best management practices to control small amounts of runoff during operation of the tritiated water storage tank system. Therefore, runoff from the tritiated water tank area during tank operation would be unlikely to affect surface waters adversely.

4.1.5.1.2 Groundwater

The tritiated water tank and its associated transfer piping and equipment will represent potential sources of spills and leaks to reach the ground, but the design of these elements will include appropriate preventive measures to prevent or mitigate the risk of spills or leaks. The tank will be inside a secondary containment tank, and TVA will design the piping to protect groundwater from leaking pipes in conjunction with the nuclear industry's voluntary groundwater protection initiative. TVA will install pipes in trenches, tunnels, or in other pipes (that is, double-walled piping systems) to provide secondary containment, or the pipes will be above ground to allow visual inspection (TVA 2011c).

4.1.5.1.3 Floodplains and Wetlands

Construction of the tritiated water tank will be outside the 100-year floodplain and will not disturb any wetlands. Therefore, the No-Action Alternative would be expected to result in no significant impacts to floodplains or wetlands in the area of the Watts Bar Nuclear Power Plant.

4.1.5.2 Alternative 1: Watts Bar Only

4.1.5.2.1 Surface Water

Under Alternative 1, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. With a conservatively high estimate for the added tritium permeating from a total of 2,500 TPBARs (10 curies per TPBAR per year) plus the baseline amounts of tritium from normal operations of Watts Bar 1 and 2 (without TPBARs), liquid effluents would include an estimated 26,820 curies of tritium each year (see Table E-1, Appendix E). In the normal plant discharge of 80 cubic feet per second, this amount of tritium would result in an estimated average concentration of 376,000 picocuries per liter in the discharge at the submerged diffusers in the Tennessee River. At times when the river flow was less than 3,500 cubic feet per second, TVA would cease discharge to the river and divert the liquid effluents, which would normally go to Outfall 101, to the yard holding pond (see Figure 3-3).[6]

6. The assumption that tritium would continue to be in the liquid effluents going to the holding pond during times of low river flow (less than 3,500 cubic feet per second) is conservative because it supports evaluation of an average tritium concentration when discharging resumes with a higher than normal discharge rate. During normal plant operations, the discharge of liquid low-level radioactive waste (with the tritium) to the cooling system blowdown is stopped whenever

During such times and with the assumption of continuous tritium production, the amount of tritium and dilution water going to the yard holding pond would be likely to remain the same as during discharges to the river, so tritium concentrations would not change. However, once discharge to the river resumed, the effluent flow could be as high as 175 cubic feet per second during some periods to accommodate the normal discharge flow and to drain the yard holding pond to normal operating levels.

With normal plant discharge of 80 cubic feet per second at Outfall 101, the plume models described above predicted that the (middle) tritium concentration of 376,000 picocuries per liter would reduce to drinking water levels (less than 20,000 picocuries per liter) within about 50 feet of the diffusers, even if the river was flowing at only 3,500 cubic feet per second (see Table 4-6). Under the worst-case condition of low river flow, the discharge plume would reach the water surface closer to the diffuser (within about 50 feet) than for typical river flow levels, and the maximum tritium concentrations in the plume would range from about 15,000 to 29,000 picocuries per liter when it reached the surface. With the maximum plant discharge of 175 cubic feet per second, the models still predicted that tritium concentrations in the plume would drop to drinking water levels within about 65 feet of the diffusers. Tritium concentrations would, however, stay slightly higher in the plume as it moved downstream in comparison with the normal discharge rate.

The estimated average tritium concentration of 376,000 picocuries per liter in the discharge to the river would be well under the limit of 10 million picocuries per liter in the Watts Bar operating license and the plant's established envelope for safe operations. Under the Alternative 1 scenarios, the models predicted the plumes would reach drinking water levels of tritium within 70 feet of the diffusers, in most cases before the plume reached the surface, and tritium concentrations would be on the order of 10,000 picocuries per liter, or less, at the extent of the mixing zone 240 feet downstream of the diffusers. At these levels, tritium concentrations would not be at significant levels at the nearest downstream drinking water intake, which is for the City of Dayton. Assuming the tritium would be completely mixed into the river flow at this distance, concentrations at the drinking water intake would be likely to average about 1,110 picocuries per liter. Monitoring of drinking water intake levels is a continuing activity. Section 4.1.11 discusses impacts to human health from tritium releases.

TPBAR Failure Scenario

NNSA evaluated the unlikely scenario of TPBAR failure by conservatively assuming that two failed TPBARs would release 20,835 curies of tritium to the liquid effluents during a single reactor operating cycle for Alternative 1 (Appendix E). That is, the liquid effluents under this scenario would include 20,835 curies in addition to the 26,820 curies per year from normal plant operations and irradiation of 2,500 TPBARs for a total of 47,655 curies of tritium. Because TPBAR failure is very unlikely, NNSA evaluated it only for a typical discharge rate (80 cubic feet per second), but included evaluations of both a typical river flow (27,000 cubic feet per second) and a low river flow (3,500 cubic feet per second). This annual amount of tritium and the typical discharge rate results in an average tritium concentration in the discharge of 667,000 picocuries per liter (Appendix E), which is about 1.8 times the evaluated concentration for normal irradiation (without failure) of 2,500 TPBARs.

NNSA evaluated the TPBAR failure scenario using the UM3 and DKHW models. Under this higher tritium release rate and a typical river flow condition, both models predicted the safe drinking water level of 20,000 picocuries per liter would be reached within 130 feet of the diffusers. Consistent with the information in Table 4-6 for the typical discharge and typical river flow scenarios (2, 4, and 6), the UM3

diffuser discharge is stopped. As a result, the low-level waste does not reach the holding pond and, when the discharge to the river resumes, the added water from the holding pond acts to reduce the tritium concentration in the normal liquid effluent. TVA will operate the tritiated water tank in a similar manner: TVA would not discharge the tank at times when the low-level waste might reach the yard holding pond (TVA 2012).

and DKHW models predicted the plumes would surface at about 317 and 1,106 feet, respectively. However, the centerline concentrations would be 11,700 and 4,300 picocuries per liter, respectively, at the point of surfacing. Under the low river flow condition, both models predicted the plume would surface within about 50 feet of the diffusers and at centerline concentrations greater than 20,000 picocuries per liter, but no higher than about 51,500 picocuries per liter. Based on the dispersion rates at the time the plumes surfaced, it was estimated the concentration would drop to the 20,000 level within about 100 feet of the diffusers, although it would take a longer time to reach that distance than under the typical river flow condition.

Using the rationale described above, the average tritium concentration at the City of Dayton drinking water intake during the time of higher tritium discharge would be about 1,980 picocuries per liter. Section 4.1.11 discusses impacts to human health from tritium releases.

4.1.5.2.2 Groundwater

Under Alternative 1, there would be no direct discharge of the tritium-containing cooling water to groundwater. Natural interconnections between groundwater and surface water (the Tennessee River in this case) are common and are expected in the area. At the Watts Bar site, groundwater movement is toward the river, but even if there are areas downstream where water from the river moves into adjacent groundwater, tritium concentrations would be no higher than the in-stream values described above for surface water. The initial movement of the effluent discharge from the diffuser is outward and upward in the river. This is by design (the angle of the diffuser ports) and because of the heat differential of the effluent, and it ensures a well-mixed plume before it reaches any river bank or bottom areas where water migration to groundwater might occur. As Section 3.1.5.2.2 describes, TVA has taken corrective actions to eliminate the known sources of tritium contamination in the groundwater beneath the Watts Bar plant.

The design of the tritiated water tank system will minimize the potential for impacts to groundwater as described in Section 4.1.5.1.2 for the No-Action Alternative.

4.1.5.2.3 Floodplains and Wetlands

Alternative 1 would have no impacts to floodplains or wetlands. There would be no changes in the quantities of discharged water or the locations of such discharges in comparison with the No-Action Alternative. There would be no physical changes to wetlands or floodplain areas. During times of high river flow, downstream waters that naturally reach floodplains or wetlands could have higher tritium concentrations than is currently the case, but as described above for impacts to groundwater, tritium concentrations would be no higher than the in-stream values discussed for surface water.

4.1.5.3 Alternative 2: Sequoyah Only

4.1.5.3.1 Surface Water

Under Alternative 2, TVA would not use the Watts Bar plant to irradiate TPBARs. Tritium releases to liquid effluent at Watts Bar would be from normal plant operation without TPBARs. With Watts Bar 2 in operation, the site would release an estimated maximum of 4,320 curies of tritium per year in the liquid effluents (see Table E-1, Appendix E). This release would be about one-quarter of the smaller amount in the plume modeling evaluations (Section 4.1.5), and the impacts would be less than the predicted values of the plume models. The estimated tritium concentration of 60,500 picocuries per liter in the discharge to the river would be well under the limit of 10 million picocuries per liter in the Watts Bar operating license and, although greater than the drinking water limit of 20,000 picocuries per liter, would be below the drinking water level soon after exiting the diffuser. At an annual release rate of 4,320 curies of tritium and average river flow [27,000 cubic feet per second or about 24.1 trillion (2.41×10^{13}) liters per year], the average tritium concentration at the downstream drinking water intake would be about 179 picocuries per liter. Section 4.1.11 discusses impacts to human health from tritium releases.

4.1.5.3.2 Groundwater

Because no TPBARs would be irradiated at Watts Bar under Alternative 2, there would be no impacts on groundwater at the Watts Bar site related to TPBAR irradiation. As Section 3.1.5.2.2 describes, TVA has taken corrective actions to eliminate the known sources of tritium contamination in the groundwater beneath the Watts Bar plant.

4.1.5.3.3 Floodplains and Wetlands

Because there would be no TPBARs irradiated at Watts Bar under Alternative 2, there would be no impacts to floodplains or wetlands at the Watts Bar site related to TPBAR irradiation.

4.1.5.4 Alternative 3: Watts Bar and Sequoyah

4.1.5.4.1 Surface Water

Under Alternative 3, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analyses of the alternative assumed each site would irradiate 1,250 TPBARs every 18 months. With the baseline amounts of tritium from normal operation of Watts Bar 1 and 2 plus a conservatively high estimate for the added tritium permeating from 1,250 TPBARs, there would be an estimated 15,570 curies in the Watts Bar liquid effluents each year (see Table E-1, Appendix E). In the normal plant discharge of 80 cubic feet per second, this amount of tritium would result in an average estimated concentration of 218,000 picocuries per liter in the discharge from the submerged diffusers in the Tennessee River. At times when the river flow was less than 3,500 cubic feet per second, TVA would stop discharge to the river and divert the liquid effluents, which would normally go to Outfall 101, to the yard holding pond. As explained for Alternative 1 (Section 4.1.5.2.1), it is conservatively assumed that liquid effluent diverted to the holding pond during such times would have the same tritium concentration as was being discharged to the river. Once TVA resumed discharge to the river, flow from the holding pond (to drain it down to normal operating levels) would be combined with the normal effluent discharge. The tritium concentration in the combined flow would be the same as in the two sources, but the volume of the combined effluent flow could be as high as 175 feet per second while the holding pond is contributing. The estimated average tritium concentration of 218,000 picocuries per liter in the discharge to the river would be well under the limit of 10 million picocuries per liter in the Watts Bar operating license and the plant's established envelope for safe operations. With normal plant discharge of 80 cubic feet per second at Outfall 101, the plume models predicted that the lower tritium concentration of 218,000 picocuries per liter would reduce to drinking water levels (less than 20,000 picocuries per liter) within 25 feet of the diffusers, even if the river was flowing at only 3,500 cubic feet per second (see Table 4-6). Under the worst-case condition of low river flow, the discharge plume would reach the water surface closer to the diffuser (within 53 feet) than for typical river flow levels, and the maximum tritium concentrations in the plume would range from 9,000 to 17,000 picocuries per liter when it reached the surface. With the maximum plant discharge of 175 cubic feet per second, the models predicted that tritium concentrations in the plume would drop to drinking water levels within about 30 feet. Tritium concentrations would, however, stay slightly higher in the plume as it moved downstream in comparison to the normal discharge rate.

At these levels, there would be no significant impacts at the nearest downstream drinking water intake, which is for the City of Dayton. Because of the distance to this drinking water intake (23 miles), it is reasonable to assume that the 15,570 curies of tritium per year would be completely mixed into the average river flow of 27,000 cubic feet per second [about 24.1 trillion (2.41×10^{13}) liters per year], and the average tritium concentration at the City of Dayton drinking water intake would be about 650 picocuries per liter. Section 4.1.11 discusses impacts to human health from tritium releases.

Under Alternative 3, TVA could irradiate all 2,500 TPBARs every 18 months at the Watts Bar plant and none at the Sequoyah plant. Conversely, there could be times when TVA did not irradiate TPBARs at Watts Bar, using Sequoyah to irradiate all 2,500. If TVA irradiated all TPBARs at Watts Bar, potential impacts would be the same as those for Alternative 1. During times when there were no TPBARs in Watts Bar reactors, impacts at Watts Bar would be the same as those for Alternative 2.

TPBAR Failure Scenario

NNSA evaluated the scenario of TPBAR failure by conservatively assuming that two failed TPBARs would release 20,835 curies of tritium to the liquid effluents during a single reactor operating cycle for Alternative 3 for irradiation of 1,250 TPBARs at Watts Bar (Appendix E) (see Section 4.2.5.4.1 for a discussion of two failed TPBARs at Sequoyah). That is, the liquid effluents under this scenario would include 20,835 curies in addition to the 15,570 curies per year from normal plant operations and irradiation of 1,250 TPBARs for a total of 36,405 curies of tritium. Because TPBAR failure would be very unlikely, NNSA evaluated it only for a typical discharge rate (80 cubic feet per second), but included evaluations of both a typical river flow (27,000 cubic feet per second) and a low river flow (3,500 cubic feet per second). This annual amount of tritium and typical discharge rate result in an average tritium concentration in the discharge of 510,000 picocuries per liter (Appendix E), which is about 2.3 times the evaluated concentration for normal irradiation (without failure) of 1,250 TPBARs.

NNSA evaluated the TPBAR failure scenario using the UM3 and DKHW models. Under this higher tritium release rate and a typical river flow condition, both models predicted the drinking water level of 20,000 picocuries per liter would be reached within 83 feet of the diffusers. Consistent with the information in Table 4-6 for the typical discharge and typical river flow scenarios (2, 4, and 6), UM3 and DKHW predicted the plumes would surface at about 317 and 1,106 feet, respectively. However, the centerline concentrations would be 8,960 and 3,290 picocuries per liter, respectively, at the point of surfacing. Under the low river flow condition, both models predicted the plume would surface within about 50 feet of the diffusers and at centerline concentrations greater than 20,000 picocuries per liter, but no higher than about 39,000 picocuries per liter. Based on the dispersion rates at the time the plumes surfaced, it is estimated the concentration would drop to the 20,000 level within about 75 feet of the diffusers, although it would take a longer time to reach that distance than under the typical river flow condition.

Using the above-described rationale, the average tritium concentration at the City of Dayton drinking water intake during the time of higher tritium discharge would be about 1,510 picocuries per liter. Section 4.1.11 discusses impacts to human health from tritium releases.

4.1.5.4.2 Groundwater

For the same reasons described in the discussion of Alternative 1, there would be no significant impacts expected on groundwater under Alternative 3. As Section 3.1.5.2.2 describes, TVA has taken corrective actions to eliminate the known sources of tritium contamination in the groundwater beneath the Watts Bar plant.

The design of the tritiated water tank system will minimize the potential for impacts to groundwater as described in Section 4.1.5.1.2 for the No-Action Alternative.

4.1.5.4.3 Floodplains and Wetlands

For the same reasons as described in the discussion of Alternative 1, there would be no significant impacts expected on floodplains and wetlands under Alternative 3.

4.1.5.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under Alternative 4, TVA would irradiate 5,000 TPBARs every 18 months at the Watts Bar plant and none at the Sequoyah plant.

4.1.5.5.1 Surface Water

Under Alternative 4, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. With the baseline amounts of tritium from normal operation of Watts Bar 1 and 2, plus a conservatively high estimate for the added tritium permeating from 5,000 TPBARs, there would be an estimated 49,320 curies in the Watts Bar liquid effluents each year (see Table E-1, Appendix E). In the normal plant discharge of 80 cubic feet per second, this amount of tritium would result in an average estimated concentration of 691,000 picocuries per liter in the discharge from the submerged diffusers in the Tennessee River. At times when the river flow was less than 3,500 cubic feet per second, TVA would stop discharge to the river and divert the liquid effluents, which would normally go to Outfall 101, to the yard holding pond. As explained for Alternative 1 (Section 4.1.5.2.1), it is conservatively assumed that liquid effluent diverted to the holding pond during such times would have the same tritium concentration as was being discharged to the river. Once TVA resumed discharge to the river, flow from the holding pond (to drain it down to normal operating levels) would be combined with the normal effluent discharge. The tritium concentration in the combined flow would be the same as in the two sources, but the volume of the combined effluent flow could be as high as 175 feet per second while the holding pond is contributing. The estimated average tritium concentration of 691,000 picocuries per liter in the discharge to the river would be well under the limit of 10 million picocuries per liter in the Watts Bar operating license and the plant's established envelope for safe operations.

With normal plant discharge of 80 cubic feet per second at Outfall 101, the plume models predicted that the high tritium concentration of 691,000 picocuries per liter would reduce to drinking water levels (less than 20,000 picocuries per liter) within about 150 feet of the diffusers, even if the river was flowing at only 3,500 cubic feet per second (see Table 4-6). Under the worst-case condition of low river flow, the discharge plume would reach the water surface closer to the diffuser (within 53 feet) than for typical river flow levels, and the maximum tritium concentrations in the plume would be higher than the drinking water standard, ranging from about 23,000 to 53,000 picocuries per liter, when it reached the surface. With the maximum plant discharge of 175 cubic feet per second, the models predicted the plume would surface before concentrations decreased to the drinking water standard at low river flow conditions and, at typical river flow conditions, the plume would be near or below the drinking water standard when it surfaced. Based on the dispersion rate predicted by the models when the plume surfaced, it is estimated that drinking water standards would be met within about 140 feet of the diffuser under either river flow condition. Under the maximum discharge rate, tritium concentrations would, however, stay slightly higher in the plume as it moved downstream in comparison to the normal discharge rate.

At these levels, there still would be no significant impacts at the nearest downstream drinking water intake, which is for the City of Dayton. Because of the distance to this drinking water intake (23 miles), it is reasonable to assume that the 49,320 curies of tritium per year would be completely mixed into the average river flow of 27,000 cubic feet per second [about 24.1 trillion (2.41×10^{13}) liters per year], and the average tritium concentration at the City of Dayton drinking water intake would be about 2,050 picocuries per liter. Section 4.1.11 discusses impacts to human health from tritium releases.

TPBAR Failure Scenario

NNSA evaluated the scenario of TPBAR failure by conservatively assuming that two failed TPBARs would release 20,835 curies of tritium to the liquid effluents during a single reactor operating cycle for Alternative 4 for irradiation of 5,000 TPBARs at Watts Bar (Appendix E) (see Section 4.2.5.4.1 for a discussion of two failed TPBARs at Sequoyah). That is, the liquid effluents under this scenario would include 20,835 curies in addition to the 49,320 curies per year from normal plant operations and irradiation of 5,000 TPBARs for a total of 70,155 curies of tritium. Because TPBAR failure would be very unlikely, NNSA evaluated it only for a typical discharge rate (80 cubic feet per second), but included evaluations of both a typical river flow (27,000 cubic feet per second) and a low river flow (3,500 cubic feet per second). This annual amount of tritium and typical discharge rate resulted in an average tritium concentration in the discharge of 983,000 picocuries per liter (Appendix E), which is about 1.4 times the evaluated concentration for normal irradiation (without failure) of 5,000 TPBARs.

NNSA evaluated the TPBAR failure scenario using the UM3 and DKHW models. Under this highest tritium release rate and a typical river flow condition, both models predicted the drinking water level of 20,000 picocuries per liter would be reached within 260 feet of the diffusers. Consistent with the information in Table 4-6 for the typical discharge and typical river flow scenarios (2, 4, and 6), UM3 and DKHW predicted the plumes would surface at about 317 and 1,106 feet, respectively. However, the centerline concentrations would be 17,300 and 6,340 picocuries per liter, respectively, at the point of surfacing. Under the low river flow condition, both models predicted the plume would surface within about 50 feet of the diffusers and at centerline concentrations greater than 20,000 picocuries per liter, but no higher than about 76,000 picocuries per liter. Based on the dispersion rates at the time the plumes surfaced, it is estimated the concentration would drop to the 20,000 level within about 150 feet of the diffusers, although it would take a longer time to reach that distance than under the typical river flow condition.

Using the above-described rationale, the average tritium concentration at the City of Dayton drinking water intake during the time of higher tritium discharge would be about 2,910 picocuries per liter. Section 4.1.11 discusses impacts to human health from tritium releases.

4.1.5.5.2 Groundwater

For the same reasons described in the discussion of Alternative 1, there would be no significant impacts expected on groundwater under Alternative 4. As Section 3.1.5.2.2 describes, TVA has taken corrective actions to eliminate the known sources of tritium contamination in the groundwater beneath the Watts Bar plant.

The design of the tritiated water tank system will minimize the potential for impacts to groundwater as described in Section 4.1.5.1.2 for the No-Action Alternative.

4.1.5.5.3 Floodplains and Wetlands

For the same reasons as described in the discussion of Alternative 1, there would be no significant impacts expected on floodplains and wetlands under Alternative 4.

4.1.5.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under Alternative 5, TVA would not use Watts Bar to irradiate TPBARs. The impacts would be the same as discussed in Section 4.1.5.3.

4.1.5.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.5.2.

4.1.5.8 Differences from 1999 EIS

The evaluations of water resources for Watts Bar actions for this SEIS differ from those of the 1999 EIS primarily as follows:

- Tritium releases from TPBAR irradiation. The 1999 EIS estimated the release of 3,060 curies each year to the Tennessee River from TPBAR irradiation of 3,400 TPBARs every 18 months. In the SEIS, NNSA has estimated the maximum amount of annual tritium releases would be 26,820 curies from irradiation of a maximum 2,500 TPBARs every 18 months and 49,320 curies from irradiation of a maximum 5,000 TPBARs every 18 months.

- Tritium releases from normal operations. The 1999 EIS used a baseline tritium release of 639 curies per year from Watts Bar 1 only; the baseline did not include releases from Watts Bar 2. For the SEIS, NNSA assumed annual releases in the conservatively high amount of 2,160 curies from each reactor (Watts Bar 1 and 2). The difference in the baseline release level assumed in 1999 and that used for this SEIS reflects the additional data now available as well as the conservatism added for the analyses in this SEIS.

- Discharge plume models. The 1999 EIS used the Cornell Mixing Zone Expert System (CORMIX) computer program to develop estimates of tritium concentrations in the Tennessee River downstream of the Watts Bar discharge diffusers. For this SEIS, NNSA used two different plume models from the suite of EPA computer programs called Visual Plumes to develop estimates for tritium concentrations in the river (http://www.epa.gov/ceampubl/swater/vplume/). The analyst chose the Visual Plumes models because they are EPA-recognized and publicly available. Neither document preparers nor reviewers who wish to know more about the models need to purchase a license for this software as is necessary for a fully functioning version of CORMIX. As a point of reference, NNSA tested the Visual Plumes models using one of the tritium discharge scenarios for Watts Bar in the 1999 EIS and found the Visual Plume results to be conservative (higher impacts) in comparison with the 1999 EIS evaluation. Specifically, the Visual Plumes models, as used in this evaluation, predicted the tritium plume would require a longer travel distance to reach the modeled concentration than did the 1999 EIS.

- Modeled discharge scenarios. The 1999 EIS modeled two scenarios under average discharge and river flow conditions: one for deploying all 3,400 TPBARs and one for deploying 1,000 TPBARs. For the SEIS, in addition to the No-Action Alternative, which models releases from 680 TPBARs at Watts Bar 1, NNSA modeled one alternative for deploying 5,000 TPBARs at Watts Bar, one for 2,500, and one for deploying 1,250 TPBARs. In addition, the analysis for the SEIS includes modeling of nine additional Watts Bar discharge scenarios that are representative of extreme discharge and river flow conditions. In this case, “extreme” means conditions within the range of expected plant operations but at the far end of an applicable range. By their nature, these extreme conditions, if they occurred, would be for relatively short periods. Because of the significant increase in the amount of tritium that the SEIS estimates TPBAR irradiation would release to the river (in comparison with the 1999 EIS), NNSA determined it was important to characterize tritium concentrations in the river during worst-case as well as average conditions.

- Tritium concentration at nearest drinking water intake. The 1999 EIS estimated an average tritium concentration of 126 picocuries per liter under average discharge and river flow conditions and the maximum amount of tritium that operations would release annually to the Tennessee River (from baseline releases and TPBAR irradiation). Under similar conditions for the SEIS, NNSA estimated an average tritium concentration of about 2,050 picocuries per liter at the nearest downstream drinking water intake. These values remain much lower than the maximum acceptable drinking water level for tritium of 20,000 picocuries per liter as identified in 40 CFR Part 141.

- Tritiated water tank system. The 1999 EIS did not consider a tank system, which is a recent change to the site infrastructure. The evaluation for the SEIS includes this system, including how it would affect tritium discharges and the potential impacts of its operation.

4.1.6 BIOLOGICAL RESOURCES

4.1.6.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at Watts Bar 1. TVA would operate Watts Bar 2, which the NRC has not authorized to irradiate TPBARs, to produce electricity if it received an NRC operating license, but would not irradiate TPBARs. Under the No-Action Alternative, TVA has completed construction of a 500,000-gallon tritiated water tank system to facilitate effluent water management (see Section 2.4.1). TVA addressed impacts from construction and operation of this system in three Categorical Exclusions (see Section 1.6).

TPBAR irradiation would result in radiological releases of gaseous emissions and liquid effluents (see Sections 4.1.3.1 and 4.1.5.1). If an organism inhales or ingests tritium, it is incorporated into bodily fluids. However, rapid elimination by exhalation, excretion in body water, and a short half-life limit long-term accumulation in the organism (DOE 1999a). According to an International Atomic Energy Agency publication (IAEA 1992 as cited in DOE 1999a), a dose rate of 100 millirem per year to the most exposed human will lead to dose rates to plants and animals that would not result in significant adverse impacts to those populations. As discussed in Section 4.1.11.1, irradiation of 680 TPBARs every 18 months could result in an annual dose to the maximally exposed individual of about 0.28 millirem per year. This potential dose would result in a dose rate to plants and animals well below the International Atomic Energy Agency benchmark. Therefore, tritium releases due to irradiation of 680 TPBARs would not be expected to result in significant adverse impacts to biological resources.

The modeling of the tritium plume under the most unfavorable modeling conditions showed the tritium concentration reduced to 20,000 picocuries per liter (the EPA drinking water standard) within about 140 feet of the diffusers (see Table 4-6), which would not affect aquatic life. Even at the maximum concentration of 691,000 picocuries per liter, the centerline plume concentration would drop below 300,000 picocuries per liter within 2 feet of exiting the diffusers under each of the flow and discharge scenarios. At 300,000 picocuries per liter, the resulting dose rate would be 60 millirem per year, which would equate to a dose to plants and animals below the International Atomic Energy Agency benchmark.

Impacts of discharging heated water and chemical treatments to the environment are of concern for an operational nuclear plant. Thermal plumes in the reservoir can attract fish to warmer water when ambient temperatures are cooler than ideal or can repel fish, thereby impeding natural migrations through the system (TVA 2011b). At Watts Bar, blowdown returns to the Tennessee River through multiport bottom diffusers 2 miles below Watts Bar Dam. To provide adequate dilution of the plant effluent, discharge from the diffusers can occur only when the release from Watts Bar Dam is at least 3,500 cubic feet per second (TVA 2007a). Water from the effluent entering the river results in an increase in temperatures of less than 5 degrees Fahrenheit. An increase in temperature due to increased TPBAR irradiation beyond that from normal plant effluent would be unlikely and, therefore, significant adverse impacts to aquatic species from thermal discharge characteristics would be unlikely.

Impingement and entrainment of aquatic organisms are the most common impacts associated with the intake of water for cooling. The entrainment of aquatic eggs and larvae at the Watts Bar water intake is extremely low, and fish impingement on the water intake traveling screens is virtually nonexistent. The Reservoir Fish Assemblage Index scores, which are a measure of community health, are good to excellent. Because TVA plans no change in the amount of water withdrawal under the No-Action Alternative, additional impacts related to entrainment or impingement would be unlikely.

Several environmental reviews for activities and projects at the Watts Bar site (DOE 1999a; TVA 2005, 2007a) have evaluated Federal and State of Tennessee threatened and endangered species in the vicinity of the site, with similar no-effects conclusions. Four mussel species, Federally listed as endangered, occur in mussel beds and mussel sanctuary in the vicinity of Watts Bar, as does the snail darter. One Federally listed mussel species and one candidate species also occur downriver of the Watts Bar site. Because TVA has not encountered snail darter larvae in entrainment sampling at Watts Bar to date, it is unlikely that snail darter larvae would be entrained at the cooling water intake under this alternative (TVA 2007a). No suitable habitat for gray bats exists on or near the site (TVA 2007a). Limited forested habitat suitable for summer roosting sites occurs on the Watts Bar site; however, no Indiana bats have been observed in the area. In addition, the proposed action would not remove trees and therefore would not be expected to have any significant impacts on the summer roosting habitat. Because there are no other known State- or Federally listed endangered or at-risk species in the area, impacts to threatened and endangered species would be unlikely. TVA has notified the U.S. Fish and Wildlife Service of the NNSA proposed action and has provided the State of Tennessee and the Fish and Wildlife Service with copies of the Draft SEIS. As discussed in Section 3.1.6.4, the Fish and Wildlife Service concurred with the NRC's 1995 Biological Assessment that the operation of Watts Bar 1 would have no significant impact on Federally listed endangered or at-risk species. Several later environmental reviews (DOE 1999a; TVA 2005, 2007a) evaluated threatened and endangered species (Federal and State) in the vicinity of the site and reached similar conclusions of no effects on listed species. TVA and NNSA would continue to comply with the requirements of the *Endangered Species Act of 1973* [16 U.S.C. § 1536(a)(2)] and Biological Opinion, and would interact with the Fish and Wildlife Service as appropriate.

4.1.6.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. Increased TPBAR irradiation at the site would not alter terrestrial or aquatic habitat at the site. Increased TPBAR irradiation would increase radiological releases in gaseous emissions and liquid effluents (see Sections 4.1.3.2 and 4.1.5.2). As discussed in Section 4.1.11.2, irradiation of 2,500 TPBARs every 18 months could result in an annual dose to the maximally exposed individual of about 0.52 millirem per year. This potential dose would result in a dose to plants and animals well below the International Atomic Energy Agency benchmark (IAEA 1992 as cited in DOE 1999a). Therefore, the increase in tritium releases due to irradiation of 2,500 TPBARs would not be likely to have a significant adverse impact on biological resources. Increases in temperature due to increased TPBAR irradiation would be unlikely, and impingement and entrainment of aquatic organisms would not be likely to change. Increased TPBAR irradiation would not be likely to have a significant adverse effect on Federal and State threatened and endangered species (see Section 4.1.6.1).

4.1.6.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would not use the Watts Bar site to irradiate TPBARs. Radiological releases in gaseous emissions and liquid effluents would decrease in comparison with those from the No-Action Alternative, as would the dose to the maximally exposed offsite individual (see Sections 4.1.3.3, 4.1.5.3, and 4.1.11.3). As a result, dose levels to plants and animals would remain well below the International Atomic Energy Agency benchmark. There would be no changes to river water temperature, entrainment and impingement of aquatic species. No significant adverse impacts on Federal and State threatened and endangered species would be expected for this alternative (see Section 4.1.6.1).

4.1.6.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analysis for this alternative assumed that each site would irradiate 1,250 TPBARs every 18 months. As discussed in Section 4.1.11.4, irradiation of 1,250 TPBARs every 18 months could result in an annual dose to the maximally exposed individual of about 0.36 millirem. This potential dose would result in a dose to plants and animals well below the International Atomic Energy Agency benchmark. Increases in water temperature due to TPBAR irradiation would be unlikely, and impingement and entrainment of aquatic organisms would also be unlikely to change. TPBAR irradiation under this alternative would not be expected to result in significant adverse impacts to Federal and State threatened and endangered species (see Section 4.1.6.1).

4.1.6.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both of the Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Increased TPBAR irradiation at the site would not alter terrestrial or aquatic habitat at the site. Increased TPBAR irradiation would increase radiological releases in gaseous emissions and liquid effluents (see Sections 4.1.3.5 and 4.1.5.5). As discussed in Section 4.1.11.5, irradiation of 5,000 TPBARs every 18 months could result in an annual dose to the maximally exposed individual of about 0.86 millirem per year. This potential dose would result in a dose to plants and animals well below the International Atomic Energy Agency benchmark (IAEA 1992 as cited in DOE 1999a). Therefore, the increase in tritium releases due to irradiation of 5,000 TPBARs would not be likely to have a significant adverse impact on biological resources. Increases in temperature due to increased TPBAR irradiation would be unlikely, and impingement and entrainment of aquatic organisms would not be likely to change. Increased TPBAR irradiation would not be likely to have a significant adverse effect on Federal and State threatened and endangered species (see Section 4.1.6.1).

4.1.6.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as discussed in Section 4.1.6.3.

4.1.6.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.6.2.

4.1.7 CULTURAL RESOURCES

4.1.7.1 No-Action Alternative

Cultural resources in the vicinity of the Watts Bar site are described in Section 3.1.7. Under this alternative, TVA would irradiate 680 TPBARs at Watts Bar 1. TVA would use Watts Bar 2, which the NRC has not authorized to irradiate TPBARs, to produce electricity if the NRC granted an operating license, but it would not irradiate TPBARs. TVA has completed construction of a 500,000-gallon tritiated water tank system to facilitate effluent water management (see Section 2.4.1). TVA addressed the impacts of the tritiated water tank system in three Categorical Exclusions (see Section 1.6). The tank will be on open ground west of the Watts Bar 1 Primary Water and Refueling Water Storage Tanks in the existing protected area, which has been dedicated to industrial use since construction began at the Watts Bar site. The foundation will be about 60 feet in diameter. Due to the small area of construction and use of previously disturbed land, NNSA does not anticipate impacts to cultural resources from construction activities. Neither irradiation of TPBARs nor operation of the tritiated water tank system would have significant adverse impact on cultural resources because no land would be disturbed.

4.1.7.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. Alternative 1 would not require additional lands, and the necessary facilities are in place and in use, so there would be no changes or impacts to cultural resources.

4.1.7.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would not use Watts Bar 1 to irradiate TPBARs. Cultural resources would be unaffected whether or not TPBARs were irradiated in a reactor. Therefore, there would be no change in impacts to this resource in comparison with the No-Action Alternative.

4.1.7.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed that each site would irradiate 1,250 TPBARs every 18 months. Alternative 3 would not require additional lands, and the necessary facilities are in place and in use, so there would be no changes or impacts to cultural resources.

4.1.7.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Alternative 4 would not require additional lands, and the necessary facilities are in place and in use, so there would be no changes or impacts to cultural resources.

4.1.7.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as discussed in Section 4.1.7.3.

4.1.7.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate

2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.7.2.

4.1.8 INFRASTRUCTURE AND UTILITIES

4.1.8.1 No-Action Alternative

Under this alternative, current activities and permitted TPBAR irradiation activities would continue. TVA would irradiate 680 TPBARs every 18 months in Watts Bar 1. Watts Bar 2, which the NRC has not authorized to produce tritium, would produce electricity if the NRC granted an operating license, but it would not irradiate any TPBARs. There would be no change in the use of site infrastructure (electricity, drinking water, steam, sanitary sewer, industrial gas, communications networks, or emergency response capabilities) from TPBAR irradiation. There would be no significant additional impacts on infrastructure demands at Watts Bar beyond current impacts (see Section 3.1.8).

TVA has completed construction of a 500,000-gallon tritiated water tank system to facilitate effluent water management to minimize the potential impacts of tritiated water releases. Operation of the tank system would not affect infrastructure demands at the Watts Bar site, and there will be no special maintenance or monitoring requirements for this system.

4.1.8.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. There would be no significant changes in the use of site infrastructure from TPBAR irradiation.

4.1.8.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. Infrastructure demands would not be significantly affected whether or not TPBARs were irradiated in a reactor. Therefore, there would be no significant change in impacts to infrastructure demands at the Watts Bar site in comparison with the No-Action Alternative.

4.1.8.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. There would be no change in the use of site infrastructure from TPBAR irradiation. Irradiation of 1,250 TPBARs would have no significant impact on infrastructure demands at the Watts Bar site.

4.1.8.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. There would be no significant changes in the use of site infrastructure from TPBAR irradiation.

4.1.8.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as discussed in Section 4.1.8.3.

4.1.8.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.8.2.

4.1.9 SOCIOECONOMICS

4.1.9.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at Watts Bar 1. TVA would operate Watts Bar 2, which the NRC has not authorized to irradiate TPBARs, to produce electricity if it received an NRC operating license, but would not irradiate TPBARs.

The Watts Bar site has a workforce of about 572 persons (TVA 2011c). Once Watts Bar 2 became operational, the Watts Bar site would employ about 1,150 workers. Irradiating 680 TPBARs every 18 months would require no additional personnel and would not generate meaningful incremental local operating expenses. This alternative would not affect population, income, employment, housing, or community services. Therefore, under the No-Action Alternative, there would be no meaningful project-related socioeconomic impacts in the region of influence.

4.1.9.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. Irradiation of 2,500 TPBARs would require no personnel in addition to the existing staff and would not generate meaningful incremental local operating expenses. Therefore, under Alternative 1 there would be no meaningful project-related socioeconomic impacts in the region of influence.

4.1.9.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would not use the Watts Bar site to irradiate TPBARs. If the plant did not irradiate TPBARs, TVA could potentially reduce the workforce by approximately 10 full-time equivalent workers. Such a reduction would not result in any meaningful project-related socioeconomic impacts in the Watts Bar region of influence.

4.1.9.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. Irradiation of 1,250 TPBARs at Watts Bar would require no additional workers and would not generate meaningful incremental local operating expenses. Therefore, under Alternative 3 there would be no meaningful project-related socioeconomic impacts in the region of influence.

4.1.9.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Irradiation of 5,000 TPBARs could require approximately 10 additional full-time equivalent workers. Such an increase would not result in any meaningful project-related socioeconomic impacts in the Watts Bar region of influence.

4.1.9.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as discussed in Section 4.1.9.3.

4.1.9.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.9.2.

4.1.10 WASTE AND SPENT NUCLEAR FUEL MANAGEMENT

Additional Low-Level Radioactive Waste

Any reactor that irradiated TPBARs would generate more low-level radioactive waste than one that did not. Much of the low-level waste would consist of TPBAR base plates and other irradiated hardware that would remain after the TPBARs were separated from their assemblies in preparation for shipping to the Savannah River Site. In the 1999 EIS, DOE and TVA estimated that low-level waste would increase by about 15 cubic feet per year for irradiation of 3,400 TPBARs (DOE 1999a), which would represent less than 0.1 percent of the low-level waste the Watts Bar site generates annually. Because this is such a small percentage, DOE and TVA do not think a more precise estimate is needed for irradiation of fewer TPBARs (a maximum of 2,500 under the proposed action in this SEIS). Therefore, this SEIS, like the 1999 EIS, estimates an additional 15 cubic feet of low-level waste annually for all reactors that irradiate TPBARs, regardless of the number of irradiated TPBARs, recognizing that this number is conservatively high for the alternatives discussed in this SEIS. For Alternatives 4 and 6, an additional 30 cubic feet of low-level waste would be generated annually at Watts Bar.

4.1.10.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs at Watts Bar 1. TVA would use Watts Bar 2, which the NRC has not authorized to irradiate TPBARs, to produce electricity if the NRC granted an operating license. Under the No-Action Alternative, Watts Bar would continue to generate wastes as described in Section 3.1.10. TPBAR irradiation would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the total low-level waste Watts Bar operations currently generate (TVA 2012). TPBAR irradiation would have no impact on hazardous and nonhazardous waste generation. Operation of the tritiated water tank system would have no impact on the quantity of or management of wastes.

Once Watts Bar 2 is operational, the two reactors would generate about 115 spent nuclear fuel assemblies annually, which would include about 3 spent nuclear fuel assemblies associated with TPBAR irradiation at Watts Bar 1 (TVA 2012). As Section 3.1.10 discusses, TVA is in the planning stages for construction and operation of a dry cask storage facility (also known as an independent spent fuel storage installation) at Watts Bar. Assuming Watts Bar 2 begins operations in 2015, the site would need this storage facility by about 2017 (TVA 2012). TPBAR irradiation under the No-Action Alternative would have no impact on the need for or operation of this dry cask storage facility.

Additional Spent Nuclear Fuel

The amount of additional spent nuclear fuel from TPBAR irradiation depends on the number of irradiated TPBARs. As TPBARs are irradiated, they absorb neutrons, which reduces the plant's power levels. In order to maintain design power levels during TPBAR irradiation, TVA would need to increase the number of fresh fuel assemblies. The increase in fresh fuel assemblies generates additional spent nuclear fuel. Irradiation of 680 TPBARs per cycle would generate about 4 additional spent nuclear fuel assemblies every 18 months (which would equate to about 3 additional spent nuclear fuel assemblies annually) in comparison with operations without TPBARs. As the number of TPBARs were increased, they would absorb an increasingly higher percentage of neutrons, which would reduce the plant's power levels. TVA would then need to increase the number of fresh fuel assemblies to maintain design power levels. The increase in fresh fuel assemblies would generate additional spent nuclear fuel.

The relationship between the number of irradiated TPBARs and the amount of additional spent nuclear fuel is not linear. For example, irradiation of 1,250 TPBARs in a reactor would generate 8 to 12 additional spent nuclear fuel assemblies every 18 months. At twice the number of TPBARs (2,500), the number of spent nuclear fuel assemblies would increase to 41 (about 3 to 5 times more than for 1,250). This non-linearity occurs because as more TPBARs are added to the reactor, fewer neutrons are available to fission uranium atoms, and increasingly greater quantities of fresh fuel are needed to maintain the design power level for the reactor.

4.1.10.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. Irradiation of 2,500 TPBARs would generate a maximum of 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the total low-level waste Watts Bar operations currently generate (TVA 2012). TPBAR irradiation would continue to have no impact on hazardous and nonhazardous waste generation.

Irradiation of 2,500 TPBARs would generate a maximum of 41 additional spent nuclear fuel assemblies every 18 months, assuming irradiation of all 2,500 TPBARs in a single reactor (TVA 2012). On an annual basis, this would increase spent nuclear fuel generation at Watts Bar by about 24 percent in comparison with the No-Action Alternative. Assuming Watts Bar 2 began operation in 2015, the site would require a dry cask storage facility by about 2017 (Section 3.1.10) to supplement the spent nuclear fuel pool storage capacity, regardless of the number of TPBARs TVA irradiated at the Watts Bar site (TVA 2012).

4.1.10.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use the Sequoyah site to irradiate a maximum of 2,500 TPBARs every 18 months. Because Watts Bar would no longer irradiate TPBARs, it would generate less low-level radioactive waste than at present. The reduction would be about 15 cubic feet per year, which is less than 0.1 percent of the total low-level waste Watts Bar operations currently generate (TVA 2012). Because Watts Bar would no longer irradiate TPBARs, about 3 fewer spent nuclear fuel assemblies would be generated annually in comparison with the No-Action Alternative.

4.1.10.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed that each site would irradiate 1,250 TPBARs every 18 months. Irradiation of 1,250 TPBARs would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the total low-level waste

Watts Bar operations currently generate (TVA 2012). TPBAR irradiation would continue to have no impact on hazardous and nonhazardous waste generation.

Irradiation of 1,250 TPBARs in a single reactor would generate a maximum of 8 to 12 additional spent nuclear fuel assemblies every 18 months (TVA 2012). On an annual basis, this would increase spent fuel generation at Watts Bar by about 5 to 7 percent in comparison with the No-Action Alternative. Assuming Watts Bar 2 began operation in 2015, the site would require a dry cask storage facility by about 2017 (Section 3.1.10) to supplement the spent nuclear fuel pool storage capacity, regardless of the number of TPBARs TVA irradiated at the Watts Bar site (TVA 2012).

4.1.10.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Irradiation of 5,000 TPBARs would generate a maximum of 30 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the total low-level radioactive waste Watts Bar operations currently generate (TVA 2012). TPBAR irradiation would continue to have no impact on hazardous and nonhazardous waste generation.

Irradiation of 5,000 TPBARs would generate a maximum of 82 additional spent nuclear fuel assemblies every 18 months. On an annual basis, this would increase spent fuel generation at Watts Bar by about 48 percent in comparison with the No-Action Alternative. Assuming Watts Bar 2 began operation in 2015, the site would require a dry cask storage facility by about 2017 (Section 3.1.10) to supplement the spent nuclear fuel pool storage capacity, regardless of the number of TPBARs TVA irradiated at the Watts Bar site (TVA 2012).

4.1.10.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as discussed in Section 4.1.10.3.

4.1.10.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.10.2.

4.1.10.8 Differences from 1999 EIS

The 1999 EIS estimated TPBAR irradiation could generate a maximum of 30 cubic feet per year of low-level radioactive waste and maximum of 60 additional spent nuclear fuel assemblies every 18 months for irradiation of 3,400 TPBARs at the Watts Bar site, and did not consider the use of Watts Bar 2 for tritium production. For this SEIS, TVA estimated a maximum of 30 cubic feet per year of low-level waste and a maximum of 82 additional spent nuclear fuel assemblies every 18 months for irradiation of 5,000 TPBARs. TVA has an infrastructure in place or has a plan at Watts Bar to manage the increase in low-level waste and spent nuclear fuel over operations without TPBAR irradiation.

4.1.11 HUMAN HEALTH AND SAFETY

This section describes the health and safety impacts of radiological releases from normal operations with and without tritium production at Watts Bar. Because tritium production would introduce no operations

Latent Cancer Fatality

A latent cancer fatality is a death from a cancer that results from, and occurs an appreciable time after, exposure to ionizing radiation. Death from radiation-induced cancers can occur any time after the exposure. However, latent cancers generally occur from 1 year to many years after exposure.

Using a conversion factor of 0.0006 latent cancer fatality per rem of radiation exposure (ISCORS 2002), the result is the increased lifetime probability of developing a latent fatal cancer. For example, if a person received a dose of 0.033 rem, that person's risk of latent cancer fatality from that dose over a lifetime would be 0.00002. This risk corresponds to a 1 chance in 50,000 of a latent cancer fatality during that person's lifetime. To place the significance of the additional risk into context, the average person has about 1 chance in 4 of dying from cancer (a risk of 0.25) (ACS 2011).

Because estimates of latent cancer fatalities are statistical, the results often indicate less than 1 latent cancer fatality for cases that involve low doses or small populations. For instance, if a population collectively received a dose of 500 person-rem, the number of potential latent cancer fatalities would be 0.3. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

at Watts Bar that would require the use of hazardous chemicals, there would be no hazardous chemical releases from irradiation of TPBARs under any alternative.

During normal operations, there would be incremental radiological releases of tritium to the environment and exposures to workers on the site. The following paragraphs describe the resultant dose and potential health effects on the public and workers. Appendix C discusses the annual increase in gaseous radioactive emissions and liquid radioactive effluents from the production of tritium at Watts Bar or Sequoyah.

Table 4-7 lists radiological impacts to the maximally exposed individual (a hypothetical individual at the site boundary) and to the public living within 50 miles of Watts Bar projected for 2025[7] for each alternative (see Appendix C for a map of Watts Bar with a 50-mile radius). Table 4-8 lists radiological impacts to facility workers. For this analysis, a facility worker is a monitored reactor plant employee.

TVA would keep doses to these workers to minimal levels through programs to ensure worker doses were as low as is reasonably achievable. The doses in Tables 4-7 and 4-8 reflect total doses from operations at Watts Bar, not just those from tritium production.

Appendix C contains background information on the effects of radiation on human health and safety. It also contains the methods and assumptions NNSA used to calculate impacts on public health and safety at Watts Bar and Sequoyah.

4.1.11.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at Watts Bar 1. TVA would operate Watts Bar 2, which the NRC has not authorized to irradiate TPBARs, to produce electricity if it received an NRC operating license, but would not irradiate TPBARs. The following estimates include radiological impacts of normal operation of both reactors at the Watts Bar site with irradiation of 680 TPBARs in Watts Bar 1:

7. Projections were based on 2010 Census data (USCB 2012). NNSA used the site population in 2025 in the impact assessments because DOE used a similar estimate in the 1999 EIS; it is assumed to be representative of the population at the approximate midpoint between now and the end of the interagency agreement.

- The annual dose to the maximally exposed offsite individual would be 0.28 millirem per year, with an associated 2×10^{-7} risk of a latent cancer fatality per year of operation.

- The collective dose to the population within 50 miles of Watts Bar would be 7.6 person-rem per year, with an associated 0 (0.005) latent cancer fatality per year of operation.

- The collective dose to facility workers would be 102.2 person-rem per year, with an associated 0 (0.06) latent cancer fatality per year of operation.

Table 4-7. Annual radiological impacts to the public including incident-free tritium production at Watts Bar.

		Maximally exposed offsite individual		Population within 50 miles projected for 2025	
Tritium production	**Release media**	**Dose (millirem)**	**Latent cancer fatality risk**	**Annual dose (person-rem)**	**Latent cancer fatalities**[a]
No-Action Alternative (680 TPBARs)	Air[b]	0.25	2×10^{-7}	3.2	0 (0.002)
	Liquid[c]	0.026	2×10^{-8}	4.4	0 (0.003)
	Totals	**0.28**	$\mathbf{2 \times 10^{-7}}$	**7.6**	**0 (0.005)**
Alternative 1 (2,500 TPBARs)	Air[b]	0.46	3×10^{-7}	5.4	0 (0.003)
	Liquid[c]	0.064	4×10^{-8}	11.3	0 (0.007)
	Totals	**0.52**	$\mathbf{3 \times 10^{-7}}$	**16.7**	**0 (0.01)**
Alternative 2 (0 TPBARs)	Air[b]	0.18	1×10^{-7}	2.4	0 (0.001)
	Liquid[c]	0.011	7×10^{-9}	1.8	0 (0.001)
	Totals	**0.19**	$\mathbf{1 \times 10^{-7}}$	**4.2**	**0 (0.003)**
Alternative 3 (1,250 TPBARs)	Air[b]	0.32	2×10^{-7}	3.9	0 (0.002)
	Liquid[c]	0.038	2×10^{-8}	6.6	0 (0.004)
	Totals	**0.36**	$\mathbf{2 \times 10^{-7}}$	**10.5**	**0 (0.006)**
Alternative 4 (5,000 TPBARs)	Air[b]	0.740	4×10^{-7}	8.5	0 (0.005)
	Liquid[c]	0.118	7×10^{-8}	20.9	0 (0.01)
	Totals	**0.86**	$\mathbf{5 \times 10^{-7}}$	**29.4**	**0 (0.02)**
Alternative 5 (0 TPBARs)	Air[b]	0.18	1×10^{-7}	2.4	0 (0.001)
	Liquid[c]	0.011	7×10^{-9}	1.8	0 (0.001)
	Totals	**0.19**	$\mathbf{1 \times 10^{-7}}$	**4.2**	**0 (0.003)**
Alternative 6 (2,500 TPBARs)	Air[b]	0.46	3×10^{-7}	5.4	0 (0.003)
	Liquid[c]	0.064	4×10^{-8}	11.3	0 (0.007)
	Totals	**0.52**	$\mathbf{3 \times 10^{-7}}$	**16.7**	**0 (0.01)**

a. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

b. NNSA based the population data for airborne releases on the projected 2025 population within 50 miles of the site, which is 1,452,511 people. The 2025 population was projected from 2010 Census data (USCB 2012) based on a growth rate consistent with that over the past 10 years.

c. NNSA based the population data for liquid releases on the projected 2025 population of persons who would use public water supplies downstream of the site within 50 miles, which is 367,652 people.

Note: All doses are much less than 1 percent of the average annual dose from natural and manmade radiation in the United States (620 millirem, see Table 3-20).

Table 4-8. Annual radiological impacts to workers including incident-free tritium production at Watts Bar.

Impact	No-Action Alternative (680 TPBARs)	Alternative 1 (2,500 TPBARs)	Alternative 2 (0 TPBARs)	Alternative 3 (1,250 TPBARs)	Alternative 4 (5,000 TPBARs)	Alternative 5 (0 TPBARs)	Alternative 6 (2,500 TPBARs)
Average worker dose (millirem)	116.2	122.3	114.0	118.1	130.5	114.0	122.3
Latent cancer fatality risk	7×10^{-5}	7×10^{-5}	7×10^{-5}	7×10^{-5}	8×10^{-5}	7×10^{-5}	7×10^{-5}
Total workforce dose (person-rem)[a]	102.2	107.4	100.2	103.8	114.7	100.2	107.4
Latent cancer fatalities[b]	0 (0.06)	0 (0.06)	0 (0.06)	0 (0.06)	0 (0.07)	0 (0.06)	0 (0.06)

a. Based on 879 workers, which includes additional workers used during refueling operations and outages.

b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

4.1.11.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both Watts Bar 1 and 2 to irradiate a maximum of 2,500 TPBARs every 18 months. The following estimates include the radiological impacts of normal operation of both reactors at the Watts Bar site with irradiation of 2,500 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.52 millirem per year, with an associated 3×10^{-7} risk of a latent cancer fatality per year of operation.
- The collective dose to the population within 50 miles of Watts Bar would be 16.7 person-rem per year, with an associated 0 (0.01) latent cancer fatality per year of operation.
- The collective dose to the facility workers would be 107.4 person-rem per year, with an associated 0 (0.06) latent cancer fatality per year of operation.

4.1.11.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. Therefore, the following estimates indicate the radiological impacts of normal operation of both reactors at the Watts Bar site without TPBAR irradiation:

- The annual dose to the maximally exposed offsite individual would be 0.19 millirem per year, with an associated 1×10^{-7} risk of a latent cancer fatality per year of operation.
- The collective dose to the population within 50 miles of Watts Bar would be 4.2 person-rem per year, with an associated 0 (0.003) latent cancer fatality per year of operation.
- The collective dose to the facility workers would be 100.2 person-rem per year, with an associated 0 (0.06) latent cancer fatality per year of operation.

4.1.11.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. The following estimates include the radiological impacts of normal operation of both reactors at the Watts Bar site with irradiation of 1,250 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.36 millirem per year, with an associated 2×10^{-7} risk of a latent cancer fatality per year of operation.
- The collective dose to the population within 50 miles of Watts Bar would be 10.5 person-rem per year, with an associated 0 (0.006) latent cancer fatality per year of operation.
- The collective dose to facility workers would be 103.8 person-rem per year, with an associated 0 (0.06) latent cancer fatality per year of operation.

4.1.11.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. The following estimates include the radiological impacts of normal operation of both reactors at the Watts Bar site with irradiation of 5,000 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.86 millirem per year, with an associated 5×10^{-7} risk of a latent cancer fatality per year of operation.
- The collective dose to the population within 50 miles of Watts Bar would be 29.4 person-rem per year, with an associated 0 (0.02) latent cancer fatality per year of operation.
- The collective dose to the facility workers would be 114.7 person-rem per year, with an associated 0 (0.07) latent cancer fatality per year of operation.

4.1.11.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. Therefore, the following estimates indicate the radiological impacts of normal operation of both reactors at the Watts Bar site without TPBAR irradiation:

- The annual dose to the maximally exposed offsite individual would be 0.19 millirem per year, with an associated 1×10^{-7} risk of a latent cancer fatality per year of operation.
- The collective dose to the population within 50 miles of Watts Bar would be 4.2 person-rem per year, with an associated 0 (0.003) latent cancer fatality per year of operation.
- The collective dose to the facility workers would be 100.2 person-rem per year, with an associated 0 (0.06) latent cancer fatality per year of operation.

4.1.11.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate

2,500 TPBARs every 18 months. The following estimates include the radiological impacts of normal operation of both reactors at the Watts Bar site with irradiation of 2,500 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.52 millirem per year, with an associated 3×10^{-7} risk of a latent cancer fatality per year of operation.
- The collective dose to the population within 50 miles of Watts Bar would be 16.7 person-rem per year, with an associated 0 (0.01) latent cancer fatality per year of operation.
- The collective dose to the facility workers would be 107.4 person-rem per year, with an associated 0 (0.06) latent cancer fatality per year of operation.

4.1.11.8 TPBAR Failure Scenario

In addition to the assumed normal operational release of tritium through permeation, an additional potential release scenario this SEIS considers is the failure of two TPBARs, with the conservative assumption that the entire tritium inventory of the TPBARs is released to the primary coolant. The occurrence of TPBAR failure is beyond that associated with normal operating conditions and, as discussed in Appendix C, such an assumption is extremely conservative. Tables 4-9 and 4-10 list the radiological consequences to the public and workers from the assumption of two TPBAR failures among a load of 2,500 TPBARs at Watts Bar 1 or 2. Releases, doses, and cancer risks associated with one TPBAR failure can be determined by dividing the values in the tables by 2.

Table 4-9. Radiological impacts to the public from failure of two TPBARs at Watts Bar.

Release pathway	Release quantity (curies)	Dose to maximally exposed individual (millirem)	Latent cancer fatality risk	Dose to population within 50 miles (person-rem)	Latent cancer fatalities[a]
Air	2,315	0.25	2×10^{-7}	2.56	0 (0.002)
Liquid	20,835	0.049	3×10^{-8}	7.34	0 (0.004)
Totals	**23,150**	**0.30**	$\mathbf{2 \times 10^{-7}}$	**9.90**	**0 (0.006)**

a. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table 4-10. Radiological impacts to workers from failure of two TPBARs at Watts Bar.

Impact type	Value
Average worker dose (millirem)	7.7
Latent cancer fatality risk	5×10^{-6}
Total workforce dose (person-rem)[a]	6.8
Latent cancer fatalities[b]	0 (0.004)

a. Based on 879 workers, which includes additional workers for refueling operations and outages.

b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

4.1.11.9 Differences from 1999 EIS

The 1999 EIS estimated the dose to the maximally exposed individual to be 0.34 millirem per year at Watts Bar (DOE 1999a, Table 5-4). For this SEIS, NNSA estimated the maximum potential dose to the maximally exposed individual would be 0.86 millirem per year (see Table 4-7 above). In either case, the radiation exposure of the public from normal operations would remain well below the NRC regulatory limit (25 millirem per year). The 1999 EIS estimated the average annual dose to workers would increase by a maximum of about 1.1 millirem per year as a result of TPBAR irradiation (DOE 1999a, Table 5-5). The analysis for the SEIS estimated this increase would be about 16.5 millirem per year (see Table 4-8 above, which shows that the difference in the average annual worker dose between Alternative 1, in which all of NNSA's tritium production requirements would be met at the Watts Bar site, and Alternative 4, in which the Watts Bar site would not be used to produce tritium, would be 16.5 millirem). In either case, worker exposure to radiation would remain well below the NRC regulatory limit of 5,000 millirem per year.

4.1.12 ACCIDENTS AND INTENTIONAL DESTRUCTIVE ACTS

This section discusses the analysis of potential accidents and impacts to workers and the public during TPBAR irradiation in the Watts Bar reactors. Appendix D contains additional information. Irradiation of TPBARs does not change the requirement for physical protection at nuclear power plants.

Analysis Method

An accident is a sequence of one or more unplanned events with potential outcomes that could endanger the health and safety of workers and the public. An accident can involve a combined release of energy and hazardous materials (radiological or chemical) that might cause prompt or latent health effects. The sequence usually begins with an initiating event, such as a human error, equipment failure, or earthquake, followed by a succession of other events that could be dependent or independent of the initial events, which dictate the accident's progression, the amount of released materials, and the extent of the affected area. Initiating events fall into three categories:

- Internal initiators normally originate in and around the facility, but are always a result of facility operations. Examples include equipment or structural failures and human errors.

- External initiators are independent of facility operations and normally originate from outside the facility. Some external initiators affect the ability of the facility to maintain its confinement of hazardous materials because of potential structural damage. Examples include aircraft crashes, vehicle crashes, nearby explosions, and toxic chemical releases at nearby facilities that affect worker performance.

- Natural phenomena initiators are natural occurrences that are independent of facility operations and occurrences at nearby facilities or operations. Examples include earthquakes, high winds, floods, lightning, and snow. Although natural phenomena initiators are independent of external facilities, their occurrence can involve those facilities and compound the progression of the accident.

NNSA followed four general guidelines in the selection of reactor facility accident scenarios:

5. Potential hazardous and accident conditions should include the largest source terms at risk and conditions for worker and public impacts.

6. The accident scenarios should cover a spectrum of situations ranging from high-probability events with low consequences to low-probability events with high consequences.

7. For each probability range, the accident with bounding consequences should be representative for the range.

8. The accident scenarios should reflect differences that result from site-specific initiators, meteorology, characteristics (for example, distance from site boundary and other adjacent facilities).

In the days immediately following the Fukushima Dai-ichi event in Japan, TVA began assessments of the implications for Sequoyah and Watts Bar. The review considered the ability of the plants to respond to (1) design-basis events, (2) beyond-design-basis events, and (3) combinations of events the nuclear power industry had not previously considered such as simultaneous or nearly simultaneous earthquakes and floods (stacked events) at a single site and at multiple sites. The objectives of the assessment of the Fukushima event were to review TVA's existing readiness to respond to natural or manmade disasters, to identify possible gaps, vulnerabilities, or enhancements, and to provide short-, intermediate-, and long-term recommendations to improve overall ability to respond to such events.

As part of the review, TVA examined the current readiness to implement mitigating strategies at each site. TVA examined whether the kinds of equipment necessary to implement mitigating strategies were available and able to perform their intended functions. In addition, TVA conducted reviews to verify that its procedures for mitigating strategies were in place and could be implemented. It examined the qualifications of operators and support personnel to ensure they were current and sufficient to implement the strategies. Finally, TVA examined applicable agreements and contracts, such as Memoranda of Understanding, to verify that they were in place and able to meet the conditions necessary to mitigate consequences of these types of events.

TVA completed initial assessments for Sequoyah and Watts Bar in April 2011 and continued to assess readiness to implement mitigating strategies. Based on these assessments, TVA has determined that, in relation to mitigating strategies in place at Sequoyah and Watts Bar:

1. Equipment is available and able to perform their intended functions (References 1 and 2 as cited in TVA 2011r). As part of the review of applicable equipment, TVA walked down or performed testing (or verified performance within the previous 90 days) of related tests, preventive maintenance, procedures, and checklists.

2. Procedures and guidance to implement mitigating strategies are in place and implementable considering the current configuration of the plants and with current staffing and skill levels. As part of the review, TVA determined that the qualifications of operators and support staff necessary to implement the procedures and related work instructions are current.

The analysis for this SEIS included severe reactor accidents (beyond-design-basis accidents) in addition to design-basis accidents. Severe reactor accidents are much less likely to occur than design-basis accidents. The consequences of these accidents could be more serious if the reactor operators took no mitigative actions. For design-basis accidents, the analysis assumed the mitigating systems would be available. For severe reactor accidents, even though the initiating event could be a design-basis event (for example, large break loss-of-coolant accident), additional failures of mitigating systems would cause some degree of physical deterioration of the fuel in the reactor core and a possible breach of the containment structure leading to releases of radioactive materials to the environment.

The analysis for this SEIS considered only severe reactor accident scenarios that would lead to containment bypass or failure. NNSA has not presented accident scenarios that do not lead to containment bypass or failure because the consequences to workers, the public, and the environment would be significantly lower.

The analysis considered accidents due to natural phenomenon such as earthquakes, tornadoes, floods, and severe weather as well as those that might result from manmade phenomenon such as an aircraft crash and fire. For example, a loss of offsite power to a plant could result from severe weather events (high wind, tornado, hurricane, and snow and ice storms), power substation breaker faults, instability in the power transmission lines, and unbalanced loading of power lines. Each of these events would lead to loss of main generator power and a reactor trip, and each would challenge the same safety functions as the others regardless of the initial cause.

Therefore, the analysis for this SEIS examined potential consequences of events such as those that occurred at the Fukushima Dai-ichi plant in Japan in 2011 (that is, loss of offsite power, loss of cooling, and core meltdown), even though the initiators would not be identical.

For each of the alternatives, NNSA estimated radiological impacts to three receptors: (1) the maximally exposed individual at the site boundary, (2) the offsite population within 50 miles of the facility, and (3) the average individual within 50 miles of the facility.

Appendix D of the 1999 EIS (DOE 1999a) described the original calculation of radiological impacts from accidents. NNSA has scaled the impacts for the current alternatives from those in the 1999 EIS. Some differences between the 1999 analysis and the analysis in this SEIS are as follows:

- <u>Numbers of TPBARs</u>. The proposed action in the 1999 EIS was a maximum tritium production rate of 6,000 TPBARs (with a maximum of 3,400 TPBARs in any one reactor). As Chapter 2 of this SEIS describes, TVA would irradiate a minimum of 680 TPBARs (at the Watts Bar site) and a maximum of 5,000 TPBARs (with a maximum of 2,500 in any one reactor), depending on the alternative. In all cases the number of TPBARs is less than the 1999 EIS analyzed. NNSA scaled the consequences of the reactor and nonreactor design-basis accidents results to account for the difference in numbers of TPBARs.

- <u>Latent cancer fatality calculation</u>. The 1999 EIS used the standard factors of the time to calculate potential latent cancer fatalities to workers and the public. These were 0.0004 latent cancer fatality per person-rem for workers and 0.0005 latent cancer fatality per person-rem for the public. The U.S. Government has changed these factors to one factor since 1999: 6×10^{-4} latent cancer fatality per person-rem for both workers and the public (ISCORS 2002). The calculation of latent cancer fatalities in this SEIS uses the newer factor.

- <u>Exposed population</u>. The 1999 analysis used 50-mile population values from the 1990 Census. This SEIS uses population distributions on the *2010 Census of Population and Housing* data (USCB 2012). Census data in this SEIS represent the latest information available from the Bureau of the Census. Projections were determined for 2025 for areas within 50 miles of the release locations at Watts Bar and Sequoyah. NNSA used the site population in 2025 in the impact assessments because it was used in the 1999 EIS and is assumed to be representative of the population at the approximate midpoint between now and the end of the interagency agreement. The population was spatially distributed on a circular grid with 16 directions and 10 radial distances up to 50 miles. The grid centers on the location from which the radionuclides would be released. The projected 50-mile 2025 populations for Watts Bar and Sequoyah are 1,452,511 and 1,294,030 people, respectively.

4.1.12.1 No-Action Alternative

Under this alternative, current plans and permitted TPBAR irradiation activities would continue. TVA would irradiate 680 TPBARs every 18 months in Watts Bar 1. Watts Bar 2, which the NRC has not authorized to produce tritium, would produce electricity if the NRC granted an operating license, but it would not irradiate any TPBARs. Table 4-11 lists the potential environmental consequences for design-basis accidents at Watts Bar for the No-Action Alternative (680 TPBARs). NNSA took the accident scenarios from Table 5-10 of the 1999 EIS (DOE 1999a) and scaled the calculated risks as described above.

The accident with the highest risk of the design-basis and handling accidents NNSA considered for this SEIS is the nonreactor design-basis accident. This scenario would entail an acute release of tritium in oxide form directly to the environment without mitigation. Table 4-11 indicates there would be insignificant impacts from design-basis reactor accidents due to the irradiation of TPBARs at the Watts Bar site. As also shown in Table 4-11, the dose to a person at the exclusion area boundary for these accidents would be well below the NRC regulatory limit (25 rem).

Table 4-11. Summary of environmental consequences for design-basis accidents at Watts Bar for the No-Action Alternative.

Accident	Number of TPBARs	Impacts on the maximally exposed individual at the exclusionary boundary: Dose (rem)	Impacts on the maximally exposed individual at the exclusionary boundary: NRC regulatory limit (rem)[a]	Impacts on the population within 50 miles: Dose (person-rem)	Impacts on the population within 50 miles: Average individual dose (rem)[b]
Design-basis accidents					
Reactor design-basis accident (large break loss-of-coolant accident)[c]	680	9.5×10^{-3}	25	10.5	7.2×10^{-6}
Nonreactor design-basis accident (waste gas decay tank rupture)[c]	680	4.4×10^{-2}	25	780	5.4×10^{-4}
Handling accidents					
TPBAR handling accident	All configurations	2.9×10^{-2}	25	0.24	1.6×10^{-7}
Truck cask handling accident	All configurations	7.0×10^{-4}	25	6.1×10^{-3}	4.0×10^{-9}

a. From 10 CFR 50.34 for design-basis accidents.

b. Average individual dose to the entire offsite projected population in 2025 (1,452,511 people) within 50 miles for the indicated accident.

c. The analysis of design-basis accidents assumed mitigation would prevent release of nontritium radionuclides. Therefore, the accident risks are based on the release of tritium only from TPBAR irradiation. The analysis conservatively assumed the entire tritium content in the TPBARs would release to the containment and ultimately to the environment. The analysis of the nonreactor design-basis accident conservatively assumed a higher than normal amount of tritium in the waste decay tank that would release directly to the environment.

Table 4-12 lists the potential environmental impacts for beyond-design-basis accidents at Watts Bar for the No-Action Alternative. Table 4-12 also lists the calculation of accident impacts for reactor operations with and without TPBARs. As shown in Table 4-12, of the analyzed beyond-design-basis accidents for Watts Bar, the early containment failure accident would represent the highest dose to the maximally exposed offsite individual, with an estimated frequency of about 1 chance in 3 million of the accident

Table 4-12. Summary of environmental consequences for beyond-design-basis accidents at Watts Bar for the No-Action Alternative.

			Impacts on the maximally exposed individual at the exclusionary boundary			Impacts on the population within 50 miles		
Accident	**Frequency**	**Number of TPBARs**	**Dose (rem)**	**Dose risk (rem/year)**[a]	**Annual risk of fatal cancer**[b]	**Dose (person-rem)**	**Average individual dose risk (rem/year)**[c]	**Risk of fatal cancer to average individual**[d]
Beyond-design-basis accidents (severe reactor accidents)								
Reactor core damage with early containment failure	3.4×10^{-7}	0	19.7	4×10^{-9}	2×10^{-12}	3.5×10^{5}	8×10^{-8}	5×10^{-11}
		680	19.7	$4.\times 10^{-9}$	2×10^{-12}	3.5×10^{5}	8×10^{-8}	5×10^{-11}
Reactor core damage with containment bypass	1.4×10^{-6}	0	6.4	5×10^{-9}	3×10^{-12}	5.1×10^{5}	5×10^{-7}	3×10^{-10}
		680	6.4	5×10^{-9}	3×10^{-12}	5.1×10^{5}	5×10^{-7}	3×10^{-10}
Reactor core damage with late containment failure	3.0×10^{-6}	0	0.5	9×10^{-10}	5×10^{-13}	3.3×10^{4}	7×10^{-8}	4×10^{-11}
		680	0.5	9×10^{-10}	5×10^{-13}	3.7×10^{4}	8×10^{-8}	5×10^{-11}

a. Dose risk to a hypothetical maximally exposed individual at the exclusion area boundary accounting for the probability of the accident occurring.
b. Annual risk of a fatality or fatal latent cancer to a hypothetical maximally exposed individual at the exclusion area boundary accounting for the probability of the accident occurring.
c. Average individual dose for the entire offsite projected population in 2025 (1,452,511 people) within 50 miles from exposure to the indicated dose and accounting for the probability of the accident occurring.
d. Annual risk of a cancer fatality to the average individual in the entire offsite projected population in 2025 within 50 miles accounting for the probability of the accident occurring.

occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the impacts of a reactor accident.

For the tritiated water storage tank, NNSA anticipates that the maximum tritium concentration in the 500,000-gallon tank would be 88 million picocuries per milliliter. The anticipated average tritium concentration in the tank would be about 20 million picocuries per milliliter (TVA 2012). The worst-case accident scenario would occur if the entire contents of the tank accidently discharged instantaneously to the river. This event would not exceed the EPA limit of 20,000 picocuries per liter downstream at the closest drinking water intake (TVA 2012).

4.1.12.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both Watts Bar 1 and 2 to irradiate a maximum of 2,500 TPBARs every 18 months. Table 4-13 lists the potential environmental consequences for design-basis accidents at Watts Bar for Alternative 1. It lists the impacts of irradiating 1,250 TPBARs every 18 months (which is applicable to Alternative 3) and 2,500 TPBARs every 18 months at Watts Bar. The accident with the highest risk of the design-basis and handling accidents NNSA considered for this SEIS is the nonreactor design-basis accident. This scenario would entail an acute release of tritium in oxide form directly to the environment without mitigation. Table 4-13 indicates there would be insignificant impacts from design-basis reactor accidents due to the irradiation of TPBARs at the Watts Bar site. As

Table 4-13. Summary of environmental consequences for design-basis accidents at Watts Bar for Alternatives 1, 3, 4, and 6.

Accident	Number of TPBARs	Impacts on the maximally exposed individual at the exclusionary boundary		Impacts on the population within 50 miles	
		Dose (rem)	NRC regulatory limit (rem)[a]	Dose (person-rem)	Average individual dose (rem)[b]
Design-basis accidents					
Reactor design-basis accident (large break loss-of-coolant accident)[c]	1,250	1.8×10^{-3}	25	20	1.4×10^{-5}
	2,500	3.4×10^{-3}	25	40	2.8×10^{-5}
Nonreactor design-basis accident (waste gas decay tank rupture)[c]	1,250	8.4×10^{-2}	25	1,400	9.6×10^{-4}
	2,500	0.16	25	2,900	2.0×10^{-3}
Handling accidents					
TPBAR handling accident	All configurations	2.9×10^{-2}	25	447	3.1×10^{-4}
Truck cask handling accident	All configurations	7.0×10^{-4}	25	10.9	7.5×10^{-6}

a. From 10 CFR 50.34 for design-basis accidents.
b. Average individual dose to the entire offsite projected population in 2025 (1,452,511 people) within 50 miles for the indicated accident.
c. The analysis of design-basis accidents assumed mitigation would prevent release of nontritium radionuclides. Therefore, the accident risks are based on the release of tritium only from TPBAR irradiation. The analysis conservatively assumed the entire tritium content in the TPBARs would release to the containment and ultimately to the environment. The analysis of the nonreactor design-basis accident conservatively assumed a higher than normal amount of tritium in the waste decay tank that would release directly to the environment.

also shown in Table 4-13, the dose to a person at the exclusion area boundary for these accidents is well below the NRC regulatory limit (25 rem).

Table 4-14 lists the potential environmental impacts for beyond-design-basis accidents at Watts Bar for Alternative 1. Table 4-14 also presents the calculation of accident impacts for reactor operations with and without TPBARs. As shown in Table 4-14, of the analyzed beyond-design-basis accidents for Watts Bar, the early containment failure accident would represent the highest dose to the maximally exposed offsite individual, with an estimated frequency of about 1 chance in 3 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the impacts of a reactor accident.

4.1.12.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would not use the Watts Bar site to irradiate TPBARs. For severe reactor accidents, Table 4-14 shows the accident risks for reactor operations without TPBARs. For design basis accidents, there would be no impacts.

4.1.12.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis, NNSA assumed each site would irradiate 1,250

Table 4-14. Summary of environmental consequences for beyond-design basis accidents at Watts Bar for Alternatives 1, 3, 4, and 6.

Accident	Frequency	Number of TPBARs	Impacts on the maximally exposed individual at the exclusionary boundary: Dose (rem)	Dose risk (rem/year)[a]	Annual risk of fatal cancer[b]	Impacts on the population within 50 miles: Dose (person-rem)	Average individual dose risk (rem/year)[c]	Risk of fatal cancer to average individual[d]
Beyond-design-basis accidents (severe reactor accidents)								
Reactor core damage with early containment failure	3.4×10^{-7}	0	19.7	4×10^{-9}	2×10^{-12}	3.5×10^{5}	8×10^{-8}	5×10^{-11}
		2,500	19.7	4×10^{-9}	2×10^{-12}	3.5×10^{5}	8×10^{-8}	5×10^{-11}
Reactor core damage with containment bypass	1.4×10^{-6}	0	6.4	5×10^{-9}	3×10^{-12}	5.1×10^{5}	5×10^{-7}	3×10^{-10}
		2,500	6.4	5×10^{-9}	3×10^{-12}	5.1×10^{5}	5×10^{-7}	3×10^{-10}
Reactor core damage with late containment failure	3.0×10^{-6}	0	0.5	9×10^{-10}	5×10^{-13}	3.3×10^{4}	7×10^{-8}	4×10^{-11}
		2,500	0.5	9×10^{-10}	5×10^{-13}	3.7×10^{4}	8×10^{-8}	5×10^{-11}

a. Dose risk to a hypothetical maximally exposed individual at the exclusion area boundary accounting for the probability of the accident occurring.

b. Annual risk of a fatality or fatal latent cancer to a hypothetical maximally exposed individual at the exclusion area boundary accounting for the probability of the accident occurring.

c. Average individual dose for the entire offsite projected population in 2025 (1,452,511 people) within 50 miles from exposure to the indicated dose and accounting for the probability of the accident occurring.

d. Annual risk of a cancer fatality to the average individual in the entire offsite projected population in 2025 within 50 miles accounting for the probability of the accident occurring.

TPBARs every 18 months. Table 4-13 lists the postulated accident risks under Alternative 3 for the Watts Bar site for the 1,250-TPBAR case.

4.1.12.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Because no more than 2,500 TPBARs would be irradiated in a reactor, the potential impacts associated with accidents would be the same as discussed in Section 4.1.12.2.

4.1.12.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as discussed in Section 4.1.12.3.

4.1.12.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.12.2.

4.1.12.8 Intentional Destructive Acts

This section provides an analysis of potential public health consequences from scenarios that involve intentional destructive acts, such as terrorism events. Unlike accident analysis, the analysis of intentional destructive acts provides an estimate of potential consequences without attempting to estimate the frequency or probability of a successful destructive act. This is because there is no accepted basis for estimating the frequency of intentional destructive acts; professional guard forces and other security measures would protect all facilities and activities associated with the alternatives in this SEIS to help prevent such attacks.

Similar to the use of duplicate backup systems to ensure safety, TVA implements a layered approach to physical security at the reactor sites in accordance with NRC regulations and guidance. Nuclear power plants are inherently secure, robust structures built to withstand extreme natural phenomena such as hurricanes, tornadoes, and earthquakes. Additional security measures are in place including physical barriers, intrusion detection and surveillance systems, access controls, and coordination of threat information and response with Federal, state, and local agencies (NRC 2008b).

Since September 11, 2001, NRC has strengthened requirements at nuclear power plants and enhanced coordination with Federal, state, and local organizations. Additional requirements (NRC 2005b) address:

- Increased physical security programs to defend against a more challenging adversarial threat,
- More restrictive site access controls for all personnel,
- Enhanced communication and liaison with the intelligence community,
- Improved capability for events involving explosions or fires,
- Enhanced readiness of security organizations by strengthening training and qualifications programs for plant security forces,
- Required vehicle checks at greater stand-off distances,
- Enhanced force-on-force exercises to provide a more realistic test of plant capabilities to defend against an adversarial force, and
- Improved liaison with Federal, state, and local agencies responsible for protection of the national critical infrastructure through integrated response training.

NRC has also performed comprehensive safety and security studies showing that a radiological release affecting public health and safety is unlikely from a terrorist attack, including one involving a large commercial aircraft. Factors supporting this conclusion included the hardened condition of power plants, which are designed to withstand extreme events such as hurricanes, tornadoes, and earthquakes (for example, thick concrete walls with heavy reinforcing steel); redundant safety systems operated by trained staff; multiple barriers protecting the reactor or serving to prevent or minimize offsite releases; and in-place mitigation strategies and measures. In addition, security measures at nuclear plants have been complemented by measures taken throughout the United States to improve security and reduce the risk of successful terrorist attacks, including measures designed to respond to and reduce the threats posed by hijacking large jet airplanes (for example, reinforced cockpit doors and Federal Air Marshals) (NRC 2005b, 2011f).

An analysis of the consequences of the crash of a large aircraft at a nuclear power reactor site has been performed by the Electric Power Research Institute for the Nuclear Energy Institute. The analysis addressed the consequences of a large jet airline being purposefully crashed into sensitive nuclear facilities or containers including nuclear reactor containment buildings, used fuel storage pools, used fuel dry storage facilities, and used fuel transportation containers. Using conservative analyses, the Electric Power Research Institute concluded that there would be no release of radionuclides from any of these facilities or containers because they are already designed to withstand potentially destructive events. The analysis used computer models in which a Boeing 767-400 was crashed into containment structures that were representative of reactor containment designs for U.S. nuclear power plants. The containment structures suffered some crushing and chipping at the maximum impact point but were not breached (EPRI 2002b).

Notwithstanding the remote risk of a terrorist attack that affected operations at a nuclear power plant, in the very remote likelihood that a terrorist attack would successfully breach the physical and other safeguards at Watts Bar resulting in the release of radionuclides, the potential consequences would be no worse than those of the most severe beyond-design-basis accident NNSA analyzed.

Section 4.1.12 discusses the potential rupture of the tritiated water tank at Watts Bar and the potential impacts from such a rupture. Those impacts would be the same whether the tank ruptured accidentally or through an intentional destructive act.

4.1.12.9 Differences from 1999 EIS

In terms of normal operations, the 1999 EIS analyzed the potential environmental impacts from irradiation of a maximum of 3,400 TPBARs in any of the analyzed TVA reactors and assumed a tritium permeation rate of 1 curie per TPBAR per year. The analysis for this SEIS used a maximum of 2,500 TPBARs in any one reactor and assumed a high and thus conservative tritium permeation rate of 10 curies per TPBAR per year. Both the 1999 EIS and this SEIS demonstrate that the potential environmental impacts from irradiation of TPBARs would be small regardless of a difference in the number of TPBARs irradiated in a reactor (3,400 or 2,500) or the tritium permeation rate (1 or 10 curies of tritium per TPBAR per year).

While the potential impacts of accidents attributable to the release of tritium to the environment would be small in either case, both the 1999 EIS and this SEIS confirm that TPBAR irradiation would not substantially increase the types of facility accidents that could occur or the potential risks from those accidents. With the exception of the nonreactor design-basis accident, the permeation rate would not affect the accident consequences or risk because the scenarios assume the loss of the total inventory of the TPBARs into the reactor containment.

The 1999 EIS did not analyze intentional destructive acts, but this SEIS indicates that the potential consequences would be no worse than those of the most severe beyond-design-basis accident NNSA analyzed.

4.1.13 TRANSPORTATION

This section describes transportation impacts in two parts: the impacts of incident-free or routine transportation and the impacts of transportation accidents. These two parts are further subdivided into nonradiological and radiological impacts. Incident-free transportation includes radiological impacts to the public and the transport crew from the radiation emitted by the package. Nonradiological impacts of incident-free transportation include vehicular emissions. Nonradiological impacts of potential transportation accidents are traffic accident fatalities. Only extremely severe accident conditions, which are of low probability, could cause damage to a transportation cask of the type NNSA would use and consequently a release of radioactivity to the environment.

The impacts of accidents are expressed in terms of probabilistic risk, which is the probability of an accident multiplied by the consequences of that accident and summed over all reasonably conceivable accidents. The impacts due to radiological accidents are measured in terms of the latent cancer fatalities that could result, while the impacts of nonradiological accidents are measured in additional immediate fatalities. Incident-free radiological effects are also expressed in terms of additional latent cancer fatalities.

Transportation Segments

The first step in the ground transportation analysis was to determine the incident-free and accident risk factors on a per-shipment basis for transportation of the various materials. NNSA evaluated three transportation segments for this SEIS: (1) shipment of TPBAR assemblies to the Watts Bar and Sequoyah Nuclear Plants from the assembly plant in Columbia, South Carolina, (2) shipment of irradiated TPBARs to the Tritium Extraction Facility at the Savannah River Site in South Carolina, and (3) shipment of irradiated hardware (low-level radioactive waste) to a waste disposal site. The number of shipments associated with each of the alternatives is presented in Table F-11 (Appendix F).

Transportation segment 1 would involve shipment of nonhazardous, nonradioactive TPBAR material in secure commercial containers, along with new (unirradiated) reactor fuel. The radiological impacts of shipping new reactor fuel are outside the scope of this EIS; the NRC examined those effects in NUREG-0170, *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). Because the fabricated TPBARs contain no radioactive elements, the impacts from transportation segment 1 would be limited to the number of traffic accidents and traffic fatalities. WesDyne, a subsidiary of Westinghouse Electric Corporation, manufactures TPBARs for NNSA. WesDyne procures and maintains an inventory of TPBAR components and assembles them in Columbia, South Carolina.

Transportation segment 2 involves shipment of irradiated TPBARs from the Watts Bar and Sequoyah Nuclear Plants to the Tritium Extraction Facility at the Savannah River Site. The metallic components of the TPBARs would be activated by the reactor flux, and they would contain radioactive tritium. Therefore, NNSA would ship the TPBARs in Type B transportation casks. Safety requirements for these are described in the NRC's regulations in 10 CFR Part 71. The analysis in this SEIS evaluated shipment of TPBARs by truck only (one cask per truck with a maximum of 289 TPBARs per cask) on public roads.

The transportation analysis examined likely routing alternatives for each of the SEIS tritium production alternatives. The analysis quantitatively addressed minimum production at a single unit (680 TPBARs per 18-month fuel cycle) and maximum production at a single site (5,000) TPBARs per 18-month fuel cycle).

Transportation segment 3 would involve shipment of irradiated hardware from the plants to a low-level radioactive disposal site on the Nevada National Security Site (formerly the Nevada Test Site). The irradiated hardware would include base plates and thimble plugs that TVA would remove from the TPBARs at the reactor sites.

Transportation Modes

NNSA assumed all shipments would occur by truck over public roads. Appendix F of this SEIS provides maps of the analyzed truck routes and other details of the transportation impact analyses.

Receptors

NNSA estimated transportation-related risks separately for workers and members of the public. The workers would be truck crew members. The affected public population would include all people who could be exposed to a shipment while it was moving or stopped en route. The analysis estimated potential risks for the collective populations of exposed people and for a hypothetical maximally exposed individual. For incident-free operation, the maximally exposed individual would be an individual stuck in traffic next to the shipment for 30 minutes. For accident conditions, NNSA estimated collective population dose risk. Collective population dose risk is a measure of the radiological risk posed to a group of people as a whole. The collective population dose risk is the primary means of comparing the impacts of the alternatives.

The sections below describe the radiological and accident impacts of transportation of unirradiated and irradiated TPBARs to and from the Watts Bar site, of low-level radioactive waste to the Nevada National Security Site, and of empty containers returning from Nevada. Appendix F provides detail on the analysis of radiological and accident impacts of that transportation.

In terms of local transportation infrastructure and traffic as described in Section 3.1.12, NNSA expects no appreciable impacts because there would be very few shipments of all materials that relate to tritium production (a maximum of about 48 every 18 months or 36 per year, a very small fraction of the current traffic volumes on local roads).

4.1.13.1 No-Action Alternative

Under the No-Action Alternative, NNSA would ship 680 TPBARs and associated low-level radioactive waste from Watts Bar every 18 months. The estimated numbers of latent cancer fatalities over 22 years (until 2035) would be 0 (0.003)[8] for crew, 0 (3×10^{-4}) for members of the public, 0 (5×10^{-6}) for radiological accidents, and 0 (0.004) traffic fatality.

In combination with the results for the No-Action Alternative at Sequoyah (Section 4.2.13.1), the estimated numbers of latent cancer fatalities for the No-Action Alternative over 22 years would be 0 (0.008) for crew, 0 (9×10^{-4}) for members of the public, 0 (2×10^{-5}) for radiological accidents, and 0 (0.009) traffic fatality.

4.1.13.2 Alternative 1: Watts Bar Only

Under Alternative 1, NNSA would ship 2,500 TPBARs and associated low-level radioactive waste from Watts Bar every 18 months. The estimated numbers of latent cancer fatalities over 22 years (until 2035) would be 0 (0.01) for crew, 0 (0.001) for members of the public, 0 (2×10^{-5}) for radiological accidents, and 0 (0.004) traffic fatality. These would be the maximum potential transportation-related impacts associated with TPBAR irradiation.

4.1.13.3 Alternative 2: Sequoyah Only

TVA would not irradiate TPBARs at Watts Bar under Alternative 2, and NNSA would not ship TPBARs or low-level radioactive waste associated with TPBAR irradiation from Watts Bar, so there would be no transportation impacts at Watts Bar.

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8. Because the numbers of latent cancer fatalities and traffic fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

4.1.13.4 Alternative 3: Watts Bar and Sequoyah

Under Alternative 3, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months; the results for Alternative 1 in Section 4.1.13.2 address irradiating and then shipping the maximum number of TPBARs from the Watts Bar site. For comparison, the analysis for Alternative 3 assumed NNSA would ship 1,250 TPBARs and the associated low-level radioactive waste from both Watts Bar and Sequoyah. The Watts Bar shipments would result in estimated numbers of latent cancer fatalities over 22 years (until 2035) of 0 (0.005) for crew, 0 (4×10^{-4}) for members of the public, 0 (1×10^{-5}) for radiological accidents, and 0 (0.004) traffic fatality.

In combination with the results for irradiating 1,250 TPBARs at the Sequoyah site (Section 4.2.13.4), the total estimated latent cancer fatalities for Alternative 3 over 22 years would be 0 (0.01) for crew, 0 (0.001) for members of the public, 0 (2×10^{-5}) for radiological accidents, and 0 (0.009) traffic fatality.

4.1.13.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under Alternative 4, NNSA would ship 5,000 TPBARs and associated low-level radioactive waste from Watts Bar every 18 months. The estimated numbers of latent cancer fatalities over 22 years (until 2035) would be 0 (0.02) for crew, 0 (0.002) for members of the public, 0 (4×10^{-5}) for radiological accidents, and 0 (0.008) traffic fatality. These would be the maximum potential transportation-related impacts associated with TPBAR irradiation.

4.1.13.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs, and NNSA would not ship them or low-level radioactive waste associated with TPBAR irradiation from Watts Bar, so there would be no transportation impacts at Watts Bar.

4.1.13.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.13.2.

4.1.13.8 Intentional Destructive Act During Transportation from Watts Bar to the Savannah River Site

This section provides an analysis of potential public health consequences of scenarios that involve intentional destructive acts, such as terrorism events. Unlike accident analysis, the analysis of intentional destructive acts provides an estimate of potential consequences without attempting to estimate the frequency or probability of a successful destructive act. This is because there is no standard, widely accepted basis for estimating the frequency of intentional destructive acts.

As with accidents this SEIS analyzes, if an intentional destructive act involved the release of radioactive materials in transit, crew members, members of the public, and the environment would be at risk. Crew members and members of the public along the route would be particularly vulnerable because of their locations. Members of the public and the surrounding environment would also be at risk of exposure to the extent that atmospheric conditions dispersed the released materials.

The SEIS analysis used the transportation accident type with the greatest potential impact (Severity level 7; see Appendix F, Section F.4.3.1.1 for details) for the population within 50 miles of the accident site as the basis for the intentional destructive act analysis (that is, Severity level set to 1.0). Therefore, the analysis assumed a Severity level 7 accident would occur and that 100 percent of the tritium inventory (2,778,000 curies) would be released as tritium oxide (tritiated water vapor). The results of the analysis estimated the dose to the maximally exposed individual 460 feet from the accident (the distance downwind from the accident at which the maximum dose would occur) would be about 34 rem. The dose to the affected population from such a transportation event would be about 10,300 person-rem.

Assuming U.S. average weather conditions and a dose-to-risk conversion factors of 0.0012 latent cancer fatality per rem[9] for the maximally exposed individual and 6×10^{-4} latent cancer fatality per person-rem for the exposed population, the estimated risk of a latent cancer fatality to the maximally exposed individual would increase by about 4 percent (1 chance in 25). Among the exposed population of almost 3 million people, there would be about 6 additional latent cancer fatalities.

4.1.14 ENVIRONMENTAL JUSTICE

As discussed in Section 3.1.13, the racial and ethnic characteristics of the population of the region of influence differ in general from those in the State of Tennessee. As a percentage, the region has a larger White population, a smaller Black or African American population, and a smaller Hispanic or Latino population. In 2009, residents of the region experienced a slightly higher rate of poverty than those in the State as a whole. The following sections discuss potential socioeconomic impacts to minority and low-income populations for each alternative.

4.1.14.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs at Watts Bar 1. TVA would operate Watts Bar 2 to produce electricity only. TVA would not irradiate TPBARs in that unit because the NRC has not authorized TVA to do so. Under the No-Action Alternative, as discussed in Section 4.1.11, there would be no meaningful health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR Part 190 (the maximally exposed individual dose would be 0.28 millirem per year, which is less than 2 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected to occur as a result of TPBAR irradiation at Watts Bar under this alternative.

4.1.14.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. As discussed in Section 4.1.11, irradiation of 2,500 TPBARs would not cause meaningful health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR Part 190 (the maximally exposed individual dose would be 0.52 millirem per year, which is less than 3 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected to occur as a result of TPBAR irradiation at Watts Bar under this alternative.

9. The dose-to-risk conversion factor is doubled when a dose is greater than 20 rem.

4.1.14.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would not use the Watts Bar site to irradiate TPBARs. As discussed in Section 4.1.11, if TVA did not irradiate TPBARs at the Watts Bar site, radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR Part 190 (the maximally exposed individual dose would be 0.19 millirem per year, which is less than 1 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected to occur as a result of TPBAR irradiation at Watts Bar under this alternative.

4.1.14.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. As discussed in Section 4.1.11, irradiation of 1,250 TPBARs at Watts Bar would not cause meaningful health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR Part 190 (the maximally exposed individual dose would be 0.36 millirem per year, which is less than 2 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected to occur as a result of TPBAR irradiation at Watts Bar under this alternative.

4.1.14.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would use both Watts Bar reactors to irradiate a maximum of 5,000 TPBARs every 18 months. As discussed in Section 4.1.11, irradiation of 5,000 TPBARs would not cause meaningful health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR Part 190 (the maximally exposed individual dose would be 0.86 millirem per year, which is less than 4 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected to occur as a result of TPBAR irradiation at Watts Bar under this alternative.

4.1.14.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would not use Watts Bar to irradiate TPBARs. The impacts at Watts Bar would be the same as discussed in Section 4.1.14.3.

4.1.14.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Watts Bar would be the same as discussed for Alternative 1 in Section 4.1.14.2.

4.1.15 PERMEATION RATE AND REGULATORY LIMITS

The analyses in Sections 4.1.1 through 4.1.14 are based on a high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year (see Section 2.2). The analyses demonstrate that no regulatory limits would be exceeded at this permeation rate for any of the quantities of TPBARs that could be irradiated at Watts Bar. To provide another perspective on the relationship between the tritium permeation rate and regulatory limits, this section analyzes how high the tritium permeation rate would need to be before a regulatory limit would be exceeded. The analysis in this section is based on the maximum production scenario of irradiating 5,000 TPBARs every 18 months at Watts Bar. In comparison with the maximum production scenario, lesser production quantities would need even higher tritium permeation rates before a regulatory limit would be exceeded. The results of this analysis are listed in Table 4-15 and discussed below.

Table 4-15. Permeation rate versus regulatory limits at Watts Bar.

Regulatory limit	Permeation rate needed to reach limit for irradiation of 5,000 TPBARs (curies per TPBAR per year)
Public drinking water limit (20,000 picocuries per liter)	106
Worker dose (5,000 millirem per year)	2,961
Public dose from normal operations (10 millirem per year from all pathways, 3 millirem per year from the liquid pathway, and 5 millirem per year from the air pathway)	88
Public dose from accidents (25 rem)	Limit could not be reached regardless of permeation rate

Drinking Water

As discussed in Section 4.1.5, the regulatory limit for tritium in drinking water is 20,000 picocuries per liter at the drinking water intake. The analysis in Section 4.1.5 shows that the tritium concentration at the drinking water intake increases linearly based on the amount of tritium released by TPBARs. The rate of increase in the tritium concentration in drinking water is about 0.042 picocuries per liter for every curie of tritium released to the water. To reach the 20,000 picocurie per liter limit, the permeation rate for 5,000 TPBARs would need to be 106 curies per TPBAR per year, based on assumption that 90 percent of the tritium released would be liquid.

Worker Dose

The regulatory limit for worker dose during normal operations is 5,000 millirem per year (see Table C-1 in Appendix C). The analysis in Section 4.1.11 shows that worker dose increases linearly based on the amount of tritium released by TPBARs. The rate of increase in worker dose is about 0.00033 millirem for every curie of tritium released. To reach the 5,000-millirem annual limit, the permeation rate for 5,000 TPBARs would need to be 2,961 curies per TPBAR per year.

Public Dose from Normal Operations

The most stringent regulatory limits for public doses from normal operations are 10 millirem per year from all pathways, 3 millirem per year from the liquid pathway, and 5 millirem per year from the air pathway (see Table C-1 in Appendix C).[10] The analysis in Section 4.1.11 shows that the public dose increases linearly based on the amount of tritium released by TPBARs. Of the three regulatory limits, the 5 millirem per year for the air pathway is the most limiting. The rate of increase in the air pathway public dose is about 0.00011 millirem for every curie of tritium released to the air. To reach the 5-millirem limit, the permeation rate for 5,000 TPBARs would need to be 88 curies per TPBAR per year.

Public Dose from Accidents

The regulatory limit for the public from accidents is 25 rem (see Table C-1 in Appendix C).[11] The analysis in Section 4.1.12 shows that tritium is an insignificant contribution to dose from accidents, and that the 25-rem dose could not be reached regardless of the permeation rate.

4.2 Sequoyah Site

This section describes potential impacts for the Sequoyah Nuclear Plant. Each subsection provides estimated impacts for:

- No-Action Alternative. TVA would irradiate TPBARs at Watts Bar 1 and Sequoyah 1 and 2 in numbers that would keep permeation levels under NRC license and regulatory limits. TVA would irradiate a maximum of 680 TPBARs every 18 months at Watts Bar 1 and 680 TPBARs every 18 months at each of Sequoyah 1 and 2 for a total of 1,360 TPBARs every 18 months at Sequoyah.

- Alternative 1. Use the Watts Bar site only to irradiate a maximum of 2,500 TPBARs every reactor fuel cycle (18 months). This could involve use of both units at Watts Bar. TVA is currently completing construction of Watts Bar 2. TVA would not irradiate TPBARs at Sequoyah under this alternative.

- Alternative 2. Use the Sequoyah site only to irradiate a maximum of 2,500 TPBARs every 18 months. This could involve use of both units at Sequoyah. TVA would not irradiate TPBARs at Watts Bar under this alternative.

- Alternative 3. Use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. This would provide the ability to supply stockpile tritium requirements at either site independently or to use both sites with each supplying a portion of the supply.

- Alternative 4. Use only the Watts Bar site to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this would involve use of both Watts Bar reactors.

- Alternative 5. Use only the Sequoyah site to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this would involve use of both Sequoyah reactors.

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10. These public dose limits are numerical guides for design objectives and limiting conditions for operations to meet the criterion "As Low as is Reasonably Achievable" for radioactive material in light-water-cooled nuclear power reactor effluents (10 CFR Part 50, Appendix I).
11. The 25-rem value is a guidance criterion used to determine the exclusion area and low population zone for a nuclear power plant site (10 CFR 100.11).

- Alternative 6. Use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. Because TVA would irradiate a maximum of 2,500 TPBARs in any one reactor, this could involve the use of one or both reactors at each of the sites. For the analyses in this SEIS, NNSA assumed for Alternative 6 that each site would irradiate 2,500 TPBARs every 18 months.

The impact discussions in Section 4.2 assume that TVA would receive either licenses or license amendments to:

1. Complete and operate the Watts Bar Unit 2 reactor,
2. Irradiate the required number of TPBARs at Watts Bar (Alternatives 1, 3, 4, and 6),
3. Irradiate the required number of TPBARs at Sequoyah (Alternatives 2, 3, 5, and 6), and
4. Continue operations at Watts Bar and Sequoyah through 2035.[12]

4.2.1 LAND USE

4.2.1.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs). Because the necessary facilities are in place and in use, there would be no significant changes or impacts to land use.

4.2.1.2 Alternative 1: Watts Bar Only

Under Alternative 1, TVA would not irradiate TPBARs at Sequoyah. The site would only generate power, and there would be no significant changes or impacts to land use in comparison with current site conditions or the No-Action Alternative.

4.2.1.3 Alternative 2: Sequoyah Only

Under Alternative 2, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. As described in Sections 2.4.1 and 2.4.2, TVA proposes to construct and operate a 500,000-gallon tritiated water tank system to facilitate effluent water management if this alternative is selected for implementation. The tank would be in the existing protected area, which has been dedicated to industrial use since construction began at the Sequoyah site. The foundation would be about 60 feet in diameter. Due to the small area of construction and use of previously disturbed land, NNSA expects no significant impacts to land use from construction activities. Operation of the tritiated water tank system would be expected to have no significant impact on land use. Other than the impacts from construction of the tritiated water tank system, irradiation of 2500 TPBARs at Sequoyah would have no significant impacts on land use.

4.2.1.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For purposes of the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. TVA proposes to construct and operate a tritiated water tank system at Sequoyah if this alternative is selected for implementation. Land use impacts from construction and operation of the tank system would be the same as those discussed for Alternative 2.

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12. Section 2.2 discusses the current status of reactor operating licenses.

Other than the impacts from the construction of the tritiated water tank system, irradiation of 1,250 TPBARs at Sequoyah would have no significant impacts on land use.

4.2.1.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under Alternative 4, TVA would not use Sequoyah to irradiate TPBARs. The impacts at Sequoyah would be the same as discussed in Section 4.2.1.2.

4.2.1.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. The impacts at Sequoyah would be the same as discussed in Section 4.2.1.3.

4.2.1.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.1.3.

4.2.2 AESTHETICS

4.2.2.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs).

Visual

The prominent visual features of the plant are already in place (the reactors, powerhouse, cooling towers, and transmission lines). The tallest buildings would continue to be the cooling towers. Vapor plumes would continue to be visible up to 10 miles away but at no greater frequency than under current conditions. There would be no significant changes or impacts to visual resources.

Noise

Whether tritium is produced at Sequoyah or not, intermittent site-generated noise would still be heard off site. As discussed in Section 3.2.2.2, estimated sound levels in rural areas near the Sequoyah site are typically about 40 A-weighted decibels during the day (TVA 2011b). Because the plant is an industrial facility, sound levels are higher on the site itself but those at the site boundary are consistent with a rural residential area (TVA 2011b). Testing of the emergency warning sirens occurs on a regular basis and results in outdoor sound levels of about 60 A-weighted decibels within a radius of about 10 miles of the site (DOE 1999a). TVA typically tests the sirens once a month at noon (TVA 2011n).

4.2.2.2 Alternative 1: Watts Bar Only

Under Alternative 1, TVA would not irradiate TPBARs at Sequoyah. Visual and noise resources would be unaffected whether or not TPBARs were irradiated in a reactor. Therefore, there would be no significant change in impacts to these resources at the Sequoyah site in comparison with the No-Action Alternative or to present conditions at the site.

4.2.2.3 Alternative 2: Sequoyah Only

Under Alternative 2, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months.

Visual

The prominent visual features of the plant are already in place and include the reactors, powerhouse, cooling towers, and transmission lines. The tallest buildings on the site would continue to be the cooling towers at about 460 feet. TVA proposes to construct and operate a 500,000-gallon tritiated water tank system within the Sequoyah site boundaries. The stainless-steel tank would be about 45 feet in diameter and 45 feet tall with a domed roof and would be visually consistent with the industrial character of the site. It would have a secondary containment consisting of a larger diameter open tank with a rain shield (about 55 feet in diameter and 30 feet high) to capture 100 percent of the stored liquid in case the main tank failed. There would be about 5 feet of space between the inner and outer tank walls, which TVA would use for maintenance and inspection activities (TVA 2011c). If necessary, TVA would erect one new high-mast light for security lighting, which would be consistent in intensity and type with existing security lighting and would be unlikely to result in significant impacts that would affect day or nighttime views. Vapor plumes would continue to be visible up to 10 miles away but at no greater frequency than under existing conditions. Therefore, significant changes or impacts to visual resources would be unlikely.

Noise

Short-term impacts during construction of the 500,000-gallon tank would include noise from large machinery such as trucks, cranes, bulldozers, dumpers, front-loaders, and excavators. This type of construction equipment generates noise levels of about 85 to 88 A-weighted decibels at 50 feet (FTA 2006). A reasonable but conservative assumption is that three pieces of loud equipment would operate simultaneously and continuously for 1 hour or more. The combined sound level of the three loudest pieces (scraper, truck, and bulldozer) is an estimated 92 A-weighted decibels at 50 feet.

To predict noise levels at distances greater than 50 feet from an active construction site, the analysis used an attenuation rate of 6 A-weighted decibels per doubling of distance (Hedge 2011 as cited in DOE 2011a). TVA would construct the tank within the site boundaries; however, the exact location is unknown. Because the location remains uncertain, the nearest receptor to the construction site is assumed to be a residence about one-half mile north-northwest of the site (TVA 2011b). At that distance, the combined sound of the scraper, truck, and bulldozer (92 A-weighted decibels) would fall to about 58 A weighted decibels. The EPA recommends an outdoor sound level of no more than 55 A-weighted decibels for avoidance of annoyance (EPA 1978). Therefore, people at the nearest residence could experience some annoyance during construction of the tank. Noise and sound levels would be typical of new construction activities and would be intermittent and short term. The estimated duration of construction activities is 24 weeks. Confining construction activities to normal working hours and using noise-controlled construction equipment to the extent possible would lessen these impacts.

During operations, tritium production would not result in any significant changes from the existing noise environment. Site-generated noise unrelated to tritium production activities would still be heard off site. The main steam safety relief valves would continue to produce an occasional loud noise for a few hours less than five days per year (TVA 2011b). TVA would continue to test the emergency sirens 1 day a month (TVA 2011b).

4.2.2.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For purposes of the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months.

Visual

The prominent visual features of the plant are already in place and include the reactors, powerhouse, cooling towers, and transmission lines. The tallest buildings on the site would continue to be the cooling towers at about 460 feet. Vapor plumes would continue to be visible up to 10 miles away but at no greater frequency than existing conditions. TVA proposes to construct and operate a tritiated water tank system at Sequoyah, and those impacts would be the same those as discussed for Alternative 2. Other than the impacts from the tritiated water tank system, irradiation of 1,250 TPBARs at Sequoyah would have no visual impacts.

Noise

During operations, tritium production would not result in changes from the existing noise environment. Site-generated noise unrelated to tritium production activities would still be heard off site. The main steam safety relief valves would continue to produce an occasional loud noise for a few hours less than five days per year (TVA 2011b). TVA would continue to test the emergency sirens 1 day a month (TVA 2011b). TVA proposes to construct and operate a tritiated water tank system at Sequoyah, and those impacts would be the same as those discussed for Alternative 2. Other than the short-term impacts from construction of the tritiated water tank system, irradiation of 1,250 TPBARs at Sequoyah would be expected to have no noise impacts.

4.2.2.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under Alternative 4, TVA would not use Sequoyah to irradiate TPBARs. The impacts at Sequoyah would be the same as discussed in Section 4.2.2.2.

4.2.2.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. The impacts would be the same as discussed in Section 4.2.2.3.

4.2.2.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.2.3.

4.2.3 CLIMATE AND AIR QUALITY

The following sections discuss environmental consequences for climate and air quality for the No-Action Alternative and Alternatives 1 through 6. The impacts refer to the site as a whole and not to separate units at the site. This SEIS uses a high and thus conservative permeation rate of 10 curies of tritium per

TPBAR per year; it also conservatively assumes release of 10 percent of this tritium to the environment as gaseous emissions[13] (Chandrasekaran et al. 1985).

4.2.3.1 No-Action Alternative

Under the No-Action Alternative, TVA would irradiate 680 TPBARs at each of the two Sequoyah reactors (a total of 1,360 TPBARs).

Nonradioactive gaseous emissions

Nonradioactive gaseous emissions would be no different from such emissions under existing conditions at Sequoyah. No additional air pollutant emission sources would occur beyond those described in Section 3.2.3.2. As a result, the emissions of criteria pollutants should not change. Therefore, NNSA anticipates no significant additional air quality impacts for nonradioactive emissions.

Greenhouse Gases

Greenhouse gas emissions would not be different from such emissions under existing conditions at Sequoyah. No air pollutant emission sources that create greenhouse gases would occur beyond those described in Section 3.2.3.2. As a result, additional air quality impacts from greenhouse gases would be unlikely. The total amount of carbon dioxide from Sequoyah activities (diesel fuel use and worker commuting) would be about 7,100 tons annually. As Section 3.2.3.3 discusses, the carbon dioxide emissions from Sequoyah activities would be much less than 1 percent of carbon dioxide emissions from other activities in the state of Tennessee. Additional significant air quality impacts from greenhouse gases would be unlikely.

Climate

Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change from existing conditions at Sequoyah. Non-tritium radioactive gaseous emissions would not change from the conditions described in the 1999 EIS. As a result, significant contribution to changes to climate would be unlikely.

Radioactive gaseous emissions

Table 4-16 lists the estimated annual radioactive gaseous emissions during tritium production at Sequoyah for the No-Action Alternative. Under the No-Action Alternative, TVA would irradiate 1,360 TPBARs at Sequoyah and the nontritium radioactive gaseous emissions would be similar to those under existing conditions. Based on operational experience and system performance information, TVA has estimated that a maximum of 2,400 curies of non-TPBAR tritium is released from reactor operations per reactor (4,800 curies total) (TVA 2012). Conservatively assuming that 10 percent of the tritium would be released to the air (Chandrasekaran et al. 1985), the two Sequoyah units would release 480 curies of tritium during reactor operations from non-TPBAR sources. Based on a high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year and the potential release of 10 percent to the environment as gaseous tritium, the total gaseous tritium emissions from irradiation of 1,360 TPBARs would be 1,360 curies. Section 4.2.11 discusses impacts to human health from radioactive gaseous emissions.

13. As indicated in Section 4.4, the actual percent of tritium released through gaseous emissions is about 3 percent.

Table 4-16. Annual estimated radioactive gaseous emissions (curies) at Sequoyah – No-Action Alternative.

Release	No-Action Alternative (1,360 TPBARs)
Tritium from TPBARs	1,360[a]
Non-TPBAR tritium	480[b]
Other radioactive	27[c]
Total	**1,867**

a. Under the No-Action Alternative, TVA would irradiate 1,360 TPBARs at Sequoyah. Based on a high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year and the potential release of 10 percent to the environment as gaseous tritium, the total tritium emissions from irradiation of 1,360 TPBARs would be 1,360 curies.
b. Based on the bounding assumption of 4,800 curies of non-TPBAR tritium releases from reactor operations per 2-unit site and the assumption that 10 percent of the tritium emissions would be air releases.
c. Based on TVA's measurement of actual annual radioactive gaseous emissions to the environment for 2010 (TVA 2011o).

TPBAR Failure Scenario

Even though the design of the TPBAR essentially precludes the potential for TPBAR failure during irradiation, NNSA assumed for the analysis that two TPBARs could fail in an operating cycle and release all tritium from the failed TPBARs to the reactor coolant system. Gaseous tritium emissions from the two failed TPBARs would be about 2,315 curies. This value is based on the following assumptions:

- Each TPBAR would generate a maximum design limit of 1.2 grams of tritium over an operating cycle; the specific activity of tritium is 9,640 curies per gram (DOE 1999a).
- Two failed TPBARs could release 23,150 curies of tritium to the reactor coolant system during the operating cycle.[14]
- Ten percent of the released tritium would be gaseous and 90 percent would be liquid (Chandrasekaran et al. 1985).

Section 4.2.11.8 presents the potential human health impacts for the releases from the two failed TPBARs.

4.2.3.2 Alternative 1: Watts Bar Only

Under Alternative 1, TVA would use one or both of the Watts Bar reactors to irradiate a maximum of 2,500 TPBARs every 18 months. TVA would not irradiate TPBARs at Sequoyah, which could change the impacts to air resources in comparison with the No-Action Alternative. This section discusses those potential changes.

14. This SEIS does not specifically present the impacts from the failure of two TPBARs in each of Sequoyah reactors (that is, a total of four failed TPBARs). The potential impacts of four failed TPBARs would produce impacts about twice those in Section 4.2.11 (Tables 4-21 and 4-22).

Nonradioactive gaseous emissions

Nonradioactive gaseous emissions would be no different from such emissions under existing conditions at Sequoyah. Air pollutant emission sources would not occur beyond those described in Section 3.2.3.2. Additional significant air quality impacts from nonradioactive emissions would be unlikely.

Greenhouse Gases

Greenhouse gas emissions would be essentially unaffected regardless of TPBAR irradiation. Therefore, greenhouse gas emissions would be essentially the same as discussed in Section 4.2.3.1.

Climate

Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change from existing conditions at Sequoyah. As a result, significant contribution to changes to climate would be unlikely.

Radioactive gaseous emissions

Table 4-17 lists annual estimated radioactive gaseous emissions during tritium production at Sequoyah for Alternative 1. The calculations in this table assume that tritium production would occur only at Watts Bar. As a result, TVA would not irradiate TPBARs at Sequoyah and no tritium emissions would occur beyond those attributable to normal reactor operation without TPBAR irradiation. Section 4.2.11 discusses impacts to human health from radioactive gaseous emissions.

Table 4-17. Annual estimated radioactive gaseous emissions (curies) at Sequoyah – Alternative 1.

Release	No-Action Alternative (1,360 TPBARs)	Alternative 1 (0 TPBARs)
Tritium from TPBARs	1,360	0
Non-TPBAR tritium	480	480
Other radioactive	27	27
Totals	**1,867**	**507**

4.2.3.3 Alternative 2: Sequoyah Only

Under Alternative 2, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. TVA proposes to construct and operate a tritiated water tank system (see Sections 2.4.1 and 2.4.2).

Nonradioactive gaseous emissions

Nonradioactive gaseous emissions would be no different from such emissions under existing conditions at Sequoyah. Air pollutant emission sources would not occur beyond those described in Section 3.2.3.2 during operations at the site. Additional air quality impacts from nonradioactive emissions would be unlikely.

Some minor emissions could occur during construction of the 500,000-gallon tank from the use of cranes and other construction equipment. The emissions would be temporary and within the levels generally experienced at the site (TVA 2011c).

Greenhouse Gases

Aside from short-term impacts associated with the operation of construction equipment during construction of the tritiated water storage tank, greenhouse gas emissions would be essentially the same as discussed in Section 4.2.3.1.

Climate

Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change from existing conditions at Sequoyah. As a result, significant contribution to changes to climate would be unlikely.

Radioactive gaseous emissions

Table 4-17 lists annual estimated radioactive gaseous emissions during tritium production at Sequoyah for Alternative 2. The calculations in this table assume a high and thus conservative tritium permeation rate of 10 curies of tritium per TPBAR per year and release of 10 percent of this tritium to the environment as gaseous emissions. For Alternative 2, the analysis for this SEIS assessed the environmental impacts of the irradiation of 2,500 TPBARs every 18 months. Section 4.2.11 discusses impacts to human health from radioactive gaseous emissions.

Table 4-17. Annual estimated radioactive gaseous emissions (curies) at Sequoyah – Alternative 2.

Release	No-Action Alternative (1,360 TPBARs)	Alternative 2 (2,500 TPBARs)
Tritium from TPBARs	1,360	2,500
Non-TPBAR tritium	480	480
Other radioactive	27	27
Totals	**1,867**	**3,007**

TPBAR Failure Scenario

Even though the design of the TPBAR essentially precludes the potential for failure during irradiation, NNSA assumed for the analysis that two TPBARs could fail in an operating cycle and release all tritium from the failed TPBARs to the reactor coolant system. Gaseous tritium emissions from the two failed TPBARs would be about 2,315 curies. This value is based on the same assumptions as described above for the No-Action Alternative. Section 4.2.11.8 presents the potential human health impacts for the releases from the two failed TPBARs.

4.2.3.4 Alternative 3: Watts Bar and Sequoyah

Under Alternative 3, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 1,250 TPBARs every 18 months. For this alternative, TVA proposes to construct and operate a tritiated water tank system at Sequoyah, as discussed for Alternative 2.

Nonradioactive gaseous emissions

Nonradioactive gaseous emissions would be no different from such emissions under existing conditions. Air pollutant emission sources would not occur beyond those described in Section 3.2.3.2. Additional air quality impacts from nonradioactive emissions would be unlikely.

Some minor emissions could occur during construction of a 500,000-gallon tank from the use of cranes and other construction equipment. The emissions would be temporary and within the levels generally experienced at the site (TVA 2011c).

Greenhouse Gases

Greenhouse gas emissions would be essentially the same as discussed in Section 4.2.3.2.

Climate
Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change from existing conditions. As a result, significant contribution to changes to climate would be unlikely.

Radioactive gaseous emissions
The tritium emissions for Sequoyah from TPBAR irradiation under Alternative 3 would be about half of the emissions under Alternative 2. Table 4-19 lists the estimated annual radioactive gaseous emissions during tritium production. The calculations used Sequoyah radioactive gaseous emissions from 2010 and estimated tritium emissions from irradiating 1,250 TPBARs. Section 4.1.3.4 discusses radioactive gaseous emissions from Watts Bar under Alternative 3. Section 4.2.11 discusses impacts to human health from radioactive gaseous emissions.

Table 4-19. Annual estimated radioactive gaseous emissions (curies) at Sequoyah – Alternative 3.

Release	No-Action Alternative (1,360 TPBARs)	Alternative 3 (1,250 TPBARs)
Tritium from TPBARs	1,360	1,250
Non-TPBAR tritium	480	480
Other radioactive	27	27
Totals	**1,867**	**1,757**

TPBAR Failure Scenario
Even though the design of the TPBAR essentially precludes the potential for failure during irradiation, NNSA assumed for the analysis that two TPBARs could fail in an operating cycle and release all tritium from the failed TPBARs to the reactor coolant system. Gaseous tritium emissions from the two failed TPBARs would be about 2,315 curies. This value is based on the same assumptions as described above for the No-Action Alternative. Section 4.2.11.8 presents the potential human health impacts for the releases from the two failed TPBARs.

4.2.3.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under Alternative 4, TVA would not use Sequoyah to irradiate TPBARs. The impacts at Sequoyah would be the same as described in Section 4.2.3.2.

4.2.3.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under Alternative 5, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. TVA proposes to construct and operate a tritiated water tank system as discussed in Section 4.2.3.3.

Nonradioactive gaseous emissions
Nonradioactive gaseous emissions would be no different from such emissions under existing conditions at Sequoyah. Air pollutant emission sources would not occur beyond those described in Section 3.2.3.2 during operations at the site. Additional air quality impacts from nonradioactive emissions would be unlikely.

Some minor emissions could occur during construction of the 500,000-gallon tank from the use of cranes and other construction equipment. The emissions would be temporary and within the levels generally experienced at the site (TVA 2011c).

Greenhouse Gases
Aside from short-term impacts associated with the operation of construction equipment during construction of the tritiated water storage tank, greenhouse gas emissions would be essentially the same as discussed in Section 4.2.3.1.

Climate
Nonradioactive gaseous emissions (including criteria pollutants and greenhouse gases) would not change from existing conditions at Sequoyah. As a result, significant contribution to changes to climate would be unlikely.

Radioactive gaseous emissions
Table 4-20 lists annual estimated radioactive gaseous emissions during tritium production at Sequoyah for Alternative 5. The calculations in this table assume a high and thus conservative tritium permeation rate of 10 curies of tritium per TPBAR per year and release of 10 percent of this tritium to the environment as gaseous emissions. For Alternative 5, the analysis for this SEIS assessed the environmental impacts of the irradiation of 5,000 TPBARs every 18 months. Section 4.2.11 discusses impacts to human health from radioactive gaseous emissions.

Table 4-20. Annual estimated radioactive gaseous emissions (curies) at Sequoyah – Alternative 5.

Release	No-Action Alternative (1,360 TPBARs)	Alternative 5 (5,000 TPBARs)
Tritium from TPBARs	1,360	5,000
Non-TPBAR tritium	480	480
Other radioactive	27	27
Totals	**1,867**	**5,507**

TPBAR Failure Scenario
Even though the design of the TPBAR essentially precludes the potential for failure during irradiation, NNSA assumed for the analysis that two TPBARs could fail in an operating cycle and release all tritium from the failed TPBARs to the reactor coolant system. Gaseous tritium emissions from the two failed TPBARs would be about 2,315 curies. This value is based on the same assumptions as described above for the No-Action Alternative. Section 4.2.11.8 presents the potential human health impacts for the releases from the two failed TPBARs.

4.2.3.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.3.3.

4.2.3.8 Differences from 1999 EIS

TPBARs
- The 1999 EIS assumed (1) TVA would irradiate 3,400 TPBARs every 18 months in either of the Sequoyah reactors, up to a maximum of 6,000 TPBARs every 18 months using both reactors, (2) that an average of 1 curie of tritium per TPBAR per year could permeate to the reactor coolant, and (3) that 10 percent of this tritium would be released to the environment as gaseous air emissions. The annual tritium gaseous emissions under these assumptions would be 340 curies from one reactor and 600 curies from both reactors.

- For this SEIS, NNSA assumed (1) TVA would irradiate up to 2,500 TPBARs every 18 months in either of the Sequoyah reactors, and up to a maximum of 5,000 TPBARs every 18 months at Sequoyah using both reactors, (2) that an average of 10 curies of tritium per TPBAR per year could permeate to the reactor coolant, and (3) that 10 percent of this tritium would be released to the environment as gaseous air emissions. The annual tritium gaseous emissions under these assumptions would be a maximum of 2,500 curies from a single reactor and a maximum of 5,000 curies from both reactors.

Non-TPBAR Tritium Releases

- The 1999 EIS estimated annual non-TPBAR tritium air releases from normal reactor operations would be 25 curies at Sequoyah. DOE based the estimation on estimated emissions at that time.

- For this SEIS, NNSA estimated annual non-TPBAR tritium air releases from normal reactor operations would be 480 curies at Sequoyah. NNSA based the estimate on 4,800 curies of total non-TPBAR tritium releases per two-reactor site (which is a bounding estimate provided by TVA) and a 10-percent release of that tritium into the air.

Other Radioactive Releases (Nontritium)

- The 1999 EIS estimated radioactive nontritium air emissions from normal reactor operations would be 120 curies at Sequoyah based on emission estimates at that time.

- For this SEIS, NNSA estimated radioactive nontritium air emissions from normal reactor operations would be 27 curies at Sequoyah based on current emission estimates, which are, in turn, based upon 2010 measurements at the site.

Greenhouse Gas Emissions

- The 1999 EIS did not assess greenhouse gas emissions.

- For this SEIS, NNSA assessed greenhouse gas emissions from existing facilities at the Sequoyah site. The irradiation of TPBARs would have essentially no impact on the quantity of greenhouse gas emissions. There would be a short-term and minor impact from the operation of construction equipment during construction of the tritiated water storage tank at Sequoyah, if an alternative involving the Sequoyah site is selected.

4.2.4 GEOLOGY AND SOILS

4.2.4.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs). Additional significant impacts to geology and soils at Sequoyah, beyond those of current conditions (Section 3.2.4), would be unlikely.

4.2.4.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would use only the Watts Bar site to irradiate TPBARs. Geology and soil resources would be unaffected whether or not TPBARs were irradiated in a reactor. Therefore, there would be no change in the impacts to these resources in comparison with the current conditions discussed in Section 3.2.4.

4.2.4.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. Additional significant impacts to geology and soils from irradiation of TPBARs at Sequoyah, beyond current conditions (Section 3.2.4), would be unlikely under this alternative.

TVA proposes to construct a tritiated water tank system (Sections 2.4.1 and 2.4.2), which would disturb land adjacent to existing facilities. The tank system would require aggregate and sand in small quantities for the 60-foot-diameter foundation. In addition, TVA would need to excavate to upgrade and install utility systems. TVA would use best management practices to control potential erosion during construction. Adverse impacts to geologic and soil resources would be unlikely during tank construction. Operation of the tritiated water tank system would have no impact on geology and soils.

4.2.4.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analysis for this alternative assumed that each site would irradiate 1,250 TPBARs every 18 months. Additional impacts to geology and soils at Sequoyah from irradiation of TPBARs, beyond current conditions (Section 3.2.4), would be unlikely under this alternative.

4.2.4.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. Therefore, there would be no change in the impacts to these resources in comparison with the current conditions discussed in Section 3.2.4.

4.2.4.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate up to 5,000 TPBARs. Additional impacts to geology and soils at the Sequoyah site, beyond those of current conditions (Section 3.2.4), would be unlikely under this alternative.

4.2.4.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. Additional impacts to geology and soils at the Sequoyah site, beyond those of the current conditions (Section 3.2.4), would be unlikely under this alternative.

4.2.5 WATER RESOURCES

The primary impact to water resources from any of the alternatives would be a change in the amount of tritium the Sequoyah site would release in liquid effluents. The use of TPBARs in the Sequoyah reactors would not change the thermal or chemical characteristics of the water the site discharges to the Chickamauga Reservoir (or Tennessee River), and it would not affect the quantities or types of radionuclides other than tritium in the discharges. Appendix E describes the evaluation of the added tritium discharges to the Tennessee River from the Sequoyah site. This section summarizes those evaluations and describes the impacts for each alternative.

NNSA evaluated the effects of tritium discharges using the EPA set of computer programs called Visual Plumes (Frick et al. 2003). EPA and contributors from private industry, academia, and a state agency developed Visual Plumes under a cooperative agreement; its purpose is to simulate surface and subsurface water jets and plumes to assist, among other uses, in mixing zone analyses. The NNSA evaluation involved the use of two models from Visual Plumes, UM3 (for the "three-dimensional Updated Merge model") and DKHW (for the "Davis, Kannberg, Hirst model for Windows"). Both are three-dimensional plume models for simulating single- and multi-port submerged discharges. As described in Appendix E, both models are designed for applications such as the Sequoyah discharge, but because there is no actual plume data available to determine which model better simulates the site-specific conditions, NNSA used both models in the evaluations. The practical limitations of measuring actual plume characteristics, particularly in a water body like the Tennessee River under varying low flow and discharge conditions, is the reason site-specific data is unavailable and why models are routinely used in such instances to provide plume simulations.

This section describes impacts based on comparisons between the in-stream tritium concentrations the plume models predicted and applicable regulatory standards. Nonradiological constituents in liquid effluents from Sequoyah Outfall 101 are regulated under the site's National Pollutant Discharge Elimination System permit, but the permit does not regulate the discharge of radionuclides in the liquid effluents from the plant. Radionuclide discharge is regulated under the plant's operating license with the NRC and NRC regulations, which require that the total effective dose equivalent to individual members of the public from each licensed operation not exceed 0.1 rem (100 millirem) in a year (10 CFR Part 20). According to the regulation, the licensee can demonstrate compliance with this requirement by measuring or calculating the dose to the individual likely to receive the highest dose, or by demonstrating that the annual average concentrations of radioactive materials in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed values specified in Table 2 of Appendix B to 10 CFR Part 20. That table specifies a concentration limit for tritium of 1 million picocuries per liter in water effluents to unrestricted areas. The Technical Specifications appended to the Sequoyah operating license (Sections 6.8.4.f.2 and 3) specify that liquid effluents to unrestricted areas are limited to 10 times the concentration values in Appendix B to 10 CFR Part 20; that is, the site-specific limit for tritium is 10 million picocuries per liter.

Another regulatory limit indirectly applicable to tritium levels in the Sequoyah effluent is in the EPA National Primary Drinking Water Regulations (40 CFR Part 141). In these regulations, EPA sets a maximum contaminant level for beta particle and photon radioactivity in drinking water as one that would produce an annual dose equivalent of 4 millirem per year to the total body or any internal organ. The regulation further specifies that a tritium concentration of 20,000 picocuries per liter meets this limit. In application, if there were other beta particle- or photon-emitting radionuclides present, the limit for tritium would have to be reduced accordingly. For example, if both tritium and strontium-90 were present in drinking water and the strontium-90 was at a concentration that would result in a dose of 2 millirem per year (half the allowable limit), the limit for tritium would be cut in half to 10,000 picocuries per liter.[15] This regulation is not directly applicable to the discharge area of the Tennessee River because water from that area is not used as drinking water. However, the river is a drinking water source (before treatment) at locations downstream.

15. Other beta particle- and photon-emitting radionuclides typically present in the Sequoyah liquid effluents are identified in Appendix E (Table E-10), where they are evaluated for their impacts on the tritium limit. Results of the evaluation indicate that none are present in sufficient concentrations to affect use of 20,000 picocuries per liter as the limit for tritium.

The evaluations in Appendix E address several variables to encompass the expected range of discharge and river conditions at the Sequoyah site. These include one parameter with three variables and another parameter with two variables as follows:

- Tritium in liquid effluents:
  - 15,570 curies per year from normal plant operations and deployment of 1,250 TPBARs under Alternative 3, resulting in an average tritium concentration of 2.03 million picocuries per liter in the discharge to the diffuser pond and 7,470 picocuries per liter in the discharge to Outfall 101 (see Table E-7, Appendix E);
  - 26,820 curies per year from normal plant operations and deployment of 2,500 TPBARs under Alternatives 2 and 6, and potentially Alternative 3, resulting in an average tritium concentration of 3.5 million picocuries per liter in the discharge to the diffuser pond and 12,900 picocuries per liter in the discharge to Outfall 101 (see Table E-7, Appendix E); and
  - 49,320 curies per year from normal plant operations and deployment of 5,000 TPBARs under Alternative 5, resulting in an average tritium concentration of 6.43 million picocuries per liter in the discharge to the diffuser pond and 23,700 picocuries per liter in the discharge to Outfall 101 (see Table E-7, Appendix E); the diffuser pond is inside of the fenced, owner-controlled area and access is limited.
- River flow:
  - Essentially no water movement (the Visual Plumes program would not support an entry of zero velocity) to represent a worst-case condition for plume dispersion, and
  - 32,000 cubic feet per second, the average river flow condition at the Sequoyah site.

The analysis modeled six scenarios to address the combinations posed by the above variables. Appendix E provides further detail on the development of these and other model parameters. Table 4-21 summarizes the modeling results in terms of the tritium concentration as the discharge plume moves away from the diffusers downstream. The table lists results for each of the six scenarios and for the UM3 and DKHW models. To present a more conservative evaluation, the concentrations in the table are the maximum plume concentrations that would be present at the centerline of the plume. The Watts Bar analysis (Section 4.1.5) included a third parameter with two variables, so there are 12 evaluated scenarios. The third Watts Bar parameter is the plant's discharge rate to the river and, in that case, the analysis considered two values because the plant cannot discharge during periods of low river flow and instead must temporarily discharge to the onsite holding pond. After such periods the discharge rate to the river can be much higher than typical for short periods as the plant discharges both normal flow and flow from the holding pond to lower it to the normal operating level. The Sequoyah plant does not have a similar discharge restriction, and use of a single average discharge rate is appropriate. In addition, it should be noted that the water discharge rate from the Watts Bar plant (about 80 cubic feet per second with Watts Bar 2 operating; see Section 4.1.5) is much lower than the 2,333 cubic feet per second discharge rate at the Sequoyah plant (Appendix E), and, as a result, the tritium concentrations in the Sequoyah discharge (with more dilution water) are much lower. This is a direct reflection of the difference in the cooling systems for the two nuclear plants. Watts Bar has a closed system that recycles much of its cooling water, so blowdown from the system is the primary discharge to the river. Sequoyah, on the other hand, has the flexibility to operate in several modes, but it operates predominantly in the open mode, in which cooling

Table 4-21. Sequoyah modeling of tritium concentration in the discharge plume.

Evaluated scenarios[a]	Distance (ft) for plume centerline to decrease to 20,000 pCi/L		Centerline concentration (pCi/L) at boundary of mixing zone (1,500 ft from diffusers)		Centerline concentration (pCi/L) where plume surfaces and distance from the diffusers	
	UM3	DKHW	UM3	DKHW	UM3	DKHW
Scenarios with the average effluent discharge of 2,333 cubic feet per second to the river						
1. Low tritium and low river flow	0	0	NM[b]	NM	4,470 at 47 ft	4,560 at 50 ft
2. Low tritium and typical river flow	0	0	NM	NM	1,810 at 136 ft	710 at 403 ft
3. Middle tritium and low river flow	0	0	NM	NM	7,710 at 47 ft	7,880 at 50 ft
4. Middle tritium and typical river flow	0	0	NM	NM	3,130 at 136 ft	1,230 at 403 ft
5. High tritium and low river flow	26	28	NM	NM	14,200 at 47 ft	14,500 at 50 ft
6. High tritium and typical river flow	18	10	NM	NM	5,570 at 136 ft	2,250 at 403 ft

ft = feet; NM = not modeled; pCi/L = picocuries per liter; surf = surfaces; ≈ = approximately.

a. Scenarios:
Low tritium = effluent with a tritium concentration of 7,470 pCi/L (therefore, the distance to decrease to 20,000 pCi/L is 0 ft).
Middle tritium = effluent with tritium concentration of 12,900 pCi/L (therefore, the distance to decrease to 20,000 pCi/L is 0 ft).
High tritium = effluent with tritium concentration of 23,700 pCi/L.
Low river flow = approximately zero – set at about 6 cubic feet per second (or 0.0001-foot-per-second velocity) because the model requires a positive value.
Typical river flow = 32,000 cubic feet per second (average flow over the course of a year).

b. The plume reached the water surface before leaving the mixing zone, and modeling stopped at that point.

water passes only once through the system to pick up heat before discharge. In addition to the six modeled scenarios in Table 4-21, Appendix E describes estimated tritium releases under the No-Action Alternative, which would include deployment of a number of TPBARs similar to the low end of the range included in the modeled scenarios.

As indicated above, other than for Alternative 5 (results reflected in the high tritium scenarios in Table 4-21), average tritium concentrations in the Sequoyah plant's effluent would be below the drinking water standard of 20,000 picocuries at the point the effluent reached the river. As a result, the first four scenarios in Table 4-21 show 0 feet as the distance it takes to decrease tritium to the drinking water standard. As the table indicates, both models predict that the high tritium concentration would reduce to the drinking water standard fairly quickly, within a maximum of about 28 feet of the diffusers under either river flow scenario. As expected, the worse-case situation at each tritium concentration was at the low river flow. Under the low river flow scenarios, the plumes surfaced much closer to the diffusers and at higher concentrations.

In addition, Table 4-21 lists predicted concentrations of tritium at other locations of potential interest, including the mixing zone boundary and the point at which the plume would first reach the water surface. As noted in the table, the models often did not compute concentrations at the boundary of the mixing zone because they stopped when the plume reached the surface. In this case, the models did not compute values because the mixing zone extends a relatively long distance of 1,500 feet downstream; the table lists this category only for comparison with the Watts Bar evaluations.

The nearest drinking water intake is the City of Chattanooga, Tennessee, which is about 8 miles southwest of the Sequoyah site and about 10 river miles downstream. Tritium concentrations are already monitored at this drinking water intake. As discussed in Appendix E, at this downstream distance it is reasonable to assume the tritium would be well mixed in the river flow. At the maximum tritium discharge and average river flow, the average tritium concentration at the downstream drinking water intake would be about 1,720 picocuries per liter, well below the drinking water limit of 20,000 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

4.2.5.1 No-Action Alternative

4.2.5.1.1 Surface Water

Under the No-Action Alternative, there would be impacts to surface-water resources from using the Sequoyah reactors for TPBAR irradiation, if the NRC issued the additional license amendments (see Section 2.3.1). For the evaluation in this SEIS, NNSA assumed the NRC would authorize irradiation of 680 TPBARs in each Sequoyah reactor (a total of 1,360).

The two reactors produce an estimated annual baseline release of about 4,320 curies of tritium in the liquid effluents without TPBARs, and there would be about 16,560 curies per year from both reactors (baseline plus TPBAR production) with a combined loading of 1,360 TPBARs. This total release range is similar to the smallest amount in the above plume modeling evaluation, and the impacts would be similar to those from the plume models for the low tritium scenarios. The estimated average tritium concentration of 2.16 million picocuries per liter in the discharge to the diffuser pond (see Table E-7, Appendix E) would be well under the limit of 10 million picocuries per liter in the Sequoyah operating license. The estimated average tritium concentration of 7,950 picocuries per liter in the subsequent discharge to the river (see Table E-7, Appendix E) would be under the drinking water limit of 20,000 picocuries per liter. Assuming the 16,560 curies of tritium would be completely mixed into the average river flow of 32,000 cubic feet per second [about 28.6 trillion (2.86×10^{13}) liters per year], the average tritium concentration at the nearest downstream drinking water intake would be about 580 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

4.2.5.1.2 Groundwater

The No-Action Alternative would have no effect on groundwater at the Sequoyah site. If the NRC approved the site for limited irradiation of TPBARs, and as is the case under current operating conditions, there would be no direct discharge of the tritium-containing cooling water to groundwater. Natural interconnections between groundwater and surface water (the Tennessee River in this case) are common and are expected in the area. At the Sequoyah site, groundwater movement is toward the river, but even if there are areas downstream where water from the river moves into adjacent groundwater, tritium concentrations would be no higher than the in-stream values described above for surface water. The initial movement of the effluent discharge from the diffuser is outward and upward in the river. This is by design (the angle of the diffuser ports) and because of the heat differential of the effluent, and it ensures a well-mixed plume before it reaches any river bank or bottom areas where water migration to groundwater might occur. As Section 3.2.5.2.2 describes, TVA has linked tritium contamination in the groundwater beneath the Sequoyah site to past inadvertent releases of radioactive liquids. TPBAR irradiation would not increase the chances for such inadvertent releases to occur in the future.

4.2.5.1.3 Floodplains and Wetlands

The No-Action Alternative would be expected to have no significant adverse impacts on floodplains or wetlands at the Sequoyah site. The quantity of discharged water and the locations of such discharges would not change in comparison with current operating conditions. There would be no physical changes to wetlands or floodplain areas. During times of high river flow, downstream waters that naturally reach floodplains or wetlands could have higher tritium concentrations, but as described above for impacts to groundwater, tritium concentrations would be no higher than the in-stream values discussed for surface water.

4.2.5.2 Alternative 1: Watts Bar Only

4.2.5.2.1 Surface Water

Under Alternative 1, TVA would not irradiate TPBARs at the Sequoyah site. There would be no changes to water discharges as given in Section 3.2.5. Operation of the two reactors (without TPBARs) would result in a baseline release conservatively estimated at 4,320 curies of tritium per year in the liquid effluents (see Table E-7, Appendix E). This release would be about one-quarter of the smaller amount in the plume modeling evaluations (Section 4.2.5), and the impacts would be less than the predicted values of the plume models. The estimated tritium concentration of 563,000 picocuries per liter in the discharge to the diffuser pond would be well under the limit of 10 million picocuries per liter in the Sequoyah operating license, and the estimated tritium concentration of 2,070 picocuries per liter in the discharge to the river would be well below the drinking water limit of 20,000 picocuries per liter. At an annual release rate of 4,320 curies of tritium and average river flow, the average tritium concentration at the downstream drinking water intake would be about 150 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

4.2.5.2.2 Groundwater

Because there would be no TPBARs irradiated under Alternative 1, there would be no significant new adverse impacts to groundwater expected at the Sequoyah site.

4.2.5.2.3 Floodplains and Wetlands

Because there would be no TPBARs irradiated at the Sequoyah site under Alternative 1, there would be no significant new adverse impacts expected to floodplains or wetlands.

4.2.5.3 Alternative 2: Sequoyah Only

4.2.5.3.1 Surface Water

Under Alternative 2, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. With the baseline amounts of tritium from normal operation of the Sequoyah reactors plus a conservatively high bounding estimate for additional tritium permeating from the TPBARs (10 curies per TPBAR per year), NNSA estimated the Sequoyah liquid effluents could contain 26,820 curies each year (see Table E-7, Appendix E). In the wastewater discharge to the diffuser pond, this quantity of tritium would result in an average concentration of 3.5 million picocuries per liter. Including cooling water, the average plant discharge to Outfall 101 is 2,333 cubic feet per second, so the average tritium concentration at the point of discharge from the submerged diffusers in the Tennessee River would be 12,900 picocuries per liter.

With normal plant discharge of 2,333 cubic feet per second at Outfall 101, and typical river flow, the plume models predicted that the tritium concentration of 12,900 picocuries per liter, already below the drinking water level, would reduce to 25 percent or less of that value by the time the plume reached the surface, some 140 to 400 feet downstream of the diffusers. Under the worse-case condition of almost no river flow, the discharge plume would reach the water surface closer to the diffuser (within about 50 feet) than for typical river flow levels, and the maximum tritium concentrations in the plume would be about 7,900 picocuries per liter or less when it reached the surface.

The estimated average tritium concentrations of 3.50 million picocuries per liter in the discharge to the diffuser pond and 12,900 picocuries per liter in the discharge to the river would both be well under the limit of 10 million picocuries per liter in the Sequoyah operating license and the plant’s established envelope for safe operations. Discharge to the river would already meet drinking water standards for tritium, be reduced in concentration by the time the plume reached the surface (within 400 feet of the diffusers under either river flow scenario), and be further reduced in concentration when the plume reached the extent of the mixing zone 1,500 feet downstream of the diffusers. At these levels, there would be no significant impacts at the nearest downstream drinking water intake, which is for the City of Chattanooga. Assuming the tritium would mix completely with the river flow at this distance, concentrations of tritium at the drinking water intake would average about 940 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

As Sections 2.4.1 and 2.4.2 discuss, TVA proposes to construct a tritiated water tank system to minimize potential impacts of tritiated water releases if the NRC authorized TPBAR irradiation in the Sequoyah reactors. This system would give TVA the flexibility to reduce the number of batch releases during the year and target them to periods of higher river flow to minimize effects. Construction of the tank would be the only construction under Alternative 2. The tank would be in the area already dedicated to plant operations, and its presence would have minor effects on stormwater runoff from the site. TVA expects the disturbed area would be less than 1 acre; if that estimate increased to more than 1 acre, TVA would submit an application to the State of Tennessee for coverage under its general permit for construction stormwater. TVA will use best management practices to control small amounts of runoff during construction. As noted in the plant's National Pollutant Discharge Elimination System permit, stormwater runoff from the site is currently authorized under the Tennessee Storm Water Multi-Sector General Permit for Industrial Activities (Permit Number TNR050015) and is subject to the requirements and controls in the plant's stormwater pollution prevention plan that the General Permit requires (TDEC 2011e). Thus, runoff from the tank area during construction and operation would be unlikely to affect surface waters adversely.

TPBAR Failure Scenario

NNSA evaluated the unlikely scenario of TPBAR failure (see Appendix E) by assuming the addition of 20,835 curies of tritium from two failed TPBARs to the liquid effluents during irradiation of 2500 TPBARs at Sequoyah, which would have the middle TPBAR irradiation rate for Sequoyah. That is, the liquid effluents under this scenario would include 20,835 curies in addition to the 26,820 curies per year from normal plant operations and irradiation of 2,500 TPBARs for a total of 47,655 curies of tritium. NNSA evaluated this scenario for a typical river flow (32,000 cubic feet per second) and, as for normal operations, for a condition of essentially no flow. This annual amount of tritium in normal discharges to the diffuser pond and to the river results in average tritium concentrations of 6.21 million picocuries per liter to the diffuser pond and 22,900 picocuries per liter to the river (Appendix E). The latter is about 1.8 times the river discharge concentration evaluated for a normal irradiation of 2,500 TPBARs.

As for Watts Bar (Section 4.1.5.2), NNSA evaluated the unlikely scenario of TPBAR failure using the UM3 and DKHW models (see Appendix E). Under this tritium release rate, average discharge to the river would be slightly above the drinking water level of 20,000 picocuries per liter. Under a typical river flow condition, both models predicted the plume would reach a centerline concentration of 20,000 picocuries per liter within less than 20 feet of the diffuser. Consistent with the information in Table 4-21 for the typical river flow scenarios (2, 4, and 6), the UM3 and DKHW models predicted the plumes would surface at about 136 and 403 feet, respectively. However, the centerline concentrations in this case would be 5,560 and 2,180 picocuries per liter, respectively, at the point of surfacing for the UM3 and DKHW models (see Table E-11, Appendix E). Under the low, or no river flow condition, both models predicted the plume would reach a centerline concentration of 20,000 picocuries per liter within less than 30 feet of the diffuser and would surface within about 50 feet of the diffusers at a centerline concentration of about 14,000 picocuries per liter.

Using the rationale described above, the average tritium concentration at the City of Chattanooga drinking water intake during higher tritium discharge would be about 1,670 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

4.2.5.3.2 Groundwater

Alternative 2 would have no impact on groundwater at the Sequoyah site for the reasons described in the discussion of the No-Action Alternative. As described in Section 3.2.5.2.2, TVA has linked tritium contamination in the groundwater beneath the Sequoyah site to past inadvertent releases of radioactive liquids. TPBAR irradiation would not increase the chances for such inadvertent releases to occur in the future.

A tritiated water tank and its associated transfer piping and equipment would represent new potential sources of spills and leaks to reach the ground but, as mitigation, the design of these elements would include appropriate preventive measures. The tank would be inside a secondary containment tank, and TVA would design the piping to protect groundwater from leaking pipes in conjunction with the nuclear industry’s voluntary groundwater protection initiative. TVA would install pipes in trenches, tunnels, or inside other pipes (that is, double-walled piping systems) to provide secondary containment, or the pipes would be above ground to allow visual inspection (TVA 2011c).

4.2.5.3.3 Floodplains and Wetlands

Construction of a tritiated water tank would be outside the 100-year floodplain and would not involve disturbance of wetlands. For the reasons described in the discussion of the No-Action Alternative, there would be no significant adverse impacts to floodplains or wetlands expected to occur under Alternative 2.

4.2.5.4 Alternative 3: Watts Bar and Sequoyah

4.2.5.4.1 Surface Water

Under Alternative 3, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. NNSA assumed for the analyses in this SEIS that each site would irradiate 1,250 TPBARs. With the baseline amounts of tritium from normal operation of the Sequoyah reactors plus a conservatively high estimate for the additional tritium permeating from 1,250 TPBARs, NNSA estimated the Sequoyah liquid effluents could contain 15,570 curies each year (see Table E-7, Appendix E). In the wastewater discharge to the diffuser pond, this quantity of tritium would result in an average concentration of 2.03 million picocuries per liter. Including cooling water, the average plant discharge to Outfall 101 is 2,333 cubic feet per second, so the 15,570 curies of tritium would result in an average concentration of 7,470 picocuries per liter in the discharge from the submerged diffusers in the Tennessee River.

With normal plant discharge of 2,333 cubic feet per second at Outfall 101, and typical river flow, the plume models predicted the tritium concentration of 7,470 picocuries per liter, already below the drinking water level, would reduce to 25 percent or less of that value by the time the plume reached the surface, some 140 to 400 feet downstream of the diffusers. Under the worst-case condition of almost no river flow, the discharge plume would reach the water surface closer to the diffuser (within about 50 feet) than for typical river flow levels, and the maximum tritium concentrations in the plume would be about 4,600 picocuries per liter or less when it reached the surface.

The estimated average tritium concentration of 2.03 million picocuries per liter in the discharge to the diffuser pond under the 1,250 TPBARs at Sequoyah scenario would be well under the limit of 10 million picocuries per liter in the Sequoyah operating license, as would be the 7,470 picocuries per liter in the discharge to the Tennessee River under the same scenarios. Because the discharge under this scenario would be in accordance with the Sequoyah operating license, the discharge would be within the established envelope for safe operations. Under the Alternative 3 conditions, the average tritium concentration would be under the drinking water standard when released to the river and, although not specifically included in the model predictions, the tritium concentration would be notably lower when the plume reached the extent of the mixing zone 1,500 feet downstream of the diffusers. At these levels, there would be no significant impacts at the nearest downstream drinking water intake, which is for the City of Chattanooga. Assuming the 15,570 curies of tritium would be completely mixed into the average river flow of 32,000 cubic feet per second [about 28.6 trillion (2.86×10^{13}) liters per year], the average tritium concentration at the nearest downstream drinking water intake would be about 540 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

TVA proposes to construct and operate a tritiated water tank system at the Sequoyah site, as discussed for Alternative 2. The potential impacts to surface waters at the site would be the same those for Alternative 2.

Under Alternative 3, TVA could at times irradiate all 2,500 TPBARs at the Sequoyah site and none at Watts Bar. Conversely, there could be times when there were none at Sequoyah while all 2,500 were at Watts Bar. If TVA irradiated 2,500 TPBARs at the Sequoyah site, the potential impacts (maximum potential impacts) would be the same as those for Alternative 2 (Section 4.2.5.3). During times when TVA did not irradiate TPBARs at Sequoyah, impacts would be the same as those for Alternative 1 (Section 4.2.5.2).

TPBAR Failure Scenario

NNSA evaluated the scenario of TPBAR failure (see Appendix E) by assuming the 20,835 curies of tritium from two failed TPBARs would be added to liquid effluents during Alternative 3 for irradiation of 1,250 TPBARs at Sequoyah. That is, the liquid effluents under this scenario would include 20,835 curies in addition to the 15,570 curies per year from normal plant operations and irradiation of 1,250 TPBARs for a total of 36,405 curies of tritium. NNSA evaluated this scenario for a typical river flow (32,000 cubic feet per second) for normal operations and for a condition of essentially no flow. This annual amount of tritium in normal discharges to the diffuser pond and to the river would result in average tritium concentrations of 4.75 million picocuries per liter to the diffuser pond and 17,500 picocuries per liter to the river (Appendix E). The latter would be about 2.3 times the river discharge concentration for a normal irradiation of 1,250 TPBARs.

NNSA evaluated the scenario of TPBAR failure using both the UM3 and DKHW models (Appendix E). Under this higher tritium release rate, average discharge to the river would be slightly below the drinking water level of 20,000 picocuries per liter. Consistent with the information in Table 4-21 for the typical river flow scenarios (2 and 4), the UM3 and DKHW models predicted the plumes would surface at about 136 and 403 feet, respectively. However, the centerline concentrations, in this case, would be 4,250 and 1,660 picocuries per liter, respectively, at the point of surfacing for the UM3 and DKHW models. Under the low or no river flow condition, both models predicted the plume would surface within about 50 feet of the diffusers at centerline concentrations of less than 11,000 picocuries per liter.

Using the rationale described above, the average tritium concentration at the City of Chattanooga drinking water intake during higher tritium discharge would be about 1,270 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

4.2.5.4.2 Groundwater

Alternative 3 would have no impact on groundwater at the Sequoyah site for the reasons discussed under the No-Action Alternative. As described in Section 3.2.5.2.2, TVA has linked tritium contamination in the groundwater beneath the Sequoyah plant to past inadvertent releases of radioactive liquids. As discussed in Section 4.2.5.3.2, TPBAR irradiation would not increase the chances for such inadvertent releases to occur in the future.

Potential impacts, or lack thereof, to groundwater from the construction and operation of a tritiated water tank system would be the same as those for Alternative 2 (Section 4.2.5.3.2).

4.2.5.4.3 Floodplains and Wetlands

TVA proposes to construct and operate a tritiated water tank system at the Sequoyah site, as discussed for Alternative 2. For the reasons discussed under the No-Action Alternative, there would be no impacts to floodplains or wetlands for Alternative 3.

4.2.5.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under Alternative 4, TVA would not use the Sequoyah plant to irradiate TPBARs. The impacts at Sequoyah would be the same as discussed in Section 4.2.5.2.

4.2.5.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

4.2.5.6.1 Surface Water

Under Alternative 5, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. With the baseline amounts of tritium from normal operation of the Sequoyah reactors plus a conservatively high bounding estimate for additional tritium permeating from the TPBARs (10 curies per TPBAR per year), NNSA estimated the Sequoyah liquid effluents could contain 49,320 curies each year (see Table E-7, Appendix E). In the wastewater discharge to the diffuser pond, this quantity of tritium would result in an average concentration of 6.43 million picocuries per liter. Including cooling water, the average plant discharge to Outfall 101 is 2,333 cubic feet per second, so the average tritium concentration at the point of discharge from the submerged diffusers in the Tennessee River would be 23,700 picocuries per liter.

With normal plant discharge of 2,333 cubic feet per second at Outfall 101, and typical river flow, the plume models predicted that the tritium concentration of 23,700 picocuries per liter would reduce to drinking water standards within 18 feet or less of the diffusers. The models also predicted the centerline concentrations would be reduced to 29 percent or less of the drinking water standard when the plume reached the surface, some 140 to 400 feet downstream of the diffusers. Under the worse-case condition of almost no river flow, the discharge plume would reach the drinking water standard within 28 feet or less, but would surface closer to the diffuser (within about 50 feet) than for typical river flow levels. With almost no river flow, the maximum tritium concentrations in the plume would be about 14,500 picocuries per liter or less when it reached the surface.

The estimated average tritium concentrations of 6.43 million picocuries per liter in the discharge to the diffuser pond and 23,700 picocuries per liter in the discharge to the river would both be well under the limit of 10 million picocuries per liter in the Sequoyah operating license and the plant's established envelope for safe operations. Discharge to the river would meet drinking water standards for tritium, under either river flow scenario, within 28 feet of the diffusers, be reduced in concentration by the time the plume reached the surface (within 400 feet), and be further reduced in concentration when the plume reached the extent of the mixing zone 1,500 feet downstream of the diffusers. At these levels, there would be no significant impacts at the nearest downstream drinking water intake, which is for the City of Chattanooga. Assuming the tritium would mix completely with the river flow at this distance, concentrations of tritium at the drinking water intake would average about 1,720 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

TVA proposes to construct and operate a tritiated water tank system at the Sequoyah site, as discussed for Alternative 2. The potential impacts to surface waters at the site would be the same those for Alternative 2.

TPBAR Failure Scenario

NNSA evaluated the unlikely scenario of TPBAR failure (see Appendix E) by assuming the addition of 20,835 curies of tritium from two failed TPBARs to the liquid effluents during Alternative 5, which would have the highest TPBAR irradiation rate for Sequoyah. That is, the liquid effluents under this scenario would include 20,835 curies in addition to the 49,320 curies per year from normal plant operations and irradiation of 5,000 TPBARs for a total of 70,155 curies of tritium. NNSA evaluated this scenario for a typical river flow (32,000 cubic feet per second) and, as for normal operations, for a condition of essentially no flow. This annual amount of tritium in normal discharges to the diffuser pond and to the river would result in average tritium concentrations of 9.15 million picocuries per liter to the diffuser pond and 33,700 picocuries per liter to the river (Appendix E). The latter is about 1.4 times the river discharge concentration evaluated for a normal irradiation of 5,000 TPBARs.

NNSA evaluated the unlikely scenario of TPBAR failure using the UM3 and DKHW models (see Appendix E). Under this tritium release rate, average discharge to the river would be above the drinking water level of 20,000 picocuries per liter. Under a typical river flow condition, both models predicted the plume would reach a centerline concentration of 20,000 picocuries per liter within 32 feet or less of the diffuser. Consistent with the information in Table 4-21 for the typical river flow scenarios (2, 4, and 6), the UM3 and DKHW models predicted the plumes would surface at about 136 and 403 feet, respectively. However, the centerline concentrations in this case would be 8,180 and 3,200 picocuries per liter, respectively, at the point of surfacing for the UM3 and DKHW models (see Table E-11, Appendix E). Under the low or no river flow condition, both models predicted the plume would reach a centerline concentration of 20,000 picocuries per liter within several feet after reaching the surface at about 50 feet from the diffusers.

Using the rationale described above, the average tritium concentration at the City of Chattanooga drinking water intake during the highest tritium discharge would be about 2,450 picocuries per liter. Section 4.2.11 discusses impacts to human health from tritium releases.

4.2.5.6.2 Groundwater

Alternative 5 would have no impact on groundwater at the Sequoyah site for the reasons discussed under the No-Action Alternative. As described in Section 3.2.5.2.2, TVA has linked tritium contamination in the groundwater beneath the Sequoyah plant to past inadvertent releases of radioactive liquids. As discussed in Section 4.2.5.3.2, due to the design features of the tritiated water tank (and its associated piping) that would be constructed at Sequoyah if TPBARs were to be irradiated at that site, TPBAR irradiation would not increase the chances for such inadvertent releases to occur in the future. Therefore, potential impacts, or lack thereof, to groundwater from the construction and operation of a tritiated water tank system would be the same as those for Alternative 2 (Section 4.2.5.3.2).

4.2.5.6.3 Floodplains and Wetlands

Construction of a tritiated water tank would be outside the 100-year floodplain and would not involve disturbance of wetlands. For the reasons described in the discussion of the No-Action Alternative, there would be no significant adverse impacts to floodplains or wetlands expected to occur under Alternative 5.

4.2.5.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.5.3.

4.2.5.8 Differences from 1999 EIS

The evaluations of water resources for Sequoyah actions for this SEIS differ from those of the 1999 EIS primarily as follows:

- Tritium releases from TPBAR irradiation. The 1999 EIS estimated the release of 3,060 curies each year to the Tennessee River from TPBAR irradiation of 3,400 TPBARs every 18 months. In this SEIS, NNSA estimated the maximum amount of annual tritium releases would be 26,820 curies from irradiation of 2,500 TPBARs and 49,320 curies from irradiation of a maximum of 5,000 TPBARs.

- Tritium releases from normal operations. The 1999 EIS used a baseline tritium release of 714 curies per year from either Sequoyah 1 or 2 (but not both); the baseline did not include releases from both reactors. For this SEIS, NNSA assumed annual releases in the conservatively high amount of 4,320 curies from both Sequoyah reactors (2,160 curies from each).

- Discharge plume models. The 1999 EIS used the Cornell Mixing Zone Expert System (CORMIX) computer program to develop estimates of tritium concentrations in the Tennessee River downstream of the Sequoyah discharge diffusers. For this SEIS, NNSA used two different plume models from the suite of EPA computer programs called Visual Plumes to develop estimates for tritium concentrations in the river (http://www.epa.gov/ceampubl/swater/vplume/). The analyst chose the Visual Plumes models because they are EPA-recognized and publicly available. Document preparers and reviewers who wish to know more about the models do not need to purchase a license for this software as is necessary for a fully functioning version of CORMIX. As a point of reference, NNSA tested the Visual Plumes models using one of the tritium discharge scenarios for Sequoyah in the 1999 EIS and found the Visual Plume results to be conservative (higher impacts) in comparison with the 1999 EIS evaluation. Specifically, the Visual Plumes models, as used in this evaluation, predicted the tritium plume would require a longer travel distance to reach the modeled concentration than did the 1999 EIS.

- Modeled discharge scenarios. The 1999 EIS modeled two scenarios under average discharge and river flow conditions: one for deploying all 3,400 TPBARs and one for deploying 1,000 TPBARs. For this SEIS, NNSA modeled one alternative for deploying 5,000 TPBARs at Sequoyah, one for 2,500 TPBARs, and one for deploying 1,250 TPBARs. In addition, the analysis for this SEIS includes modeling of three additional Sequoyah discharge scenarios that are representative of an extreme (low) river flow condition. In this case, "extreme" means a flow condition within the range of expected plant operations but at the far low end of the range. By its nature, this extreme condition, if it occurred, would be for a relatively short period. Because of the significant increase in the amount of tritium that this SEIS estimates TPBAR irradiation would release to the river (in comparison with the 1999 EIS), NNSA determined it was important to characterize tritium concentrations in the river during an extremely adverse case as well as average conditions.

- Tritium concentration at nearest drinking water intake. The 1999 EIS estimated an average tritium concentration of 195 picocuries per liter under average discharge and river flow conditions and the maximum amount of tritium that operations would release annually to the Tennessee River (from baseline releases and TPBAR irradiation). Under similar conditions for this SEIS, NNSA estimated an average tritium concentration of about 1,720 picocuries per liter at the nearest downstream drinking water intake. These values are much lower than the maximum acceptable drinking water level for tritium of 20,000 picocuries per liter identified in 40 CFR Part 141.

- Tritiated water tank system. The 1999 EIS did not consider a tank system. The evaluation for this SEIS includes this system, and analyzes how it would affect tritium discharges and the potential impacts of its operation.

4.2.6 BIOLOGICAL RESOURCES

4.2.6.1 No-Action Alternative

Under the No-Action Alternative, TVA would irradiate 680 TPBARs at each of the two Sequoyah reactors (a total of 1,360 TPBARs).

Irradiation of 1,360 TPBARs would increase radiological releases in gaseous emissions and liquid effluents (see Sections 4.2.3.1 and 4.2.5.1). If an organism inhales or ingests tritium, it is incorporated into bodily fluids. However, rapid elimination by exhalation, excretion in body water, and a short half-life limit long-term accumulation in the organism (DOE 1999a). According to an International Atomic Energy Agency publication (IAEA 1992 as cited in DOE 1999a), a dose rate of 100 millirem per year to the most exposed human will lead to dose rates to plants and animals that would not result in significant adverse impacts to those populations. As discussed in Section 4.2.11.1, irradiation of 1,360 TPBARs every 18 months could result in an annual dose to the maximally exposed individual of about 0.24 millirem per year. This potential dose would results in a dose to plants and animals well below the International Atomic Energy Agency benchmark. Therefore, the increase in tritium releases due to irradiation of 1,360 TPBARs would not be expected to have significant adverse impacts on biological resources.

The modeling of the tritium plume under the most unfavorable modeling conditions showed the tritium concentration reduced to 20,000 picocuries per liter (the EPA drinking water standard) within about 30 feet of the diffusers (see Table 4-21), which would not affect aquatic life. Even at the maximum concentration of 23,700 picocuries per liter, where the effluent exited the diffusers, the resultant dose rate to a person would be 5.0 millirem per year, which would equate to a dose to plants and animals well below the International Atomic Energy Agency benchmark.

Impacts of discharging heated water and chemical treatments to the environment are concerns for an operational nuclear plant. Thermal plumes can attract fish to warmer water when ambient temperatures are cooler than ideal or can repel fish, thereby impeding natural migrations through the system (TVA 2011b). At Sequoyah, coolant water currently discharged under a National Pollutant Discharge Elimination System permit enters the Tennessee River at less than 10 degrees Fahrenheit warmer from two 350-foot-long diffusers that extend into the navigation channel. An underwater dam crosses the river channel about 250 feet upstream from the diffuser, decreasing the likelihood of a warm water wedge extending upstream from the thermal discharge to the plant intake and impounding cooler water from lower strata of the reservoir near the intake (TVA 2011b). The mixing zone downstream of the diffusers is 750 feet wide and extends 1,500 feet downstream and 275 feet upstream of the diffusers (TVA 2011b). Tritium production would not affect the thermal discharge characteristics of the plant (DOE 1999a) and, therefore, is not expected to have significant adverse impacts on aquatic resources.

Hydraulic entrainment occurs in the portion of Chickamauga Reservoir that TVA diverts to the Sequoyah site. TVA measures effects of entrainment and impingement on fish communities through the Reservoir Fish Assemblage Index program (see Section 3.2.6.3.2). Average Index scores from 2000 to 2009 indicate stability over time in the fish community. Effects of entrainment on fish populations in Chickamauga Reservoir are, therefore, minor. TPBAR irradiation would not change the amount of entrainment and impingement to fish communities.

There are no known Federally or State-listed at-risk or endangered plant or animal species on or adjacent to the Sequoyah site, and no suitable habitats for listed species occur on the site due to its disturbed nature and because of ongoing operations. Therefore, impacts to Federally or State-listed terrestrial endangered or at-risk species would be unlikely. Changes in the radiological impacts from tritium production would be below the International Atomic Energy Agency benchmarks, and changes in water temperature would be unlikely. Three Federally listed mussel species—the orange-foot pimpleback, the pink mucket, and the Dromedary pearly mussel—might occur in the Chickamauga Reservoir near the Sequoyah site; however, according to the Natural Heritage Database, there have been no reported individuals near the site in recent years. Although snail darters have occurred in the Chickamauga Dam tailwater within the last decade, the Federally listed species does not occur in the Chickamauga Reservoir pool near the site (TVA 2009a); therefore, NNSA expects this alternative would not impact the snail darter. TVA has notified the U.S. Fish and Wildlife Service of the NNSA proposed action and has provided the State of Tennessee and the Fish and Wildlife Service with copies of the Draft SEIS. TVA and NNSA would continue to comply with the requirements of the *Endangered Species Act of 1973* and interact with the Fish and Wildlife Service, as appropriate.

Adoption of the No-Action Alternative is not expected to result in any significant adverse impacts to local or regional terrestrial life because site conditions would remain unchanged. Because operational conditions would remain at levels currently permitted, additional significant adverse impacts to ecological resources would be unlikely under this alternative.

4.2.6.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would not use the Sequoyah site to irradiate TPBARs. Radiological releases in gaseous emissions and liquid effluents at that site would decrease in comparison with the No Action alternative, as would the dose to the maximally exposed individual off site (see Sections 4.2.3.3, 4.2.5.3, and 4.2.11.3). As a result, the dose levels to plants and animals would remain well below the International Atomic Energy Agency benchmarks. There would be no changes to river water temperature, entrainment and impingement of aquatic species, or significant adverse impacts on Federal and State threatened and endangered species (see Section 4.2.6.1).

4.2.6.3 Alternative 2: Sequoyah Only

Under Alternative 2, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. TVA proposes to construct and operate a tritiated water tank system (see Sections 2.4.1 and 2.4.2). Land disturbances would be minor with the construction of the tank system and would occur in previously disturbed areas; therefore, significant construction-related adverse impacts to terrestrial plants and wildlife would be unlikely.

TPBAR irradiation would increase radiological releases in gaseous emissions and liquid effluents (see Sections 4.2.3.3 and 4.2.5.3). As discussed in Section 4.2.11.3, irradiation of a maximum of 2,500 TPBARs every 18 months could result in an annual dose to the maximally exposed individual of about 0.33 millirem per year. This potential dose would result in a dose to plants and animals well below the International Atomic Energy Agency benchmark. Therefore, the increase in tritium releases due to irradiation of 2,500 TPBARs would be expected to have no significant adverse effect on ecological resources. No increase in temperature due to increased TPBAR irradiation would occur and impingement and entrainment of aquatic organisms would not change. TPBAR irradiation would not be expected to result in any significant adverse impacts to Federal or State threatened and endangered species (see Section 4.2.6.1).

4.2.6.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analysis for this alternative assumed that each site would irradiate 1,250 TPBARs every 18 months. As discussed in Section 4.2.11.4, irradiation of 1,250 TPBARs every 18 months could result in an annual dose to the maximally exposed individual of about 0.23 millirem per year. This potential dose results in a dose to plants and animals well below the International Atomic Energy Agency benchmark. Increases in temperature due to TPBAR irradiation would be unlikely and impingement and entrainment of aquatic organisms would not change. TPBAR irradiation would not be expected to result in any significant adverse impacts to Federal or State threatened and endangered species (see Section 4.2.6.1).

The potential impacts associated with construction and operation of a tritiated water tank system would be the same as those described for Alternative 2.

4.2.6.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. The impacts would be the same as discussed in Section 4.2.6.2.

4.2.6.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under Alternative 5, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. TVA proposes to construct and operate a tritiated water tank system as discussed in Section 4.2.6.3, and the impacts would be the same as discussed in that section. Irradiation of 5,000 TPBARs would increase radiological releases in gaseous emissions and liquid effluents (see Sections 4.2.3.6 and 4.2.5.6). As discussed in Section 4.2.11.6, irradiation of a maximum of 5,000 TPBARs every 18 months could result in an annual dose to the maximally exposed individual of about 0.55 millirem per year. This potential dose would result in a dose to plants and animals well below the International Atomic Energy Agency benchmark. Therefore, the increase in tritium releases due to irradiation of 5,000 TPBARs would be expected to have no significant adverse effect on ecological resources. No increase in temperature due to increased TPBAR irradiation would occur and impingement and entrainment of aquatic organisms would not change. TPBAR irradiation would not be expected to result in any significant adverse impacts to Federal or State threatened and endangered species (see Section 4.2.6.1).

4.2.6.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.6.3.

4.2.7 CULTURAL RESOURCES

4.2.7.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs). Because the necessary facilities are in place and in use, there would be no changes or impacts to cultural resources.

4.2.7.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would not use the Sequoyah site to irradiate TPBARs. Cultural resources would be unaffected whether or not TPBARs were irradiated in a reactor. Therefore, there would be no change in impacts to this resource in comparison with current conditions and site operations.

4.2.7.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. For this alternative, TVA proposes to construct and operate a tritiated water tank system to facilitate effluent water management (see Sections 2.4.1 and 2.4.2). The tank system would be in the existing protected area, which has been dedicated to industrial use since construction began at the Sequoyah site. The foundation would be about 60 feet in diameter. Due to the small area of construction and use of previously disturbed land, NNSA does not anticipate impacts to cultural resources from construction activities. Operation of the tritiated water tank system would have no significant adverse impact on cultural resources.

4.2.7.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. TVA proposes to construct and operate a tritiated water tank system at Sequoyah, and those impacts would be the same those as discussed for Alternative 2. As indicated in Section 4.2.7.3, there would be no impacts on cultural resources from construction or operation of the tritiated water tank system. Irradiation of 1,250 TPBARs at Sequoyah would have no significant adverse impacts on cultural resources.

4.2.7.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. Cultural resources would be unaffected whether or not TPBARs were irradiated in a reactor. The impacts at Sequoyah would be the same as discussed in Section 4.2.7.2.

4.2.7.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. TVA proposes to construct and operate a tritiated water tank system as discussed in Section 4.2.7.3, and the impacts would be the same as discussed in that section.

4.2.7.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.7.3.

4.2.8 INFRASTRUCTURE AND UTILITIES

4.2.8.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs). Under the No-Action Alternative, there would be no significant impacts to infrastructure demands (electricity, drinking water, steam, sanitary sewer, industrial gas, communications networks, or emergency response capabilities) at Sequoyah beyond the impacts of existing activities (see Section 3.2.8).

4.2.8.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. Infrastructure demands would be largely unaffected whether or not TPBARs were irradiated in a reactor. Therefore, there would be no change in impacts to infrastructure demands in comparison with the No-Action Alternative.

4.2.8.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. TVA proposes to construct and operate a 500,000-gallon tritiated water storage tank system to minimize the potential impacts of tritiated water releases (see Sections 2.4.1 and 2.4.2). The tank system at Sequoyah would be essentially the same as that for Watts Bar (Section 2.4.1). This could result in small changes in the use of welding gases such as acetylene and oxygen for construction of the storage tank and associated equipment. Operation of the tank system would not result in significant changes to infrastructure demands at the Sequoyah site, and there would be no special maintenance or monitoring requirements for the system.

4.2.8.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. Impacts to infrastructure at Sequoyah for the construction and operation of the tritiated water tank system would be the same as those under Alternative 2. Irradiation of 1,250 TPBARs would not have significant adverse impacts on infrastructure demands at the Sequoyah site.

4.2.8.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. Infrastructure demands would be largely unaffected whether or not TPBARs were irradiated in a reactor. The impacts at Sequoyah would be the same as discussed in Section 4.2.8.2.

4.2.8.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. The impacts would be the same as discussed in Section 4.2.8.3.

4.2.8.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.8.3.

4.2.9 SOCIOECONOMICS

4.2.9.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs at each of the two Sequoyah reactors (a total of 1,360 TPBARs). TVA estimated that operation of Sequoyah 1 and 2 for TPBAR irradiation would require fewer than 10 full-time equivalent workers per reactor in addition to normal plant operations staff (DOE 1999a). The addition of 20 full-time equivalent workers (10 per reactor) would increase the existing workforce (1,150 persons) by about 2 percent. Adding 20 full-time equivalent workers to the normal operations staff would increase local socioeconomic factors such as income, housing requirements, and indirect employment by about 2 percent in comparison with normal plant operations for power production.

4.2.9.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would not use the Sequoyah site to irradiate TPBARs. If the plant did not irradiate TPBARs, it would not require the additional 20 full-time equivalent workers (10 per reactor) discussed above. Instead, present staffing requirements and socioeconomic conditions would be maintained.

4.2.9.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. TVA proposes to construct and operate a 500,000-gallon tritiated water tank system to facilitate effluent water management (see Sections 2.4.1 and 2.4.2). TVA estimates the complete design and engineering process would require 30 weeks. In-house personnel would be responsible for the preparing the engineering change package. Therefore, additional personnel would not be necessary. Construction, including piling, foundation, and tank construction, would take an estimated 24 weeks (TVA 2011c) and require a workforce of about 100 persons. As noted in Section 3.2.9, employment in Hamilton County includes about 12,460 construction positions. The region of influence would be able to provide the workforce to prepare the site and build the tank. Worker inmigration would not be expected to occur, and there would therefore be no project-related change to the population. Capital expenses for the purchase and manufacture of the tank would occur outside the region and, therefore, would not affect local income. Because there would be no change in the population or meaningful spending in the region, there would be no socioeconomic impacts expected from the engineering and construction of the tank under this alternative. The alternative would not affect population, income, employment, housing, or community services. Operation of the tritiated water tank system would not require additional workers and would have no significant socioeconomic impacts.

Irradiation of 2,500 TPBARs would require no personnel in addition to the potential increase of 20 plant staff discussed above for the No-Action Alternative.

4.2.9.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analysis for this alternative assumed each site would irradiate 1,250 TPBARs every 18 months. Irradiation of 1,250 TPBARs at Sequoyah would require no additional personnel other than the plant staff discussed above for the No-Action Alternative. TVA proposes to construct and operate a tritiated water tank system at the Sequoyah site, as discussed for Alternative 2. The potential socioeconomic impacts would be the same as those for Alternative 2.

4.2.9.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. The impacts at Sequoyah would be the same as discussed in Section 4.2.9.2.

4.2.9.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Irradiation of 5,000 TPBARs could require approximately 10 additional full-time equivalent workers. Such an increase would not result in any meaningful project-related socioeconomic impacts in the Sequoyah region of influence.

4.2.9.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.9.3.

4.2.10 WASTE AND SPENT NUCLEAR FUEL MANAGEMENT

4.2.10.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs). Sequoyah would continue to generate wastes as described in Section 3.2.10. TPBAR irradiation would generate about 15 cubic feet per year of additional low-level radioactive waste, which is less than 0.1 percent of the total low-level waste Sequoyah operations currently generate (TVA 2012). TPBAR irradiation would have no impact on hazardous and nonhazardous waste generation.

As discussed in Section 3.2.10, the Sequoyah site currently discharges about 107 spent nuclear fuel assemblies each year. Under the No-Action Alternative, Sequoyah would generate about 113 spent nuclear fuel assemblies annually, which would include approximately 6 spent nuclear fuel assemblies associated with TPBAR irradiation at Sequoyah 1 and 2 (TVA 2012). As Section 3.2.10 discusses, TVA operates a dry cask storage facility (also called an independent spent fuel storage installation) at the Sequoyah site. No additional storage facilities would be necessary at the Sequoyah site for TPBAR irradiation.

4.2.10.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would not use the Sequoyah site to irradiate TPBARs. Sequoyah would generate less low-level radioactive waste in comparison with the No-Action Alternative. The reduction would be about 15 cubic feet per year, which is less than 0.1 percent of the total low-level waste Sequoyah operations currently generate (TVA 2012). Because Sequoyah would not irradiate TPBARs, about 107 spent nuclear fuel assemblies would be generated annually, which would represent a decrease of about 5 percent in comparison with to the No-Action Alternative.

4.2.10.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. Irradiation of 2,500 TPBARs would generate a maximum of about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the total low-level waste Sequoyah operations currently generate. TPBAR irradiation would have no impact on hazardous and nonhazardous waste generation. Construction and operation of a tritiated water tank system (see Sections 2.4.1 and 2.4.2) would have no impact on the quantity or management of wastes.

Irradiation of 2,500 TPBARs would generate a maximum of 41 additional spent nuclear fuel assemblies every 18 months, assuming irradiation of all 2,500 TPBARs in a single reactor (TVA 2012). On an annual basis, this would increase spent nuclear fuel generation at Sequoyah by about 24 percent in comparison with the No-Action Alternative. This increase in spent nuclear fuel generation would not require additional storage facilities beyond what TVA already has in place at the Sequoyah site.

Additional Low-Level Radioactive Waste

Any reactor that irradiated TPBARs would generate more low-level radioactive waste than one that did not. Much of the low-level waste would consist of TPBAR base plates and other irradiated hardware that would remain after the TPBARs were separated from their assemblies in preparation for shipping to the Savannah River Site. In the 1999 EIS, DOE and TVA estimated that low-level waste would increase by about 15 cubic feet per year for irradiation of 3,400 TPBARs (DOE 1999a), which would represent less than 0.1 percent of the low-level waste the Sequoyah site generates annually. Because this is such a small percentage, DOE and TVA do not think a more precise estimate is needed for irradiation of fewer TPBARs (a maximum of 2,500 under the proposed action in this SEIS). Therefore, this SEIS, like the 1999 EIS, estimates an additional 15 cubic feet of low-level waste annually for all reactors that irradiate TPBARs, regardless of the number of irradiated TPBARs, recognizing that this number is conservatively high for the alternatives discussed in this SEIS. For Alternatives 5 and 6, an additional 30 cubic feet of low-level waste would be generated annually at Sequoyah.

4.2.10.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. Irradiation of 1,250 TPBARs would generate about 15 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the total low-level waste

Sequoyah operations currently generate (TVA 2012). TPBAR irradiation would have no significant impact on hazardous and nonhazardous waste generation. Construction and operation of a tritiated water tank system (see Sections 2.4.1 and 2.4.2) would have no significant impact on the quantity or management of wastes.

Additional Spent Nuclear Fuel

The amount of additional spent nuclear fuel from TPBAR irradiation depends on the number of irradiated TPBARs. As TPBARs are irradiated, they absorb neutrons, which reduces the plant's power levels. In order to maintain design power levels during TPBAR irradiation, TVA needs to increase the number of fresh fuel assemblies. The increase in fresh fuel assemblies generates additional spent fuel. Irradiation of 680 TPBARs per cycle would generate about 4 additional spent fuel assemblies every 18 months (which would equate to about 3 additional spent fuel assemblies annually) in comparison with operations without TPBARs. As the number of TPBARs was increased, they would absorb an increasingly higher percentage of neutrons, which would reduce the plant's power levels. TVA would then need to increase the number of fresh fuel assemblies to maintain design power levels. The increase in fresh fuel assemblies would generate additional spent fuel.

The relationship between the number of irradiated TPBARs and the amount of additional spent fuel is not linear. For example, irradiation of 1,250 TPBARs in a reactor would generate 8 to 12 additional spent fuel assemblies every 18 months. At twice the number of TPBARs (2,500), the number of spent fuel assemblies would increase to 41 (about 3 to 5 times more than for 1,250).

Irradiation of 1,250 TPBARs in a single reactor would generate a maximum of 8 to 12 additional spent nuclear fuel assemblies every 18 months (TVA 2012). On an annual basis, this would increase spent nuclear fuel generation at Sequoyah by 5 to 7 percent in comparison with the No-Action Alternative. This increase in spent nuclear fuel generation would not require additional storage facilities beyond what TVA already has in place at the Sequoyah site.

4.2.10.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. The impacts at Sequoyah would be the same as discussed in Section 4.2.10.2.

4.2.10.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Irradiation of 5,000 TPBARs would generate a maximum of 30 cubic feet per year of low-level radioactive waste, which is less than 0.1 percent of the total low-level waste Sequoyah operations currently generate (TVA 2012). TPBAR irradiation would continue to have no impact on hazardous and nonhazardous waste generation.

Irradiation of 5,000 TPBARs would generate a maximum of 82 additional spent nuclear fuel assemblies every 18 months. On an annual basis, this would increase spent nuclear fuel generation at Sequoyah by about 48 percent in comparison with the No-Action Alternative. This increase in spent nuclear fuel generation would not require additional storage facilities beyond what TVA already has in place at the Sequoyah site.

4.2.10.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate

2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.10.3.

4.2.10.8 Differences from 1999 EIS

The 1999 EIS estimated TPBAR irradiation could generate a maximum of 30 cubic feet per year of low-level radioactive waste and a maximum of 60 additional spent nuclear fuel assemblies every 18 months for irradiation of 3,400 TPBARs. For this SEIS, TVA estimated a maximum of 30 cubic feet per year of low-level waste and a maximum of 82 additional spent nuclear fuel assemblies for irradiation of 5,000 TPBARs. TVA has an infrastructure in place at Sequoyah that is capable of managing the increase in spent nuclear fuel over operations without TPBAR irradiation.

4.2.11 HUMAN HEALTH AND SAFETY

This section describes the health and safety impacts of radiological releases from normal operations with and without tritium production at the Sequoyah site. Because tritium production would introduce no operations at Sequoyah that would require the use of hazardous chemicals, there would be no hazardous chemical releases expected from irradiation of TPBARs under any alternative.

During normal operations, there would be incremental changes in radiological releases of tritium to the environment and exposures to workers on the site. The following paragraphs describe the resultant dose and potential health effects on the public and workers. Appendix C discusses the annual increase in gaseous radioactive emissions and liquid radioactive effluents from the production of tritium at Watts Bar and/or Sequoyah.

Latent Cancer Fatality

A latent cancer fatality is a death from a cancer that results from, and occurs an appreciable time after, exposure to ionizing radiation. Death from radiation-induced cancers can occur any time after the exposure. However, latent cancers generally occur from 1 year to many years after exposure.

Using a conversion factor of 0.0006 latent cancer fatality per rem of radiation exposure (ISCORS 2002), the result is the increased lifetime probability of developing a latent fatal cancer. For example, if a person received a dose of 0.033 rem, that person's risk of latent cancer fatality from that dose over a lifetime would be 0.00002. This risk corresponds to a 1 chance in 50,000 of a latent cancer fatality during that person's lifetime. To place the significance of the additional risk into context, the average person has about 1 chance in 4 of dying from cancer (a risk of 0.25) (ACS 2011).

Because estimates of latent cancer fatalities are statistical, the results often indicate less than 1 latent cancer fatality for cases that involve low doses or small populations. For instance, if a population collectively received a dose of 500 person-rem, the number of potential latent cancer fatalities would be 0.3. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table 4-22 lists radiological impacts to the maximally exposed individual (a hypothetical individual at the site boundary) and public living within 50 miles of the Sequoyah site projected for 2025[16] for each of the alternatives (see Appendix C for a map of Sequoyah with a 50-mile radius). Table 4-23 lists radiological impacts to the facility worker. For this analysis, a facility worker is a monitored reactor plant employee. TVA would keep doses to these workers to minimal levels through programs to ensure worker doses are

16. NNSA used the site population in 2025 in the impact assessments because DOE used a similar estimate in the 1999 EIS; it is assumed to be representative of the population at the approximate midpoint between now and the end of the interagency agreement.

Table 4-22. Annual radiological impacts to the public including incident-free tritium production at Sequoyah.

Tritium production	Release media	Maximally exposed offsite individual		Population within 50 miles projected for 2025	
		Dose (millirem)	**Latent cancer fatality risk**	**Annual dose (person-rem)**	**Latent cancer fatalities[a]**
No-Action Alternative (1,360 TPBARs)	Air[b]	0.21	1×10^{-7}	4.4	0 (0.003)
	Liquid[c]	0.033	2×10^{-8}	6.4	0 (0.004)
	Totals	**0.24**	$\mathbf{1 \times 10^{-7}}$	**10.8**	**0 (0.006)**
Alternative 1 (0 TPBARs)	Air[b]	0.12	7×10^{-8}	2.7	0 (0.002)
	Liquid[c]	0.009	5×10^{-9}	1.7	0 (0.001)
	Totals	**0.13**	$\mathbf{8 \times 10^{-8}}$	**4.4**	**0 (0.003)**
Alternative 2 (2,500 TPBARs)	Air[b]	0.28	2×10^{-7}	5.9	0 (0.004)
	Liquid[c]	0.053	3×10^{-8}	10.3	0 (0.006)
	Totals	**0.33**	$\mathbf{2 \times 10^{-7}}$	**16.2**	**0 (0.01)**
Alternative 3 (1,250 TPBARs)	Air[b]	0.20	1×10^{-7}	4.3	0 (0.003)
	Liquid[c]	0.031	2×10^{-8}	6.00	0 (0.004)
	Totals	**0.23**	$\mathbf{1 \times 10^{-7}}$	**10.3**	**0 (0.006)**
Alternative 4 (0 TPBARs)	Air[b]	0.12	7×10^{-8}	2.7	0 (0.002)
	Liquid[c]	0.009	5×10^{-9}	1.7	0 (0.001)
	Totals	**0.13**	$\mathbf{8 \times 10^{-8}}$	**4.4**	**0 (0.003)**
Alternative 5 (5,000 TPBARs)	Air[b]	0.450	3×10^{-7}	9.1	0 (0.005)
	Liquid[c]	0.096	6×10^{-8}	19.0	0 (0.01)
	Totals	**0.55**	$\mathbf{3 \times 10^{-7}}$	**28.1**	**0 (0.02)**
Alternative 6 (2,500 TPBARs)	Air[b]	0.28	2×10^{-7}	5.9	0 (0.004)
	Liquid[c]	0.053	3×10^{-8}	10.3	0 (0.006)
	Totals	**0.33**	$\mathbf{2 \times 10^{-7}}$	**16.2**	**0 (0.01)**

a. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

b. NNSA based the population data for airborne releases on the projected 2025 population within 50 miles of the site, which is 1,294,030 people. The 2025 population was projected from 2010 Census (USCB 2012) data based on a growth rate consistent with that over the past ten years.

c. NNSA based the population data for liquid releases on the projected 2025 population of persons who would use public water supplies downstream of the site within 50 miles, projected to 2025, which is 407,699 people.

Note: All doses are much less than 1 percent of the average annual dose from natural and manmade radiation in the United States (620 millirem, see Table 3-20).

as low as is reasonably achievable. The doses in Tables 4-22 and 4-23 reflect the total doses from operations at Sequoyah, not just the doses from tritium production. Appendix C contains background information on the effects of radiation on human health and safety. It also contains the methods and assumptions used to calculate impacts on public health and safety at Watts Bar and Sequoyah.

4.2.11.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs). The following estimates include the radiological impacts of normal operation of both reactors at the Sequoyah site with irradiation of 1,360 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.24 millirem per year, with an associated 1×10^{-7} risk of a latent cancer fatality per year of operation.

Table 4-23. Annual radiological impacts to workers including incident-free tritium production at Sequoyah.

Impact	No-Action Alternative (1,360 TPBARs)	Alternative 1 (0 TPBARs)	Alternative 2 (2,500 TPBARs)	Alternative 3 (1,250 TPBARs)	Alternative 4 (0 TPBARs)	Alternative 5 (5,000 TPBARs)	Alternative 6 (2,500 TPBARS)
Average worker dose (millirem)	108.7	105.4	111.4	108.4	105.4	117.4	111.4
Latent cancer fatality risk	7×10^{-5}	6×10^{-5}	7×10^{-5}	7×10^{-5}	6×10^{-5}	7×10^{-5}	7×10^{-5}
Total workforce dose (person-rem)[a]	131.9	127.9	135.2	131.6	127.9	142.4	135.2
Latent cancer fatalities[b]	0 (0.08)	0 (0.08)	0 (0.08)	0 (0.08)	0 (0.08)	0 (0.09)	0 (0.06)

a. Based on 1,214 workers, which includes additional workers used during refueling operations and outages.
b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

- The collective dose to the population within 50 miles of Sequoyah would be 10.8 person-rem per year, with an associated 0 (0.006) latent cancer fatality per year of operation.

- The collective dose to facility workers would be 131.9 person-rem per year, with an associated 0 (0.08) latent cancer fatality per year of operation.

4.2.11.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would not use the Sequoyah site to irradiate TPBARs. The following estimates indicate the radiological impacts of normal operation of both reactors at Sequoyah without TPBAR irradiation:

- The annual dose to the maximally exposed offsite individual would be 0.13 millirem per year, with an associated 8×10^{-8} risk of a latent cancer fatality per year of operation.

- The collective dose to the population within 50 miles of Sequoyah would be 4.4 person-rem per year, with an associated 0 (0.003) latent cancer fatality per year of operation.

- The collective dose to facility workers would be 127.9 person-rem per year, with an associated 0 (0.08) latent cancer fatality per year of operation.

4.2.11.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. The following estimates include the radiological impacts of normal operation of both reactors at Sequoyah with irradiation of a total of 2,500 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.33 millirem per year, with an associated 2×10^{-7} risk of a latent cancer fatality per year of operation.

- The collective dose to the population within 50 miles of Sequoyah would be 16.2 person-rem per year, with an associated 0 (0.01) latent cancer fatality per year of operation.

- The collective dose to facility workers would be 135.2 person-rem per year, with an associated 0 (0.08) latent cancer fatality per year of operation.

4.2.11.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed each site would irradiate 1,250 TPBARs every 18 months. The following estimates include the radiological impacts of normal operation of both reactors at the Sequoyah site with irradiation of a total of 1,250 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.23 millirem per year, with an associated 1×10^{-7} risk of a latent cancer fatality per year of operation.

- The collective dose to the population within 50 miles of Sequoyah would be 10.3 person-rem per year, with an associated 0 (0.006) latent cancer fatality per year of operation.

- The collective dose to facility workers would be 131.6 person-rem per year, with an associated 0 (0.08) latent cancer fatality per year of operation.

4.2.11.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. The following estimates indicate the radiological impacts of normal operation of both reactors at Sequoyah without TPBAR irradiation:

- The annual dose to the maximally exposed offsite individual would be 0.13 millirem per year, with an associated 8×10^{-8} risk of a latent cancer fatality per year of operation.

- The collective dose to the population within 50 miles of Sequoyah would be 4.4 person-rem per year, with an associated 0 (0.003) latent cancer fatality per year of operation.

- The collective dose to facility workers would be 128.0 person-rem per year, with an associated 0 (0.08) latent cancer fatality per year of operation.

4.2.11.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. The following estimates include the radiological impacts of normal operation of both reactors at Sequoyah with irradiation of a total of 5,000 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.55 millirem per year, with an associated 3×10^{-7} risk of a latent cancer fatality per year of operation.

- The collective dose to the population within 50 miles of Sequoyah would be 28.1 person-rem per year, with an associated 0 (0.02) latent cancer fatality per year of operation.

- The collective dose to facility workers would be 142.4 person-rem per year, with an associated 0 (0.09) latent cancer fatality per year of operation.

4.2.11.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The following estimates include the radiological impacts of normal operation of both reactors at Sequoyah with irradiation of a total of 2,500 TPBARs:

- The annual dose to the maximally exposed offsite individual would be 0.33 millirem per year, with an associated 2×10^{-7} risk of a latent cancer fatality per year of operation.

- The collective dose to the population within 50 miles of Sequoyah would be 16.2 person-rem per year, with an associated 0 (0.01) latent cancer fatality per year of operation.

- The collective dose to facility workers would be 135.2 person-rem per year, with an associated 0 (0.08) latent cancer fatality per year of operation.

4.2.11.8 TPBAR Failure Scenario

In addition to the assumed normal operational release of tritium through permeation, this SEIS considers the failure of two TPBARs, such that the inventory of the TPBARs is released to the primary coolant. The occurrence of TPBAR failure is beyond that associated with normal operating conditions and extremely conservative. Tables 4-24 and 4-25 list the radiological consequences to the public and workers from the assumption of two TPBAR failures from a load of 2,500 TPBARs at Sequoyah 1 or 2. Releases, doses, and cancer risks associated with one TPBAR failure can be determined by dividing the values in the tables by 2.

Table 4-24. Radiological impacts to the public from failure of two TPBARs at Sequoyah.

Release pathway	Release quantity (curies)	Dose to maximally exposed individual (millirem)	Latent cancer fatality risk	Dose to population within 50 miles (person-rem)	Latent cancer fatalities[a]
Air	2,315	0.21	1×10^{-7}	2.7	0 (0.002)
Liquid	20,835	0.040	2×10^{-8}	7.2	0 (0.004)
Totals	**23,150**	**0.25**	$\mathbf{2 \times 10^{-7}}$	**9.9**	**0 (0.006)**

a. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table 4-25. Radiological impacts to workers from failure of two TPBARs at Sequoyah.

Impact type	Value
Average worker dose (millirem)	5.6
Latent cancer fatality risk	3×10^{-6}
Total workforce dose (person-rem)[a]	6.8
Latent cancer fatalities[b]	0 (0.004)

a. Based on 1,214 workers, which includes additional workers used during refueling operations and outages.

b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

4.2.11.6 Differences from 1999 EIS

The 1999 EIS estimated the dose to the maximally exposed individual would be 0.11 millirem per year at the Sequoyah site (DOE 1999a, Table 5-14). For this SEIS, NNSA estimated the highest dose to the maximally exposed individual would be 0.55 millirem per year (see Table 4-22 above). In either case, the results indicate that radiation exposure of the public from normal operations would remain well below the NRC regulatory limit (25 millirem per year). The 1999 EIS estimated the average annual dose to workers would increase by a maximum of about 0.82 millirem per year as a result of TPBAR irradiation (DOE 1999a, Table 5-15). The analysis for the SEIS estimated this increase would be about 12.0 millirem per year (see Table 4-23 above, which shows that the difference in the average annual worker dose between Alternatives 1 and 5 is 12.0 millirem). In either case, worker exposure to radiation under normal operating conditions, with or without TPBAR irradiation, would remain well below the NRC regulatory limit of 5,000 millirem per year.

4.2.12 ACCIDENTS AND INTENTIONAL DESTRUCTIVE ACTS

This section discusses the analysis of potential accidents and potential impacts to workers and the public during TPBAR irradiation in the Sequoyah reactors. Appendix D contains additional information. Section 4.1.12 discusses the analytical method NNSA used for the accident analysis. Irradiation of TPBARs is not expected to change the requirements for physical protection at nuclear power plants.

4.2.12.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs). Table 4-26 lists the potential environmental consequences for design-basis accidents at Sequoyah for the No-Action Alternative. NNSA took the accident scenarios from Table 5-10 of the 1999 EIS (DOE 1999a) and scaled the calculated risks (see Section 4.1.12).

The accident with the highest risk of the design-basis and handling accidents NNSA considered for this SEIS would be the nonreactor design-basis accident. This scenario would entail an acute release of tritium in oxide form directly to the environment without mitigation. Table 4-26 indicates there would be insignificant impacts from design-basis reactor accidents due to the irradiation of TPBARs at the Sequoyah site. As also shown in Table 4-26, the dose to a person at the exclusion area boundary for these accidents would be well below the NRC regulatory limit (25 rem).

Table 4-27 lists the potential environmental impacts for beyond-design-basis accidents at Sequoyah for Alternative 2. Table 4-26 also lists the calculation of accident risks for reactor operations with and without TPBARs. As shown in Table 4-27, of the analyzed beyond-design-basis accidents for Sequoyah, the early containment failure accident would represent the highest dose to the maximally exposed offsite individual, with an estimated frequency of about 1 chance in 1.5 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident.

4.2.12.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would not use the Sequoyah site to irradiate TPBARs. Therefore, for severe reactor accidents, Table 4-26 shows the accident risks for reactor operations without TPBARs. For design-basis accidents, there would be no impacts, because reactor mitigation features would prevent release of non-tritium radionuclides.

Table 4-26. Summary of environmental consequences for design-basis accidents at Sequoyah for the No-Action Alternative.

Accident	Number of TPBARs	Impacts on the maximally exposed individual at the exclusionary boundary		Impacts on the population within 50 miles	
		Dose (rem)	NRC regulatory limit (rem) [a]	Dose (person-rem)	Average individual dose (rem) [b]
Design-basis accidents					
Reactor design-basis accident (large break loss-of-coolant accident)[c]	680	1.3×10^{-3}	25	20	1.5×10^{-5}
Nonreactor design-basis accident (waste gas decay tank rupture)[c]	680	1.1×10^{-2}	25	1,100	8.5×10^{-4}
Handling accidents					
TPBAR handling accident	All configurations	3.7×10^{-2}	25	368	2.8×10^{-4}
Truck cask handling accident	All configurations	9.0×10^{-4}	25	9.1	7.0×10^{-6}

a. From 10 CFR 50.34 for design-basis accidents.
b. Average individual dose to the entire offsite projected population in 2025 (1,294,030 people) within 50 miles for the indicated accident.
c. The analysis of design-basis accidents assumed mitigation would prevent release of nontritium radionuclides. Therefore, the accident risks are based on the release of tritium only from TPBAR irradiation. The analysis conservatively assumed the entire tritium content in the TPBARs would release to the containment and ultimately to the environment. The analysis of the nonreactor design-basis accident conservatively assumed a higher than normal amount of tritium in the waste decay tank that would release directly to the environment.

4.2.12.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. Table 4-28 lists the potential environmental consequences for design-basis accidents at Sequoyah for Alternative 2. It lists the impacts of irradiating 1,250 TPBARs every 18 months (which is applicable to Alternative 3) and 2,500 TPBARs every 18 months at Sequoyah. The accident with the highest risk of the design-basis and handling accidents NNSA considered for this SEIS would be the nonreactor design-basis accident. This scenario would entail an acute release of tritium in oxide form directly to the environment without mitigation. Table 4-28 indicates there would be insignificant impacts from design-basis reactor accidents due to the irradiation of TPBARs at the Sequoyah site. As also shown in Table 4-28, the dose to a person at the exclusion area boundary for these accidents would be well below the NRC regulatory limit (25 rem).

Table 4-29 lists the potential environmental impacts for beyond-design-basis accidents at Sequoyah for Alternative 2. Table 4-29 also lists the calculation of accident risks for reactor operations with and without TPBARs. As shown in Table 4-29, of the analyzed beyond-design-basis accidents for Sequoyah, the early containment failure accident would represent the highest dose to the maximally exposed offsite individual, with an estimated frequency of about 1 chance in 1.5 million of the accident occurring per year of operation. The effects of radionuclide releases inherent to reactor operations without TPBARs would dominate the risk of a reactor accident.

Table 4-27. Summary of environmental consequences for beyond-design-basis accidents at Sequoyah for the No-Action Alternative.

Accident	Frequency	Number of TPBARs	Impacts on the maximally exposed individual at the exclusionary boundary			Impacts on the population within 50 miles		
			Dose (rem)	Dose risk (rem/yr) [a]	Annual risk of fatal cancer[b]	Dose (person-rem)	Average individual dose risk (rem/yr)[c]	Risk of fatal cancer to average individual[d]
Beyond-design-basis accidents (severe reactor accidents)								
Reactor core damage with early containment failure	6.8×10^{-7}	0	25[e]	8×10^{-6}	1×10^{-8}	6.2×10^{5}	2×10^{-7}	1×10^{-10}
		680	25[e]	8×10^{-6}	5×10^{-8}	6.2×10^{5}	2×10^{-7}	1×10^{-10}
Reactor core damage with containment bypass	4.0×10^{-6}	0	10.5	2×10^{-5}	8×10^{-9}	9.2×10^{5}	1×10^{-6}	6×10^{-10}
		680	10.5	2×10^{-5}	8×10^{-9}	9.2×10^{5}	1×10^{-6}	6×10^{-10}
Reactor core damage with late containment failure	9.2×10^{-6}	0	0.8	2×10^{-6}	1×10^{-9}	6.6×10^{4}	2×10^{-7}	9×10^{-11}
		680	0.8	2×10^{-6}	1×10^{-9}	6.6×10^{4}	2×10^{-7}	9×10^{-11}

a. Dose risk to a hypothetical maximally exposed individual at the exclusion area boundary accounting for the probability of the accident occurring.
b. Annual risk of a fatality or fatal latent cancer to a hypothetical maximally exposed individual at the exclusion area boundary accounting for the probability of the accident occurring.
c. Average individual dose for the entire offsite projected population in 2025 (1,294,030 people) within 50 miles from exposure to the indicated dose and accounting for the probability of the accident occurring.
d. Annual risk of a cancer fatality to the average individual in the entire offsite projected population in 2025 within 50 miles accounting for the probability of the accident occurring.
e. A risk factor of 0.0012 was used for individual doses of 20 rem or greater.

For the potential tritiated water tank system, NNSA anticipates that the maximum tritium nuclide concentration in the 500,000-gallon tank would be 88 microcuries per milliliter. The average tritium concentration in the tank would be about 20 microcuries per milliliter (TVA 2011e). The worst-case accident scenario would occur if the entire contents of the tank accidently discharged all at once to the river. This highly conservative postulated event would not result in tritium concentrations above the EPA limit of 20,000 picocuries per liter at the closest downstream drinking water intake (TVA 2011e).

4.2.12.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. The analysis for this alternative assumed that each site would irradiate 1,250 TPBARs every 18 months. Table 4-29 shows the accident frequencies and risks for Alternative 3 for the Sequoyah site for the 1,250-TPBAR case.

4.2.12.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. The impacts would be the same as discussed in Section 4.2.12.2.

Table 4-28. Summary of environmental consequences for design-basis accidents at Sequoyah for Alternatives 2, 3, 5, and 6.

Accident	Number of TPBARs	Impacts on the maximally exposed individual at the exclusionary boundary: Dose (rem)	Impacts on the maximally exposed individual at the exclusionary boundary: NRC regulatory limit (rem)[a]	Impacts on the population within 50 miles: Dose (person-rem)	Impacts on the population within 50 miles: Average individual dose (rem)[b]
Design-basis accidents					
Reactor design-basis accident (large break loss-of-coolant accident)[c]	1,250	2.4×10^{-3}	25	36	2.7×10^{-5}
	2,500	4.8×10^{-3}	25	70	5.4×10^{-5}
Nonreactor design-basis accident (waste gas decay tank rupture)[c]	1,250	2.0×10^{-2}	25	1,900	1.5×10^{-3}
	2,500	4.0×10^{-2}	25	4,000	3.1×10^{-3}
Handling accidents					
TPBAR handling accident	All configurations	3.7×10^{-2}	25	368	2.8×10^{-4}
Truck cask handling accident	All configurations	9.0×10^{-3}	25	9.1	7.0×10^{-6}

a. From 10 CFR 50.34 for design-basis accidents.

b. Average individual dose to the entire offsite projected population in 2025 (1,294,030 people) within 50 miles for the indicated accident.

c. The analysis of design-basis accidents assumed mitigation would prevent release of nontritium radionuclides. Therefore, the accident risks are based on the release of tritium only from TPBAR irradiation. The analysis conservatively assumed the entire tritium content in the TPBARs would release to the containment and ultimately to the environment. The analysis of the nonreactor design-basis accident conservatively assumed a higher than normal amount of tritium in the waste decay tank that would release directly to the environment.

4.2.12.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. Because no more than 2,500 TPBARs would be irradiated in a reactor, the potential impacts associated with accidents would be the same as presented in Section 4.2.12.3.

4.2.12.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.12.3.

4.2.12.8 Intentional Destructive Acts

This section provides an analysis of potential public health consequences of scenarios that involve intentional destructive acts, such as terrorism events. Unlike accident analysis, the analysis of intentional destructive acts provides an estimate of potential consequences without attempting to estimate the frequency or probability of a successful act. This is because there is no standard, widely accepted basis for estimating the frequency of intentional destructive acts. Professional guard forces and other security measures would protect all facilities and activities associated with the alternatives in this SEIS to help prevent such attacks.

Table 4-29. Summary of environmental consequences for beyond-design-basis accidents at Sequoyah for Alternatives 2, 3, 5, and 6.

Accident	Frequency	Number of TPBARs	Impacts on the maximally exposed individual at the exclusionary boundary: Dose (rem)	Dose risk (rem/year)[a]	Annual risk of fatal cancer[b]	Impacts on the population within 50 miles: Dose (person-rem)	Average individual dose risk (rem/year)[c]	Risk of fatal cancer to average individual[d]
Beyond-design-basis accidents (severe reactor accidents)								
Reactor core damage with early containment failure	6.8×10^{-7}	0	25[e]	1.7×10^{-5}	2×10^{-8}	6.2×10^{5}	3×10^{-7}	2×10^{-10}
		2,500	25[e]	1.7×10^{-5}	2×10^{-8}	6.2×10^{5}	3×10^{-7}	2×10^{-10}
Reactor core damage with containment bypass	4.0×10^{-6}	0	10.5	4.2×10^{-5}	2×10^{-8}	9.2×10^{4}	3×10^{-6}	1×10^{-9}
		2,500	10.5	4.2×10^{-5}	2×10^{-8}	9.2×10^{4}	3×10^{-6}	1×10^{-9}
Reactor core damage with late containment failure	9.2×10^{-6}	0	0.8	7.7×10^{-6}	4×10^{-9}	6.6×10^{4}	5×10^{-7}	3×10^{-10}
		2,500	0.8	7.9×10^{-6}	4×10^{-9}	6.7×10^{4}	5×10^{-8}	3×10^{-10}

a. Dose risk to a hypothetical maximally exposed individual at the exclusion area boundary accounting for the probability of the accident occurring.
b. Annual risk of a fatality or fatal latent cancer to a hypothetical maximally exposed individual at the exclusion area boundary accounting for the probability of the accident occurring.
c. Average individual dose for the entire offsite projected population in 2025 (1,294,030 people) within 50 miles from exposure to the indicated dose and accounting for the probability of the accident occurring.
d. Annual risk of a cancer fatality to the average individual in the entire offsite projected population in 2025 within 50 miles accounting for the probability of the accident occurring.
e. A risk factor of 0.0012 was used for individual doses of 20 rem or greater.

Similar to the use of duplicate backup systems to ensure safety, TVA implements a layered approach to physical security at the reactor sites in accordance with NRC regulations and guidance. Nuclear power plants are inherently secure, robust structures built to withstand extreme natural phenomena such as hurricanes, tornadoes, and earthquakes. Additional security measures are in place including physical barriers, intrusion detection and surveillance systems, access controls, and coordination of threat information and response with Federal, state, and local agencies (NRC 2008b).

Since September 11, 2001, NRC has strengthened requirements at nuclear power plants and enhanced coordination with Federal, state, and local organizations. Additional requirements (NRC 2005b) address:

- Increased physical security programs to defend against a more challenging adversarial threat,
- More restrictive site access controls for all personnel,
- Enhanced communication and liaison with the intelligence community,
- Improved response capability for events involving explosions or fires,
- Enhanced readiness of security organizations by strengthening training and qualifications programs for plant security forces,
- Required vehicle checks at greater stand-off distances,

- Enhanced force-on-force exercises to provide a more realistic test of plant capabilities to defend against an adversarial force, and
- Improved liaison with Federal, state, and local agencies responsible for protection of the national critical infrastructure through integrated response training.

NRC has also performed comprehensive safety and security studies showing that a radiological release affecting public health and safety is unlikely from a terrorist attack at a reactor facility, including one involving a large commercial aircraft. Factors supporting this conclusion included the hardened condition of power plants (for example, thick concrete walls with heavy reinforcing steel), which are designed to withstand extreme events such as hurricanes, tornadoes, and earthquakes; redundant safety systems operated by trained staff; multiple barriers protecting the reactor or serving to prevent or minimize offsite releases; and in-place mitigation strategies and measures. In addition, security measures at nuclear plants have been complemented by measures taken throughout the United States to improve security and reduce the risk of successful terrorist attacks, including measures designed to respond to and reduce the threats posed by hijacking large jet airplanes (for example, reinforced cockpit doors and Federal Air Marshals) (NRC 2005b, 20011f).

An analysis of the consequences of the crash of a large aircraft at a nuclear power reactor site has been performed by the Electric Power Research Institute for the Nuclear Energy Institute. The analysis addressed the consequences of a large jet airline being purposefully crashed into sensitive nuclear facilities or containers including nuclear reactor containment buildings, used fuel storage pools, used fuel dry storage facilities, and used fuel transportation containers. Using conservative analyses, the Electric Power Research Institute concluded that there would be no release of radionuclides from any of these facilities or containers because they are already designed to withstand comparable impacts from potentially destructive events. The analysis used computer models in which a Boeing 767-400 was crashed into containment structures that were representative of reactor containment designs for U.S. nuclear power plants. The containment structures suffered some crushing and chipping at the maximum impact point but were not breached (EPRI 2002b).

Notwithstanding the remote risk of a terrorist attack that affected operations at a nuclear power plant, in the very remote likelihood that a terrorist attack would successfully breach the physical and other safeguards at Sequoyah resulting in the release of radionuclides, the potential consequences would be no worse than those of the most severe beyond-design-basis accident NNSA analyzed.

Section 4.2.12 discusses the potential rupture of the tritiated water tank at Sequoyah and the potential impacts from such a rupture. Those impacts would be the same whether the tank ruptured accidentally or through an intentional destructive act.

4.2.12.9 Differences from 1999 EIS

In terms of normal operations, the 1999 EIS analyzed the potential environmental impacts from irradiation of a maximum of 3,400 TPBARs in any of the TVA reactors and assumed a tritium permeation rate of 1 curie per TPBAR per year. The analysis for this SEIS used a maximum of 2,500 TPBARs in any one reactor and assumed a high and thus conservative tritium permeation rate of 10 curies per TPBAR per year. Comparing the results of the 1999 EIS and this SEIS demonstrates that the potential environmental impacts from irradiation of TPBARs would be small regardless of the difference in the number of TPBARs in a reactor (3,400 or 2,500) or the tritium permeation rate (1 or 10 curies of tritium per TPBAR per year).

While the potential impacts of accidents would be small in either case, both the 1999 EIS and this SEIS confirm that TPBAR irradiation would not substantially increase the types of facility accidents that could occur or the potential risks from those accidents. With the exception of the nonreactor design-basis accident, the permeation rate would not affect the accident consequences or risk because the scenarios assume the loss of the total inventory of the TPBARs into the reactor containment.

The 1999 EIS did not analyze intentional destructive acts, but this SEIS indicates that the potential consequences would be no worse than those of the worst beyond-design-basis accident NNSA analyzed.

4.2.13 TRANSPORTATION

Section 4.1.13 broadly describes the transportation analysis; Appendix F contains details. In addition, Section 4.1.13.5 discusses the analysis of intentional destructive acts.

The sections below describe the radiological and accident impacts for transportation of unirradiated and irradiated TPBARs to and from the Sequoyah site, of low-level radioactive waste to the Nevada National Security Site, and of empty containers returning from Nevada.

In terms of local transportation infrastructure and traffic as described in Section 3.2.12, NNSA expects no significant adverse impacts because there would be very few shipments of all materials in relation to tritium production (a maximum of about 48 every 18 months or 36 per year, a very small fraction of the current traffic volumes on local roads). In addition, TVA would not hire new workers for tritium production, so there would be no increase in the number of commuting vehicles.

4.2.13.1 No-Action Alternative

Under the No-Action Alternative, NNSA would ship 1,360 TPBARs and associated low-level radioactive waste from the Sequoyah site. The numbers of estimated latent cancer fatalities over 22 years (until 2035) would be 0 (0.005)[17] for crew, 0 (6×10^{-4}) for members of the public, 0 (1×10^{-5}) for radiological accidents, and 0 (0.005) traffic fatality.

In combination with Watts Bar results (Section 4.1.13.1), the total estimated latent cancer fatalities under the No-Action Alternative over 22 years would be 0 (0.008) for crew, 0 (9×10^{-4}) for members of the public, 0 (2×10^{-5}) for radiological accidents, and 0 (0.009) traffic fatality.

4.2.13.2 Alternative 1: Watts Bar Only

TVA would not irradiate TPBARs at the Sequoyah site under Alternative 1, and NNSA would not ship TPBARs or low-level radioactive waste from Sequoyah, so there would be no transportation impacts related to the irradiation of TPBARs at Sequoyah under this alternative.

4.2.13.3 Alternative 2: Sequoyah Only

Under Alternative 2, NNSA would ship 2,500 TPBARs and associated low-level radioactive waste from the Sequoyah site. The estimated numbers of latent cancer fatalities over 22 years (until 2035) would be 0 (0.01) for crew, 0 (0.002) for members of the public, 0 (2×10^{-5}) for radiological accidents, and 0 (0.005) traffic fatality.

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17. Because the numbers of latent cancer fatalities and traffic fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

4.2.13.4 Alternative 3: Watts Bar and Sequoyah

Under Alternative 3, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months; the results for Alternative 2 in Section 4.2.13.3 address the maximum. For comparison, the analysis for Alternative 3 assumed NNSA would ship 1,250 TPBARs and the associated low-level radioactive waste from both Watts Bar and Sequoyah. The Sequoyah shipments would result in estimated numbers of latent cancer fatalities over 22 years of 0 (0.005) for crew, 0 (5×10^{-4}) for members of the public, 0 (1×10^{-5}) for radiological accidents, and 0 (0.005) traffic fatality.

In combination with the results for the Watts Bar site (Section 4.1.13.4), the total estimated latent cancer fatalities for Alternative 3 over 22 years would be 0 (0.01) for crew, 0 (0.001) for members of the public, 0 (2×10^{-5}) for radiological accidents, and 0 (0.009) traffic fatality.

4.2.13.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

TVA would not irradiate TPBARs at Sequoyah under Alternative 4, and NNSA would not ship TPBARs or low-level radioactive waste from Sequoyah, so there would be no transportation impacts in relation to irradiation of TPBARs at Sequoyah under this alternative.

4.2.13.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under Alternative 5, NNSA would ship 5,000 TPBARs and associated low-level radioactive waste from the Sequoyah site. The estimated numbers of latent cancer fatalities over 22 years (until 2035) would be 0 (0.02) for crew, 0 (0.004) for members of the public, 0 (4×10^{-5}) for radiological accidents, and 0 (0.01) traffic fatality.

4.2.13.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.13.3.

4.2.13.8 Intentional Destructive Acts During Transportation from Sequoyah to the Savannah River Site

Applying the assumptions from Section 4.1.13.5 for the Watts Bar analysis, but using the populations along the route from Sequoyah to the Savannah River Site, the dose to the maximally exposed individual would be about 34 rem. The dose to the affected population would be about 10,120 person-rem.

Using the dose-to-risk conversion factors of 0.0012 latent cancer fatality per rem[18] for the maximally exposed individual and 6×10^{-4} latent cancer fatality per person-rem for members of the general population, the estimated risk of a latent cancer fatality to the maximally exposed individual would increase by about 4 percent (1 chance in 25). Among the exposed population of almost 3 million people, there would be about 6 additional latent cancer fatalities.

18. The dose-to-risk conversion factor is doubled when a dose is greater than 20 rem.

4.2.14 ENVIRONMENTAL JUSTICE

As discussed in Section 3.2.13, racial and ethnic characteristics of Hamilton County reflect racial and ethnic characteristics similar to those of the residents of the State of Tennessee as a whole. In 2009, residents of Hamilton County experienced a slightly higher rate of poverty than those in the State. The following sections discuss potential socioeconomic impacts to minority and low-income populations for each alternative.

4.2.14.1 No-Action Alternative

Under this alternative, TVA would irradiate 680 TPBARs every 18 months at each of the two Sequoyah reactors (a total of 1,360 TPBARs). As discussed in Section 4.2.11, there would be no meaningful health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR Part 190 (the maximally exposed individual dose would be 0.24 millirem per year, which is less than 1 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected as a result of TPBAR irradiation at Sequoyah under this alternative.

4.2.14.2 Alternative 1: Watts Bar Only

Under this alternative, TVA would not use the Sequoyah site to irradiate TPBARs. As discussed in Section 4.2.11, if TVA did not irradiate TPBARs at the Sequoyah site, there would not be significant health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR Part 190 (the maximally exposed individual dose would be 0.13 millirem per year, which is less than 1 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected as a result of TPBAR irradiation at Sequoyah under this alternative.

4.2.14.3 Alternative 2: Sequoyah Only

Under this alternative, TVA would use one or both of the Sequoyah reactors to irradiate a maximum of 2,500 TPBARs every 18 months. As discussed in Section 4.2.11, there would not be meaningful health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR 190 (the maximally exposed individual dose would be 0.33 millirem per year, which is less than 2 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected as a result of TPBAR irradiation at Sequoyah under this alternative.

4.2.14.4 Alternative 3: Watts Bar and Sequoyah

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 2,500 TPBARs every 18 months. For the analysis of this alternative, NNSA assumed that each site would irradiate 1,250 TPBARs every 18 months. As discussed in Section 4.2.11, irradiation of 1,250 TPBARs at Sequoyah would not cause meaningful health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR 190 (the maximally exposed individual dose would be 0.23 millirem per year, which is less than 1 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected as a result of TPBAR irradiation at Sequoyah under this alternative.

4.2.14.5 Alternative 4: Watts Bar Only (5,000 TPBARs)

Under this alternative, TVA would not use Sequoyah to irradiate TPBARs. The impacts at Sequoyah would be the same as discussed in Section 4.2.14.2.

4.2.14.6 Alternative 5: Sequoyah Only (5,000 TPBARs)

Under this alternative, TVA would use both Sequoyah reactors to irradiate a maximum of 5,000 TPBARs every 18 months. As discussed in Section 4.2.11, irradiation of 5,000 TPBARs would not cause meaningful health risks to the public and radiological doses would remain well below the annual dose limit of 25 millirem set by 40 CFR Part 190 (the maximally exposed individual dose would be 0.55 millirem per year, which is less than 3 percent of the 25-millirem limit). Under normal or accident conditions, there would be no disproportionately high and adverse consequences to minority or low-income populations. In addition, no unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected to occur as a result of TPBAR irradiation at Sequoyah under this alternative.

4.2.14.7 Alternative 6: Watts Bar and Sequoyah (5,000 TPBARs)

Under this alternative, TVA would use both the Watts Bar and Sequoyah sites to irradiate a maximum of 5,000 TPBARs every 18 months. The analysis of this alternative assumed that each site would irradiate 2,500 TPBARs every 18 months. The impacts of Alternative 6 at Sequoyah would be the same as discussed for Alternative 2 in Section 4.2.14.3.

4.2.15 PERMEATION RATE AND REGULATORY LIMITS

The analyses in Sections 4.2.1 through 4.2.14 are based on a high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year (see Section 2.2). The analyses demonstrate that no regulatory limits would be exceeded at this permeation rate for any of the quantities of TPBARs that could be irradiated at Sequoyah. To provide another perspective on the relationship between the tritium permeation rate and regulatory limits, this section analyzes how high the tritium permeation rate would need to be before a regulatory limit would be exceeded. The analysis in this section is based on the maximum production scenario of irradiating 5,000 TPBARs every 18 months at Sequoyah. In comparison with the maximum production scenario, lesser production quantities would need even higher tritium permeation rates before a regulatory limit would be exceeded. The results from this analysis are listed in Table 4-30 and discussed below.

Drinking Water

As discussed in Section 4.2.5, the regulatory limit for tritium in drinking water is 20,000 picocuries per liter at the drinking water intake. The analysis in Section 4.2.5 shows that the tritium concentration at the drinking water intake increases linearly based on the amount of tritium released by TPBARs. The rate of increase in the tritium concentration in drinking water is about 0.035 picocuries per liter for every curie of tritium released to the water. To reach the 20,000 picocurie per liter limit, the permeation rate for

Table 4-30. Permeation rate versus regulatory limits at Sequoyah.

Regulatory limit	Permeation rate needed to reach limit for irradiation of 5,000 TPBARs (curies per TPBAR per year)
Public drinking water limit (20,000 picocuries per liter)	126
Worker dose (5,000 millirem per year)	4,079
Public dose from normal operations (10 millirem per year from all pathways, 3 millirem per year from the liquid pathway, and 5 millirem per year from the air pathway)	148
Public dose from accidents (25 rem)	Limit could not be reached regardless of permeation rate

5,000 TPBARs would need to be 126 curies per TPBAR per year, based on assumption that 90 percent of the tritium released would be liquid.

Worker Dose
The regulatory limit for worker dose during normal operations is 5,000 millirem per year (see Table C-1 in Appendix C). The analysis in Section 4.2.11 shows that worker dose increases linearly based on the amount of tritium released by TPBARs. The rate of increase in worker dose is about 0.00024 millirem for every curie of tritium released. To reach the 5,000-millirem annual limit, the permeation rate for 5,000 TPBARs would need to be 4,079 curies per TPBAR per year.

Public Dose from Normal Operations
The most stringent regulatory limits for public doses from normal operations are 10 millirem per year from all pathways, 3 millirem per year from the liquid pathway, and 5 millirem per year from the air pathway (see Table C-1 in Appendix C).[19] The analysis in Section 4.2.11 shows that the public dose increases linearly based on the amount of tritium released by TPBARs. Of the three regulatory limits, the 5 millirem per year for the air pathway is the most limiting. The rate of increase in the air pathway public dose is about 0.000066 millirem for every curie of tritium released to the air. To reach the 5-millirem limit, the permeation rate for 5,000 TPBARs would need to be 148 curies per TPBAR per year.

Public Dose from Accidents
The regulatory limit for the public from accidents is 25 rem (see Table C-1 in Appendix C).[20] The analysis in Section 4.2.12 shows that tritium is an insignificant contribution to dose from accidents, and that the 25-rem dose could not be reached regardless of the permeation rate.

4.3 Unavoidable Adverse Impacts

Irradiating as many as 5,000 TPBARs every 18 months in the Watts Bar or Sequoyah reactors would result in adverse environmental impacts. The impact assessment for this SEIS identified these potential adverse impacts along with measures TVA could implement either to avoid or to minimize them. The residual adverse impacts that would remain after mitigation are unavoidable. Sections 4.3.1 and 4.3.2 discuss these impacts for the Watts Bar and Sequoyah sites, respectively.

19. These public dose limits are numerical guides for design objectives and limiting conditions for operations to meet the criterion "As Low as is Reasonably Achievable" for radioactive material in light-water-cooled nuclear power reactor effluents (10 CFR Part 50, Appendix I).
20. The 25-rem value is a guidance criterion used to determine the exclusion area and low population zone for a nuclear power plant site (10 CFR 100.11).

4.3.1 WATTS BAR

There would be no construction at Watts Bar, so there would be no unavoidable adverse impacts of construction. During operations, the irradiation of TPBARs and transportation of the irradiated TPBARs to the Tritium Extraction Facility at the Savannah River Site would result in unavoidable impacts to the human environment. In general, the unavoidable adverse impacts from the operation of Watts Bar are the incremental increases in radiological impacts attributed to the irradiation and transportation of TPBARs for the alternatives analyzed in this SEIS.

Irradiation of TPBARs at Watts Bar would result in unavoidable routine releases of tritium that could affect air and water quality (see Sections 4.1.3 and 4.1.5, respectively). The releases would cause radiation exposures to workers and the public. Section 4.1.11 discusses annual doses from routine radiological air emissions under the proposed action to the maximally exposed individual, general population, and workers. TPBAR irradiation would generate additional spent nuclear fuel as an unavoidable result of reactor operations (see Section 4.1.11). The irradiation would generate a small amount of additional low-level radioactive waste, which would be transported for management off site at the Nevada National Security Site.

4.3.2 SEQUOYAH

Under Alternatives 2, 3, 5, and 6, TVA proposes to construct and operate a 500,000-gallon tritiated water tank and associated pumps and piping at the Sequoyah site. TVA would use this tank system to store tritiated water from the Sequoyah reactors after it passed through the existing liquid radioactive waste processing system and a planned reverse osmosis and demineralizer system. TVA would release the stored tritiated water to the Tennessee River through the existing pathway. Construction of the tritiated water storage tank would disturb less than 1 acre of land in the existing protected area. Material requirements and infrastructure demands for the tank system construction would be minimal. The small temporary construction workforce would not result in adverse socioeconomic impacts.

Irradiation of TPBARs for the alternatives analyzed in this SEIS that use the reactors at Sequoyah would result in unavoidable adverse impacts similar to those for Watts Bar identified in Section 4.3.1.

4.4 Potential Impacts under Expected Conditions

This section provides an analysis of potential environmental impacts from irradiation of 2,500 TPBARs every 18 months at Watts Bar 1 using TVA observations about current conditions. In Sections 4.1 to 4.3, NNSA used conservative assumptions to provide reasonable bounding estimates of potential environmental impacts from TPBAR irradiation in TVA reactors. These assumptions included the following:

- An assumed high and thus conservative permeation rate of 10 curies of tritium per TPBAR per year, which is more than twice the observed permeation rate at Watts Bar 1.

- In agreement with NRC guidance (Chandrasekaran et al. 1985), tritium releases would be 10 percent to the atmosphere as tritiated water vapor (air emissions) and 90 percent in the liquid effluent. Based on operational data from the TVA reactors, the actual tritium releases are about 3 percent to the atmosphere and 97 percent in the liquid effluent. The assumption from NRC guidance is conservative because the dose from inhaling tritiated water vapor is higher than the dose from ingesting tritium in liquid effluent, assuming the same curie content in both.

- Tritium releases from non-TPBAR sources would be 2,400 curies per reactor, which is more than twice the expected releases and affords sufficient operational margin (TVA 2012). Based on operational data from the TVA reactors, the actual tritium releases from non-TPBAR sources are about 900 curies per reactor.

Using TVA observations about current conditions, NNSA assumed for this expected-case scenario that:

- The permeation rate would be 5 curies of tritium per TPBAR per year.
- Tritium releases would be 3 percent to the atmosphere and 97 percent in the liquid effluent.
- Tritium releases from non-TPBAR sources would be 900 curies per reactor.
- TVA would irradiate 2,500 TPBARs every 18 months in Watts Bar 1, which reflects the preference to continue to use Watts Bar 1 for TPBAR irradiation.

As discussed in Sections 4.1 and 4.2, many environmental resource areas would be essentially unaffected by TPBAR irradiation at a reactor. TPBAR irradiation, in and of itself, does not change impacts to land use, aesthetics, noise, geology and soils, cultural resources, infrastructure, or socioeconomics. In addition, the amount of tritium permeation and the amount per pathway of released tritium do not change impacts to waste management and transportation. The resource areas that TPBAR irradiation could affect include water resources, air resources, human health and safety, biological resources, accidents, and environmental justice. Therefore, the analysis in this section focuses on these resources.

4.4.1 AIR QUALITY

The revised assumptions would not change the nonradiological characteristics of the air quality, and it would not affect the quantity or types of radionuclides other than tritium in the emissions. As such, the analysis focuses on tritium releases. Based on the revised assumptions, if TVA irradiated 2,500 TPBARs in Watts Bar 1, 429 curies of tritium (375 curies from TPBARs and 54 curies from non-TPBAR sources) could be part of the Watts Bar air emissions each year. Section 4.4.4 discusses the potential impacts of these tritium emissions on human health.

4.4.2 WATER RESOURCES

The assumptions for the expected case would not change the thermal or chemical characteristics of the water TVA discharges to the Chickamauga Reservoir (or Tennessee River), and it would not affect the quantity or types of radionuclides other than tritium in the discharges. As such, the analysis focuses on tritium concentrations.

Based on the revised assumptions, if TVA irradiated 2,500 TPBARs in Watts Bar 1, 13,871 curies of tritium (12,125 curies from TPBARs and 1,746 curies from non-TPBAR sources) could be part of the Watts Bar liquid effluents each year. The estimated tritium concentration of 194,000 picocuries per liter in the discharge to the river would be well under the limit of 10 million picocuries per liter in the Watts Bar operating license and, although greater than the drinking water limit of 20,000 picocuries per liter, would be below the drinking water level soon after exiting the diffuser. At an annual release rate of 13,871 curies of tritium and typical river flow, the average tritium concentration at the downstream drinking water intake would be about 580 picocuries per liter. Section 4.4.4 discusses the potential impacts of these tritium emissions on human health.

4.4.3 BIOLOGICAL RESOURCES

The revised assumptions would change the estimated radiological releases in gaseous emissions and liquid effluents as noted above. As discussed in Section 4.4.4, irradiation of 2,500 TPBARs every 18 months (with an assumed permeation rate of 5 curies of tritium per TPBAR per year) could result in an annual dose to the maximally exposed individual of about 0.174 millirem per year. This potential dose would be well below the International Atomic Energy Agency benchmarks (Section 4.1.6). There would be no increase in temperature, and impingement and entrainment of aquatic organisms would also not change. The revised assumptions would be expected to result in no significant adverse impacts to Federal or State of Tennessee special-status species.

4.4.4 HUMAN HEALTH AND SAFETY

The revised assumptions would change the estimated radiological exposure of workers and the public to radiation from tritium. Table 4-31 lists the radiological impacts for the maximally exposed individual and the projected 2025 population within 50 miles of Watts Bar based on the revised assumptions. Table 4-32 lists the radiological impacts on the facility worker.

Table 4-31. Annual radiological impacts to the public including incident-free tritium production at Watts Bar 1 under expected conditions.

		Maximally exposed offsite individual		**Projected 2025 50-mile population**	
Tritium production	**Release media**	**Dose (millirem)**	**Latent cancer fatality risk**	**Annual dose (person-rem)**	**Latent cancer fatality[c]**
2,500 TPBARs	Air[a]	0.14	8×10^{-8}	2.3	0 (0.001)
	Liquid[b]	0.034	2×10^{-8}	5.9	0 (0.004)
	Totals	**0.**174	$\mathbf{1 \times 10^{-7}}$	8.2	**0 (0.**005**)**

a. NNSA based the population data for airborne releases on the projected 2025 population within 50 miles of the site, which is 1,452,511 people. The 2025 population was projected from 2010 Census data (USCB 2012) based on a growth rate consistent with that over the past 10 years.

b. NNSA based the population data for liquid releases on the projected 2025 population of persons who would use public water supplies downstream of the site within 50 miles, which is 367,652 people.

c. Estimated number of latent cancer fatalities to the projected 2025 population from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table 4-32. Annual radiological impacts to workers including incident-free tritium production at Watts Bar 1 under expected conditions.

Tritium production	**Average worker dose (millirem)**	**Average worker latent cancer fatality risk**	**Total workforce dose (person-rem)**	**Total worker latent cancer fatalities[a]**
2,500 TPBARs	122	7×10^{-5}	107	0 (0.06)

a. Estimated number of latent cancer fatalities to the projected 2025 population from exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

As listed in Tables 4-31 and 4-32, the radiological impacts of normal operation from the production of 1,700 TPBARs at Watts Bar 1 with an assumed permeation rate of 5 curies of tritium per TPBAR per year would be as follows:

- The annual dose to the maximally exposed offsite individual would be 0.174 millirem per year, with an associated 1×10^{-7} risk of a latent cancer fatality per year of operation.
- The collective dose to the population within 50 miles of Watts Bar would be 8.2 person-rem per year, with an associated 0 (0.005) latent cancer fatality per year of operation.
- The collective dose to the facility workers would be 107 person-rem per year, with an associated 0 (0.06) latent cancer fatality per year of operation.

4.4.5 ACCIDENTS

The tritium permeation rate and the amount per pathway of released tritium from normal operations is not a factor in the reactor accident analysis, which assumes the entire tritium content in the TPBARs would be released to the containment in both design-basis and beyond-design-basis reactor accidents (severe reactor accidents). For those accidents, NNSA assumed each TPBAR would produce an average of 1 gram of tritium through the 18-month irradiation cycle. Because 1 gram of tritium contains 9,640 curies, the 1,700 TPBARs would contribute 16.4 million curies to the analyzed accidents. The results in Sections 4.1.12 and 4.2.12 also show that the effects of the radionuclide releases inherent to the reactor operations, rather than the tritium from TPBAR irradiation, dominate the accident risks.

In relation to accidents that would not involve a reactor, Section 4.1.12.2 indicates that a release of 25,000 curies of tritium from 2,500 TPBARs would result in a dose of 0.0016 rem to the maximally exposed individual and a dose of 29 person-rem to the 50-mile population surrounding the Watts Bar site in 2025. For 2,500 TPBARs and an assumed permeation rate of 5 curies of tritium per TPBAR per year, a release of 12,500 curies of tritium would result in a dose of about 0.0008 rem to the maximally exposed individual and a dose of about 15 person-rem to the 50-mile population in 2025.

4.4.6 ENVIRONMENTAL JUSTICE

The revised assumptions would change the estimated exposure of the public from those in Sections 4.1 and 4.2. The irradiation of 2,500 TPBARs could result in an annual dose to the maximally exposed individual of about 0.174 millirem per year. This dose would not cause significant health risks to the public, and radiological doses would remain well below the annual dose limit of 25 millirem in 40 CFR Part 190. No unique exposure pathways that could increase doses were identified. Therefore, no disproportionately high and adverse consequences to minority or low-income populations would be expected to occur as a result of TPBAR irradiation at Watts Bar.

4.5 Mitigation Measures

To mitigate potential impacts from tritium releases, TVA proposes to construct and operate a 500,000-gallon tritiated water tank system at Sequoyah in the event of a decision to irradiate TPBARs at that site or to facilitate routine tritium management (see Section 2.4.2). Such a system would be the same as the system that TVA recently built at the Watts Bar site (see Section 1.6). TVA would use the Watts Bar and Sequoyah tank systems to store tritiated water after it passed through the liquid radioactive waste processing system. TVA would release the stored tritiated water to the Tennessee River by the existing pathways. The tank systems that TVA would potentially have in place at both the Watts Bar and Sequoyah sites would have sufficient capacity to store and release the water at appropriate times (that is, TVA will release the water from the tank during times of higher river flows for better dilution), and it will enable TVA to minimize the potential impacts of tritiated water releases. The systems would enable TVA to plan fewer releases each year and to ensure that site effluents would continue to remain well below regulatory concentration limits.

Other features are in place at both sites to mitigate the impacts of radiological releases to workers at the nuclear plants and to the public in the vicinity of the plants. These include, for example, the TVA program to keep radiological releases and resultant worker doses As Low As is Reasonably Achievable (the "ALARA" program), the worker dosimetry program intended to track radiation exposure and ensure that it is within administrative and regulatory limits, the environmental monitoring program around the site, the engineered safety features such as the reactor containment buildings (which prevent or mitigate the releases to the public associated with normal operations and accident conditions), and the site security forces and physical measures that are in place to assist in the prevention of intentional destructive acts. Each of these measures is in place in compliance with NRC requirements, which mandate these measures in order to acquire plant operating licenses. While none of these measures is in place specifically as a result of TPBAR irradiation activities, the fact that they are in place assists in the prevention or mitigation of impacts to workers and the public associated with operation of the facilities both with and without TPBARs.

CHAPTER 5. CUMULATIVE IMPACTS

5.1 Introduction

The Council on Environmental Quality regulations (40 CFR 1508.7) that implement the *National Environmental Policy Act of 1969* (NEPA; 42 U.S.C. §§ 4321 *et seq.*) define cumulative impact as the "impact on the environment which results from the incremental impact of the action when added to past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." The National Nuclear Security Administration (NNSA) based the cumulative impact analysis for this Supplemental Environmental Impacts Statement (SEIS) for tritium production on the proposed actions at the Tennessee Valley Authority (TVA) Watts Bar and Sequoyah sites, other actions associated with TVA at these sites, and other activities in the surrounding region with the potential to contribute to cumulative environmental impacts.

Based on the analysis in Chapter 4 of this SEIS, the cumulative impact analysis focused on the resources with the greatest potential to be meaningfully affected by potential environmental impacts resulting from the proposed action to irradiate as many as 5,000 TPBARs at either the Watts Bar or Sequoyah sites in combination with other sources of ongoing or potential impact. These resource areas include human health, biological resources, and air and water quality, which have the potential to be impacted by releases of radiological materials into the environment. NNSA conducted the analysis in accordance with the Council on Environmental Quality NEPA regulations and handbook, "Considering Cumulative Effects Under the National Environmental Policy Act" (CEQ 1997b), as well as the U.S. Department of Energy's (DOE) NEPA implementing regulations (10 CFR Part 1021).

The cumulative impact analysis examined potential impacts for the same timeframe as that for the alternatives in this SEIS, which is through 2035. Consistent with other NEPA documents that address reactor operations, NNSA examined a 50-mile radius around each of the Watts Bar and Sequoyah sites as the potential region of influence for impacts to human health and safety, biological resources, and air and water quality.

5.2 Current and Reasonably Foreseeable Actions

In addition to the proposed action of this SEIS, actions that can contribute to cumulative impacts include other activities at the sites and other Federal, State of Tennessee, local government, private sector, and individual projects in the regions of influence of the actions the SEIS considers. This section identifies current and reasonably foreseeable actions to which the impacts from the irradiation of TPBARs at the Watts Bar and Sequoyah sites could contribute. In some cases, NNSA has considered, discussed, and dismissed the actions from further evaluation.

5.2.1 CURRENT ACTIONS

Oak Ridge Reservation

The DOE Oak Ridge Reservation is in eastern Tennessee about 40 miles northeast of the Watts Bar site and 70 miles northeast of the Sequoyah site. DOE operates three sites on the reservation: the East Tennessee Technology Park (formerly the K-25 Site), the Oak Ridge National Laboratory, and the Y-12 National Security Complex. The three sites are government-owned, contractor-operated facilities; under DOE oversight, private companies manage day-to-day operations of the sites according to Federal laws, DOE Orders, and State of Tennessee laws and regulations.

In a February 2011 Site-Wide EIS for the Y-12 National Security Complex (DOE 2011b), NNSA, among other things, analyzed the potential radiological impacts to the offsite public from operations at the facilities on the Oak Ridge Reservation. Table 4.12.1-4 of the Y-12 Site-Wide EIS (DOE 2011b) lists estimates of potential radiological impacts to the public from normal operations at the Oak Ridge Reservation; it reported a potential population dose of 26 person-rem to the population within a 50-mile radius of the Oak Ridge facilities. This area overlaps more than half of the 50-mile region of influence for the Watts Bar site, but does not overlap that for the Sequoyah site. To put this potential impact into perspective, NNSA estimated in the Site-Wide EIS that the population that would receive this potential 26-person-rem dose would be more than 1 million people. This would equate to about 0.008 percent of the dose that this population receives annually from naturally occurring radiation sources (the Y-12 Site-Wide EIS calculated the population dose from naturally occurring radiation sources to be 312,012 person-rem) (DOE 2011b).

Kingston Coal Ash Spill

During the scoping process for this SEIS, some commenters requested that NNSA consider the cumulative impacts of the Kingston coal ash spill. Although this was an "event" that impacted the environment rather than an action, this SEIS includes consideration of this event in this cumulative impact analysis.

On December 22, 2008, a dike failed at the TVA Kingston Fossil Plant in Roane County, Tennessee. More than 5.4 million cubic yards of coal ash spilled from an onsite landfill and covered more than 300 acres of surrounding land and water (TVA 2011s). While there were no immediate injuries, the spill has affected local citizens and the area's natural environment. The event immediately affected the adjacent Emory River and subsequently had impacts to the Clinch River and the Tennessee River on the upper reaches of the Watts Bar Reservoir. The Tennessee Department of Environment and Conservation (TDEC) has been actively engaged in the immediate and long-term responses to the release—working with the U.S. Environmental Protection Agency (EPA) to oversee a wide range of sampling and cleanup activities.

On May 11, 2009, EPA entered into an enforceable agreement to oversee the TVA cleanup of the coal ash from the site and the Emory River. According to EPA, the coal ash could contain hazardous chemicals such as arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc (EPA 2009).

According to TDEC, TVA completed the time-critical activities of the cleanup in 2010 (TDEC 2012). Since then, TVA has been removing the remaining ash from the embayments, sloughs, tributaries, and ground surface and taking the steps necessary to close the failed landfill. The cleanup requires restoration of the Swan Pond Embayment and requires TVA to store the ash from the embayment area permanently in an onsite area enclosed by a perimeter dike. The dike will occupy the same area as the failed dredge cells, but TVA has reengineered and reinforced the dike. The final height of the disposal area will be about 30 feet lower than the previous landfill. Once TVA has completed the ash disposal, it will cover the site with 2 feet of clay, topsoil, and vegetation. TVA will regularly inspect the landfill for stability and conduct long-term groundwater testing to monitor for potential impacts.

Sampling began immediately after the spill and included drinking water, private wells, surface water, air quality, ash, and soil. The Tennessee Department of Health laboratory analyzes the results to determine potential health effects. The Tennessee Department of Health posts the test results on the TVA Kingston Update website at www.tn.gov/environment/kingston. Sampling locations include areas on the Tennessee River near its confluence with the Clinch River about 40 miles northeast of Watts Bar Dam. In the August 2011 sampling report (TVA 2011t), TVA listed test data for arsenic and selenium for locations on the Emory, Clinch, and Tennessee Rivers. None of the samples from the Tennessee River included in this report exceeded Tennessee Drinking Water Standards for arsenic or selenium. The average sample concentration of arsenic was 0.00084 parts per million, which is about 8.4 percent of the standard (0.01 parts per million); the average selenium concentration was 0.00044 parts per million, which is less than 1 percent of the standard (0.05 parts per million) (TVA 2011t).

Watts Bar Land Management Plan

In February 2009, TVA issued the Final Watts Bar Reservoir Land Management Plan EIS (TVA 2009a) to assess the potential environmental impacts of a reasonable range of alternatives for managing 16,000 acres of TVA public land in the Watts Bar Reservoir area. The purpose of the land planning effort is to apply a systematic method of evaluating and identifying the most suitable use of land under TVA stewardship. The EIS included three alternatives to guide land use approvals, private water-use facility permitting, and resource management decisions about the Watts Bar Reservoir. Under Alternative A (No Action), TVA would continue to use its existing plans with minor updates to reflect changes over the past 17 years. Alternative B (Modified Development and Recreation) would provide a stronger emphasis on economic and recreational development. Alternative C (Modified Conservation and Recreation) would provide a stronger emphasis on natural resource conservation and informal recreation activities. TVA chose Alternative B as its preferred alternative and formally adopted it in the Record of Decision (75 FR 6257; February 8, 2010), which TVA is currently implementing.

5.2.2 REASONABLY FORESEEABLE ACTIONS

Irradiation of Mixed-Oxide Fuel

As stated in Section 1.6, DOE issued an amended Notice of Intent on July 19, 2010, to prepare an SEIS for surplus plutonium disposition (75 FR 41850). The proposed actions in that SEIS include the irradiation of mixed-oxide fuel assemblies in as many as five TVA reactors at the Sequoyah and Browns Ferry Nuclear Plants. TVA is a cooperating agency with DOE for preparation and review of the sections of that SEIS that address operation of TVA reactors.

Section 1.6 of this SEIS states that NNSA would not simultaneously irradiate TPBARs in any TVA reactor that is burning mixed-oxide fuel. Accordingly, if the Record of Decision for the Surplus Plutonium Disposition SEIS includes the use of mixed-oxide fuel in the Sequoyah reactors, NNSA would not use those reactors for TPBAR irradiation during the same fuel cycle.

Blended Low-Enriched Uranium at Browns Ferry and Sequoyah

In May 2011, TVA issued an Environmental Assessment (TVA 2011u) and a Finding of No Significant Impact (TVA 2011v) for *Additional Use of Blended Low-Enriched Uranium (BLEU) in Reactors at TVA's Browns Ferry and Sequoyah Nuclear Plants*. TVA uses enriched uranium-235 nuclear fuel at its Browns Ferry and Sequoyah Nuclear Plants from commercially available low-enriched uranium or from weapons-grade highly enriched uranium that is surplus to the defense needs of the United States. Low-enriched uranium contains less than 5 percent of uranium-235; highly enriched uranium contains more than 20 percent. For comparison, natural uranium contains about 0.7 percent. The highly enriched uranium material can be blended with other concentrations to lower the enrichment to produce fuel for use in commercial reactors. Under an agreement with DOE in the mid-1990s, TVA acquired about 33 metric tons of highly enriched uranium for blending. To date, the use of this blended fuel in TVA reactors has provided a reliable source of lower cost fuel and resulted in substantial cost savings to TVA and its customers.

In 2005, the U.S. Government declared an additional 200 tons of highly enriched uranium as surplus. In its environmental assessment (TVA 2011v), TVA proposed using an additional 28 metric tons of this surplus to produce blended fuel for the Browns Ferry or Sequoyah Nuclear Plants, or both. This would result in TVA taking responsibility for 61 metric tons of highly enriched uranium to process into blended fuel. The final environmental assessment reported that the differences of the potential impacts from using typical fuel versus those from blended fuel depends mainly on whether there are differences in radiological releases between the two types. TVA determined that those differences would be none to minor. TVA (2011v) reports that the blended low-enriched uranium radiological characteristics are so similar to those of low-enriched uranium fuel that differences in effects between the no-action alternative and the proposed action alternative of the environmental assessment would not be discernible.

Clinch River Small Modular Reactors

TVA released an Integrated Resource Plan (TVA 2011w) and associated Programmatic EIS (TVA 2011x) in March 2011 to address the demand for power in the TVA service area, available options for meeting the demand, and potential environmental, economic, and operating impacts of the options. The plan describes the TVA strategy for meeting the energy needs of its customers over the next 20 years and evaluates various alternatives including increased power generation from nuclear power at Watts Bar 2 and Bellefonte 1 and 2.

Although the strategies do not include small modular reactors, TVA is exploring the construction and operation of one or more small modular reactor nuclear plants. At least seven different corporations are developing these reactors, which would produce from 10 to 335 megawatts of electricity. Manufacturers would ship completed reactors by rail, truck, or barge to the plant sites. In most designs, the reactor containment vessel would be underground, and refueling cycles would be longer than those of current reactors. Several of the developers intend to submit design certification applications to the U.S. Nuclear Regulatory Commission (NRC) in 2013 (TVA 2011x).

As a part of the Technology Innovation areas identified in the Integrated Resource Plan, TVA is exploring the construction and operation of one or more small modular reactor nuclear plants. At least four different corporations are developing these reactors, which would produce between 45 and 225 megawatts of electricity. Manufacturers would ship completed reactors by rail, truck, or barge to the plant sites. In most designs, the reactor containment vessel would be underground and refueling cycles would be longer than those of current reactors. Several of the developers are preparing design certification applications for submittal to the NRC in the next several years.

TVA is working to prepare an early site permit application for NRC approval of the Clinch River Site as a possible future location of a small modular reactor nuclear plant. TVA expects to submit the early site permit application in the fourth quarter of 2015. To support the early site permit development, site characterization is under way including hydrological analysis, groundwater model development, and subsurface geotechnical investigations.

Bellefonte Unit 1 Nuclear Reactor

On August 18, 2011, the TVA Board of Directors approved the completion of Bellefonte Unit 1, a 1,260-megawatt-electric nuclear reactor near Scottsboro in northern Alabama. The timeline for the completion of construction of Bellefonte Unit 1 is uncertain. The Bellefonte site is more than 50 miles from both Sequoyah and Watts Bar.

5.3 Potential Cumulative Impacts

The proposed action in this SEIS and many of the current and reasonably foreseeable actions described in Sections 5.2.1 and 5.2.2 would not produce cumulative impacts for the reasons described below:

- For the Watts Bar Land Management Plan, based on consultations with TVA, NNSA concluded that TVA's implementation of that plan would not result in any change in radiological impacts to the maximally exposed individual or to the population within 50 miles of Watts Bar. Therefore, there would be little to no cumulative impact from the proposed action in this SEIS and TVA's implementation of decisions related to the Watts Bar Reservoir Land Management Plan EIS.

- For the irradiation of mixed-oxide fuel, because the Browns Ferry Nuclear Plant near Decatur, Alabama, is very far (more than 150 miles) from the Sequoyah site, NNSA determined irradiation of mixed-oxide fuel at Browns Ferry would not result in cumulative impacts in combination with TPBAR irradiation at either the Sequoyah or Watts Bar site. If irradiation of mixed-oxide fuel occurred in the Sequoyah reactors, no major differences in potential environmental impacts would be expected to workers or the public [see Appendices I and J of NNSA (2012), which concludes that there would be no significant differences between operations with mixed-oxide fuel and low-enriched uranium fuel]. Therefore, this reasonably foreseeable action and the proposed action in this SEIS would not produce significant cumulative impacts.

- For the use of blended low-enriched uranium at Browns Ferry and Sequoyah, because this action would affect only the Browns Ferry and Sequoyah areas, there would be no cumulative impacts to the Watts Bar region of influence. In addition, because there would be no discernible difference in radiological releases from normal or accident conditions from using blended fuel, that action would have no cumulative impacts at Sequoyah.

- For the Clinch River Small Modular Reactors, the Clinch River site for the proposed reactors is 30 to 40 miles upstream of the Watts Bar site, and 60 to 80 miles north of the Sequoyah site, both of which are on the Tennessee River. As with all licensed and operating nuclear plants in the United States, TVA would design and operate the facility to maintain radiological releases from normal operations and under accident conditions as low as is reasonably achievable. When TVA submits a site-specific application for the proposed reactors to the NRC, the application will include preliminary estimates available to the public of releases under normal and accident conditions. Until that time, estimates of radiological releases from these proposed facilities would be speculative.

- For the Bellefonte Unit 1 Nuclear Reactor, because the Bellefonte site is more than 50 miles from both Sequoyah and Watts Bar, NNSA determined that there would be no cumulative impacts in combination with TPBAR irradiation at either the Sequoyah or Watts Bar site.

The analysis of potential impacts for the proposed action in this SEIS indicates that most resource areas would not experience significant impacts from the implementation of any analyzed alternative. However, the alternatives do have the potential to increase the cumulative impacts in the designated region of influence for the following resource areas: air quality, water resources, biological resources, and human health and safety.

5.3.1 AIR QUALITY

For the Watts Bar site, Section 4.1.3 discusses potential environmental consequences to air quality from the alternatives. The highest potential impacts would result from the alternative in which TVA could irradiate up to 5,000 TPBARs at Watts Bar (Alternative 4). For that alternative, the potential impact to air quality could be an annual airborne release of 5,516 curies of tritium. Operations at DOE's Oak Ridge Reservation release tritium and other radiological materials to the air that can affect human health. Other than the potential Clinch River small modular reactors, for which there is no information on potential radiological release currently available, there are no other identified current or reasonably foreseeable actions near Watts Bar that would release radiological materials. The highest measured concentration of tritium in air samples in 2011 was 7.77×10^{-6} picocuries per milliliter. The highest measured concentration of any other radionuclide in 2011 was 5.3×10^{-8} picocuries per milliliter (DOE 2011c).

Section 5.3.4 discusses the potential cumulative human health impacts from Watts Bar tritium releases to the air and Oak Ridge Reservation tritium and radiological material releases to the air.

For the Sequoyah site, Section 4.2.3 discusses potential environmental consequences to air quality. The highest impacts would result from the alternative in which TVA could irradiate up to 5,000 TPBARs at Sequoyah (Alternative 5). For that alternative, the potential impact to air quality could be an annual airborne release of 5,507 curies of tritium. No other identified reasonably foreseeable actions within 50 miles of the Sequoyah site would release airborne radiological materials.

5.3.2 WATER RESOURCES

For the Watts Bar site, Section 4.1.5 describes potential environmental consequences to water resources from the alternatives. The highest impacts would result from the alternative in which TVA could irradiate up to 5,000 TPBARs at Watts Bar (Alternative 4). The primary potential impact to water resources from that alternative would be a change in the amount of tritium the site would release in liquid effluents. The analysis determined that the maximum tritium concentration in the river would be less than the maximum permissible EPA drinking water limit of 20,000 picocuries per liter identified in 40 CFR Part 141 within about 140 feet of the discharge point. The Oak Ridge Reservation releases tritium and other radiological materials to the water that can affect human health. In 2011, the Oak Ridge Reservation released about 320 curies of tritium to the water (DOE 2011c). Section 5.3.4 discusses the potential cumulative human health impacts from Watts Bar tritium releases to the water and Oak Ridge Reservation radiological material releases to the water.

For the Sequoyah site, Section 4.2.5 describes potential environmental consequences to water resources. The highest impacts would result from the alternative in which TVA could irradiate up to 5,000 TPBARs at Sequoyah (Alternative 5). The primary potential impact to water resources from that alternative would be a change in the amount of tritium TVA would release in liquid effluents. The analysis determined that the tritium concentration in the discharge plume would be below the EPA-established drinking water limit within 18 feet or less of the diffusers. Because the Sequoyah site is more than 50 miles from the Oak Ridge Reservation, this SEIS does not analyze any potential cumulative impacts from TPBAR irradiation at Sequoyah and operations at the Oak Ridge Reservation.

5.3.3 BIOLOGICAL RESOURCES

Sections 4.1.6 and 4.2.6 describe potential environmental consequences to biological resources for the Watts Bar and Sequoyah sites, respectively. Potential impacts to populations of flora and fauna would relate to the projected exposure to the maximally exposed human individual. For both sites, the estimated doses would be small (less than about 0.86 millirem per year). As discussed in Section 5.3.4, the potential cumulative impacts to flora and fauna would be less than 2.6 millirem, which would be well below the International Atomic Energy Agency publication (IAEA 1992 as cited in DOE 1999a) dose rate of 100 millirem per year that could cause an adverse effect.

With respect to the Kingston Coal Ash Spill, TVA compared test results to fish and aquatic life criteria to evaluate potential impacts to biological resources from the spill. The most recent samples indicate that the concentration of arsenic is 0.01 percent of the criteria, while the concentration of selenium is 8.8 percent of the criteria (TVA 2011t). These results indicate that concentrations of these pollutants of concern are well below the Tennessee criteria for potential bioaccumulation in fish and aquatic life. Because the samples came from close to the spill site, which is over 40 Tennessee River Miles from the Watts Bar site, NNSA concluded there would be little to no cumulative impact from the proposed action in this SEIS and the Kingston coal ash spill.

5.3.4 HUMAN HEALTH AND SAFETY

For the Watts Bar site, Section 4.1.11 describes potential environmental consequences to human health from the alternatives. The highest impacts would result from the alternative in which TVA could irradiate up to 5,000 TPBARs at Watts Bar (Alternative 4). During TPBAR irradiation, there would be incremental radiological releases of tritium to the environment, which could affect the offsite population. The only action identified in Section 5.2 that could have a notable cumulative impact when combined with TPBAR irradiation at Watts Bar would be operations at the Oak Ridge Reservation, 40 miles northeast of Watts Bar. Table 5-1 lists projected doses and radiological impacts (in terms of additional risk of latent cancer fatality) to the maximally exposed offsite individual and the offsite population for Alternatives 1 and 3 and from operations at the Oak Ridge Reservation.

Table 5-1. Potential cumulative impacts to the public from TPBAR irradiation at Watts Bar and operations at the Oak Ridge Reservation.

	Maximally exposed offsite individual		Population within 50 miles	
Operation	**Dose (millirem)**	**Latent cancer fatality risk**	**Annual dose (person-rem)**	**Latent cancer fatalities**[d]
TPBAR irradiation at Watts Bar[a]	0.86	5×10^{-7}	29.4	0 (0.02)
Oak Ridge Reservation[b]	1.7	1×10^{-6}	27.3	0 (0.02)
Totals[c]	2.6	2×10^{-6}	56.7	0 (0.04)

a. Data from Section 4.1.11.5 of this SEIS.
b. Data from Table 6.3.5-1 of DOE 2011b (with Watts Bar contribution excluded).
c. Total based on addition of TPBAR irradiation at Watts Bar and Oak Ridge Reservation operations. This is a very conservative assumption because it assumes the maximally exposed individual and 50-mile population (in relation to Watts Bar and the Reservation) is the same for both sites.
d. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

As shown in Table 5-1, the potential cumulative dose to the maximally exposed individual could be up to 2.6 millirem. This would result in a latent cancer fatality risk of 2×10^{-6}, meaning that 1 additional latent cancer fatality could be expected to occur every 500,000 years. For the population within 50 miles, the potential cumulative dose could be 56.7 person-rem. This would result in 0 (0.04) latent cancer fatality annually. Because of the 40-mile distance separating the two sites, there would be no notable cumulative impacts to workers at either Watts Bar or the Oak Ridge Reservation.

For the Sequoyah site, Section 4.2.11 describes potential environmental consequences to human health from the alternatives. The highest impacts would result from the alternative in which TVA could irradiate up to 5,000 TPBARs at Sequoyah (Alternative 5). During TPBAR irradiation, there would be incremental radiological releases of tritium to the environment, which could affect the offsite population. Because the Sequoyah site is more than 50 miles from the Oak Ridge Reservation, this SEIS does not analyze any cumulative impacts from TPBAR irradiation at Sequoyah and operations at the Oak Ridge Reservation

Potential Cumulative Impacts for 25 Years of TPBAR Irradiation

Sections 4.1.11 and 4.2.11 present the potential human health impacts to workers and the public at Watts Bar and Sequoyah respectively, on an annual basis. Because TPBAR irradiation could occur over about 25 years at Watts Bar and/or Sequoyah, NNSA has considered the potential cumulative human health impacts to the public and workers over that period. Tables 5-2 through 5-5 list these potential cumulative impacts. The tables present impacts for irradiation of 5,000 TPBARs at each site, which would produce the highest impacts. As indicated in Chapter 4, most of the dose impacts result from normal reactor operation exclusive of TPBAR irradiation.

Table 5-2. Cumulative radiological impacts to the public at Watts Bar.

Tritium production	Maximally exposed offsite individual		Population within 50 miles projected for 2025[a]	
	Dose (millirem)	**Latent cancer fatality risk**	**Annual dose (person-rem)**	**Latent cancer fatalities**
Alternative 4 (5,000 TPBARs)	21.5	1×10^{-5}	735	0 (0.44)

a. NNSA based the population data for airborne releases on the projected 2025 population within 50 miles of the site, which is 1,452,511 people. The 2025 population was projected from 2010 Census data (USCB 2012) based on a growth rate consistent with that over the past 10 years. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table 5-3. Cumulative radiological impacts to workers at Watts Bar.

Tritium production	Total worker dose[a]	
	Dose (person-rem)	**Latent cancer fatalities**
Alternative 4 (5,000 TPBARs)	2,868	2 (1.7)

a. Based on 879 workers, which includes additional workers for refueling operations and outages. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses.

Table 5-4. Cumulative radiological impacts to the public at Sequoyah.

Tritium production	Maximally exposed offsite individual		Population within 50 miles projected for 2025[a]	
	Dose (millirem)	**Latent cancer fatality risk**	**Annual dose (person-rem)**	**Latent cancer fatalities**
Alternative 5 (5,000 TPBARs)	13.8	8×10^{-6}	702	0 (0.42)

a. NNSA based the population data for airborne releases on the projected 2025 population within 50 miles of the site, which is 1,294,030 people. The 2025 population was projected from 2010 Census (USCB 2012) data based on a growth rate consistent with that over the past ten years. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table 5-5. Cumulative radiological impacts to workers at Sequoyah.

Tritium production	Total worker dose[a]	
	Dose (person-rem)	**Latent cancer fatalities**
Alternative 5 (5,000 TPBARs)	3,560	2 (2.1)

a. Based on 1,214 workers, which includes additional workers used during refueling operations and outages. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses.

The results in Tables 5-2 through 5-5 are conservative because they assume that each site would irradiate the maximum number of TPBARS continuously (up to 5,000 TPBARs) throughout the 25 years and that the population and workers would remain in-place and therefore receive the maximum annual exposure each year throughout the 25-year period.

CHAPTER 6. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF THE ENVIRONMENT AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The Council on Environmental Quality regulations that implement the procedural requirements of the *National Environmental Policy Act of 1969* (NEPA; 42 U.S.C. §§ 4321 *et seq*.) require consideration of the relationship between short-term uses of the human environment and the maintenance and enhancement of long-term productivity (40 CFR 1502.16). Irradiation of as many as 5,000 tritium-producing burnable absorber rods (TPBARs) every 18 months in the Watts Bar or Sequoyah reactors would require short-term use of land and other resources, as discussed in Chapter 4 of this Supplemental Environmental Impact Statement (SEIS). For this SEIS, the National Nuclear Security Administration (NNSA) considered short-term uses of the environment through 2035, during which the Tennessee Valley Authority (TVA) would irradiate TPBARs, and long-term productivity in the period after that irradiation when the TVA reactors had ceased operation and been decontaminated and decommissioned.

Short-term use of the project site for the proposed action would not affect the long-term productivity of the area because the TVA reactors would operate with or without TPBAR irradiation. Similarly, the resource requirements of the proposed action would be minimal because reactor operations would occur regardless of the proposed action. At the Sequoyah Nuclear Plant, construction of a tritiated water storage tank system would require disturbance of additional land (less than 1 acre), and such short-term use would remove this land from other beneficial uses. However, because this land is within the site boundary and the existing protected area, TVA is unlikely to use it for non-plant-related activities as long as the plants are operating. Construction of the storage tank system is underway at Watts Bar; the short-term effects will be similar.

Each site would require the use of the Energy Solutions licensed low-level radioactive waste disposal facility in Clive, Utah, for disposal of very small amounts (less than 30 cubic feet per year) of low-level waste from TPBAR irradiation. This waste would require space for storage and processing and would involve the commitment of associated land, transportation, and other disposal resources. Because the Energy Solutions facility is licensed for this activity and will comply with Federal and state environmental requirements, short-term use for the small amount of low-level waste from the proposed action would have an insignificant impact on long-term productivity. TPBAR irradiation would have no impact on decontamination and decommissioning activities at Watts Bar or Sequoyah.

CHAPTER 7. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

This chapter describes the irreversible and irretrievable commitments of resources necessary to implement the proposed action in this Supplemental Environmental Impact Statement (SEIS). A commitment of resources is irreversible when its primary or secondary impacts limit future options for use of a resource. An irreversible commitment refers to the use or consumption of resources that are neither renewable nor recoverable for later use. Examples of irretrievable types of resources include nonrenewable resources such as minerals and energy and renewable resources such as loss of production, harvest, or habitat.

Under Alternatives 4, 5, or 6, the U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA) would require irradiation of as many as 5,000 tritium-producing burnable absorber rods (TPBARs) every 18 months for the duration of the program. The materials for fabrication of the TPBARs, including lithium, aluminum, stainless steel, and zirconium, would become radioactive during the tritium production process. They would be consumed or reduced to unrecoverable forms of waste. In large part, however, the TPBARs would replace normal burnable absorber rods in the reactors, and both types of rods would involve similar quantities of irretrievable material resources. While the materials that make up in the TPBARs are somewhat different, primarily in that the neutron absorbing material is lithium rather than boron, none of the associated material resources necessary for fabrication of the TPBARs is in short supply. In addition, as indicated in Section 5.2.7 of the 1999 Environmental Impact Statement (DOE 1999a; the 1999 EIS), the materials for the fabrication of TPBARs have been mined and processed and are part of the DOE inventory of material resources. That section also addressed the quantities of materials necessary for TPBAR production and, because the 1999 EIS assumed a significantly larger requirement for tritium production than is now the case, the quantities of materials the 1999 EIS estimated bound those necessary to meet the requirements in this SEIS.

Additional materials for nuclear fuel assemblies would be necessary to operate the reactors while irradiating more TPBARs than the No-Action Alternative would allow. Materials for nuclear fuel assemblies include uranium, steel, and Zircaloy. After irradiation, these materials and byproducts of the fission and irradiation process would constitute the high-level radioactive waste constituents of the spent nuclear fuel. At this time, all constituents of spent fuel are nonrecoverable because the United States does not reprocess spent nuclear fuel. Section 5.2.7 of the 1999 EIS discussed the environmental impacts of fabrication and assembly of the fuel assemblies. Those impacts, which are still applicable, bound the impacts of the proposed action in this SEIS, and this SEIS does not repeat that discussion.

At the Sequoyah site, construction of the tritiated water tank storage system would require wood, concrete, sand, gravel, plastics, aluminum, steel, and other materials. NNSA and TVA determined there are no unusual construction materials necessary for this system, and none of the resources is in short supply. At the Watts Bar site, TVA would not require additional facilities for tritium production beyond the levels described in the SEIS for the No-Action Alternative.

The land for the tritiated water tank storage system at Sequoyah and the storage of additional spent nuclear fuel at Watts Bar or Sequoyah from tritium production, beyond the levels necessary for the No-Action Alternative, would be unavailable for other uses during the lifetimes of the plants. However, the sites would be available for other uses after decontamination and decommissioning.

TPBAR irradiation would require materials that would become low-level radioactive waste during the process. TVA would transport these wastes to the licensed Energy Solutions low-level waste disposal facility in Clive, Utah. These materials in the low-level waste would be unavailable for future use.

CHAPTER 8. APPLICABLE LAWS, REGULATIONS, AND OTHER REQUIREMENTS

8.1 Introduction

Chapter 8 identifies the Federal and State of Tennessee statutes and regulations that require licenses, permits, or actions in relation to environmental protection, emergency planning, and public and worker safety and health. In addition, the chapter summarizes the regulatory compliance history of the three operating nuclear reactors that the U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA) is considering for tritium production.[1]

To ensure that individual facilities satisfy established nuclear safety and environmental protection requirements, some of the applicable laws require the facilities to have licenses or permits. Among the most comprehensive of these are the operating licenses the U.S. Nuclear Regulatory Commission (NRC) issues under the *Atomic Energy Act of 1954*. As the licensee of the NRC for the operation of its nuclear reactors, the Tennessee Valley Authority (TVA) has the legal responsibility to comply with the terms of its operating license and all associated NRC regulatory requirements. After the issuance of reactor operating licenses, the NRC closely regulates proposed changes to reactor facilities, including those involving the use of tritium-producing burnable absorber rods (TPBARs) in place of traditional burnable absorber rods. Under the original operating licenses for Watts Bar Unit 1 (Watts Bar 1) and Sequoyah Units 1 and 2 (Sequoyah 1 and 2), issued before the origination of NNSA's tritium production program, TVA was not authorized to irradiate TPBARs in those facilities. In 2002, TVA received license amendments from the NRC to insert TPBARs to produce tritium at those units. Watts Bar 1 has been producing tritium for NNSA since 2003.

TVA is currently is in the process of completing construction of Watts Bar 2 and expects to seek license renewal for Sequoyah 1 and 2 beginning in 2013. TVA would seek additional license amendments to permit tritium production in the selected reactor(s) based on current information. Other than the substitution of TPBARs for traditional burnable absorber rods, tritium production at the Sequoyah units and at Watts Bar 2 would require no significant changes to compliance plans and activities at these facilities. (See Section 1.5 for a more in-depth discussion of the license amendments.)

The Tennessee Department of Environment and Conservation issues permits for air emissions and liquid effluent discharges under programs approved by the U.S. Environmental Protection Agency (EPA) pursuant to the *Clean Air Act* and the *Clean Water Act*. Continued compliance with the terms of these permits would be necessary under all alternatives in this Supplemental Environmental Impact Statement (SEIS). Based on the projections for air emissions and liquid effluents, no changes to the existing permits for the Watts Bar or Sequoyah Nuclear Plants should be necessary for the production of tritium. TVA has noted that it ships all hazardous wastes to permitted offsite facility contractors; therefore, it does not need its own hazardous waste permits. This practice is unlikely to change as a result of the proposed action and, therefore, new hazardous waste permits should not be necessary. Each facility has a Hazardous Waste Generator Identification Number and a Special Waste Permit.

Some applicable laws, such as the *National Environmental Policy Act of 1969* (NEPA), the *Endangered Species Act of 1973,* and the *Emergency Planning and Community Right-To-Know Act*, require specific reports and consultations rather than ongoing permits or activities. Other applicable laws establish

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1. While NNSA is considering the use of Watts Bar's Unit 2 reactor for tritium production as well, construction is not yet complete on Watts Bar 2. Moreover, NRC has not yet issued an operating license for Watts Bar 2. Therefore, there is no regulatory compliance history to consider for this reactor.

general requirements that must be satisfied, but do not include processes (such as the issuance of permits or licenses) to consider compliance before the occurrence of specific instances of violations or other events that trigger their provisions. These include the *Toxic Substances Control Act of 1976* (affecting polychlorinated biphenyl transformers and other designated substances); the *Federal Insecticide, Fungicide, and Rodenticide Act* (affecting pesticides and herbicides); the *Hazardous Materials Transportation Act*; and (if there was a release of a hazardous substance) the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.

Both TVA and NNSA have their own internal requirements that would be applicable to the proposed production of tritium. Occupational safety and health programs constitute the most important internal requirements. The *Occupational Safety and Health Act* and the U.S. Department of Labor regulations under it do not apply directly to government agencies (such as NNSA) or government-owned corporations (such as TVA). However, both agencies are required by statute or regulation (29 U.S.C. § 668, 29 CFR Part 1910) and Executive Order 12196 to have their own programs to protect worker safety and health "consistent" with *Occupational Safety and Health Act* standards. The NRC licensing process addresses radiological aspects of worker safety and health.

DOE has set forth numerous requirements in DOE Orders to ensure its activities provide general protection of health, safety, and the environment. Most of these, however, do not apply to activities at non-DOE facilities (such as production of tritium in TVA reactors for NNSA).

Section 8.2 discusses the major Federal and State of Tennessee statutes and regulations that impose nuclear safety and environmental protection requirements on the subject facilities. Each of the applicable regulations and statutes establishes how potential releases of pollutants and radioactive materials are to be controlled or monitored. These regulations and statutes include requirements for the issuance of permits or licenses for new operations or new emission sources and for amendments to existing permits or licenses to allow new types of operations at existing sources. In addition to nuclear and environmental license and permit requirements, the regulations and statutes might require consultations with authorities to determine if an action requires a permit, or if protective or mitigative measures in relation to the action's effect on cultural, natural, or biological resources might be necessary. Sections 8.2.1 and 8.2.2 discuss the nuclear and environmental licensing and permitting processes, respectively, and list the licenses and permits applicable to tritium production in the subject facilities.

Section 8.3 addresses general requirements for environmental protection, emergency planning, and worker safety and health. Section 8.4 discusses why DOE regulations and Orders that pertain to DOE activities do not apply to activities at TVA reactor facilities.

8.2 Statutes and Regulations Requiring Licenses or Permits

The *Atomic Energy Act of 1954*, as amended by the *Energy Reorganization Act of 1974*, gives the NRC jurisdiction over the construction and operation of commercial nuclear reactors (including those of TVA) and over the possession, use, transportation, and disposal of radioactive materials (including wastes) from those facilities. The NRC carries out this role by applying extensive regulations and performance standards to specific facilities and operations through a required licensing process. Although DOE is generally not subject to NRC jurisdiction, the proposed tritium production services that TVA would provide to NNSA would be subject to the NRC regulations and license requirements that apply to TVA.

In addition to the radiation protection requirements for NRC- and DOE-regulated facilities, applicable Federal and State of Tennessee environmental laws and regulations establish requirements to limit exposure to other sources of radiation and sources of air pollution, water pollution, and hazardous waste. Some of these standards apply to specific facilities and operations through required permits. To obtain these permits, the facility operator (in this case, TVA) must submit plans and specifications for construction and operation of new or modified sources of pollutants for review by the appropriate government agencies. The environmental permits (1) contain specific conditions governing construction and operation of a new or modified emission source, (2) describe pollution abatement and prevention methods to reduce pollutants, and (3) contain emission limits for the pollutants the facility will emit. Section 8.2.2 discusses the environmental regulations and statutes under which TVA might require new or amended permits for tritium production at the candidate facilities.

8.2.1 NUCLEAR REGULATORY COMMISSION PERMITS AND LICENSES

Atomic Energy Act of 1954 (42 U.S.C. §§ 2011 et seq.); 10 CFR Part 50

The Atomic Energy Act requires entities that operate nuclear power plants, such as TVA, to have an NRC-issued plant operating license. The regulations that implement this requirement applicable at the time the NRC licensed these reactors provide for permits for the construction or alteration of such facilities. Utilities apply for operating licenses after completion of the construction or appropriate amendments associated with the alteration of the facilities (10 CFR 50.23, 50.56, and 50.57). Construction permits and operating licenses include detailed provisions about their duration and the design, safety, and quality assurance requirements for the subject facilities (10 CFR Sections 50.54 and 50.55). These regulations have since been amended to provide the option of a one-step licensing process (see 10 CFR Part 52), but do not apply here.

The NRC is addressing permits and licensing requirements for completion of Watts Bar 2 for electricity production as part of its consideration of the TVA operating license application. After the issuance of an operating license by the NRC for Watts Bar 2, if TVA determined at some point that the use of that facility is necessary to meet NNSA tritium production requirements, TVA would have to apply to the NRC for appropriate amendments to its operating license for Watts Bar 2 as it would also do if it selected either Sequoyah 1 or Unit 2 (or both) for tritium production. Watts Bar 1 has license amendments authorizing the production of tritium. TVA will seek further license amendments as necessary to produce tritium based on current information and NNSA tritium requirements.

Regulatory Limits on Radiation Exposure; 10 CFR Part 50, Appendix I; 10 CFR Part 20

Limits of radiation exposure to members of the public and workers are based on International Commission on Radiological Protection recommendations. For nuclear facilities in the United States, the NRC establishes annual exposure limits for protection of the public and workers in 10 CFR Part 20, “Standards for Protection Against Radiation,” and 10 CFR Part 50, Appendix I, “Numerical Guides for Design Objectives and Limiting Conditions for Operation,” as well as requirements that relate to meeting the as-low-as-is-reasonably-achievable criterion for radioactive exposures in commercial nuclear power plants.

8.2.2 ENVIRONMENTAL PROTECTION PERMITS

Clean Air Act (42 U.S.C. §§ 7401 et seq.); EPA Regulations (40 CFR Parts 50 to 99); Tennessee Air Quality Act (Title 68, Tennessee Code Chapter 201); Tennessee Regulations Chapter 1200.3; Air Pollution Ordinances of Relevant Municipal and County Governments

The purpose of the *Clean Air Act* is to “protect and enhance the quality of the nation’s air resources so as to promote the public health and welfare and the productive capacity of its population.” Section 118 of the Act requires each Federal agency (including TVA and DOE) with jurisdiction over any property or facility that might result in the discharge of air pollutants to comply with “all Federal, state, interstate, and local requirements” in relation to the control and abatement of air pollution.

The Act requires EPA to establish National Ambient Air Quality Standards as necessary to protect public health and welfare with an adequate margin of safety from any known or anticipated adverse effects of a regulated pollutant (42 U.S.C. § 7409). The Act also requires the establishment of national standards of performance for new or modified stationary sources of atmospheric pollutants (42 U.S.C. §§ 7411 and 7412), and it requires specific emission increases to be evaluated to prevent a significant deterioration in air quality (42 U.S.C. §§ 7470 *et seq*.). The EPA regulates air emissions in 40 CFR Parts 50 through 99. It regulates hazardous air pollutants, including radionuclide emissions from Federal facilities, under the National Emission Standards for Hazardous Air Pollutants Program (40 CFR Part 61).

States that have an EPA-approved air pollution control program implement these national standards. In Tennessee, the Department of Environment and Conservation administers the program under the *State Air Quality Act* (Title 68 Tennessee Code Chapter 201). The Department regulates air emissions under Chapter 1200-3 of the Tennessee Rules (http://www.tn.gov/sos/rules/1200/1200.htm). The National Emission Standards for Hazardous Air Pollutants for radionuclides (40 CFR Part 61, Subparts H and I) are not applicable to NRC-licensed facilities such as TVA reactors. As cited in an EPA Final Rule (60 FR 46206), compliance with NRC regulations constitutes compliance with 40 CFR Part 61, Subparts H and I. As indicated in Chapter 4, radiation exposure of the public from the proposed action would be well within regulatory limits.

EPA establishes standards for radiation protection for members of the public in the general environment and for radioactive materials introduced into the general environment as the result of operations that are part of a nuclear fuel cycle. These standards are in 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations." TVA reactors are subject to these standards.

Federal Clean Water Act (33 U.S.C. §§ 1251 et seq.); Tennessee Water Quality Control Act (Title 69 Tennessee Code Chapter 3); Tennessee Rules Chapter 1200-4

Congress enacted the *Federal Water Pollution Control Act* (commonly known as the *Clean Water Act*) to "restore and maintain the chemical, physical, and biological integrity of the nation's water." The Act prohibits the "discharge of toxic pollutants in toxic amounts" to navigable waters of the United States (Section 101). Section 313 of the Act requires all branches of the Federal Government engaged in any activity that might result in a discharge or runoff of pollutants to surface waters to comply with Federal, state, interstate, and local requirements.

In addition to setting water quality standards for the nation's waterways, the *Clean Water Act* supplies guidelines and limitations (Sections 301 to 303) for effluent discharges from point-source discharges and provides authority (Sections 401 and 402) for EPA to implement the National Pollutant Discharge Elimination System permitting programs pursuant to 40 CFR Part 122 and subsequent regulations.

EPA has delegated primary enforcement authority for the *Clean Water Act* and the National Pollutant Discharge Elimination System permitting program to the State of Tennessee for the waters therein. The Tennessee Department of Environment and Conservation regulates water quality and discharges under Chapter 1200-4 of the Tennessee Rules (http://www.tn.gov/sos/rules/1200/1200.htm).

Safe Drinking Water Act (42 U.S.C. §§ 300f et seq.); 40 CFR Parts 41 to 149; Tennessee Safe Drinking Water Act (Title 68 Tennessee Code Chapter 221)

The primary objective of the *Safe Drinking Water Act* is to protect the quality of public water supplies and all sources of drinking water. The implementing regulations, administered by EPA unless delegated to the states, establish standards applicable to public water systems. They promulgate maximum contaminant levels (including those for radioactivity) in public water systems, which are defined as water systems that serve at least 15 service connections used by year-round residents or that regularly serve at least 25 year-round residents. EPA has promulgated *Safe Drinking Water Act* requirements in 40 CFR

Parts 100 to 149; for tritium, 40 CFR 141.16 establishes a concentration limit of 20,000 picocuries per liter. As indicated in Chapter 4, tritium concentrations under the proposed action would remain well below regulatory limits.

The Resource Conservation and Recovery Act (42 U.S.C. §§ 6901 et seq.); Tennessee Hazardous Waste Management Act (Title 68 Tennessee Code Chapter 212)

The *Resource Conservation and Recovery Act* governs the treatment, storage, and disposal of hazardous and nonhazardous waste. Pursuant to Section 3006 of the Act, any state that seeks to administer and enforce a hazardous waste program pursuant to that Act may apply for EPA authorization of its program. Tennessee has such authorization. EPA regulations implementing the Act (40 CFR Parts 260 to 280) define hazardous wastes and specify hazardous waste transportation, handling, treatment, storage, disposal, recordkeeping, and reporting requirements. The regulations imposed on a generator or a treatment, storage, or disposal facility vary according to the type and quantity of material or waste. The method of treatment, storage, or disposal affects the extent and complexity of the requirements. These regulations require that facilities obtain a *Resource Conservation and Recovery Act* permit if they store hazardous waste on site more than 90 days (for large quantity generators) or 180 days (for small quantity generators) or treat hazardous waste. TVA does not store waste beyond the periods allowed for hazardous waste generators or conduct treatment of hazardous wastes that require such a permit at its nuclear facilities; therefore, TVA does not have such permits for those facilities. Each facility does have a State of Tennessee Hazardous Waste Generator identification number and files the required documents for the generation of hazardous waste.

The *Resource Conservation and Recovery Act* does not apply to radioactive source, special nuclear, and byproduct material. In addition, the *Resource Conservation and Recovery Act* does not apply to the radioactive constituents of mixed radioactive waste (waste containing both hazardous and radioactive constituents). However, it does apply to the hazardous (that is, nonradioactive) constituent of mixed radioactive wastes [*Legal Environmental Assistance Foundation (L.E.A.F.) v. Hodel*, 586 F. Supp. 1163 (E.D. Tenn.1984)].

Federal Facility Compliance Act (42 U.S.C. § 6961)

The *Federal Facility Compliance Act* amended the *Resource Conservation and Recovery Act*. The Act waived sovereign immunity from fines and penalties for violations at the facilities of Federal agencies (including DOE and government-owned corporations such as TVA) associated with the management of mixed waste. However, TVA does not store hazardous waste at any of its nuclear facilities for longer than 90 or 180 days.

8.3 Other Requirements Related to Environmental Protection, Emergency Planning, and Worker Safety and Health

8.3.1 ENVIRONMENTAL PROTECTION

National Environmental Policy Act of 1969 (42 U.S.C. §§ 4321 et seq.); DOE Order O 451.1A.

NEPA establishes a national policy promoting awareness of the environmental consequences of human activity on the environment and consideration of environmental impacts during the planning and decision-making stages of a Federal project. This Act requires Federal agencies to prepare a detailed statement on the environmental effects of proposed major Federal actions that might significantly affect the quality of the human environment.

NNSA, with the cooperation and input of TVA, has prepared this SEIS in response to NEPA requirements and policies and in accordance with the Council on Environmental Quality (40 CFR Parts

1500 to 1508), DOE (10 CFR Part 1021, DOE Order O 451.1A), and TVA provisions for implementing the procedural requirements of NEPA. It discusses the proposed action as well as reasonable alternatives to the proposal, and their potential environmental consequences.

Executive Order 11514, Protection and Enhancement of Environmental Quality; 40 CFR Parts 1500 to 1508

Executive Order 11514 (regulated by 40 CFR Parts 1500 to 1508) requires Federal agencies to monitor and control their activities continually to (1) protect and enhance the quality of the environment, and (2) to develop procedures to ensure timely public participation and understanding of Federal plans and programs that might have environmental impacts so the views of interested parties can be obtained.

Executive Order 11988, Floodplain Management; 10 CFR Part 1022; 18 CFR Part 725

Executive Order 11988 (regulated by 10 CFR Part 1022 and 18 CFR Part 725) requires Federal agencies to establish procedures to ensure that the potential effects of flood hazards and floodplain management are considered for any action undertaken in a floodplain, and that floodplain impacts be avoided to the extent practicable. The production of tritium in the Watts Bar and Sequoyah facilities would not require further consideration of this Executive Order.

Executive Order 11990, Protection of Wetlands; 10 CFR Part 1022; 18 CFR Part 725

Executive Order 11990 (regulated by 10 CFR Part 1022 and 18 CFR Part 725) requires Federal agencies to avoid any short- and long-term adverse impacts on wetlands if there is a practicable alternative. The production of tritium in the Watts Bar and Sequoyah facilities would not require further consideration of this Executive Order.

Endangered Species Act of 1973 (16 U.S.C. §§ 1531 et seq.)

The *Endangered Species Act of 1973* prohibits Federal actions that might harm a listed endangered species or designated critical habitat, unless a special exemption is granted. Consultation with the U.S. Fish and Wildlife Service of the U.S. Department of the Interior is necessary if a proposed action is likely to affect a listed species or critical habitat (50 CFR Part 17). Preparation of a biological assessment of potential effects on listed species is also necessary for Federal actions that are "major construction activities." TVA has notified the U.S. Fish and Wildlife Service of the proposed action. As discussed in Section 3.1.6.4, the Fish and Wildlife Service concurred with the NRC's 1995 Biological Assessment that the operation of Watts Bar 1 would have no effect on Federally listed endangered or at-risk species. Several later environmental reviews (DOE 1999a; TVA 2005, 2007a) evaluated threatened and endangered species (Federal and State of Tennessee) in the vicinity of the site and reached similar conclusions of no effects on listed species. TVA and NNSA would continue to comply with the requirements of this Act, and would interact with the Fish and Wildlife Service as appropriate.

National Historic Preservation Act of 1966 (16 U.S.C. §§ 470 et seq.)

This Act provides for the placement of sites with significant national historic value on the *National Register of Historic Places* maintained by the Secretary of the Interior. Section 106 of the Act provides for an expanded *National Register* and establishes the Advisory Council on Historic Preservation (36 CFR 800.3). No permits or certifications are necessary under the Act. However, if a particular Federal activity might affect a historic resource, 16 U.S.C. § 470f requires consultation with the Advisory Council on Historic Preservation. Section 110 of the Act requires Federal agencies to identify, evaluate, inventory, and protect National Register resources on properties they control. Such consultation usually generates a Memorandum of Agreement that includes mandatory stipulations to minimize adverse impacts. Coordination with the State Historic Preservation Officer occurs to ensure proper identification of potentially significant sites and implementation of appropriate mitigative actions. Due to the small area of construction and use of previously disturbed land, NNSA does not anticipate impacts to cultural resources from construction activities. NNSA and TVA have provided information to the Tennessee State Historic Preservation Officer about the proposed action.

Pollution Prevention Act of 1990 (42 U.S.C. §§ 13101 et seq.)

The *Pollution Prevention Act of 1990* establishes a national policy for waste management and pollution control that focuses first on source reduction, then on environmentally safe recycling, treatment, and disposal. Disposal or releases to the environment should occur only as a last resort. In response, DOE has committed to participation in the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) Amendments and Reauthorization Act Section 313, U.S. EPA 33/50 Pollution Prevention Program. The goal for facilities already involved in Section 313 compliance was to achieve by 1997 a 33-percent reduction in the release of 17 priority chemicals from a 1993 baseline. On November 12, 1999, then-U.S. Secretary of Energy Bill Richardson established 14 pollution prevention and energy efficiency goals for DOE to build environmental accountability and stewardship into its decisionmaking process. Under these goals, DOE strives to minimize waste and maximize energy efficiency as measured by continuous cost-effective improvements in the use of materials and energy.

Comprehensive Guideline for Procurement of Products Containing Recovered Materials (40 CFR Part 247)

This regulation was issued under the authority of Section 6002 of the *Resource Conservation and Recovery Act* and Executive Order 12873, which established requirements for Federal agencies (including government-owned corporations) to procure products that contain recovered materials for use in their operations according to EPA guidelines. The purpose of these regulations is to promote recycling by using government purchasing to expand markets for recovered materials. Section 6002 requires that any purchasing agency, when using appropriated funds to procure an item, must purchase it with the highest practicable percentage of recovered materials. The procurement of materials TVA and NNSA would use in the tritium production program must be consistent with these regulations.

Executive Order 12856, Right-to-Know Laws and Pollution Prevention Requirements,

Executive Order 12856 requires all Federal agencies to reduce toxic chemicals entering any waste stream. This Order also requires Federal agencies to report toxic chemicals entering waste streams; improve emergency planning, response, and accident notification; and encourage clean technologies and testing of innovative prevention technologies.

Executive Order 12898, Environmental Justice

Executive Order 12898 requires Federal agencies to identify and address any disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. Sections 3.1.13, 3.2.13, 4.1.14, and 4.2.14 of this SEIS discuss environmental justice.

Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management

Executive Order 13423 requires Federal agencies to conduct their environmental, transportation, and energy-related activities under the law in support of their missions in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner. It establishes goals for energy efficiency, renewable energy, water efficiency, green procurement, toxic and hazardous chemicals and materials use reduction, sustainable buildings, vehicle energy use, and efficient electronic products.

Executive Order 13514, Federal Leadership in Environmental, Energy and Economic Performance

Executive Order 13514 requires Federal agencies to increase their energy efficiency; measure, report, and decrease their greenhouse gas emissions; preserve and protect water resources; and construct, maintain, and operate high-performance sustainable buildings.

Executive Order 12902, Energy Efficiency and Water Conservation at Federal Facilities

Executive Order 12902 requires Federal agencies, including NNSA and TVA, to develop and implement a program for conservation of energy and water resources.

8.3.2 EMERGENCY PLANNING AND RESPONSE

This section discusses laws and regulations that address the protection of public health and worker safety and require the establishment of emergency plans and coordination with local and Federal agencies. These laws relate to the operation of facilities, such as nuclear reactors, that engage directly or indirectly in the production or use of Special Nuclear Material.

NRC Requirements for Commercial Reactor Emergency Plans (10 CFR 50.47)

These regulations establish detailed requirements for the content of commercial reactor emergency plans including, among other things, roles and responsibilities; communications; training; arrangements for requesting and utilizing assistance resources; establishment of an emergency classification and action level scheme; alerting of the public, response organizations, and emergency personnel; adequacy of emergency facilities and equipment; adequacy of provisions for assessing and monitoring actual and potential offsite consequences; means for controlling exposure of emergency workers; adequacy of medical services; and the establishment of a range of protective actions for the public and emergency workers.

Commercial Nuclear Power Plant Emergency Preparedness Planning (44 CFR Part 352)

These regulations generally establish the policies, procedures, and responsibilities of the Federal Emergency Management Agency, the NRC, and NNSA for implementing a Federal Emergency Preparedness Program.

Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C. §§ 11001 et seq.) (also Known as SARA Title III)

The *Emergency Planning and Community Right-to-Know Act of 1986* requires emergency planning and notice to communities and government agencies of the presence and release of specific chemicals. EPA implements this Act under regulations in 40 CFR Parts 355, 370, and 372. Under Subtitle A of this Act, Federal facilities provide information (such as inventories of specific chemicals used or stored and any releases that occur) to the State Emergency Response Commission and the Local Emergency Planning Committee to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances.

Transportation of Hazardous Materials (49 U.S.C. §§ 5101 et seq.); Hazardous Materials Tables and Communications, Emergency Response Information Requirements (49 CFR Part 172)

These regulations define the regulatory requirements for marking, labeling, placarding, and documenting hazardous material shipments. They specify requirements for providing hazardous material information and training. Shipments of hazardous materials to and from NNSA and TVA facilities must comply with these regulations.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (42 U.S.C. §§ 9601 et seq.); National Oil and Hazardous Substance Contingency Plan (40 CFR Part 300)

More popularly known as the "Superfund Act," this Act and the implementing regulations provide the necessary general authority for Federal and state governments to respond directly to hazardous substance incidents. The regulations require reporting spills of hazardous substances to the EPA National Response Center, including [in the limited circumstances specified in 40 CFR 302.6(b)(2)] radionuclides specified in 40 CFR 302.4. Tritium production operations would have to comply with these regulations if a hazardous substance spill occurred.

8.3.3 WORKER SAFETY AND HEALTH

Occupational Safety and Health Act of 1970 (29 U.S.C. §§ 651 et seq.); Occupational Safety and Health Administration Emergency Response, Hazardous Waste Operations, and Worker Right to Know (29 CFR Part 1910)

The *Occupational Safety and Health Act of 1970* establishes standards to enhance safe, healthy working conditions in places of employment throughout the United States. The Occupational Safety and Health Administration, a U.S. Department of Labor agency, administers the Act. While that agency and EPA each have a mandate to reduce exposure to toxic substances, the Administration's jurisdiction is limited to safety and health conditions in the workplace environment. In general, under the Act, each employer must furnish all employees a place of employment that is free of recognized hazards that are likely to cause death or serious physical harm. Employees have a duty to comply with the occupational safety and health standards and all related rules, regulations, and orders. The implementing regulations (29 CFR 1910) establish specific standards that tell employers what they must do to achieve a safe, healthy working environment. These regulations establish requirements for employee safety in a variety of working environments; these requirements include employee emergency and fire prevention plans (29 CFR 1910.38), hazardous waste operations and emergency response (29 CFR 1910.120), and hazards communication (29 CFR 1910.1200) to increase employee awareness of the dangers they face from hazardous materials at their workplace.

The Act and its associated regulations do not directly apply to Federal agencies or government-owned corporations. However, Section 19 of the Act (29 U.S.C. § 668) requires all Federal agencies to have occupational safety programs "consistent" with the Act's standards. This requirement applies to government-owned corporations as well as agencies, through 5 U.S.C. § 7902 and Executive Order 12196, "Occupational Safety and Health Programs for Federal Employees." The NRC regulates radiological protection for employees of facilities it licenses.

8.4 DOE Regulations and Orders

The Atomic Energy Act makes DOE responsible for establishing a comprehensive health, safety, and environmental program for its activities. DOE carries out this responsibility through the promulgation of regulations (for example, those set forth in 10 CFR Part 830) and the issuance of DOE Orders. DOE regulations, however, do not apply to activities regulated by the NRC [see 10 CFR 830.2(a), 835.1(b)]. Therefore, DOE regulations do not apply to tritium production at the TVA reactors.

8.5 Compliance History

This SEIS considers two TVA reactor sites for tritium production. At present, only three of the four reactors proposed for potential tritium production are operating: Watts Bar 1 and Sequoyah 1 and 2. Watts Bar 2 is still under construction and not expected to be operational until 2015. This section describes each operating reactor's performance in the following areas: (1) compliance with NRC regulations, (2) compliance with environmental and nonnuclear safety regulations, (3) NRC Performance Indicators, and (4) Systematic Assessments of Licensee Performance. NNSA based the discussion on the following information sources:

- The most recent Individual Plant Performance Summaries published quarterly by the NRC,
- Other historical performance snapshots of plant performance from previous quarters, and
- NRC enforcement actions.

8.5.1 REACTOR OVERSIGHT PROCESS

The purpose of this section is not for NNSA to assess the adequacy of TVA operation of its reactors. Such an assessment is the responsibility of the NRC. This section provides information useful in determining if there are any compliance issues that would interfere with the production of tritium or create a potentially significant environmental impact. The NRC Reactor Oversight Process consists of three key strategic performance areas: reactor safety, radiation safety, and safeguards. Each area has cornerstones that reflect the essential safety aspects of facility operation. These seven cornerstones include initiating events, mitigating systems, barrier integrity, emergency preparedness, public radiation safety, occupational radiation safety, and physical protection. The NRC evaluates plant performance by analyzing two distinct inputs: findings from its inspection program and performance indicator reports by the plant operator. The Commission evaluates both inspection findings and performance indicators and gives them a color designation based on their safety significance. Green inspection findings indicate that while licensee performance is generally acceptable and meets cornerstone objectives, a deficiency has been identified that has very low risk significance and little or no impact on safety. Both Green inspection findings and performance indicators allow the licensee to implement initiatives to correct performance issues before additional NRC regulatory involvement is necessary. White, Yellow, or Red inspection findings or performance indicators represent greater degrees of safety significance and, therefore, trigger increased NRC regulatory attention. These inspection findings do not normally result in civil penalties.

8.5.2 PERFORMANCE SUMMARY

The Reactor Oversight Process combines inspection findings and performance indicators in a performance summary by quarter for each operating plant. Figures 8-1, 8-2, and 8-3 show the latest performance summaries for Watts Bar 1, Sequoyah 1, and Sequoyah 2, respectively. Because Watts Bar 2 is not yet operating, there is no performance summary.

8.5.3 NOTICES OF VIOLATIONS AND ENFORCEMENT ACTIONS

The review of each facility's NRC enforcement history presents an overview of day-to-day compliance with NRC regulations. The NRC enforcement program seeks to protect public health and safety by ensuring compliance with NRC regulations and license conditions, obtaining prompt correction of violations and conditions adverse to quality, deterring future violations, and encouraging improvement of licensee performance.

Inspections and investigations identify violations. There are three primary enforcement sanctions: Notices of Violation, civil penalties, and orders.

- A Notice of Violation summarizes the results of an inspection and formalizes a violation. Severity levels for Notices of Violation of NRC regulations range from Level I for the most significant violations to Level IV for minor concerns.

- A civil penalty is a monetary fine issued under the authority of the Atomic Energy Act. The NRC can assess civil penalties up to $110,000 per violation per day. The Commission bases Notices of Violation and civil penalties on violations of NRC requirements.

- The NRC can issue orders for violations of NRC requirements or, in the absence of a violation, as the result of the identification of any condition potentially hazardous to workers or the public.

The NRC, in the last 10 years, has issued three enforcement actions for Watts Bar 1 as listed in Table 8-1.

Table 8-1. NRC enforcement actions for Watts Bar 1 (NRC 2012b).

Action number(s)	Action type (severity) and civil penalty	Date issued	Description
EA-05-169	Notice of Violation (White)	April 7, 2006	Notice of Violation associated with a White finding involving a challenge to the reactor cooling system caused by a failure to adhere to a Technical Specification.
EA-05-036	Notice of Violation (White)	April 11, 2005	Notice of Violation associated with a White finding involving failure to identify promptly and correct silt blockage in the cooling water lines; cited failure to establish measures to ensure prompt identification and correction of conditions adverse to quality.
EA-98-327	Notice of Violation and Civil Penalty (Severity Level II) $88,000	October 15, 2001	Notice of Violation and proposed imposition of civil penalty of $88,000 for a violation involving employment discrimination against a power maintenance specialist for engaging in protected activities.

In the last 10 years, the NRC has issued two enforcement actions for Sequoyah 1 and 2 as listed in Table 8-2.

Table 8-2. NRC enforcement actions for Sequoyah 1 and 2 (NRC 2012c).

Action number(s)	Action type (severity) and civil penalty	Date issued	Description
EA-08-211	Order	January 5, 2009	Confirmatory order to confirm a settlement agreement for a violation of site security procedures involving falsification of an inventory form to verify inventory as required.
EA-04-223	Notice of Violation (White)	January 26, 2005	Notice of Violation for failure to correct conditions adverse to quality based on the identification of a problem during previous surveillance testing.

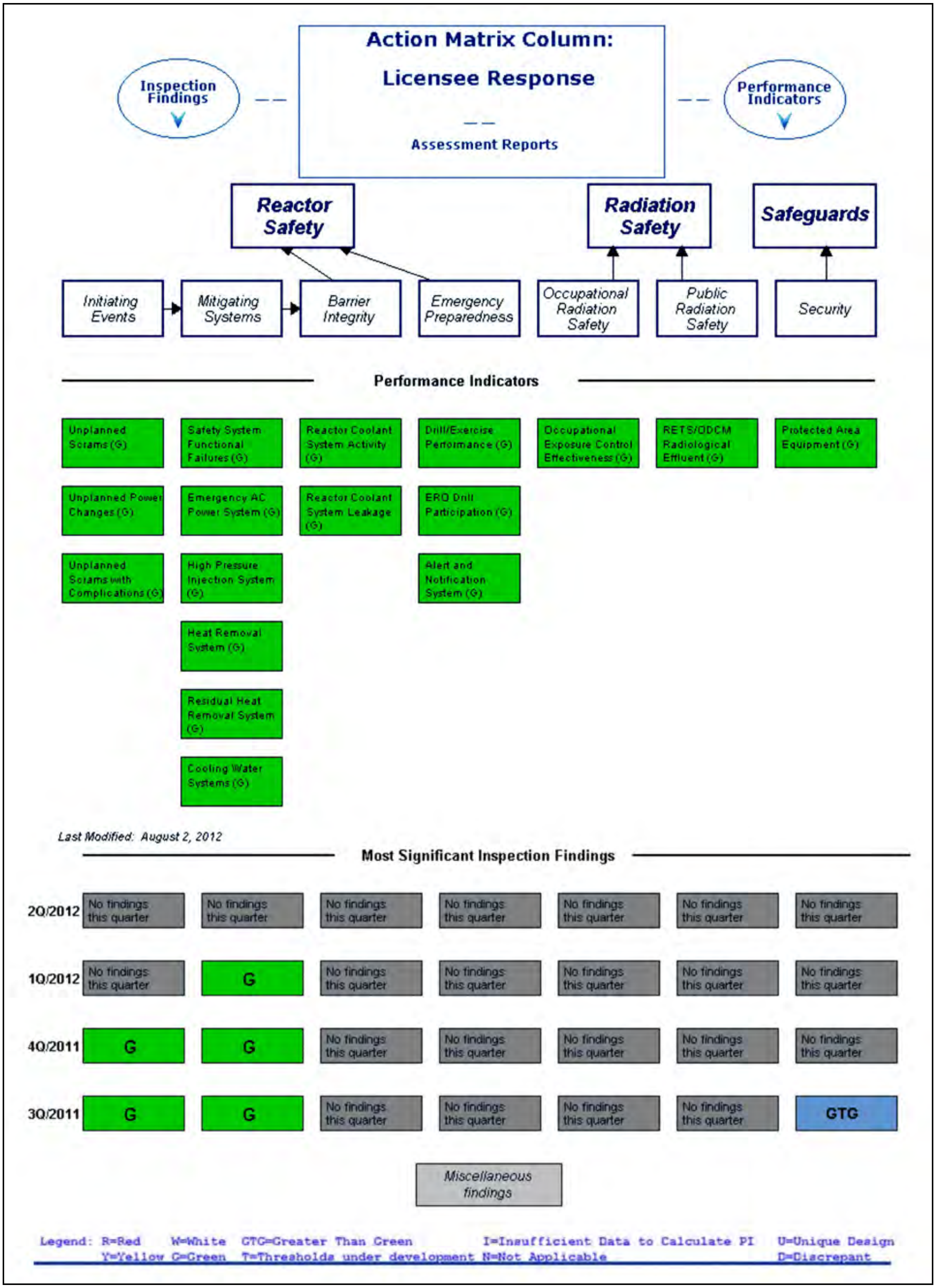

Figure 8-1. Performance summary for Watts Bar 1 (NRC 2012d).

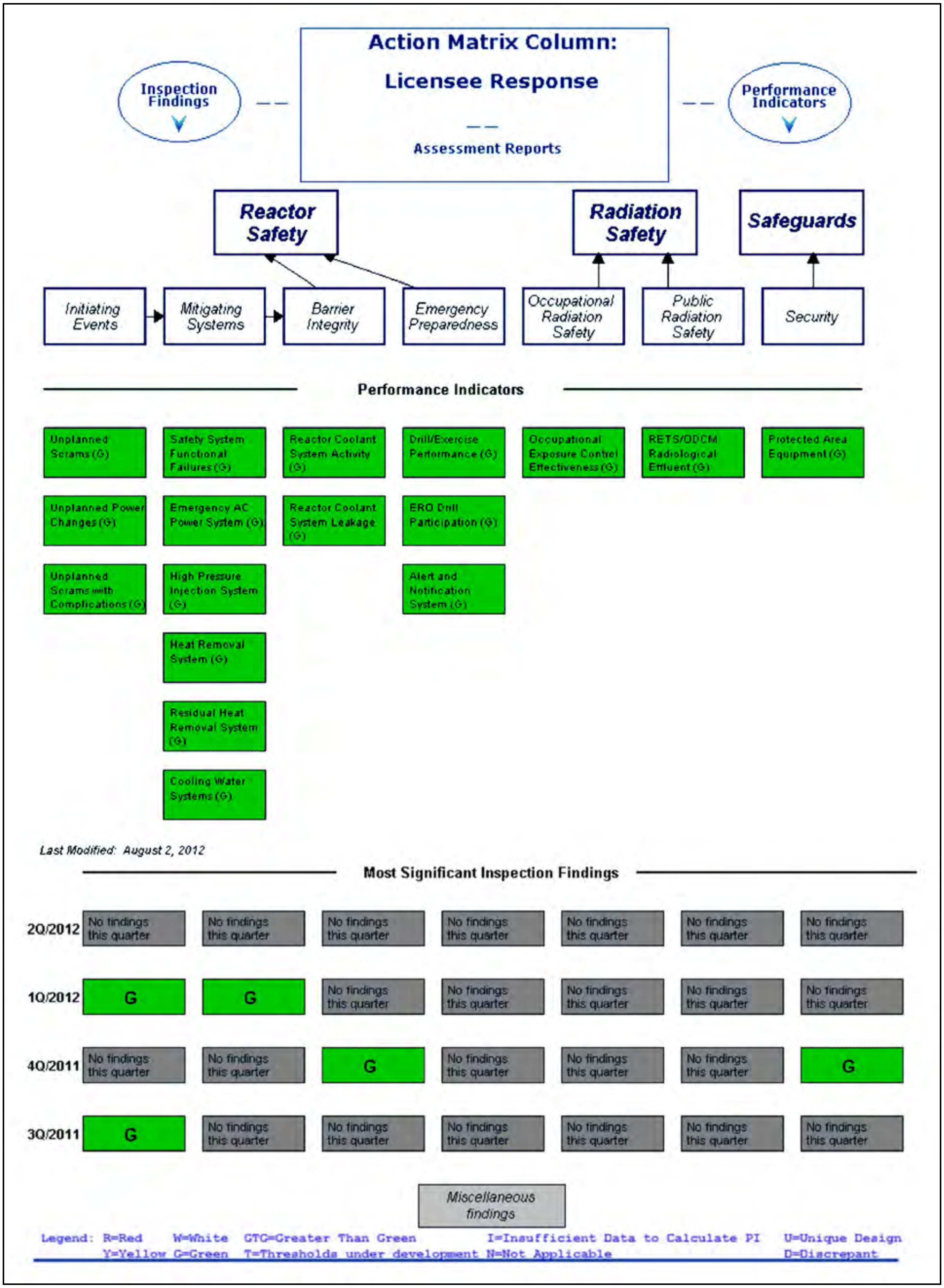

Figure 8-2. Performance summary for Sequoyah 1 (NRC 2012e).

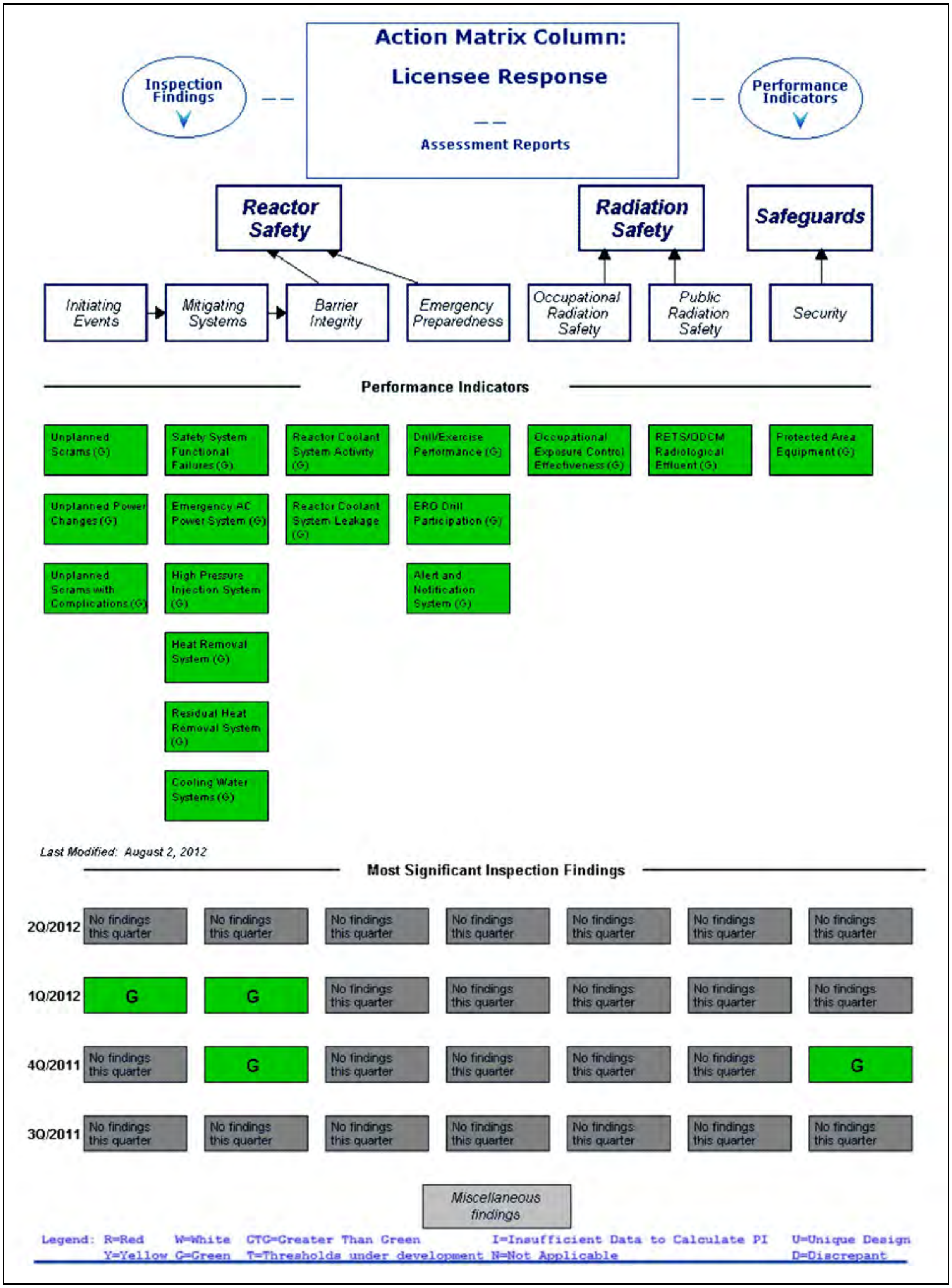

Figure 8-3. Performance summary for Sequoyah 2 (NRC 2012f).

CHAPTER 9. LIST OF PREPARERS

This chapter lists the individuals who filled primary roles in the preparation of this Supplemental Environmental Impact Statement (SEIS). Curtis Chambellan of the U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA) directed the preparation of this document. The SEIS Team, led by Steve Sohinki of JAD Environmental, provided primary support and assistance to NNSA; Tetra Tech provided additional technical assistance.

NNSA provided direction to the SEIS Team, which was responsible for developing the analytical methodology and alternatives, coordinating the work tasks, performing the impact analyses, and producing the document. NNSA was responsible for data quality, the scope and content of the SEIS, and issue resolution.

NNSA independently evaluated all supporting information and documentation these organizations prepared. Further, NNSA retained the responsibility for determining the appropriateness and adequacy of incorporating any data, analyses, and results of other work by these organizations for this SEIS. The Team was responsible for integrating such work in the document.

As required by Federal regulations [40 CFR 1506.5(c)], JAD Environmental and Tetra Tech have signed *National Environmental Policy Act* (NEPA) disclosure statements in relation to the work they performed on this SEIS. These statements appear at the end of this chapter.

Name	Education	Experience	Document responsibilities
National Nuclear Security Administration			
Curtis Chambellan	• M.S., Industrial Engineering, 2007 • M.S., National Security Strategy, 2004 • B.S., Chemical Engineering, 1979	• 28 years of experience with DOE in national defense programs including nuclear materials and tritium supply	NEPA Document Manager
Contractor			
Steve Sohinki JAD Environmental	• J.D., 1974 • B.A., Political Science, 1971	• 30 years of extensive NEPA experience • Managed several commercial reactor-related tritium EISs • Worked extensively with state and Federal regulators and stakeholder groups	Project Manager
Jay Rose Tetra Tech	• J.D., 1996 • B.S., Ocean Engineering, 1983	• 20 years of experience managing NEPA documents • U.S. Navy nuclear engineer with direct experience and expertise related to tritium-related NEPA documentation	Deputy Project Manager
Ernie Harr JAD Environmental	• B.S., Zoology, 1977	• 30 years of experience successfully managing DOE NEPA evaluations • Successfully managed numerous large multi-corporate teams using the virtual office concept	JAD Program Manager

Name	Education	Experience	Document responsibilities
Susan Walker JAD Environmental	• Ph.D., Pathology, 1982 • B.S., Zoology, 1975	• 34 years of NEPA experience • Expertise in DOE and U.S. Nuclear Regulatory Commission NEPA requirements	Document Integrator (until May 2011)
Jim Denier JAD Environmental	• M.B.A., Business, 1990 • B.A., Zoology, 1978	• 25 years managing and developing DOE and other agency NEPA documentation	Document Integrator (since May 2011)
John Shipman JAD Environmental	• B.A., English, 1966	• 45 years of experience writing, editing, and managing the production of scientific documents, including DOE NEPA documents • Fellow of the Society for Technical Communication	Document Production Manager
Wendy Arjo JAD Environmental	• Ph.D., Fish and Wildlife Biology, 1998 • M.S., Biology, 1992 • B.S., Biology, 1990	• 10 years of NEPA experience in conducting Endangered Species Act Section 7 consultations, special species and habitat status, and potential impacts to sensitive resources	Lead Analyst – Biological Resources
Tonya Bartels JAD Environmental	• M.S., Analytical Chemistry, 1994 • B.S., Chemistry, 1991	• 14 years of NEPA experience for DOE, U.S. Department of Defense, and U.S. Army Corps of Engineers projects	Lead Analyst – Land Use, Noise, and Visual Resources
Pixie Baxter JAD Environmental	• M.B.A., Management and Economics • B.A., Art History	• 25 years of professional experience in multidisciplinary economic and business area applications in planning and research capacities and regulatory analysis	Lead Analyst – Socioeconomics and Environmental Justice
Jacqueline Boltz Tetra Tech	• M.B.A., Business, 1991 • B.A., French Language and Literature, 1991	• 21 years of experience providing public outreach support, planning and executing public meetings and related workshops, and coordinating meeting logistics for NEPA documents	Public Affairs
Max Clausen Tetra Tech	• M.B.A., 1980 • B.S., Nuclear Engineering, 1970	• 40 years of nuclear experience • Project Manager/Office Director in DOE Office of Tritium Supply and Recycling	Technical Consultant
Steve Connor Tetra Tech	• M.S., Physics, 1974 • B.S., Physics, 1973	• 30 years of professional experience, including radiological transportation risk assessments for NEPA documentation	Transportation

Name	Education	Experience	Document responsibilities
David Crowl JAD Environmental	• B.A., Computer Science, 1985	• 27 years NEPA documentation, technical editing and writing, publications management	Document Production Team – Lead Editor
Keith Davis JAD Environmental	• M.S., Civil and Environmental Engineering, 1976 • B.S., Civil Engineering, 1973	• 30 years of diverse environmental experience • Extensive experience with Federal and numerous state environmental regulations • Registered Professional Engineer (Civil) in Idaho, Arizona, and Utah	Lead Analyst – Water Quality and Resources
Greg Fasano JAD Environmental	• M.B.A., Business Administration, 1988 • B.S., Geology, 1982	• 27 years of extensive environmental experience • Extensive experience with state and Federal regulators and tribal and other stakeholder groups	Lead Analyst – Archaeological and Cultural Resources
Al Feldt Tetra Tech	• B.A., Economics, 1971	• 25 years of experience in environmental regulatory compliance and managing DOE NEPA documents	Lead Analyst – Waste Management
Henry Garson Tetra Tech	• J.D., 1967 • B.S., Finance, 1964	• 30 years of experience in the preparation, review, and management of NEPA documents for DOE/NNSA and other Federal agencies • Expert in developing strategy for complex NEPA documents	Regulatory Compliance and Comment Response
Tracy Ikenberry JAD Environmental	• M.S., Radiology and Radiation Biology, 1982 • B.A., Biology, 1979	• 28 years of relevant radiological and nonradiological assessment experience for fuel-cycle and non-fuel-cycle commercial and defense nuclear facilities • Certified Health Physicist; Diplomate, American Board of Health Physics (Comprehensive), 1988	Lead Analyst – Health and Safety, Accidents, and Intentionally Destructive Acts
Maher Itani Tetra Tech	• M.E.A., Engineering Administration, 1987 • B.S., Civil Engineering, 1985	• 20 years of experience in commercial construction management and environmental engineering • Project manager, technical lead, and quality assurance officer for more than 25 DOE NEPA documents	Lead Analyst – Infrastructure and Utilities

Name	Education	Experience	Document responsibilities
Robin Klein JAD Environmental	• One year of college courses	• 27 years of experience in word processing, desktop publishing, and graphic design	Document Production Team – Word Processing and Graphics
Joe Rivers JAD Environmental	• B.S., Mechanical Engineering, 1982 • Engineering Science and Mechanics post-graduate work	• 30 years of experience in commercial and DOE nuclear projects, NEPA and regulatory compliance, systems engineering, and safety analysis	Cumulative Impacts
Gene Rollins JAD Environmental	• M.S.P.H., Radiological Hygiene, 1976 • B.S., Nuclear Engineering, 1973	• 33 years of experience in health physics and risk assessments related to the nuclear fuel cycle • Certified Health Physicist (American Board of Health, 1982) • Certified Hazardous Materials Manager, Master Level (Ret.)	Project Engineer; Lead Analyst – Transportation
Leroy Shaser JAD Environmental	• M.S., Geology, 1978 • B.S., Geology, 1976	• 15 years of experience in NEPA analysis, including air quality, health and safety, and utilities and infrastructure • Geographic Information Systems and computer mapping proficiency	Lead Analyst – Air Quality and Climate
Ali Simpkins JAD Environmental	• M.S., Nuclear Engineering, 1991 • B.S., Nuclear Engineering, 1989	• 20 years of experience in the areas of environmental assessment and nuclear safety analyses	Analyst – Human Health and Safety
Mike Skougard Tetra Tech	• M.S., Botany, 1976 • B.S., Law Enforcement, 1970	• 29 years of NEPA experience • Hands-on site/facility NEPA experience • Broad experience in various environmental areas	Quality Assurance
Joanne Stover JAD Environmental	• B.S., Business Administration, 1997	• 23 years of experience with technical document development, including preparing administrative records for NEPA documents	Records Management
David Wertz Tetra Tech	• M.S., Geophysics, 2001 • B.S., Environmental Science, 1998	• 10 years of experience with geologic and hydrogeologic site investigations • Geology resource lead for several DOE NEPA documents	Lead Analyst – Geology and Soils

Name	Education	Experience	Document responsibilities
Phil Young Tetra Tech	• M.S., Health Physics, 1989 • B.S., Radiation Health, 1988	• 23 years of professional experience in environmental radiological programs • Lead analyst for accident analysis for major nuclear facility EISs	Analyst – Accidents and Intentionally Destructive Acts

NEPA DISCLOSURE STATEMENT
SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR THE PRODUCTION OF TRITIUM IN A COMMERCIAL LIGHT WATER REACTOR
DOE/EIS-0288-S1

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare an EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purposes of this disclosure is defined in the March 23, 1981 guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations," 46 FR 8026-18038 at Question 17a and b.

> "*Financial or other interest in the outcome of the project*" includes "*any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)*." 46 FR 18026-18038 at 18031.

In accordance with these requirements, the offeror and any proposed subcontractors hereby certify as follows: (check either (a) or (b) to assure consideration of your proposal).

(a) ___X____ Offeror and any proposed subcontractor have no financial or other interest in the outcome of the project.

(b) _______ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interests
1.
2.
3.

Certified by:

Ernest C. Harr, Jr. Manager
J.A.D. Environmental, LLC

July 20, 2012
Date

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE *SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR THE PRODUCTION OF TRITIUM IN A COMMERCIAL LIGHT WATER REACTOR*

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare an EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purposes of this disclosure is defined in the March 23, 1981 guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations," 46 FR 8026-18038 at Question 17a and b.

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In accordance with these requirements, the offeror and any proposed subcontractors hereby certify as follows: (check either (a) or (b) to assure consideration of your proposal).

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<u>Financial or Other Interests</u>

1.

2.

3.

Certified by

Signature

Mark E. Smith, Vice President
Printed Name and Title

Tetra Tech
Company

July 20, 2012
Date

CHAPTER 10. GLOSSARY

The U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA) has provided this glossary to assist readers in the interpretation of this *Supplemental Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (SEIS). The glossary includes definitions of technical and regulatory terms common to DOE *National Environmental Policy Act of 1969* documents and explains these terms with their most likely meanings in the context of this SEIS. To better aid the reader, a number of terms in this glossary emphasize their project-specific relationship to the proposed action in the SEIS.

***accident sequence* —** An initiating event followed by system failures or operator errors, which can result in significant core damage, confinement system failure, or radionuclide releases.

***activation products* —** Nuclei, usually radioactive, formed by the bombardment and absorption of material with neutrons, protons, or other nuclear particles.

***acute exposure* —** The exposure incurred during and shortly after a radiological release. In general, the period of acute exposure ends with the establishment of long-term interdiction, as necessary. The period of acute exposure is generally assumed to end 1 week after the inception of a radiological accident.

***air pollutant* —** Any substance in the air that could, if in a high enough concentration, harm man, animals, vegetation, or material.

***alpha activity* —** The emission of alpha particles by radioactive materials. Gross alpha activity is a measure of disintegration of radioactive elements in terms of the total emitted alpha particles with no determination of their energy or the specific radionuclides involved.

***alpha particle* —** A positively charged particle, consisting of two protons and two neutrons, that is emitted during radioactive decay from the nucleus of certain nuclides. An alpha particle is identical to the nucleus of a helium-4 atom. It is the least penetrating of the three common types of radiation (alpha, beta, and gamma).

***alpha radiation* —** See alpha particle.

***ambient air* —** The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air closest to an emission source.

***aquatic* —** Living or growing in, on, or near water.

***aquatic biota* —** The sum total of living organisms in a designated aquatic area.

***aquatic macrophytes* —** Visible plants occurring in water.

***aquifer* —** A saturated geologic unit through which significant quantities of water can migrate under natural hydraulic gradients.

***archaeological site* —** Any location where humans have altered the terrain or left artifacts during prehistoric or historic times.

***Archaic period* —** The North American archaeological period dating from 8000 B.C. to 1000 B.C.

***as low as is reasonably achievable* —** A concept applied to ensure the quantity of radioactivity released to the environment and the radiation exposure of onsite workers in routine operations, including “anticipated operational occurrences,” is maintained as low as is reasonably achievable. It takes into account the state of technology, economics of improvements in relation to benefits to public health and safety, and other societal and economic considerations in relation to the use of nuclear energy in the public interest.

***atmospheric dispersion* —** The process of air pollutants being dispersed in the atmosphere. This is due to the wind that carries the pollutants away from their source, and to turbulent air motion that results from solar heating of the Earth’s surface and air movement over rough terrain and surfaces.

***Atomic Energy Act of 1954* —** The statute that established U.S. requirements with respect to nuclear energy and nuclear materials. This Act, as amended, provides the statutory framework for government control of the possession, use, and production of atomic energy, Special Nuclear Material, and other radioactive material, whether owned by the government or others.

atomic mass — The atomic mass is the total mass of protons, neutrons, and electrons in an atom. An approximation of the atomic mass can be determined by adding up the number of protons and neutrons in an atom.

atomic number — The number of positively charged protons in the nucleus of an atom.

***A-weighted decibel* —** A unit of sound pressure level that accounts for the frequency response of the human ear. The decibel is a logarithmic unit of sound measurement that describes the magnitude of a particular quantity of sound pressure in relation to a standard reference value. In general, a sound doubles in loudness for every increase of 10 decibels.

***barrier* —** Any material or structure that prevents or substantially delays movement of radionuclides toward the accessible environment.

***baseline* —** A quantitative expression of conditions, costs, schedule, or technical progress to serve as a base or standard for comparison during the performance of an effort; the established plan against which the status of resources and progress of a project can be measured. For this SEIS, the environmental baseline consists of site environmental conditions as they exist or have been estimated to exist in the absence of the proposed action.

***benthic* —** Plants and animals dwelling at the bottom of oceans, lakes, rivers, and other surface waters.

***beta particle* —** A charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron; a positively charged beta particle is called a “positron.” Of the three common types of radiation (alpha, beta, and gamma), beta is more penetrating than alpha, but less penetrating than gamma.

beta radiation — See beta particle.

***biocide* —** In this document, chemicals added to cooling water to keep the water and system surfaces clear of biological buildup (as might be caused by algae or mollusks).

***biodiversity* —** The diversity of life in all its forms and all its levels of organization. Also called “biological diversity.”

***biota (biotic)* —** The plant and animal life of a region (pertaining to biota).

***blowdown* —** A maintenance procedure to remove sediment in power plant components.

***boost* —** The process by which fusion of deuterium-tritium gas inside the pit of a nuclear weapon produces neutrons that increase the fission output of the primary.

***boron-10* —** An isotope of the element boron that has a high-capture cross-section for neutrons. It is used in reactor absorber rods for reactor control.

Bureau of Labor Statistics — The principal fact-finding agency for the Federal Government in the broad field of labor economics and statistics. The Bureau is an independent national statistical agency that collects, processes, analyzes, and disseminates essential statistical data to the American public, the U.S. Congress, other Federal agencies, State and local governments, business, and labor. The Bureau also serves as a statistical resource to the U.S. Department of Labor.

***burnable absorber* —** A material, such as boron or lithium, that captures neutrons and transmutes or changes to another isotope.

***cancer* —** The name given to a group of diseases characterized by uncontrolled cellular growth with cells having invasive characteristics such that the disease can transfer from one organ to another.

***capacity factor* —** The ratio of the annual average power production of a power plant to its rated capacity.

***carbon dioxide (CO_2)* —** A colorless, odorless gas that is a normal component of the ambient air; it results from fossil fuel combustion and is an expiration product.

***carbon monoxide (CO)* —** A colorless, odorless, poisonous gas produced by incomplete fossil fuel combustion.

***cesium* —** A silver-white alkali metal. A radioactive isotope of cesium, cesium-137, is a common fission product.

***chronic exposure* —** Low-level radiation exposure incurred over a long period due to residual contamination.

***cladding* —** The metal tube that forms the outer jacket of a nuclear fuel rod or burnable absorber rod. It prevents the release of radioactive material into the coolant. Stainless steel and zirconium alloys are common cladding materials.

***Class I areas* —** National parks and wilderness areas designated by the Prevention of Significant Deterioration section of the Clean Air Act amendments. These amendments and the implementing regulations provide special protection to air quality and air quality-related values in such areas. Only very slight deterioration of air quality is allowed in Class I areas.

***Clean Air Act* —** This Act mandates and provides for enforcement of regulations to control air pollution from various sources.

***Code of Federal Regulations (CFR)* —** All Federal regulations in force are published in codified form in the Code of Federal Regulations.

commercial light water reactor (CLWR) — A term used to describe commercially operated power-producing U.S. reactors that use "light" (as opposed to "heavy") water for cooling and neutron moderation.

committed dose equivalent — The predicted total dose equivalent to a tissue or organ over a 50-year period after an intake of a radionuclide into the body. It does not include external dose contributions. Committed dose equivalent is expressed in units of rem or Sievert. The committed effective dose equivalent is the sum of the committed dose equivalents to various tissues of the body, each multiplied by the appropriate weighting factor.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 — A Federal law (also known as "Superfund") that provides a comprehensive framework to deal with past or abandoned hazardous materials. The Act provides for liability, compensation, cleanup, and emergency response for hazardous substances released to the environment that could endanger public health, welfare, or the environment, as well as the cleanup of inactive hazardous waste disposal sites.

consolidation — Inserting the irradiated tritium-producing burnable absorber rods (TPBARs) from several fuel assemblies into a container in preparation for shipment to the Tritium Extraction Facility at the Savannah River Site in South Carolina.

consumptive water use — The difference in the volume of water withdrawn from a body of water and the amount released back into the body of water.

control rod — A rod containing material such as boron that is used to control the power of a nuclear reactor. By absorbing excess neutrons, a control rod prevents the neutrons from causing further fissions (that is, increasing power).

coolant — A substance, either gas or liquid, circulated though a nuclear reactor or processing plant to remove heat.

criteria pollutants — The *Clean Air Act* required the U.S. Environmental Protection Agency to set air quality standards for common and widespread pollutants after preparing "criteria documents" summarizing scientific knowledge on their health effects. Today there are standards in effect for six "criteria pollutants": sulfur dioxide, carbon monoxide, particulate matter with aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) and less than or equal to 2.5 micrometers in diameter ($PM_{2.5}$), nitrogen dioxide, ozone, and lead.

critical habitat — Defined in the *Endangered Species Act of 1973* as "specific areas within the geographical area occupied by [an endangered or threatened] species, essential to the conservation of the species and which may require special management considerations or protection; and specific areas outside the geographical area occupied by the species that are essential for the conservation of the species."

cultural resources — Artifacts, archaeological sites, historical sites, architectural features, traditional use areas, and American Indian sacred sites.

cumulative impacts — In an environmental impact statement, the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal), private industry, or individual(s) undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over time (40 CFR 1508.7).

***curie* —** A unit of radioactivity equal to 37 billion disintegrations per second; also, a quantity of any nuclide or mixture of nuclides with 1 curie of radioactivity.

***day-night average sound level* —** The 24-hour A-weighted equivalent sound level expressed in decibels, with a 10-decibel penalty added to sound levels between 10:00 p.m. and 7:00 a.m. to account for increased annoyance due to noise during nighttime hours.

***decay (radioactive)* —** The decrease in the amount of any radioactive material with the passage of time due to the spontaneous transformation of an unstable nuclide to a different nuclide or a different energy state of the same nuclide; the emission of nuclear radiation (alpha, beta, or gamma radiation) is part of the process.

***deciduous* —** Trees that shed leaves at a certain season.

***decontamination* —** Actions taken to reduce or remove substances that pose a substantial present or potential hazard to human health or the environment, such as radioactive or chemical contamination from facilities, equipment, or soils by washing, heating, chemical or electrochemical action, mechanical cleaning, or other techniques.

***design-basis* —** For nuclear facilities, information that identifies the specific functions to be performed by a structure, system, or component and the specific values (or ranges of values) chosen for controlling parameters for reference bounds for design. These values can be (1) restraints derived from generally accepted state-of-the-art practices for achieving functional goals; (2) requirements derived from analysis (based on calculation or experiment) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals; or (3) requirements derived from Federal safety objectives, principles, goals, or requirements.

***design-basis accident* —** For nuclear facilities, a postulated abnormal event that is used to establish the performance requirements of structures, systems, and components that are necessary to (1) maintain them in a safe shutdown condition indefinitely; or (2) prevent or mitigate the consequences of the design-basis accident so the general public and operating staff are not exposed to radiation in excess of appropriate guideline values.

***design-basis events* —** Postulated disturbances in process variables that can potentially lead to design-basis accidents.

***deuterium* —** A naturally occurring, stable isotope of the element hydrogen (also called hydrogen-2), with a nucleus consisting of a single proton and a single neutron. Deuterium is chemically identical to hydrogen-1 and tritium. Approximately 0.01% of all hydrogen is deuterium. Both "H-2" and "D" are used as the symbols for deuterium.

***direct jobs* —** The number of workers required at a site to implement an alternative.

***dispersants* —** In this SEIS, chemicals added to cooling water to keep particulate matter suspended and less likely to adhere to cooling system surfaces and possibly cause fouling.

***diurnal* —** Showing a periodic alteration with day and night.

***dose* —** The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad.

dose commitment — The dose an organ or tissue would receive during a specified period (for example, 50 to 100 years) as a result of intake (by ingestion or inhalation) of one or more radionuclides from a defined release, frequently over a year's time.

dose equivalent — The product of absorbed dose in rad (or grays) and a quality factor, which quantifies the effect of this type of radiation in tissue. Dose equivalent is expressed in units of rem or sievert, where 1 rem equals 0.01 sievert.

drift — Effluent mist or spray carried into the atmosphere from cooling towers.

drinking water standards — The level of constituents or characteristics in a drinking water supply specified in regulations under the *Safe Drinking Water Act* as the maximum permissible.

dual use (dual benefit) — Projects that have uses in or benefits for the defense sector and the private industry or civilian sector.

effective dose equivalent — The sum of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health effects risk to the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides, and the effective dose equivalent due to penetrating radiation from sources external to the body. Effective dose equivalent is expressed in units of rem or sievert.

effluent — A gas or fluid discharged to the environment.

effluent (liquid) — Wastewater, treated or untreated, that flows from a treatment plant, sewer, or industrial outfall; generally refers to wastes discharged to surface waters.

electron — An elementary particle with a negative charge and a mass 1/1,837 that of a proton. Electrons surround the positively charged nucleus of an atom and determine its chemical properties.

emergency condition — For a nuclear facility, occurrences or accidents that might occur infrequently during startup testing or operation of the facility. Equipment, components, and structures might be deformed by these conditions to the extent that repair is required before reuse.

emission — A material discharged to the atmosphere from a source operation or activity.

emission standards — Legally enforceable limits on the quantities and kinds of air contaminants that might be emitted to the atmosphere.

endangered species — A species that is in danger of extinction throughout all or significant portions of its range. The *Endangered Species Act of 1973*, as amended, establishes procedures for placing species on the Federal lists of endangered or threatened species.

Endangered Species Act of 1973 — The Act requires Federal agencies, with the consultation and assistance of the Secretaries of the Interior and Commerce, to ensure that their actions will be unlikely to jeopardize the continued existence of any endangered or threatened species or adversely affect the habitat of such species.

***enriched uranium* —** Uranium in which the abundance of the isotope uranium-235 is increased above the normal (naturally occurring) level of 0.711 weight percent.

***entrained gases* —** In this SEIS, gases entrapped as small bubbles in flowing liquid, as opposed to dissolved gases that might be dispersed at the molecular level in the same flowing liquid.

***entrainment* —** The involuntary capture and inclusion of organisms in streams of flowing water; a term often applied to the cooling water systems of power reactors. The organisms involved can include phyto- and zooplankton, fish eggs and larvae (ichthyoplankton), shellfish larvae, and other forms of aquatic life.

***environmental impact statement (EIS)* —** A document required of Federal agencies by the *National Environmental Policy Act of 1969* for major proposals or legislation significantly affecting the environment. A tool for decisionmaking, it describes the positive and negative effects of the undertaking and alternative actions.

***environmental justice* —** The fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment implies that no population of people should be forced to shoulder a disproportionate share of the negative environmental impacts of pollution or environmental hazards due to a lack of political or economic influence.

***epidemiology* —** The science concerned with the study of events that determine and influence the frequency and distribution of disease, injury, and other health-related events and their causes in a defined human population.

***equivalent sound (pressure) level* —** The equivalent steady sound level that, if continuous during a specified period, would contain the same total energy as the actual time varying sound. For example, L_{eq}(1-hr) and L_{eq} (24-hr) are the 1-hour and 24-hour equivalent sound levels, respectively.

***exposure limit* —** The level of exposure to a hazardous chemical (set by law or a standard) at which or below which adverse human health effects are unlikely to occur:

(1) Reference dose is the chronic exposure dose (milligrams or kilograms per day) for a given hazardous chemical at which or below which adverse human noncancer health effects are unlikely to occur.

(2) Reference concentration is the chronic exposure concentration (milligrams per cubic meter) for a given hazardous chemical at which or below which adverse human noncancer health effects are unlikely to occur.

***fault* —** A fracture or a zone of fractures in a rock formation along which vertical, horizontal, or transverse slippage has occurred. A normal fault occurs when the hanging wall has been depressed in relation to the footwall. A reverse fault occurs when the hanging wall has been raised in relation to the footwall.

***fissile materials* —** Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning, namely, any material fissionable by thermal (slow) neutrons. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239.

fission (fissioning) — The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

fission products — Nuclei formed by the fission of heavy elements (primary fission products); also, the nuclei formed by the decay of the primary fission products, many of which are radioactive.

floodplain — The lowlands adjoining inland and coastal waters and relatively flat areas.

formation — In geology, the primary unit of formal stratigraphic mapping or description. Most formations possess certain distinctive features.

fuel assembly — A cluster of fuel rods. Also called a fuel element. Approximately 200 fuel assemblies make up a reactor core.

fuel rod — Nuclear reactor component that includes the fissile material.

gamma radiation — See gamma rays.

gamma rays — High-energy, short-wavelength, electromagnetic radiation that accompanies fission and either emitted from the nucleus of an atom or emitted by some radionuclide or fission product. Of the three common types of radiation (alpha, beta, and gamma), gamma rays are the most penetrating and can be stopped only by dense materials (such as lead) or a thick layer of shielding materials.

genetic effects — The outcome resulting from exposure to mutagenic chemicals or radiation that results in genetic changes in germ line or somatic cells.

(1) Effects on genetic material in reproductive cells cause trait modifications that can be passed from parents to offspring.

(2) Effects on genetic material in nonreproductive cells result in tissue or organ modifications (for example, liver tumors) that do not pass from parents to offspring.

geology — The science that deals with the Earth: the materials, processes, environments, and history of the planet, including the rocks and their formation and structure.

getter — Material that absorbs free tritium gas and chemically binds it within its own structure. One such structure is zirconium alloy.

global warming — The theory that certain gases such as carbon dioxide, methane, and chlorofluorocarbon in the Earth's atmosphere effectively restrict radiation cooling, thereby elevating the Earth's ambient temperatures.

groundwater — The supply of water found beneath the Earth's surface, usually in aquifers, that can supply wells and springs.

habitat — The environment occupied by individuals of a particular species, population, or community.

half-life — The time in which half the atoms of a radioactive isotope decay to another nuclear form. Half-lives vary from millionths of a second to billions of years.

***hazardous air pollutants* —** Air pollutants known or suspected to cause serious health problems such as cancer, poisoning, or sickness; might have immunological, neurological, reproductive, developmental, or respiratory effects.

***hazardous chemical* —** Under 29 CFR 1910, Subpart Z, "hazardous chemicals" are defined as "any chemical which is a physical hazard or a health hazard." Physical hazards include combustible liquids, compressed gases, explosives, flammables, organic peroxides, oxidizers, pyrophorics, and reactive substances. A health hazard is any chemical for which there is good evidence that acute or chronic health effects occur in exposed employees. Hazardous chemicals include carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes, or mucous membranes.

***hazardous material* —** A material, including a hazardous substance, as defined by 49 CFR 171.8, that poses a risk to health, safety, and property when transported or handled.

***hazardous waste* —** A byproduct of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity) or appears on special U.S. Environmental Protection Agency lists.

heavy water — A rare form of water; it is a molecule with two hydrogen-2 (deuterium) atoms and one oxygen atom (D_2O).

heavy water reactor — A nuclear reactor in which circulating heavy water is used to cool the reactor core and to moderate (reduce the energy of) the neutrons created in the core by the fission reactions.

***helium-3* —** A nonradioactive isotope of the element helium that is produced as a tritium decay product.

***helium-4* —** The naturally occurring isotope of the element helium that is a byproduct in the atomic conversion of lithium to tritium.

***historic resources* —** Archaeological sites, architectural structures, and objects produced after the advent of written history dating to the time of the first Euro-American contact in an area.

hydrogen-1 — A naturally occurring, stable isotope of the element hydrogen, with a nucleus consisting of a single proton. Approximately 99.99% of all hydrogen is hydrogen-1.

hydrogen-2 — See deuterium.

hydrogen-3 — See tritium.

***hydrology* —** The science dealing with the properties, distribution, and circulation of natural water systems.

***impingement* —** The process by which aquatic organisms too large to pass through the screens of a water intake structure become caught on the screens and are unable to escape.

***ionizing radiation* —** Alpha particles, beta particles, gamma rays, neutrons, high-speed electrons, high-speed protons, and other particles or electromagnetic radiation that can displace electrons from atoms or molecules, thereby producing ions.

***irradiation* —** The process of applying radiation to an object or substance.

***isotope* —** An atom of a chemical element with a specific atomic number and atomic mass. Isotopes of the same element have the same number of protons, but different numbers of neutrons and different atomic masses.

***joule* —** A metric unit of energy, work, or heat, equivalent to 1 watt-second, 0.737 foot-pound, or 0.239 calories.

***lacustrine* —** Found or formed in lakes; also, a type of wetland situated on or near a lake.

***latent cancer fatalities* —** Fatalities due to cancer from acute or chronic exposure to radiation or environmental pollutants that occur substantially after the exposure. That is, the fatality, and most often the cancer itself, is not an immediate effect.

***license amendment* —** Changes to a reactor's operating license that are approved by the U. S. Nuclear Regulatory Commission.

***light water* —** The common form of water; a molecule with two hydrogen-1 atoms and one oxygen atom (that is, H_2O).

***light water reactor* —** A nuclear reactor in which circulating light water is used to cool the reactor core and to moderate (reduce the energy of) the neutrons created in the core by the fission reactions.

***lithium-6* —** The isotope of the element lithium that changes to tritium and helium-4 when a neutron is absorbed by the lithium nucleus.

***loss-of-coolant accident* —** An accident that results from the loss of reactor coolant because of a break in the reactor coolant system.

***low-level radioactive waste* —** Waste that contains radioactivity, but is not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined by Section 11e (2) of the *Atomic Energy Act of 1954*, as amended. Test specimens of fissionable material irradiated for research and development only, and not for the production of power or plutonium, can be classified as low-level waste, provided the concentration of transuranic waste is less than 100 nanocuries per gram. Some low-level waste is classified because of the nature of the generating process or constituents, because the waste would tell too much about the process.

***macrophyte* —** A member of the macroscopic plant life, especially in a body of water.

***maximally exposed offsite individual* —** A hypothetical person who could receive the maximum dose of radiation or hazardous chemicals.

***megawatt* —** A unit of power equal to 1 million watts. "Megawatt-thermal" is commonly used to define heat produced, while "megawatt-electric" defines electricity produced.

***Mississippian period* —** The North American archaeological period dating from 500 A.D. to 1200 A.D.

***mixed waste* —** Waste that contains both "nonradioactive hazardous waste" and "radioactive waste" as defined in this glossary.

***mixed-oxide fuel* —** A blend of plutonium oxide and depleted uranium dioxide in reactor fuel form that behaves similarly to the low-enriched uranium U.S. commercial nuclear power reactors use.

***modeling* —** The use of a computer to develop a mathematical model of a complex system or process and to provide conditions for testing it.

***moderator* —** A material used to decelerate neutrons in a reactor from high energies to low energies.

***Modified Mercalli Intensity Scale* —** The effect of an earthquake on the Earth's surface is called the intensity. The Modified Mercalli Intensity Scale consists of a series of certain key responses such as people awakening, movement of furniture, damage to chimneys, and—finally—total destruction. The scale consists of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, which are designated by Roman numerals. It does not have a mathematical basis; rather, it is an arbitrary ranking based on observed effects.

***mollusks* —** Unsegmented, invertebrate animals including gastropods, pelecypods, and cephalopods.

***National Ambient Air Quality Standards* —** Uniform, national air quality standards established by the Environmental Protection Agency under the authority of the *Clean Air Act* that restrict ambient levels of criteria pollutants to protect public health (primary standards) or public welfare (secondary standards), including plant and animal life, visibility, and materials. Standards have been set for ozone, carbon monoxide, particulates, sulfur dioxide, nitrogen, nitrogen dioxide, and lead.

***National Emission Standards for Hazardous Air Pollutants* —** A set of national emission standards for listed hazardous pollutants emitted from specific classes or categories of new and existing sources.

***National Environmental Policy Act of 1969 (NEPA)* —** This Act is the basic national charter for the protection of the environment. It requires the preparation of an environmental impact statement for every major Federal action that could significantly affect the quality of the human or natural environment. Its main purpose is to provide environmental information to decisionmakers so their actions are based on an understanding of the potential environmental consequences of a proposed action and its reasonable alternatives.

***National Historic Preservation Act of 1966* —** This Act provides that property resources with significant national historic value be placed on the *National Register of Historic Places*. It does not require any permits, but, pursuant to Federal code, if a proposed action might affect an historic property resource, it mandates consultation with the proper agencies.

***National Nuclear Security Administration (NNSA)* —** A separately organized agency within the U.S. Department of Energy that was established in March 2000 to be responsible for providing the Nation with nuclear weapons and ensuring those weapons remain safe and reliable.

***National Pollutant Discharge Elimination System* —** Federal permitting system required for water pollution effluents under the *Clean Water Act*, as amended.

***National Register of Historic Places* —** A list maintained by the Secretary of the Interior of districts, sites, buildings, structures, and objects of prehistoric or historic local, state, or national significance under Section 2(b) of the *Historic Sites Act of 1935* (16 U.S.C. § 462) and § 101(a)(1)(A) of the National *Historic Preservation Act of 1966*.

natural and manmade radiation — Ionizing radiation present in the environment. Natural radiation includes radiation from cosmic rays and from the Earth's rocks and soil. Manmade sources of radiation include medical and dental x-rays, household smoke detectors, and materials released from nuclear and coal-fired power plants. The levels of natural and manmade radiation vary considerably with location.

neutron — An uncharged elementary particle with a mass slightly greater than that of the proton, found in the nucleus of every atom heavier than hydrogen-1. A free neutron is unstable and decays with a half-life of about 13 minutes into an electron and a proton; used in the fission process.

nitrogen oxides — The oxides of nitrogen, primarily nitrogen oxide (NO) and nitrogen dioxide (NO_2). These are produced in the combustion of fossil fuels and can constitute an air pollution problem. Nitrogen dioxide emissions contribute to acid deposition and formation of atmospheric ozone.

noise — Any sound that is undesirable because it interferes with speech and hearing, or is intense enough to damage hearing, or is otherwise annoying (unwanted sound).

nonattainment area — An air quality control region (or portion thereof) in which the Environmental Protection Agency has determined that ambient air concentrations exceed national ambient air quality standards for one or more criteria pollutants.

nonpotable (or nonpotable water system) — not fit for drinking

Notice of Intent — Announces the scoping process. The Notice of Intent is usually published in the *Federal Register* and a local newspaper. The scoping process includes holding at least one public meeting and requesting written comments on what issues and environmental concerns an environmental impact statement should address.

nuclear fuel cycle — The path followed by nuclear fuel in its various states from mining the ore to waste disposal. The basic fuel materials for the generation of nuclear power are the elements uranium and thorium.

nuclear material — Composite term applied to (1) Special Nuclear Material; (2) source material such as uranium, thorium, or ores that contain uranium or thorium; and (3) byproduct material, which is material that becomes radioactive by exposure to a radiation incident or to the process of producing or using Special Nuclear Material.

Nuclear Nonproliferation Treaty — An international treaty signed in 1968 and extended in 1996 that seeks to limit nuclear weapons capabilities to the five countries (United States, France, England, Russia, and China) that possessed such weapons before 1967.

nuclear power plant — A facility that converts nuclear energy into electrical power. In a commercial light water reactor, heat produced in the reactor is used to make steam, which drives a turbine connected to an electric generator.

nuclear reaction — A reaction in which an atomic nucleus is transformed into another isotope of that respective nuclide, or into another element altogether; it is always accompanied by the liberation of either particles or energy.

nuclear reactor — A device that sustains a controlled nuclear fission chain reaction that releases energy in the form of heat.

***nuclide* —** A species of atom characterized by the constitution of its nucleus and, hence, by the number of protons, the number of neutrons, and the energy content.

***Occupational Safety and Health Administration* —** Federal agency that oversees and regulates workplace health and safety, created by the *Occupational Safety and Health Act of 1970*.

***outfall* —** The discharge point of a drain, sewer, or pipe as it empties into a body of water.

***ozone* —** The triatomic form of oxygen; in the stratosphere, ozone protects the Earth from the sun's ultraviolet rays, but in lower levels of the atmosphere, ozone is considered an air pollutant.

***palustrine* —** Found or formed in marshes; also, a type of wetland situated in or near a marsh.

***particulate matter* —** Air pollutants including dust, dirt, soot, smoke, or liquid droplets emitted into the air. "Total suspended particulate" was first used as the indicator for particulate concentrations. Current standards use the indicators "PM_{10}" and "$PM_{2.5}$," which include only particles with an aerodynamic diameter smaller than or equal to 10 micrometers and 2.5 micrometers, respectively. The smaller particles are more responsible for adverse health effects because they reach further into the respiratory tract.

***permeation* —** In relation to tritium, the movement of radionuclides from within a tritium-producing burnable absorber rod into the reactor coolant water.

***person-rem* —** The unit of collective radiation dose to a given population; the sum of the individual doses received by a population segment.

***plume* —** A flowing, often somewhat conical, trail of emissions from a continuous point source.

***potable (or potable water system)* —** Fit for drinking.

***Prevention of Significant Deterioration* —** An Environmental Protection Agency program, mandated by the *Clean Air Act*, in which state or Federal permits are required to limit increases in air pollutant concentrations by restricting emissions for new or modified sources in places where air quality is already better than required to meet primary and secondary ambient air quality standards.

***primary system* —** In relation to nuclear reactors, the system that circulates a coolant (for example, water) through the reactor core to remove the heat of reaction.

***probable maximum flood* —** Flood levels predicted for a scenario with hydrological conditions that maximize the flow of surface waters.

***proliferation (nuclear)* —** The spread of nuclear weapons and the materials and technologies used to produce them.

proton — An elementary nuclear particle with a positive electric charge located in the nucleus of an atom.

***rad* —** The basic unit of absorbed dose equal to the absorption of 0.01 joule per kilogram of absorbing material. The word derives from *radiation absorbed dose*.

***radiation* —** See *ionizing radiation*.

radioactive waste — Materials from nuclear operations that are radioactive or are contaminated with radioactive materials, and for which use, reuse, or recovery are impractical.

radioactivity — The spontaneous decay or disintegration of unstable atomic nuclei, accompanied by the emission of radiation.

radionuclide — A radioactive element characterized according to its atomic mass and atomic number, which can be manmade or naturally occurring.

radon — Gaseous, radioactive element with the atomic number 86 resulting from the radioactive decay or radium. Radon occurs naturally in the environment, and can collect in unventilated enclosed areas, such as basements. Large concentrations of radon can cause lung cancer in humans.

RADTRAN — A computer program that combines user-determined meteorological, demographic, transportation, packaging, and material factors with health physics data to calculate expected radiological consequences and accident risk of transporting radioactive material.

reactor coolant system — The system used to transfer energy from the reactor core directly or indirectly to the heat rejection system.

reactor core —In a light water reactor, the fuel assemblies including the fuel and target rods, control rods, and coolant or moderator.

Record of Decision — A document prepared in accordance with the requirements of the Council on Environmental Quality and *National Environmental Policy Act of 1969* regulations (40 CFR 1505.2) that provides a concise public record of the decision on a proposed Federal action for which an agency prepared an environmental impact statement. A Record of Decision identifies the alternatives the agency considered in reaching the decision, the environmentally preferable alternative(s), factors balanced in making the decision, whether the agency adopted all practicable means to avoid or minimize environmental harm and if not, why not.

recycling — In relation to tritium in nuclear weapons, the recovery, purification, and reuse of tritium in tritium reservoirs in the nuclear weapons stockpile.

region of influence — A site-specific geographic area in which impacts could occur. Regions of influence are specific to each resource area.

rem — A measure of radiation dose (the average background radiation dose is 0.3 rem per year). The unit of biological dose equal to the product of the absorbed dose in rads; a quality factor, which accounts for the variation in biological effectiveness of different types of radiation; and other modifying factors. The word derives from *roentgen equivalent in man*.

remediation — The process, or a phase in the process, of rendering radioactive, hazardous, or mixed waste environmentally safe, whether through processing, entombment, or other methods.

Resource Conservation and Recovery Act — The Act that provides a "cradle-to-grave" regulatory program for hazardous waste that established, among other things, a system for managing hazardous waste from its generation to its ultimate disposal.

riparian — Of, on, or relating to the banks of a natural course of water.

***risk* —** A quantitative or qualitative expression of possible loss that considers both the probability that a hazard will cause harm and the consequences of that event.

***risk assessment (chemical or radiological)* —** The qualitative and quantitative evaluation performed to define the risk to human health or the environment from the presence or potential presence or use of specific chemical or radiological materials.

***roentgen* —** A unit of exposure to ionizing, X- or gamma-ray radiation equal to or producing 1 electrostatic unit of charge per cubic centimeter of air. It is approximately equal to 1 rad.

***runoff* —** The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and eventually enters streams.

***Safe Drinking Water Act* —** This Act protects the quality of public water supplies, water supply and distribution systems, and all sources of drinking water.

***sanitary waste* —** Wastes generated by normal housekeeping activities, liquid or solid (including sludge), which are not hazardous or radioactive.

***scope* —** In a document an agency prepares pursuant to the *National Environmental Policy Act of 1969*, the range of actions, alternatives, and impacts the agency considered.

***scoping* —** The solicitation of comments from interested persons, groups, and agencies at public meetings, public workshops, in writing, electronically, or by facsimile to assist in defining the proposed action, identifying alternatives, and developing preliminary issues to be addressed in an environmental impact statement.

***secondary system* —** The system that circulates a coolant (water) through a heat exchanger to remove heat from the primary system.

***seismic* —** Pertaining to any Earth vibration, especially an earthquake.

***severe accident* —** An accident with a frequency of less than 1×10^{-6} per year that would have more severe consequences than a design-basis accident, in terms of damage to the facility, offsite consequences, or both. This SEIS also calls them “beyond-design-basis accidents.”

***sewage* —** The total of organic waste and wastewater generated by an industrial establishment or community.

***shielding* —** In relation to radiation, any material of obstruction (bulkheads, walls, or other construction) that absorbs radiation to protect personnel or equipment.

***short-lived nuclides* —** Radioactive isotopes with half-lives no greater than about 30 years (for example, cesium-137 and strontium-90).

***silt* —** A sedimentary material consisting of fine mineral particles intermediate in size between sand and clay.

***source term* —** The estimated quantities of radionuclides or chemical pollutants released to the environment.

Special Nuclear Material — Defined by Title I of the *Atomic Energy Act of 1954* as plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235. The definition includes any other material the U.S. Nuclear Regulatory Commission determines to be Special Nuclear Material, but does not include source material. The Commission has not declared any other material as Special Nuclear Material.

sulfur oxides — Common air pollutants, primarily sulfur dioxide (SO_2), a heavy, pungent, colorless gas formed in the combustion of fossil fuels, which is a major air pollutant, and sulfur trioxide. Sulfur dioxide is involved in the formation of acid rain. It can irritate the upper respiratory tract and cause lung damage.

surface water — Water on the Earth's surface, as distinguished from water in the ground (groundwater).

surfactants — In this SEIS, chemicals added to cooling water to keep unwanted constituents, often insoluble hydrocarbons, dispersed so they do not coalesce and possibly foul the cooling system.

technical specifications — In relation to U.S. Nuclear Regulatory Commission regulations, part of a license authorizing the operation of a nuclear reactor facility. A technical specification establishes requirements for items such as safety limits, limiting safety system settings, limiting control settings, limiting conditions for operation, surveillance requirements, design features, and administrative controls.

threatened species — Any species designated under the *Endangered Species Act of 1973* as likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Toxic Substances Control Act of 1976 — This Act authorizes the Environmental Protection Agency to secure information on all new and existing chemical substances and to control any of these substances determined to cause an unreasonable risk to public health or the environment. It requires that the Environmental Protection Agency review the health and environmental effects of all new chemicals before they are manufactured for commercial purposes.

toxic waste — Any solid waste (can be semisolid or liquid, or contain gaseous material) with the characteristics of ignitability, corrosivity, toxicity, or reactivity, defined by the *Resource Conservation and Recovery Act* and identified or listed in 40 CFR Part 261 or by the *Toxic Substances Control Act of 1976*.

tritiated water — Water in which some water molecules have one or more tritium (hydrogen-3) atoms (that is, HTO or T_2O) rather than normal hydrogen-1 atoms (that is, H_2O).

tritium — A radioactive isotope of hydrogen. It has two neutrons and one proton in the nucleus (ordinary hydrogen contains one proton and no neutrons in the nucleus). Tritium is chemically identical to hydrogen-3 and deuterium. Both "H-3" and "T" are used as symbols to designate tritium. Tritium has a half-life of 12.3 years, meaning that every 12.3 years half of the tritium atoms decay to another nuclear form. As a result of this relatively short half-life, an amount of tritium will reduce by 10 percent in 2 years, 25 percent in 5 years, 50 percent in 12.3 years, and 90 percent in 42 years.

Tritium Extraction Facility — A facility for the extraction of tritium from tritium-producing burnable absorber rods at the Savannah River Site in Aiken, South Carolina.

tritium-producing burnable absorber rods (TPBARs) — Rods that replace the normally used burnable absorber rods in a reactor to produce tritium. TPBARs contain lithium-6.

***U.S. Nuclear Regulatory Commission* —** The Federal agency that regulates the civilian nuclear power industry in the United States.

***uranium* —** A heavy, silvery-white metallic element (atomic number 92) with several radioactive isotopes that is used as fuel in nuclear reactors.

***volatile organic compounds* —** A broad range of organic compounds, often halogenated, that vaporize at ambient or relatively low temperatures, such as benzene, chloroform, and methyl alcohol. With regard to air pollution, any organic compound that participates in atmospheric photochemical reaction, with the exception of those designated by the Environmental Protection Agency administrator as having negligible photochemical reactivity.

***waste minimization and pollution prevention* —** An action that economically avoids or reduces the generation of waste and pollution by source reduction, reducing the toxicity of hazardous waste and pollution, improving energy use, or recycling. These actions will be consistent with the general goal of minimizing present and future threats to human health, safety, and the environment.

***whole-body dose* —** In relation to radiation, the dose from the uniform exposure of all organs and tissues in a human body.

***Woodland period* —** The North American archaeological period dating from 1000 B.C. to 500 A.D.

***zebra mussel* —** An imported mussel that interferes with, among other things, water intake structures.

***Zircaloy* —** An alloy of zirconium metal used as getter material in tritium-producing burnable absorber rods.

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APPENDIX A. PUBLIC NOTICES

APPENDIX A. PUBLIC NOTICES

This appendix provides copies of public notices the National Nuclear Security Administration (NNSA) issued in relation to this Supplemental Environmental Impact Statement (SEIS). It includes copies of:

- The *Federal Register* Notice of Intent NNSA issued to announce its intention to prepare this SEIS and solicit comments about its scope, and

- The newspaper advertisement for the public scoping meeting.

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DEPARTMENT OF ENERGY

National Nuclear Security Administration

Notice of Intent To Prepare a Supplemental Environmental Impact Statement (SEIS) for the Production of Tritium in a Commercial Light Water Reactor

AGENCY: National Nuclear Security Administration (NNSA), U.S. Department of Energy (DOE).

ACTION: Notice of intent to prepare a supplemental environmental impact statement and conduct public scoping meetings.

SUMMARY: The Council on Environmental Quality's implementing regulations for the National Environmental Policy Act (NEPA) and DOE's NEPA implementing regulations require the preparation of a supplement to an environmental impact statement (EIS) when there are substantial changes to a proposal or when there are significant new circumstances or information relevant to environmental concerns. DOE may also prepare a SEIS at any time to further the purposes of NEPA. Pursuant to these provisions, the NNSA, a semi-autonomous agency within DOE, intends to prepare a SEIS to update the environmental analyses in DOE's 1999 EIS for the Production of Tritium in a Commercial Light Water Reactor (CLWR EIS; DOE/EIS–0288). The CLWR EIS addressed the production of tritium in Tennessee Valley Authority (TVA) reactors using tritium-producing burnable absorber rods (TPBARs). In the Record of Decision (ROD) for the CLWR EIS, NNSA selected TVA's Watts Bar Unit 1 and Sequoyah Units 1 and 2, located in Spring City and Soddy-Daisy, Tennessee, respectively, for tritium production. TVA has been producing tritium for NNSA at Watts Bar Unit 1 since 2004.

After several years of tritium production experience at TVA's Watts Bar Unit 1, NNSA has determined that tritium permeation through TPBAR cladding into the reactor cooling water occurs at a higher rate than previously projected. The proposed SEIS will analyze the potential environmental impacts associated with increased tritium permeation levels observed since 2004; DOE's revised estimate of the maximum number of TPBARs required to support the current Nuclear Posture Review tritium supply requirements; and proposed changes to TVA facilities that may be used for future tritium production. TVA will be participating as a cooperating agency in the preparation of the SEIS. Any other agency that would like to be a cooperating agency in the preparation of the SEIS is requested to contact the SEIS Document Manager as noted in this Notice under **ADDRESSES**.

DATES: NNSA invites comments on the scope of the SEIS. The public scoping period starts with the publication of this Notice in the **Federal Register** and will continue until November 14, 2011. NNSA will consider all comments received or postmarked by that date in defining the scope of the SEIS. Comments received or postmarked after that date will be considered to the extent practicable. A public scoping meeting is scheduled to be held on October 20, 2011, from 6:30 p.m. to 10 p.m.

ADDRESSES: The public scoping meeting will be held at the Southeast Tennessee Trade and Conference Center, Athens, TN. NNSA will publish additional notices on the date, time, and location of the scoping meeting in local newspapers in advance of the scheduled meeting. Any necessary changes will be announced in the local media. The scoping meeting will provide the public with an opportunity to present comments, ask questions, and discuss issues with NNSA officials regarding the SEIS.

Written comments or suggestions concerning the scope of the SEIS or requests for more information on the SEIS and public scoping process should be directed to: Mr. Curtis Chambellan, Document Manager for the SEIS, U.S. Department of Energy, National Nuclear Security Administration, Box 5400, Albuquerque, New Mexico 87185–5400; facsimile at 505–845–5754; or e-mail at: *tritium.readiness.seis@doeal.gov*. Mr. Chambellan may also be reached by telephone at 505–845–5073.

FOR FURTHER INFORMATION CONTACT: For general information on the NNSA NEPA process, please contact: Ms. Mary Martin, NNSA NEPA Compliance Officer, U.S. Department of Energy, 1000 Independence Avenue, SW., Washington, DC 20585, or telephone 202–586–9438. For general information about the DOE NEPA process, please contact: Ms. Carol Borgstrom, Director, Office of NEPA Policy and Compliance (GC–54), U.S. Department of Energy, 1000 Independence Avenue, SW., Washington, DC 20585, or telephone 202–586–4600, or leave a message at 1–800–472–2756. Additional information about the DOE NEPA process, an electronic archive of DOE NEPA documents, and other NEPA resources are provided at *http://energy.gov/nepa*.

SUPPLEMENTARY INFORMATION NNSA is responsible for supplying nuclear materials for national security needs and ensuring that the nuclear weapons stockpile remains safe and reliable. Tritium, a radioactive isotope of hydrogen, is an essential component of every weapon in the U.S. nuclear weapons stockpile. Unlike other nuclear materials used in nuclear weapons, tritium decays at a rate of 5.5 percent per year. Accordingly, as long as the Nation relies on a nuclear deterrent, the tritium in each nuclear weapon must be replenished periodically. The last reactor used for tritium production during the Cold War was shut down in 1988. Since then, tritium requirements for the stockpile have largely been met from the existing original inventory through the harvest and recycle of tritium gas during the dismantlement of weapon systems, and the replacement of tritium-containing weapons components as part of Limited Life Component Exchange programs. In December 1999, a new tritium production capability was established through an Interagency Agreement with TVA in which TPBARs are irradiated in the Watts Bar Unit 1 commercial nuclear power reactor and undergo extraction at the Tritium Extraction Facility (TEF) located at DOE's Savannah River Site (SRS) in South Carolina. In order to continue to provide the required supply, irradiation will increase from today's 544 TPBARs per fuel cycle to a projected steady state rate of approximately 1,700 TPBARs per fuel cycle, *i.e.*, approximately every 18 months.

To provide sufficient capacity to ensure the ability to meet projected future stockpile requirements, NNSA and TVA anticipate requesting authorization for TPBAR irradiation to be increased in fiscal year 2016 to a level that is beyond currently licensed rates for one reactor. Meeting the increased demand will require a license amendment from the Nuclear Regulatory Commission (NRC) to permit the irradiation of a greater number of TPBARs per reactor than can currently be irradiated at either the Watts Bar or Sequoyah site. License amendments are reactor specific. NNSA and TVA will supplement the 1999 CLWR EIS with analyses supporting the anticipated license amendment requests that also evaluate a higher level of tritium permeation through TPBAR cladding into the reactor cooling water than was previously analyzed. The tritium releases associated with the proposed increase in the number of TPBARs that could be irradiated at Watts Bar, Sequoyah, or both sites (compared to the number currently authorized by the NRC) would remain below Environmental Protection Agency (EPA) and NRC regulatory limits. Subsequently, TVA plans to adopt the SEIS for use in obtaining the necessary NRC license amendment(s).

The production of tritium in a CLWR is technically straightforward. All of the Nation's supply of tritium has been produced in reactors. Most commercial pressurized water reactors were designed to utilize 12-foot-long rods containing an isotope of boron (boron-10) in ceramic form. These rods are sometimes called burnable absorber rods. The rods are inserted in the reactor fuel assemblies to absorb excess neutrons produced by the uranium fuel in the fission process for the purpose of controlling power in the core at the beginning of an operating cycle. DOE's tritium program developed TPBARs in which neutrons are absorbed by a lithium aluminate ceramic rather than boron ceramic. While the two types of rods function in a very similar manner to absorb excess neutrons in the reactor core, there is one notable difference: When neutrons strike the lithium aluminate ceramic material in a TPBAR, tritium is produced inside the TPBAR. These TPBARs are placed in the same locations in the reactor core as the standard boron burnable absorber rods. There is no fissile material (uranium or plutonium) in the TPBARs. Tritium produced in TPBARs is captured almost instantaneously in a solid zirconium material in the rod, called a "getter." The getter material that captures the tritium is very effective. During each reactor refueling cycle, the TPBARs are removed from the reactor and transported to SRS. At SRS, the TPBARs are heated in a vacuum at the TEF to extract the tritium from the getter material.

DOE's May 1999 Consolidated Record of Decision for Tritium Supply and Recycling (64 FR 26369) announced the selection of TVA's Watts Bar Unit 1, Sequoyah Unit 1 and Sequoyah Unit 2 for use in irradiating TPBARs and stated that a maximum of approximately 3,400 TPBARs would be irradiated per reactor during each 18-month fuel cycle. Since then, the projected need for tritium has decreased significantly. NNSA has determined that tritium demand to supply the Nuclear Weapons Stockpile could be satisfied using a maximum of approximately 2,500 TPBARs per fuel cycle, with a projected steady state number of approximately 1,700 TPBARs per fuel cycle.

Purpose and Need

Although NNSA's projected need for tritium to support the nuclear weapons stockpile today is less than originally planned, a higher than expected rate of permeation of tritium from TPBARs into reactor coolant water and subsequent release to the environment has restricted the number of TPBARs irradiated at TVA's Watts Bar Unit 1. Before TVA increases tritium production rates to meet expected national security requirements, the environmental analyses in the CLWR EIS are being updated to analyze and evaluate the effects of the higher tritium permeation, as well as any potential effects related to other changes in the regulatory and operating environment since publication of the original CLWR EIS.

As a cooperating agency in the preparation of the SEIS, TVA plans to use the SEIS in pursuing NRC licensing amendments to increase TPBAR irradiation at TVA's Watts Bar Nuclear Plant (WBN) at Spring City, Tennessee, and/or the Sequoyah Nuclear Plant at Soddy-Daisy, Tennessee, beyond levels set in 2002. Four alternatives are expected to be analyzed in the SEIS: The No Action Alternative and three action alternatives, one using only the Watts Bar site, one using only the Sequoyah site, and one using both the Watts Bar and Sequoyah sites. As a matter of note, in a separate proceeding, DOE and TVA are also analyzing the potential use of mixed oxide fuel during some fuel cycles at the Sequoyah Nuclear Plant as part of the U.S. program for surplus plutonium disposition (75 FR 41850, July 19, 2010).

Proposed Action and Alternatives

The CLWR EIS assessed the potential impacts of irradiating up to 3,400 TPBARs per reactor unit operating on 18 month fuel cycles. It included TPBAR irradiation scenarios using multiple reactor units to achieve a maximum level of 6,000 TPBARs every 18 months. Subsequently, tritium production requirements have been reduced such that irradiation of approximately 1,700 TPBARs every reactor fuel cycle is expected to be sufficient to fulfill current requirements, consistent with the 2010 Nuclear Posture Review. To provide flexibility in future tritium supply decisions, the revised environmental analysis is expected to consider irradiation of up to a total of 2,500 TPBARs every 18 months. This approach would provide sufficient reserve capacity to accommodate potential future changes in requirements and to allow for production above currently expected annual requirement levels for short durations (i.e., several years) to recover from potential future shortfalls should that become necessary.

In the CLWR EIS, the permeation of tritium through the TPBAR cladding into the reactor coolant systems of potential tritium production reactors was estimated to be less than or equal to one tritium curie/TPBAR/year. After several years of tritium production experience at Watts Bar Unit 1, NNSA has determined that tritium permeation through TPBAR cladding is approximately three to four times higher than this estimate; nevertheless, tritium releases have been below regulatory limits. To conservatively bound the potential environmental impacts, the SEIS will assess the impacts associated with tritium production in CLWRs based on a permeation rate of approximately five tritium curies/TPBAR/year.

An assessment of tritium mitigation and management measures will be included as part of the environmental analyses in the SEIS. Mitigation and management measures include an assessment of technologies commercially available to treat tritiated effluents, transportation of tritiated effluents and/or low level radioactive waste streams, and other applicable effluent management actions.

The SEIS, which will supplement the 1999 CLWR EIS, will support agency deliberations regarding potential changes in the tritium production at NRC licensed TVA facilities in order to meet the requirements of TVA's agreement with NNSA. These changes also require TVA to pursue an NRC license amendment request for these facilities. Accordingly, the SEIS is expected to substantially meet NRC requirements for an environmental report necessary to support TVA's license amendment request(s) for tritium production at the Watts Bar and/or Sequoyah Nuclear Plants.

No Action Alternative: Produce tritium at currently approved TVA facilities (Watts Bar Unit 1 and Sequoyah Units 1 and 2) at appropriate levels to keep permeation levels within currently approved NRC license and regulatory limits.

Alternative 1: Utilize TVA's Watts Bar site only to a maximum level of 2,500 TPBARs every reactor fuel cycle (18 months).

Alternative 2: Utilize TVA's Sequoyah site only to a maximum level of 2,500 TPBARs every 18 months.

Alternative 3: Utilize both the Watts Bar and Sequoyah sites to a maximum total level of 2,500 TPBARS every 18 months. The level of production per site would be determined by TVA. This alternative would provide the ability to supply stockpile requirements at either site independently, or using both sites with each supplying a portion of the supply.

Preliminary Identification of Environmental Issues

NNSA has tentatively identified the issues for analysis in the SEIS. Additional issues may be identified as a result of the scoping comment process. The SEIS will analyze the potential impacts on:

1. Air, water, soil, and visual resources.
2. Plants and animals, and their habitats, including state and Federally-listed threatened or endangered species and their critical habitats.
3. Irretrievable and irreversible consumption of natural resources and energy, including transportation issues.
4. Cultural resources, including historical and pre-historical resources and traditional cultural properties.
5. Infrastructure and utilities.
6. Socioeconomic conditions.
7. Human health under routine operations and accident conditions, including potential impacts from seismic events.
8. Minority and low-income populations (Environmental Justice).
9. Intentional Destructive Acts, including terrorist acts.
10. Other past, present, and reasonably foreseeable actions (cumulative impacts).

SEIS Process and Invitation to Comment. The SEIS scoping process provides an opportunity for the public to assist the NNSA in determining issues and alternatives to be addressed in the SEIS. One public scoping meeting will be held as noted under DATES in this Notice. The purpose of the scoping meeting is to provide attendees with an opportunity to present comments, ask questions, and discuss issues regarding the SEIS with NNSA officials. Comments can also be mailed to Mr. Chambellan as noted in this Notice under ADDRESSES. The SEIS scoping meeting will include an informal open house from 6:30–7 p.m. to facilitate dialogue between NNSA and the public. Once the formal scoping meeting begins at 7:00 pm, NNSA will present a brief overview of the SEIS process and provide individuals the opportunity to give written or oral statements. NNSA welcomes specific scoping comments or suggestions on the SEIS. Copies of written comments and transcripts of oral comments provided to NNSA during the scoping period will be available on the Internet at *http://nnsa.energy.gov/nepa/clwrseis.*

After the close of the public scoping period, NNSA will begin preparing the Draft SEIS. NNSA expects to issue the Draft SEIS for public review in 2012. A **Federal Register** Notice of Availability, along with notices placed in local newspapers, will provide dates and locations for public hearings on the Draft SEIS and the deadline for comments on the draft document. Persons who submit comments with a mailing address during the scoping process will receive a copy of or link to the Draft SEIS. Other persons who would like to receive a copy of or link to the Draft SEIS for review should notify Mr. Chambellan at the address noted under ADDRESSES. NNSA will include all comments received on the Draft SEIS, and responses to those comments in the Final SEIS.

Issuance of the Final SEIS is currently anticipated to take place in 2013. NNSA

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will issue a ROD no sooner than 30 days after publication of EPA's Notice of Availability of the Final SEIS.

Issued in Washington, DC, this 23rd day of September 2011.

Thomas P. D'Agostino,

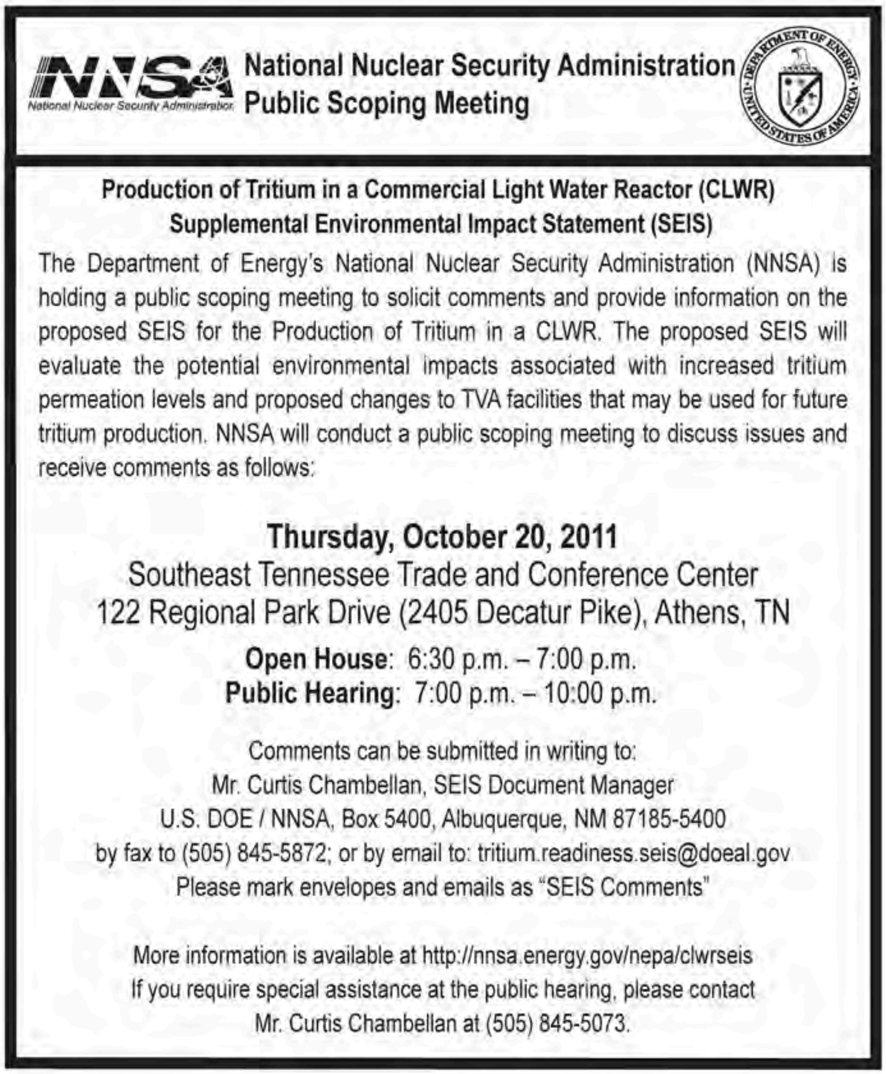
Administrator, National Nuclear Security Administration.

[FR Doc. 2011–24947 Filed 9–27–11; 8:45 am]

BILLING CODE 6450–01–P

NNSA placed the advertisement below in the following newspapers on the indicated dates:

- *The Daily Post-Athenian*, Athens, Tennessee, October 13 and 19;
- *The Herald News*, Dayton, Tennessee, October 12 and 19;
- *Advocate and Democrat*, Monroe County, Tennessee, October 12 and 20;
- *Chattanooga Times Free Press*, Chattanooga, Tennessee, October 13, 14, and 19;
- *Knoxville News Sentinel*, Knoxville, Tennessee, October 14 and 18;
- *The Oak Ridger*, Oak Ridge, Tennessee, October 14 and 19;
- *Crossville Chronicle*, Crossville, Tennessee, October 14 and 19; and
- *Roane County News*, Roane County, Tennessee, October 14 and 19.



National Nuclear Security Administration
Public Scoping Meeting

Production of Tritium in a Commercial Light Water Reactor (CLWR)
Supplemental Environmental Impact Statement (SEIS)

The Department of Energy's National Nuclear Security Administration (NNSA) is holding a public scoping meeting to solicit comments and provide information on the proposed SEIS for the Production of Tritium in a CLWR. The proposed SEIS will evaluate the potential environmental impacts associated with increased tritium permeation levels and proposed changes to TVA facilities that may be used for future tritium production. NNSA will conduct a public scoping meeting to discuss issues and receive comments as follows:

Thursday, October 20, 2011
Southeast Tennessee Trade and Conference Center
122 Regional Park Drive (2405 Decatur Pike), Athens, TN

Open House: 6:30 p.m. – 7:00 p.m.
Public Hearing: 7:00 p.m. – 10:00 p.m.

Comments can be submitted in writing to:
Mr. Curtis Chambellan, SEIS Document Manager
U.S. DOE / NNSA, Box 5400, Albuquerque, NM 87185-5400
by fax to (505) 845-5872; or by email to: tritium.readiness.seis@doeal.gov
Please mark envelopes and emails as "SEIS Comments"

More information is available at http://nnsa.energy.gov/nepa/clwrseis
If you require special assistance at the public hearing, please contact
Mr. Curtis Chambellan at (505) 845-5073.

APPENDIX B. DISTRIBUTION LIST

APPENDIX B. DISTRIBUTION LIST

The National Nuclear Security Administration (NNSA) provided copies of this *Draft Supplemental Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (SEIS), or the Summary of the SEIS, to Federal, state, and local elected and appointed government officials and agencies; American Indian representatives; national, state, and local environmental and public interest groups; and other organizations and individuals. NNSA sent the SEIS—complete printed copy, a printed Summary with an electronic copy (CD-ROM), or an electronic copy of the entire SEIS, as requested—to interested parties. NNSA will provide printed or electronic copies of the Summary or the complete SEIS on request, and has posted the SEIS on the Internet at http://nnsa.energy.gov/nepa/tritiumseis and http://energy.gov/nepa/nepa-documents.

U.S. Senate

Lamar Alexander, Tennessee
Bob Corker, Tennessee

U.S. Senate Committees

Barbara Mikulski, Chairman, Committee on Appropriations
Richard Shelby, Ranking Member, Committee on Appropriations
Mary Landrieu, Chairman, Committee on Energy and Natural Resources
Lisa Murkowski, Ranking Member, Committee on Energy and Natural Resources
Barbara Boxer, Chairman, Committee on Environment and Public Works
David Vitter, Ranking Member, Committee on Environment and Public Works
Dianne Feinstein, Chairman, Subcommittee on Energy and Water Development, Committee on Appropriations
Lamar Alexander, Ranking Member, Subcommittee on Energy and Water Development, Committee on Appropriations
Al Franken, Chairman, Subcommittee on Energy, Committee on Energy and Natural Resources
James Risch, Ranking Member, Subcommittee on Energy, Committee on Energy and Natural Resources
Sheldon Whitehouse, Chairman, Subcommittee on Clean Air and Nuclear Safety, Committee on Environment and Public Works
Jeff Sessions, Ranking Member, Subcommittee on Clean Air and Nuclear Safety, Committee on Environment and Public Works

U.S. House of Representatives

John "Jimmy" Duncan, Jr., Tennessee
Chuck Fleischmann, Tennessee

U.S. House of Representatives Committees

Hal Rogers, Chairman, Committee on Appropriations
Nita Lowey, Ranking Member, Committee on Appropriations
Buck McKeon, Chairman, Armed Services Committee
Adam Smith, Ranking Member, Armed Services Committee
Fred Upton, Chairman, Energy and Commerce Committee
Henry Waxman, Ranking Member, Energy and Commerce Committee
Lamar Smith, Chairman, Committee on Science, Space, and Technology
Eddie Bernice Johnson, Ranking Member, Committee on Science, Space, and Technology
Mike Simpson, Chairman, Subcommittee on Energy and Water Development, Committee on Appropriations
Marcy Kaptur, Ranking Member, Subcommittee on Energy and Water Development, Committee on Appropriations

Ed Whitfield, Chairman, Subcommittee on Energy and Power, Committee on Energy and Commerce
Bobby Rush, Ranking Member, Subcommittee on Energy and Power, Committee on Energy and Commerce
John Shimkus, Chairman, Subcommittee on Environment and the Economy, Committee on Energy and Commerce
Paul Tonko, Ranking Member, Subcommittee on Environment and the Economy, Committee on Energy and Commerce
Cynthia Lummis, Chairman, Subcommittee on Energy, Committee on Science, Space, and Technology
Eric Swalwell, Ranking Member, Subcommittee on Energy, Committee on Science, Space, and Technology
David Schweikert, Chairman, Subcommittee on Environment, Committee on Science, Space, and Technology
Suzanne Bonamici, Ranking Member, Subcommittee on Environment, Committee on Science, Space, and Technology

Federal Agencies

Anita Barnett, National Park Service – Southeast Regional Office
Deana Scoggins, Tennessee Valley Authority
Heinz Mueller, U.S. Environmental Protection Agency
Mary Jennings, Field Supervisor, U.S. Fish and Wildlife Service, Cookeville Field Office

Federally Recognized Tribes

Cherokee Nation
Eastern Band of Cherokee Indians
United Keetoowah Band of Cherokee Indians in Oklahoma
Choctaw Nation of Oklahoma
The Chickasaw Nation
Seminole Tribe of Florida
Muscogee (Creek) Nation of Oklahoma
Alabama-Coushatta Tribe of Texas
Alabama Quassarte Tribal Town
Kialegee Tribal Town
Thlopthlocco Tribal Town
Absentee Shawnee Tribe of Oklahoma
Eastern Shawnee Tribe of Oklahoma
Shawnee Tribe

Governors

Bill Haslam, Tennessee

State Senators

Mike Bell, District 9
Bo Watson, District 11
Ken Yager, District 12

State Representatives

Eric Watson, District 22
Gerald McCormick, District 26
Richard Floyd, District 27
JoAnne Favors, District 28
Mike Carter, District 29

Vince Dean, District 30
Ron Travis, District 31

State Agencies
Robert Martineau, Jr., Commissioner, Tennessee Department of Environment and Conservation
Chudi Nwangwa, Tennessee Department of Environment and Conservation
Patrick McIntyre, Executive Director, Tennessee Historical Commission
John Schroer, Commissioner, Tennessee Department of Transportation
Toks Omishakin, Chief, Environment and Planning Bureau, Tennessee Department of Transportation
Ed Carter, Executive Director, Tennessee Wildlife Resources Agency
Robert Todd, Environmental Services Division, Tennessee Wildlife Resources Agency

Mayors
Hal Buttram, Athens, Tennessee
Andy Berke, Chattanooga, Tennessee
Gary Louallen, Dayton, Tennessee
Bill James, Decatur, Tennessee
Ted Doss, Graysville, Tennessee
Jim Coppinger, Hamilton County
Madeline Rogero, Knoxville, Tennessee
John Gentry, McMinn County, Tennessee
Garland Lankford, Meigs County, Tennessee
George Thacker, Rhea County, Tennessee
Janice Cagle, Soddy-Daisy, Tennessee
Billy Ray Patton, Spring City, Tennessee

City Officials
Hardie Stulce, City Manager, Soddy-Daisy, Tennessee
Vicki Doster, City Manager, Spring City, Tennessee

County Officials
Tony Reavley, Director of Emergency Services, Hamilton County, Tennessee
Bill Tittle, Chief of Emergency Management, Hamilton County, Tennessee
Tony Finnell, Director, Emergency Management Agency, Meigs County, Tennessee
Jacky Reavley, Director, Emergency Management Agency, Rhea County, Tennessee

Environmental Organizations
Joni Arends, Concerned Citizens for Nuclear Safety
Sara Barczak, Southern Alliance for Clean Energy
Beatrice Brailsford, Snake River Alliance
Glenn Carroll, Nuclear Watch South
Donald B. Clark, Cumberland Mountains for Peace & Justice
Tom Clements, Friends of the Earth
Jay Coghlan, Nuclear Watch New Mexico
Susan Gordon, Alliance for Nuclear Accountability
Gloria Griffith, Sierra Club
Kristi Hanson, Regional Association of Concerned Environmentalists
Alice Hirt, Don't Waste Michigan
Ralph Hutchison, Oak Ridge Environmental Peace Alliance
Michael Keegan, Coalition for a Nuclear Free Great Lakes
Marylia Kelley, Tri-Valley CAREs

Sandra Kurtz, Bellefonte Efficiency and Sustainability Team
Michael Mariotte, Nuclear Information and Resource Service
LeRoy Moore, Rocky Mountain Peace and Justice Center
Brian Paddock, Sierra Club
Lewis Patrie, Western North Carolina Physicians for Social Responsibility
Bobbie Paul, Women's Action for New Directions
Gerry Pollet, Heart of America Northwest
Jerry Stein, Peace Farm
Scott Yundy, Tri-Valley CAREs
Lou Zeller, Blue Ridge Environmental Defense League

Individuals
Geraldine Abbott
Nancy Adadow Gray
Jimmy Bell
Kenneth Bergeron
Caroline Best
Rick Brown
Beverly Davis
Linda Ewald
Lydia Garvey
MacBryan Green
Ann Harris
Richard Henighan
Donald & Grace Inglis
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Frances Lamberts
Martha Lammers
Hugh Mann
June Parker
Penny Piper
Catherine Rumschlag
Leona Wieland
R.G. Wymer

Public Reading Rooms and Libraries
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Freedom of Information Act Reading Room
1000 Independence Avenue, SW, 1G-033
Washington, D.C. 20585-0001
(202) 586-5955

Knoxville Public Library/Lawson McGhee Library
500 West Church Avenue
Knoxville, TN 37902
(865) 215-8750

Chattanooga-Hamilton County Bicentennial Library
1001 Broad Street
Chattanooga, TN 37402
(423) 757-5310

E.G. Fisher Public Library
1289 Ingleside Avenue
Athens, Tennessee 37303
(423) 745-7782

Clyde W. Roddy Public Library
371 First Avenue
Dayton, TN 37321
(423) 775-8406

TVA Research Library
1101 Market Street, LP 4A
Chattanooga, TN 37402

TVA Research Library
400 West Summit Hill Drive, WT CC
Chattanooga, TN 37902

APPENDIX C. HUMAN HEALTH EFFECTS FROM NORMAL OPERATIONS

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APPENDIX C. HUMAN HEALTH EFFECTS FROM NORMAL OPERATIONS

This appendix discusses radiation health effects and the methods and assumptions the National Nuclear Security Administration (NNSA) used to estimate potential impacts and risks to workers and the public from exposure to the release of radioactivity and hazardous chemicals during normal operations at the Watts Bar and Sequoyah reactor facilities. The purpose of this information is to assess impacts from normal operation during tritium production in the reactors, as described in Chapter 4 of this Supplemental Environmental Impact Statement (SEIS). Appendix D contains information about potential radiological impacts resulting from facility accidents.

This appendix uses engineering and/or scientific notation to present numerical information. See the inside front and back covers for information on scientific notation.

C.1 Radiological Impacts on Human Health

Radiation exposure and its consequences are topics of interest to the public. For this reason, this SEIS emphasizes the consequences of exposure to radiation, provides background information on the nature of radiation, and explains the basic concepts of radiation health effects. In addition, it describes the characteristics of tritium and its potential health effects.

C.1.1 BACKGROUND INFORMATION

C.1.1.1 Nature of Radiation and its Effects on Humans

What Is Radiation?

Radiation is energy transferred in the form of particles or waves. Humans are exposed constantly to radiation from the solar system and from the Earth's rocks and soil. This radiation contributes to the natural background radiation that always surrounds us. Manmade sources of radiation include medical and dental x-rays, household smoke detectors, and materials released from nuclear and coal-fired power plants.

All matter in the universe consists of atoms. Radiation comes from the activity of particles in an atom. An atom consists of a positively charged nucleus (central part of the atom) with a number of negatively charged electron particles in orbits around the nucleus. There are two types of particles in the nucleus: neutrons that are electrically neutral and protons that are positively charged. Atoms of different types are known as elements. There are more than 100 natural and manmade elements. An element has equal numbers of electrons and protons. When atoms of an element differ in their number of neutrons, they are called isotopes of that element. All elements have three or more isotopes, some or all of which could be unstable (that is, decay with time). For example, tritium (also known as hydrogen-3) has two neutrons and is an unstable isotope of hydrogen, which has no neutrons.

Unstable isotopes undergo spontaneous change, known as radioactive disintegration or radioactive decay. The process of continuously undergoing spontaneous disintegration is called radioactivity. The radioactivity of a material decreases with time. The time it takes a material to lose half of its original radioactivity is its half-life.

An isotope's half-life is a measure of its decay rate; for example, an isotope with a half-life of 8 days will lose half of its radioactivity in that amount of time. In 8 more days, half of the remaining radioactivity will be lost, and so on. Each radioactive element has a characteristic half-life. The half-lives of radioactive elements can vary from millionths of a second to millions of years.

As unstable isotopes change into more stable forms, they emit electrically charged particles. These particles can be either an alpha particle (a helium nucleus) or a beta particle (an electron) with various levels of kinetic energy. Sometimes these particles are emitted in conjunction with gamma rays, a form of electromagnetic radiation emitted when the nucleus of an atom moves from a higher to a lower energy state. The alpha and beta particles are frequently referred to as “ionizing radiation.” Ionizing radiation refers to the fact that the charged particle energy force can ionize, or electrically charge, an atom by stripping off one of its electrons. Gamma rays, even though they do not carry an electric charge as they pass through an element, can ionize its atoms by ejecting electrons. Thus, they cause ionization indirectly. Ionizing radiation can cause a change in the chemical composition of many things, including living tissue (organs), which can affect the way they function.

When a radioactive isotope of an element emits a particle from the nucleus, it changes to an entirely different element, one that might or might not be radioactive. Eventually, a stable element forms. This transformation, which can take several steps, is known as a “decay chain.” For example, radium, which is a member of the radioactive decay chain of uranium, has a half-life of 1,622 years. It emits an alpha particle and becomes radon, a radioactive gas with a half-life of only 3.8 days. Radon decays first to polonium, then through a series of further decay steps to bismuth, and ultimately to lead, which is a stable element. Meanwhile, the decay products build up and eventually die away over time. The following and the table at right describe the characteristics of forms of ionizing radiation (see the Glossary for further definition):

Radiation type	Typical travel distance in air	Barrier
α	Couple of centimeters	Sheet or paper or skin’s surface
β	Few meters	Thin sheet of aluminum foil or glass
γ	Very large[a]	Thick wall of concrete, lead, or steel
n	Very large	Water, paraffin, graphite

a. Would be infinite in a vacuum.

- Alpha (α). Alpha particles are the heaviest type of ionizing radiation. They can travel only a few centimeters in air. Alpha particles lose their energy almost as soon as they collide with anything. They can be stopped easily by a sheet of paper or by the skin’s surface.

- Beta (β). Beta particles are much (7,330 times) lighter than alpha particles. They can travel farther than alpha particles in the air; a high-energy beta particle can travel a few meters. Beta particles can pass through a sheet of paper, but a thin sheet of aluminum foil or glass can stop them. Tritium emits a very-low-energy beta particle.

- Gamma (γ). Gamma rays (and x-rays), unlike alpha or beta particles, are waves of pure energy. Gamma rays travel at the speed of light. Gamma radiation is very penetrating and requires a thick wall of concrete, lead, or steel to stop it.

- Neutrons (n). Neutrons are particles that contribute to radiation exposure both directly and indirectly. The most prolific source of neutrons is a nuclear reactor. Indirect radiation exposure occurs when a reactor emits gamma rays and alpha particles after neutron capture in matter. A neutron has about one-quarter the weight of an alpha particle. It will travel in the air until another element absorbs it.

Units of Radiation Measure

During the early days of radiological experience, there was no precise unit of radiation measure. Therefore, a variety of units were used to measure radiation. These units were used to determine the amount, type, and intensity of radiation. Just as heat can be measured in terms of its intensity or effects using units of calories or degrees, amounts of radiation or its effects can be measured in units of curies, radiation absorbed dose (rad), or dose equivalent (rem). The following summarizes these units (see the definitions in the Glossary, Chapter 10 of this SEIS):

- Curie. The curie, named after the French scientists Marie and Pierre Curie, describes the "intensity" of a sample of radioactive material. The rate of decay of 1 gram of radium is the basis of this unit of measure. It is equal to 3.7×10^{10} disintegrations (decays) per second.

- Rad. The rad is the unit of measurement for the physical absorption of radiation. The total energy absorbed per unit quantity of tissue is referred to as "absorbed dose" (or simply "dose"). As sunlight heats pavement by giving up an amount of energy to it, radiation similarly gives up rads of energy to objects in its path. One rad is equal to the amount of radiation that leads to the deposition of 0.01 joule of energy per kilogram of absorbing material.

- Rem. The rem is a measurement of the dose equivalent from radiation based on its biological effects. The rem is used in measuring the effects of radiation on the body as degrees Celsius are used in measuring the effects of sunlight heating pavement. Thus, 1 rem of one type of radiation is presumed to have the same biological effects as 1 rem of any other kind of radiation. This enables comparison of the biological effects of radionuclides that emit different types of radiation.

Radiation Units and Conversions to International System of Units

1 curie = 3.7×10^{10} becquerels
1 rad = 0.01 gray
1 rem = 0.01 sievert
1 gray = 1 joule per kilogram
1 becquerel = 1 disintegration per second

The units of radiation measure in the International Systems of Units are becquerel [a measure of source intensity (activity)], gray (a measure of absorbed dose), and sievert (a measure of dose equivalent).

An individual can be exposed to ionizing radiation externally (from a radioactive source outside the body) or internally (from ingesting or inhaling radioactive material). The external dose is different from the internal dose because an external dose is delivered only during the actual time of exposure to the radiation source, but an internal dose continues to be delivered as long as the source is in the body. The dose from internal exposure is calculated over 50 years after the initial exposure; both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate over time.

Sources of Radiation

The average American receives about 620 millirem per year[1] from all sources of radiation, both natural and manmade, of which about 300 millirem per year are from natural sources (NCRP 2009). The sources of radiation can be divided into six categories: (1) cosmic radiation, (2) terrestrial radiation, (3) internal radiation, (4) consumer products, (5) medical diagnosis and therapy, and (6) other sources (NCRP 2009). The following discusses these categories:

- Cosmic radiation. Cosmic radiation is ionizing radiation from energetic charged particles from space continuously hitting the Earth's atmosphere. These particles and the secondary particles

1. The actual value is 624.3 millirem. NNSA has rounded this value to 620 millirem in this SEIS.

and photons they create comprise cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with the altitude above sea level. The average dose to people in the United States from this source is about 33 millirem per year.

- External terrestrial radiation. External terrestrial radiation is radiation emitted from radioactive materials in the Earth's rocks and soils. The average dose from external terrestrial radiation is about 21 millirem per year.

- Internal radiation. Internal radiation results from the human body metabolizing natural radioactive material that has entered the body by inhalation or ingestion. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, polonium, bismuth, potassium, rubidium, and carbon. The major contributors to the annual dose equivalent for internal radioactivity are the short-lived decay products of radon, which contribute about 228 millirem per year. The average dose from other internal radionuclides is about 29 millirem per year.

- Consumer products. Consumer products contain sources of ionizing radiation. In some products, such as smoke detectors and airport x-ray machines, the radiation source is essential to product operation. In other products, such as televisions and tobacco, the radiation occurs as the product's function. The average dose from consumer products is about 13 millirem per year.

- Medical diagnosis and therapy. Radiation is an important diagnostic medical tool and cancer treatment. The average medical exposure of patients is about 300 millirem per year.

- Other sources. A few additional sources of radiation contribute minor doses to people in the United States. The estimated dose from nuclear fuel cycle facilities (for example, uranium mines, mills, and fuel processing plants), nuclear power plants, and transportation routes is less than 1 millirem per year. Radioactive fallout from atmospheric nuclear weapons tests, emissions of radioactive material from other nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials contribute less than 1 millirem per year to the average dose to an individual. Air travel contributes about 1 millirem per year to the average dose.

Exposure Pathways

As stated above, an individual can be exposed to ionizing radiation externally and internally. The ways that could result in radiation exposure to an individual are called "exposure pathways." The following discusses each type of exposure:

- External exposure. External exposure can result from several different pathways, all having in common the fact that the radiation causing the exposure is external to the body. These pathways include exposure to a cloud of radiation passing over the receptor (for example, an individual member of the public) or standing on ground that is contaminated with radioactivity. If the receptor leaves the source of radiation exposure, the dose rate will be reduced. External exposure is assumed to occur uniformly during the year. The appropriate measure of dose is called the "effective dose equivalent."

- Internal exposure. Internal exposure results from a radiation source that enters the human body through inhalation of contaminated air or ingestion of contaminated food and water. In contrast to external exposure, once a radiation source enters the body, it remains there for a period that varies depending on decay and biological half-life. The absorbed dose to each organ of the body is calculated for 50 years after the intake. The dose equivalent of this absorbed dose is called the "committed dose equivalent." Various organs have different susceptibilities to harm from radiation. The quantity that takes these susceptibilities into account, the "committed effective dose equivalent," provides a broad indicator of the risk to the health of an individual from radiation. The committed effective dose equivalent is a weighted sum of the committed dose equivalent in each major organ or tissue. The concept of committed effective dose equivalent applies only to internal pathways.

Radiation Protection Guides

Various organizations have issued radiation protection guides. The following summarizes the responsibilities of the main radiation safety organizations, particularly those that affect policies in the United States.

- International Commission on Radiological Protection. The Commission provides guidance in matters of radiation safety. Its operating policy is to prepare recommendations to deal with basic principles of radiation protection and to leave to the national protection committees the responsibility of introducing the detailed technical regulations, recommendations, or codes of practice best suited to the needs of their countries.

- National Council on Radiation Protection and Measurements. In the United States, this Council has the responsibility to adapt and provide detailed technical guidelines for implementing International Commission on Radiological Protection recommendations. It consists of technical experts who are specialists in radiation protection and scientists who are experts in disciplines that form the basis for radiation protection.

- National Research Council of the National Academy of Sciences. The National Research Council is an organization within the National Academy of Sciences that associates the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the Federal Government.

Limits of Radiation Exposure

Limits of exposure to members of the public and radiation workers are based on International Commission on Radiological Protection recommendations. Each regulatory organization adopts such recommendations and sets specific annual exposure limits (usually less than those specified by the Commission). For nuclear facilities, the U.S. Nuclear Regulatory Commission (NRC) provides annual exposure limits to the public in 10 CFR Part 20 and 10 CFR Part 50, Appendix I. For accidents of unlikely probability of occurrence, (a likelihood of between 1-in-100 to 1-in-10,000 years), 10 CFR Part 100 provides the maximum exposure to the public residing at the site boundary. The dose limits for radiation workers are in 10 CFR Part 20. In addition, the U.S. Department of Energy (DOE) has established a set of limits for radiation workers in 10 CFR Part 835. Table C-1 lists the exposure limits set by the NRC, DOE, and the U.S. Environmental Protection Agency (EPA) for radiation workers and members of the public.

C.1.1.2 Health Effects

Radiation exposure and its consequences are topics of interest to the public. To provide the background for discussions of impacts, this section explains the basic concepts used in the evaluation of radiation effects. Radiation can cause a variety of damaging health effects in people. The most significant effects are induced cancer fatalities. These effects are referred to as "latent" cancer fatalities because the cancer might take many years to develop. The paragraphs below consider all fatal cancers to be latent; therefore, the word "latent" is not used. DOE Guidance (DOE 2003) recommends that agencies use a conversion factor of 6×10^{-4} fatal cancer per rem total effective dose equivalent for mortality for workers and members of the public. The DOE guidance recommends use of factors developed by the Interagency

Table C-1. Exposure limits for members of the public and radiation workers.

Guidance criteria (organization)	Public exposure limits at site boundary	Worker exposure limits
Normal operations		
10 CFR Part 20 (NRC)	100 millirem[a] per year, all pathways	5,000 millirem per year
10 CFR Part 50, Appendix I (NRC)[b]	5 millirem per year, air (external) 3 millirem per year, liquid (total body)	N/A
40 CFR Part 190 (EPA)	25 millirem per year, all pathways	N/A
10 CFR Part 835 (DOE)[c]	N/A	5,000 millirem per year
DOE Order 458.1 (DOE)[c]	100 millirem per year (all pathways)	N/A
40 CFR Part 141 (EPA)	4 millirem per year (drinking water pathway)	
40 CFR Part 61 (EPA)	10 millirem per year (all air pathways)	N/A
Facility accidents		
10 CFR 100.11 (NRC)[d]	25 rem (total body)	N/A

N/A = not applicable.

a. An NRC licensee can apply for prior NRC authorization to operate up to an annual dose limit of 500 millirem for an individual member of the public.

b. Design objectives for equipment to control releases of radioactive materials in effluents from nuclear power reactors.

c. The NRC regulates the nuclear facilities. DOE exposure limits are included for comparison purposes.

d. This guidance criterion is used to determine the exclusion area and low population zone for a nuclear power plant site.

Steering Committee on Radiation Standards (ISCORS 2002). This differs from what DOE used in the 1999 EIS (DOE 1999), but the Department has approved the new value.

Health Effect Risk Factors Used in This SEIS

Health impacts from radiation exposure, whether from sources external or internal to the body, generally are identified as "somatic" (affecting the exposed individual) or "genetic" (affecting descendants of the exposed individual). Radiation is more likely to produce somatic than genetic effects. The somatic risks of most importance are induced cancers. With the exception of leukemia, which can have an induction period (time between exposure to carcinogen and cancer diagnosis) of as little as 2 to 7 years, most cancers have an induction period of more than 20 years.

For a uniform irradiation of the body, the incidence of cancer varies among organs and tissues; the thyroid and skin demonstrate a greater sensitivity than other organs. Such cancers, however, also produce relatively low mortality rates because they are relatively amenable to medical treatment. Because of the readily available data for cancer mortality rates and the relative scarcity of prospective epidemiologic studies, this SEIS presents somatic effects leading to cancer fatalities rather than cancer incidence. The numbers of cancer fatalities can be used to compare risks among the alternatives.

Based on the preceding discussion, fatal cancers to the public and workers are calculated using a health risk factor of 6×10^{-4} latent cancer fatality per rem or person-rem (ISCORS 2002). The risk factors are used to calculate the statistical expectation of the effects of exposing a population to radiation. For example, in a population of 100,000 people exposed only to natural background radiation (300 millirem per year), about 18 latent cancer fatalities per year of exposure should result from this radiation (100,000 persons × 0.3 rem per year × 0.0006 latent cancer fatality per person-rem = 18 latent cancer fatalities per year).

Calculations of the number of excess cancer fatalities associated with radiation exposure do not always yield whole numbers; calculations might yield numbers less than 1.0, especially in environmental impact applications. For example, if a population of 100,000 was exposed to a total dose of 0.001 rem per person, the collective dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.06 (100,000 persons × 0.001 rem × 6 × 10^{-4} latent cancer fatality per person-rem = 0.06 latent cancer fatality). The latent cancer fatality of 0.06 is the "expected" number of deaths that would result if the same exposure situation was applied to many different groups of 100,000 people. In most groups, no person (0 people) would incur a latent cancer fatality from the 0.001-rem dose each member received. In a small fraction of the groups, 1 latent cancer fatality would result; in exceptionally few groups, 2 or more latent cancer fatalities would occur. The "average" expected number of deaths over all the groups would be 0.06 latent cancer fatality (just as the average of 0, 0, 0, and 1 is 1 ÷ 4, or 0.25). The most likely outcome is 0 latent cancer fatality.

These concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The "number of latent cancer fatalities" corresponding to a single individual's exposure over a (presumed) 72-year lifetime to 0.3 rem per year is 0.013 latent cancer fatality (1 person × 0.3 rem per year × 72 years × 0.0006 latent cancer fatality per person-rem = 0.013 latent cancer fatality).

Again, this is a statistical estimate; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.3-percent chance that the individual might incur a latent cancer fatality caused by the exposure over his full lifetime. Presented another way, this method estimates that about 1.3 percent of the population might die of cancers induced by background radiation.

C.1.1.3 Genetic Effects of Radiation

The following is from the NRC Fact Sheet on the Biological Effects of Radiation (NRC 2011):

> *Genetic effects and the development of cancer are the primary health concerns attributed to radiation exposure. The likelihood of cancer occurring after radiation exposure is about five times greater than a genetic effect (e.g., increased still births, congenital abnormalities, infant mortality, childhood mortality, and decreased birth weight). Genetic effects are the result of a mutation produced in the reproductive cells of an exposed individual that are passed on to their offspring. These effects may appear in the exposed person's direct offspring, or may appear several generations later, depending on whether the altered genes are dominant or recessive.*
>
> *Although radiation-induced genetic effects have been observed in laboratory animals (given very high doses of radiation), no evidence of genetic effects has been observed among the children born to atomic bomb survivors from Hiroshima and Nagasaki.*

C.1.2 TRITIUM CHARACTERISTICS AND BIOLOGICAL PROPERTIES

C.1.2.1 Tritium Characteristics

Ordinary hydrogen, deuterium, and tritium are the three isotopes of hydrogen. Tritium is the only isotope that is radioactive. The nucleus of a hydrogen atom contains one proton, a positively charged particle. Around this nucleus orbits a single electron, a negatively charged particle that has a significantly smaller mass than the proton. Ordinary hydrogen, comprising over 99.9 percent of all naturally occurring hydrogen, has one proton and no neutrons. The nucleus of a deuterium atom contains one proton and one neutron. Deuterium comprises about 0.015 percent of all hydrogen. The nucleus of the tritium atom contains one proton and two neutrons. Tritium makes up only 1 × 10^{-18} percent of natural hydrogen. The chemical symbol for hydrogen is H (DOE 2008).

In the radioactive decay of tritium, the nucleus emits a beta particle, a negatively charged particle similar to an electron. On emission of the beta particle, the tritium atom is transformed to a helium atom, helium-3, with two protons and one neutron. Tritium has a half-life of about 12.3 years. Any amount of tritium will be reduced by about 11 percent in 2 years, 25 percent in 5 years, 50 percent in 12.3 years, and 90 percent in 42 years.

As stated above, the emitted beta particle is a form of ionizing radiation. It will interact with the atoms and molecules in the environment around the tritium atom, ionizing atoms by removing electrons from their orbit. The beta particles emitted from a decaying tritium atom are relatively low-energy particles and can be stopped by a sheet of paper or skin. Therefore, health effects on humans can result from ingestion (either eating or drinking), inhalation, or skin absorption of tritium. External exposure to tritium does not pose a significant health risk.

Natural sources of tritium result from the interaction of cosmic radiation and gases in the upper atmosphere. Nuclear power reactors are a manmade source for producing tritium. In a reactor core, lithium can be transformed into tritium through neutron capture. The lithium atom, with three protons and three neutrons, and the captured neutron combine to form a lithium atom with three protons and four neutrons that will instantaneously split to form an atom of tritium (one proton and two neutrons) and an atom of helium (helium-4, with two protons and two neutrons).

C.1.2.2 Biological Properties of Tritium

The following information on the biological impacts of tritium is from *Tritium Handling and Safe Storage* (DOE 2008).

At most tritium facilities, the most commonly encountered forms of tritium are tritium gas and tritium oxide, also called "tritiated water." Water in the body readily takes up and retains tritiated water vapor. In addition, tritiated water can be absorbed through the skin. If tritium gas is inhaled, almost all of the gas is exhaled with a very small fraction retained in the lungs. Organically bound tritium is a type of tritiated material in which the tritium has formed a chemical bond with an organic material—typical via a carbon-tritium bond (DOE 2008).

This discussion is limited to the effects of tritium gas, tritium oxide, and organically bound tritium—the compounds with the potential to have the most significant impact on workers and the public.

Metabolism of Gaseous Tritium

> *During a brief exposure to tritium gas, the gas is inhaled and a small amount is dissolved in the bloodstream. The dissolved gas circulates in the bloodstream before being exhaled along with the gaseous waste products (carbon dioxide) and normal water vapor. If the exposure persists, the gas will reach other body fluids. A small percentage of the gaseous tritium is converted to the oxide (HTO), most likely by oxidation in the gastrointestinal tract. Early experiments involving human exposure to a concentration of 9 µCi/mL* [microcuries per milliliter] *resulted in an increase in the HTO concentration in urine of* 7.7×10^{-3} *µCi/mL per hour of exposure. Although independent of the breathing rate, this conversion can be expressed as the ratio of the HTO buildup to the tritium inhaled as HT at a nominal breathing rate (20 L/min* [liters per minute]*). In this context, the conversion is 0.003% of the total gaseous tritium inhaled. More recent experiments with six volunteers resulted in a conversion of 0.005%.*
>
> *For gaseous tritium exposures, there are two doses: (a) a lung dose from the tritium in the air inside the lung and (b) a whole body dose from the tritium gas that has been*

converted to HTO. The tritiated water converted from the gas in the body behaves as an exposure to tritiated water.

Intake of gaseous tritium through the skin has been found to be negligible compared with that from inhalation. Small amounts of tritium can enter the skin through unprotected contact with contaminated metal surfaces, which results in organically bound tritium in skin and in urine. Ordinarily this is not a serious problem because surfaces highly contaminated with tritium gas are inaccessible to skin contact. Also, most tritium exposed to air will be converted to the oxide form (water vapor) before the internal surfaces of equipment are handled during maintenance or repair operations.

Metabolism of Tritiated Water

The biological incorporation (uptake) of airborne HTO can be extremely efficient: up to 99% of inhaled HTO is taken into the body by the circulating blood. Ingested liquid HTO is also almost completely absorbed by the gastrointestinal tract and quickly appears in the blood stream. Within minutes, it can be found in varying concentrations in the organs, fluids, and tissues of the body. Skin absorption of airborne HTO is also important, especially during hot weather, because of the normal movement of water through the skin. For skin temperatures between 30 and 40 degrees C, the absorption of HTO is about 50% of that for HTO by inhalation (assuming an average breathing rate associated with light work, 20 L/min). No matter how it is absorbed, the HTO will be uniformly distributed in all biological fluids within one to two hours. This tritium has a retention that is characteristic of water. In addition, a small fraction of the tritium is incorporated into easily exchanged hydrogen sites in organic molecules. Hence, retention of tritiated water can be described as the sum of several terms: one characteristic of body water, and one or more longer-term components that represent tritium incorporated into organic hydrogen sites.

Organically Bound Tritium (OBT)

Soluble OBT migrates through the skin or lung into the bloodstream by the physical processes of dissolution and diffusion. The two processes are inseparably linked and often simply called "absorption." Soluble OBT is also readily absorbed through the GI [gastrointestinal] *tract following ingestion. Rapid dispersion minimizes organ-specific (e.g., lung) differential doses. Following absorption into the body, soluble OBT is excreted via urine. A biokinetic model is available which relates intakes of soluble OBT to urine excretion rates, and a dose conversion factor is available for soluble OBT intakes. Urine bioassay is therefore considered to be a viable approach to estimating intake and dose from soluble OBT.*

Of the HTO that is absorbed into the bloodstream, 3% is converted to organically bound tritium (OBT) that is retained in the body with a 40-day half-life and the remaining 97% remains as HTO and is retained with a 10-day half-life. All of the OBT is excreted into the urinary bladder and ultimately the urine.

Biological Half-Life of Tritium Oxide (Tritiated Water)

Studies of biological elimination rates of body water in humans date back to 1934, when the body water turnover rate was measured using heavy water (HDO). Since that time, several additional studies have been conducted with HDO and HTO. A simple average of the data suggests a value of 9.5 days for the measured biological half-life of water in the body with a deviation of ±50%. Calculations based on total fluid intake indicate a similar value. This is reasonable because the turnover rate of HTO should be identical to *that of body water. In other words, the biological half-life of tritium is a function of the average daily throughput of water.*

The biological half-life of HTO has been studied when outdoor temperatures varied at the time of tritium uptake. The data suggest that biological half-lives are shorter in warmer months. For example, the 7.5-day half-life measured in southern Nigeria is not surprising because the mean outdoor temperature there averages 27 degrees C. In contrast, an average 9.5-day half-life was measured in North America, where the mean outdoor temperature averages 17 degrees C. Such findings are consistent with metabolic pathways involving sensible and insensible perspiration. As such, the skin absorption and perspiration pathways can become an important part of body water exchange routes. It is important to note that personnel who are perspiring will have a greater absorption of tritium from contact with tritiated surfaces. For planning purposes, it is customary to use an average half-life of 10 days. However, it is not used to calculate doses from actual exposures.

Prolonged exposures can be expected to affect the biological half-life. Tritium's interaction with organic hydrogen can result in additional half-life components ranging from 21 to 30 days and 250 to 550 days. The shorter duration indicates that organic molecules in the body retain tritium relatively briefly. The longer duration indicates long-term retention by other compounds in the body that do not readily exchange hydrogen or that metabolize more slowly. However, the overall contribution from organically bound tritium is relatively small, that is, less than about 5% for acute exposures and about 10% for chronic exposures. Methods used to compute the annual limits on intake of air and water specify only the body water component and include the assumption of a 10-day biological half-life, as mentioned above.

Bioassay and Internal Dosimetry

Exposure to tritium oxide (HTO) is by far the most important type of tritium exposure. The HTO enters the body by inhalation or skin absorption. When immersed in tritiated water vapor, the body takes in approximately twice as much tritium through the lungs as through the skin. Once in the body, it is circulated by the blood stream and finds its way into fluids both inside and outside the cells.

According to International Commission on Radiological Protection (ICRP), the derived air concentration (DAC)[2] *for tritium gas (HT) and HTO are 200,000 $\mu Ci/m^3$* [microcuries per cubic meter] *and 20 $\mu Ci/m^3$, respectively. The ratio of these DACs (10,000) is based on the fraction of the gas converted to HTO in the lines. During exposure to HT, a small fraction of the tritium exchanges in the lung and is transferred by the blood to the gastrointestinal tract where it is oxidized by enzymes. This process results in a buildup of HTO until the HT is removed by exhalation at the end of the exposure. The resultant dose from exposure to this HTO is roughly comparable to the lung dose from exposure to HT. Thus, the total effective dose from an HT exposure is about 10,000 times less than the total effective dose from an equal exposure to airborne HTO. For both HTO and HT exposures, a bioassay program that samples body water for HTO is essential for personnel monitoring at tritium facilities.*

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2. The DAC is defined as that concentration of an airborne material, which, if a worker was exposed to it for one working year (2,000 hours), would result in a dose of 5 rem to the whole body or 50 rem to any organ or tissue.

C.2 Methodology for Estimating Radiological Impacts to the Public

NNSA calculated the radiological impacts from normal operation of the Watts Bar and Sequoyah reactor facilities using Version 2.10 of the GENII computer program (Napier et al. 2009). Site-specific input data included location, meteorology, population, food production and consumption, and source terms if available. Section C.3.1 describes GENII and outlines the approach used for normal operations.

C.2.1 GENII COMPUTER PROGRAM

The GENII program, developed by Pacific Northwest National Laboratory, is an integrated system of computer modules that analyze environmental contamination from acute or chronic releases to, or initial contamination in, air, water, or soil. The program calculates radiation doses to individuals and populations. The program and its mathematical models are well documented for assumptions, technical approach, method, and quality assurance issues (Napier 2010). GENII has gone through extensive quality assurance and quality control steps, including comparison of results of code computations with those from hand calculations and performance of internal and external peer reviews.

C.2.2 DATA AND GENERAL ASSUMPTIONS

To perform the dose assessments for this SEIS, NNSA collected and generated different types of data. In addition, it made calculational assumptions. This section discusses the data NNSA collected and generated for use in performing the dose assessments and the assumptions for this SEIS. Simpkins (2012) documents additional data assumptions.

Meteorological Data

The meteorological data used for all normal operational scenarios in this SEIS were in the form of joint frequency data files. A joint frequency data file is a table that lists the fractions of time the wind blows in a certain direction, at a certain speed, and in a certain stability class. Measurements made in 2010 at Watts Bar and Sequoyah were the bases for these files. NNSA used the frequency data converter to convert the files to GENII format.

Population Data

NNSA based population distributions on *2010 Census of Population and Housing* data (USCB 2012). Census data in this SEIS represent the latest information available from the Bureau of the Census. Projections were determined for 2025 for areas within 50 miles of the release locations at Watts Bar and Sequoyah (Figures C-1 and C-2 depict the 50-mile radius around Watts Bar and Sequoyah, respectively). NNSA used the site population in 2025 in the impact assessments because DOE used it in the 1999 EIS (DOE 1999) and it is assumed to be representative of the population at the approximate midpoint between now and the end of the interagency agreement. The population was spatially distributed on a circular grid with 16 directions and 10 radial distances up to 50 miles. The grid was centered at the location from which radionuclides would be released.

The 50-mile population for exposure to water was determined from the downriver populations in the offsite dose calculation manuals (TVA 2010a, 2010b) and scaled as appropriate for 2025. Downriver populations include those who would ingest water from public drinking water facilities as well as those using the river for recreation. The same population growth factor developed for the entire 50-mile population was applied to the downriver population. The 50-mile 2025 populations for Watts Bar and Sequoyah were 1,452,511 and 1,294,030, respectively. The 50-mile 2025 downriver populations for Sequoyah and Watts Bar were 407,699 and 367,652, respectively.

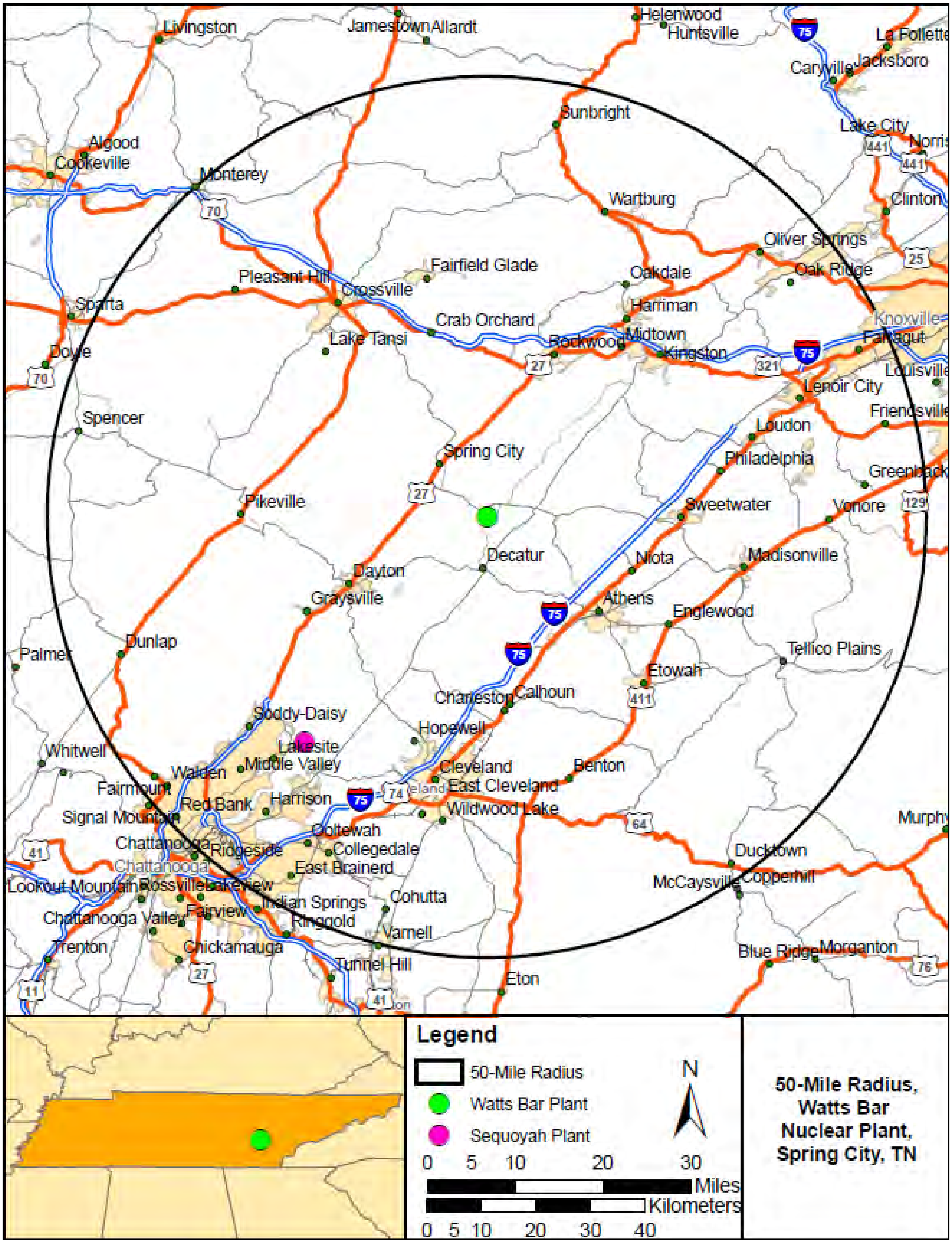

Figure C-1. Watts Bar 50-mile radius.

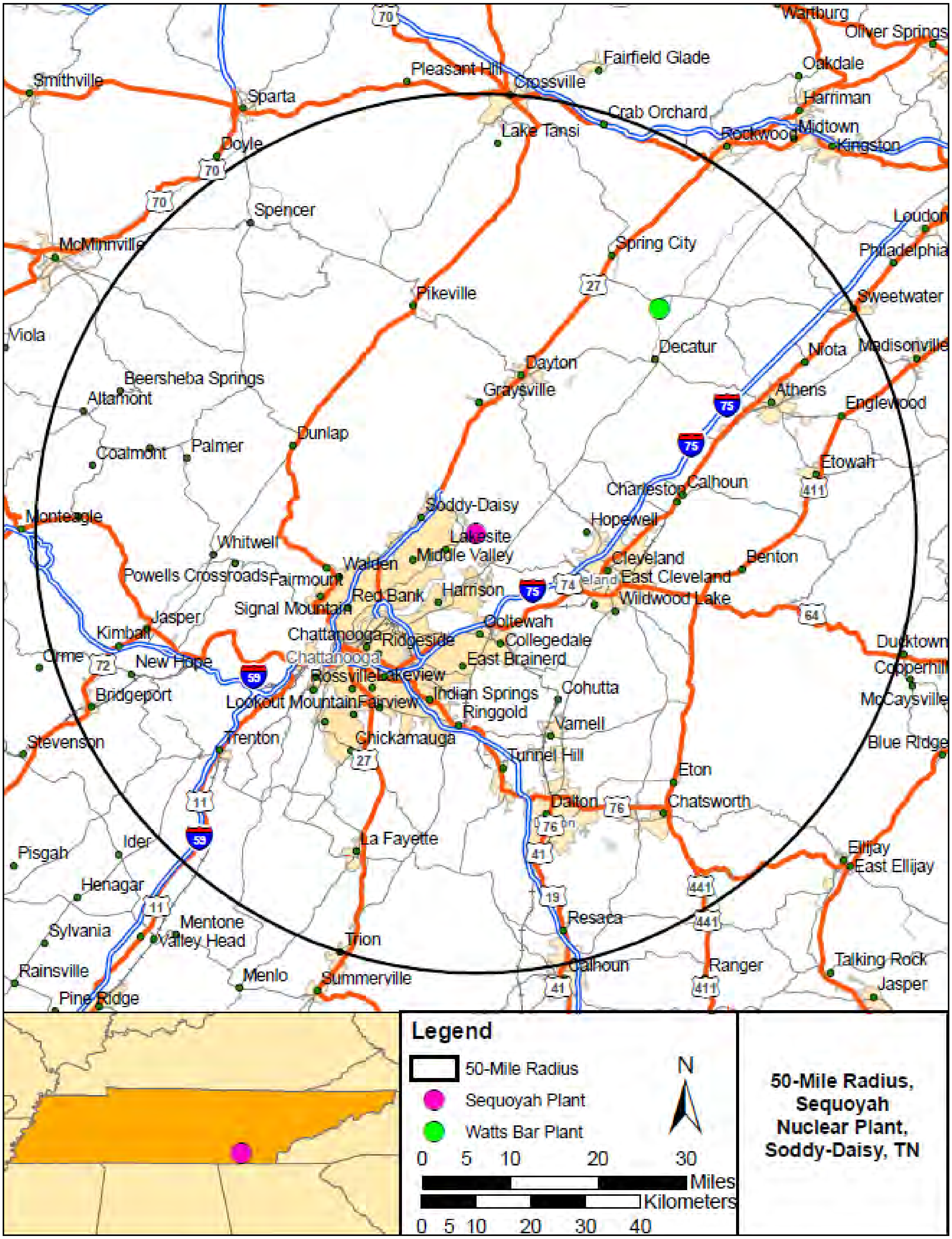

Figure C-2. Sequoyah 50-mile radius.

Source Term Data

NNSA based its estimates of the tritium-producing burnable absorber rod (TPBAR) source terms [that is, quantities of tritium (in the form of tritium oxide) released to the environment over a given period] on estimated TPBAR characteristic releases. Section C.3 contains the source terms used to generate the estimated incremental impacts of normal operations for Watts Bar and Sequoyah.

Food Production and Consumption Data

NNSA used data from TVA (2010a, 2010b) to generate site-specific data for food consumption. The consumption rates used in GENII were those for the maximum individual and the average individual (used for population doses). People living within the 50-mile assessment area were assumed to consume only food grown in that area.

Calculational Assumptions

NNSA performed dose assessments for members of the public and workers for Watts Bar and Sequoyah. The purpose of these assessments was to determine the doses that would be associated with the tritium production alternatives in this SEIS. Doses for members of the public were calculated (using GENII) for two types of receptors:

- <u>Maximally Exposed Offsite Individual</u>. The maximally exposed individual was assumed to be at a position on the site boundary that would yield the highest impacts during normal operations for a given alternative.

- <u>Population</u>. The general population living within 50 miles of the facility in 2025.

To estimate radiological impacts from normal operations, NNSA considered the following additional assumptions and factors in using GENII:

- Radiological gaseous emissions were assumed to be released to the atmosphere through the plant stack; for Watts Bar or Sequoyah, the stack height is 131 feet.

- Ground surfaces were assumed to have no previous deposition of radionuclides.

- The annual external exposure time to the plume and to soil contamination was 0.7 year (16.8 hours per day) for the maximally exposed offsite individual (NRC 1977a).

- The annual external exposure time to the plume and to soil contamination was 0.5 year (12 hours per day) for the population (NRC 1977a).

- The annual inhalation exposure time to the plume was 1 year for the maximally exposed individual and general population.

- The exposed individual or population was assumed to have the characteristics and habits (for example, inhalation and ingestion rates) of an adult human.

- A semi-infinite/finite plume model was used for air immersion doses. Other pathways evaluated were ground exposure, inhalation, ingestion of food crops and animal products contaminated by deposition of radioactivity from the air, ingestion of fish raised in contaminated water, and drinking contaminated water. All applicable pathways (for example, inhalation, drinking water, external exposure) were analyzed at Watts Bar and Sequoyah.

- Reported release heights were used for atmospheric releases and were assumed to be the effective stack height. The resultant doses were conservative because use of the actual stack height negates plume rise.

- The calculated doses were 50-year committed doses from 1 year of intake.

- Average volumetric river flow rates (measured locally downstream of each site; see Table C-6 below) were used.

- Individual annual exposure times to shoreline recreation were taken from site environmental reports and NRC Regulatory Guide 1.109, as appropriate (TVA 2010a, 2010b; NRC 1977a).

- The 2025 drinking water population was estimated by applying the same growth factor as that for the entire 50-mile radius population.

- Drinking water treatment was assumed, with a holdup (transit) time of 1 day for Watts Bar and Sequoyah.

- Annual drinking water quantities for the average and maximally exposed individual were referenced from NRC Regulatory Guide 1.109 (NRC 1977a).

- Fish consumption data were referenced from NRC Regulatory Guide 1.109 (NRC 1977a).

- Doses for Watts Bar included a terrain adjustment factor (TVA 2010b). A terrain adjustment factor increases the dose to account for topographic and diurnal-related factors.

The location of the maximally exposed individual for atmospheric releases was determined by calculating the dose along the site boundary for each of the 16 sector and distance combinations. Table C-2 lists the distance to the nearest boundary location for each of the 16 sectors. The location of the maximally exposed individual was the sector-distance combination that yielded the highest dose. For Watts Bar, the maximally exposed individual location was in the northeast sector at a distance of 1,580 meters and for Sequoyah it was in the south sector at a distance of 1, 570 meters (Simpkins 2012). For Watts Bar, a terrain adjustment factor was included, as discussed below.

For Watts Bar, the offsite dose calculation manual (TVA 2010b) indicates that a terrain adjustment factor should be applied to the dose. This factor takes into account spatial and temporal variations in the expected airflow from the southwest-northeast aligned river valley. These values were determined by the comparison of variable trajectory model results with straight-line model results using onsite meteorological data. Table C-3 lists the terrain adjustment factors by sector.

The location of the maximally exposed individual in relation to releases of water was assumed to be downriver at Tennessee River Mile 510, where complete mixing is expected to occur. This is the assumed location from which the individual would ingest water and fish and would engage in recreation along the shore.

Tables C-4 to C-7 list the exposure, uptake, and usage parameters used in GENII for normal operations.

C.2.3 CONSIDERATION OF UNCERTAINTY

The sequence of analyses performed to generate the radiological impact estimates from normal operation include (1) selection of normal operational modes, (2) estimation of source terms, (3) estimation of

Table C-2. Distance to the site boundary (meters).[a]

Sector	Watts Bar	Sequoyah
N	1,580	950
NNE	1,980	2,260
NE	1,580	1,910
ENE	1,370	1,680
E	1,280	1,570
ESE	1,250	1,460
SE	1,250	1,460
SSE	1,250	1,550
S	1,340	1,570
SSW	1,550	1,840
SW	1,670	2,470
WSW	1,430	910
W	1,460	670
WNW	1,400	660
NW	1,400	660
NNW	1,460	730

Sources: TVA 2010a, 2010b.

a. The inside back cover provides conversion factors from metric to English units.

Table C-3. Watts Bar terrain adjustment factor.

Sector	Terrain adjustment factor
N	1.70
NNE	1.80
NE	2.10
ENE	1.70
E	1.60
ESE	1.80
SE	1.50
SSE	1.50
S	1.90
SSW	2.00
SW	2.10
WSW	1.80
W	1.20
WNW	2.50
NW	1.70
NNW	1.60

Source: TVA 2010b.

environmental transport and uptake of radionuclides, (4) calculation of radiation doses to exposed individuals, and (5) estimation of health effects. There are uncertainties with each of these steps.

Uncertainties exist in the way the physical systems being analyzed are represented by the computational models and in the data required to exercise the models (due to measurement, sampling, or natural variability).

Table C-4. GENII exposure parameters to plumes and soil contamination.

Maximally exposed individual				General population			
External exposure		Inhalation of plume		External exposure		Inhalation of plume	
Plume (hours)	Soil contamination (hours)	Exposure time (hours)	Breathing rate (cubic centimeters per second)[a]	Plume (hours)	Soil contamination (hours)	Exposure time (hours)	Breathing rate (cubic centimeters per second)[a]
6,132	6,132	8,760	270	4,380	4,380	8,760	270

Source: NRC 1977a.
a. The inside back cover provides conversion factors from metric to English units.

Table C-5. GENII usage parameters for consumption of terrestrial food.

Food type	Maximally exposed offsite individual				General population			
	Growing time (days)	Yield (kilograms per square meter)[a]	Holdup time (days)	Consumption rate (kilograms per year)[a]	Growing time (days)	Yield (kilograms per square meter)[a]	Holdup time (days)	Consumption rate (kilograms per year)[a]
Leafy veg	60	1.85	1	64	60	1.85	1	19
Root veg	90	0.57	1	520	90	0.57	1	171

Sources: NRC 1977a; TVA 2010a, 2010b.
a. The inside back cover provides conversion factors from metric to English units.

Table C-6. GENII usage parameters for consumption of animal products.

Food type	Human consumption rate (kilograms per year)[a]	Holdup time (days)	Animal stored feed			Animal fresh forage		
			Growing time (days)	Yield (kilograms per square meter)[a]	Storage time (days)	Growing time (days)	Yield (kilograms per square meter)[a]	Storage time (days)
Maximally exposed individual								
Beef	110	13	90	0.64	180	30	1.18	0
Milk	310	1	45	0.64	100	30	1.18	0
Population								
Beef	95	13	90	0.64	180	30	1.18	0
Milk	110	1	45	0.64	100	30	1.18	0

Sources: NRC 1977a; TVA 2010a, 2010b; Napier et al. 2009.
a. The inside back cover provides conversion factors from metric to English units.

Table C-7. GENII liquid pathway parameters.

Parameter	Plant	
	Sequoyah	Watts Bar
Average river volumetric flow rate (cubic meters per year)[a]	2.74×10^{10}	2.25×10^{10}
River shoreline exposure time per year (hours)	500	500
Transit time for release to aquatic recreation	0	0
2025 population ingesting drinking water and fish	407,699	367,652
Drinking water holdup time (days)	1	1
Drinking water consumption rate (liters per year)[a]	730 maximum 370 average	730 maximum 370 average
Fish consumption rate (pounds per year)	21 maximum 6.9 average	21 maximum 6.9 average
River shoreline exposure time per year for the entire 50-mile population (hours)	3.09×10^{7}	3.21×10^{7}

Sources: NRC 1977a; TVA 2010a, 2010b.
a. The inside back cover provides conversion factors from metric to English units.

In principle, one can estimate the uncertainty associated with each source and predict the remaining uncertainty in the results of each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final results. However, conducting such a full-scale quantitative uncertainty analysis is neither practical nor a standard practice for a study of this type. Rather, the analysis is designed to ensure—through judicious selection of release scenarios, models, and parameters—that the results represent the potential risks. This is accomplished by making assumptions in the calculations at each step. The models, parameters, and release scenarios used in the calculations are selected in such a way that most intermediate results and, consequently, the final estimates of impacts, are greater than would be expected. As a result, even though the range of uncertainty in a quantity might be large, the value calculated for the quantity would be close to one of the extremes in the range of possible values, so the chance of the actual quantity being greater than the calculated value would be low (or the chance of the quantity being less than the calculated value if the criteria are such that the quantity has to be maximized). The goal of the radiological assessment for normal operation in this study has been to produce results that are conservative.

The degree of conservatism in the calculated results is closely related to the range of possible values the quantity can have. This range is determined by what is likely realistically to occur. Thus, the only processes considered are those that are credible for the conditions under which the physical system being modeled operates. NNSA has incorporated this consideration for the normal operation analyses.

Although the radionuclide compositions of source terms are reasonable estimates, there are uncertainties in the radionuclide inventory and release reactions that could affect estimated impacts.

C.2.4 RADIOLOGICAL RELEASES TO THE ENVIRONMENT AND ASSOCIATED IMPACTS

TVA provided radiological release data from normal operations (TVA 2012) based on a 3-year average from 2008 through 2010. To assess the potential radiation dose to the individual and population from the operation of Watts Bar and Sequoyah in a tritium-producing mode, this SEIS uses radiological releases from normal operations and superimposes the doses that would result from additional releases of tritium. However, under normal operations without TPBARs, NNSA assumed the total tritium releases would be 2,400 curies per reactor at each plant (TVA 2012).

The dose assessment uses the method prescribed by the NRC in Regulatory Guides 1.109 (NRC 1977a), and 1.111 (NRC 1977b), with adjustments as needed.

Radiological Releases to the Environment

Normal operational radiological assessments were determined (modeled) for the No-Action Alternative and the three tritium production scenarios: (1) production of tritium by the irradiation of 2,500 TPBARs at Watts Bar, and (2) production of tritium by the irradiation of 2,500 TPBARs at Sequoyah, (3) production of tritium by the loading of 1,250 TPBARs each at Watts Bar and Sequoyah, (4) production of tritium by the irradiation of 5,000 TPBARs at Watts Bar, and (5) production of tritium by the irradiation of 5,000 TPBARs at Sequoyah.

During tritium production, some tritium permeates through the TPBARs, leading to an increase in the quantity of tritium in the reactor coolant water system. Tritium released from the TPBARs during normal plant operation enters the coolant system and is distributed throughout the reactor coolant, chemical volume control, liquid radioactive waste, and gaseous radioactive waste systems. The rate of this accumulation depends on coolant system capacities and water volume exchanges associated with the required water chemistry and soluble boron adjustments. Tritium released to the coolant system is processed along with the rest of the coolant, and this evolution provides the pathway for the transport and release of tritium outside the coolant system. This analysis assumed that the design tritium permeation per TPBAR, on average, would be 10 curies per year. Table C-8 lists the anticipated increases in tritium releases (in curies) to the atmosphere (air emission) and the water pathways (liquid effluent) as a result of this design permeation rate. These values are based on the assumption that about 90 percent of the tritium in the reactor coolant system would be released in the liquid effluent and 10 percent would be released to the atmosphere as tritiated water vapor (air emissions).

Table C-8. Annual increase in tritium releases (curies) to the environment.

Alternative	Site	TPBARs	Watts Bar		Sequoyah	
			Air	**Liquid**	**Air**	**Liquid**
No Action	Watts Bar and Sequoyah	680 Watts Bar 1,360 Sequoyah	680	6,120	1,360	12,240
1	Watts Bar	2,500	2,500	22,500	0	0
2	Sequoyah	2,500	0	0	2,500	22,500
3	Watts Bar and Sequoyah	1,250 each	1,250	11,250	1,250	11,250
4	Watts Bar	5,000	5,000	45,000	0	0
5	Sequoyah	5,000	0	0	5,000	45,000
6	Watts Bar and Sequoyah	2,500 each	2,500	22,500	2,500	22,500

Tables C-9 and C-10 list the current radioactivity releases in the air emissions and the liquid effluents from normal operation (without TPBARs) at Watts Bar and Sequoyah, respectively, based on a 3-year average from 2008 through 2010 as supplied by TVA (2012). The estimated radioactivity releases during tritium production at Watts Bar and Sequoyah would be the sum of the values in these tables and those listed in Table C-8.

Radiological Impacts

As stated above, doses to members of the public from tritium releases during normal operations were calculated using the GENII program (Napier et al. 2009). GENII uses "special" transport assumptions in its evaluation of tritiated water movement through various food chains. The concentration of tritium in each food type is assumed to have 0.9 times specific activity in plant water for leafy vegetables and 0.8 times the specific activity in plant water for other vegetables and grains (Napier et al. 2009). When soil is contaminated with residual tritium and no tritium from air and water is continually added to the soil, the contamination would be likely to escape rapidly (by evaporation) from the soil or plants that had taken up this tritium. GENII, however, assumes that the soil retains the tritium, which remains available for plant uptake over time.

As a result, the effective dose associated with the ingestion pathway calculated by GENII is bounding. The assumption that people living within 50 miles of each site would eat all the contaminated food produced in that area makes the dose calculations even more bounding. Even with this overestimation, all calculated doses resulting from tritium releases during normal operation are within the limits for the operation of the Watts Bar and Sequoyah reactors (Tables C-11 and C-12, respectively). These two dose receptors are the maximally exposed member of the public and the population living within 50 miles of each site in 2025. Each table lists estimated doses from gaseous emissions (air) and liquid effluents (liquid) under the No-Action Alternative (current plant conditions), and the estimated incremental doses from tritium releases to air and liquid resulting from up to 2,500 TPBARs irradiated in the reactors.

Table C-9. Average annual radioactivity releases to the air and in liquid at Watts Bar (curies).

Radionuclide	Liquid effluents	Air emissions
Tritium (hydrogen-3)[a]	$3.60 \times 10^{+3}$	$8.49 \times 10^{+1}$
Carbon-14 (as CO_2)		3.77
Barium-139	1.35×10^{-5}	
Bromine-82		2.14×10^{-7}
Cerium-141	3.18×10^{-6}	
Cobalt-57	5.54×10^{-5}	
Cobalt-58	2.09×10^{-2}	2.21×10^{-5}
Cobalt-60	6.45×10^{-3}	1.40×10^{-4}
Chromium-51	4.35×10^{-3}	
Cesium-134	6.26×10^{-4}	1.10×10^{-7}
Cesium-137	2.25×10^{-3}	1.79×10^{-7}
Iron-55	7.32×10^{-2}	
Iron-59	4.05×10^{-4}	
Iodine-131	6.52×10^{-3}	2.29×10^{-4}
Iodine-132	5.42×10^{-4}	7.17×10^{-4}
Iodine-133	2.31×10^{-5}	4.69×10^{-5}
Manganese-54	9.85×10^{-4}	2.42×10^{-5}
Molybdenum-99	3.68×10^{-5}	
Sodium-24	1.83×10^{-5}	
Niobium-95	6.42×10^{-4}	
Rubidium-88	3.94×10^{-5}	
Rhodium-106	4.68×10^{-5}	
Ruthenium-103	4.71×10^{-5}	
Ruthenium-106	4.68×10^{-5}	
Antimony-122	1.68×10^{-5}	
Antimony-124	3.77×10^{-5}	
Antimony-125	5.68×10^{-3}	
Tin-113	2.74×10^{-6}	
Tin-117m	8.21×10^{-5}	
Strontium-89	6.98×10^{-4}	
Strontium-90	8.53×10^{-5}	
Technetium-99m	3.68×10^{-5}	
Tellurium-132	6.94×10^{-4}	
Zirconium-95	1.93×10^{-3}	
Argon-41	4.10×10^{-5}	3.32
Krypton-85	1.18×10^{-3}	3.84×10^{-2}
Krypton-85m	6.03×10^{-5}	4.22×10^{-4}
Krypton-88		3.58×10^{-4}
Xenon-131m	1.36×10^{-3}	2.96×10^{-2}
Xenon-133	4.92×10^{-1}	6.22
Xenon-133m	7.90×10^{-3}	1.38×10^{-3}
Xenon-135	1.43×10^{-2}	1.50

CO_2 = carbon dioxide.

a. For the calculations, NNSA assumed non-TPBAR total (liquid and air) tritium releases would be 2,400 curies per unit.

Table C-10. Average annual radioactivity releases to the air and liquid at Sequoyah (curies).

Radionuclide	Liquid effluents	Air emissions
Tritium (hydrogen-3)[a]	$1.54 \times 10^{+3}$	$3.23 \times 10^{+1}$
Carbon-14 (as CO_2)		2.09
Argon-41		2.36
Silver-110m	2.29×10^{-4}	
Barium-140	5.10×10^{-6}	
Cobalt-57	1.16×10^{-4}	
Cobalt-58	1.93×10^{-2}	9.85×10^{-5}
Cobalt-60	6.39×10^{-3}	3.57×10^{-6}
Chromium-51	2.75×10^{-3}	
Cesium-134	8.69×10^{-6}	
Cesium-137	2.05×10^{-4}	
Cesium-138	8.02×10^{-6}	
Iron-55	9.93×10^{-3}	
Iron-59	5.28×10^{-4}	
Iodine-131	6.76×10^{-5}	6.88×10^{-6}
Iodine-132	4.38×10^{-5}	
Lanthanum-140	5.27×10^{-6}	
Manganese-54	2.39×10^{-4}	
Niobium-95	2.23×10^{-4}	
Antimony-124	6.48×10^{-4}	
Antimony-125	1.92×10^{-3}	
Technetium-99m	3.60×10^{-6}	
Tellurium-132	1.91×10^{-5}	
Zinc-65	1.05×10^{-4}	
Zinc-69m	1.08×10^{-6}	
Zirconium-95	1.03×10^{-4}	
Krypton-85	2.06×10^{-3}	7.19×10^{-2}
Krypton-85m		1.49×10^{-4}
Krypton-87		5.86×10^{-4}
Xenon-131m	1.17×10^{-3}	2.41×10^{-1}
Xenon-133	1.89×10^{-2}	5.81×10^{-1}
Xenon-133m	$9.75 \times 10\text{-}^{5}$	
Xenon-135	$7.77 \times 10\text{-}^{5}$	4.53×10^{-4}

CO_2 = carbon dioxide.

a. For the calculations, NNSA assumed non-TPBAR total (liquid and air) tritium releases would be 2,400 curies per unit.

C.3 Methodology for Estimating Radiological Impacts to Workers

NNSA used current worker data from TVA and information from the 1999 EIS (DOE 1999) to calculate impacts to workers. Worker doses in the 1999 EIS were calculated for both 1,000 TPBARs and 3,400 TPBARs and an assumed permeation rate of 1 curie per TPBAR per year. The current permeation rate is assumed to be 10 curies of tritium per TPBAR per year. NNSA used worker exposure data for the Watts Bar and Sequoyah sites from 2005 through 2010 to determine the average total worker dose and average number of exposed workers (TVA 2012). NNSA added the current worker dose estimates with the appropriate scaled TPBAR amount and permeation rate to calculate worker doses for this SEIS. For instance, the estimated worker doses in the 1999 EIS were divided by the assumed amount of tritium

Table C-11. Annual radiological impacts to the public including incident-free tritium production operations at Watts Bar.

Tritium production	Release medium	Maximally exposed offsite individual: Dose (millirem)	Maximally exposed offsite individual: Latent cancer fatality risk[a]	Population within 50 miles for 2025: Annual dose (person-rem)	Population within 50 miles for 2025: Latent cancer fatalities[b]
No Action (680 TPBARs)	Air	0.25	2×10^{-7}	3.2	0 (0.002)
	Liquid	0.026	2×10^{-8}	4.4	0 (0.003)
	Totals	**0.28**	**2×10^{-7}**	**7.6**	**0 (0.005)**
Alternative 1 (2,500 TPBARs)	Air	0.460	3×10^{-7}	5.4	0 (0.003)
	Liquid	0.064	4×10^{-8}	11.3	0 (0.007)
	Totals	**0.52**	**3×10^{-7}**	**16.7**	**0 (0.01)**
Alternative 2 (0 TPBARs)	Air	0.180	1×10^{-7}	2.4	0 (0.001)
	Liquid	0.011	7×10^{-9}	1.8	0 (0.001)
	Totals	**0.19**	**1×10^{-7}**	**4.2**	**0 (0.003)**
Alternative 3 (1,250 TPBARs)	Air	0. 32	2×10^{-7}	3.9	0 (0.002)
	Liquid	0.038	2×10^{-8}	6.6	0 (0.004)
	Totals	**0.36**	**2×10^{-7}**	**10.5**	**0 (0.006)**
Alternative 4 (5,000 TPBARs)	Air	0.740	4×10^{-7}	8.5	0 (0.005)
	Liquid	0.118	7×10^{-8}	20.9	0 (0.01)
	Totals	**0.86**	**5×10^{-7}**	**29.4**	**0 (0.02)**
Alternative 5 (0 TPBARs)	Air	0.18	1×10^{-7}	2.4	0 (0.001)
	Liquid	0.011	7×10^{-9}	1.8	0 (0.001)
	Totals	**0.19**	**1×10^{-7}**	**4.2**	**0 (0.003)**
Alternative 6 (2,500 TPBARs)	Air	0.460	3×10^{-7}	5.4	0 (0.003)
	Liquid	0.064	4×10^{-8}	11.3	0 (0.007)
	Totals	**0.52**	**3×10^{-7}**	**16.7**	**0 (0.01)**

a. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per rem.

b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table C-12. Annual radiological impacts to the public including incident-free tritium production operations at Sequoyah.

Tritium production	Release medium	Maximally exposed offsite individual: Dose (millirem)	Maximally exposed offsite individual: Latent cancer fatality risk[a]	Population within 50 miles for 2025: Annual dose (person-rem)	Population within 50 miles for 2025: Latent cancer fatalities[b]
No Action (1,360 TPBARs)	Air	0.21	1×10^{-7}	4.4	0 (0.003)
	Liquid	0.033	2×10^{-8}	6.4	0 (0.004)
	Totals	**0.24**	**1×10^{-7}**	**10.8**	**0 (0.006)**
Alternative 1 (0 TPBARs)	Air	0.12	7×10^{-8}	2.7	0 (0.002)
	Liquid	0.009	5×10^{-9}	1.7	0 (0.001)
	Totals	**0.13**	**8×10^{-8}**	**4.4**	**0 (0.003)**
Alternative 2 (2,500 TPBARs)	Air	0.28	2×10^{-7}	5.9	0 (0.004)
	Liquid	0.053	3×10^{-8}	10.3	0 (0.006)
	Totals	**0.33**	**2×10^{-7}**	**16.2**	**0 (0.01)**
Alternative 3 (1,250 TPBARs)	Air	0.20	1×10^{-7}	4.3	0 (0.003)
	Liquid	0.031	2×10^{-8}	6.0	0 (0.004)
	Totals	**0.23**	**1×10^{-7}**	**10.3**	**0 (0.006)**
Alternative 4 (0 TPBARs)	Air	0.12	7×10^{-8}	2.7	0 (0.002)
	Liquid	0.009	5×10^{-9}	1.7	0 (0.001)
	Totals	**0.13**	**8×10^{-8}**	**4.4**	**0 (0.003)**
Alternative 5 (5,000 TPBARs)	Air	0.450	3×10^{-7}	9.1	0 (0.005)
	Liquid	0.096	6×10^{-8}	19.0	0 (0.01)
	Totals	**0.55**	**3×10^{-7}**	**28.1**	**0 (0.02)**
Alternative 6 (2,500 TPBARs)	Air	0.28	2×10^{-7}	5.9	0 (0.004)
	Liquid	0.053	3×10^{-8}	10.3	0 (0.006)
	Totals	**0.33**	**2×10^{-7}**	**16.2**	**0 (0.01)**

a. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per rem.

b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

release to determine the worker dose per released curie. NNSA used this number in the SEIS to calculate estimated doses using the current expected tritium release amounts in curies. Tables C-13 and C-14 list the doses to workers at Watts Bar and Sequoyah, respectively.

Table C-13. Annual radiological impacts to workers including incident-free tritium production operations at Watts Bar.

Impact	No-Action Alternative (680 TPBARs)	Alternative 1 (2,500 TPBARs)	Alternative 2 (0 TPBARs)	Alternative 3 (1,250 TPBARs)	Alternative 4 (5,000 TPBARs)	Alternative 5 (0 TPBARs)	Alternative 6 (2,500 TPBARs)
Average worker dose (millirem)	116.2	122.3	114.0	118.1	130.5	114.0	122.3
Latent cancer fatality risk	7×10^{-5}	7×10^{-5}	7×10^{-5}	7×10^{-5}	8×10^{-5}	7×10^{-5}	7×10^{-5}
Total worker dose (person-rem)[a]	102.2	107.4	100.2	103.8	114.7	100.2	107.4
Latent cancer fatalities[b]	0 (0.06)	0 (0.06)	0 (0.06)	0 (0.06)	0 (0.07)	0 (0.06)	0 (0.06)

a. Based on 879 exposed workers, which includes additional workers used during refueling operations and outages.
b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table C-14. Annual radiological impacts to workers including incident-free tritium production operations at Sequoyah.

Impact	No-Action Alternative (1,360 TPBARs)	Alternative 1 (0 TPBARS)	Alternative 2 (2,500 TPBARS)	Alternative 3 (1,250 TPBARS)	Alternative 4 (0 TPBARs)	Alternative 5 (5,000 TPBARs)	Alternative 6 (2,500 TPBARS)
Average worker dose (millirem)	108.7	105.4	111.4	108.4	105.4	117.4	111.4
Latent cancer fatality risk	7×10^{-5}	6×10^{-5}	7×10^{-5}	7×10^{-5}	6×10^{-5}	7×10^{-5}	7×10^{-5}
Total worker dose (person-rem)[a]	131.9	127.9	135.2	131.6	128.0	142.4	135.2
Latent cancer fatalities[b]	0 (0.06)	0 (0.06)	0 (0.06)	0 (0.06)	0 (0.08)	0 (0.09)	0 (0.06)

a. Based on 1,214 workers, which includes additional workers used during refueling operations and outages.
b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

C.4 Methodology for Estimating Dose from Failed TPBARs

In addition to the assumed normal operation release of tritium through permeation, an additional potential release scenario considered in this SEIS is the failure of 1 or more TPBARs, such that the inventory of the TPBARs is released to the primary coolant. The occurrence of TPBAR failure is considered to be beyond that associated with normal operating conditions. Thus, such an assumption is extremely conservative. The radiological consequences to the public and workers resulting from the assumption of two TPBAR failures in a given core load of 2,500 TPBARs at each of the sites are presented in Tables C-15 through C-18. Releases, doses, and cancer risks associated with 1 TPBAR failure can be determined by dividing the values in the tables by two.

Table C-15. Radiological impacts to the public from failure of two TPBARs at Watts Bar.

Release pathway	Release quantity (curies)	Dose to maximally exposed individual (millirem)	Latent cancer fatality risk	Dose to population within 50 miles (person-rem)	Latent cancer fatalities[a]
Air	2,315	0.25	2×10^{-7}	2.6	0 (0.002)
Liquid	20,835	0.049	3×10^{-8}	7.3	0 (0.004)
Totals	**23,150**	**0.30**	$\mathbf{2 \times 10^{-7}}$	**9.90**	**0 (0.006)**

a. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table C-16. Radiological impacts to the public from failure of two TPBARs at Sequoyah.

Release pathway	Release quantity (curies)	Dose to maximally exposed individual (millirem)	Latent cancer fatality risk	Dose to population within 50 miles (person-rem)	Latent cancer fatalities[a]
Air	2,315	0.21	1×10^{-7}	2.7	0 (0.002)
Liquid	20,835	0.040	2×10^{-8}	7.2	0 (0.004)
Totals	**23,150**	**0.25**	$\mathbf{2 \times 10^{-7}}$	**9.9**	**0 (0.006)**

a. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per person-rem Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table C-17. Radiological impacts to workers from failure of two TPBARs at Watts Bar.

Impact type	Value
Average worker dose (millirem)	7.7
Latent cancer fatality risk	5×10^{-6}
Total worker dose (person-rem)[a]	6.8
Latent cancer fatalities[b]	0 (0.004)

a. Based on 879 exposed workers, which includes additional workers used during refueling operations and outages.

b. Estimated number of latent cancer fatalities in the entire offsite population within 50 miles from exposure to the indicated dose. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

Table C-18. Radiological impacts to workers from failure of two TPBARs at Sequoyah.

Impact type	Value
Average worker dose (millirem)	5.6
Latent cancer fatality risk	3×10^{-6}
Total worker dose (person-rem)[a]	6.8
Latent cancer fatalities[b]	0 (0.004)

a. Based on 1,214 exposed workers, which includes additional workers used during refueling operations and outages.

b. Estimated number of latent cancer fatalities to the total workforce given exposure to the indicated dose. The number of latent cancer fatalities is calculated by multiplying the dose by the risk factor of 0.0006 LCFs per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

C.5 Radiological Impacts to Shared Population

Figure C-3 shows 50-mile radii circles around the Watts Bar and Sequoyah sites. The circles overlap, which means there is a population that is within 50 miles of both sites. This section refers to that population as the "shared population." Operations from both Watts Bar and Sequoyah have the potential to impact this shared population. This section presents a specific analysis of the potential human health impacts on this shared population from normal operations at Watts Bar and Sequoyah for the alternatives analyzed in this SEIS.

The shared population is estimated to be about 690,750 (USCB 2013). As such, this shared population represents about 58 percent of the 50-mile population around Watts Bar and about 64 percent of the 50-mile population around Sequoyah. This SEIS assumes that these population percentages would not change in 2025, which is the basis for the human health analysis in this SEIS. Based on these population percentages, Table C-19 provides the human health impacts to the shared population for each alternative in the SEIS.

Table C-19. Annual radiological impacts to shared population from Watts Bar and Sequoyah.

	Alternative						
Impact	No-Action	1	2	3	4	5	6
Annual dose from Watts Bar (person-rem)	4.4	9.7	2.4	6.1	17.0	2.4	9.7
Annual dose from Sequoyah (person-rem)	6.9	2.8	10.4	6.6	2.8	18.0	10.4
Total annual dose to shared population (person-rem)	11.3	12.5	12.8	12.7	19.8	20.4	20.1
Total latent cancer fatalities among shared population[a]	0 (0.007)	0 (0.008)	0 (0.008)	0 (0.008)	0 (0.01)	0 (0.01)	0 (0.01)

a. Estimated number of latent cancer fatalities in the shared population (Figure C-3) from exposure to the indicated dose. Latent cancer fatalities calculated using 6×10^{-4} latent cancer fatality per person-rem. Because the numbers of latent cancer fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

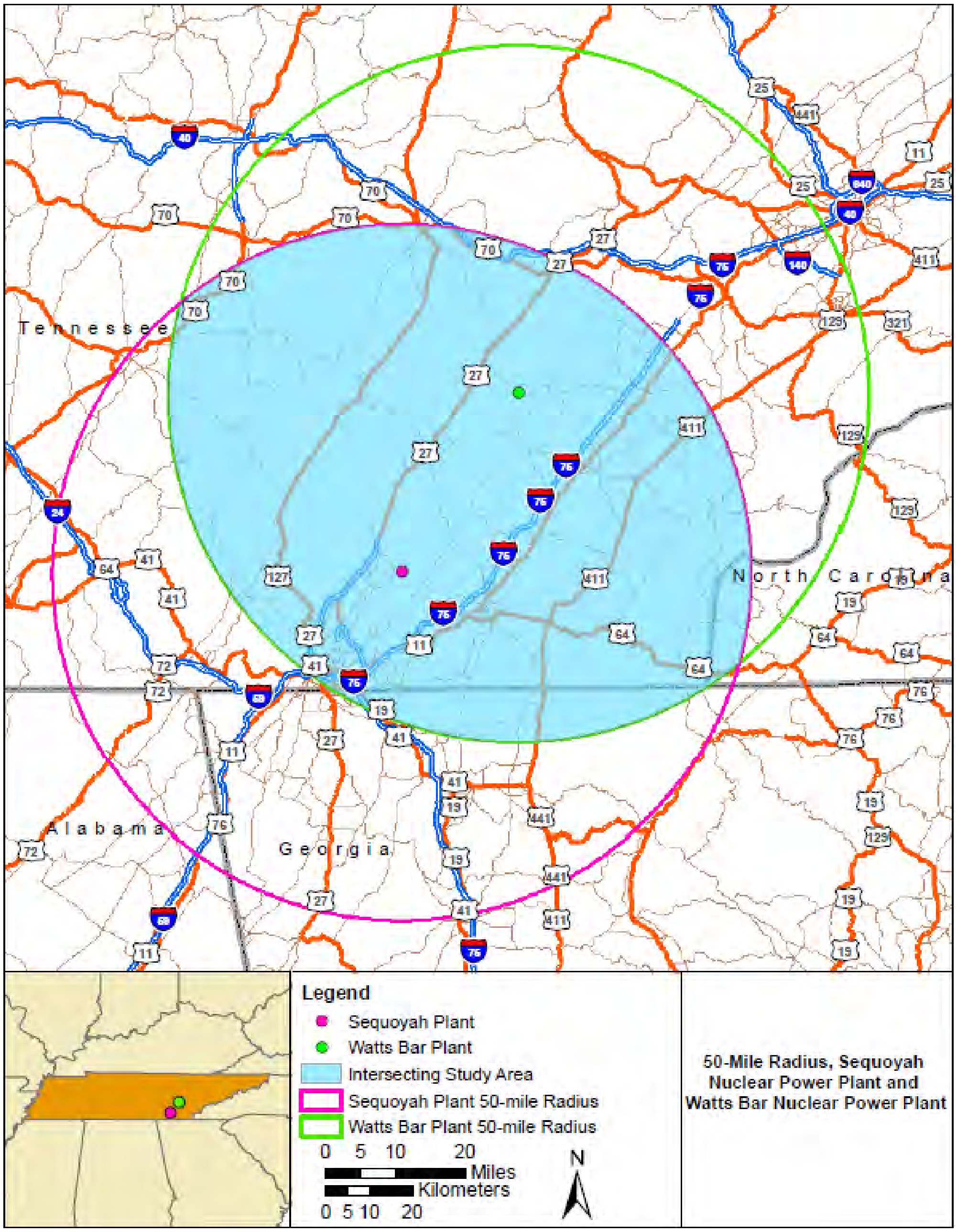

Figure C-3. 50-mile radii circles around Watts Bar and Sequoyah.

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APPENDIX D. HUMAN HEALTH EFFECTS FROM FACILITY ACCIDENTS

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APPENDIX D. HUMAN HEALTH EFFECTS FROM FACILITY ACCIDENTS

This appendix presents the methods and assumptions the National Nuclear Security Administration (NNSA) used to estimate potential impacts and risks to workers and the general public from exposure to releases of radioactive and hazardous chemical materials during hypothetical accidents at the Watts Bar and Sequoyah Nuclear Plants.

In March 1999, the U.S. Department of Energy (DOE) issued the *Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (1999 EIS; DOE 1999a). Appendix D of the 1999 EIS included a detailed analysis of potential health effects from the production of tritium in a commercial light water reactor (CLWR). This appendix summarizes and updates that description based on the current tritium production planning assumptions and alternatives described in Chapter 2 of this Supplemental Environmental Impact Statement (SEIS).

Section D.1 describes the process NNSA used to select accident scenarios for analysis and describes them. Section D.2 describes the calculation methods NNSA used to determine the estimated effects on human health.

D.1 Accident Scenario Selection and Descriptions

D.1.1 ACCIDENT SCENARIO SELECTION

The accident analysis considered a spectrum of potential accident scenarios. The range of accidents included reactor design-basis accidents, nonreactor design-basis accidents, tritium-producing burnable absorber rod (TPBAR) handling accidents, transportation cask handling accidents, and beyond-design-basis accidents (that is, severe reactor accidents).

In the 1999 EIS, NNSA reviewed the spectrum of reactor and nonreactor design-basis accidents in the Watts Bar and Sequoyah Safety Analysis Reports (DOE 1999a). In that EIS, NNSA selected the large break loss-of-coolant accident as the representative reactor design-basis accident because it would have the potential to damage more TPBARs than any other reactor design-basis accident. NNSA selected the waste gas decay tank failure accident as the nonreactor design-basis accident for analysis because it would have the potential to release more tritium than other nonreactor design-basis accidents. This SEIS analyzes the same reactor and nonreactor design-basis accidents.

After irradiation of the fuel assemblies in the reactor core, the Tennessee Valley Authority (TVA) would remove them (with or without TPBARs) from the reactor and transfer them to the spent fuel pool. There, TVA would remove the TPBAR assemblies from the fuel assemblies and insert them into a consolidation container, which is a 17-by-17 array of tubes that hold the TPBARs. The consolidation container is the same size and shape as a fuel assembly and can accommodate as many as 289 TPBARs.

This appendix evaluates three TPBAR handling accident scenarios, which are the same as those in the 1999 EIS:

- Scenario 1 assumes a consolidation container with 289 TPBARs would be dropped during loading into a transportation cask. If the container landed vertically on the spent fuel pool floor, the scenario assumes the impact would not damage any of the TPBARs. However, if the container landed on an edge or struck an object (for example, an unoccupied fuel rack or the shelf in the cask loading pit), the container shell and one row of tubes with TPBARs could be damaged, breaching as many as 17 TPBARs.

- Scenario 2 assumes an irradiated fuel assembly, with a TPBAR assembly and 24 TPBARs, would be dropped in the spent fuel pool. If the assembly landed vertically, the scenario assume the impact would not damage any of the TPBARs. However, if the assembly landed on an edge or was struck by an object on the side or corner, the impact could damage as many as 3 TPBARs.

- Scenario 3 assumes a TPBAR assembly with 24 TPBARs would be dropped in the spent fuel pool as it was removed from an irradiated fuel assembly and the impact would breach all 24 TPBARs. NNSA selected Scenario 3 for analysis in this SEIS because it would have the potential to damage more TPBARs than the other TPBAR handling accidents.

The analysis evaluated two truck cask drop accidents that could cause a release of tritium from the casks:

- A cask drop before the cask was sealed, and
- A cask drop that could breach a sealed cask.

The postulated beyond-design-basis reactor accident analyses NNSA selected for use in this SEIS address core damage accident scenarios that would lead to the loss of containment integrity. This includes scenarios that fall into three performance categories:

- Early containment failures,
- Late containment failures, and
- Containment bypass.

NNSA did not evaluate accident scenarios that do not fall into these categories because those would lead to significantly lower consequences.

As discussed in Section 1.6 of the SEIS, NNSA is currently preparing a Surplus Plutonium Disposition SEIS to analyze the potential environmental impacts of alternatives to dispose of about 13 metric tons of weapons-grade plutonium (75 FR 41850; July 19, 2010). That SEIS will supplement the original EIS DOE issued in November 1999 (DOE 1999b). Among other things, the Surplus Plutonium Disposition EIS analyzed the impacts of using mixed-oxide fuel in certain domestic CLWRs to generate electricity. DOE and TVA have entered into an interagency agreement to evaluate the use of mixed-oxide fuel in TVA's Browns Ferry and Sequoyah reactors, and the Surplus Plutonium Disposition SEIS will discuss the potential environmental impacts of such use.

Although both the Surplus Plutonium Disposition SEIS and this SEIS involve the Sequoyah reactors as alternatives, there are differences in the description and analysis of the No-Action Alternative for the Sequoyah reactors in the two SEISs. The No-Action Alternative in this CLWR SEIS includes the irradiation of TPBARs in the Sequoyah reactors; that for the Surplus Plutonium Disposition SEIS does not. In addition, the offsite population dose and risk estimates in this SEIS use a projected 2025 population. NNSA selected this date because (1) it is near the mid-point of the remaining life of the interagency agreement between TVA and DOE, and (2) it allows comparison with the 1999 EIS (DOE 1999a), which also used a projected 2025 population. In the Surplus Plutonium Disposition SEIS, DOE will use a projected 2020 population. DOE selected the 2020 population for the Surplus Plutonium Disposition SEIS for consistency with the anticipated plutonium disposition duration.

D.1.2 REACTOR DESIGN-BASIS ACCIDENT

A reactor design-basis accident is a Condition IV occurrence. Condition IV occurrences are faults that are unlikely to take place, but are postulated because they would have the potential to release significant amounts of radioactive material. The analyzed reactor design-basis accident for this SEIS is a large break loss-of-coolant accident. This accident would have the potential to damage more TPBARs than any other reactor loss-of-coolant design-basis accident (DOE 1999a). This scenario assumes rupture of both ends of a pipe more than 6 inches in diameter in the reactor coolant system. During the initial phase of the accident, the reactor water (coolant) level would drop below the top of the reactor core for a short period before the emergency core cooling systems would automatically inject additional water to cover the core. During this period the core would overheat and the cladding on some of the fuel rods and overheating would breach all of the TPBARs (DOE 1999a). The analysis assumed that the entire tritium content in the TPBARs would be released to the containment. Each TPBAR produces 1 gram of tritium on average by the end of the 18-month irradiation cycle (DOE 1999a). For the analyses in this SEIS, 1 gram of tritium contains 9,640 curies (DOE 1999a). The analysis also assumed that all tritium that permeated from the TPBARs and into the reactor coolant system during 18 months of normal operation would be released to the containment during the accident. This would include release of an amount of tritium corresponding to 10 curie per TPBAR per year (DOE 1999a). The accident consequence calculations consider applicable reactor site-specific, protective action guidelines.

Table D-1 lists the total source term release to the containment from the number of TPBARs in all scenarios for the Watts Bar and Sequoyah reactors. Table D-2 lists the tritium source term release from the containment to the environment. The reduction in the amount of tritium available for release would be the result of postaccident processing of the containment atmosphere to reduce iodine release to the environment, operation of hydrogen recombiners, and absorption of elemental and oxidized tritium by water in the containment (DOE 1999). The design-basis accident would release tritium, in the form of tritiated water vapor, from the containment to the atmosphere through containment leakage. Section D.2.4.2 discusses containment release pathways. The analysis assumed the accident would release tritiated water vapor to the atmosphere for 30 days after the accident. After 30 days, all the

Table D-1. Reactor design-basis accident tritium inventory (curies).

Source term	Tritium production		
	680 TPBARs	**1,250 TPBARs**	**2,500 TPBARs**
TPBARs breached during accident	6.57×10^6	1.21×10^7	2.41×10^7
TPBAR leakage during normal operations	1.02×10^3	1.88×10^3	3.75×10^3
Total release to containment	6.56×10^6	1.21×10^7	2.41×10^7
Total available for release to the outside air[a]	6.56×10^5	1.21×10^6	2.41×10^6

a. Tritium releases would be in the form of tritiated water vapor.

Table D-2. Source term of reactor design-basis accident tritium release to the outside air.

Site	Tritium production (TPBARs)	Tritium release (curies)[a,b]		
		0–24 hours	**24–720 hours**	**Total 0–30 days**
Watts Bar	680	573	7,533	8,106
	1,250	1,018	13,375	14,393
	2,500	2,035	26,750	28,785
Sequoyah	680	554	7,276	7,830
	1,250	1,018	13,375	14,393
	2,500	2,035	26,750	28,785

a. Tritium releases would be in the form of tritiated water vapor.
b. Source terms for a single reactor from DOE (1999a).

tritiated water vapor in the containment atmosphere would have condensed and, therefore, would not be available for further release.

D.1.3 NONREACTOR DESIGN-BASIS ACCIDENT

NNSA selected the waste gas decay tank rupture, a Condition III occurrence, as the nonreactor design-basis accident for the SEIS analysis. The consequences of a Condition III occurrence would be less severe than those of a Condition IV occurrence. The release of radioactivity would not be sufficient to interrupt or restrict public use of areas beyond the exclusion area boundary (DOE 1999a).

Exclusion Area Boundary

The area around a nuclear plant over which the reactor licensee has the authority to determine all activities, including exclusion or removal of personnel and property from the area. This area can be traversed by a highway, railroad, or waterway, provided these are not so close to the facility that they interfere with normal operations and there are appropriate and effective arrangements to control traffic and protect public health and safety on the highway, railroad, or waterway in an emergency. Residences would not normally be allowed within the exclusion area. In any event, residents would be subject to prompt evacuation if necessary. Activities unrelated to operation of the reactor can be permitted in an exclusion area under appropriate limitations, provided no significant hazards to the public health and safety would result.

Figures 2-3 and 2-5 in Chapter 2 show the exclusion area boundaries for the Watts Bar and Sequoyah Nuclear Plants, respectively.

The gaseous waste processing system removes fission product gases from the reactor coolant. The maximum storage of waste gases occurs before a refueling shutdown, when the gas decay tanks store the radioactive gases the system strips from the reactor coolant. The accident analysis conservatively assumed that 10 percent of the TPBAR-generated tritium in the reactor coolant, as well as radioactive xenon and krypton fission product gases, would be stripped from the coolant before a refueling shutdown and stored in waste decay tanks. Therefore, it would have the potential to release more tritium than other nonreactor design-basis accidents. The analysis made the conservative assumption that all tritium that permeated from the TPBARs to the coolant during the entire fuel cycle would be released to and retained in the coolant.

The postulated nonreactor design-basis accident is an unexpected, uncontrolled release of the gases in a single gas decay tank due to the failure of the tank or the associated piping. The analysis assumed that tritium would be released directly to the environment in an oxide form. Accident consequence calculations consider applicable reactor site-specific protective action guidelines. Table D–3 lists the tritium source term that would be released to the environment.

Table D-3. Nonreactor design-basis accident tritium source term (curies).

680 TPBARs	1,250 TPBARs	2,500 TPBARs
1,020	1,875	3,750

D.1.4 TPBAR HANDLING ACCIDENT

The TPBAR handling accident scenario assumes that a TPBAR assembly with 24 TPBARs would be dropped during removal from an irradiated fuel assembly during the TPBAR consolidation process. The analysis assumed all TPBARs would be unprotected and would be breached when the assembly struck the spent fuel pool floor. The gaseous tritium in the 24 breached TPBARs would be released into the fuel pool and directly to the environment. The analysis conservatively assumed that the entire tritium inventory in the breached TPBARs (231,360 curies) would be released into the fuel pool (DOE 1999a). The released tritium would be in oxide form (tritiated water vapor). The analysis assumed all tritium that was released to the fuel pool would also be released to the outside air continuously over a 1-year period by evaporation from the pool and would be exhausted by the area ventilation system through the auxiliary building stack (DOE 1999a). The purpose of this assumption was to estimate the maximum dose to the public from this accident. (Release of tritium through liquid effluents would result in a public dose, which is an order of magnitude lower than that from release to the outside air.) If a TPBAR handling accident occurred, TVA would take action to limit the tritium release from the breached TPBARs. However, the analysis took no credit for mitigating actions to limit the release of tritium to the fuel pool (for example, placing the breached TPBARs in a sealed container) or to reduce accident consequences to the public (for example, interdiction of contaminated food and drinking water).

D.1.5 TRUCK TRANSPORTATION CASK HANDLING ACCIDENT AT THE REACTOR SITE

TVA would load one TPBAR consolidation chamber with 289 TPBARs into the truck cask under water in the spent fuel pool cask loading pit. The analysis assumed that, after insertion of the consolidation container, the cask cover would be installed but not tightly sealed. The cask would be raised above the water level where it would be hosed down and drained before being moving to the decontamination area. There it would be sealed, the air vacuumed out, backfilled with inert gas, and decontaminated before loading on the truck trailer bed.

The analysis considered an option to seal the cask cover before lifting the cask; in this case, the only potential for a tritium release would be if a drop breached the cask. In accordance with the requirements of 10 CFR Part 71 the truck cask design must be able to withstand a 30-foot drop onto an unyielding surface without loss or dispersal of the radioactive contents of the cask. The cask could drop more than 30 feet in the spent fuel pool cask loading pit. It could fall about 9 feet through the air and about 40 feet through the water. The terminal velocity of such a fall would exceed that of a 30-foot drop through air (DOE 1999a). The analysis assumed such a fall would breach the cask.

NNSA reviewed spent fuel pool designs to determine if there was a potential for cascading effects of the cask drop that would initiate releases of additional radionuclides. If the spent fuel pool liner in the cask pit area was breached and the water level in the spent fuel pool dropped, the water level would not drop to a level that uncovered the spent fuel in the storage racks. The cask loading area of the spent fuel pool is separated from the storage area by a shelf. The shelf height maintains the water level in the storage area above the top of the spent fuel when the cask pit area is drained. Additional defense-in-depth is provided when the spent fuel pool gates are installed after loading the cask. With the gates in place, one on each side of the cask loading pit access channel to the spent fuel pool, a breach of the liner in the cask loading pit area would result in a drop in the spent fuel water level to the top of the gates.

The analysis determined the drop would not damage any of the TPBARs. TPBARs in the cask would be protected not only by the cask, but also by the consolidation container structure. However, the analysis did assume that the structural loads on the TPBARs from the drop could breach as many as 17 TPBARs, the same number as for a dropped TPBAR consolidation container. The gaseous tritium in the breached TPBARs would be released into the fuel pool and directly to the environment by evaporation. NNSA considered two accident scenarios:

- Scenario 1 postulates that the cask drop would occur before draining and drying the cask interior. The analysis conservatively assumed that the 17 breached TPBARs would release tritium into the flooded cask at the rate of 50 curies per TPBAR per day (DOE 1999a) until the cask could be drained into the fuel pool and the cask interior could be vacuum-dried. The analysis further assumed the cask would be drained and vacuum-dried within 7 days of the accident to limit the release of tritium from the breached TPBARs. The analysis took no credit for additional mitigating actions to reduce the released tritium in the fuel pool (for example, draining the cask into a storage tank). A total of 5,950 curies of tritium, in oxide form, would be released to the fuel pool area and exhausted up the auxiliary building stack over a 1-year period (DOE 1999a).

- Scenario 2 postulates that the cask drop of more than 30 feet would occur while loading the cask on a trailer after it was loaded with TPBARs, sealed, and decontaminated. It assumed this accident would breach the cask and 17 TPBARs. The breached TPBARs would release tritiated water vapor to the auxiliary building atmosphere at a rate of 0.00001 gram per breached TPBAR per hour (DOE 1999a). The analysis assumed that the tritium release would end when the TPBARs were placed in a replacement cask after 30 days. During this period, 1,180 curies of tritium would be released to the atmosphere through the auxiliary building stack.

The consequences for Scenario 1 would bound the consequences of Scenario 2, so the analysis did not consider Scenario 2 further.

D.1.6 TRUCK TRANSPORTATION CASK HANDLING ACCIDENT AT THE TRITIUM EXTRACTION FACILITY

Cask handling accidents at the Tritium Extraction Facility are in the scope of the Tritium Extraction Facility EIS (DOE 1999c) and are not within the scope of this SEIS.

D.1.7 BEYOND-DESIGN-BASIS ACCIDENT

Beyond-design-basis accidents are severe reactor accidents, which are less likely to occur than design-basis accidents. The consequences of these accidents could be more serious if TVA took no mitigative actions afterward. For design-basis accidents, the mitigating systems are assumed to be available. In severe reactor accidents, even though the initiating event could be a design-basis event (for example, a large break loss-of-coolant accident), additional failures of mitigating systems would cause some degree of physical deterioration of the fuel in the reactor core and a possible breach of the containment structure leading to releases of radioactive materials to the environment. The analysis considered only the severe reactor accident scenarios that could lead to containment bypass or failure. It did not consider accident scenarios that would not lead to containment bypass or failure because the public and environmental consequences would be significantly less in those cases.

In 1988, the NRC asked all licensees of operating plants to perform individual plant examinations for severe accident vulnerabilities (DOE 1999a). The NRC indicated that a probabilistic risk assessment is an acceptable approach to use in performing a plant examination. Those analyses evaluated in full (quantitatively) the consequences of all potential events from operating disturbances (known as internal initiating events) in each plant (see Section D.1.7.1). The state-of-the-art probabilistic risk assessment uses realistic criteria and assumptions to evaluate accident progression and the systems necessary to mitigate each accident.

In 1991, the NRC requested all licensees of operating plants to conduct individual plant examinations of external events for severe accident vulnerabilities (DOE 1999a). This analysis covered accidents that could begin naturally (for example, earthquakes, tornadoes, floods, or strong winds) or be manmade (for example, aircraft crash and fire). Plant examinations of external event analyses are less quantitative and results-oriented than those performed under the original individual plant examination that addresses internal events. The analyses confirmed that no vulnerabilities or issues exist and that the plants would have sufficient capacity such that critical safety systems would continue functioning in beyond-design-basis external events.

D.1.7.1 Severe Reactor Accident Scenarios

Before identifying accident scenarios that would lead to failure of the containment, a brief overview of severe accident analysis techniques for plant-specific probabilistic risk assessments or individual plant examinations for severe accident vulnerabilities is important (DOE 1999a). The analysis starts with identification of initiating events (that is, challenges to normal plant operation or accidents) that require successful mitigation to prevent core damage. These events are grouped into initiating event classes that have similar characteristics and require the same overall plant response.

For example, a loss of offsite power to a plant could result from severe weather events (high wind, tornado, hurricane, and snow and ice storms), power substation breaker faults, instability in the power transmission lines, unbalanced loading of power lines, etc. Each of these events would lead to loss of main generator power and a reactor trip, which would challenge the same safety functions. These events are grouped together and analyzed under the loss-of-offsite-power initiating event.

Event trees for each initiating event class outline the possible sequence of events that could occur during the plant's response to each initiating event class. The trees delineate the possible combinations (sequences) of functional or system successes and failures that would lead either to successful mitigation of the initiator or to core damage. Functional or system success criteria are based on the plant response to the class of accidents. Failure modes of systems that are functionally important to preventing core damage are modeled. This modeling process is usually done with fault trees that define the combinations of equipment failures, equipment outage, and human errors that would cause the failure of systems to perform the desired function.

Quantification of the event trees leads to thousands of end states representing various accident sequences that lead to core damage. Each accident sequence and its associated end state have a unique "signature" because of the particular combination of system successes and failures events. These end states are grouped together into plant damage states, each of which collects sequences for which the progression of core damage, the release of fission products from the fuel, the status of containment and its systems, and the potential for mitigating source terms are similar. The sum of all core damage accident sequences represents an estimate of plant core damage frequency. The analysis of core damage frequency calculations is called a level 1 probabilistic risk assessment, or front-end analysis.

Next, an analysis of accident progression, containment loading resulting from the accident, and structural response to the accident loading is performed. The primary objective of this analysis, which is called a level 2 probabilistic risk assessment, is to characterize the potential for, and magnitude of, a release of radioactive material from the reactor fuel to the environment, given the occurrence of an accident that damages the core. The analysis includes an assessment of containment performance in response to a series of severe accidents. Analysis of the progression of an accident (an accident sequence in a plant damage state) generates a timeline of loads that would be imposed on the containment pressure boundary. These loads are compared with the containment's structural performance limits. If the loads would exceed the performance limits, the containment would be expected to fail; conversely, if the containment performance limits would exceed the calculated loads, the containment would be expected to survive. Table D-4 shows the three defined modes of containment failures: containment bypass, early containment failure, and late containment failure.

The magnitude of the radioactive release to the atmosphere in an accident depends on the timing of the reactor vessel failure and the containment failure. To determine the magnitude of the release, a

Table D-4. Definitions and causes of containment failure mode classes.

Failure mode	Definition and causes
Containment bypass	Involves failure of the pressure boundary between the high-pressure reactor coolant and low-pressure auxiliary system. For pressurized water reactors, steam generator tube rupture, either as an initiating event or as a result of severe accident conditions, leads to containment bypass. In these scenarios, if core damage occurs, a direct path to the environment can exist.
Early containment failure	Involves structural failure of the containment before, during, or slightly after (within a few hours) reactor vessel failure. A variety of mechanisms can cause structure failure such as direct contact of core debris with containment, rapid pressure and temperature loads, hydrogen combustion, and fuel coolant interaction (ex-vessel steam explosion). Failure to isolate containment and an early vented containment after core damage are early containment failures.
Late containment failure	Involves structural failure of the containment several hours after reactor vessel failure. A variety of mechanisms can cause late structure failure such as gradual pressure and temperature increase, hydrogen combustion, and basemat melt-through by core debris. Venting containment late in the accident is a late containment failure.

containment event tree representing the sequence of major phenomenological events that could occur during the formation and relocation of core debris (after core melt), the availability of the containment heat removal system, and the expected mode of containment failures (that is, bypass, early, and late), is developed. A reduced set of plant damage states are defined by culling the lower frequency plant damage states into higher frequency states that have relatively similar severity and consequence potential. This condensed set is known as the key plant damage states (a functional sequence that either has a core damage frequency greater than or equal to 1×10^{-6} per reactor year or leads to containment bypass at a frequency of greater than or equal to 1×10^{-7} per reactor year (DOE 1999a). (A reactor year is 1 year of operation with loaded fuel; it does not include periods of shut down such as for refueling.) These key plant states become the initiating events for the containment event tree. The outcome of each sequence in this event tree represents a specific release category. Release categories that can be represented by similar source terms are grouped. Source terms for the various release categories describe the fractional releases for representative radionuclide groups, as well as the timing, duration, and energy of release.

Most of the current plant probabilistic risk assessment analyses end at this stage. Only some plants have performed an analysis of consequences to the public and environment from releases of radioactive materials after a core melt and containment failure. The NRC first performed this type of analysis, which is known as a level 3 probabilistic risk assessment, in WASH-1400, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors* (NRC 1975). In the late 1980s, the NRC performed a comprehensive, full-scope severe accident analyses for five different plant types and documented the results in NUREG-1150, *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, Final Summary Report* (NRC 1990). The analyses for the SEIS used the insights from this NRC report and followed its methods and assumptions to estimate consequences to the public and the environment.

Afterward, the NRC initiated the State-of-the-Art Reactor Consequence Analyses project to develop best estimates of the offsite radiological health consequences for potential severe reactor accidents. The project analyzed the potential consequences of severe accidents at the Surry Power Station near Surry, Virginia, and the Peach Bottom Atomic Power Station near Delta, Pennsylvania. The project, which began in 2007, combined up-to-date information about plant layouts and operations with local population data and emergency preparedness plans. This information was then analyzed using state-of-the-art computer programs that incorporated decades of research into severe reactor accidents.

The main findings of the project fell into three basic areas: (1) how a reactor accident progresses, (2) how existing systems and emergency measures can affect accident outcome, and (3) how an accident could affect public health. The project's preliminary findings include:

- Existing resources and procedures can stop an accident, slow it down, or reduce its impact before it can affect public health.
- Even if accidents proceed uncontrolled, they take much longer to happen and release much less radioactive material than earlier analyses suggested.
- The analyzed accidents would cause essentially zero immediate deaths and only a very, very small increase in the risk of long-term cancer deaths.

NRC published a draft report for the project, including an appendix discussing the accident at the Fukushima Dai-ichi nuclear plant in Japan, in January 2012 (Chang et al. 2012). The Surplus Plutonium Disposition EIS summarized that discussion and TVA's plans (NNSA 2012):

> *On March 11, 2011, a magnitude 9.0 earthquake occurred near the northeast coast of Honshu, Japan. This earthquake caused tsunami waves as high as 29.6 meters (97.1 feet) along the coast of Japan. The 14-meter (46-foot) tsunami that occurred at the Fukushima Daiichi nuclear power plant site 2 resulted in extended periods of time when the plant was without emergency system power and emergency cooling water. This, in turn, resulted in significant core damage to three of the six nuclear power plants, including hydrogen explosions that breached the containment. All of the reactors at Fukushima Daiichi are now in a safe shutdown condition with continuing active cooling.*
>
> *Shortly after this accident began to unfold, NRC formed a Fukushima Near-Term Task Force to conduct a systematic and methodical review of NRC processes and regulations to determine whether the agency should make additional improvements to its regulatory system and to make recommendations to NRC for its policy direction. The Near-Term Task Force issued its report in July 2011 (NRC 2011), which was followed by extensive discussions between NRC, the industry, and the public. Based on the Near-Term Task Force report and subsequent discussions, NRC directed its staff to initiate appropriate regulatory changes through issuance of orders and rulemaking processes.*
>
> *The Near-Term Task Force has developed three prioritized tiers of recommended actions: Tier 1, which should be started without unnecessary delay; Tier 2, which requires further assessment and depends on Tier 1 issues and resources; and Tier 3, which requires further NRC staff study and is associated with longer-term actions. Tier 1 recommendations include: seismic, flooding, and other external hazard reevaluations and walk downs; extended station blackout coping capability; reliable hardened vents for some early designs of BWRs [boiling water reactors]; enhanced survival instrumentation for the used fuel pool, nuclear reactor, and containment; strengthening of emergency procedures, as well as severe accident management guidelines, damage mitigation guidelines; and improvements in staffing and communication during an emergency. Tier 2 and 3 recommendations involve additional improvements and enhancements to mitigate the effects of extreme seismic and flooding events in terms of used fuel pool integrity, hydrogen control, long-term station blackout, venting, training, monitoring, decisionmaking, emergency preparedness, and public education.*
>
> *In February 2012, NRC issued policy guidance to implement the aforementioned actions in the form of proposed orders requiring safety enhancements of operating reactors, construction permit holders, and combined license holders (NRC 2012b). On March 12, 2012, the NRC issued three orders as well as a request for information regarding additional concerns (NRC 2012c). The orders addressed mitigation strategies for beyond-design basis external events (NRC 2012d),*

reliable hardened containment vents [Mark I and II BWRs] (NRC 2012e), and reliable spent fuel pool instrumentation (NRC 2012f). The request for information directed each reactor licensee to provide specific information following a reevaluation of seismic and flooding hazards, emergency communications systems and staffing levels. Information from licensees was also requested after the licensees conduct walkdowns of reactor facilities to ensure protections against potential design basis hazards.

The NRC has issued an advance notice of proposed rulemaking for station blackout regulatory actions. It also anticipates issuing an advanced notice of proposed rulemaking on the strengthening and integration of emergency operating procedures, severe accident management guidelines, and extensive damage mitigation guidelines (NRC 2012c).

TVA will institute applicable NRC regulatory updates at Watts Bar and Sequoyah when they are promulgated in their final approved form. TVA took proactive steps in response to the events at Fukushima, forming a review team to assess early lessons learned and determine their potential applicability to the safety of TVA's reactors, including Watts Bar and Sequoyah. Based on this assessment, TVA has taken steps to procure additional equipment to further ensure adequate cooling during the extremely unlikely event of an extended loss of offsite power, known as a station blackout, that could affect multiple reactors at TVA sites. In addition, TVA is working with various industry groups such as the Institute for Nuclear Power Operators and the Nuclear Energy Institute to conduct a more comprehensive assessment of the Fukushima events. TVA continues, through its engagement with the Nuclear Energy Institute and the Institute for Nuclear Power Operators, to work with NRC to ensure that the regulations governing the operation of U.S. nuclear plants appropriately protect public health and safety and the environment in light of the Fukushima events.

D.1.7.2 Representative Severe Reactor Accident Scenarios for the Watts Bar and Sequoyah Nuclear Plants

As stated above, the analysis for the SEIS considered only plant damage states that would lead to containment failure (failure mode defined as bypass, early, and late) and release of radioactive materials to the environment. The description of the representative accident scenarios is limited to the dominant sequence (or sequences) in a plant damage state that is a major contributor to the release level categories for each of the containment failures defined above. For the Watts Bar and Sequoyah reactors, NNSA based the information on the most recent analysis of severe accidents by TVA under the individual plant examination program that covers level 1 and level 2 probabilistic risk assessments in detail. TVA submitted its original analyses of the Watts Bar and Sequoyah individual plant examinations to the NRC in September 1992 and has revised each of them (DOE 1999a).

NNSA selected release categories and examples of accident scenarios that would lead to containment failure or bypass for the Watts Bar and Sequoyah reactors. Table D-5 lists reactor core radionuclide inventories that apply to each of Watts Bar 1 and Sequoyah 1 and 2. Table D-6 lists information on time to core damage, containment failure, release duration, and the isotope release fractions for each release level. Table D-7 provides a representation of the dominant accident scenarios that lead to each release category, along with its likelihood of occurrence. Release Category I would result from a reactor vessel breach with early containment failure. Release Category II would result from a reactor vessel breach with containment bypass. Release Category III would result from a reactor vessel breach with late containment failure.

Table D-5. Watts Bar 1 and Sequoyah 1 and 2 core inventory.[a]

Nuclide	Isotope	Inventory (curies)
Cobalt	Co-58	8.74×10^5
	Co-60	6.68×10^5
Krypton	Kr-85	6.71×10^5
	Kr-85m	3.14×10^7
	Kr-87	5.74×10^7
	Kr-88	7.76×10^7
Rubidium	Rb-86	5.12×10^4
Strontium	Sr-89	9.73×10^7
	Sr-90	5.25×10^6
	Sr-91	1.25×10^8
	Sr-92	1.30×10^8
Yttrium	Y-90	5.64×10^6
	Y-91	1.19×10^8
	Y-92	1.31×10^8
	Y-93	1.48×10^8
Zirconium	Zr-95	1.50×10^8
	Zr-97	1.56×10^8
Niobium	Nb-95	1.42×10^8
Molybdenum	Mo-99	1.65×10^8
Technetium	Tc-99m	1.43×10^8
Ruthenium	Ru-103	1.23×10^8
	Ru-105	8.01×10^7
	Ru-106	2.80×10^7
Rhodium	Rh-105	5.55×10^7
Antimony	Sb-127	7.56×10^6
	Sb-129	2.68×10^7
Tellurium	Te-127	7.30×10^6
	Te-127m	9.66×10^5
	Te-129	2.51×10^7
	Te-129m	6.62×10^6
	Te-131m	1.27×10^7
	Te-132	1.26×10^8
Iodine	I-131	8.69×10^7
	I-132	1.28×10^8
	I-133	1.84×10^8
	I-134	2.02×10^8
	I-135	1.73×10^8
Xenon	Xe-133	1.84×10^8
	Xe-135	3.45×10^7
Cesium	Cs-134	1.17×10^7
	Cs-136	3.57×10^6
	Cs-137	6.55×10^6
Barium	Ba-139	1.70×10^8
	Ba-140	1.69×10^8
Lanthanum	La-140	1.72×10^8
	La-141	1.58×10^8
	La-142	1.52×10^8

Table D-5. Watts Bar 1 and Sequoyah 1 and 2 core inventory (continued).

Nuclide	Isotope	Inventory (curies)
Cerium	Ce-141	1.53×10^{8}
	Ce-143	1.49×10^{8}
	Ce-144	9.23×10^{7}
Praseodymium	Pr-143	1.46×10^{8}
Neodymium	Nd-147	6.54×10^{7}
Neptunium	Np-239	1.75×10^{9}

Source: NUREG/CR-4551 (Gregory et al. 1990).

a. The types and quantities of radionuclides are reasonable and representative of reactor core conditions for preparing the SEIS accident analysis. Because the types and quantities of radionuclides can change over a reactor operating cycle, the data in Table D-5 are not meant to represent the only core inventory possibilities.

Table D-6. Release category timing and source terms.

Release times, heights, energies, and source terms for Watts Bar and Sequoyah release categories					
Release category	**Release height (meters)[a]**	**Warning time (hours)**	**Release time (hours)**	**Release duration (hours)**	**Release energy[b] (megawatts)**
I	10	8	10	2	28
II	10	20	24	4	1
III	10	20	30	10	3.5

Fission product source terms (fraction of total inventory)										
Release category	**NG**	**I**	**Cs**	**Te**	**Sr**	**Ru**	**La**	**Ce**	**Ba**	**Mo**
I	9.0×10^{-1}	4.2×10^{-2}	4.3×10^{-2}	4.4×10^{-2}	2.7×10^{-3}	6.5×10^{-3}	4.8×10^{-4}	4.0×10^{-3}	4.6×10^{-3}	6.5×10^{-3}
II	9.1×10^{-1}	2.1×10^{-1}	1.9×10^{-1}	4.0×10^{-4}	2.3×10^{-3}	7.0×10^{-2}	2.8×10^{-4}	5.5×10^{-4}	2.5×10^{-2}	7.0×10^{-2}
III	9.4×10^{-1}	7.1×10^{-3}	1.1×10^{-2}	5.2×10^{-3}	3.6×10^{-4}	5.1×10^{-4}	4.2×10^{-6}	4.0×10^{-6}	1.3×10^{3}	5.1×10^{-4}

Source: DOE 1999a.

NG = noble gases; I = iodine; Cs = cesium; Te = tellurium; Sr = strontium; Ru = ruthenium; La = lanthanum; Ce = cerium; Ba = barium; Mo = molybdenum.

a. The modeling programs for this accident analysis use metric units of measurement. The inside back cover provides conversion factors from metric to English units.

b. These values were taken from similar accident scenarios as given in NUREG/CR-4551 (Gregory et al. 1990).

D.2 Method for Estimating Radiological Impacts

The GENII and MACCS2 computer programs perform analyses of radiological impacts. NNSA used GENII Version 2 (Napier et al. 2009; discussed in Appendix C) to estimate consequences of the reactor design-basis, nonreactor design-basis, TPBAR-handling, and cask-handling accidents; it used MACCS2 (Chanin et al. 1998; discussed in Section D.2.1) for beyond-design-basis accidents. Further, NNSA performed deterministic analyses using the method in the site safety analysis reports for the release of tritium in the reactor and the nonreactor design-basis accidents. This additional analysis provides a basis for direct comparison between design-basis analysis results with and without the release of tritium from TPBARs.

Sections 4.1.2 and 4.2.12 of this SEIS discuss the calculated radiation doses and latent cancer fatality results for Watts Bar and Sequoyah, respectively.

Table D-7. Release category frequencies and related accident sequences for Watts Bar and Sequoyah representative severe accident scenarios.[a]

Release category[b]	Release frequency	Representative accident scenario
Watts Bar		
I	6.8×10^{-7}	The major accident contributors to this release event would be initiated by loss of offsite power and loss of the essential raw cooling water system with failure of the emergency diesels to start or failures in the 125-volt direct current distribution system, in conjunction with loss of secondary cooling and no recovery before core melt.
II	6.9×10^{-6}	The main contributor to this release event would be initiated by a steam generator tube rupture in conjunction with an operator error or random failure of electrical distribution systems, leading to failure of the coolant system and failure to control the affected steam generator before core melt occurs.
III	9.1×10^{-6}	The major accident contributors to this release event would be initiated by loss of offsite power with failures in the alternating current distribution systems and no recovery of power before core melt, and by a reactor loss-of-coolant accident (large- and medium-sized loss-of-coolant accident) with failure to establish long-term core cooling.
Sequoyah		
I	6.8×10^{-7}	The major accident contributors to this release event would be initiated by loss of the 125-volt battery boards and loss of all offsite power with the failure of emergency diesels to start (station blackout: loss of all alternating current power to all emergency core cooling systems), as well as the failure of the auxiliary feedwater system (loss of secondary cooling) with no recovery before core melt.
II	4.0×10^{-6}	The accident scenario for this release event is similar to that for Watts Bar, above.
III	9.2×10^{-6}	The major accident contributors to this release event would be initiated by loss of offsite power with failures in the alternating current or direct current distribution systems and no recovery of power before core melt, and by reactor coolant system small break loss-of-coolant accident (caused by loss of the component cooling system leading to development of reactor coolant pump seals failure or another nonisolatable break in the reactor coolant system) with failure to depressurize the reactor or establish long-term reactor core cooling.

a. Source: DOE 1999a.

D.2.1 MACCS2 PROGRAM

Version 1.12 of the MACCS2 program estimates radiological doses and health effects that could result from postulated accidental releases of radioactive materials to the atmosphere. The specification of the release characteristics, designated a "source term," can consist of as many as four Gaussian plumes that are often referred to simply as "plumes."

The released radioactive materials were modeled as being dispersed in the atmosphere while being transported by the prevailing wind. During transport, whether or not there is precipitation, particulate material can be modeled as being deposited on the ground. If contamination levels exceed a user-specified criterion, mitigative actions can be triggered to limit radiation exposures.

Two aspects of the program's structure are basic to understanding its calculations: (1) the calculations are divided into modules and phases, and (2) the region surrounding the facility is divided into a polar - coordinate grid. The following paragraphs and sections describe these concepts.

MACCS2 has three primary modules: ATMOS, EARLY, and CHRONC. Three phases are defined as the emergency, intermediate, and long-term phases. The relationship among the three modules and the three phases of exposure are summarized below.

The ATMOS module performs all calculations for atmospheric transport, dispersion, and deposition, as well as the radioactive decay that occurs before release and while the material is in the atmosphere. It uses a Gaussian plume model with Pasquill-Gifford dispersion parameters. The treated phenomena include building wake effects, buoyant plume rise, plume dispersion during transport, wet and dry deposition, and radioactive decay and ingrowth. The program stores the results of the calculations for later use by EARLY and CHRONC. In addition to air and ground concentrations, ATMOS stores information on wind direction, arrival and departure times, and plume dimensions.

The EARLY module models the period immediately after a radioactive release, which is commonly referred to as the emergency phase. The emergency phase begins at each successive downwind distance point when the first plume of the release arrives. The user specifies the duration of the emergency phase, which can range from 1 to 7 days. The exposure pathways the module considers during this period are direct external exposure to radioactive material in the plume (cloudshine), exposure from inhalation of radionuclides in the cloud (cloud inhalation), exposure to radioactive material deposited on the ground (groundshine), inhalation of resuspended material (resuspension inhalation), and skin dose from material deposited on the skin. Mitigative actions that can be specified for the emergency phase include evacuation, sheltering, and dose-dependent relocation.

The CHRONC module performs all calculations for the intermediate and long-term phases. CHRONC calculates the individual health effects that result from direct exposure to contaminated ground and from inhalation of resuspended materials, as well as indirect health effects from consumption of contaminated food and water by people who resided on or off the computational grid.

The intermediate phase begins at each successive downwind distance point on conclusion of the emergency phase. The user can configure the calculations with an intermediate phase that has a duration as short as zero or as long as 1 year. Essentially, there is no intermediate phase and a long-term phase begins immediately on conclusion of the emergency phase.

These models are implemented on the assumption that the radioactive plume has passed and the only exposure sources (groundshine and resuspension inhalation) are from ground-deposited material. This is why MACCS2 requires the total duration of a radioactive release to be no more than 4 days. Potential doses from food and water ingestion during this period are not considered.

The mitigative action model for the intermediate phase is very simple. If the intermediate phase dose criterion is satisfied, the resident population is assumed to be present and subject to radiation exposure from groundshine and resuspension for the entire phase. If the intermediate phase exposure exceeds the dose criterion, the population is assumed to relocate to uncontaminated areas for the entire phase.

The long-term phase begins at each successive downwind distance point on conclusion of the intermediate phase. The exposure pathways for this phase are groundshine, resuspension inhalation, and food and water ingestion, which result from ground-deposited material. Several protective measures can be modeled in the long-term phase to reduce doses to user-specified levels such as decontamination, temporary interdiction, and condemnation. The decisions on mitigative action in the long-term phase are based on two sets of independent actions: (1) decisions on whether land at a specific location and time is suitable for human habitation (habitability), and (2) decisions on whether land at a specific location and time is suitable for agricultural production (farmability).

MACCS2 stores the calculations on the basis of a polar-coordinate spatial grid with a treatment that differs somewhat between calculations of the emergency phase and calculations of the intermediate and long-term phases. The region potentially affected by a release is represented with an (r,θ) grid system centered on the location of the release. The radius *r* represents downwind distance. The angle θ is the angular offset from north, going clockwise.

The user specifies the number of radial divisions and their endpoint distances. The angular divisions that define the spatial grid are fixed in the program and correspond to the 16 points of the compass, each being 22.5 degrees wide. The 16 points of the compass are used in the United States to express wind direction. The compass sectors are referred to as the coarse grid.

Because emergency phase calculations use dose-response models for early fatalities and early injuries that can be highly nonlinear, these calculations are performed on a finer grid basis than the calculations of the intermediate and long-term phases. For this reason, the calculations of the emergency phase are performed with the 16 compass sectors divided into 3, 5, or 7 equal angular subdivisions. The subdivided compass sectors are referred to as the fine grid.

The compass sectors are not subdivided into fine subdivisions for the intermediate and long-term phases because these calculations do not include estimation of the often highly nonlinear early fatality and early injury health effects, which are limited to cancer and genetic effects. In contrast to the emergency phase, the calculations for these phases use doses averaged over the full 22.5-degree compass sectors of the coarse grid.

The program can calculate two types of doses: "acute" and "lifetime." Acute doses enable estimation of deterministic health effects that can result from high doses from at high dose rates. Such conditions could occur in the immediate vicinity of a nuclear power plant after hypothetical severe accidents in which containment failure has occurred. Examples of the health effects based on acute doses are early fatality, prodromal vomiting, and hypothyroidism. Lifetime doses are the conventional measure of effects for radiological protection. These are 50-year dose commitments to specific tissues (for example, red bone marrow and lung tissue) or a weighted sum of tissue doses defined by the International Commission on Radiological Protection and referred to as "effective dose." Lifetime doses can be used to calculate the stochastic health effect risk from exposure to radiation. MACCS2 uses the calculated lifetime dose in cancer risk calculations.

D.2.2 DATA AND GENERAL ASSUMPTIONS

To assess consequences of the accidents, with the exception of the beyond-design-basis accidents, data were collected and produced and assumptions were made for incorporation in the GENII analyses. Section D.1 describes the source terms for the accidents. The meteorological and population data are identical to those described in Appendix C. Ingestion parameters are based on Regulatory Guide 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50* (NRC 1977).

To assess the consequences of beyond-design-basis accidents, NNSA incorporated the following data and assumptions in the MACCS2 analysis.

- Section D.1 discusses the **nuclide inventory** at accident initiation (for example, reactor trip) of those radioactive nuclides important for the calculation of offsite consequences for each reactor.

- The **atmospheric source term** from the accident is described by the number of released plume segments, sensible heat content, timing, duration, height of release for each plume segment, time when offsite officials are warned that an emergency response should be initiated and, for each important radionuclide, the release fraction for that radionuclide for each plume segment. Section D.1 discusses the source terms for each accident scenario.

- **Meteorological data** characteristics of the site region are described by 1 year of hourly wind speed, atmospheric stability, and rainfall recorded at each site. Although 1 year of hourly readings contains 8,760 weather sequences, MACCS2 calculations examine only a representative subset, which is selected by sampling the weather sequences after sorting them into weather bins using wind speed, atmospheric stability, and intensity and distance of the occurrence of rain.

- The **population distribution information** about each reactor site in the original 1999 analysis used 50-mile population values derived from the 1990 Census. This SEIS uses population distributions on the *2010 Census of Population and Housing* data (USCB 2012). Census data in this SEIS represent the latest information available from the Bureau of the Census. Projections were determined for 2025 for areas within 50 miles of the release locations at Watts Bar and Sequoyah. NNSA used the site population in 2025 in the impact assessments because the 1999 EIS used it and assumed it to be representative of the population at the approximate midpoint between now and the end of the interagency agreement. The population was spatially distributed on a circular grid with 16 directions and 10 radial distances up to 50 miles. The grid centers on the location of the radionuclide release. The projected 50-mile 2025 populations for Watts Bar and Sequoyah are 1,452,511 and 1,294,030 people, respectively.

- **Habitable land fractions** for the region around each reactor site were determined in a manner similar to the population distribution. The census block group boundary files include polygons that are classified as water features. The percentage of each sector covered by water is determined by fitting this data to the polar coordinate grid.

- **Farmland fractions** are the percentage of land devoted to farming.

- **Emergency response assumptions** for evacuation, including delay time before evacuation, area evacuated, average evacuation speed, and travel distance, are in Tennessee Multi-Jurisdictional Plans. Average evacuation speeds are based on the most conservative general population evacuation times.

- **Shielding and exposure data** must be input to MACCS2, which requires shielding factors specified for people evacuating in vehicles (cars, buses); taking shelter in structures (houses, offices, schools), and continuing normal activities outdoors, in vehicles, or indoors. Because inhalation doses depend on breathing rate, breathing rates must be specified for people who are continuing normal activities, taking shelter, and evacuating. Because indoor concentrations of gas-borne radioactive materials are usually substantially less than outdoor concentrations, MACCS2 requires inhalation and skin protection shielding factors (indoor-to-outdoor concentration ratios).

  The analysis used the protection factors in Table D-8 for all three reactors; the values are for Sequoyah from NUREG/CR-4551, *Evaluation of Severe Accident Risks: Sequoyah, Unit 1* (Gregory et al. 1990).

Table D-8. Protection factors.

Protection factor[a]	Evacuees	Sheltering	Normal activities
Cloud shielding factor	1.0	0.65	0.75
Skin protection factor	1.0	0.33	0.41
Inhalation protection factor	1.0	0.33	0.41

a. Source: NUREG/CR-4551 (Gregory et al. 1990).
b. A protection factor of 1.0 indicates no protection, while a protection factor of 0.0 indicates 100-percent protection.

For this analysis, the evacuation and sheltering region is the area within a 10-mile radius of the plant. A sheltering period is the phase that occurs before initiation of the evacuation. During the sheltering phase, shielding factors appropriate for sheltered activity are used to calculate doses for individuals in contaminated areas.

At the end of the sheltering phase, the resident individuals begin their travel out of the region. Travel speeds and delay times are based on Tennessee Multi-Jurisdictional Plans. The general population evacuation times for the areas within the 10-mile radius are averaged to determine an overall evacuation delay time and evacuation speed for the Watts Bar and Sequoyah sites.

- **Maximally exposed offsite individual dose** is the total estimated dose for a hypothetical individual assumed to reside at a particular location on the spatial grid. Population data have no bearing on the generation of this consequence measure. Only direct exposure is considered in these results. Exposures from the ingestion of contaminated food and water are not included. In addition, the generation of these results takes full account of any mitigative action models activated by exceeding the dose thresholds. During evacuation, individuals have no protection from direct exposure. Therefore, in certain scenarios, an evacuee could incur a larger direct exposure dose than an individual who did not evacuate.

- **Long-term protective measures** such as decontamination, temporary relocation, contaminated crops, milk condemnation, and farmland production prohibition are based on U.S. Environmental Protection Agency (EPA) Protective Action Guides.

- **Mitigative actions** (relocation, evacuation, interdiction, condemnation) are implemented for beyond-design-basis accidents (vessel breach with containment bypass, vessel breach with early containment failure, and vessel breach with late containment failure).

- MACCS2 requires **dose conversion factors** for the calculation of committed effective dose equivalents are cloudshine dose rate factor, groundshine dose rate factor, lifetime 50-year committed inhalation dose (for calculation of individual and societal doses and stochastic health effects), and 50-year committed ingestion dose (for calculation of individual and societal doses and stochastic health effects from food and water ingestion).

  MACCS2 has a module, FGRDCF that modifies dose conversion factors. The only change to the dose conversion factors by FGRDCF was to the tritium inhalation factor. The module increased the 50-year committed inhalation dose for tritium by 50 percent to account for skin absorption (DOE 1999a).

D.2.3 HEALTH EFFECTS CALCULATIONS

The following sections describe the technical approach used to calculate potential consequences to human health from exposure to radionuclides.

The analysis calculated health consequences from exposure to radionuclides from accidental releases. It converted total effective dose equivalents to estimates of cancer fatalities using dose conversion factors from the International Commission on Radiological Protection. For individuals, the SEIS reports the estimated probability of a latent cancer fatality for the maximally exposed individual and the average individual within 50 miles of the facility. For populations, the SEIS reports the estimated total number of latent cancer fatalities for the population within 50 miles.

The nominal values of lifetime cancer risk for low doses or low dose rate exposure (less than 20 rad) in this SEIS are 0.0006 per person-rem for a population of all ages (ISCORS 2002).

GENII uses a straight-line plume method for calculating doses to receptors. In the model, the plume disperses outward from the release point in one direction. Plume dispersion refers to the plume spreading over a larger area and becoming less concentrated, which leads to lower doses. Certain weather conditions are better for plume dispersion than others. Therefore, it is necessary to analyze doses to each receptor (for example, the maximally exposed individual population) for the 16 compass sectors at each site to determine the maximum sector doses. This SEIS presents the maximum receptor dose. The analysis conservatively assumed that, after the accident, the wind would blow toward the sector that produces maximum dose. Further, the GENII analyses assumed that the accident would occur in autumn, which maximizes the estimated dose from contaminated food ingestion. Dose calculation for each receptor used 50-percent meteorology, which indicates a distribution with median weather conditions (half of the weather conditions are worse and half are better). This meteorology is consistent with the guidance in NRC Regulatory Guide 4.2, *Preparation of Environmental Reports for Nuclear Power Stations* (NRC 1976).

The analysis applied MACCS2 in a probabilistic manner using a weather bin sampling technique, which sorts weather sequences into categories and assigns a probability to each category according to the initial conditions (wind speed and stability class) and the occurrence of rain. The program applies each sampled meteorological sequence to each of the 16 sectors (accounting for the frequency of occurrence of the wind blowing in that direction). The program then calculated individual doses as a function of distance and direction for each meteorological sequence sample and generated mean dose values for each sequence for each of the 16 sectors. The program used the highest of these dose values for the maximally exposed individual. Population doses are the sum of the individual doses in each sector.

D.2.4 DETERMINISTIC CALCULATIONS

D.2.4.1 Introduction

In addition to the GENII and MACCS2 calculations, NNSA performed deterministic analyses for the reactor and nonreactor design-basis accidents (large break loss-of-coolant accident and waste gas decay tank rupture). The purpose of these analyses was to provide a comparison of the effect of tritium on the calculated doses in the Watts Bar and Sequoyah Updated Final Safety Analysis Reports, which present the thyroid inhalation, whole-body beta, and whole-body gamma doses at the exclusion area boundary and the low population zone. The deterministic analyses calculated the additional dose attributable to tritium using the same method as that in the Updated Final Safety Analysis Reports.

Low Population Zone

The low population zone is the area immediately surrounding the exclusion area that contains residents whose total number and density indicate there is a reasonable probability that appropriate protective measures could be taken on their behalf in the event of a serious accident. These guides do not specify a permissible population density or total population in a zone because the situation could vary from case to case. For example, whether a specific number of people could be evacuated from a specific zone or instructed to take shelter on a timely basis would depend on factors such as location, number and size of highways, scope and extent of advance planning, and actual distribution of residents in the zone.

D.2.4.2 Large Break Loss-of-Coolant Accident

To determine the effects of a tritium release after a postulated design-basis accident, NNSA adopted a deterministic analysis based on Regulatory Guide 1.4, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant*

Accident for Pressurized Water Reactors (NRC 1974), which the Watts Bar and Sequoyah Safety Analysis Reports also incorporated for calculation of the environmental effects from a design-basis large break loss-of-coolant accident event. The following paragraphs describe the release paths from containment to the environment, the conservatisms NNSA used, and the dose calculation method.

The primary containment leak rate in the Watts Bar and Sequoyah Updated Final Safety Analysis Report analyses for the first 24 hours was the design-basis leak rate (in the technical specifications on containment leakage), which reduced to 50 percent of that value for the duration of the accident. The Updated Final Safety Analysis Reports assumed the primary containment (steel containment vessel) leak rates would be 0.25 percent of the containment atmosphere per day for the first 24 hours after the accident and 0.125 percent per day for the remainder of the 30-day period.

For the Watts Bar and Sequoyah reactors, the leakage from the steel containment vessel falls into two categories: leakage into the auxiliary building and leakage into the annulus (the space between the steel containment vessel and shield building where leakage from primary containment collect before release).

The analyses assumed 25 percent of the total primary leakage would go to the auxiliary buildings. This is an estimated upper bound of leakage to the auxiliary buildings based on 10 CFR Part 50, Appendix J, "Testing of All Containment Penetrations." Selecting an upper bound is conservative because an increased leakage fraction to the auxiliary building would result in an increased offsite dose.

At Watts Bar and Sequoyah, there is an auxiliary building ventilation system. After a large break loss-of-coolant accident, TVA would shut down and isolate the ventilation systems to all areas of the auxiliary building. After isolation, TVA would activate the auxiliary building gas treatment system to ventilate the area and filter the exhaust to the atmosphere. This filtration system would not remove airborne tritium.

Fission products that leaked from the primary containment to areas of the auxiliary building would be diluted in the room atmosphere and would travel through ducts and other rooms to areas near the air inlets for the auxiliary building gas treatment system or environmental control system. The Updated Final Safety Analysis Report analyses allow a holdup time for airborne activity after an initial period of direct release. However, the tritium analysis conservatively assumed that radioactivity leaking to the auxiliary building would release directly to the outside air through the auxiliary building gas treatment system or environmental control system. The analysis conservatively ignored holdup time in the auxiliary building before release to the outside air.

NNSA assumed that 75 percent of the primary containment leakage would be to the annulus (DOE 1999a). The presence of the annulus between the steel containment vessel and the secondary containment (or shield building) would reduce the probability of direct leakage from the containment to the outside air and enable holdup and plate-out of fission products in the shield building. The analysis conservatively ignored plate-out in the annulus.

Modeling of the transfer of activity from the annulus volume to the emergency gas treatment system air inlets for is a statistical process mathematically similar to the decay process (that is, the rate of removal from the annulus is proportional to the activity in the annulus). This corresponds to an assumption that the activity is homogeneously distributed throughout the mixing volume. A high degree of mixing is likely because of low flow rates in the emergency gas treatment system or secondary containment cleanup system in comparison with the annulus volume, the thermal convection due to heating of the containment structure, and the relative locations of the emergency gas treatment system or secondary containment cleanup system suctions and recirculation exhausts. NNSA conservatively assumed that only 50 percent of the free volume in the annulus would be available for mixing of the activity.

The emergency gas treatment system and secondary containment cleanup system are essentially annulus recirculation systems with pressure-activated valves that allow part of the system flow to exhaust to the atmosphere to maintain an adequate annulus pressure. This analysis assumed that, for the first hour after the accident, the applicable system would exhaust all available tritium. The holdup time is a function of the flow and exhaust rates of the emergency gas treatment system or secondary containment cleanup system, as well as the annulus volume. The holdup time before release is defined as 50 percent of the annulus volume divided by the exhaust flow rate of the emergency gas treatment system or secondary containment cleanup system.

The systems maintain annulus pressure at less than the auxiliary building's internal pressure during normal operation; therefore, leakage between the two volumes after a loss-of-coolant accident would be to the annulus. NNSA conservatively assumed there would be no leakage by this route.

The Updated Final Safety Analysis Report analyses calculated thyroid inhalation and external whole-body gamma and beta doses at the exclusion area boundary and low population zone. The analyses calculated inhalation and beta doses for tritium; gamma dose calculation was and is unnecessary because tritium decays only by beta emission.

The calculations used hourly time steps. This time step size is appropriate because of the large primary containment volume and low leakage rate; the tritium concentration (activity per volume) would decrease only a few tenths of a percent per hour. At each hour, the analyses calculated the activity and used them in the thyroid inhalation and beta dose formulas to determine the doses for that hour for each pathway (annulus, auxiliary building, bypass). The calculations incorporated Updated Final Safety Analysis Report time-dependent atmospheric dispersion factors, breathing rates, and dose conversion factors. The analyses summed the doses for each hour (for each pathway) to obtain total doses.

D.2.4.3 Waste Gas Decay Tank Accident

NNSA analyzed the effects of a tritium release after a postulated waste gas decay tank rupture using a deterministic approach. As for the Updated Final Safety Analysis Reports, this analysis was based on Regulatory Guide 1.24, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Pressurized Water Reactor Radioactive Gas Storage Tank Failure* (NRC 1972). Section D.1 describes and lists the tritium source term available for release from the waste gas decay tank. NNSA assumed the source term would leak out at ground level over a 2-hour period. The analysis calculated thyroid inhalation and whole-body beta doses for the exclusion area boundary and the low population zone using the methods described Section D.2.4.2 incorporating time-dependent atmospheric dispersion factors, breathing rates, and dose conversion factors from the Updated Final Safety Analysis Reports.

D.2.5 UNCERTAINTIES

The sequence of analyses for estimation of radiological impacts from normal operation of CLWRs, facility accidents, and overland transportation included (1) selection of normal operational modes and accident scenarios and their probabilities, (2) estimation of source terms, (3) estimation of environmental transport and uptake of radionuclides, (4) calculation of radiation doses to exposed individuals, and (5) estimation of health effects in terms of individual risk of latent cancer fatality and latent cancer fatalities in a population. Each step of this type of analysis involves uncertainties. There are uncertainties in the way the computational models analyze physical systems and in the data necessary to run the models (due to measurement errors, sampling errors, or natural variability).

Of particular interest are the uncertainties in the estimates of risk and incidence of cancer deaths from exposure to radioactive materials. Studies low-dose exposures have so far been inadequate to demonstrate the actual level of risk. There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiological observation, and the work so far cannot exclude the possibility of no risk, or even health benefits (hormesis effects). Because the analysis used conservative assumptions to calculate radiological doses and health risk conversion factors to predict latent cancer fatality risks, the values in this SEIS are likely to be overestimates.

There are also uncertainties when using accident analyses for similar facilities as a major source of data. Although the radionuclide compositions of source terms are reasonable estimates, uncertainties in the radionuclide inventory and release fractions affect the estimated consequences. Accident frequencies for low-probability sequences of events are difficult to estimate, even for operating facilities, because there is little or no record of historical occurrences.

In summary, NNSA obtained the radiological impact estimates in this SEIS by:

- Using the latest available data;
- Considering the reasonably foreseeable processes, events, and accidents for tritium production in a CLWR and overland transportation of irradiated TPBARs; and
- Making conservative assumptions if there was doubt about the exact nature of the processes and events that could take place, such that the chance of underestimating health impacts would be small.

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APPENDIX E. TRITIUM IN DISCHARGE PLUMES

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APPENDIX E. TRITIUM IN DISCHARGE PLUMES

The primary impact to water resources from the alternatives in this Supplemental Environmental Impact Statement (SEIS) would be an increase in the amount of tritium the Tennessee Valley Authority (TVA) would release in liquid effluents from the Watts Bar and Sequoyah facilities. The use of tritium-producing burnable absorber rods (TPBARs) in reactors at either facility would not change the thermal or chemical characteristics of the water they discharge to the Chickamauga Reservoir (or Tennessee River). In addition, it would not affect the quantity or types of radionuclides other than tritium in the discharges. This appendix describes the National Nuclear Security Administration (NNSA) evaluation of the potential effects of additional tritium in the discharges from the Watts Bar and Sequoyah sites. These evaluations support the discussions in Sections 4.1.5 and 4.2.5 of the SEIS. Section E.1 provides background for the evaluations, including the standards applicable to the discharges, and it describes the models the analysis used to characterize the discharge from each nuclear plant under the alternatives in the SEIS. Sections E.2 and E.3 address the specific evaluations of the Watts Bar and Sequoyah discharges, respectively.

E.1 Background Information for Tritium Discharge Evaluations

At either the Watts Bar or the Sequoyah site, TVA would mix the additional tritium with the existing discharges to the Tennessee River. The primary discharge point at each site is designated Outfall 101. The nonradioactive liquid effluents from these outfalls are regulated under each plant’s National Pollutant Discharge Elimination System permit. However, the permits do not regulate the discharge of radionuclides in the liquid effluents; these are regulated under each plant’s U.S. Nuclear Regulatory Commission (NRC) operating license and required compliance with NRC regulations. Specifically, 10 CFR Part 20 requires that the total effective dose equivalent to individual members of the public from each licensed operation must not exceed 0.1 rem per year. According to the regulation, the licensee can demonstrate compliance with this requirement (1) by measuring or calculating the dose to the individual likely to receive the highest dose or (2) by demonstrating that the annual average concentrations of radioactive materials it releases in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed values specified in Table 2 of Appendix B to 10 CFR Part 20. Table 2 of Appendix B specifies a concentration limit for tritium of 1 million picocuries per liter in water effluents to unrestricted areas. The Technical Specifications appended to each plant’s operating license (Sections 5.7.2.7.b and c of the Watts Bar Technical Specifications and Sections 6.8.4.f.2 and 3 of the Sequoyah Technical Specifications) specify that liquid effluents to unrestricted areas are limited to 10 times the concentration values in Appendix B to 10 CFR Part 20 (that is, the site-specific limit for tritium at both plants is 10 million picocuries per liter).

The U.S. Environmental Protection Agency (EPA) National Primary Drinking Water Regulations in 40 CFR Part 141 provide another regulatory limit that is indirectly applicable to tritium levels in the Watts Bar and Sequoyah effluents. In this regulation, EPA sets a maximum contaminant level for beta particle and photon radioactivity in drinking water as one that would produce an annual dose equivalent of 4 millirem per year to the total body or any internal organ. The regulation further specifies a tritium concentration of 20,000 picocuries per liter as meeting this limit. In application, if there were other radionuclides present that emitted beta particles or photons, TVA would have to reduce the limit for tritium accordingly. For example, if both tritium and strontium-90 were present in drinking water and the strontium-90 was at a concentration that would result in a dose of 2 millirem per year (half the allowable limit), the limit for tritium would be cut in half to 10,000 picocuries per liter. This regulation is not directly applicable to the discharge areas of the Tennessee River because they are not used as drinking water, but the river is a drinking water source (before treatment) at locations downstream from the Watts Bar and Sequoyah sites.

The tritium concentrations this appendix evaluates are average values over the course of a typical year (as if the plants released the tritium at a constant rate). In existing Watts Bar and Sequoyah operations, the majority of the tritium is in radiologically contaminated wastewater TVA releases in batches along with the normal plant discharges. Therefore, during a batch release, tritium concentrations would generally be higher than the average values but would involve relatively short periods. For example, TVA released the majority (99.9 percent) of the tritium in liquid effluents from the Watts Bar site in 2010 in 166 batch releases that took place over a combined 466 hours (TVA 2011a). Similarly, the vast majority (99.96 percent) of the tritium in liquid effluents TVA released from the Sequoyah site in 2010 was in 135 batch releases that took place over a combined 368 hours (TVA 2011b). It is reasonable to assume that future releases of tritium-containing water, which would include tritium from TPBAR irradiation, would be predominantly in batches. NNSA evaluated average values because of the nature of the primary requirements and standards against which it compared the modeled discharge tritium concentrations. Appendix B to 10 CFR Part 20 sets liquid effluent limits in term of annual averages, and the indirectly applicable drinking water standard is in terms of an annual dose. Using standard exposure pathways and dose calculations, the same annual dose would result whether using the varying concentrations over short periods or using average concentrations over the entire year.

NNSA evaluated the effects of the increased tritium discharges on the Tennessee River using the suite of EPA computer programs called Visual Plumes. EPA and contributors from private industry, academia, and a state agency developed Visual Plumes, which is available, along with its manual, *Dilution Models for Effluent Discharges* (Frick et al. 2003), for download by the public from the EPA website. The purpose of Visual Plumes is to simulate surface and subsurface water jets and plumes to assist, among other uses, in mixing zone analyses. The NNSA evaluation in this SEIS involved the use of two models from Visual Plumes, UM3 and DKHW. Both are three-dimensional plume models for simulating single- and multi-port submerged discharges. UM3 is an acronym for the "three-dimensional Updated Merge (UM) model" and DKHW is an acronym for the "Davis, Kannberg, Hirst model for Windows" (Frick et al. 2003).

Both the UM3 and DKHW models are designed to predict the same behavior of plumes in the initial dilution region for submerged discharges such as those at Watts Bar and Sequoyah. However, the two models are based on different mathematical approaches for plume formation and mixing. For example, in the UM3 model the plume is described as being in a steady state and following a fixed trajectory, while other elements move through it and those elements change their shape and position with time, so that time is the independent variable. In the DKHW model, on the other hand, the plume characteristics (trajectory, size, concentration, and temperature) change with distance, so distance is the independent variable (Frick et al. 2003). EPA describes both models as having long histories of verification, but in this case there was no applicable site-specific data for Watts Bar and Sequoyah that indicated if one model fit better than the other. Therefore, NNSA used both. An intended use of Visual Plumes is to support comparison of results from multiple models.

Visual Plumes can be fairly simple to use, as it was for this evaluation, but can also address more rigorous evaluations dependent on the complexity of the situation and the amount of information available. In this evaluation, NNSA entered information on the characteristics of the submerged diffuser and its discharge into a prepared computer window and key information on the characteristics of the receiving stream into another. The individual site discussions that follow provide this information about the diffuser and ambient receiving stream windows of Visual Plumes along with justifications and sources for the information, as appropriate. Other values the models used were default values from the program unless the manual provided a typical range, in which case NNSA used a value at the conservative end of the range (conservative, in this case, means a value that would tend to lessen dilution or dispersion of the plume and thereby result in higher tritium concentrations). NNSA ran either the UM3 or DKHW model, and the program provided text and numerical output as well as results in graphic form. If the models were run in succession, without deleting the previous output, the program's graphics showed both model results for easy comparison.

As discussed in the subsequent sections, model inputs on diffuser and discharge characteristics were adjusted because the Visual Plumes models accommodate ports in a single row but the diffusers at the Watts Bar and Sequoyah sites have multiple rows of ports. The models were run using only a single row of ports from the diffusers, then results from each row were superimposed on one another to generate a composite plume. This was done simply by multiplying individual concentrations from plots of the single-row-plume by the number of rows on the diffusers. For example, if a point on the single row plume indicated a concentration of 10 picocuries per liter and the diffusers actually had two rows, the composite plume would have a concentration of 20 picocuries per liter at that point. This represents a significant simplification but, as can easily be envisioned, it results in conservatively high values. In actuality, the ports on the different rows would discharge at different locations and angles (from the horizontal) and the resulting combined plume would immediately be more diffuse and diluted than represented by superimposing the plume from each row. This was verified by running the models under different port spacing and port diameter scenarios, while keeping discharge velocities from each port consistent with the actual configuration. Using this methodology caused the Sequoyah results to be more conservative than the Watts Bar results because the Sequoyah diffusers have 17 rows of staggered ports in comparison with the two rows of ports at Watts Bar.

E.2 Watts Bar Tritium Discharge Evaluations

This section discusses the evaluations NNSA performed to consider a range of tritium discharge and river flow conditions that bound the alternatives for the Watts Bar site.

The number of TPBARs TVA would irradiate at the Watts Bar facility would range from 0 under Alternatives 2 and 5 to 5,000 under Alternative 4. Under the No-Action Alternative, TVA would use only Watts Bar 1 to irradiate 680 TPBARs; under Alternatives 1 and 6, NNSA assumed TVA would potentially use Watts Bar 1 and 2 to irradiate 2,500 TPBARs. Alternative 3, Watts Bar and Sequoyah, would involve irradiation of TPBARs at both sites and NNSA assumed irradiation of 1,250 TPBARs at each site, but with the possibility of irradiating all 2,500 at either site for some periods. Under Alternative 4, TVA would irradiate up to 5,000 TPBARS at Watts Bar. Under Alternatives 2 and 5, TVA would irradiate as many as the maximums of 2,500 and 5,000 TPBARs per cycle, respectively, at the Sequoyah site, with no TPBAR irradiation at the Watts Bar site.

Table E-1 lists the number of TPBARs TVA would irradiate at the Watts Bar site under the alternatives in this SEIS. The table also lists the estimated amounts of tritium that the site would release in liquid effluents on an annual basis as a result of TPBAR irradiation under each scenario. The estimates are based on the assumption that 10 curies of tritium (2 times the maximum value currently expected by NNSA) would permeate from each TPBAR on an annual basis and that 90 percent of the tritium would find its way to the liquid effluents. The third row of data in the table identifies baseline quantities of tritium the Watts Bar site releases independent of TPBAR irradiation. Normal operations of nuclear plants include the generation of tritium and its release in wastewater effluent. The baseline value in the table represents a bounding number, well above the annual average of 855 curies of tritium reported for Watts Bar liquid effluents during the 5-year period from 1999 through 2003 (TVA 2000, 2001, 2002, 2003, 2004) before the TPBAR irradiation and its effects began. This period is assumed to be representative of Watts Bar conditions before TPBAR irradiation began. NNSA assumed that Watts Bar 2, when operational, would result in a similar amount of baseline tritium generation and release. Rows 5 and 6 of the table list the typical discharge volume that would go to Outfall 101 and the resulting tritium concentrations based on the total tritium release in the fourth row.

Table E-1. Parameters for evaluation of tritium discharges at Watts Bar.

Parameter	Evaluated alternatives				
	No Action	**Alternative 1 and 6: Watts Bar**	**Alternatives 2 and 5: Sequoyah only**	**Alternative 3: Watts Bar and Sequoyah**	**Alternative 4: Watts Bar only**
1. TPBARs per fuel cycle	680	2,500	0	1,250–2,500	5,000
2. Tritium release to liquid effluents from TPBARs (curies per year)	6,120	22,500	0	11,250–22,500	45,000
3. Tritium release to liquid effluents from baseline operations (curies per year)					
Watts Bar 1[a]	2,160	2,160	2,160	2,160	2,160
Watts Bar 2	2,160	2,160	2,160	2,160	2,160
4. Total tritium release to liquid effluents (curies per year)	10,440	26,820	4,320	15,570–26,820	49,320
5. Typical discharge to Outfall 101 with Watts Bar 2 operational (liters per year)[b]	7.14×10^{10}	7.14×10^{10}	7.14×10^{10}	7.14×10^{10}	7.14×10^{10}
6. Typical tritium concentration in discharge to Outfall 101 (picocuries per liter)	146,000	376,000	60,500	218,000–376,000	691,000

a. As a bounding value, each reactor was assumed to release 2,400 curies of tritium per year to the cooling water system, of which 90 percent (that is, 2,160 curies) was assumed to reach the liquid effluents.

b. From Section 3.1.5.1.3, typical discharge to Outfall 101 is expected to be 80 cubic feet per second with Watts Bar 2 in operation. This converts to 7.14×10^{10} (that is, 71.4 billion) liters per year.

The tritium and liquid effluents would be part of the primary plant discharges going to Outfall 101 (see Section 3.1.5.1.3); that is, TVA would discharge the tritium, along with plant cooling water and process wastewaters, to the Tennessee River through two multiport diffusers on the bottom of the river. The tritium contamination would be part of the plant process wastewaters that make their way to Outfall 101 from the yard holding pond. The tritium contamination would not reach the condenser cooling water system (Figure 3-3) and would not be part of the associated discharges to Outfall 113.

Table E-2 lists the information NNSA entered into the diffuser and ambient receiving stream windows of Visual Plumes. Included in the table, as appropriate, are justifications and sources for the information.

Several values in Table E-2 represent parameters that are likely to change over the course of a year. For example, effluent and ambient river temperatures vary significantly by season, and several parameters are based specifically on a typical surface water elevation of 680 feet above mean sea level, but normal high and low elevations range from 682.5 to 676 feet above mean sea level (TVA 2010a). The modeling evaluation used only the typical values in the table in such cases because they were not likely to have a significant effect on the model results. To do otherwise would result in an unreasonable number of scenarios to consider. Even though NNSA attempted to keep the evaluation as simple as possible, the data in Table E-2 indicate that there are two parameters with two values each and a third with three values. These are parameters that would be likely to have significant effects on the modeling results. In the case of tritium concentration, the three values represent the range of estimated values for tritium release in liquid effluents under Alternatives 1, 3, and 4. In the case of the effluent flow and current

Table E-2. Primary Watts Bar information used in the Visual Plumes program.

Parameter	Values used as model input	Basis and source
Diffuser characteristics		
Port diameter	1.0 inches	Source: TVA 1993, Figure A.4.
Port elevation	1.5 feet	Source: TVA 1993, Figure A.4, weighted average height of the two different diameter diffusers.
Vertical angle	45 degrees	Source: TVA 1993, Figure A.4, average angle of the two rows of ports.
Number of ports	960	Adjusted from 1,920 actual ports (TVA 1993, Figure A.4) because only one of two rows is being modeled.[a]
Port spacing	2.0 inches	Source: TVA 1993, Figure A.4.
Chronic mix zone[b]	240 feet	NPDES permit mixing zone (downstream distance).
Port depth	24.5 feet	Source: TVA 1993, Figure A.5, which is a schematic of river bottom elevations at the site of the diffusers (at 654 feet), a water surface elevation of 680 feet, and a port elevation of 1.5 feet above river bottom.
Effluent flow	a. 40 cfs b. 87.5 cfs	a. Source: TVA 2007a – half of the normal 80 cfs effluent flow expected with both Watts Bar 1 and 2 in operation to accommodate modeling only 1 row.[a] b. Source: TVA 2007a – half of the temporary maximum effluent flow of 175 cfs (to accommodate modeling of only 1 row) after periods of curtailed discharge due to low river flow (<3,500 cfs) with both Watts Bar 1 and 2 in operation.[a]
Effluent temperature	74.9°F	Source: TVA 2007a – average of monthly means predicted for discharge when both Watts Bar 1 and 2 are operational.
Effluent concentration	a. 218,000 pCi/L b. 376,000 pCi/L c. 691,000 pCi/L	Table E-1 – range of tritium concentrations estimated for Alternatives 1 (and 6), 3, and 4 entered as parts per billion due to limited selection of units in the program.
Ambient conditions		
Current speed	a. 0.227 fps b. 1.75 fps	a. Source: TVA 1993 – river velocity used in TVA modeling when the river is flowing at 3,500 cfs (the lowest flow rate at which Watts Bar can still discharge) and the water surface is at a typical elevation of 680 feet – at this flow rate and velocity, the effective channel cross-section can be calculated at 15,420 square feet. b. River velocity calculated based on typical flow of 27,000 cfs (Section 3.1.5.1.1) and the effective channel cross-section described above.
Ambient temperature	62.5°F	Source: TVA 2007a – average of monthly means for in stream temperature upstream of Outfall 101
Ambient concentration	0 pCi/L	Per Section 3.1.5.1.2 (Table 3-5), only 3 of 52 samples of ambient water conditions over 2 years indicated tritium at concentrations above the detection limit; zero best represents ambient tritium conditions.

cfs = cubic feet per second; fps = feet per second; NPDES = National Pollutant Discharge Elimination System; pCi/L = picocuries per liter.

a. The Watts Bar diffusers have 1-inch ports that are arranged in two rows with eight ports per foot (four per row) and 2-inch spaces (vertically and horizontally) in between. The Visual Plumes models are designed for ports in a single row. Accordingly, input to the models was adjusted to model a plume from a single row of ports with actual dimensions and spacing. The results from a second row plume were superimposed on the first to generate a combined two-row plume by simply multiplying predicted concentrations for a single row plume by 2.

b. The model input provides the capability to identify, or flag, a couple of distances of particular concern or interest. The model designates these distances the "acute mix zone" and "chronic mix zone." The first zone is to accommodate a distance where there might be an acute toxicity concern for a specific receptor exposed to a high contaminant concentration. The second zone is for a greater distance from the discharge, but for which there might still be a chronic exposure concern. The model output includes a calculation of the plume concentration at those distances from the discharge point (unless the model predicts the plume surfaces before it reaches them). In this case, the acute and chronic designations were not applicable to running the models, so the distance to the end of the NPDES mixing zone was entered as the chronic mix zone and, as applicable, the models calculated a concentration at that distance. A shorter distance was entered as the acute mix zone, but was not used as any part of the result summary.

speed, the two values represent a worst-case extreme and a typical condition. The NNSA evaluation considered 12 scenarios to address the various combinations of the three parameter variables.

Figures E-1 and E-2 show typical text and numerical output and graphic results, respectively, from the Visual Plumes program under one of the 12 evaluated scenarios. The figures show results from both the UM3 and DKHW models for the scenario with the typical effluent discharge (40 cubic feet per second for one row of ports), the middle tritium concentration (376,000 picocuries per liter), and the typical river flow (27,000 cubic feet per second). The graphic output in this case plots dilution factor by distance downstream of the diffusers. The dilution factor is a description of the pollutant (tritium) concentration. Visual Plumes defines this as the original discharge concentration divided by the plume concentration.

```
Diffuser: WB4-w10-TD-HT-TR.vpp.db | Ambient: C:\Plumes\WB4-w10-TD-HT-TR.001.db | Special Settings | Text Output | Graphical Output |
Clear text display    Clear +    Output options    Numerical only

/ UM3. 5/2/2012 11:01:44 AM
Case 1; ambient file C:\Plumes\WB4-w10-TD-HT-TR.001.db; Diffuser table record 1: ---------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0     0.533       0.0     0.001     16.94       0.0       0.0     0.533       0.0    0.0001    -1.151
       7.9     0.533       0.0     0.001     16.94       0.0       0.0     0.533       0.0    0.0001    -1.151

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
    (in)    (ft)   (deg)   (deg)      ()    (in)    (ft)    (ft)    (ft) (ft3/s)   (psu)     (F)   (ppb)
     1.0     1.5    45.0     0.0   960.0     2.0   120.0   240.0    24.5    40.0 1.00E-3    74.9 3.76E+5

Simulation:
Froude number:       227.1; effleunt density (sigma-T)    -2.599; effleunt velocity     3.817(m/s);
          Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn
Step       (ft)   (ft/s)     (in)    (ppb)       ()       ()     (ft)     (ft)
   0       24.5     1.75    0.781 376000.0      1.0      1.0      0.0      0.0;
  53      24.34     1.75    2.023 131637.2    2.853    1.285     0.19      0.0; merging;
  67      24.27     1.75    2.787  99764.6    3.765    1.838    0.289      0.0; stream limit reached;
 100      24.01     1.75    7.086  51900.4    7.235    4.104    0.781      0.0;
 200      21.02     1.75    81.15   7164.0    52.41    24.64    20.44      0.0;
 250      15.14     1.75    230.0   2661.6    141.1    64.54    122.0      0.0; acute zone;
 271      10.19     1.75    352.1   1756.1    213.8    97.28    246.2      0.0; chronic zone, matched energy radial ve;
 279      7.667     1.75    413.8   1498.8    250.5    113.8    317.0      0.0; surface;
Outside chronic zone

11:01:44 AM. amb fills: 2
/ DKHW
Case 1; ambient file C:\Plumes\WB4-w10-TD-HT-TR.001.db; Diffuser table record 1: ---------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0     0.533       0.0     0.001     16.94       0.0       0.0     0.533       0.0    0.0001    -1.151
       7.9     0.533       0.0     0.001     16.94       0.0       0.0     0.533       0.0    0.0001    -1.151

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
    (in)    (ft)   (deg)   (deg)      ()    (in)    (ft)    (ft)    (ft) (ft3/s)   (psu)     (F)   (ppb)
     1.0     1.5    45.0     0.0   960.0     2.0   120.0   240.0    24.5    40.0 1.00E-3    74.9 3.76E+5

Simulation:
Froude number:       227.1; effleunt density (sigma-T)    -2.599; effleunt velocity     3.817(m/s);
          Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn
Step       (ft)   (ft/s)     (in)    (ppb)       ()       ()     (ft)     (ft)
   0       24.5     1.75    0.781 376000.0      1.0      0.0      0.0      0.0;
   2      24.24     1.75    2.047 162559.4    2.313    1.292    0.292      0.0; merging;
  22      24.19     1.75    2.756 117573.5    3.198    2.665    0.356      0.0;
  23      24.19     1.75    2.835 113973.9    3.299    2.749    0.364      0.0;
  38      24.09     1.75    4.724  75608.3    4.973    4.144    0.559      0.0; stream limit reached;
  41      24.07     1.75    5.236  70175.4    5.358    4.465    0.616      0.0;
  54      23.89     1.75    9.213  45708.7    8.226    6.855    1.191      0.0;
  60      23.78     1.75    11.81  37698.0    9.974    8.312    1.677      0.0;
  73      23.46     1.75    19.92  24802.1    15.16    12.63    3.813      0.0;
  86      22.99     1.75    32.95  16213.9    23.19    19.33    9.441      0.0;
 100      22.29     1.75    53.43  10599.0    35.48    29.56    24.04      0.0;
 113      21.27     1.75    84.49   6977.7    53.89    44.91    58.58      0.0;
 124      19.74     1.75    130.3   4653.8     80.8    64.17    127.7      0.0;
 125      19.52     1.75    136.7   4449.0    84.51    67.33    138.3      0.0; acute zone;
 125      19.52     1.75    136.7   4449.0    84.51    70.43    138.3      0.0;
 134      17.17     1.75    201.8   3064.3    122.7    96.67    255.2      0.0;
 135      16.74     1.75    213.2   2907.1    129.3    102.3    276.5      0.0; chronic zone;
 135      16.74     1.75    213.2   2907.1    129.3    107.8    276.5      0.0;
 144      12.02     1.75    333.9   1881.2    199.9    166.6    510.4      0.0;
 153      3.247     1.75    545.8   1162.0    323.6    269.6    935.6      0.0;
 155     -0.309     1.75    629.4   1009.8    372.4    310.3   1105.6      0.0; local maximum rise or fall;
Outside chronic zone

Print active window
```

Figure E-1. Typical printout from Visual Plumes program for Watts Bar using both the UM3 and DKHW models for a single row of ports. (Arrows added to show start of different model output data.)

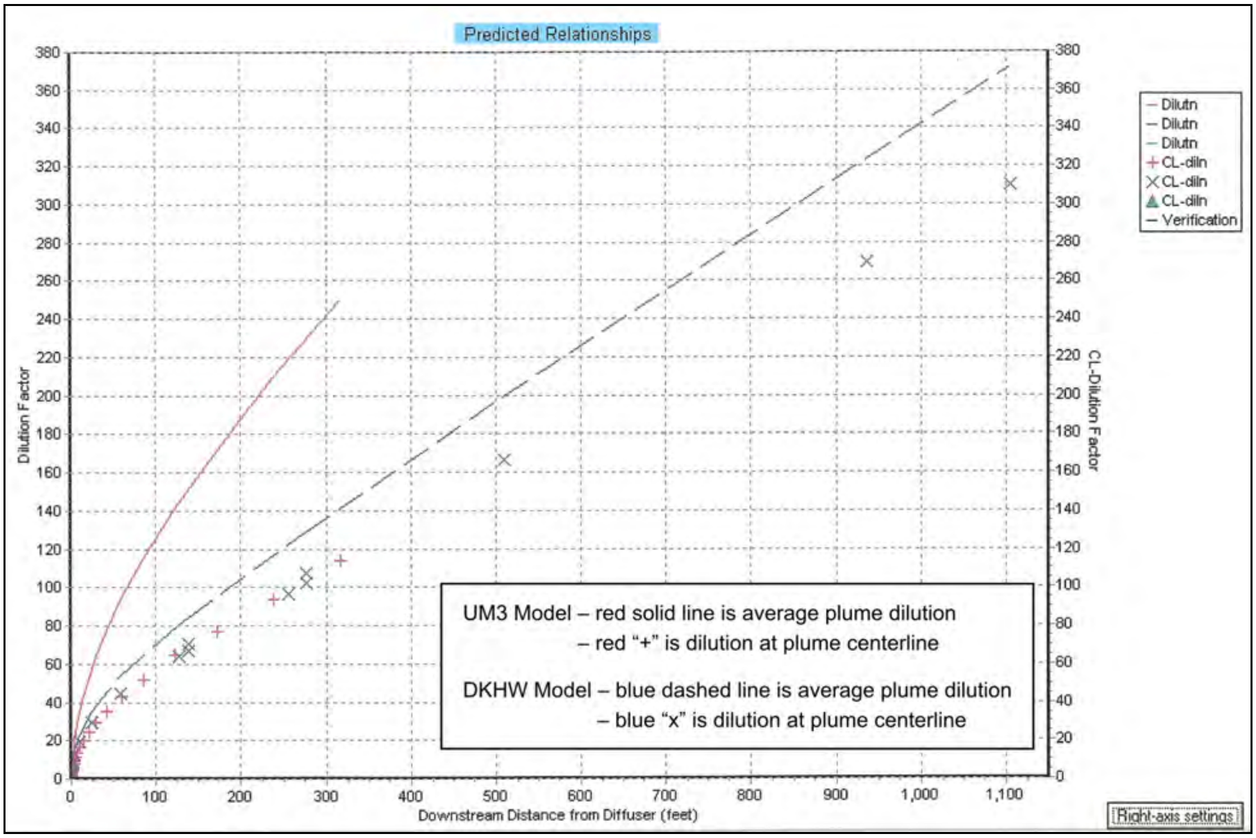

Figure E-2. Typical graph from Visual Plumes program for Watts Bar using both the UM3 and DKHW models for a single row of ports.

The graph shows plots for both the maximum plume concentration at the plume centerline and the average plume concentration as it moves downstream from the source. For the Watts Bar scenarios, the DKHW model consistently predicted the plume would surface farther from the discharge point than did the UM3 model; the difference was greater for some scenarios than others. The scenario depicted in Figures E-1 and E-2 had the greatest difference. Figure E-2 shows that the DKHW model continued calculating plume concentrations at a distance of 1,100 feet, whereas the UM3 model reached just beyond 300 feet when the plume surfaced and calculations stopped. Corresponding to this trend, the DKHW model consistently predicted a more dilute (lower concentration) plume at the point of surfacing in comparison with the UM3 results.

Table E-3 lists the modeling results in terms of the tritium concentration as the discharge plume moved downstream, away from the diffusers, for each of the 12 evaluated scenarios for both the UM3 and DKHW models. In the scenario descriptions in the table, the three evaluated tritium concentrations are identified as low, middle, and high. To present a more conservative evaluation, the concentrations in the table are the maximum plume concentrations that would be present at the centerline of the plume. Average plume concentrations, which the models also calculated, can be significantly lower. For example, in the UM3 model output (Figure E-1), the centerline dilution factor was 64.54 at a distance of 122 feet downstream from the diffusers, while the average dilution factor at this distance was 141.1. These dilution factors represent tritium concentrations of about 11,650 and 5,330 picocuries per liter, respectively, after superimposing results from both rows of ports.

As the data in the table indicate, both models predicted that maximum tritium concentrations reduced to drinking water levels very quickly, before the plume surfaced, for each of the different tritium

Table E-3. Watts Bar modeling results in terms of the tritium concentration in the discharge plume.

Evaluated scenarios[a]	Distance (ft) for plume centerline to decrease to 20,000 pCi/L[b]		Centerline concentration (pCi/L) at boundary of mixing zone (240 ft from diffusers)		Centerline concentration (pCi/L) where plume surfaces and distance from the diffusers	
	UM3	DKHW	UM3	DKHW	UM3	DKHW
Scenarios with the typical effluent discharge of 80 cfs to the river						
1. Low tritium and low river flow	25	14	NM[c]	NM	16,800 at 32 ft	8,770 at 53 ft
2. Low tritium and typical river flow	17	13	4,480	4,510	3,830 at 317 ft	1,410 at 1,106 ft
3. Middle tritium and low river flow	Surf[d] (≈51)	35	NM	NM	29,000 at 32 ft	15,100 at 53 ft
4. Middle tritium and typical river flow	48	42	7,730	7,780	6,610 at 317 ft	2,420 at 1,106 ft
5. High tritium and low river flow	Surf[d] (≈110)	Surf[d] (≈80)	NM	NM	53,300 at 32 ft	27,800 at 53 ft
6. High tritium and typical river flow	142	146	14,200	14,300	12,100 at 317 ft	4,450 at 1,106 ft
Scenarios with the maximum short-term effluent discharge of 175 cfs to the river						
7. Low tritium and low river flow	Surf[d] (≈30)	19	NM	NM	20,700 at 28 ft	14,300 at 32 ft
8. Low tritium and typical river flow	19	12	NM	4,660	7,830 at 102 ft	2,700 at 595 ft
9. Middle tritium and low river flow	Surf[d] (≈65)	Surf[d] (≈43)	NM	NM	35,800 at 28 ft	24,600 at 32 ft
10. Middle tritium and typical river flow	51	38	NM	8,030	13,500 at 102 ft	4,660 at 595 ft
11. High tritium and low river flow	Surf[d] (≈130)	Surf[d] (≈90)	NM	NM	65,700 at 28 ft	45,200 at 32 ft
12. High tritium and typical river flow	Surf[d] (≈140)	136	NM	14,800	24,800 at 102 ft	8,560 at 595 ft

cfs = cubic feet per second; ft = feet; pCi/L = picocuries per liter; ≈ = approximately.

a. Scenarios:
Low tritium = effluent with a tritium concentration of 218,000 pCi/L.
Middle tritium = effluent with tritium concentration of 376,000 pCi/L.
High tritium = effluent with tritium concentration of 691,000 pCi/L.
Low river flow = 3,500 cfs (the lowest river flow during which effluent discharges can still take place)
Typical river flow = 27,000 cfs (average flow over the course of a year)

b. Values in these two columns are estimates based on visual interpretations of graphic outputs from the models. Values in other columns are based on specific numbers in the models' text printouts.

c. NM = not modeled. The plume reached the water surface before leaving the mixing zone, and the models stopped at that point.

d. Surf = surfaces; the model predicts the plume would reach the surface before the concentration reduced to 20,000 pCi/L. The value in parentheses is a rough estimate of the distance at which the concentration would be reached.

concentrations when both the effluent discharge and river flow were at typical conditions (that is, scenarios 2, 4, and 6 in the table). Figure E-2, as an example, shows output for Scenario 4 in the table and the middle tritium concentration of 376,000 picocuries per liter in the effluent reduced to the drinking water level at a dilution factor of 37.6, which both models show being reached very quickly. The dilution factor of 37.6 represents a concentration of 10,000 picocuries per liter but, after superimposing the results from the second row of ports, the drinking water level of 20,000 picocuries per liter is reached. The "low river flow" and "maximum effluent discharge" variables both acted to cause the plume to surface closer to the diffusers and at higher tritium concentrations. In five of the six low-flow scenarios, for example, one or both of the models predicted the plume would surface before the centerline concentration reduced to 20,000 picocuries per liter and, as a result, the models stopped at that point.

Table E-3 also lists predicted concentrations of tritium at other locations of potential interest including the mixing zone boundary and the point at which the plume first reached the water surface. The models often did not compute concentrations down to the drinking water level or at the boundary of the mixing zone because they stopped once the plume reached the surface. In the low river flow scenarios in which one or both models stopped before a drinking water level was reached, but were reasonably close, Table E-3 includes a rough approximation of the distance at which it would be reached. These estimates were made by extending the lines of the "Dilution Factor versus Downstream Distance" graphs the models generated (for example, Figure E-2) to the applicable dilution factor. The plumes' rate of dispersion and dilution would be expected to vary at this point but, because the plume surfaces at a centerline concentration relatively close to 20,000 picocuries per liter, the straight line should represent a reasonable approximation.

The nearest drinking water intake is the City of Dayton, Tennessee, which is southwest of the Watts Bar site and about 23 miles downstream as the river flows. At this downstream distance, it is reasonable to assume the tritium would be well mixed in the river flow. At the maximum bounding tritium discharge of 49,320 curies per year and an average river flow of 27,000 cubic feet per second (which equates to about 24.1 trillion liters per year), the average tritium concentration at the downstream drinking water intake would be about 2,050 picocuries per liter. If 20,000 picocuries per liter in drinking water equates to an average annual dose of 4 millirem, 2,050 picocuries per liter would equate to an annual dose of 0.41 millirem. The middle tritium discharge value above is roughly half of the maximum value, so the average annual concentrations and dose under that discharge scenario would be roughly half of the values shown for the maximum tritium scenario.

Other Beta Particle or Photon Emitters

One additional evaluation is worth describing in relation to the drinking water standard for tritium. As noted above, the applicable drinking water standard is actually an annual dose equivalent of 4 millirem per year from all beta particle and photon radioactivity. Tritium is by far the most significant beta particle or photon emitter in the Watts Bar liquid effluents, but it is not the only one. For example, *Watts Bar Nuclear Plant – 2010 Annual Radioactive Effluent Release Report* (TVA 2011a) indicates the liquid effluents included 17 different radionuclides over the course of the year, in addition to tritium, that are beta particle or photon emitters. There are variations over time in the specific radionuclides reported in the liquid effluents such that when the similar reports for 2008 and 2009 (TVA 2009a, 2010b) are also considered, the number of beta particle and photon emitters increases to 27 in addition to tritium. As with tritium, EPA has developed concentrations for each of these radionuclides that correspond to an annual dose of 4 millirem (EPA 2011). Consistent with the relatively low radiotoxicity of tritium, the derived values for these other radionuclides are generally less than 20,000 picocuries per liter; that is, it takes less of these other radionuclides to result in the dose limit. However, they were released at much lower concentrations than tritium. Table E-4 identifies the other beta particle or photon emitters that were released in the Tennessee River during 2008 through 2010 from Watts Bar and their contribution to the 4-millirem limit, if they occurred in a drinking water source at their average concentrations over that period. At their average release concentrations, and as indicated in Table E-4, these radionuclides would contribute about 2 percent of the drinking water limit. Once these low concentrations were discharged and mixed with the river, their contributions to the drinking water limit would be negligible and it becomes appropriate to compare the entire limit to the tritium concentration.

Table E-4. Other beta particle or photon emitters released to the Tennessee River in 2008 through 2010 from Watts Bar and their contribution to the 4-millirem-per-year drinking water limit.

Radionuclide[a]	**Total released to liquid effluents 2008 to 2010 (Ci)**[a] **(A)**	**Total liquid effluents released in 2008 to 2010 (liters)**[a] **(B)**	**Average concentration as discharged (pCi/liter) (C)=(A/B) × 10^{12}**	**Amount resulting in 4-mrem/yr dose (pCi/liter)**[b] **(D)**	**Dose contribution (mrem/yr) (E)=(C/D) × 4**	**Fraction of 4-mrem/yr dose limit (F)=(E)/4**
Na-24	9.13×10^{-6}	1.57×10^{11}	5.81×10^{-5}	600	3.88×10^{-7}	9.69×10^{-8}
Cr-51	6.53×10^{-3}	1.57×10^{11}	4.16×10^{-2}	6,000	2.77×10^{-5}	6.93×10^{-6}
Mn-54	1.48×10^{-3}	1.57×10^{11}	9.40×10^{-3}	300	1.25×10^{-4}	3.13×10^{-5}
Fe-55	1.10×10^{-1}	1.57×10^{11}	6.99×10^{-1}	2,000	1.40×10^{-3}	3.50×10^{-4}
Fe-59	4.05×10^{-4}	1.57×10^{11}	2.58×10^{-3}	200	5.16×10^{-5}	1.29×10^{-5}
Co-57	8.32×10^{-5}	1.57×10^{11}	5.29×10^{-4}	1,000	2.12×10^{-6}	5.29×10^{-7}
Co-58	3.14×10^{-2}	1.57×10^{11}	2.00×10^{-1}	300	2.66×10^{-3}	6.66×10^{-4}
Co-60	9.67×10^{-3}	1.57×10^{11}	6.16×10^{-2}	100	2.46×10^{-3}	6.16×10^{-4}
Sr-89	1.05×10^{-3}	1.57×10^{11}	6.66×10^{-3}	20	1.33×10^{-3}	3.33×10^{-4}
Sr-90	8.53×10^{-5}	1.57×10^{11}	5.43×10^{-4}	8	2.72×10^{-4}	6.79×10^{-5}
Nb-95	9.62×10^{-4}	1.57×10^{11}	6.13×10^{-3}	300	8.17×10^{-5}	2.04×10^{-5}
Zr-95	9.63×10^{-4}	1.57×10^{11}	6.13×10^{-3}	200	1.23×10^{-4}	3.07×10^{-5}
Mo-99	3.68×10^{-5}	1.57×10^{11}	2.34×10^{-4}	600	1.56×10^{-6}	3.90×10^{-7}
Tc-99m	3.68×10^{-5}	1.57×10^{11}	2.34×10^{-4}	20,000	4.68×10^{-8}	1.17×10^{-8}
Ru-103	2.36×10^{-5}	1.57×10^{11}	1.50×10^{-4}	200	3.00×10^{-6}	7.50×10^{-7}
Ru-106	2.34×10^{-5}	1.57×10^{11}	1.49×10^{-4}	30	1.99×10^{-5}	4.97×10^{-6}
Sn-113	1.37×10^{-6}	1.57×10^{11}	8.72×10^{-6}	300	1.16×10^{-7}	2.91×10^{-8}
Sb-122	2.52×10^{-5}	1.57×10^{11}	1.61×10^{-4}	90	7.14×10^{-6}	1.78×10^{-6}
Sb-124	3.77×10^{-5}	1.57×10^{11}	2.40×10^{-4}	60	1.60×10^{-5}	4.01×10^{-6}
Sb-125	8.52×10^{-3}	1.57×10^{11}	5.42×10^{-2}	300	7.23×10^{-4}	1.81×10^{-4}
I-131	9.78×10^{-3}	1.57×10^{11}	6.23×10^{-2}	3	8.30×10^{-2}	2.08×10^{-2}
I-132	5.42×10^{-4}	1.57×10^{11}	3.45×10^{-3}	90	1.53×10^{-4}	3.83×10^{-5}
I-133	3.47×10^{-5}	1.57×10^{11}	2.21×10^{-4}	10	8.84×10^{-5}	2.21×10^{-5}
Te-132	3.47×10^{-4}	1.57×10^{11}	2.21×10^{-3}	90	9.82×10^{-5}	2.45×10^{-5}
Cs-134	9.39×10^{-4}	1.57×10^{11}	5.98×10^{-3}	80	2.99×10^{-4}	7.47×10^{-5}
Cs-137	3.37×10^{-3}	1.57×10^{11}	2.15×10^{-2}	200	4.30×10^{-4}	1.07×10^{-4}
Ce-141	1.59×10^{-6}	1.57×10^{11}	1.01×10^{-5}	300	1.35×10^{-7}	3.37×10^{-8}
Totals	**1.86×10^{-1}**	**N/A**	**N/A**	**N/A**	**9.34×10^{-2}**	**2.34×10^{-2} (or 2.3%)**

Ci = curies; mrem/yr = millirem per year; N/A = not applicable; pCi = picocuries.

a. Source: TVA 2009a, 2010b, 2011a.

b. Source: EPA 2011.

TPBAR Failure Scenarios

This SEIS also evaluates the unlikely scenario of having two TPBAR failures during a routine 18-month operating cycle for a reactor. As assumed in the 1999 EIS (DOE 1999, Appendix C, Section C.3.4), two failed TPBARs could release a total of about 23,150 curies of tritium to the reactor coolant system and about 90 percent of this tritium (that is, 20,835 curies) could be released in the plant’s liquid effluents (DOE 1999). Because a TPBAR failure is very unlikely, this evaluation assumed it would only happen in a single reactor, although both reactors could be operating at the same time. The evaluation considers both typical and low river flows of 27,000 and 3,500 cubic feet per second, respectively. However, considering the scenarios in Table E-3, it addresses only a typical discharge to the river of 80 cubic feet per second. If water with TPBAR failure levels of tritium were to accumulate in the yard holding pond, that water (plus the normal operational discharges) would be sent to the river at a much lower rate than the maximum 175 cubic feet per second evaluated for normal conditions. This evaluation considered a two-TPBAR failure scenario at Watts Bar for Alternatives 1 and 4 (Watts Bar Only) and Alternatives 3 and 6 (Watts Bar and Sequoyah). Under Alternative 1 or 6, there would be 26,820 curies of tritium in the annual discharge as a result of normal reactor operations and tritium permeation rate from the 2,500 TPBARs (Table E-1) as well as the tritium from the TPBAR failures. Under Alternative 3, there would be 15,570 curies of tritium from normal plant operations with 1,250 TPBARs (Table E-1), plus the tritium from the TPBAR failures. Under Alternative 4, there would be 49,320 curies of tritium from normal plant operations with 5,000 TPBARs (Table E-1), plus the tritium from the TPBAR failures.

The average tritium concentration as discharged to the river is derived as follows:

- Total tritium discharge:

  - Alternative 1 or 6 – 47,655 curies per year (as described above, 20,835 plus 26,820);
  - Alternative 3 – 36,405 curies per year (20,835 plus 15,570); and.
  - Alternative 4 – 70,155 curies per year (20,835 plus 49,320).

- Typical discharge volume to river: 80 cubic feet per second or 7.14×10^{10} liters per year (Table E-1).

- Tritium concentration:

  - Alternative 1 or 6 – 667,000 picocuries per liter;
  - Alternative 3 – 510,000 picocuries per liter; and
  - Alternative 4 – 983,000 picocuries per liter.

As described above, NNSA evaluated the discharges for the TPBAR failure scenarios using both the UM3 and DKHW models; Table E-5 summarizes the results. The results are in the same format as Table E-3 for ease of comparison. As the table indicates, even with the high tritium releases that would result from the failure of two TPBARs, the models predict that with typical river flow conditions the drinking water level of 20,000 picocuries per liter would be reached in all portions of the plume within about 130 feet of the diffuser under Alternative 1 or 6, within about 83 feet of the diffuser under Alternative 3, and within about 260 feet of the diffuser under Alternative 4. With low river flow conditions, both models predict the plume would surface before reaching a tritium concentration of 20,000 picocuries per liter for each of the tritium concentration evaluations. The plume surfaces much closer to the diffuser and at higher tritium concentrations under low river flow conditions.

As in the evaluation above, the discharge water should be well mixed in the river by the time it travelled about 23 miles by river to the nearest drinking water intake (City of Dayton, Tennessee). At the maximum tritium discharge of 70,155 curies per year (Alternative 4 with the TPBAR failures) and an average river flow of 27,000 cubic feet per second (which equates to about 24.1 trillion liters per year), the annual average tritium concentration at the downstream drinking water intake during the time of high tritium discharge would be about 2,910 picocuries per liter. If 20,000 picocuries per liter in drinking water equates to an average annual dose of 4 millirem, 2,910 picocuries per liter would equate to an annual dose of about 0.6 millirem. Under similar conditions, Alternatives 1 or 6 with two failed TPBARs would involve about two-thirds as much tritium and result in two-thirds of the Alternative 4 dose; Alternative 3 would have about half as much tritium and result in about half of that dose.

Table E-5. Watts Bar modeling results in terms of the tritium concentration in the discharge plume for the two-TPBAR failure scenarios.

Two TPBAR failure scenario[a]	Distance (ft) for plume centerline to decrease to 20,000 pCi/L		Centerline concentration (pCi/L) at boundary of mixing zone (240 ft from diffusers)		Centerline concentration (pCi/L) where plume surfaces and distance from the diffusers	
	UM3	DKHW	UM3	DKHW	UM3	DKHW
1. Middle (other) tritium, typical discharge, low river flow	Surf[b] (≈101)	Surf (≈80)	NM[c]	NM	51,500 at 32 ft	26,800 at 53 ft
2. Middle (other) tritium, typical discharge, typical river flow	130	126	13,710	13,800	11,700 at 317 ft	4,300 at 1,106 ft
3. Low (other) tritium, typical discharge, low river flow	Surf (≈74)	Surf (≈56)	NM	NM	39,400 at 32 ft	20,500 at 53 ft
4. Low (other) tritium, typical discharge, typical river flow	83	77	10,490	10,550	8,960 at 317 ft	3,290 at 1,106 ft
5. High (other) tritium, typical discharge, low river flow	Surf (≈150)	Surf (≈130)	NM	NM	75,800 at 32 ft	39,600 at 53 ft
6. High (other) tritium, typical discharge, typical river flow	260	260	20,200	20,300	17,300 at 317 ft	6,340 at 1,106 ft

cfs = cubic feet per second; ft = feet; pCi/L = picocuries per liter; ≈ = approximately.

a. Scenarios:
Middle (other) tritium = Two-TPBAR failure with Alternative 1 tritium, effluent tritium concentration of 667,000 pCi/L.
Low (other) tritium = Two-TPBAR failure with Alternative 3 tritium, effluent tritium concentration of 510,000 pCi/L.
High (other) tritium = Two-TPBAR failure with Alternative 4 tritium, effluent tritium concentration of 983,000 pCi/L.
Typical discharge = Watts Bar plant discharge of 80 cfs (with both reactors operating).
Typical river flow = 27,000 cfs (average flow over the course of a year).
Low river flow = 3,500 cfs (the lowest river flow during which effluent discharges can still take place).

b. Surf = surfaces; the model predicts the plume would reach the surface before the concentration reduced to 20,000 pCi/L. The value in parentheses, if present, is a rough estimate of the distance at which the concentration would be reached.

c. NM = not modeled. The plume reached the water surface before leaving the mixing zone, and the models stopped at that point.

Expected Case

The 12 scenarios evaluated for Watts Bar (results in Table E-3) represent bounding conditions for the discharge of tritium in liquid and air effluents. Both the baseline quantities of tritium in the liquid discharges without TPBARs (that is, 2,160 curies of tritium per year from each reactor per Table E-1) and the permeation rate of 10 curies per year per TPBAR are higher than expected. NNSA anticipates that the annual permeation rate from each TPBAR would be about 5 curies. Tritium in liquid discharges to the Watts Bar cooling system before the use of any TPBARs was about 900 curies per year (from one reactor) and 97 percent of that remained in the water as discharged to the river. Further, NNSA anticipates that deployment of 2,500 TPBARs would meet tritium production requirements and, of the tritium permeating from the TPBARs, 97 percent would make its way to the liquid effluents. Under these expected conditions, deployment of 2,500 TPBARs at Watts Bar would release about 12,500 curies of tritium to the reactor cooling system and about 97 percent of this tritium (that is, 12,125 curies) would be released to the plant's liquid effluents. This would combine with about 1,746 curies of baseline tritium in the liquid effluents once both Watts Bar reactors were operational. Because the expected case is being evaluated only for comparison to the bounding case scenarios, it was only considered during typical river flow and discharge conditions; that is, given the scenarios in Table E-3, the evaluation addresses only a liquid discharge to the river of 80 cubic feet per second and a river flow of 27,000 cubic feet per second.

The average tritium concentration discharged to the river is derived as follows:

- Total tritium discharge: 13,871 curies per year (as described above, 12,125 plus 1,746);
- Typical discharge volume to river: 80 cubic feet per second or 7.14×10^{10} liters per year (Table E-1); and
- Tritium concentration: 194,000 picocuries per liter.

As described above, the discharge for the expected case scenario was evaluated using both the UM3 and DKHW models (results in Table E-6). Although there is only a single row of results, they are listed as in Table E-3 for ease of comparison. As the table indicates, under the expected case, the models predicted the drinking water level of 20,000 picocuries per liter would be reached in all portions of the plume within about 14 feet, or less, of the diffuser.

Table E-6. Watts Bar modeling results in terms of the tritium concentration in the discharge plume for the expected case scenario.

	Distance (ft) for plume centerline to decrease to 20,000 pCi/L		**Centerline concentration (pCi/L) at boundary of mixing zone (240 ft from diffusers)**		**Centerline concentration (pCi/L) where plume surfaces and distance from the diffusers**	
Scenario[a]	**UM3**	**DKHW**	**UM3**	**DKHW**	**UM3**	**DKHW**
Expected case tritium, typical discharge, and typical river flow	14	10	3,990	4,010	3,410 at 317 ft	1,250 at 1,106 ft

cfs = cubic feet per second; ft = feet; pCi/L = picocuries per liter.

a. Scenario:
Expected case tritium = effluent with a tritium concentration of 194,000 pCi/L.
Typical discharge = Watts Bar plant discharge of 80 cfs (with both reactors operating).
Typical river flow = 27,000 cfs (average flow over the course of a year)

As in the previous evaluation, the discharge water should be well mixed in the river by the time it travelled about 23 miles by river to the nearest drinking water intake (City of Dayton, Tennessee). At the tritium discharge of 13,871 curies per year and an average river flow of 27,000 cubic feet per second (which equates to about 24.1 trillion liters per year), the annual average tritium concentration at the downstream drinking water intake would be about 580 picocuries per liter. If 20,000 picocuries per liter in drinking water equates to an average annual dose of 4 millirem, 580 picocuries per liter would equate to an annual dose of 0.12 millirem.

E.3 Sequoyah Tritium Discharge Evaluations

This section discusses the evaluations NNSA performed to consider a range of tritium discharge and river flow conditions that bound the alternatives for the Sequoyah site.

The number of TPBARs TVA would irradiate at the Sequoyah nuclear plant would range from zero under Alternatives 1 and 4 to 5,000 under Alternative 5. Under the No-Action Alternative, TVA would irradiate 680 TPBARs in each of the Sequoyah reactors (a total of 1,360). Under Alternatives 2 and 6, NNSA assumed TVA would use the Sequoyah site to irradiate 2,500 TPBARs. Alternative 3 would involve irradiation of TPBARs using both sites and, as a result, NNSA assumed irradiation of 1,250 TPBARs at each site, but with the possibility of irradiating 2,500 at either site for some periods.

Table E-7 lists the number of TPBARs TVA would irradiate at the Sequoyah site under the alternatives in this SEIS. The table also lists the estimated amounts of tritium the site would release in liquid effluents on an annual basis as a result of TPBAR irradiation under each scenario. The estimates are based on the conservative bounding assumption that 10 curies of tritium would permeate from each TPBAR on an annual basis and that 90 percent of the tritium would find its way to the liquid effluents. The third row of data in the table identifies baseline quantities of tritium the Sequoyah site releases independent of TPBARs irradiation.

Table E-7. Parameters for evaluation of tritium discharges at Sequoyah.

	Alternative				
Parameter	**No Action**	**Alternatives 1 and 4: Watts Bar only**	**Alternative 2 and 6: Sequoyah**	**Alternative 3: Watts Bar and Sequoyah**	**Alternative 5: Sequoyah only**
1. TPBARs per fuel cycle	1,360	0	2,500	1,250–2,500	5,000
2. Tritium release to liquid effluents from TPBARs (curies per year)	12,240	0	22,500	11,250–22,500	45,000
3. Tritium release to liquid effluents from baseline operations (curies per year)[a]	4,320	4,320	4,320	4,320	4,320
4. Total tritium release to liquid effluents (curies per year)	16,560	4,320	26,820	15,570–26,820	49,320
5. Typical radioactive liquid waste effluents to the diffuser pond (liters per year)[a]	7.67×10^9	7.67×10^9	7.67×10^9	7.67×10^9	7.67×10^9
6. Typical curie concentration in liquid waste effluents to the diffuser pond (#4 / #5) (picocuries per liter)	2,160,000	563,000	3,500,000	2,030,000–3,500,000	6,430,000
7. Typical discharge to Outfall 101 (liters per year)[b]	2.084×10^{12}	2.084×10^{12}	2.084×10^{12}	2.084×10^{12}	2.084×10^{12}
8. Typical curie concentration in discharge to Outfall 101 (#4 / #7) (picocuries per liter)	7,950	2,070	12,900	7,470–12,900	23,700

a. As a bounding value, each reactor was assumed to release 2,400 curies of tritium per year to the cooling water system, of which 90 percent (that is, 2,160 curies for each reactor) was assumed to reach the liquid effluents.

b. From January 2006 through August 2011, the average reported discharge to Outfall 101 was 1,508 million gallons per day. This converts to 2,084 billion liters per year.

Normal operations of nuclear plants include generation of tritium and its release in wastewater effluent. The baseline value in Table E-7 (4,320 curies) represents a bounding number, well above the annual average of 1,740 curies of tritium for Sequoyah liquid effluents during the 5-year period from 2006 through 2010 (TVA 2007b, 2008, 2009, 2010c, 2011b). The fourth row lists total tritium release quantities (baseline plus TPBAR contribution). The fifth and sixth rows provide information on the liquid effluents and associated average tritium concentration going to the diffuser pond. These data are provided because the Sequoyah diffuser pond is not in the plant's permanent restricted area (TVA 2010d) and thus could be considered the compliance point for meeting the plant's effluents limits under 10 CFR Part 20 (see Section E.1). The last two rows in the table list the typical discharge volume that would go to Outfall 101 and the resulting tritium concentrations based on the total tritium release in the fourth row. The typical discharge for Sequoyah in the seventh row of Table E-7 is much greater than the typical discharge for Watts Bar in Table E-1. This is a direct result of the difference in the cooling systems for the two nuclear plants. Watts Bar has a closed system that recycles much of its cooling water, so blowdown from the system is the primary discharge to the river. Sequoyah, on the other hand, has the flexibility to operate in several modes, but it operates predominantly in an open mode in which cooling water is used once to pick up heat and then discharged.

The tritium and liquid effluents would be part of the primary plant discharges going to Outfall 101 (see Section 3.1.5.1.3). That is, TVA would discharge the tritium, along with plant cooling water and process wastewaters, to the Tennessee River through the two multiport diffusers on the bottom of the river. Because tritium contamination would be part of the plant process wastewaters that make their way to the diffuser pond after treatment and processing, they are not part of the cooling water systems; the tritium would not reach any of the other site outfalls described in Section 3.1.5.1.3.

Table E-8 lists the information NNSA entered into the diffuser and ambient receiving stream windows of Visual Plumes. The table includes justifications and sources for the information, as appropriate. As the data in the table indicate, there are only three effluent concentrations for the modeling evaluation. The identified values (7,470, 12,900, and 23,700 picocuries per liter) are the concentrations that span Alternatives 2, 3, and 5 for the Sequoyah plant. The No-Action Alternative involves another range of possible tritium concentrations (Table E-7), but they are very similar to the lower concentration already identified for modeling. As a result, modeling of another concentration specifically to simulate the No-Action Alternative was not warranted.

Several values in Table E-8 represent parameters that are likely to change over the course of a year. For example, effluent and ambient river temperatures vary significantly by season and, while the typical current speed is based specifically on an average flow and a typical water surface elevation of 680 feet above mean sea level, normal high and low elevations range from 682.5 to 676 (TVA 2010a). The modeling evaluation used only the typical values in the table in such cases because they were not likely to have a significant effect on the model results, and to do otherwise would result in an unreasonable number of scenarios to consider. Even though NNSA attempted to keep the evaluation as simple as possible, the data in Table E-8 indicate there are one parameter with three values and another with two values; these parameters would be likely to have significant effects on the modeling results. In the case of tritium concentration, the three values represent the range of estimated values for tritium release in liquid effluents under Alternatives 2, 3, and 5 (as well as approximating conditions under the No-Action Alternative). In the case of the current speed, the two values represent a worst-case extreme and a typical condition. The NNSA evaluation considered six scenarios to address the various combinations of the two parameter variables.

Figures E-3 and E-4 show typical text and numerical output and graphic results, respectively, from the Visual Plumes program under one of the six evaluated scenarios. The figures show results from both the UM3 and DKHW models for the scenario with the middle tritium concentration (12,900 picocuries per liter), the typical river flow (32,000 cubic feet per second), and a single row of discharge ports. The graphic output in this case plots dilution factor by distance downstream of the diffusers. The dilution factor is a description of the pollutant (tritium) concentration. Visual Plumes defines this as the original discharge concentration divided by the plume concentration. The graph shows plots for both the maximum plume concentration at the plume centerline and the average plume concentration as it moves downstream from the source.

Table E-8. Primary Sequoyah information used in the Visual Plumes program.

Parameter	Values used as model input	Basis and source
Diffuser characteristics		
Port diameter	2.0 inches	Source: Harper and Hopping 2009.
Port elevation	4.85 feet	Source: Harper and Hopping 2009 – 2-inch ports start at 24 degrees from ground level and extend upward to 58 degrees – 58 inches is the middle or average elevation.
Vertical angle	36 degrees	Source: Harper and Hopping 2009 – mid-area of 2-inch ports.
Number of ports	700	Adjusted from 11,900 actual ports (Harper and Hopping 2009) because only 1 of 17 rows is being modeled.[a]
Port spacing	10 inches	Source: Harper and Hopping 2009 – within each row, ports are spaced at 12 inches on center or 10 inches from edge-to-edge.[a]
Chronic mix zone[b]	1,500 feet	NPDES permit mixing zone (downstream distance).
Port depth	40.15 feet	Source: Harper and Hopping 2009 – schematic of river bottom elevations at site of submerged diffusers – port elevation of 635 plus 4.85 and a water surface elevation of 680 feet.
Effluent flow	137.2 cfs	To accommodate modeling 1 of 17 rows, this is one-seventeenth of 1,508 million gallons per day (or 2,333 cfs), the average flow to Outfall 101 from January 2006 through August 2011, as reported for the NPDES permit.[a]
Effluent temperature	72.0°F	A average temperature of discharge to Outfall 101 from January 2006 through August 2011, as reported for the NPDES permit.
Effluent concentration	a. 7,470 pCi/L b. 12,900 pCi/L c. 23,700 pCi/L	Table E-7 – range of tritium concentrations estimated for Alternatives 2 (and 6), 3, and 5 entered as parts per billion due to limited selection of units in the program.
Ambient conditions		
Current speed	a. 0.0001 fps b. 0.54 fps	a. Assumed worst case is when there is essentially no water movement – the program would not allow entry of a zero. b. Source: Harper and Hopping 2009 – schematic of river bottom at site of diffusers – estimate based on calculated river cross-section of 59,200 square feet and typical flow of 32,000 cfs.
Ambient temperature	65°F	Source: Hopping et al. 2009 – rough approximation of annual median based on ambient temperature studies in 1982/1983 and 2007.
Ambient concentration	0 pCi/L	Per Section 3.2.5.1.2 of the SEIS (Table 3-27), only two of eight samples of ambient water conditions over 2 years indicated tritium at concentrations above the detection limit of 270 pCi/L – zero best represents ambient tritium conditions.

cfs = cubic feet per second; fps = feet per second; NPDES = National Pollutant Discharge Elimination System; pCi/L = picocuries per liter.

a. The Sequoyah diffusers have 17 2-inch-diameter ports per linear foot, in vertical rows 6 inches apart (on center) and alternating between 9 and 8 ports in each (Harper and Hopping 2009); within the vertical rows, ports are 4 inches apart. Horizontal rows are only 2 inches apart, but because ports alternate none are that close together. The Visual Plumes models are designed for ports in a single row. Therefore, NNSA adjusted the input to the models to a single row of ports. The results from each successive row were superimposed on the first to generate a composite, 17-row plume by multiplying predicted concentrations for a single row by 17.

b. The model input provides the capability to identify, or flag, a couple of distances of particular concern or interest. The model designates these distances the “acute mix zone” and “chronic mix zone.” The first zone is named to accommodate a distance where there might be an acute toxicity concern for a specific receptor exposed to a high contaminant concentration. The second zone is for a greater distance from the discharge, but for which there might still be a chronic exposure concern. The model output then includes a calculation of the plume concentration at those distances from the discharge point (unless the model predicts the plume surfaces before it reaches them). In this case, the acute and chronic designations were not applicable to running the models, so the distance to the end of the NPDES mixing zone was entered as the chronic mix zone and, as applicable, the models calculated a concentration at that distance. A shorter distance was entered as the acute mix zone, but was not used as part of the result summary.

Diffuser: SQ4-w10-TD-HT-TR.vpp.db | Ambient: C:\Plumes\SQ4-w10-TD-HT-TR.001.db | Special Settings | Text Output | Graphical Output |

Clear text display | Clear + | Output options | Numerical only

```
/ UM3. 5/2/2012 6:04:25 PM
Case 1; ambient file C:\Plumes\SQ4-w10-TD-HT-TR.001.db; Diffuser table record 2: ------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0     0.165       0.0     0.001     18.33       0.0       0.0     0.165       0.0    0.0001    -1.403
      13.3     0.165       0.0     0.001     18.33       0.0       0.0     0.165       0.0    0.0001    -1.403

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
    (in)    (ft)   (deg)   (deg)      ()    (ft)    (ft)    (ft) (ft3/s)   (psu)     (F)   (ppb)
     2.0    4.85    36.0     0.0   700.0   500.0  1500.0   40.15   137.2 1.00E-3    72.0 12900.0

Simulation:
Froude number:       251.9; effleunt density (sigma-T)    -2.217; effleunt velocity     4.489(m/s);
       Depth  Amb-cur     P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn
Step    (ft)   (ft/s)      (in)    (ppb)       ()       ()     (ft)     (ft)
   0   40.15     0.54     1.562  12900.0      1.0      1.0      0.0      0.0; stream limit reached;
  99   39.13     0.54     10.09   1816.2    7.098     3.34     1.59      0.0; merging;
 100   39.11     0.54     10.28   1780.6    7.239    3.418    1.628      0.0;
 200   29.87     0.54     184.3    245.8    52.44    27.87    30.02      0.0;
 244   15.26     0.54     540.1    102.8    125.3    61.56    110.9      0.0; matched energy radial vel =  0.143m/s;
 251   11.47     0.54     633.3    89.53    144.0    70.08    136.0      0.0; surface;
Const Eddy Diffusivity.  Farfield dispersion based on wastefield width of      193.63 m
    conc  dilutn    width distnce     time
   (ppb)              (m)     (m)    (hrs)    (ppb)    (s-1)  (ft/s)(m0.67/s2)
 89.3103   144.3    196.1   100.0   0.0988      0.0      0.0    0.54 1.00E-4
 89.4114   144.2    200.2   200.0    0.268      0.0      0.0    0.54 1.00E-4
 89.4514   144.1    204.2   300.0    0.436      0.0      0.0    0.54 1.00E-4
 89.4737   144.1    208.2   400.0    0.605      0.0      0.0    0.54 1.00E-4
 89.4816   144.0    212.1   500.0    0.774      0.0      0.0    0.54 1.00E-4
count: 5

6:04:25 PM. amb fills: 2
/ DKHW
Case 1; ambient file C:\Plumes\SQ4-v10-TD-HT-TR.001.db; Diffuser table record 2: ------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T

6:04:25 PM. amb fills: 2
/ DKHW
Case 1; ambient file C:\Plumes\SQ4-v10-TD-HT-TR.001.db; Diffuser table record 2: ------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0     0.165       0.0     0.001     18.33       0.0       0.0     0.165       0.0    0.0001    -1.403
      13.3     0.165       0.0     0.001     18.33       0.0       0.0     0.165       0.0    0.0001    -1.403

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
    (in)    (ft)   (deg)   (deg)      ()    (ft)    (ft)    (ft) (ft3/s)   (psu)     (F)   (ppb)
     2.0    4.85    36.0     0.0   700.0   500.0  1500.0   40.15   137.2 1.00E-3    72.0 12900.0

Simulation:
Froude number:       251.9; effleunt density (sigma-T)    -2.217; effleunt velocity     4.489(m/s);
       Depth  Amb-cur     P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn
Step    (ft)   (ft/s)      (in)    (ppb)       ()       ()     (ft)     (ft)
   0   40.15     0.54     1.562  12900.0      1.0      0.0      0.0      0.0; stream limit reached;
   2   39.69     0.54     4.213   6332.8    2.037    1.138    0.646      0.0; stream limit reached;
  25   39.57     0.54      6.26   4108.3     3.14    1.754    0.827      0.0;
  26   39.56     0.54     6.457   3970.5    3.249    1.815    0.845      0.0;
  37   39.38     0.54     9.449   2555.5    5.048     2.82    1.126      0.0;
  47   39.07     0.54     14.17   1656.4    7.788    4.351     1.67      0.0; merging;
  58   38.47     0.54     25.12   1090.9    11.82    9.854    2.952      0.0;
  69   37.44     0.54      46.3    719.0    17.94    14.95    5.768      0.0;
  79   35.98     0.54     79.84    488.5    26.41     22.0    11.24      0.0;
  90   33.65     0.54     138.0    324.6    39.74    33.12    23.67      0.0;
 102   29.93     0.54     236.8    211.7    60.93    50.78    52.75      0.0;
 113    23.9     0.54     400.5    136.6    94.43    78.69    116.4      0.0;
 123   14.17     0.54     656.3    88.74    145.4    121.1    233.3      0.0;
 131  0.0908     0.54    1008.7    60.11    214.6    178.8    403.2      0.0; local maximum rise or fall;
Const Eddy Diffusivity.  Farfield dispersion based on wastefield width of      203.17 m
    conc  dilutn    width distnce     time
   (ppb)              (m)     (m)    (hrs)    (ppb)    (s-1)  (ft/s)(m0.67/s2)
 59.9847   215.1    206.4   200.0     0.13      0.0      0.0    0.54 1.00E-4
 60.0392   214.9    210.6   300.0    0.299      0.0      0.0    0.54 1.00E-4
 60.0634   214.8    214.7   400.0    0.468      0.0      0.0    0.54 1.00E-4
 60.0772   214.7    218.7   500.0    0.636      0.0      0.0    0.54 1.00E-4
count: 4
```

Print active window

Figure E-3. Typical printout from Visual Plumes program for Sequoyah using both the UM3 and DKHW models from a single row of ports. (Arrows added to show start of different model output data.)

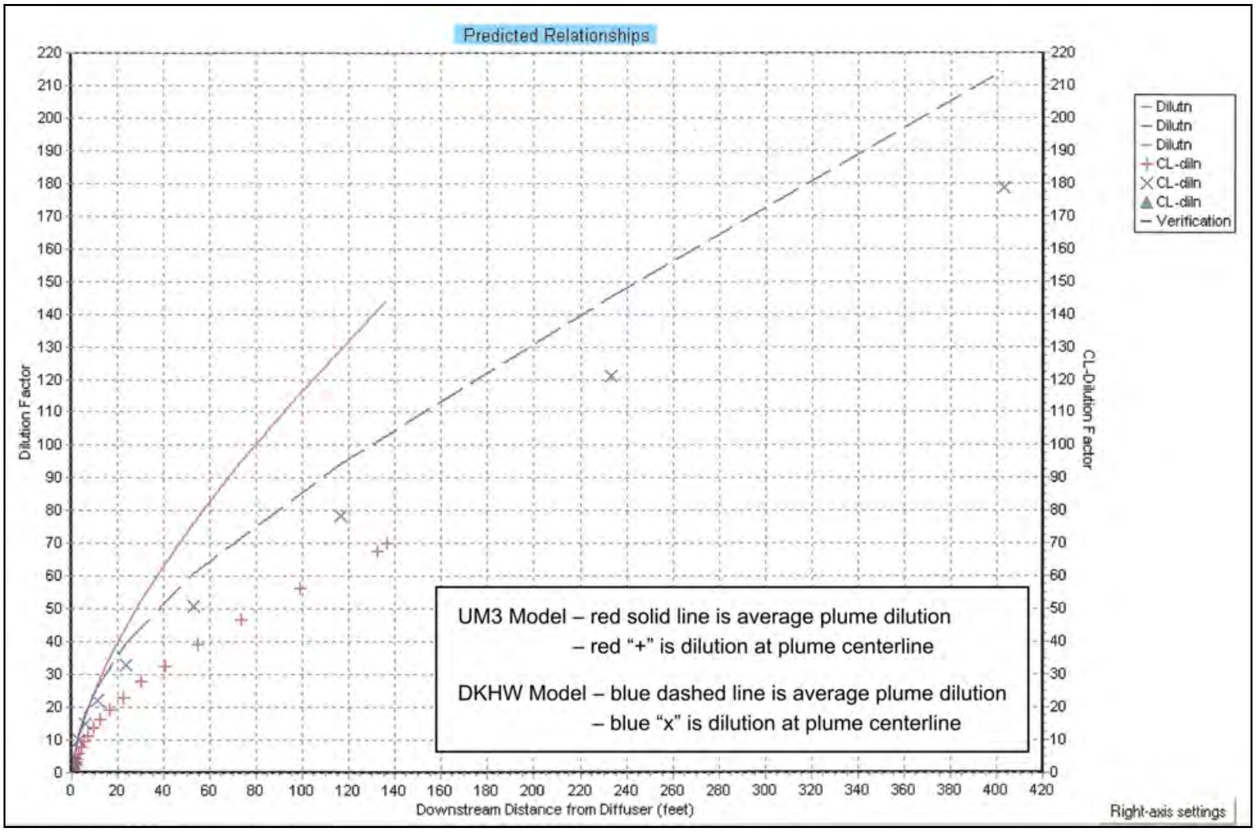

Figure E-4. Typical graph from Visual Plumes program for Sequoyah using both the UM3 and DKHW models from a single row of ports.

Table E-9 lists the modeling results in terms of the tritium concentration as the discharge plume moved downstream, away from the diffusers, for each of the six evaluated scenarios and for both the UM3 and DKHW models. In the scenario descriptions in the table, the three different tritium concentration values are identified as low, middle, and high. To present a more conservative evaluation, the concentrations in the table are the maximum plume concentrations that would be present at the centerline of the plume. Average plume concentrations, which the models also calculated, could be significantly lower. For example, in the UM3 model output (Figure E-3), the centerline dilution factor was 27.87 at a distance of 30.02 feet downstream from the diffusers, while the average dilution factor at this distance was 52.44. These dilution factors represent tritium concentrations of about 7,870 and 4,180 picocuries per liter, respectively, after superimposing results from all 17 rows of ports.

Other than for Alternative 5 (the high tritium scenarios), average tritium concentrations in the Sequoyah plant's effluent would be below the drinking water standard of 20,000 picocuries at the point the effluent reached the river. As a result, the first four scenarios in Table E-9 show 0 feet as the distance it takes to decrease tritium to the drinking water standard. As the data in the table indicate, both models predicted that the high tritium concentration was reduced to the drinking water standard fairly quickly, within 28 feet of the diffusers under either river flow scenario. As expected, the worse case at each tritium level was at the low river flow. Under the low river flow scenarios, the plumes surfaces much closer to the diffusers and at higher concentrations.

Table E-9 lists predicted concentrations of tritium at other locations of potential interest including the mixing zone boundary and the point at which the plume first reached the water surface. The models often did not compute concentrations at the boundary of the mixing zone because they stopped once the plume

Table E-9. Sequoyah modeling results in terms of the tritium concentration in the discharge plume.

Scenario[a]	Distance (ft) for plume centerline to decrease to 20,000 pCi/L[b]		Centerline concentration (pCi/L) at boundary of mixing zone (1,500 ft from diffusers)		Centerline concentration (pCi/L) where plume surfaces and distance from the diffusers	
	UM3	**DKHW**	**UM3**	**DKHW**	**UM3**	**DKHW**
Scenarios with the average effluent discharge of 2,333 cfs to the river						
1. Low tritium and low river flow	0	0	NM[c]	NM	4,470 at 47 ft	4,560 at 50 ft
2. Low tritium and typical river flow	0	0	NM	NM	1,810 at 136 ft	710 at 403 ft
3. Middle tritium and low river flow	0	0	NM	NM	7,710 at 47 ft	7,880 at 50 ft
4. Middle tritium and typical river flow	0	0	NM	NM	3,130 at 136 ft	1,230 at 403 ft
5. High tritium and low river flow	26	28	NM	NM	14,200 at 47 ft	14,500 at 50 ft
6. High tritium and typical river flow	18	10	NM	NM	5,750 at 136 ft	2,250 at 403 ft

cfs = cubic feet per second; ft = feet; pCi/L = picocuries per liter;.

a. Scenarios:
Low tritium = effluent with a tritium concentration of 7,470 pCi/L (therefore, the distance to decrease to 20,000 pCi/L is 0 ft).
Middle tritium = effluent with tritium concentration of 12,900 pCi/L (therefore, the distance to decrease to 20,000 pCi/L is 0 ft).
High tritium = effluent with tritium concentration of 23,700 pCi/L.
Low river flow = approximately 0 cfs, but set at about 6 cfs (or 0.0001-foot-per-second velocity) because the model requires a positive value.
Typical river flow = 32,000 cfs (average flow over the course of a year).

b. Values in these two columns are estimates based on visual interpretations of graphic outputs from the models. Values in other columns are based on numbers in the models' text printouts.

c. NM = not modeled. The plume reached the water surface before leaving the mixing zone and the models stopped at that point.

reached the surface. In this case, because the mixing zone extends to a relatively long distance of 1,500 feet downstream, no values were computed; the category is left in the table for comparison with the Watts Bar evaluations.

The nearest drinking water intake is the City of Chattanooga, Tennessee, which is about 8 miles southwest of the Sequoyah site and about 10 miles downstream as the river flows. At this downstream distance, it is reasonable to assume the tritium would be well mixed in the river flow. At the maximum tritium discharge of 49,320 curies per year and an average river flow of 32,000 cubic feet per second (which equates to about 28.6 trillion liters per year), the average tritium concentration at the downstream drinking water intake would be about 1,720 picocuries per liter. If 20,000 picocuries per liter in drinking water equates to an average annual dose of 4 millirem, 1,720 picocuries per liter would equate to an annual dose of about 0.34 millirem. The middle tritium discharge value above is roughly half of the maximum value, so the average annual concentrations and dose under that discharge scenario would be roughly half of the values for the maximum tritium scenario.

Other Beta Particle or Photon Emitters

One additional evaluation is worth describing in relation to the drinking water standard for tritium. As noted above, the applicable drinking water standard is an annual dose equivalent of 4 millirem per year from all beta particle and photon radioactivity. Tritium is by far the most significant beta particle or photon emitter in the Sequoyah liquid effluents, but it is not the only one. For example, *Effluent and*

Waste Disposal Annual Report – Sequoyah Nuclear Plant 2010 (TVA 2011b) indicates the liquid effluents included 16 different radionuclides over the course of the year, in addition to tritium, that are beta particle or photon emitters. There are variations over time in the specific radionuclides reported in the liquid effluents such that when the similar reports for 2008 and 2009 (TVA 2009b, 2010c) are also considered, the number of beta particle and photon emitters increases to 22 in addition to tritium. As with tritium, EPA has developed concentrations for each of these radionuclides that correspond to an annual dose of 4 millirem (EPA 2011). Consistent with the relatively low radiotoxicity of tritium, the derived values for these other radionuclides are generally less than 20,000 picocuries per liter; that is, it takes less of these other radionuclides to result in the dose limit. However, they were released at much lower concentrations than tritium. Table E-10 identifies the other beta particle or photon emitters Sequoyah

Table E-10. Other beta particle or photon emitters released to the Tennessee River from 2008 through 2010 from Sequoyah and their contribution to the 4-millirem-per-year drinking water limit.

Radionuclide[a]	**Total released to liquid effluents in 2008 to 2010 (Ci)**[a] **(A)**	**Total liquid effluents released in 2008 to 2010 (liters)**[b] **(B)**	**Average concentration as discharged (pCi/liter) (C)=(A/B) × 10^{12}**	**Amount resulting in 4 mrem/yr dose (pCi/liter)**[c] **(D)**	**Dose contribution (mrem/yr) (E)=(C/D) × 4**	**Fraction of 4 mrem/yr dose limit (F)=(E)/4**
Cr-51	8.25×10^{-3}	6.27×10^{12}	1.32×10^{-3}	6,000	8.78×10^{-7}	2.19×10^{-7}
Mn-54	7.16×10^{-4}	6.27×10^{12}	1.14×10^{-4}	300	1.52×10^{-6}	3.81×10^{-7}
Fe-55	2.98×10^{-2}	6.27×10^{12}	4.75×10^{-3}	2,000	9.50×10^{-6}	2.38×10^{-6}
Fe-59	1.06×10^{-3}	6.27×10^{12}	1.69×10^{-4}	200	3.38×10^{-6}	8.45×10^{-7}
Co-57	3.48×10^{-4}	6.27×10^{12}	5.56×10^{-5}	1,000	2.22×10^{-7}	5.56×10^{-8}
Co-58	5.80×10^{-2}	6.27×10^{12}	9.26×10^{-3}	300	1.23×10^{-4}	3.09×10^{-5}
Co-60	1.92×10^{-2}	6.27×10^{12}	3.06×10^{-3}	100	1.22×10^{-4}	3.06×10^{-5}
Zn-65	2.01×10^{-4}	6.27×10^{12}	3.21×10^{-5}	300	4.28×10^{-7}	1.07×10^{-7}
Zn-69M	1.08×10^{-6}	6.27×10^{12}	1.72×10^{-7}	200	3.45×10^{-9}	8.62×10^{-10}
Zr-95	3.08×10^{-4}	6.27×10^{12}	4.91×10^{-5}	200	9.83×10^{-7}	2.46×10^{-7}
Nb-95	6.68×10^{-4}	6.27×10^{12}	1.07×10^{-4}	300	1.42×10^{-6}	3.55×10^{-7}
Tc-99M	3.60×10^{-6}	6.27×10^{12}	5.74×10^{-7}	20,000	1.15×10^{-10}	2.87×10^{-11}
Ag-110M	4.58×10^{-4}	6.27×10^{12}	7.32×10^{-5}	90	3.25×10^{-6}	8.13×10^{-7}
Sb-124	1.65×10^{-3}	6.27×10^{12}	2.64×10^{-4}	60	1.76×10^{-5}	4.40×10^{-6}
Sb-125	6.16×10^{-3}	6.27×10^{12}	9.83×10^{-4}	300	1.31×10^{-5}	3.28×10^{-6}
Te-132	3.82×10^{-5}	6.27×10^{12}	6.09×10^{-6}	90	2.71×10^{-7}	6.77×10^{-8}
I-131	1.35×10^{-4}	6.27×10^{12}	2.16×10^{-5}	3	2.88×10^{-5}	7.19×10^{-6}
I-132	8.76×10^{-5}	6.27×10^{12}	1.40×10^{-5}	90	6.21×10^{-7}	1.55×10^{-7}
Cs-134	2.61×10^{-5}	6.27×10^{12}	4.16×10^{-6}	80	2.08×10^{-7}	5.20×10^{-8}
Cs-137	6.17×10^{-4}	6.27×10^{12}	9.84×10^{-5}	200	1.97×10^{-6}	4.92×10^{-7}
Ba-140	5.10×10^{-6}	6.27×10^{12}	8.14×10^{-7}	90	3.62×10^{-8}	9.04×10^{-9}
La-140	5.27×10^{-6}	6.27×10^{12}	8.41×10^{-7}	60	5.61×10^{-8}	1.40×10^{-8}
Totals	**1.28×10^{-1}**	**N/A**	**N/A**	**N/A**	**3.30×10^{-4}**	**8.25×10^{-5} (or 0.0082%)**

Ci = curies; mrem/yr = millirem per year; N/A = not applicable; pCi = picocurie.

a. Source: TVA 2009b, 2010c, 2011b.

b. This value is a conversion of the sum of 1,550, 1,449, and 1,537 million gallons per day, the average flows to Outfall 101 during 2008, 2009, and 2010, respectively, as reported for the NPDES permit.

c. Source: EPA 2011.

released to the Tennessee River from 2008 through 2010 and their contribution to the 4 millirem per year limit if they occurred in a drinking water source. At their release concentrations, and as listed in Table E-10, these radionuclides would contribute about 0.01 percent of the drinking water limit. Once these low concentrations were discharged and mixed with the river, their contributions to the drinking water limit would be negligible and it becomes appropriate to compare the entire limit to the tritium concentration.

TPBAR Failure Scenario

As described in Section E.2 for Watts Bar, NNSA also evaluated the unlikely scenario of having two TPBAR failures during a routine 18-month operating cycle for a reactor for the Sequoyah site. As assumed in the 1999 EIS (DOE 1999, Appendix C, Section C.3.4), two failed TPBARs could release a total of about 23,150 curies of tritium to the reactor coolant system and about 90 percent of this tritium (that is, 20,835 curies) could be released in the plant's liquid effluents. Because a TPBAR failure is very unlikely, this evaluation assumed it would only happen in a single reactor, although both reactors could be operating at the same time. The evaluation considers a typical river flow condition of 32,000 cubic feet per second and, as for normal operations, it also considers effects when there is essentially no flow in the river. The evaluation considers a two-TPBAR failure scenario at Sequoyah for Alternatives 2 and 5 (Sequoyah Only) and Alternatives 3 and 6 (Watts Bar and Sequoyah). Under Alternative 2 or 6, there would be 26,820 curies of tritium in the annual discharge as a result of normal reactor operations and tritium permeation from the maximum 2,500 TPBARs (Table E-7) as well as the tritium from the failed TPBARs. Under Alternative 3, there would be 15,570 curies of tritium from normal reactor operations with 1,250 TPBARs (Table E-7), plus the tritium from the TPBAR failures. Under Alternative 5, there would be 49,320 curies of tritium from normal plant operations with 5,000 TPBARs (Table E-7), plus the tritium from the TPBAR failure.

The average tritium concentrations as discharged to the diffuser pond and to the river are derived as follows:

- Total tritium discharge:
  - Alternative 2 or 6 – 47,655 curies per year (as described above, 20,835 plus 26,820);
  - Alternative 3 – 36,405 curies per year (20,835 plus 15,570); and
  - Alternative 5 – 70,155 curies per year (20,835 plus 49,320).
- Typical discharge to the diffuser pond: 7.67×10^9 liters per year (Table E-7).
- Tritium concentration going to diffuser pond:
  - Alternative 2 or 6 – 6,210,000 picocuries per liter;
  - Alternative 3 – 4,750,000 picocuries per liter; and
  - Alternative 5 – 9,150,000 picocuries per liter.
- Typical discharge volume to river: 2.084×10^{12} liters per year (Table E-7).
- Tritium concentration going to river:
  - Alternative 2 or 6 – 22,900 picocuries per liter;
  - Alternative 3 – 17,500 picocuries per liter; and
  - Alternative 5 – 33,700 picocuries per liter.

As described above, NNSA evaluated the discharges for the TPBAR failure scenarios using both the UM3 and DKHW models; Table E-11 summarizes the results. The results are in the same format as Table E-9 for ease of comparison. As discussed above and as the table indicates, even with the high tritium releases that would result from Alternative 5 and the failure of two TPBARs, average discharge to the river would have tritium levels only slightly above the drinking water level of 20,000 picocuries per liter. Under typical river flow conditions, the models predicted a level of 20,000 picocuries per liter in all portions of the plume within less than 32 feet of the diffuser and within less than about 53 feet under the low (or no) river flow condition. Under Alternative 3 and the failure of two TPBARs, average discharge to the river would be below the drinking water limit, so the distance for the plume to decrease to 20,000 picocuries is shown as 0 feet.

Table E-11. Sequoyah modeling results in terms of the tritium concentration in the discharge plume for the two-TPBAR failure scenarios.

Two TPBAR Failure Scenario[a]	**Distance (ft) for plume centerline to decrease to 20,000 pCi/L**		**Centerline concentration (pCi/L) at boundary of mixing zone (1,500 ft from diffusers)**		**Centerline concentration (pCi/L) where plume surfaces and distance from the diffusers**	
	UM3	**DKHW**	**UM3**	**DKHW**	**UM3**	**DKHW**
1. Middle (other) tritium, typical discharge, and low river flow	24	26	NM[c]	NM[c]	13,700 at 47 ft	14,000 at 50 ft
2. Middle (other) tritium, typical discharge, and typical river flow	17	10	NM[c]	NM[c]	5,560 at 136 ft	2,180 at 403 ft
3. Low (other) tritium, typical discharge, and low river flow	0	0	NM[c]	NM[c]	10,500 at 47 ft	10,700 at 50 ft
4. Low (other) tritium, typical discharge, and typical river flow	0	0	NM[c]	NM[c]	4,250 at 136 ft	1,660 at 403 ft
5. High (other) tritium, typical discharge, and low river flow	Surf[b] (≈48 ft)	Surf[b] (≈53 ft)	NM[c]	NM[c]	20,200 at 47 ft	20,600 at 50 ft
6. High (other) tritium, typical discharge, and typical river flow	32	19	NM[c]	NM[c]	8,180 at 136 ft	3,200 at 403 ft

cfs = cubic feet per second; ft = feet; pCi/L = picocuries per liter; ≈ = approximately.

a. Scenario:
Middle (other) tritium = Two-TPBAR failure with Alternative 2 tritium, effluent tritium concentration of 22,900 pCi/L.
Low (other) tritium = Two-TPBAR failure with Alternative 3 tritium, effluent tritium concentration of 17,500 pCi/L (therefore, the distance to reach 20,000 pCi/L is 0 ft).
High (other) tritium = Two-TPBAR failure with Alternative 5 tritium, effluent tritium concentration of 33,700 pCi/L.
Typical discharge = Sequoyah plant discharge of 2,333 cfs.
Typical river flow = 32,000 cfs (average flow over the course of a year).
Low river flow = approximately zero – set at about 6 cfs (or 0.0001-foot-per-second velocity) because the model requires a positive value

b. Surf = surfaces; the model predicts the plume would reach the surface before the concentration reduced to 5,000 pCi/L. The value in parentheses is a rough estimate of the distance at which the concentration would be reached.

c. NM = not modeled. The plume reached the water surface before leaving the mixing zone, and the models stopped at that point.

As in the previous evaluation, the discharge water should be well mixed in the river by the time it travelled about 10 miles to the nearest drinking water intake (City of Chattanooga, Tennessee). At the maximum tritium discharge of 70,155 curies per year (Alternative 5 plus the TPBAR failures) and an average river flow of 32,000 cubic feet per second (about 28.6 trillion liters per year), the average tritium concentration at the downstream drinking water intake during that time of high tritium discharge would be about 2,450 picocuries per liter. If 20,000 picocuries per liter in drinking water equates to an average annual dose of 4 millirem, 2,450 picocuries per liter would equate to an annual dose of about 0.5 millirem. Under similar conditions, Alternatives 2 or 6 with two failed TPBARs would involve about two-thirds as much tritium and result in two-thirds of the Alternative 5 dose; Alternative 3 would have about half as much tritium and result in about half of that dose.

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APPENDIX F. HUMAN HEALTH EFFECTS OF OVERLAND TRANSPORTATION

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APPENDIX F. HUMAN HEALTH EFFECTS OF OVERLAND TRANSPORTATION

The overland transportation of any commodity involves a risk to transportation crew members and members of the public. This risk results directly from transportation-related accidents and indirectly from increased levels of pollution from vehicle emissions, regardless of the cargo. The transportation of certain materials, such as hazardous or radioactive waste, can pose an additional risk due to the unique nature of the material. To permit a complete appraisal of the environmental impacts of the proposed action and alternatives, the National Nuclear Security Administration (NNSA) assessed the human health risks associated with the overland transportation of tritium-producing burnable absorber rods (TPBARs) and associated low-level radioactive waste.

This appendix provides an overview of the approach NNSA used to assess human health risks that could result from overland transportation. It discusses the scope of the analysis, analytical methods used for risk analysis (computer models), analysis assumptions, and determination of potential transportation routes. In addition, it presents the results of the analysis. To aid in the understanding and interpretation of the results, the appendix describes specific areas of uncertainty with an emphasis on how uncertainties could affect comparisons of the alternatives.

This appendix presents risk analysis results in terms of "per-shipment" risk factors, as well as for the total risks for a given alternative. Per-shipment risk factors provide an estimate of the risk from a single TPBAR or waste shipment. The total risks for a given alternative are found by multiplying the expected number of shipments by the appropriate per-shipment risk factors.

F.1 Scope of Analysis

The following paragraphs describe the scope of the overland transportation human health risk analysis, including the alternatives and options, transportation activities, potential radiological and nonradiological impacts, and transportation modes. Sections F.2 to F.5 provide more details.

Proposed Action and Alternatives

The transportation risk analysis NNSA conducted for this Supplemental Environmental Impact Statement (SEIS) estimated human health risks from the transportation of TPBARs and low-level radioactive waste for each of the alternatives.

Transportation-Related Activities

NNSA limited the transportation risk analysis to estimating human health risks during overland transportation for each alternative. The analysis did not include risks to workers or the public during loading, unloading, and handling before or after shipment; Appendix C addresses such risks. Similarly, the analysis does not address possible impacts from increased transportation levels on local traffic flow, noise levels, or infrastructure.

Radiological Impacts

For each alternative, NNSA assessed radiological risks (that is, risks that result from the radioactive nature of irradiated TPBARs and waste) for both incident-free (normal) and accident transportation conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation near a loaded shipment. The risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people.

All radiological impacts are calculated in terms of committed dose and associated health effects in the exposed populations. The calculated radiation dose is the total effective dose equivalent (see 10 CFR Part 20), which is the sum of the effective dose equivalent from external radiation exposure and the 50-year committed effective dose equivalent from internal radiation exposure. Radiation doses are in units of rem for individuals and person-rem for collective populations. The impacts are further expressed as health risks in terms of the risk of latent cancer fatalities and cancer incidence in exposed populations using the dose-to-risk conversion factor of 0.0006 cancer fatality per rem (see Section F.3.5 for details).

Nonradiological Impacts

In addition to the radiological risks of overland transportation activities, NNSA assessed vehicle-related risks for nonradiological causes (that is, causes related to the transport vehicles and not the radioactive cargo) for the same transportation routes. Nonradiological transportation risks would be incurred for similar shipments of any commodity. The nonradiological accident risk refers to the potential occurrence of transportation accidents that directly result in fatalities unrelated to the shipment of cargo. NNSA used state-specific transportation fatality rates in the analysis. Nonradiological risks are in terms of estimated accidents and fatalities.

Transportation Modes

NNSA assumed all shipments to the reactors or to the Nevada National Security Site (formerly the Nevada Test Site) would be by truck.

Receptors

NNSA calculated transportation-related risks separately for workers and members of the public. The workers would be truck crew members involved in overland transportation. The public would include all people who could be exposed to a shipment while it was moving or stopped en route. The analysis estimated potential risks for the collective populations and for the hypothetical maximally exposed individual. For incident-free operation, the maximally exposed individual would be a person stuck in traffic next to the shipment for 30 minutes. For accident conditions, the maximally exposed individual would be a person 460 feet directly downwind from the accident. The collective population risk is a measure of the radiological risk to a group of people as a whole by the alternative under consideration. As such, the collective population risk is the primary means of comparing alternatives.

F.2 Packaging and Representative Shipment Configurations

The purpose of the regulations that govern the transportation of radioactive materials is to protect the public from the potential loss or dispersal of radioactive materials and from routine radiation doses during transit. The primary regulatory approach to promote safety is through the specification of standards for the packaging of radioactive materials. Because packaging represents the primary barrier between the radioactive material and radiation exposure to the public and the environment, packaging requirements are an important consideration for transportation risk analysis. Appendix E of the *Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (DOE 1999; referred to in this appendix as the 1999 EIS) discusses regulatory packaging requirements; those requirements have not changed. The following paragraphs discuss the assumed representative packaging and shipment configurations for this SEIS.

F.2.1 PACKAGING OVERVIEW

Since the publication of the 1999 EIS (DOE 1999), DOE/NNSA has decided that all shipments of TPBARs and low-level radioactive waste will use Type B casks by truck. Section E.3.2 of the 1999 EIS discusses these casks and shipping requirements.

F.2.2 GROUND TRANSPORTATION ROUTE SELECTION PROCESS

According to DOE guidelines, TPBAR and waste shipments must comply with U.S. Nuclear Regulatory Commission (NRC) and U.S. Department of Transportation regulatory requirements. NRC regulations cover the packaging and transport of irradiated TPBARs and waste; the Department regulates carriers and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. The highway routing of nuclear material is systematically determined according to Department regulations (49 CFR Parts 171 to 179 and 49 CFR Part 397) for commercial shipments. Specific routes cannot be identified publicly in advance for DOE Transportation Safeguards Division shipments because they are classified to protect national security interests.

U.S. Department of Transportation routing regulations require shipment of a highway route-controlled quantity of radioactive material over a preferred highway network, including Interstate Highways, with preference toward Interstate Highway System bypasses and beltways around cities and state-designated preferred routes. A state or tribe can designate a preferred route to replace or supplement the Interstate Highway System in accordance with Department guidelines (DOT 1992).

Carriers of highway route-controlled quantities must use the preferred network unless they are moving from their origin to the nearest Interstate Highway or from an Interstate Highway to their destination, are making necessary repair or rest stops, or emergency conditions render the Interstate Highway unsafe or impassable. The primary criterion for selecting the preferred route for a shipment is travel time. Preferred routing considers accident rate, transit time population density, activities along the route, time of day, and day of the week.

This analysis assumed shipment by truck for all shipments of TPBARs and low-level radioactive waste. To assess impacts of radioactive material transportation, the characteristics of transportation routes between the origin of the shipment and its destination must be defined. These route characteristics are quantities such as distance, exposed populations, and weighted population density. Population density is often binned into three zones—rural, suburban, and urban—where rural is an area with a density of fewer than 139 people per square mile, suburban is an area with a density between 139 and 3,326, and urban is an area with a density greater than 3,326 (Johnson and Michelhaugh 2000). Typically, the distance traveled in each population zone is estimated, as is the total distance.

For shipments from the TPBAR fabrication facility to the Watts Bar and Sequoyah sites and to the low-level radioactive waste disposal site at the Nevada National Security Site, NNSA used the routing computer program TRAGIS (Johnson and Michelhaugh 2000) and 2000 Census data projected to 2008 (Bhaduri 2007) to analyze highway routes. Route characteristics include total shipment distances; the distances traveled in rural, suburban, and urban population density zones; and the weighted population densities in these population density zones. The TRAGIS database contains more than 240,000 miles of Interstate Highways, U.S. highways, state highways, turnpikes, county roads, and local roads, more than 20,000 highway segments (known as links) and 13,000 intersections (known as nodes), including nodes for many NRC and Agreement State-licensed facilities, DOE nuclear facilities, several nuclear facilities in Canada, and airports.

TRAGIS estimates routes by minimizing the total impedance of a route, which is a function of distance and driving time between the origin and the destination. TRAGIS can also plot routes that maximize the use of Interstate Highways. For unirradiated TPBARs, NNSA used the commercial route setting to generate highway routes generally used by commercial trucks. Routes were constrained to only those approved for highway route-controlled quantities of radioactivity. However, the routes chosen might not be the actual routes NNSA would use in the future, because NNSA does not announce either the routes or times of such shipments. The highway function of TRAGIS has been updated periodically to reflect current road conditions. NNSA used the population summary module of TRAGIS to determine exposed populations within 800 meters of the route (that is, about a half-mile of either side).

F.3 Methods for Calculating Transportation Risks

Figure E-4 of the 1999 EIS (DOE 1999) summarized the overland transportation risk analysis method; it is not shown in this SEIS. The exception to the earlier method was the use of the RADTRAN 6 computer program (Weiner et al. 2009), which negates the use of the Transportation Incident Center Line Dose program to calculate doses to maximally exposed individuals and downwind populations because RADTRAN 6 incorporates a fully integrated plume dispersion model that calculates the dose to these receptors.

F.3.1 ALTERNATIVES, PARAMETERS, AND ASSUMPTIONS

NNSA evaluated three transportation segments: (1) shipment of TPBAR assemblies to Watts Bar and Sequoyah, (2) shipment of irradiated TPBARs to the Savannah River Site, and (3) shipment of irradiated hardware to a waste disposal site.

Segment 1 involves shipment of nonhazardous, nonradioactive TPBAR material in secure commercial casks, along with new (fresh, unirradiated) reactor fuel. The radiological impacts of shipping fresh reactor fuel are outside the scope of this SEIS; they are covered in *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). WesDyne, a subsidiary of Westinghouse Electric Corporation, manufactures TPBARs for NNSA. WesDyne maintains an inventory of TPBAR components and assembles them at a facility in Columbia, South Carolina. In addition, this facility supplies nuclear fuel for Watts Bar 1 (GAO 2010). The 1999 EIS (DOE 1999, Section 5.2.7) discusses the TPBAR fabrication process and the differences from that for standard burnable absorber rods. That discussion is still applicable, and this SEIS does not repeat it.

Segment 2 involves shipment of irradiated TPBARs from the Watts Bar and Sequoyah sites to the Tritium Extraction Facility at the Savannah River Site (see Section F.4.1.2.1). The TPBAR radiation field would result from neutron activation of the metallic components of the TPBARs, which would contain the tritium. Therefore, NNSA would ship these TPBARs in a Type B cask. NNSA has evaluated the shipment of TPBARs by trucks only (one cask per truck) on public roads.

Segment 3 involves shipment of irradiated hardware (low-level radioactive waste) from Watts Bar and Sequoyah to the Nevada National Security Site for disposal. Irradiated hardware would include base plates and thimble plugs removed from the TPBARs at Watts Bar and Sequoyah.

F.3.2 REPRESENTATIVE ROUTES

The analysis selected representative overland truck routes for the following shipments:

- Unirradiated TPBARs from Columbia, South Carolina, to the Watts Bar and Sequoyah sites; after delivery, the transportation casks would return to Columbia.

- Irradiated TPBARs from Watts Bar and Sequoyah to the Savannah River Site in South Carolina; after delivery, the casks would return to the original site, whether Watts Bar or Sequoyah.

- Low-level radioactive waste from Watts Bar and Sequoyah to the Nevada National Security Site; the empty waste casks would return to Watts Bar or Sequoyah.

Route selection was consistent with current routing practices and all applicable routing guidelines (DOT 1992). Section F.5 contains maps that show the representative routes.

Route characteristics important to the radiological risk analysis include the total shipment distance and the population distribution along the route. The selected route would determine the total potentially exposed population and the expected frequency of transportation-related accidents. Table F-1 summarizes route characteristics.

Table F-1. One-way distances and exposed populations for truck routes for shipments.[a]

		Population densities, (people per square kilometer)			Distance (kilometers)				
From	**To**	**Rural**	**Suburban**	**Urban**	**Rural**	**Suburban**	**Urban**	**Total (kilometers)**	**Number of affected people**
Columbia	WBN	16.1	247.5	1,391.4	265	212	35	511	167,162
Columbia	SQN	19.4	256.5	1,726.2	255	229	76	560	311,120
WBN	SRS	18.1	251.9	1,698.9	272	153	80	506	304,995
SQN	SRS	17.9	256.5	1,703.4	241	192	79	511	300,354
WBN	NNSS	10.3	220.8	1,794.0	2,694	504	166	3,364	797,388
SQN	NNSS	9.5	225.8	1,783.3	2,644	517	174	3,336	724,753

Source: Johnson and Michelhaugh 2000.
km = kilometer; WBN = Watts Bar Nuclear Plant; SQN = Sequoyah Nuclear Plant; SRS = Savannah River Site; NNSS = Nevada National Security Site.

F.3.3 MATERIAL INVENTORY

The 1999 EIS (DOE 1999, Appendix E, Section E.5.3) provided material inventories for irradiated TPBARs and low-level radioactive waste; it is not repeated here.

F.3.4 EXTERNAL DOSE RATES

Even though the TPBARs and used hardware would be highly irradiated, the external dose rate of the shipping casks would not be as high as the regulatory limits. For analysis, NNSA made the conservative assumption that the dose rate for the TPBAR and low-level radioactive waste shipments would be equal to the regulatory limit of 10 millirem per hour at 2 meters.

F.3.5 HEALTH RISK CONVERSION FACTORS

For the 1999 EIS (DOE 1999), the health risk conversion factors DOE used to estimate latent cancer fatalities were 0.0005 and 0.0004 fatal cancer cases per person-rem for members of the public and workers, respectively (NCRP 1993). For this SEIS, the health risk conversion factor NNSA used to estimate latent cancer fatalities was 0.0006 for all individuals (see Appendix C, Section C.1.1.2 for details).

F.3.6 ACCIDENT INVOLVEMENT RATES AND TPBAR AND CASK ACCIDENT RESPONSES

NNSA has determined that shipment of irradiated TPBARs and low-level radioactive waste will be in Type B casks with metallic seals by truck only. The 1999 EIS (DOE 1999, Appendix E, Sections E.5.6 through E.7.3.3) described accident involvement rates and accident responses of these casks; it is not repeated here.

F.4 Risk Analysis Assumptions and Results

F.4.1 INCIDENT-FREE TRANSPORTATION IMPACTS

Shipments of irradiated TPBARs and low-level radioactive waste emit some ionizing radiation externally during routine incident-free transportation. People exposed to this radiation would receive an external dose. The exposed population would include the truck crew and members of the public. The following sections provide an overview of the calculation method and assumptions for collective dose. For calculation of estimated radiological impacts from incident-free transportation, the analysis considered only shipments of casks that would contain radioactive material; it did not include return shipments of empty casks.

F.4.2 INCIDENT-FREE COLLECTIVE DOSE

Incident-free doses are calculated by assuming the external dose rate from the shipping package (that is, irradiated TPBARs and low-level radioactive waste) is the radiation source that exposes receptors at various distances from the package. For this analysis, the dose rate at 1 meter was set at 14 millirem per hour, which results in the regulatory limit of 10 millirem per hour at 2 meters (AEC 1972) and the regulatory limit to the truck crew of 2 millirem per hour (10 CFR 173.441).

The analysis considered exposure to moving and stationary vehicles. NNSA used RADTRAN 6 to calculate incident-free doses to workers (truck crews) and members of the public. Separate calculations were performed for the following receptors:

- Off-link population dose. Members of the public who reside along the transportation route or are pedestrians along the route, and are exposed to the moving truck carrying the radioactive shipping package.

- On-link population dose. Occupants of vehicles that share the transportation route with the truck while it is moving.

- Resident rest stop dose. Members of the public who live within a half-mile of a rest stop area where the truck stops to rest crew or refuel.

- Crew dose. Truck crewmembers when the truck is moving.

- Truck stop population dose. Members of the public who are at rest and refueling stops when the truck carrying the shipment stops for refueling or to give the crew a rest.

The analysis assumed truck stops would occur only for routes longer than 220 miles and a stop would occur after 4 hours of driving time at a speed of 55 miles per hour.

F.4.2.1 Assumptions

The model NNSA used to calculate collective population incident-free doses assumed these doses to be directly proportional to the number of shipments that move past the receptor (Neuhauser et al. 2000). The collective incident-free population dose is proportional to the number of exposed people. For truck transportation, the model assumed that the exposed population would occupy an 800-meter (0.5-mile)-wide corridor on either side of the route and that the population density in this corridor would be the population density of the census block group that abuts or contains the route. Section F.3.2 discusses population assumptions and calculations.

The following paragraphs present the assumptions and parameters NNSA used in RADTRAN 6 to calculate off- and on-link doses. RADTRAN 6 includes a table of standard parameter values, as well as suggested values for other parameters. This section provides input parameters for calculating collective doses from a moving truck and doses to nearby populations when the truck stops for refueling and crew rest periods.

Parameters and Assumptions for Calculating Doses from Moving Trucks

Table F-2 lists the assumptions and input parameters the analysis for calculation of incident-free doses from moving truck shipments for irradiated TPBARs and low-level radioactive waste. The tables include national average traffic volumes as well as assumptions about package type, package dimensions, external dose rate, and ratio of gamma to neutron radiation. The analysis assumed freeway truck speeds would be constant in the absence of rush-hour traffic. It also assumed buildings along the transportation route and vehicles sharing the route would provide no shielding from the shipping package external radiation. The analysis used national average one-way vehicle speeds to calculate the on-link dose for truck shipments. The evaluated receptors along the route for incident-free truck transportation were:

- Members of the public who reside along the route and pedestrians (off-link),
- Occupants of vehicles that share the route (on-link), and
- Crew dose (truck drivers).

Parameters and Assumptions for Calculating Truck Stop Doses

Figure F-1 in Section F.4.2.2 shows the rest and refueling stop model. Doses at stops, or stop doses, are proportional to the exposure time and inversely proportional to the square of the distance and to the distance, for distant and nearby receptors, respectively. The receptors at stops modeled in the incident-free truck transportation analysis are:

- Members of the public at rest and refueling stops (truck stops), and
- Residents within 800 meters of the truck stops.

Analysis of Doses from Moving Vehicles

This section describes the RADTRAN 6 model (Neuhauser and Kanipe 2000) and deals only with specific details of the application of RADTRAN 6 in this analysis. NNSA used RADTRAN 6 to calculate radiological impacts of transporting irradiated TPBARs and low-level radioactive waste using appropriate input parameters. The basic features of the RADTRAN 6 model are (1) the shipping package and truck bed combination is modeled as spherically symmetric and (2) the radiation source is the shipping package external dose rate, which is modeled as an isotropic emission at the center of the sphere (Neuhauser et al. 2000). The dose to a distant receptor is directly proportional to the dose rate buildup, which is the product of a buildup factor and an attenuation factor. For gamma radiation, this product is considered equal to 1 in RADTRAN 6 because it is always less than or equal to 1 (Neuhauser et al. 2000).

The dose is inversely proportional to the square of the distance between the receptor and the center of the cargo (the truck bed). When the receptor is within about a package length of the package, as could be the case for crew and inspectors, the external dose rate is modeled as a line source, and the dose to the receptor is inversely proportional to the distance between the receptor and the center of the cargo.

Dose is directly proportional to exposure time. The dose to a stationary receptor from a moving vehicle carrying radioactive cargo, the off-link dose, is modeled as inversely proportional to the speed of the vehicle.

Truck crew in-transit doses are calculated using the assumption that the crew remains at a fixed distance (3.1 meters) from the package for the duration of the route. RADTRAN 6 estimates the end-on radiation

Table F-2. Assumptions and parameters for incident-free doses from moving trucks.

Parameter	Value for TPBARs	Value for LLW	Comments and reference
Package			
Package dimension	5.08 meters[a]	1.3 meters[a]	TVA 2012
Dose rate at 1 meter from vehicle	14 millirem per hour	14 millirem per hour	AEC 1972; approximate dose at 1 meter that is equal to the legal limit of 10 millirem per hour at 2 meters
Fraction of emitted radiation that is gamma	1	1	
Fraction of emitted radiation that is neutrons	0	0	
Crew			
Number of crew	2	2	AEC 1972; NRC 1977; DOE 2002
Distance from source to crew	3.1 meters[a]	3.1 meters[a]	Neuhauser et al. 2000
Crew shielding factor	1	1	Analytical assumption—results in no shielding of the drivers from the radioactive cask
Route-specific parameters			
Rural Suburban Urban	88.49 kilometers per hour[b]	88.49 kilometers per hour[b]	Average speed in rural areas from DOE 2002; conservative in-transit speed of 55 miles per hour assumed; predominately Interstate Highways used
Number of people per vehicle sharing route	1.5	1.5	DOE 2002
One-way traffic volumes			
Rural	530 vehicles per hour	530 vehicles per hour	DOE 2002
Suburban	760 vehicles per hour	760 vehicles per hour	DOE 2002
Urban	2,400 vehicles per hour	2,400 vehicles per hour	DOE 2002
Minimum and maximum distances to exposed resident off-link population	10 to 800 meters		Sprung et al. 2000
Distances (kilometers)/population densities (people per square kilometer)			
Rural	(c)	(c)	
Suburban	(c)	(c)	
Urban	(c)	(c)	

LLW = low-level radioactive waste.

a. To convert meters to feet, multiply by 3.2808.

b. To convert kilometers to miles, multiply by 0.62137.

c. Population densities along transportation routes from Johnson and Michelhaugh 2000, Table F-1.

d. Assumes a maximum of 289 TPBARs per shipment.

dose rate based on the given transport index. In addition, in-transit truck crew dose was developed for a package with an end-on diameter (that is, crew view) of 1 meter.

Doses to occupants of other vehicles sharing the transportation corridor, the on-link dose, require a more complex set of assumptions about vehicle speed (Neuhauser et al. 2000). The relative speed of vehicles moving in the same direction as the truck is assumed to be twice the nuclear fuel vehicle speed when the vehicle is passing the truck (the truck is modeled as stationary), and zero if the vehicle is traveling in a lane next to the nuclear fuel vehicle. In addition, the density of vehicles moving in the opposite direction is inversely proportional to the vehicle speed. Overall, the on-link dose is inversely proportional to the square of the vehicle speed (Neuhauser et al. 2000).

National per-kilometer on-link doses were calculated for each shipment for each population zone, incorporating national average vehicle densities. Rush-hour segments were accounted for by taking a weighted average of the rush hour and non-rush-hour speeds and vehicle density ratios.

F.4.2.2 Analysis of Doses at Stops

RADTRAN 6 allows individual modeling of dose to truck crew and residents near each stop, or type of stop, along a route. The analysis modeled truck stops for rest and refueling. Figure F-1 shows the rest and refueling stop model for the analysis. Table F-3 lists the assumptions and parameters for the stop model.

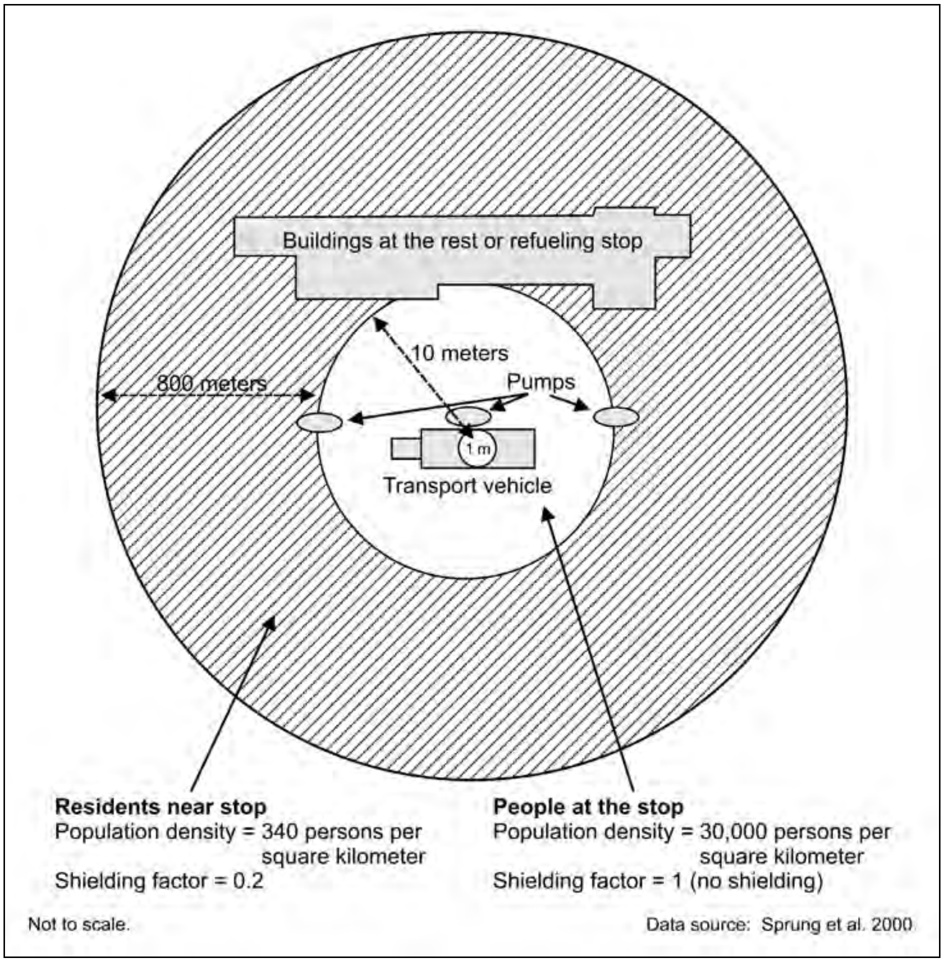

Figure F-1. Truck stop model.

Table F-3. Assumptions and parameters for incident-free doses to members of the public at truck stops.

Parameter	Parameter value
Minimum to maximum radii of annular area around vehicle at stops	1 to 10 meters[b]
Minimum to maximum radii of annular area around truck stop	10 to 800 meters[b]
Population density at stops	30,000 people per square kilometer[c]
Population density surrounding truck stops	340 people per square kilometer[c]
Shielding factor applied to annular area around vehicle at stops	1
Shielding factor applied to area around truck stop	0.2
Stop time	30 minutes per 4-hour driving time

Source: Sprung et al. 2000.

a. NRC 2006.

b. To convert meters to feet, multiply by 3.2808.

c. To convert square kilometers to square miles, multiply by 0.3861.

Exposure data for members of the public at rest and refueling stops are from Sprung et al. (2000). RADTRAN 6 calculates a population dose per stop. The analysis assumed 30-minute stops after each 4 hours of driving time at 55 miles per hour.

RADTRAN 6 calculates the collective dose to residents who live near places where the truck stops using a population density of 340 people per square kilometer at a distance from 10 to 800 meters from the nuclear fuel transport vehicle (Sprung et al. 2000). In addition, RADTRAN 6 calculates the dose to a population near the source (that is, 1 to 10 meters), assuming a population density in this area of 30,000 people per square kilometer, which results in the exposure of nine people within 10 meters of the nuclear fuel transport vehicle.

F.4.2.3 Incident-Free Radiological Transportation Impacts

As discussed in Section F.4.1.1, RADTRAN 6 calculates incident-free impacts (that is, dose in person-rem) for the truck crew, people along the transportation corridor (off link), people sharing the transportation route (on link), and people at the rest and refuel stop and residents within 800 meters of the rest or refueling stop. Table F-4 lists the incident-free RADTRAN doses for these receptors. These doses would be multiplied by the total number of shipments each year to obtain annual impacts. Because the assumption is made that the irradiated TPBAR and the low-level radioactive waste shipments have the same external radiation levels (that is, the regulatory limit of 10 millirem per hour at 2 meters) and, therefore, the same truck cab dose rate, the larger calculated doses for the low-level radioactive waste shipments in comparison with the irradiated TPBAR shipments is due primarily to the distance and time each shipments represents (about 2,000 miles for the low-level waste shipments versus about 350 miles for the TPBAR shipments). The doses from the shipment of irradiated TPBARs from Sequoyah and Watts Bar to the Savannah River Site are almost the same because the relative distances are almost the same (511 kilometers versus 506 kilometers).

F.4.3 TRANSPORTATION ACCIDENTS

For calculation of estimated radiological impacts from accidents, the analysis considered only shipments of casks that would contain radioactive material; it did not include return shipments of empty casks.

Table F-4. Incident-free collective doses (person-rem) per shipment for people sharing and living along the transportation corridor.

From	To	Crew	Off link	On link	Total	Stop
	Irradiated TPBARs					
WBN	SRS	2.51×10^{-2}	1.70×10^{-3}	6.35×10^{-3}	3.32×10^{-2}	1.77×10^{-1}
SQN	SRS	2.33×10^{-2}	1.66×10^{-3}	6.04×10^{-3}	3.10×10^{-2}	1.79×10^{-1}
	Low-level radioactive waste					
WBN	NNSS	1.53×10^{-1}	9.08×10^{-4}	8.21×10^{-3}	1.63×10^{-1}	3.24×10^{-1}
SQN	NNSS	1.52×10^{-1}	9.34×10^{-4}	8.22×10^{-3}	1.61×10^{-1}	3.21×10^{-1}

WBN = Watts Bar Nuclear Plant, SQN = Sequoyah Nuclear Plant, SRS = Savannah River Site; NNSS = Nevada National Security Site.

F.4.3.1 Radiological Transportation Accident Impacts

RADTRAN 6 assesses accident risk by calculating a risk value, which is the product of the probabilities and consequences of accidents. It considers a spectrum of potential transportation accidents, ranging from those with high frequencies and low consequences (for example, “fender-benders”) to those with low frequencies and high consequences (for example, accidents in which the shipping cask is exposed to severe mechanical and thermal conditions).

Radionuclide inventories are important parameters in the calculation of accident risks. The inventories NNSA used in this analysis are from the 1999 EIS (DOE 1999, Appendix E, Table E-2), and are not repeated here.

Shipping casks for transportation of irradiated TPBARs and low-level radioactive waste have significant radiation shielding and are designed to meet the licensing requirements of 10 CFR Part 71. These shipping casks must be certified Type B packaging systems, which means they must withstand a series of severe hypothetical accident conditions with essentially no loss of containment or shielding capability. The tests include a 30-foot free drop onto an unyielding surface, a drop onto a puncture probe, an exposure to an engulfing fire for 30 minutes, and an underwater immersion. According to Sprung et al. (2000), the probability of encountering accident conditions more severe than these tests that could lead to shipping cask failure are less than 0.01 percent of all accidents (that is, more than 99.99 percent of all accidents would not result in a release of radioactive material from the shipping cask).

Transportation accident risk analysis in RADTRAN 6 uses an accident severity and package release model. The user can define as many as 30 severity categories, with each category increasing in magnitude. Severity categories are related to fire, puncture, crush, and immersion environments that are created in vehicular accidents. This analysis used the seven severity categories from the 1999 EIS (DOE 1999, Appendix E, Section E.5.7.3.2).

Each severity category has an assigned conditional probability (the probability, given that an accident occurs, that it will be of the specified severity). The user can further define accident scenarios by inputting release fractions and aerosol and respirable fractions for each severity category. These fractions are a function of the physical and chemical properties of the materials being transported as well as the mechanical and thermal accident conditions that define the severity categories. The severity categories and release fractions used here are from the 1999 EIS (DOE 1999, Appendix E, Tables E-3, E-4, and E-6) Tables F-5 and F-6 list the severity and release fractions for accident transportation conditions for two cases: one in which all TPBARs in the cask would be undamaged, and one in which two TPBARs would already be damaged (prefailed) before the accident.

Table F-5. Severity and release fractions used to model TPBAR and low-level radioactive waste transportation accidents with no prefailed TPBARs (DOE 1999).

Group	Severity fractions[b]	Release fractions[a]			
		T_2/HT[c]	T_2O/HTO	NTBC	Crud[d]
SEVER: 1	9.940×10^{-1}	0	0	0	0
SEVER: 2	5.574×10^{-5}	0	0	0	0
SEVER: 3	3.828×10^{-3}	4.18×10^{-6}	0	3×10^{-10}	2×10^{-3}
SEVER: 4	1.542×10^{-7}	4.18×10^{-6}	1.50×10^{-2}	1×10^{-8}	$2. \times 10^{-3}$
SEVER: 5	1.799×10^{-3}	4.18×10^{-6}	1×10^{-2}	1×10^{-8}	$2. \times 10^{-3}$
SEVER: 6	1.076×10^{-7}	4.18×10^{-6}	2.50×10^{-2}	1×10^{-8}	2×10^{-3}
SEVER: 7	9.641×10^{-6}[c]	4.18×10^{-6}	1	1×10^{-7}	2×10^{-3}

HTO = tritiated water; NTBC = nontarget-bearing components (see DOE 1999, Section E.5.3 for details).

a. RADTRAN 6 models the fraction of the released particulate material that is small enough to be dispersible in prevailing wind conditions and the fraction that is respirable. This analysis set these parameters to 1.0 (that is, 100 percent dispersible and 100 percent respirable).

b. Severity fractions are the conditional probabilities, given the occurrence of an accident, that the mechanical and thermal conditions experienced by a spent fuel shipping cask are within the conditions defined by the Severity Category. See the 1999 EIS (DOE 1999, Section E.5.7.3.3) for detailed information about the derivation of these data. Generic steel-depleted uranium-steel cask designs were assumed for the severity fractions.

c. T_2/HT is molecular tritium [see the 1999 EIS (DOE 1999, Section E.7.2.2) for details]. This analysis made the conservative assumption that, on release, the molecular tritium will immediately oxidize to tritiated water (HTO).

d. Crud is material deposited on the outside surfaces of the TPBARs; it was conservatively bounded using worst-case measurements of crud from pressurized water reactor spent nuclear fuel; see the 1999 EIS (DOE 1999, Section E.5.3) for details.

Table F-6. Severity and release fractions used to model TPBAR and low-level radioactive waste transportation accidents with two prefailed TPBARs (DOE 1999).

Group	Severity fractions[b]	Release fractions[a]			
		T_2/HT[c]	T_2O/HTO	NTBC	Crud[d]
SEVER: 1	9.940×10^{-1}	0	0	0	0
SEVER: 2	5.574×10^{-5}	0	0	0	0
SEVER: 3	3.828×10^{-3}	4.15×10^{-6}	8.29×10^{-3}	3.10×10^{-10}	2.00×10^{-3}
SEVER: 4	1.542×10^{-7}	4.15×10^{-6}	2.32×10^{-2}	1.00×10^{-8}	2.00×10^{-3}
SEVER: 5	1.799×10^{-3}	4.15×10^{-6}	1.83×10^{-2}	1.00×10^{-8}	2.00×10^{-3}
SEVER: 6	1.076×10^{-7}	4.15×10^{-6}	3.32×10^{-2}	1.00×10^{-8}	2.00×10^{-3}
SEVER: 7	9.641×10^{-6}[c]	4.15×10^{-6}	1	1.00×10^{-7}	2.00×10^{-3}

HTO = tritiated water; NTBC = nontarget-bearing components (see DOE 1999, Section E.5.3 for details).

a. RADTRAN 6 models the fraction of the released particulate material that is small enough to be dispersible in prevailing wind conditions and the fraction that is respirable. This analysis set these parameters to 1.0 (that is, 100 percent dispersible and 100 percent respirable).

b. Severity fractions are the conditional probabilities, given the occurrence of an accident, that the mechanical and thermal conditions experienced by a spent fuel shipping cask are within the conditions defined by the Severity Category. See the 1999 EIS (DOE 1999, Section E.5.7.3.3) for detailed information about the derivation of these data. Generic steel-depleted uranium-steel cask designs were assumed for the severity fractions.

c. T_2/HT is molecular tritium; see the 1999 EIS (DOE 1999, Section E.7.2.2) for details. This analysis made the conservative assumption that, on release, the molecular tritium will immediately oxidize to tritiated water (HTO).

d. Crud is material deposited on the outside surfaces of the TPBARs; it was conservatively bounded using worst-case measurements of crud from pressurized water reactor spent nuclear fuel; see the 1999 EIS (DOE 1999, Section E.5.3) for details.

For accidents that would result in a release of radioactive material, RADTRAN 6 assumes the material is dispersed to the environment according to standard Gaussian diffusion models. The program allows the user to choose two different methods for modeling the atmospheric transport of radionuclides after a potential accident. The user can input either Pasquill atmospheric stability category data or averaged time-integrated concentrations. This analysis used the default standard cloud option (with time-integrated concentrations).

RADTRAN 6 also allows the user to select the fraction of release material that is aerosolized and respirable. This analysis set these parameters to 1, which assumes that, of the small amount of material that would be released in an accident, 100 percent would be aerosolized and respirable.

NNSA used RADTRAN 6 to calculate the population dose from the released radioactive material for four of six possible exposure pathways:

1. External dose from exposure to the passing cloud of radioactive material (cloudshine).

2. External dose from radionuclides deposited on the ground by the passing plume (groundshine). The analysis included radiation exposures from this pathway even though the area around a potential accidental release would be evacuated and decontaminated, thereby preventing long-term exposures from this pathway.

3. Internal dose from inhalation of airborne radioactive contaminants (inhalation).

4. Internal dose from radioactive materials that were deposited on the ground and then resuspended (resuspension). The analysis included radiation exposures from this pathway even though evacuation and decontamination of the area around a potential accidental release would prevent long-term exposures.

NNSA did not consider the fifth possible pathway, which would result in internal dose from contaminated foodstuffs, because it assumed evacuation and subsequent interdiction of contaminated foodstuffs after a potential transportation accident.

NNSA considered a sixth pathway, external doses from increased radiation fields around a shipping cask with damaged shielding. The shielding materials that are part of the cask structures could become damaged as a result of an accident. For example, casks with lead shielding could undergo a slumping phenomenon in which impact or fire caused gaps to form in the lead. Radiation would penetrate through the gaps in the shielding at higher intensities, leading to higher radiation dose rates. This analysis did not include these events, which are called "loss of shielding events," because their contribution to TPBAR and low-level radioactive waste transportation risks would be much smaller than dispersal accident risks.

RADTRAN 6 incorporates standard radionuclide uptake and dosimetry models. It combines accident consequences and frequencies of each severity category, sums the severity categories, and then integrates across all the shipments. Accident risk impacts are in the form of a collective population dose (person-rem) per shipment.

The analysis used the same shipping distances and population distributions for the routes as those for incident-free transportation (see Table F-1) to calculate potential accident impacts. It assumed the representative shipping casks described above.

RADTRAN 6 allows the user to modify parameters in the program that calculate dose to various receptors under incident-free and accident conditions. This analysis used the RADTRAN 6 default values for these parameters. Table F-7 lists these default parameters.

Accident risk factors are called "dose risk" because the values incorporate the spectrum of accident severity probabilities and associated consequences. They are presented for normal transportation (that is,

Table F-7. RADTRAN default parameters (Neuhauser et al. 2000).

Parameter	Value
Building dose factor (BDF)	5.00×10^{-2}
Contamination cleanup level (microcuries per square meter) (CULVL)	2.00×10^{-1}
Breathing rate (cubic meters per second) (BRATE)	3.30×10^{-4}
Interdiction threshold (microcuries per curie) (INTERDICT)	4.00×10^{-1}
Evacuation time (days) (EVACUATION)	1
Survey interval (days) (SURVEY)	1.00×10^{-1}
Campaign length (years) (CAMPAIGN)	8.33×10^{-2}
Fraction of urban areas with buildings (UBF)	5.20×10^{-1}
Fraction of urban areas with sidewalks (USWF)	4.80×10^{-1}
Ratio of sidewalk pedestrian density (RPD)	6
Maximum in-transit dose distance (meters) (MITDDIST)	$3.00 \times 10^{+1}$
Maximum in-transit dose velocity (kilometers per hour) (MITDVEL)	$2.40 \times 10^{+1}$
IACC value: 1 = nondispersal, 2 = dispersal	2
Regulatory check: 1 = do checks, 0 = no checks	1
Building shielding option (IUOPT)	2
Rural shielding factor	1
Suburban shielding factor	8.70×10^{-1}
Urban shielding factor	1.80×10^{-2}
Distance of freeway vehicle carrying radioactive cargo to pedestrians (meters)	$3.00 \times 10^{+1}$
Distance of freeway vehicle carrying radioactive cargo to right-of-way edge (meters)	$3.00 \times 10^{+1}$
Distance of freeway vehicle carrying radioactive cargo to maximum exposure distance (meters)	$8.00 \times 10^{+2}$
Distance of non-freeway vehicle carrying radioactive cargo to pedestrians (meters)	$2.70 \times 10^{+1}$
Distance of non-freeway vehicle carrying radioactive cargo to right-of-way edge (meters)	$3.00 \times 10^{+1}$
Distance of non-freeway vehicle carrying radioactive cargo to maximum exposure distance (meters)	$8.00 \times 10^{+2}$
Distance of city street vehicle carrying radioactive cargo to pedestrians (meters)	5
Distance of city street vehicle carrying radioactive cargo to right-of-way edge (meters)	8
Distance of city street vehicle carrying radioactive cargo to maximum exposure distance (meters)	$8.00 \times 10^{+2}$
Perpendicular distance to freeway vehicle going in opposite direction (meters)	$1.50 \times 10^{+1}$
Perpendicular distance to non-freeway vehicle going in opposite direction (meters)	3
Perpendicular distance to city vehicle going in opposite direction (meters)	3

no failed TPBARs) and the abnormal event of two failed TPBARs in a shipment. The risks would be slightly higher if the failed TPBARs were shipped in a single cask. Table F-8 lists the accident impacts.

F.4.3.2 Nonradiological Transportation Accident Impacts

For calculation of estimated traffic fatality impacts, the analysis considered all shipments.

NNSA derived route-specific accident rates (that is, accidents per kilometer) for the RADTRAN 6 accident risk analysis. It used the following approach to develop accident rates for TPBAR and low-level radioactive waste shipments. TRAGIS data provided estimates of the travel distance in each state along a route. Saricks and Tompkins (1999) provided state-specific total accident rates applicable for all types of roads. These rates were later revised upward to account for under-reporting (Blower and Matteson 2003). The approach to estimate route-specific accident rates was to multiply the state-level accident or fatality rates by the travel distances in each state and then sum over all the states on each route. Table F-9 lists the accident and fatality rates for affected states.

Table F-8. TPBAR and low-level radioactive waste transportation accident dose risk (person-rem per shipment).

From	To	Risk
No prefailed TPBARs		
Watts Bar	Savannah River Site	1.65×10^{-4}
Sequoyah	Savannah River Site	1.61×10^{-4}
Two prefailed TPBARs		
Watts Bar	Savannah River Site	2.55×10^{-4}
Sequoyah	Savannah River Site	2.51×10^{-4}
Low-level radioactive waste		
Watts Bar	Nevada National Security Site	5.58×10^{-10}
Sequoyah	Nevada National Security Site	5.35×10^{-10}

Table F-9. Accident and fatality rates for affected states.

State	Adjusted composite accident rates (accidents per truck-kilometer)				Adjusted composite fatality rates (fatalities per truck-kilometer)			
	Interstate	Primary	Other	Total	Interstate	Primary	Other	Total
Arizona	2.17×10^{-7}	1.33×10^{-7}	6.56×10^{-9}	1.76×10^{-7}	1.48×10^{-8}	1.69×10^{-8}	0	1.48×10^{-8}
Arkansas	2.20×10^{-7}	3.82×10^{-7}	3.77×10^{-8}	2.43×10^{-7}	9.76×10^{-9}	8.10×10^{-8}	0	3.50×10^{-8}
Georgia	(a)	(a)	(a)	1.10×10^{-6}	(a)	(a)	(a)	3.07×10^{-8}
Nebraska	5.24×10^{-7}	9.55×10^{-7}	8.16×10^{-7}	7.12×10^{-7}	2.16×10^{-8}	4.32×10^{-8}	2.17×10^{-8}	2.95×10^{-8}
Nevada	3.69×10^{-7}	6.24×10^{-7}	4.76×10^{-8}	4.02×10^{-7}	1.04×10^{-8}	2.63×10^{-8}	5.20×10^{-9}	1.40×10^{-8}
New Mexico	1.85×10^{-7}	1.67×10^{-7}	1.69×10^{-7}	1.77×10^{-7}	1.86×10^{-8}	1.78×10^{-8}	1.20×10^{-8}	1.73×10^{-8}
Oklahoma	4.40×10^{-7}	5.19×10^{-7}	3.79×10^{-7}	4.53×10^{-7}	2.09×10^{-8}	3.34×10^{-8}	1.21×10^{-8}	2.32×10^{-8}
South Carolina	(a)	(a)	(a)	7.70×10^{-7}	(a)	(a)	(a)	4.09×10^{-8}
Tennessee	2.02×10^{-7}	4.61×10^{-7}	2.54×10^{-7}	2.61×10^{-7}	1.57×10^{-8}	4.09×10^{-8}	6.14×10^{-9}	2.05×10^{-8}
Texas	9.85×10^{-7}	1.14×10^{-6}	1.21×10^{-6}	1.08×10^{-6}	2.05×10^{-8}	4.50×10^{-8}	1.31×10^{-7}	4.25×10^{-8}

Sources: Saricks and Tompkins 1999; Blower and Matteson 2003.

a. Data unavailable – total accident rate used.

Nonradiological impacts are human health impacts from traffic accidents involving shipments of unirradiated TPBARs from the manufacturing facility in Columbia, South Carolina, to the Watts Bar and Sequoyah sites, irradiated TPBARs from Watts Bar and Sequoyah to the Savannah River Site, low-level radioactive waste from Watts Bar and Sequoyah to the Nevada National Security Site near Mercury, Nevada, and return of empty casks from Nevada to the sites; they do not consider radiological or hazardous characteristics of the cargo. Nonradiological impacts would include the estimated number of traffic accidents and fatalities from those shipments as well as return shipments of empty casks from Nevada to Watts Bar and Sequoyah.

NNSA calculated nonradiological impacts using accident and fatality rates from published sources (see Table F-9). This analysis used the rates for Interstate Highways because NNSA would use these roads predominately. The rates (impacts per vehicle-kilometer of travel) are multiplied by estimated travel distances. The general formula for calculating nonradiological impacts is:

Impacts per shipment = unit rate × round-trip shipping distance

In this formula, impacts are in units of the number of accidents, number of injuries, and number of fatalities per shipment. Annual impacts would be calculated by multiplying the impacts per shipment by the total number of shipments for unirradiated and irradiated TPBARs and low-level radioactive waste expected to occur over 40 years. Table F-10 lists the nonradiological impacts from shipment of unirradiated and irradiated TPBARs and low-level radioactive waste.

Table F-10. Nonradiological impacts, per shipment, resulting from shipment of unirradiated and irradiated TPBARs and low-level radioactive waste.

From	To	Material type	Round-trip distance (kilometers)	Accidents	Fatalities
Columbia	WBN	TPBAR	1,024	5.02×10^{-4}	2.69×10^{-5}
Columbia	SQN	TPBAR	1,120	1.07×10^{-3}	3.52×10^{-5}
WBN	SRS	TPBAR	1,100	1.02×10^{-3}	3.18×10^{-5}
SQN	SRS	TPBAR	1,023	1.01×10^{-3}	3.07×10^{-5}
WBN	NNSS	LLW	6,728	3.16×10^{-3}	1.12×10^{-4}
SQN	NNSS	LLW	6,671	2.16×10^{-3}	1.09×10^{-4}

WBN = Watts Bar Nuclear Plant; SQN = Sequoyah Nuclear Plant; SRS = Savannah River Site; NNSS = Nevada National Security Site; LLW = low-level radioactive waste.

F.4.4 40-YEAR SHIPMENTS BY ALTERNATIVE

To determine the 40-year transportation risks, the analysis determined the numbers of the various types of shipments over this period. Based on information in AEC (1972), the number of unirradiated fuel shipments to a standard pressurized-water reactor would be about 6.3 per year. This number was normalized for an 18-month reactor cycle to 9.5 shipments. The conservative assumption was made that there would be some unirradiated TPBARs in each shipment to the Watts Bar and Sequoyah sites. The number of irradiated TPBAR shipments was based on the 1999 EIS (DOE 1999, Sections 3.1.2 and E.5.1), which assumed that each shipment would contain a single consolidated assembly consisting of 289 TPBARs in a 17-by-17 array. This number was divided into the number of TPBARs per cycle by each alternative. The number of low-level radioactive waste shipments was based on the 1999 EIS, Section E.5.3, which estimated a maximum of eight shipments for 3,400 TPBARs per cycle. This number was normalized to provide the number of shipments by alternative. Table F-11 lists the number of one-way shipments per reactor cycle. The total number of shipments would be twice the numbers in the table to account for empty casks returning to their points of origin.

Table F-11. Numbers of one-way shipments of unirradiated and irradiated TPBARs and low-level radioactive waste per reactor cycle by alternative.

Alternative	TPBARs per cycle	Reactor site	Unirradiated TPBAR shipments per cycle[a]	Irradiated TPBAR shipments per cycle[b]	LLW shipments per cycle[c]
No Action	680	Watts Bar	10	3	2
	1,360	Sequoyah	10	5	4
1	2,500	Watts Bar	10	9	6
2	2,500	Sequoyah	10	9	6
3	1,250	Watts Bar	10	5	3
	1,250	Sequoyah	10	5	3
4	5,000	Watts Bar	10	18	12
5	5,000	Sequoyah	10	18	12
6	2,500	Watts Bar	10	9	6
	2,500	Sequoyah	10	9	6

LLW = low-level radioactive waste.

a. Source: AEC (1972) estimate of 6.3 unirradiated fuel shipments per year normalized to the 18-month cycle. Number of shipments rounded up to the next higher whole number.

b. Based on the DOE (1999, Section 3.1.2) estimate of 289 TPBARs per shipment. Number of shipments rounded up to the next higher whole number.

c. Based on the DOE (1999, Section E.5.3) estimate of maximum of eight low-level radioactive waste shipments per cycle for 3,400 TPBARs per cycle. Number of shipments rounded up to the next higher whole number.

F.4.5 40-YEAR TRANSPORTATION RISKS BY ALTERNATIVE

To determine the 40-year transportation risks, NNSA multiplied the impacts per shipment in Tables F-4, F-8, and F-10 by 27 (the number of 18-month cycles in 40 years) and by 6.0×10^{-4} latent cancer fatality per person-rem. Table F-12 lists the results. These values are for comparison with those in Table 5-54 of DOE (1999).

Table F-12. Latent cancer fatalities and traffic accident fatalities over 40 years by alternative.

Alternative	Incident-free		Radiological accident[a]	Traffic accident[a]
	Crew[a]	Public[a]		
No-Action–Watts Bar	0 (5.19×10^{-3})	0 (5.64×10^{-4})	0 (9.91×10^{-6})	0 (6.90 × 10-3)
No-Action–Sequoyah	0 (9.65×10^{-3})	0 (1.06×10^{-3})	0 (1.91×10^{-5})	0 (9.03 × 10-3)
No-Action total	0 (1.48×10^{-2})	0 (1.62×10^{-3})	0 (2.90×10^{-5})	0 (1.59 × 10-2)
Alternative 1 (Watts Bar only)	0 (1.82×10^{-2})	0 (2.01×10^{-3})	0 (3.59×10^{-5})	0 (6.91 × 10-3)
Alternative 2 (Sequoyah only)	0 (1.78×10^{-2})	0 (3.54×10^{-3})	0 (3.54×10^{-5})	0 (9.03 × 10-3)
Alternative 3–Watts Bar	0 (8.94×10^{-3})	0 (9.89×10^{-4})	0 (1.78×10^{-5})	0 (6.90 × 10-3)
Alternative 3–Sequoyah	0 (8.76×10^{-3})	0 (9.66×10^{-4})	0 (1.75×10^{-5})	0 (9.03 × 10-3)
Alternative 3 total	0 (1.77×10^{-2})	0 (1.96×10^{-3})	0 (3.52×10^{-5})	0 (1.59 × 10-2)
Alternative 4 (Watts Bar only)	0 (3.62×10^{-2})	0 (3.99×10^{-3})	0 (7.15×10^{-5})	0 (1.38×10^{-2})
Alternative 5 (Sequoyah only)	0 (3.55×10^{-2})	0 (7.06×10^{-3})	0 (7.03×10^{-5})	0 (1.81×10^{-2})
Alternative 6–Watts Bar	0 (1.82×10^{-2})	0 (2.01×10^{-3})	0 (3.59×10^{-5})	0 (6.91×10^{-3})
Alternative 6–Sequoyah	0 (1.78×10^{-2})	0 (3.54×10^{-3})	0 (3.54×10^{-5})	0 (9.03×10^{-3})
Alternative 6 total	0 (3.60×10^{-2})	0 (5.55×10^{-3})	0 (7.13×10^{-5})	0 (1.59×10^{-2})

a. Because the numbers of latent cancer fatalities and traffic fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

As stated in Chapter 2, TVA would complete the proposed action in 2035. Therefore, NNSA analyzed a 22-year period from 2012 to 2035. Table F-13 lists the results, which are in Sections 4.1.13 and 4.2.13 of the main body of this SEIS.

Table F-13. Latent cancer fatalities and traffic fatalities over 22 years by alternative.

Alternative	Incident-free		Radiological accident[a]	Traffic accident
	Crew[a]	Public[a]		
No-Action–Watts Bar	0 (2.85×10^{-3})	0 (3.10×10^{-4})	0 (5.45×10^{-6})	0 (3.80×10^{-3})
No-Action–Sequoyah	0 (5.31×10^{-3})	0 (5.83×10^{-4})	0 (1.05×10^{-5})	0 (4.97×10^{-3})
No-Action total	0 (8.16×10^{-3})	0 (8.94×10^{-4})	0 (1.60×10^{-5})	0 (8.76×10^{-3})
Alternative 1 (Watts Bar only)	0 (9.99×10^{-3})	0 (1.10×10^{-3})	0 (1.98×10^{-5})	0 (3.80×10^{-3})
Alternative 2 (Sequoyah only)	0 (9.80×10^{-3})	0 (1.95×10^{-3})	0 (1.95×10^{-5})	0 (4.97×10^{-3})
Alternative 3–Watts Bar	0 (4.92×10^{-3})	0 (5.54×10^{-4})	0 (9.77×10^{-6})	0 (3.80×10^{-3})
Alternative 3–Sequoyah	0 (4.82×10^{-3})	0 (5.32×10^{-4})	0 (9.62×10^{-6})	0 (4.97×10^{-3})
Alternative 3–Total	0 (9.74×10^{-3})	0 (1.08×10^{-3})	0 (1.94×10^{-5})	0 (8.76×10^{-3})
Alternative 4 (Watts Bar only)	0 (1.99×10^{-2})	0 (2.20×10^{-3})	0 (3.93×10^{-5})	0 (7.60×10^{-3})
Alternative 5 (Sequoyah only)	0 (1.95×10^{-2})	0 (3.88×10^{-3})	0 (3.97×10^{-5})	0 (9.94×10^{-3})
Alternative 6–Watts Bar	0 (9.99×10^{-3})	0 (1.10×10^{-3})	0 (1.98×10^{-5})	0 (3.80×10^{-3})
Alternative 6–Sequoyah	0 (9.80×10^{-3})	0 (1.95×10^{-3})	0 (1.95×10^{-5})	0 (4.97×10^{-3})
Alternative 6–Total	0 (1.98×10^{-2})	0 (3.05×10^{-3})	0 (3.93×10^{-5})	0 (8.77×10^{-3})

a. Because the numbers of latent cancer fatalities and traffic fatalities are whole numbers, the statistically calculated values are provided in parentheses when the reported result is a small fraction of 1.

F.5 Representative Transportation Routes

Figures F-2 through F-7 show representative routes for the transportation of TPBARs and low-level radioactive waste as described in Section F.3.4.

Figure F-2. Representative route – Columbia, South Carolina, to Watts Bar Nuclear Plant.

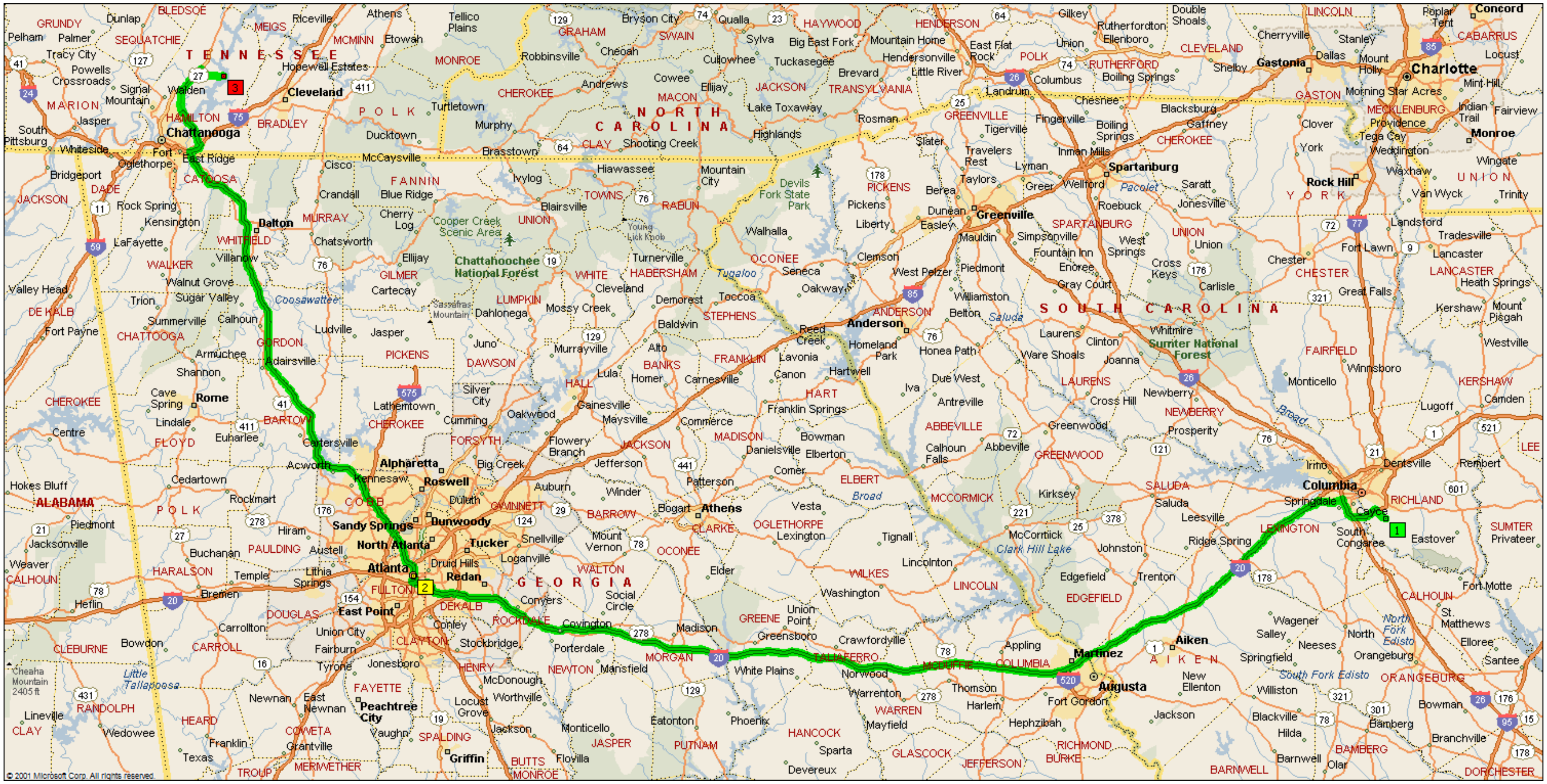

Figure F-3. Representative route – Columbia, South Carolina, to Sequoyah Nuclear Plant.

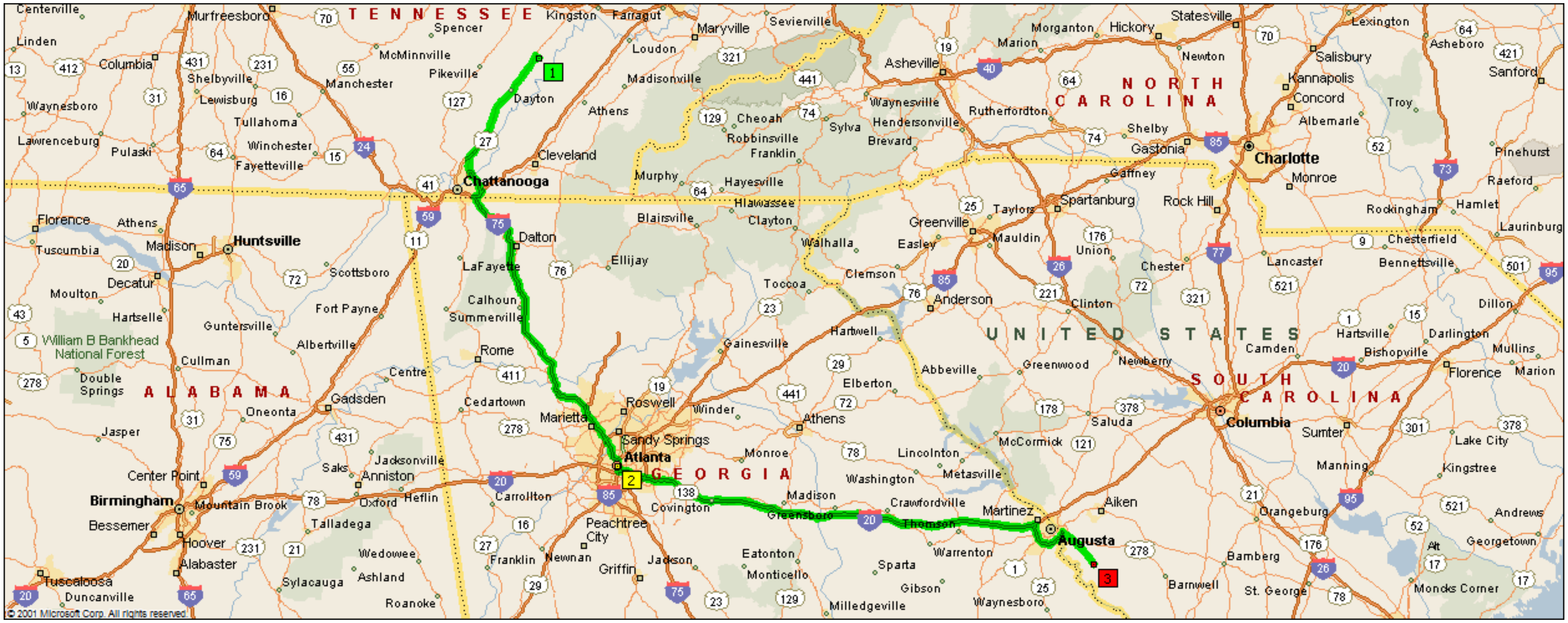

Figure F-4. Representative route – Watts Barr Nuclear Plant to the Savannah River Site.

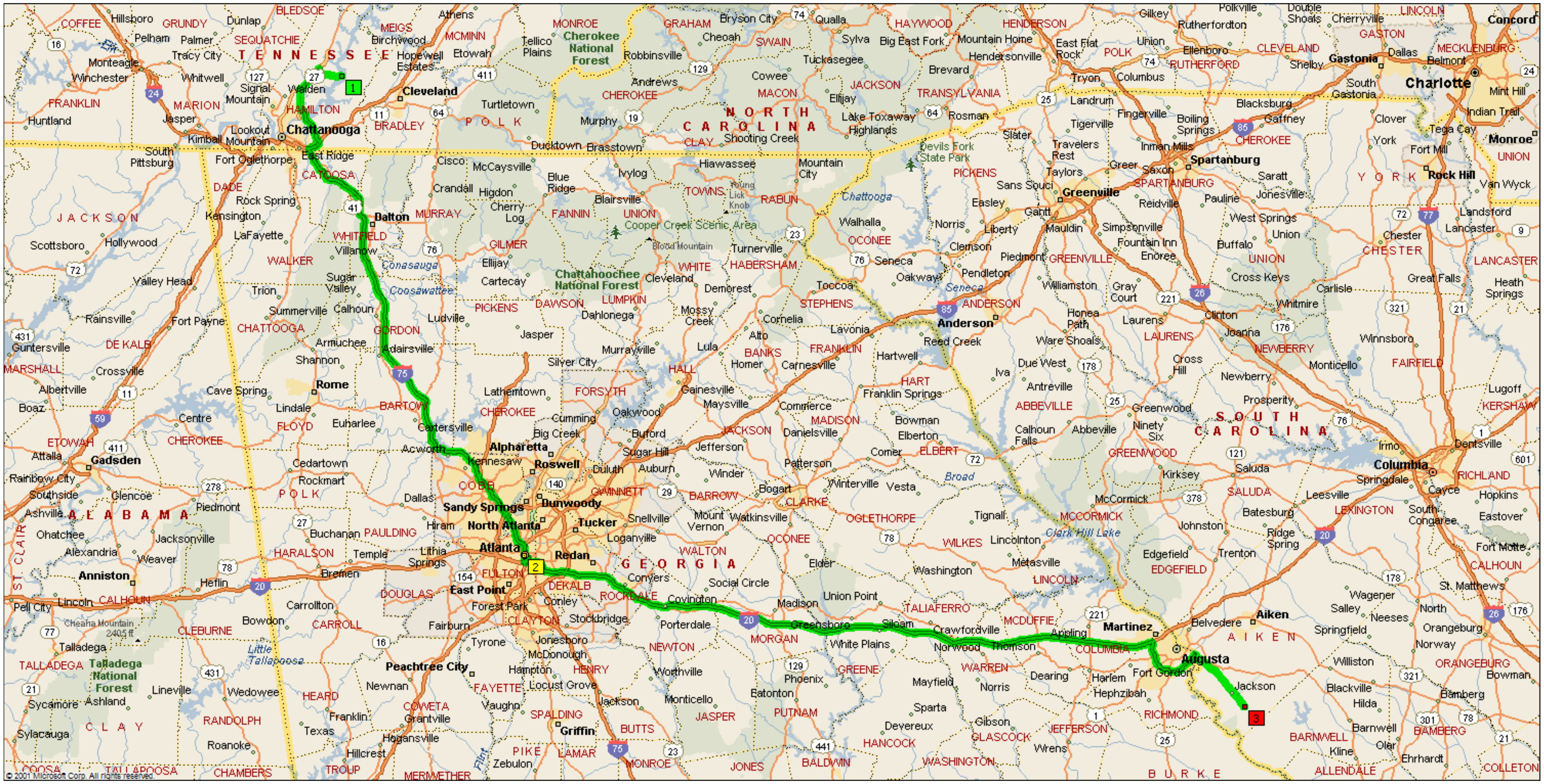

Figure F-5. Representative route – Sequoyah Nuclear Plant to the Savannah River Site.

Figure F-6. Representative route – Watts Bar Nuclear Plant to Nevada National Security Site.

Figure F-7. Representative route – Sequoyah Nuclear Plant to Nevada National Security Site.

F.6 References

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